Sky & Telescope Digital Extra

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WEB EXTRAS

MARCH 2013 ISSUE

- Lifting Titan's Veil
- Predicting Auroras
- Remembering Patrick Moore

Photo Gallery

Image by Steve Yerby

March Audio Sky Tour

THIS WEEK'S

Sky at a Glance

Shop @ Sky

New Elevation Moon Globe

Explore!

- Eight Tips for Starting Right in Astronomy
- Binocular Basics
- Astro Product Videos with Dennis di Cicco
- *Sky & Telescope* Editors' Personal Observatories

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Observing Highlights

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GREAT COMET IN MARCH? p. 50

THE ESSENTIAL GUIDE TO ASTRONOMY

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MARCH 2013

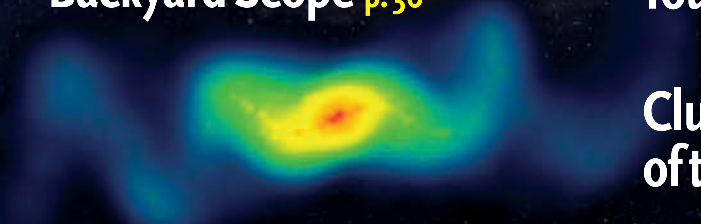
Northern Exposure:
Take Amazing Aurora Photos p. 70

Titan's Rain Mystery p. 26

Top 10 COSMIC EXTREMES

The fastest planet & other oddities p. 18

Cosmic Jets in Your Backyard Scope p. 36



The Brightest Galaxy You've Never Seen p. 60

Club Meetings of the Future p. 32

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SKY & TELESCOPE

March 2013 VOL. 125, NO. 3

On the cover: Exoplanet HD 80606b (whimsically depicted) whips around its host star 529,000 miles per hour at closest approach.

S&T: LEAH TISCIONE

FEATURES

OBSERVING MARCH

S&T TEST REPORT

ALSO IN THIS ISSUE

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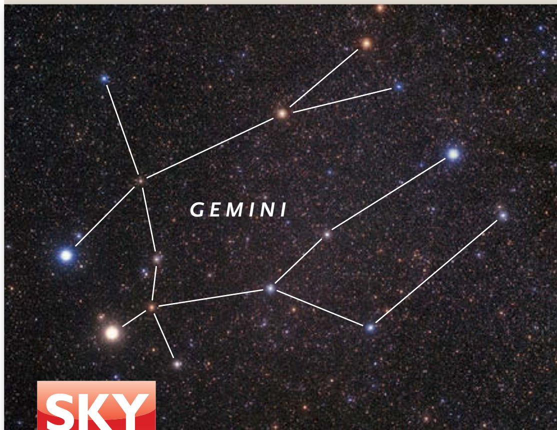

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AKIRA FUJII

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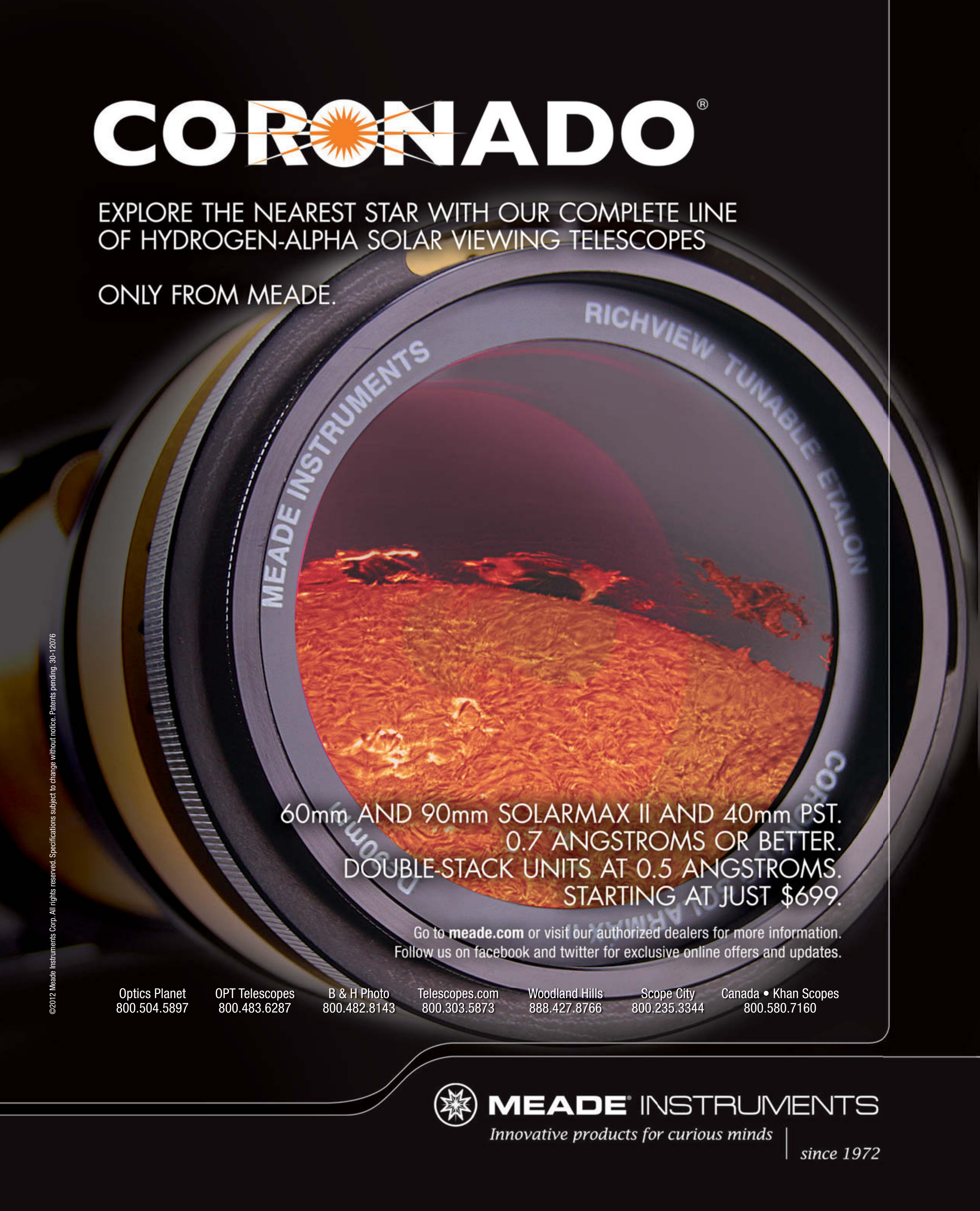
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Eclipses Past & Future

S&T: ROBERT NAEYE

I WRITE THESE WORDS in early December, shortly after returning from a trip to Australia. My time away included a 2-week cruise to view the November total solar eclipse from the Holland America ship *Oosterdam*.

I thank our travel partner, Insight Cruises, for a great experience. I particularly enjoyed meeting many dozens of *S&T* readers from the U.S., Australia, Canada, Brazil, and elsewhere. I also reconnected with several readers I knew from star parties and previous trips. We saw about 80 seconds of totality before a cloud blocked the eclipsed Sun. But as the Sun emerged from behind the Moon, the cloud lit up suddenly, a spectacular light show the likes of which I had never seen. I wish the cloud hadn't been there, but at least it provided a dramatic visual effect. To view a beautiful eclipse video from Brazilian members of our group, visit **skypub.com/BrazilVideo**. My favorite photo that I took of the partial phase appears above.

We're partnering with Spears Travel for an exciting Kenya tour to view the November 3, 2013, total solar eclipse. Because the Moon will just barely cover the Sun, totality should have some interesting effects along the lunar limb. The trip will include visits to cultural areas, a chimpanzee sanctuary, and game reserves (where the group can look for lions, giraffes, elephants, rhinos, and zebras). Visit **skypub.com/KenyaEclipse** for more details.

We've produced a new app for Apple mobile devices. *JupiterMoons* enables you to identify the Galilean satellites and accurately predict Great Red Spot crossings along with moon transits and eclipses. You can download *JupiterMoons* from the iTunes App Store for just $2.99. We thank Tim DeBenedictis at Southern Stars for helping us create this app.

In other product news, we have reissued our *Space: 50 Years and Counting* special issue that we originally published in 2007. We updated the text to include results from recent missions such as Kepler, Dawn, and Curiosity. We also added a bunch of new images and revised the title to *Space: From Sputnik to Curiosity*. If you didn't buy the special issue when it came out six years ago, I invite you to check out the new edition.

Last but certainly not least, the staff and I were saddened to learn of the passing of Sir Patrick Moore, one of the world's greatest popularizers of astronomy. Please read Timothy Lyster's tribute on page 16. ✦

Editor in Chief

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The Essential Guide to Astronomy

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GOTO

Lens Making at GOTO INC

GOTO INC has been in the lens grinding business for nearly a century. In fact, even before there was a GOTO INC, there was a Goto grinding glass for a famous Japanese camera company. That man was Seizo Goto, founder of GOTO INC. Seizo soon mastered the skills necessary to grind quality lenses and set off to start his own business – making telescopes.

Over the years, GOTO moved from telescopes, to periscopes, to planetariums and fisheye movie camera and projection lenses. Today, one of the main lines of business for GOTO is the production of quality video projection lenses. This business is so good that GOTO's optical lab is working full time to keep up with video lens orders!

The dome environment is a challenging one for most lens manufacturers. Especially at the outer edges of a projected image, many dome systems show lack of focus, asymmetrical star images, or chromatic aberration. Likewise, internal reflections can cause contrast loss, and a poorly designed lens can lose light output.

All of these challenges have been met by GOTO for decades now, since GOTO began designing and manufacturing wide angle and fisheye lenses for GOTO Astrovision large format film projectors. In fact, every lens produced for use inside a planetarium is optimized for use on spherical, not flat, surfaces.

Special anti-reflective coatings and internal, motorized irises keep contrast extremely high, and help realize GOTO's goal of inky-black skies with tiny, beautiful stars.

GOTO's line of video projection lenses include models designed for the latest SONY and JVC 4K projectors, as well as many projectors which can be used in 2K applications. Future lens development continues, so users are encouraged to contact GOTO if they have specific questions or requests for lenses to match any new projectors.

JVC 4K projector lens

CHIRON Ⅱ star plate

Mr. Ikeda has been grinding and polishing lenses at GOTO for 40 years. From roughing out shapes to final testing and polishing, he and several other optical craftsmen do it all.

To learn more, contact:

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Please limit your comments to 250 words.

Astronomical Feast

The picture of Per Collinder and colleagues in the December issue's "Exploring Those Odd-Named Star Clusters" (page 39) in fact shows not a lobster dinner but a traditional Swedish crayfish party (*Astacus astacus*, now unfortunately at a high risk of extinction in the wild). The crayfish party is traditionally held in mid-August, shortly after the legal opening of the harvesting season. On the table sit the dish of crayfish, the beer, and conical aquavit glasses. Judging from the stern faces, the picture was taken early in the evening.

I hope you do not take my note as more serious than I mean it to be — just a note about a quaint Swedish tradition.

Nils Olof Carlin
Skövde, Sweden

SkyWeek Celebrity

I just wanted to drop you a line on behalf of my eighth-grade earth science class and say thank you for your website, and especially the weekly *SkyWeek* webcast featuring associate editor Tony Flanders. Tony has rock-star status with my kids and has inspired many of them to download apps so that they can interpret the sky at night. I started showing the videos last year and all the kids love them — you can hear a pin drop while they watch. They especially liked the "sea goat" broadcast from last October. I learn something new every Monday when we watch the latest episode together.

Dwight Wells
Shanahan Middle School
Lewis Center, Ohio

Editor's Note: *We're tickled pink to think of Tony as a rock star. Around here he's more often seen as the man who rides his scooter down the hall.*


S&T: LEAH TISCIONE

Multiple Universes

I really enjoyed Camille Carlisle's multiverse article (December issue, page 20). It seems like whenever I read articles that expand my knowledge of a subject, I have trouble understanding them and tend to fall asleep — but Carlisle's article, in spite of the complexity of the subject, was very understandable. It amazes me that just a few hundred years ago we considered the solar system to be the universe. Later it was our galaxy, then the Big Bang universe, and now the multiverse.

Darryl Davis
Albany, Oregon

I was taught that an indication of the weakness of the Ptolemaic system of astronomy was the addition of a few epicycles to make the theory fit the data. Now, however, it seems we can have 10^{500} additional universes to allow string theory to be correct. Now that is inflation!

Andrew Smith
Delamere, United Kingdom

I didn't understand the multiverse before (and frankly still don't), but you clarified for me how astrophysicists view the concept. I haven't read an article this interesting since the 1980s, when *Scientific American* did a piece on how the concept of multiple universes lay behind advances in quantum computers. In that case, a multiverse would be the connection between quantum mechanics' probabilistic weirdness and our concrete, one-result experience. Is the multiverse that astrophysicists are trying to detect the same one that quantum computer theorists exploit? If it is, are these other universes considered to be far away, or right next to us, perhaps even interwoven with ours?

At age 61, I hope I live long enough to see some kind of resolution to the multiple universe issue, but I suspect that the true nature of the universe is always going to prove slightly more elusive than we think.

Tom Sales
Somerset, New Jersey

Author's Note: *No, the quantum multiverse and the cosmological one are not the same. Several different developments in theoretical physics have raised the multiverse issue, but each theory envisions the multiverse in distinct ways. (Apparently, there are multiple ways to invoke multiple universes.) For example, in some versions of the "many worlds" interpretation of quantum mechanics, every time an experiment is run and we see one result before us, another reality splits off from ours in which a different result occurred. It's unclear where that reality would "exist" — concepts such as "next door" or "far away" don't really apply. On the other hand, the pocket universes of the cosmological multiverse I discussed are distinct patches of spacetime that came into being independent of one another. From our perspective inside our bubble universe, these other bubbles are infinitely far away. One way to think of the difference between the two frameworks might be to compare a bubble bath and a branching tree. I recommend Brian Greene's book* The Hidden Reality *for more information: he looks at several multiverse theories and talks about their differences.*

I loved Camille Carlisle's article "Cosmic Collisions." She did an exemplary job of putting abstruse material into laypersons' terms. At one point, though, she wrote that "The universe . . . [grew] to be at least 1,000 times bigger than the universe we can actually observe." How can the universe be bigger than what we can observe if we are now able to observe (almost) back to the Big Bang?

Joel Marks
New Haven, Connecticut

Author's Note: *Basically, we don't observe the real edge of the universe, we only observe our horizon. There are two points. First, the cosmic microwave background isn't a real edge: it's a glow suffusing the whole universe, coming at us from all directions. Second, light has only had about 13.7 billion years to travel, so we can only see parts of the universe from which photons have been able to reach us in that time. A loose analogy would be standing on Earth's surface, where you only see what's within your horizon. It might look like the world has an edge, but that's because you can only see the light that reaches you. The same thing goes for the "surface" of the CMB: it's an edge in the sense of being a horizon. The physical radius of this horizon is not 13.7 billion light-years, but about 45 billion light-years. However, inflation requires that the observable universe is a tiny patch of a larger region of spacetime. How large that region is, we don't know.*

For the Record

✷ *The Byurakan Observatory mentioned on page 38 in the December issue is in Armenia, not Georgia as stated.*

✷ *Asteroid 6 Hebe occulted a star, not the other way around (December issue, page 29).*

75, 50 & 25 Years Ago

Roger W. Sinnott

March 1938

Old-Fashioned Winters "The Leander McCormick Observatory [in Charlottesville, Virginia] . . . is a U.S. Weather Bureau Station. The director himself makes the weather observations each day. . . .

"The sage of [nearby] Monticello, Thomas Jefferson, was himself an indefatigable weather observer . . . [and wrote in an 1804 publication]: 'A change in our climate is taking place very surely. Both heat and cold are becoming more moderate within the memory of even the middle-aged, and snows are less frequent and less deep.' . . .

"For Charlottesville, both the summer and the winter records show unmistakable signs that the temperatures are on the average now warmer than they used to be in 1900. . . . As far as one can see off-hand, there is no reason whatever for this continuous increase."

Samuel Alfred Mitchell, an expert on stellar parallaxes, directed McCormick Observatory from 1913 to 1945.

March 1963

Sirius B "[T]he faint companion of Sirius has receded far enough from its dazzlingly bright primary to become visible in moderate-size telescopes. F. Holden, of Lowell Observatory, reports . . . he could see Sirius B faintly but steadily with a 6-inch aperture stop on the 24-inch Clark refractor, at 330×.

"During the next few years, the pair will continue to widen. Even with large telescopes, excellent seeing and first-class optics are required to show the elusive Sirius B."

This note in the "Observer's Page" is also apt now: Sirius B's period is 50.09 years, and it has returned to the same point in its elongated orbit as it was when this note appeared in 1963.

March 1988

Phantom in M31 "At the Central Bureau for Astronomical Telegrams we are responsible for announcing to the world discoveries of transient astronomical phenomena. . . . Let me share with you the events of last November 24th, a day I call . . . Black Tuesday.

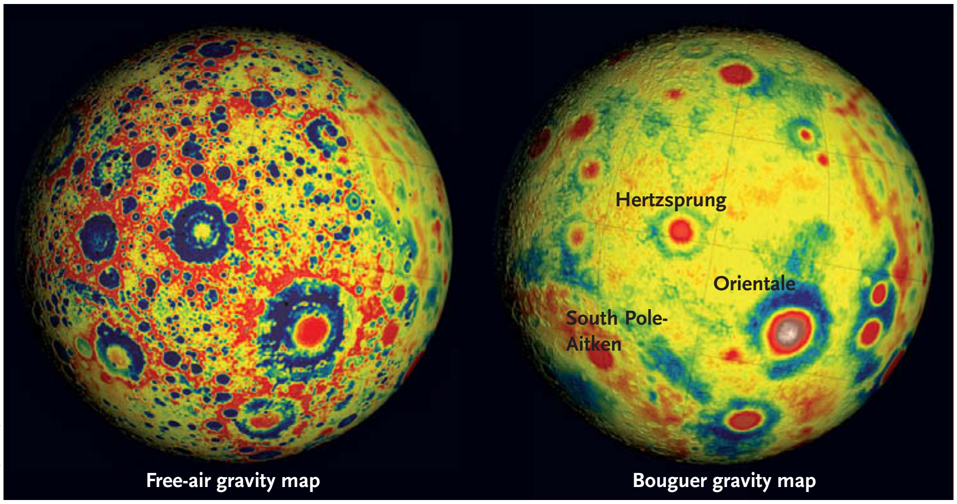
"[My] colleague Dan Green shows me a telex claiming the discovery three days earlier of an 11th-magnitude supernova in M31, the Andromeda galaxy, by Crimean astronomer Nataliya Metlova. . . . The rumor spreads like wildfire, and soon astronomers everywhere appear to be gearing up to observe the supernova. . . .

"It occurs to me that more astronomers must have wasted more time on Black Tuesday than on any other single day — all because one erroneous report was 'leaked' to the scientific community before it was confirmed. I worry that today's instant communications and widespread use of computer information networks could easily lead to many similar fiascos."

Brian G. Marsden's worry came true many times in his long career at the telegram bureau. He died in 2010.

To get astronomy news as it breaks, visit skypub.com/newsblog.

LUNAR I Gravity Probes "See" Moon's Interior



Gravitational field deviations caused by both the Moon's bumpy surface and its lumpy interior (left) look quite different from a map with topographic effects removed to reveal density variations underneath the surface (right). These views show the lunar farside, centered on 120° west.

NASA's twin Gravity Recovery And Interior Laboratory (GRAIL) spacecraft have revealed unexpected details about the Moon's interior, scientists announced December 5th at the American Geophysical Union meeting. The lunar crust has been pulverized so violently that it's a jumble of rubble at least to a few miles down.

Launched in September 2011, GRAIL mapped in detail the Moon's gravity field by measuring tiny changes in the gravitational attraction the Moon exerted on the two spacecraft as they orbited. The craft measured their separation five times per second to extreme precision, detecting orbital velocity changes as small as 0.05 micron per second — "one twenty-thousandth the velocity that a snail moves," says principal investigator Maria Zuber (MIT).

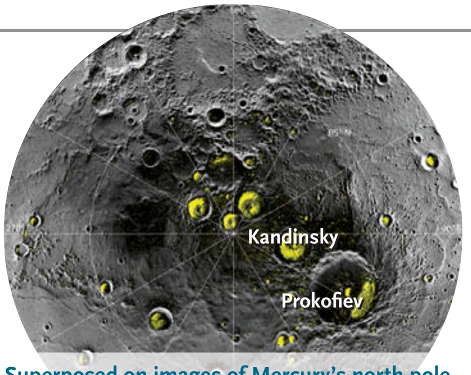
Three immediate findings:

- The upper lunar crust is full of gaps and spaces, like a rock pile. On average this pulverized outer layer (excluding the maria) has a porosity of 12%. The porosity is even greater (up to 20%) around fresher mega-impacts, such as the farside's Orientale and Moscoviense basins.
- The Moon's crust is only two-thirds as thick as post-Apollo measurements pegged it to be: about 27 miles (43 km) thick at most, and far less in many spots. This thinner skin implies a composition in keeping with a "big splat" lunar origin.
- Narrow veins of solidified magma lie buried all over the globe. To explain these veins, the lunar interior must have started out cooler than the exterior, then later heated after the crust solidified. This outside-in heating scenario would have occurred if the Moon built itself up from collisional debris.

NASA crashed GRAIL into the Moon in December after the fuel supply ran out.

■ **J. KELLY BEATTY**

IRON PLANET I Mercury's Polar Ice Confirmed



Superposed on images of Mercury's north pole, radar data (yellow) reveal areas of high reflectivity. All large deposits sit on the floors of craters.

NASA / JHU APL / CARNEGIE INST. OF WASHINGTON

NASA's Messenger mission has finally confirmed that water ice hides in permanently shadowed craters near the poles of blazing Mercury, scientists reported online November 29th in *Science*.

In 1991, astronomers mapping Mercury with radar echoes first detected something that lit up the planet's north pole like a beacon (*S&T*: January 1992, page 35). Water ice was the most likely compound to create such a strong echo. Over the years, support for this notion of snowballs in hell grew stronger (*S&T*: April 2012, page 26).

Messenger finally gave scientists the tools to prove it using three lines of evidence. First, the spacecraft detected water ice indirectly by counting the neutrons reaching it from Mercury. These neutrons are released when high-energy cosmic rays strike the planet's surface. Hydrogen atoms gobble up slow-moving neutrons, so a drop-off in the neutrons over certain areas implied plentiful hydrogen — presumably in H_2O — near the planet's surface.

Second, laser pulses from the craft's altimeter revealed bright bits of surface that match water ice's reflectivity. Third, thermal modeling shows that the floors and inner walls of many shadowed polar craters never get warmer than –370°F (50 K).

Team member David Lawrence (Johns Hopkins University Applied Physics Laboratory) says the layer of ice is at least 20 inches (50 cm) deep. All told, Mercury's polar regions might hold 100 billion to a trillion tons of ice — somewhere between a Lake Tahoe and a Lake Erie's worth.

■ **J. KELLY BEATTY**

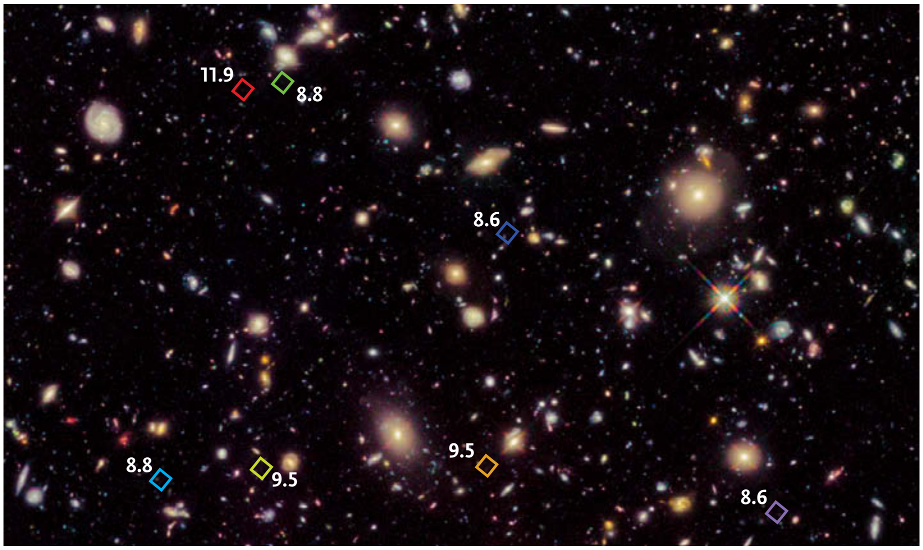
IN BRIEF

NASA's recently launched Van Allen Probes, formerly known as the Radiation Belt Space Probes (December issue, page 12), have detected dramatic changes in the Van Allen belts around Earth despite a relatively quiet Sun, scientists announced at the American Geophysical Union. As part of their two-year mission, the probes are mapping the altitudes above Earth's atmosphere where energetic particles fly and how these particles are accelerated. Surprising variations have shown up in the height of the outer Van Allen electron belt. These changes could affect GPS satellites, which spend considerable amounts of time in that environment. The mission aims to decipher the connection between the solar wind and belt activity.
■ **MONICA YOUNG**

NASA has announced plans for an extended Mars program, including a second science rover modeled after Curiosity. The program also includes supporting the currently active Curiosity and Opportunity rovers, a 2013 launch for the atmosphere-studying MAVEN orbiter, the interior-exploring Insight mission slated for 2016 (December issue, page 16), and participation in the European Space Agency's 2016 and 2018 ExoMars missions. The new rover would launch in 2020, its mission as-yet undetermined. These plans assume no budget hiccups.
■ **CAMILLE M. CARLISLE**

Even little failed stars can form planets, a study in the December 20th *Astrophysical Journal Letters* suggests. Using part of the growing Atacama Large Millimeter/submillimeter Array, Luca Ricci (Caltech) and his colleagues observed the brown dwarf Rho Ophiuchi 102, which hosts a thin dusty disk of gas. Rho Oph 102's small mass, 60 Jupiters, had suggested that its disk would be too puny to form planets. But the ALMA study reveals particles have already grown to millimeter size, meaning grains might one day stick together enough to make rocky planets.
■ **JOHN BOCHANSKI**

GALAXIES | Hubble Finds Faraway Galaxies



NASA / ESA / RICHARD ELLIS (CALTECH) AND UDF 2012 TEAM

Hiding in this Hubble Ultra Deep Field image are seven galaxies seen as they appeared only a few hundred million years after the Big Bang. The numbers refer to the estimated redshifts.

Astronomers have used the Hubble Space Telescope to take a census of the universe's first galaxies. The results, reported in the *Astrophysical Journal Letters*, confirm that galaxies started forming gradually in the early universe and not in a dramatic spurt.

The team used four near-infrared filters on Hubble's Wide Field Camera 3 to search for star-forming galaxies about 400 to 600 million years after the Big Bang. The scope stared for 100 hours at a square of sky in Fornax about one-tenth the diameter of the Moon, known as the Hubble Ultra Deep Field (HUDF). The team then combined these observations with 2009 HUDF work to produce the new results.

Cosmic expansion shifts distant galaxies' light to longer wavelengths, and highly redshifted galaxies are visible only at infrared wavelengths. Judging by the galaxies' visibility with different Hubble filters, the astronomers calculated the galaxies' *photometric redshifts* — estimates of how much space has expanded since the galaxies shone as we see them.

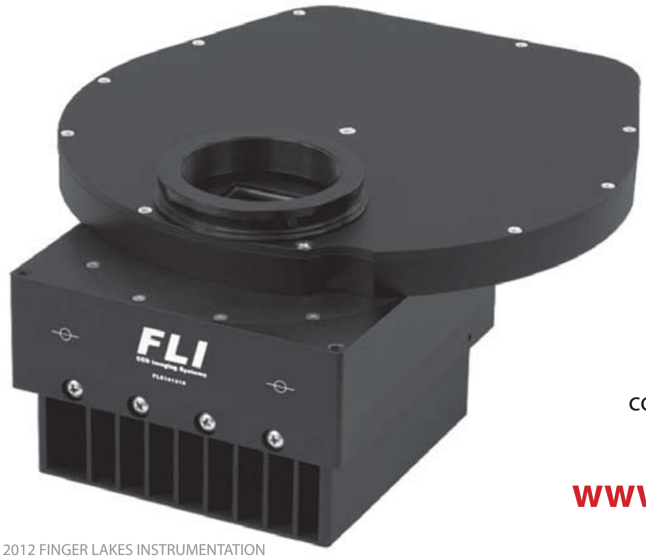
Photometric redshifts are less accurate than spectroscopic ones, which measure narrow spectral lines. But the broad-brush approach requires less exposure time.

Using this method, the team found seven galaxies that fit the target time range. The redshifts range from 8.6 (590 million years after the Big Bang) to 9.5 (520 million years). One outlier is potentially at redshift 11.9. That source, UDF j-39546284, was first reported at redshift 10.3 in 2009 using HUDF photometry. But the new 11.9 measurement, which would put the galaxy 380 million years after the Big Bang, is not airtight. The astronomers only detected the galaxy in one filter, and there's a chance that it's some exotic foreground source, says study leader Richard Ellis (Caltech). He says that the ultimate test will be a true infrared spectrum, which he hopes to obtain using one of the Keck telescopes.

The census provides a crucial look deep into the *reionization era*. During this epoch, ultraviolet radiation from the first post-Big-Bang light sources knocked electrons from the neutral hydrogen atoms filling space. These sources started the synthesis of heavy elements. The new study is basically "the deepest archaeological dig that we have" into this part of cosmic history, says Abraham Loeb (Harvard-Smithsonian Center for Astrophysics).

When compared with lower redshift studies, the new results show that the number of galaxies grew steadily as the universe aged. If the transition was smooth, reionization was probably gradual, extending over several hundred million years.
■ **CAMILLE M. CARLISLE**


Lagoon Nebula Region in Hα
ProLine PL16803 | John Gleason


FLI

MISSIONS | Voyager's On-ramp to Interstellar Space

After 35 years in space, NASA's long-distance interplanetary probe Voyager 1 finds itself on the cusp of leaving the Sun's magnetic bubble.

After their grand tours of the outer planets in the 1970s and '80s, Voyagers 1 and 2 headed outward. Mission scientists dreamed that one or both probes would keep working long enough to report when they crossed the outer limit of the *heliosphere,* the Sun's magnetospheric bubble, and entered true interstellar space. But no one knew how large the heliosphere would be.

Now more than 120 astronomical units from the Sun, Voyager 1 is still inside the heliosphere — but apparently not for long. Project scientist Edward Stone (Caltech) and his colleagues announced December 3rd that Voyager 1 has entered a new and unexpected zone that puts it on the doorstep of interstellar space.

Since late 2004 Voyager 1 has been immersed in a stagnant region of slow-moving solar-wind particles, something like a plasma swamp. But midway through 2012, Voyager 1's instruments detected a precipitous drop in the number of solar-wind particles recorded per second. It simultaneously noted a surge in cosmic rays arriving from interstellar space. This two-way flow soon became the new normal.

"Things have changed dramatically," says Stamatios Krimigis (Johns Hopkins University Applied Physics Laboratory), principal investigator for Voyager's Low-Energy Charged Particle (LECP) instrument. "The [solar-wind] particles are a thousand times less than what we had before. We can hardly measure them."

Ordinarily, scientists would read this sudden shift as a clear signal that the craft had entered the domain of interstellar space. But although the surrounding magnetic field intensified dramatically, its orientation remained rock-steady, aligned east-west roughly along the ecliptic. (In contrast, scientists expect the orientation of the interstellar field to be roughly north-south.)

Mission scientists think the heliospheric and interstellar magnetic fields have somehow become linked, allowing charged particles to flow freely inward and outward. The link is kind of like a "magnetic highway" to and from interstellar space.

Stone thinks this unexpected zone will prove narrow and that Voyager 1 will punch through it in a few months to a couple of years. He expects the spacecraft to still be operating when that happens. Four instruments are still taking data, and the remaining handful of mission engineers at NASA's Jet Propulsion laboratory figures there will be enough electricity to run them until about 2020.

About 100 a.u. from the Sun, Voyager 2 has seen similar changes in its magnetospheric environment, but nothing like those experienced by its more distant twin. The second probe appears to have some distance yet to go before reaching this on-ramp to interstellar space.

■ J. KELLY BEATTY

IN BRIEF

Scientists might be closer than they thought to directly detecting gravitational waves in spacetime, a key prediction of Einstein's theory of gravity. Weak gravitational-wave ripples should be created by any accelerating mass. Astronomers have only indirect evidence of their existence so far, because it takes a large, dense mass accelerating rapidly to make strong gravitational waves. But new work suggests they're on the horizon. Sean McWilliams (Princeton) and his colleagues and Alberto Sesana (Max Planck Institute for Gravitational Physics, Germany) suggest that careful timings of pulsar blips from all around the sky — nature's most precise clocks — could reveal errant beats caused by spacetime ripples in the next few years. McWilliams' team concludes that such signals might even be detectable in current data. If measured well enough, gravitational waves could open a whole new eye on events in the universe, the way observing new wavelengths beyond visible light did during the 20th century.

■ CAMILLE M. CARLISLE

NASA's Curiosity rover has detected water vapor and simple organic molecules in samples of Martian sand, scientists announced at the December 3rd American Geophysical Union meeting. The organic molecules are almost certainly byproducts of the testing process, created when the rover's tiny ovens released different compounds from heated grains. But the water vapor is natural to Mars and shows five times as much deuterium to hydrogen as Earth's seawater. That's as expected: scientists think that, over the eons, ultraviolet sunlight has steadily broken down water molecules at the top of Mars's atmosphere, and the lighter hydrogen atoms preferentially escaped to space while the heavier deuterium atoms more often stayed put. In principle, this five-fold deuterium enrichment can be used to figure out just much water the Red Planet has lost.

■ J. KELLY BEATTY

Simulations by an American and Finnish team suggest that widely separated binary stars formed not as twins but as triplets. Most binaries are tight enough that they could have formed in the same interstellar cloud core, but some are far too wide for that. Reported December 13th in *Nature*, the new simulations followed the evolution of newborn triple systems. More than 90% of systems were disrupted; those that survived as triplets ended up with two stars closely orbiting each other and the third flung to a far distance, like the red dwarf Proxima Centauri that drifts far from the Alpha Centauri AB pair. From far away, some of these systems would look like wide binaries, the authors suggest. ✦

■ CAMILLE M. CARLISLE

Alas, No Moore

Patrick Moore was the face of astronomy for many in Britain — and around the world.

S&T PHOTO ARCHIVE

SIR PATRICK MOORE died December 9th at his home in southern England; he was 89. Best known as the colorful host of the BBC's *The Sky at Night*, the longest-running program in television history with the same presenter, he missed just one of the show's 721 monthly episodes (having been hospitalized with a near-fatal dose of food poisoning in July 2004). Moore was the instantly recognizable face of amateur astronomy for millions of Britons, the quintessentially eccentric Englishman — and mad scientist — with machine-gun delivery, bushy eyebrows, outsized suits, and his trademark monocle lodged firmly over his right eye.

Patrick Alfred Caldwell-Moore was born March 4, 1923, in Middlesex, England. His interest piqued as a child, he used a newly acquired 3-inch Broadhurst Clarkson refractor to observe the Moon and published his first scientific paper, "Small Craterlets in the Mare Crisium," at age 13, in the *Journal of the British Astronomical Association*. Thus began a lifelong fascination with Earth's satellite.

After serving as a navigator in Bomber Command during World War II, Moore returned to civilian life to teach and resume his observations of the night sky. From his home observatory, he mapped lunar features through a 12½-inch reflector, and his resulting descriptions were used by NASA and the Soviet Union during the early years of the space race.

Following his appearance in a televised debate about UFOs, he was asked to host three pilot episodes of *The Sky at Night* in 1957. Over the next 55 years, Moore's unique personality and natural ability to communicate complex subjects in layman's terms kindled the interest of countless numbers of future astronomers, and turned his show into a cult hit. As presenter, he was witness to the chief astronomical events of the era, from the first man in space to Curiosity on Mars, and he interviewed many of the leading lights of astronomy and space exploration.

John Mason, past president of the British Astronomical Association, knew Moore for 44 years and often accompanied him on trips. "He was the most incredible company, with a wicked sense of humor," he said. "Patrick made astronomy accessible. Millions around the world picked up a book by him that sparked their interest. I believe he was the greatest popularizer of science that ever lived."

Another longtime friend, Terry Moseley, former President of the Irish Astronomical Association, recalled the time when Moore was the director of the Armagh Planetarium in Northern Ireland from 1965–68. "He trod his own path and really enjoyed a good astronomical — and at times, political — debate."

Despite being an almost universally beloved figure, Moore could occasionally court controversy, as when he referred to immigrants as "parasites," and stated that the BBC was being "ruined by women." As he said of himself: "I may be accused of being a dinosaur, but I would remind you that dinosaurs ruled the Earth for a very long time."

Of his many contributions to the field, the Caldwell Catalog may be familiar to many readers (*S&T:* December 1995, page 38), a collection of 109 deep-sky objects that Moore assembled as an adjunct to Messier's list. It now stands as a fitting tribute to a man who spent his life bringing the wonders of the night sky to the public. ✦

Former S&T *managing editor* ***Timothy A. Lyster*** *worked with Patrick Moore on the British periodical* Astronomy Now.

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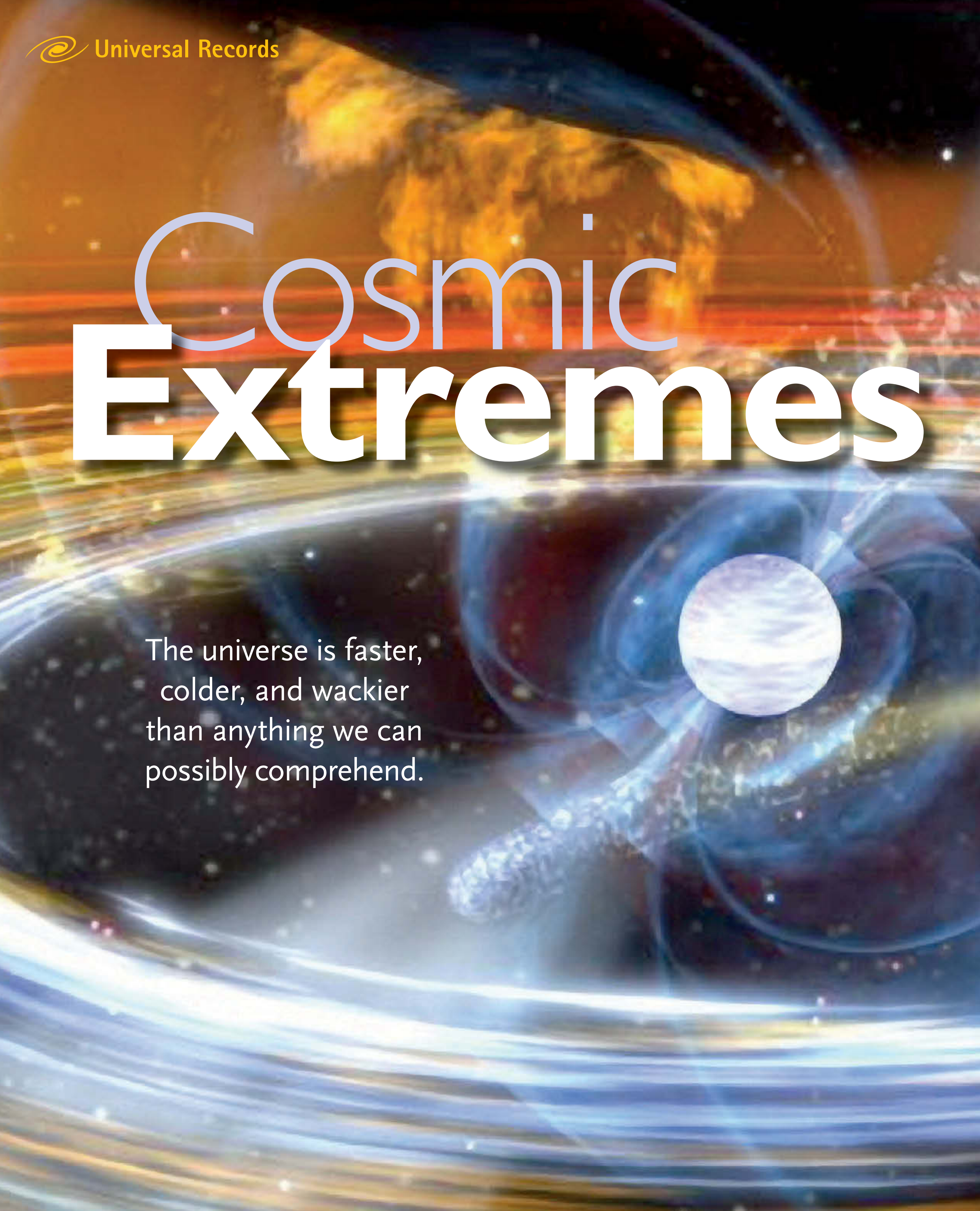
Cosmic Extremes



The universe is faster, colder, and wackier than anything we can possibly comprehend.

NASA

Bryan Gaensler

The universe extends far beyond our everyday experience in every imaginable way. But at the same time, it's truly remarkable that we can actually measure some of the universe's properties. What's more, we think we understand what most of these objects are, how they formed, and why they have their incredible characteristics.

Below I run through some of the concepts we experience on a daily basis: speed, temperature, gravity, density, and size. For each example there are extremes in our own experience: we all feel blazing heat and bitter cold, we see a jet plane speed overhead, and we watch a snail creep through a garden. But what are the absolute extremes that the cosmos can offer?

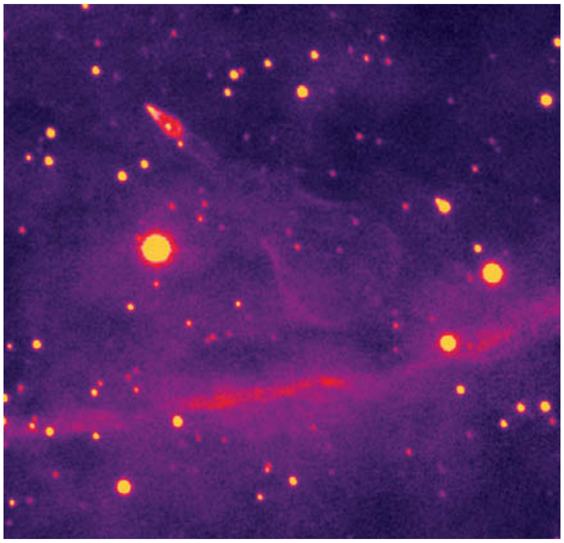
Fastest Spinning Star

Neutron stars are generally born spinning 30 to 50 times per second. But powerful magnetic fields gradually brake their rotation speeds as they age. Millions of years after its birth, a neutron star might spin only once every 5 to 10 seconds. This is still ridiculously rapid compared to most stars and planets, but it's glacially slow for a neutron star.

Bizarrely, some neutron stars can reverse their gradual spin-down. Despite now being hundreds of millions or even billions of years old, these stars spin more rapidly than at any previous point in their lives. The current record holder is a neutron star in Sagittarius named PSR J1748–2446ad, which is spinning 716 times per second! And what's more, this and dozens of other rapid rotators are not only spinning unusually fast, they are barely slowing down at all. A billion years from now, PSR J1748 will probably still be spinning more than 500 times per second — faster than a kitchen blender.

Such neutron stars were originally in a binary system with a normal star. If the orbit is sufficiently small, the neutron star's extreme gravity will strip gas off its companion's surface and drag it down toward its own surface. As this gas swirls downward to the neutron star and impacts its surface, it gradually adds its angular momentum, making the neutron star spin faster and faster. Given enough time, it can reach rotation rates of hundreds of times per second.

WHIRLING DERVISH This illustration depicts a pulsar that is siphoning material from a companion star. The gas forms a disk around the pulsar and eventually spirals in, gradually spinning up its rotation rate. A pulsar named PSR J1748–2446ad is the fastest-spinning star known; it rotates an incredible 716 times per second, near the theoretical maximum rate it can spin without breaking apart.



SHAMI CHATTERJEE / JAMES CORDES (CORNELL UNIVERSITY) / PALOMAR OBSERVATORY

Fastest Known Star:

Neutron stars also hold the record for the fastest-moving stars. If a supernova explosion were perfectly spherical and symmetric, debris would shoot out evenly in all directions, and the newly produced neutron star would sit stationary at the center.

But for reasons that we're still struggling to understand, these detonations are often asymmetric — material is blasted outward in some directions faster than others. Even if the asymmetries are minor, the explosion's energy is so large that if material is blasted away at higher speed in one direction, it can kick the newborn neutron star in the opposite direction at an extreme speed

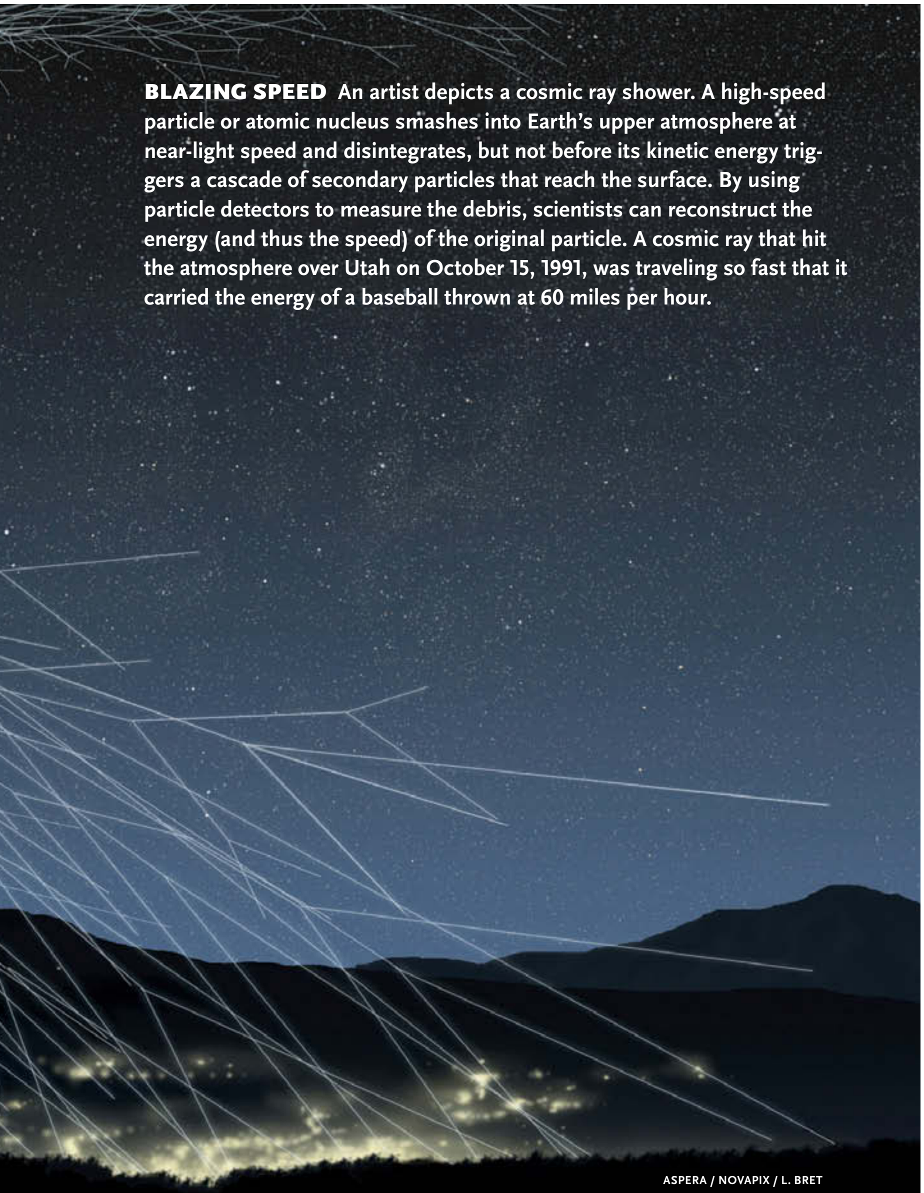
The fastest known neutron star, and indeed the fastest known star of any kind, is PSR B2224+65, an estimated 6,000 light-years away in Cepheus. PSR B2224+65 rotates at the comparatively sedate rate of 1.5 times per second. But what it lacks in spin it makes up for in sheer speed. If the distance estimate is accurate, the pulsar is racing through space at an incredible 3.6 million miles per hour. This is 4,700 times the speed of sound in Earth's atmosphere, 50 times faster than Earth's orbital speed around the Sun, and about twice as fast as the recently discovered population of hypervelocity stars that have been ejected from the Milky Way by a close encounter with the central supermassive black hole. PSR B2224+65 travels the distance from New York to Los Angeles every 2.5 seconds, and the Earth-Moon distance every 4 minutes.

GUITAR NEBULA ***Top of page:*** **The pulsar PSR B2224+65 races through space at an estimated 3.6 million miles per hour, making it the fastest known star. As it plows through interstellar gas, it produces a bow-shock nebula resembling a guitar. This image was taken through a hydrogen-alpha filter by the 200-inch Hale Telescope on Palomar Mountain.**

Fastest Known Object Other Than Light:

Trillions of cosmic rays crash into Earth every second. Cosmic rays are not actually "rays" per se; they are subatomic particles and atomic nuclei that typically travel at around 99% of the speed of light. This is faster than almost anything else in the universe, but it's still almost 7 million miles (11 million kilometers) per hour slower than light itself. But a tiny fraction of cosmic rays makes 99% of light-speed seem downright sluggish. This rare population of ultrahigh-energy cosmic rays approaches the fastest speeds possible under the laws of physics.

The definitive record for the fastest speed ever measured in the universe, except for light itself, was set at 1:34:16 a.m. local time on Tuesday, October 15, 1991, at the High Resolution Fly's Eye Cosmic Ray Detector near Dugway, Utah. A cosmic ray slammed into Earth's atmosphere, detonating into a spectacular shower of secondary particles. Using the pattern and extent of this debris, scientists reconstructed the speed at which this proton or atomic nucleus must have



BLAZING SPEED An artist depicts a cosmic ray shower. A high-speed particle or atomic nucleus smashes into Earth's upper atmosphere at near-light speed and disintegrates, but not before its kinetic energy triggers a cascade of secondary particles that reach the surface. By using particle detectors to measure the debris, scientists can reconstruct the energy (and thus the speed) of the original particle. A cosmic ray that hit the atmosphere over Utah on October 15, 1991, was traveling so fast that it carried the energy of a baseball thrown at 60 miles per hour.

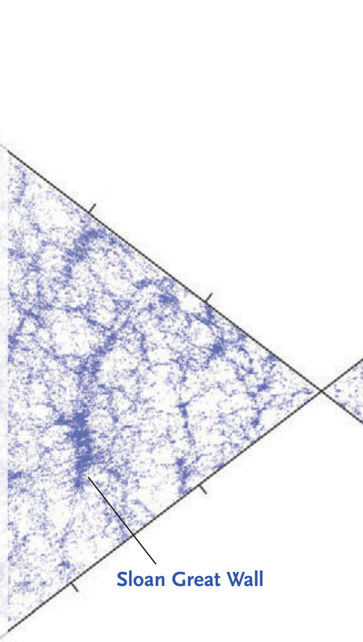
ASPERA / NOVAPIX / L. BRET

hit our planet, and the result was astonishing: it was moving at 99.9999999999999999999996% of the speed of light! Put another way, suppose this particle raced a light ray over a length of a million light-years. The light ray would beat the proton to the finish line by only about 1.5 inches (4 cm). Talk about a photo finish!

The cosmic ray seen in October 1991 earned its own moniker: the "Oh-My-God Particle." This particle's energy was staggering: more than 12 calories of energy when it arrived at Earth. To put this in perspective, consider the Large Hadron Collider (LHC) — the most powerful particle accelerator ever constructed. The LHC can boost subatomic particles up to a maximum energy of only around 0.0000002 calorie. Some unknown natural process in the cosmos can accelerate a tiny particle to an energy 50 million times greater than we humans can achieve. Such particles carry the same energy as a baseball thrown at 60 miles per hour.

Largest Object:

The largest known structure in the universe is a colossal filament of thousands of galaxies known as the Sloan Great Wall, discovered in 2003. The Sloan Great Wall is approximately 1.4 billion light-years across, and runs behind the constellations of Hydra, Sextans, Leo, and Virgo, stretching across almost a quarter of the sky. It's not a single linear thread; instead, it writhes and twists, even splitting up into two separate tendrils for a few hundred million light-years, which then rejoin farther along.



THE 2DF GALAXY REDSHIFT SURVEY TEAM

Fastest Orbiting Planet:

The record for the fastest known orbital motion of any planet goes to HD 80606b. A few times more massive than Jupiter, HD 80606b traces out a highly elongated, cometary-style orbit, completing its path around its parent star every 16 weeks. For part of its orbit, HD 80606b moves relatively slowly, and sits about as far from its star as Venus does from the Sun. But for a brief interval in every orbit, it swings inward, venturing 13 times closer to its star than Mercury's distance from the Sun. At closest passage, HD 80606b hits a top speed of 529,000 miles per hour, or almost 150 miles every second.

S&T: LEAH TISCIONE

Deepest Known Note:

The deepest note in space yet identified belongs to the galaxy cluster Abell 426, often nicknamed the Perseus Cluster because of its location in that constellation. Abell 426 is about 250 million light-years away.

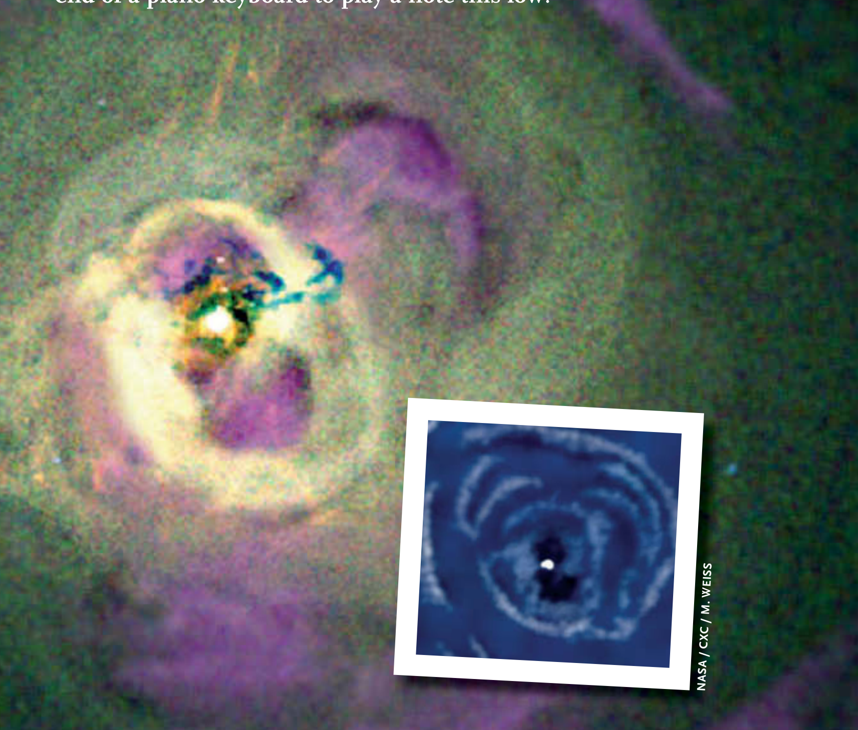
Although we can never directly hear Abell 426's tune, we can see the pressure waves it generates. The gas that permeates the cluster, is incredibly hot, with a temperature exceeding 50,000,000°F. At this extreme heat, this gas becomes incandescent, and radiates extremely energetic and copious X rays.

In 2002 Andrew Fabian (University of Cambridge, U.K.) used NASA's Chandra X-ray Observatory to make a detailed image of the X-rays produced by Abell 426's hot gas. These observations surprisingly revealed a series of concentric ripples like those we see around a stone thrown into a pond. Fabian and his colleagues showed that these ripples correspond to places in the cluster where the gas density is slightly higher than the average. In the gaps between the ripples, they found that the gas density is slightly lower than average. Since a higher density means a higher pressure (and a lower density means a lower pressure), these ripples are oscillations in pressure, a giant sound wave that thrums throughout this vast cluster.

The origin of this racket is a supermassive black hole at the cluster's center. This black hole blasts out two oppositely directed high-speed jets of material that travel outward over millions of light-years at nearly the speed of light. These twin jets must force their way through the cluster's hot gas. Like a garden hose running underwater, the jets' collision with the cluster's gas generates a series of bubbles that inflate under the jets' power, and then break off and drift outward. As these bubbles expand, they shove the surrounding gas outward, setting up the pressure oscillations that ring through the cluster.

Determining the pitch of the corresponding note is relatively easy. The speed of sound in this 50,000,000°F gas is about 2.6 million miles per hour, and the spacing between each ripple is about 36,000 light-years. We simply need to divide the speed of the wave by the spacing of the ripples to determine the rate at which the pressure wave oscillates, and thus which note is playing. Fabian and his colleagues reached the conclusion that Abell 426 is humming in B flat.

But this B flat is unlike any note you've heard. The sound waves have an oscillation rate of once every 9 million years, which is 57 octaves below the B flat that's above middle C, or about 6,000 trillion times deeper than the lowest note that the human ear can hear. You would need to add another 635 keys to the left end of a piano keyboard to play a note this low!



NASA / CXC / M. WEISS

AN ULTRADEEP B FLAT The main image, from NASA's Chandra X-ray Observatory, shows how a giant black hole in galaxy NGC 1275 is affecting the entire galaxy cluster Abell 426. The black hole shoots out two powerful jets (not seen in this picture), which blow through the hot, X-ray-emitting intergalactic gas, creating bubbles that push aside surrounding gas. This energetic interaction generates sound waves that oscillate through the cluster and create ripples *(inset)*. In musical terms, the spacing of the ripples is a B flat 57 octaves below the B flat above middle C.

NASA / CXC / IOA / J. SANDERS, ET AL.

Strongest Electrical Current:

Abell 426's jets produce the gas vibrations associated with a deep note. But the jets from many other supermassive black holes travel unimpeded for a million light-years. Full of charged particles flying outward at high speeds, these jets carry the highest observed currents in the universe, typically at the level of 1 million trillion amps. Their power output is so large that in a single millisecond, one of these jets could provide enough electricity to cover humanity's energy needs for the next 20 trillion years.

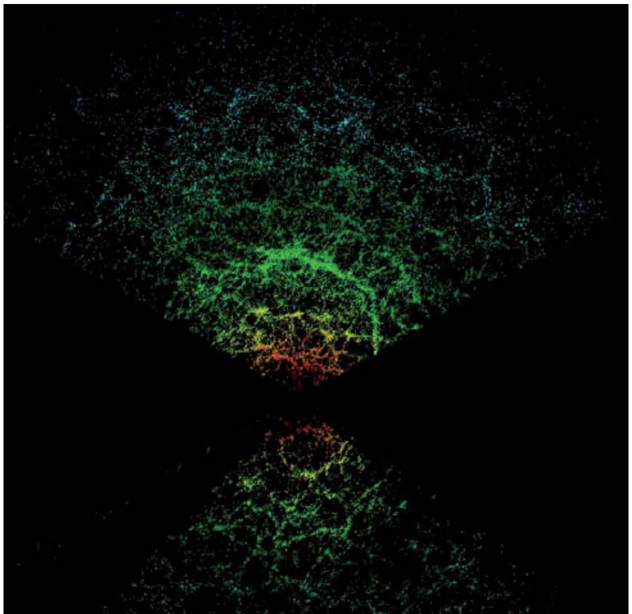
NASA / ESA / S. BAUM / C. O'DEA / R. PERLEY / W. COTTON / HUBBLE HERITAGE TEAM (STSCI / AURA), ET AL

Lowest Density

For centuries, laboratory scientists found clever ways to push to increasingly lower densities, creating ever more rarefied environments. The current state of the art, involving experiments that take several months, results in a gas density of just 500 to 1,000 atoms per cubic centimeter. By all reasonable measures, a gas in this state is a near-perfect vacuum. But the universe can effortlessly deliver far lower densities than this.

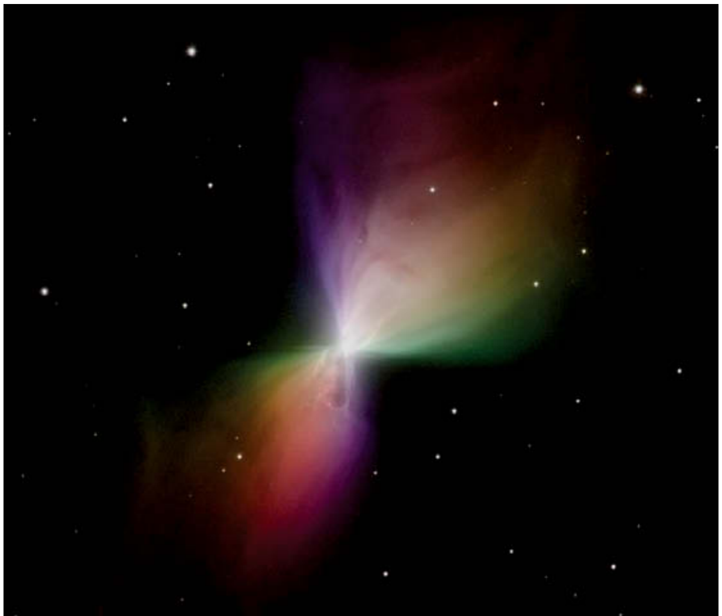
Galaxies are not scattered uniformly throughout the universe, but are arranged into a spectacular web of sheets, filaments, and shells. The walls of these intergalactic soap bubbles are busy agglomerations of stars and galaxies. But the bubble interiors are unimaginably, frighteningly empty. In these vast wastelands, often stretching across space for more than 100 million light-years, there is often nothing more than the occasional lone atom of hydrogen.

The density of a typical void is an incredibly desolate 0.00000002 atom per cubic centimeter. This is so sparse that even in a volume the size of a large room, you would be lucky to find a single atom. Put another way, if you were to grind a bowling ball into its individual constituent atoms, you would have to spread them over a volume 4 million miles across to achieve the same density as in a cosmic void. The massive surveys of the universe that astronomers have undertaken over the last 20 years have now revealed that these voids occupy around 90% of the volume of the universe, with everything else in the margins.



AVOID THE VOIDS Maps of cosmic large-scale structure, such as these slices from the Sloan Digital Sky Survey, reveal that matter is clumped in sheets and filaments that surround vast regions (dark areas) of virtually empty space. Such voids have only an occasional atom per cubic meter.

SLOAN DIGITAL SKY SURVEY COLLABORATION



COSMIC FREEZER Several Hubble Space Telescope visible-light images taken through polarization filters were combined to produce this false-color image of the Boomerang Nebula. The central star is casting off its outer layers, which expand and cool to just 2°F (1°C) above absolute zero. Each lobe is about a light-year long.

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

Coldest Known Place

The coldest temperature allowed by the laws of physics is absolute zero, at –459.67°F (–273.15°C). Laboratory experiments have reached temperatures within a billionth of a degree of absolute zero, but to reach these unbelievably frigid depths requires complicated and expensive equipment. The natural universe has no such equipment at its disposal, so how cold can it get?

The usual answer is the cosmic microwave background (CMB), the afterglow radiation from the Big Bang. The CMB has a temperature of –454.76°F, just 2.73°C above absolute zero, so it heats up space to a few degrees above the minimum possible temperature. But the Boomerang Nebula is even colder.

The Boomerang is a protoplanetary nebula, the result of layers of gas being shed by a star nearing the end of its life. The dying star that created this nebula had an extremely strong wind. For the last 1,500 years of its life, the star has been blasting this wind material into space at almost 370,000 miles (590,000 km) per hour. The star sheds about 70,000,000,000,000,000 tons of material through this wind every second. Besides its high speed, the stellar wind also expands rapidly as it flows outward. This rapid expansion causes a dramatic drop in temperature — essentially the reverse of the effect you experience when your bicycle pump heats up as you squeeze air into a tire.

The result is that the Boomerang Nebula's gas is at a bone-chilling –457.8°F (–272.1°C), even colder than the CMB. Although the central star powering the Boomerang Nebula is very hot, the combination of a high-speed wind and rapid expansion has produced the coldest natural place we know of in the universe, with a temperature even lower than the extreme chill of the surrounding space.

Weakest Gravity:

Black holes exert powerful gravitational forces, but what lies at the other end of the spectrum? How weak can gravity get? Or to rephrase the question more carefully, what is the gentlest pull that any object in the universe exerts, and yet is still able to force another body to orbit it?

Many small galaxies have correspondingly weak gravity. But if two low-mass galaxies can somehow come together in an isolated region of space such that they can move without being affected by larger galaxies, they can reach out with their feeble gravity and take up a fragile orbit around each other.

Of the many binary pairs of small galaxies we know of, the pair that is bound together most weakly is an obscure duo known as SDSS J113342.7+482004.9 and SDSS J113403.9+482837.4, or as I like to call them, Napoleon and Josephine. These two galaxies are 139 million light-years from Earth in Ursa Major. Napoleon and Josephine are 40,000 times too faint to see with the naked eye and, even through a telescope, they make a rather unimpressive couple. Each galaxy is about a thousand times less massive than the Milky Way, and both appear as unremarkable smudges in deep astronomical images.

But what's surprising about these two galaxies is the weakness of the gravity with which they hold each other together in their orbit. The larger of the two, Napoleon, reaches across 370,000 light-years to its companion with a gravitational attraction 900 trillion times lower than an apple experiences when it falls from a tree. If you hovered at the position of Napoleon and dropped an apple toward Josephine, you would have to watch the apple for 50,000 years for it to accelerate up to a speed of about an inch per second, slightly faster than a garden snail. Wait another 4 million years or so, and it would move up to around walking speed.

Not surprisingly, with this incredibly weak gravity between them, these galaxies take an eternity to orbit around each other. In fact, in the billions of years since these two galaxies formed, they have probably passed through barely one-fifth of their first orbit. And it's unlikely they will ever complete that orbit. The gravitational attraction between Napoleon and Josephine is so weak that it's merely a matter of time before some wandering galaxy interloper passes through their neighborhood and uses its stronger gravity either to capture these two into its own orbit, or to scatter this delicate pairing to the winds.

HEADING FOR DIVORCE The two circled galaxies that the author has nicknamed Josephine (top) and Napoleon appear as faint smudges in this Sloan Digital Sky Survey image. The galaxies are just barely bound to each other gravitationally. Other points of light in this field are either foreground stars or background galaxies.

SLOAN DIGITAL SKY SURVEY COLLABORATION

Extreme Cosmos

The numbers that measure cosmic extremities can at first seem difficult to comprehend. But on closer inspection, the universe's extremes become not only comprehensible, but turn out to be the vital keys needed to unlock the true wonder and elegance of the heavens. Despite the seemingly hopeless mismatch between our limited human imaginations and the size and complexity of the universe, it's astonishing that we understand so much of what we see. As baffled and cowed as we often find ourselves when confronted by the cosmos, it's perhaps humanity's ultimate accomplishment that we nevertheless can explain and appreciate the grandeur we observe in the night sky. ✦

Bryan Gaensler *is an Australian Laureate Fellow at the University of Sydney and is the Director of the Australian Research Council Centre of Excellence for All-sky Astrophysics. Follow him on Twitter at* ***@SciBry****.*

Where Goes the Rain?

Donald F. Robertson

It is raining. A stream emerges from a wide canyon cut through low hills. It meanders across a fine-grained beach and runs gently down to a calm sea.

At first glance, the scene looks remarkably like Earth. Look closer, though, and this rain is fantastically strange. The raindrops are half again the size of drops on our planet. They fall with dreamlike slowness in the low gravity beneath a hazy, orange sky. This rain is not made of water: it's methane (CH_4).

This vision of Saturn's giant moon Titan is not pure fiction. Since the paired NASA Cassini spacecraft and ESA Huygens probe first arrived in the system in 2004 (*S&T*: January 2005, page 20), scientists have discovered indirect but strong evidence for rain on Titan. Cassini has observed temporary discoloration of desert sands in the wake of cumulus clouds, and radar images show canyons and dendritic channels, which imply drainage from precipitation.

Some of these channels may be active riverbeds emptying into dark areas near the poles. These areas can be the size of North American Great Lakes. Specular reflections — like sparkles on a lake at sunset — and other evidence imply that the dark features are liquid-filled seas. If so, they are mirror-flat. The moon's weak surface winds are typically predicted to blow below the threshold necessary to make waves, but they might kick up occasional ones up to a half meter (less than 2 feet) tall during summer, says planetary scientist Alex Hayes (Cornell University).

Flat, lake-like features, dendritic channels, river deltas, and discolored sands — it all adds up to strong, albeit circumstantial, evidence for rainfall.

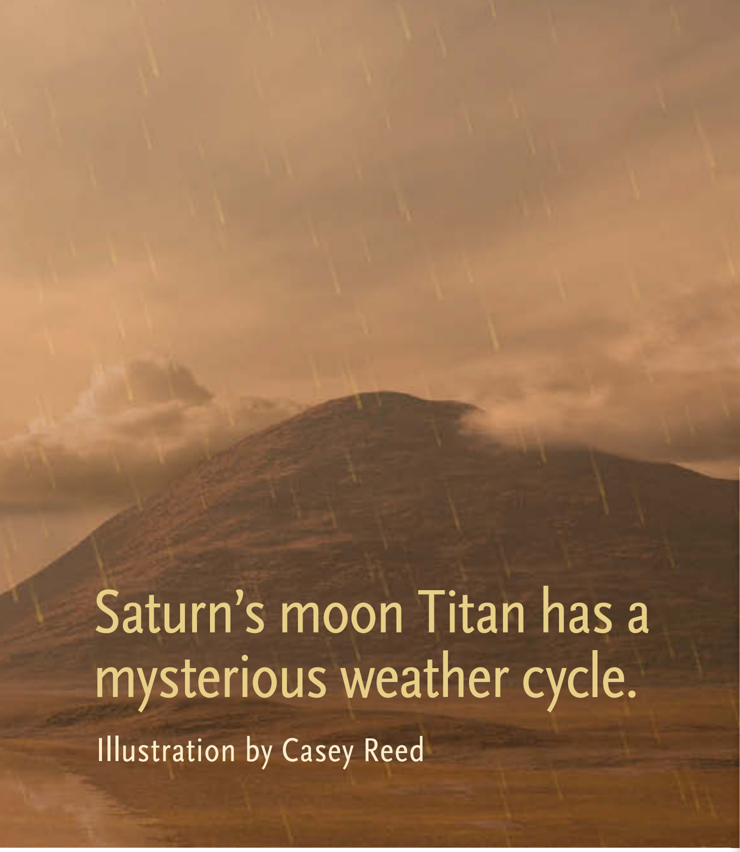
If it does rain methane on Titan, the compound must return to the sky through evaporation so that it can fall as new rain. Scientists have had a hard time finding that return path and closing Titan's weather cycle. But recent studies have uncovered strong evidence of evaporation — and potentially from an unexpected source.

Mysterious Methane

Scientists think Titan's rain is methane because this compound is both abundant in the atmosphere (it accounts for 5% of the atmosphere at the surface, around the same amount as water vapor on Earth) and exists on Titan near its triple point. A triple point is the combination of pressure and temperature that allows a compound to be stable as a solid, liquid, or gas. On Earth, conditions match water's triple point, and water's rapid dance between states, absorbing and releasing solar energy at every step, drives the immense complexity of our weather.

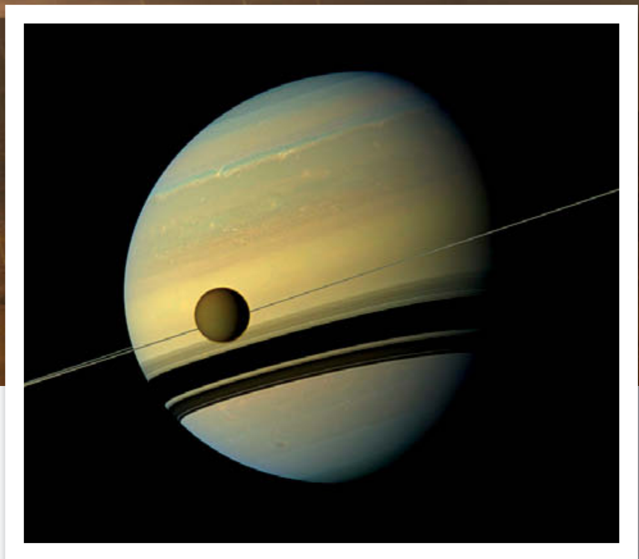
In addition to methane, Titan has a second climate actor: ethane (C_2H_6), which is produced when methane interacts with sunlight. Ethane is not quite at its triple point, but it's not so far off that it lies frozen as an inactive solid. Cassini observations have identified ethane as one of the principal constituents in the lakes. Like a godfather figure pulling hidden strings behind the scenes, ethane is probably active just enough to be important in Titan's long-term climate cycle.

If all it did was rain on Titan, the clouds and methane would soon disappear from the atmosphere. The poles appear to receive annual rainfall, whereas some equatorial



Saturn's moon Titan has a mysterious weather cycle.

Illustration by Casey Reed



NASA / JPL-CALTECH / SPACE SCIENCE INST.

HAZY MOON Larger than the planet Mercury, Titan hides a fascinating landscape beneath its orange haze, visible here in a natural-color composite from NASA's Cassini spacecraft.

regions might wait 100 or even 1,000 years for a torrential storm — the morphology of streambeds suggest that clouds could dump tens of centimeters or even meters of rain. However rare, these storms and the polar rains should deplete the atmospheric methane much faster than typical geologic processes can restore it.

That brings up a second issue, one acting on a far longer timescale. Methane is unstable over geologic times, because solar radiation destroys atmospheric methane. Calculations suggest the moon must generate some 50 million tons of methane each year just to keep its atmosphere enriched to present-day levels. There must be some source of methane seeping out of Titan itself, but it remains unclear what that source is.

Although scientists still don't have the answer to the geologic side of Titan's methane mystery, they're much closer to understanding methane on the seasonal timescales relevant to weather.

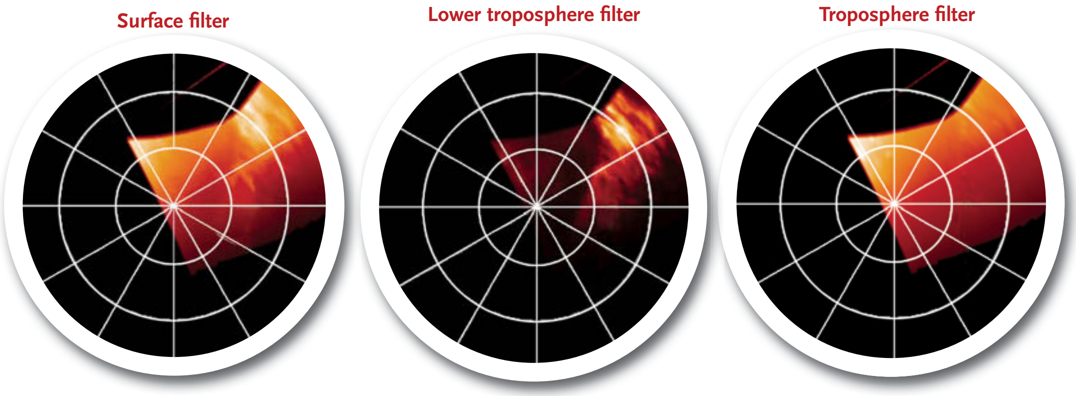
Alien Fog

Titan's extraordinarily deep atmosphere prevents the Cassini orbiter from flying closer to the moon's surface than about 900 kilometers. Because of that great distance and the perpetual haze, Cassini's images have resolutions of hundreds of meters (compared with some orbital images of Mars, where we can distinguish person-size objects).

While Cassini has observed changes in south polar lakes using both its Imaging Science Subsystem (ISS) cameras and its radar — including the disappearance of some small lakes — the exact reasons behind the changes remain unclear, says Hayes. If the removal of liquid is to blame, the hydrocarbons could have either seeped into the ground or directly evaporated into the atmosphere. Last year, researchers discovered potential oases or mudflats near the desert-like equator, patches of sand that might be dampened by liquid only a few inches deep welling up from the ground (October issue, page 12). Careful study of Ontario Lacus, a large lake near the south pole, also suggests it might be a depression that drains and fills from below, implying some sort of "groundwater" (in this case, ground methane).

However, the river-like channels indicate that rain does fall and drain into lakes. And even if the lakes primarily fill from a subsurface reservoir instead of the atmosphere, evaporation must still play a role, Hayes explains. "The methane needs to return to the atmosphere somehow," he says. "The only difference is whether the liquid interacts with the subsurface (either by flowing in a porous medium or by wetting water-ice) before evaporating, or evaporates directly from the pooled liquid."

Earlier in the Cassini mission, Michael Brown (Caltech) and his colleagues found evidence for direct



FOG RISING Fog-like features appear in shots of Titan's surface (*near right*) and also in the lower troposphere (*center*), but are not as pronounced higher up.

MICHAEL E. BROWN ET AL. / *ASTROPHYSICAL JOURNAL*

evaporation, in the form of two different kinds of condensation. The first is lake-effect clouds near the large north polar seas. Lake-effect clouds form as colder air flows over a relatively warm lake, picking up vapor which then condenses over land. One terrestrial example is the heavy snowfall that blows off Lake Michigan and onto residents of Chicago. (But Titan is too warm for methane snow.)

The second type of direct evaporation from the surface is fog. Any fog must lie close to the ground, a long way from prying orbital eyes. In a clever and elegant experiment, Brown's team used an artificial filter to split existing images from Cassini's Visible and Infrared Mapping Spectrometer (VIMS) into four wavelength ranges. Each range penetrated to a different altitude. The scientists looked for temporary features visible near the surface, but not visible higher in the atmosphere.

ALIEN LAKE Cassini caught this flash of sunlight off a lake's surface in 2009. This glint, called a specular reflection, confirmed the presence of liquid in the moon's northern hemisphere.

NASA / JPL / UNIVERSITY OF ARIZONA / DLR

SUBSURFACE OCEAN?

Deep below Titan's icy surface could lie a liquid water-ammonia ocean. Analyses of Cassini observations suggest that an ocean starts somewhere between 50 and 200 km below the crust and is possibly 300 km thick.

After carefully reviewing some 9,000 images by eye, the team found four low-lying wisps near Ontario Lacus. Their spectra were unlike that of any nearby surface, but they were similar to the spectra of methane clouds seen higher in the troposphere. The best fit to the data were clouds of vapor just 750 meters above the ground — fog.

Finding fog and lake-effect clouds does not explain how they got there. Fog generally forms when a compound (such as water on Earth) condenses from nearly saturated air. The only reasonable explanation for such high methane humidity on Titan is that the hydrocarbon evaporates from the moon's surface. Brown and his colleagues suggested that nearly pure evaporating liquid methane would be the best explanation for their results: the fog-like features were made of large particles, such as those found in methane clouds in the troposphere, meaning they probably formed from the condensation of an abundant compound. Methane is the only major surface constituent that could evaporate in the conditions present.

Fog also needs cooled air to persist. Terrestrial fog forms when air temperatures cool to within a couple of degrees of the dew point, the temperature at a given pressure where water condenses. Titan's atmosphere is too dense to cool much on short timescales, even during the world's Earth-day-long evenings. But pools of evaporating liquid methane could drain heat from overlying air, explaining how temperatures could drop to fog-sustaining conditions, the scientists concluded.

Although pure methane could evaporate on Titan, the compound would disappear far too quickly to explain the seas, which are stable on a seasonal timescale. Ethane lies at the other end of the scale. Ethane does not easily evaporate, and its presence in large concentrations actually inhibits the effective evaporation of methane. Scientists think that the lakes are primarily ethane with a bit of methane mixed in, which would make the lakes stable long enough to explain their growth in summer and waning in winter. Titan's year lasts 29½ Earth years, so that stability has to last several Earth years.

Still, the lakes cover only 20% or less of the polar regions during summer; overall, they make up a few percent of the moon's total surface. Whether direct evaporation from the lakes could close the methane cycle on its own is an open question.

By Land, Not by Sea

To understand Titan's meteorology, "one has to show up and observe," says F. Michael Flasar (NASA Goddard Space Flight Center). On January 14, 2005, researchers did just that when the Huygens probe became the first vessel to make landfall in the outer solar system (*S&T*: April 2005, page 34).

Huygens's equatorial landing site (10.2°S, 192.4°W) looks like a sandy flood plain, just off a rugged highland called Adiri. Recent analyses of Huygens's data show that the probe made a 12-centimeter-deep hole when it landed, then bounced out to slide along the moon's surface and wobble to a halt. The landing's dynamics suggest the probe fell on damp sand covered by a dry dust layer, possibly organic particles that drizzled out of the atmosphere. The sand, probably made of water ice or organic material like the dunes, supports pebbles that appear rounded in the same way silicate rocks are eroded in streams on Earth.

During the landing, the Gas Chromatograph Mass Spectrometer's warm inlet tube was shoved into the sand and saw a sudden increase in methane gas, as well as other hydrocarbons. Ralph Lorenz (Johns Hopkins University Applied Physics Lab) argues the GCMS's inlet appeared to be embedded in a surface that acted as an effective heat sink, most plausibly ground that's wet or damp with liquid methane. Erich Karkoschka and Martin Tomasko (both of the University of Arizona's Lunar and Planetary Lab) think the probe's camera might even have seen a methane dewdrop falling from a cold baffle on the descent imager.

The presence of moisture in the sand at the landing site was the clue scientists needed to look for another potential source for the fog. There's no standing methane near Huygens's landfall, but Hayes points out that lakes cover only a small fraction of Titan's surface. "You have a much larger surface area of potentially wet ground," he says. "So, if the liquid is at or very near the surface, the total volume of evaporated methane could be greater over the sand than over a lake surface with a similar composition."

If methane evaporates from the ground, moisture-laden air pulled from the land could pass over lake margins, where it would encounter lower air pressures and temperatures, says Tetsuya Tokano (University of

Descend with Huygens through Titan's haze and see more awesome Titan sights at skypub.com/TitanUnveiled.

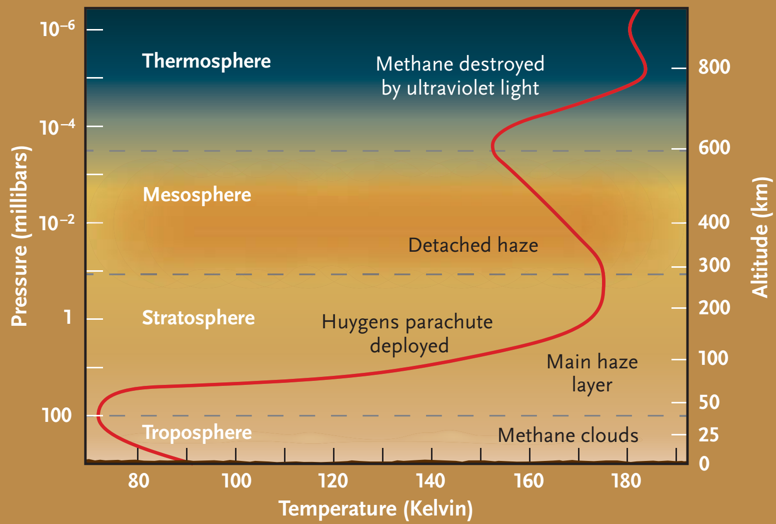
A Foreign Atmosphere

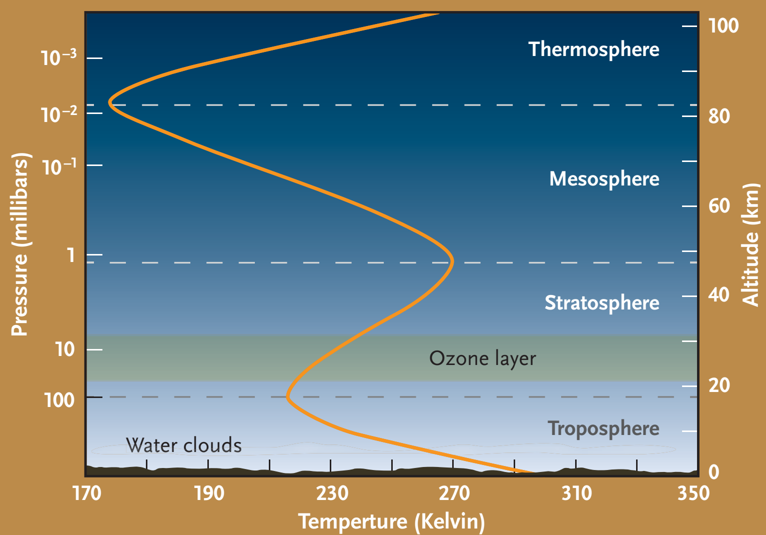
Saturn's moon Titan features many Earth-like landscapes: elevated terrains cut by what look like rain-fed streams and river canyons, the largest dune fields discovered in the solar system, and lakes that rival those on Earth. Even the atmosphere is often described as similar to Earth's.

It's not. Titan's atmosphere is predominately molecular nitrogen and supports cumulus clouds in the troposphere, like Earth, but that is where any resemblance ends. The second most abundant gas is not the chemically hyper-reactive oxygen, or even water vapor, but methane — with the addition of a lot of smog-like complex organic chemicals.

Relative to the planet's size, Earth's atmosphere is about as thin as an eggshell. Three-quarters of the gas lies within 11 kilometers of the surface, and "space" is defined as beginning at 100 kilometers.

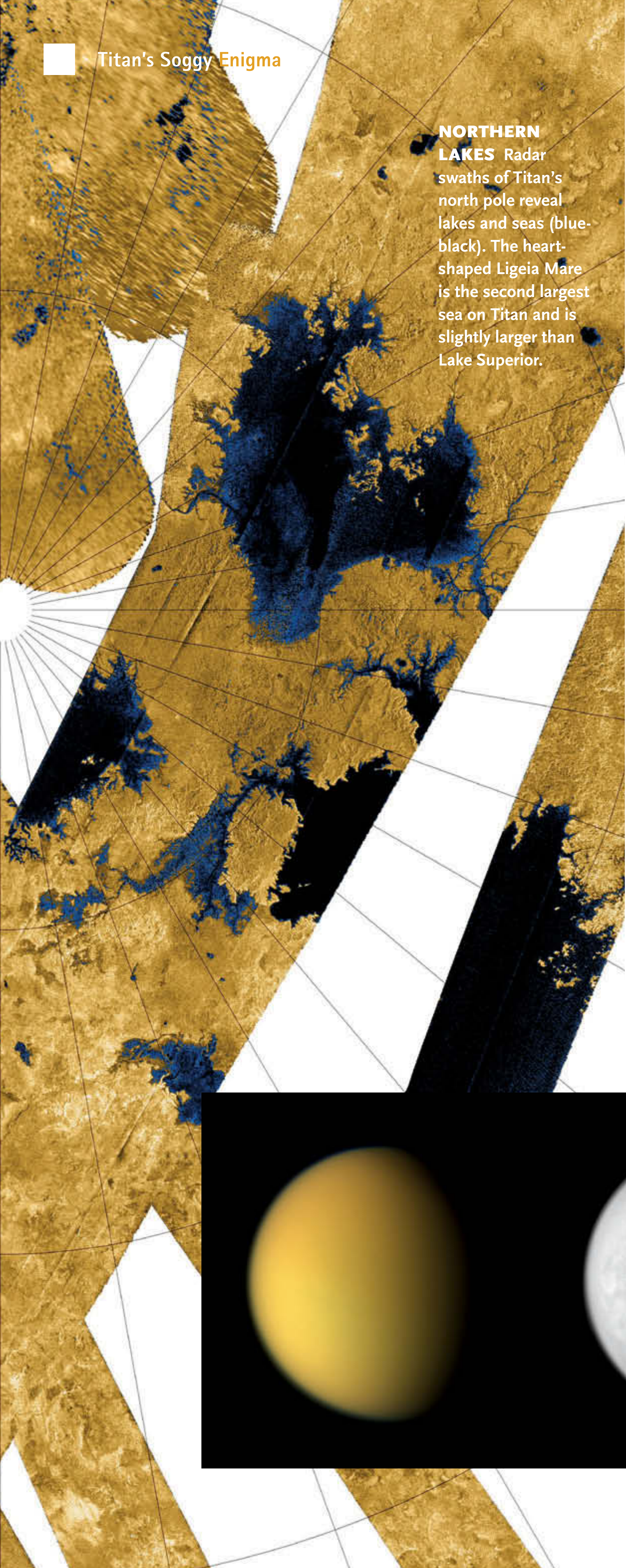
Titan's atmosphere is deep: the atmosphere extends more than 600 kilometers, over one-fourth of the moon's radius. Most of Titan's rain clouds reside above 10 kilometers, many times higher than on Earth. The mass of all that gas on this small world, even in Titan's low gravity, results in a surface pressure 50% higher than Earth's.





S&T: GREGG DINDERMAN

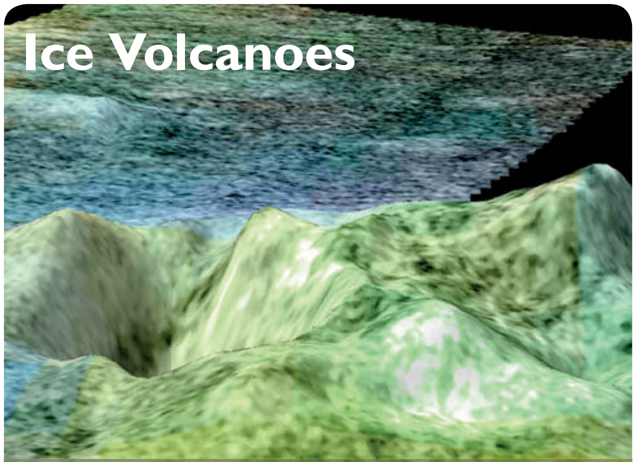
TWINS? NOT SO MUCH Titan's atmosphere *(top)* has similarities to Earth's *(bottom)*, but notice the altitudes: Titan's stratosphere reaches roughly six times higher than Earth's does.



NORTHERN LAKES Radar swaths of Titan's north pole reveal lakes and seas (blue-black). The heart-shaped Ligeia Mare is the second largest sea on Titan and is slightly larger than Lake Superior.

NASA / JPL-CALTECH / USGS

Ice Volcanoes



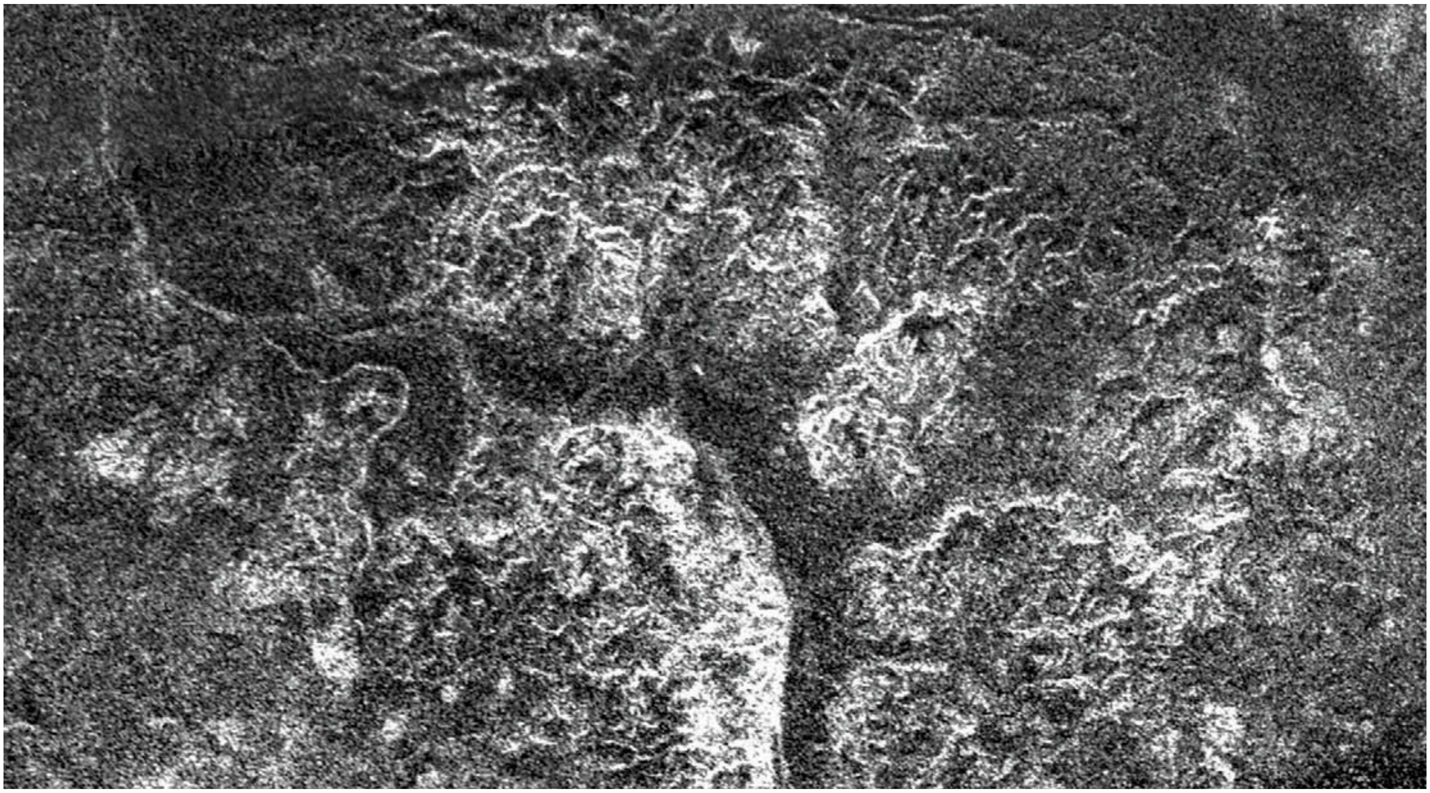
SIMULATED FLYOVER In a 3-D computer model of Titan's surface, created from Cassini data, scientists discovered a 1-km-high peak and a 1.5-km-deep pit (shown) in a region called Sotra Facula. Green marks possible volcanic areas, including potential flows that spread outward from the pit. A blend of water, ammonia, and methane erupting from the pit could explain the features, though scientists still debate whether Titan has cryovolcanism.

NASA / JPL-CALTECH / ASI / USGS / UNIVERSITY OF ARIZONA

Cologne, Germany), who uses detailed climate models to study connections between Titan's lakes and atmosphere. These conditions would encourage methane to condense and rain back out — primarily over and near the sea. Surface darkening associated with cloud activity has indeed appeared near Ontario Lacus, suggesting that rain wet the ground shortly before the images were taken. Hayes thinks these particular features are too far from Ontario Lacus for the rain to have been generated by Tokano's mechanism, but

PEELING THE PEACH Titan's fuzzy orange glow is the only thing visible in a natural-color composite (left), but the surface appears in images taken in near-infrared light (middle) and in a composite of visual and infrared wavelengths (right).

NASA / JPL / SPACE SCIENCE INSTITUTE (3)



NASA / JPL

RAIN-FED RIVERS Cassini's radar revealed this canyon system on Titan in 2009. The channels flow from high plateaus to lowland areas, and their many tributaries suggest that rainfall erodes the surface.

the process could still work elsewhere.

Answers could come in the near future. Brown and his colleagues have used 3-D simulations to track Titan's weather cycle. They suggest that the methane accumulates in polar regions during summer, then somehow travels — either on or below the surface — to lower latitudes and evaporates. Their work not only predicts the rare, intense rainstorms observed in low latitudes, but also that clouds should form around the north pole in the next two years, as that hemisphere transitions to summer. With those clouds should come precipitation, raising northern lake levels over the next 15 years. These changes should be clearly observable by Cassini.

Determining the final answer to how Titan's weather cycle works might have to wait for another surface mission. NASA didn't select the proposed Titan Mare Explorer from its list of Discovery-class applicants, but European scientists are in the early stages of exploring a similar project to sail a Titan sea. Called the Titan Lake In-situ Sampling Propelled Explorer (TALISE), the mission would send a probe to float on Ligeia Mare, one of the moon's largest seas. Perhaps that mission's future discoveries, paired with Cassini's phenomenal work, will help solve the case of Titan's mysterious evaporation. ✦

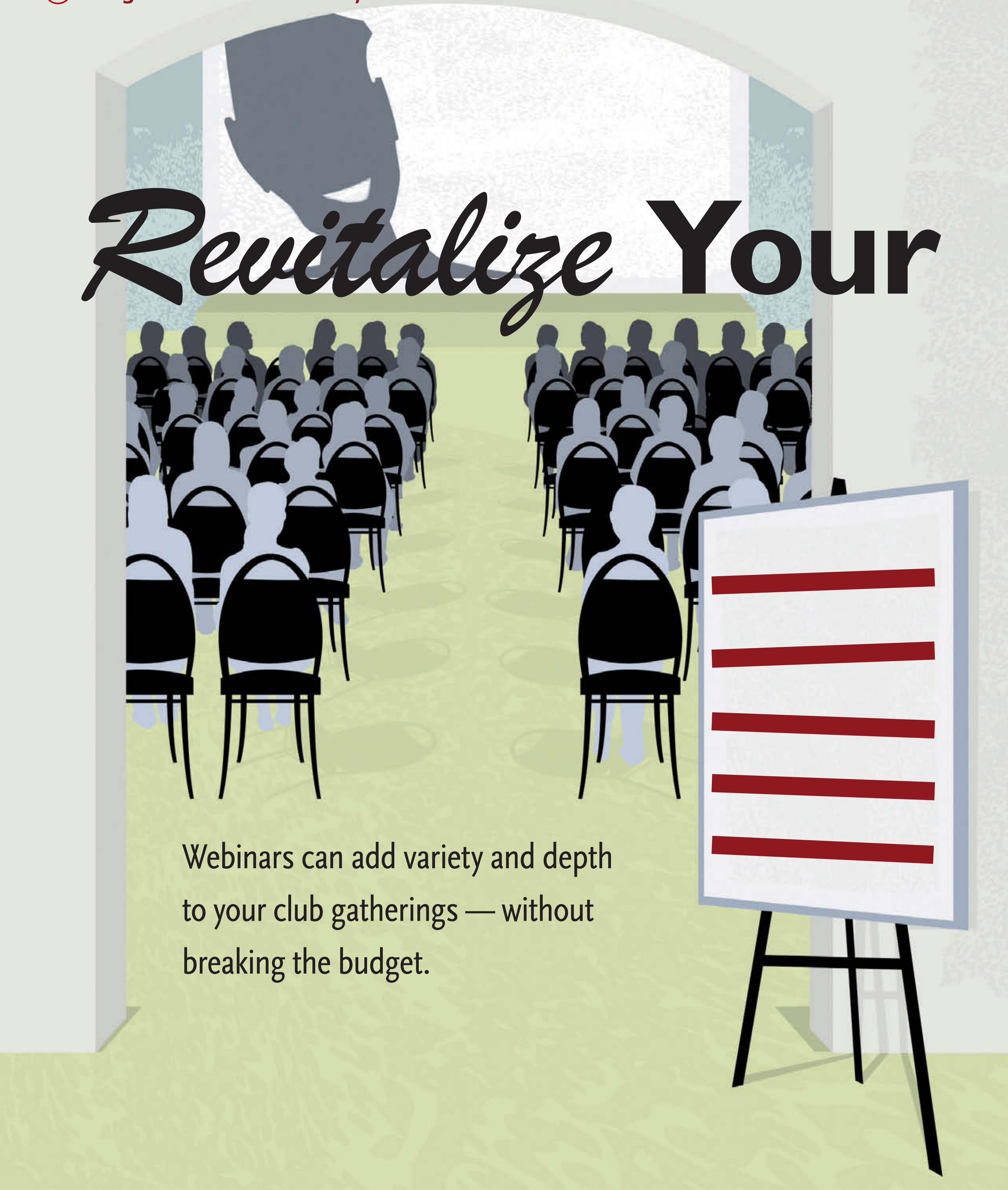
__Donald F. Robertson__ is a freelance writer based in San Francisco. See **www.donaldfrobertson.com** *for more of his work.*

Backyard Titan Observer

Amateur astronomers can help monitor Titan's weather, too, says Ralph Lorenz. At the moment Titan appears fainter than magnitude 9, and although it's above the horizon most of the night it's only 0.8 arcsecond wide, making it a challenging target to resolve. Short-exposure and video imaging can circumvent seeing problems, especially if you stack images. Under good skies a skilled backyard observer with a suitable telescope just might resolve Titan's disk, says Lorenz.

Amateur observations could bridge the gap between Cassini and whatever comes next. It looks increasingly like that gap will be large: no flagship-class mapping missions are on NASA's budgetary horizon. In the meantime, a 20-centimeter telescope with a commercial CCD can obtain useful spectra of seasonal changes in Titan's haze. Several years ago Antonin Bouchez (Caltech), then a grad student doing CCD photometry with a 35-cm telescope in Pasadena, successfully plotted Titan's light curve from night-to-night variations as the moon rotated, although he wasn't able to conclusively determine that the transient bright spots he saw were clouds. Atmospheric structure can also be measured during stellar occultations. You can find out more about observing Titan with amateur equipment on Lorenz's website: **www.lpl.arizona.edu/~rlorenz**.

Revitalize Your



Webinars can add variety and depth to your club gatherings — without breaking the budget.

Club Meetings

Tom Field

Want to watch someone run from a room faster than an Olympic sprinter? Suggest that he or she serve as the speaker coordinator for your club meetings. It's a tough job and few people want it. Whether you live in a big city or a rural area, it can be an enormous challenge to arrange engaging talks month after month. Yet many clubs have managed to dramatically expand their pool of public speakers, even in the most remote locations. Rather than relying on local talent, these clubs invite lecturers to appear live over the web from anywhere in the world.

Now, I know what you're thinking. Web-based talks? Wouldn't that be too impersonal? And wouldn't the quality of the presentation suffer? Years ago, watching a presentation over the web meant enduring grainy video and poor voice quality. But, as I've learned from firsthand experience, advancements in technology have vastly improved the quality of remote presentations.

Without leaving my office, I've spoken for dozens of clubs in locations all over the world, and I've received rave reviews. Meeting attendees feel like I'm right there with them because in addition to high-quality video, most software now includes two-way audio, enhancing interaction during Q&A sessions. I can even see the audience from where I'm sitting in my office in Seattle.

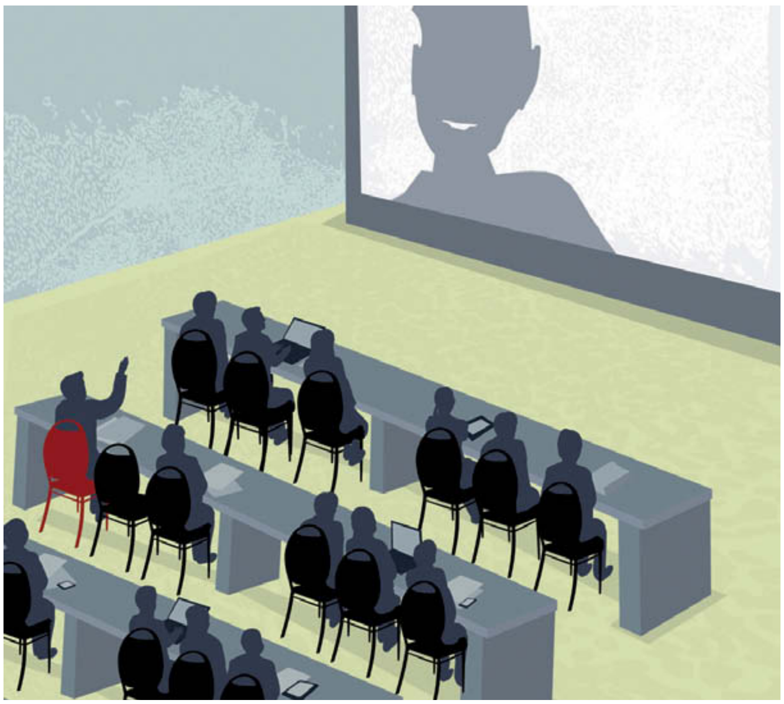
More and more clubs have discovered that web-based presentations (commonly called webinars) can re-energize their club meetings by making available a larger community of fascinating speakers. Businesses regularly use webinars for cross-country and even international meetings; why shouldn't amateur astronomers do the same?

WWW: World Wide Webinars

Last year, three clubs in the Seattle area wanted to hear from renowned imager and supernova hunter Tim Puckett. So the International Dark-Sky Association/Dark Skies Northwest, the Seattle Astronomical Society, and the Tacoma Astronomical Society invited Puckett to speak via the web. Without leaving his home in Georgia, Puckett spoke to the groups about his supernova-search experiences, discussing the tools and skills needed for the job, as well as the challenges involved. Afterwards, club members posed questions to Tim in a two-way Q&A session.

"Many clubs, including ours, don't have the budget to fly speakers into town," explained David Ingram, one of the meeting's organizers. "We had never hosted a webinar speaker and were a bit apprehensive, but it worked wonderfully. It was almost like Tim was in the room with us."

"Our meeting attendees were really excited to have a chance to listen to such an important and well-known expert," Ingram added. "In fact, we are so happy with



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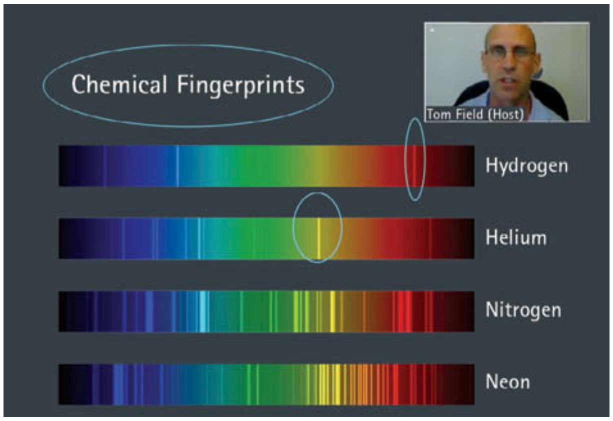


TOM FIELD

NOT SO REMOTE **Tom Field has used *Cisco WebEx* to talk with clubs across four continents from the comfort of his Seattle office. The software shares his slides, shows his video image, and allows him to highlight important features just as one would do with a laser pointer. He can even see and hear the audience as he speaks.**

the outcome that we're planning to use the web to host a variety of other remote speakers at other meetings in the near future."

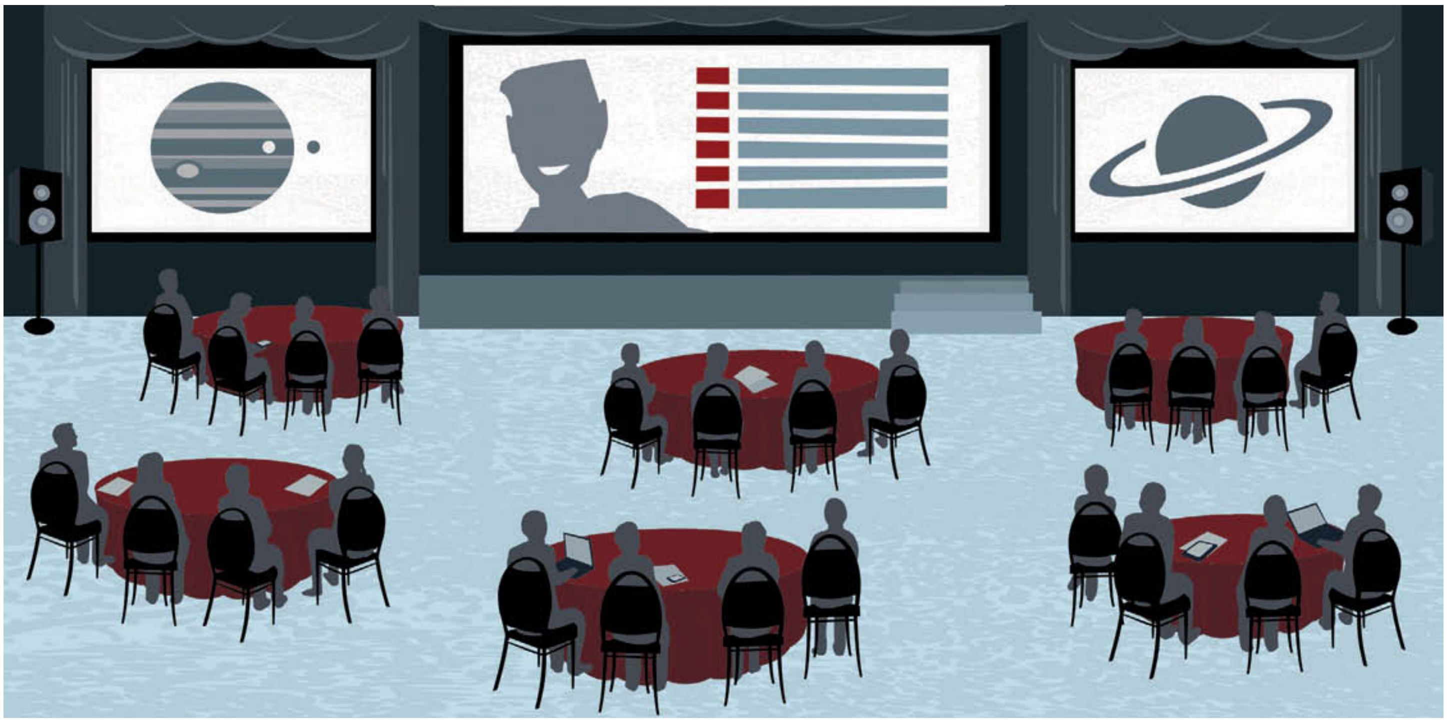
Puckett agreed — he felt that the presentation, his first by webinar, had gone smoothly. "I'm actually surprised more clubs aren't asking for these kinds of remote presentations," Puckett mused. "It's a great way for them to add variety to their meeting agendas. I think this is the wave of the future."

Webinars have become more common at club meetings, and not just in the U.S. In the past year, I've talked with clubs on four continents, including the imagers at Norman Lockyer Observatory, U.K., the Scope-X conference in South Africa, and several clubs in Australia. Distance isn't a factor, except when speaking from the U.S. to a club Down Under — I needed several cups of coffee to stay up long after midnight!

Making Webinars Work for Your Club

Webinar speakers can enrich club meetings, but before hosting a webinar, make sure you have web access. Fortunately, access speed from your club's meeting site doesn't have to be blazingly fast — if you can conduct a video chat from your meeting room, you probably have enough bandwidth. In fact, since the live video window in a webinar is typically a small window on the screen, you need even less bandwidth than a full-screen video call requires.

In most cases, the hosting club won't need special software. Speakers would host the show on their computer, selecting from a wide range of webinar software programs. One option is *Skype*, the video-chat software program. If speakers install *Skype Premium*, they can share their *PowerPoint* slides, along with live video of themselves. Personally, I prefer to use online programs specifically designed for webinars, such as *Cisco WebEx*, because the screen updates more quickly and the program offers more flexibility. Other webinar programs include *Citrix GoToMeeting*, *Adobe Connect*, or *TeamViewer*. Most of these programs run right over the web with no local software installation required. And you'll find that some of them are free for noncommercial use.



Of course, Murphy's Law can strike even the best technology. So in advance of the meeting, I always send the hosting club a backup copy of my *PowerPoint* file. If we happen to run into a technical glitch, the club moderator can step through the presentation on the club computer while I narrate over a cell phone held up to a microphone feeding their public-address system. I've never had to resort to using this backup, but it's a comfort to know that we have a fail-safe way for me to address the meeting in case of technological problems.

Putting it all together

Now that you know how to host lectures from anywhere in the world, you have an enormous speaker pool to draw from. To find speakers who would be willing to appear remotely, you might have to dig a bit. Use your creativity. Since distance is no longer a limit, contact speakers you've seen at NEAF, the Winter Star Party, or other gatherings and star parties. You could also contact authors of articles you've read online or in *S&T*. You can even turn to online forums — if you belong to one, you might notice some participants stand out as being well informed. (Of course, not every expert will be a good speaker. You might want to ask for a 5-minute demonstration or references from groups he or she might have spoken to in the past.)

One resource that can help you find speakers is the free lecture referral service offered by the Astronomy Outreach Network. Founded by Scott Roberts of Explore Scientific, this site has a Lecturers page that lists a variety of speakers (**www.astronomyoutreach.net**). Clubs looking for webinar speakers can contact any of the speakers on the site directly and ask them about their availability. (By the way, if you're a speaker, or would like to be, I encourage you to list yourself there.)

Some lecturers speak for free; others might ask for an honorarium. One budget-friendly possibility is to team up with other clubs and, as a group, invite the leaders in the field to give presentations. With modern webinar software, the clubs don't even have to be in the same place — audiences in different locations (and with different computers) can listen and interact with the same speaker.

Over the next several years, I think we'll continue to see more and more clubs using the web to host remote speakers at their meetings. Webinars open up a whole new world of potential presenters for your club. They not only make the meeting coordinator's job easier, your club members will thank you for the added variety and richness of your meetings. ✦

***Tom Field** of Field Tested Software is the developer of the real-time spectroscopy program* RSpec. *He enjoys giving talks over the web and has spoken to dozens of astronomy clubs and science classrooms around the world. You can see a recorded video demonstration of one of his webinars at* **www.rspecastro.com/outreach**.

Preparing for Your 45 Minutes of Fame

Have you given a talk to your local club that you think other clubs might enjoy? Giving a presentation via the web isn't all that different from giving one in person. A few tips will help you make the transition.

- **Practice, practice, practice.** Once you've selected the webinar software you'll use, learn the basics of how to start a meeting, share your slides, and transmit your video image via webcam. Then practice giving your presentation over the web to your spouse, your children, or your friends — anyone who will listen.

- **Prepare a demo.** Clubs will want to know beforehand if you're a good speaker. When making contact with a club, offer to do a short demonstration talk for the decision-makers or provide a "demo reel" showing a short clip of your presentation.

- **Test it out.** It's always a good idea to conduct a test session with the host well before the actual webinar. Make sure that the meeting room has adequate bandwidth to support your presentation, and confirm that the host club's computer can hook up to the public-address system.

- **Decide how to do Q&A.** Although not absolutely necessary, it's helpful if a microphone and webcam are built into the meeting room's computer so that you can see and hear the audience. But even if a club's computer doesn't have a microphone, the host can conduct Q&A with a cell phone. I've done this on several occasions with good results.

- **Make eye contact.** Look directly into your webcam during your presentation.

- **Keep your audience engaged.** Most webinar programs offer drawing capabilities, so you can circle, highlight, or draw arrows for your audience to see on the screen. Highlighting key points focuses your audience's attention in the same way as a laser pointer does.

- **Ask for feedback.** The day after your talk, ask your contact at the club what you could improve in your next presentation.

My Hunt for Cosmic Jets

A crucial phenomenon throughout the universe is visible in amateur scopes, but just barely.

Dave Tosteson

Astrophysical jets are common in the cosmos, but not in amateurs' observing logs. We read about them in regard to the physics of black holes, the shaping of galaxies, and the birth of stars — but not as observing projects to tackle outdoors in the dark. I decided to try changing that.

Many different things in astronomy produce narrow outflows that go streaming away, on scales differing in size by tens of millions of times. Individual stars squirt jets during their formation. The cores of whole galaxies can emit giant streams at nearly the speed of light.

Think of jets as a cosmic recycling mechanism. They arise when too much material falls toward a massive central body. Infalling matter usually forms an orbiting disk as it gets close, for the same reason water draining from a bathtub forms a whirlpool: angular momentum must be conserved. If the disk becomes overloaded, its inner part ejects the excess away from its poles at high speed — by extreme heat, magnetic fields winding up tightly and bursting away, or both. The processes are complex, not always alike, and not completely understood.

That such a useful and efficient process repeats all over the cosmos isn't surprising. But for a lot of observers, the visibility of jets in amateur scopes may be.

Protostar: Rosette HH1

The jets from prenatal stars are among the smallest and least powerful, but for telescope users, they have the advantage of being relatively nearby.

A gestating star is normally hidden in the cocoon of dust and gas feeding its formation. Deep within this cocoon, the protostar is typically surrounded by a protoplanetary disk. The central body accretes material via the disk until it becomes massive enough to ignite hydrogen fusion and officially turn into a star. But the central mass may be unable to assimilate all the infalling material, due to magnetic and hydrodynamic forces. These forces shape the excess into bipolar (oppositely paired) jets.

Such jets are usually hidden by thick material surrounding the growing system. A stripped-bare exception stands in view within the dim Rosette Nebula in Monoceros, now high in the evening sky. The Rosette's central region is shown on page 39, with the tiny jet arrowed.

This jet is part of **Rosette HH1**, a Herbig-Haro object. These form a class of odd little nebulae named for George Herbig and Guillermo Haro, who studied them 80 years ago. They proved to be jets from protostars, often with bright blobs or shells where the jet impacts the surrounding medium. They sometimes change in just a few years.

Travis Rector, now at the University of Alaska in Anchorage, studied Rosette HH1 in 2003 and noted that its inner jet was distinctly visible telescopically. At 14th magnitude, it can be seen in an 8- to 12-inch telescope under a dark sky. With my 15-inch reflector at home several years ago, under a less-than-ideal sky, I found the jet and its outer bow shock fairly easily.

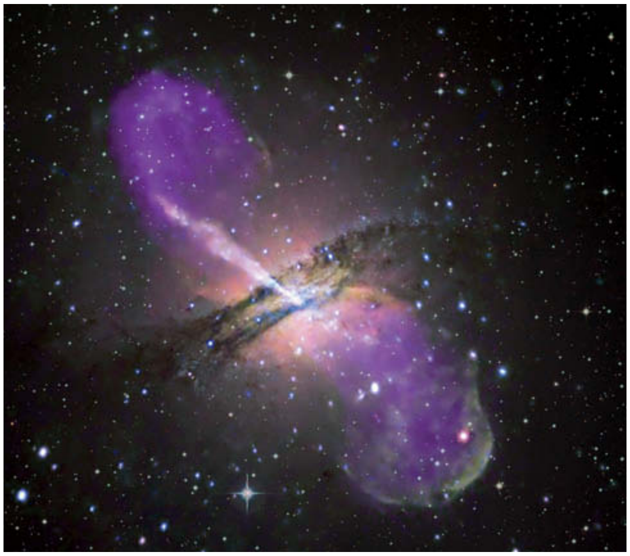
Rector says that Rosette HH1 is one of just a few cases where the protostar and its inner jet are directly visible. This is because stellar winds from the brilliant young stars nearby have cleared out the usual obscuring material. Thus, an object normally seen only at infrared and radio wavelengths is visible by eye.

A related type of object is the V-shaped **Gyulbudaghian's Nebula** in Cepheus, coming from the variable protostar PV Cephei. The nebula is a small open mouth in the wall of a large dark cloud, spewing what the professional literature calls a “giant Herbig-Haro outflow.” The outflow itself is not visible, but the nebula lining its inner portion is. About 1′ in size, it’s a favorite of large-scope observers because it changes shape on a timescale of months. It was easy to see in my 25-inch f/5 reflector.

You need photos to locate correctly such an off-the-beaten-track object as this. An essential resource for really-deep-sky observers is the Digitized Sky Survey (DSS), based on the Palomar Observatory Sky Surveys. Enter your object or coordinates at **stdatu.stsci.edu/cgi-bin/dss_form**, choose either .gif or .fits image format, and you’re served a frame as large as 1° square centered on your chosen point. Gyulbudaghian’s Nebula is at right ascension 20^h 45^m 58^s, declination +67° 58′ 30″ (2000.0).

Active galaxy: Centaurus A

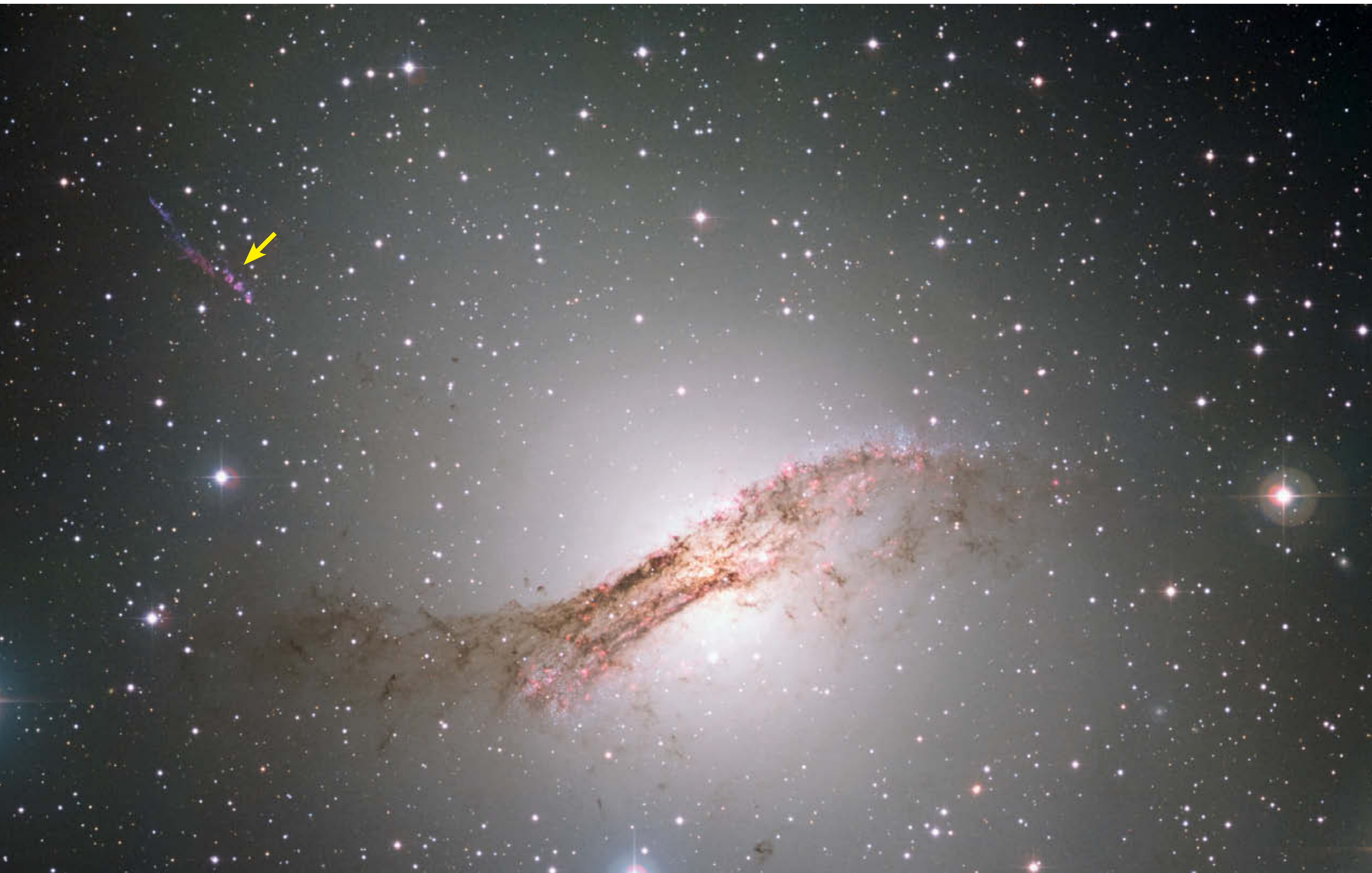
The southern galaxy **NGC 5128**, also known as the radio source Centaurus A, is the closest active galaxy to us at 12 million light-years. Its nucleus may be in the early stages of a reignition. Its jets, however, are known mostly from their spectacular radio and X-ray images. Using my 32-inch under the dark sky of the 2011 Texas Star Party, I saw the visible-light traces of the northeastward jet as a faint wisp several arcminutes long. What I saw correlates well with the streak arrowed in the image below.



NASA/CXC/CFA/R. KRAFT; NSF/VLA/UNIV. HERTFORDSHIRE/M. HARDCASTLE; ESO/WFI/M. REJKUBA

Above: **Big, bright NGC 5128, also named Centaurus A, emits a powerful pair of jets blazing in radio (purple above) and X-rays (shown as blue-white, green, yellow, and orange). This composite image also includes a visible-light view. *Below:* In this deep visible-light image, only a few thin outer traces of the northeastward jet show at all. But the little arrowed streak can be detected in very large amateur telescopes. You’ll also need a very dark sky, high magnification, and this image to find the exact spot.**

EUROPEAN SOUTHERN OBSERVATORY



Active galaxy: M87 in Virgo

Active galactic nuclei arise around the supermassive black holes at the centers of galaxies, especially if the galaxy's inner region has been stirred up by gravitational tides, as seems to be the case in Centaurus A. That galaxy seems to be a tumultuous merger in progress, nearly completed.

M87, an easy find in small scopes at 10th magnitude, is one of the brightest giant elliptical galaxies in the heart of the Virgo Cluster, 55 million light-years away, and is thought to be the most massive of them. It contains one of the most massive black holes known (6 to 7 billion solar masses) and is shooting one of the most famous visible-light jets at close to the speed of light. Recent studies with the Hubble Space Telescope have shown variability within it, likely as a result of interaction with surrounding gas.

This jet too is visible in large amateur scopes. In my 25-inch at the Texas Star Party, I could see M87's jet at 661× during good seeing. It extended northwest from the core by one-third of the galaxy's visible diameter.

Microquasar: SS 433

Once a mystery, the variable star **SS 433** in Aquila was the first "microquasar" discovered. It's a hot binary system in which a primary star feeds so much gas toward a collapsed object — either a neutron star or a black hole — that the X-ray-hot disk around the tiny collapsed object emits jets at a quarter the speed of light. This is an exact miniature version of what happens close to the supermassive black hole in a quasar or active galactic nucleus — just millions of times smaller.

SS 433, located 18,000 light-years away, shows many fascinating features, including radio blobs being ejected every few minutes. Turbulence within the jets heats them to 50 million kelvins as far as a half light-year from the star. The disk and its jets precess like a top with a 164-day period, drawing a corkscrew, as seen in the small radio image at the bottom of the page.

About twice a year, this wobble allows us a glimpse at the spectrum of the primary star that feeds the collapsed object. It seems to be a white, type-*A* supergiant of 11 solar masses. The pair's orbital period is 13.08 days, which corresponds to most of the variability in visible light (about 0.6 magnitude). The accretion disk seems to have an additional wobble with a 6-day period.

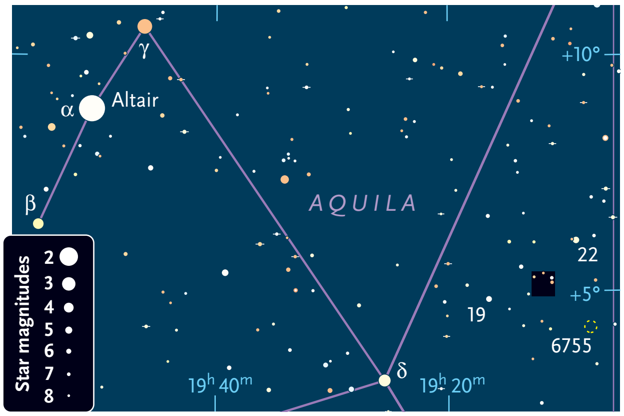
SS 433 is relatively bright for something so exotic, hovering around magnitude 14.0. Although I saw it easily with the 25-inch scope from my home, it appeared stellar and I noted no hint of its jet.

I have also tried to view another microquasar in our galaxy: V1487 Aquilae, or GRS 1915+105, located 5° farther north. This one emits even faster jets and 40 times as much power. But it's twice as distant and heavily obscured in visible light. At magnitude 20-plus, even its central point was out of reach in my 32-inch.

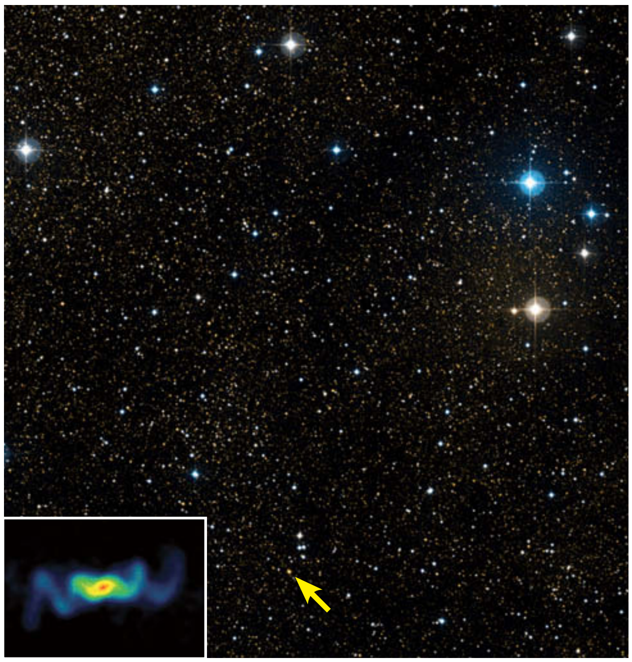
Quasar: 3C 273

The brightest quasar in the sky (though not the nearest) is **3C 273** in Virgo. It varies between magnitude 12 and 13, and at a distance of 2.0 billion light-years, it's the most distant thing that's reasonably easy to see in most backyard scopes. Quasars are active galactic nuclei so bright that they outshine their surrounding galaxies. The famous jet of 3C 273 is tiny. I saw it in my 25-inch at the Texas Star Party as an 8″-long structure extending southwest from the quasar, as in the image at lower right.

Quasars were much more plentiful in the universe's

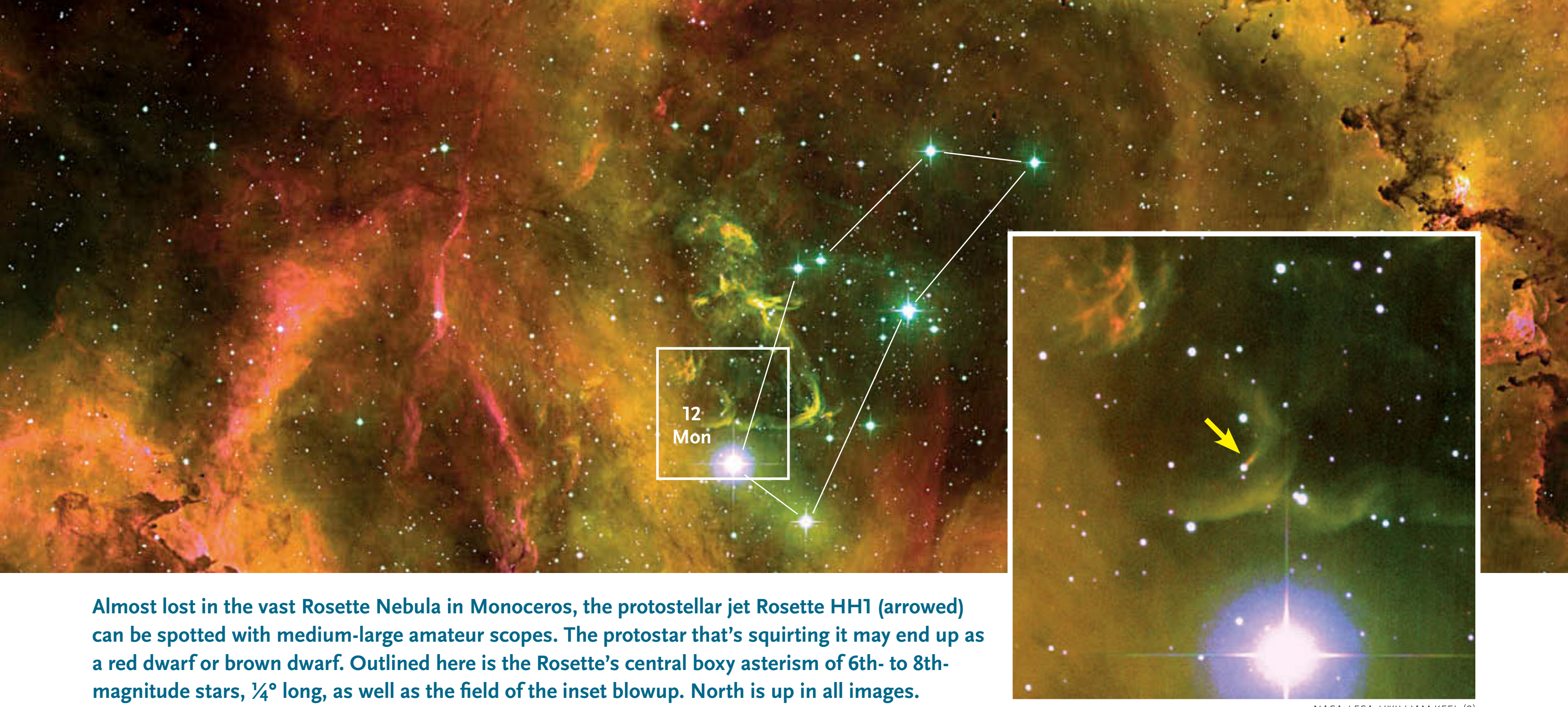


At 14th magnitude, the microquasar SS 433 in Aquila is a unique pickup for your observing list. No sign of its relativistic corkscrew radio jets were visible. On the chart above, the little black box between 19 and 22 Aquilae shows the field of the Digitized Sky Survey view at right, which is ½° wide. The radio image of the jets *(inset)* is from the Very Large Array. Watch a movie of radio blobs being expelled along the inner parts of the precessing jets at www.nrao.edu/pr/2004/ss433.



NRAO

DIGITIZED SKY SURVEY / COLOR COMPOSITING BY *S&T*: SEAN WALKER



Almost lost in the vast Rosette Nebula in Monoceros, the protostellar jet Rosette HH1 (arrowed) can be spotted with medium-large amateur scopes. The protostar that's squirting it may end up as a red dwarf or brown dwarf. Outlined here is the Rosette's central boxy asterism of 6th- to 8th-magnitude stars, ¼° long, as well as the field of the inset blowup. North is up in all images.

NASA / ESA / WILLIAM KEEL (2)

youth, when they had more material to work with. The comparative scarcity of nearby quasars such as 3C 273 suggests that while the proper black-hole equipment remains in galaxies everywhere, the processes that feed the holes have died way down.

Ex-quasar: IC 2497 & Hanny's Voorwerp

A quasar that turned off very recently, astronomically speaking, is thought to lie in **IC 2497**, a 15th-magnitude galaxy about 650 million light-years away in Leo Minor. This is the spiral galaxy next to the curious Hanny's Voorwerp ("Hanny's Object"), a tattered green nebular glob that a Dutch schoolteacher found in 2007 on a Sloan Digital Sky Survey image while volunteering in the Galaxy Zoo project (*S&T:* November 2011, page 28). The object defied inquiry — until astronomers figured that within IC 2497, a quasar that we now see as dormant was shining brightly until no more than 200,000 years ago as viewed from Earth. We still see the quasar's light striking the Voorwerp from the side, making it glow — a form of delayed "light echo." The Voorwerp also appears to have been shaped and eroded by a particle jet from the quasar. At the 2012 Texas Star Party, several people spied the Voorwerp through a 36-inch scope. It lies 20″ south of the galaxy, which is located at $9^h\ 41^m\ 04.8^s$, +34° 43′ 55″.

At a distance of 2.0 billion light-years, 3C 273 in Virgo is the farthest thing you can see with a 6-inch telescope. A much larger scope is needed to detect its jet as a very thin streak running from 12″ to 20″ to the quasar's southwest.

NASA / JOHN BAHCALL

Gamma-Ray Bursts

The most violent jets in the universe, one of the most powerful events of any kind, are what we see as gamma-ray bursts (GRBs). These jets are thought to arise in a special kind of core-collapse supernova. Narrow beams of matter moving at just a hair under the speed of light punch from the core right out of the star; colliding particles within the beams generate the gamma rays. We see a gamma-ray burst when one of these beams happens to be aimed at Earth. Looking down the barrel of the beast, astronomers can decipher fantastic processes billions of light-years away, across most of the visible universe.

Several amateurs, including my friend Tim Parson, have visually observed GRB afterglows by subscribing to the AAVSO International High Energy Network (**www.aavso.org/aavso-international-high-energy-network**), which was set up to image such things rapidly. Some observers have seen the fading afterglows hours after the arrival of the gamma rays. So far I've been shut out in my attempts to join this exclusive club.

But maybe that's just bad luck. On March 19, 2008, a record-breaking GRB went off at redshift 0.937, a look-back time of 7.5 billion years — more than halfway back to the Big Bang. An automated sky survey caught it peaking at an incredible visual magnitude 5.8 for several seconds. Had someone been watching just the right spot in Boötes, this would have been the most distant object ever seen with the naked eye — by a factor of 3,000 — and certainly the brightest astronomical jet ever seen! ✦

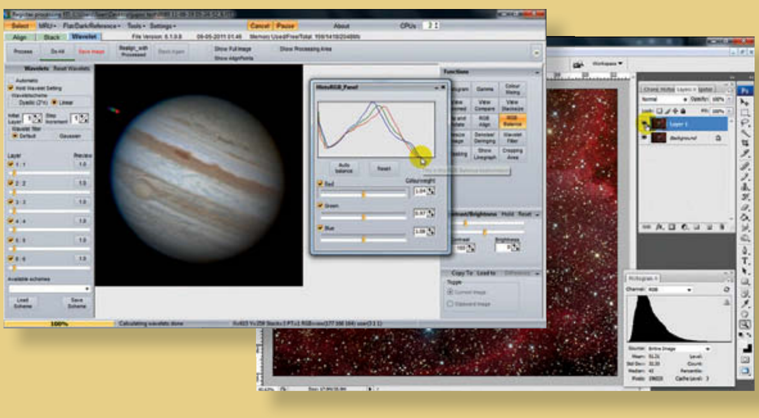
***Dave Tosteson**, a family-practice physician in Chisago City, Minnesota, has used his giant scopes to see brown dwarfs, gravitationally lensed arcs, globular clusters in the Virgo Galaxy Cluster, high-redshift quasars, and galaxies in the Hubble Deep Field.*

◄ **TINY TRACKER** iOptron introduces its SkyTracker ($399), a portable camera drive. The SkyTracker is a 6-by-4-by-2-inch drive unit with a 156-tooth aluminum-alloy gear that attaches to any standard camera tripod, allowing you to take perfectly tracked wide-field photos with your camera. It can reliably support up to 6.6 pounds (3 kg) of gear, and runs for 24 hours on four internal AA batteries. SkyTracker comes with an integrated latitude adjustment wedge with an adjustment range of 0° to 70°, an illuminated polar-alignment scope, and a padded case. A DC power adapter and ball-head are available at additional cost.

iOptron
6F Gill St., Woburn, MA 01801
866-399-4587; www.ioptron.com

▼ **PROCESSING CLASS** Are you interested in getting the most out of your astrophotos? If so, consider the new online video series *Astrophotography Studio* by *Sky & Telescope* imaging editor Sean Walker. Sean takes you through the steps necessary to produce wonderful color images using astronomical CCD and video cameras from raw, uncalibrated data all the way to the final sharpened color images. Two series are currently available. *Astrophotography Studio: Planetary Imaging* details planetary stacking and sharpening using the programs *Registax*, *MaxIm DL*, and *Adobe Photoshop*. The second series, *Processing Deep-Sky Images*, walks the viewer through calibration, combining, and deconvolution processing of galaxies, nebulae, and star clusters with *MaxIm DL*, *CCDStack*, and *Adobe Photoshop*. Each series is divided into convenient chapters and is viewable as streaming, online content.

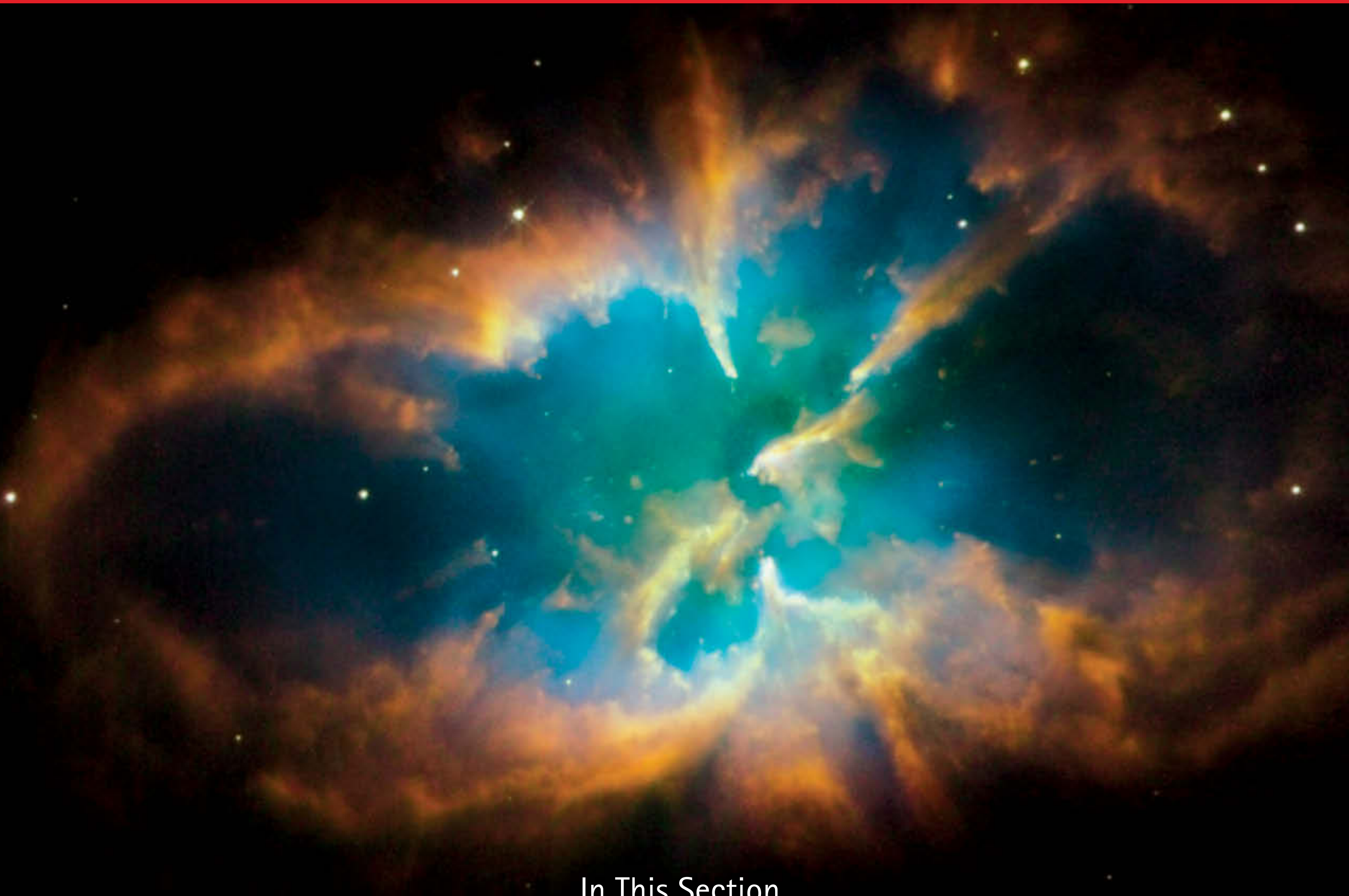
Sky & Telescope
www.skyandtelescope.tv



▲ **AFFORDABLE BIG CCD** QHY Cameras integrates Sony's new large Super HAD CCD detectors in the company's latest release, the QHY12 ($2,699). The camera features a 14-megapixel Sony one-shot color sensor with 5.12-micron-square pixels in a 4,610 × 3,080 array. This low-noise Sony Super HAD sensor with microlensing typically does not require dark calibration, and it downloads a full-frame image in approximately 25 seconds via a USB 2.0 high-speed interface. The camera weighs 400 grams (14 ounces) and includes regulated, dual-stage thermoelectric cooling down to 45°C below ambient temperature. Its adjustable camera housing allows you to square the chip to your telescope's optical axis. See the distributor's website for additional details.

Available in North America through AstroFactors
Building 5, 6000 Custer Rd., Plano, TX 75023
214-764-1323; www.astrofactors.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 Stories:

The remarkable planetary nebula NGC 2818 is discussed in the *Deep-Sky Wonders* column on page 58.

PHOTOGRAPH: NASA / ESA / HUBBLE HERITAGE TEAM / STSCI / AURA

MARCH 2013

Feb. 27 – Mar. 12 **EARLY EVENING:** The zodiacal light is on excellent display from dark locations at mid-northern latitudes. Look west starting about 80 minutes after sunset for a huge, tall, left-sloping pyramid of light reaching up toward Jupiter; see page 51.

1–2 **NIGHT TO DAWN:** Saturn rises around 11 p.m. on the night of the 1st roughly 5° left or lower left of the waning gibbous Moon. The pair remains close for the rest of the night.

7–10 **DUSK:** Comet PanSTARRS (C/2011 L4) should become visible through binoculars, and possibly to the unaided eye, somewhere in this time frame. Look very low in the west shortly after sunset; see page 50 for details.

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

12–18 **DUSK:** Comet PanSTARRS is expected to be most prominent this week. It's immediately left of a very thin crescent Moon on the 12th and well below a more substantial crescent on the 13th.

17 **EVENING AND NIGHT:** Jupiter is spectacularly close to the waxing crescent Moon amid Aldebaran, the Hyades, and the Pleiades.

20 **SPRING BEGINS** in the Northern Hemisphere at the equinox, 7:02 a.m. EDT.

28, 29 **NIGHT:** The Moon, just past full, rises upper right of Saturn on the 28th and below Saturn on the 29th.

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

	◀SUNSET	MIDNIGHT	SUNRISE▶
Mercury		Visible with binoculars in late March	E
Venus		Hidden in the Sun's glow all month	
Mars		Hidden in the Sun's glow all month	
Jupiter	SW	NW	
Saturn		E	S SW

Moon Phases

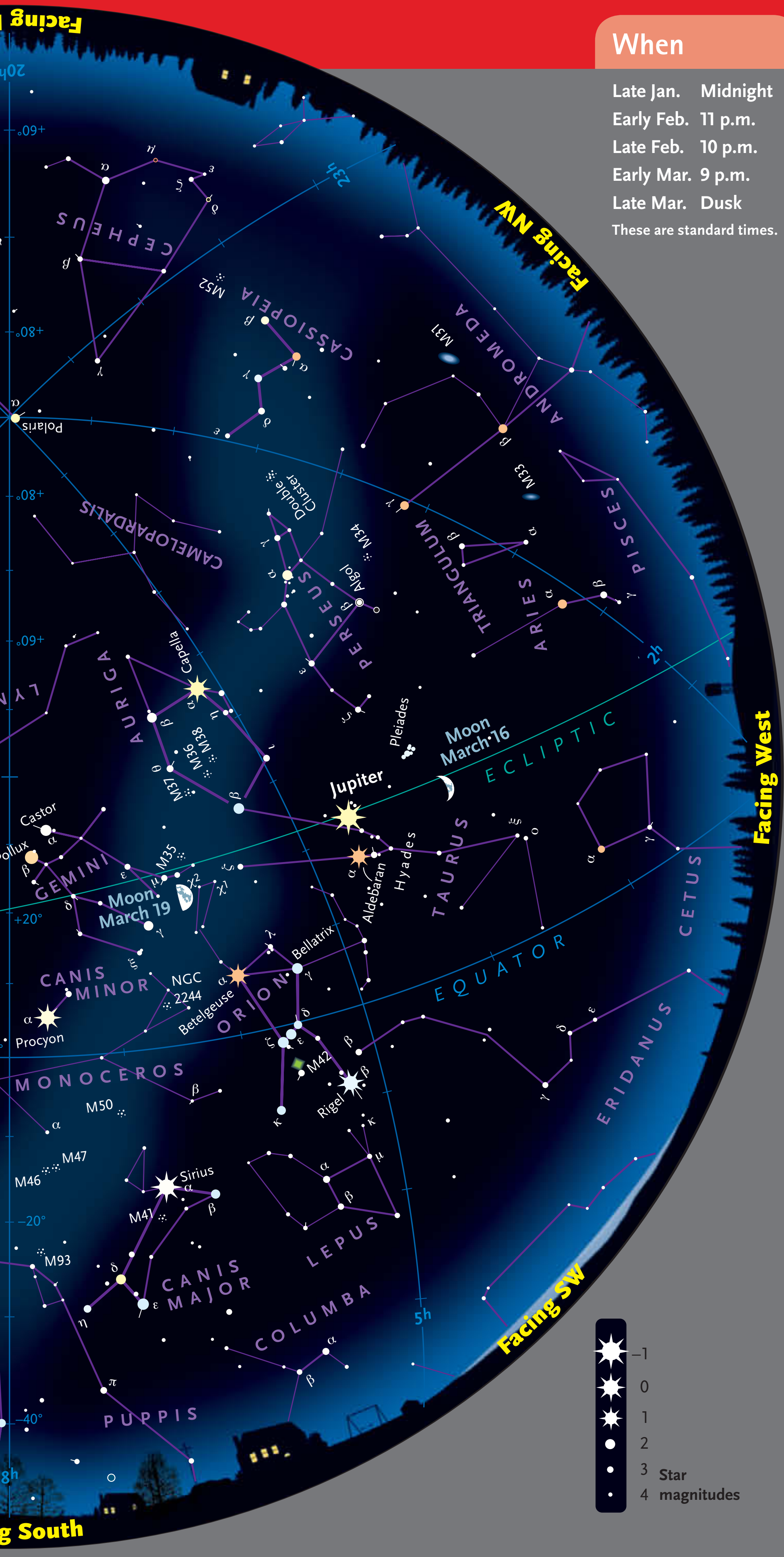
Last Qtr	March 4	4:53 p.m. EST	
New	March 11	3:51 p.m. EDT	
First Qtr	March 19	1:27 p.m. EDT	
Full	March 27	5:27 a.m. EDT	

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

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 Jan.	Midnight
Early Feb.	11 p.m.
Late Feb.	10 p.m.
Early Mar.	9 p.m.
Late Mar.	Dusk

These are standard times.

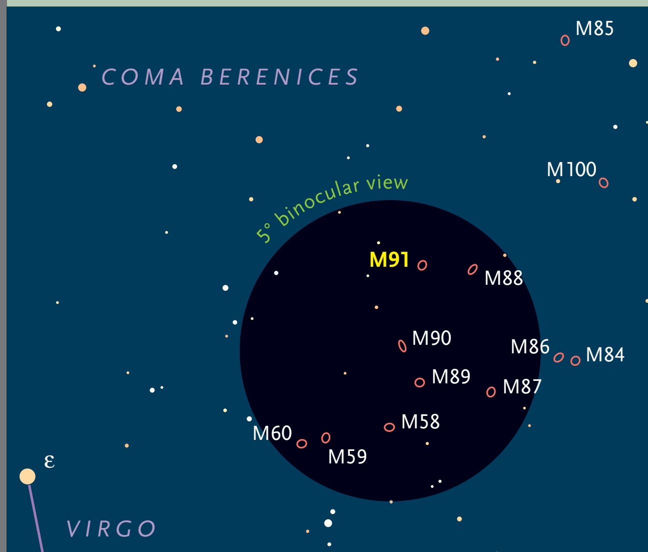
Messier Marathon Season

Every spring, the Sun's journey along the ecliptic returns it to a Messier-free zone near the border between Pisces and Aquarius. During that brief period, it's possible to log all 109 objects in the Messier catalog in a single night. The key word here is *possible* — actually accomplishing that goal is difficult. Invariably, marathoners fight to claim globular cluster M30 before it sets during evening twilight, and to glimpse galaxy M74's faint glow before it's overwhelmed by predawn light. But for binocular observers, these are just two among many significant challenges.

Even without the pressures and fatigue that accompany a marathon session, tracking down all the Messiers in regular binoculars will test your abilities. To have a fighting chance, use binos that magnify at least 10×, and are either image-stabilized or mounted in some fashion. Good, detailed charts are also a must — the *Pocket Sky Atlas* is particularly well suited to the task.

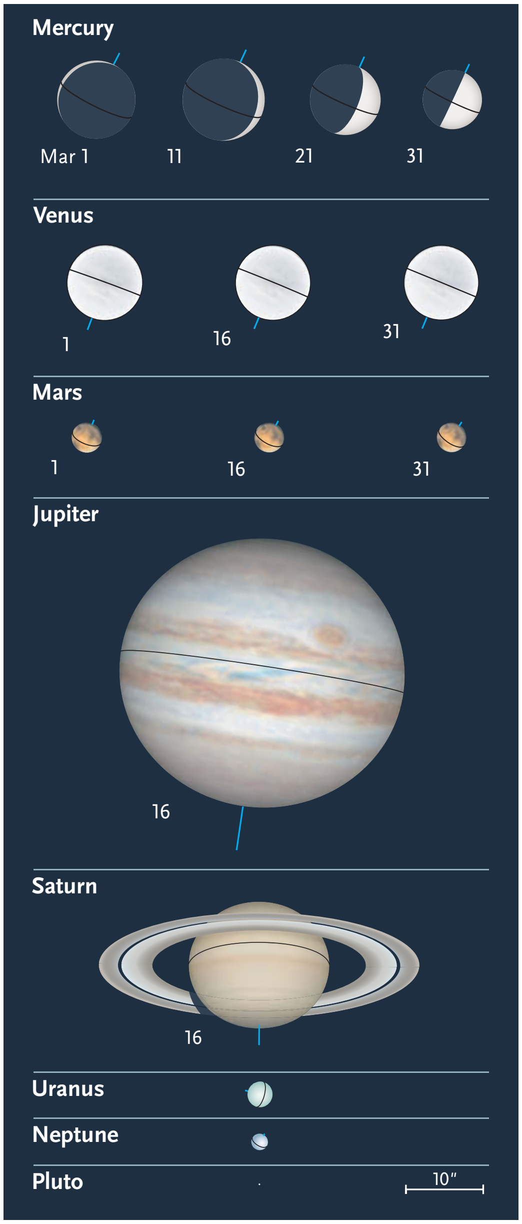
In my non-marathon, binocular Messier survey, I was able to observe every object but one: galaxy **M91**. Try as I might, this 10.4-magnitude puffball eluded me. And M91 is by no means the only tough target. As I noted in the October 2012 issue (page 68), the list of challenging Messiers is long even under ideal conditions. Fortunately, M91 and the swarm of similar galaxies west of Epsilon (ε) Virginis are well placed during marathon season. If you're able to make good headway here, your tally at the end of the night will be pretty impressive.

This year's prime marathon weekends begin on March 9th and 16th. How many Messiers will you see? For observers working under decent skies, it should be possible to log more than half the catalog, and perhaps significantly more. The fun, though, is in the challenge — the results are secondary. ✦



Watch a SPECIAL VIDEO

To watch a video tutorial on how to use the big sky map on the left, hosted by *S&T* senior editor Alan MacRobert, visit SkyandTelescope.com/maptutorial.

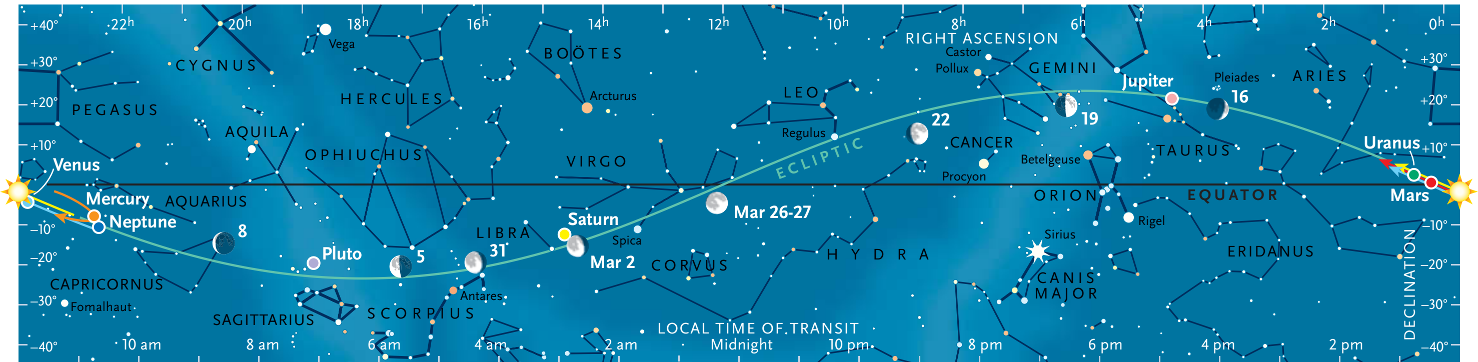


Sun and Planets, March 2013

	March	Right Ascension	Declination	Elongation	Magnitude	Diameter	Illumination	Distance
Sun	1	$22^h\ 47.6^m$	–7° 41′	—	–26.8	32′ 17″	—	0.991
	31	$0^h\ 37.7^m$	+4° 04′	—	–26.8	32′ 01″	—	0.999
Mercury	1	$23^h\ 07.5^m$	–1° 42′	8° Ev	+3.7	10.1″	4%	0.663
	11	$22^h\ 34.2^m$	–6° 03′	13° Mo	+2.8	10.6″	8%	0.632
	21	$22^h\ 30.3^m$	–8° 59′	24° Mo	+0.7	9.1″	31%	0.735
	31	$22^h\ 57.7^m$	–8° 14′	28° Mo	+0.2	7.7″	49%	0.877
Venus	1	$22^h\ 23.5^m$	–11° 29′	7° Mo	–3.9	9.8″	99%	1.701
	11	$23^h\ 10.5^m$	–6° 52′	5° Mo	–3.9	9.7″	100%	1.713
	21	$23^h\ 56.4^m$	–1° 56′	2° Mo	–3.9	9.7″	100%	1.721
	31	$0^h\ 41.9^m$	+3° 06′	1° Ev	—	9.7″	100%	1.724
Mars	1	$23^h\ 28.3^m$	–4° 20′	11° Ev	+1.2	4.0″	100%	2.352
	16	$0^h\ 11.1^m$	+0° 25′	7° Ev	+1.2	3.9″	100%	2.380
	31	$0^h\ 53.5^m$	+5° 06′	4° Ev	+1.2	3.9″	100%	2.406
Jupiter	1	$4^h\ 23.4^m$	+21° 06′	87° Ev	–2.3	39.2″	99%	5.034
	31	$4^h\ 40.1^m$	+21° 46′	61° Ev	–2.1	35.9″	99%	5.498
Saturn	1	$14^h\ 38.5^m$	–12° 46′	119° Mo	+0.4	17.9″	100%	9.287
	31	$14^h\ 33.9^m$	–12° 18′	150° Mo	+0.3	18.6″	100%	8.936
Uranus	16	$0^h\ 28.9^m$	+2° 23′	12° Ev	+5.9	3.4″	100%	21.024
Neptune	16	$22^h\ 22.5^m$	–10° 48′	22° Mo	+8.0	2.2″	100%	30.909
Pluto	16	$18^h\ 47.5^m$	–19° 42′	74° Mo	+14.1	0.1″	100%	32.659

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

Fred Schaaf *has authored 13 books on astronomy.*

Fred Schaaf

Fantasian Skies

Some star myths span entire sectors of the sky.

Raindrop fireflies sparkle on the shop blinds,
Echoes of summertime flicker in the street signs,
Terminal eyes at the edge of the night. . . .

Terminal eyes
Only the lonely Fantasian skies.
Terminal eyes
Calling you home from your restless disguise.
Al Stewart, *Terminal Eyes*

These next few months, I want to take us on an unusual tour of spring's evening skies. It will be organized around sky myths so big and potent that they link together a number of constellations.

Unlike the Fantasian skies of Al Stewart's 1973 song, this particular kind of sky fantasy isn't lonely. Indeed, it's so rich with names, images, and characters that it adds a social dimension to the starry heavens — and helps us better remember and appreciate the locations of interesting celestial sights.

The Orion myth-group. Although much of the great Perseus myth-group of constellations has set by the time of our all-sky map, the Orion myth-group is still well placed for observation.

One Greek myth about Orion describes his lascivious chase of the seven Pleiades sisters. The Pleiades used to be considered a full-fledged constellation, but they're now part of Taurus.

Another ancient myth states that Scorpius killed Orion. But Orion is already setting by the time Scorpius rises: that's the whole point of this story.

Fortunately, Orion the Hunter is so bright that skywatchers have always connected it with neighboring constellations in simple situational dramas. So Canis Major and Minor, the Big and Little Dogs, which follow the Hunter west across the sky each night, must be that hunter's hounds. And the pattern of Taurus suggests a bull lowering its head to charge east — no doubt toward Orion, who must face the onslaught. Finally, Lepus the Hare is just south of Orion and west of Canis Major, so perhaps it's the Big Dog's quarry.

The detailed geometry of the Orion myth-group seems almost too good to be true. Orion's Belt points northwest to Aldebaran and southeast to Sirius — and is equidistant from both. For telescopic observers it's also wonderful that the Orion Nebula is just below the Belt, the star cluster M41 just below Sirius, and M1, the Crab Nebula, very close to Zeta (ζ) Tauri, one of the horn-stars of Taurus.

Taurus the Bull squares off against Orion in this mirror-reversed chart from Johannes Hevelius's 1690 star atlas.

The Argo myth-group. Castor and Pollux, the Gemini Twins, sailed on Jason's great ship, the Argo. And in ancient times, the giant constellation Argo Navis lay far to the south of Gemini. In the 18th century Argo was divided into three constellations: Puppis the Stern, Vela the Sails, and Carina the Keel. Unfortunately, Carina remains permanently below the horizon from latitude 40° north.

East of Puppis and north of Vela is Pyxis the Box Compass, another nautical constellation created when Argo was divided. Hercules was also an Argonaut for a while — but his constellation hasn't risen yet at this hour.

There is one more constellation which belongs in the Argo myth-group, however. Low under Lepus and Canis Major is Columba the Dove. This was the dove that the Argonauts released to test the Symplegades, rock cliffs that would briefly pull apart and then smash together again. The bird just barely got through, though losing some tail feathers, so Jason judged the Argo could get through, too — and it did, losing just a bit of its stern.

What's interesting for observers about the Argo myth-group are its many bright stars and open clusters (see page 56). Argo sails on the Milky Way band, its stars almost directly behind us on our journey around the galaxy. ✦

Giants in the Dark

Jupiter and Saturn take turns shining high on March nights.

Five of Earth's seven fellow major planets are difficult or impossible to see in March. Three have conjunctions with the Sun, and two more have conjunctions in adjoining months: Neptune on February 21st and Mars on April 18th. Sadly, this means that when Mars and Uranus meet on March 22nd — the closest conjunction of two planets since 1942 — the event will be unobservable.

There is some good consolation for observers, however. Jupiter and Saturn, the two planets that remain visible throughout March, are well placed for observation and appear unusually interesting right now.

In addition, a comet low in the dusk may grow sensationally bright.

DUSK

Mars may still be visible through binoculars and telescopes a bare 3° or so above the western horizon a half hour after sunset on March 1st. The sky will be too bright for you to see its 1.2-magnitude light without optical aid.

Mars moves even closer to the Sun as the month progresses, so we won't be able to see its phenomenally close conjunction with **Uranus** on March 22nd. According to master astronomical calculator Steve Albers, this is the tightest conjunction of two planets between 1942 and 2022. Mars is closest to Uranus at 18:17 UT, when their centers are just 39″ apart, and it passes due north of Uranus 10 minutes later.

This occurs during dusk in England, but the two planets are less than 5° above the horizon at the moment of sunset. It's conceivable that Mars (magnitude 1.2, 3.9″ wide) will be detectable through a telescope, but Uranus (magnitude 5.9 and 3.4″ wide) seems out of the question.

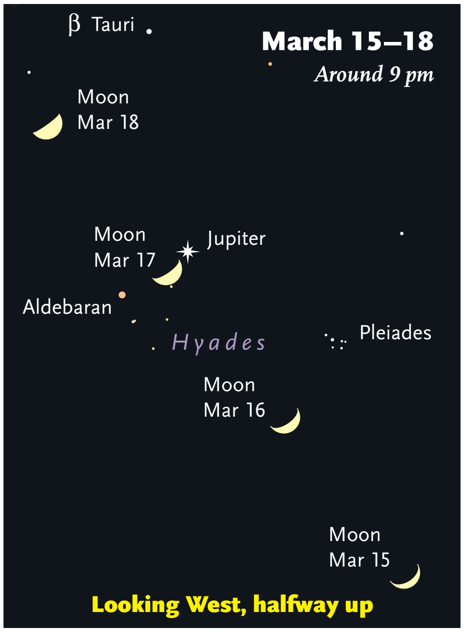
Comet PanSTARRS (C/2011 L4) is the real excitement this month. It may reach magnitude zero or brighter as it passes through perihelion within the orbit of Mercury on March 10th. See page 50 for details.

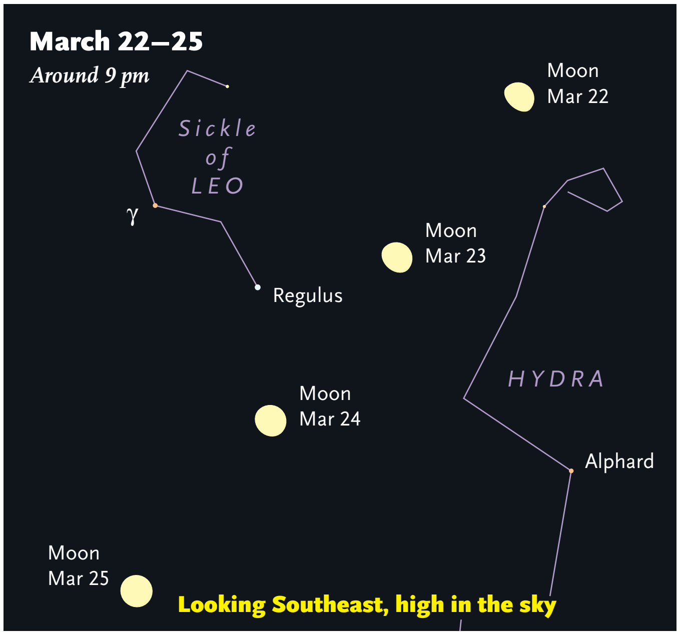
EVENING AND NIGHT

Jupiter treks past Aldebaran and the Hyades in March, appearing about 2/3 of the way up the sky at dusk on the 1st and still halfway up in the west at dusk on March 31st. The behemoth world dims from magnitude –2.3 to –2.1 this month, and its apparent diameter diminishes from 39″ to 36″.

Perhaps most fascinating, however, is the naked-eye or binocular view of Jupiter, which is now picking up speed with direct (eastward) motion against the stars. Jupiter passes due north of light-orange Aldebaran, remaining slightly more than 5° from this brighter (magnitude +0.8 or +0.9) of Taurus's two eyes. Many people consider 3.5-magnitude Epsilon (ε) Tauri, the northwestern end of the Hyades V, to be Taurus's other eye. Jupiter passes just 2.1° from Epsilon on March 8th but ends the month 4° from the star.

Aldebaran, Epsilon, and Jupiter form a straight line on March 1st and a nearly isosceles right triangle on March 31st.





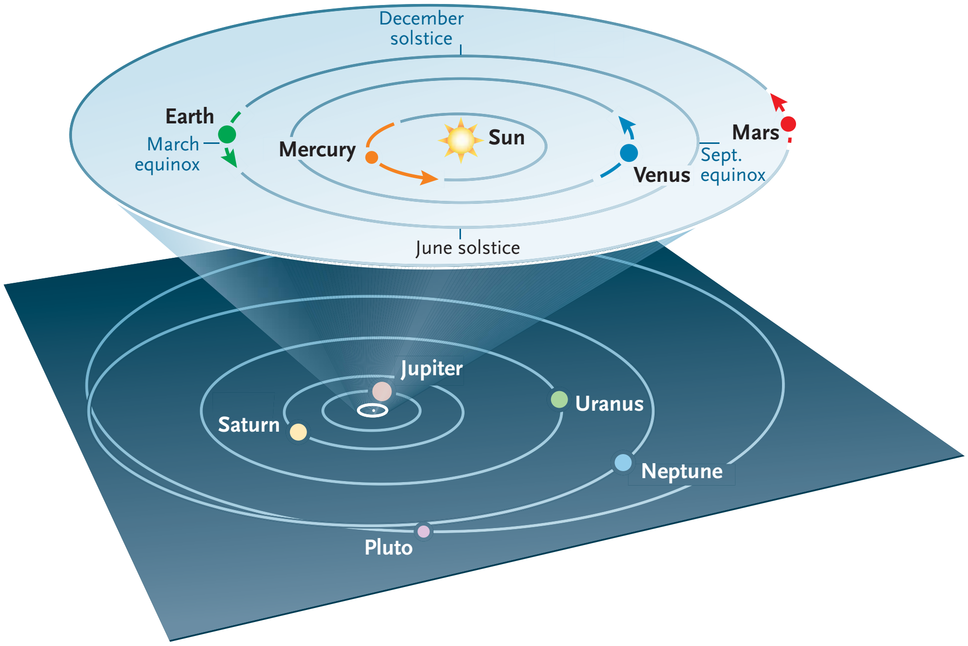
These scenes are always drawn for near the middle of North America (latitude 40° north, longitude 90° west); European observers should move each Moon symbol a quarter of the way toward the one for the previous date. In the Far East, move the Moon halfway. The blue 10° scale bar is about the width of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

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

Fred Schaaf

ORBITS OF THE PLANETS

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



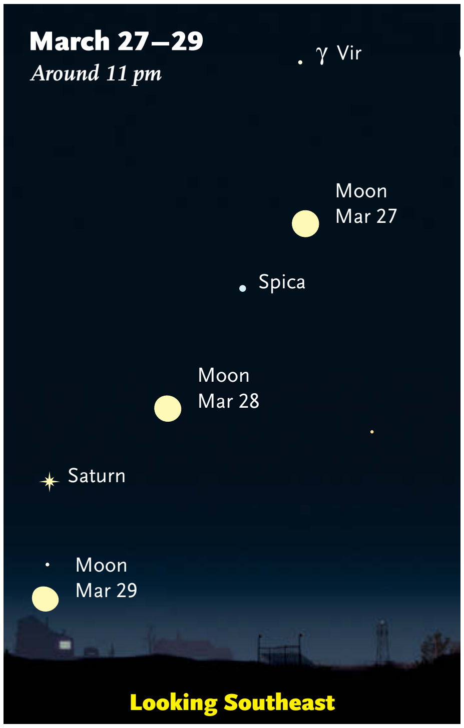
LATE NIGHT

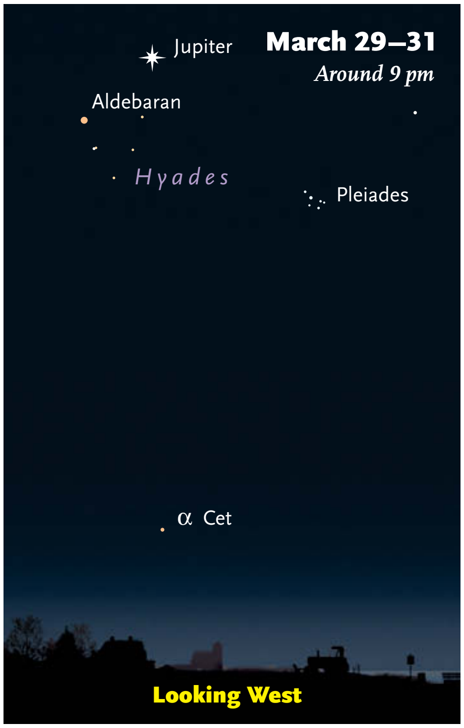
Saturn, in Libra, brightens marginally from magnitude +0.4 to +0.3 on its way toward opposition in late April. Saturn starts March rising around 10 or 11 p.m. (depending on where you live in your time zone) but ends the month rising less than an hour after twilight ends. It's highest in the south in the hours after midnight.

Saturn is now retrograding (moving westward against the stars) and enlarges the gap between it and Alpha Librae from 4½° to 5½° this month. The rings remain magnificent, closing imperceptibly from a 19.2° tilt to an 18.8° tilt.

DAWN

Mercury goes through inferior conjunction with the Sun on March 4th and emerges into dawn view late in the month. But this is a poor apparition for skywatchers at mid-northern latitudes, likely visible only through binoculars and telescopes. Although Mercury moves out to a greatest elongation of 28° on March 31st, the ecliptic makes a shallow angle with the dawn horizon at this time of year. So even by late in the month, Mercury appears very low in the east-southeast in bright dawn.





Venus reaches superior conjunction with the Sun on March 28th at 17^h UT, so it's not visible this month. **Uranus** arrives at conjunction with the Sun only 8 hours later. **Neptune** and **Pluto** are theoretically observable in early dawn by the end of March, but they're both painfully low.

MOON AND SUN

The **Moon** is waning gibbous when it rises late in the evening on March 1st, upper right of Saturn. It's below Saturn by the following dawn. The waxing lunar crescent is very close to Jupiter on the evening of March 17th, between it and Aldebaran. The second waning gibbous Moon of the month appears well upper right of Saturn on the evening of March 28th, and well below Saturn the next evening.

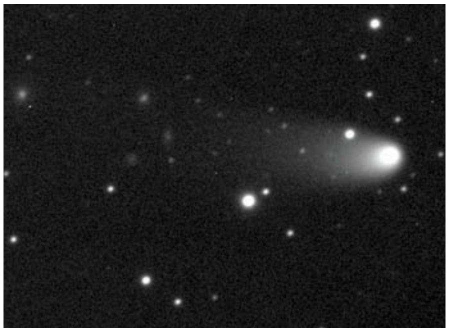
The **Sun** reaches the March equinox at 7:02 a.m. EDT on March 20th, crossing the celestial equator to initiate spring in the Northern Hemisphere and autumn in the Southern Hemisphere. ✦

Comet PanSTARRS at Dusk

Awaited for nearly two years, will it be a spectacle or a speck?

If you don't already have an observing spot with a view very low to the west and northwest, find one now — and plan to be there after sunset each clear evening in early and mid-March. There will be Comet PanSTARRS (C/2011 L4), likely to be the best comet in several years for observers at mid-northern latitudes. It may or may not be easy to see low in the twilight; bring binoculars. Its head could become as bright as magnitude zero, but because this is apparently a fresh comet making its first venture into the inner solar system, it could yet fade below expectations.

Comet PanSTARRS was still between the orbits of Jupiter and Saturn, 7.9 a.u. from the Sun, when the PanSTARRS automated sky-survey project in Hawaii discovered it at 19th magnitude almost two years ago. It will reach perihelion, its closest point to the Sun, on March 10th at a solar distance of 0.30 a.u., inside the orbit of Mercury. It's likely to grow a large tail by that time. The comet is nearest to Earth around the same date, on March 5th, though at a fairly distant 1.10 a.u. from us.



K. ROCHOWICZ / E. GUIDO / N. HOWES / G. SOSTERO

The comet was still a 13th-magnitude bit of fluff in Hydra on September 10th, when a group of astronomers in Italy imaged it remotely with a 2-meter telescope in Australia.

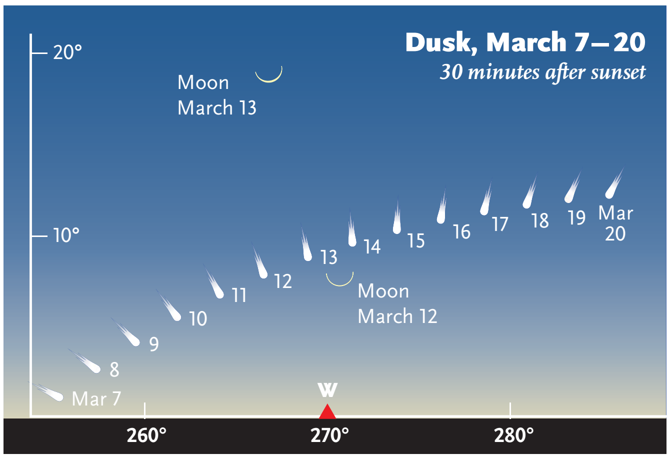
Mid-northern skywatchers can expect it to be at its best from about March 8–20, especially March 12–17.

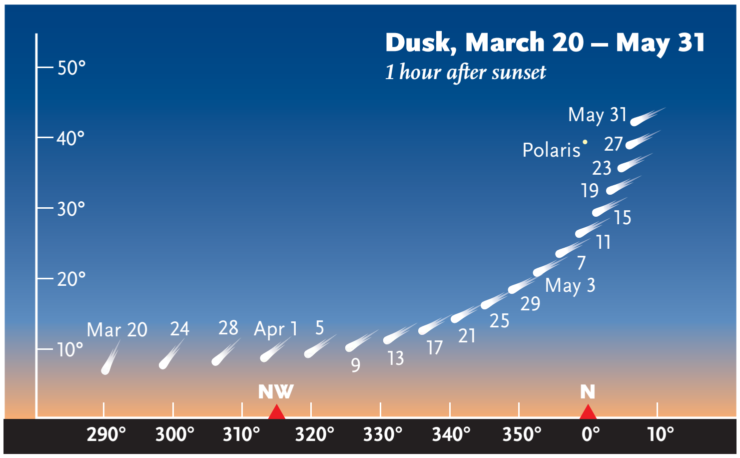
The charts below are drawn for a skywatcher at our standard latitude of 40° north. Your difference from this latitude will matter in early March, and again from mid-March onward. Early in the month, southerners are best placed and are likely to pick up the comet first. After mid-March, skywatchers north of 40° N will be the ones seeing the comet higher than the charts indicate. See the caption for how to draw your own horizon line on the left chart.

Through April and May the comet dims as it climbs high into the north. Current predictions put it at magnitude –0.2 on March 10th, 1.3 on the 20th, 3.6 on April 1st, 6.7 on May 1st, and 8.7 on June 1st. It passes within 5° of the north celestial pole on May 28th and remains in the far northern sky through the first half of the summer, requiring larger and larger telescopes as it departs back into the outer dark.

On April 4th, PanSTARRS will pass 2° west of M31, the Great Andromeda Galaxy, when they should be about equally bright. On April 21st for North America, it goes almost across the big, dim galaxy IC 10, whose 11th-magnitude light is spread over a region 0.1° wide in Cassiopeia. At that time the comet should be magnitude 6.

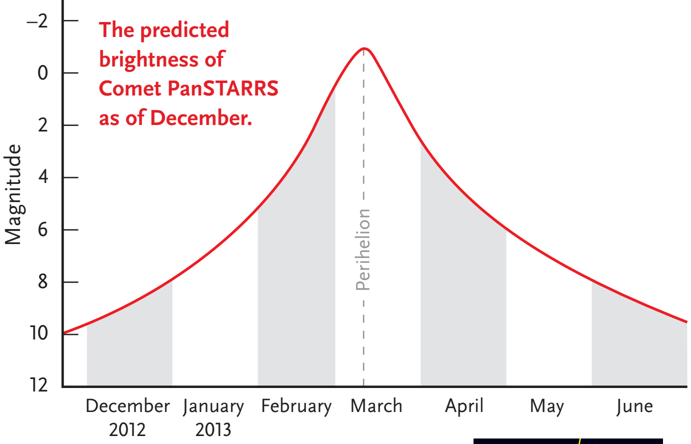
For updates, keep an eye on **skypub.com/panstarrs**.





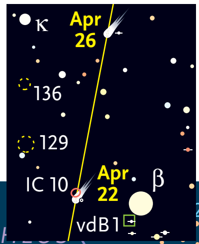
Left: Look west a half hour after sunset; this chart shows the altitude and azimuth (compass direction) where PanSTARRS will be — if you're at latitude 40° north. At other latitudes, draw a different horizon on the diagram as follows. Find your latitude's difference from 40° north. (For instance if you're at 32° N, it's 8°.) Using a protractor, draw a line through the horizon's West point tilted by that much. Tilt the left side of your line down if you're south of 40°, or up if you're north of there. *Right:* As the comet fades, it moves higher in twilight or night. Ten degrees is about a fist-width at arm's length.

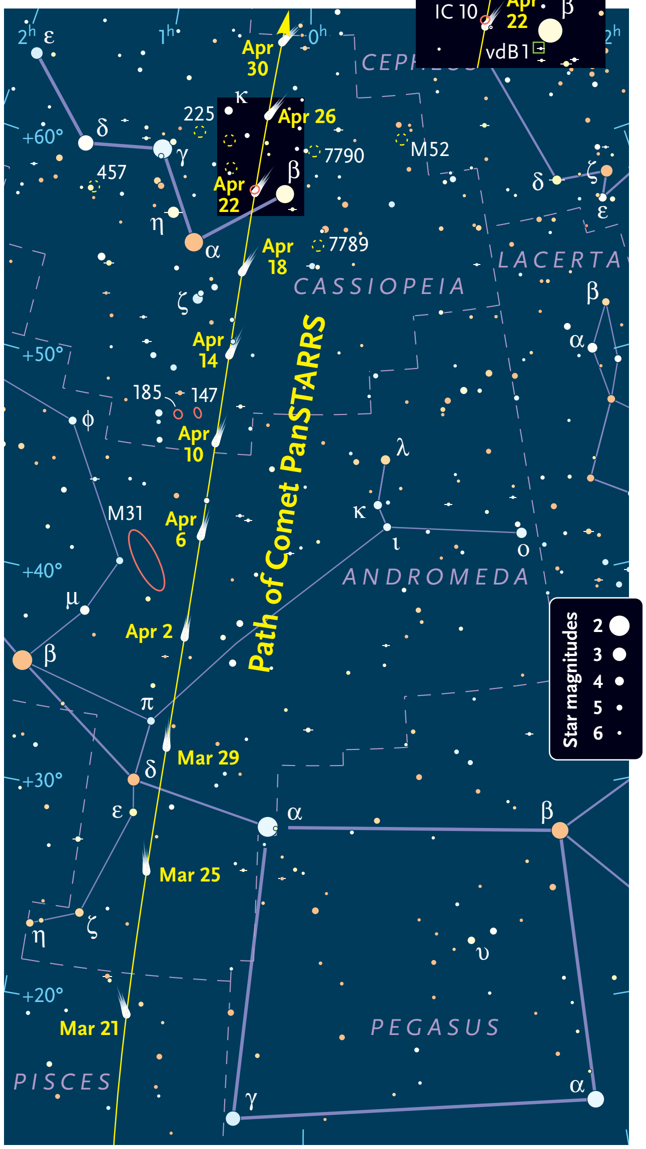
Alan MacRobert



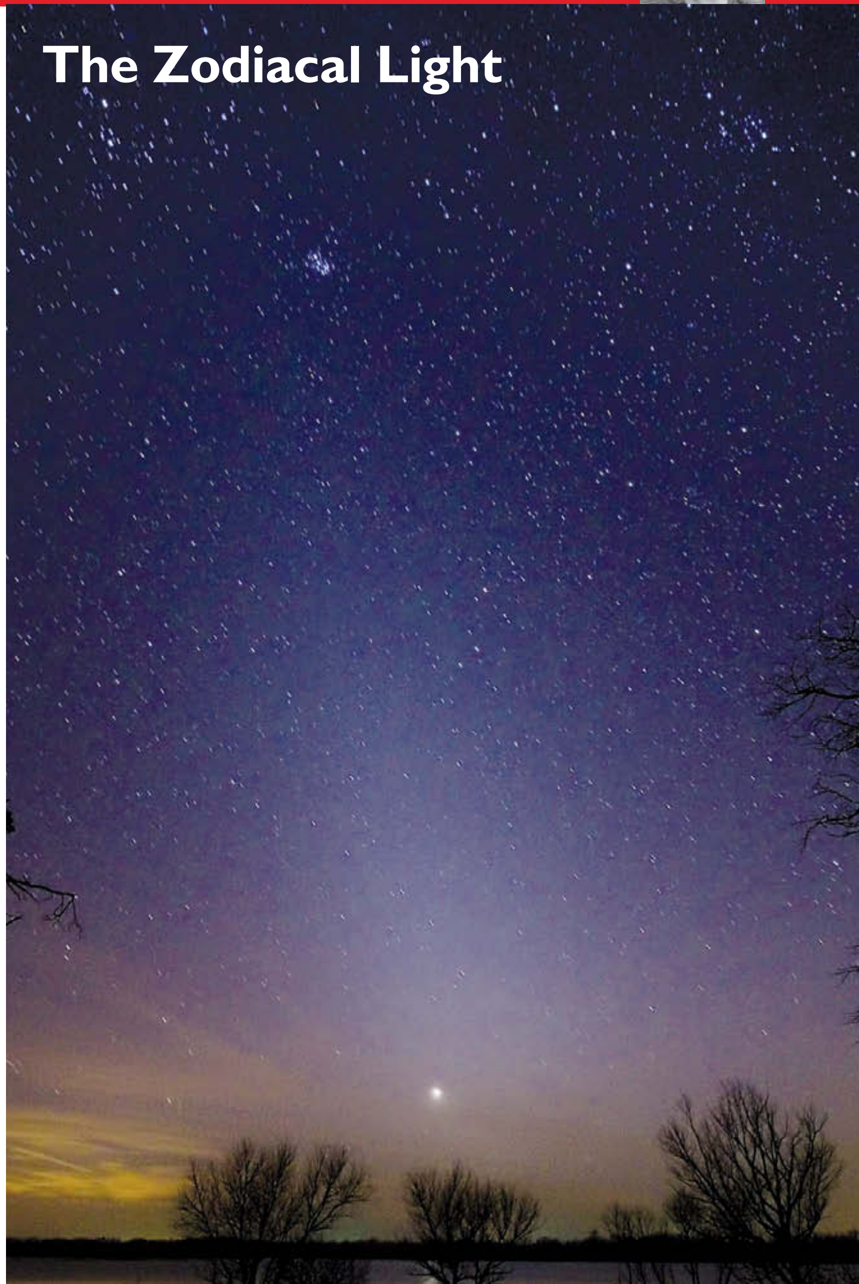
SEIICHI YOSHIDA / AERITH.NET

Below and right: **The dates along this plot of the comet's track are for 0^h UT. The tails point away from the Sun.**





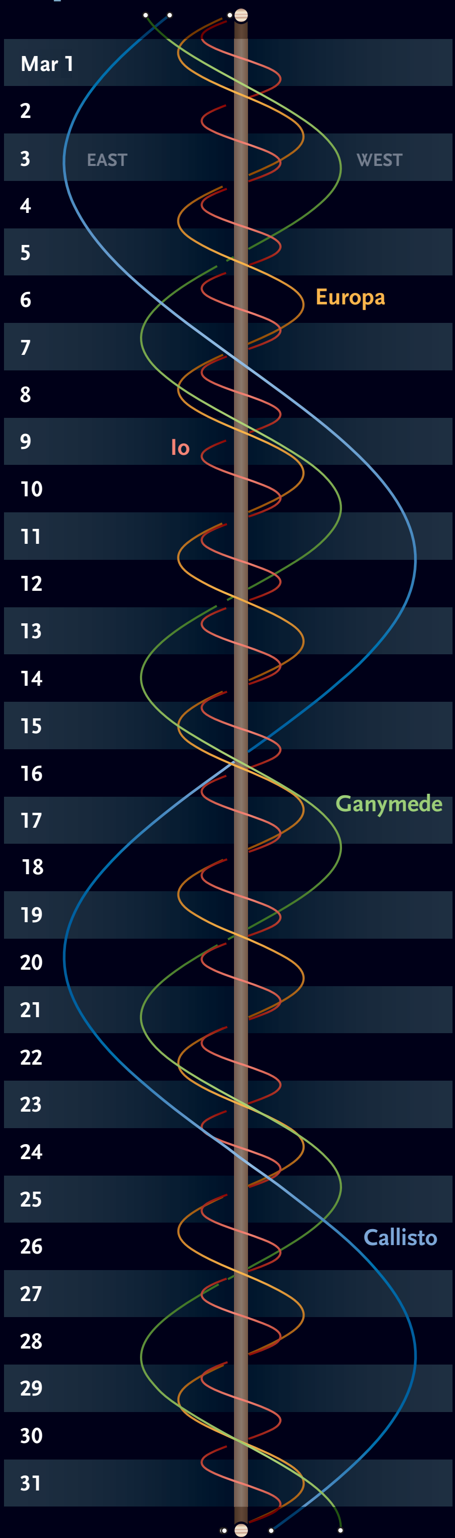
The Zodiacal Light



Moonless February and March evenings are excellent times for spotting the zodiacal light as twilight fades away. This is the season when the ecliptic — the plane of the solar system — tilts highest with respect to the western dusk horizon for skywatchers at mid-northern latitudes. The zodiacal light is interplanetary dust, mostly from disintegrated short-period (Jupiter-family) comets, that has gradually spiraled into the inner solar system. It's lit up by sunlight. Jim Saueressig II took this shot from Kansas on the evening of March 2, 2011. The zodiacal light runs from Jupiter low in Pisces up left of Aries toward the Pleiades in Taurus.

Subtle as it may be, the zodiacal light is actually the brightest thing in the solar system after the Sun. It reflects more total sunlight than Venus or Jupiter, as you would see if you could collect it all into one spot. The "zodiacal light" around other stars could prove to be a serious obstacle to detecting the light of any small planets that may be orbiting within it.

Jupiter's Moons



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

Action at Jupiter

Earth is leaving Jupiter behind in March as we speed along our faster orbit around the Sun. Jupiter is still in fine view high in the south to southwest as twilight ends, but it shrinks from 43 arc-seconds wide on February 1st to 39″ on March 1st and 36″ on April 1st — quite a bit smaller than Jupiter's 48″ around its December opposition.

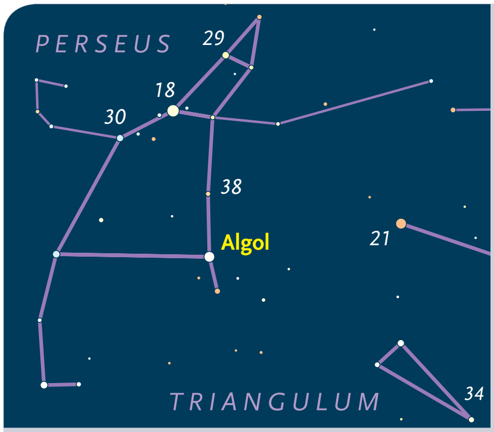
Any decent telescope shows Jupiter's four large Galilean moons. Binoculars usually reveal at least two or three. Identify them with the diagram at left. On the facing page are all of the moons' many interactions with Jupiter's disk and shadow in March.

Jupiter's Great Red Spot is becoming harder to identify as the planet shrinks. Following are the times, in Universal Time, when the Great Red Spot should cross Jupiter's central meridian. The dates, also in UT, are in bold. The Red Spot appears closer to the central meridian than to the limb for 50 minutes before and after these times:

February 1, 1:07, 11:03, 20:59; **2,** 6:54, 16:50; **3,** 2:46, 12:42, 22:37; **4,** 8:33, 18:29; **5,** 4:25, 14:20; **6,** 0:16, 10:12, 20:07; **7,** 6:03, 15:59; **8,** 1:55, 11:50, 21:46; **9,** 7:42, 17:38; **10,** 3:34, 13:29, 23:25; **11,** 9:21, 19:17; **12,** 5:12, 15:08; **13,** 1:04, 11:00, 20:55; **14,** 6:51, 16:47; **15,** 2:43, 12:38, 22:34; **16,** 8:30, 18:26; **17,** 4:22, 14:17; **18,** 0:13, 10:09, 20:05; **19,** 6:00, 15:56; **20,** 1:52, 11:48, 21:43; **21,** 7:39, 17:35; **22,** 3:31, 13:27, 23:22; **23,** 9:18, 19:14; **24,** 5:10, 15:06; **25,** 1:01, 10:57, 20:53; **26,** 6:49, 16:45; **27,** 2:40, 12:36, 22:32; **28,** 8:28, 18:23.

March 1, 4:21, 14:17; **2,** 0:13, 10:08, 20:04; **3,** 6:00, 15:56; **4,** 1:52, 11:47, 21:43; **5,** 7:39, 17:35; **6,** 3:31, 13:26, 23:22; **7,** 9:18, 19:14; **8,** 5:10, 15:05; **9,** 1:01, 10:57, 20:53; **10,** 6:49, 16:44; **11,** 2:40, 12:36, 22:32; **12,** 8:28, 18:24; **13,** 4:19, 14:15; **14,** 0:11, 10:07, 20:03; **15,** 5:58, 15:54; **16,** 1:50, 11:46, 21:42; **17,** 7:38, 17:33; **18,** 3:29, 13:25, 23:21; **19,** 9:17, 19:13; **20,** 5:08, 15:04; **21,** 1:00, 10:56, 20:52; **22,** 6:48, 16:43; **23,** 2:39, 12:35, 22:31; **24,** 8:27, 18:22; **25,** 4:18, 14:14; **26,** 0:10, 10:06, 20:02; **27,** 5:57, 15:53; **28,** 1:49, 11:45, 21:41; **29,** 7:37, 17:33; **30,** 3:28, 13:24, 23:20; **31,** 9:16, 19:12.

To obtain Eastern Standard Time from UT, subtract 5 hours; for Eastern Daylight Time (which begins March 10th), subtract 4. The times above assume that the spot is centered at about System II longitude 190°.



On February and March nights, Perseus declines in the northwest. Estimate Algol's brightness using the comparison stars above, labeled with their magnitudes (decimal points omitted). At right are Algol's predicted mid-eclipse times, when it will be magnitude 3.4 instead of its usual 2.1.

Minima of Algol

Feb.	UT	Mar.	UT
1	17:05	2	9:19
4	13:54	5	6:08
7	10:44	8	2:58
10	7:33	10	23:47
13	4:23	13	20:36
16	1:12	16	17:26
18	22:01	19	14:15
21	18:51	22	11:04
24	15:40	25	7:54
27	12:29	28	4:43
		31	1:32

Lunar Occultations

The waxing crescent Moon occulted 3rd-magnitude Zeta Tauri as seen from Normandy, France, on April 25, 2012. Mohamed Laaifat shot this series over the course of about 50 minutes through a Meade 70-mm f/5 ETX refractor.

Here are two nice lunar occultations for your March celestial calendar:

On the **evening of March 19th**, the dark limb of the first-quarter Moon will black out the 5.2-magnitude star 71 Orionis for telescope users across most of North America except the Southwest and West. Some times: from central Massachusetts, 11:02 p.m. EDT; Miami, 11:47 p.m. EDT; Chicago, 9:49 p.m. CDT; Denver, 8:33 p.m. MDT.

On the **morning of March 31st**, observers south of a line from central Florida through Oregon can watch the double star Beta Scorpii, magnitudes 2.6 and 4.8, emerge from behind the dark limb of the waning gibbous Moon. Some times for the bright component: Miami, 4:45 a.m. EDT; Austin, 3:13 a.m. CDT; Los Angeles, 12:57 a.m. PDT. The faint component reappears up to a minute or two earlier.

For maps and timetables of these and other occultations, see **lunar-occultations.com/iota/bstar/bstar.htm**.

Gone are the days when backyard occultation timers did cutting-edge work mapping elevations along the Moon's limb; lunar orbiters do it much better. But occultations are still fun to watch. ✦

Phenomena of Jupiter's Moons, March 2013

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

Every day, interesting events happen between Jupiter's satellites and the planet's disk or shadow. The first columns give the date and mid-time of the event, in Universal Time (which is 5 hours ahead of Eastern Standard Time; 4 hours ahead of Eastern Daylight Time). Next is the satellite involved: **I** for Io, **II** Europa, **III** Ganymede, or **IV** Callisto. Next is the type of event: **Oc** for an occultation of the satellite behind Jupiter's limb, **Ec** for an eclipse by Jupiter's shadow, **Tr** for a transit across the planet's face, or **Sh** for the satellite casting its own shadow onto Jupiter. An occultation or eclipse begins when the satellite disappears **(D)** and ends when it reappears **(R)**. A transit or shadow passage begins at ingress **(I)** and ends at egress **(E)**. Each event is gradual, taking up to several minutes. Courtesy IMCCE.

A Lunar Curiosity

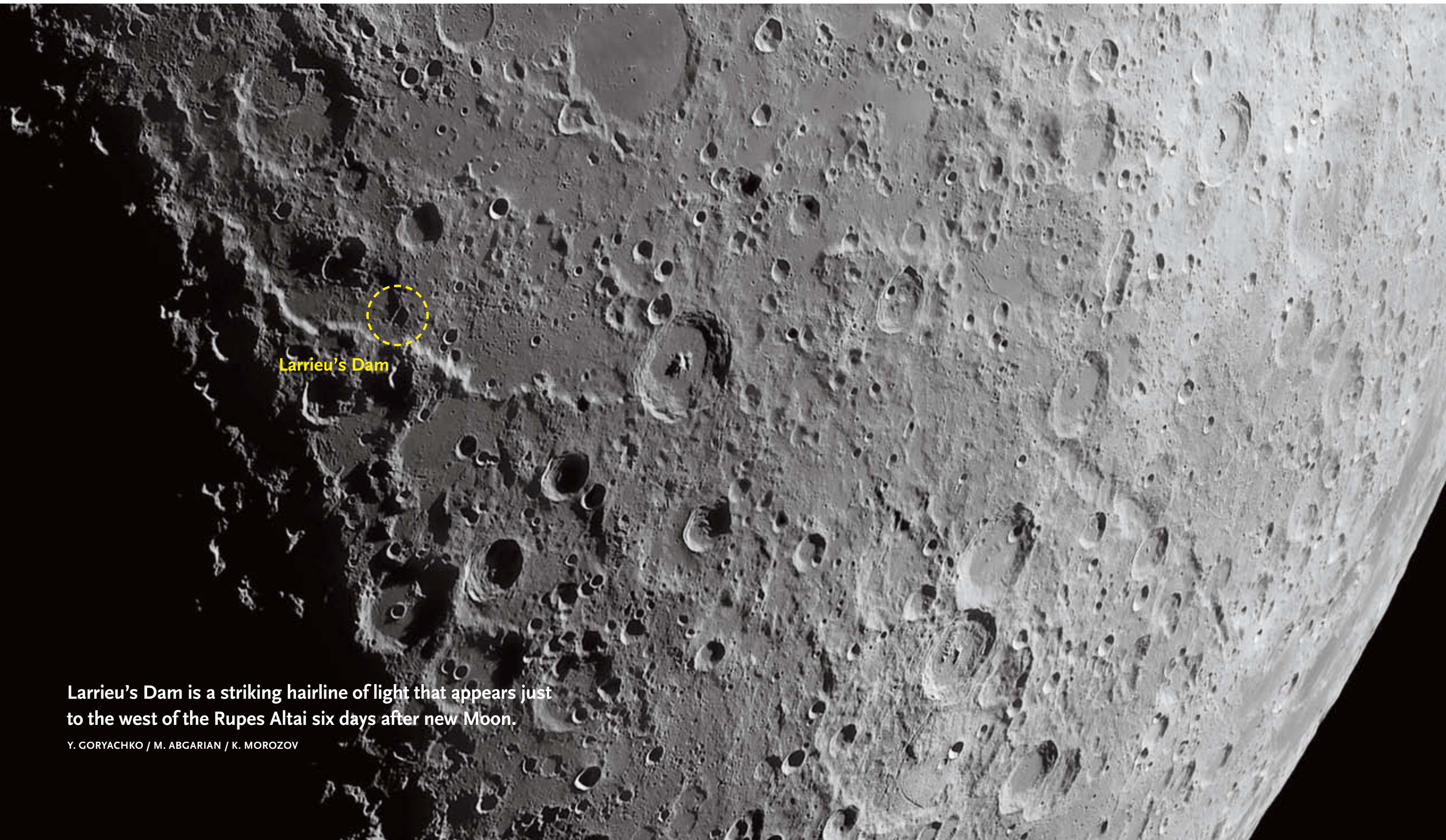
The author serendipitously rediscovers Larrieu's Dam.

On the sultry evening of June 26, 2001, I trained an 8-inch reflector on the 6-day-old Moon. The seeing was quite steady, with slow, low-amplitude turbulence that permitted sharp views at 240×. The morning Sun illuminated the face of the spectacular mountains of **Rupes Altai**, a 480-kilometer (300-mile) curved segment of the rim of the giant Nectaris impact basin, which can tower to heights of 1 km above the surrounding terrain.

My eye was soon drawn to a brilliant hairline of light cutting across the receding shadows that filled several depressions in the lunar foothills. Straight as an arrow and aligned roughly perpendicular to the Altai Scarp, this delicate feature appeared to slowly undulate as if it were tethered at one end and immersed in a gently flowing current of water. Its "motion" called to mind a worm wriggling at the end of a fish hook. All of the other features in the field of view appeared essentially stationary, although intermittently and subtly blurred. I marveled at how the effect of atmospheric turbulence on a bright linear feature against a black background could differ so dramatically from its effect on the extended objects in the field and the detached sunlit peaks just beyond the terminator.

Confronted by one of the most striking illusions I've witnessed in more than four decades of lunar observing, I dashed inside and grabbed my copy of Antonín Rükl's *Atlas of the Moon*. After comparing Chart 57 to the view in the eyepiece, it soon became apparent that the exceedingly narrow thread of light was the unusually straight northwestern rim of the D-shaped crater **Polybius K** catching the first rays of the morning Sun. The lower slopes were still immersed in the deep shadows cast by the crater's eastern wall and the ridges to the north.

This memorable observation languished in my notebook until 2008, when I stumbled across an article by Nigel Longshaw in the *Journal of the British Astronomical Association* recounting several independent rediscover-



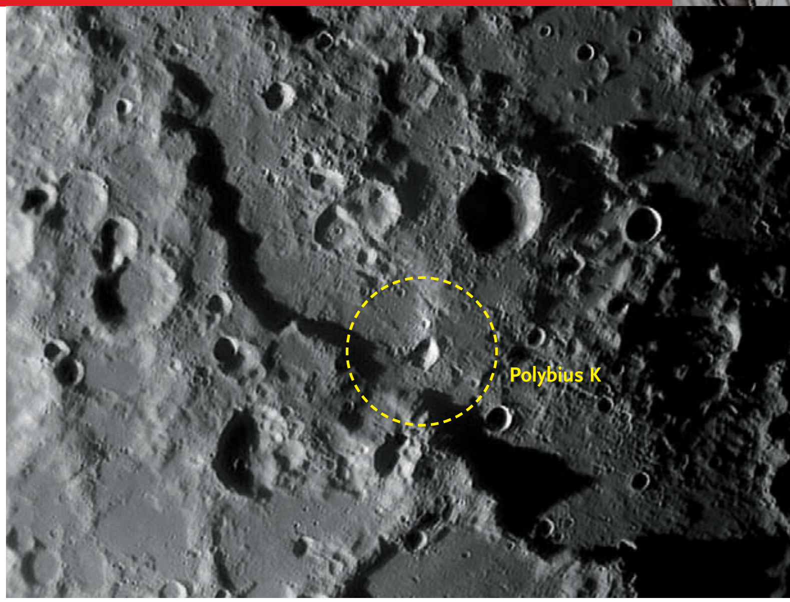
Larrieu's Dam is a striking hairline of light that appears just to the west of the Rupes Altai six days after new Moon.
Y. GORYACHKO / M. ABGARIAN / K. MOROZOV

ies of this obscure feature. Longshaw characterized it as a prime example of those "minor lunar features seldom described in the mainstream literature, yet which often present an intriguing image in the eyepiece when captured under favorable illumination."

First reported in 1955 by the French observer A. C. Larrieu, who described it as "very thin and rectilinear" and resembling a "bridge or hydraulic barrier," the feature was soon christened "Larrieu's Dam" by the noted British historian of astronomy Richard Baum. Others have compared its appearance to a brightly lit roadway stretching across a reservoir filled with inky black water.

Located at lunar coordinates 25°S 25°E, Larrieu's Dam is visible under sunrise conditions on a waxing Moon over colongitudes 343° to 355° (1.6 to 0.5 days before First Quarter). Under ideal lighting it spans a length of about 14 kilometers but subtends less than ¼ arcsecond in width. It's exceedingly narrow at its eastern extremity, where the sunlit rim is only about 200 meters wide. Apertures of 6-inches or more may reveal gentle swellings that seem to correspond to slightly elevated segments.

Despite its modest dimensions, Larrieu's Dam is easily discernible with a 60-millimeter refractor at a magnification of only 75× or so. Visual acuity is much better for linear objects than for point sources like double stars. As the British author J. B. Sidgwick explained in his classic *Amateur Astronomer's Handbook*: "A linear object may stimulate a sufficient number of cones to produce sight even though its width is 20 or 30 times less than the threshold diameter of a spot."



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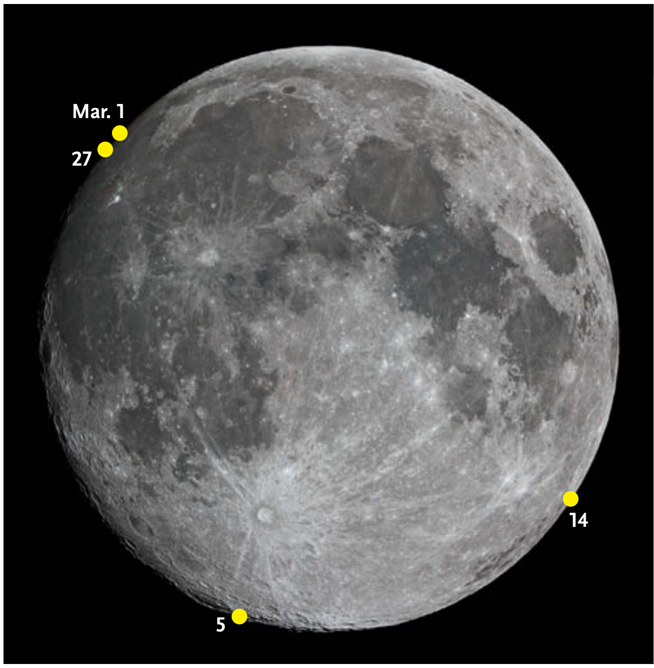
As the Sun sets over the region, Polybius K is lost among the host of other small, nondescript craters that dot the foothills of the Altai Scarp.

Under sunset lighting at colongitudes 140° to 153° (4 to 5 days after full Moon), the dramatic "thread of light" appearance is absent, but a set of linear spurs running down the crater's outer wall are revealed. According to Longshaw, they resemble the buttresses of a dam.

Larrieu's Dam is a mere curiosity, a trick of light and shadow. Yet I am compelled to wonder why such a captivating phenomenon that is repeated once every month and persists for more than a day went unheralded for so many years. How many comparable spectacles still lie in store for lunar observers? ✦



S&T: DENNIS DI CICCO

The Moon • March 2013

Phases

LAST QUARTER
March 4, 21:53 UT

NEW MOON
March 11, 19:51 UT

FIRST QUARTER
March 19, 17:27 UT

FULL MOON
March 27, 9:27 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	March 5, 23^h UT
229,881 miles	diam. 32′ 18″
Apogee	March 19, 3^h UT
251,196 miles	diam. 29′ 33″
Perigee	March 31, 4^h UT
228,357 miles	diam. 32′ 31″

Librations

Ulugh Beigh (crater)	March 1
Casatus (crater)	March 5
Humboldt (crater)	March 14
Galvani (crater)	March 27

Sailing South

Puppis and Pyxis host some amazing clusters and nebulae.

Last month we navigated the northern reaches of Puppis, part of the mythical ship Argo crewed by Jason and the Argonauts on their heroic quest for the Golden Fleece. We'll now set a course for southern Puppis and then swiftly sail into eastern Pyxis. Representing a magnetic compass, Pyxis may seem a fitting addition to Argo, but the device was unknown to the ancient Greeks. The compass was added to the sky centuries later by the French astronomer and mathematician Nicolas Louis de Lacaille, who also divided Argo into three smaller constellations.

The northernmost deep-sky wonder on our tour is the open cluster **NGC 2571**. In 14×70 binoculars it appears as a nebulous patch sporting two stars in its center. My 105-mm refractor at 87× shows about 25 stars of 9th magnitude and fainter, most forming an 8′ × 6′ M with rounded peaks that point southwest. The cluster is quite irregular, and it's guarded by a 6th-magnitude, yellow-orange star 20′ southwest.

Additional stars visible in my 10-inch reflector at 68× lengthen NGC 2571 to 13′, elongated southeast-northwest, and some faint stars to the south plump its breadth to about 8′. With the wide-angle eyepiece used for this observation, **NGC 2567** occupies the southern part of the field when NGC 2571 is consigned to the north. Most of its stars make a 4½′ zigzag with the amplitude of the zigs decreasing from northeast to southwest. Another 20 stars, mostly fainter and to the northeast, expand the cluster to 8′.

Virginia amateur Mike Klosterman brought up the unusual star pattern in NGC 2567 at Florida's Winter Star Party a few years ago. We decided that it looks like ~1 in both the inverted view of his reflector and the mirror-reversed view of my refractor. Since some folks use the symbol ~ to signify "approximately," we dubbed this group the Approximately One Cluster.

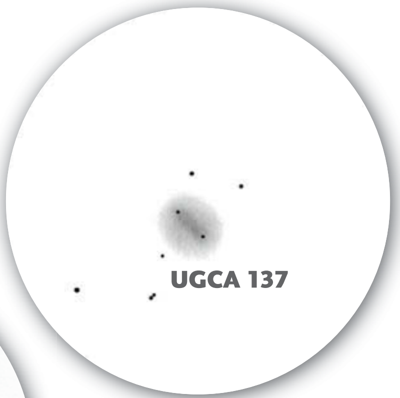
The barred spiral galaxy **UGCA 137** lies 8′ south of the yellow-orange star near NGC 2571. Although the galaxy's magnitude is 12.4, its surface brightness is very low. Despite this impediment, Finnish amateur Jaakko Saloranta drew an impressive sketch of UGCA 137 (shown at lower left) as seen through his 120-mm refractor at 360×. The points at each end of the bar are superposed 14th-magnitude stars. Saloranta was observing at high altitude in Spain's Canary Islands.

NGC 2571, NGC 2567, and UGCA 137 give us a feel for the depth of the sky with their distances of roughly 4,400, 5,500, and 60 million light-years, respectively.

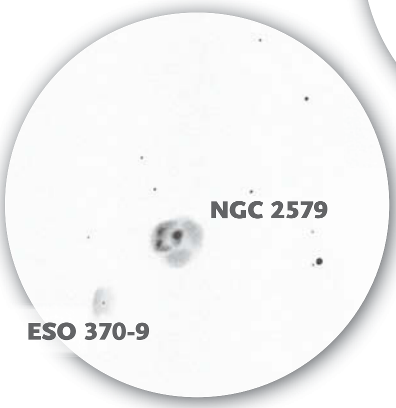
Now we'll drop several degrees southward to **NGC 2546**. Through 15×45 binoculars this open cluster is a large, ragtag group of many faint stars at the south-southwestern border of a big region of showy bright stars. My 10-inch reflector at 68× reveals 75 stars ranging widely in brightness and loosely strewn across 40′ of sky. A denser patch of stars decorates the cluster's northwestern edge, and a 6th-magnitude star pins its south-southeastern rim.

Although the rest of the deep-sky wonders in our tour have about the same declination as NGC 2546, I've never logged them from my upstate New York home. These observations were all made at Florida's Winter Star Party, where southern objects crest 18° higher in the sky.

The same splashy collection of stars that hugs NGC 2546 also wears the compact emission nebula **NGC 2579** on its eastern side. Through my 105-mm refractor at 153×, it's a little oval glow with a bright star embedded. The nebula stands out much better when I use an O III filter. NGC 2579 is quite obvious in my 10-inch scope at 118×. The bright star is nestled in the west-northwestern part (see the sketch at left), and a faint star is ensconced in the nebula's brighter east-southeastern section. The faint star shows up much better at 308×, and the nebula is more



Right: **Finnish stargazer Jaakko Saloranta sketched UGCA 137 as seen through his 120-mm refractor at 360× from the island of La Palma at latitude 29° north.**



Left: **German stargazer Uwe Glahn also traveled to La Palma, where he viewed and sketched these nebulae through his 20-inch Dobsonian telescope at 321×.**

prominent with a narrowband nebula filter.

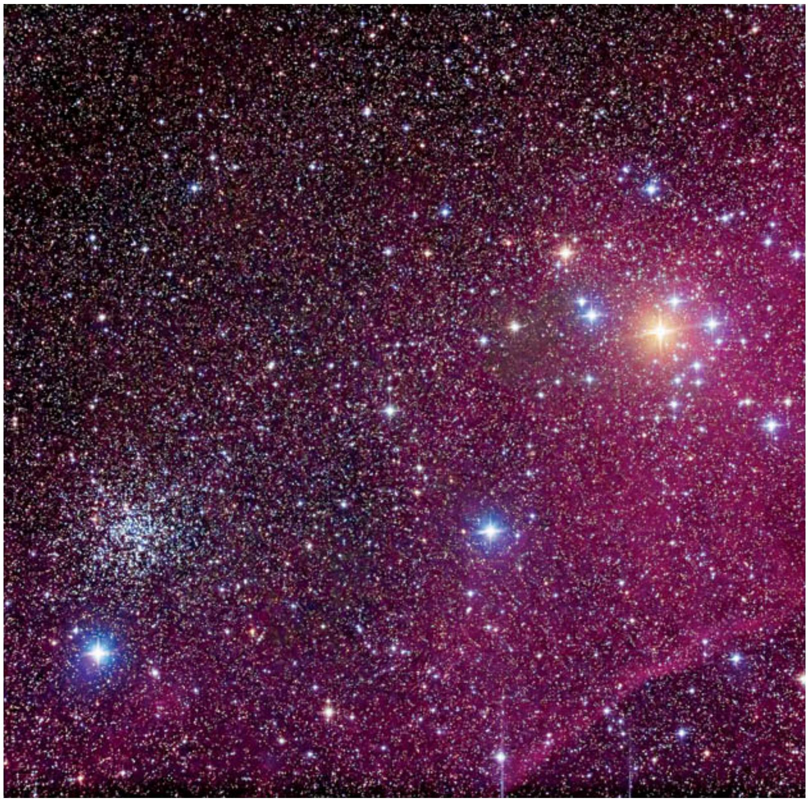
Some images of NGC 2579 show that both stars have close companions. The bright star is actually a foreground object, while the three faint ones are the hot blue stars of spectral type *O* that are the sources of the ionizing radiation that makes the nebula glow.

The 13½-magnitude, type-*O* star 1.2′ southwest of NGC 2579 rests at the heart of the small emission nebula **ESO 370-9** and is responsible for its ionization. I didn't see this nebula with my 10-inch scope, but it has been spotted in 14.5-inch and larger scopes. Can you spot it?

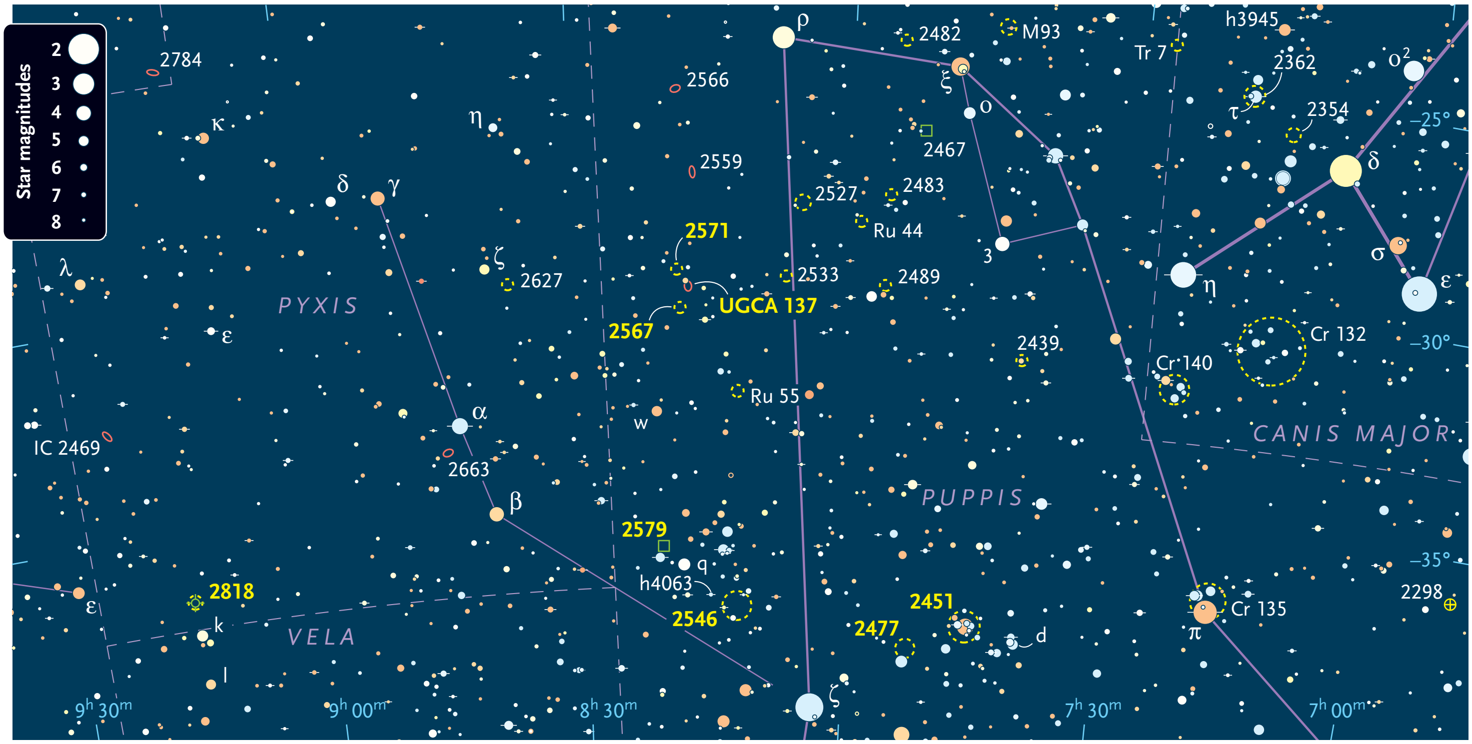
NGC 2579 and ESO 370-9 have been confused with nearby objects and mistaken for reflection nebulae and planetary nebulae. Their natures and identities were unsnarled in a 2007 paper by Marcus Copetti and colleagues. The authors place these nebulae 25,000 light-years away in the outer reaches of the galactic disk and suggest that they may be physically related.

The stunning cluster couple **NGC 2451** and **NGC 2477** lies 4.6° west of NGC 2579 and 3.3° west-northwest of Zeta (ζ) Puppis. The duo seems like an exaggerated version of another striking Puppis pair, M47 and M46. NGC 2451 is even looser and flashier than M47, while NGC 2477 looks finer grained and more compact than M46.

In my 105-mm refractor with a wide-angle eyepiece giving a magnification of 17×, NGC 2451 and 2477 share the field of view with plenty of room to spare. NGC 2451 is a large, sprawling, coarse group centered on a fiery orange



S&T contributing editor Alan Dyer's photograph of the rich star cluster NGC 2477 (*left*) and splashy 2451 (*right*) shows that the entire region is pervaded with faint nebulosity. The bright star near NGC 2451's center is sometimes called c Puppis.



ember, the cluster's brightest star. Another orange star adorns the northeastern side of the cluster, and a yellow one gilds the eastern edge. I count 40 mixed bright and faint stars in 47′. NGC 2477 offers a lovely contrast to its companion, displaying a beautiful, 23′ mound of minute diamond chips growing more concentrated toward the center and too densely packed to tally.

At 28× the clusters still inhabit a single field of view. The arrangement of NGC 2451's stars gives the delightful impression of a multi-armed spiral galaxy. NGC 2477 yields up many more individuals, and a raggedy chain of slightly brighter stars springs from its northeast quadrant.

NGC 2451 consists of two separate clusters along the same line of sight, one at 600 light-years and the other at 1,000 light-years. As you'd expect from the faintness of its stars, NGC 2477 is considerably more distant at 4,000 light-years.

Now we take our dogleg tack into eastern Pyxis to end our voyage with **NGC 2818**, a remarkable pairing of an open cluster and planetary nebula. James Dunlop discovered them on May 28, 1826, with the 9-inch reflector at his home in Parramatta, New South Wales. Dunlop describes his find as: "A pretty large faint nebula of a round figure, 6′ or 8′ diameter; the nebulosity is faintly diffused to a considerable extent. There is a small nebula in the north preceding side, which is probably a condensation of the faint diffused nebulous matter; the large nebula is resolvable into stars with nebula remaining."

Daniel Verschatse captured NGC 2818, an unusual superposition of a planetary nebula and open cluster, from Antilhue Observatory near his home in Santiago, Chile.

Clusters and Nebulae in Puppis and Pyxis

Object	Type	Mag(v)	Size/Sep	RA	Dec.
NGC 2571	Open cluster	7.0	13′	8^h 19.0^m	–29° 45′
NGC 2567	Open cluster	7.4	10′	8^h 18.5^m	–30° 39′
UGCA 137	Barred spiral galaxy	12.4	3.2′ × 2.3′	8^h 17.7^m	–30° 08′
NGC 2546	Open cluster	6.3	40′	8^h 12.4^m	–37° 37′
NGC 2579	Emission nebula	7.5	1.6′ × 1.5′	8^h 20.9^m	–36° 13′
ESO 370-9	Emission nebula	13.0	1.1′ × 0.8′	8^h 20.9^m	–36° 14′
NGC 2451	Open cluster	2.8	50′	7^h 45.4^m	–37° 57′
NGC 2477	Open cluster	5.8	27′	7^h 52.2^m	–38° 32′
NGC 2818	Open cluster	8.2	9′	9^h 16.2^m	–36° 37′
NGC 2818	Planetary nebula	11.6	93″ × 55″	9^h 16.0^m	–36° 38′

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.

Through my 130-mm refractor at 23×, the open cluster is a rich gathering of extremely faint stars about 7′ across with an 11th-magnitude star at its northern edge. The stars are widely spread at 102×, and I count about 35 in the group. The planetary is a wonderful addition to the cluster, sitting west of center. It's large, quite oval east-west, and fainter at the tips. A brighter bar runs north-south across the nebula's center. With the help of a narrowband filter, the bar looks pinched in at its waist, but the filter wipes out most of the cluster's stars.

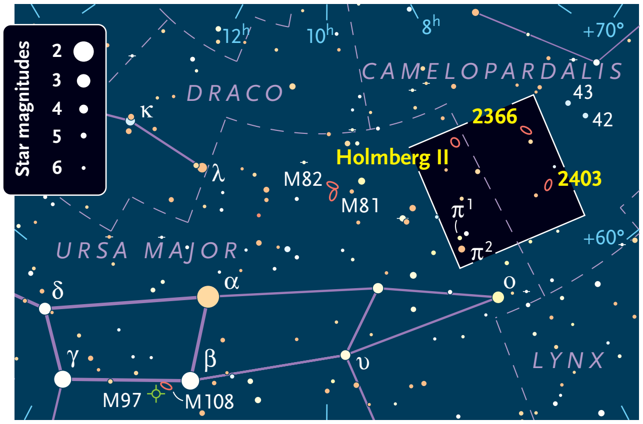
Although NGC 2818's cluster and planetary nebula coincide on the dome of the sky, they're generally thought to be unrelated. Their radial velocities (motion along our line of sight) are considerably different, so they are not moving together through space. ✦

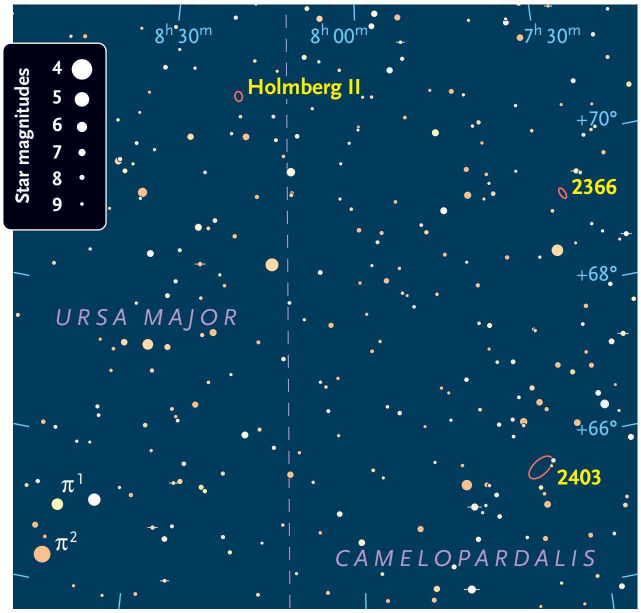
Celestial Fireworks

Three extraordinary galaxies congregate in and near Camelopardalis.

WHAT'S THE BRIGHTEST northern galaxy not included in the Messier catalog? You might be surprised to hear that distinction belongs to 8.4-magnitude **NGC 2403**, a prominent spiral that would be better known if it wasn't isolated within the dimly lit outlines of the sprawling constellation Camelopardalis.

In terms of structure and size, NGC 2403 is a virtual twin to M33. Both are late Hubble-type Scd spirals with small central bulges and chaotic spiral arms containing numerous sites of intense star formation. NGC 2403 resides at a distance of roughly 10 million light-years and is an outlying member of the M81 group — a collection of more than 30 galaxies neighboring our Local Group.





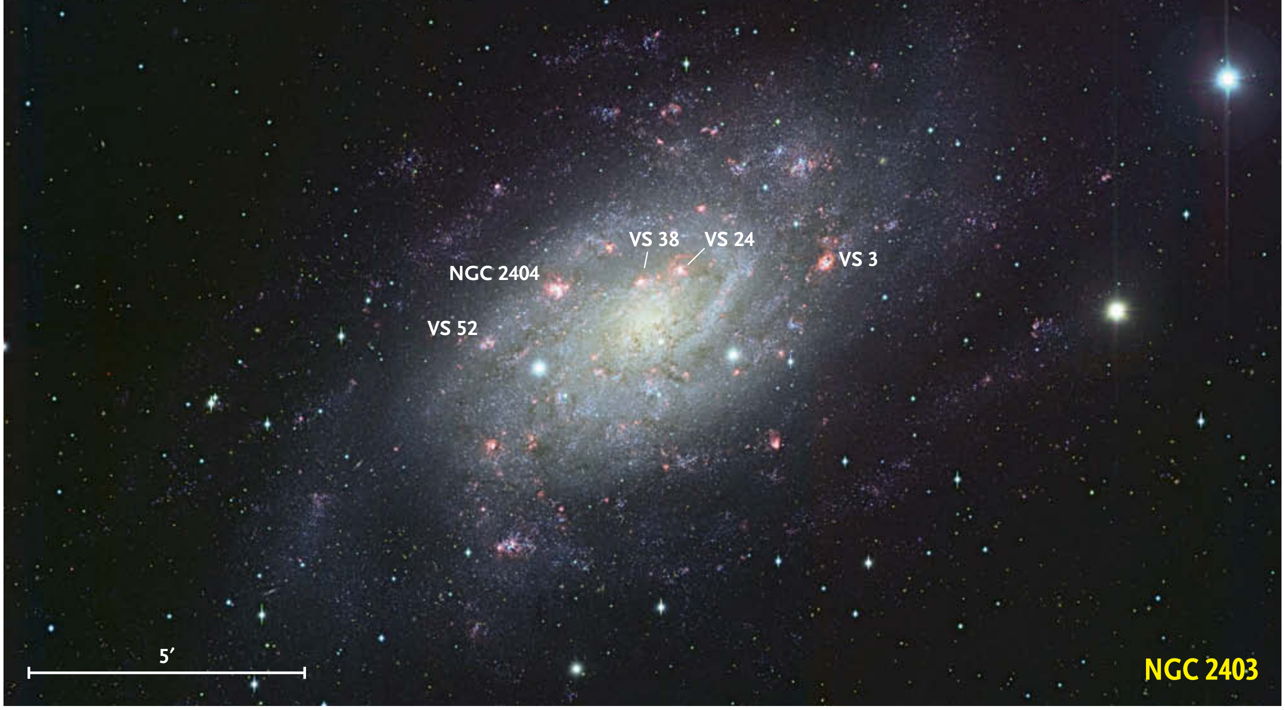
NGC 2403 can be swept up in 50-mm binoculars as a hazy glow, and the galaxy is an impressive sight in 6- to 10-inch scopes. In good conditions, a 12-inch or larger scope will resolve a number of the brighter emission regions that stud the spiral arms.

In my 18-inch Dobsonian the galaxy spreads out 12′ × 5′ and broadly brightens to a 1.5′ core with a 12.5-magnitude star pinned to its south side. With careful study, two fairly wide spiral arms emerge near the northwest and southeast side of the central region and curl counterclockwise nearly 180°. The more prominent arm on the northern side is separated from the core by a slightly darker gap. Several stars are superposed in the halo, including two 10th-magnitude luminaries on the southwest and southeast sides.

The distribution of NGC 2403's H II regions — pink patches of hydrogen ionized by the ultraviolet radiation of hot, massive *O*- and *B*-class stars — has been well studied by professional astronomers. A 1965 catalog by French astronomers Philippe Véron and Alain Sauvayre includes 52 H II regions (referred to here as VS 1 through VS 52), and a comprehensive 1983 survey by Paul Hodge and Robert Kennicutt netted more than 600 H II regions peppering the spiral arms. For the best view of these glowing knots, head to dark skies, push the magnification up to 250× to 350×, and use the labeled image on the facing page to pick them off individually.

NGC 2404, located 1.7′ east-northeast of the galaxy's center in the northern spiral arm, is the easiest H II target. At 323× NGC 2404 appears fairly bright, 15″ across, and irregularly round. This immense cloud of ionized hydrogen is comparable in size to NGC 604 in M33 and the Tarantula Nebula in the Large Magellanic Cloud, the two largest stellar nurseries in our Local Group.

VS 3 is a fuzzy 12″ knot on the northwest side of the halo, 3.4′ from the center. It forms a straight line with two 14th-magnitude stars to its northeast. A bit tougher are **VS 24** and **VS 38**, a pair of barely nonstellar 14th-magnitude knots at the north edge of the core. If you've made it



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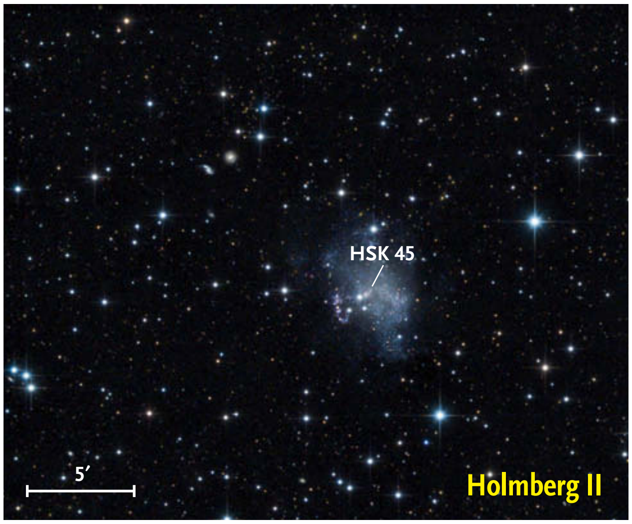

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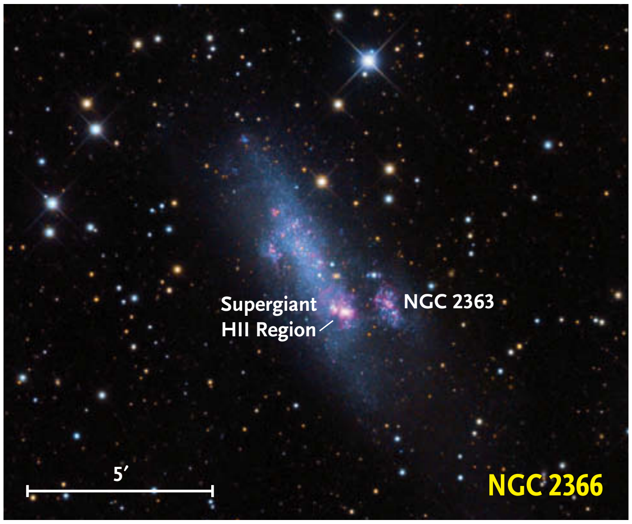

STEPHEN LESHIN

this far, see if you can identify **VS 52**, a very dim glow at the eastern tip of the spiral arm containing NGC 2404.

NGC 2403 has two unusual neighbors — the Magellanic-type dwarf irregular galaxies Holmberg II (6.4° to the northeast) and NGC 2366 (3.7° north). Swedish astronomer Erik Holmberg discovered **Holmberg II** (also cataloged as UGC 4305) in 1950 during a survey of galaxies in the M81 Group. I can detect it easily at 175× in my 18-inch as a fairly faint, low-surface-brightness patch, roughly 5′ × 3.5′ across. An 11th-magnitude star is near the north edge and a trio of 12th- and 13th-magnitude stars is superposed just east of center.

Halton Arp, in his *Atlas of Peculiar Galaxies*, placed Holmberg II (Arp 268) in the category of "Galaxies with irregular clumps" due to its numerous bubbles of glowing gas. My 18-inch only hints at these regions, but using Jimi Lowrey's 48-inch behemoth Dob in West Texas, I saw several H II splotches in the central region, including a fairly bright 15″ knot with the designation **HSK 45**.

At first glance **NGC 2366** appears as a low-surface-brightness glow stretching 3.5′ × 1.0′ south-southwest to north-northeast. But at the south end of the galaxy is an extraordinary 12th-magnitude starburst region that's twice as luminous as the Tarantula Nebula. At 323× this high-surface-brightness knot appeared irregular in shape, 15″ to 20″ in size, and occasionally resolved into two or three components. Try using a narrowband filter — I found it increased the contrast of the knot and extinguished the glow of the galaxy.

Many sources misidentify this giant H II complex as NGC 2363. But **NGC 2363** properly refers to a detached star cloud or independent satellite galaxy just west of the south end of NGC 2366. I'd be interested in hearing if you're successful in detecting this phantom glow. ✦

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*Contributing editor **Steve Gottlieb** has observed almost all the NGC objects and many of the IC objects. Do a web search for "Gottlieb NGC" to find his observing notes.*

 Dennis di Cicco

Celestron's SkyProdigy 6

Could this telescope set a new standard for a beginner's ideal instrument?

Celestron SkyProdigy 6

U.S. price: $999
Available from Celestron dealers worldwide.
www.celestron.com; 310-328-9560

MAYBE IT WAS the piercingly cold nights. Or perhaps it was Orion marching out of the eastern sky leading the seasonal parade of winter constellations. But for whatever the reason, while testing Celestron's new SkyProdigy 6 telescope late last fall, I kept envisioning the gift-giving holidays ahead. I imagined budding amateur astronomers unwrapping new telescopes on Christmas morning in scenes that have played out with uncanny similarity since the dawn of mass-marketed telescopes.

I knew the excitement these new telescope owners would carry with them as they headed outside

Celestron's SkyProdigy telescope line is the company's first to feature 100% automatic alignment, making its computerized object-finding virtually foolproof for people with limited knowledge of the night sky.

ALL PHOTOS BY THE AUTHOR

on the first clear night to explore the Moon and perhaps a bright planet or two. But I also knew the struggles and frustrations that would befall many of them as they started looking for star clusters, nebulae, and galaxies.

That last vision, however, was one of Christmas past, because the coming holidays were sure to have many newly minted observers receiving Celestron SkyProdigy telescopes. For them, hunting celestial targets would be different. Dramatically different.

There are five telescopes in the SkyProdigy line: 70- and 102-mm achromatic refractors ($499 and $699, respectively), a 90-mm Maksutov-Cassegrain ($599), a 130-mm Newtonian reflector ($699), and the 6-inch Schmidt-Cassegrain I tested. The telescopes are standard, time-tested Celestron fare. It is the SkyProdigy alt-azimuth mount that makes them noteworthy. In addition to Go To pointing, the mount is Celestron's first-ever with a self-aligning feature. Turn it on, and a built-in digital camera automatically finds stars to initialize the Go To pointing and tracking. Once that's done, you just press a few buttons to select things you want to see from the scope's internal 4,000-object database (which includes planets, stars, and deep-sky objects), and the scope points to them. Yesterday's science fiction has become today's reality.

When computerized Go To pointing was introduced on modestly priced telescopes in the 1990s, it was widely touted that it would revolutionize observing for beginners. Many pundits felt that Go To technology would banish the difficulty of finding deep-sky objects for people unfamiliar with star charts and the complexities of the moving celestial sphere. For some it did, but for too many others the technology failed. The problem usually came down to the observer being unable to identify the stars needed to initialize the Go To system.

The digital camera in Celestron's SkyProdigy does the star identification automatically. It's not the first telescope with that ability. Meade's 6- and 8-inch LS (for LightSwitch) scopes, reviewed in our December 2010 issue, page 54, also have a built-in camera for star identification. But with a starting price of $1,399, the LS series is a bit steep for a typical beginner's budget. Celestron's starting price of $499 is much closer to the amount many first-time telescope buyers are willing to spend.

First Night

We borrowed the 6-inch SkyProdigy from Celestron for this review, since its weight would place the most demands on the mount. If it worked, then the smaller SkyProdigy scopes should perform equally well. Likewise, the 6-inch scope's low-power eyepiece has a 0.8° field of view — the smallest of any scope in the SkyProdigy line, putting the most demands on the accuracy of the mount's Go To pointing. It's also the most expensive scope in the SkyProdigy line, but that extra cost gets you a scope with enough "serious" aperture to give many observers years of celestial viewing.

WHAT WE LIKE:

Virtually foolproof automatic alignment and Go To pointing

Intuitive hand control

Excellent 6-inch telescope

WHAT WE DON'T LIKE:

6-inch telescope is near the upper limit for the mount and tripod

Thickening haze almost scuttled my first night with the SkyProdigy 6. The stars of Cassiopeia were barely visible in the northwest as I carried the scope to the back deck of my suburban-Boston home. The scope is remarkably easy to set up, and the fully illustrated quick-start guide walks you through all the steps, including ones that are blatantly obvious. It took me longer to unpack the box that the telescope was shipped in than it did to assemble the various components into a working telescope. Furthermore, the whole setup, including the battery pack with eight D cells, weighs less than 23 pounds (10 kg), so you can easily assembly everything inside and carry it outdoors in one trip.

When I flipped the power switch on, I expected the hand control to ask me to enter the date, time, and my location — information typically required by Go To scopes such as the SkyProdigy that aren't equipped with a GPS receiver. But it didn't. Instead, the scrolling display said to just press the Align button. Doing so launched an automated sequence of events that Celestron calls its StarSense Technology. The internal camera (which is a fixed part of the mount and not the telescope) snaps a picture, identifies stars, and determines where the telescope is pointed. It does this for three widely spaced locations on the sky, after which the scope is ready to use. The process

Celestron's StarSense Technology uses a digital camera (inside the small, red tube) to identify stars and automatically initialize the Go To pointing. Telescopes attach to the SkyProdigy mount with a standard Vixen-style dovetail.

took barely more than 2 minutes.

To a novice, this may all seem relatively simple, but it's not. Furthermore, my sky conditions that evening were terrible. Had the StarSense camera really found enough stars for the internal pattern-matching algorithms to figure out where the scope was pointed? And wait a minute, I never entered the date, time, or my location. I know it's possible to gather the necessary information from a set of star-field images — interplanetary spacecraft have similar abilities as a backup in case their primary navigation systems hiccup. But had this relatively inexpensive telescope just done it in 2 minutes under my crummy sky conditions? It didn't seem possible, but I was about to find out.

A few button pushes let me select Jupiter from the database and send the scope slewing across the sky toward the giant planet. When it stopped moving, Jupiter was at the edge of the eyepiece field. Not perfect pointing, but close enough to be successful. Next, I sent the scope to the bright star Capella in Auriga. It too ended up at the edge of the field. What about Auriga's well-known star clusters M36, M37, and M38? Bing, bing, bing, the scope found all three, even though the haze was making it increasingly difficult for me to see them in the eyepiece. The whole experience reminded me of the comment by the late science-fiction author and visionary Arthur C. Clarke, who noted that "any sufficiently advanced technology is indistinguishable from magic." It's not an exaggeration to say that SkyProdigy's out-of-the-box debut seemed a bit like magic.

In the final minutes before the sky completely closed in, I did a quick calibration that I had earlier read about in the scope's manual. I returned to Capella and, using the direction keys on the hand control, centered the star in the scope's eyepiece. I then selected the calibrate routine from the hand control's Utilities menu. The process took only a minute, and I did it by following the instructions displayed on the hand control. The calibration teaches the StarSense system where the center of the telescope's field is, and it improves the alignment and Go To performance when you next use the scope.

***Left*: Simple features such as a bubble level, hand-control bracket, and accessory tray make the Sky-Prodigy a pleasure to use. The mount attaches to the tripod with a single, captive hand-knob and a conical fitting — it's extremely easy to assemble, even in the dark. *Upper right:* The optional SkyQ Link WiFi module ($99) lets you control the scope with Celestron's *SkyQ* app for Apple's iPhone, iPad, and iPod Touch. It works very well, but requires a manual alignment rather than one using the automatic StarSense procedure. *Bottom right:* Large, illuminated buttons make the SkyProdigy hand control easy to operate in the dark even while wearing heavy winter gloves.**

A Few Details

The SkyProdigy 6 worked equally well on subsequent nights. StarSense Technology never failed to achieve automatic alignment when the sky became dark enough for the camera to find stars, which usually occurred between 45 minutes and an hour after sunset. The main requirement for a good automatic alignment is for the telescope to have a reasonably clear sweep of about half the sky in a clockwise direction from where it is initially pointed (the initial position can be in any direction). This was the case from my back deck, but barely so, since the house blocked about half of the sky. In locations where there are lots of trees or buildings, you can do a StarSense alignment by manually pointing the telescope at three unobstructed parts of the sky. The quality of this alignment (and subsequence Go To pointing) may be reduced if the sky locations are not well separated.

The StarSense camera doesn't work in daylight, but you can still align the mount for Go To pointing and tracking. This requires using the Sun (after acknowledging appropriate warnings displayed on the hand control), Moon, or any planet as a single alignment point. (You can also use this alignment method in twilight when it's too bright for the camera to find stars.) But the procedure requires you to enter your geographic location (and it's a good idea to confirm that the scope's internal clock, which was set when the telescope

Although this is an extreme example from the author's early nights of testing (the protective paper hadn't yet been removed from the candy-apple red tube), most observers will want an aftermarket dew cap or dew heater if they have the SkyProdigy Schmidt-Cassegrain or Maksutov telescopes. Despite the obviously bad conditions, the StarSense camera never fogged up.

was manufactured, has the correct time).

The LCD on SkyProdigy's hand control displays scrolling-text instructions for operating the scope. Cold weather makes the LCD sluggish, rendering this text illegible, but it's only a problem if you haven't yet learned the scope's basic functions or don't have the printed manual at hand. Some of the scope's lesser-used features, such as the calibration process mentioned above, display instructions that you have to manually scroll with buttons on the hand control. As such, they were readable even on the coldest nights — a nice feature.

The scope's illustrated manual is well done, with clear and concise information. But there are a few goofs that might trip up a beginner. For example, I found several names in the manual that didn't match what was printed or displayed on the hand-control. Likewise, some of the scrolling text on the hand control refers to the "Option" button, but you'll need the manual to learn that this button is the one with the Celestron logo at lower left on the keypad.

***Top:* The StarSense Technology works under a wide variety of less-than-favorable sky conditions, including moonlight and urban light pollution. This view shows what the author was up against on his first night with the SkyProdigy (described in the accompanying text). *Above:* The SkyProdigy 6 comes with a star diagonal and 25- and 9-mm eyepieces that yield magnifications of 60× and 167×, respectively. The red-dot finder is useful for manually aiming the scope at celestial targets that you don't know by name, after which you can identify them with a single button press on the hand control.**

The Optics

Because Celestron optics are already highly regarded, most of my testing was focused on the SkyProdigy mount. Nevertheless, the 6-inch Schmidt-Cassegrain easily lived up to the company's reputation. My views of the Moon, Jupiter, and Saturn were first rate. And although I do much of my own deep-sky observing with larger apertures, the 6-inch can show a lot, especially when it comes to the brighter objects that most beginning observers turn to first.

The telescope is, however, close to the weight limit that the mount can adequately handle. Vibrations that jiggled the view as I turned the focus knob took about 5 seconds to settle out. That's relatively long, but the numbers alone don't tell the entire story. Given the scope's excellent optical quality, coupled with its easy set up and foolproof Go To pointing, the overall observing experience was superb. The SkyProdigy is the most straightforward Go To telescope I have ever used.

It's unlikely that a group of telescope experts could ever agree on what constitutes a "perfect" beginner's telescope, but I think that many would feel as I do — the SkyProdigy is getting pretty close. ✦

Although he knows it's a lot, senior editor ***Dennis di Cicco*** *doubts that he can recall every Go To telescope he's used.*


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My Outback Travelscope

Built to take flight, this 8-inch Dob makes the grade with today's baggage regulations.

In this magazine's December 2001 issue I described my airline-portable 8-inch Dobsonian. That scope was a big hit with readers, and I've logged a lot of miles with it over the years. But if you fly regularly these days, I don't need to tell you how precious overhead storage space has become. I began to fear that someday my scope would be "gate checked" and end up being tossed into the luggage hold with all the other checked bags, where it might not fare very well. Thus, when my plans were laid for travel to Australia for last November's total solar eclipse and some dark-sky observing in the Outback, I decided it was time to rebuild my travelscope for safe transport in my checked luggage.

GEORGE BRANDIE

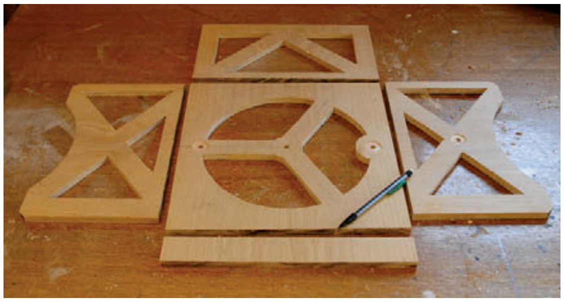
The author with his travelscope ready for a night of southern-sky observing in the Australian Outback, near Uluru.

To achieve this goal, I needed to make two major changes. First, the new scope had to be compact enough to fit inside my suitcase with enough extra space for a few inches of protective padding. Second, it needed to go on a diet. The original scope weighed 25 pounds (11 kg). When packed into my 10-pound suitcase, I had only 15 pounds of the airline's 50-pound weight budget remaining for my eyepieces, cameras, clothes, and everything else that travels in my checked bag.

I started planning my Outback travelscope with the premise that the lightest and most compact design would likely require the greatest amount of field assembly. But I was fine with that. When I fly for stargazing events, I usually spend a few days at my destination, so setup and teardown isn't a nightly ritual. I also decided to use the 8-inch, f/4.2 primary mirror, as well as the secondary mirror and holder, from my original travelscope. I would build everything else from scratch with an eye towards trimming as much weight as possible without sacrificing stability or rigidity.

A conventional Newtonian's tube mainly serves to hold the optical elements and focuser in their correct positions. The key to making a minimalist Dob is to find other ways to accomplish this task. In the case of my new travelscope, the "tube assembly" consists of a secondary cage and the cell for the primary mirror joined by a pair of aluminum struts. Arriving at the design required a lot of rough sketches, weighing components, and a generous helping of trial and error.

I used ½-inch plywood for the main parts and ¾-inch for the side-bearing rings. I worked with a jigsaw to cut out as much excess wood as possible from the rocker-box panels, leaving the remaining wood in the form of triangular elements, which offered maximum rigidity. At the travelscope's front end I saved weight by reducing the original scope's secondary cage to a single plywood ring with a plate that accommodates the focuser, and a pair of mounting blocks that act as supports for the curved-



GARY SERONIK (3)

***Far left*: Weighing only 15 pounds (7 kg), the travelscope functions like a regular Dobsonian. The side bearings are attached with hand knobs that thread into holes tapped in the aluminum struts.**

***Above:* The rocker-box panels are seen prior to assembly. The large cutouts reduced the weight of the mount by nearly half.**

***Left:* A view of the travelscope's optical tube during test assembly. This step is crucial for determining the scope's balance point so that the side bearings can be correctly positioned, which in turn sets the minimum height of the rocker box.**

vane secondary holder. At the back end I dispensed with a traditional Dobsonian's mirror box and simply attached the aluminum struts directly to the rear disk of the double-plate mirror cell. The front ring, rear mirror-cell plate, and side bearings share the same 11-inch outside diameter, so I saved construction time by using just one setting on my router's circle-cutting jig. Likewise, the secondary ring and side bearings also share the same 8¾-inch inside diameter.

To complete the tube assembly, I dispensed with the original scope's four, ½-inch aluminum poles and replaced them with a pair of 29¼-inch-long, 1-inch-square aluminum tubes. Since fewer struts meant less mounting hardware, the weight savings were multiplied. I glued sockets (consisting of ¼-20 T-nuts mounted in wooden cubes) into the ends of the square tubes. As such, the front ring and rear mirror cell can be attached to the struts with socket-head cap screws. This two-strut arrangement turned out to be more rigid than my previous four-pole configuration.

I made two versions of the scope's ground board. The first is a tabletop design that is simply a round disk of plywood with three Teflon pads on its top side and three feet underneath. The second is a more elaborate assembly that attaches to my Bogen camera tripod. This ground board is similar to the one described in the December 2007 issue as part of my Easy-Go-Round binocular mount. The key to a stable support is to ensure that the scope's weight is transferred directly to the tripod legs. Although the tripod is additional weight, it's an item I always take with me for photography.

One aspect of this travelscope that isn't apparent in pictures of it fully assembled is that the individual parts are made to fit together inside the rocker box, for safe transport. With the exception of the ground board, everything is secured by a pair of bolts that pass through holes in all the parts and the bottom of the rocker box. Once I tighten down a pair of wing nuts, the individual components are locked down and ready to be packed into my suitcase.

So how did my new travelscope perform on its maiden voyage? Beautifully. The new design trimmed 10 pounds off the original, resulting in a lightweight, 15-pound package. The scope made it to Australia (and back) unharmed in a checked suitcase, and it took me only 10 minutes to assemble the scope in my hotel room. Best of all, I had an 8-inch scope in the Outback to explore the wonders of the far-southern skies from a dark location. All it took was an hour of blissfully scanning the Large Magellanic Cloud for me to be convinced the effort was worthwhile. ✦

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*Contributing editor **Gary Seronik** combines travel and stargazing whenever possible. More information on his travelscope is available at* **www.garyseronik.com**.

Northern Exposure

Follow these simple suggestions to take stunning aurora photographs.

Babak A. Tafreshi

It's March 5, 2012. I'm sitting at my computer and checking the website **spaceweather.com** for the latest news on solar activity. A giant sunspot has appeared on the solar limb, roaring with potential X-class flares and gas eruptions that could shower Earth's magnetosphere with streams of solar-wind particles. This activity might cause spectacular auroral displays during the next two weeks. It's time to pack!

Viewing a strong auroral display is the experience of a lifetime. The magical lights shimmer and dance in colorful rays, forming ever-changing shapes in the sky. If you're anxious to see a majestic display, March is a great time of year. Plus, the current solar cycle is expected to peak in 2013, promising numerous flare events and major auroras.

Individual auroras are unpredictable. Some are the result of coronal mass ejections (CMEs) that launched off the Sun days earlier, while others are produced by high-speed solar wind particles shooting toward Earth from coronal holes (see the cover story of last month's issue for an in-depth discussion of auroras).

Capturing the aurora borealis is fun and easy, but unless you live near the Arctic Circle, you'll need to travel to catch a bright display. Contributing photographer Babak Tafreshi captured this display of the northern lights from northern Sweden. All images are courtesy of the author.

Neither of these events guarantees beautiful auroras, but either can increase the possibility of one.

Auroras can last anywhere from a few minutes to several hours. For a successful imaging session, you should plan to run your camera throughout the entire night.

Most auroras appear a pale green color that is easy to see because our eyes are most sensitive to the green region of the spectrum. Purple, blue, and yellow are sometimes visible during strong activity, and deep red auroras will appear in the most intense storms. Even a faint aurora that appears colorless visually might be dramatically colorful in your photographs. An aurora's color comes from photons emitted by oxygen and nitrogen atoms and molecules in our atmosphere after they're excited by solar wind particles spiraling along Earth's magnetic field.

Gearing Up

Capturing stunning aurora pictures, like all types of photography today, has been revolutionized by digital SLR cameras. Even with a modest point-and-shoot digital camera, auroras are easy and fun to photograph with the proper settings. If you're planning a trip to shoot auroras, here's a list of things to take along.

First, bring two cameras. One camera can be a backup to your primary camera, or you can use it to capture additional stills of alternate parts of the sky while your main camera is snapping frames for a time-lapse video. Also, because your target is a large swath of the aurora and not faint nebulosity, many

of the new budget multi-megapixel cameras with small pixels will work well for photographing bright auroras. However, small pixels often saturate point sources such as stars, and they have lower dynamic range at high ISOs (1600 or greater). Although not essential, full-frame DSLRs with large pixels generally provide better color performance overall in aurora photography, though rapid developments in sensor technology are beginning to counter this oft-stated rule of thumb.

If your main camera is a DSLR, then a high-quality, wide-angle lens with a fast focal ratio will produce your best images. Bargain lenses from third-party manufacturers tend to produce distorted star images and flaring near the edge of the frame, seriously degrading the overall quality of your photos. Also, avoid wide-range zoom lenses such as 18-to-200-mm and 24-to-105-mm. Zoom lenses are often much slower photographically than fixed-focal-length lenses. A wide-angle f/2 lens will record much fainter auroras in shorter exposures than an f/3.5 zoom. Under low light conditions, long exposures with slow lenses will cause fast-moving auroras to blur, so it's generally better to use lenses with focal ratios of f/2.8 or faster. One of the best lenses for shooting the northern lights is an ultra-wide-angle lens that covers 100° of sky or more, enabling you to capture sweeping auroral arcs in a single shot. A 10-mm f/2.8 fisheye lens is great for cameras with APS-sized sensors, while full-frame cameras perform best with a 15-mm f/2.8 fisheye lens.

During geomagnetic storms that produce extremely bright auroras shimmering all across the sky, only circular fisheye lenses, such as an 8-mm fisheye, can record the entire sky in a single frame. Although these lenses are photographically slow with apertures of f/3.5 or greater, their huge fields of view and small image scale allows you to take long exposures with minimal blurring.

Make sure to bring at least two memory cards per camera. Cheap memory cards tend to malfunction in cold temperatures, so having a backup can often save an otherwise wasted evening.

Avoid using most photographic filters when shooting auroras. Ultraviolet- or infrared-blocking filters that are excellent for daylight photography and for protecting the lens surface can produce unattractive banding in aurora photographs because they block some of the wavelengths that auroras emit. This banding is difficult to remove in post-processing. In the cold temperatures of high latitudes where auroras are frequently seen, frost also forms on filters more quickly than on an exposed lens element. Even in warm temperatures and humid conditions, condensation on your lens is a common problem

***Top:* Interesting foreground objects, such as this thin stand of trees, can help create a more interesting composition. *Bottom:* A tall, sturdy tripod enables you to quickly compose your images without having to crouch in uncomfortable positions.**

when temperatures rapidly fall. A fresh pack of lens cloths is helpful under such conditions. Dew heaters made for telescopes are also useful in holding off frost or dew, but they require an additional power source.

In the cold nighttime temperatures of northern latitudes, spare batteries or external power supplies are a smart addition to your gear, because cold temperatures significantly reduce battery life. Keep your extra batteries warm in your pocket, to help them maintain their charge. Older DSLR cameras often use more power than newer models, and they can drain batteries after only a few dozen shots in extremely cold conditions. Newer models are often more power-efficient and will function for several hundred to roughly 1,000 exposures even at extreme temperatures, so having at least one spare set of batteries is usually sufficient for a night of photography. When shooting time-lapse photos, a battery grip or a larger external battery may be best to avoid the gaps caused in a series of exposures when you swap out a depleted battery.

Chemical hand warmers are also an excellent accessory. You can use them to warm your fingers and extra batteries, but also your equipment: they can easily be affixed to your camera's battery compartment to extend its life.

A shutter-release cable is an essential accessory for aurora photography. Programmable models are useful for time-lapse imaging or when taking exposures longer

Strong auroral displays can change shape and brightness within seconds, so having a fast, wide-angle lens is important to freeze the motion using short exposures. The author recorded these two images only 30 seconds apart using a Canon EOS 5D DSLR at ISO 1600 and an 8-mm f/4 fisheye lens.

than 30 seconds. You can record bright auroral displays, however, with the longer timed exposures available on even the simplest camera models.

I strongly recommend bringing a sturdy tripod. Even if it's heavy and awkward to transport, it will reward you by helping you avoid the blurry images with wiggly stars caused by your camera shaking in windy conditions. When shooting auroras with a picturesque landscape, a tall tripod also enables you to compose your shot without having to contort to see through your camera's viewfinder. Ball-head accessories are also lighter than the standard three-axis tripod heads and allow you to frame your composition quickly.

When imaging the horizon at night, it's often difficult to judge if the camera is level with the horizon, so a small bubble level is also a helpful accessory.

Just like other types of astrophotography, the best locations are usually far from civilization. Consider bringing along a friend for safety, or make sure someone knows where you're going. If you travel alone, bring some form

of predator repellent, such as sprays or ultrasonic devices. Wild animals usually avoid human contact, but you should minimize the risk of dangerous encounters.

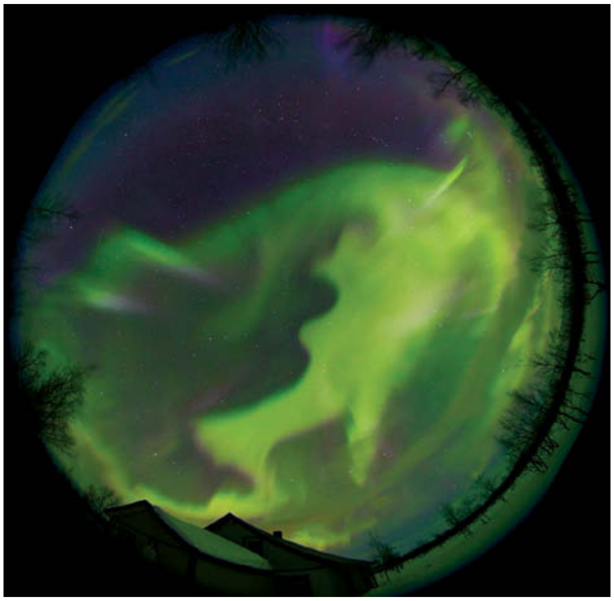
Destination: North

When heading out on an aurora expedition, it's important to know where to go for the best chance of witnessing a display. A popular misconception is that the northern lights appear strongest right at the geomagnetic pole. In reality, auroras usually occur in a giant ring roughly 4,000 kilometers (2,500 miles) wide that surrounds each of the geomagnetic poles. At the center of this oval, auroras become less frequent and appear over the southern horizon, such as in northern Alaska and Canada.

Although powerful geomagnetic storms can occasionally produce auroras at temperate latitudes, these are rare. So your best bet is to plan a trip to a location known for frequent displays, such as Iceland, Alaska, and the Scandinavian Peninsula.

Whether you live in a location that experiences frequent auroral displays or prefer to wait for a strong geomagnetic display to push the auroral oval down to your latitude, you can monitor solar activity to know the best time to head out to shoot. Some websites, including **spaceweather.com**, track worldwide measurements of geomagnetic activity

Left: **Although aurora photographers generally travel far from urban locations to capture their best photographs, small settlements, such as this settlement near Kiruna, Sweden, can enhance your compositions.** ***Below:*** **From far northern regions such as northern Alaska, Canada, and the Scandinavian Peninsula, aurora often appear in the southern sky. The author recorded this photo from northern Sweden, where the brightest arc of activity crosses the southern constellation Orion, visible at right.**



Circular fisheye lenses enable you to shoot the entire sky in one shot. These tend to be photographically slow, but their inherently small image scale allows longer exposures than possible with conventional lenses before blurring becomes objectionable.

with a scale known as the Kp index. This index ranges from 0, which is low activity, to 9, which means that a powerful geomagnetic storm is underway. An index of 5 or greater indicates a good chance of auroral activity at mid-northern latitudes in the Western Hemisphere of roughly 40° or higher. But at northerly latitudes of around 60°, such as in northern Canada, a Kp index of 3 will produce bright auroras visible at the zenith.

Although intense geomagnetic storms are rare, the most powerful tend to occur roughly once per solar cycle. The last one occurred in late October 2003, so we may be due for one soon. You can learn more about the Kp index and aurora predictions at the NOAA/Space Weather Prediction Center: **www.swpc.noaa.gov/Aurora**.

Catching the Northern Lights

How to shoot the best aurora photos depends on how strong the display is. But first, you need to focus your camera. Set the lens focus at infinity and fine-tune the focus using the camera's Live View (if your camera includes this feature), or take test exposures and zoom in on a star to judge focus. Although sharp focusing is not as critical as it is with telescopic imaging, it's still an important factor for capturing the best nightscape photos. But remember that your subject is the sky, so don't use foreground objects as your focus point.

Once your camera is in focus, you can take a few test exposures to see how short they can be while both adequately recording the display and minimizing blur. From an ideal location, auroras appear regularly in the form of multiple bright arcs stretching from the northwestern to the northeastern horizon. These bright displays are best captured with short exposures of roughly 10 seconds at an ISO of 800, in order to "freeze" any motion. Fainter displays may require higher ISO speeds and longer exposures of 30 seconds or more.

As with more general nightscape astrophotography (*S&T:* November 2012, page 71), spend some time composing your foreground to ensure a good overall composition. Avoid power lines, highways, and bright urban locations if you want to achieve the best results.

The aurora has diverse colors, so setting your camera's color balance can be crucial to taking great photos. I often select a custom white balance of around 4500–5500 kelvin with my Canon EOS 5D to produce the most colorfully diverse results that still look natural. You can also correct the white balance in the post-processing of RAW files.

When shooting for an entire evening, I use two cameras — one that I can move around to take varied compositions, and the other I leave stationary for the entire evening to capture a time-lapse sequence that I can later assemble into a stunning movie using popular software packages such as *Startrails*, *StarStaX*, *AVIedit*, or *Adobe Photoshop* (*S&T*: August 2009, page 66).

The unpredictability of auroras combined with their often rapidly-changing appearance make these polar attractions a popular target for astrophotographers and visual observers alike. By following this simple guide, you'll be well on your way to taking world-class aurora photos and movies! ✦

Contributing photographer ***Babak A. Tafreshi*** *is the founder of The World at Night (***www.twanight.org***) and is the 2009 corecipient of the Lennart Nilsson Award for scientific photography. See more of his nightscapes at* **www.dreamview.net**.

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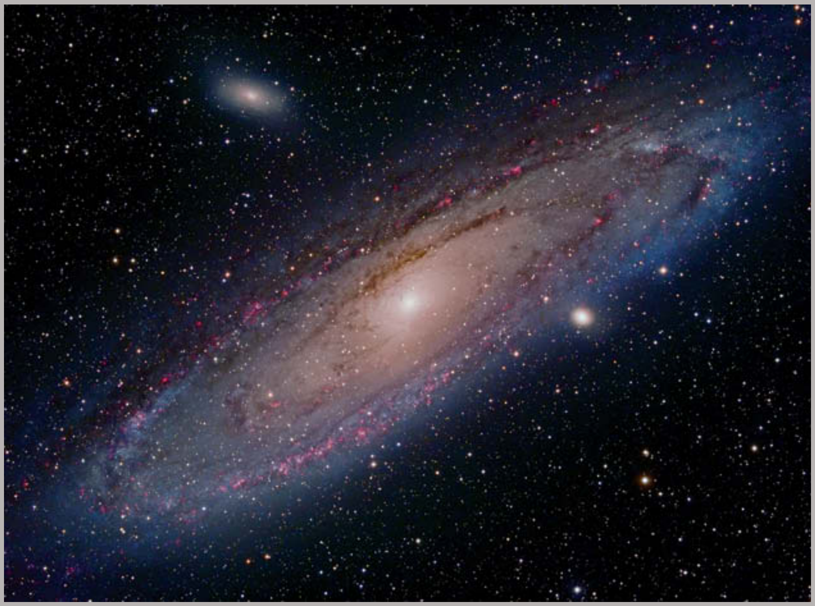
▸ **THE ANDROMEDA GALAXY**
Terry Hancock
M31 presents numerous dust lanes and a bluish outer halo punctuated by a ring of pinkish star-forming regions in this enhanced-color photograph.
Details: *TMB 92SS refractor with QHY9M CCD camera. Total exposure was 22 hours through color and hydrogen-alpha filters.*

▾ **PAC-MAN UNVEILED**
Fabian Neyer
This extremely deep photo reveals the faintest outer extremities of the molecular cloud NGC 281, the Pac-Man Nebula, in Cassiopeia.
Details: *Telescope Engineering Company APO140ED refractor with SBIG STL-11000M CCD camera. Total exposure was 30.8 hours through Baader Planetarium color and hydrogen-alpha filters.*



CORONAL STREAMERS

Robert B. & Elisabeth L. Slobins

The total solar eclipse of November 13–14, 2012, featured wonderfully symmetrical streamers such as those often seen during eclipses that occur near solar maximum.

Details: *Canon EOS 5D DSLR camera with 300-mm lens. Composite of multiple exposures ranging from 1⁄2000 second to 1 second.*

NEBULOUS WRAITH
Gerald Rhemann
The large bluish reflection nebula IC 4592 in Scorpius is seen by some to resemble a horse or dragon. It's shown here with south up.
Details: *8-inch F/2.8 ASA astrograph with FLI ProLine PL16803 CCD camera. Total exposure was just over 2½ hours through FLI color filters.*

Visit SkyandTelescope.com/gallery for more gallery online.

◀ **DIAMOND RING**
Koen van Gorp
The first glint of sunlight peeks out between lunar mountains at the moment of third contact, marking the end of totality as seen near Mount Carbine in Queensland, Australia, on November 14, 2012.
Details: *Canon EOS 40D DSLR camera with 300-mm lens. Single exposure of 1⁄8000 second at f/5.6, ISO 100.*

▼ **TRIANGULUM PINWHEEL**
Chris Cook
The face-on spiral galaxy M33 in Triangulum is noted for its delicate spiral arms punctuated by numerous pinkish knots of nebulosity.
Details: *Astro-Physics 130EDFGT refractor with SBIG ST-8300M CCD camera. Total exposure was 8⅔ hours through Astrodon color filters.* ✦

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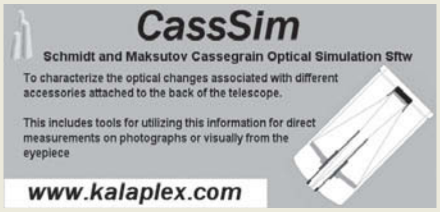

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FOR SALE: Items from the estate of the late William Shawcross, past President of Sky Publishing Corp. Items include Lunt Solar Systems H-alpha LS60THa scope with additional LS50F Ha filter and BF600, Lunt Calcium LS60T CaK scope, Orion 127, 8-inch Cassegrain from TAL, 4-inch f/10 TAL refractor, plus various eyepieces and accessories. Each telescope has its own medium-weight German equatorial mount with manual slow-motion controls. For complete descriptive list send email to ads@skyandtelescope.com.

AUTHORS/SOFTWARE DEVELOPERS: is your passion astronomy and would you like to see your work published by Willmann-Bell? If so, let's explore the possibilities. Call 1-800-825-7827 or write PO Box 35025, Richmond, VA 23235.

SOUTHERN UTAH CANYON COUNTRY: Land, remote and beautiful, for sale near Capitol Reef National Park. Wonderful homes away from the lights of the small communities are on the market. The elevation ranges from 4000 to 7000 feet. Cathy Bagley, Boulder Mountain Realty, Inc. Torrey, Utah. 435-425-3200. www. bouldermountainrealty.com.

FOR RENT: 3 BR/2BA fully furnished adobe home in ARIZONA SKY VILLAGE in Portal, AZ. Observe and photograph under the darkest, clearest and most transparent skies with astronomers from all over the world. Contact irkitzman@gmail.com 520-203-8500 www.arizona-dreaming.com.

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Index to Advertisers

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IN THE NEXT ISSUE

Caving on Other Worlds
Spacecraft have revealed caves on the Moon and Mars, ideal habitats for future human colonists.

Remembering Comet Kohoutek
Forty years ago astronomers predicted a "Comet of the Century," but it didn't turn out that way.

Imaging Messier Marathon
An astrophotographer imaged all 109 Messier objects in a single night. You can too.

Top Ten Neglected Objects
A veteran deep-sky observer describes his favorite under-appreciated deep-sky wonders.

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Hooked on the Heavens

After two decades, a DSLR camera rekindles the author's passion for astronomy.

It started when I was in 8th grade. My parents bought me a pair of 7×35 binoculars for my birthday. They intended my targets to be terrestrial objects and wildlife, but out of curiosity, I aimed at the night sky instead.

I remember seeing a bright "star" with four smaller "stars" nearby. I had no idea what I was seeing, but I knew it was something special. My inspiring science teacher, Mr. Schmidt, advised me to start a journal and draw what I saw. After reviewing sketches, he told me it was Jupiter and its moons. I couldn't believe that I could see the moons of Jupiter with inexpensive binoculars in the light-polluted skies of Austin, Texas. I was hooked.

The following summer I saved my lawn-mowing money to buy my dream telescope. It was a department store's best model, a 90-mm refractor with low-quality lenses. I spent countless nights camping in my backyard, observing and taking notes. I remember the first time I saw Saturn in all of its ringed glory. I remember star-hopping for hours in freezing weather. But my resources were limited and I was never able to see many deep-sky objects.

In high school my chemistry teacher, Dr. Robert Suder, took me under his wing. With his sponsorship and mentoring, I started an astronomy club. We visited NASA's Johnson Space Center in Houston, had a couple of star parties, and viewed sunspots. Then life happened. I went to college, graduated, got a job, and started a family. Life's financial and time commitments kept me from returning to the dark skies . . . until now, two decades later.

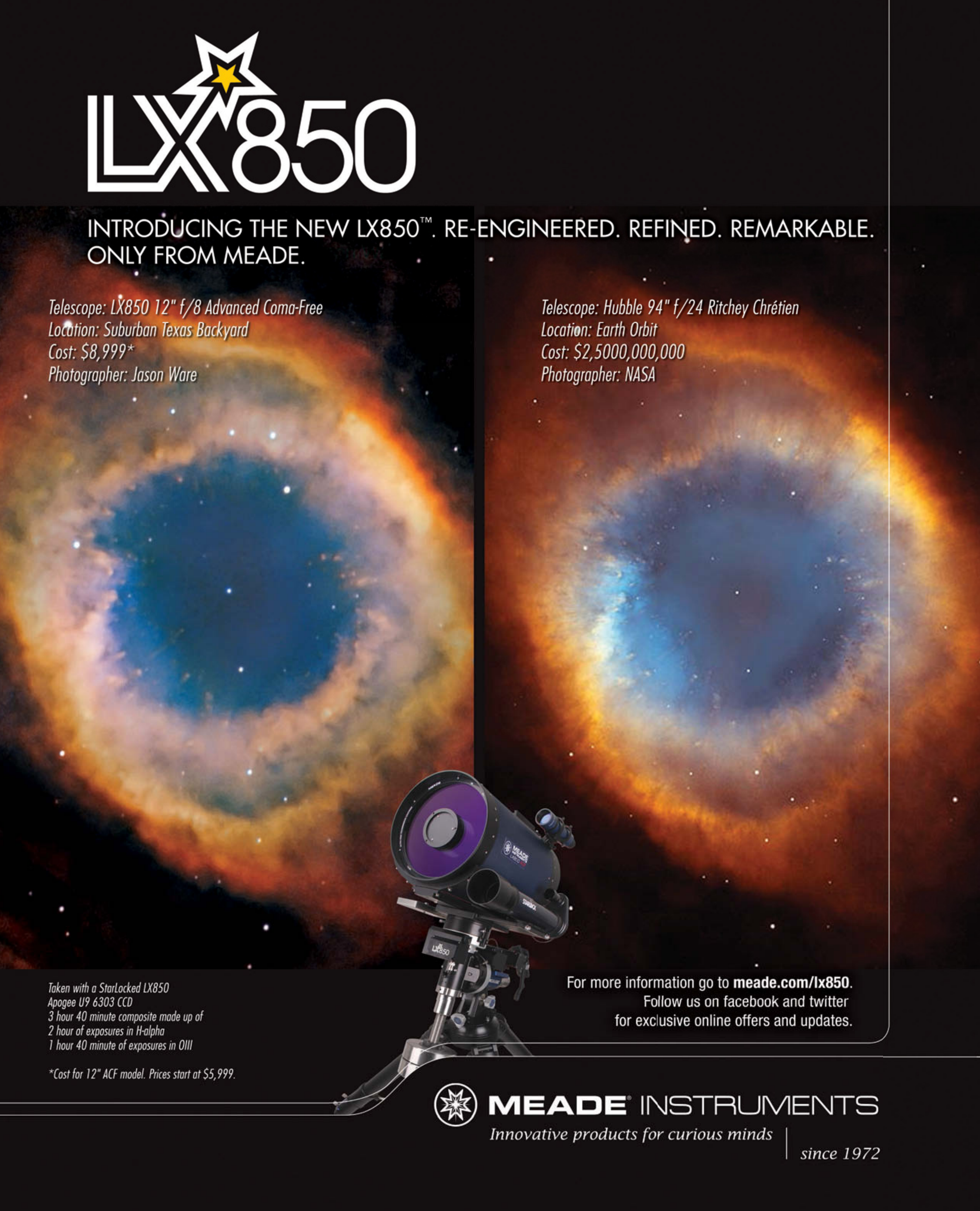
Last year I purchased a DSLR camera and a sturdy tripod for family vacations and events. Then it happened. I pointed the camera at the night sky and captured some Quadrantid meteors, and then anything else I could shoot with short, unguided exposures. I was hooked again and needed a telescope.

On a budget, I sought one with crisp optics, basic tracking capability, and portability. I purchased a refurbished 6-inch Schmidt-Cassegrain telescope with advanced coma-free optics. Despite its relatively small aperture, it has brought a completely new world within my reach — even in my neighborhood's light-polluted skies. Its portability and Go To functionality has ensured it gets plenty of use.

I recently snapped my first picture through my telescope of the Orion Nebula. I was blown away when I saw the reds and blues in my 30-second exposure. Now I can't resist a clear night. I have captured several other deep-sky objects. I realize my setup doesn't yield the best astrophotography, but it has revitalized my excitement for exploring the heavens.

I keep looking back to those 7×35 binoculars of my youth. Many of you can probably remember the magical moment that first introduced you to amateur astronomy. Share your excitement with others, and if you've been away for awhile, look again at the dark skies that once inspired you. Don't wait for the perfect opportunity; take the first opportunity. You'll get hooked on the heavens again too! ✦

***Steve Lewis** started in amateur astronomy when he was 14. He went on to become an English teacher and, following graduate school, now works in the space industry on the Colorado Front Range.*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