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AUGUST 2014

New Products @ NEAF p. 68

To Catch a Comet

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August 2014 VOL. 128, NO. 2

On the cover: The Rosetta orbiter will launch a lander to touch down on a comet's nucleus.

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FEATURES

OBSERVING AUGUST

ALSO IN THIS ISSUE

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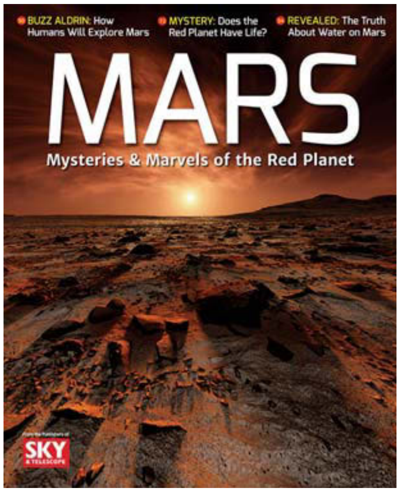
Robert Naeye
Spectrum

Our Special Mars Issue

MOST OF YOU KNOW that our staff does a lot more than produce monthly issues of *Sky & Telescope*. Besides our website and assorted products, we publish two annual special issues: *SkyWatch* and *Beautiful Universe*. New editions of these magazines will be coming out later this year.

Last year, we also published a special science issue titled *Astronomy's 60 Greatest Mysteries*, which went on sale in June (*S&T:* Aug. 2013, p. 6). That issue was such a journalistic and commercial success that we decided to follow it up with another science magazine devoted to mysteries. During an editorial staff meeting about 6 months ago, assistant editor Camille Carlisle suggested an issue devoted to Mars. The staff quickly reached a consensus, and we went into planning mode almost immediately.



COVER ILLUSTRATION: KEES VEENEBOS

After a lot of work, and a lot of help from distinguished authors and artists, I'm very pleased to announce that *Mars: Mysteries & Marvels of the Red Planet* is now on sale at our **ShopatSky.com** website, and also on leading newsstands in the U.S. and Canada.

I admit to being biased, but I think it's a great publication, and I'm confident that anyone interested in Mars will agree. We lined up leading experts to write the articles: Chris McKay on the search for life, Jim Bell on the planet's extreme geology and weather, Erik Asphaug on Mars's two-faced personality, Matt Golombek on Mars's interior, Margarita Marinova on atmospheric methane, William Sheehan on the greatest blunders of Mars observations, and Gregory Benford on science fiction's changing portrayals of the Red Planet. Of particular note, the issue contains a special contribution from Apollo 11 moonwalker Buzz Aldrin and coauthor Leonard David about future human exploration. Leading science journalists Kelly Beatty and Emily Lakdawalla chipped in with articles about Mars's early history and water, respectively, and Camille and I contributed stories as well. We also loaded the issue with great photos and art.

I extend special thanks to Camille and design director Pat Coppola, who did the lion's share of the editorial and design work, respectively. I extend my deepest gratitude to all the authors and illustrators who committed their time and talents to this project. If you want a thorough understanding of what we know about Mars right now, and what are the most compelling remaining mysteries, this 100-page special issue is a must-read! ✦

Robert Naeye
Editor in Chief

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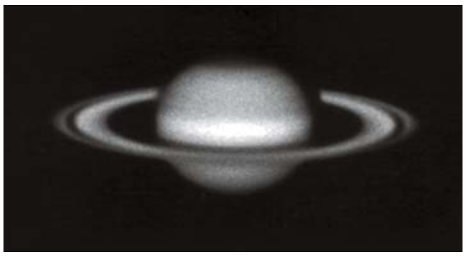
Photographic Memories

Klaus Brasch's article "The Origin of Stacking" (*S&T*: Mar. 2014, p. 68) brought back long-ago memories. I had the distinct pleasure of being Chick Capen's understudy at JPL's Table Mountain Observatory (now Table Mountain Facility) from 1962–70. At his prompting, I developed a technique that we called *composite imaging*. From 1964–69, I made more than 450 such images of Venus, Mars, Jupiter, and Saturn, with the majority of the Mars images being for JPL Technical Report No. 32-990, "The Mars 1964–1965 Apparition," published in 1966. We took 3¼-inch × 4¼-inch Kodak spectroscopic plates with a special planetary camera on the observatory's 16-inch f/50 reflecting telescope. We acquired as many as 36 images on individual plates, using five different wavelengths from ultraviolet to infrared.

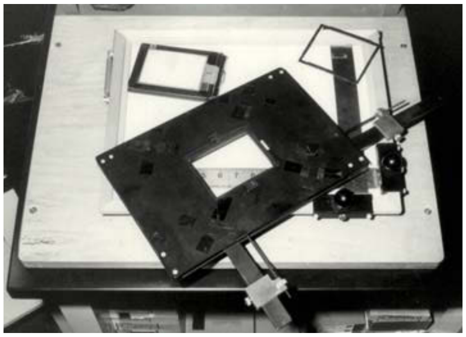
We thus composited up to 15 superior images per plate, making a positive image on Dupont cronopaque film paper. We then made a negative for producing the final "prints" in the technical report.

A unique plate holder with micro-fine adjustable x-y axes was designed for our Beseler enlarger. We centered image projection on a fixed, circular graph paper target, directly on top of a 3¼-inch × 4¼-inch plate holder. We manually adjusted each projected image to an exact position centered on the circular graph target. With the fixed graph target removed and the plate-holder slide pulled out, the film received the proper exposure. Then we returned the slide, repositioned the graph target, and selected and positioned the next image. We repeated this process for each of the superior images selected from each photographic plate.



JAMES YOUNG

This nine-image composite of Saturn was taken in September 1968 with the 16-inch telescope at JPL's Table Mountain Facility.



JAMES YOUNG

Reader James Young built this x-y axis plate holder (largest rectangle) in the 1960s. The smaller 3¼-inch × 4¼-inch plate holder appears above the adjustable holder (with the graph target in position).

I spent close to one thousand hours from 1963–69 performing this interesting task, up to the final prints (which were third-generation) for the Mars report and for numerous other studies, documents, and PR for NASA JPL.

James W. Young
Retired JPL astronomer (1962–2009)
Via e-mail

Surprise Discovery

Alan MacRobert's short note in Celestial Calendar about the Moon's occultation of bright Lambda Geminorum (*S&T*: Mar. 2014, p. 52) brought to pass a special event for me.

I was watching the lunar occultation the evening of March 10th, near the Moon's culmination. I have watched hundreds of occultations over the past 53 years, but this one was different. In my 8-inch at 102×, the star went *blink, blink*. That is, it was a step disappearance, not an instantaneous one.

Intrigued, I looked up the event in the Royal Astronomical Society of Canada's *Observer's Handbook 2014*. It lists Lambda Gem as a very tight double, with component stars of magnitudes 4.0 and 5.0 and a separation 0.04 arcsecond, position angle 300°. I did not know Lambda Gem was a double before the occultation.

Fortunately for me, the star was well south of the lunar disk's center — the event was far from a graze, but the binary took longer to be occulted on this chord (from longitude 119.6°W, latitude 49.4°N) than if the Moon had moved more centrally across the star. Now my list of resolved double stars includes a 0.04 arcsecond double. Thanks Luna!

Alan Whitman
Via e-mail

Going Super-Deep from Your Backyard

I enjoyed Bob Cava's "New Jersey Quasar Quest" (*S&T*: Mar. 2014, p. 34). I myself started a small quasar quest with my 10-inch Dobsonian a few years ago, in the deserts of southern California and Nevada. Cava's article does a great job introducing readers to observing some of the most distant objects that we can visually observe with amateur equipment.

I was surprised, however, by the list of bright quasars available in the northern sky. Although it's a nice list, it is missing several much easier "beginner quasars." When I first stepped out on my quasar quest I was guided to **http://washedoutastronomy.com/content/fist-full-quasars** as a good source of information. Contained are quasars ranging from magnitude 12.8 to 14.2, which provide a nice progression in hunting these super-deep objects.

Although my quasar hunt has been put on pause with a recent move to suburban Virginia, Cava's article has rekindled my desire to peer ever deeper. Best wishes and happy hunting.

Mike Lyons
Stafford, Virginia

Editor's Note: *We excluded three of the four objects in the beginner's list mentioned (Mrk 421, Mrk 501, and OJ 287) because they are classified as BL Lacertae objects rather than quasars. (Two of them appear in Steve Gottlieb's 2010 article on blazars;* S&T: *April 2010, p. 70.) The distinction between different types of active galactic nuclei is somewhat arbitrary, but BL Lac objects and quasars aren't usually lumped together, so we excluded them.*

Distance to Your Horizon

Standing on a seashore or a flat plain, you might have wondered "How far is the horizon?" I learned a neat shortcut you can do in your head, skipping most of the math.

Estimate how many feet your eyes are above the water, or the plain. Multiply this number by 1.5, then take the square root of the answer. That's the distance to the true horizon on Earth in miles — to a remarkable accuracy of nearly 1 part in 1,000.

For instance, if you're standing on a beach with your eyes 6 feet above sea level, the distance to your true horizon is 3 miles. If you're looking from a mountaintop 6,667 feet high, it's 100 miles.

Knowing this, you can find the horizon distance on any large world if you know its diameter compared with Earth's. For instance, the Moon is about ¼ of Earth's size. Take the square root of that (i.e. ½) and multiply by the horizon distance on Earth. So for an astronaut with eyes 6 feet high standing on the Moon, the horizon is 1.5 miles away. On Mars, it's 2.2 miles.

This works as long as your elevation is small compared to the world you're on, and if you ignore any atmospheric effects.

For metric, use 12.8 not 1.5, with height in meters and distance in kilometers.

Tom Sales
Somerset, New Jersey

Enjoyable April Issue

Thanks for your fine April issue. I was thoroughly intrigued and delighted by Chuck Hards's article "A 70-inch Amateur Telescope" (p. 68) — an inspired leviathan such as Mike Clements's Dob is a rare occurrence with this section of the magazine. I would have been pleased to see more diagrams of this crazy-giant telescope.

I'm also glad you balanced Karl Battams's sentimental article on Comet ISON with John Bortle's more dispassionate Focal Point commentary. Celestial objects don't "underperform" — they're not athletes trying to win a game for human cheerleaders! They are what they are, and we as scientists should learn from and appreciate each of them for just that.

Overall a very good issue. Well done!

Ted Aranda
Chicago, Illinois

For the Record

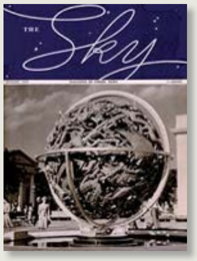
✷ *On page 39 of the May 2014 issue, the photo caption describes small clouds drifting over lakes in Chile. This caption is correct: the lakes are the small, blue-gray blotches on the landscape and not the clouds' dark shadows, which several readers wrote in to clarify. Unfortunately, we cropped the image to remove most of the lakes, so they are less obvious than in the original image. Our apologies for the confusion.*

✷ *The photos of the ARI scopes on pages 26 and 29 of the June 2014 issue should be credited to Mike Lockwood, not Bob Holmes.*

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

75, 50 & 25 Years Ago

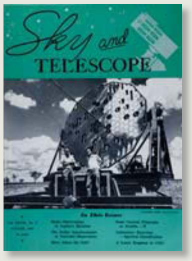
Roger W. Sinnott



August 1939

No Bigger Eye "In a recent lecture in Kansas City, Dr. Harlow Shapley is quoted as saying that, wonderful as it is, the 200-inch telescope on Mt. Palomar in California cannot accurately be said in itself to mark the rebirth of astronomy. At least two other developments are of equal importance[: the enormous speeding up of photographic plates and the invention of] the Schmidt telescope. 'The great difficulty in our present telescopes has been that they cover only a little of the field at a time,' said Dr. Shapley. 'Even that great 200-inch telescope will enable us to survey only about one-tenth of a square degree. . . . [With a] Schmidt, it will be possible to cover about 10 degrees at one time. So probably the 200-inch telescope will be the largest telescope ever built.'"

Not until 1975, three years after Shapley's death, was the 200-inch surpassed in aperture by the Russian BTA 236-inch reflector. About a dozen even-larger giants now probe the skies, with more in planning phases.



August 1964

Oblate Sun? "The most reliable astronomical test for the theory of general relativity is afforded by the motion of Mercury. The perihelion point of its orbit is moving eastward at a faster rate than is predicted from perturbations by other planets. This difference amounts to 43 seconds of arc per century, and is exactly accounted for by Einstein's theory of general relativity.

"R. H. Dicke of Princeton University makes the suggestion that this agreement may be merely a coincidence. If the sun were very slightly oblate, its gravitational field would produce an additional drift of Mercury's perihelion. The sun is generally regarded as spherical, [but] if the sun can be shown to be nonspherical, the chief astronomical evidence for general relativity would be undermined."

Dicke's idea led to many efforts to measure the Sun with extreme accuracy. Astronomers now think that the Sun's polar and equatorial diameters differ by only about 7 milliarcseconds. In this regard, Einstein is vindicated.

August 1989

Tumbling Moon "Hyperion, a small satellite of Saturn, is apparently tumbling chaotically as it orbits that ringed planet. It is perhaps the most pristine example of chaos in action. Hyperion is an oddly shaped moon, looking like a 120-mile-long jellybean. Its shape, asserts [MIT's Jack] Wisdom, is the main reason for its tumbling. Hyperion also travels in a highly elliptical orbit, rather than a nearly circular one, and this contributes to its bizarre behavior as well. . . . [T]here is no way it can rotate at a uniform rate and always point the same face toward the planet."

Anita Killian (MIT) was describing how Jack Wisdom had divined Hyperion's chaotic rotation theoretically, using measurements of which face the moon showed Saturn during its closest passes and how fast this orientation changed at each pass. Only later did astronomers confirm this behavior observationally. Hyperion is currently the only natural satellite that tumbles chaotically, although other moons might well have done so in their pasts, too.

STELLAR | Helium-shell Flash in Action and . . .

MATT BOBROWSKY / OSC / NASA

The Stingray Nebula, seen in this Hubble image, is the youngest known planetary nebula. Astronomers think they've detected the central star passing through a transitional upheaval in its evolution.

The odd behavior of a star in the heart of the Stingray Nebula (Henize 3–1357) provides tantalizing evidence that we might be seeing an abrupt acceleration of nuclear burning near the end of a star's life.

This phase, called the *helium-shell flash*, occurs after a low-mass star has finished fusing its core hydrogen into helium. Fusion continues in a surrounding layer of hydrogen, raining down helium onto the core. Eventually, the pressure and temperature build up enough to suddenly ignite helium-shell fusion in the so-called flash. This then leads to a thermal pulse during which the star expands and brightens for a short period of time.

Astronomers think that is what's happening to SAO 244567, the star nestled inside the Stingray. The Stingray is a young planetary nebula in the southern constellation Ara and was created when the aging star blew off its outer layers. It's only 0.16 light-year across — one-tenth the size of most known planetary nebulae and roughly 130 times larger than the average distance

. . . Sun's Newfound Chilly Neighbor

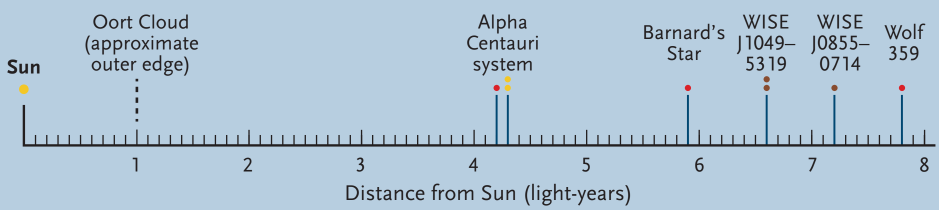
Infrared observations have uncovered a cool brown dwarf that's only about 7.2 light-years away. The object, WISE J085510.83–071442.5, is the fourth-closest stellar system to the Sun and the coolest brown dwarf yet discovered.

Kevin Luhman (Penn State University) found WISE J0855–0714 using data from NASA's Wide-field Infrared Survey Explorer (WISE) and Spitzer Space Telescope, as part of his ongoing search for cool, nearby brown dwarfs. The object is special for a few reasons.

First, at 7.2 light-years away (6.5 to 8 is the error range), it's farther only than the Alpha Centauri triple system (4.2 light-years for Proxima and 4.3 light-years for Alpha Cen AB), Barnard's Star (5.9 light-years), and the brown dwarf binary WISE J1049–5319 known as Luhman 16 (6.6 light-years; *S&T*: July 2013, p. 12). It displaces Wolf 359, which lies 7.8 light-years away.

Second, it's moving fast. Part of that movement is its high parallax, which shows that WISE J0855–0714 is close to the Sun. But the object's parallax is small compared with its proper motion: the object traverses 8.1 arcseconds per year, the third largest proper motion of any object outside the solar system (trailing only Barnard's Star and Kapteyn's Star). In comparison, most of the brightest stars have a proper motion of a few tenths of an

Solar Neighborhood



This diagram illustrates the distances of the five star systems closest to the Sun, with the newest find (WISE J0855–0714) bumping Wolf 359 to fifth place. Two of the five systems contain solely brown dwarfs.

S&T: LEAH TISCIONE

between the Sun and Pluto. It only started glowing in the last few decades.

Observations from 1971 give a temperature of 21,000 kelvin for the central star. But in 2002, it was up to 60,000 K. So Nicole Reindl (Eberhard Karls University of Tübingen, Germany) and colleagues dug through archived ultraviolet and optical observations from a range of space- and ground-based telescopes in order to understand this rapidly evolving star.

The team found that between 1988 and 2002, the temperature increased from 38,000 K to 60,000 K. During this time the star also contracted, dimmed, and reduced its mass-loss rate, while its winds sped up from 1,800 km/second to 2,800 km/sec (4 to 6.3 million mph). Then between 2002 and 2006 it cooled down again, dropping to 55,000 K.

The team thinks the star's jump in temperature and wind speed are telltale signs of a helium-shell flash. It could, however, also be the byproduct of an evolving close binary system, the team reports in *Astronomy & Astrophysics*. The star is probably less than half the Sun's mass.

■ **SHANNON HALL**

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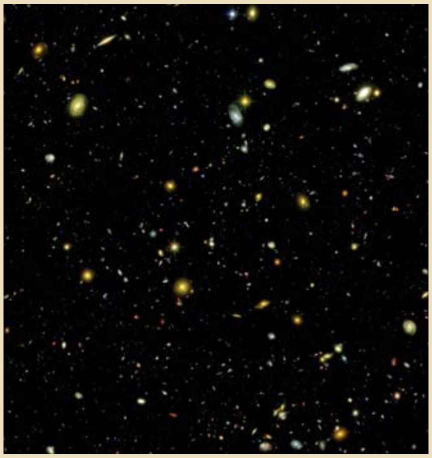
arcsecond per year or less.

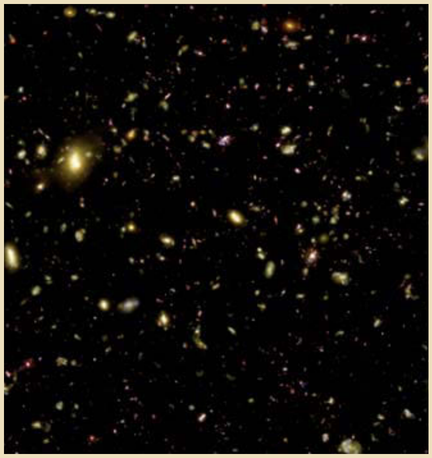
Third, WISE J0855–0714 is literally cool. Using images of the object taken in different filters, Luhman estimates its temperature to be about 250 kelvin, or about 10 degrees below zero in Fahrenheit. This makes WISE J0855–0714 not only the coldest neighbor to the Sun but also the coldest brown dwarf ever discovered.

The discovery of WISE J0855–0714 points out just how important large-scale sky surveys such as WISE really are. This cold brown dwarf was discovered relatively close to the plane of our Milky Way, which astronomers often avoid because of "crowding." But as Luhman has shown, this region of the sky might be a fertile hunting ground for finding more close companions to the Sun. The discovery appears in the May 10th *Astrophysical Journal Letters*.

■ **JOHN BOCHANSKI**

COSMOLOGY | Universe in a Box 2.0





NASA / ILLUSTRIS COLLABORATION

The results of the recent Illustris cosmological simulation are so realistic that a field of galaxies taken with the Hubble Space Telescope (*left*) looks just like a simulated view (*right*). Illustris was unable to accurately reproduce low-mass galaxies, however.

Astronomers have created the most realistic computer simulation of the universe's large-scale evolution to date, tracking activity across 13 billion years of cosmic history, Mark Vogelsberger (Massachusetts Institute of Technology) and colleagues report in the May 8th *Nature*.

Supercomputer simulations allow cosmologists to study how the laws of physics worked together to build up the universe we observe today. By tracking the behavior of matter, researchers learn more about the universe's evolution as they work to match their simulated webs of galaxies to those observed in the real universe.

Vogelsberger's team is the first to simultaneously re-create both the large-scale network of filaments formed by massive galaxy clusters and the smaller-scale gas and stellar buildup within large galaxies.

The phenomenal detail of this simulation required supercomputers in France, Germany, and the U.S. The model, Illustris, begins from initial conditions resembling the very young universe 12 million years after the Big Bang. The team then unleashed complex physical processes — the gravitational pull of matter, the chemical processes in diffuse gas, radiation, and magnetic fields, as well as the physics of star and black hole formation — and allowed everything to evolve for 13 billion years, then sat back and watched.

The Illustris simulation matched the observable universe remarkably well. It succeeded in producing a variety of galaxies (41,416 of them), including spiral galaxies like our own Milky Way. But it struggled to produce realistic low-mass galaxies. As in many previous simulations, these smaller galaxies formed far too early, ending up with prematurely aged stellar populations — stars two to three times older than what observations show.

Other simulations working on smaller scales have successfully reproduced the delay in starbirth (*S&T*: May 2014, p. 12). Phil Hopkins (Caltech), who's involved in that work, explains that the zoomed-in studies' successes come from their ability to follow the nitty-gritty physics of star formation and stellar feedback. The method enables them to predict what these processes do to small, growing galaxies.

The simulations by Hopkins and others can watch gravity's effects on scales of a few light-years, whereas Illustris only resolves gravity's effects down to about 2,300 light-years. But the smaller-scale studies only look at an individual galaxy and its immediate neighbors, not the large-scale cosmic structure that Illustris does. Combining both approaches and using the results from the small-scale simulations to inform the large-scale ones will allow cosmologists to improve on Illustris's results, Hopkins says.

■ **SHANNON HALL**

EXOPLANETS | Hot Jupiters Keep Stars Young

Sizzling gas giants circling close to their host stars keep the stars looking young past their prime, a new study suggests.

Hot young stars are wildly active. They emit giant, energetic flares and are 1,000 times more luminous in X-rays than middle-aged stars. This bright emission is thought to arise from intense magnetic fields driven by their rapid rotation.

As stars age they naturally become less active: their rotation slows and so their X-ray emission weakens. But astronomers have theorized that a hot Jupiter might be able to prolong this stellar activity. If the planet orbits faster than the star rotates, then it should transfer angular momentum to the star, inhibiting the star's spin-down and therefore making it appear young even as it ages.

Now, astronomers Katja Poppenhaeger and Scott Wolk (both at Harvard-Smithsonian Center for Astrophysics) have shown that hot Jupiters do in fact cause their host stars to shine with prolonged youthfulness.

The work — which is the first systematic test for this idea using a controlled sample — looked at five binary systems in which only one star has a known planet. Both stars in these binary systems should be the same age, so if the star with the hot Jupiter gives off more X-rays than its twin, the apparent youth must be triggered by the planet's involvement.

In the two systems with extremely close-in hot Jupiters, the planet-hosting star was more active and spun faster than its twin, therefore looking younger (by a few billion years). In the pairings with more distant or less massive hot Jupiters, the two stars looked the same age.

The result implies that X-ray-based age estimates for some planet-hosting stars might be too young and need reconsideration. The work appears in the May *Astronomy & Astrophysics Letters*.

■ **SHANNON HALL**

COSMOLOGY | New Cosmic Yardstick

A new method using active galactic nuclei (AGN) can successfully measure the universe's expansion, report Yuzuru Yoshii (University of Tokyo) and colleagues in the March 20th *Astrophysical Journal Letters*.

The key is in looking at the size of the gap between the black hole's accretion disk and a larger ring of dust that lies around it. The size of this gap depends on how much radiation is coming from the bright accretion disk. Measure the size of the gap, and you'll have a measure of the AGN's intrinsic brightness — and hence its distance.

But astronomers can't see the dust ring directly. So they watch the AGN's light vary over time. The ultraviolet light from the accretion disk must travel across the gap before reaching the inner edge of the dust ring, where it's absorbed and re-emitted in the infrared a short time later. The process should manifest as peaks in ultraviolet light followed by peaks in infrared light.

Yoshii's team watched for this echo from 17 AGN. It took the team 6 years on a dedicated 2-meter telescope at the Haleakalā Observatory on Maui to measure the sizes of all the dust rings.

Using the inferred distances, the team measured a current value for the Hubble constant of 70–76 km/sec/megaparsec, which is in pretty good agreement with the 71.4–76.2 km/sec/Mpc calculated using supernovae. (Those still conflict with the Planck and WMAP values for reasons as-yet unknown; *S&T*: June 2014, p. 10.) Bonus: the new method extends Hubble's Law from roughly 100 million light-years to 500 million light-years.

"It's important to stress that new methods of course do not have the maturity of the old ones," says Bożena Czerny (Nicolaus Copernicus Astronomical Center, Poland). "But it's equally important to have them, as many as possible, and to develop them to maturity."

■ **SHANNON HALL**

IN BRIEF

Squeaky-clean Rover. Strong winds blowing over the rim of Endeavour Crater in mid-March cleaned most of the dust off the solar panels of NASA's 10-year-old Mars rover Opportunity. The mission team estimates that the rover is now as clean as it was during its first Martian winter in 2004. As a result, the amount of electricity available for the rover's ongoing work jumped from 375 watt-hours per day in January to 620 watt-hours in mid-April.

■ **EMILY POORE**

Smallest Habitable-zone Planet. Kepler-186f is the first Earth-size exoplanet circling in its star's habitable zone, Elisa Quintana (SETI Institute and NASA Ames) and colleagues report April 18th in *Science*. Of the more than 1,700 confirmed exoplanets, only about 10 orbit in their stars' habitable zones. Before Kepler-186f, the smallest one was Kepler-62f, at 1.4 Earth radii (ergo not necessarily rocky). Kepler-186f is between 0.97 and 1.25 Earth radii but its host star is too distant and therefore too faint for radial-velocity observations, which would yield the planet's mass. Using several assumptions, the team estimates that the mass ranges from 0.32 to 3.77 Earths. Kepler-186f is part of a five-planet system around an *M* dwarf and its orbit is along the habitable zone's outer edge, so surface water might still be in danger of freezing.

■ **SHANNON HALL**

Oddly Bright Supernova Explained. Robert Quimby (University of Tokyo) and colleagues have detected a heretofore unseen galaxy lying between Earth and the host galaxy of supernova PS1-10afx. The supernova appeared in 2010 with an implied brightness *much* greater than expected for its distance. Astronomers have debated whether it was caused by an unnaturally luminous supernova or a typical supernova brightened due to gravitational lensing. The new galaxy settles the debate in favor of lensing, Quimby's team claims in the April 25th *Science*. ✦

■ **SHANNON HALL**

Stuff Just Got Real

An astrobiologist comes to grips with the new cosmology results.

So they found ripples from the origin of the universe: gravitational waves from tiny quantum fluctuations in the instant after the Big Bang (last month's issue, p. 18). It's clearly an incredibly important discovery, and my friends all want to know what I think. Even worse, they want me to explain it.

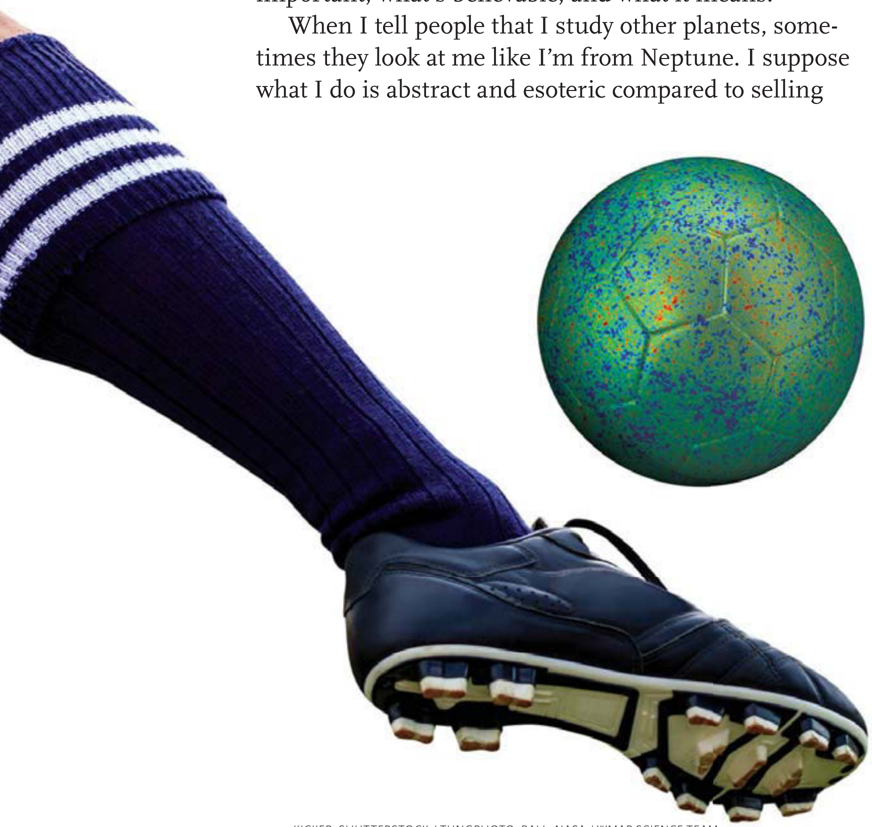
But dammit Jim, I'm an astrobiologist, not a cosmologist. People think that I know all about this stuff because it's out there in space, just like those stars, planets, and moons I'm always going on about. I follow cosmology and particle physics on the level of reading *S&T* and *Scientific American*, and if I were a 19th-century natural philosopher, I might be able to know all of science, or at least make a better stab of it. But now science has grown to a sprawling, branching tree of knowledge, and we rely on the authority of those in other fields to tell us what's important, what's believable, and what it means.

When I tell people that I study other planets, sometimes they look at me like I'm from Neptune. I suppose what I do is abstract and esoteric compared to selling cars, fixing bridges, or running a frozen yogurt company. But compared to cosmology or particle physics, it feels so concrete. At least I can picture planets as cratered, rocky plains or wave-tossed seas under an alien sun.

But what about the worlds of subatomic particles and baby universes ballooning out of nothingness? There are good reasons to believe. The math is elegant and, most importantly, predicts other patterns and phenomena that we then observe. I've taken university courses in general relativity and quantum mechanics, and though I couldn't reproduce the logic or math in any depth now, having been through it once gave me an appreciation for their depth and veracity. I've taught the cosmic microwave background in intro astronomy courses and planetarium shows. I dutifully report on how tiny quantum bumps became frozen into the distribution of matter as the cosmos expanded from unimaginable tininess to inconceivable vastness, and miniscule vacillations evolved into massive superclusters of trillions of stars. I know the drill, but I also have a voice in my head saying "Really? It's a good story, but do we really *know* this?"

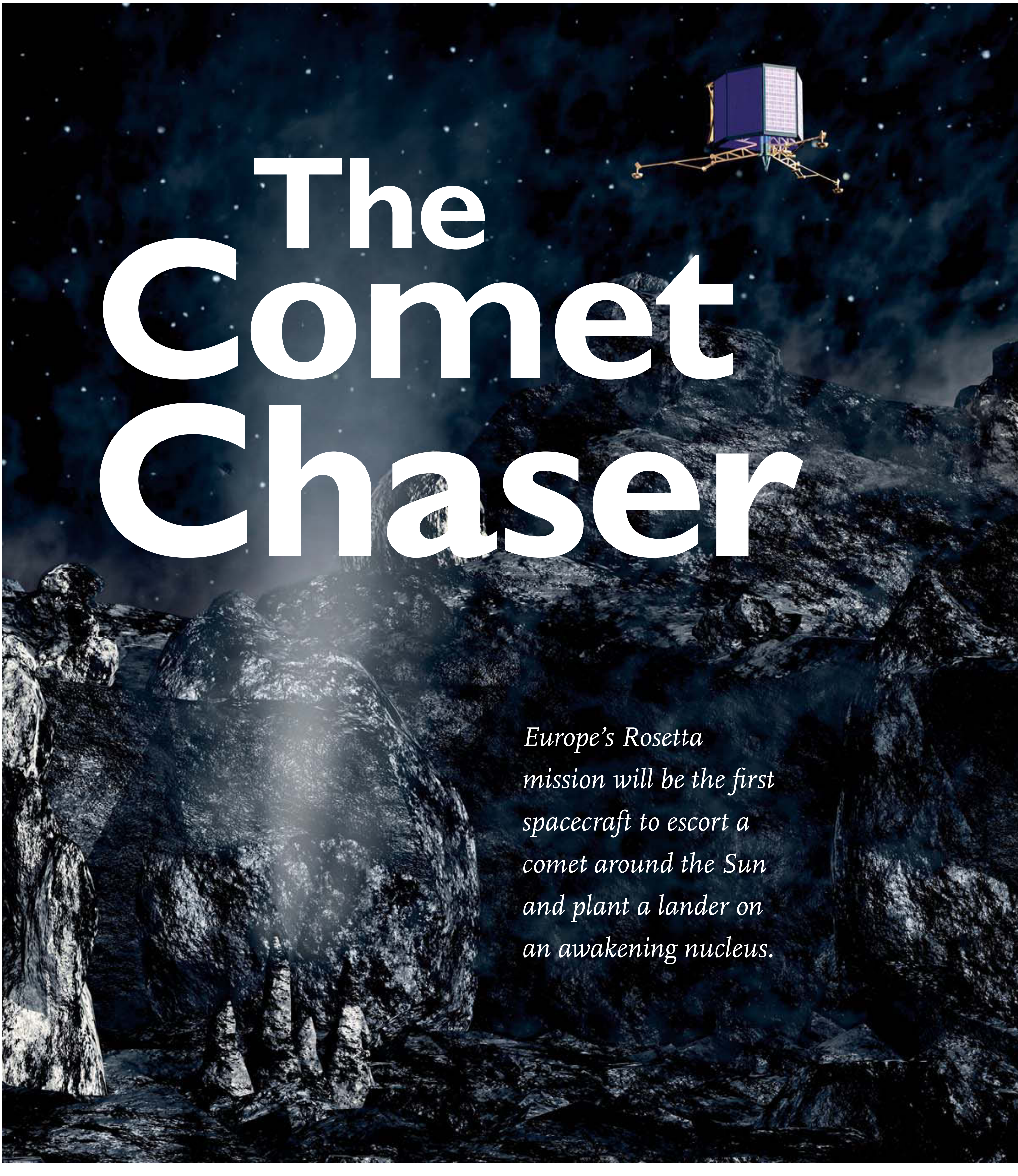
I must confess to having doubts about the Big Bang. Not that I have any better ideas, it's just that ideas about the early universe seem to rest on so many layers of abstraction. I get that it fits an impressive amount of data, but I can imagine that it might all somehow be wrong, a beautiful and complex edifice that may someday come crashing down in a paradigm-shifting upheaval of reality.

We'll never visit the early universe. But that's also true of Earth's early Archean era, and perhaps the exoplanets, and yet planetary scientists study these times and places. We do, at least, have rocks from the Moon and mineral grains from the Archean (June issue, p. 16). And now, it seems, we have the equivalent for the primordial universe. Detecting these gravitational waves, closely conforming to predictions, makes it a lot more real to me. Maybe these folks really are on to something! I'm very glad people are studying these things, and I'm glad that someone keeps the yogurt machines running too. ✦



KICKER: SHUTTERSTOCK / TUNGPHOTO; BALL: NASA / WMAP SCIENCE TEAM

***David Grinspoon** is a senior scientist at the Planetary Science Institute, which is based in Tucson, Arizona. Follow him on Twitter at @DrFunkySpoon.*



The Comet Chaser

Europe's Rosetta mission will be the first spacecraft to escort a comet around the Sun and plant a lander on an awakening nucleus.

Rosetta will begin scoping out touchdown sites for its Philae lander (illustrated above) soon after it catches up with its comet. It'll deploy its lander in November 2014. ***Right***: Head of ESA Operations Paolo Ferri (left) and ESA Rosetta Spacecraft Operations Manager Andrea Accomazzo wait in the control room for a signal from Rosetta.

ESA / AOES MEDIALAB

JOEL PARKER

It is not uncommon that someone you are waiting for is 15 minutes late — even if, as in the case here, the gathering is in their honor. But in the high-precision world of space missions, 15 minutes is an eternity.

It is January 20th, 2014, and I'm sitting in a large room at the European Space Agency's Mission Operations Center in Germany, waiting for a signal from the Rosetta spacecraft. This signal will indicate that the comet chaser has woken up after more than two and a half years of silence in hibernation. I'm sitting next to project scientist Matt Taylor (ESA), though most of our conversation is taking place online (Matt: "Tense factor level ten." Me: "It goes to 11.").

As the wait continues, we can't help but think of worst-case scenarios, like what parents think while waiting for their child to come home from the first solo drive after getting a license. Rosetta is such a complex system, with so many things that could go wrong . . .

Sixteen minutes. The tense silence increases as the clock ticks.

Seventeen minutes.

Eighteen minutes . . . then Matt nudges me and nods toward the screen. "I think that's it," he whispers. It's just a tiny blip, off-center, and barely above the noise. Statistically there is no reason to think it's real, but my astronomer "spidey senses" immediately tell me he's right. Yet the blip appears in data from only one ground station. Then it's gone. I guess my instincts were wrong.

A moment later, the blip returns in the same spot. Still almost in the noise, but it persists. A twin blip appears in data from the second ground station, then both grow stronger. We know *that's it. After a moment, we see it in the face of the lead flight controller. He suddenly stands up, eyes wide. A smile. Finally, the fist pump.*

The room around me explodes in excitement as the blip grows into an undeniable signal. Rosetta is awake and just called out, "Hello world!"

ESA / JÜRGEN MAI

ESA / JÜRGEN MAI

After a tense wait, mission controllers celebrate the arrival of Rosetta's first signal after the spacecraft woke up from hibernation on January 20th.

Unlike previous cometary missions, which were all relatively brief encounters, ESA's Rosetta mission will have a long-term relationship with its dirty snowball. Rosetta will rendezvous with Comet 67P/Churyumov-Gerasimenko (we call it "C-G" to avoid endless tongue-twisting conversations) in August 2014. It will then escort the comet for more than a year as it flies past the Sun.

During that time, we will watch — up close and personal — the life of the comet. We will watch as increasing solar heating drives the vaporization of ices (such as water and CO_2) from the nucleus as it approaches our star. We will also see how those escaping gases may form ghostly, geyser-like jets with entrained dust, watch the comet grow a tail and coma and how these interact with the nucleus, and finally observe the activity quiet down again after C-G passes the Sun and heads back out to the deep-freeze portion of its orbit.

As if those aren't enough "firsts" for a mission, Rosetta also carries a smaller spacecraft that will land on the comet and do in situ studies of the surface. This lander will work for several days or perhaps several weeks before things get too hot or the solar panels become too dust-covered to operate anymore.

The long hibernation and the upcoming adventure of operating a spacecraft in the dangerous and dirty environment of an active comet are just some of the mission's risks. But taking risks is often necessary when doing cutting-edge research: if it were easy and safe, it would have been done already. Rosetta will take those risks in order to see in real time how a comet behaves, on a level of detail that can't be seen from ground-based telescopes or even space telescopes such as Hubble.

Two Laboratories

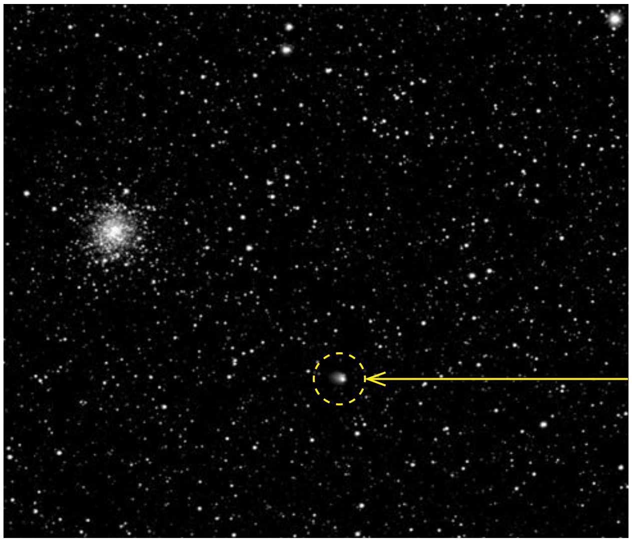
To do this detailed level of study, you need an advanced laboratory. Since we can't bring a comet to the laboratory, we are sending the laboratory to the comet. In fact, we are sending *two* laboratories to the comet: there are 11 instruments on the orbiter and 10 more on the lander (see sidebars on pages 23 and 24). These include instruments that study the dust particles, that take in and directly sample the gas, and that study the plasma (ions and electrons) around the comet and its interaction with the solar wind. There are instruments that take images and instruments that take spectra. We also have instruments that observe over a wide range of wavelengths — from ultraviolet to visible to infrared to microwave and out to radio. I like to call this wide range of investigations "CSI Rosetta," since we have to look at all the clues to figure out what happened, as well as when, where, and how it happened. Each instrument studies different clues so that scientists can put together the whole picture.

The instrument I work with is Alice, an ultraviolet spectrometer led by principal investigator Alan Stern (Southwest Research Institute). Alice is the first UV spectrometer to visit a comet and is one of three instruments contributed by NASA to support this European-led mission. With Alice, we'll observe the comet's surface and the coma's gas to figure out the relative proportion of certain elements and molecules. For instance, one of Alice's science objectives is to determine how abundant the noble gases (e.g. helium, neon, argon) and molecular nitrogen are in the gas coming from the nucleus. Both the trapping of noble gases into cometary ice and their release are temperature dependent, so based on the relative amounts that we measure of those species and the timing of when we detect them, we can deduce how cold it was in the corner of the solar system where the comet formed and the history of C-G's previous passes around the Sun.

We'll also be able to tell how the temperature changes inside the nucleus over time. Different types of ices sublimate at different temperatures, so changes in the proportions of the compounds coming out can reveal the internal temperature.

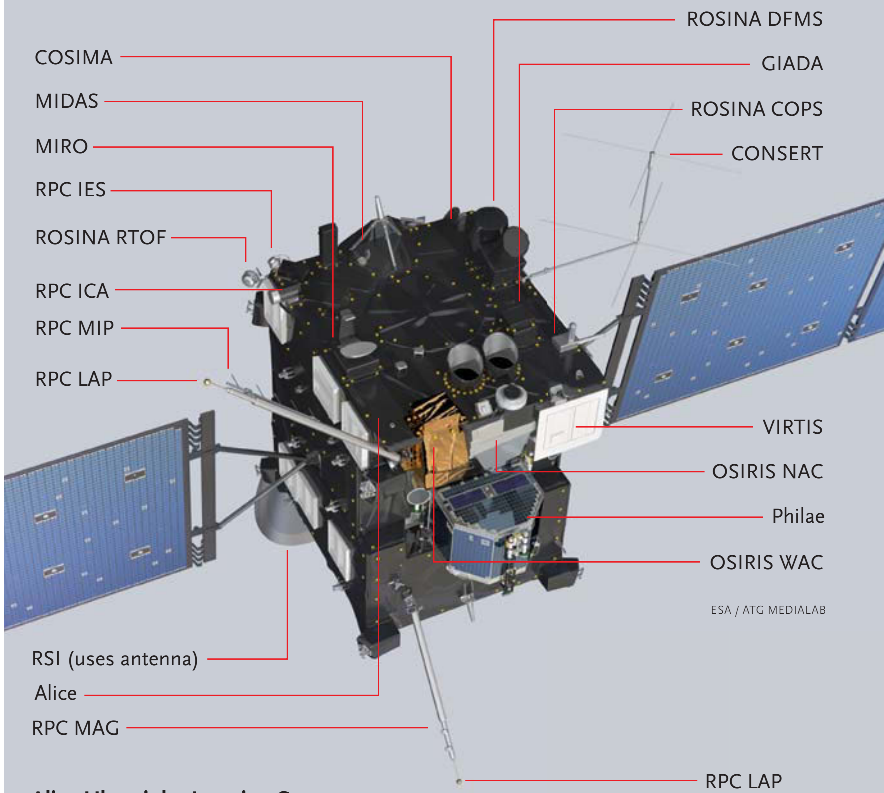
Rosetta is an impressive spacecraft. The core is a roughly 2.5-meter (8-foot) cube containing propulsion, avionics, communications, computers, and all the instruments. *Star Trek* fans might liken it to a small Borg spaceship. What really stand out are the huge solar panels. With a tip-to-tip wingspan of 32 meters and a collecting area of 64 square meters, it's the largest solar-power array for any interplanetary spacecraft, just beating out the

Rosetta's OSIRIS Narrow-Angle Camera took this image of Comet C-G (circled) on April 30th from more than 2 million kilometers away. The 12-minute exposure reveals the growing dusty coma. The globular cluster M107 shines at left.



ESA / ROSETTA / MPS FOR OSIRIS-TEAM MPS / UPD / LAM / IAA / SSO / INTA / UPM / DASP / IDA

Instruments on Rosetta Orbiter



ESA / ATG MEDIALAB

Alice Ultraviolet Imaging Spectrometer
Analyzes gases in the coma and tail, measures UV surface properties

Comet Nucleus Sounding Experiment by Radiowave Transmission (CONSERT)
Uses radio waves to probe the comet's interior

Cometary Secondary Ion Mass Analyzer (COSIMA)
Chemical analysis of dust grains, including composition and whether they are organic or inorganic

Grain Impact Analyzer and Dust Accumulator (GIADA)
Measures the number, mass, momentum, and velocity distribution of dust grains coming from the nucleus and from other directions (reflected by solar radiation pressure)

Micro-Imaging Dust Analysis System (MIDAS)
Provides information on population, size, volume, and shape of dust grains

Microwave Instrument for the Rosetta Orbiter (MIRO)
Determines abundances of major gases, surface outgassing rate, and the nucleus's subsurface temperature

Optical, Spectroscopic, and Infrared Remote Imaging System (OSIRIS)
Wide-angle and narrow-angle cameras

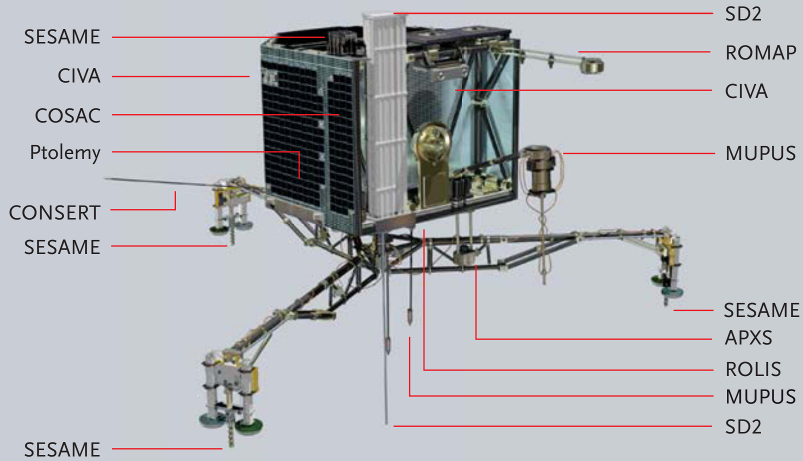
Rosetta Orbiter Spectrometer for Ion and Neutral Analysis (ROSINA)
Chemical analysis of the comet's atmosphere (composition, particle velocities, and reactions)

Rosetta Plasma Consortium (RPC)
Five sensors; examine the nucleus's physical properties and the inner coma's structure, monitor activity, study comet's interaction with the solar wind

Radio Science Investigation (RSI)
Measures the nucleus's mass and density, defines comet's orbit, and studies the inner coma

Visible and Infrared Thermal Imaging Spectrometer (VIRTIS)
Maps nature of the solids and temperatures on the nucleus's surface, identifies comet gases, and characterizes the coma's physical conditions

Instruments on Philae Lander



ESA / ATG MEDIALAB

Alpha Particle X-ray Spectrometer (APXS)
Studies surface composition by detecting helium nuclei and X-rays

Comet Infrared and Visible Analyzer (CIVA)
Takes surface panoramas with six microcameras; spectrometer studies the composition, texture, and albedo of surface samples

Comet Nucleus Sounding Experiment by Radiowave Transmission (CONSERT)
Probes the nucleus's internal structure

Cometary Sampling and Composition experiment (COSAC)
Gas analyzer that identifies complex organic molecules

Ptolemy
Gas analyzer that measures isotopic ratios of light elements

Multipurpose Sensors for Surface and Subsurface Science (MUPUS)
Measures the surface's density and thermal and mechanical properties using sensors on the lander's anchor, probe, and exterior

Rosetta Lander Imaging System (ROLIS)
CCD camera, will take high-resolution images during descent and stereo panoramas of sample areas

Rosetta Lander Magnetometer and Plasma Monitor (ROMAP)
Magnetometer and plasma monitor for the local magnetic field and interaction of the comet and solar wind

Sample and Distribution Device (SD2)
Drills more than 20 cm into the surface, collects samples, and delivers them to ovens for microscope inspection

Surface Electrical, Seismic, and Acoustic Monitoring Experiments (SESAME)
Three instruments; measure the surface's electrical characteristics, the way sound travels through it, and dust falling back to the surface

60 square meters of Juno's solar panels. Yet Rosetta's orbit took it so far away from the Sun (out to the orbit of Jupiter), and the power to run such a large spacecraft and suite of instruments is so demanding, that mission planners knew even this solar array wouldn't be able to generate enough power to keep the craft awake. That's why Rosetta had to be put into hibernation for so long.

The lander, Philae, itself bristles with instruments packed into a space the size of a washing machine, about 1 meter on a side. More than a half-dozen countries have contributed to the lander and its instrument suite. Although the lander mass is about 100 kg (220 pounds), its effective weight on the comet will only be about the weight of a sheet of paper on Earth. So the lander has a combination of ice screws on its feet and harpoons that will shoot out on contact to secure the lander to the comet's surface. The lander instruments will spend a busy several days of lab work drilling into the surface, taking samples, testing the surface's physical properties, and analyzing nearby gases.

One instrument shares a spot on both the orbiter and the lander: the Comet Nucleus Sounding Experiment by Radiowave Transmission (CONSERT) instrument. When the lander and orbiter are on opposite sides of the comet, the orbiter's CONSERT instrument will send radio signals to its counterpart on the lander. By analyzing the returned signal and how the radio waves are reflected and scattered back as they travel through the comet, scientists will be able to study the interior of C-G's nucleus.

A Long-term Relationship

One thing you learn working on Rosetta is patience, and not just the patience of waiting for the post-hibernation

ESA / ANNEKE LE FLOC'H

Engineers check the deployment of one of Rosetta's wings. Each wing is made up of five hinged panels, and together the two wings span 32 meters.

ESA / STEPHANE CORVAJA

Surrounded by four 100-meter lightning towers, the first Ariane 5G+ vehicle waits on the launch platform at the Guiana Space Centre, Europe's spaceport. Rosetta launched from here in 2004 and is now about to rendezvous with its comet.

signal (though every minute felt like another year). It was more than a decade from when the mission was first approved by ESA in 1993 to when it launched in 2004. The craft has spent another 10 years in flight as we've waited for it to reach its prime target, Comet C-G, this August. There were long periods of waiting punctuated by episodes of frenzied activity, such as when the launch was delayed due to the failure of an Ariane rocket just a few months prior to Rosetta's launch date. The delay caused by the investigation prevented Rosetta from launching in time to catch its original target, Comet 46P/Wirtanen. The mission's science and operations teams had to scramble to find a new target and trajectory, plus pick different asteroids for science flybys.

Pre-planning for a comet mission is tricky. The target is constantly changing in unpredictable ways as its distance from the Sun changes, so each moment in the mission is unique. We don't know ahead of time when and where jets will sprout up on the nucleus, or even where on the surface we'll find a spot for the lander. Nor do we know for sure how strong the activity will be when Rosetta arrives, so instrument and mission planners need to prepare for multiple scenarios. All of this planning also needs to be negotiated among the many instrument teams, some of which have conflicting preferences, and with the mission operations and flight dynamics teams responsible for the flying and safety of the spacecraft.

We hope that C-G's activity level is still low when Rosetta arrives, so that the spacecraft can get close to the comet to do detailed mapping, select a landing site, and deploy Philae safely. The activity level will increase substantially as C-G approaches perihelion in August 2015. At that point, the nucleus will be spewing out about 4×10^{26} (low-activity case) to 1×10^{28} (high-activity case) water molecules per second, which is about 30 to 80 gallons of water per second. For comparison, when the instrument teams first try to detect water and carbon monoxide activity in July 2014 (when the spacecraft is still more than 10,000 km from the comet), the production rates are predicted to be a factor of 100 to 10,000 lower. That is like trying to detect the evaporation of a thimbleful of water each second from somewhere on the other side of Earth (assuming Earth wasn't in the way).

The advantage of Rosetta is that we'll be able to watch and measure that activity over the course of the comet's orbit. The mission will spend an unprecedented amount of time close to C-G, studying how its activity turns on, how much of the surface is active or if that activity is primarily from discrete jets, how the nucleus interacts with the "collisional region" (the inner part of the coma where the gas density is high enough for collisions between atoms and molecules), and how all of that forms and

This illustration depicts the Philae lander at work on Comet 67P/Churyumov-Gerasimenko. Immediately after touchdown in November 2014, the lander will fire a harpoon to anchor itself and prevent it from escaping the comet's extremely weak gravity. The minimum targeted mission time for Philae is one week, but surface operations might continue for many months.

ESA / AOES MEDIALAB

drives the coma and tail.

That advantage is also the difficulty of the mission — to design a spacecraft and instruments that can live so long in a dirty environment of water, gas, dust, and even possibly snowballs and pebbles. Not only does the hardware need to survive, but the onslaught also makes it difficult to fly. The comet's gravity is so weak that the outward push of the gas and dust on the spacecraft, particularly against the large surface area of the solar panels, quickly will make it impossible to continue orbiting the comet. Depending on C-G's activity level, Rosetta might only have a few months in which to orbit the comet at distances less than 50 km. The rest of the mission can be better described as Rosetta "escorting" the comet, flying back and forth at distances farther than 70 km with occasional close, dive-bombing flybys down to maybe 10 km. A comet's coma can extend out to hundreds of thousands of kilometers, so the spacecraft should still be inside the coma even when keeping the nucleus at arm's length. But as in any dance, Rosetta will have to continuously adapt to its partner in order to have a successful, many-months tango with C-G.

What Can We Learn from One Comet?

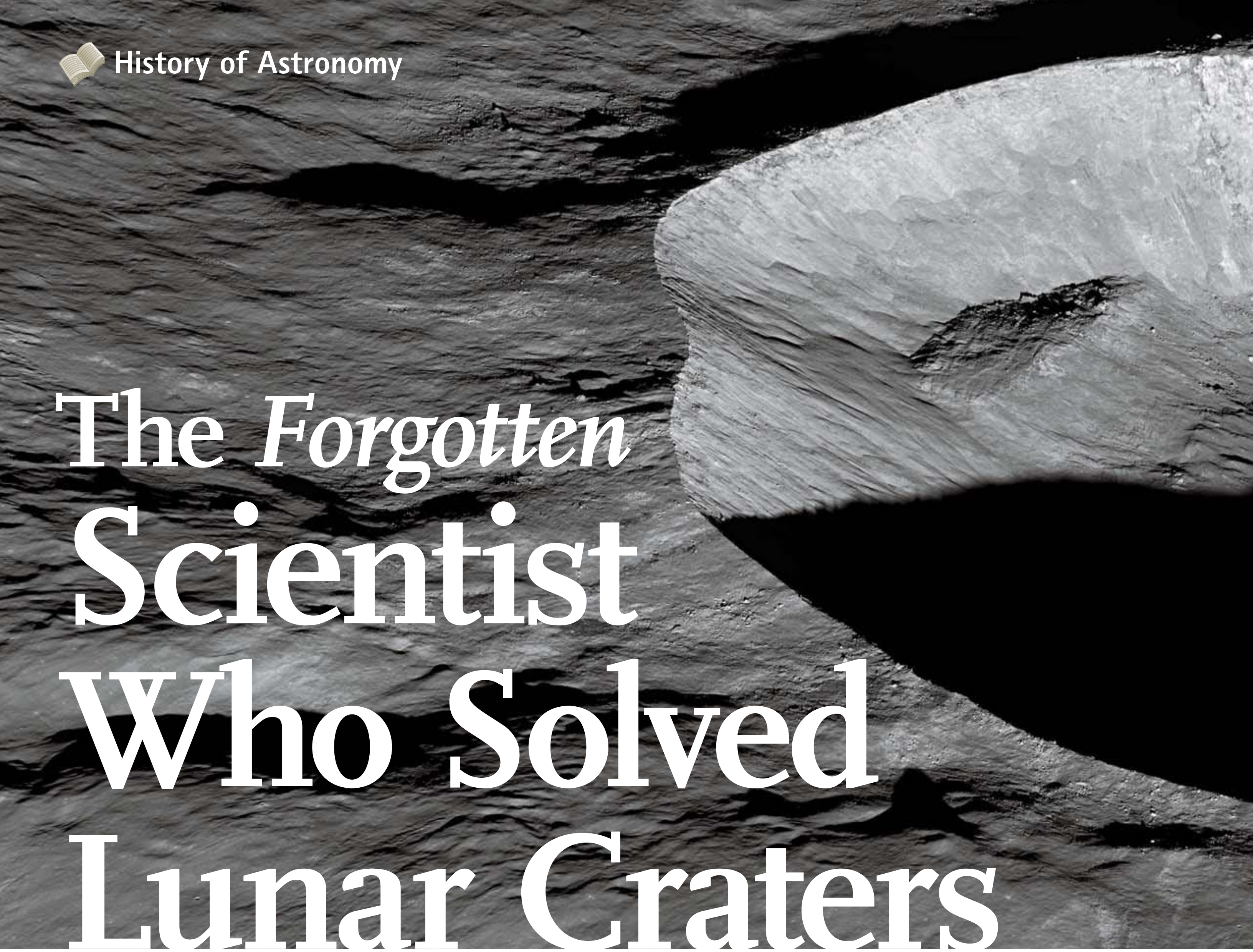
Comet C-G is a Jupiter-family comet, meaning that its orbit is "controlled" mostly by Jupiter. It has an aphelion of 5.7 a.u. and a perihelion of 1.2 a.u. The incident solar energy changes by a factor of 23 during an orbit. That change in solar heating is what drives the activity.

C-G has a short orbital period of about 6.5 years and a rotation period of about 12.4 hours. From Earth-based observations of C-G's light curve, we have an estimated model of the nucleus's shape, which is somewhat irregular with an effective diameter of about 4 to 5 km.

Comets interest space scientists in many fields because they are relics, the leftover flotsam and jetsam from the solar system's birth. They may represent some of the most unprocessed material from 4.5 billion years ago, when the planets formed. Having said that, comets are not *completely* unprocessed. Any comet that has made several passes by the Sun — and that includes these short-period, Jupiter-family comets — will already have experienced some modification of its structure and physical makeup by solar heating during previous passes. So the trick is to disentangle the relative chemical abundances that are due to the original composition from those that are due to changes from past heating episodes. That's why it is necessary to have many instruments, so that we can study the interior, surface, gas, and dust and parse the clues of the comet's origin from its evolution.

C-G is just one example, but we'll be able to compare what we learn from it with what we have seen during the other, briefer visits we have made to comets. The Rosetta mission will enable us to "translate" comets — much as scholars used its namesake, the Rosetta Stone, to decipher ancient Egyptian hieroglyphics. What we learn from C-G will help us understand the connection between what is happening on the small scale of the nucleus and the large scale of the coma and tail, the latter two of which are all we can observe from Earth. This knowledge will be a powerful key in unlocking Earth-based observations of other comets past, present, and future. ✦

***Joel Parker** is a director at the Southwest Research Institute and the host and producer of the radio science show "How on Earth." He has been a project manager and science team member on several space missions, including LRO and New Horizons, and is the deputy PI on the Rosetta-Alice project.*



The *Forgotten* Scientist Who Solved Lunar Craters

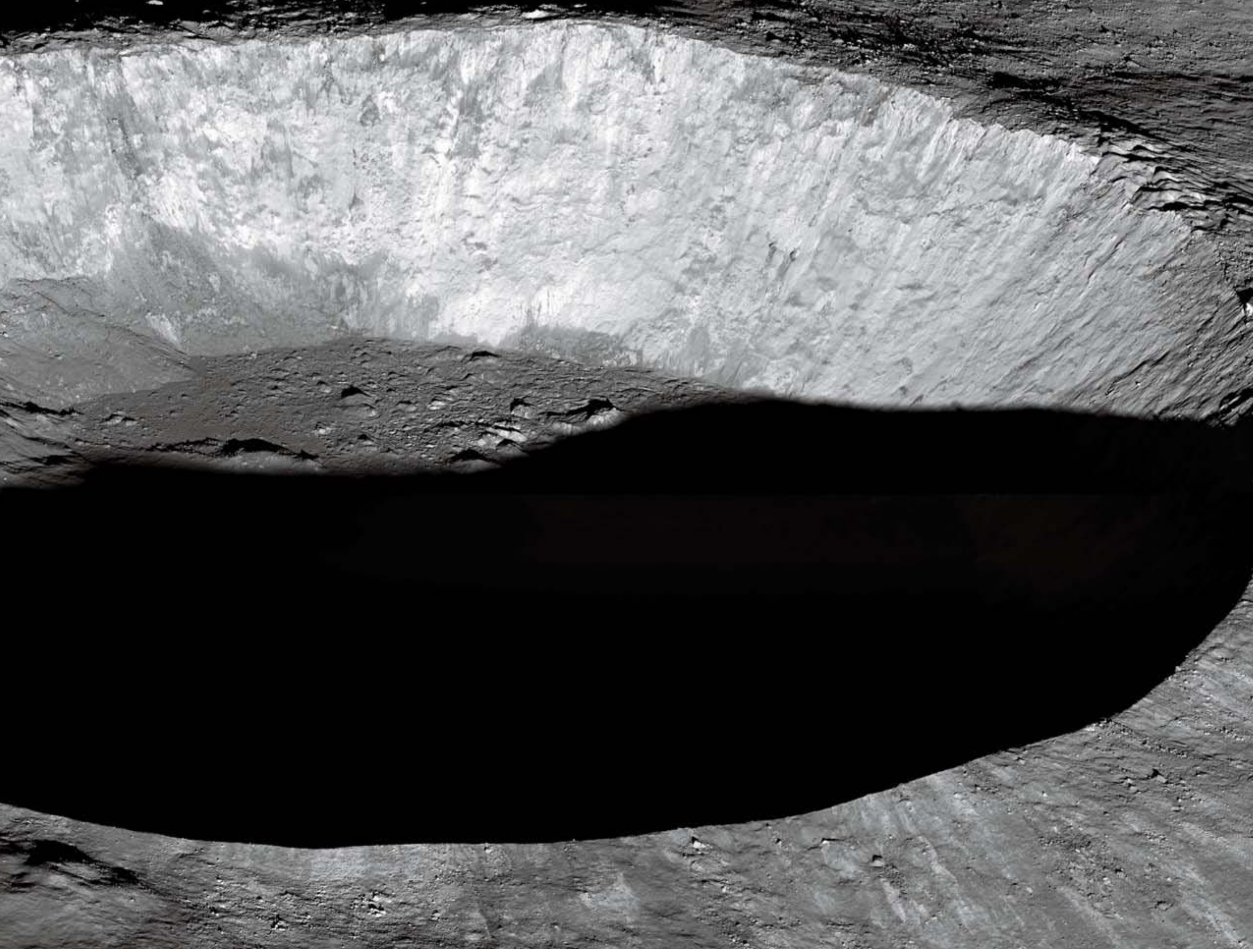
By studying World War I battlefields, Charles Gifford developed the theory that lunar craters were formed by impacts.

William Sheehan

THIS AUGUST MARKS the centennial of the outbreak of World War I. At the time, astronomers were still debating the origin of the Moon's craters, but most thought they were volcanic rather than impact features. In part, this was because no examples of comparable features formed by impact on Earth were definitively known. Even Coon Butte in Arizona had been declared a *maar*, a volcanic feature produced by a steam explosion, by the great Grove Karl Gilbert of the U.S. Geological Survey.

But not everyone agreed. In particular, Harvard-trained mining geologist Daniel Moreau Barringer presented convincing evidence by 1909 that it had been formed by a meteorite impact. He was eventually vindicated, and Meteor Crater remains the first-established and best-known meteorite-impact feature on Earth.

There was one primary objection to the meteorite-impact theory for lunar craters, which had been proposed by a number of investigators since the early 19th century.



NASA / GSFC / ARIZONA STATE UNIVERSITY

CIRCULAR CRATER Like most of its brethren, the lunar crater Giordano Bruno, pictured here in an image from NASA's Lunar Reconnaissance Orbiter, has a nearly circular shape. For many decades, scientists thought lunar craters were volcanic in origin because they imagined that impact structures, formed mostly by projectiles arriving at an oblique angle, should be oblong.

It seemed that oblique impacts ought to form elongated craters, whereas almost all the lunar craters are circular in outline.

As this debate was unfolding in the scientific community, the rattling explosions of World War I artillery shells showed by direct example how meteorites might form craters on the Moon. The first scientist to work out the meteorite-impact theory in mathematical detail and explain the predominance of circular craters was Algernon Charles Gifford of Wellington College in New Zealand — who did so shortly after the war. Indeed, many of Gifford's students fought for the Empire, serving with distinction on the Gallipoli Peninsula in 1915 and in Flanders and the Somme in 1916. No Man's Land between the Somme's trenches was saturated with gaping cavities, creating a scene that the British poet Wilfred Owen described as "like the face of the moon, chaotic, crater-ridden, uninhabitable, awful, the abode of madness."

Master of the Moon

Charlie Gifford seemed fated to an adventurous career from the very moment of his birth in 1861, which occurred at sea somewhere off Africa's Cape of Good Hope. His father, 10 years an Anglican curate in Labrador, was en route to a new parish, Waitaki, on the South Island of New Zealand. Young Charlie grew up in the village of Oamaru, receiving his primary education at the local grammar school.

He was sent to England in 1876 to obtain a solid British education, and won, by virtue of his outstanding math-

ALEXANDER TURNBULL LIBRARY/ NATIONAL LIBRARY OF NEW ZEALAND

MASTER OF THE MOON Algernon Charles Gifford (1861–1948) performed rigorous mathematical analyses after World War I to show that lunar craters formed by meteorite impacts. Unfortunately, being a resident of New Zealand worked against him. He published in an obscure New Zealand science journal, and never received the credit he deserved.

ematical ability, a scholarship to St. John's College, Cambridge. In the rigorous Cambridge mathematics tripos in 1883, he received the prestigious John Herschel Prize for mathematical astronomy. He could have remained in England, but he was homesick for the beautiful mountains and fjords of New Zealand's South Island, and instead opted for an appointment as teacher of mathematics at the new Boys' School in Oamaru. Five years later he moved on to a higher-paying position at Christ's College in Christchurch.

An overworked headmaster dismissed Gifford, scapegoating him for the school's shortcomings in mathematics and science. Gifford drifted for a while. For a time he tried his hand at selling photographs of New Zealand landscapes, but there was no demand! Finally, in 1895, he was hired at Wellington College, on New Zealand's North Island, and began a teaching career that would last 32 years, becoming a beloved figure known by his students as "Uncle Charlie." As one of them recalled, "Anyone who has read *Goodbye Mr. Chips* will know Mr. Gifford."

Meanwhile, he had become a disciple of another magnetic personality, Alexander William Bickerton, 19 years his senior. From their first meeting in Christchurch in the 1890s until the latter's death in 1929, the two men engaged in voluminous correspondence, much of it concerned with the "Partial Impact Theory," an eccentric notion hardly remembered today but the seed from which Gifford would develop a coherent theory of the impact process.

Bicky

Alexander Bickerton, often referred to affectionately as "Bicky," was a native of Alton, Hampshire (England). He was not at first a promising student. One of his teachers at the grammar school — trying to be positive — agreed that he was "not a complete idiot." After various attempts to make a living, including setting up a woodworking factory in England's Cotswolds using machinery of his own invention, Bicky began attending night classes in science at age 21. He had discovered his niche. After winning a Royal Exhibition Scholarship to the Royal School of Mines in London, he started to present his own night classes in science. But his first well-advertised lecture drew an audience of precisely one!

Ever the empiricist, he made a point of attending the services of noted religious preachers to learn their techniques. His conclusion: "To instruct a Londoner the lecture must be made as entertaining as a music hall and as sensational as a circus." As physics and chemistry teachers ever since have found, "explosions and loud bangs were most effective in keeping students awake, in retaining their interest, and in increasing attendance." Before long, Bicky was attracting large audiences, and was widely known as "Fireworks."

Summoned to New Zealand in 1874 to be professor of chemistry at Canterbury College (the precursor of the University of Canterbury in Christchurch), he continued his dramatic demonstrations, and gave popular lectures that commanded large fees. Two years later, his attention was riveted by a bright nova in Cygnus. Nova Cygni 1876 followed the usual trajectory and faded to obscurity (it is now known as Q Cygni, and remains visible as a 15th-magnitude object except during its occasional flare-ups). Bicky had a flash of insight and conjectured that a partial grazing collision of two dark stars had produced the nova. Thus he unveiled his "partial impact theory," giving a paper, "On Temporary and Variable Stars," on July 4, 1878, to the Philosophical Institute of Canterbury.

The upshot of his idea was that stars, being distant hot bodies in the process of radiating away their energy, must cool and eventually become dark. Countless dead suns presumably populate the universe. Traveling unseen through space, two of these dark stars, moving at tremendous speed, must sometimes collide, usually in glancing blows. On impact, material would be torn from each body. Part of the collision's kinetic energy would heat this torn-off material, producing the nova. As it cooled, the nova would darken then disappear forever.

The idea was reasonable, if quirky. Bicky soon began to extend it to explain numerous other heavenly phenomena — variable stars, double and multiple stars, planetary nebulae, even occasional bright flashes seen on Mars. He

CHARLES CHILTON PHOTOGRAPHS / MACMILLAN BROWN LIBRARY / UNIVERSITY OF CANTERBURY

BICKY Alexander William Bickerton (1842–1929), known as "Bicky" to his friends, was an imaginative thinker who served as a mentor to Gifford. Although Bicky had the right ideas about the formation of lunar craters, he lacked the mathematical training to turn them into a publishable theory.

LOCHNAGAR CRATER MEMORIAL

TERRESTRIAL ANALOG **Lochnagar Crater in northern France, the largest crater formed in World War I, was produced on July 1, 1916 by a massive British mine explosion detonated in the Battle of the Somme during an Allied attempt to break through German lines. The Germans repulsed the attack. The crater is approximately 300 feet (90 meters) across and 70 feet deep.**

came to believe that the solar system itself was the product of a dark star's encounter with the Sun.

Bicky was a qualitative thinker in a field that demanded rigor, so the scientific establishment closed ranks against him. He submitted 15 letters on the partial impact theory to the leading scientific journal *Nature* — all were rejected. Meanwhile, he was becoming engaged in a bitter and protracted row with Canterbury College's Board of Governors. One of his supposed offenses was that he, as a professor of chemistry, was spending too much time on astronomy. By 1902 he had been summarily dismissed from his post.

For a time he tried to make a living by operating a theme park in a Christchurch suburb. In 1910 he left his wife and children behind and moved back to England to try to campaign for his partial impact theory, hoping to gain the assistance of his most famous pupil, Ernest Rutherford, the recent recipient of a Nobel Prize in chemistry. Rutherford always spoke gratefully of his one-time teacher, and made some encouraging noises about the partial impact theory; but his endorsement had little influence because he was not an astronomer.

Fortunately, Bicky had a more dedicated champion: Gifford. Gifford was an independent thinker with a penchant for unorthodox causes. For example, he was an amateur Shakespearean who insisted to the bitter end that Francis Bacon was the true author of Shakespeare's plays. But Gifford was not a crank, and Bicky's partial impact theory became, and would remain, Gifford's ruling passion. Most importantly, Gifford was something Bicky was not: an outstanding mathematician who could subject his mentor's "hunches" to rigorous mathematical analysis.

Gifford's serious work on developing the impact theory began with an insight Bicky presented at a June 1915 meeting in London of the British Astronomical Association (B.A.A.). The origin of lunar craters was being discussed, with the usual arguments being trotted out that the craters must, if produced by impacts, be predominantly elongated in form. Bicky, now 73, slowly rose to his feet and pointed out that the energy of infalling meteorites ought to produce "a pretty fair bang." "The normal speed of a meteor in space," he supposed, ". . . would produce an explosive action . . . consequently [even] oblique impacts would produce roughly circular volcanic rings." Trying to have his cake and eat it too, he argued that the meteorite's energy would heat the lunar crust and cause an outpouring of lava onto the surface.

The Experience of the Somme

By the time Bicky spoke to the B.A.A., the war had been grinding on for nearly a year. A year hence, on July 1, 1916, the massive bloodbath known as the Battle of the Somme got underway. In an attempt to terrorize and throw their German adversaries into disarray, the Royal Engineers set off a huge mine at Lochnagar, south of the village of La Boisselle. Loaded with 24 tons of ammonal, the mine was scheduled to be ignited at 7:28 a.m., two minutes before

METEOR CRATER At the beginning of the 20th century, most scientists thought that Arizona's Meteor Crater (known then as Coon Butte) was a volcanic structure. Detailed work by Algernon Charles Gifford, Daniel Moreau Barringer, Ernst J. Öpik, Ralph Baldwin, Eugene Shoemaker, and other scientists showed how craters such as this one were formed explosively by infalling meteorites.

BIGSTOCK PHOTO: ACTIONSPORTS

the main attack was to begin. But due to confusion on the Allied side, the attack didn't actually get underway for another two hours. The blast made a noise said to have been heard as far away as London, and was witnessed from the air by 2nd Lieutenant Cecil Arthur Lewis of the Royal Flying Corps' No. 3 Squadron, who gave the following description:

> The whole earth heaved and flashed, and a tremendous and magnificent column [of smoke] rose up in the sky. . . It hung . . . in the air, like the silhouette of some great Cyprus tree, then fell away in a widening cone of dust and debris.

When the dust settled, a crater very much like those on the Moon, measuring 300 feet across and 70 feet deep, scarred the landscape. It was the largest man-made crater produced during World War I, though a mere pinprick by lunar standards. The experience of the Somme's scarred battlefields — where shells produced saturation cratering in No-Man's Land — gradually inspired new thinking about the features on Earth's satellite. Gigantic craters such as Lochnagar were particularly influential.

Also in 1916, Estonian astronomer Ernst J. Öpik realized that a meteorite crashing into the Moon would be sufficient by itself to excavate a circular crater even without the help of volcanic forces. Three years later, American physicist Herbert Eugene Ives concluded, after studying craters formed by aerial bombs in tests at Langley Field, Virginia, that these manmade features closely resembled those on the Moon.

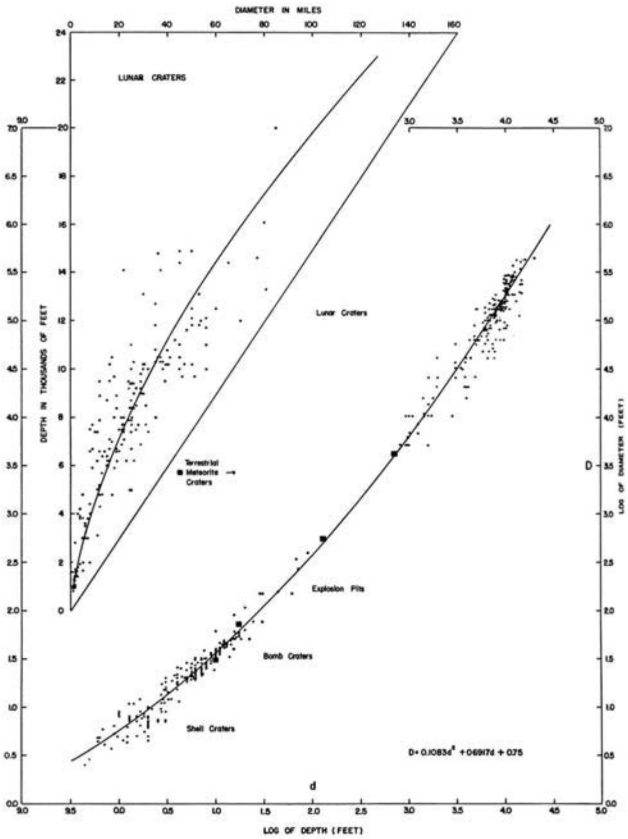
Unaware of their work, Gifford, in the splendid isolation of New Zealand, worked on, trying to determine mathematically the consequences of Bicky's "pretty fair bang." In the early 1920s he arrived at the answer. As one of his math pupils at Wellington College remembered, during one of Gifford's lectures,

> a dry beginning . . . changed into forty minutes of wide-eyed interest and learning illustrated by full width chalkboard drawings of a meteor of certain mass, velocity, and approach angle, causing the release of energy, a nearly round crater, and the trajectory and mass of the exploded moon material showing formation of the rim and central pip, all supported by detailed calculations.

The student was recalling a preview of the classic paper Gifford published in the September 1924 *New Zealand Journal of Science and Technology*, where it was guaranteed to have virtually no impact whatever. There he compared the energies of various explosives used during the war with those of meteorites moving at various velocities, and deftly showed that "when a meteorite strikes a surface with a velocity of many miles per second it becomes an explosive compared with whose violence that of dynamite is insignificant.” He demonstrated this by the following table:

Energy of explosives in Calories per gram	
Tri-nitro-toluene (T.N.T.)	924
Dynamite	1,100
Nitroglycerin	1,478
Energy per gram of a meteorite moving with a velocity of 1 mile per second	310
3 "	2,779
5 "	7,745
10 "	30,980
20 "	123,900
40 "	494,700

From an analysis of meteor shower orbits as well as the few cases of authenticated observed meteorite falls to date, he showed that cosmic velocities in the range of 10 to 45 miles per second (16 to 72 km per second) would hardly be exceptional. What would result from the impact of a meteorite moving with such velocity on the lunar surface? Regardless of the impact angle, the resulting explosion would form a circular crater. Furthermore, Gifford derived profiles for lunar craters such as Copernicus and Theophilus — and even accounted for the existence of their central peaks.



UNIVERSITY OF CHICAGO PRESS

TELLTALE GRAPH Drawing upon data on bomb craters and explosion pits from World War II, Ralph Baldwin produced this graph showing empirically the relationship between diameter and depth of terrestrial explosion craters, meteoritic craters, and lunar craters that Gifford had surmised from his 1924 calculations. Adapted from Baldwin’s *The Face of the Moon*, 1949, page 132.

PAUL MOSS / WIKIMEDIA COMMONS

THE LEGACY CONTINUES The Gifford Observatory on Mount Victoria, near Wellington, N.Z., was named after the astronomer whose work anticipated later research proving the impact origin of lunar craters. The Gifford Observatory Trust and Wellington Astronomical Society operate the observatory, which is frequently used by students. Its largest telescope is a 130-mm Zeiss refractor.

After retiring from teaching, Gifford lived on in idyllic retirement at Silverstream, outside Wellington, until his death in 1948 at age 86. Only a year later, American planetary scientist Ralph Baldwin published his classic account of lunar impact theory, *The Face of the Moon*. Drawing on the experience of World War II and hitherto censored U.S. Army and Navy data on the diameters and depths of craters taken from the firing records of hundreds of shells, Baldwin showed that the profiles of these manmade craters fitted precisely on a line with those of lunar features. Finally, in the 1950s, Eugene M. Shoemaker of the U.S. Geological Survey definitively showed, from his studies of atomic bomb test craters and of the geological structure of Meteor Crater, that lunar craters were impact features.

Although Shoemaker deserves to be remembered as the founder of the modern paradigm for the impact features on the Moon and other solar system bodies, it detracts nothing from him to remember, in this centennial of the onset of the Great War, that the key result — the explosive nature of the impact — was first worked out in detail by Charlie Gifford of New Zealand. ✦

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*Contributing editor **William Sheehan** spent a delightful year, 1999–2000, working in beautiful Aeoteoroa (New Zealand), while filling the margins of his time observing Southern stars and researching the contributions of “Uncle Charlie.”*

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Toddlers at the Telescope

Alice Altair Enevoldsen

Have some fun engaging with children ages 5 and younger at your next star party with some tools and tips in hand.

ONE OF MY EARLIEST memories is of watching a lunar eclipse with my father. I must have been about 2 or 3 because I was wearing my favorite yellow pajamas under my coat. Despite that experience, when I first hosted star parties as an adult astronomer I used to feel that children under the age of 6 or 7 rarely gained much out of the experience, mostly because they did not understand how to use a telescope. Often these youngsters pretended to see something through the telescope even when their eye was clearly not aligned with the eyepiece. I have met many amateur astronomers who have faced similar challenges with very young children at star parties.

Yet we should not discount this young audience. Preschooler and toddler brains are growing fast and are

 

BUILDING SKILLS ***Left:*** **This 3-year-old knocked the telescope off of its target when he leaned on the eyepiece in his enthusiasm. The author simply re-aimed the optics. Setting the tripod to its widest setting prevented the whole telescope from toppling over.** ***Right:*** **Binoculars can make the best first telescopes. Young children often can't close one eye to look through a telescope, so observing with binoculars may be easier and more comfortable, in addition to providing a wide field of view.**

primed for scientific observation, pattern matching, and amazement. It's a joy to watch them discover new things — and so many things are new to them. Viewing objects through a telescope is a skill they can learn.

At Pacific Science Center in Seattle, Washington, we have been working to include all ages in our planetarium, so we designed a show tailored specifically to preschoolers. A couple of years ago, I began tackling the idea of bringing those methods out to star parties. With some toilet-paper tubes and a little patience, I have had immense success. I would like to share the tools and tips I have learned that will help you create early stargazing memories with your youngest guests and their families.

But before I begin, there are some key points I should mention about working with 2- to 5-year-olds. First, kids this age have limited attention spans. They can change focus as quickly as every few minutes or become engrossed in a particularly interesting activity for up to half an hour. They move and wiggle all the time. Toddlers especially are just learning how to move their bodies and manipulate objects, and they have tons of energy.

So let's talk about expectations: what knowledge or skills do you want to pass on? Rote learning is important, but it's not the same as understanding. At this age, learning to look through a telescope or asking questions while looking up at the sky is much more important than, say, naming all the planets. Even learning to climb the ladder to your telescope (with parental supervision) might be the most important skill your youngest stargazers can practice. Most important is that even the youngest children have enough fun at the star party to want to come back, because that means they *will* come back.

Tools of the Trade

Adding a few gadgets to your observing kit will help you engage the toddlers and preschoolers who attend your star parties, as well as teach them to truly see objects through the telescope.

Tool #1: Toilet-paper tubes. For youngsters, one of the most difficult parts of using a telescope is realizing that they need to look *through* the eyepiece rather than *at* the eyepiece. A toilet-paper tube can solve this instantly. Hand a child a pair of toilet-paper-tube binoculars or a paper-towel tube and they will probably peer through it before you can even tell them what to do. Point out some things for them to observe through the paper telescope. They can be stars, trees, their parents' faces — anything at all. This simple act helps them expect to look through a telescope eyepiece without ever being told how.

Tool #2: A good eyepiece. The second most useful tool I have used with young children is an eyepiece with a wide apparent field of view and the best eye relief I can afford. I recommend eyepieces with an apparent field of view (AFOV) greater than 60° and eye relief that is greater than 12 or 13 mm.

We use three eyepieces: a 40-mm eyepiece with a 68° AFOV and 14-mm eye relief, a 25-mm eyepiece with a 72° AFOV and 24-mm eye relief, and a 28-mm Plössl with a 45° AFOV and 24-mm eye relief. The Plössl's eye relief compensates for its narrower AFOV.

The first two eyepieces have 2-inch barrels. If you plan to do a lot of public viewings, it is worth upgrading to the 2-inch barrels, but otherwise pick the largest AFOV eyepiece you have on hand. The combination of good AFOV and eye relief makes it easier for children to catch

HOLDING HANDS **The author gives this boy something to grasp other than the telescope body or lens. For young children, holding hands has the added benefit of aiding balance.**

GENTLE TOUCH A preschool-age girl takes her turn at the telescope.

a glimpse through the eyepiece even when they are not lined up exactly right.

Tool #3: A step stool. You probably have this already for those times when your eyepiece is in an inconvenient orientation, but you will need it for your younger viewers as well. Parents or caregivers should always assist children when using step stools and ladders.

Tool #4: Books, balls, and other physical toys. Alternative activities that fit the evening's theme will be important for young children with short attention spans. Depending on your lighting conditions, a stack of good astronomy picture books is perfect to have on the side to fill waiting time or enable a change of focus. If it's too dark, bring glow-in-the-dark or tactile activities.

Tool #5: A pair of binoculars. Since young kids are not necessarily able to close one eye, they might find looking through binoculars easier. Most binoculars designed for children do not have clear enough optics for stargazing, but the GeoSafari Jr. Kidnoculars from Educational Insights work impressively well for being so lightweight.

Tool #6: A small telescope. Since the children are not allowed to touch the big telescope, they will love having a (relatively childproof) option that they can use by themselves, even if they are not entirely successful. The Edmund Scientific Astroscan is a good candidate, as is the Orion StarBlast 4.5 Astro Reflector.

Tips for Success

Some specific advice will help you work effectively with children younger than 5 years old.

Tip #1: Teach telescope use as a skill. You can start the process with the toilet-paper tube then continue by demonstrating how to look through a telescope. Look through it yourself and narrate what you are doing. Emphasize recommendations and techniques you are using, such as what you can do with your hands while looking through the telescope.

Tip #2: Tell children what they *can* do. Give children positive alternatives to grabbing equipment such as, "You can clasp your hands together" or "You may hold onto the ladder." Negative commands such as "Don't touch the telescope" or "Keep your hands off the eyepiece" unintentionally plant those very ideas in their heads. "Don't think about a blue teddy bear." See? You're probably thinking about a blue teddy bear.

Tip #3: Look at bright objects. Begin with the Moon or a simple first-magnitude star even if you feel these targets are too bright or uninteresting. For a child's first view through a telescope, picking a target that is easy to notice is better than aiming for one that is astronomically fascinating. See the box on page 37 for some late-summer observing suggestions.

THE RIGHT EQUIPMENT *Left:* Place a relatively childproof telescope where children can do their best to manipulate it on their own. Here, a 3-year-old catches a glimpse through an Edmund Scientific Astroscan, where the eyepiece has a wide apparent field of view and long eye relief. *Above:* Many kid-friendly binoculars don't have clear enough optics for stargazing, but one good option is GeoSafari Jr. Kidnoculars (right).

RAM WHITE

ANELA RAMOS

ASTRONOMICAL SOCIETY OF THE PACIFIC / PABLO

DAYTIME OBSERVING Some celestial events seem to be made for young children's participation. *Top:* A group of preschoolers gathers around a solar telescope for some daytime observing. *Bottom left:* A young boy enjoys watching the annular eclipse of May 2012 from Point Reyes, California. *Bottom right:* Another boy views the June 2012 transit of Venus from Berkeley, California.

Tip #4: Don't worry about both eyes being open. Young children may not yet have the ability to close one eye while keeping the other open. If necessary, have the parent or caregiver cover the other eye while the child looks through the telescope.

Tip #5: Make a wide variety of activities available. To address short attention spans, set up stations and let the kids take breaks when they start squirming. They will come back to you when they are ready for more. You may occasionally need to remind parents to let their young children unwind for a few minutes and play with something else for a while.

Tip #6: Ask the right questions. Next time you're out at a star party, listen to yourself ask questions. There are many types of questions, but I'm willing to bet that you will ask, "Do you see ___?" the most. I know, because I ask this question all the time. The problem is that the answer is either yes or no, which does not prompt further conversation or thought. "What do you see?" requires a more complex answer. Asking, "What color is it?" (an easier question to answer) gives you additional information about whether your observer is looking at the object that you are expecting him or her to notice.

Tip #7: Don't shy away from long words. Toddlers understand much more than we think they do, even if they aren't speaking much yet. Their vocabularies are constantly expanding, and they love to learn new words. So go ahead and use the big words — just be sure to explain them or use them in sentences that are self-explanatory. If you are looking at the Moon, you can call it a crescent, or you can ask the children what shape they see. If they say, "It's a banana Moon," you might reply, "Yup, that banana shape is a crescent." This response uses the correct vocabulary while honoring the accuracy of the child's original statement.

Tip #8: Focus their energy to your advantage. Tell squirmy kids, "Go run in a big circle, *an orbit*, around the telescopes!" Ta-da, they burn some energy, you get a second to talk to the adults, and you have introduced a key vocabulary term in a way that incorporates kinesthetic learning. That's grant-fundable education-speak right there with all those buzzwords!

Tip #9: Choose the date carefully. Winter nights are often too cold and summer nights too late for young children. Fall and spring are better times of year. Aim for the Sun to set about an hour before bedtime, remembering that twilight can be plenty dark to see the Moon and the first stars. Tell parents to be prepared for the temperature drop that comes as night sets in: mittens and hats may be warranted for kids even if the day was warm.

If you are interested in engaging with toddlers and preschoolers at star parties, try out these suggestions and get those kids observing. You will soon see how rewarding this age group can be. ✦

READY TO TAKE THE KIDS OUT TONIGHT?

Here are some of my favorite late-summer targets:

The waxing Moon provides easy visibility in the evening for the early-bedtime crowd. August 2014 will have the Moon in the evening sky (i.e., before 9 pm) until August 11th, and then again from approximately August 27th until September 10th.

You'll also find bright Saturn and Mars gracing August's evening skies. They are appealing targets because their names might already be familiar to young children.

If the kids are ready to look at dimmer objects, try aiming for Albireo in Cygnus or the Double Cluster in Perseus. Both of these targets will show different types of stars in the same field of view.

Alice Altair Enevoldsen is Pacific Science Center's planetarium supervisor and the author behind Alice's AstroInfo online and the Skies over West Seattle articles in the West Seattle Blog. She tweets as **@AlicesAstroInfo** *and does volunteer outreach as one of NASA's Solar System Ambassadors.*

HOW TO Clean Your Optics

GARY SERONIK

Keeping your telescope and eyepieces in tip-top condition doesn't have to be intimidating or time consuming.

The delivery truck has just pulled away leaving you with a big cardboard box containing your brand new telescope. A few minutes later, the scope is unpacked and you marvel at the sight of factory-fresh, pristine optics — mirrors, lenses, or a combination of both. Enjoy it. Chances are your optics will never be this clean again.

If that thought fills you with worry and consternation, don't let it. Consider these basic facts. A little dust has virtually zero impact on the views your telescope will deliver. And even if your efforts to clean the optics won't restore them to factory-fresh condition, with a little care and effort, you can get pretty darn close.

To Clean or Not To Clean

When you're taking care of telescope optics, it pays to follow the medical dictum: first, do no harm. A cautious approach is warranted. A mirror or lens that has dust on it can always be cleaned, but one that gets scratched through overzealous attention is damaged for keeps. Thus, the most important step in the cleaning process is deciding if it's really time to take action. How will you know? If you look at your optics and aren't sure, it's not yet time. Here's why.

Dust and smudges on your telescope's optics are bad mainly because they absorb and scatter light, reducing contrast and making the resulting images dimmer. How bad things can get really depends on how much dust we're talking about. But even if so much crud accumulates on your optics that only 50% of the incoming light makes it through to the eyepiece, you're only losing ½ magnitude of brightness. In other words, your 10-inch reflector will work like a 7-inch. That's not good, but it's not exactly catastrophic either. And your optics need to be quite dirty to suffer that much light loss. Usually when things are bad enough that you feel like you need to clean your telescope's objective, you're in the 20% or less light-loss range.

Another important consideration is the material we're trying to clean. Most glass is pretty hard stuff — just ask anyone who has ground a telescope mirror. It takes serious effort with silicon-carbide abrasive to grind away a significant amount of glass. Unfortunately, what we're really trying to clean most of the time is a relatively fragile coating deposited on the surface of the glass. This is true whether we're talking about a reflector's mirror, a refractor's objective, or the corrector plate of a Maksutov or Schmidt-Cassegrain telescope.

Regardless, cleaning optics is a two-step process. First, we remove the loose dust and debris, and then we use some kind of solvent to take care of the more stubborn material. If you've decided it's time to clean your optics, let's roll up our sleeves and get started.

For many telescope mirrors, a simple running-water rinse described in the accompanying text is all that's needed to keep them clean. All images are courtesy of the author.

Telescope Mirrors

Among common telescope designs, the primary mirror in a Newtonian reflector requires the most involved cleaning job because it's usually not readily accessible. But there's also a substantial benefit of the Newtonian design, and that is once you've removed the optics from the tube assembly, the cleaning task is very easy. In most cases you'll only have to undo a few screws to liberate the

After rinsing, most of the water will naturally slide off the mirror's surface when it's stood on edge, but you can remove any remaining droplets with puffs of air from a rubber dusting bulb.

For removing stubborn grime after the initial running-water rinse, you can lightly drag pure cotton balls soaked in a highly diluted solution of dishwashing liquid across the mirror's surface. This should be followed by another rinse and drying of the mirror's surface.

primary-mirror cell from the tube, and then a few more screws to remove the mirror from the cell. There are too many variations to give specific instructions here, but if you take care to note which screws come from where (using a digital camera to record step-by-step photos is a big help), you should do fine.

Before you begin the cleaning process, take a moment to remove any rings or other jewelry you may be wearing.

Although not for everyone, the author's preferred method for removing stubborn dirt involves substituting soapy fingertips for cotton balls. The process relies on the incredible sensitivity of human touch to avoid damaging optical surfaces.

There's no point in risking a scratch that can be avoided with a little preparation. Next, lay a clean, folded towel in a sink and place the mirror on it with the reflective surface facing up. Aim the faucet at the surface of the primary and run warm (not hot) water over its entire face. If you can direct the stream at the mirror's center, you'll get a nice flow radiating outward over the entire mirror. This will wash away all the loose dirt and dust particles. After five minutes or so, turn off the tap. If you live in a location with especially hard water, it's a good idea to give the mirror a quick, final rinse with distilled water.

Carefully remove the mirror from the sink and place it on its edge on a new towel to let the water run off the mirror's surface. Be very careful not to let your mirror roll away or fall face-first onto the countertop. I find it helpful to chase the last few water droplets off the mirror by blowing them to the edge of the glass with a rubber dusting bulb. If you don't have one handy, you can also wick up these droplets by touching them with the corner of a paper towel.

Once the mirror is dry, carefully inspect it. In many cases this running-water bath is all the washing your mirror will require and you can call the job done. But if the surface still looks a little grubby, it's time to move on to stage two.

Begin by stopping up the sink drain and putting the mirror face up on a folded towel. Fill the sink with warm water until the mirror's reflective surface is completely submerged. Let it soak while you prepare a cleaning solution by mixing a couple of drops of dishwashing liquid (Ivory and Dawn are the brands most often recommended) with a half cup of warm water. Drop a few cotton balls into this solution. Be sure to use pure cotton balls, not ones made of rayon or other synthetic "cotton." Leaving the mirror submerged, take a soapy cotton ball and gently drag it across the surface of the mirror, rolling the cotton as you do.

The idea is to keep fresh cotton continually in contact with the mirror's surface — you don't want to pick up a tiny piece of grit and drag it across the mirror. You'll use a lot of cotton this way, but if you take your time and change the cotton frequently, you'll minimize the risk of creating fine scratches (called sleeks) in the reflective coating. Once you've made your way over the entire mirror, give it a good rinse (again, finishing with distilled water if needed), then dry and inspect as before. Your mirror should now be nice and clean. While you have all your supplies handy, you might as well clean the scope's secondary mirror using the same techniques, but only if it needs it!

Another Way

The method outlined above is tried and true, and it's the one most often described in books and online. But it's not how I clean my mirrors. I prefer an approach that I find is quicker, easier, and often produces better results. Here's how I go about it.

First, I do the full 5-minute, running-water rinse described above. Then I adjust the water stream so that the entire mirror's surface has water flowing over it. For the next cleaning step I use a much stronger concentration of dish soap — 1 part soap to 3 parts water. I dip the fingers of one hand into this cleaning solution, ensuring my fingertips are completely coated. Then, while the water continues to run, I very gently place my fingertips on the center of the mirror and wipe its surface, using a slow, circular motion, spiraling out toward the edge of the mirror. The key to this technique is to not exert any pressure — my fingertips should feel as if they're gliding over the surface of the glass, floating on the stream of flowing water. As soon as I feel my fingers starting to stick to the glass, I recoat them with fresh cleaning solution and continue where I left off. Once I've done the entire mirror, I let the water continue to flow for another five minutes to ensure any residual soap is washed away. I dry the mirror as outlined above.

The beauty of this approach is that it takes advantage of the superb sensitivity of your fingertips — you can feel the tiniest grit particles and react before any harm is done. I also find that this technique works better than the cotton-ball method for getting rid of any buildup of haze that sometimes forms on a mirror's surface with age. That said, this approach isn't for everyone. If touching your mirror makes you nervous, stick with the tried and true.

Corrector Plates and Refractor Lenses

The good news is that if you own a refractor, Maksutov, or Schmidt-Cassegrain, your cleaning task is relatively straightforward because no disassembly is required — only the glass's front surface is exposed to dust and dew, so it's almost always the only one that needs attention. As with mirrors, this is a two-step cleaning process. The first step is to remove all the loose dust with a rubber blower bulb or a camel's hair brush. Take your time and do a thorough job.

Next, it's time to use a cleaning solvent. Everyone seems to have an opinion about which ones are safest and most effective. I, and many others, use regular Windex glass cleaner. I find it works well. Al Nagler of Tele Vue Optics suggests using acetone and lens-cleaning tissues, but only if there is no chance that the acetone will come into contact with any plastic parts or paint.

The key to this process is to never apply the solvent directly to a lens. Instead, I lightly dampen a cotton ball

To clean stubborn material from a refractor's objective, after blowing or brushing the loose dust away, use a pure cotton ball dampened with a cleaning solution. The result (shown on the following page) will be a lens that appears almost as clean as the day it was new.

Cleaning the small lenses in eyepieces is just like cleaning a telescope objective lens, except that cotton swabs rather than cotton balls are used.

with Windex, then slowly and gently wipe from the center of the optic outward with a circular motion, continuously using fresh cotton. I don't need to apply pressure for the cleaning solution to do its work, but I may need to go over the glass a couple of times before it's completely clean. Finally, I fog the glass by breathing on it, and I use a fresh cotton ball to wipe the surface one last time.

Telescopes and eyepieces will deliver a lifetime of first-rate views if cleaning is done carefully and only when necessary.

Sometimes you'll see spots and blemishes that simply won't go away. Chances are these aren't stains, but rather places where the coating has been damaged by acid dew or some other cause. There's nothing you can do about these, just recognize them for what they are and console yourself with the knowledge that they don't affect the view.

Eyepieces and Filters

Eyepieces and filters should receive the same treatment as objective lenses, except that they require more frequent attention because they get handled a lot. Even if you're careful, it's likely that the outermost lenses of your eyepieces will eventually accumulate a coating of eyelash oil. This means that you'll need to use a cleaning solvent once you've blown away or brushed off all the loose dust. The only real difference with cleaning these small surfaces is that you'll use Q-Tip cotton swabs rather than cotton balls. As above, Windex works well, but acetone is an option if you're certain there are no plastic or painted parts in the eyepiece or filter. It's also important to ensure you don't apply liquids directly to the glass — lightly dampen the Q-Tip with the liquid, then gently and slowly wipe the lens, using a circular motion.

Use as little of the cleaning solution as you can and avoid wiping too quickly. If you don't, little droplets of solvent can remain on the glass, and when these evaporate they often form small spots that require additional cleaning. As a final step, fog the lens with your breath, then go over the surface with a clean Q-Tip. If you have a lot of oily build up on your eyepiece, you may have to repeat the process several times before it's completely removed.

Under no circumstances should you ever take an eyepiece apart. If you have an objectionable amount of dust on the interior lenses of an eyepiece, a trip back to the factory is your best bet. Al Nagler tells me that one of the main reasons an eyepiece is returned for servicing is because its owner took it apart and couldn't put it back together properly.

Cleaning optics is just part of the package when you become a telescope owner. Although the process can seem intimidating at first, eventually it will become routine. And this is when you have to exercise the greatest care. Don't become complacent, and make sure you take all the necessary precautions when cleaning your optics. And don't start cleaning them more frequently than necessary because you've become comfortable with the process. If you use the methods described here, and only do so when you really have to, your telescopes and eyepieces should last a lifetime. ✦

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*Contributing editor **Gary Seronik** has been building and cleaning scopes for more than three decades. He authors this magazine's* Telescope Workshop *column and can be contacted through his website: **www.garyseronik.com**.*

In This Section

PHOTOGRAPH: HUNTER WILSON

Messier 20, the Trifid Nebula, is a showpiece for telescopes of all sizes when viewed under dark skies. See page 57 for a sketch.

AUGUST 2014

2 **DUSK:** The waxing crescent Moon floats about 5° to the right of Mars (for North America), as shown on page 48.

3 **DUSK:** The first-quarter Moon lies between Mars and Saturn as seen from Europe and the Americas. Roughly 8 hours later, the Moon occults (hides) Saturn for Australia, where it's August 4th.

10 **THE LARGEST FULL MOON** of the year. The Moon is exactly full at 18:09 Universal Time (UT), when it's shining over Asia. The Moon appears nearly as large and full when it sets around sunrise and rises around sunset in the Americas.

12–13 **LATE NIGHT TO DAWN:** The Perseid Meteor Shower peaks, but the waning gibbous Moon will hide the faintest meteors; see page 52.

18 **DAWN:** Venus and Jupiter are just 0.2° apart around 5h UT, their closest approach in 14 years. They're still well within 0.5° of each other when they rise in the Americas.

23 **DAWN:** The waxing crescent Moon forms an elegant triangle with Venus and Jupiter, as shown on page 49.

23–26 **DUSK:** Mars passes 3½° south of Saturn.

31 **DUSK:** The Moon forms a fairly tight triangle with Mars and Saturn in the Americas. The Moon occults Saturn in west-central Africa.

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

	◀SUNSET	MIDNIGHT	SUNRISE▶
Mercury		Hidden in the Sun's glare all month	
Venus			E
Mars	SW W		
Jupiter		Visible starting August 6	E
Saturn	SW W		

Moon Phases

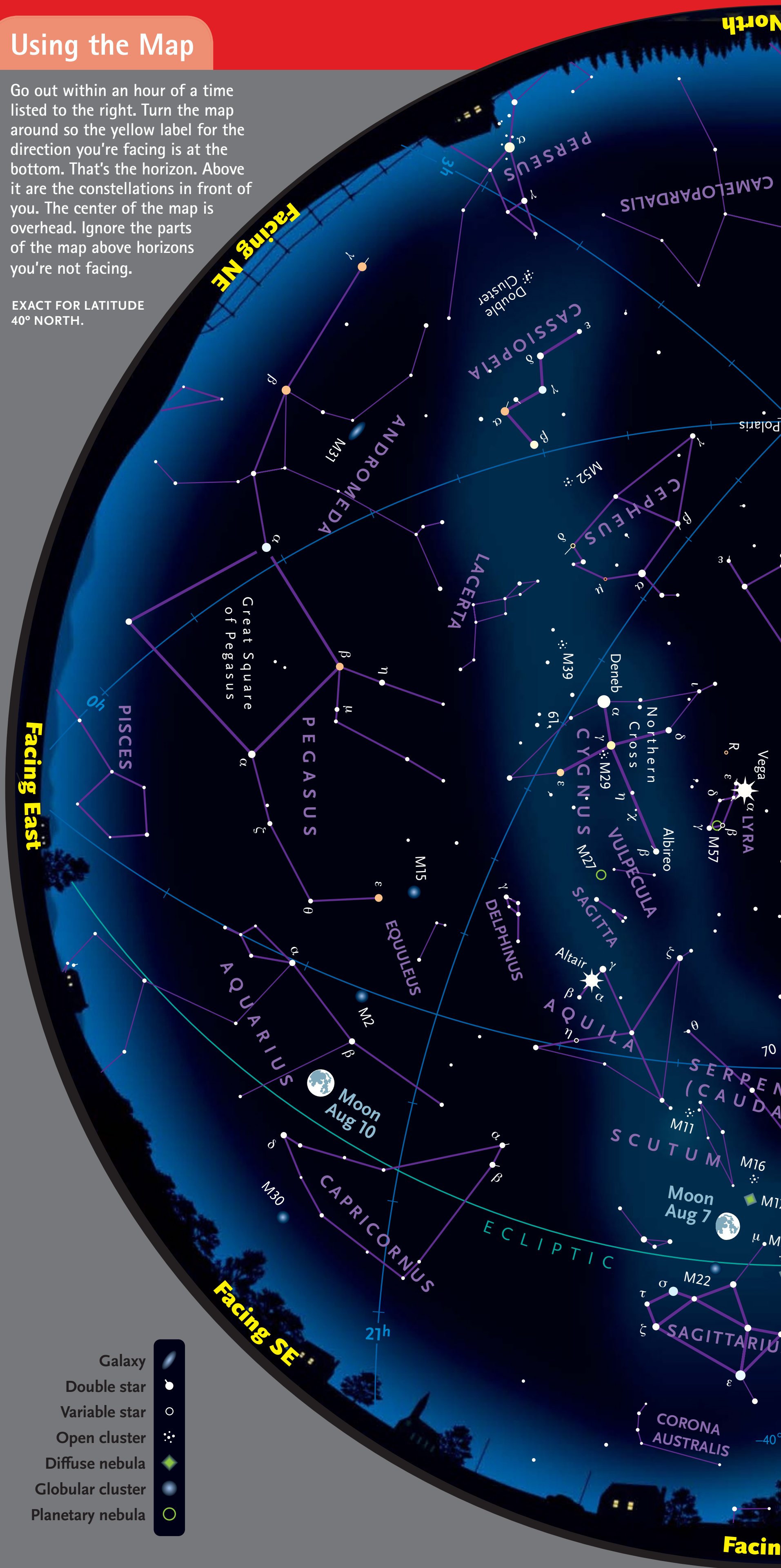
First Qtr August 3 8:50 p.m. EDT
Full August 10 2:09 p.m. EDT
Last Qtr August 17 8:26 a.m. EDT
New August 25 10:13 a.m. EDT

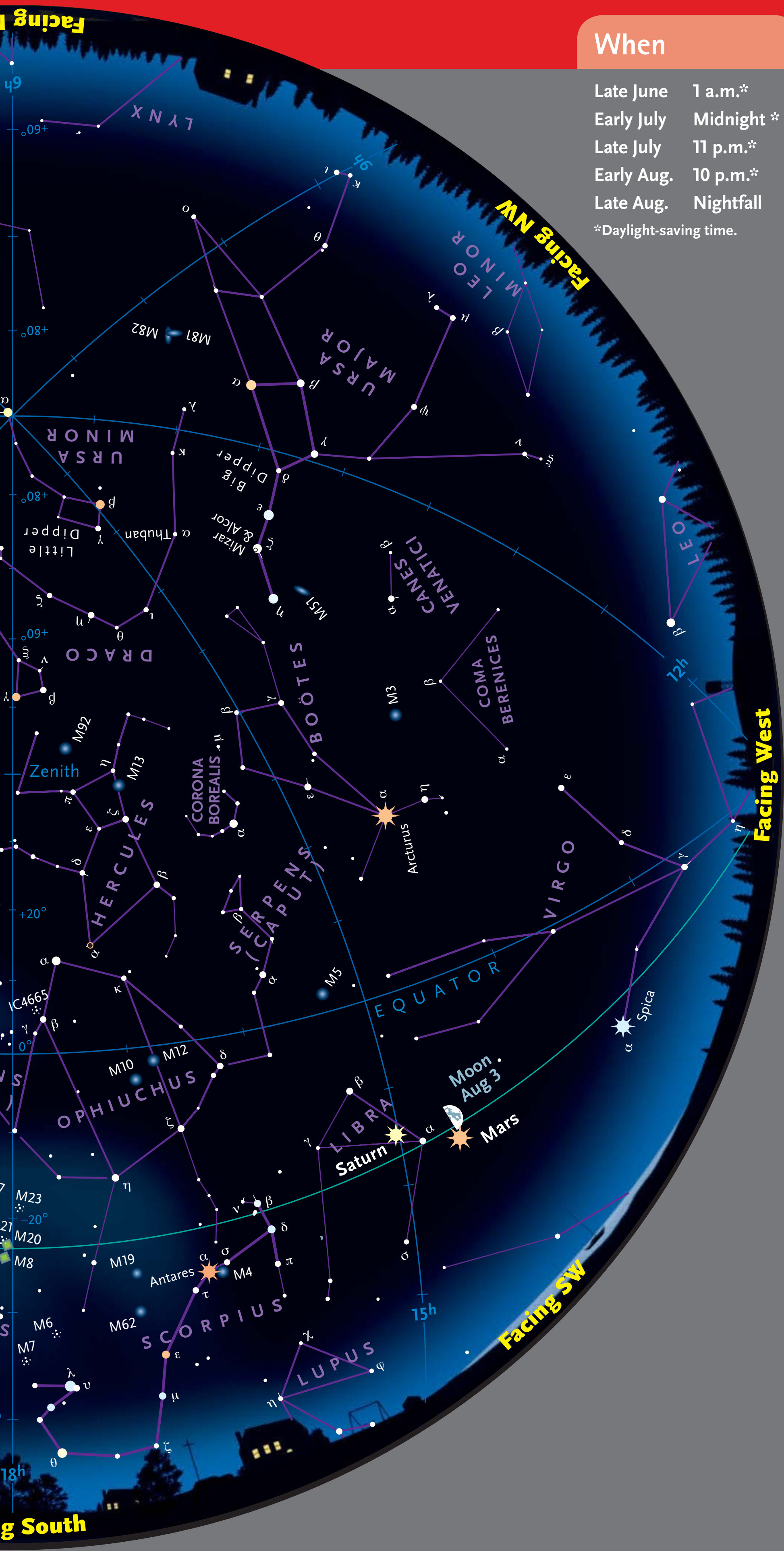
SUN	MON	TUE	WED	THU	FRI	SAT
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24 / 31	25	26	27	28	29	30

Using the Map

Go out within an hour of a time listed to the right. Turn the map around so the yellow label for the direction you're facing is at the bottom. That's the horizon. Above it are the constellations in front of you. The center of the map is overhead. Ignore the parts of the map above horizons you're not facing.

EXACT FOR LATITUDE 40° NORTH.





When

Late June	1 a.m.*
Early July	Midnight *
Late July	11 p.m.*
Early Aug.	10 p.m.*
Late Aug.	Nightfall

*Daylight-saving time.

Gary Seronik

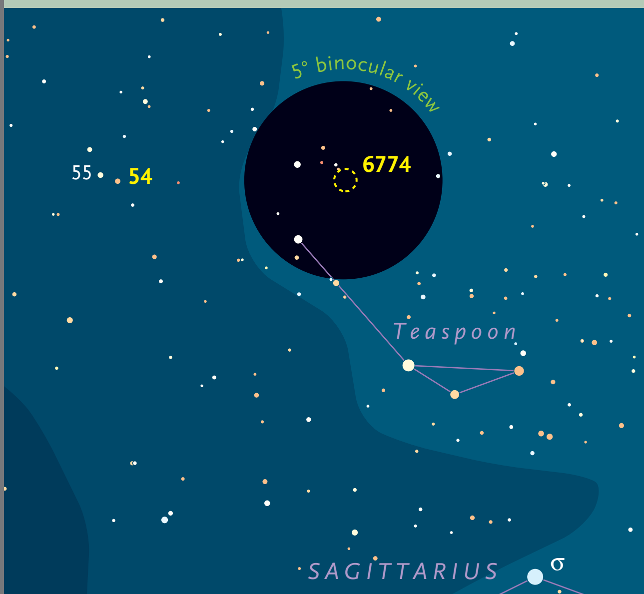
Binocular Highlight

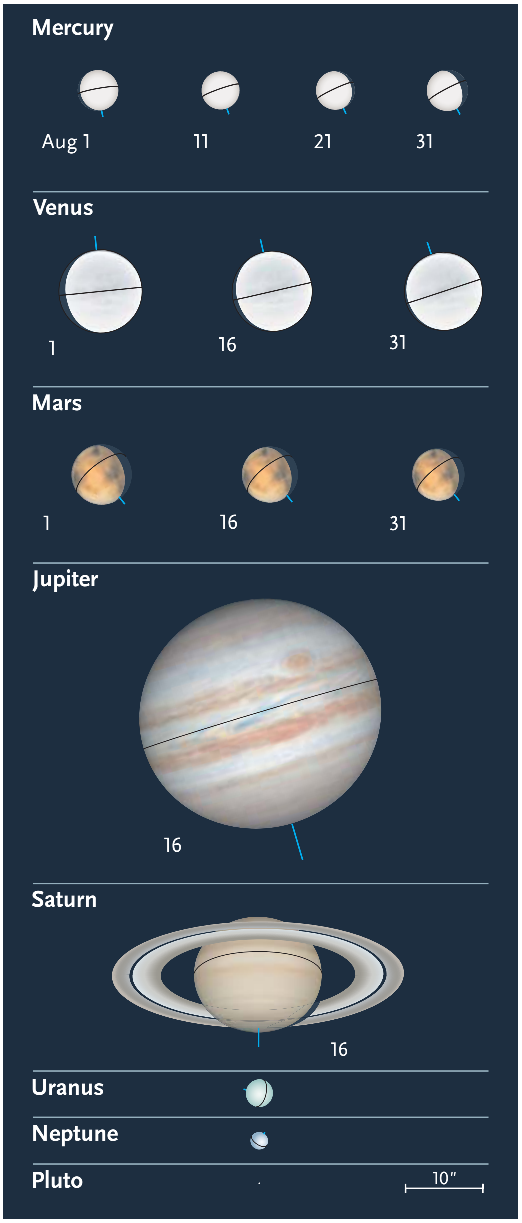
A Teaspoon of Sky Sugar

In his Ramblings column for the August 1973 issue of this magazine, George Lovi presented the constellation Sagittarius in a way that has always stayed with me. The main grouping of stars form the familiar Teapot, depicted approaching the meridian on our all-sky map at left. Below the Teapot lies Corona Australis, which Lovi reimagined as a slice of lemon. And Lovi showed how to form a Teaspoon from the four brightest stars of northeastern Sagittarius.

The Teapot and the bright mist of Milky Way "steam" rising from its spout are so rich with deep-sky treasures (including a baker's dozen Messier objects), that it's little wonder that the rest of the constellation is often overlooked. The Teaspoon, for example, holds two nice but seldom observed binocular sights. The more striking one is the open cluster **NGC 6774**. The grouping, oddly, is not plotted in the Pocket Sky Atlas, even though it's an easy catch in my 10×30 image-stabilized binos. The cluster stars are arranged in a ragged V with the eastern side forming a conspicuous curve. The greatest concentration of starlight is found where the two halves of the V meet. I can pick out roughly a dozen stars there.

While NGC 6774 is fairly easy in binos, our next target is more of challenge. Double star **54 Sagittarii** lies off the end of the teaspoon's handle and forms a very wide, equal-brightness pairing with 55 Sagittarii. But the real catch is 54 itself. Although challenging, I can split the star in two with my 15×45 image-stabilized binoculars. The components are far enough apart (45″) to be resolved at binocular magnifications, but are of disparate brightnesses — magnitudes 5.4 and 7.6 — which makes it difficult to tease the companion from the primary's glare. Indeed, I had no luck splitting 54 in my 10×30s. ✦



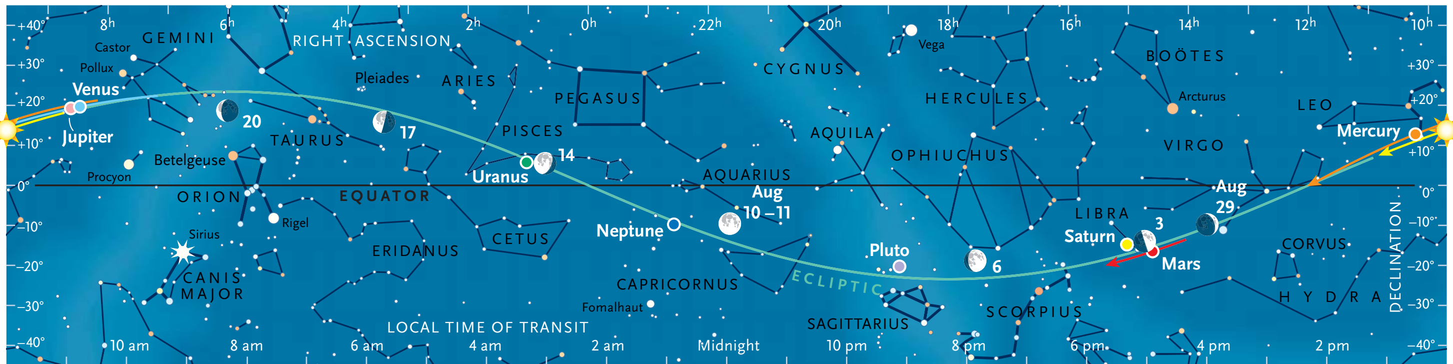


Sun and Planets, August 2014

	August	Right Ascension	Declination	Elongation	Magnitude	Diameter	Illumination	Distance
Sun	1	$8^h\,43.7^m$	+18° 08′	—	–26.8	31′ 31″	—	1.015
	31	$10^h\,36.1^m$	+8° 49′	—	–26.8	31′ 41″	—	1.010
Mercury	1	$8^h\,09.4^m$	+21° 17′	9° Mo	–1.5	5.3″	93%	1.272
	11	$9^h\,34.2^m$	+16° 18′	3° Ev	–1.8	5.0″	99%	1.355
	21	$10^h\,46.6^m$	+9° 10′	12° Ev	–0.8	5.0″	93%	1.334
	31	$11^h\,46.9^m$	+1° 38′	19° Ev	–0.3	5.3″	84%	1.257
Venus	1	$7^h\,09.5^m$	+22° 23′	22° Mo	–3.8	10.8″	92%	1.545
	11	$8^h\,01.5^m$	+20° 52′	20° Mo	–3.8	10.5″	94%	1.585
	21	$8^h\,52.4^m$	+18° 20′	17° Mo	–3.8	10.3″	95%	1.620
	31	$9^h\,41.8^m$	+14° 56′	15° Mo	–3.9	10.1″	97%	1.649
Mars	1	$14^h\,01.5^m$	–13° 27′	84° Ev	+0.4	7.9″	87%	1.189
	16	$14^h\,34.7^m$	–16° 26′	79° Ev	+0.5	7.3″	87%	1.281
	31	$15^h\,11.7^m$	–19° 14′	73° Ev	+0.6	6.8″	87%	1.368
Jupiter	1	$8^h\,22.6^m$	+19° 49′	5° Mo	–1.8	31.4″	100%	6.279
	31	$8^h\,49.3^m$	+18° 15′	28° Mo	–1.8	32.0″	100%	6.154
Saturn	1	$14^h\,58.9^m$	–14° 39′	98° Ev	+0.5	17.1″	100%	9.732
	31	$15^h\,03.7^m$	–15° 07′	70° Ev	+0.6	16.3″	100%	10.223
Uranus	16	$1^h\,00.2^m$	+5° 41′	127° Mo	+5.8	3.6″	100%	19.394
Neptune	16	$22^h\,33.5^m$	–9° 53′	167° Mo	+7.8	2.4″	100%	28.987
Pluto	16	$18^h\,47.5^m$	–20° 28′	138° Ev	+14.1	0.1″	100%	31.945

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-August; 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

August: Milky Way County

Visit the magical land where the Milky Way reigns supreme.

Earlier this year the movie *August: Osage County* was nominated for the Academy Awards. It was based on the Pulitzer-Prize-winning play of the same name. I haven't seen either the play or the movie. But I like the idea of taking that sort of phrase, which sounds like the name of a still-life painting, and using it unexpectedly as the title of a play or film — or an astronomy column. So let me explain why "August: Milky Way County" seems like an appropriate title for this column.

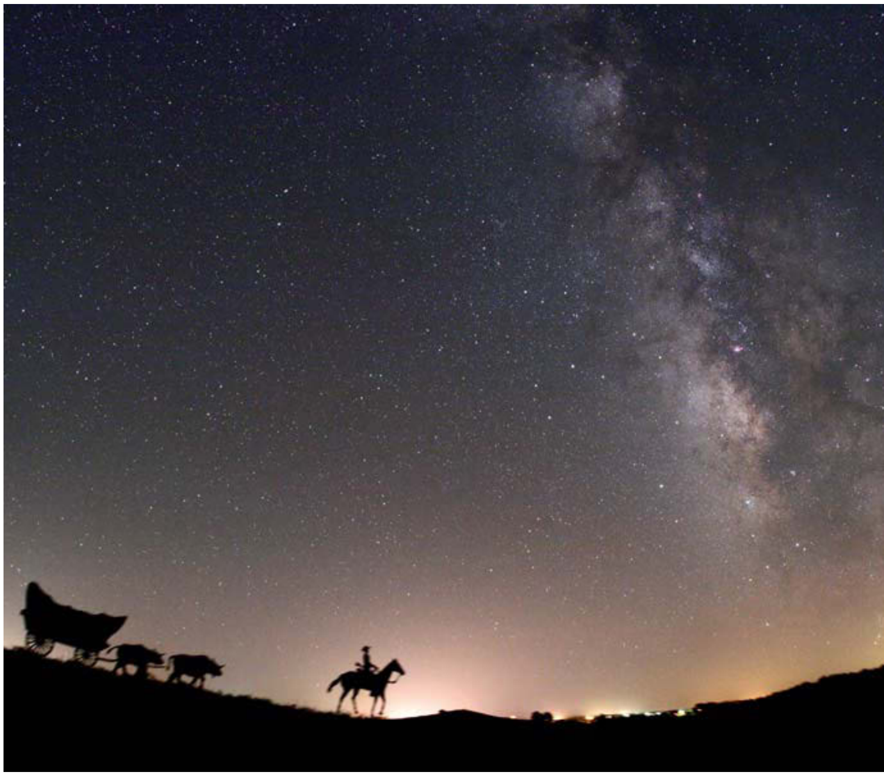
August: Astronomy and Anticipation. Let's start with the month. I have always loved August as a time for astronomy. For many of us at mid-northern latitudes, August offers not only rapidly lengthening nights but also, after June and July's long spells of hot, hazy nights, an increasing number of cold fronts rushing through to give us transparent skies.

It's also a great month for anticipation. In late August, we get hints of the beautiful colored foliage and bird migrations of autumn. And in many locales, we can look forward to September and early October offering the year's most cloud-free and transparent skies. August even offers us glimpses of splendors beyond autumn. Astronomy writer Guy Ottewell notes that in this month: "Before dawn, we see Orion rise again into the eastern sky, a foretaste of the glories of winter." And August offers strong incentives to be up before dawn.

In many years, people rise early to view, from about August 10th to 14th, the 4 a.m nightly peak of the Perseids, the most popular meteor shower. Earlier in the night Perseid watchers see first Cassiopeia, then Perseus, then even the dazzling winter star Capella climb into easy view in the northeast. In some years — including 2014 — a bright Moon hampers observing the Perseids. Yet even then, there's often a good reason to be out as dawn nears. This year, make sure you're up in plenty of time to view the very rare and strikingly close conjunction of Venus and Jupiter during morning twilight on August 18th.

Fortunately, every August there are Moon-free evenings when an even grander phenomenon than the Perseids can be seen at its best. This is the best time to view the brightest part of the Milky Way band.

Milky Way County. When the corn is at its highest, so is the most glorious stretch of the Milky Way band. There was a time when most people had dark enough skies to see this great splendor well on August evenings. You might be fortunate enough to live in a place where that's still possible. But most people have to drive away from the city they live in, first by highway and then by back road, to a rural location where the Milky Way still rules. We can call such a place Milky Way County.



DOUG ZUBENEL

The Milky Way glows behind a monument to 19th-century settlers in rural Morris County, Kansas, 50 miles southwest of Topeka.

In a sense, we see the Milky Way all the time, because everything on Earth — sticks, stones, plants, animals, even ourselves — is part of the Milky Way Galaxy. But that's a far cry from seeing the Milky Way band as a whole. We're lucky that something as prosaic as a car ride can transport us to the awesome star clouds of our home galaxy. They're right out there, decorated with glowing puffs of naked-eye nebulae such as M8 in Sagittarius and star clusters such as M6 and M7 in Scorpius. This is nature's hugest and grandest sight — the vast span of the Milky Way's equatorial disk. And to see it you have to be somewhere special: a place called Milky Way County. ✦

Venus Meets Jupiter at Dawn

The two brightest planets have a remarkably close conjunction in August.

Two planetary conjunctions add extra excitement and beauty to our late-summer skies. In the evening, Mars passes Saturn near the end of August. In the dawn sky, bright Jupiter climbs out of the Sun's glow and engages even brighter Venus in a spectacular, very close conjunction on August 18th.

DUSK

Mercury is easy to spot from the Southern Hemisphere after sunset in late August. But from mid-northern latitudes, Mercury appears very low and will be difficult to spot even with optical aid.

EARLY EVENING

Mars and **Saturn** come into view in the southwest at dusk, and modestly dimmer Spica becomes visible shortly afterward.

As August begins, Saturn, Mars, and Spica are lined up in that order, from upper left to lower right. Mars is the brightest of the three, shining at magnitude 0.4. That's slightly brighter than 0.5-magnitude Saturn 13° to Mars's upper left, and significantly brighter than 1.0-magnitude Spica 10° lower right of Mars. But as the month progresses, Mars closes the gap on Saturn as both move eastward relative to the stars. Mars nudges 1½° under 3rd-magnitude Alpha Librae (Zubenelgenubi) on the American evening of August 21st, then 3½° under Saturn from August 23rd through 26th. By then the two planets are identically bright, magnitude 0.6. Can you distinguish them by their colors alone?

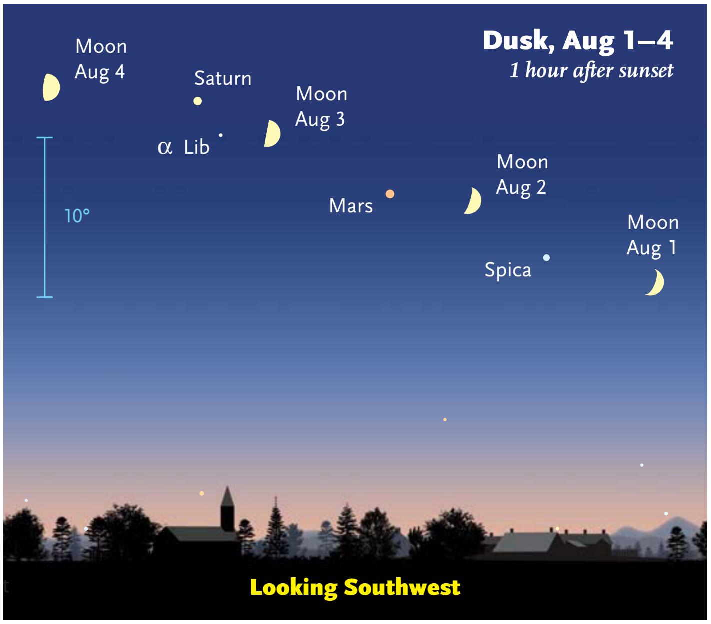
With a telescope, observe them early before they sink too low. Saturn's 17″-wide globe and its much larger rings are still impressive even when viewed through the unsteady air near the horizon. But Mars shrinks from 8″ to 7″ wide in August and will probably appear featureless.

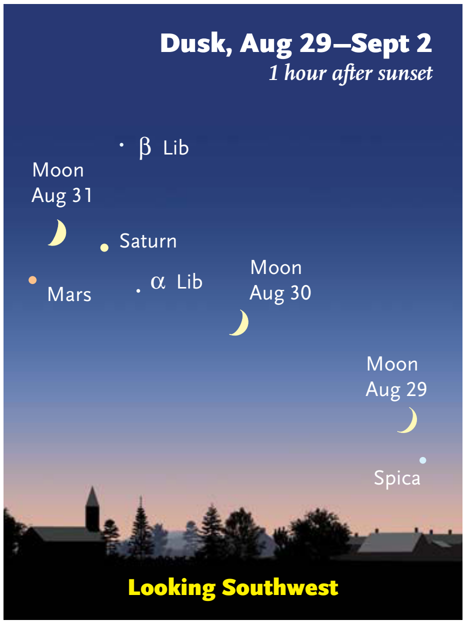
Dim **Pluto**, in northern Sagittarius, is near its highest in the south at nightfall — but that's still not very high for mid-northerners. See page 50 of the June issue if you wish to seek it.

LATE NIGHT TO DAWN

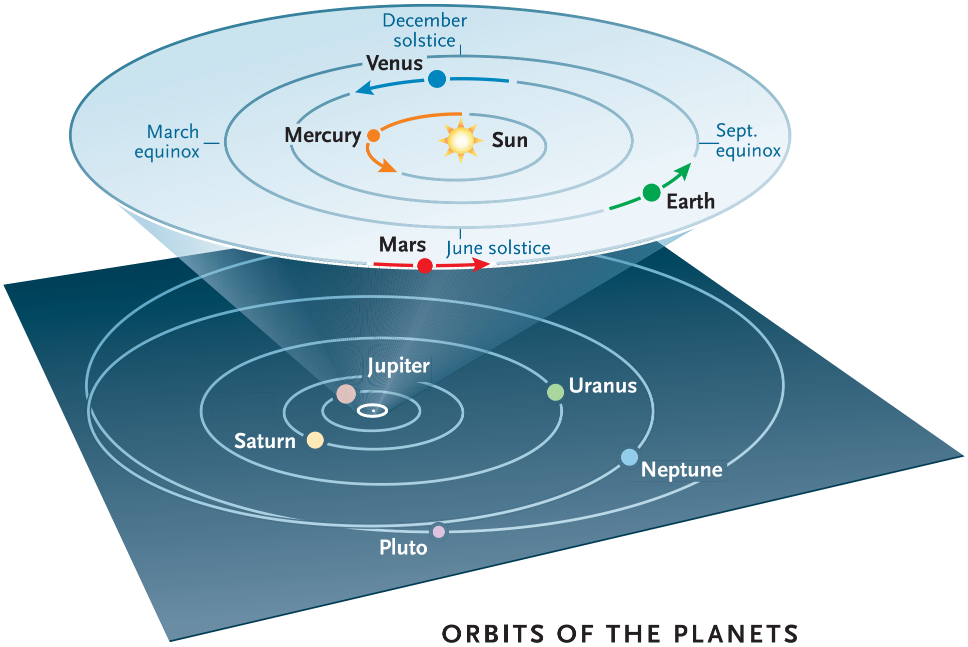
Neptune comes to opposition on August 29th, but even then this most distant official planet shines only at magnitude 7.8 and shows a disk just 2.4″ wide in telescopes. It's best observed at its highest, an hour or two after midnight (daylight-saving time). Neptune is currently retrograding westward in Aquarius, but it will resume its slow eastward trek in November. It will cross into Pisces in 2022.

Uranus is in Pisces now and will remain there until 2018. It rises about 1½ hours after Neptune (at mid-northern latitudes) and is fairly high just before the sky begins to brighten. At that point, the 5.8-magnitude planet may be faintly visible to the unaided eye from a dark site, and its 3.6″-wide disk should be apparent through a telescope at 100×. For finder charts, see **skypub.com/urnep**.





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

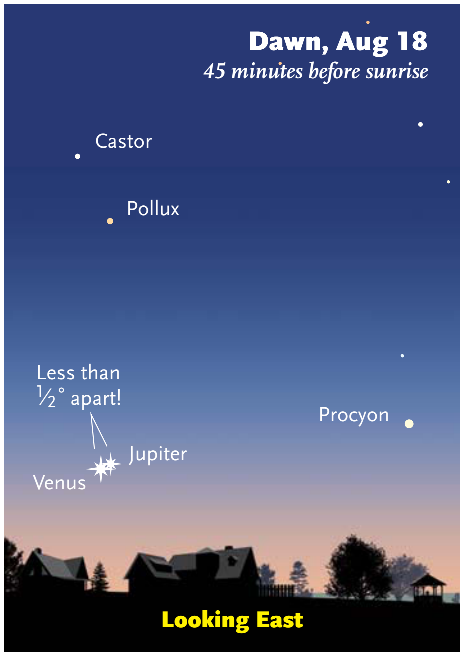


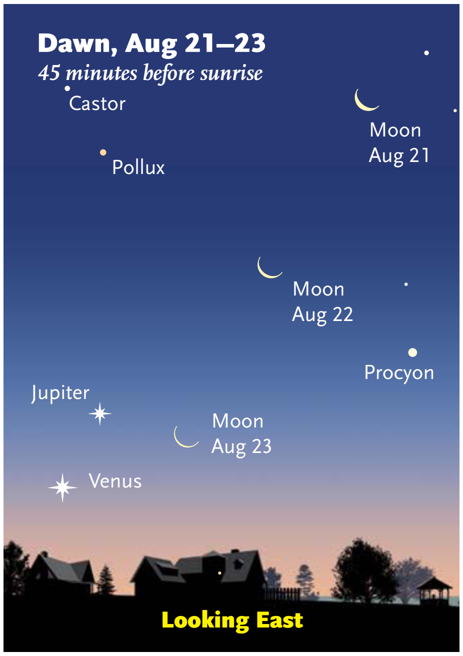
ORBITS OF THE PLANETS

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

DAWN

Venus and **Jupiter**, the two brightest planets, have their closest conjunction since 2000. August starts with only Venus in sight at dawn; it's low in the east-northeast but bright at magnitude –3.8. Jupiter was in conjunction with the Sun on July 24th, and on August 1st it's still too close to the Sun to be visible without optical aid. But Jupiter appears ⅔° higher each morning, and a week into August it should be visible to Venus's lower left shortly before sunrise, appearing dim in the bright twilight even though it shines at magnitude –1.8.





Venus and Jupiter shine within 4° of each other from August 14th through 21st. They're just 0.2° apart at their closest, around 5ʰ UT on August 18th, and they're still less than 0.3° apart a few hours later, when they rise in eastern North America. The majestic pair stands about 5° above the horizon an hour before sunrise (for skywatchers at about 40° north latitude). At that hour, telescopes and binoculars may also show the much fainter stars of M44, the Beehive Cluster, just to their left. The telescopic view of the planets will improve as they rise higher and the sky grows brighter. Venus, just 10″ wide and almost fully lit, will fit easily in the same field of view at 100× with 32″-wide Jupiter. Note how much dimmer Jupiter appears. It's 7 times farther from the Sun, so sunlight on Jupiter is just 2% as bright as on Venus.

After that, Jupiter moves rapidly off to Venus's upper right, climbing into better morning view as its year-long apparition gets under way.

MOON PASSAGES

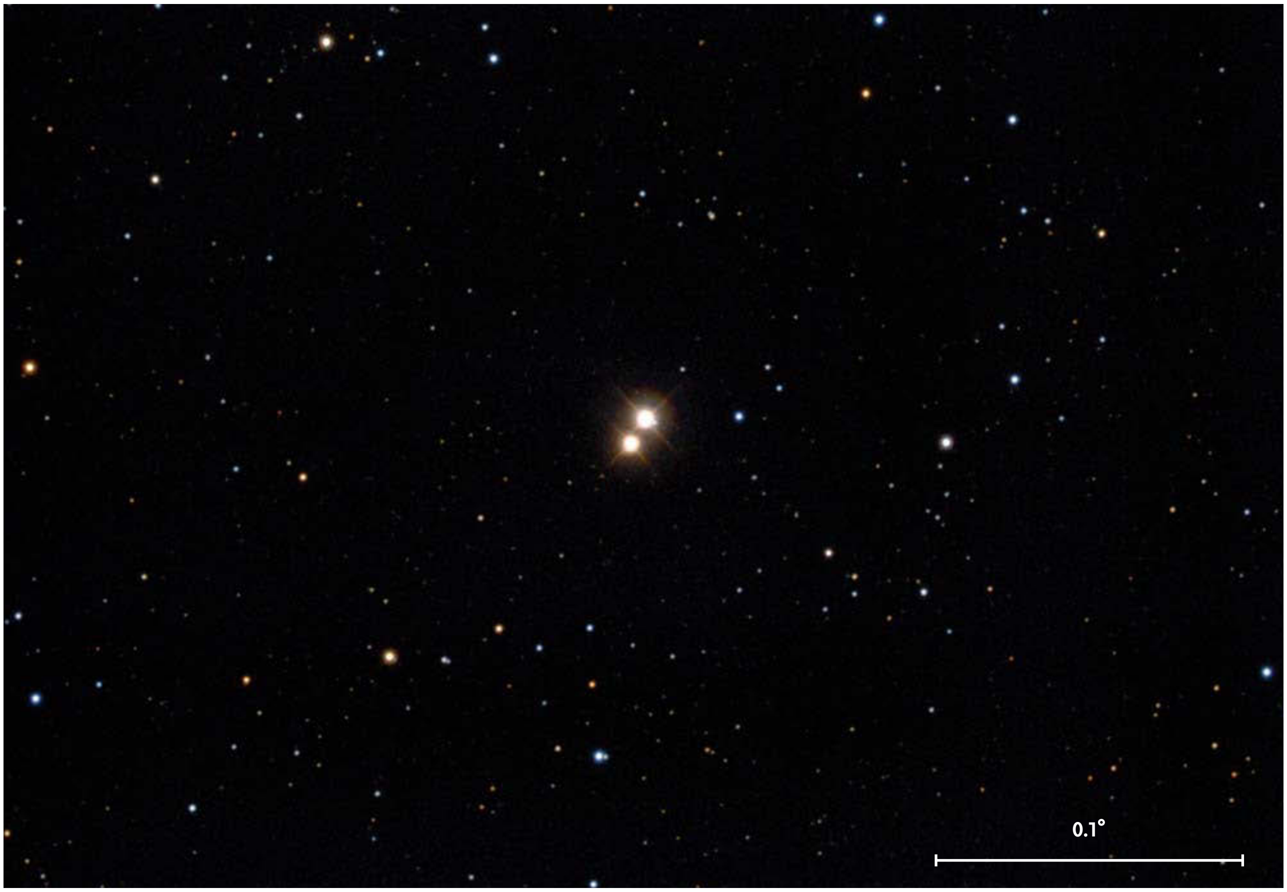
The **Moon** is a waxing crescent lower right of Spica on August 1st and between Mars and Spica on the 2nd. On August 3rd the nearly half-lit Moon lies between Mars and Saturn.

The full Moon on August 10th is the largest of the year, occurring almost precisely at perigee. At dawn on August 23rd, the Moon forms a compact triangle with Jupiter and Venus. On the 29th the lunar crescent is back in the evening sky just upper left of Spica, then forms a triangle less than 5° on a side with Mars and Saturn on August 31st.

The Moon occults Saturn in Australia on the evening of August 4th and in west-central Africa on the evening of the 31st. It's conceivable that telescopes will show the August 31st occultation in the eastern U.S. in broad daylight, a little after 1 p.m. EDT. But even in Boston, on the northern graze line, where the pairing is highest, the 32%-lit crescent Moon will be just 15° above the east-northeast horizon, making it hard to spot. Dim Saturn will be much more difficult. ✦

The Flight of 61 Cygni

Watch the proper motion of this famous double orange dwarf.

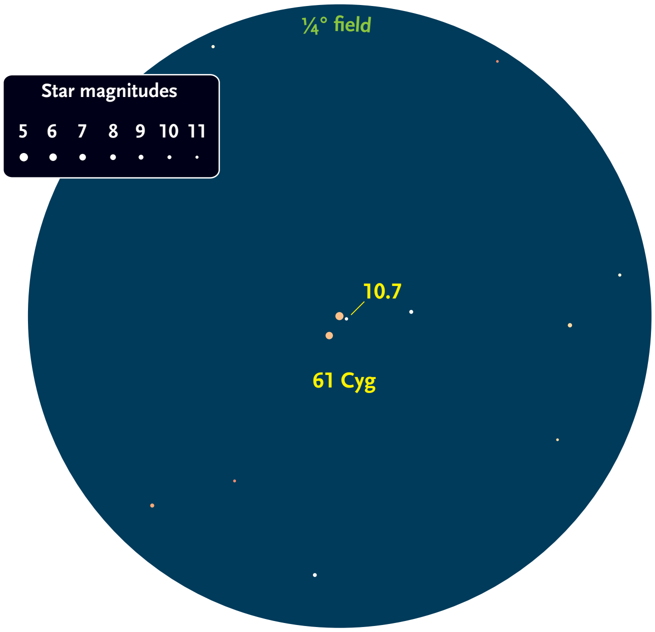


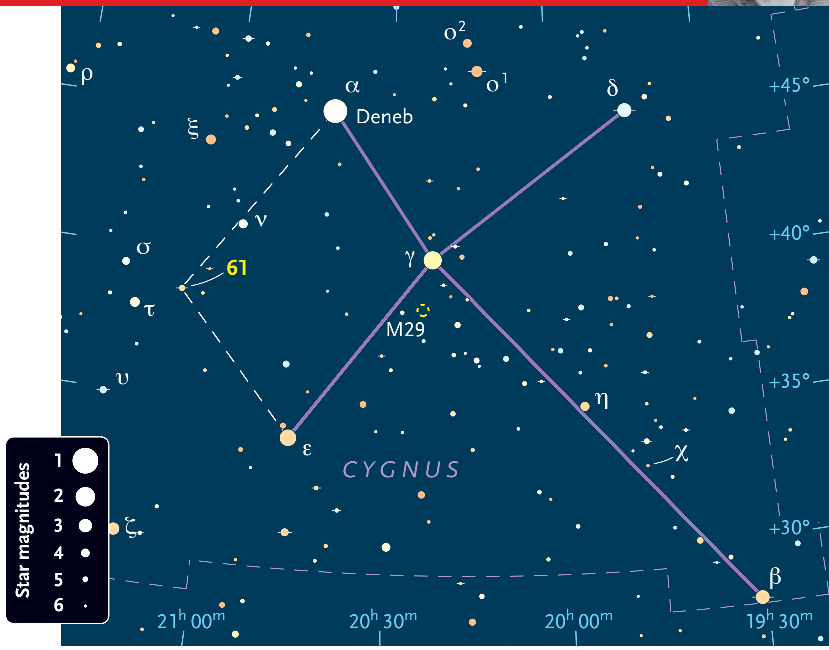
Two of the four closest *K* dwarfs in the sky glow against the rich Cygnus Milky Way. They form a fine double star for small telescopes, and if you pay attention over the years, you can watch their fast common proper motion away from a faint background star. *S&T*'s Dennis di Cicco took this image on May 11th. An enlargement is below.

High overhead in late summer, near Deneb, is an unassuming pair of orange dwarf stars just visible to the naked eye at magnitudes 5.2 and 6.0. Humble they may appear, but they've held a grand place in astronomical history since 1838. That year they became the first stars to have their parallax and distance measured, proving once and for all that stars are suns extremely far away.

Why did such an insignificant-looking pair of stars win this honor? Friedrich Wilhelm Bessel, an astronomer at Königsberg Observatory in Germany, took an educated guess that 61 Cygni was especially close to us because of its fast proper motion across the sky. In 1804 the Italian star cataloger Giuseppe Piazzi had discovered that the pair was crossing the starry background at 5 arcseconds

Alan MacRobert





Right: **Point your scope to the fourth corner of the parallelogram made with bright Deneb, Gamma (γ), and Epsilon (ε) Cygni. That will land you on the double star 61 Cygni. The round chart above is a high-power view 15′ wide; north is up. Can you detect the 10.7-magnitude star just 10″ west-southwest of 61 Cygni A? In another year they'll be 15″ apart. Careful eyepiece sketches should show the change.**

per year, the greatest proper motion of any star known at the time. It gained the name "Piazzi's Flying Star."

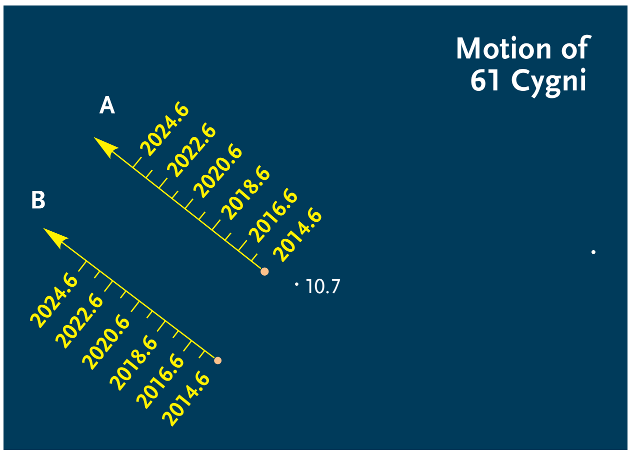
For two centuries, astronomers since Galileo and his student Benedetto Castelli had sought to detect the annual parallax motion that nearby stars ought to show if Earth were circling the Sun. But the stars were too far and their parallax motions too small for early instruments to detect. By the 1830s the measurement of star positions was being enormously refined, and several astronomers were competing intensely to measure the first parallax. Working at the limit of one of the best instruments' capabilities, Bessell announced finding an annual parallax motion of 0.314″ for the two stars of 61 Cygni. This corresponds in modern terms to a distance of 10.3 light-years, impressively near today's value of 11.41 light-years.

In a small telescope, 61 Cygni is a lovely, wide pair of yellow-orange points, spectral types *K*5 and *K*7, currently separated by 31″. For the next few years, they offer an unusually fine chance to see stellar proper motion with an amateur scope.

The round chart above shows a ¼° field of view, as you might see in a 250× eyepiece. Use such a high power because a faint background star, magnitude 10.7, is 10″ from the brighter component, 61 Cygni A. Component A is currently drawing away from it at 5″ per year.

Carefully sketch the positions of the three stars as they appear in your eyepiece this summer. Do the same next year, and the year after. The changing shape of the triangle they make should be obvious.

The pair orbit each other in about 680 years, too slow to show change with respect to each other from year to year. They emit only 9% and 4% of the Sun's visible light.



Asteroid Occultation

On the evening of August 19th, the faint asteroid 232 Russia will black out a 9.8-magnitude star in Libra for up to 2 or 3 seconds as seen from a narrow track predicted to run from North Dakota to south of the Great Lakes and across Pennsylvania and southern New Jersey. The occultation will happen within a couple minutes of 1:47 on the 20th UT in Minnesota, and a minute later on the East Coast. The star will be about 25° up in the south-southwestern sky.

For a map, finder charts, more about timing asteroid occultations, and additional predictions, see **skypub.com/aug2014asteroidoccultation**.

The Moon & the Perseids

Every three years the Moon displays similar phases on the same dates on the calendar. The rule of thumb is that every phase happens just three days earlier than it did three years ago, on average.

So if you remember the 2011 Perseid meteor shower contending with an almost-full Moon, well, now it happens again.

This time the Moon will be two days past full on the peak Perseid night, August 12–13. So it won't be quite as bright as when it's full, but it will illuminate the sky all night — especially from midnight to dawn, when the shower's radiant in Perseus is high and the meteors should be most numerous.

But at nightfall the Moon will still be low in the east, and as explained starting on page 64, this is when to watch for *earth-grazing* Perseids. These are the infrequent, but unusually long and graceful, meteors that you may see when a shower's radiant is low above the horizon.

On their peak night, the Perseids typically produce about 100 meteors visible per hour (by a single person) when the radiant is near the zenith and the sky is very dark. The peak Perseid rate typically runs for about 12 hours centered on the predicted time, which this year is 0^h August 13th Universal Time (near nightfall on the 12th in the North American time zones).

The moonlight will hide faint meteors, but a nice bright one may show through every few minutes late in the night.

Don't limit yourself to the peak night. The shower stays above half its maximum strength for two days running, and you may see a few Perseids from late July through about August 18th, as shown in last year's activity graph below. The dropoff happens faster than the rise.

Next year's peak Perseid nights will be moonless and ideal.

Meeting Expectations

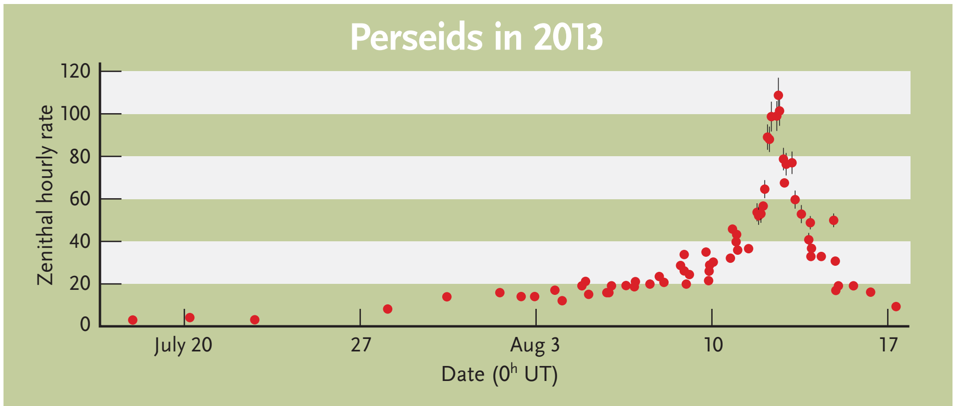
Meteor watching has become much more of a public event than it used to be. The media promote the main annual showers in a way that never happened a generation ago. We're proud to have played a part in this; since the 1990s we've been aggressive about sending press releases to news media before the major showers, and the grand Leonid displays from 1999 to 2002 certainly helped.

But we underestimated how modest a success it takes to get people hooked. Most people know better now that to expect fireworks. Vacationing families with no astronomy experience are often thrilled to see just two or three shooting stars on Perseid night, and many have made it a family tradition to look. And of course you need no fancy equipment or even knowledge of the constellations to enjoy a meteor shower. Just bring reclining chairs to a dark open spot, face whatever direction is darkest, lie back, and watch the stars overhead. ✦

Minima of Algol

July	UT	Aug.	UT
2	20:13	3	9:08
5	17:01	6	5:57
8	13:50	9	2:45
11	10:39	11	23:34
14	7:27	14	20:23
17	4:16	17	17:11
20	1:05	20	14:00
22	21:53	23	10:49
25	18:42	26	7:37
28	15:31	29	4:26
31	12:19		

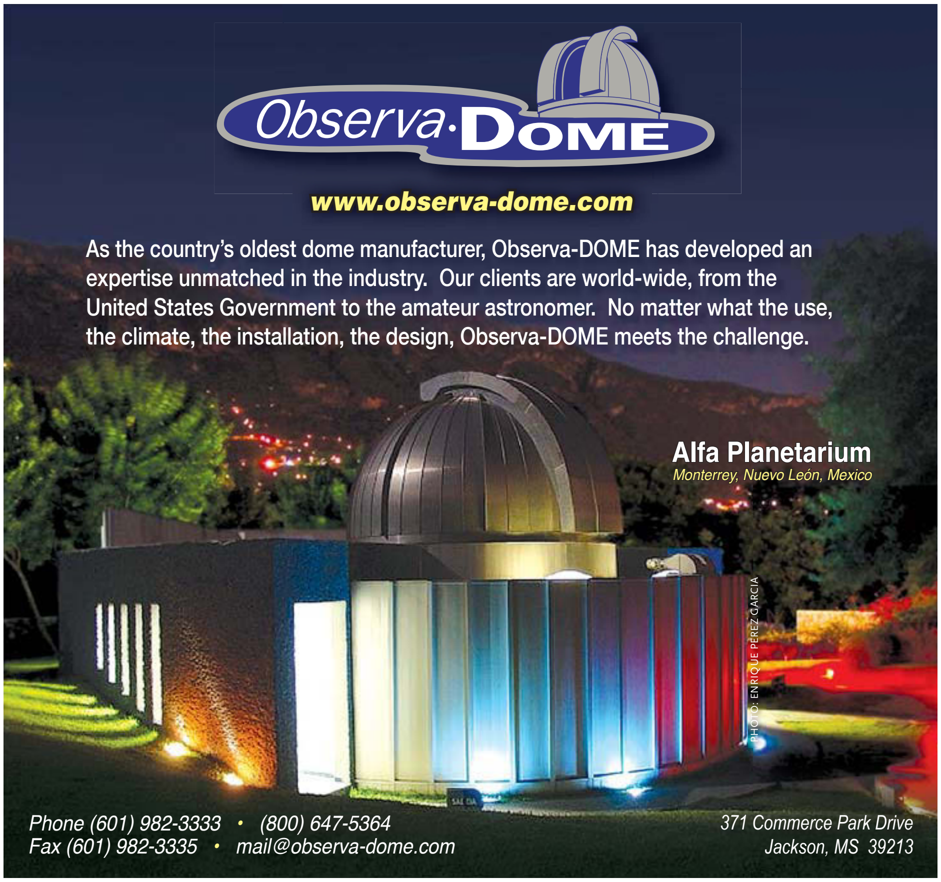
These geocentric (Earth-centered) predictions are from the heliocentric (Sun-centered) elements Min. = JD 2452253.559 + 2.867362*E*, where *E* is any integer. Courtesy Gerry Samolyk (AAVSO). For a comparison-star chart and more info, see skypub.com/algol.



Think of the Perseids, and you probably think "August 12th" or thereabouts. But last year, as usual, the Perseids qualified as a respectable minor shower beginning in late July, on a par with the April Lyrids or the November Taurids at their peaks. This activity profile includes more than 34,000 Perseids reported to the International Meteor Organization by systematic observers worldwide. Most dots are the means of several zenithal hourly rates derived from different people's counts, corrected for the different sky conditions reported by each person. *Right:* A composite image of several Perseids last year, caught as the background stars rose.

INTERNATIONAL METEOR ORGANIZATION

DAVID MAYHEW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Lunar Highs and Lows

An online tool lets you measure a crater's depth.

Looking at the lunar surface from Earth's perspective, it's often difficult to detect even significant changes in topography. Ordinarily, you'd slew your telescope to a spot illuminated by the grazing light of a rising or setting Sun, so that even small bumps cast long shadows on the lunar landscape. This technique works well for hills, scarps, and crater rims, but it's less successful for detecting gentle changes in elevation.

For example, I've observed the 77-mile-wide (124-km) crater **Fracastorius** hundreds of times. When the seeing is excellent, I can occasionally spy a thin rille that bisects the crater floor from east to west. Fracastorius formed on a rim of the Nectaris impact basin that bounds a region of subsidence inside the basin. The Fracastorius rille marks where this drop-off toward the deep central basin floor begins. It turns out that this regional change in elevation is rather extreme: the terrain drops more than 0.5 mile from the rille to the north edge of the crater floor — much more than I expected from mere visual inspection.

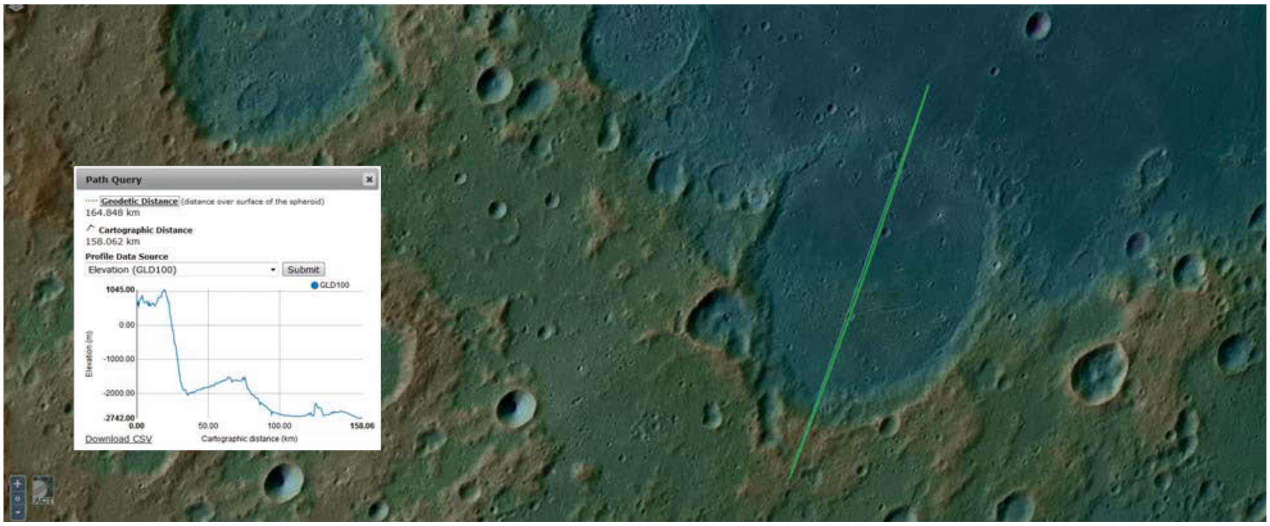
The Lowdown on Lunar Features

It's still fun to judge the lunar highs and lows by eye, but now there's a much more accurate method. Since 2009 the cameras on NASA's Lunar Reconnaissance Orbiter (LRO) spacecraft have provided an unending torrent of extraordinary, ultra-high-resolution images of the Moon — and, thanks to its stereo imagery, the elevations of 100 billion individual points on the surface.

These data are available through the *QuickMap* interface (**target.lroc.asu.edu/q3**). I introduced *S&T* readers to this impressive, fun-to-use utility in my August 2012 column (page 54), and the 300-terabyte database is so rich with possibilities that it's worth a second look.

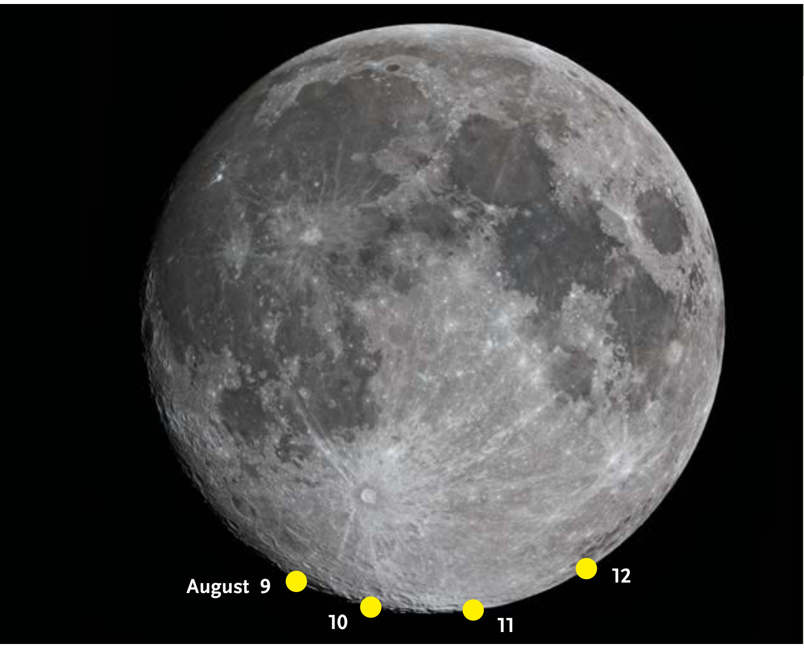
You might start by using the Path Tool (found by clicking the "wrench" icon at the top-right of the screen) to create a topographic cross-section across a big crater. Do that for **Copernicus** and you'll find that the rim rises about 0.6 mile above the surrounding terrain, and that the crater floor is about 2.4 miles below the rim crest. Considering that Copernicus has a diameter of 58 miles, it's actually a quite shallow depression — its depth-to-diameter ratio is only 0.04. (The original, just-formed crater would have been deeper, but a combination of rim slumping and pooling of debris filled in the floor.)

You can use the LRO *QuickMap* to examine the topography of other interesting craters. For example, watch the Sun rise over 110-mile-wide **Petavius** when the Moon is a thin waxing crescent, and you'll see that its high central



ACT-REACT QUICKMAP

DECEPTIVELY FLAT The lunar crater Fracastorius seems to have a broad, flat floor with a narrow, challenging-to-see east-west rille. However, altimetry data from NASA's Lunar Reconnaissance Orbiter shows that the crater floor slopes downward toward its northern rim. In the display from the *QuickMap* interface at target.lroc.asu.edu/q3, the plot shows elevations along the green line at right.



S&T: DENNIS DI CICCO

The Moon • August 2014

Phases

FIRST QUARTER
August 4, 0:50 UT

FULL MOON
August 10, 18:09 UT

LAST QUARTER
August 17, 12:26 UT

NEW MOON
August 25, 14:13 UT

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

Distances

Perigee	August 10, 18h UT
221,765 miles	diam. 33′ 29″
Apogee	August 24, 6h UT
252,601 miles	diam. 29′ 23″

Librations

Bailly (crater)	August 9
Casatus (crater)	August 10
Boguslawsky (crater)	August 11
Peirescius (crater)	August 12

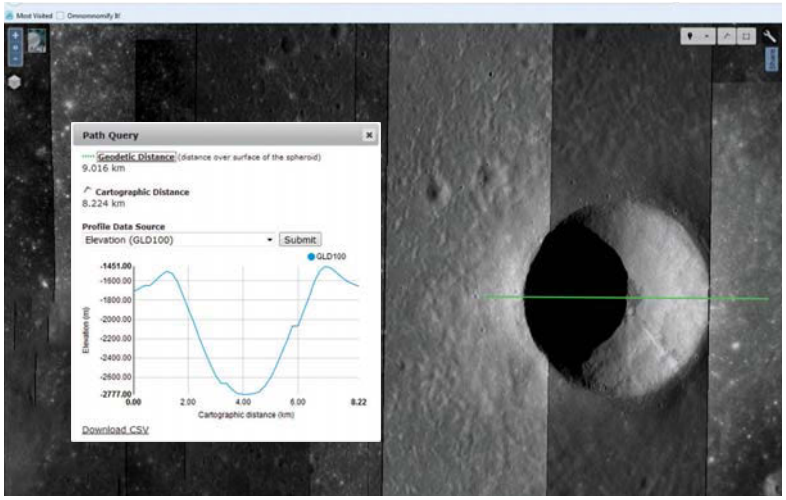
region catches glints of sunlight before the rest of the floor does. The LRO data confirm this: the entire floor of Petavius gently rises toward its center, which is nearly ½ mile higher than its outer edges, and its central peaks steeply rise another 1¼ to 1½ miles.

The floor of **Mersenius**, just west of Mare Humorum, is much the same. Watch it cast a sliver of shadow when the illumination angle is very low, revealing a broadly domed floor. LRO altimetry confirms that the center of its floor rises about 1,600 feet above its edges, a slope that's steeper on its eastern half.

Petavius and Mersenius are examples of *floor-fractured craters*, features that were volcanically modified after they formed. Pressure from rising magma beneath them raised and fractured their floors, producing spectacular systems of radial and concentric rilles. **Gassendi**, **Posidonius**, **Pitatus**, and **Alphonsus** are other dramatic examples that you can explore both at the eyepiece and with the *QuickMap* Path Tool.

For contrast, make a path across some small, bowl-shaped craters such as **Moltke**, a 4-mile-wide divot near the southern edge of Mare Tranquillitatis. LRO's topographic profile reveals that Moltke is about 0.8 mile deep, so its depth-to-diameter ratio is 0.2 — very typical of such simple craters. A transition to shallower ratios occurs when lunar craters reach diameters of about 10 to 15 miles.

The Path Tool also reveals global trends and gives you, literally, an entire new dimension to explore and understand the Moon. For example, a topographic traverse all around the equator shows that the farside highlands average 2½ to 4 miles higher than the lunar equivalent of "sea level," whereas the nearside maria basins are typically a mile below that datum.



ACT-REACT QUICKMAP

SIMPLE BOWL The small crater Moltke is relatively easy to spot in Mare Tranquillitatis despite being just 4 miles across. Topographic data plotted using the *QuickMap* Path Tool reveal its simple bowl shape.

Here's one more suggestion: To get a sense of how a giant basin truly "impacts" the lunar elevations in its vicinity, compare the elevation of the center of the South Pole–Aitken Basin on the lunar farside and the towering Montes Leibnitz peaks that form part of its rim. *QuickMap*'s altimetry tools reveal unexpected vertical relief, which can enhance our understanding of the Moon. ✦

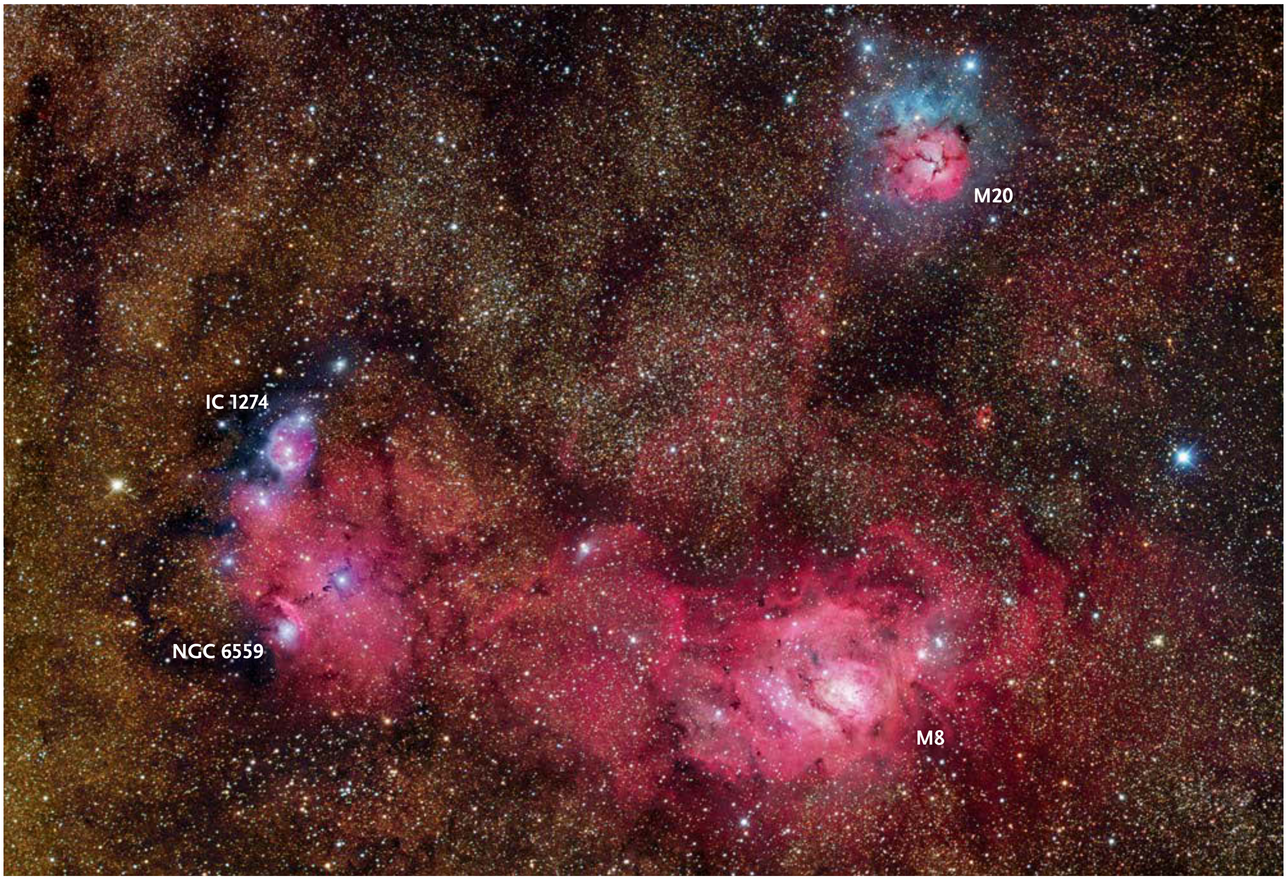
Where Glows the Milky Way

Sagittarius is the mother lode of star clusters and nebulae.

I stand at night and gaze up at the sky,
A huge, inverted bowl above my head;
Upon its blue-black concave surface spread,
Unnumbered twinkling lights intrigue my eye . . .
Across their background glows the Milky Way,
The cradle-place of new-born stars untold,
Whose light shall shine adown eternity,
When those now bright have long been dark and cold.
— A. C. Holm, *The Infinite Stars*, 1925

The summer Milky Way in Sagittarius is a breathtaking sight when it graces a dark sky. In *Round the Year with the Stars*, Garrett P. Serviss describes it as falling to the horizon "in flakes and sheets of silvery splendor." Through binoculars we behold a vista of seemingly countess stars, "like a stupendous cavern of space all ablaze and aglitter with millions of sparkling gems." The Sagittarius Milky Way is also a cradle place of newborn stars, a home for aged stars, and a resting place for those that have reached the end of their lives.

One striking nursery of youthful stars is the **Lagoon Nebula** (M8), which appears as a brighter patch in the Milky Way from my semirural home. Even a small telescope reveals fledgling suns enmeshed in a beautiful blend of bright and dark nebulae. The sketch on the facing page shows the view through my 105-mm refractor at 87×. The prominent star cluster in the eastern side of the nebula is only a few million years old, and lingering dark regions are pregnant with stars-to-be. If you observe in a light-polluted area, an O III or narrowband filter can help unveil the Lagoon's glowing clouds, but a filter also mutes the glory of its suns.

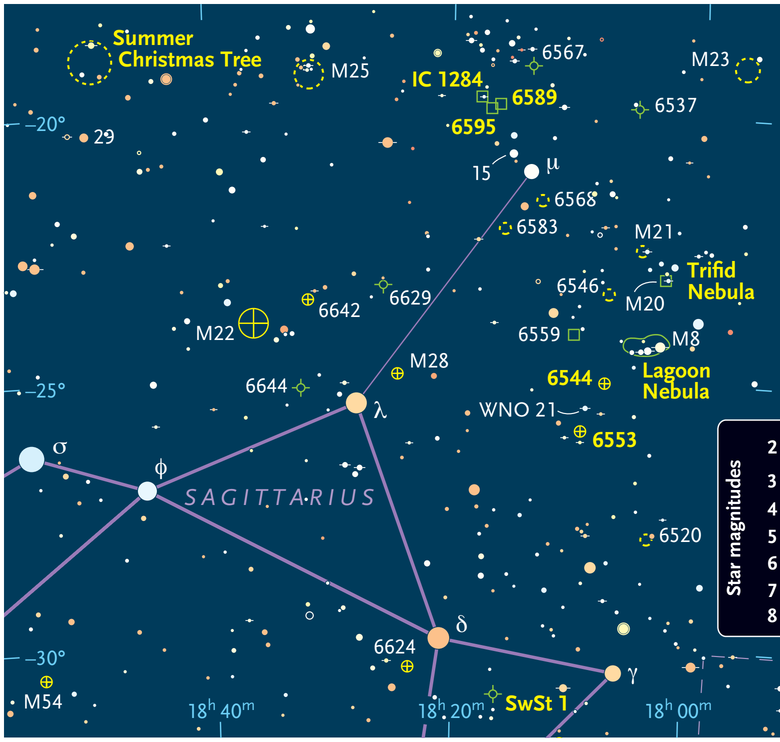


ROBERT GENDLER

Just 1.4° north-northwest of the Lagoon Nebula, the **Trifid Nebula** (M20) is another site of recent and ongoing star formation. I've seen it look wonderful in a dark sky through a 92-mm refractor, but it can be disappointing even through an 8-inch scope in a suburban sky. At home my 105-mm refractor isn't quite up to the task of showing a lot of detail in the Trifid, so I sketched it with my 130-mm refractor at 117×. Careful study shows that dark nebulae carve the southern part of the Trifid into a more complex shape than its name implies. Although a narrowband filter may help you discern details here, it won't offer much aid when it comes to the nebulosity surrounding the 7th-magnitude star to the north. This is primarily a reflection nebula that scatters light from the *A*-type supergiant star at its heart, and such filters are designed for nebulae that emit their own light.

The ancient stars of globular clusters can be seen in **NGC 6553** and **NGC 6544**, southeast of the Lagoon Nebula. They share the field of view through my 105-mm refractor at 28×. NGC 6553 sits 27′ south-southeast of the double star WNO 21, an unequal pair (magnitudes 6.8 and 8.8) whose companion star lies east-northeast of its primary. NGC 6553 presents a granular hazy patch about 3′ across that grows softly brighter toward its center. An 11th-magnitude star pins its west-southwestern edge. NGC 6544 lies 36′ northwest of WNO 21. It's about the same size as its neighbor, but it appears highly granular in a field richly speckled with faint stars. At 87× NGC 6544 presents a bright core and seems augmented by the field stars sprinkled around it. NGC 6553 looks a bit larger, and a superimposed star gleams in the northwest.

Through my 10-inch scope at 213×, I count 10 stars freckling the face of NGC 6544, but only a few extremely faint glints favor NGC 6553. This isn't surprising once we realize that the former is 9,800 light-years distant, whereas the latter is twice as far away.

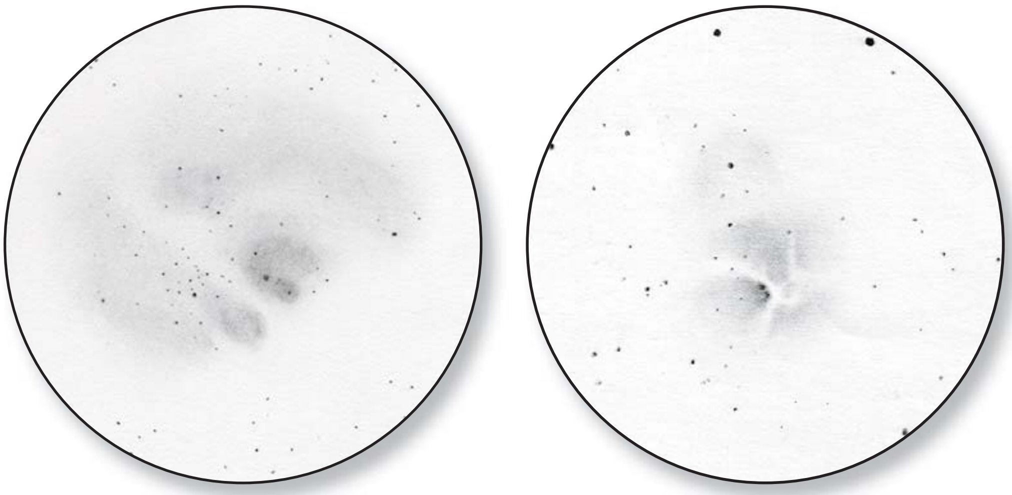


These globular clusters are indeed timeworn. NGC 6544 is roughly 11 billion years old, while NGC 6553 may need as many as 13 billion candles on its birthday cake.

Although not as elderly as globular clusters, the central stars of planetary nebulae are near the ends of their active lives. According to a 2010 paper in *Astronomy & Astrophysics* by Walter J. Maciel and colleagues, the age distribution of these stars peaks at 2 billion to 4 billion years.

One seldom-visited planetary nebula in Sagittarius is **Swings-Struve 1**, also called PN G1.5-6.7 or PK 1-6.2. It's named for Pol Swings and Otto Struve, who revealed its

Facing page: The area around M20, the Trifid Nebula, and M8, the Lagoon, is awash in both bright and dark nebulosity. The Trifid's southern half glows reddish from narrowband emissions, which respond well to filters. The blue northern section is a reflection nebula, best viewed without a filter. *Right:* The author sketched M8 as seen in her 105-mm refractor at 87× and M20 as seen in her 130-mm refractor at 117×.



true nature with a complete spectroscopic analysis in 1940.

Swings-Struve 1 is an interesting little gem, and my observations of it stretch across the past 13 years. My 105-mm refractor at 174× shows a fairly bright but very tiny disk, and sometimes I think I also see a stellar point inside or near it. The planetary nebula sits just outside a 2.3′-tall V of six stars that points north-northeast, about halfway between the two stars at the open end of the V's eastern side. Adding a narrowband filter to the eyepiece makes the nebula shine brighter than the stars.

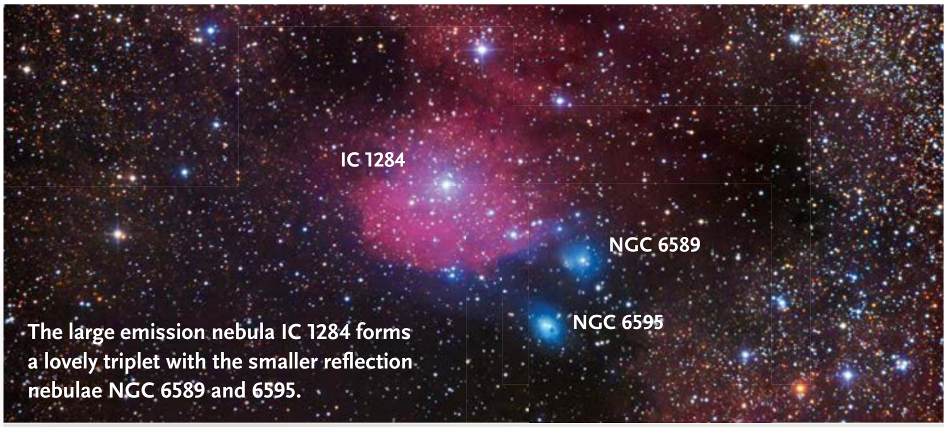
Viewing through a 10-inch reflector at 213×, I see a very faint star close south-east of SwSt 1, perhaps the star suspected through my little refractor. Although the planetary's central star is a respectable magnitude 11.7, it remains lost in the glow of the nebula itself. Listed magnitudes for SwSt 1 cover a rather large range, but I estimate a visual magnitude of 11.4 by comparison with nearby stars. The nebula appears blue-gray to me. Observers with larger telescopes have reported a reddish hue. What color do you see? SwSt 1 responds well to an H-beta filter, leaving it the brightest object in the field.

A noteworthy and astrophotographically beautiful complex of nebulosity and stars awaits us about 1½° north-northeast of Mu (μ) Sagittarii. With my 105-mm scope at 28×, the emission nebula **IC 1284** is easily visible around the 7.6-magnitude star HD 167815 (SAO 161273) and covers about 11′ × 7′ of sky. A smaller and fainter swath of nebulosity encloses a star of similar brightness 11.4′ north-northwest. A narrowband filter accentuates portions of both nebulae. At 47× two small reflection nebulae southwest of IC 1284 blossom in the field of view. **NGC 6595** is clearly visible around a pair of 11th-magnitude stars, while more subtle **NGC 6589** involves a 10th-magnitude star 6′ to the north-northwest. The unimpressive star cluster Collinder 371 runs northeast-southwest through the nebula trio. I count 22 stars, including five pairs, most strung along two jagged lines about 20′ long.

In my 10-inch scope at 68×, IC 1284 spans 14′ × 10′ and nearly reaches the nebulosity to its north. NGC 6595 and NGC 6589 have apparent sizes of approximately 2½′ × 4′ and 2′ × 3′, respectively. Collinder 371 looks more charming through this scope, like a pair of snakes pausing for a kiss as they wind their way northeast. Do you see them? About 35 stars bespot this viperous cluster. The two reflection nebulae are better appreciated at 115×, especially NGC 6595, which is unevenly illumined and considerably brighter in an elongated, patchy area around its star pair.

Don't be surprised if the atlas you use has different designations for these objects. IC 1284 is sometimes called IC 1283, but the latter is part of the former. NGC 6595 is identical with NGC 6590, and Collinder 371 is often mistakenly labeled as NGC 6595.

Our last stop, where glows the Milky Way, is the **Summer Christmas Tree**, a pretty asterism noted by North Carolina amateur David Elosser. Through my 105-mm refractor at 28×, I see about 25 stars forming a fir tree, 35′ tall with its tip pointed north-northwest. A yellow star tops the tree, and an orange one marks its southwestern corner. Fittingly, the treetop star (HD 173928 or SAO 161848) is the brightest. This is a nice treat when winter's Christmas Tree (NGC 2264 in Monoceros) isn't available for our admiration. ✦



SERGIO EGUIVAR

The large emission nebula IC 1284 forms a lovely triplet with the smaller reflection nebulae NGC 6589 and 6595.

Nebulae and Globular Clusters in Western Sagittarius

Object	Type	Mag(v)	Size/Sep	RA	Dec.
Lagoon Nebula	Emission nebula	~3	90′ × 40′	18^h 03.7^m	–24° 23′
Trifid Nebula	Emission/reflection nebula	~7	20′	18^h 02.4^m	–22° 59′
NGC 6553	Globular cluster	8.1	7′	18^h 09.3^m	–25° 55′
NGC 6544	Globular cluster	7.8	6′	18^h 07.3^m	–25° 00′
Swings-Struve 1	Planetary nebula	11.4	5.6′ × 5.2′	18^h 16.2^m	–30° 52′
IC 1284	Emission nebula	—	19′ × 14′	18^h 17.5^m	–19° 41′
NGC 6595	Reflection nebula	—	5.6′ × 3.3′	18^h 17.1^m	–19° 52′
NGC 6589	Reflection nebula	—	4.0′ × 3.1′	18^h 16.9^m	–19° 47′
Summer Xmas Tree	Asterism	4.9	40′	18^h 49.0^m	–18° 55′

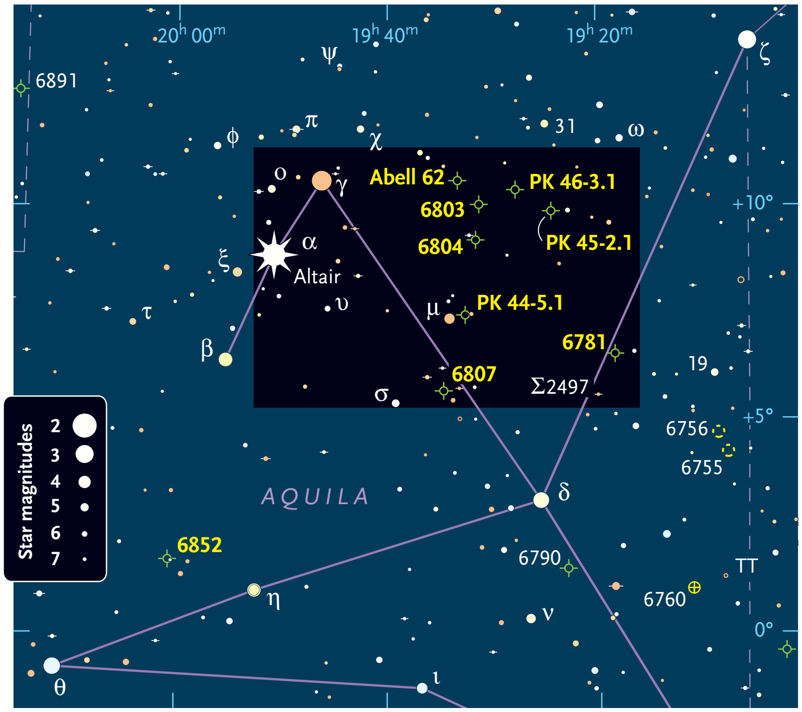
Angular sizes and separations are from recent catalogs. Visually, an object's size is often smaller than the cataloged value and varies according to the aperture and magnification of the viewing instrument. Right ascension and declination are for equinox 2000.0.

Dots and Donuts in Aquila

These nine planetary nebulae range from easy to . . . not so easy.

On a dark country night a few summers ago, I issued myself a somewhat arbitrary challenge: select and observe a variety of planetary nebulae inside the "diamond" of Aquila outlined by alpha (α), zeta (ζ), delta (δ), and theta (θ) Aquilae. The subsequent fieldwork was satisfying indeed, as my 17.5-inch f/4.5 Dobsonian revealed a pleasing range of sizes, shapes, and luminosities among the nine chosen objects. You might like to give this project a try yourself.

I began my tour with the 11.4-magnitude planetary nebula **NGC 6803**, located about 3¾° west-southwest of the 2.7-magnitude star gamma (γ) Aquilae, also known as Tarazed. At 83× this planetary appeared starlike and was flanked by a 13th-magnitude star 1′ to its south-southwest and a 10.6-magnitude star almost 3′ to the north. Adding an O III filter dimmed the brighter star and obliterated the dimmer one, leaving the nebula between them as the dominant dot. And it was no longer starlike. At 222×, filter removed, the tiny disk appeared bluish.



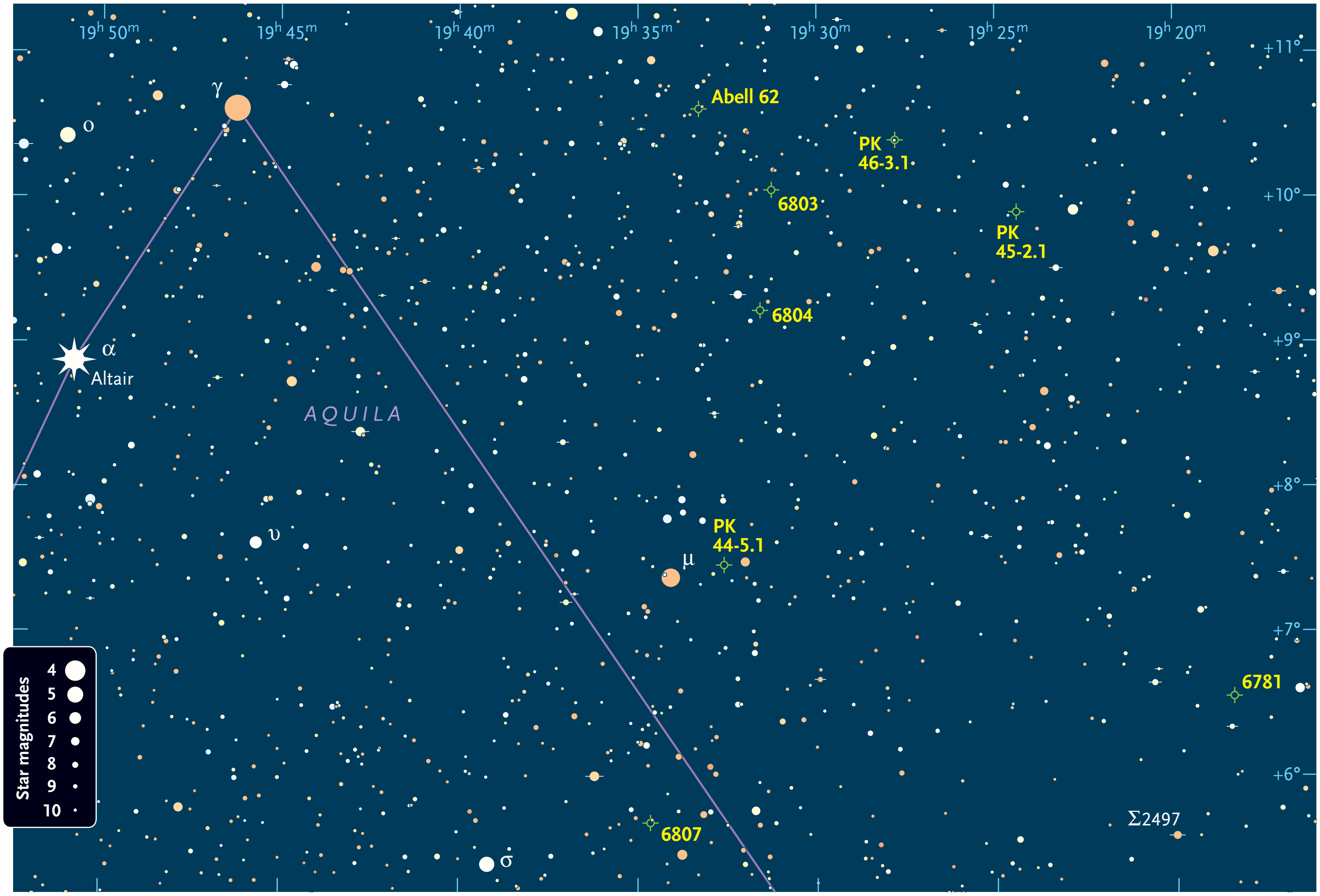
Dropping almost 1° southward, I swept up 12.0-magnitude **NGC 6804** about ¼° southwest of the 7th-magnitude star HD 184061 (SAO 124749). Unfiltered at 83×, the 66″-wide splotch resembled a fan-tailed comet: its "tail" being the diffuse nebulosity and its "nucleus" a 12.5-magnitude star on the nebula's northeast edge. My 222× ocular revealed a fainter star farther northeast, another one on the west edge of the nebula, plus the 14.3-magnitude central star — in all, a crooked line of four dim points. The O III filter blunted the stars but produced a disk that appeared oval and mottled.

Trending farther southward brought me to my teensiest target, **NGC 6807**, less than 1¾° below 4th-magnitude Mu (μ) Aquilae. In a wide-angle eyepiece generating 83×, the 12.0-magnitude planetary shared the field with two attractive stars: the reddish, 6th-magnitude variable V450 Aquilae ¼° to its southwest and the orangey 6.6-magnitude double star Σ2543 ½° on the opposite side of the planetary. Σ2543's 10th-magnitude companion is 11″ from the primary star.

The nebula itself appeared stellar beside a 10th-magnitude star 1.5′ northeast. With the filter, the nebula outshone the star and seemed bigger than a pinpoint. Ramping up to 285× produced a minuscule disk wavering in the less-than-perfect seeing.

I found **NGC 6852** roughly 2° east-northeast of 4th-magnitude eta (η) Aquilae. At magnitude 12.6, it showed readily at 83× despite the glare from 7.4-magnitude HD 189511 (SAO 125338) just 4′ to the planetary's west-southwest. Although a respectable 28″ in size, NGC 6852 appeared tiny at low power, and a 13.2-magnitude star immediately west-northwest of it imparted a binary-like effect. Increasing the magnification to 285× revealed an obvious disk with a 14.4-magnitude star near its southeast edge, a fainter star overlaying the same side, and a starlike brightening on the northwest edge. Adding an O III filter suppressed the starlight and, to my delight, produced an unevenly bright ring.

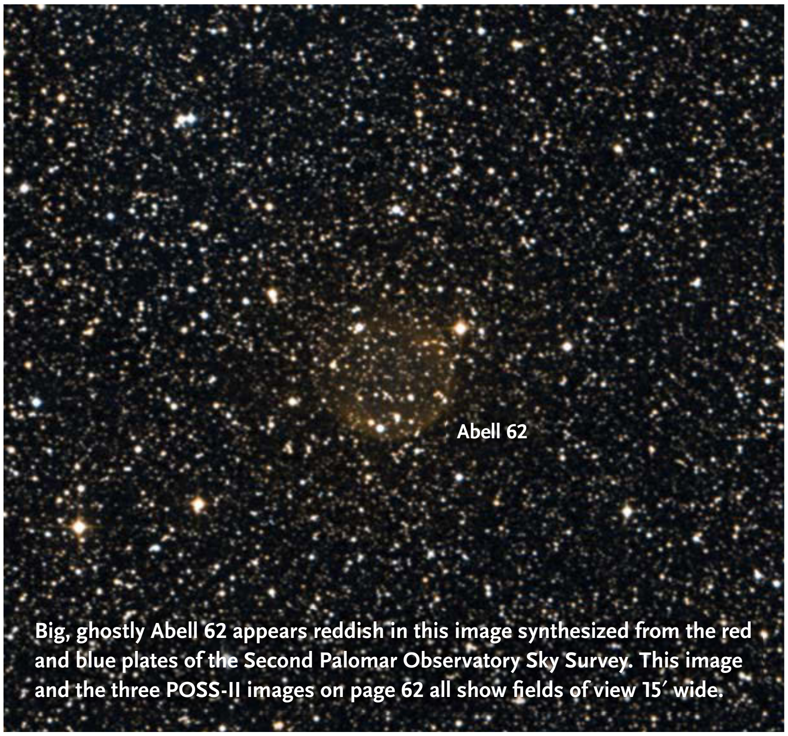
The most appealing specimen that night, 11.4-magnitude **NGC 6781**, was easy to find almost 4° north-northwest of δ Aquilae and less than ½° east of the 6.7-magnitude star HD 180504 (SAO 124457). At lowest power I saw a 1.5′-wide, doughnut-shaped cloud that was bright across



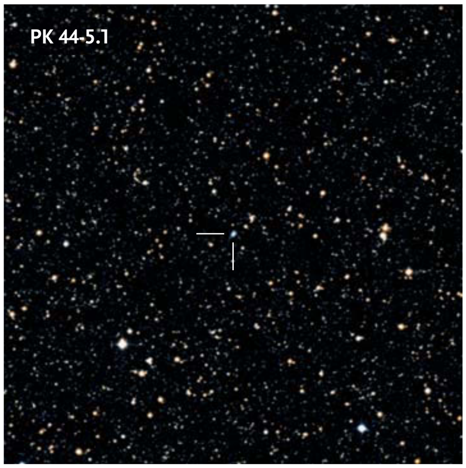
the south, faint in the north, and not completely black in the middle. My 222× ocular revealed a 13th-magnitude star hugging the northeast edge. Higher magnification hinted at other stars embedded in the nebulosity but, alas, not the 17th-magnitude central star. The "hole" around the missing star remained dusky, not perfectly black. Filtering the view helped define the nebula's slightly diffuse circumference, even across the pale northern half.

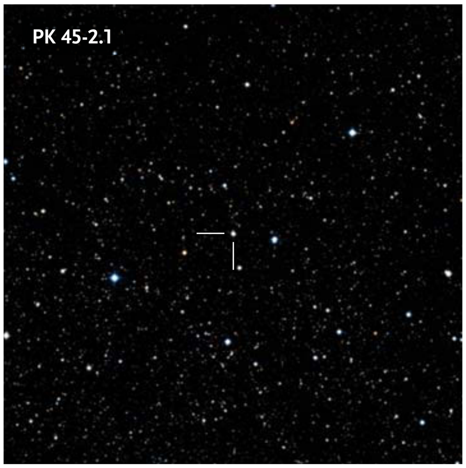
The prize for size went to **Abell 62** (PK 47-4.1), which spans 2.6′ of sky. Images indicate an annular shape, but the ghostly bubble barely showed in my scope. To ensure that I'd found the correct spot a bit more than 3° east of gamma Aquilae, I followed a 1°-long chain of successively dimmer stars, beginning with 6.0-magnitude HD 185018 (SAO 105045) and ending at the 10.1-magnitude star TYC 1060-2892-1, which overlays the nebula on its northwest side. Only by adding the O III filter and staring into the 67× field with averted vision could I glimpse the nebula's tenuous, vaguely spherical glow against the Milky Way. The most pleasing view was provided by a filtered 13-mm ultrawide ocular yielding 154×.

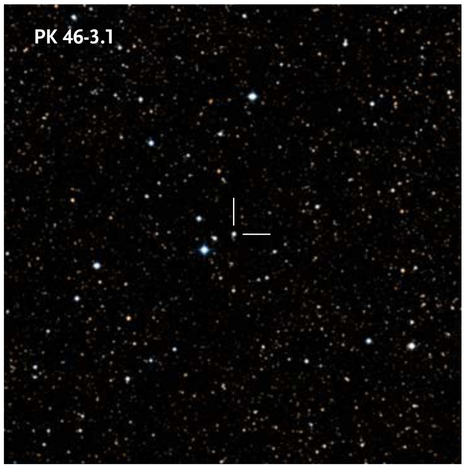
Throttling back to 83×, I tracked down two minuscule planetaries. For the first, I looked between Mu Aquilae



Big, ghostly Abell 62 appears reddish in this image synthesized from the red and blue plates of the Second Palomar Observatory Sky Survey. This image and the three POSS-II images on page 62 all show fields of view 15′ wide.

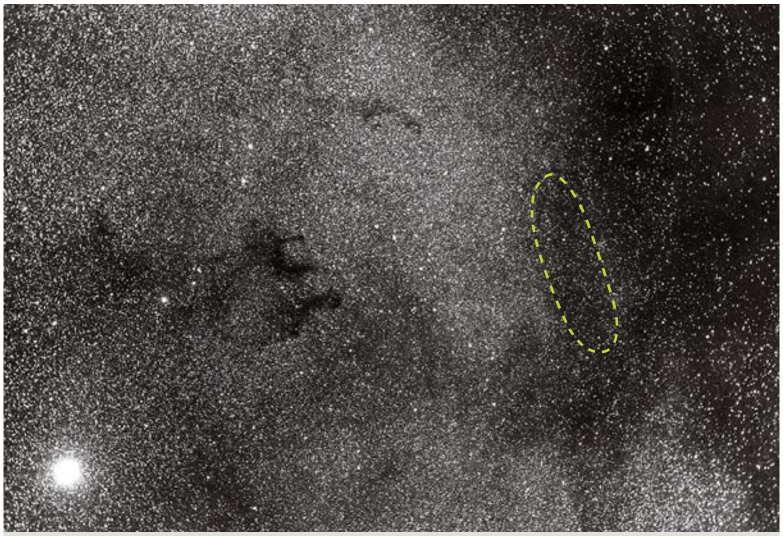






POSS-II / CALTECH / PALOMAR OBSERVATORY (3)

Below: **In addition to being a treasure trove of planetary nebulae, Aquila contains many superb dark nebulae, notably Barnard's E (B142/3) near the center of this plate from Barnard's *Atlas*. B333, which harbors PK 46-3.1 nears its southern end, is much less clearly defined.**



Planetary Nebulae in Northern Aquila

Name	Alias	Mag(v)	Size	RA	Dec.
NGC 6803	PK 46-4.1	11.4	5″	19^h 31.3^m	+10° 03′
NGC 6804	PK 45-4.1	12.0	62″ × 49″	19^h 31.6^m	+9° 14′
NGC 6807	PK 42-6.1	12.0	2″	19^h 34.7^m	+5° 41′
NGC 6852	PK 42-14.1	12.6	28″	20^h 00.7^m	+1° 44′
NGC 6781	PK 41-2.1	11.4	1.9′ × 1.8′	19^h 18.5^m	+6° 32′
Abell 62	PK 47-4.1	14.7	2.7′ × 2.5′	19^h 33.3^m	+10° 37′
PK 44-5.1	K3-36	~14.5	~15″	19^h 32.6^m	+7° 28′
PK 45-2.1	Vy 2-2	~13	stellar	19^h 24.4^m	+9° 54′
PK 46-3.1	PB 9	~14	< 5″	19^h 27.8^m	+10° 24′

Data for the NGC objects are from the NGC/IC Project website. Data for the non-NGC objects are from www.blackskies.org; most of the visual magnitudes and sizes listed for these objects are estimates.

and a 7th-magnitude star ½° west of it for 9th-magnitude HD 184152 (SAO 124767), a wide double. Roughly 5′ northwest of the double, I spotted 12.4-magnitude **PK 44-5.1** (Kohoutek 3-36) just 45″ southeast of a 12th-magnitude star. When I added an O III filter at 222×, the nebula overpowered its companion and yielded a fuzzy disk. For the second planetary, I aimed almost 3.5° northwest of Mu to pick up 6.4-magnitude HD 182101 (SAO 124564). About 20′ east of that beacon was 12.7-magnitude **PK 45-2.1** (Vyssotsky 2-2) — again beside a 12th-magnitude star. Filtering the field brought the nebula forward, though even at 285× the disk was difficult to discern.

My final — and greatest — challenge was **PK 46-3.1** (Peimbert 9), an obscure planetary within the dark nebula B333 about 1° northeast of PK 45-2.1. The dusky cavern of B333 is roughly 1° north-south and ½° wide, and I was searching for a 14th-magnitude smudge near its southern end. I trolled the area at 285× until I hooked a 1′-wide right triangle comprising the 10.4-magnitude star TYC 1059-1453-1, a 12.5-magnitude star to its north, and a third star of magnitude 13.0 that marked the right-angle vertex. Adding the O III killed that faintest star while producing a tiny disk 40″ west of it. In the process, the asterism changed from a tiny right triangle into a somewhat larger equilateral triangle. Cool!

In the end, my trusty O III filter held the diminutive PK 46-3.1 at magnifications as low as 83×. With practice, I could pick it up unfiltered with averted vision at 150×. In fact, all these Aquila planetaries (except Abell 62) are visible without a filter given sufficient aperture and magnification. Pick a dark, steady night and give them a try yourself. ✦

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*Contributing editor **Ken Hewitt-White** wrote his first* Sky & Telescope *book review in 1979 and has been a regular contributor since 2000. He observes deep-sky objects under the dark skies of British Columbia, Canada.*

Earthgrazing Meteors

When a meteor shower's radiant is low, meteors are infrequent but spectacularly long.

STÉPHANE VETTER

Alan MacRobert

Remember your favorite meteor? Don McCarthy saw his during the Leonid meteor storm of November 2001. McCarthy, an infrared astronomer at the University of Arizona, went out to watch the sky earlier in the night than all the experts were advising the public. The shower's radiant in Leo was still practically on the eastern horizon. "I can still see the meteor rising up the eastern sky like the bright exhaust of a dark-tipped missile," he says. "It gained speed and just kept going! We ducked as it passed overhead and continued westward, seemingly forever. We saw thousands of meteors later as Leo rose high, but two of those early 'earthgrazers' spoiled me — until last August's Perseids."

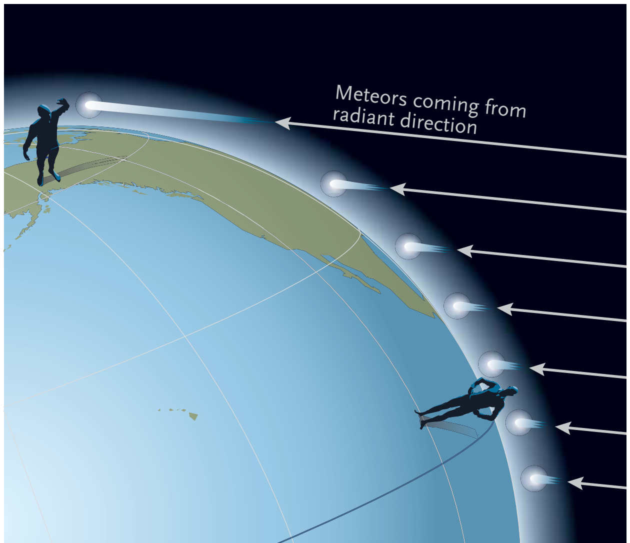
The standard advice for skywatchers has always been to plan your meteor watch for when a shower's radiant is high in the sky. This usually means staying up until (or waking up for) the pre-dawn hours, when your side of Earth faces forward as Earth flies along its orbit. Earth's motion, adding to the meteoroid stream's motion, tends to push showers' radiants into the morning sky.

All the particles in a meteor shower travel nearly in parallel. The *radiant* is the spot among the stars where they would all appear to be coming from if we could see them approaching in the far distance, instead of just in their last moments as they hit Earth's upper atmosphere. When the radiant is high, you see more meteors all over the sky than you would if the radiant were low.

That's why we're always told that the early-morning hours are "best" for the August Perseids, for instance. The Perseid radiant, in northern Perseus near Cassiopeia, doesn't reach its highest altitude until just before dawn.

But at 10 p.m. last August 12th, on the shore of Lake Superior in northern Minnesota, McCarthy and his family were roasting marshmallows over a campfire. A hill blocked the north, and the lights of nearby towns brightened the sky. Nevertheless, out the corner of his eye, "I saw a long meteor coming from the north and passing overhead — and it kept going!" He called out to his family. They turned and saw it. "I knew this was Perseid night, and it was coming from the right direction, but the

Left: **Many meteors change from blue-green to red during their plunge. This one did so as it skimmed from low in the east all the way across the zenith and almost down to the western horizon. Stéphane Vetter was shooting through an all-sky fisheye lens from Champ du Feu in Alsace, France, on November 17, 2012, during the annual Leonid shower. But this does not seem to be a Leonid! The shower's radiant in the Sickle of Leo was rising just above the trees off to the left of the meteor's direction of origin. The brightest object is Jupiter in Taurus. Below it is Orion.**



S&T: LEAH TISCIONE

Grazing & Nongrazing Meteors

Above: **A shower's meteors all travel in parallel. Where they hit Earth's upper atmosphere straight on, a skywatcher sees them numerous but fairly short. In the parts of the world where they graze in at a low angle — that is, where the shower's radiant appears low in the sky — the meteors are few but long. (Not to scale.)**

Your Observations Wanted!

If you go out watching for earthgrazing meteors, you can contribute to a project that Don McCarthy is starting. He hopes to measure the frequency of these dramatic events and determine several things:

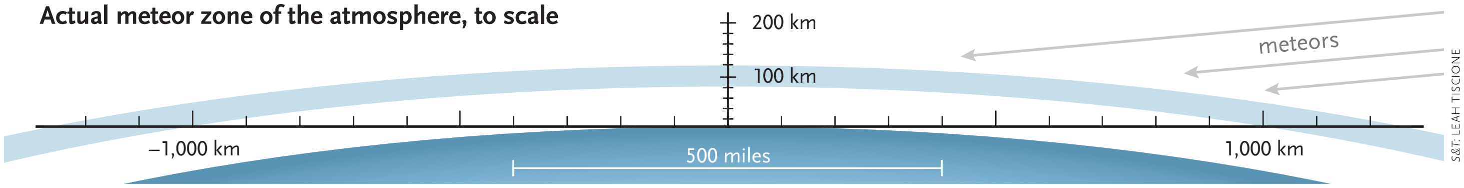
· Do their numbers scale down as geometry would predict due to their low incoming angle? Or are they more (or less) visible than expected — perhaps due to their attention-getting length and duration?

· Are they numerous enough to justify promoting them to the public? Could they attract new meteor watchers to the field?

· Can they predict the intensity of a shower's activity later in the night?

To collect your observations, McCarthy has set up an earthgrazer report form at astronomycamp.org, the website of Arizona's Astronomy Camp, which he directs. Click on the "Fireball Meteor Report Form" link on the home page. Report meteors even if they're not fireballs.

Actual meteor zone of the atmosphere, to scale



Earth's atmosphere is quite thin compared to Earth's diameter, as this true-scale diagram shows. This enhances the difference between grazing and straight-down meteors. Most meteors shine in the upper blue zone: from about 120 to 80 kilometers (75 to 50 miles) high.

hour was still fairly early.

"In the next 20 minutes we saw 20 more like this," he recalls. "We could not avoid seeing them!" The experience was all the more remarkable because the radiant was only about 25° to 30° up, so in theory, they were seeing only 40% to 50% as many meteors as they would have seen had the radiant been overhead.

Earthgrazers (extreme cases are called "skippers") are memorable enough to make up for their rarity. The meteors in a shower are tiny pieces of low-density comet material — dust clumps rather than rocks or iron — arriving at 30 to 70 km/second (70,000 to 160,000 mph). When they dive into Earth's atmosphere at a steep angle, they burn out fast. But when they enter at a low angle, they can survive long and travel far. This is especially true if the meteor is inherently big and bright.

An earthgrazer may seem to move slowly, but this can easily be an illusion due to its long duration. It will indeed appear slow if it's near your horizon and therefore is very far away, especially if you're looking toward or away from the radiant and the motion is foreshortened along your line of sight.

A New Way to Watch Meteors

Watching for earthgrazers means violating the standard advice. Wait until the radiant is high? That's for watchers who hope to see the greatest numbers, or for those seeking to make a statistically significant meteor count. But early evening is, on average, the most likely time to see meteors coming in at a shallow slant.

This year Earth should pass through the thickest part of the Perseid stream for 12 hours or more centered on 0^h August 13th Universal Time. This covers nightfall on

Below: **The historic "Earth skimming" fireball of August 10, 1972, caught peoples' attention in broad daylight from Utah to Alberta. At Jackson Lake, Wyoming, James M. Baker grabbed his camera and shot pictures of it passing behind Teton Mountain. Estimated to be a few meters in diameter, it continued on right out of the upper atmosphere and back into space.**

Tuesday the 12th for the North American time zones. (For more on this year's bright-Moon Perseids, see page 50). For viewers near 40° north latitude, the radiant will be 15° high in the north-northeast at the end of twilight.

The main reason why you see fewer meteors from a low radiant is the same reason the ground is less bright under slanting sunlight than when the Sun is overhead. Particles coming in at a low angle get spread over a larger area than they would if they were coming straight down. That's true whether we're talking about photons hitting the ground or meteoroids hitting the upper atmosphere. The same effect is what causes the low Sun of winter to heat the land less than the high Sun of summer.

Although you may see only one or two earthgrazers in an evening, if you're lucky, each is a memorable event. For a chance at catching a true horizontal skimmer — a rare but truly remarkable sight — you can begin watching even a little before a shower's radiant rises. Earth's gravity bends the trajectory of incoming meteors enough to elevate a radiant that's near the horizon by a few degrees compared to its nominal position among the stars. (The exact amount depends on the meteoroid stream's velocity.) You'll be able to follow such a long flyer for perhaps 15 seconds or longer, a seeming eternity compared to typical meteors. In theory, a large skimmer passing from horizon to horizon, and arriving at only a little more than Earth's escape velocity, can shine in an observer's view for about a minute.

Watching for earthgrazers widens your scope to include showers that we normally think of as Southern Hemisphere specialties. So, northerners might add the rich Eta Aquariids around May 6th to their meteor calendars. On the northern side of the sky, the January Quadrantids, with their north-circumpolar radiant that lingers along the horizon all evening, offer excellent prospects for evening earthgrazers in years when the timing is right (the Quadrantid peak lasts just a few hours).

Whatever its brightness, any meteor that lasts long and travels far is likely to be noticed by more people than a short, quick one. Artist Frederic Church saw, and later painted, the great horizontal skimmer that made news across the northeastern United States on the evening of July 20, 1860 (*S&T*: July 2010, p. 28).

Similarly, skywatchers as far south as Australia can keep an eye out for stray northern specialties such as the Perseids, Geminids, and Quadrantids.

And you gain wider perspectives to the east and west too. One of the year's stronger showers is the Daytime Arietids, which lasts for nearly the first half of June. During that time, it's supplemented by the weaker but similarly protracted Daytime Zeta Perseids from a radiant nearby. The "daytime" label is not quite true. Both radiants rise above the east-northeast horizon just before dawn for the mid-northern latitudes. When the radiants are high in the middle of the day, they might produce 40 to 80 meteors visible per hour if daylight weren't present — which suggests that they offer fair prospects for an earthgrazer or two at the beginning of dawn. Have you ever seen a meteor from a "daytime" shower? ✦

Alan MacRobert *had no trouble counting Perseids as a child in the light-polluted suburbs of Boston.*

Spring into NEAF

Sean Walker

The annual Northeast Astronomy Forum has something for every amateur astronomer regardless of age, experience, or field of interest.

Every year I make an effort to scout all the vendor booths at NEAF in search of new and innovative astronomy gear that our readers will find useful. This year's event had a particularly bountiful crop of telescopes, mounts, cameras, eyepieces, and other gadgets to make our hobby more enriching. Some of the highlights are featured on the following 7 pages.

1. www.stellarvue.com Vic Maris proudly showed off a variety of new Stellarvue products, including twin 130-mm triplet apo refractors — one designed with an f/6.6 air-spaced objective (right) and the other an f/7 with oil-spaced elements (left). Both were riding on the company's new M150-2 Isostatic mount head and TSL 10 cherry-wood tripod.

AISLES OF GEAR The showroom floor at Rockland Community College in Suffern, N.Y., was chock full of the lastest accessories, as well as attractions for children. All photos by the author.

2. www.luntengineering.com Lunt Engineering USA, a sister company of Lunt Solar Systems, made its debut at NEAF with a line of apo refractors with ED objectives ranging from 80 to 152 mm in aperture. The company is also the exclusive U.S. dealer of APM products, including triplet apo refractors and observatory-class instruments.

3. www.celestron.com Celestron unveiled the Rowe-Ackermann f/2.2 Schmidt Astrograph, which is a 21st-century optical update of Celestron's Schmidt cameras from the film era. This 11-inch Rowe-Ackermann astrograph boasts a 70-mm-diameter image circle, and is designed to accommodate DSLR and CCD cameras alike.

4. www.telescopehercules.com A newcomer to the U.S. market, Hercules Telescopes proudly displayed its carbon-fiber truss-tube Newtonian astrographs with lightweight cellular primary and secondary mirrors made from borosilicate glass. The astrographs feature a secondary mirror that rotates to 4 indexed positions, allowing users to rapidly switch between photographic and visual configurations.

5. www.inova-ccd.com Another newcomer to the U.S. market, iNova Technologies demonstrated its series of modular CCD cameras for capable autoguiding, high-speed planetary imaging, and deep-sky imaging.

6. www.sxccd.com Starlight Xpress rolled out its newest line of CCD cameras. The Trius series features a built-in USB hub for controlling filter wheels, focusers, and autoguiders, as well as an argon-filled chamber for the detectors to reduce the possibility of frost buildup on the sensor in humid conditions.

7. www.vixenoptics.com A highlight of the Vixen booth was a new motorized attachment for the Polarie Star Tracker that slowly pans your camera during time-lapse recordings.

8. Saturday's Solar Star party featured crystal-clear skies and good seeing so visitors could enjoy some great views of the Sun through dozens of solar instruments. CCD pioneer Richard Berry offers an attendee a helping hand viewing the solar spectrum through a Lhires Lite visual spectroscope from Shelyak Instruments.


4


Peltier module TEC (maximum power: 5.7W).
Aluminium case that also serves as heat sink for TEC.
Electronic card with a microcontroller to manage the Peltier module.
iNova
iNova
5


6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9. www.atik-cameras.com Atik Cameras gave attendees an up-close look at its new Atik One Integrated Kit cameras, which utilize an internal filter wheel and off-axis guiding unit. See additional details in last month's New Product Showcase, page 42.

10. www.polarisprecision.co.uk Polaris Precision showcased an innovative line of telescope piers and tripods that can be raised or lowered electrically at the push of a button without compromising alignment.

11. www.celestron.com Celestron also revealed its newest line of Schmidt-Cassegrain telescopes, the Evolution series. The scopes include a host of features, including complete smartphone app control, an internal rechargeable battery, and several mechanical improvements.

12. www.meade.com Meade Instruments had one of the largest booths on the floor. The company displayed its impressive line of Go To telescopes and solar instruments. It also introduced a new series of binoculars and spotting scopes.

13. www.jimsmobile.com Among the neat gadgets at the Woodland Hills booth was the hefty Nightrider Equatorial Wedge and tripod for fork-mounted Schmidt-Cassegrains from JMI Telescopes.

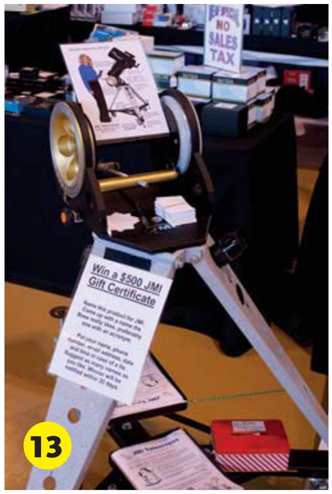
14. explorescientificusa.com Attendees check out the latest refractors and a prototype 8-inch imaging Newtonian at the Explore Scientific booth.

15. www.sxccd.com Starlight Xpress also debuted its newest compact autoguider, the Lodestar X2 built around the ultra-low-noise Sony ICX829 Exview2 CCD.

16. www.sbig.com SBIG adds the large-format AO-X active-optics guider for its large-format camera series. It enables users to make high-speed guiding corrections to obtain the sharpest images with its biggest CCD cameras.

17. www.williamoptics.com The new WO-Star 71 from William Optics is a 5-element corrected astrograph made with FPL-53 ED glass with a 45-mm corrected field.


12


NO
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SBIG
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18. www.luntsolarsystems.com Solar telescope pioneers Lunt Solar Systems unveiled the LS50T, a dedicated 50-mm solar Hα telescope with pressure tuning. The company also offers a new double-stacking option for its flagship LS152THA Solar Telescope, seen here with outreach coordinator Stephen Ramsden. Completing the company's trifecta of new products was a prototype solar Hα observing system for Schmidt-Cassegrain telescopes.

19. www.innovationsforesight.com Innovations Foresight unveiled its *SharpLock* autofocus software that monitors the guide star in its ONAG on-axis guider and constantly adjusts a telescope's focus in real time to keep images razor sharp for the imaging camera. Innovations Foresight also partners with Sky Vision, a company that introduced the robotic Nova 120 direct-drive German equatorial mount at NEAF. The mount is capable of bearing scopes and accessories weighing in excess of 260 pounds (118 kg).


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20. www.skywatcherusa.com Though currently available in North America only from Canadian dealers, SkyWatcher showcased its heavy-duty EQ8 SynScan GPS mount with Freedom Find encoders. These allow users to manually slew telescopes and cameras around the field of view without the mount losing its positional accuracy.

21. planewave.com The team at PlaneWave Instruments was on hand to answer questions and demonstrate its attractive line of corrected Dall-Kirkham astrographs and German equatorial mounts.

22. www.televue.com Tele Vue showed its new 3-inch BIG Paracorr for visual and photographic use on large-aperture, fast Newtonian telescopes with 3-inch focusers.

23. www.qhyccd.com Camera manufacturer QHYCCD showcased its new completely wireless CCD camera. The QHY InterCam 8300 includes a built-in wireless router, internal USB drive, and Pentium processor, enabling users to take deep-sky CCD images without the need for an external computer at the telescope.

24. www.newmoontelescopes.com New Moon Telescopes had a great display of its custom mid- and large-aperture Dobsonians. Of special note were the company's new lightweight-aluminum altitude bearings with a textured powder coating that produced just the right amount of "stiction" for a Dob mount.

25. www.vixenoptics.com Vixen also showed off its new Transformer German equatorial mount, which is offered in five configurations, ranging from all-manual controls to Go-To slewing with the Star Book One controller. Additionally, all of its equatorial mounts now have an updated design for their polar-alignment finders. ✦

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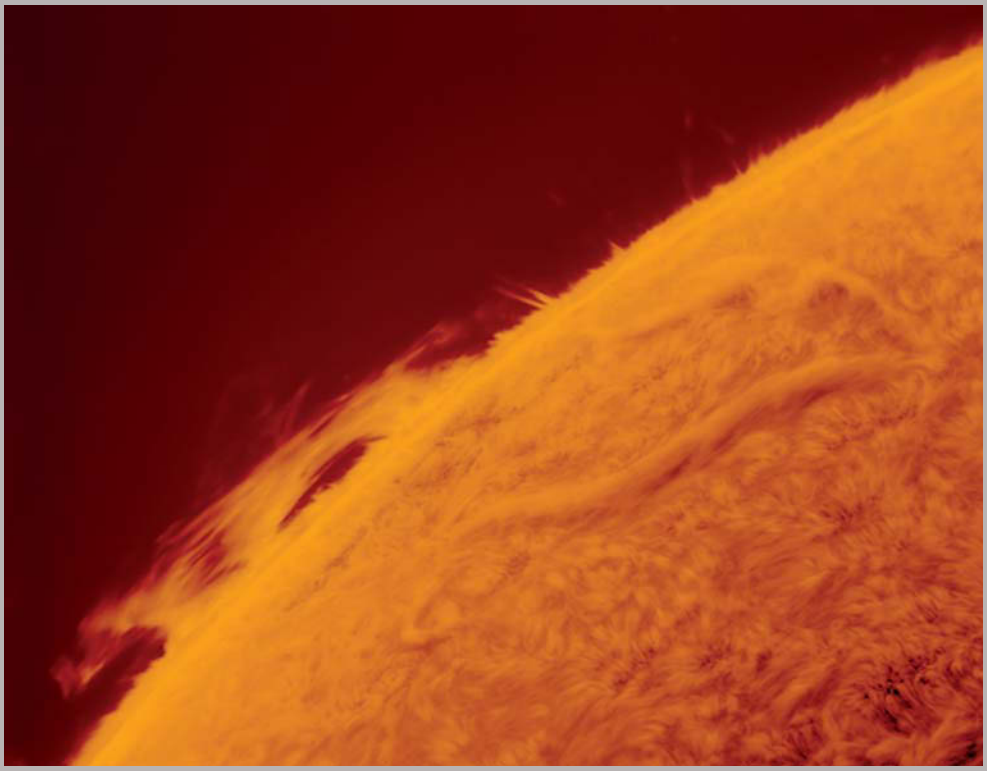


◀ **PLASMA ARC**

Paolo Porcellana

A broad prominence and thin spiculae appear along the solar limb while a long filament curves across the solar atmosphere at right.

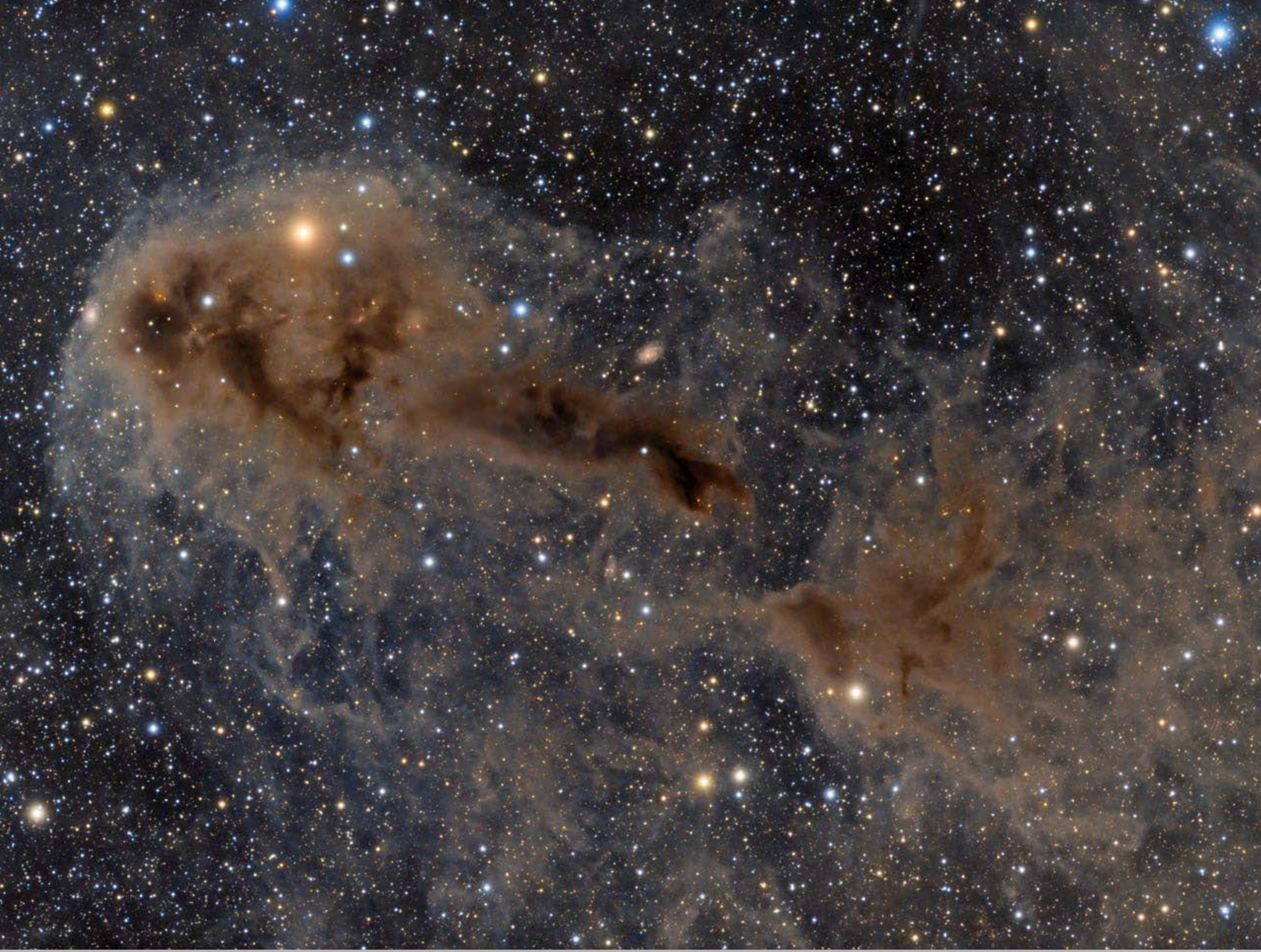
Details: *150-mm refractor with DayStar Quantum 0.5-angstrom solar Hα filter and Point Grey Research Chameleon video camera. Stack of multiple exposures recorded on April 20th. Both negative and positive images were combined to produce this image.*

▼ **WHIRLPOOL FLYBY**

Rolando Ligustri

Moderately bright Comet C/2012 K1 PanSTARRS is caught slipping by M51 in Canes Venatici on the evening of May 2nd.

Details: *Takahashi FSQ-106N astrograph with FLI ProLine PL11002M CCD camera. Total exposure was 21 minutes through color filters.*



▲ **DUSTY APPARITION**

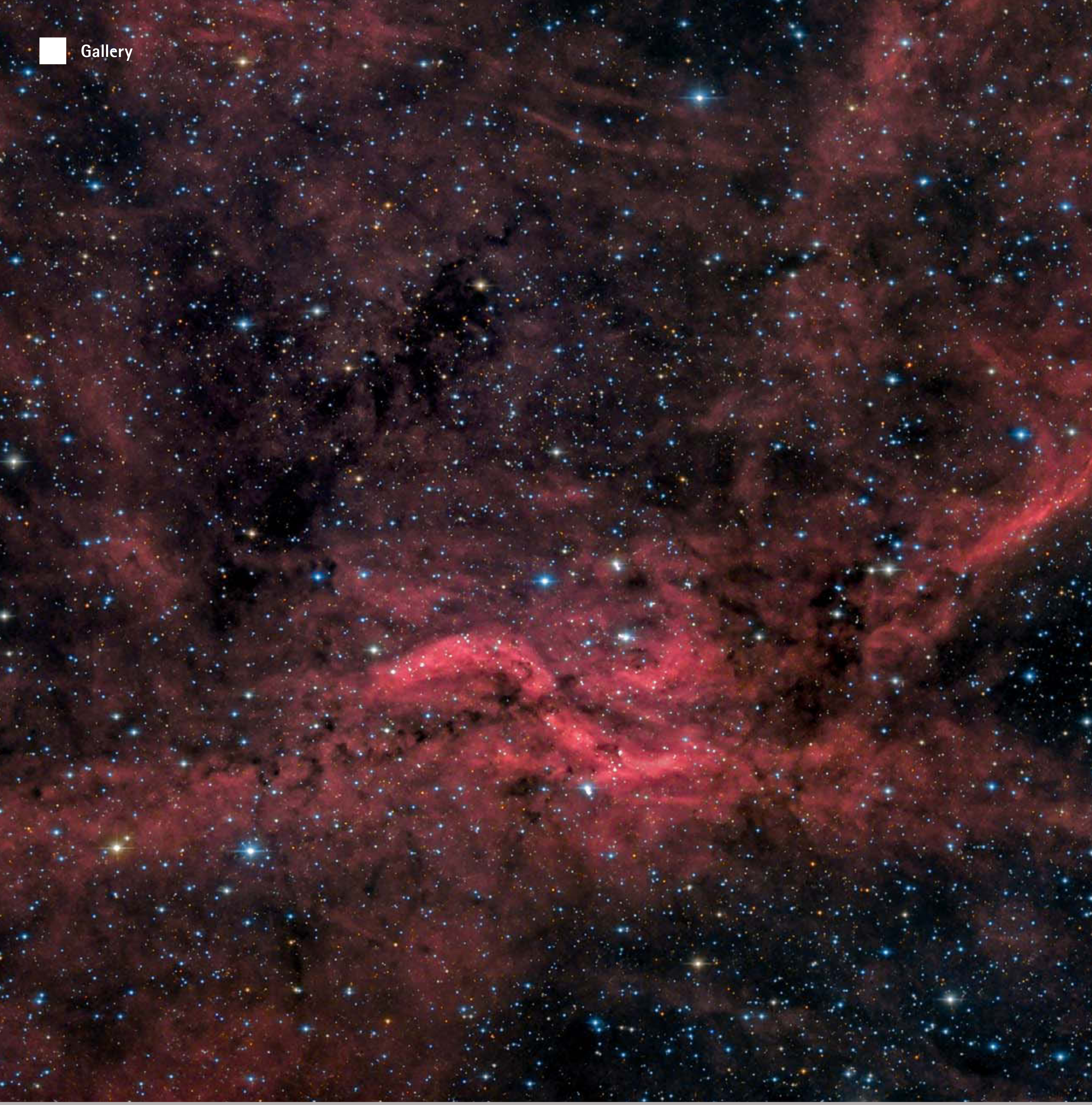
Fabian Neyer

Obscure dark nebula LBN 558 in Cepheus reddens the distant background galaxies PGC 69472 (left) and PGC 166755 (above center). **Details:** *TEC 140APO refractor with SBIG STL-11000M CCD camera. Total exposure was 19.7 hours through Baader color filters.*

◀ **TROPICAL ECLIPSE**

Tunç Tezel

The Milky Way arches majestically to the left of the eclipsed Moon (right). Mars shines to the right of the Moon as seen on the morning of April 15th from the Florida Keys. **Details:** *Canon EOS 6D DSLR camera with 24-mm lens at f/2.8. Panorama of multiple exposures, each totaling 15 seconds at ISO 3200.*



PROPELLER IN THE WINGS

John Davis

The oddly symmetrical Propeller Nebula, DWB 111, is a denser concentration of a much larger cloud of pinkish hydrogen gas permeating the constellation Cygnus. **Details:** *Celestron 11-inch Rowe-Ackermann Schmidt Astrograph with QSI 583ws CCD camera. Total exposure was 1⅓ hours through Astrodon color and Hα filters.* ✦

Visit SkyandTelescope.com/gallery to view more of our readers' astrophotos.

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MAJOR $200,000 PRICE REDUCTION! Stunning, unique, one-of-a-kind research grade 1-inch f12.2 D&G refractor of superb optical quality (plus companion telescopes) on unique, custom-made Byers Series III mounting. Details in February 2013 issue of S&T, pp 66-69. See more details (plus a video) on SkyandTelescope.com's online MarketPlace under "refractors." Entire package now offered at $595,000. Contact Ed Noffsinger: TheDigmaModel@aol.com or 831-427-1011.

ROLL-OFF-ROOF OBSERVATORY with 11" Celestron and Hyperstar, in Unique southeast Arizona location. 3 Bdrm 3 Baths 2787-sq-ft home on 10 acres, built 2003, 40x40 RV/workshop and views! Pure enjoyment under the stars! $525k Sonoita Realty, Kathy O'Brien 520 405-1800.

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FOR SALE: TAL 200mm Klevtsov-Cassegrain Telescope. TAL200K 8.5 Klevtsov/Cassegrain optical design telescope in excellent condition. 200mm aperture, includes these accessories: 8X50 Finderscope with mounting bracket, 90 degree star diagonal, 2X Barlow lens, 10mm Super Plossl eyepiece, 25mm Super Plossl eyepiece, crosshair reticle for eyepiece. Manufacturer's web page: www.talteleoptics.com/tal200k.html Price: $1,495 plus shipping. Write ads@SkyandTelescope.com

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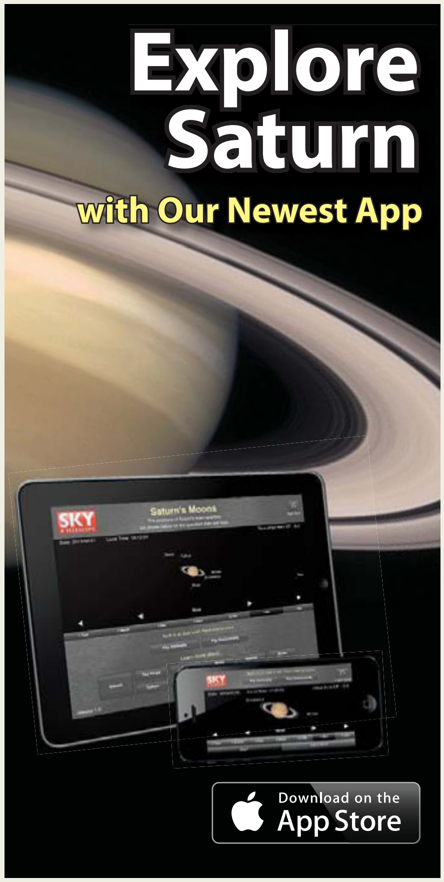

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Paramount (Page 27)
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PlaneWave.com
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Fisch Image Lab (Page 88)
ExploreScientific.com
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OKLAHOMA
Astronomics (Page 59)
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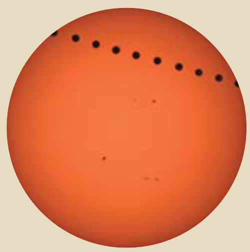

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Canada's Dark-Sky Preserves

The large nation has become a choice destination for amateur astronomy.

When you think of dream locations for observing, your thoughts probably turn to Chile's Atacama Desert or the Australian Outback. But thanks to strenuous efforts to control light pollution, many parts of Canada should now be on this list.

Sure, the country doesn't have as many clear nights as these other places, but it has developed the world's largest network of astronomy parks. Over the past 15 years, Canada has quietly set aside 80,000 square kilometers of parkland — *almost 1%* of the land area of the world's second largest nation — in the form of 19 dark-sky preserves. In these sky-gazing havens, local ordinances defend the night against urban light pollution.

Such locales are approved by the Royal Astronomical Society of Canada, which grants dark-sky designations to parks after a process that requires applicants to demonstrate lighting control, local support, and the ability to provide public astronomy interpretation.

Some of these astronomy parks are based in previously established national parks, such as New Brunswick's Fundy National Park and Nova Scotia's Kejimkujik National Park. The latter boasts some of the darkest skies in the maritime provinces and an aboriginal Sky Circle amphitheater that local star seekers call their "outdoor planetarium."

Another dark-sky preserve is centered on Québec's Mont Mégantic. During the day you can see Maine and New Hampshire from the 1,102-meter (3,615-foot) summit. At night, the most powerful telescope on the Eastern seaboard — a 1.6-meter Ritchey-Chrétien telescope in nearly pristine darkness — scans the skies for a team of international researchers. A few dozen meters down the mountain, park staffers take requests at the controls of a 24-inch public telescope.

The dark-sky parks of Ontario span from Canada's southern tip to the shipwrecks of Lake Huron, where naturalists guide ferry passengers through the heavens with image-stabilized binoculars.

But the hands-down darkest stargazing experience in Canada is in Saskatchewan's Grasslands National Park, on the Montana border. Here, vast plains of green above fossil-strewn badlands form a natural baffling effect, where even light from far away seems absorbed and intricate galactic details resolve right down to the horizon. Visitors frequently report sightings of airglow, which is visible only in the darkest places on Earth.

Jasper Dark-Sky Preserve

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More than 2 million people a year flock to Jasper National Park in the Alberta Rockies. This is one of the few national parks in the world that offers stargazing packages, where one can take a ride on a stargazing bus that may include evening tours to some of the park's most iconic canyons, glaciers, and waterfalls.

Wood Buffalo National Park on the Alberta/Northwest Territories border is the largest dark-sky preserve on Earth, able to fit Switzerland (or Saturn's moon Mimas) along its longest dimension. A mecca for aurora viewing, the park recently purchased a 35-person portable planetarium to simulate starry skies on cloudy nights or during the day.

Spanning the diameter of Mars, Canada is literally an observing destination the size of a world, harboring nearly half of Earth's designated astronomy parks. Although a dark-sky pub-crawl of all these locales may require more than one visit, perhaps that fact might be just the excuse you need to take in this observing dream destination again and again. ✦

__Peter McMahon__ has reported on dark-sky parks for magazines and currently writes the "Wilderness Astronomer" column in SkyNews: The Canadian Magazine of Astronomy & Stargazing, *where he is a contributing editor. For more on these parks, visit* ***WildernessAstronomy.com***.