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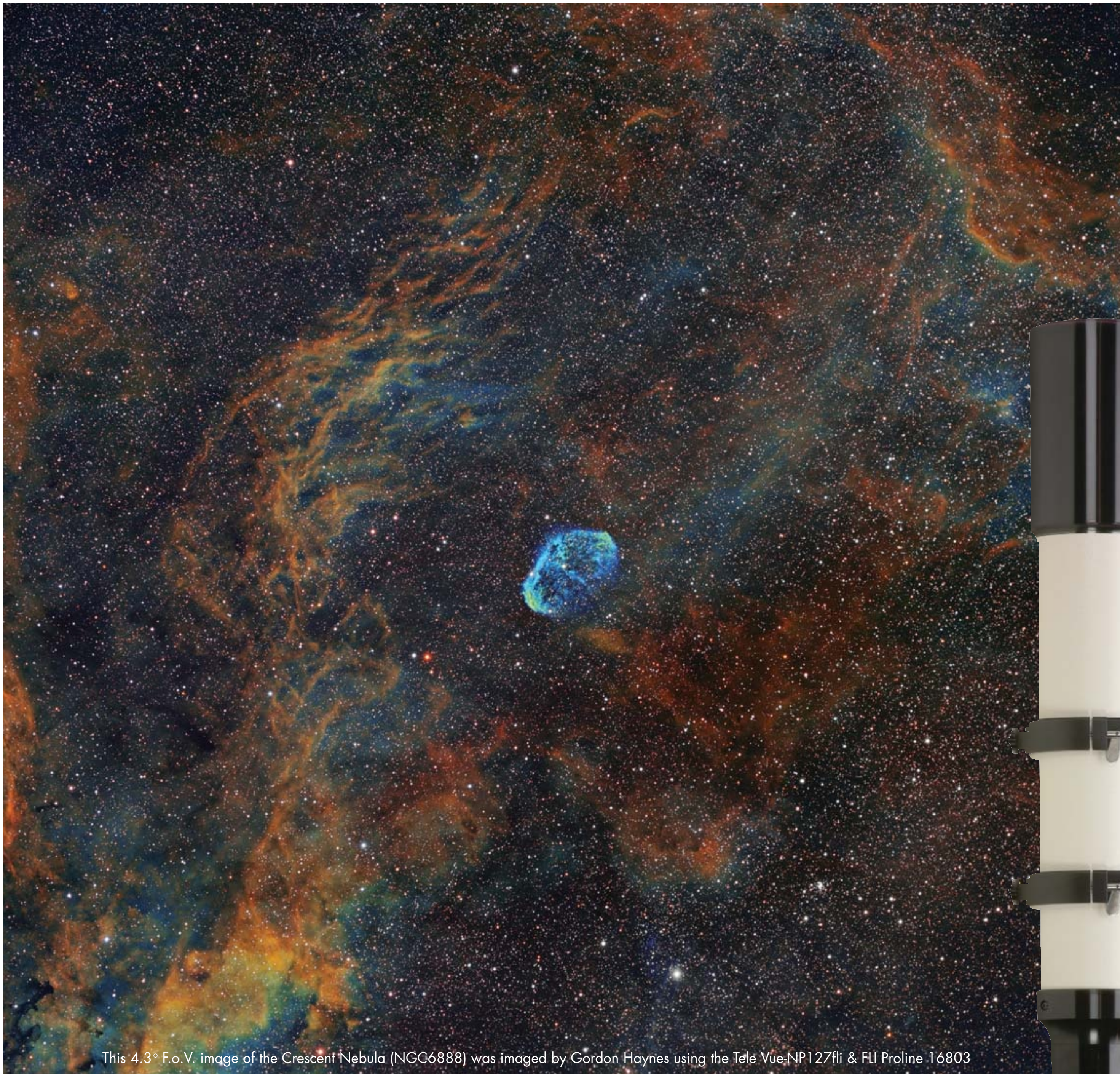

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February 2015

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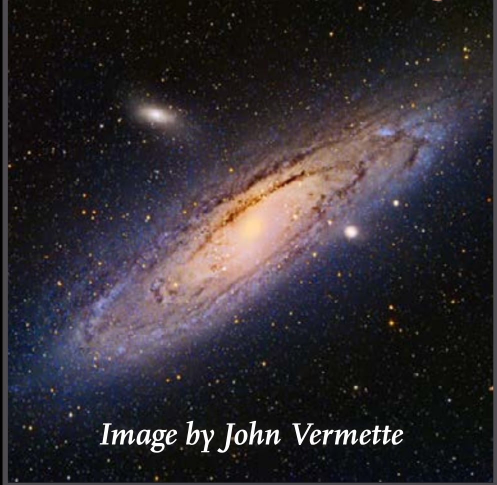

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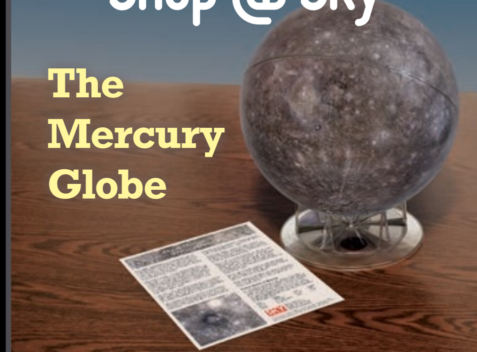

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ONLINE PHOTO GALLERY

Jeff Dai captures the Milky Way suspended over Gyirong Valley in Tibet, China.

Birth of Astro Imaging

It wasn't long after the invention of photography in 1839, when Louis Daguerre unveiled the process that bears his name, that amateur astronomers began turning their cameras to the heavens. As early as 1840, for instance, John Draper, a professor of chemistry and physiology at New York University, made a daguerreotype of the Moon.

But no one worked as hard to establish astrophotography as did a team based at the Harvard College Observatory (HCO), just up the street from the *S&T* offices in Cambridge. There the Boston-based daguerreotypist John Adams Whipple, working with HCO director William Cranch Bond and his son George, spent several years in the late 1840s and early 1850s trying to take successful daguerreotypes through the HCO's 15-inch Great Refractor.

HARVARD COLLEGE OBSERVATORY

Whipple daguerreotype, February 26, 1852

One of the team's triumphs was a 100-second daguerreotype of Vega. Bond noted that the light captured on this plate — the first photograph ever made of a star other than the Sun — "took its departure from the star more than twenty years ago, long before Daguerre had conceived his admirable invention."

The team's chief focus, though, was the Moon. "Nothing could be more interesting than its appearance through that *magnificent* instrument," Whipple wrote. "[B]ut to transfer it to the silver plate, to make something tangible of it, was quite a different thing." (Daguerreotypes are positive images fixed on a silver-coated copper plate.)

One hurdle was timing exposures to work in conjunction with the telescope's clock-driven movements. Another was coping with the tremulous coastal atmosphere of Boston. At last, on the nights of March 12-14, 1851, the team secured its first great daguerreotypes of our satellite.

One earned top prizes that year at London's Crystal Palace Exhibition, where the winning image was declared "one of the most satisfactory attempts that has yet been made to realize by a photographic process the telescopic appearance of a heavenly body, and must be regarded as indicating the commencement of a new era in astronomical representation."

I can't help thinking: if only Whipple and the Bonds could see what amateurs can achieve today with modern astrographs, CCD cameras, and computer processing!

But what I'm really wondering is: how much further along will amateur astroimagers be 165 years from *now*? Will some future *S&T* editor be describing images in "Astrophotography Today" (see p. 72) in the same quaint historic terms as I describe Whipple's? Will future astrophotographers' creations be orders of magnitude more advanced than ours today? I guess we'll just have to wait for the January 2180 issue.

Peter

Editor in Chief

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S&T: LEAH TISCIONE

Cleaning Optics, Reprise

I enjoyed the practical tips on cleaning optics in the August 2014 issue (p. 38). I had a fairly dirty primary mirror in my astrograph and was somewhat intimidated by the thought of cleaning the delicate surface. However, armed with Gary Seronik's helpful advice, I got up the courage and cleaned my first mirror. I used his first method with the cotton balls, and though it was effective, I ran into a lot of water spotting after it had dried. I then stepped up to his soapy fingertip method, which did create a cleaner surface and reduced the water spotting, though I still wasn't satisfied. It was my wife's great idea to use her hair dryer on the cool setting, moving its nozzle in a circular motion a few inches above the surface. That eliminated the water spotting almost completely. Thanks for continuing to publish these extremely practical articles, and keep up the great work!

David Timm
Auburn, Alabama

Seronik's suggestion to use your fingers (after thoroughly washing them, of course) to clean the mirror surface makes sense to me. A number of years ago an optometrist told me that soapy fingers are good for cleaning eyeglasses, and I have always followed his advice. But a person with heavy callouses on his or her fingertips should be extra careful. Even after washing your hands, you might not feel any abrasive dirt particles still lodged in your fingertips. Also, callouses can reduce a person's sense of touch, and you can end up pressing too hard on the mirror surface.

William DeBuvitz
Mendham, New Jersey

Seronik's article on cleaning optics was informative. As an optics professional, I would like to add a few more recommendations to his:

- Baby shampoo also works as a cleaning liquid.
- If you need a solvent for cleaning, alcohol (>90%) is a good choice and will not harm plastics that are part of the eyepiece or lens housing.
- The downside of using cotton balls or swabs is that the fibers can catch on the sharp edges of the retaining rings that hold the objective or lenses in eyepieces. Lens tissue or a tech wipe folded into a rectangle or triangle works for cleaning around the edges, without catching.
- Lighting is very important for general cleaning. Optical manufacturers use a simple desk lamp with a frosted light bulb or a fluorescent lamp. You can also use diffused LED lighting. (Avoid high-intensity light sources for general cleaning.) Tilting the optical surface under the lamp will show most contaminants.

I agree with Seronik that you should limit how often you clean. For a primary or secondary, every 2 to 3 years is probably enough, depending on the use. You can clean eyepieces more often, to remove eye splash on the eye lens. And, of course, prevention goes a long way: when putting your equipment away, always cover your telescope optics and store eyepieces in containers or have them capped.

Robert Schalck
North Bend, Oregon

Toddling Toward Telescoping

The article "Toddlers at the Telescope" (*S&T*: Aug. 2014, p. 34) reminded me of when I gave a friend's preschool-age son his first look through my telescope. At age 3½ the boy could not hold his head still enough to keep his eye in the eyepiece beam. Six months later, on his fourth birthday, he had gained the necessary reflexes in his neck and upper body and got a good look at Saturn. He said something like, "It looks like a spaceship."

Keith Brescia
Falls Church, Virginia

Flying Stars

With regard to "The Flight of 61 Cygni" in Alan MacRobert's August Celestial Calendar column (p. 50), I have charted the movement of both 61 Cygni and a number of other stars for many years using charts in *Burnham's Celestial Handbook*. Thanks to these charts, I've tracked Barnard's Star in Ophiuchus, Krüger 60 in Cepheus, UV Ceti, Van Maanen's Star in Pisces, Groombridge 34 in Andromeda, Ross 614 in Monoceros, Struve 2398 in Draco, and Groombridge 1830 in Ursa Major. I have even been able to detect a slight shift in the position of Arcturus as it plunges through the galaxy on its visit to the Sun. I last charted 61 Cygni in 2004, using the photos on page 770 of *Burnham's*. In 2004, the pair had not yet reached the 10.7-magnitude star that MacRobert pointed out and which the pair has now just passed. Thanks for another great issue.

Thomas Wilson
Huntington, West Virginia

CubeSats to the Planets

I read the September issue's Focal Point on CubeSats to the nearer planets (p. 86). I think it's a good idea to send small probes to such worlds, including the Moon, Venus, Mars, and the nearby asteroids.

Many of these CubeSats could have tiny ion engines as their main propulsion systems. A 1-inch-wide engine could deliver a thrust of 0.00002 gravity to a CubeSat of 8 kilograms. Such a probe could get to

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Venus after 700 days of constant thrust, burning 2.8 kg of fuel. A probe to the planet Mars would take 800 days and 3.1 kg of fuel.

Such small probes could be useful in cheap missions to the moons of Mars, as well as scanning the clouds of Venus. Most of all, they could help us develop new technologies for future space flights.

Arthur Haapoja
Mount Prospect, Illinois

***Editor's Note:** A fuel supply of 2.8 kg might be feasible for a 3-unit CubeSat and certainly for the 6U platforms mentioned in the column. A number of firms are working on several different ion propulsion devices. The challenge is to pack the system into the small volume. But because these vehicles are small, even tiny amounts of thrust can generate significant velocities over time.*

Sketching Certificate from the Astronomical League

Why sketch at the eyepiece? With the advent of astrophotography, some might think sketching a thing of the past. But sketching can improve your observing skills and can capture what you actually see in ways that photos and writing can't. To encourage amateurs to sketch, we're introducing the Astronomical League Sketching Observing Award.

Before you say, "But I can't sketch," understand that we didn't create this certificate for "artists." If you can put a pencil to paper and make a smudge with your finger, you have the ability to complete this program. Our main focus is not to make artists out of amateur astronomers but to help slow down the observing process and improve observing skills over time.

To receive the certificate, you need to submit sketches of 75 objects. We've put together an object list, tutorial links, and other resources for those new to astronomical sketching on our webpage: **www.skypub.com/ALsketching**. There are also advanced tips for more detailed sketching and for those with more experience.

We hope this program will help you gain a greater appreciation for sketching and enhance your observing skills.

Cindy L. Krach
Maui, Hawaii

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75, 50 & 25 Years Ago

Roger W. Sinnott

January–February 1940

Fast-Moving Stars "The discovery of faint stars of large proper motion has for many years been one of the profitable lines of astronomical investigation. The technique is simple. One compares two negatives of the same star field taken with the same telescope, one taken thirty years ago, the other of more recent vintage. . . . Dr. Willem J. Luyten, now of the University of Minnesota, decided to use the collection of plates taken with Harvard's 24-inch Bruce refractor in the southern hemisphere for a survey of large proper motions in the southern sky. . . .

"Luyten's catalogue contains 895 stars with total proper motions in excess of [half an arcsecond per year]. The catalogue is apparently complete for the southern hemisphere down to apparent photographic magnitude 14.5. . . .

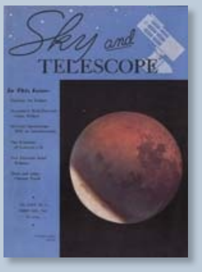
"The major result of Luyten's labors is that we now have accurate information on the distribution of the intrinsic brightnesses of the stars over a range of fifteen magnitudes. . . . [T]he stars included in Luyten's survey contribute two-thirds of the total density of matter in the vicinity of the sun, the remaining third presumably coming from interstellar dust, interstellar gas, and perhaps from [even fainter] stars."

Fast-moving stars must be nearby, so Luyten's catalog also gave a rather accurate census of stars in the Sun's neighborhood. In his article, Bart J. Bok extolled the value of this and other surveys involving great numbers of stars.

February 1965

Canals on Mars "What are the Martian canals? On one hand it has been contended that they are illusory. . . . At the other extreme, Percival Lowell suggested an artificial origin to account for the geometrical network that he observed. Between these views are many other interpretations. . . .

"If the Martian deserts are covered by finely divided mineral material resembling sand, then the action of prevailing winds should produce long, straight, narrow systems of sand dunes [proposes F. A. Gifford, Jr., of the U. S. Weather Bureau]. In the deserts of Africa and Arabia there are many straight, narrow chains of dunes, running for several hundred miles. These chains often consist of parallel pairs, reminding Dr. Gifford of the reported doubling (germination) of certain Martian canals."

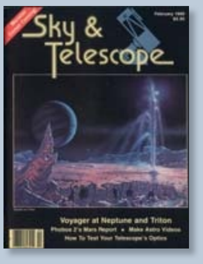


Observations by the Mariner 4 spacecraft, already winging its way to Mars when the February 1965 issue was published, would soon demolish belief in the canals. Spacecraft data revealed that the networks were the combination of fleeting surface features and the human mind.

February 1990

Missing Pulsar "Flashes of visible light coming at a rate of almost 2,000 per second were observed in the direction of Supernova 1987A during a 7-hour interval on January 18, 1989. . . . Presumably they were from a pulsar, or magnetized neutron star, spinning once every 0.5 millisecond (0.0005 second). Since then, however, regular searches have turned up nothing. What's going on? . . .

"[Norman K. Glendenning (Lawrence Berkeley Laboratory)] suggests that precession of a neutron star could cause cyclic disappearances of the beamed pulsar radiation."



However, the 1989 detection proved spurious. Numerous other searches have yet to confirm a pulsar in the Large Magellanic Cloud's supernova remnant. Yet an early neutrino pulse matched what's expected from a neutron star's creation. Perhaps the large amount of dust SN 1987A made is blocking our view.

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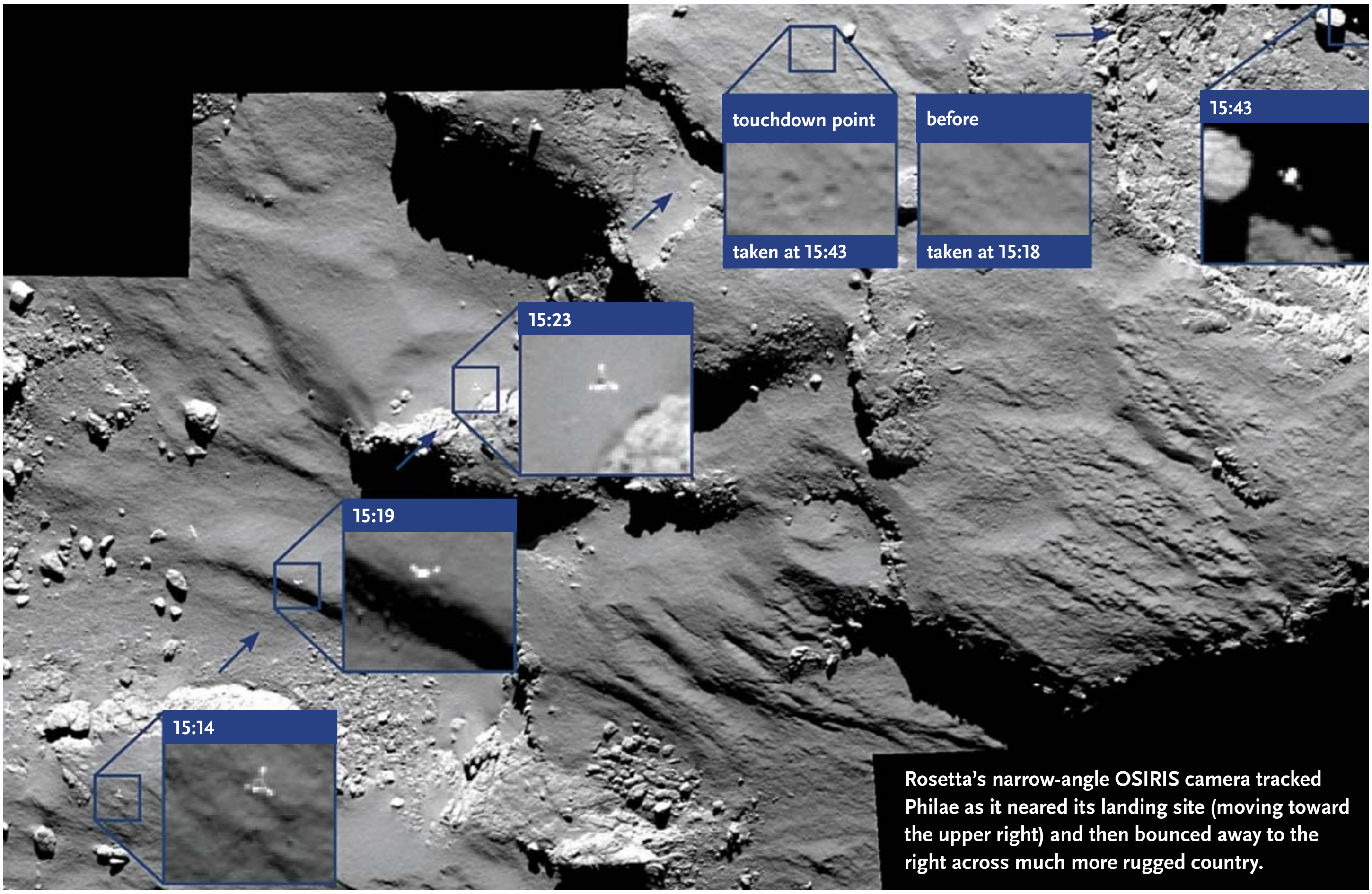
SOLAR SYSTEM | Philae Lands on Comet



Rosetta's narrow-angle OSIRIS camera tracked Philae as it neared its landing site (moving toward the upper right) and then bounced away to the right across much more rugged country.

EUROPEAN SPACE AGENCY / ROSETTA / OSIRIS TEAM

In a historic space-exploration first, on November 12th the European Space Agency's Philae spacecraft settled onto the 4-km (2.5-mile) wide nucleus of Comet 67P/Churyumov-Gerasimenko. But it did not land in the way intended, nor where.

The day began with the Rosetta orbiter releasing Philae for a 7-hour free fall toward a relatively smooth plain on the "head" of the double-lobed comet nucleus. The comet has such weak gravity, less than 1/100,000 that on Earth, that Philae carried two systems designed to anchor it the moment it touched. Both failed. Philae bounced twice in slow motion during the next couple of hours, then came to rest many hundreds of meters away — deeply shadowed in rugged terrain, tipped by at least 30°, and only able to image a few patches of close-up surface material.

Meanwhile, the clock was ticking. Philae was designed to complete its primary activities within 64 hours if it could not obtain solar power. The deep shadowing allowed the lander only 1½ hours of sunlight during the comet's 12.4-hour rotation, not enough to recharge Philae's batteries to power extended activities.

Even so, during its last communication with the orbiting Rosetta after 57 hours, Philae successfully relayed findings from all 10 of its instruments before slipping into electronic hibernation. Mission controllers called Philae "a huge success."

Some of the first announced results came from a surface probe called MUPUS (Multipurpose Sensors for Surface and Subsurface Science). It found that a vertical face looming next to the lander showed wide day-night temperature swings, implying that it's thickly coated with a fluffy mix of mineral and organic grains.

But there was nothing fluffy about the material that the MUPUS sensor "pen" tried to penetrate. All attempts failed, and the pen ultimately broke. The instrument team estimates that the surface in that spot must be very solid ice or rock.

Meanwhile, the Rosetta orbiter's 11 instruments continue to monitor the comet's growing activity as it glides toward its August 13th perihelion, 1¼ a.u. from the Sun. And mission controllers said they expect the lander to reawaken in the months ahead as the sunlight changes direction and intensifies.

■ **J. KELLY BEATTY**

might·y /mī′tē/

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SUN | IRIS Finds Solar Tornadoes, Bombs

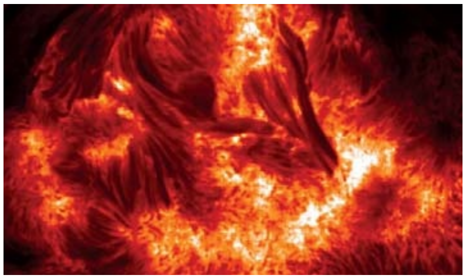
The Sun gets ever more complicated and confusing the closer we look. NASA's new Interface Region Imaging Spectrograph (IRIS) is showing a Sun unexpectedly rife with twisting and snapping magnetic fields at small scales. IRIS's views may, among other things, help address the seemingly endless puzzle of what heats the Sun's corona to millions of degrees.

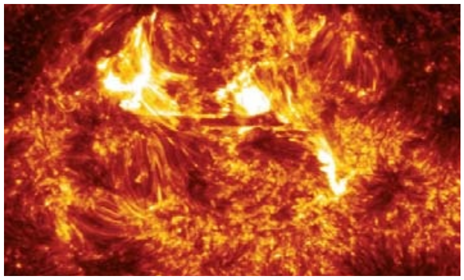
First results from the sungrazing spacecraft, published in the October 17th *Science*, shed light on the *interface region*, the thin layer between the Sun's relatively cool chromosphere (just above the visible photosphere) and the bottom of the corona (*S&T*: Oct. 2013, p. 11). In active and quiet regions alike, the interface region turns out to be writhing with small loops of twisted magnetic field lines. Plasma races along these lines at 10 to 30 km/s (22,000 to 67,000 mph), report Bart de Pontieu (Lockheed Martin and the University of Oslo, Norway) and colleagues.

Two other intriguing results deal with *solar bombs* and *nanoflares*. Hardi Peter (Max Planck Institute for Solar System Research, Germany) and colleagues discovered tiny, round bright features appearing briefly in the photosphere. These explosions, which last roughly 5 minutes, are pockets of gas that heat suddenly to 80,000K despite their cool (6000K) surroundings. It's unclear whether they are a new type of blast or a hotter analog to "Ellerman bombs," which are created when a small, U-shaped magnetic loop in the chromosphere dips down into the photosphere, pinches off, and dumps its energy.

Back in 1988, Eugene Parker first suggested that many millions of nanoflares could be what heat the corona. Nanoflares are too small to observe directly, but Paola Testa (Harvard-Smithsonian Center for Astrophysics) and colleagues report that they may explain the churning and flickering of plasma that IRIS is seeing near the footprints of large coronal loops.

■ **MONICA YOUNG**





IRIS / LMSAL-NASA (2)

IRIS took these sharp images of twisting plasma in an active region. The top one shows the relatively cool chromosphere; the bottom one shows the transition region just above it. Some features change from dark to bright at the wavelengths by which the two layers were separated.

GALAXIES | The Ghost Glow of Galaxies Past

Astronomers with the Hubble Frontier Fields program (*S&T*: Jan. 2015, p. 20) have measured the combined light of "ghost stars" floating loose in the galaxy cluster Abell 2744. The stars add up to more than 100 billion Suns' worth of mass adrift in the cluster's intergalactic spaces, cast loose by galaxy collisions and tidal interactions. They emit an extremely faint overall glow known as *intracluster light*.

Mireia Montes and Ignacio Trujillo (University of La Laguna, Spain) used Hubble's long stare to construct visible and near-infrared images of Abell 2744, also called Pandora's Cluster, a near-simultaneous pileup of four smaller clusters. Light from its hundreds of galaxies has traveled 3.5 billion years to reach Earth (the swarm has a redshift of 0.3).

The team finds that the ghost stars are bluer than the cluster's galaxies, implying that they are on average 3 to 9 billion years younger than stars in the galaxies. This makes them closer in age and (presumably) metallicity to the stars of the Milky Way. The researchers propose that, relatively recently in the cluster's history, violent collisions tore apart at least four to six Milky Way-size galaxies, scattering many of their stars into intergalactic space.

Montes and Trujillo plan similar studies to piece together the collision history for the other five clusters of the Frontier Fields project. They will also expand their study of Abell 2744 to include Hubble's ultraviolet observations in order to pin down the ghost stars' ages better, a step necessary to understanding the violent history that this cluster has undergone.

■ **MONICA YOUNG**

NASA / ESA / IAC / J. LOTZ / M. MOUNTAIN / A. KOEKEMOER / THE HFF TEAM (STSCI) (2)

***Left above*: Abell 2744 in Sculptor includes the foreground swarm of yellowish galaxies in this deep-field image from the Hubble Space Telescope's Wide Field Camera 3. *Left*: The "ghost light" of stars in the cluster's intergalactic spaces has been greatly enhanced here and colored blue.**

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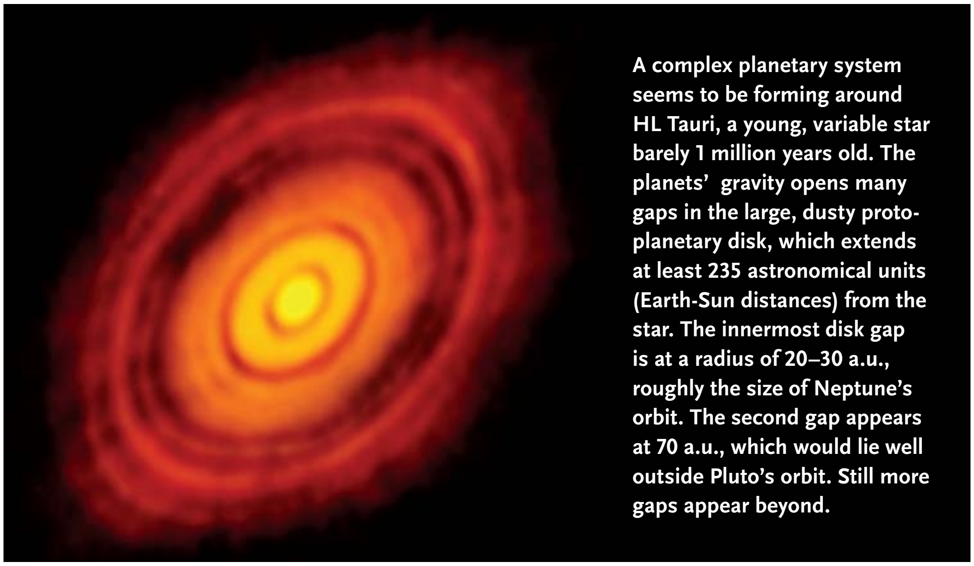
EXOPLANETS | ALMA Reveals Multi-Planet Birth . . .



ALMA (NRAO / ESO / NAOJ) / C. BROGAN / B. SAXTON

A complex planetary system seems to be forming around HL Tauri, a young, variable star barely 1 million years old. The planets' gravity opens many gaps in the large, dusty protoplanetary disk, which extends at least 235 astronomical units (Earth-Sun distances) from the star. The innermost disk gap is at a radius of 20–30 a.u., roughly the size of Neptune's orbit. The second gap appears at 70 a.u., which would lie well outside Pluto's orbit. Still more gaps appear beyond.

ALMA, the powerful new array of millimeter-wave dishes high in the Chilean Andes, has produced an extraordinarily detailed image of the protoplanetary disk around the newborn star HL Tauri, which reveals the disk's millimeter-wave glow. It is riddled with dense and sparse zones that betoken planets in the making. This astonishing image could revolutionize theories of how planets form. More such views are sure to come.

The 66 dishes of the Atacama Large Millimeter/submillimeter Array (ALMA) can be placed as far as 16 kilometers (10 miles) apart, producing nearly the resolving power of a 16-km-wide telescope. The result is crazy-fine detail even at millimeter wavelengths, a little-explored part of the electromagnetic spectrum between the far infrared and microwave radio. The image here was made with the antennas separated by 15 km, almost the full baseline.

ALMA has been operational since March 2013 but has continued to ramp up, adding dishes and more configurations. Now the science team is testing the longest-baseline configurations: arrangements of the antennae that allow for the most detailed images ever recorded at millimeter wavelengths.

In visible light, HL Tauri can't even be seen. The newly formed star still hides in a cocoon of dust and gas. ALMA imaged the system at 1.28 mm (233 gigahertz) to see through the dust to the planet-forming disk at its center. ALMA has imaged planet-induced gaps before, but never at this resolution: details 35 milliarcseconds across are resolved in the image, or 5 a.u. at HL Tauri's distance of 450 light-years.

"These new observations really supersede any previous data on HL Tau," says Laura Perez (NRAO). "In comparison with previous CARMA observations, this new ALMA image is 5 times better in spatial resolution and at least a factor of 20 more sensitive."

HL Tauri's solar system is much bigger than our own. All our planets except possibly Neptune would fit within the innermost visible gap. No planets are detected at ALMA's wavelengths, but each gap might mark a large body's orbit.

The discovery of disk gaps around a star less than 1 million years old is surprising — planets aren't supposed to be big enough to create such gaps this early.

And there's more to this image than the gaps. "I am also super excited by the ripples," says Leonardo Testi (University of Arcetri, Italy, and ESO). These undulations in density may hold clues on how dust grains stick together to start forming planets — a poorly understood process that's key to the standard, core-accretion scenario for how planets begin.
■ **MONICA YOUNG**

. . . and Zodiacal Light Around Other Stars?

Astronomers have spotted what they think is *exozodiacal light* in nine planetary systems. This light is starlight reflected off dusty debris in the systems. Unlike protoplanetary disks, where gas and dust are coalescing into new planets, debris disks show up after planets have formed and the protoplanetary disk has been blown away. They can be made of grains left in space by passing comets or collisions between rocky bodies (such as asteroids).

In our solar system, we see a sparse dust disk of this kind as the zodiacal light, visible along the ecliptic in a clear dark sky before dawn and after dusk.

Now astronomers say they have spotted the same phenomenon, albeit much brighter, in nine other systems. "We are slowly reaching the point where a few other extrasolar planetary systems will be well documented . . . from the giant planets down to the smallest grains," says Jean-Charles Augereau (University of Grenoble, France).

His team combined near-infrared light beams from four 1.8-meter units of the Very Large Telescope Interferometer, resolving telltale glows near the habitable zones around nine stars. Any such dust must have been created recently, because the action of starlight clears it out of a system fairly fast.

Other astronomers, however, remain skeptical that the near-infrared glow is definitely exozodiacal dust. It's unclear whether the team is seeing starlight scattered off the dust, or heat emission from the dust itself, or instead emission from some stellar phenomenon.
■ **SHANNON HALL**

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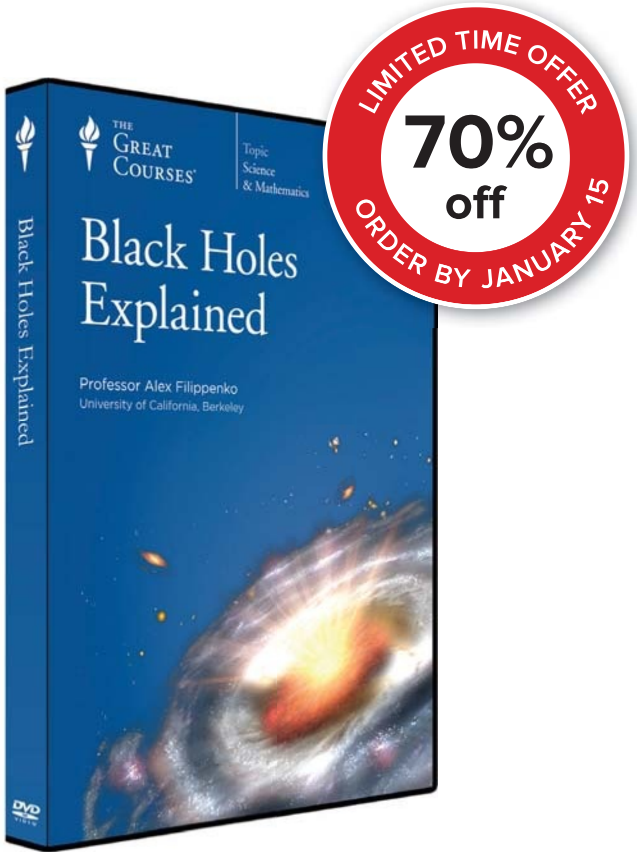

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SCOPES | Closure Averted for Some Major Observatories

Lick Observatory in California and the UKIRT infrared telescope and the James Clerk Maxwell Telescope in Hawai'i will not be defunded and closed after all. But the long-term fate of others remains uncertain.

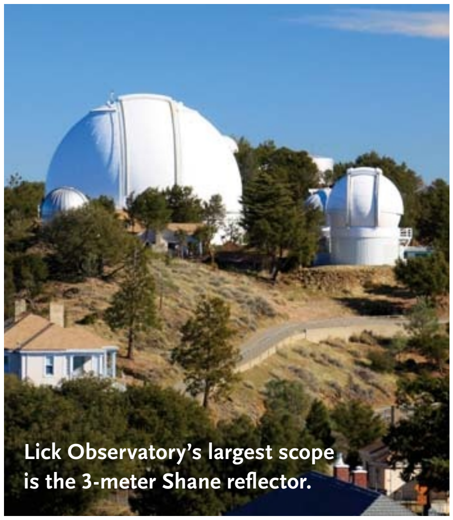
• Lick Observatory on California's Mount Hamilton has been saved. The president of the University of California has reversed a previous decision to pull funding from Lick by 2018. Lick will continue to operate under the management of UC Observatories, a multi-campus astronomical research unit.

• The University of Hawai'i has assumed ownership of the United Kingdom Infrared Telescope (UKIRT). One of the world's leading infrared observatories, UKIRT will continue surveying nearby brown dwarfs, distant supermassive black holes, and everything in between. Despite its high productivity, UKIRT faced closure when the UK's Science and Technology Facilities Council pulled funding in 2012 (*S&T*: Sept. 2012, p. 14).

• A similar turnabout seems to be in place for the 15-meter submillimeter-wave James Clerk Maxwell Telescope in Hawaii, also placed on the chopping block in 2012. In early 2015 JCMT operations will transfer to the University of Hawai'i in partnership with the East Asian Core Observatories Association.

This news may cheer astronomers at a number of other observatories still facing closure. As limited funds funnel towards giant next-gen scopes such as ALMA, the European Extremely Large Telescope, the Thirty Meter Telescope, and the Square Kilometer Array, current observatories around the world are often becoming severely pinched.

In 2012 the U.S. National Science Foundation announced plans to divest from two radio telescopes, the Green Bank Telescope and the Very Long Baseline Array, as well as three optical telescopes at Kitt Peak National Observatory. Green Bank has received a $1 million boost from West Virginia University, but it will need more to survive long-term.


Lick Observatory's largest scope is the 3-meter Shane reflector.

LICK OBSERVATORY

■ **MONICA YOUNG**

IN BRIEF

Two Comet Families Around Beta Pic. Eight years of spectra reveal two distinct populations of "exocomets" in the planetary system forming around Beta Pictoris, report Flavien Kiefer (Paris Institute of Astrophysics) and colleagues in the October 23rd *Nature*. Astronomers already knew that cometary bodies fill the disk, thanks to work by members of the same team in the 1980s and 1990s. The new results come from analysis of 1,106 spectra. These show temporary absorption features from the gas of an estimated 493 individual exocomets passing in front of the star. They fall into two groups: "Population D" bodies all approach Beta Pic from the same direction and emit lots of gas. Those in "Population S" have a variety of orbits and spew less gas — yet they come twice as close to the star.

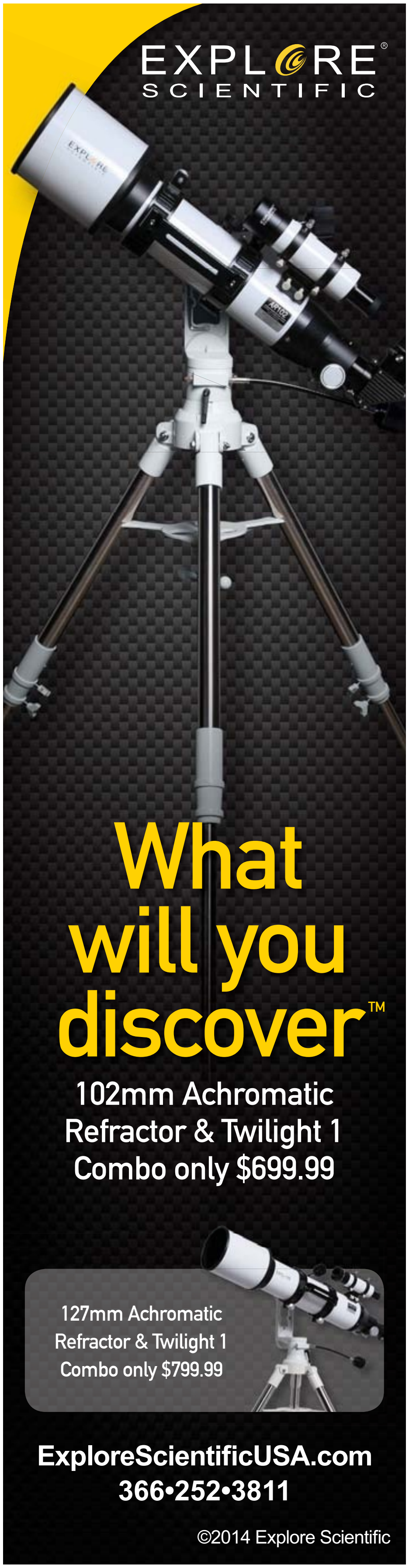
■ **CAMILLE M. CARLISLE**

A New Handle on Galaxy Evolution. Astronomers have taken a novel approach to exploring how jets from supermassive black holes curtail star formation in their galaxies, a process suspected to be a major factor in galaxy evolution. Megan Gralla (Johns Hopkins University) and colleagues used the Sunyaev-Zel'dovich effect, in which cosmic microwave background (CMB) photons steal energy from electrons in hot gas they pass through. The effect leaves distinctive fingerprints on the CMB. Researchers usually use the SZ effect to study galaxy clusters, which are full of hot gas. But Gralla's team instead used it to study the much smaller halos of hot gas around galaxies hosting active galactic nuclei. The results confirm that galaxies with jet-shooting black holes typically produce hot halos, the team reports in the November 21st *Monthly Notices of the Royal Astronomical Society*. Hot gas cannot condense to form stars, so the observations favor the idea that the black holes have helped make these galaxies red and dead.

■ **CAMILLE M. CARLISLE**

Great Red Spot Likely a Sunburn. You might think that planetary scientists would have figured out by now what makes Jupiter's red markings red. But they haven't — unless a new study is on target. Kevin Baines, Robert Carlson, and Thomas Momary (all Jet Propulsion Laboratory) say the pigment in Jupiter's Great Red Spot is not red matter upwelling from below, but likely a product of ammonia and acetylene molecules being broken apart by ultraviolet sunlight in the planet's upper atmosphere. They combined data from Cassini's December 2000 flyby of Jupiter with lab experiments exposing known chemicals in Jupiter's atmosphere to ultraviolet light. The resulting red concoction matched the spectral properties of Jupiter's reddish markings. "Our models suggest most of the Great Red Spot is actually pretty bland in color, beneath the upper cloud layer of reddish material," Baines says. The particles would be scattered in a layer only a few kilometers thick. The researchers say altitude is the key: the high-pressure system is much taller than the surrounding clouds and thus more exposed to the Sun's UV rays. Jupiter's brown belts, Baines says, are the opposite: places where thin, high white clouds allow views into innately colorful depths. ✦

■ **ALAN MACROBERT**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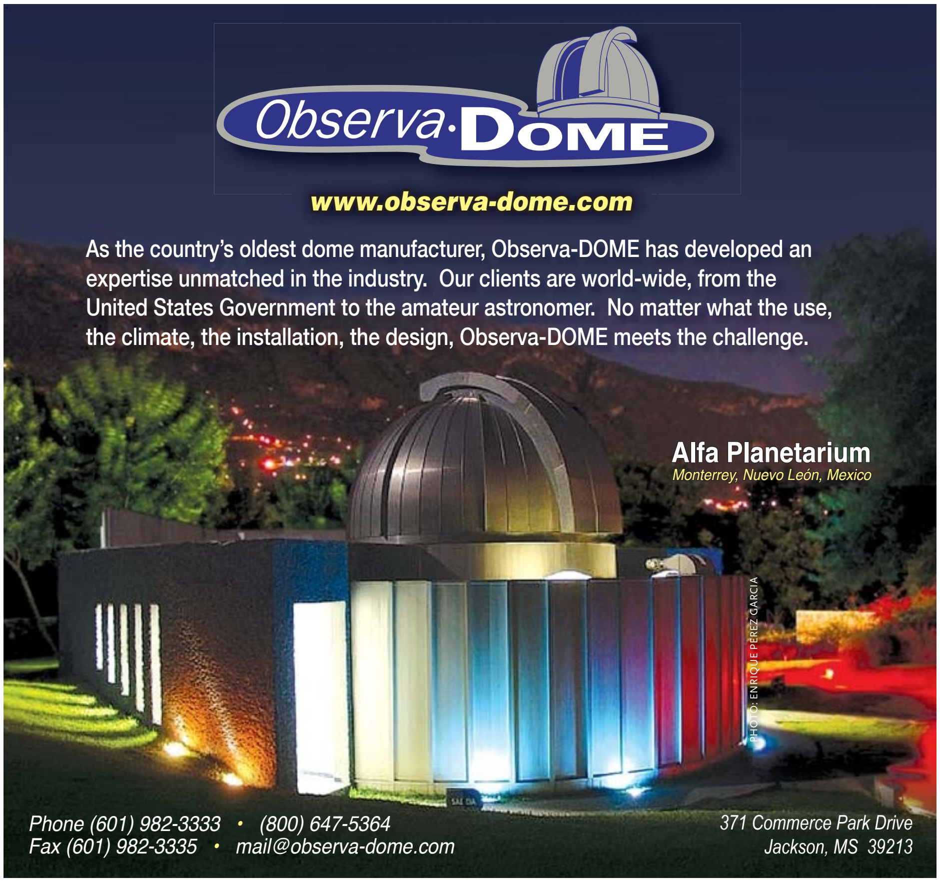
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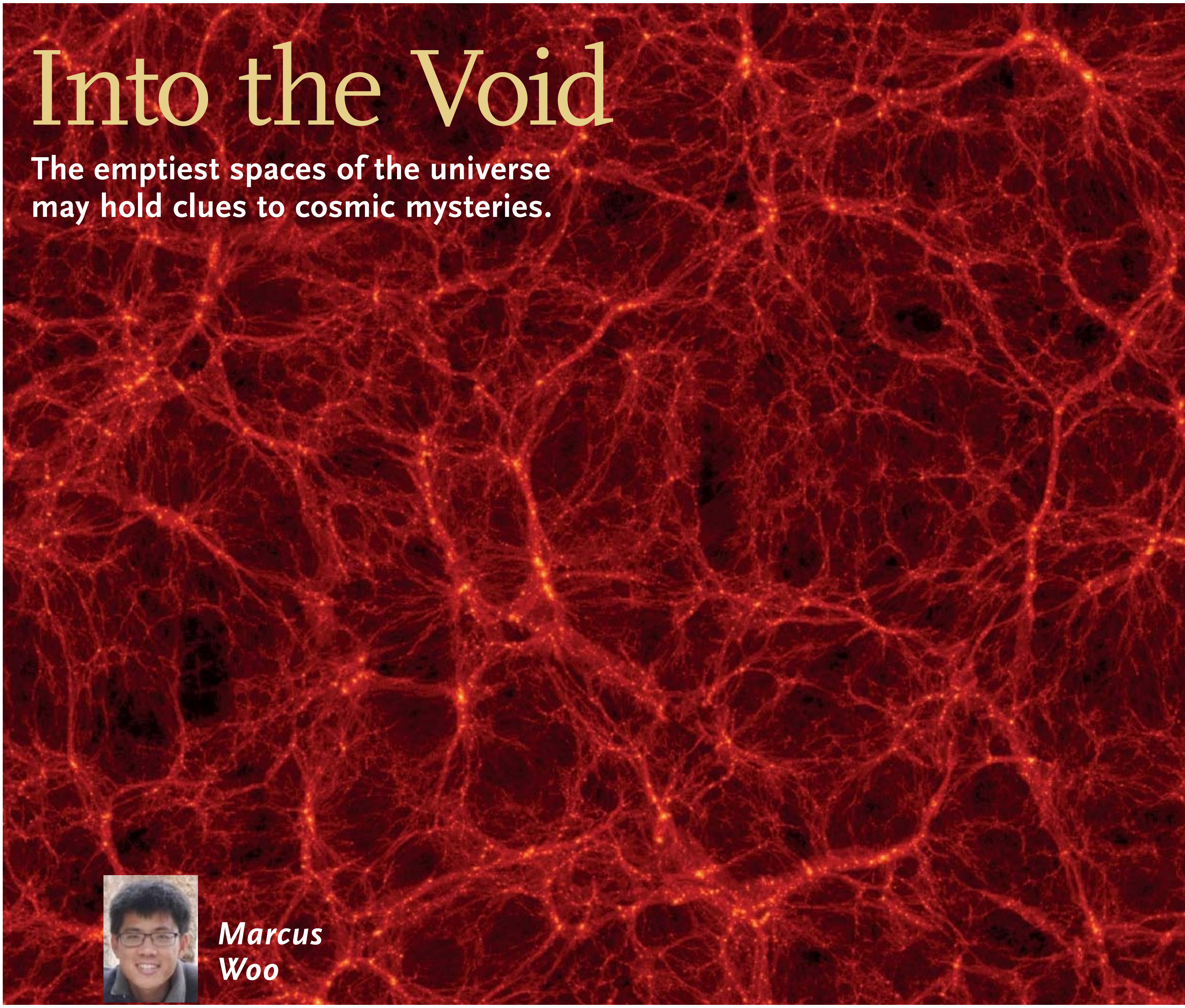


Into the Void

The emptiest spaces of the universe may hold clues to cosmic mysteries.

Marcus Woo

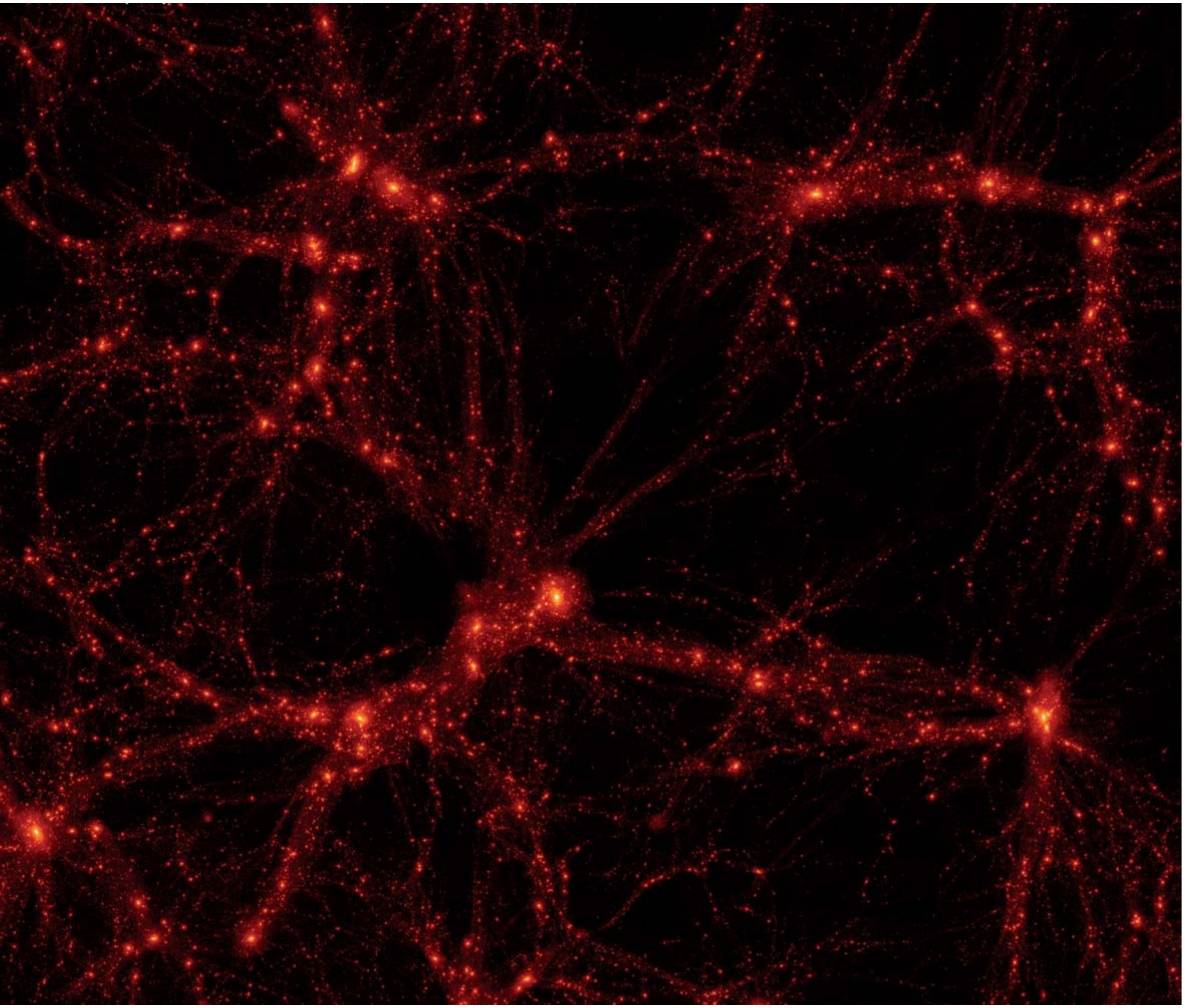
SPACE IS PRETTY EMPTY. And Paul Sutter likes empty. He likes it so much, in fact, that he spends his time exploring the most barren regions of the universe, vast gaps known as cosmic voids.

Almost all the matter in the universe — galaxies and the mysterious, invisible stuff known as dark matter — stretches across space like a giant cobweb. Astronomers call this structure of narrow filaments and thin walls the cosmic web. The vacant expanses in between, akin to the holes inside a sponge, are the voids.

The web varies in density from compact, bustling metropolises, where thousands of galaxies cluster at the intersection of filaments, to calmer suburbs such as our Local Group. But as on Earth, most of the universe is sparsely populated — voids make up about two-thirds of the cosmos by volume. Though not entirely free of galaxies, voids have about a tenth of the universe's average density. And Sutter feels right at home in this "rural" habitat.

"I'm a rural person myself," says Sutter, who grew up on the outskirts of Lancaster, Ohio, a small town about 30 miles southeast of Columbus. "When looking at a map of the cosmic web, most people's eyes are drawn to the bright stuff, the glowing bits. But I'm drawn to the holes, the big empty spaces."

Sutter, now at the Astronomical Observatory of Trieste, Italy, and Ohio State University, is one of a growing num-



STEFAN GOTTLÖBER / LEIBNIZ-INSTITUT FÜR ASTROPHYSIK POTSDAM (2)

ber of astronomers who have been turning their attention toward cosmic voids during the past few years.

Although voids were discovered more than three decades ago, they remained on the periphery of astronomy research for a long time. Recently, dedicated surveys, and the improved technology that made those surveys possible, have exposed the cosmic web's intricacies and unveiled a multitude of voids. Meanwhile, more powerful computers have enabled increasingly detailed simulations of the formation of large-scale structures, such as galaxy clusters and filaments. Combined with a more sophisticated understanding of cosmology, all of this progress has created a field that is just beginning to flourish.

UNIVERSE IN A BOX ***Above left:*** **Simulations have been modeling the evolution of large-scale structure at ever-increasing resolutions. This slice of the recent Bolshoi simulation is roughly 1 billion light-years across.**

COSMIC WEB ***Above right:*** **A zoomed-in slice of the Bolshoi simulation just 300 million light-years across showcases the webby filaments, but the voids are what dominate the simulation's volume.**

Astronomers such as Sutter are finding that voids are not boring empty spaces, but rather powerful tools that may help us unravel the mysteries behind dark energy, dark matter, and galaxy evolution. There may be next to nothing inside voids, but there's definitely something to them.

In the Beginning

The first voids were discovered in 1978, when Stephen Gregory (then at Bowling Green State University) and Laird Thompson (then at the University of Nebraska) noticed a curiously empty expanse between our own Virgo Supercluster and the Coma Supercluster more than 300 million light-years away. But some astronomers were skeptical — could these gaps just be a trick of the eye?

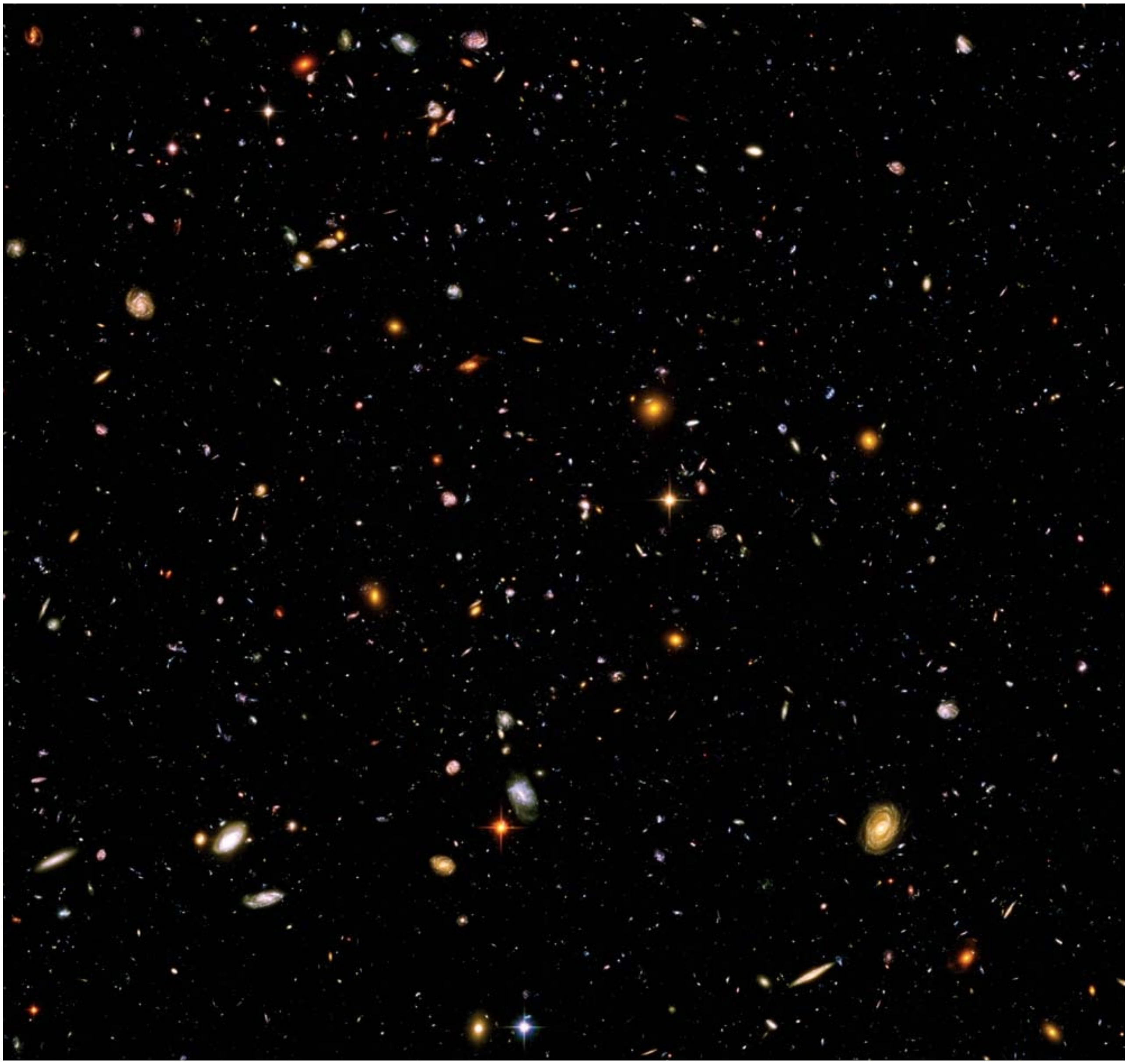
In 1981, Robert Kirshner (then at the University of Michigan) and his colleagues settled that question when they detected the Boötes void, a gap roughly 300 million light-years across. This was the discovery that convinced astronomers of voids' existence, says Rien van de Weygaert (University of Groningen, The Netherlands).

Improvements in detector technology have enabled astronomers to scan the sky for galaxies at ever greater distances, leading to three-dimensional maps of small segments of the universe. In 1986, a team of astronomers based largely at the Harvard-Smithsonian Center for Astrophysics published the first such map. The CfA Redshift Survey revealed a web-like arrangement to the universe, with walls containing more than a thousand galaxies separated by vast empty spaces.

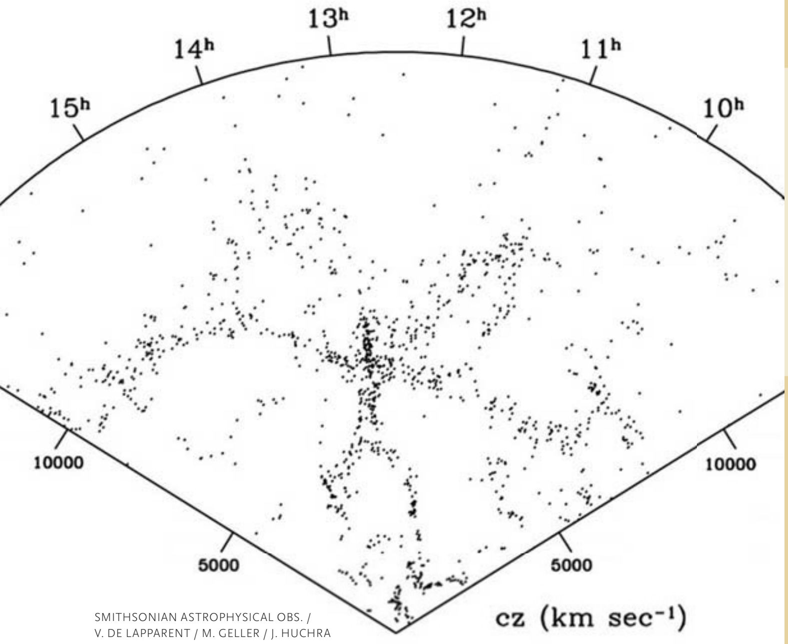
"Voids had been known before, but that image was striking," recalls Michael Vogeley (Drexel University), who was a Harvard undergraduate at the time.

Theorists were making progress, too, modeling the primordial density fluctuations that would eventually grow into the cosmic web. The question became, how did small clumps evolve into gigantic sheets and filaments? With Cold War tensions still high in the 1980s, the astronomy community formed two opposing camps.

PERSPECTIVE The Hubble Ultra Deep Field peers into a narrow cut of the universe; its most distant galaxies live in a universe just 800 million years old. Yet even in an image filled with some 10,000 galaxies, the volume of empty space is apparent.



NASA / ESA / STEVE BECKWITH / HUDF TEAM



SMITHSONIAN ASTROPHYSICAL OBS. / V. DE LAPPARENT / M. GELLER / J. HUCHRA

CELESTIAL STICK MAN *Left*: The CfA Redshift Survey mapped 1,100 galaxies to reveal large voids. For example, empty spaces surround the Coma Cluster, where hundreds of galaxies form the famous "stick man." Earth is at the apex of this wedge, which extends out to about 700 million light-years. The plot marks distance in redshift units of km/sec.

Astronomers in the West ascribed to a so-called bottom-up theory of structure formation. The first galaxies were small, they argued, and lumped together over time to form larger galaxies, clusters, and superclusters. The theory predicted a clumpy distribution of galaxies rather than a web with voids — prompting surprise when the CfA Redshift Survey revealed such structure.

Soviet astronomers, on the other hand, held to a top-down theory, in which supercluster-size clouds formed first, then fragmented into galaxies. But even though the Soviets' theory correctly predicted a cosmic web, it also predicted (among other things) young, recently formed galaxies, a conclusion not upheld by observations.

After the Soviet Union broke up, astronomers from both sides began to share ideas, van de Weygaert says. "In the end, you get a synergy and you get a new theory and a new view." By the 1990s, the bottom-up scenario had won out, but with theoretical improvements (including the addition of cold dark matter) that recreated the observed cosmic web.

These developments coincided with advances in computer simulations. Astronomers tried to simulate structure formation as early as the 1970s but were only able to follow the motions of at most a thousand or so particles. In the 1980s, simulations with hundreds of thousands of particles were able to form filaments, clusters, and voids. Nowadays, simulations involve 10 billion particles and are capable of modeling not only dark matter but also the evolution within galaxies. "Because of the enormous increase in computer power, we're talking about a completely different order-of-magnitude view of how structure forms," van de Weygaert says.

Nothing to See Here

The earliest galaxy surveys unveiled only a handful of voids, easily picked out by eye, but that number continues to grow.

"As time has gone on, some large surveys and more careful work have revealed that these voids essentially fill the

Galaxies in Isolation

Despite what the name implies, voids aren't completely empty. The Boötes void, for example, contains 60 known galaxies in a region about 300 million light-years across. For comparison, the Local Group — of which the Milky Way is a member — has roughly the same number of galaxies squeezed into a space just 10 million light-years across.

Roughly speaking, voids have 10 times fewer galaxies per volume than the cosmic average, and 1,000 times fewer galaxies per volume than a galaxy cluster, Vogeley says.

Void galaxies are unique because they form and evolve in such a desolate environment. Galaxies in groups tend to collide, whether in glancing interactions or in full-on mergers; both serve to disrupt the gas into stellar baby booms. In crowded cluster environments, a hot gas halo may complicate collisions further by stripping gas from galaxies that are passing through, stopping star formation in its tracks.

Far from the influence of other galaxies and their hot gas halos, evolution instead depends on primordial gas flowing in along cosmological filaments. As a result, voids serve as pristine laboratories, where galaxies evolve much more slowly and simply.

Surveys of nearby void galaxies have found that most are faint and blue — in other words, small spiral galaxies. Due to their shorter evolutionary history, these galactic runts are still forming lots of new stars for their size compared to similar galaxies in nearby groups, which have largely ceased significant amounts of star formation.

Void Galaxy Survey #1

Void Galaxy Survey #30

Void Galaxy Survey #32

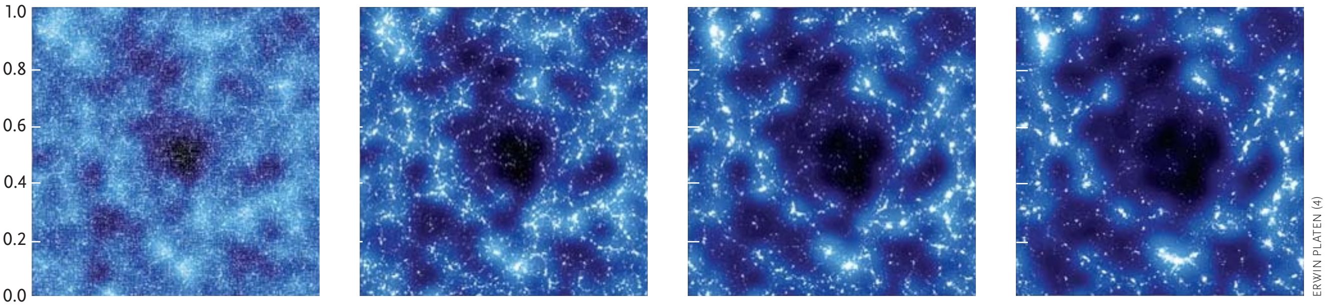
Void Galaxy Survey #38

Void Galaxy Survey #44

Void Galaxy Survey #58

SDSS, SOURCE: KRECKEL ET AL. 2011

DESERTED GALAXIES *Right*: Six examples from the Void Galaxy Survey show a youthful appearance. Galaxies reared in relative isolation tend to be fainter and bluer, with high star formation rates for their masses.

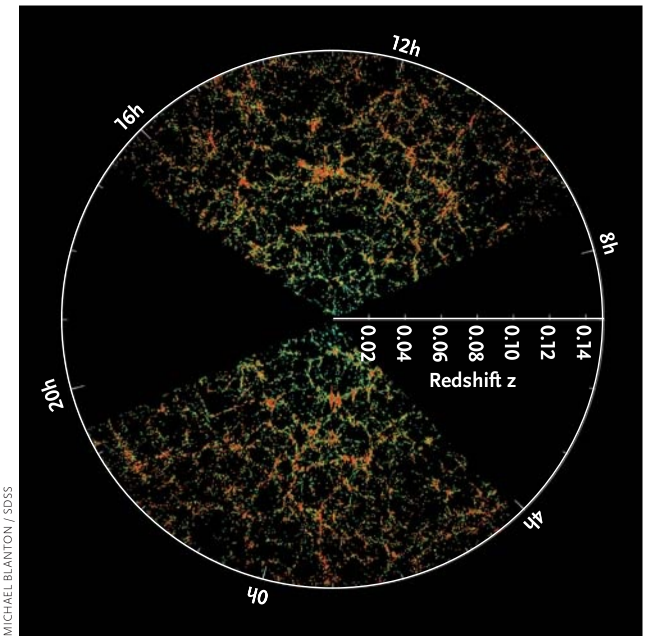


GROWING A VOID In these simulation frames, matter streams out from the center of a void to collect along its edges. The simulation box is more than 200 million light-years on a side, and about 50 million light-years thick.

universe," Vogeley says. "They're ubiquitous and perhaps the most important feature of large-scale structure."

As surveys have grown, astronomers needed a systematic way to define and identify voids. For a while, van de Weygaert says, devising these kinds of search algorithms became one of the main challenges of the field. How do you determine a void's boundaries? What's considered a void and what's just a less-dense part of space?

Vogeley and his colleagues, for instance, have used an algorithm that spots sparser regions of space by calculating the distance to each galaxy's nearest neighbors. In 2004 Vogeley and Fiona Hoyle (now at Widener University) used this algorithm to find 289 voids in the Two-degree-Field Galaxy Redshift Survey, which contains more than 245,000 galaxies. Then in 2012, Vogeley, Hoyle, and others sifted through 700,000 galaxies in the Sloan Digital Sky Survey, the biggest three-dimensional map of the universe, to find 1,054 voids.



MAPPING THE UNIVERSE Every dot is a galaxy in this slice through SDSS data. Redder points tend to be galaxies with older stars. The survey has vastly expanded astronomers' view of the cosmic web — and the voids contained within.

In the past few years, however, another algorithm called the watershed method has gained traction, van de Weygaert says. Originally an image-processing technique, the watershed algorithm transforms the cosmic web into a topographical map. Dense galaxy clusters become mountain peaks, smaller groups become foothills, and emptier regions turn into lowlands. If you filled this landscape with water, it would collect in deep basins — the voids — whose boundaries are defined by the ridges surrounding them. Using this technique on Sloan data, Sutter and colleagues have built a public catalog of more than 2,000 cosmic voids so far.

If voids will ever help us glean deeper insight into the universe, finding more of them is essential. "With thousands of things," Sutter explains, "you can start doing statistics, you can start doing comparisons, you can start doing some pretty serious science."

One void might boast a strange shape or contain a couple of odd galaxies, he adds, but on average, voids have surprisingly regular features. For example, Nico Hamaus (Sorbonne University, France) recently led a team including Sutter that analyzed computer-simulated voids. They found that the relationship between a void's density and its size obeys a simple universal law.

Although voids are important in their own right as part of the structure of the universe, what's really stirring excitement is something more tantalizing. Astronomers are realizing that voids could help untangle the nature of dark energy, the unknown force that's driving the acceleration of the universe's expansion.

Pristine Laboratories

Dark energy dominates within voids due to minimal gravitational influence from galaxies and dark matter. So voids act as natural laboratories to explore this weird antigravitational force.

Voids expand more quickly than denser regions of the universe even without the effects of dark energy. Since more mass surrounds a void than exists inside it, inner matter will stream toward the edge under gravity's influence to push on the void's inner walls. Individual voids may have a blob-like asymmetry, with certain parts expanding faster than others, but combine enough voids

DARK MATTER VS. DARK ENERGY

Though the names are similar, dark matter and dark energy are opposite in concept: dark matter attracts and dark energy repels. Dark matter holds roughly 27% of the universe's energy. It doesn't emit or absorb light, making it all but impossible to detect except by its gravitational effects. Dark energy, on the other hand, is thought to be a negative force that pervades the entire cosmos and accelerates cosmic expansion. It's the dominant form of energy in the universe, making up 68% of the total energy budget. That leaves less than 5% of the universe's total energy in normal matter.

and you can generate a statistical average, a "standard sphere." This generic void expands over cosmic time in a predictable way.

Dark energy changes that equation. By assessing the shapes of 1,500 voids found in the Sloan data in 2014, Sutter and colleagues measured what fraction of the universe's energy comes in the form of dark energy. Although their answer currently lacks competitive precision, with bigger void samples they expect to measure the fraction of dark energy as well as, if not better than, other, independent methods.

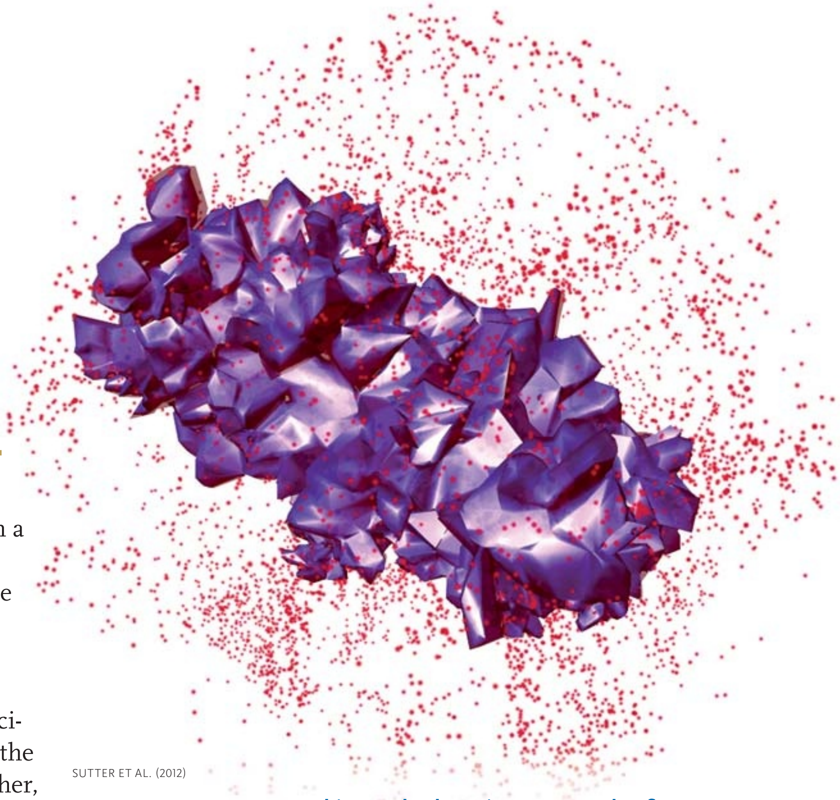
And this technique is only one way voids can help astronomers untangle the universe's mysteries. The precise amounts of dark matter and dark energy set the initial conditions of the cosmos and determine the evolution of voids and the rest of large-scale structure. So despite their lack of matter, voids' role in large-scale structure can help pin down how much dark matter exists and how it interacts with the rest of the universe.

As with dark energy, it's a void's emptiness that's useful for studying dark matter, Sutter says. Voids are simple places, free from the complicated physics of crowded galaxy clusters where dark matter is traditionally studied. So any influence from dark matter edging the void can easily be isolated.

"Inside a void, life is simple," Sutter adds. "You get out of the cities and get in the rural areas, and it's just corn. And you can model corn a lot more easily than you can model a city."

Voids may help peg the exact fractions of dark matter and dark energy in the leading cosmological model, or they could be used to test alternate theories. Some astronomers have speculated that dark matter and dark energy aren't actually exotic new entities; they could instead be explained by modifying our law of gravity. One such model predicts more large voids, a difference that is potentially measurable given a big enough void sample and a strong enough modification to gravity.

The study of voids adds to a long list of well-established cosmology techniques. Astronomers currently determine cosmic expansion by measuring the brightness of standard candles known as Type Ia supernovas. They can also gauge distances via the standard ruler of baryon acoustic oscillations, the echo of primordial density fluctuations



SUTTER ET AL. (2012)

A WATERSHED VOID This purple shape is one example of 2,000 voids detected in Sloan data so far; red dots mark SDSS galaxies. The bumpy surface is a side effect of the algorithm used to define its edges. Combining many voids creates a statistical average — a "standard sphere" to test different cosmologies.

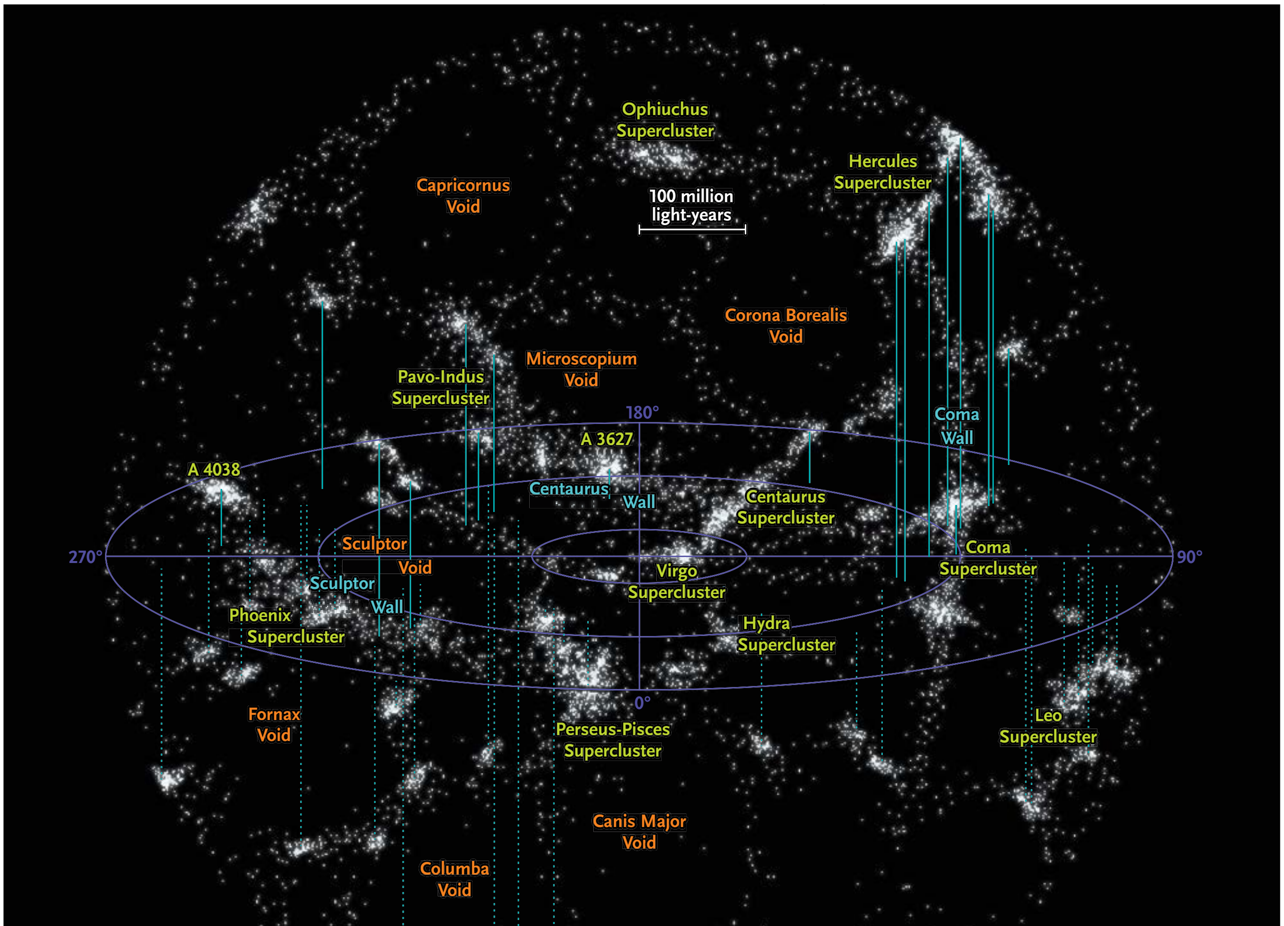
Soar through the universe, theoretical and observed, via galaxy surveys and large-scale simulations. Watch online at skypub.com/voids.

Night Skies in the Void

Even inside a void, an extraterrestrial's night sky wouldn't look that different from our own — most of the celestial objects we see, after all, are stars within our own galaxy. In fact, a void galaxy would have a higher star formation rate for its size than the Milky Way, so star-forming features such as the Orion Nebula might be more prevalent.

But peering through a telescope would probably not show any other luminous galaxies for many millions of light-years. Vogeley estimates that galaxies in a typical void are an average 50 million light-years apart, twice the average distance between galaxies in the Local Group, and 10 times the distance between galaxies in a typical cluster. So there would be no nearby Andromeda Galaxy, and no nearby Virgo Cluster. Any void-living aliens might have a far different understanding of cosmology. Still, if their technology advanced to the point of seeing beyond the void's edge, an alien's map of large-scale structures would begin to show a universe statistically similar to ours.

— ***Monica Young***



OUR NEIGHBORHOOD This simplified map shows clusters and voids within 500 million light-years of the Milky Way. Some galaxies were removed to clarify this two-dimensional representation. The supergalactic coordinates are based on the plane of the Virgo Supercluster.

S&T: GREGG DINDERMAN, SOURCE: RICHARD POWELL / WWW.ATLASOFTHEUNIVERSE.COM

seen in today's web of galaxies. Astronomers can test the growth of large-scale structure by comparing galaxy clusters near and far. And, of course, one of the best methods of estimating cosmological parameters is to model the temperature fluctuations in the cosmic microwave background, the Big Bang's remnant radiation.

According to some astronomers, voids could turn out to surpass all of these cosmological probes, van de Weygaert says. But he remains cautious: "I hope it's true, but I'm not entirely convinced."

The key, Sutter and Vogeley argue, is more voids.

Toward a Million Voids

The case for voids as a powerful cosmological probe has only come close to reality as observational datasets have expanded in the past few years.

"We're really just scratching the surface," Vogeley says of recent work. "People only now are getting their hands dirty on actual data."

"We're right at the edge," Sutter adds, "at the stage where we're proving that it works, that it's not crazy."

In coming years, the Sloan survey will continue to provide larger galaxy maps — and more voids. But the study of voids won't realize its full potential until the next generation of telescopes and associated surveys help push the void count to a million. The European Space Agency's Euclid spacecraft, scheduled for launch in 2020, will survey galaxies in a universe just 3 billion years old. NASA's planned Wide-Field Infrared Survey Telescope could deliver a similar map. And the planned Large Synoptic Survey Telescope and Square Kilometer Array will also provide a glut of galaxy data.

The study of voids is a burgeoning field, and Sutter's mission is to continue spreading the word. As he says, "Voids are awesome and voids are the future." ✦

Marcus Woo, formerly a freelance science writer based in the San Francisco Bay Area, now writes for Wired *magazine.*

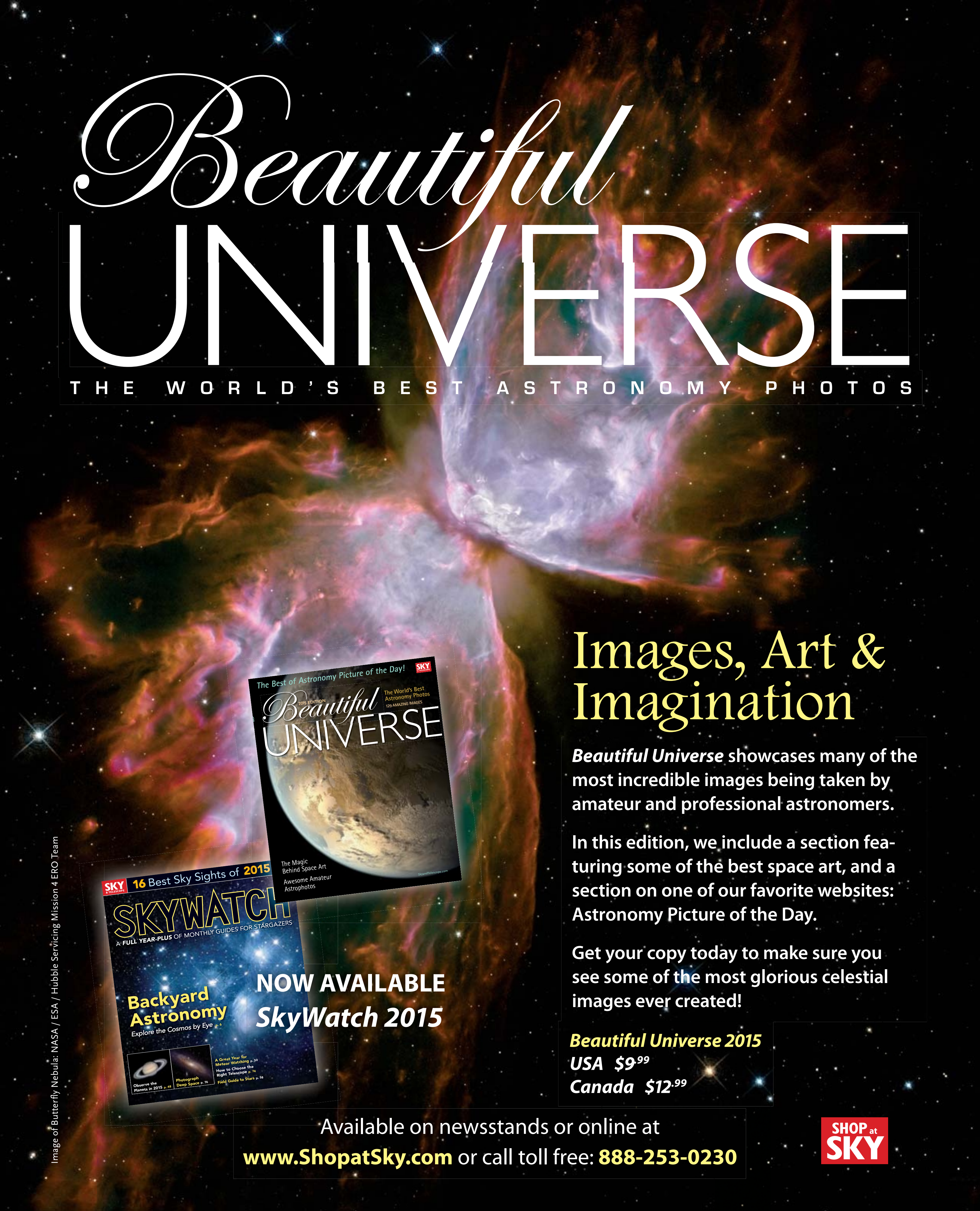


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Image of Butterfly Nebula: NASA / ESA / Hubble Servicing Mission 4 ERO Team

Observing Moons

Look for some of the solar system's more challenging objects.

TERRY N. TREES

My earliest memories out under the stars are of observing Mars during its close approach in 1954. That's 60 years ago, and when I think back to that time, I don't think anyone I knew ever thought of trying to see Phobos or Deimos — or, for that matter, any other of the smaller solar system moons. Back then, we knew that all the planets except Mercury, Venus, and Pluto had moons, but we also *knew* you were limited to viewing Earth's moon, the four brighter moons of Jupiter, and Saturn's largest moon, Titan. Maybe your telescope was large enough to allow you to identify a few more of Saturn's moons as well, but I don't remember anyone trying for Neptune's Triton or any of the moons of Uranus.

Times have changed. The smaller-sized telescopes of visual observers have been supplanted by large Dobsonians. And while light pollution has limited the value of urban/suburban observing sites, many amateurs haul large light buckets to remote dark sky sites and see many objects considered impossible by amateurs in the 1950s.

Thus, the observation of solar system moons has progressed from the large, bright moons, such as the Galilean moons of Jupiter, to the medium-bright moons, like Titan and Rhea, to dim ones such as the Uranian moons and Triton, and on to challenging moons like Phobos, Deimos, Himalia, and Phoebe. As amateur instruments increased in size, visual limits dissolved, and dimmer targets became more possible.

What Have I Seen?

I've observed 22 solar system moons: 1 of Earth (of course), 2 of Mars, 5 of Jupiter, 8 of Saturn, 5 of Uranus, and 1 of Neptune. These are visual observations, using just a telescope and an eyepiece. No cameras or image intensifiers were involved.

The first truly minor moons I observed were Phobos and Deimos. They were shown to me through the 11-inch Brashear Refractor of Wagman Observatory, owned and operated by the Amateur Astronomers Association of Pittsburgh, Pennsylvania, during the close approach of Mars in 2003. The club member running the telescope at the time employed

Illustrations by *S&T*: Leah Tiscione

Minor Moons

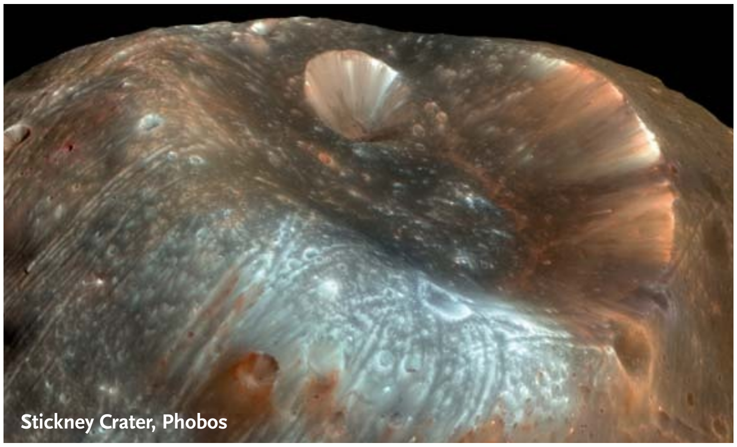
an occulting bar eyepiece to help defeat Mars's glare. Later I found Deimos with my 8-inch LX-200 while using an occulting filter eyepiece to snag it. (See p. 33 for more on occulting bars and filters.) Both observations were conducted in the light-polluted skies of suburban Pittsburgh. Over the years, I've also observed Uranus's challenging moon Miranda and Jupiter's challenging moon Himalia in the very dark skies of the Okie-Tex Star Party.

How Do You Find Them? What Do You See?

As you can imagine, observing minor moons is much like observing asteroids. The fun and challenge is not in the details you see; it's in proving that you successfully observed your target, i.e., proving which of the small objects in the field of view is that target. And how do you do that? At first I drew what I saw and compared that to data from planetarium programs. I now use the asteroid-hunting method described by the Astronomical League

Artist's impression of how Triton, Neptune's largest moon, might look from high above its surface. The distant Sun appears at the upper left and the blue crescent of Neptune right of center.

ESO / L. CALÇADA



NASA / JPL / UNIVERSITY OF ARIZONA

20 Challenging Moons Targetable by Larger Amateur Telescopes

Moon	Mean Diameter (km)	Mag (v)	Discovery
Mars			
I – Phobos	22	11.4	A. Hall, 1877
II – Deimos	12	12.5	A. Hall, 1877
Jupiter			
V – Amalthea	167	14.1	E. Barnard, 1892
VI – Himalia	170	14.2	C. Perrine, 1904
VII – Elara	85	16.3	C. Perrine, 1905
Saturn			
I – Mimas	396	12.8	W. Herschel, 1789
II – Enceladus	504	11.8	W. Herschel, 1789
III – Tethys	1066	10.3	J. Cassini, 1684
IV – Dione	1123	10.4	J. Cassini, 1684
V – Rhea	1529	9.7	J. Cassini, 1672
VII – Hyperion	270	14.4	Bond & Bond, Lassell, 1848
VIII – Iapetus	1471	11.0 (var)	J. Cassini, 1671
IX – Phoebe	220	16.5	W. Pickering, 1898
X – Janus	180	14.4	A. Dollfus, 1966
Uranus			
I – Ariel	1158	13.7	W. Lassell, 1851
II – Umbriel	1169	14.5	W. Lassell, 1851
III – Titania	1578	13.5	W. Herschel, 1787
IV – Oberon	1523	13.7	W. Herschel, 1787
V – Miranda	472	15.8	G. Kuiper, 1948
Neptune			
I – Triton	2706	13.5	W. Lassell, 1856

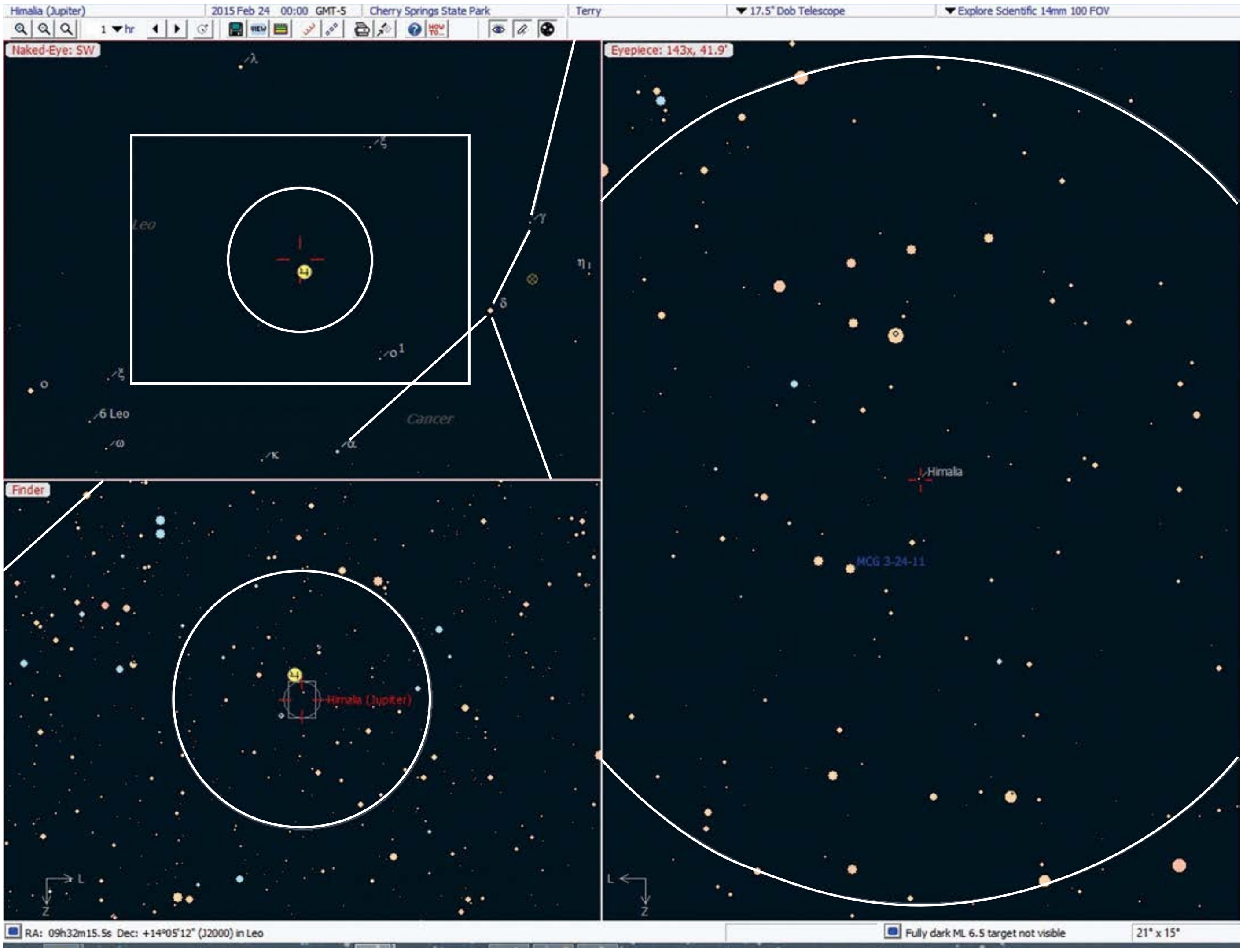
(**astroleague.org/al/obsclubs/asteroid/astrclub.html**). On Day 1, locate an asteroid (or moon) and mark its location on a star chart. On Day 2 (perhaps the next night or the first clear night after Day 1, which could be many days later), locate the same object and mark its new location on the star chart. Finally, using the object's original marked position, return your telescope to that spot and verify that it's no longer there.

A year ago, Tom Dobbins wrote about the visual observation of Galilean moon details (*S&T*: Jan. 2014, p. 54). Nothing like that is even remotely possible with these much smaller bodies. The following are some examples of what I've seen as described in my logs.

When I observed Deimos with my 8-inch scope, I used a 25-mm Orthoscopic eyepiece with a violet occulting filter and 3× Barlow, resulting in 240×. I drew a map of the field of view (FOV), showing Mars, a few field stars, and a very faint dot about three Martian diameters from the planet. Comparing the angle of lines going from the dot to Mars, and from Mars to the brightest nearby star, I saw the same pattern in my planetarium software. Deimos was seen right where it was predicted to be. There was no sign of Phobos, which my software indicated should have been between Deimos and Mars, about one planetary diameter from Mars. I imagine it was buried in light pollution and/or Mars's glare.

I found Uranus's moon Miranda by a somewhat similar technique. While using my 17.5-inch Dobsonian telescope at the 2009 Okie-Tex Star Party, a 9-mm Nagler eyepiece resulted in 223×. I observed Uranus and made a sketch of the FOV. The very few visible field stars were later confirmed by my planetarium software. Miranda's predicted magnitude that night was +16.5. That's dim, but the skies were very dark. Nevertheless, I was surprised to later find a dot in my drawing right where Miranda was predicted to be. There were no field stars displayed near Miranda in my drawing or by the software.

Jupiter's VI moon, Himalia, was my next target after I failed on several attempts to find the planet's V moon, Amalthea. Amalthea is somewhat brighter than Himalia, but is very near the planet, masked in glare. My Himalia observations were also made at the Okie-Tex Star Party, this time in 2010. We've had good luck with Okie-Tex weather over the years, maybe losing only four nights of the 25 or 30 we've been there. I used a 20-mm eyepiece for 100× and a 12-mm eyepiece for 167× with my 17.5-inch Dobsonian. The beginning of the week suffered from wind gusts. Sunday night, I had several weak "maybes" for Himalia. Monday was similar. Tuesday, I was sure I'd observed Himalia, and it was a dim dot, slowly blinking on and off. I assumed the wind gusts were causing much of that. On Wednesday, I confirmed Tuesday's Himalia observations by returning to my previous position and verifying nothing was visible there. I then went to Himalia's next predicted position and easily located it. I showed it to two of my friends. Thursday,



Reliable planetarium software increases the accuracy of minor moon searches. The author used *SkyTools 3 Pro* to plot a naked-eye diagram, finder diagram, and eyepiece field-of-view chart for the target moon, Himalia (Jupiter VI).

one of my friends used my charts to find Himalia with his 12.5-inch f/6 Dobsonian.

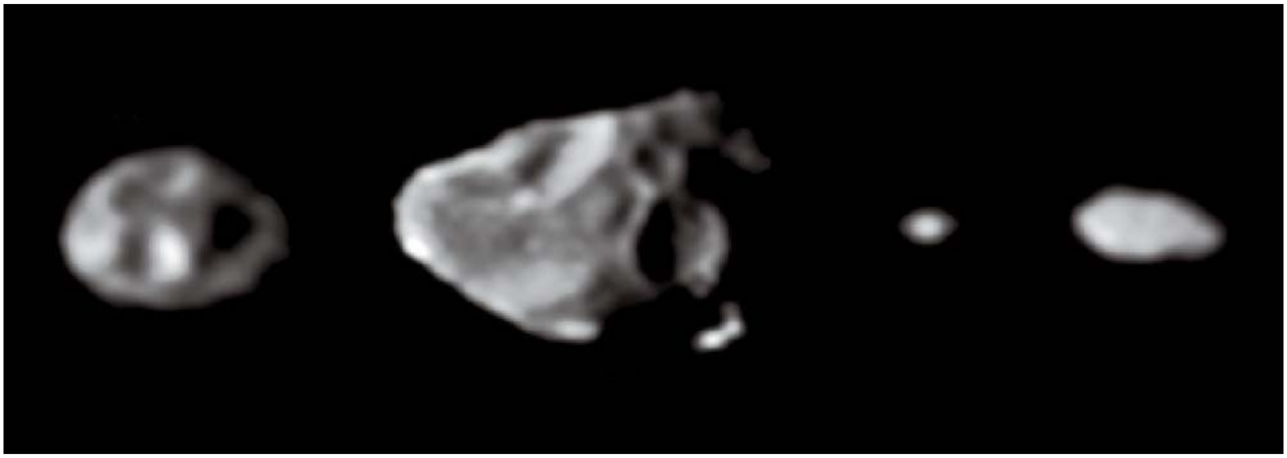
When printing charts for Himalia, I inserted a circle that represented the FOV for my 20-mm eyepiece and my f/4.5 17.5-inch Dobsonian. Himalia was about ¾ of the FOV away from Jupiter. As soon as Jupiter was off the eyepiece, dim stars appeared, allowing me to star-hop to Himalia's location. This became easier as the days passed and I became more familiar with the patterns of these dim stars. Because we saw Himalia move from one day to the next, there is no question in our minds we observed Jupiter VI. But even though Himalia was fairly distant from Jupiter at the time, the glare was still significant.

Techniques

There are many planetarium programs that give excellent asteroid position predictions. Add a FOV circle representing your eyepiece and scope to aid in the asteroid's identification and have at it. I learned the hard way that many software packages' minor moon predictions are not accurate at all, so I use the NASA/JPL HORIZONS Web-Interface (**http://ssd.jpl.nasa.gov/horizons.cgi**) to produce an ephemeris. If you're not familiar with the term "ephemeris," it's a table that lists an astronomical object's predicted positions. (See **skypub.com/ephemeris** for more tips on generating ephemerides.)

Generate an ephemeris for your target and compare its output with what's predicted by your planetarium software. If you find it checks out, generate ephemerides for several moons on several different widely separated dates and again compare them with your software's predictions. You might be able to prove complete reliability for your program and not need to generate any future ephemerides.

I've successfully tested both *SkyTools 3 Pro* (**skyhound.com**) and *Guide 9.0* (**www.projectpluto.com**). They're very straightforward, and I use them without concern for

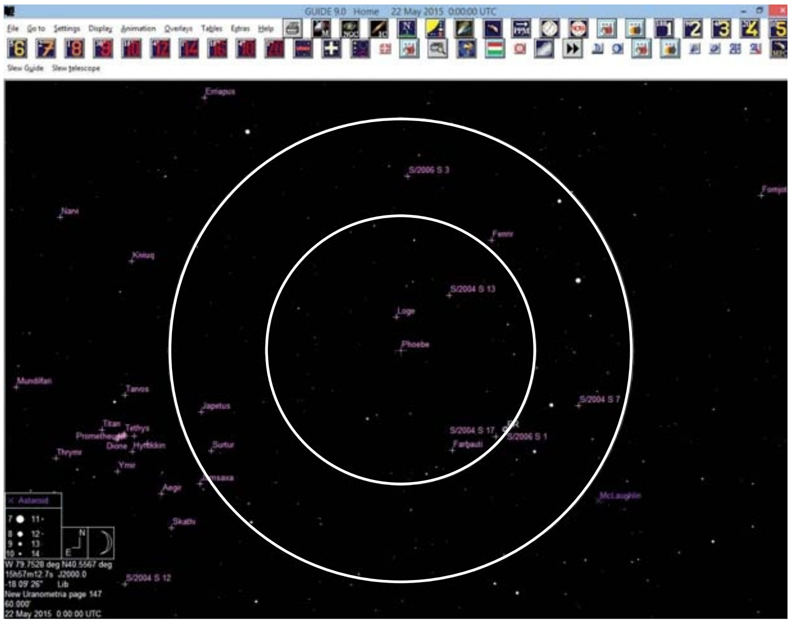


NASA / JPL / CORNELL UNIVERSITY

NASA's Galileo spacecraft provided our best look at the inner Jovian moons Thebe, Amalthea, Adrastea, and Metis (left to right) in January 2000. The moons are shown in their correct relative sizes; the large impact crater on Amalthea is about 55 miles (89 km) across.

predictive accuracy. The Himalia chart included here was produced with *SkyTools*. It shows a naked-eye diagram, a finder diagram and, most importantly, an eyepiece FOV diagram for the target moon, Himalia. A minor shortcoming of *SkyTools* is that it doesn't yet provide predictions for Jupiter's moon Elara or Saturn's moon Janus, but Version 4 will correct that. (The absence of Janus may not be an issue since it has never been visually observed to the best of my knowledge.) By the way, either moon can be manually plotted from ephemeris data for a given point in time by using what *SkyTools* calls "Sky Marks."

Guide has a reputation for plotting solar system moons with extreme accuracy. It certainly does for me. While its graphics might not be as modern as those of some of its competitors, they are customizable and perform excellently. The authors of both software packages are easy to contact and provide excellent support.



PROJECT PLUTO

Let's walk through a set-up for minor moon observations, assuming we want to observe Phoebe (Saturn IX). Saturn will be at opposition and high in the sky at midnight on May 22, 2015. Open *Guide*, set the date, time, and observing location as accurately as possible. Use the "Go to > Planets" option to retrieve positional data for Phoebe. Zoom in and out to get the desired level of chart detail and, finally, increase/decrease the number of shown stars to bring the dimmer ones to a magnitude comparable to Phoebe's. The results should resemble the *Guide* chart pictured here. (NB: Since I had previously successfully tested *Guide* against the NASA/JPL HORIZONS data, I saw no need to generate and compare an ephemeris to *Guide* for this observation attempt.)

The inner circle represents the FOV of a 9-mm 100° eyepiece with my 17.5-inch Dobsonian. Notice that Saturn is buried in the plots of its major moons in the lower left of the chart and out of the FOV. Thus, glare should be reduced as you search for Phoebe's dim dot. Theoretically, Phoebe should be easy to identify based on the pattern of stars in the eyepiece, but if it's not visible, the next step would be to go to a similar focal length Orthoscopic or Plössl eyepiece and try again. With much less glass, these eyepieces should absorb less light; that might help Phoebe's visibility. An eyepiece of higher magnification may also be of assistance, since it increases contrast. A benefit of both is that Saturn might be out of the FOV.

What Future Targets Remain?

When I first began this project, I thought it would be a nice challenge to observe all the solar system's moons that were known when I was a child: Earth 1, Mars 2, Jupiter 12, Saturn 9, Uranus 5, and Neptune 2. I then

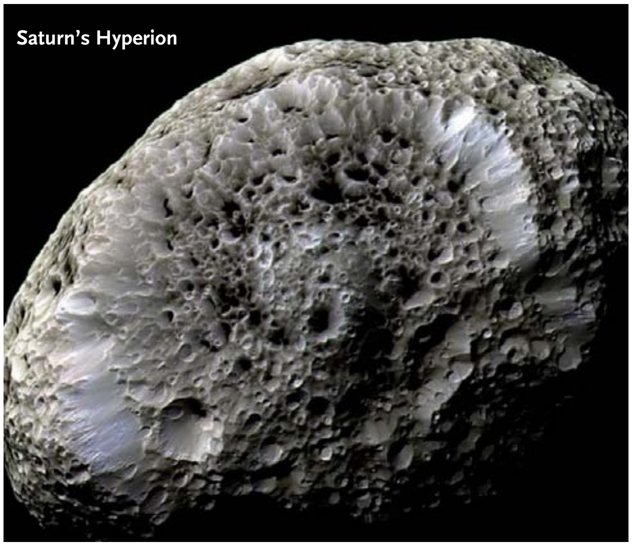
When simulating your telescope's field of view with your planetarium software, include stars with magnitudes comparable to that of your target object, as the author has done in this *Guide 9.0* finder chart for Phoebe (Saturn IX).

noted the magnitudes of some of Jupiter's and Neptune's minor moons and very quickly ruled them out.

Jupiter and Saturn do, however, provide some moons I have yet to see that are *possibly* within the magnitude range of our current scopes. Jupiter has Amalthea (magnitude 14.1) and Elara (magnitude 16.3). Saturn has Janus (magnitude 14.4) and Phoebe (magnitude 16.5). Perhaps some are possible from a very dark site, but Amalthea never ventures much more than 1 Jovian diameter from Jupiter so perpetually resides in intense glare. Someone once related to me that no one has ever visually observed Amalthea except for E. E. Barnard when he first discovered it. In fact, there have been other sightings: it's been observed through the 18-½-inch Clark refractor at the Dearborn Observatory (Northwestern University); the 23-inch Clark at the Halsted Observatory (Princeton University); the 26-inch Clark at McCormick Observatory (University of Virginia); and the 26-inch Clark at the United States Naval Observatory. At least a few astronomers have tracked it down, thanks to Alvan Clark & Sons!

Another possibility is Janus, but it orbits in Saturn's ring system; even when the rings are edge-on, Saturn provides more than enough glare necessary to block its observation. So, Elara and Phoebe are probably the only targets that realistically remain. Both follow orbits fairly distant from their planets, but they're also very dim. I might need a larger telescope, but that certainly won't prevent me from trying. ✦

Terry N. Trees has been an amateur astronomer since he was a child, and has taught astronomy and other science courses at a small western Pennsylvania university. He and his wife travel extensively to star parties in Canada and the United States. Trees can be reached at ***TreesT@Comcast.net****.*



Saturn's Hyperion

NASA / CASSINI IMAGING TEAM

When to Seek Minor Moons in 2015-16

Planet	Opposition Dates	New Moons	Distance from Earth
Mars	May 21, 2016	May 6 & June 4, 2016	0.5 a.u.
Jupiter	Feb 6, 2015	Jan 19 & Feb 18, 2015	4.3 a.u.
	Mar 7, 2016	Feb 7 & Mar 8, 2016	4.4 a.u.
Saturn	May 22, 2015	May 17 & June 15, 2015	9.0 a.u.
	June 2, 2016	May 6 & June 4, 2016	9.0 a.u.
Uranus	Oct 11, 2015	Sept 12 & Oct 12, 2015	19 a.u.
	Oct 14, 2016	Sept 30 & Oct 30, 2016	19 a.u.
Neptune	Aug 31, 2015	Aug 13 & Sept 12, 2015	29 a.u.
	Sept 2, 2016	Aug 31 & Sept 30, 2016	28.9 a.u.

Creating an Occulting Filter Eyepiece

Some moons orbit near their planets, so planetary glare is of great concern when trying to locate them. Phobos and Deimos are classic examples of this, but I had glare issues the first time I tracked down Himalia, even though it was distant from Jupiter at the time. Occulting bar or filter eyepieces may be of assistance with these problems.

While an occulting bar will entirely block out a planet, an occulting filter will provide a dim image of it. If you have an accurate predictive chart, this may help you locate a dim moon; you'll know where to look in relation to its planet. The bar or filter must be mounted at the eyepiece's focal plane, or a crisp edge won't be generated in the image.

I've created two occulting filter eyepieces. I removed a violet filter from its cell, scored it with a glass cutter and straight edge, broke it in half, and rubbed the "diameter edges" against emery cloth to eliminate small burrs. I then epoxied the two semicircular filter segments to the inside of the field stops of two old, low-power Orthoscopic eyepieces. I attached the pieces to the inside of the field stops in case the glue failed; this position lowered the chances of a loose filter falling onto a mirror surface. Be sure to use something like an Orthoscopic, Kellner, or Plössl. Most modern wide-field eyepieces are unsuitable for this project as their focal planes are between internal glass elements.

TERRY N. TREES

The author constructed this occulting filter eyepiece by gluing the halves of a violet filter to the inside stops of a low-power eyepiece.

See skypub.com/martianmoons for more advice on constructing occulting eyepieces.

Cosmic Dread

THE ASTRONOMY OF H. P. LOVECRAFT

SHADOW OVER PROVIDENCE Each year around the date of H. P. Lovecraft's death, a crowd gathers to honor his memory at Brown University's Ladd Observatory.

FRANK C. GRACE / TRIG PHOTOGRAPHY

JOHN FRANCH & ALAN MACROBERT

In 1906 a fifteen-year-old amateur astronomer in Providence, Rhode Island, penned a letter to *Scientific American* urging the world's observatories to "band together and minutely photograph the ecliptic" in a quest for planets beyond Neptune. The discovery of Pluto 24 years later excited this amateur, now a published author of horror tales, "more than any other happening of recent times" — so much so that he featured the dwarf planet in a story that he was writing. In his classic "The Whisperer in Darkness," the eerie Vermont woods and their stream-trickling glens are settled by malign, crablike creatures from Yuggoth — "a strange dark orb at the very rim of our solar system."

Lovecraft in 1915.

LOVECRAFT COLLECTION / BROWN UNIVERSITY LIBRARY

The amateur astronomer was Howard Phillips

Lovecraft (1890–1937). Almost unknown during his lifetime, he is now regarded as the seminal weird-horror writer of the 20th century. He was a key transitional figure, carrying the genre from its traditional ghost stories (which he considered petty and unimaginative) into the wild cosmic immensities revealed by astronomy, finally merging into science fiction.

Lovecraft's nightmarish tales arose from several sources: his own actual nightmares, which he claimed to remember in perfect detail, his intimate love of the 18th-century antiquities around him in Providence, and a philosophical dread regarding the starry voids overhead. His tales are filled with haunting astronomical images — a waning crescent moon casting its feeble light on moldering gravestones; frosty Aldebaran seeming to balance on a steeple over an ancient, worm-bedeviled Massachusetts seaport; Polaris, steeped in prehistoric secrets from its 26,000-year precessional cycle, "winking hideously like an insane watching eye."

From his childhood studies in astronomy, Lovecraft came to regard humans as insignificant dust on the infinite cosmic stage, ludicrous in their self-centeredness. "When Kleiner showed me the skyline of New-York I told him that man is like the coral insect," he wrote, "designed to build vast, beautiful, mineral things for the moon to delight in after he is dead." His stories draw their peculiar power in part from this detached, awestruck worldview.

In "The Call of Cthulhu," for example, the protagonist learns of a monstrous tentacled thing from the stars, dead and dreaming in the ocean depths for geologic ages, waiting for "when the stars were right" to emerge. In "At the Mountains of Madness," Antarctic explorers stumble onto a vast fossil city constructed eons ago by starfish-headed, plantlike creatures that "seeped down from the stars" not long "after the earth had flung off the moon"; they had started Earth life as an accident, or a jest. In "The Shadow Out of Time," his last major story, a professor comes to the bone-chilling realization that during years of amnesia he had switched bodies with a scholarly conical entity from an extraterrestrial race which resided on Earth in "the world of the Permian or Triassic age," and which had bottled up horrible, semi-supernatural things in Earth's interior.

Lovecraft in 1934.

LUCIUS B. TRUESDELL / LOVECRAFT COLLECTION, BROWN UNIVERSITY LIBRARY

STRUGGLING TO DESCRIBE H. P. Lovecraft's iconic creation is Cthulhu, deliberately named to represent an unpronounceable thought-sound of something truly alien. Although it was very non-human in his tales, he consented to sketch this "trivial Design" for a friend.

OBSERVATORY NIGHTS

Howard Phillips Lovecraft discovered what he called "the myriad suns and worlds of infinite space" in 1902 at the age of eleven or twelve. He credited the "excellent but somewhat obsolete collection" of astronomy volumes amassed by his maternal grandmother for sparking his interest in the science. He had always been precocious: he was reading voraciously by five or six, entranced by the poetry of Coleridge, *The Arabian Nights*, and the Greek and Roman classics. When in 1903 his patrician mother gave him a 2¼-inch refractor, Lovecraft reported that his "gaze was ever upward at night." He would own two more telescopes during his lifetime, the last one a Bardou 3-inch refractor bought from Montgomery Ward in 1906 for $50—roughly $1,300 in today's dollars.

The melancholy teenager began haunting Brown University's Ladd Observatory. His tall, gaunt figure could often be seen on clear nights trudging up the hill to the observatory or bicycling back down in "a glorious coast." Winslow Upton, a Brown University astronomer and family friend, gave Lovecraft "free access" to the observatory, which boasted a fine Brashear 12-inch refractor that remains there today. Taking full advantage of this permission, the enthusiastic amateur pestered the observatory staff "half to death," Lovecraft later confessed, but fortunately the director and his two assistants were, Lovecraft admitted, "infinitely tolerant of a pompous juvenile ass with grandiose astronomical ambitions."

Lovecraft spent much of his time observing the moon and Venus. The brilliant, cloud-shrouded planet, which revealed little to the telescopic observer, attracted him because of its very mystery. "In boyish egotism I fancied I might light upon something with my poor little 2¼-inch telescope which had eluded the users of the 40-inch telescope," he informed a correspondent in 1918. Lovecraft also liked to view comets — his first was Comet Borrelly, which reached naked-eye visibility in July 1903. He missed seeing perhaps the most spectacular comet of the early 20th century, the Daylight Comet of 1910, because of "a hellish case of measles" that kept him confined to bed. He did observe Comet Halley during its very favorable apparition later that year.

The frequent observing took a toll on the frail teenager's health. "So constant were my observations that my neck became much affected by the strain of peering at a difficult angle," Lovecraft would maintain. "It gave me much pain, & resulted in a permanent curvature perceptible today to a close observer."

Nevertheless, the pleasures of astronomy were too great for Lovecraft to resist, and he was soon sharing his love of the science. At 12 he self-published the first edition of a newsletter for family and friends that he titled *The Rhode Island Journal of Astronomy*. Issued irregularly from 1903 to 1909, it showcased Lovecraft's growing astronomical knowledge. Soon he broke into bigger leagues. At 16 he began penning astronomy columns for two newspapers — the rural *Pawtuxet Valley Gleaner* and then the *Providence Tribune,* one of New England's leading dailies.

In a typical article, Lovecraft would inform his readers of the visible planets and constellations for the month. But he sometimes devoted his column to a single subject such as "Comets" or "The Fixed Stars" or "Can the Moon Be Reached by Man?" In this last piece, Lovecraft argued that a trip to the Moon was "not a scientific impossibility" and predicted that "some day an inhabitant of this earth may set foot on the soil of our satellite!"

In 1908 Lovecraft was struck by a debilitating attack of depression and suddenly stopped writing his astronomy columns. Financial ruin several years earlier had cost the family its grand, beloved old house, and Lovecraft never recovered from the loss of his childhood surroundings. As a young teen he was at times "so exhausted by the sheer burden of consciousness & mental & physical activity that I had to drop out of school for a greater or lesser period & take a complete rest from all responsibilities," he wrote years later. His 1908 breakdown caused him to abandon high school forever a few months before he would have graduated. S. T. Joshi, Lovecraft's chief biographer, speculates that the breakdown was brought on by his realization that he could never become a professional astronomer. He had been, in his own words, "repelled and exhausted" by mathematics, especially algebra, and astronomy, alas, was "a mass of mathematics. . . . That was the first major set-back I ever received — the first time I was ever brought up short against a consciousness of my own limitations," he bitterly recalled. "It was clear to me that I hadn't brains enough to be an astronomer — and that was a pill I couldn't swallow with equanimity."

That may not be the entire story; around this time he suffered a severe head injury in a long fall, following which his head was kept "packed in ice" day and night.

Lovecraft spent the next five years as a hermit, seeing few people and rarely venturing from his "skimpy flat" at 598 Angell Street, where he resided with his overprotective and increasingly mentally ill mother (she was finally institutionalized). "I could hardly bear to see or speak to anyone, & liked to shut out the world by pulling down dark shades & using artificial light." He suffered blinding headaches, and his vivid nightmares increased.

His love for astronomy seems to have sustained him during this bleak period. He kept an astronomical notebook in which he recorded his observations of the Moon, the Orion Nebula and other deep-sky objects, the planets, meteor showers, occultations, and various comets including Halley and Delavan. Comet Delavan was "indeed a beautiful sight" in his 3-inch refractor, though the view was "somewhat hampered by electric street lights." The notebook grew to at least 100 closely-written pages.

He considered himself frightfully ugly. As early as 13 or 14 he planned suicide and often bicycled to the spot on the Barrington River where he intended to drown

LOVECRAFT COLLECTION, BROWN UNIVERSITY LIBRARY

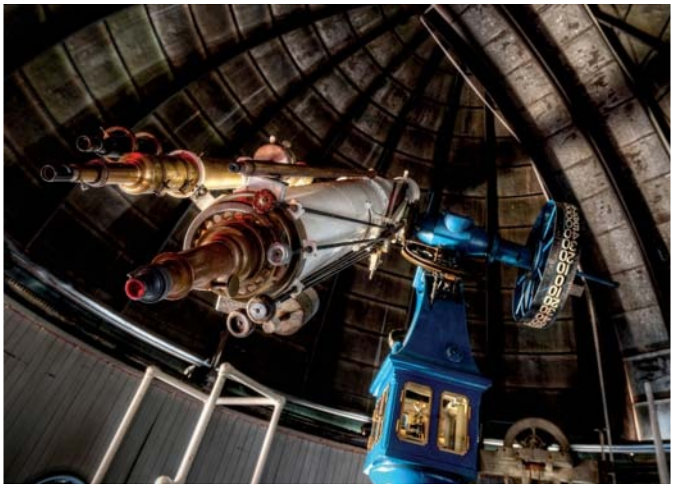
IN HIS OWN EYES **Shortly after Lovecraft's death, pulp-magazine illustrator Virgil Finlay drew him as he wished to be considered: in the wig and dress of his beloved 18th century.**

XIV: Star-Winds

It is a certain hour of twilight glooms,
Mostly in autumn, when the star-wind pours
Down hilltop streets, deserted out-of-doors
But shewing early lamplight from snug rooms.
The dead leaves rush in strange, fantastic twists,
And chimney-smoke whirls round with alien grace,
Heeding geometries of outer space,
While Fomalhaut peers in through southward mists.

This is the hour when moonstruck poets know
What fungi sprout in Yuggoth, and what scents
And tints of flowers fill Nithon's continents,
Such as in no poor earthly garden blow.
Yet for each dream these winds to us convey,
A dozen more of ours they sweep away!

— From Lovecraft's "Fungi from Yuggoth,"
a cycle of 36 sonnets.



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EYE TO THE PAST Ladd Observatory's 12-inch Brashear refractor in its early years (with an unidentified user) and now.

himself. "And yet certain elements — notably scientific curiosity & a sense of world drama — held me back," he later wrote. "Much in the universe baffled me, yet I knew I could pry the answers out of books if I lived and studied longer." That, and a certain intense poetic awe that the scenery around him inspired almost wherever he went, would always remain his delights and reasons for living.

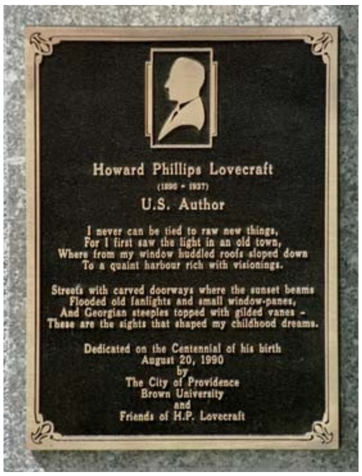
Late in 1913 Lovecraft emerged from his five-year funk and resumed his astronomical writing, this time a monthly column for the *Providence Evening News*. In addition to current sky highlights, he regaled his readers with the mythology of the constellations, the history of astronomy, and the latest discoveries. He assailed the fanciful theories of Percival Lowell, the famous exponent of Martian canals, whom he met on one of Lowell's lecture tours. Lovecraft took especial delight in puncturing the pretensions of "the sordid astrologer, who beholds in infinity only a cheap little fortune-telling contrivance." He charged into a print feud with the astrologer J. F. Hartmann; Lovecraft's rebuttals morphed from serious and reasoned to, finally, florid Swiftian satires with astrological predictions spanning the next 2,000 years.

This exchange caught the attention of the community of amateur journalists and printing-press hobbyists, small but flourishing in the 1910s, and they recruited him in. He was soon a leader in this little world and a mentor to would-be writers within it. It provided an appreciative audience for his essays on everything from atheism and scientific materialism to literature and world history; his often lugubrious poetry; and his increasingly serious stabs at weird fiction. He was off and running.

While Lovecraft was waging his word war with J. F. Hartmann, a real Great War raged overseas. Educated by his astronomy books to think in cosmic terms, Lovecraft was not impressed in the least by the scale and magnitude of the conflict. "The fiercest battles between mortals are of small consequence in the vast system of infinity," he asserted in September 1914, a month after World War I began, "and the celestial bodies perform their accustomed motions without regard to the state of war or peace upon this one tiny sphere."

AWE AND TERROR

On the other hand, the enormous extent of the universe more than impressed Lovecraft: it absolutely terrified him. In the 1910s astronomers were beginning to get a handle on the true size of the universe beyond the known stars, thanks to the Cepheid variables, the great celestial yardsticks. Even earlier, the German astronomer Max Wolf had estimated the distance to the farthest so-called "spiral nebula" to be a staggering 578,000 light-years. "Humanity with its pompous pretensions sinks to complete nothingness when viewed in relation to the unfathomed abysses of infinity and eternity which yawn about it," Lovecraft declared in one of his later astronomy columns for the *Providence Evening News*. "Man, so far from



PLAQUE: WILL HART / STREET SIGN: ZIGAMORPH

REMEMBERED Recent memorials mark Lovecraft's lifelong neighborhood on Providence's College Hill.

being the central and supreme object of Nature, is clearly demonstrated to be a mere incident, perhaps an accident, of a natural scheme whose boundless reach relegates him to total insignificance. His presence or absence, his life or death, are obviously matters of utter indifference to the plan of Nature as a whole."

Lovecraft would later refer to this view of human insignificance — a view derived from astronomy — as *cosmicism*. This philosophy would inform much of his fiction writing.

Lovecraft gave up his astronomy column in 1918 after an editor asked him to dumb it down. He turned more to the crafting of "cosmic horror" tales, many of which deal with godlike entities that he loosely termed the Great Old Ones. Lovecraft's human characters tend to be cutouts; their purpose is often to be gradually overcome by terror as they slowly grasp the existence of super-powerful things from Outside, and are brought to madness as they realize the utter unimportance of humanity. Over the course of Lovecraft's life, these entities gradually morphed from Elder Gods echoing classical mythology to utterly nonhuman but material creatures, at a time when science fiction was taking shape in pulp magazines. Lovecraft questioned the validity of "organic life, good and evil, love and hate, and all such local attributes of a negligible and temporary race called mankind." His bold rejection of the centrality of human concerns gave his fiction, despite its flaws, staying power. In his tales, Lovecraft continually struggles to evoke the feelings of horror and awe that his youthful astronomy books sparked in him.

Yet he was always disappointed by his stories and felt

I have whirled with the Earth at the dawning,
When the sky was a vaporous flame;
I have seen the dark universe yawning
Where the black planets roll without aim,
Where they roll in their horror unheeded, without knowledge or luster or name.

— From "Nemesis," 1917, anticipating loose planets between the stars.

SHAUN YOW KEN JIE

that they never really conveyed what he was striving for. His lifetime output of fiction was small, though he wrote an estimated 80,000 letters to friends and literary acquaintances, often filled with intense, tightly written essays. (Some 20,000 letters still exist.) He believed that his fiction style had been fatally compromised by the pulp magazines he consumed as a youth and by the demands of the pulp *Weird Tales,* practically the only paying outlet where he could try to slow his descent into increasingly dire poverty.

After several years in which he had barely enough to eat, H. P. Lovecraft died of cancer in 1937 at age 46. Nothing he wrote appeared in book form in his life. His work would have been lost and forgotten had not a few fans organized to find and rescue it after his death. In 1941 they discovered a stack of his papers piled by a furnace to be used as fuel.

Whatever the quirks and flaws in Lovecraft's writing, the intensity and sincerity of his efforts to convey his fright-bedazzled scientific vision have gained him an ever greater following decade after decade, to the point that he is now an item of pop culture among people who have never read him. You can buy Cthulhu plush toys and Yog-Sothoth T-shirts. On the other end of the cultural spectrum, in 2005 the prestigious Library of America accepted him into its canon of great American authors, pulp style and all.

EMERGENCE OF CTHULHU **"The Thing cannot be described — there is no language for such abysms of shrieking and immemorial lunacy, such eldritch contradictions of all matter, force, and cosmic order. A mountain walked or stumbled." Lovecraft's deliberate vagueness has left plenty of room for artists' imaginations.**

Lovecraft remained an astronomer until the end. He visited the Hayden Planetarium in New York (a city he loathed as soulless and modern) twice after it opened in 1935. The "lover of the sky must needs marvel at the callousness of those whose nocturnal gaze never mounts above the garish glare of the sordid city," Lovecraft once wrote. "How trivial seem the rays of the lamp to him who is wont to look upon assembled suns and worlds!" ✦

John Franch, *a freelance writer and researcher, is the author of* Robber Baron: The Life of Charles Tyson Yerkes. ***Alan M. MacRobert,*** *a* Sky & Telescope *senior editor, discovered Lovecraft at age 13 and was marked for life by the final passages of "The Rats in the Walls."*

New Product Showcase

▼ **TINY AUTOGUIDER** Starlight Xpress announces the Lodestar X2 Autoguider ($649). This tiny imaging and autoguiding camera features a low-noise Sony ICX829ALA EXview HAD CCD II detector with a 752 × 580 array of 8.2 × 8.4-micron pixels. Weighing 3 ounces, this ultra-light camera is housed in a convenient 1¼-inch-diameter aluminum body that fits into any standard 1¼-inch focuser. The detector end also includes C-mount threads for additional interface requirements. The camera connects to your computer via a USB 2.0 Mini interface (which also provides power) and downloads a full-resolution image in 0.2 seconds. The autoguider also has an RJ12 connector port to directly connect to your telescope mount.

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+44(0)1184026898; www.sxccd.com

▼ **EXTREME EYEPIECES** Meade Instruments unveils its new Series 5000 Mega Wide Angle eyepieces (starting at $199.95). These wide-field oculars feature an expansive 100° apparent field of view with comfortable eye-relief of 13 to 20 millimeters that can accommodate observers wearing eyeglasses. Both of the 5- and 10-mm models fit 1¼-inch focusers, while the 15- and 21-mm versions are 2-inch format only. Each Mega Wide Angle eyepiece incorporates blackened lens edges to enhance contrast, and their parfocal design requires little or no focus change when switching between eyepieces within the series.

Meade Instruments
27 Hubble, Irvine, CA 92618
800-626-3233; www.meade.com

▲ **MULTI-MOUNT** Sky-Watcher introduces its AZ-EQ5 GT Mount ($1,649). This multi-purpose Go To telescope mount is equally useful as a German equatorial mount, or operating in alt-azimuth mode. The AZ-EQ5 GT features hybrid stepper motor drives on both axes for smooth slewing at up to 4.2° per second. Capable of supporting up to 33 pounds of gear excluding counterweights, the mount accepts the standard ST-4 style autoguider input for astrophotography, and also has a DSLR shutter control port. Its SynScan Go To controller contains a database of more than 42,000 objects, including all the Messier, NGC, IC, and Caldwell catalogs, and much more. The AZ-EQ5 GT also provides two 7¾ lb. counter-weights, an adjustable tripod with 1¾-inch stainless steel legs, and a DC power adapter. See the manufacturer's website for additional details and accessories.

Sky-Watcher USA
855-327-1587
www.skywatcherusa.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.

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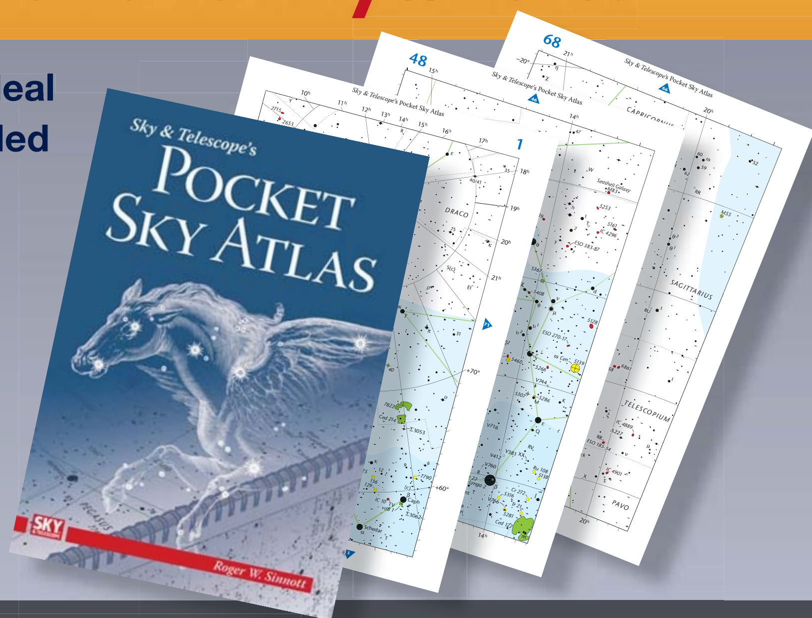

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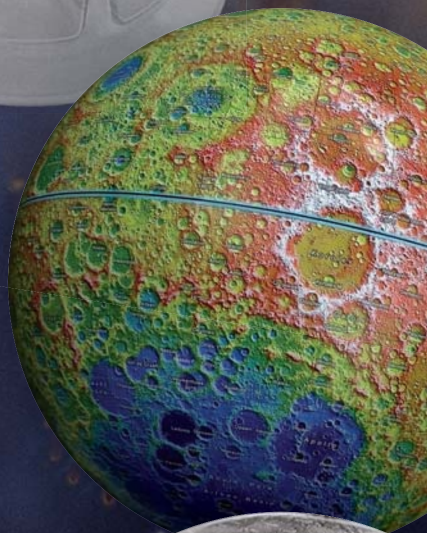

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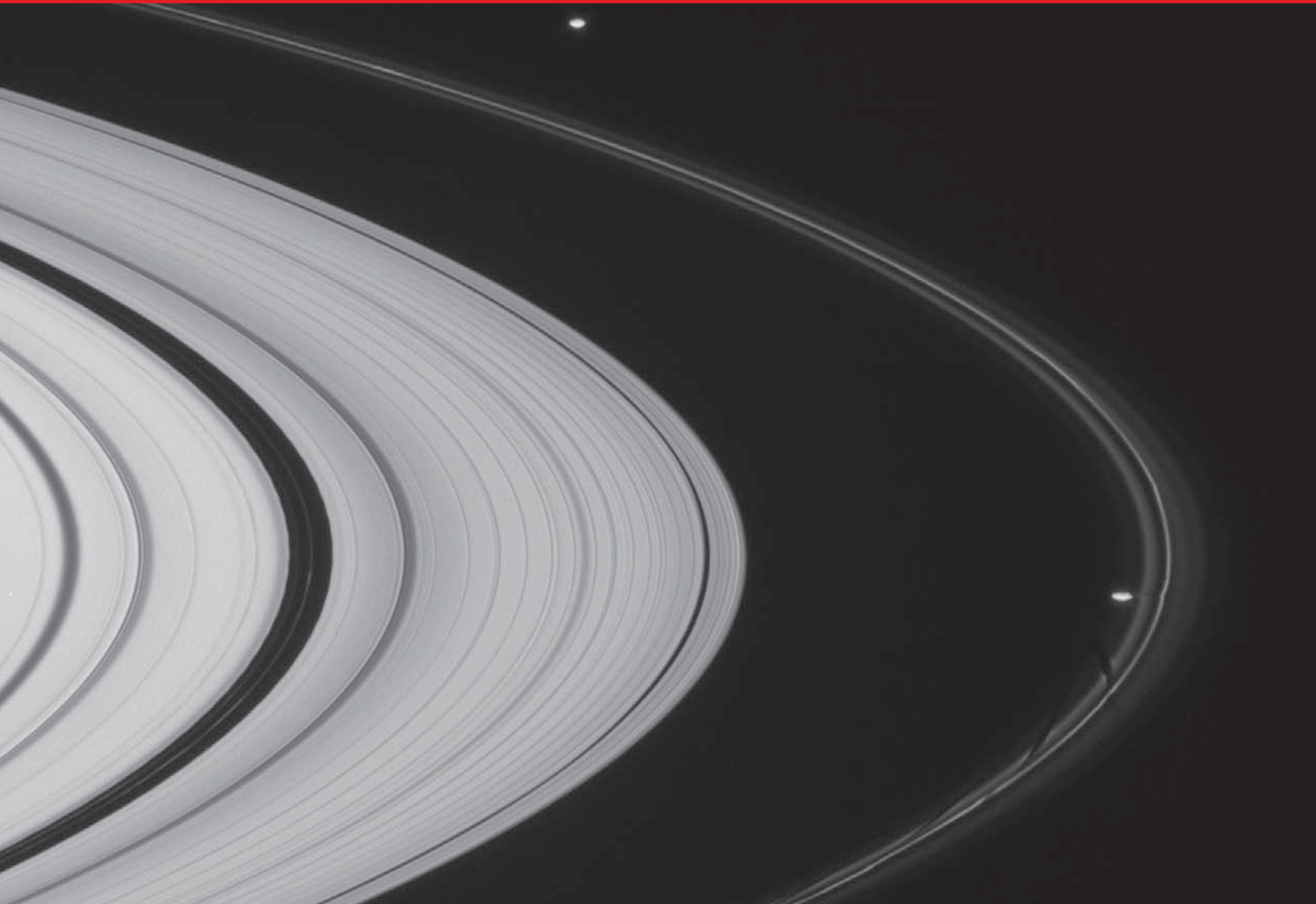

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The minor shepherd moons Prometheus and Pandora mark Saturn's F-ring (page 28).

PHOTOGRAPH: NASA / JPL / SPACE SCIENCE INSTITUTE

Sky at a Glance

FEBRUARY 2015

3–4 **NIGHT:** Jupiter shines about 6° from the full Moon. Watch through the night as they cross the sky together.

4–5 **NIGHT:** The Moon shines about 5° from Regulus, with Jupiter farther to their west.

6–20 **DUSK:** The zodiacal light is on good display for observers at mid-northern latitudes. Look to the west about 80 minutes after sunset for a huge, tall pyramid of diffuse light; it slopes left along the ecliptic, with Venus and Mars at its base.

9 **NIGHT:** The waning gibbous Moon rises about an hour before midnight (local time). Look about 6° to its upper right to find Spica.

13 **PRE-DAWN:** The last quarter Moon trails Saturn by about 5° in the eastern sky.

16–17 **NIGHT:** Algol is at minimum for roughly two hours centered at 12:19 a.m. on the 17th EST (February 16, 9:19 p.m. PST); see page 53.

20 **NIGHT:** Algol shines at minimum for roughly two hours centered at 9:08 p.m. EST.

21 **EVENING:** Look west to see Mars less than 1° from brighter Venus. The planets set about two hours after sunset, with a thin crescent Moon chasing them down.

25 **DUSK:** Aldebaran shines close to the Moon.

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

	◄SUNSET	MIDNIGHT	SUNRISE►
Mercury		Visible Feb 9 through March 4	SE
Venus	W		
Mars	W		
Jupiter	E	S	W
Saturn		SE	S

Moon Phases

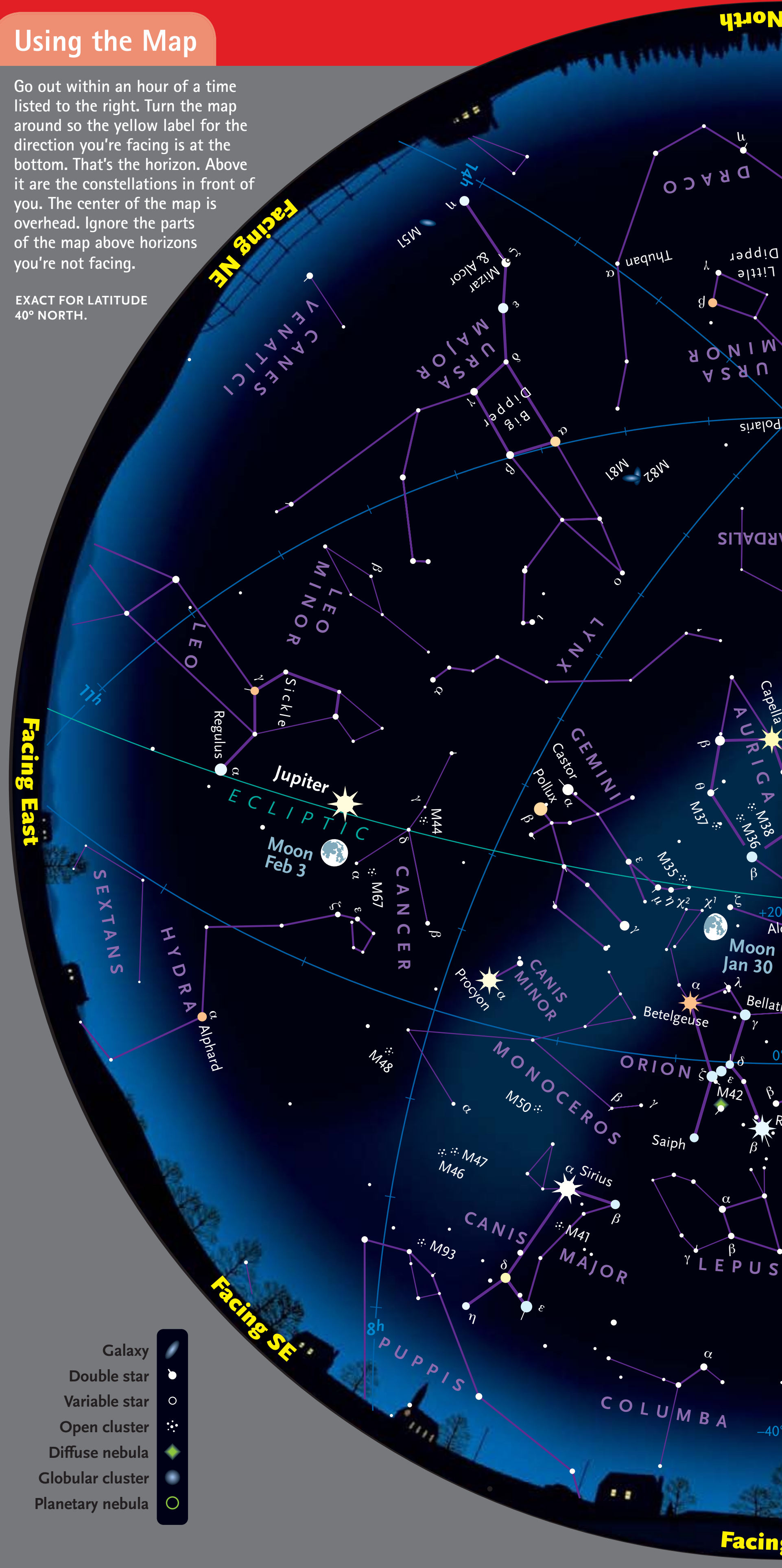
- Full February 3 6:09 p.m. EST
- Last Qtr February 11 10:50 a.m. EST
- New February 18 6:47 p.m. EST
- First Qtr February 25 12:14 p.m. EST

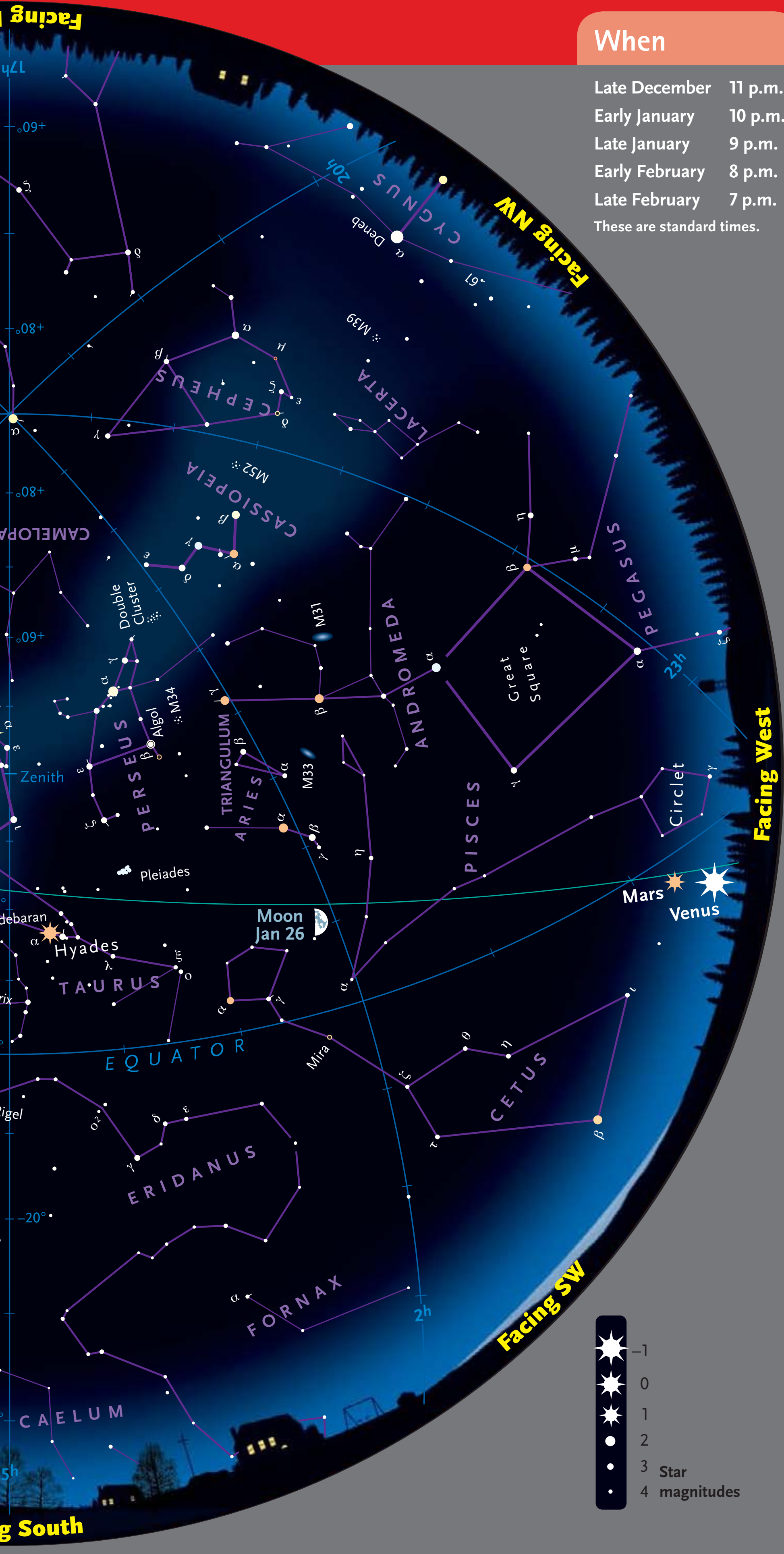
SUN	MON	TUE	WED	THU	FRI	SAT
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

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 December	11 p.m.
Early January	10 p.m.
Late January	9 p.m.
Early February	8 p.m.
Late February	7 p.m.

These are standard times.

Gary Seronik
Binocular Highlight

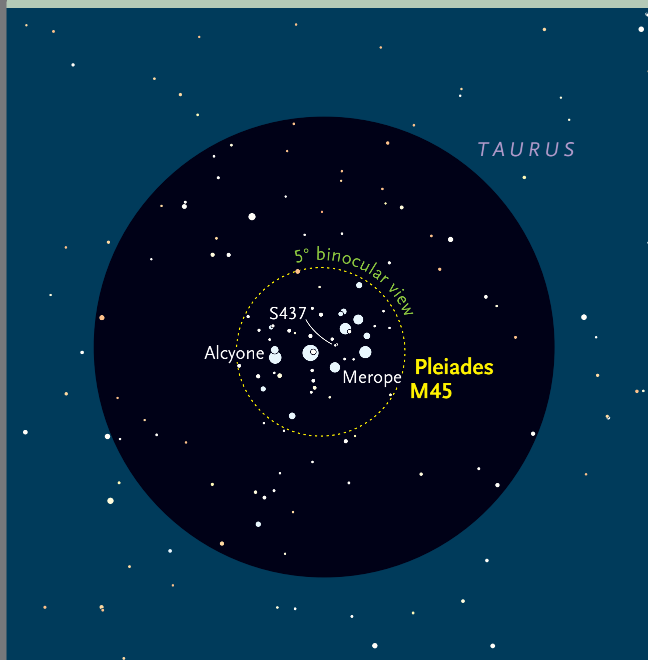
The Splendid Pleiades

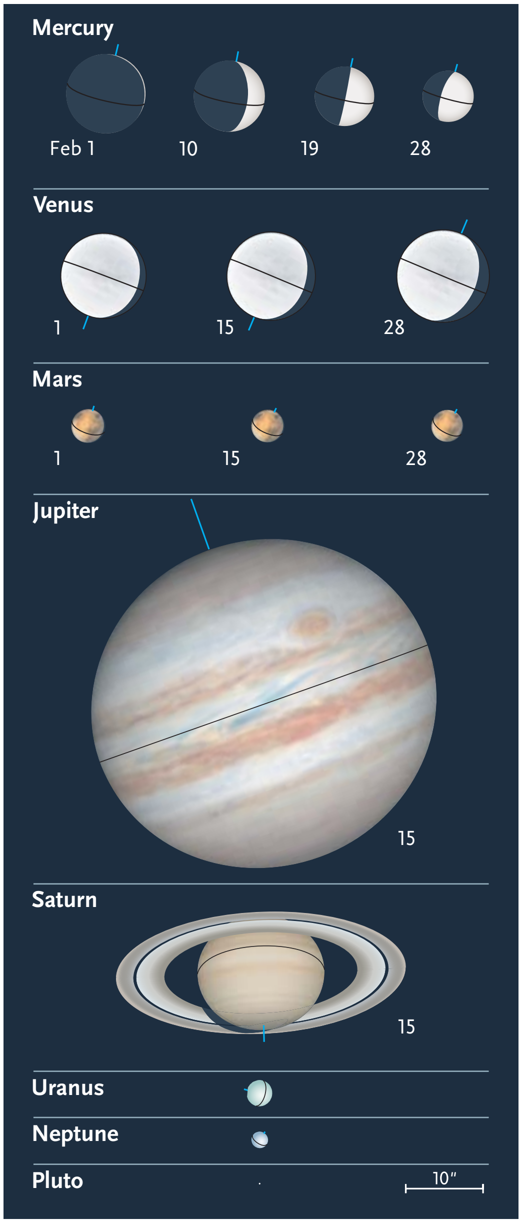
If I had to choose just one deep-sky object to demonstrate the appeal of binocular astronomy, it would probably be the Pleiades (M45) in Taurus. The cluster has two things going for it. First, you can see it without optical aid, which means even casual stargazers are drawn to it. Second, the Pleiades are visually impressive in any binocular under a wide range of sky conditions. You don't need pristine country skies to appreciate the splendor of this deep-sky wonder.

The Pleiades have inspired countless observers. In his 1965 memoir, *Starlight Nights*, famed variable-star observer and comet hunter Leslie Peltier recounts an early childhood view of the cluster and describes it as his "first meeting with the stars." Keen-eyed observer Stephen James O'Meara poetically likens the sight to "a forest of starlight bathed in moonlit mist."

Part of the cluster's visual appeal is its clutch of bright stars. These are the so-called Seven Sisters, though most naked-eye observers can clearly perceive only five. The stellar quintet ranges in brightness from magnitude 2.8 (Alcyone) to 4.1 (Merope) and is neatly arrayed as a tiny "little dipper." In binoculars, the sister stars are joined by a large gathering of fainter siblings. My eye is always drawn to the neat arc of five, 7th-magnitude stars under the dipper handle. And if you have 10× binos, try for the difficult 8th-magnitude double star, South 437, situated near the middle of the bowl.

Like the Alpha Persei Association discussed last month, the Pleiades are one of a handful of deep-sky treasures best appreciated with binoculars. The field of view provided by many telescopes is too restrictive to contain the entire cluster and its surroundings. ✦



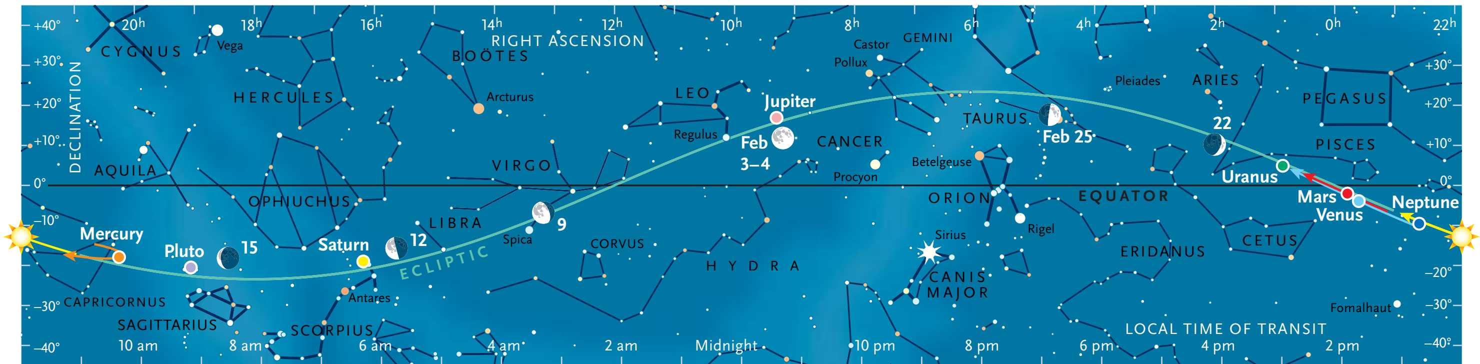


Sun and Planets, February 2015

	February	Right Ascension	Declination	Elongation	Magnitude	Diameter	Illumination	Distance
Sun	1	$20^h\ 56.2^m$	–17° 19′	—	–26.8	32′ 28″	—	0.985
	28	$22^h\ 41.9^m$	–8° 15′	—	–26.8	32′ 18″	—	0.990
Mercury	1	$20^h\ 39.3^m$	–14° 42′	5° Mo	+4.7	10.3″	2%	0.656
	10	$20^h\ 11.4^m$	–17° 09′	20° Mo	+0.9	9.2″	24%	0.729
	19	$20^h\ 23.8^m$	–18° 18′	26° Mo	+0.1	7.7″	48%	0.872
	28	$20^h\ 59.9^m$	–17° 38′	27° Mo	0.0	6.6″	64%	1.013
Venus	1	$22^h\ 30.5^m$	–11° 00′	24° Ev	–3.9	11.0″	92%	1.510
	10	$23^h\ 12.1^m$	–6° 37′	26° Ev	–3.9	11.3″	90%	1.473
	19	$23^h\ 52.7^m$	–1° 59′	28° Ev	–3.9	11.6″	89%	1.433
	28	$0^h\ 32.8^m$	+2° 43′	30° Ev	–3.9	12.0″	87%	1.390
Mars	1	$23^h\ 06.3^m$	–6° 38′	34° Ev	+1.2	4.4″	96%	2.111
	15	$23^h\ 46.1^m$	–2° 13′	30° Ev	+1.2	4.3″	97%	2.173
	28	$0^h\ 22.5^m$	+1° 54′	27° Ev	+1.3	4.2″	97%	2.231
Jupiter	1	$9^h\ 23.7^m$	+16° 17′	173° Mo	–2.6	45.3″	100%	4.351
	28	$9^h\ 10.0^m$	+17° 21′	156° Ev	–2.5	44.6″	100%	4.420
Saturn	1	$16^h\ 06.7^m$	–18° 52′	68° Mo	+0.5	16.2″	100%	10.282
	28	$16^h\ 11.9^m$	–19° 01′	94° Mo	+0.5	16.9″	100%	9.841
Uranus	15	$0^h\ 51.1^m$	+4° 47′	48° Ev	+5.9	3.4″	100%	20.652
Neptune	15	$22^h\ 34.6^m$	–9° 45′	11° Ev	+8.0	2.2″	100%	30.937
Pluto	15	$19^h\ 01.7^m$	–20° 34′	41° Mo	+14.2	0.1″	100%	33.552

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

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

Fred Schaaf

The Dog Nights of Winter

Sirius is mighty in winter — and summer, too.

Before dawn on August 18, 2014, I stood near my favorite local pond looking at Venus and Jupiter and their reflections. That morning, I beheld the two planets forming a brilliant pair only about ⅓° apart — not too much farther apart or much differently situated in the sky than they were when the Magi of Christian tradition might have seen them in August of 3 BC.

Three days earlier, on August 15th, I had observed something just as interesting: the brightest of all stars at its famed "heliacal rising." Of course, I'm talking about Sirius, which in February is at its highest and most convenient for viewing in the evening hours.

The prime season for Sirius. Orion the Hunter, the brightest of all constellations, leads his two hounds across the sky in each winter night's procession. In Canis Major, the Big Dog, we find Sirius, a star so bright that you'd need to combine the light of the second, third, and fourth brightest stars of mid-northern latitudes — spring's Arcturus, summer's Vega, and winter's Capella — to match its brilliance.

Among winter's star patterns, Canis Major is second only to Orion in overall brightness. At magnitude 1.5, Epsilon (ε) Canis Majoris, more commonly known as Adhara, is the brightest of all 2nd-magnitude stars. In addition, Adhara is part of a triangle of stars at the south end of Canis Major that rivals Orion's Belt in total brightness. Yet these other fine luminaries of Canis Major are often overlooked because they can't compete with the –1.44 radiance of Sirius itself.

The marvelous distraction of Sirius. Sirius is often paired with Procyon, the brightest star in Canis Minor, the Little Dog. But even though this lesser Dog Star is the 8th brightest star in the heavens, shining at magnitude 0.4, it's often overlooked because of Sirius.

Sirius pulls our gaze away from more than just the other stars of the Big Dog. Sometimes we're so enthralled by its glow that we forget to scan just 4° south of the mighty star to observe one of winter's loveliest open clusters. M41 shines at magnitude 4.5, so if you have suitably dark skies, you can spot it with the unaided eye.

The Dog Days and the heliacal rising. The term "Dog Days," used since at least the period of Ancient Greece, refers to the hottest and sultriest part of the summer. The name may have been derived from the older belief that Sirius, the Dog Star, added its heat to the day when it shared the sky with the Sun. After the Dog Days of summer comes the first sight of Sirius rising just before sunrise — its "heliacal rising." For the Egyptian Middle and New Kingdoms (and possibly earlier periods), the heliacal rising of Sirius was the welcome harbinger of the life-giving annual flood of the Nile. The heliacal rising of Sirius was so important that it marked the New Year in the Egyptian calendar.

SURAJ BAADKAR

SUNSET ON THE NILE In ancient Egypt, the heliacal rising of Sirius marked the beginning of the flood season on the Nile.

In modern times, how many of us who enjoy the Dog Nights of winter, observing Sirius on February evenings, also try to look for the heliacal rising of Sirius at August dawns? I've often been up so many hours watching Perseid meteors that I had to go to bed before Sirius could rise in the later stages of morning twilight. From latitude 40° north, the heliacal rising can be spotted by about August 10th or earlier. On August 15th last year, I saw Venus and Jupiter, Procyon, and then the last "herald" of Sirius, Beta (β) Canis Majoris — also known as Mirzam (or Murzim). At magnitude 1.98, Mirzam was easy in binoculars but at the edge of possibility for naked-eye vision; it was just a few degrees above the horizon about 50 minutes before sunrise. But then, about 10 minutes later, there glittered above a distant tree a bright, sparkling light — my dear friend of winter nights, Sirius. ✦

Another Close One

Venus and Mars come together for a study in contrasts.

I think 2015 truly deserves to be called the "Year of the Conjunctions."

What remarkable conjunctions do we have in February? After January's close meet-up of Venus and Mercury, February features a similarly close and prolonged pairing of Venus and Mars at dusk, this time a little higher in the sky. Viewers in North America also get to see a tight grouping of Venus, Mars, and the Moon in the west-southwest on February 20th.

The east holds its own attraction at dusk: Jupiter comes up at its brightest and biggest, and is visible essentially all night long. Saturn rises after midnight and shines reasonably high at dawn. Late in the month, Mercury appears at dawn — but very low for viewers at mid-northern latitudes.

DUSK & EARLY EVENING

Venus and **Mars** make a remarkably contrasting pair this month. Brilliant Venus shines at magnitude –3.9, while faint Mars glows at only magnitude +1.2 or +1.3. That's more than 100 times fainter. By February 7th, viewers observing an hour after sunset around latitude 40° north will find Venus more than 10° high in the west-southwest with Mars about 8° above it. Watch as they draw closer together each evening. Starting on February 17th, Mars shines less than 2° from Venus for 9 days. They're less than 1° from each other from the 20th through the 23rd. On Saturday, February 21st (a day after the Moon appears so close to Venus and Mars), the two planets have their closest pairing, appearing just 0.4° apart at dusk in the Americas. Little Mars may be hard to see in Venus's glare without optical aid, depending on your vision, but both worlds will fit together in a medium-power telescopic view. Compare the dazzling, 11.8″-wide, 88%-illuminated disk of yellow-white Venus with the much dimmer, 4.2″ dot of orange-gold Mars.

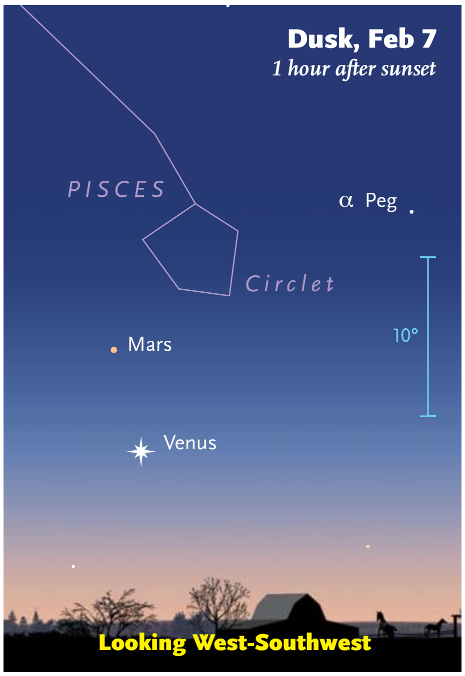
Mars is still less than 4° from Venus at the end of February, but is lower in the sky than its bright sister planet. As the month closes, Mars sets not much more than two hours after the Sun, about 20 minutes before Venus.

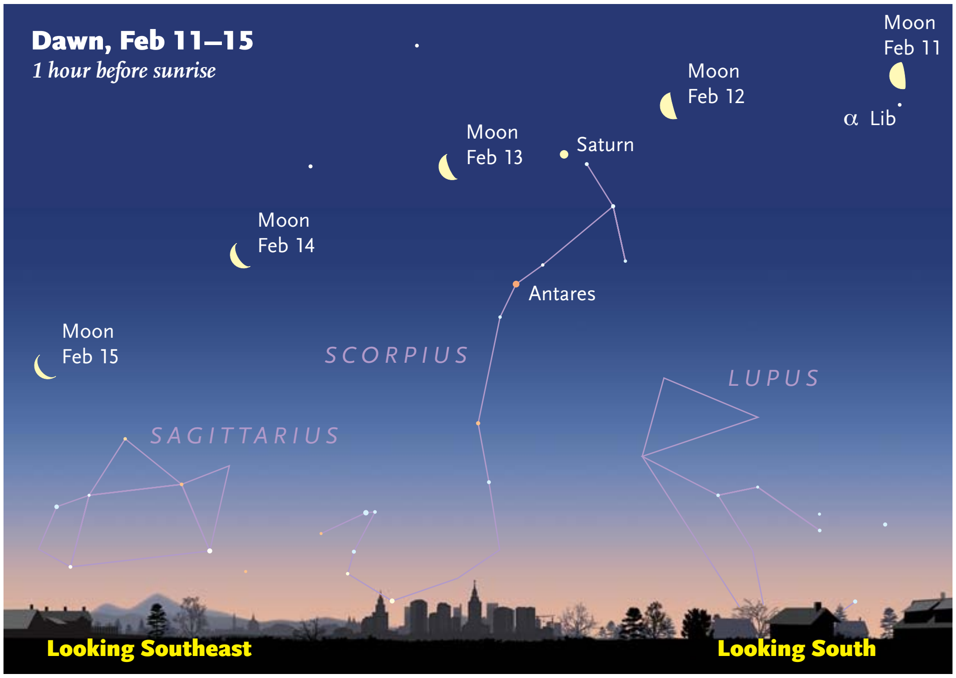
Uranus is some 4° to the upper left of Venus at the end of the month, pretty low for finding a 6th-magnitude speck. Uranus will pass sensationally close to Venus on March 4th (see **skypub.com/urnep** for a finder chart).

Neptune starts the month near Venus, but at 8th magnitude it's very difficult to see in the evening twilight. It's invisible the rest of the month, going through conjunction with the Sun on February 26th.

ALL NIGHT LONG

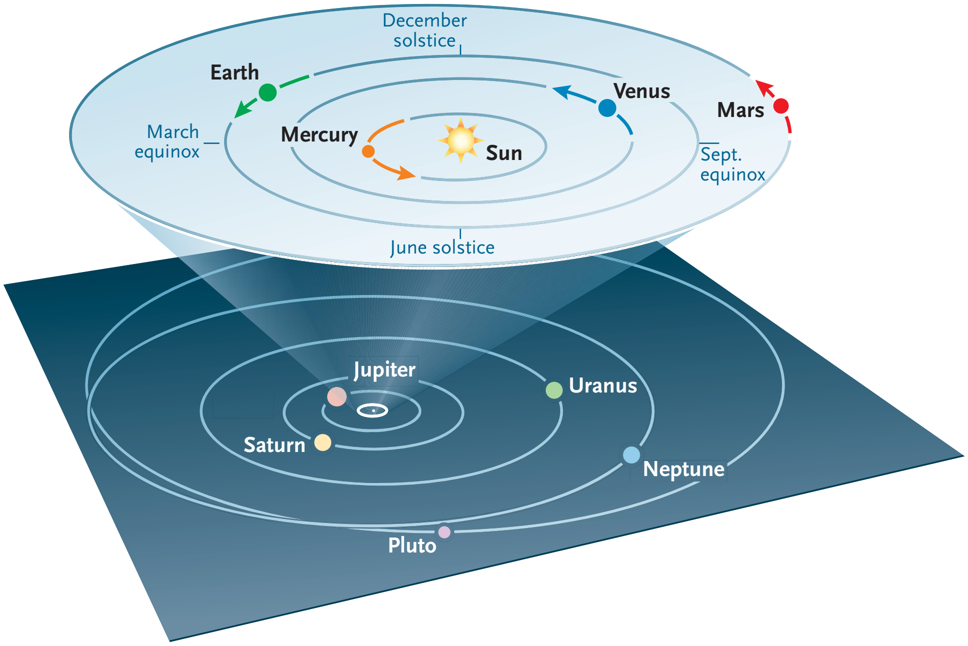
Jupiter comes to opposition on February 6th, so is visible essentially from dusk until dawn. The giant planet shines





ORBITS OF THE PLANETS

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



brightly between Leo and Cancer: low in the east in twilight, higher in the southeast in late evening, and highest in the south around the middle of the night. You'll find it retrograding from Leo back into Cancer during the first half of February, its brightness peaking at magnitude –2.6. Its equatorial diameter stays close to 45″ from mid-January to February's end.

Once Jupiter is high in the sky on a night of steady atmosphere, a good medium-size telescope can show several dark belts, light zones, and hints of luxurious details within them. Jupiter is at a fairly high northern declination now, so it shines quite far above the horizon for viewers at mid-northern latitudes. See more about observing Jupiter and its moons on p. 52.

Juno, the third-discovered asteroid, was at opposition last month, but is now well-placed for viewing. It remains 8th magnitude near the head of Hydra for most of January and February. See the finder chart on p. 50.

MIDNIGHT TO DAWN

For observers around latitude 40° north, **Saturn** rises around 2 or 3 a.m. at the start of February, depending on where you live in your time zone, and midnight or 1 a.m. at the end of the month. The golden world shines at magnitude +0.5, but its equatorial diameter is only 16″ to 17″ this month. You'll find it perched dramatically just above the nearly vertical line of stars that forms the front of Scorpius. The ringed planet is highest in morning twilight. A telescope shows its gorgeous rings tilted almost 25° from an edgewise presentation, practically the most open they ever become.

DAWN

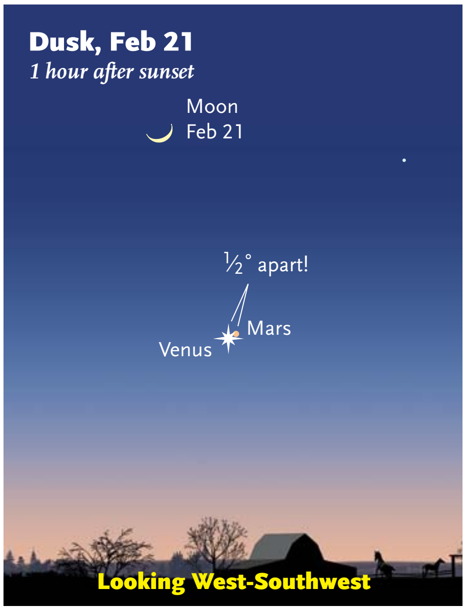
Mercury leaps out to a greatest elongation of 27° from the Sun on February 26th, but even then appears very low for observers at mid-northern latitudes. Scan for it in the southeast before dawn grows too bright.

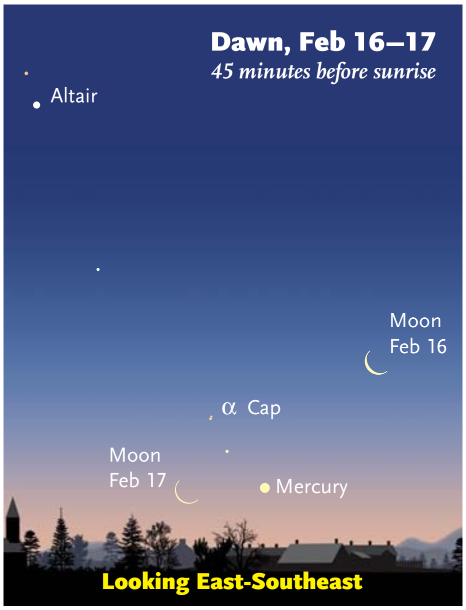
MOON PASSAGES

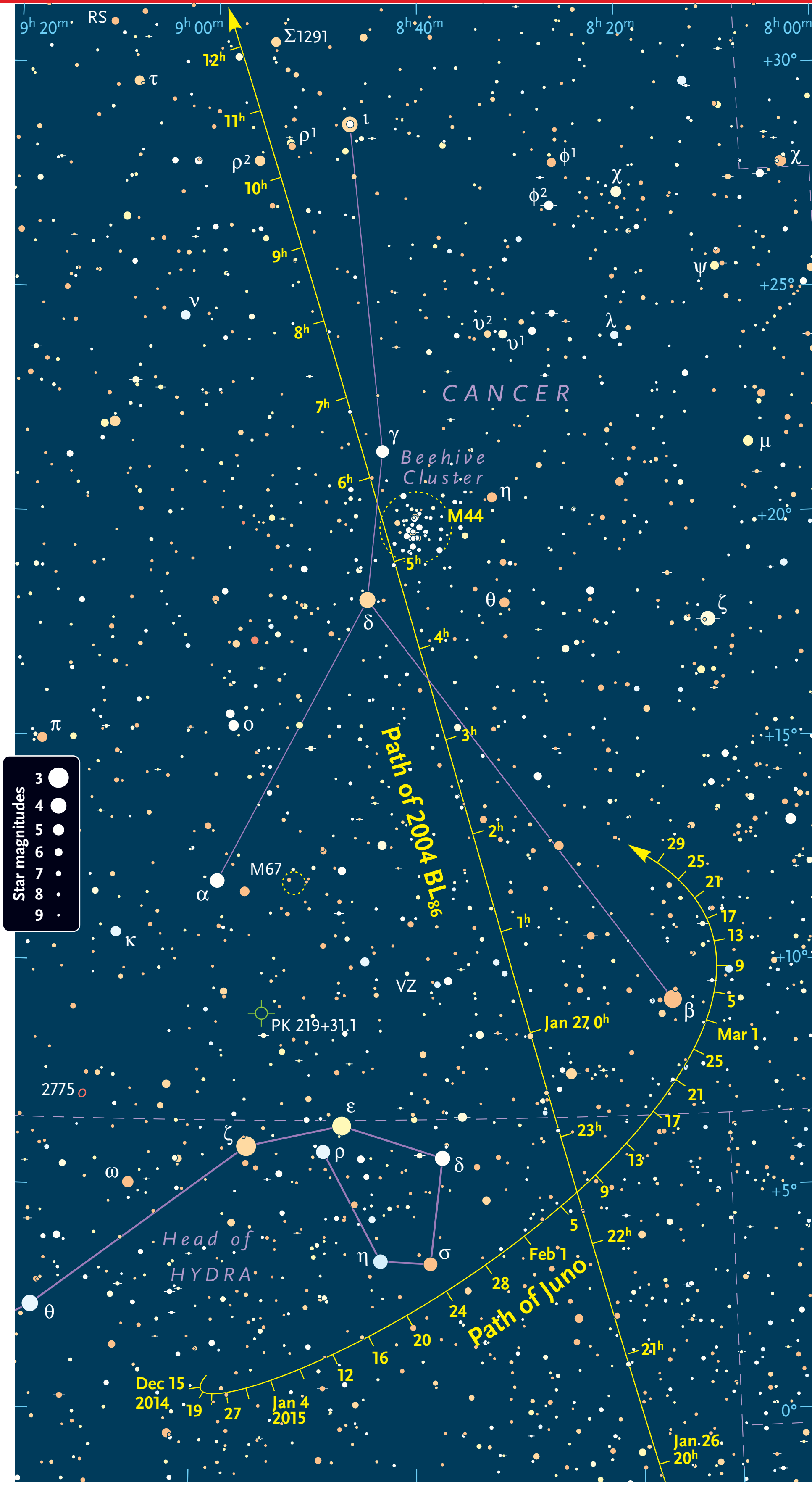
On the American nightfall of February 3rd, the exactly full **Moon** glows to the right of Jupiter. The next night it's much closer to the right of Regulus.

The waning Moon is well to either side of Saturn at dawn on February 12th and 13th. It forms a nearly equilateral triangle with Saturn and Antares for most North American viewers on the latter date. A very thin waning crescent is just a few degrees left of elusive Mercury, low in morning twilight, on February 17th. At nightfall on the 20th, the waxing lunar crescent is within a few degrees of Venus and Mars, themselves within 1° of each other.

On February 21st, the crescent's dark limb occults 6th-magnitude Uranus for parts of the United States. A waxing gibbous Moon is very near Aldebaran on February 25th. ✦







Earth to Dodge a Bullet

Watch a near-Earth asteroid race across Cancer on the night of January 26–27.

Asteroids that buzz Earth make the news either by being especially close or especially large. The one that's going to miss us on the night of January 26–27 is especially large as near-Earth objects go, and it will become bright enough to follow with a 3- or 4-inch telescope as it moves across the stars.

Most known Earth-grazers are just meters across, but this one is roughly a half kilometer wide. As a result it will become as bright as magnitude 9.2 shortly after it misses us by 1.2 million km (750,000 miles). That's 3.1 times the distance of the Moon.

The asteroid is 2004 BL_{86}, discovered 11 years ago by the LINEAR project hunting for near-Earth objects. Its well-defined orbit has earned it an asteroid number: 357439, likely making it the highest-numbered asteroid you've ever had a chance to see.

The Americas, Europe, and Africa have the best seats for when it should be brightest: from 1^h to 6^h Universal Time January 27th. It will be crawling northward across Cancer and will skim the Beehive Cluster.

A fast little asteroid and a slow big one move northward past the head of Hydra into Cancer this winter. One flies through in hours, the other in months. The ticks on their paths are labeled in Universal Time (at 0:00 UT each date in the case of Juno). Put a pencil dot on their paths for when you plan to go look. Juno will be 8th to 9th magnitude; 2004 BL_{86} should be 9th to 10th. Stars are plotted to magnitude 9.2.

It will be traveling about 2° per hour, or 2 arcseconds per second of time. You should be able to see it creeping in real time when it passes close by a star.

Its closest approach comes earlier, around 16^h UT January 26th while climbing through Hydra. But it will be only about magnitude 10.0 then, because it's showing only part of its sunlit side.

According to a NASA group that's planning radar imaging, "The encounter will be the closest known by an object this large until 1999 AN_{10} approaches within one lunar distance in 2027."

And Juno Too

As it happens, this little whizzer cuts right across the winter track of 3 Juno, one of the *largest* asteroids: about 500 times bigger (270 km wide). Juno will be at its peak brightness, magnitude 8.1, on the night of the flyby. It spends all January and February brighter than 8.7.

Jupiter's Great Red Spot

Any telescope shows Jupiter's four big moons. Binoculars usually show at least two or three, occasionally all four. Identify them using the diagram on page 53.

Interactions between Jupiter and its satellites and their shadows are tabulated below.

And here are the times, in Universal Time, when the Great Red Spot should cross Jupiter's central meridian. The dates, also in UT, are in bold. (Eastern Standard Time is UT minus 5 hours.)

January 1, 6:19, 16:14; **2,** 2:10, 12:06, 22:01; **3,** 7:57, 17:52; **4,** 3:48, 13:44, 23:39; **5,** 9:35, 19:30; **6,** 5:26, 15:21; **7,** 1:17, 11:13, 21:08; **8,** 7:04, 16:59; **9,** 2:55, 12:51, 22:46; **10,** 8:42, 18:37; **11,** 4:33, 14:28; **12,** 0:24, 10:20, 20:15; **13,** 6:11, 16:06; **14,** 2:02, 11:58, 21:53; **15,** 7:49, 17:44; **16,** 3:40, 13:35, 23:31; **17,** 9:27, 19:22; **18,** 5:18, 15:13; **19,** 1:09, 11:04, 21:00; **20,** 6:56, 16:51; **21,** 2:47, 12:42, 22:38; **22,** 8:34, 18:29; **23,** 4:25, 14:20; **24,** 0:16, 10:11, 20:07; **25,** 6:03, 15:58; **26,** 1:54, 11:49, 21:45; **27,** 7:40, 17:36; **28,** 3:32, 13:27, 23:23; **29,** 9:18, 19:14; **30,** 5:10, 15:05; **31,** 1:01, 10:56, 20:52.

February 1, 6:47, 16:43; **2,** 2:39, 12:34, 22:30; **3,** 8:25, 18:21; **4,** 4:17, 14:12; **5,** 0:08, 10:03, 19:59; **6,** 5:54, 15:50; **7,** 1:46, 11:41, 21:37; **8,** 7:32, 17:28; **9,** 3:24, 13:19, 23:15; **10,** 9:10, 19:06; **11,** 5:02, 14:57; **12,** 0:53, 10:48, 20:44; **13,** 6:39, 16:35; **14,** 2:31, 12:26, 22:22; **15,** 8:17, 18:13; **16,** 4:09, 14:04; **17,** 0:00, 9:55, 19:51; **18,** 5:47, 15:42; **19,** 1:38, 11:33, 21:29; **20,** 7:25, 17:20; **21,** 3:16, 13:12, 23:07; **22,** 9:03, 18:58; **23,** 4:54, 14:50; **24,** 0:45, 10:41, 20:36; **25,** 6:32, 16:28; **26,** 2:23, 12:19, 22:15; **27,** 8:10, 18:06; **28,** 4:01, 13:57, 23:53.

These times assume that the spot is centered at System II longitude 221°, a change from recent issues based on new observations. Any feature on Jupiter appears closer to the central meridian than to the limb for 50 minutes before and after transiting. A light blue or green filter slightly boosts the contrast of Jupiter's reddish, orange, and tan markings.

Phenomena of Jupiter's Moons, February 2015

Feb. 1	3:45	I.Ec.D
	6:12	I.Oc.R
	10:49	IV.Ec.D
	16:53	IV.Oc.R
Feb. 2	0:57	I.Sh.I
	1:04	I.Tr.I
	3:14	I.Sh.E
	3:21	I.Tr.E
	3:31	II.Ec.D
	6:37	II.Oc.R
	9:11	III.Sh.I
	9:37	III.Tr.I
	12:50	III.Sh.E
	13:15	III.Tr.E
	22:13	I.Ec.D
Feb. 3	0:38	I.Oc.R
	19:25	I.Sh.I
	19:30	I.Tr.I
	21:43	I.Sh.E
	21:47	I.Tr.E
	22:22	II.Sh.I
	22:30	II.Tr.I
Feb. 4	1:17	II.Sh.E
	1:25	II.Tr.E
	16:42	I.Ec.D
	19:04	I.Oc.R
Feb. 5	13:54	I.Sh.I
	13:55	I.Tr.I
	16:11	I.Sh.E
	16:13	I.Tr.E
	16:48	II.Ec.D
	19:43	II.Oc.R
	23:11	III.Ec.D
Feb. 6	2:55	III.Oc.R
	11:10	I.Ec.D
	13:30	I.Oc.R
Feb. 7	8:21	I.Tr.I
	8:22	I.Sh.I
	10:39	I.Tr.E
	10:40	I.Sh.E
	11:38	II.Tr.I
	11:41	II.Sh.I
	14:33	II.Tr.E
	14:35	II.Sh.E
Feb. 8	5:37	I.Oc.D
	7:58	I.Ec.R
Feb. 9	2:47	I.Tr.I
	2:51	I.Sh.I
	5:05	I.Tr.E
	5:08	I.Sh.E
	5:57	II.Oc.D
	8:57	II.Ec.R
	12:52	III.Tr.I
	13:09	III.Sh.I
	16:30	III.Tr.E
	16:48	III.Sh.E
	20:28	IV.Tr.I
	21:11	IV.Sh.I
Feb. 10	0:03	I.Oc.D
	1:12	IV.Tr.E
	2:00	IV.Sh.E
	2:26	I.Ec.R
	21:13	I.Tr.I
	21:19	I.Sh.I
	23:30	I.Tr.E
	23:37	I.Sh.E
Feb. 11	0:45	II.Tr.I
	0:59	II.Sh.I
	3:40	II.Tr.E
	3:53	II.Sh.E
	18:29	I.Oc.D
	20:55	I.Ec.R
Feb. 12	15:39	I.Tr.I
	15:48	I.Sh.I
	17:56	I.Tr.E
	18:05	I.Sh.E
	19:04	II.Oc.D
	22:14	II.Ec.R
Feb. 13	2:32	III.Oc.D
	6:51	III.Ec.R
	12:55	I.Oc.D
	15:24	I.Ec.R
Feb. 14	10:05	I.Tr.I
	10:16	I.Sh.I
	12:22	I.Tr.E
	12:34	I.Sh.E
	13:53	II.Tr.I
	14:17	II.Sh.I
	16:48	II.Tr.E
	17:12	II.Sh.E
Feb. 15	7:21	I.Oc.D
	9:52	I.Ec.R
Feb. 16	4:31	I.Tr.I
	4:45	I.Sh.I
	6:48	I.Tr.E
	7:02	I.Sh.E
	8:11	II.Oc.D
	11:31	II.Ec.R
	16:08	III.Tr.I
	17:08	III.Sh.I
	19:46	III.Tr.E
	20:46	III.Sh.E
Feb. 17	1:47	I.Oc.D
	4:21	I.Ec.R
	22:57	I.Tr.I
	23:13	I.Sh.I
Feb. 18	1:14	I.Tr.E
	1:31	I.Sh.E
	2:10	IV.Oc.D
	3:01	II.Tr.I
	3:35	II.Sh.I
	5:55	II.Tr.E
	6:30	II.Sh.E
	9:43	IV.Ec.R
	20:13	I.Oc.D
	22:50	I.Ec.R
Feb. 19	17:23	I.Tr.I
	17:42	I.Sh.I
	19:40	I.Tr.E
	19:59	I.Sh.E
	21:18	II.Oc.D
Feb. 20	0:49	II.Ec.R
	5:49	III.Oc.D
	10:50	III.Ec.R
	14:39	I.Oc.D
	17:18	I.Ec.R
Feb. 21	11:49	I.Tr.I
	12:10	I.Sh.I
	14:06	I.Tr.E
	14:28	I.Sh.E
	16:09	II.Tr.I
	16:54	II.Sh.I
	19:04	II.Tr.E
	19:49	II.Sh.E
Feb. 22	9:05	I.Oc.D
	11:47	I.Ec.R
Feb. 23	6:15	I.Tr.I
	6:39	I.Sh.I
	8:32	I.Tr.E
	8:56	I.Sh.E
	10:25	II.Oc.D
	14:06	II.Ec.R
	19:26	III.Tr.I
	21:07	III.Sh.I
	23:03	III.Tr.E
Feb. 24	0:45	III.Sh.E
	3:31	I.Oc.D
	6:16	I.Ec.R
Feb. 25	0:41	I.Tr.I
	1:07	I.Sh.I
	2:58	I.Tr.E
	3:25	I.Sh.E
	5:17	II.Tr.I
	6:12	II.Sh.I
	8:11	II.Tr.E
	9:07	II.Sh.E
	21:58	I.Oc.D
Feb. 26	0:44	I.Ec.R
	10:43	IV.Tr.I
	15:11	IV.Sh.I
	15:28	IV.Tr.E
	19:07	I.Tr.I
	19:36	I.Sh.I
	19:59	IV.Sh.E
	21:24	I.Tr.E
	21:53	I.Sh.E
	23:32	II.Oc.D
Feb. 27	3:23	II.Ec.R
	9:07	III.Oc.D
	14:49	III.Ec.R
	16:24	I.Oc.D
	19:13	I.Ec.R
Feb. 28	13:33	I.Tr.I
	14:05	I.Sh.I
	15:51	I.Tr.E
	16:22	I.Sh.E
	18:26	II.Tr.I
	19:31	II.Sh.I
	21:20	II.Tr.E
	22:25	II.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). Next is the satellite involved: **I** for Io, **II** Europa, **III** Ganymede, or **IV** Callisto. Next is the type of event: **Oc** for an occultation of the satellite behind Jupiter's limb, **Ec** for an eclipse by Jupiter's shadow, **Tr** for a transit across the planet's face, or **Sh** for the satellite casting its own shadow onto Jupiter. An occultation or eclipse begins when the satellite disappears **(D)** and ends when it reappears **(R)**. A transit or shadow passage begins at ingress **(I)** and ends at egress **(E)**. Each event is gradual, taking up to several minutes. Predictions courtesy IMCCE / Paris Observatory.

For links to many Jupiter sites, including some with recent images and instructions for uploading yours, see www.britastro.org/jupiter/links.htm.

Jupiter at Opposition

Jupiter has been at its biggest and best in the winter for the last few years (for those of us in the Northern Hemisphere), and it's happening again. Jupiter comes to opposition on February 6th and blazes between Leo and Cancer all winter.

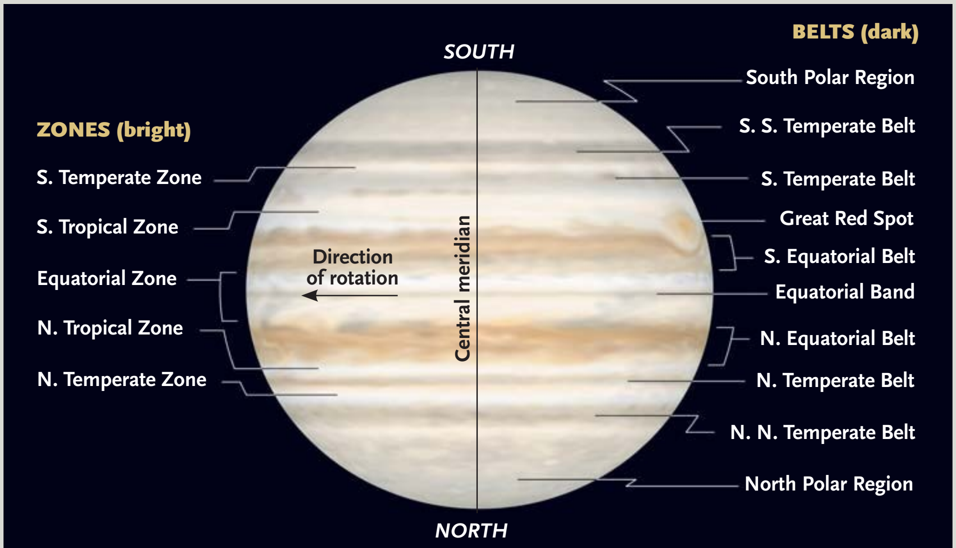
From mid-January through the end of February, Jupiter appears 45° across its equator and 42° from pole to flattened pole. That's not quite as big as it becomes at its closest oppositions every 12 years, but the changing quality of the seeing from night to night is usually more important than minor size differences.

Jovian Features

There's always something happening on Jupiter. Not only does it change from year to year and often month to month, it also rotates fast, in just under 10 hours. If you watch for 30 minutes you'll see features at the middle of its disk shift 20% of the way from there to the planet's celestial western limb.

DAMIAN PEACH (5)

Jupiter can change a lot from year to year. It's shown here with south up. During its last five apparitions the North Equatorial Belt has been wide or narrow, the North Temperate Belt has been strong or weak, and in 2010 the South Equatorial Belt disappeared.



Not all the belts and zones of Jupiter are always present, and often they change width. South is up to match the view in many telescopes. Features rotate from celestial east to west.

The illustration at bottom labels Jupiter's major markings, though with all the changes, it's sometimes a judgment call where to assign these standard names. The Great Red Spot is rounder now than in past decades as it continues its long-term shrinkage. It stays squeezed like a watermelon seed between the South Equatorial Belt (SEB) and the South Tropical Zone (STrZ), in an indentation in the SEB named the Red Spot Hollow.

The whirls, knots, and storms that churn the belts and zones can be grouped into categories. Various terms have been applied to them; here are some of the most common:

Ovals, white, gray, or red, are similar to the Great Red Spot but smaller. White ovals often inhabit the South Temperate Belt. The biggest long-enduring oval (after the Great Red Spot) goes by the name BA; it resulted from the dramatic merger of two smaller ovals, BE and FA, in 2000 — then turned from white to reddish.

Tiny, bright **white spots,** often no bigger than the shadows of Jupiter's moons, mark upwellings of fresh material and sometimes the start of large atmospheric disturbances.

Festoons are thin dark streamers, often bluish, extending diagonally from a belt into a zone. The Equatorial Zone is especially prone to them.

Rifts are long bright lines inside a belt.

Bars, rods, or **barges** are distinctively dark and more like line segments than ovals.

Knots are lumpy thickenings in a belt.

Making Observations

If there's one great rule of visual observing, it's this: The more you look, the more you see. It takes time at the eyepiece to catch brief moments of good seeing, and it also takes time to build up impressions of difficult, fleeting details. Taking the time is what turns you into an accomplished observer.

The most productive form of planetary observing, however, is stacked-video imaging. Done well, it makes features crystal clear that you couldn't glimpse by eye. So don't expect to see views in any scope that are as vivid as printed images.

But still and always, there's nothing like watching the real thing.

Mutual Events of Jupiter's Moons

Jupiter's four Galilean satellites continue to perform mutual eclipses and occultations *among themselves*. These events will continue until Jupiter sinks into the sunset this summer. Jupiter is at opposition in February, so observers in any given part of the world can now see lots of them while Jupiter is well up a dark sky. Most, however, involve only slight dimmings of the satellites' light.

Listed below are the deepest events that will be visible from at least part of North America — those where the shadowed satellite, or the blend of two during a mutual occultation, will fade by at least 0.5 magnitude at mid-event.

Under "Event" in the table, satellite 1 is Io, 2 is Europa, 3 is Ganymede, and 4 is Callisto; *o* means *occults,* and *e* means *eclipses*. Notice that some happen much faster than others.

For instance, from 3:30 to 3:33 February 2nd UT (10:30 to 10:33 p.m. February 1st EST), Io goes across Europa. Their combined light dims by 0.5 magnitude at mid-occultation. That much dimming (a 37% loss of light) should be observable if you compare carefully with the other satellites. Drops of 1 magnitude or more will be much plainer.

Note the pairs of events less than an hour apart on the American evenings of February 14th, 21st, 23rd, and 26th, and on the morning of the 18th.

For the complete list of all the events visible from anywhere worldwide, sortable by your location, see **skypub.com/jovianmutualevents**. There you'll also find links to the global campaign to record these events photometrically, in order to refine the slight but interesting and important long-term changes in the Jovian satellites' orbits. ✦

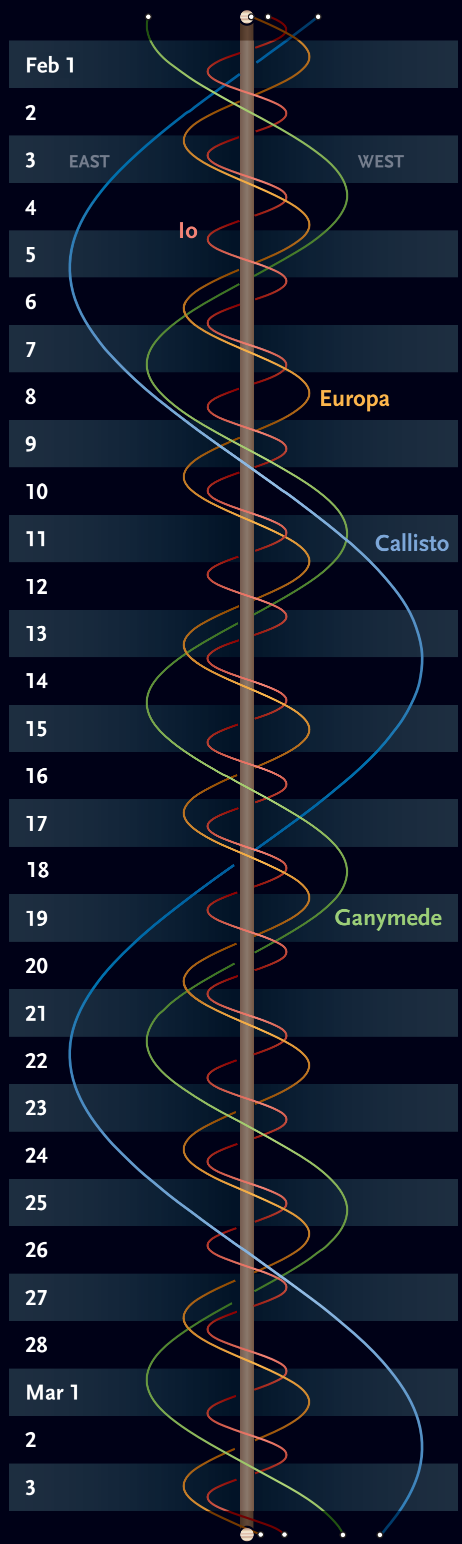
Deep Mutual Events of Jupiter's Moons (for North America)

Date (UT)	Event	Start (UT)	End (UT)	Mag. drop
Feb. 2	1*o*2	3:30	3:33	0.5
2	3*o*2	7:54	8:00	0.5
4	2*e*1	8:44	8:53	0.6
9	1*o*2	5:26	5:30	0.5
9	3*o*2	10:34	10:40	0.5
9	4*e*2	13:34	13:42	0.8
11	2*e*1	11:09	11:17	0.8
11	4*e*3	13:25	13:51	1.4
15	2*o*1	0:00	0:06	0.5
15	2*e*1	0:20	0:28	0.8
18	2*o*1	13:02	13:09	0.5
18	2*e*1	13:31	13:38	0.9
20	1*e*3	0:35	0:43	0.8
22	2*o*1	2:05	2:11	0.6
22	2*e*1	2:41	2:49	0.9
24	3*o*1	1:42	1:48	0.6
24	3*e*1	2:38	2:45	0.6
27	1*e*3	3:31	3:41	1.0
27	4*e*3	4:28	4:39	0.6

Minima of Algol

Jan.	UT	Feb.	UT
2	8:18	2	21:20
5	5:07	5	18:10
8	1:56	8	14:59
10	22:46	11	11:49
13	19:35	14	8:38
16	16:24	17	5:27
19	13:14	20	2:17
22	10:03	22	23:06
25	6:52	25	19:56
28	3:42	28	16:45
31	0:31		

These geocentric predictions are from the heliocentric elements Min. = JD 2452253.559 + 2.867362*E*, where *E* is any integer. Courtesy Gerry Samolyk (AAVSO). For a comparison-star chart and more info, see SkyandTelescope.com/algol.



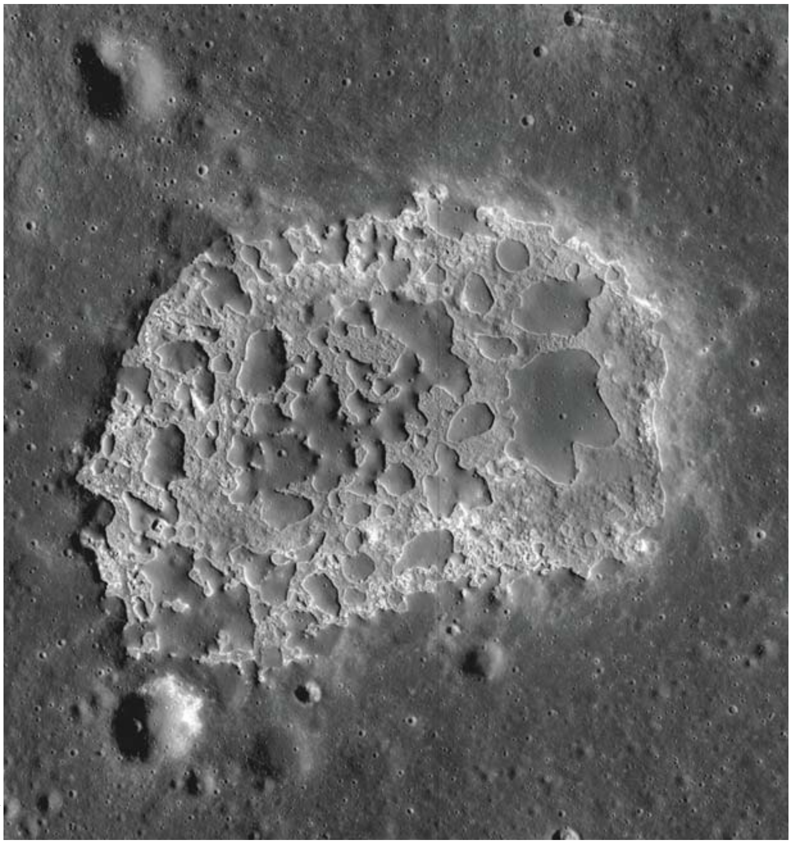
The wavy lines represent Jupiter's four big satellites. The central vertical band is Jupiter itself. Each gray or black horizontal band is one day, from 0^h (upper edge of band) to 24^h UT (GMT). UT dates are at left. Slide a paper's edge down to your date and time, and read across to see the satellites'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

Strange Little IMPs

These lunar mystery features will challenge backyard observers.

It began when keen-eyed analysts of photographs taken by the Apollo 15 astronauts discovered a small, enigmatic landform on the inconspicuous mare patch **Lacus Felicitatis**, amid the jumbled backsides of the **Montes Apenninus**. It was a depression about 3 km (2 miles) wide at the summit of a very gentle dome. Originally the feature was called the "D-Caldera" because of its shape and its interpretation as the collapsed top of a small volcano. Later, it was formally named **Ina** (see *S&T*: Mar. 2012, p. 10). Raising questions about our understanding of the Moon's history, this tiny feature remains a challenge for telescopic imagers and visual observers.

Ina has always been considered an oddity, but now, thanks to the 0.5-meter resolution of the Narrow Angle Camera on the Lunar Reconnaissance Orbiter (LRO), we know that it's not unique. Seventy similar features have been discovered since LRO launched in 2009. All are tiny and occur in mare lavas along a band stretching from near **Aristarchus** in western **Mare Imbrium** almost to **Messier** in **Mare Fecunditatis**. The LRO team calls this new class of lunar landform an Irregular Mare Patch, or IMP. IMPs are places where the original mare surface has been disrupted, leaving small, smooth-surfaced mesas standing ten meters or so above networks of uneven terrain. In some IMPs, the smooth areas display very few impact craters, suggesting they formed within the last few tens of millions of years — long after the Moon was supposed to be dead.



NASA / LRO

INA (D-CALDERA). A scattering of dark hillocks and rounded mesas rise above Ina's bright, blocky floor.

IMPs occur exclusively on mare lavas; their smooth surfaces have been assumed to be very young lava. If that's correct, our understanding of the Moon's thermal history is wrong. Judging from Apollo samples and crater counts, most mare lavas erupted between 3.7 and 2.5 billion years ago, with only small amounts of volcanism continuing until about 1 billion years ago. Building on those conclusions, lunar geologists have constructed thermal models showing that the Moon has largely cooled, except for perhaps a small molten core. Current seismic data also support the idea of a cold mantle. Lunar volcanism is impossible today according to our understanding of the Moon's geology.

The question is: are IMPs volcanic, or were they formed by some other processes that didn't require the melting of the lunar mantle to create magma? We don't know. The LRC team interprets the smooth material as young lava flows because the spectral reflectance and morphology are consistent with nearby lunar lavas. But I'm not sure about that interpretation. Typically, the smooth material consists of many individual patches that aren't connected to each other. This could mean that each patch represents a separate eruption, which would be very unusual indeed.

In general, IMPs lack flow structures characteristic of lavas elsewhere on the Moon. With their generally round outlines and curved edges, the smooth surfaces look like beads of liquid defined by surface tension. In many cases, it seems as if a formerly continuous mare surface dissolved or was somehow broken up from below. I don't know what a non-volcanic physical explanation could be, but if it doesn't require melting of the lunar mantle, it would be consistent with all other information about

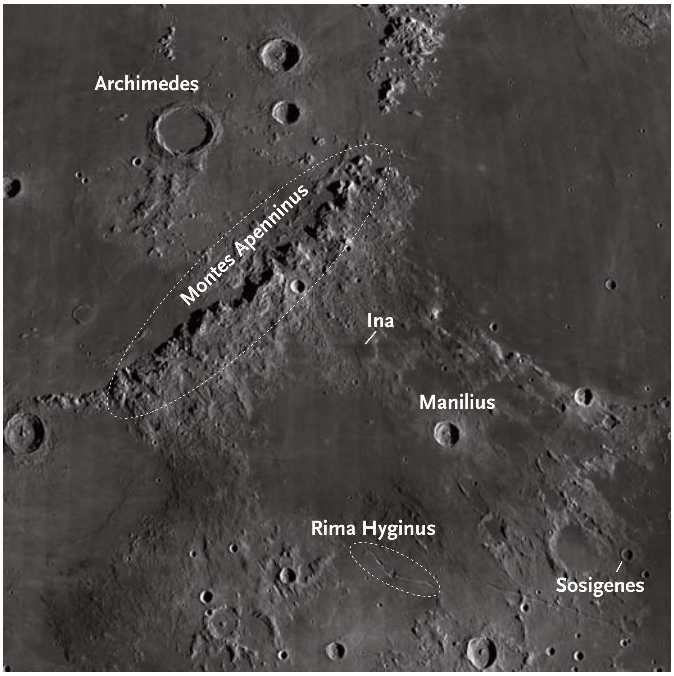
lunar volcanism. In any case, these are mysterious little features that require more study.

Earth-based observers can't detect most IMPs, but persistent telescope users may be able to see a few in addition to the general areas where others occur. The biggest IMP covers the floor of the 9-km crater **Hyginus** on the famous **Rima Hyginus** near the center of the Moon's disk. This crater and its associated rilles have long been recognized as volcanic. The smooth IMP deposit on the crater floor is fairly continuous, interrupted by a few holes. You can just see the flat floor through a medium-sized amateur telescope, but its details are far too small to be detected from Earth.

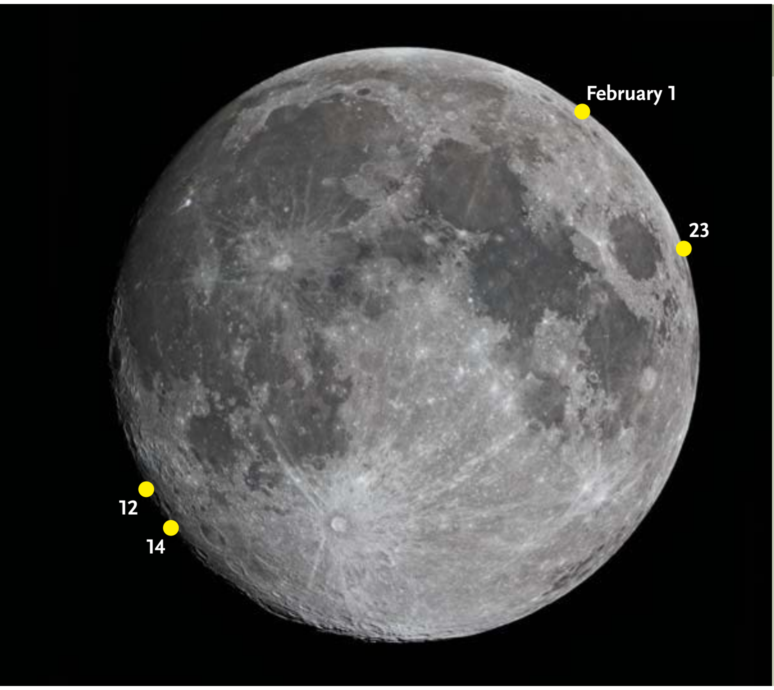
The second-largest IMP is near the crater **Sosigenes** along the western edge of **Mare Tranquillitatis**. This one is a depression that measures 7 × 3 km, with a depth of approximately 300 m. It perpendicularly crosses the just visible **Rimae Sosigenes**. The depression, as well as smaller hollows nearby, came from obvious volcanic collapses in the mare surface, presumably occurring after the eruption of the Tranquillitatis lavas about 3.7 billion years ago.

The final IMP that can just barely be detected from Earth is **Ina**. This little depression is so hard to see that it's #99 on my "Lunar 100" list, which is arranged from easiest to most difficult. Ina's location on a low volcanic dome demonstrates that some IMPs are clearly related to volcanic landforms beyond simple lava flows.

No one yet understands why IMPs are located where they are, nor why more than a dozen cluster together in the northwestern quadrant of Mare Tranquillitatis between the craters **Manners** and **Carrel**. This isn't a remarkable area in any obvious way, yet the greatest concentration of IMPs occurs here, so it must be geologically exceptional. When you observe this section of the first quarter Moon from Earth, perhaps you can imagine what geologic truths you would discover while driving a rover inside one of these mysterious little IMPs. ✦



S&T: SEAN WALKER



S&T: DENNIS DI CICCO

The Moon • February 2015

Phases

FULL MOON
February 3, 23:09 UT

LAST QUARTER
February 12, 3:50 UT

NEW MOON
February 18, 23:47 UT

FIRST QUARTER
February 25, 17:14 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

Apogee	February 6, 6^{h} UT
252,370 miles	diam. 29′ 25″
Perigee	February 19, 7^{h} UT
221,826 miles	diam. 33′ 28″

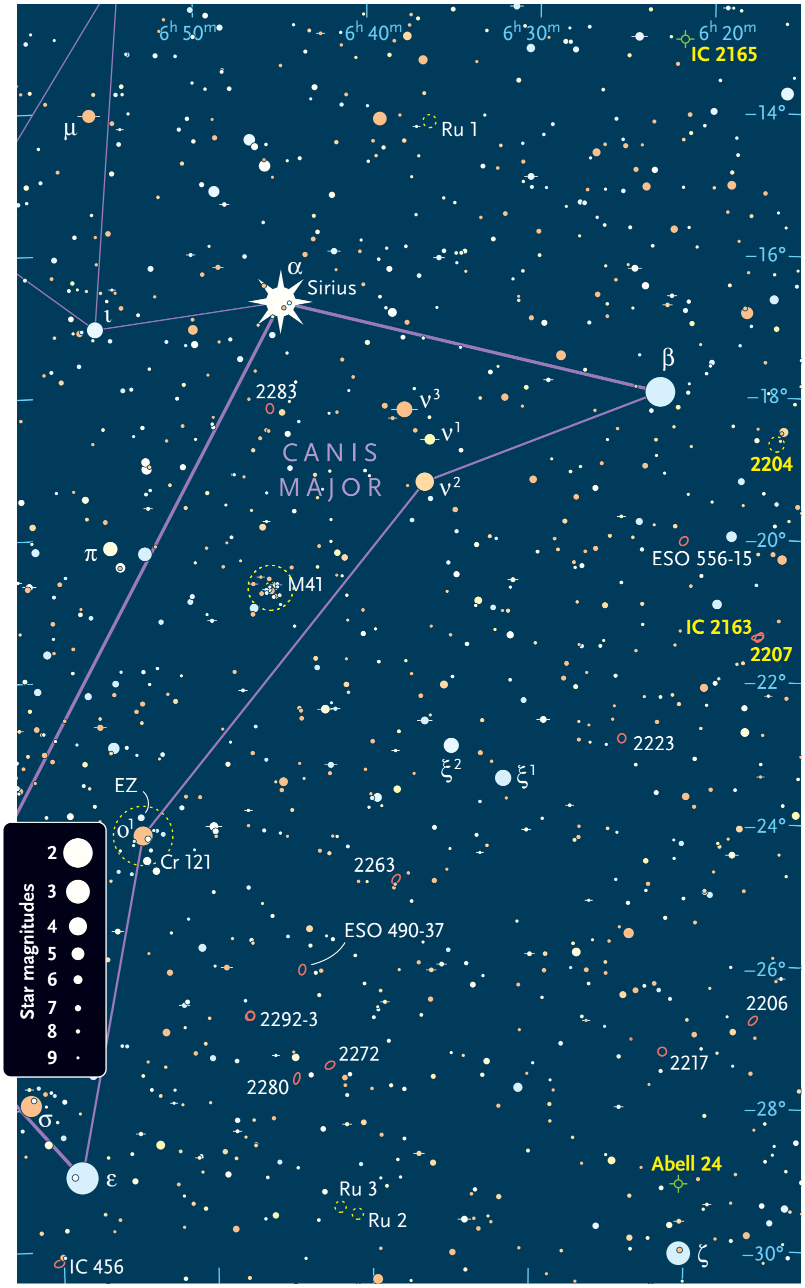
Librations

Compton (crater)	February 1
Nicholson (crater)	February 12
Vallis Bouvard	February 14
Mare Marginis	February 23

Going to the Dogs

Spend an evening out with our canine companions.

When I'm bundled up like the younger brother from the movie *A Christmas Story*, the deep-freeze of a winter's night makes me wonder if Canis Major and Canis Minor are Labrador retrievers. Mine always laid down on spring's last patch of snow and were never fond of summer's heat. I've always loved canines, so going to the dogs sounds pretty good to me, either here on Earth or in the night sky.



Canis Minor gets short shrift when it comes to attention. The Little Dog hosts few bright stars or deep-sky wonders to draw us its way. Yet there are some worthy of homage if you know where to look. One of the most interesting for small-scope enthusiasts is the possible open cluster, the **ADS 6366 Group**, also known as Herschel 1. On December 20, 1827, John Herschel swept up the multiple star at the heart of the group. He noted that it was "in a small cluster of 8 stars," which he sketched.

Despite its early discovery, the ADS 6366 Group was not specifically cataloged until 2003, when Brent A. Archinal and Steven J. Hynes included it in their book, *Star Clusters*. The cluster was brought to the authors' attention by Brian Skiff of Lowell Observatory, who noticed the group observationally as a possible cluster in 1988. More recently, Skiff determined that the group's bluer stars could be related physically.

Through my 130-mm refractor at 23×, I see four stars in a curvy line and a brighter star to the south. Boosting the magnification to 164×, there are six stars in the curve, looking much like the distinctive bend of seagull wings in flight. The bright star below could be the bird's head, and two more stars to its west complete the gull's body. This charming group spans 4.2′, wingtip to wingtip. My 10-inch reflector at 299× reveals a dozen stars gathered into a shape that resembles a double-convex lens.

Sky & Telescope contributing editor Steve Gottlieb introduced me to a curious asterism at the western edge of Canis Minor that he calls the **Triple Trapezoid**, "a small group of 6 stars that essentially forms three nearly isosceles trapezoids!" Two small trapezoids use the same two stars to make their narrow tops, while their four base stars also form a larger trapezoid encompassing all.

The exterior trapezoid is easily visible in my 130-mm scope at 63×, and at 117× one of the interior stars appears. Although the final star is glimpsed at 164×, I need 273× to hold it steadily in view. The Triple Trapezoid is readily seen with my 10-inch scope at 171×, but one of the interior stars is considerably dimmer than the rest. The exterior trapezoid's base is only 1.6′ long.

Canis Minor contains three Abell planetary nebulae,

Objects in Canis Major and Canis Minor

Object	Type	Magnitude(v)	Size/Sep	RA	Dec.
ADS 6366 Group	Possible cluster	7.5	1.9′ × 1.8′	7^h 47.0^m	+00° 01′
Triple Trapezoid	Asterism	—	1.3″	7^h 10.8^m	+06° 00′
Abell 24	Planetary nebula	13.5	2.5′ × 1.1′	7^h 51.6^m	+03° 00′
IC 2165	Planetary nebula	10.6	9″ × 7″	6^h 21.7^m	–12° 59′
NGC 2204	Open cluster	8.6	16′ × 12′	6^h 15.6^m	–18° 40′
NGC 2207 & IC 2163	Galaxy in pair	11	4.3′ × 2.8′	6^h 16.4^m	–21° 22′
Sharpless 2-308	Wolf-Rayet shell	—	41′	6^h 54.4^m	–23° 56′
Douglas's Triangle	Asterism	—	9′	7^h 05.6^m	–26° 13′

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.

which were discovered in the 1950s and 1960s by George O. Abell, Albert G. Wilson, Robert G. Harrington, and Rudolph Minkowski. So far, the only one that I've seen, and I use the term lightly, is **Abell 24**, located 1.2° due north of Zeta (ζ) Canis Minoris.

With my 10-inch reflector at 90×, all I can see of Abell 24 is two little, east-west spots about 2¼′ apart. Neither can be steadily held in view. My 15-inch scope at 79× fares a bit better. The nebula seems large, extremely faint, and possibly annular. Adding a narrowband nebula filter changes the appearance, and I just get a sense of two ghostly patches northeast and southwest of each other. Images of Abell 24 show that each observation has some merit, showing different parts of Abell 24's complex structure.

Let's now segue from the realm of the Little Dog to that of his big brother, starting with a different sort of planetary nebula. Tiny and bright, **IC 2165** resides in the northwestern corner of Canis Major. Although it's a minuscule dot through my 105-mm refractor at 36×, IC 2165 is recognizable as a planetary nebula by its blue-gray color. At 122× it remains bluish and wears a fainter fringe. The nebula holds its color even at 320× in my 10-inch scope and looks slightly oval with a small, somewhat darker center. Descriptions of this planetary seem to vary quite a bit among observers. What do you see?

A tenant of the Astronomical League's Herschel 400 observing program, **NGC 2204** is an open cluster found 1.8° west-southwest of Beta (β) Canis Majoris. Through my 105-mm refractor at 17×, I see a misty glow with a 10th-magnitude star on the west-southwestern edge and a 9th-magnitude star closely guarding the north-northwestern edge. A magnification of 87× pries 18 dim stars (magnitudes 12 and 13) out of the haze. NGC 2204 morphs into a rich group of about 40 faint to extremely faint stars when viewed with my 10-inch scope at 220×.

NGC 2204 is a senior citizen among open clusters, about 2.6 billion years old. Most open clusters don't last more than a few hundred million years before their stars disperse.

We don't often think of Canis Major as a place to observe galaxies, but a classic interacting duo dwells 2.7°

POSS-II / ST SCI / CALTECH / PALOMAR OBSERVATORY

A small group of six stars forms the butterfly-like asterism Triple Trapezoid at the western edge of Canis Minor.

Don Goldman enhanced the faint nebulosity of Sh 2-308 with O III and Hα filters. The orange supergiant, Omicron[1], burns at the right edge of the Wolf-Rayet shell.

POSS-II / ST SCI / CALTECH / PALOMAR OBSERVATORY

Composed of 11th- and 12th-magnitude stars, the modest Douglas's Triangle presents a rewarding challenge for observers.

south of NGC 2204. **NGC 2207** and **IC 2163** are clearly visible as a single oval glow in my 105-mm scope at 28×. At 87× they look quite strange. Their halos are blended together, making a southeast-northwest oval with a bump on its eastern side. The combined glow has a brighter core that seems offset to the west, while careful study shows a very subtle brightening within the bump. A faint star sits just beyond the northwestern tip of the pair, while another hangs 2′ south of the core. With my 10-inch scope at 118×, it's more obvious that there are two galaxies here rather than one peculiar galaxy. NGC 2207, the owner of the more obvious core, is about 2′ long and two-thirds as wide. IC 2163 appears roughly 1½′ long east-west and only half as wide.

Next we'll slide down to the yellow-orange gem Omicron[1] (o^1) Canis Majoris, which is pinned to the edge of the Wolf-Rayet shell **Sharpless 2-308**. This cosmic bubble was created when fierce winds from the intensely hot star, EZ Canis Majoris, seen near the shell's center, plowed into slower-moving material shed earlier in the star's history.

Sh 2-308 looks so delicate in photographs that you might think it's an impossible visual target. But with the help of an O III filter, much of the nebula's patchy rim is visible even in a small scope. When looking for it, think of a more gauzy version of the Veil Nebula in Cygnus.

I enjoy seeing Sh 2-308 with my 105-mm refractor when at the Southern Cross Astronomical Society's Winter Star Party. Compared to the situation at home, the object is higher, the sky is darker, and the observer is warmer. A magnification of 28× works well, showing a smoky ring about 40′ across and 4′ wide at most. The brightest section starts near Omicron[1] and curves up toward the west while passing through the northeastern half of a skinny, 10½′-tall kite made by four fairly bright stars. It fades in the northwest just a bit after skirting outside a 9th-magnitude star, then starts to show up again in the north-northwest. This dimmer section continues to the northeast where it pretty much disappears. It then picks up again in the south-southeast to return full circle to Omicron[1].

For the March 1999 issue of this magazine, Roger Sinnott penned an article called *Hunting for Equilateral Triple Stars*, a pastime quite a few amateur astronomers pursue. In 2012 California amateur Robert J. Douglas wrote to me about a remarkably compact one with sides only 9″ long. **Douglas's Triangle** rests 39′ west-northwest of Delta (δ) Canis Majoris. Look for it 2.8′ north of the western of two golden, 8.8-magnitude stars 2.3′ apart. Through my 10-inch scope at 213×, this petite triangle is a cute sight, with stars of about 11th and 12th magnitude. Give it a try! ✦

Best in Show

Take a tour of four top planetary nebulae visible in the mid-winter sky.

THE FEBRUARY SKY IS HOME to several of the season's top planetary nebulae. These ephemeral celestial gas bubbles are among the most beautiful and fascinating objects in the sky. Many have a high surface brightness, making them excellent targets for small scopes and revealing a wide variety of structural features through larger instruments.

Most planetaries glow brightest in the greenish light of 5007 angstroms, emitted when oxygen is doubly ionized by ultraviolet radiation from the central star. As a result, an O III line filter or a narrow bandpass filter can dramatically increase the contrast, both from light-polluted locations and dark sites. When the seeing permits, remove the filter and pump up the magnification to search for small structural details.

William Herschel picked up **NGC 2392** in a January 1787 sweep, adding it to the list of "nebulous stars" spotted through his 18.7-inch speculum reflector. In a letter read before the Royal Society in 1791, he described it as "a star with a pretty strong milky nebulosity, equally dispersed all around; the star about the 9th magnitude." Through my 80-mm refractor at low power, NGC 2392 shows up as a fuzzy, bloated star about 2.5° southeast of 3.5-magnitude Delta (δ) Geminorum and less than 2′ south of an 8th-magnitude star. When I blink the planetary — quickly moving a filter in and out between the eyepiece and my eye — it flickers in brightness.

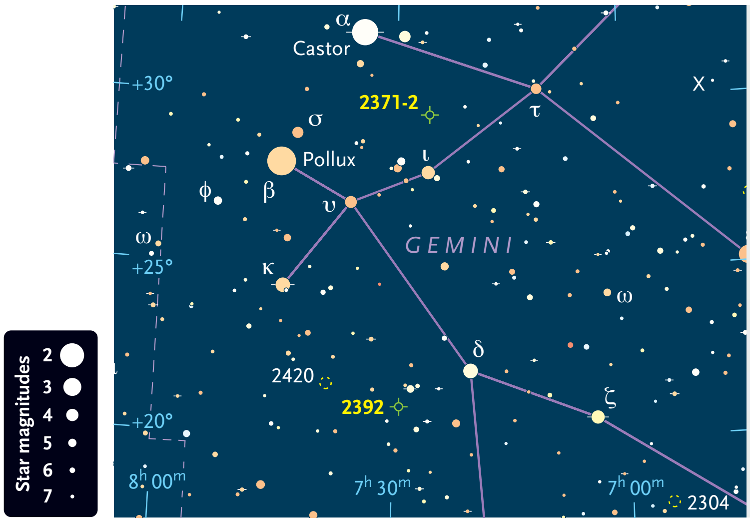
The central star glows bright in the turquoise nebulosity of NGC 2392 in this image taken during the Advanced Observing Program at Kitt Peak Visitor Center.

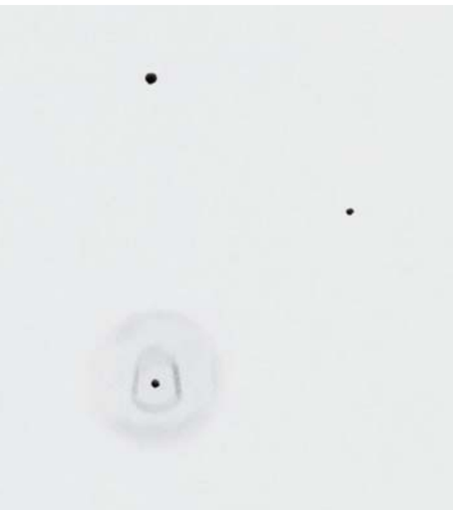
S. KEMPTON & K. BRISTER / A. BLOCK / NOAO / AURA / NS

With my 18-inch, the aqua-colored nebula handles extreme powers beyond 800× in good seeing, and the double-shell structure is gorgeous. The 9th-magnitude central star is surrounded by a fairly narrow annulus, perhaps 20″ in diameter, with a darker central hole. A thin strip of darkness separates the inner portion from a 1′ outer halo (resembling a lion's mane or the hood of a parka), which is uneven in brightness.

At high power in my 24-inch scope, the inner annulus is irregularly shaped and extends slightly farther to the north. This bulge has a slightly darker interior, creating a small pouch within the ring.

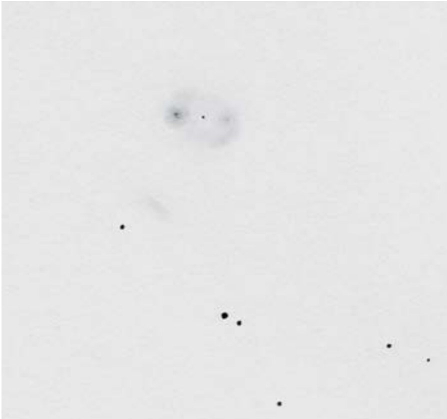
NGC 2371-72 is an excellent example of a bipolar planetary, with two symmetric lobes straddling a hot





German stargazer Uwe Glahn sketched the planetary nebula NGC 2392 as seen with an O III filter at 600× through his 16-inch Dobsonian.

ALL SKETCHES BY UWE GLAHN



Left: **Uwe Glahn sketched NGC 2371-72 as seen through a 16-inch Dobsonian with an ultra-high contrast nebula filter at 280×.**

Right: **Jim Misti's image, captured with a 32-inch Ritchey-Chrétien telescope, reveals the double "polar caps" of NGC 2371-72.**

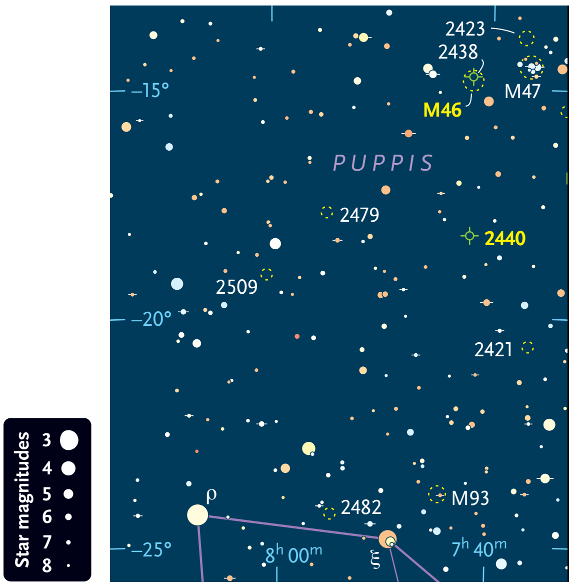
central star. William Herschel discovered this unusual planetary in 1785 with his 18.7-inch reflector. In his first *Catalogue of One Thousand New Nebulae and Clusters of Stars*, he reported it as a double nebula, resulting in two NGC designations.

A 4-inch scope will show a small, hazy patch 3° southwest of Castor, and an 8-inch will resolve Herschel's twin bubbles. In my 18-inch, the bright lobes slant southwest to northeast and span 15″ to 20″ in diameter. At 380× unfiltered, the southwest lobe appears brighter, the 15th-magnitude central star glowing dimly at the midpoint. A weak bridge of nebulosity connects the two lobes, and an ethereal halo encases the structure. In my 24-inch, two detached ghostly "polar caps," or *ansae*, can be glimpsed 1′ northwest and southeast of the central star.

Four years ago, I viewed this planetary through Jimi

Left: **Uwe Glahn used an O III filter to draw out the features of NGC 2440 as seen through his 16-inch Dobsonian at 400X.**

Below: **Hubble's Wide Field Planetary Camera brings the wings of NGC 2440 to full prominence.**



Lowrey's 48-inch super-sized Dobsonian. At 488×, the nodules varied in surface brightness and shape; both were adorned with filamentary wisps, as if they were revolving about the central star. The outer symmetrical caps each extended 40″ × 10″ and floated like two graceful wings around the central orb.

NGC 2440, located 3.4° due south of M46 in Puppis, has an unusually complex morphology. When William Herschel reported his March 1790 discovery, he described it as a "beautiful planetary nebula, of a considerable degree of brightness," but noted that it was "not very well defined." Deep images reveal an irregular, bow-tie shape with central condensations, radial filaments, gas blobs, and a second pair of butterfly wings. The central white dwarf radiates mostly in the ultraviolet (only 18th-magnitude visually) and is one of the hottest known stars, with a surface temperature of 200,000°C (360,032°F).

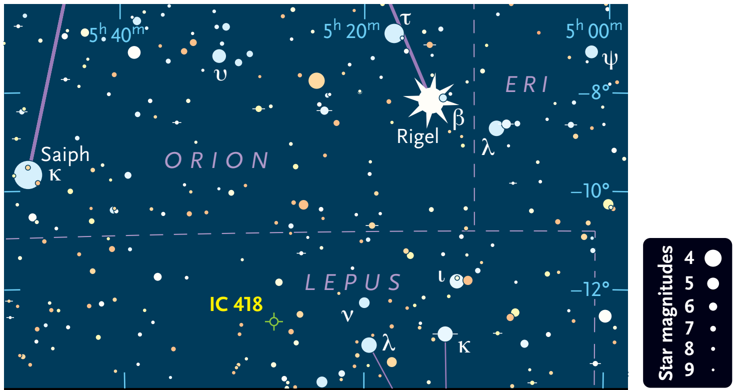
A 6-inch scope at 75× displays a small, hazy oval, 20″ to 25″ in diameter, with a relatively high surface brightness and a slight cyan tint. High power will resolve two compact knots near the center. In my 18-inch at 380×, the bright, boxy inner region contains two condensations. A fainter halo extends 2:1 southwest to northeast, though it's weaker on the southwest end, forming a cup-shaped dark notch. Two outer wings, mimicking spiral arms in a galaxy, extend northwest and southeast.

Through Lowrey's 48-incher, the irregularly-shaped central region harbors three intense knots; the ragged periphery appears tattered, as if the object had exploded. A prominent wing attached on the northwest edge swings clockwise to the west and a large, outer loop spans the entire eastern end.

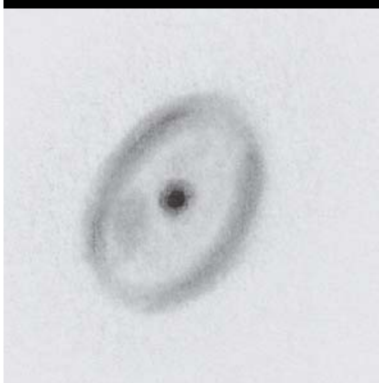
According to Harvard College Observatory records, **IC 418**, also known as the "Spirograph Nebula," was spotted first by Williamina Fleming while she was working as an assistant to Edward Pickering, then director of the observatory. IC 418 is a young, carbon-rich planetary in Lepus that flaunts an interlaced network of filaments in the Hubble Space Telescope image. To locate IC 418, drop 4° south of Rigel to a trapezoid-shaped group of 4th- and 5th-magnitude stars. Our target is 2° east-northeast of Lambda (λ) Leporis, the southeast star in this group.

A 6-inch scope at 100× will resolve a tiny disc surrounding a prominent 10th-magnitue central star. IC 418 has relatively strong H-beta emission, so try blinking with an H-beta filter — it will mute the bright central star and enhance the halo.

Although diminutive in size, IC 418 rates high on my list of favorite planetaries because of its very unusual reddish halo in larger scopes. Observing with my 18-inch at 150×, the bright central star is centered in a 10″ halo with a rosy hue at its fringe. When I bump the magnification up to 565×, IC 418 appears annular with a slightly darker center and brighter rim, but the color is suppressed. ✦



This false-color image, composed from a series of photographs taken by Hubble's Wide Field Planetary Camera, displays the ionized oxygen as a blue ring around the central star.



Glahn observed IC 418 without a filter during a visit to Roque de los Muchachos, on the island of La Palma, Spain. This sketch shows his view at 900× through a 20-inch reflector.

Winter Planetary Nebulae

Object	Cons.	Mag. (v)	Size	RA	Dec.
NGC 2392	Gem	9.1	47″ × 43″	7^h 29.2^m	+20° 55′
NGC 2371-72	Gem	11.2	74″ × 54″	7^h 25.6^m	+29° 29′
NGC 2440	Pup	9.4	74″ × 42″	7^h 41.9^m	–18° 13′
IC 418	Lep	9.3	14″ × 11″	5^h 27.5^m	–12° 42′

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

*Contributing editor **Steve Gottlieb** welcomes questions and comments at steve_gottlieb@comcast.net.*

Aligning Go To Mounts

Get the most out of your computerized scope with these helpful tips.

Rod Mollise When I bought my first telescope that automatically pointed at objects with the push of a button a decade ago, I was embarrassed to admit it to my fellow amateur astronomers. In my mind, that wasn't the way real astronomers worked; we squinted through finder scopes and star-hopped to targets with the aid of star charts.

It didn't take long for me to get over my embarrassment. After 35 years of hunting, I realized I was more interested in looking *at* objects than looking *for* them. Today, the majority of amateur astronomers agree, and most telescopes are sold with Go To mounts.

You can see plenty of objects with a Go To telescope once it's aligned. The problem is getting it aligned properly. Before your scope can work its magic, its computer has to know where it is and what time it is, and it has to build a model of the sky. With at least a dozen competing Go To systems on the market, I won't give detailed ins and outs of

Whether you're out for a casual look at the sky or setting up for a busy night of astrophotography, aligning your Go To telescope is the most critical step to enjoying a night under the stars. Follow these tips to avoid a frustrating first night out with your equipment.

UNLESS OTHERWISE NOTED, ALL PHOTOS ARE COURTESY THE AUTHOR.

each. All are similar enough that what follows should, with the aid of your scope's manual, get you going.

Before you start pushing the buttons of the scope's hand paddle, let's talk about what doesn't matter in Go To alignment. Some new owners obsess over leveling the tripod, going so far as to carry around a bubble level. The truth is, precise leveling doesn't matter much for many Go To mounts. A precisely leveled mount might slew a little closer to initial alignment stars, but final pointing accuracy won't be affected. What's important for good Go To performance is that the telescope's position matches its model of the sky using the alignment stars you center. "Level by eye" is good enough.

Go To Alignment

The first thing most Go To controllers require is that you input your local time, date, and location. Without that, the telescope won't know which alignment stars are above the horizon, or where everything else is in the sky. If your mount has a built-in GPS receiver, it will input all this information for you. If not, then the time shown on your watch, plus the latitude and longitude coordinates from a map, are good enough. In addition to entering time in 12- or 24-hour format, you must set the correct time zone. Most controllers will allow you to enter that as EST (for Eastern Standard Time), CST, etc., though some require hours east or west of the Greenwich Meridian. For example, EST is normally considered "-5," five hours west of Greenwich.

Most people run into a problem with time in the U.S. during daylight saving time (DST). If in effect, choose "yes," or "on." If you don't, your scope will point 15° away from its alignment stars. Remember "spring forward, fall back" — DST moves the clock an hour forward in the

Most Go To telescopes, like this Meade ETX 125PE, require you to begin with the mount in its "home" position. Usually that requires pointing the telescope due north and leveling the tube.

Hand paddles of three popular Go To mounts by Celestron, Meade, and Orion. Although they arrange the command keys differently, they all contain the same basic components: an LCD display, command buttons, directional keys, and a numeric keypad.

spring and back in the fall. Not all locations in the U.S. use DST, so be sure to check your location when traveling far to observe.

Next up is location, usually represented in latitude and longitude coordinates. Some Go To users have it easy; their telescopes allow them to select the name of the nearest city. But how close does a city have to be to be accurate? Within about 60 miles is fine. If you have to enter latitude and longitude, make sure you punch them in correctly. Enter both figures in degrees and minutes. Some controllers allow you to enter seconds or decimal minutes, but that kind of precision isn't required, so you can just enter 00 at the end. What's important is that you get the proper designations of latitude and longitude correct. If you're in the Northern Hemisphere, enter an N or + before the latitude coordinates, and if you're in the

Before you can begin slewing to your alignment stars, most Go To mounts require you to input important information about your location, including the time, your time zone, daylight saving (if applicable), and your latitude and longitude coordinates. Each Go To system is slightly different.

Western Hemisphere, enter a W or – before the longitude coordinates.

After data entry, most controllers will ask if you want to begin alignment. Before you do, make sure the mount's clutches are locked. If you don't, the drive motors will spin, but the telescope won't move anywhere. Also, some mounts require that you place the scope in a home position before alignment. Consult the manual for the particulars, but this often means just pointing the telescope due north.

Now you can start the alignment procedure. Many different alignment systems are in use today, though most involve centering two or three stars. The difference lies in how those stars are centered in the telescope's eyepiece. Celestron's SkyAlign system for its alt-azimuth-mounted telescopes, for example, has you point at three bright stars or planets manually with the hand paddle's directional buttons. You don't even have to know the names of the objects. Meade's Easy Align chooses two stars for you, slews the telescope close to them, and then requires you to center the stars in the eyepiece (also using the hand paddle's directional keys). Both of these systems work well if you center the correct stars carefully.

Once you begin the alignment process, follow the prompts on the controller to start the telescope slewing to its first alignment star. When the telescope stops, center the alignment star in the finder and in the main scope eyepiece using the hand paddle's directional keys. How you do that is critically important — it matters more than anything else for a good alignment. The difficulty for beginners is knowing which star to center. Even if the telescope slews automatically to alignment stars, you'll need some way to identify them, since they will rarely be centered in the finder when the telescope stops.

Most Go To computers list alignment stars by their proper names rather than by the more common Bayer designations. Try to have a star chart handy so you'll quickly know which star your scope is looking for.

Unfortunately, most Go To systems display the proper names of stars rather than their easier-to-remember Bayer designations. Even after almost 50 years as an amateur astronomer, I have a difficult time remembering which star "Mesarthim" (γ Arietis) is. Keep a simple star chart at hand that labels stars with their proper names. Don't know the sky well enough for that to be much help? You'll usually be okay if you assume the brightest star closest to the center of the finder's field is your target. Basic knowledge of the stars is a big help, however. Most controllers will often give an "alignment successful" message once completed, even if you centered the wrong stars. Pointing accuracy will be lousy, though, so you'll quickly realize you need to re-do the alignment routine.

Not only do you have to pick the correct stars, you must center them precisely. Use a medium power eyepiece, at least 100x, and for best results, one with a crosshair reticle. If you don't have a crosshair reticle eyepiece, defocus the alignment star until it nearly fills the eyepiece field, and you'll be able to center it easily.

Some beginners get frustrated when their telescope stops a long way from alignment stars. Have patience; often the first alignment star will be 5° or more from the finder's center. The second should be closer, but even then it might not be visible in the telescope's eyepiece. Just center the alignment stars and keep on trucking.

If you do everything correctly, you should get an "align successful" message on the hand paddle display after centering the last star. But when it comes to Go To telescopes, my motto is "trust but verify." Before you pack away the crosshair eyepiece, slew the scope to a bright object far from your final alignment star as a test. Is it in the eyepiece at roughly 100×? If not, consult the tips section at the end of this article.

Some of the newest Go To mounts include GPS or other features that can help automatically align your mount. Celestron's StarSense accessory uses a small camera to photograph a star field and quickly match the image to its internal database to accurately determine where the scope is pointing.

Equatorial Mounts

German equatorial mounts and other equatorial mount designs are popular with amateurs, especially those interested in astrophotography. In most ways the alignment process is the same for them as it is for alt-azimuth mounts. You enter the initial location information the same way, and the same considerations apply. But there is one big difference. Before you can do a Go To alignment, you must do a polar alignment.

Polar alignment is the process of pointing an equatorial mount's right ascension (east-west) axis at the celestial pole, which in the Northern Hemisphere is roughly ½° from the bright star Polaris, and a little more than 1° from the star Sigma Octantis in the Southern Hemisphere. So how close do you have to be pointed to the celestial pole for reliable Go To performance? That depends on the particular brand of your mount.

Poor polar alignment does not affect the Go To accuracy of some equatorial mounts. One night, a fellow club member of mine mistakenly polar aligned his equatorial mount on Kochab instead of Polaris, and yet his Go To pointing was great. Tracking was horrible, of course, since with an equatorial mount, that depends on the quality of polar alignment. But some equatorial mounts demand at least a rough alignment for good pointing accuracy. How do you know whether your mount's Go To accuracy is dependent on polar alignment? A tip-off is if the computer's Go To alignment routine requires only one or two alignment stars. Several additional alignment targets are often required to compensate for poor polar alignment.

So what should you do if your mount needs an accurate polar alignment for reliable Go To pointing? If it has a built-in polar-alignment bore scope, use it. If not, there are various easy methods of achieving a close enough polar alignment for good Go To performance. One easy method known as "Kochab's Clock" is useful in the Northern Hemisphere, and you can find instructions online. Some of today's mounts have routines built into their controllers that will allow you to easily polar align by centering stars using the mount's altitude (latitude) and azimuth adjustment knobs.

While there are many excellent features in some of the latest Go To mounts, none will automatically polar align an equatorial mount. German equatorial mounts such as the Celestron VX shown above require you to point the polar axis at Polaris using its built-in polar finder scope before continuing its Go To alignment procedures.

S&T: SEAN WALKER

Far left: **One thing essential to an enjoyable night of observing with a Go To system is adequate power. Make sure your batteries are fully charged, or you have access to an AC outlet so your mount doesn't start losing its way as its batteries begin to fail.**

Left: **Be sure to clean any electrical connections regularly; dirt, moisture, or corrosion can often lead to erratic mount behavior.**

Once you've completed your Go To alignment, you should have smooth sailing. The telescope should slew to thousands and thousands of objects with a few button presses. Well, it *should*, anyway. If your mount isn't landing objects in the eyepiece, don't panic — the cause is usually easy to diagnose and fix.

Tips and Troubleshooting

• Alignment Star Centering

In addition to a star chart with star names, the biggest help I've found for centering alignment stars is a reflex finder such as the reliable Telrad. A correctly oriented, unmagnified view makes it easier for me to be sure I'm pointed at the proper star.

• All Alignment Stars Are not Equal

Go To controllers are usually good at choosing alignment stars, but not always. One night my telescope chose Antares, which was low on the horizon. Go To pointing was way off until I shut the scope down, restarted it, and picked an alignment star higher in the sky. Avoid alignment stars lower than about 20° or near the zenith. If your controller chooses one, reject it and have it pick another (see your mount's manual).

Adding a unit-power reflex finder such as the Rigel QuickFinder shown above can speed up your Go To alignment routine.

• Adequate Power

Computerized mounts draw plenty of power, as I discovered on my first night with a new Go To system. During alignment, the telescope slewed toward the first alignment star, passed it, and kept on going until I pulled the plug. Was my brand-new mount broken? No. The problem was my battery wasn't up to the task. Always use a fully charged 12-volt battery or an AC power supply recommended by the telescope manufacturer. Try to avoid using C- or D-cell batteries if possible.

• Check your Connections

A frequent cause of erratic mount behavior is loose connections. Check the power cable, the hand paddle cable, and motor cables. If you keep your mount outside in an observatory, expect to clean connector pins once in a while. A few cotton swabs and some denatured alcohol will usually take care of the problem.

• Computer Gremlins

A Go To telescope's hand paddle is a computer, and like all computers it can get confused; its onboard program can become "corrupt." If your mount that was formerly well-behaved begins missing Go To targets, try resetting the controller. Most have the menu option "reset to factory defaults," which reinitializes the computer. If you use the option, don't forget to re-enter basic information like time, date, and location.

• Precise Go To

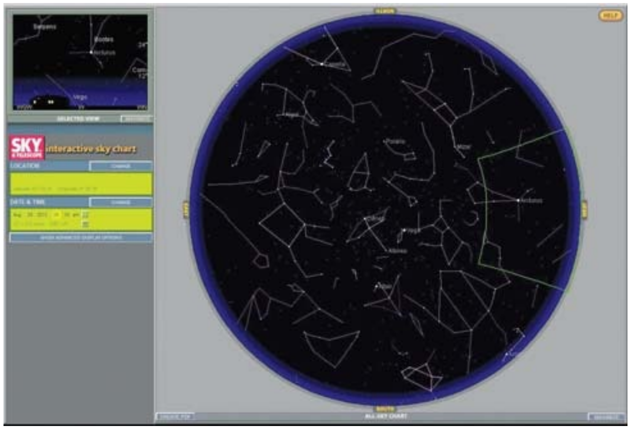
Certain objects will cause Go To problems for most mounts no matter how good their alignment, usually ones close to the horizon or zenith. If you're having problems in a particular area of the sky, try the "precise Go To" option featured in most Go To controllers. When you select an object with precise Go To activated, the scope will first slew to a bright star near the target. Center this star using the hand paddle directional keys, press Enter, and the scope will continue on to the chosen object.

• Additional Sync Points

If your mount doesn't have a "precise Go To" function, or you don't like centering a star before each object, the "sync" function featured in most controllers can improve pointing accuracy. When you have a star or other object centered, press the hand paddle's sync button, and the computer will remap the sky, usually making slews more accurate. Unfortunately, if you move the telescope far from the sync point, slews will be off again and you may need to sync on another star.

• Strange Behavior

Go To mounts sometimes do things that seem counter-intuitive but that actually serve an important purpose. If a slew requires crossing the Meridian, an imaginary north-south line in the sky, an equatorial mount will often take what seems like the long away around in order to position itself properly for tracking. Similarly, an alt-azimuth mount may go the wrong way to avoid tugging out the hand paddle or motor cables.



When setting up your Go To telescope for the first time, it's best to walk through the alignment procedure at home. Use a planisphere to ensure your telescope is slewing in the proper directions before heading out under the stars.

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Fork-mounted telescopes only require polar alignment if you intend to photograph the night sky. Consult your telescope's manual for its polar alignment instructions, or use one of the common methods to quickly polar align. One easy routine known as Kochab's Clock can be found at www.arksky.org/Kochab.htm.

• Get Comfortable

What's the worst possible place to learn to use a Go To mount? On a dark observing field far from home. Before taking a new mount outdoors, I do a simulated alignment in my living room. A computer planetarium program, *Sky & Telescope*'s Interactive Sky Chart, or a simple planisphere set for the current date and time will tell me if the scope has pointed in approximately the correct directions of alignment stars. I accept those stars and, with the aid of the planisphere, check to see if the scope points in the area of an object when I initialize a slew.

Learning Go To technology takes a bit of work. New technologies such as Celestron's SkySense or Meade's LightSwitch will automatically align your mount without intervention (though nothing will automatically polar align your mount). These technologies are just coming to market, however, and even when they become common, the tips discussed here will keep you out of Go To trouble.

Once you master your mount, the rewards are great. A few years ago, I set out on a big observing project, observing all of the nearly 2,500 Herschel deep-sky objects. Given my weather, I wouldn't have lived long enough to see them all if I'd had to rely on star-hopping. Go To telescopes enabled me to see every Herschel object in just three years, and I had a ball doing it, spending my time admiring thousands of wonders instead of wondering where they were. ✦

S&T *contributing editor* ***Rod Mollise*** *writes an astronomical blog at* **www.uncle-rods.blogspot.com**.

A Simple Homebuilt Focuser

This inexpensive focuser doesn't require a machine shop to build.

I HIGHLIGHTED Jerry Oltion's 12.5-inch binocular telescope in the January issue (p. 68). That scope has many interesting and novel features, but one I feel merits particular attention is its superb focuser. As Jerry notes, "when you make two of everything, you favor designs that are cheap and simple!" All told, the parts for his focuser add up to less than $10. That's the "cheap" part of the equation, but what about "simple"?

Jerry's focuser is essentially a Crayford design, which means it doesn't utilize the usual rack-and-pinion mechanism found in many commercial units. In a Crayford focuser, a rotating shaft presses against the focusing barrel, which moves back and forth against a set of bearings. In Jerry's version, the mechanism is contained in a $3\frac{5}{8}$-inch-square, $1\frac{3}{4}$-inch-deep box made from $\frac{1}{2}$-inch plywood. As the picture on the facing page shows, the four bearing assemblies each consist of a 1-inch long piece of 1/8-inch brass rod, a small bearing, and two nylon spacers. "Any small bearings will do," Jerry says. "I got mine from Surplus Shed (**www.surplusshed.com**), but model helicopters and model cars often have bearings the right size, too." Add a 0.1-inch-diameter knitting needle for the focuser shaft, a length of 2-inch inside-diameter PVC tubing, a couple of knobs, and a nylon screw, and you have the entire parts list.

The first step in construction is to hollow out cavities in two of the wood body panels to accommodate the bearing assemblies. A router works well for this task, or you can improvise as Jerry did. "I used a drill bit that I snapped off near the bottom as a makeshift router bit, and put that in my drill press," he explained. "I lowered the bit and pushed the wood around to carve out the bearing cavity and the groove for the axle."

Accurately positioning the bearings is the only crucial part of construction. You must ensure that each bearing assembly is recessed by an equal amount. As Jerry says, "for the drawtube to sit square, you have to make sure all the bearings are the same height." And if you're going to err, do it on the side of going too deep; you can fine-tune the bearing axle height later using shims.

Once the box is assembled, the next step is to drill a hole for the knitting-needle drive shaft. "It's better to make the shaft too tight against the drawtube than too loose, because you can always widen the hole outward if you need to," Jerry advises. Ideally, when the focuser is assembled, the shaft is nice and snug against the draw

JERRY OLTION (2)

Jerry Oltion's binocular telescope requires two of just about everything, which pushed him to design components that are both inexpensive and easy to make. *Left:* His Crayford-type focuser is one of the scope's most innovative features. *Right:* The focuser partly disassembled. The nylon screw at the bottom of the housing is used to increase friction between the focuser shaft (a knitting needle) and the draw tube (a length of 2-inch inside-diameter PVC tubing).

JERRY OLTION

The main elements of Oltion's focuser are shown here; the only component missing is the PVC draw tube. All the parts can be sourced at a well-stocked hobby shop or hardware store.

tube, but not so tight that it bends. The nylon tension-adjustment screw on the bottom of the housing allows you to fine-tune the friction according to your needs.

Finally, it's a good idea to include a pair of safety stops at each end of the focuser draw tube to prevent it from falling into your scope, or extending out too far and crashing to the ground (taking an expensive eyepiece along with it). "I used small pan-head screws spaced to hit the knitting needle before the end of the draw tube travels too far past the bearings," Jerry says.

Of course, a focuser that's inexpensive and simple to make isn't worth much if it doesn't work well. The beauty of this design is that good results are practically guaranteed if you take the time to position the bearings with care. "In use, the focusing action is a little finer than most single-speed units, and a little coarser than the slow speed of most two-speed focusers," Jerry reports. "Overall, it's smooth, solid, and makes finding the focus sweet spot easy. After a while you'll even forget it's homemade."

Readers wishing to learn more about Jerry's Crayford focuser can visit his web site at **www.sff.net/people/j.oltion/boxycrayfords.htm**. ✦

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*Contributing editor **Gary Seronik** is an experienced telescope maker and observer. You can contact him via his website, **www.garyseronik.com**.*

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Art of the Universe

Cosmigraphics: Picturing Space Through Time

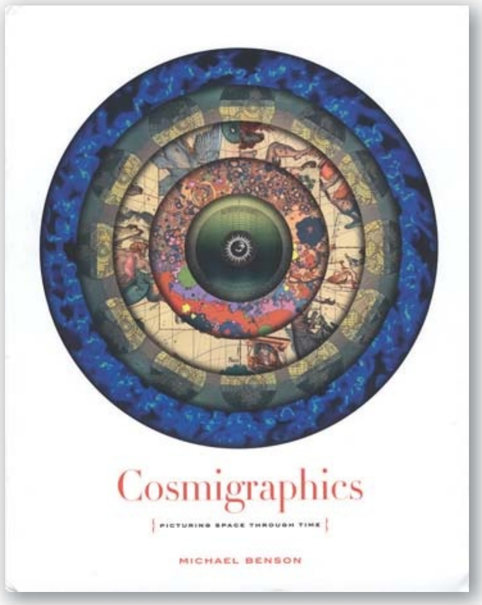
Michael Benson
Abrams, 2014
320 pages, ISBN 978-1-4197-1387-3, $50.00, hardcover.

WE AMATEUR ASTRONOMERS spend a lot of time explaining the allure of our hobby to non-observers. How many of us have settled friends (or strangers) in front of the scope, waiting for that *Aha!* moment when they finally understand why we do what we do? A view of Saturn's rings or Jupiter's moons can make the argument for us. But what if we don't have recourse to that immediate viewing experience? How do we explain our passion to others, particularly on a frigid February night?

Michael Benson's *Cosmigraphics: Picturing Space Through Time* is a meditation on this problem and more. In a lavishly illustrated, beautifully bound volume, Benson presents a selection of images — some produced during the practice of astronomy, others as descriptions of that practice — extracted from some 4,000 years of material documenting humans' fascination with the sky. The images trace what Benson sees as an evolution of thought, the incremental development of an awareness and understanding of our place in the universe.

Cosmigraphics is arranged thematically, opening with a reflection on origins, expanding to consider the solar system, galaxy, and cosmos, and closing with a section on atmospheric phenomena and auroras. Each chapter follows a loose chronology, with images slightly shuffled to show a development of knowledge and method of representation. Brief essays and captions flesh out the book.

There is much here to inspire amateur astronomers. The Moon is only occasionally my observing target, but after sifting through the chapter on the topic, I began to question my priorities. Benson maps the arc from "discovery" to "convention" in lunar studies, as astronomers and artists chose between tradition (producing an image of the Moon with north at the top of the page, as in a terrestrial map) and veracity (inverting the Moon to duplicate the view in the eyepiece). Anyone who has spent time sketching at the eyepiece will appreciate the challenges worked through by lunar cartographers.



In fact, this book works well as a history of cartography, a discipline long allied with astronomy. I expected to see included topographic maps of Mars and other planets, but was delighted to find maps of the Mississippi River meander belt as well. Readers will enjoy visiting with old friends — a selection from Galileo's *Sidereus nuncius*, for instance — but also savor the heady rush produced by an encounter with the unfamiliar.

While this is largely a survey of historical material, Benson has pushed most chapters to the present tense (and even into the future with predictive diagrams for the 2117 Transit of Venus). However you choose to engage with the sky, something here will catch your eye. Benson has given readers much to consider with his curatorial choices, managing to share the workings — as well as the wonder — of the universe. ✦

S&T *Observing Editor* ***S. N. Johnson-Roehr*** *loves reading even more than she loves astronomy.*

Astrophotography Today

Advanced imagers define the trends of the 21st century.

The excellent sensitivity of modern DSLR cameras has given rise to a new breed of astro imaging: nightscape photography. Pioneer Babak Tafreshi captured this view above São Miguel Island, Portugal, with a modified Canon EOS 7D Mark II DLSR.

Sean Walker

There's no question these days that digital media have revolutionized amateur astronomy and, in particular, astrophotography. From the super-sensitivity of CCD and CMOS detectors in our cameras, through inexpensive memory cards, to computer processing suites that completely eliminate the toxic chemicals of the darkroom, never before has the pursuit of astrophotography been so inviting to the amateur.

With all these new tools, imagers have been making leaps and bounds in their ability to reveal new details of the cosmos surrounding us, particularly when looking towards the nearby galactic neighborhood. So what are the hottest trends in the imaging community? Let's take a look.

Nightscapes: Land and Sky Intertwined

A decade ago, DSLR camera technology was just beginning to reach the level of sensitivity needed to take quality images of the night sky. While some pioneering astro-imagers were beginning to shoot pleasing deep-sky images with DSLR cameras attached to their telescopes, a different breed of astrophotographer was emerging: the nightscape photographer, one who doesn't use a telescope at all.

Nightscape photographers such as stalwarts Babak Tafreshi (**www.dreamview.net**) and Wally Pacholka (**www.astropics.com**) travel the world to capture breathtaking views of picturesque locations surmounted by the Milky Way above using DSLR cameras and lenses. Their work is meant to connect the casual viewer with the beauty of the sky that surrounds us all. Tafreshi formed the international photography group The World At Night, or TWAN (**www.twanight.org**), which is dedicated to his philosophy that the sky is free for us all to enjoy.

Their craft has improved with the increasing sensitivity of the latest DSLR cameras, particularly ones modified to increase their sensitivity to hydrogen-alpha (Hα) light. The popularity of nightscape photography has led to a burgeoning industry of small tracking mounts specifically designed for DSLR cameras and lenses.

Deep and Wide

Nightscape photographers aren't the only ones shooting wide-angle panoramas of the night sky. A related pursuit is the growing popularity of assembling sprawling mosaics of wide areas in the sky, up to and including deep photographic maps of the entire sky. Trailblazer Nick Risinger (**http://skysurvey.org**) currently holds the mantle for having imaged the entire sky from both hemispheres with a custom rig of FLI cameras attached to Zeiss 85-mm lenses. With this outfit, he's produced a seamless mosaic of the entire sky in visible light down to at least 14th magnitude. You might even have a version of it in your pocket — it's used as the basis for his company Fifth Star Labs' planetarium app *Sky Guide*.

Going much deeper, photographer Rogelio Bernal Andreo (**www.deepskycolors.com**) has made a name by shooting extremely deep panoramas of dusty regions within the Milky Way, often revealing faint nebulosity practically unknown in the amateur community. Andreo combines his mastery of image processing with his love of expansive vistas to produce panoramas of entire constellations, nebulous regions, and galaxy groupings using the popular Takahashi FSQ-106EDX astrograph and SBIG STL-11000 CCD cameras.

Other imagers, including former *S&T* senior editor Dennis di Cicco, take the panoramic-mosaic to another level. By concentrating his efforts on a particular section of the Milky Way throughout an entire season, di Cicco has mapped hydrogen-alpha nebulosity to an extent only seen previously in professional surveys at radio wavelengths.

Narrowband Nebulae

Moving a bit farther out in the galaxy, narrowband imaging at multiple wavelengths has become a staple of

In this colorful rendition of the "Mexico" portion of NGC 7000, Ken Crawford combines narrowband and broadband images to achieve a unique, heightened color palette.

deep-sky imagers, but with a distinct twist. High-end imager Ken Crawford (**www.imagingdeepsky.com**) of Camino, California, produces ultra-deep and colorful photos of nebulosity within the Milky Way by imaging through narrowband and color filters. Crawford blends deep images taken through specialized hydrogen-alpha, sulfur, and oxygen filters, which highlight the chemical make-up of star-forming regions. When combined as red, green, and blue in a color image, the result is an attractive representative-color image that helps scientists visualize the distribution of these specific elements in our galaxy.

The planetary photography by Damian Peach may seem like magic to some, but meticulous attention to detail and a mastery of his chosen equipment are what have kept Peach at the forefront of planetary imaging.

From the mountaintop observatory at the Mount Lemmon SkyCenter in Arizona, Adam Block produces a steady stream of dazzling deep-sky imagery that rivals that of the pros.

Narrowband images make colorful nebulae images but have the side effect of giving odd hues to stars. So Crawford also blends in broadband red, green, and blue data to recover their natural palette, resulting in mesmerizing scenes of nebulosity that benefit from the best of both tricolor techniques.

Crawford isn't the only practitioner of narrowband/broadband technique. Another imager from California, Don Goldman (**www.astrodonimaging.com**) uses it to produce the deepest amateur photos of extremely faint and obscure planetary nebulae with a remotely controlled telescope in Australia. Many of Goldman's targets can only be found on professional surveys of the sky, bearing catchy names such as KjPn 8 or LoTr 5.

Imaging for Science

The exceedingly deep astrophotography produced by amateurs today has even piqued the interest of professional researchers. One night while browsing online through amateur astrophotos, astronomer David Martínez-Delgado of the Max Planck Institute happened upon an exceedingly deep image of spiral galaxy NGC 5907 captured by R. Jay GaBany (**www.cosmotography.com**) that displayed faint loops surrounding the galaxy. This led to a collaborative partnership between Martínez-Delgado and GaBany, who have since published 13 papers in leading journals on the discovery of tidal star streams and rings in the outer halos of large spiral galaxies (*S&T*: Jan. 2009, p. 92).

GaBany primarily uses a 20-inch Ritchey-Chrétien telescope with an Apogee U16M CCD camera to take extremely deep exposures, often lasting dozens of hours recorded over several nights.

There are other amateurs whose imaging straddles the border between the amateur and professional worlds. Readers will be familiar with Adam Block's high-resolution astrophotography (**http://caelumobservatory.com**). Using the 32-inch Schulman telescope at the Mount Lemmon SkyCenter, Block takes advantage of the often superior conditions at this mountaintop facility to record high-resolution images of targets often beyond the reach of amateur equipment. And though he manages the facility, his roots are firmly grounded in the amateur community, from giving public presentations and sky tours, to authoring a monthly column on imaging techniques.

Pushing the Limits of Resolution

While on the topic of high-resolution astrophotography, when someone says something can't be done, there's a certain kind of person who takes the statement as a challenge. For example, there's Chilean imager Daniel Verschatse (**www.verschatse.cl**). He and Ricardo Serpell used

a technique known as "lucky imaging" to resolve subarcsecond features in the famous Homunculus Nebula in Eta Carinae. Lucky imaging is performed by recording many short exposures and combining only the sharpest results to resolve extremely small-scale features in a target. The team used Daniel's 14.5-inch RCOS Ritchey-Chrétien telescope with an SBIG ST-10XE CCD camera operating at an astounding 13.7-meter focal length!

Using the same basic technique, New Zealand amateur Rolf Wahl Olsen (**www.rolfolsenastrophotography.com**) achieved a similar feat with decidedly more modest equipment. Olsen resolved the circumstellar disk that surrounds the nearby star Beta Pictoris using a 10-inch Newtonian reflector and a modified webcam. Again, Olsen recorded many short exposures and combined only the sharpest to produce his tour de force.

Planetary Feats

Lucky imaging isn't new. It's a technique pioneered by planetary imagers around the turn of this century to overcome the scintillation caused by Earth's atmosphere. Originally developed to take advantage of the video capability of webcams, today's practitioners use high-speed video cameras (borrowed from the manufacturing industry) and large telescopes to record short videos, which are then sorted to identify the sharpest frames to combine. This technique has led to an explosion in the popularity of planetary imaging while simultaneously producing a few true artists known around the world.

Damian Peach (**www.damianpeach.com**) has long been counted as one of the world's best planetary imagers, known for his eye-popping portraits of Jupiter, Saturn, and Mars. Peach methodically images the major planets on every clear night, often travelling to remote locations

Deep color images like this dusty region in Ursa Major dubbed the Angel Nebula are the specialty of Rogelio Bernal Andreo using Takahashi astrographs and an SBIG STL-11000 CCD camera.

known for steady air. While his cameras change with each improving model, Peach has settled on the Celestron C14 Schmidt-Cassegrain as his primary instrument.

Another world-renowned planetary imager, Australian amateur Anthony Wesley (**www.acquerra.com.au/astro**) also concentrates his efforts on recording the major planets for both science and art. His approach has paid off handsomely: on July 19, 2009, Wesley captured the distinct signature of an impact event on Jupiter, which was confirmed by Hubble observations only days later. Not one to rest on his laurels, Wesley captured an impacting asteroid during the act hardly a year later!

Wesley continues to push the resolution limits of his equipment. In recent months, he has resolved storms on both Uranus and Neptune in infrared light using his home-built 16-inch Newtonian reflector and a Point Grey Research Grasshopper 3 high-speed video camera.

All these imagers share one trait in common: perseverance. Each continually works to improve his skills, and, as a result, each has attained the pinnacle of recognition in his respective area of expertise.

With the impressive quality of commercial optics, cameras, and software tools, it isn't that hard to dive into the hobby of imaging, no matter what your level of interest is. And each of these pioneers is easily accessible on the Web and will gladly offer advice to help you climb the learning curve of astrophotography. ✦

Sky & Telescope *Imaging Editor* ***Sean Walker*** *still gets excited to see the latest astro-images each day.*

Gallery showcases the finest astronomical images submitted to us by our readers. Send your best shots to gallery@SkyandTelescope.com. See SkyandTelescope.com/aboutsky/guidelines.

▼ CALCIUM ECLIPSE

Chris Schur

The Moon appears to take a substantial bite from the Sun during the partial solar eclipse of October 23, 2014. The massive sunspot group AR 2192 is seen just below center of the solar disk.

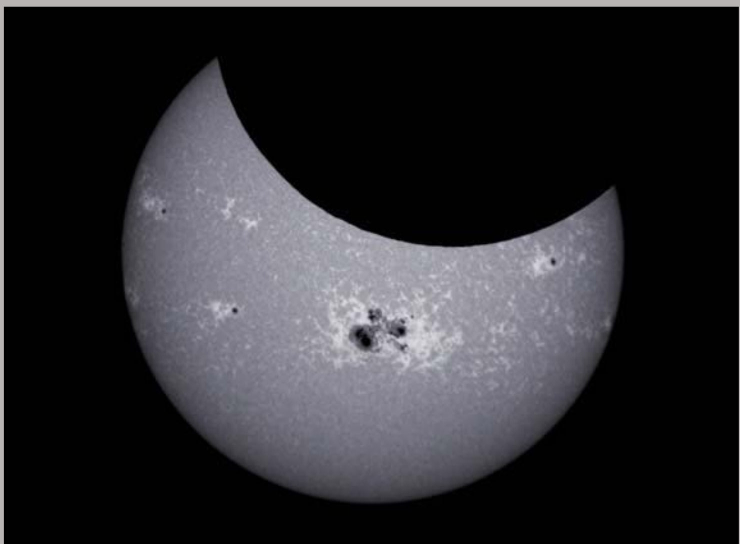
Details: *Stellarvue SV80 refractor with Lunt Solar Systems Calcium K filter and Imaging Source DMK51AU02.AS video camera. Stack of 25 video frames captured from Payson, Arizona.*

▼ ▼ THE CRAB NEBULA

Ron Brecher

Perhaps the most famous supernova remnant, Messier 1 in Taurus displays reddish tendrils that are the remains of the progenitor star's atmosphere expanding into space.

Details: *AstroSysteme Austria ASA10N-OK3 astrograph with SBIG STL-11000M CCD camera. Total exposure was 11⅓ hours through Baader color and narrowband filters.*



COLORFUL ECLIPSE

Brian Simpson

Using high-dynamic-range processing techniques, Brian Simpson enhanced the subtle colors of the partially eclipsed Moon on October 8, 2014 to reveal the purplish hues of Earth's stratosphere.

Details: ***Celestron EdgeHD 8 Schmidt-Cassegrain telescope with Nikon D610 DSLR camera. Composite of two images totaling 8 seconds at ISO 100.***

◂ **TIBETAN HUNTER**

Jeff Dai

The constellation Orion, with its assortment of colorful nebulae, rises above the Himalayan Mountains as seen from the Tibetan Plateau.

Details: *Modified Canon EOS 6D DSLR with 35-mm f/1.4 lens at f/2. Total exposure was 30 seconds at ISO 5000.*

▾ **SPIRAL OR ELLIPTICAL?**

Fred Herrmann

NGC 5128 in Centaurus is a peculiar galaxy formed from the collision of a spiral and an elliptical galaxy sometime in the distant past.

Details: *PlaneWave Instruments 20-inch CDK with FLI ProLine PL9000 CCD camera. Total exposure was 30 minutes through color filters.*

▴ **ARC OF THE SOUTHERN SKY**

Julien Martel

The Milky Way spanning from Aquila at left through Vela at far right curves above the Atacama Desert in Chile.

Details: *Canon EOS 6D DSLR camera with 14mm lens. Mosaic of 7 photos, each exposed for a total of 30 seconds at ISO 6400.*

▲ **SHARPLESS IN BLOOM**
Gordon Haynes
This colorful region known as Sh2-101, the Tulip Nebula, lies roughly ¾° west of the naked-eye star Eta Cygni (right).
Details: *Tele Vue and Finger Lakes Instrumentation NP127fli APO astrograph with FLI ProLine PL16803 CCD camera. Total exposure was 12½ hours through narrowband filters.* ✦

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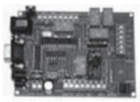

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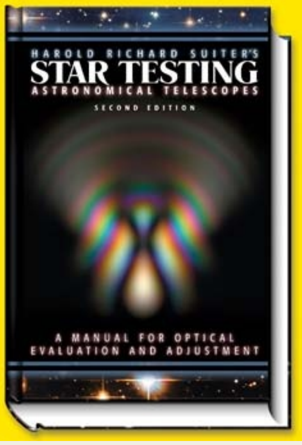

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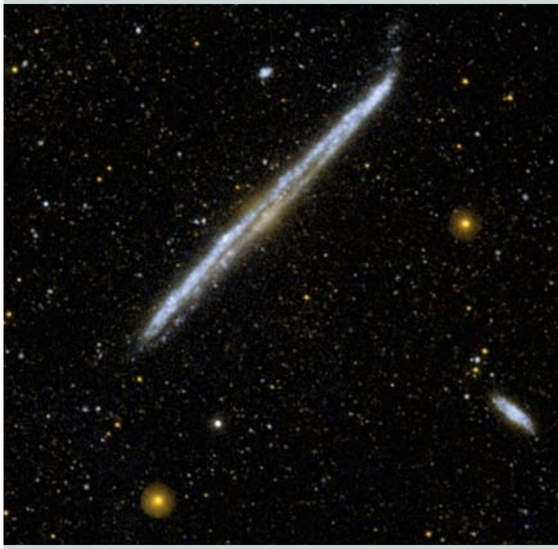

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Howard L. Ritter, Jr.

In Praise of Serious Dark

A trip to Big Bend — a Dark Sky Park — opens unimaginable new vistas overhead.

As observers, we all know that a dark-sky site improves the view of deep-sky objects. But how many of us *really* know what this is like when taken to its ultimate? Likely only a few percent of us have enjoyed observing from a seriously dark location: black sky, not a spark of artificial light, trees visible only as silhouettes against airglow. Until you first experience it, you can't properly envision it; too much emerges, with increasing rapidity, as you progress into deep dark.

I learn this firsthand on an RV trip to Big Bend, a national park in West Texas. I want to turn my 25x100 astronomical binoculars on the Milky Way from a place with Serious Dark, and Big Bend, an International Dark Sky Park, has the darkest measured skies in the lower 48 states, according to the National Park Service.

It's low season, and the six of us are alone in the RV park. There are no artificial lights or other people, as far as we know, for 30 miles, and the nearest tiny towns are 45 and 90 miles away. When I step out of the RV, the full, encompassing darkness is startling. The depth of darkness of foreground and landscape is utterly foreign — profound and assertive.

Then I look up. The southern summer Milky Way glows like night clouds illuminated by suburbs. Stars are large and close, and those barely seen back home in Ohio now so clutter the sky that familiar constellations are lost in the riot.

I set up the binoculars, sit down at the eyepieces, and venture a look, star chart in hand. But after starting at the Teapot and prowling though the Scutum star cloud, I put the chart aside and just wander gawking through the glories of the galactic bulge.

The big binoculars show endless sights as I've never seen them. They appear in wild profusion: open clusters, globulars, emission nebulae, and clouds of pinpoints as well as mists of uncountable unresolved stars. Omega, Eagle, Trifid, Lagoon, Wild Duck, Ptolemy's, other Ms too numerous to count — practically every field is crowded with sights more stunning than those in the last.

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The experience recalls a foundational event for my love of binocular astronomy. It's the magical night, at age 13, when I lay under an impossibly dark and starry sky on an Appalachian camping trip. I gazed through binoculars at the Milky Way straight overhead, lost in wonder at the multitudes of stars and objects whose mysterious and enchanting symbols I had pored over in my *Norton's Star Atlas*. That long-ago sky, like the sky over me now at Big Bend, is a holy sky, a God's-eye view, immortal and known only to us pilgrims.

Hours later, after a cruise through Cygnus, I've had my fill. I'm tired, and Andromeda and Triangulum won't be up before dawn. I stumble into bed, trying in vain to describe my elation to my sleepy wife. In the end, I settle on the simple wish that every observer who possibly can will, even if just once, make the pilgrimage to Serious Dark. ✦

Howard L. Ritter, Jr., a hematologist, has been an enthusiastic advocate of binocular astronomy ever since that night in the Appalachians. His bucket list includes a longer visit to Big Bend. And bigger binoculars.

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

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

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

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