Timeless Shots: FROM OLD DATA TO NEW SCIENCE p. 20

Comet Lovejoy: A DARK-SKY DELIGHT p. 62

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MAY 2015

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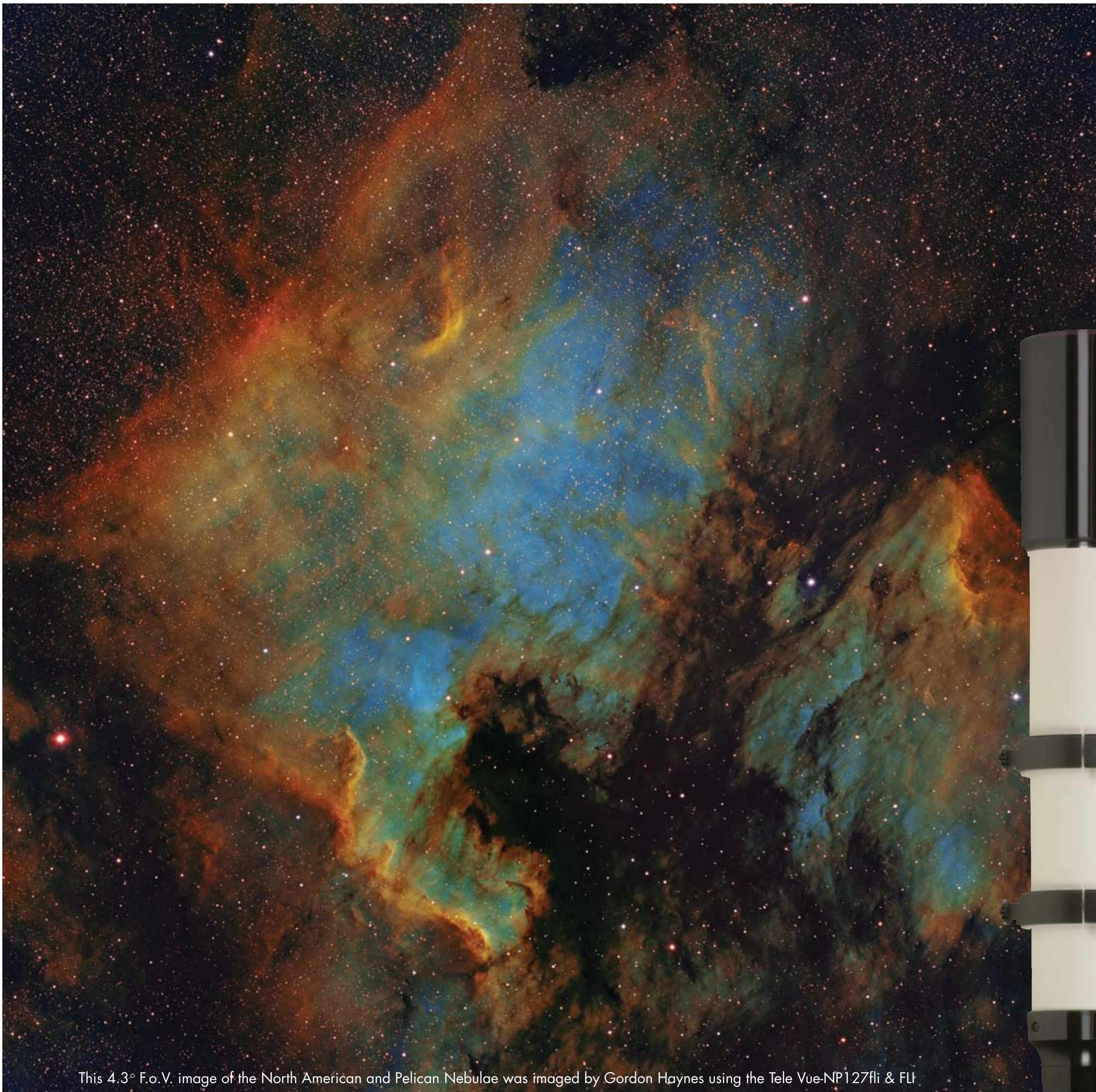

This 4.3° F.o.V. image of the North American and Pelican Nebulae was imaged by Gordon Haynes using the Tele Vue-NP127fli & FLI

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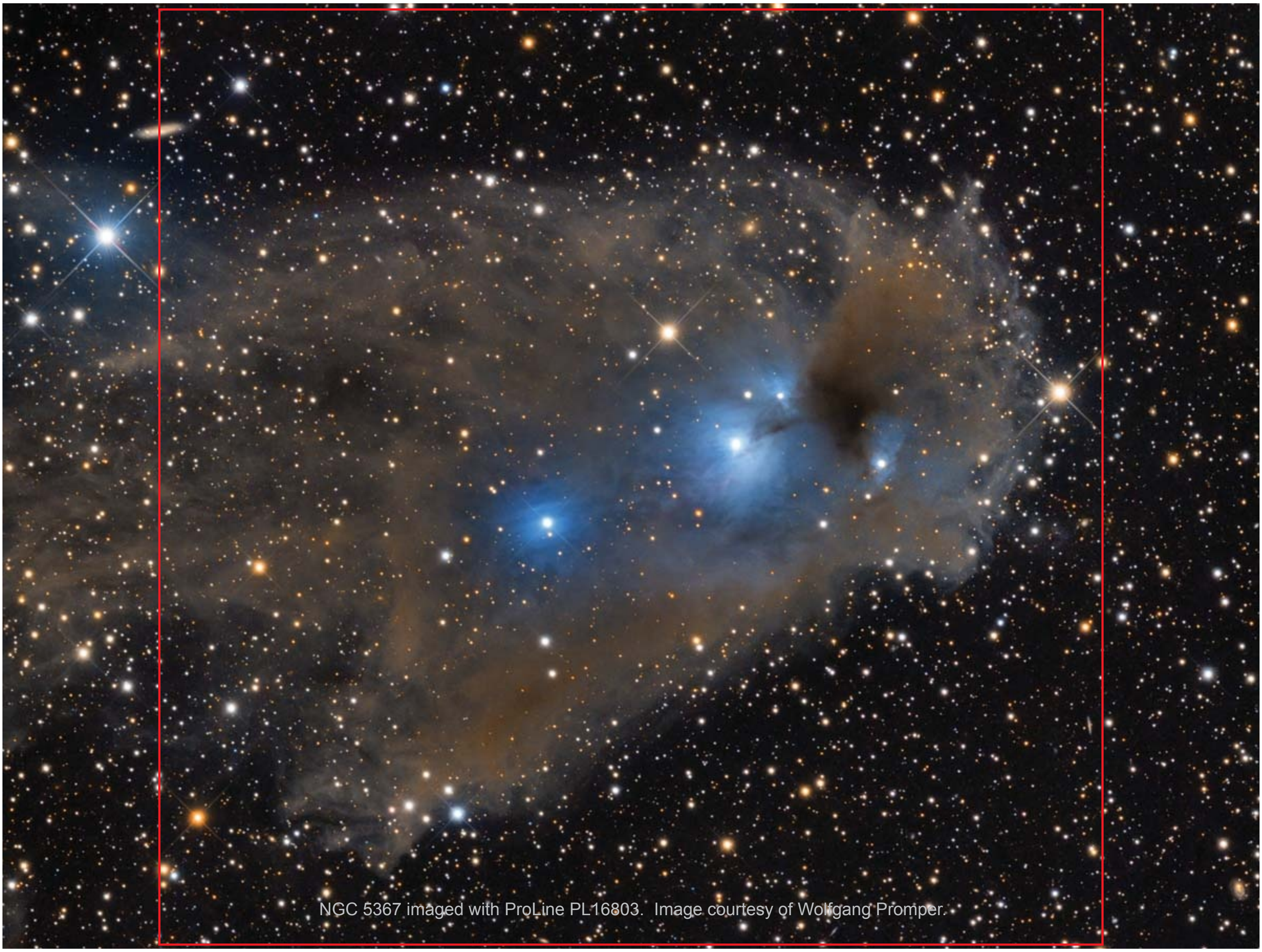

NGC 5367 imaged with ProLine PL16803. Image courtesy of Wolfgang Promper.

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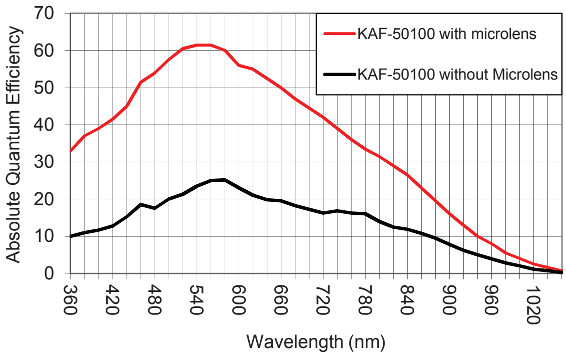

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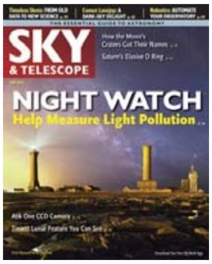

On the cover: The best measurements of light pollution come not from space but from those of us on the ground.

PHOTO: LAURENT LAVEDER

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  See a photo gallery from the airplane that was repurposed into a telescope.

- **Mutual Events among Jupiter's Moons**
  Jovian moons are eclipsing and occulting each other – find out how to watch.

- **Explore Astro History**
  View a century's worth of data collected from Harvard University's glass plates.

Photo Gallery

Image by Ken Miller

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ONLINE PHOTO GALLERY

Maximilian Teodorescu captured the Alphonsus and Eudoxus crater duo close to the terminator on a cold October morning.

Peter Tyson
Spectrum

Rising Above

IN EARLY FEBRUARY, I found myself perusing the many comments readers had submitted to Alan MacRobert's web article, "Where to See Comet Lovejoy Tonight" (see **is.gd/lovejoy2015**).

It's clear from those remarks just what a hit C/2014 Q2 turned out to be. Comet Lovejoy was brighter than expected, though still not naked-eye for most people, and it faded more slowly than predicted. It skirted iconic sky features such as M79 and the Pleiades, resulting in some dazzlingly unique photos. It offered a naked-eye challenge to determined viewers. And that tail! Bulgy and nebulous in December, it narrowed in mid-January into twin beams, like a pair of headlights in fog. As one observer put it, "All in all, this comet has proved to be quite a pleasant surprise." (See "A Comet to Capture the Heart," page 62.)

But what really struck me in reading those comments was the geographic diversity of those who wrote in. Amateurs hailed from across the U.S. — from Charleston, South Carolina to Ellensburg, Washington, from El Paso, Texas to Two Harbors, Minnesota. They corresponded from Toronto, Canada and Pachuca, Mexico, and from across the world in Cebu, Philippines and Johor Bahru, Malaysia. One gentleman stood for the entire Southern Hemisphere when he dropped a line from Foxton, New Zealand. Having so far failed to observe Lovejoy because of multiple cloudy nights and the comet's low altitude at its best, he wrote: "I hardly need to ask you lucky northerners to keep watching!"

SEAN WALKER

Comet Lovejoy on January 19, 2015

Some lucky northerners had the pleasure of regarding Lovejoy from dark-sky sites, like the man who, despite a full moon, managed to discern it from the Davis Mountains (site of the Texas Star Party). Others did their best from light-polluted cities, like the writer who spied the comet from the balcony of his apartment in central Rome, or the 15-year-old who viewed it through a new pair of 7x50 binoculars from a Chicago suburb.

What this global spread reveals in microcosm — beyond our shared passion, of course — is our shared humanity. A celestial wonder like Comet Lovejoy unites us as human beings in a way that no earthbound event quite does. What happens here on Earth is of first importance, naturally, because this is our home and these are our lives. But a cosmic thespian like Lovejoy reminds us that we are but bit players in a far grander spectacle going on above. And that we're all just regular people, ready to gawk like children at something spectacular.

So thank you, Comet Lovejoy. ✦

Peter

Editor in Chief

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My Town,Our Planetarium # 188

GOTO

Rebirth of a Czech Jewel

Ostrava, the third largest city in the Czech Republic, lies in the eastern part of the country, near the border with Poland. Once known primarily as a coal mining and heavy industry city, it now proudly offers new opportunities in the arts, culture, music, and education, including the VSB Technical University and its planetarium.

Opened in 1980, it is now named for the famous Czech astronomer Johann Palisa, who discovered more than 122 asteroids in the early 1900's. The entire planetarium building has recently undergone a total to-the-walls renovation and has re-emerged as a true jewel of astronomy and science education. Exhibits on astronomy, astronautics, physics, geology and seismology join a beautiful observatory which is also open to the public.

About the planetarium's new GOTO INC projection system, Tomas Graf, scientific manager of the renovation project said, "The HYBRID planetarium allows us to satisfy the interest of many people, not only pupils and students from all kinds of schools but also the general public, parents, young children and even amateur and professional astronomers, who would appreciate an authentic image of the night sky." Graf even utilizes the system in popular programs featuring jazz, classical, and relaxation music.

The essential, authentic sky image is provided by the GOTO PANDIA HYBRID system. The GOTO PANDIA produces a spectacular sky from a tiny starball only 48 cm in diameter. It shines 8,500 brilliant stars onto the 13 meter dome, along with hundreds of deep sky objects and a 40,000,000 micro-star Milky Way. A fulldome video system from EVANS & SUTHERLAND is seamlessly linked and synchronized with the PANDIA through GOTO's unique HYBRID software and manual control console.

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Staying the Course at *S&T*

Mario Motta is correct in his admonition to Peter Tyson (*S&T*: Jan. 2015, p. 6): Do not "dumb it down." But, then again, you wouldn't do that as the editor of the best astronomy magazine going.

Do you realize that *Sky & Telescope* is not just an astronomy magazine? We learn geology, math, history, art, geography, and the biographies of many learned scientists and people of history — and surely I'm missing a few categories. In reading more than 50 years of issues (all still with me, to my wife's wonderment), I have learned so much about this wonderful universe and planet that I feel I've gotten an entire college education. I write a small astronomy newsletter, and *S&T* is invaluable to me in this endeavor. So keep up the great work.

Al Schober
Ash Fork, Arizona

Grave Findings

I was pleased to read Jason Todoroff's letter about his search for Charles Messier's final resting place (*S&T*: Nov. 2014, p. 8), especially when he mentioned that Wikipedia helped him locate it. I happen to be the Wikipedian who contributed to the Messier article about the grave and how to find it, and it was very satisfying to know that such small efforts (in my case, very small) do make a difference. I too was helped in my search by an earlier, anonymous astronomy enthusiast. I've posted the story of my own search in a short video on YouTube (**http://is.gd/na8FPX**), which includes a walk-through to help fellow *Sky & Telescope* readers find the grave.

Robin Heisey
Toronto, Ontario

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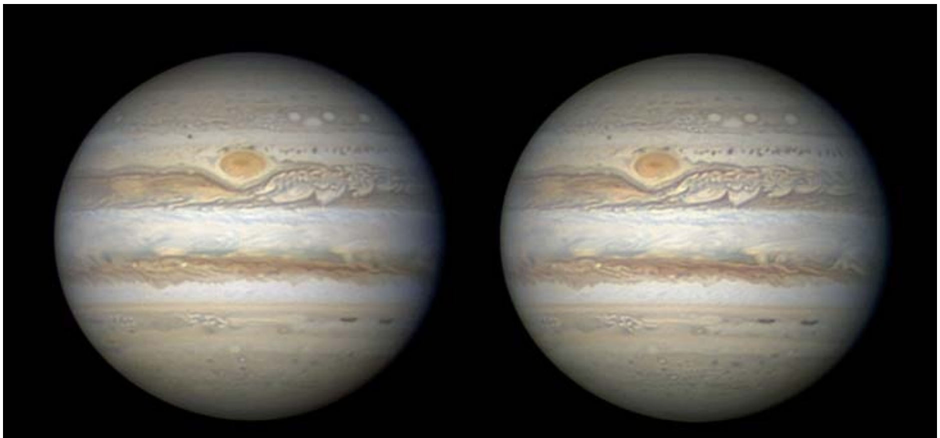


If you stare "through" these two images of Jupiter from March 4th, 2014, you'll see a 3D image of the planet appear. Once it does, explore the enhanced features you see.

DAMIAN PEACH

Jupiter in Stereo

One can see a very fine 3D image of Jupiter by staring "through" the two images taken by Damian Peach in the December 2014 issue (p. 52 and above). The 3D effect arises from the change in viewing angle created by the 17-minute delay between the two images. The difference is quite significant, even after so little time, because Jupiter's rotation is so fast (roughly one rotation every 10 hours).

Keep up your great astronomy reporting. I've read (almost?) every issue since August 1965!

Bill Fusfield
Pittsburgh, Pennsylvania

Editor's Note: *To see the 3D image, hold the page squarely in front of you, relax your eyes to look "through" the page into the distance, and let the two images of Jupiter merge. It helps to be nearsighted or use reading glasses; you can also place a thin partition between the photos so that each eye sees only one.*

The Not-So-Great Red Spot

Some things in the sky never seem to change. But other things, like the Great Red Spot (GRS) of Jupiter, are not so indelible. Regrettably, over the last few decades, the GRS has shrunk in size (*S&T*: July 2014, p. 16) and become pale and difficult to spot — especially in small- to medium-size instruments. Last year, while providing a young group of new observers with their first view of the GRS in my 8-inch scope, a number of them expressed disappointment and wondered what all the fuss was about.

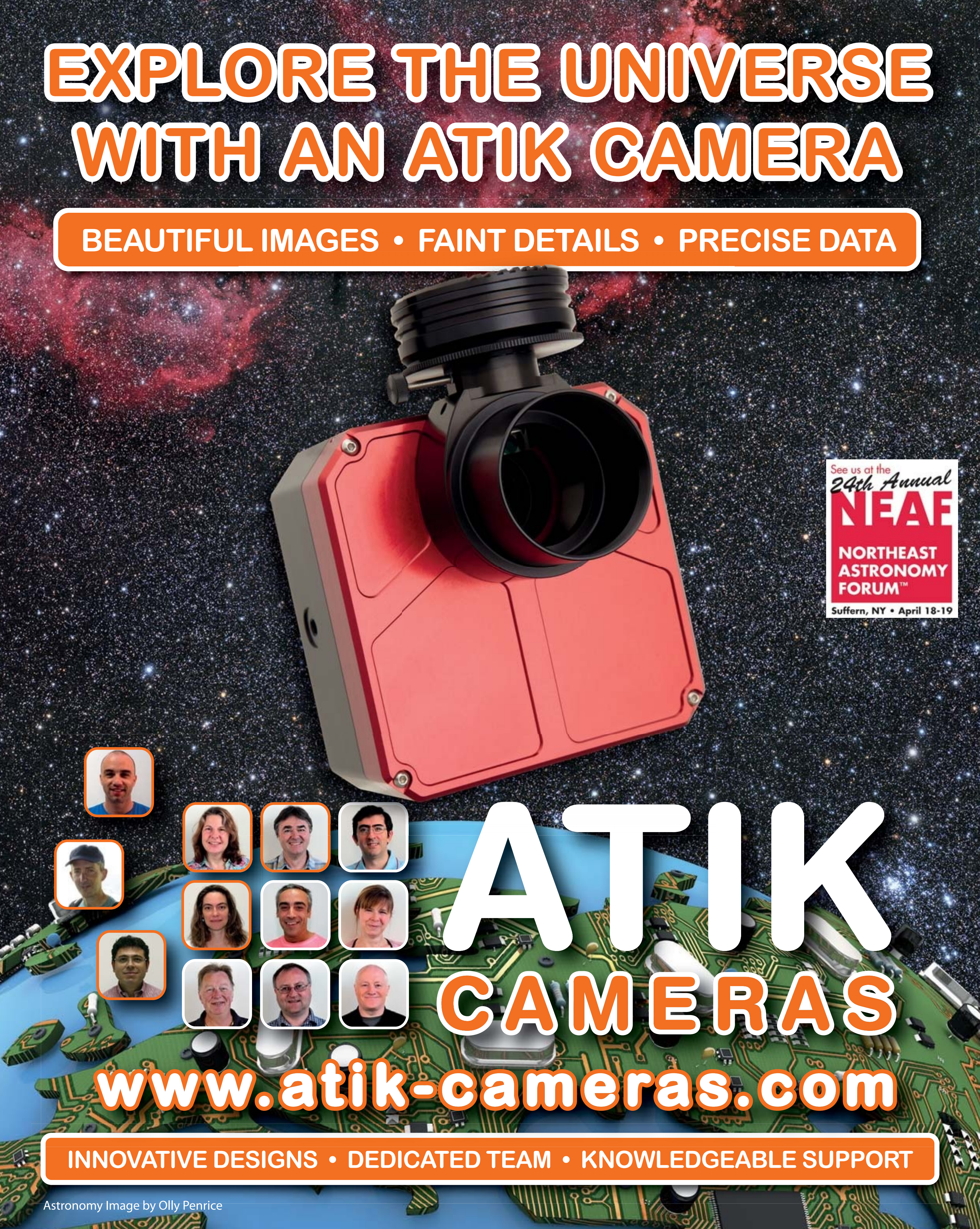
Years ago it was easy to see even in small telescopes, and in larger apertures you could often observe a distinct brick-red color. In fact, while reviewing my old observing logs recently, I encountered numerous drawings and descriptions of the Red Spot as observed with my humble 60-mm refractor. Perhaps most revealing was an entry made on October 13, 1974, that notes, "GRS easily seen at 35×!!"

My advice to fellow amateurs is to enjoy what remains of this iconic feature. Its glory days may be long gone, but it is still a viable target. A light blue or yellow-green eyepiece filter might help boost its contrast. Also be sure to better prepare new observers for what they can actually see — otherwise they might think you've been staring into the eyepiece for a bit too long.

Frank Ridolfo
Bloomfield, Connecticut

A Really Giant Jupiter?

I always look forward to reading the observing articles in *Sky & Telescope*. But a minor typo in the article about Jupiter at opposition (*S&T*: Feb. 2015, p. 52) produced a mind-blowing "what if?" experience. Imagine looking up and seeing Jupiter 45° in diameter (as the article states), instead of the real-life 45 arcseconds — heart-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stopping! But we couldn't enjoy it for long. This would place Jupiter's surface only about 115,000 kilometers away from us, and we'd be immersed in its lethal radiation belts. And although we would be a little beyond Jupiter's Roche limit for pulling Earth apart completely, our tides would be out of this world!

Joe Prusa
Boca Raton, Florida

Editor's Note: *Maybe that was a Freudian slip for wanting to see Jupiter 3,600 times closer up!*

In Search of North America

Reading Gary Seronik's Binocular Highlight about NGC 7000 (*S&T*: Oct. 2014, p. 45) inspired me to dig into my observing diary. It shows that on September 12, 2009, I made a naked-eye observation of elusive NGC 7000. The site was a small cemetery in the southern part of Adams County, Ohio. It was about 11 p.m. Three of us, all members of the Ohio Lepidopterists, were scanning the Milky Way to the musical accompaniment of nearby coyotes, when I was surprised to see the familiar North America shape right where it should be. The other two agreed that they too could make out the nebula's "Gulf of Mexico." I am curious to learn how many others have seen NGC 7000 this way.

Roger Grossenbacher
Lancaster, Ohio

Flying High and Gazing Higher

I saw the most amazing moonrise while flying from Bahrain to Diego Garcia. I had been admiring the night sky for some time, amazed by the stars visible at 35,000 feet over the Indian Ocean. Suddenly, a magnificent glow loomed on the horizon. At first I thought it was a massive fire on some distant shore. Then I assumed it marked the coming sunrise, an intensely red ball that contrasted starkly with the hours of darkness I'd seen. Finally, despite my jet lag, it "dawned" on me that this was the Moon, just below the horizon! I watched as the crimson red semi-orb rose, first becoming a golden-gilded gibbous, and then shifting spectacularly to its silver beauty.

How sad that no one else seemed to notice this precious moment of space and time. This celestial gift made me glad that I never stop looking up!

Kevin Russo
St. Marys, Georgia

For the Record

* *R Monocerotis (*S&T*: Jan. 2015, p. 38) is not an old, evolved star but rather a T Tauri variable — a pre-main-sequence star still partially enshrouded in its molecular cloud.*
* *In the finder chart for the Pleiades (*S&T*: Feb. 2015, p. 45), the star labeled "Alcyone" is actually Atlas. Alcyone, the cluster's brightest star, is nearer to the center.*
* *The illustration (*S&T*: Mar. 2015, p. 30) is of the Large Synoptic Survey Telescope.*
* *The computer simulation of the PSR 1257+12 system (*S&T*: Mar. 2015, p. 33) found that, after the progenitor star's death, roughly 0.001 solar mass of material (not 1,000 solar masses) could remain bound to the pulsar.*

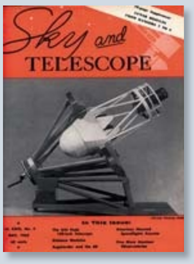
75, 50 & 25 Years Ago

Roger W. Sinnott

May 1940

Eclipse on TV "The [April 7th] eclipse was successfully televised by the RCA-NBC studios, assisted by the Optical Division of the Amateur Astronomers Association. Excellent reception was reported throughout the New York area. This was the first time in history that an eclipse of the sun had been broadcast by television to the public. From 4:30 p.m. to 5:15 p.m., a 4-inch reflecting telescope and eyepiece projected an enlarged image of the phenomenon on the photosensitive surface of the television camera, from which it was transmitted over the air. The resulting image almost filled the screens of the receiving sets, according to reports received from persons viewing the broadcast."

Operating the telescope was Robert Cox, who in future decades would orchestrate S&T*'s Gleanings for ATMs department. The eclipse was a deep partial event in New York but annular along a path that stretched from northwestern Mexico through Texas to northern Florida.*

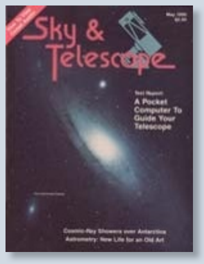


May 1965

Spacewalk "The first man to face the rigors of space without the protection of a rigid spacecraft climbed cautiously out of his airlock at 3:30 a.m. Eastern standard time on March 18th. Soviet cosmonaut Alexey Leonov then removed the protective cover from the lens of a television camera, revealing his space gymnastics to the whole world.

"Inside Voskhod 2, Pavel Belyayev supervised the operation, communicating with Lt. Col. Leonov via a connecting cable. Leonov spent 20 minutes in space, 10 of them floating free from the capsule except for a slim 16-foot tether connecting him to the spacecraft's life-support system. . . ."

Only decades later did the world learn that the spacewalk nearly killed Leonov. The vacuum of space caused his suit to expand so much that he could not reenter the capsule. Desperate, he reduced the suit's pressure using a small valve and finally squeezed himself back inside.



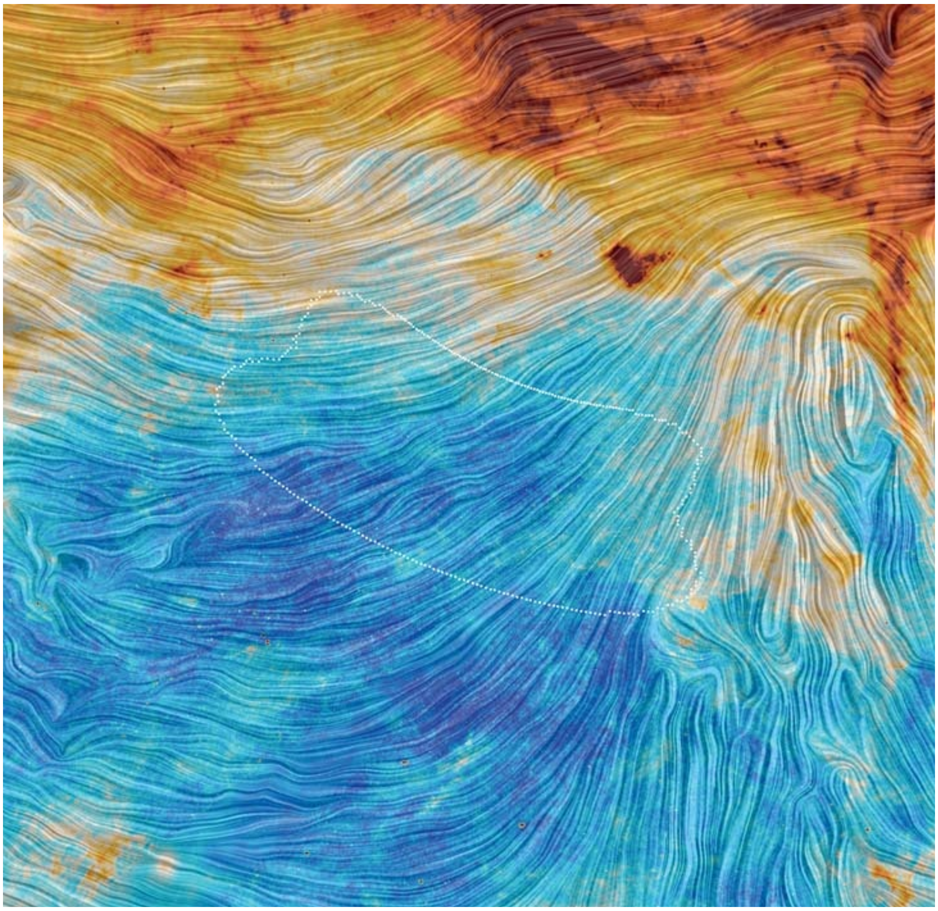
May 1990

Really Big Eye "At the January meeting of the American Astronomical Society in Arlington, Virginia, Debra Meloy Elmegreen (Vassar College) and colleagues . . . described their study of 'ocular' galaxies, those that resemble human eyes. Such systems turn up in supercomputer simulations when a disk (spiral) galaxy is perturbed by a companion passing at a distance of a few galaxy diameters. Tidal forces from the companion disrupt the circular orbits of the disk galaxy's stars, drawing out elongated stellar streams that form two spiral arms. One arm is always double, made up of both rapidly moving stars and a slower 'tidal tail'. . . .

"Combing through hundreds of photographs of real galaxies, the researchers found two dozen oculars, most of which do indeed have apparent companions . . . ."

Good examples are IC 2163 in Canis Major and NGC 2535 in Cancer, each hauntingly shaped like an eye with oval lids.

COSMOLOGY | Inflation Signal Reduced to Dust



ESA / PLANCK

This map from ESA's Planck satellite shows the patch of the Southern Hemisphere sky analyzed by the BICEP2/Keck projects (white outline, 400 square degrees). Colors represent emission from dust (orange is more, blue less) and lines represent the orientation of the Milky Way's magnetic field. The knot of red to the upper right of the BICEP2 field is the Small Magellanic Cloud.

The long-awaited analysis of swirly polarization patterns called B-modes affirms that these signals, purportedly from the universe's brief but stupendous spurt of inflationary growth, are probably instead from dust in our galaxy.

Last March, researchers with the BICEP2 and Keck Array experiments at the South Pole reported the detection of B-modes in their cosmic microwave background (CMB) observations (*S&T*: June 2014, p. 10). These B-modes, if in fact in the CMB itself, would come from spacetime ripples called *gravitational waves* that were created by the hypothesized 10 nano-nano-nano-nanoseconds (10^{-35} s) of inflationary growth.

Yet skepticism soon replaced euphoria when two other teams using data from the Planck spacecraft suggested the signals might instead be from dust in the Milky Way (*S&T*: Sept. 2014, p. 12). Aligned with our galaxy's magnetic field, interstellar dust grains produce polarized emission of the same pattern and angular scale (a couple of degrees) as the primordial B-modes cosmologists are hunting for.

To settle the debate, the BICEP2/Keck and Planck teams combined forces (and data) in a joint analysis. On January 30th the teams announced that the analysis shows that dust in the Milky Way can completely explain the B-modes detected by the South Pole experiments. At most, gravitational waves from inflation could make up only half of the observed signal.

Planck's full data set was crucial in this investigation because it obviates the need to extrapolate. Both BICEP2 and the Keck Array focused on a frequency of 150 GHz, favorable for CMB studies but challenging for dust identification. The Planck satellite, on the other hand, observed nine frequency bands, with seven of those — 30, 44, 70, 100, 143, 217, and 353 GHz — including polarization measurements. Using those data, astronomers can directly see how dust emission changes from frequency to frequency.

Emission from our galaxy's dust is strongest at 353 GHz (25 times stronger than it is at 150 GHz, in fact). And because Planck reveals the relationship between emission strengths at different frequencies, the researchers could use Planck's exquisite 353-GHz dust map to analyze the detected B-modes. They carefully compared, combined, and cross-analyzed the observations in order to calculate the implied ratio of how big the spacetime ripples were compared with the ordinary density fluctuations in the material filling space, a ratio called r. Basically, r measures the strength of the gravitational waves and how energetic inflation was. A higher r means more energy behind inflation.

The teams calculated an upper limit of $r < 0.12$, which agrees with the upper limit of $r < 0.11$ from Planck's 2013 results (those included only the first 15.5 months of satellite data). These upper limits favor simpler forms of inflation, with an energy scale of 2×10^{16} gigaelectron volts. Paired with Planck's full data (more on that next month), the limit shows cosmologists should focus on "slow-roll" inflation models, in which the potential energy that drives inflation decreases slowly (well, for inflation), like a ball rolling down a gentle hill. A lower energy scale would also be friendlier to string theories, which seek to unite quantum mechanics and gravity.

■ **CAMILLE M. CARLISLE**

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GALACTIC | Charting the Andromeda Galaxy

This composite image of M31 spans 48,000 light-years. At full resolution, you can see individual stars, even though the galaxy is 2.5 million light-years away. Explore the full image at http://is.gd/m31zoom.

NASA / ESA / J. DALCANTON / B. F. WILLIAMS / L. C. JOHNSON / PHAT / R. GENDLER

Astronomers working with the Panchromatic Hubble Andromeda Treasury (PHAT) project released the biggest, sharpest image yet of M31 on January 5th at the winter American Astronomical Society meeting in Seattle.

The final image includes 12,834 shots from more than 400 pointings taken through ultraviolet, visible, and near-infrared filters. Astrophotographer Robert Gendler stitched the images together to create the seamless mosaic, a stitching so careful that it's aligned at the level of individual stars — 117 million of them — or to better than one-tenth of an arcsecond.

Estimating the amount of dust needed to redden more distant stars, Julianne Dalcanton (University of Washington) and colleagues mapped dust across the galaxy, creating a 3D map of M31 with more than four times better resolution than previous dust-mapping methods. Surprisingly, the team found that other widely used maps predict twice as much dust as is really there, potentially from a calibration issue. Nearby galaxies might therefore have much less dust than previously thought.

Another surprise lies in M31's structure. Astronomers know that star-forming regions riddled with young, massive stars trace out spiral galaxies' iconic arms. Computer simulations show that such arms should move and evolve over time. Because stars' colors and luminosities reveal their ages, the PHAT images enable astronomers to look back in time and determine M31's star-forming history in various locations.

What the team found is that the arms aren't all transitory: a ring present today was also forming stars between 500 and 630 million years ago, a time scale much longer than astronomers predicted for the structure's survival. (The inner and outer rings vary as expected.)

"This was really a surprise," Dalcanton says. The density of stars in this ring is about 40% higher than in other regions in Andromeda, and it contains both old and young stars — it's not just the young stars tracing it out, as is common with spiral structure. "So it's this long-lived dynamical thing that's just kind of sitting there, for reasons we don't understand," she says.

■ **CAMILLE M. CARLISLE & MONICA YOUNG**

BLACK HOLES | Binary En Route to Merger?

Two decades of observations reveal what looks like a pair of supermassive black holes closing in for a merger.

When galaxies merge, astronomers expect the supermassive black holes lurking in the galaxies' cores to form their own dancing duos, inspiraling and finally coalescing. Yet black hole binaries have proven difficult to find, and astronomers only have circumstantial evidence for them.

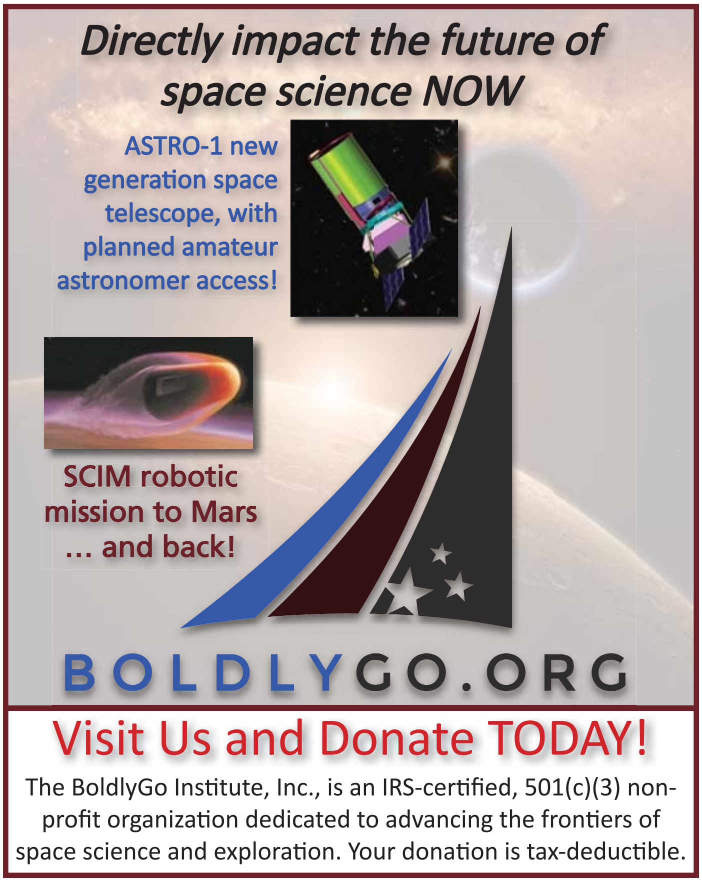
Now astronomers have found the closest-hugging black hole binary candidate yet, Matthew Graham (Caltech) and colleagues announced January 7th in *Nature* and at the American Astronomical Society.

The team's source, PG 1302–102, is a "vanilla" quasar that mysteriously pulsates with a period of about 5 years. Quasars are notoriously variable at all wavelengths, but randomly so — usually there's no regularity to the changes in brightness. Yet when on a whim the team ran algorithms to check a sample of 247,000 quasars for regular pulsations in brightness, 20 sources popped up, including PG 1302–102, which is the "best-looking" of the bunch. That discovery rate (20 out of 247,000) is close to what's expected by theorists for binaries separated by less than a tenth of a light-year, as this one seems to be.

The exact distance between the two black holes depends on what their masses are. The team estimates a combined mass for PG 1302–102's pair of a few hundred million solar masses; the individual masses are unknown but are likely comparable.

Astronomers still don't have a good handle on what happens in the final few light-years of a black hole merger, but PG 1302–102's (purported) black holes will likely merge in a few hundred thousand to a couple million years. The elliptical galaxy they sit in also shows signs of being the product of a merger; it's hard to say exactly how long ago it formed, but probably a few hundred million years ago.

■ **CAMILLE M. CARLISLE & MONICA YOUNG**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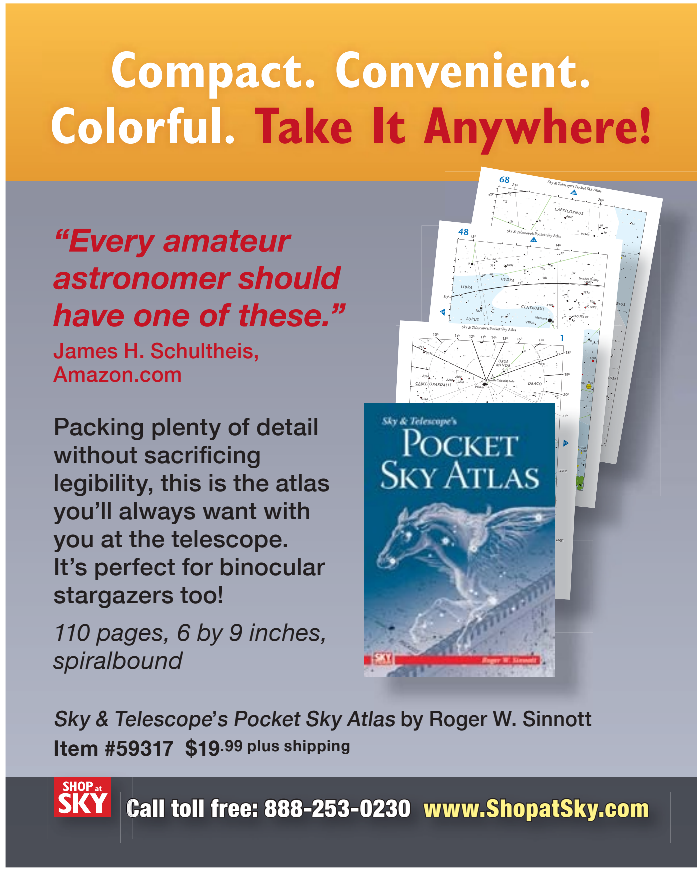
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IN BRIEF

Ancient Five-Planet System Found. Astronomers have confirmed a five-planet system around the 11 billion-year-old star Kepler-444 (HIP 94931, in the constellation Lyra). With estimated sizes ranging from 0.4 to 0.7 times Earth, all five should be rocky, but not one is in the star's habitable zone: they all orbit the red dwarf within 0.08 astronomical unit, or less than one-fifth the size of Mercury's orbit. An optimistic habitable zone would start at 0.47 a.u., nearly six times farther out, Tiago Campante (University of Birmingham, UK, and Aarhus University, Denmark) and colleagues report in the February 1st *Astrophysical Journal*. Kepler-444 is not the first star of this age with planetary children: astronomers have also found two planets around Kepler-10 (10 billion years old) and two planets around Kapteyn's Star (11 billion years old, *S&T*: Sept. 2014, p. 14). But those planets are super-Earth-size or larger.
■ CAMILLE M. CARLISLE

Citizen Scientists Find Disks. Volunteers with Disk Detective have found 37 planet-forming disk candidates for follow-up study. Led by Marc Kuchner (NASA Goddard) and the Zooniverse team, Disk Detective uses data from the Wide-field Infrared Survey Explorer (WISE) satellite, which found hundreds of thousands of infrared sources that could be disks around nearby stars — or far-off galaxies, interstellar dust clouds, or other extended infrared sources. Volunteers can classify each of the 278,000 infrared sources after a brief tutorial at www.diskdetective.org. Thus far they've turned up 478 "objects of interest" (possible disks) and 37 strong candidates. The strong candidates range in distance from 80 to 3,300 light-years. By 2018 the project should net more than 1,000 disks.
■ MONICA YOUNG

EXOPLANETS | Spin-up to Habitability? . . .

Exoplanets tightly circling their stars might have a better chance of being habitable than previously thought.

Red dwarfs are the most abundant type of star in the galaxy. They're also roughly one-quarter the Sun's mass, bringing their habitable zones closer in and making it easier to spot Goldilocks planets. But a planet that orbits close enough to a red dwarf to be in the star's habitable zone could become tidally locked. Having a perpetual night side could in turn destabilize chemical exchanges between the atmosphere and surface or even cause the atmosphere to collapse.

New research, however, suggests that the effect of the planet's atmosphere might be strong enough to break any tidal locking, allowing the planet to rotate freely.

Jérémy Leconte (University of Toronto and Pierre Simon Laplace Institute, France) and colleagues created a 3D climate model to predict the effect of a planet's atmosphere on the speed of its rotation. It all goes back to the amount of starlight able to penetrate the planet's atmosphere and reach its surface. Temperature differences at the surface drive winds. Those winds constantly push against the planet by running into mountains or creating waves on the ocean. Such friction then influences the rotation rate of the planet, helping to speed it up or slow it down.

Astronomers have long seen this effect on the planet Venus, where the atmosphere's influence is so powerful that it forces the planet out of synchronous rotation into a slow retrograde rotation. But planetary scientists didn't think thinner atmospheres like Earth's could throw their weight around as effectively.

Leconte's simulations show that thinner atmospheres actually have a *larger* rotational effect on their planets. With less scattered sunlight, extra heat reaches the deepest atmospheric layer and creates stronger winds. If Venus had an atmosphere like Earth's, it would spin 10 times faster, the team reports January 15th in *Science*. This is radically different from previous research, which suggested that it would spin 50 times slower. An unlocked planet should therefore have strong atmospheric mixing and stable temperatures.

Although a large number of known terrestrial exoplanets should thus have a day-night cycle, the duration of their days could last between a few weeks and a few months. So these planets would still be far from Earth-like, with only a few days per year, cautions René Heller (McMaster University, Canada).
■ SHANNON HALL

. . . and New Exoplanet Hunters Rising

Several near-future exoplanet hunters are in development. Here's a non-exhaustive list of projects to keep an eye on:

• Searching for transiting planets around bright (i.e. nearby) stars are the European Southern Observatory's Next-Generation Transit Survey, which recently achieved first light, and the Transiting Exoplanet Survey Satellite (TESS), slated for launch in August 2017. By targeting nearby stars, these two projects both hope to find exoplanets that will be easier to follow up on.

• The transit hunter Evryscope is in the construction phase. Led by Nicholas Law (University of North Carolina at Chapel Hill), the prototype array places 27 individual 61-mm telescopes into a common mount; an attached 780 million-pixel detector records a continuous movie of the entire night sky in 2-minute exposures. First light will be later this year.

• Direct imaging is really coming into its own. In its first-light observations, the Gemini Planet Imager (GPI) found that planets c and d around HR 8799 appear to be unexpectedly different in composition, maybe due to differences in cloud cover. The instruments SPHERE (Spectro-Polarimetric High-contrast Exoplanet Research, installed at the VLT) and SCEXAO (Subaru Coronagraphic Extreme Adaptive Optics) are also on the direct-imaging hunt.
■ MONICA YOUNG

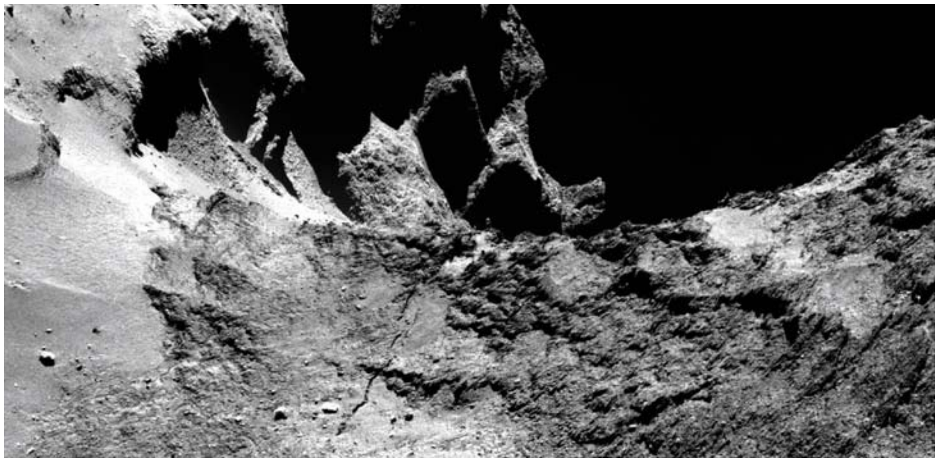
IN BRIEF

Long-lost Beagle 2 Found. On December 25, 2003, the British-built lander Beagle 2 dropped to the Martian surface and disappeared. Now, thanks to the Mars Reconnaissance Orbiter's HiRISE instrument, scientists have found the lander's remains as a bright spot in images taken of the touchdown area in Isidis Planitia. The reflection changes position slightly from image to image, consistent with sunlight reflecting off different solar-cell panels. Two other spots a few hundred meters away appear to be the lander's parachute and part of the cover that served as a shield during the 5½-km-per-second (12,000-mph) atmospheric descent. The fully opened lander would have been less than 2 meters across, and HiRISE's limiting resolution is 0.3 meter, so the craft is barely resolved. Apparently Beagle 2 made it to the surface intact, opened its clamshell cover, and had partially deployed its four petal-shaped solar-cell panels before something went awry.

■ J. KELLY BEATTY

Mountain-size Asteroid Passes Earth. On January 26–27, asteroid 2004 BL_{86} passed 1.2 million km (745,000 miles) from Earth, or three Earth-Moon distances away. The pass is the closest flyby of a space rock this size (325 meters) until asteroid 1999 AN_{10} flies past Earth in 2027. During the flyby, observers discovered that 2004 BL_{86} has a moon, with an estimated diameter between 50 and 100 meters. Credit for the moonlet's discovery goes to Joseph Pollock (Appalachian State University) and Petr Pravec (Ondrejov Observatory, Czech Republic), among others, who detected its signature in their light-curve observations. Radar confirmation came from Lance Benner (JPL) and colleagues using NASA's huge radio dish at Goldstone, California. Radar observers have now detected companions around 44 minor planets passing close to Earth (eight of those were discovered first via optical photometry), and at least two such minor planets have more than one companion.

■ ALAN MACROBERT



ESA / ROSETTA / MPS FOR OSIRIS TEAM

This image of Comet 67P/Churyumov-Gerasimenko reveals a large fracture, roughly 500 meters long, running through the nucleus.

COMETS | Rosetta Reveals Comet 67P

Scientists with ESA's Rosetta mission have released their summary of the first two months of observations of Comet 67P/Churyumov-Gerasimenko, reported in seven articles published January 23rd in *Science*. Arguably, the most far-reaching discovery was that 67P's water molecules have a deuterium-to-hydrogen ratio far higher than that in Earth's oceans (*S&T*: Apr. 2015, p. 12), suggesting our planet's water doesn't come from comets. But five other details about the nucleus are particularly intriguing.

First, the narrow waist that joins the nucleus's two lobes (one 4.1 km long, the other 2.6 km long) has to date been the source of most of the comet's escaping gas and dust. It's unclear whether the comet assembled as two large masses or if its midsection was once much plumper but has eroded away.

Second, the nucleus is very dark overall, with an average reflectivity of just 6% — nearly black, much like charcoal. This jibes with the albedos found for Comet 9P/Tempel 1, 103P/Hartley 2, and 1P/Halley. In comparison, the Moon's average albedo is 12%. The blackness likely comes from a veneer of dust particles that were originally launched with rapidly escaping gas but then settled back onto the surface in an even coating as the comet spun.

Third, based on how strongly it attracts Rosetta, the nucleus must have a mass of about 10 billion metric tons. But the comet's overall density is just 0.47 g/cm^3 — similar to wood. The ice-and-rock interior must be very "fluffy," with a porosity of 70% to 80%.

Fourth, scans by Rosetta's VIRTIS instrument haven't found any ice on the comet's surface, contrary to what's seen on other Jupiter-family comets. Instead, the dark exterior is covered with complex, carbon-rich organic molecules. It's possible that these compounds are polycyclic aromatic hydrocarbons (PAHs) — much like the stuff coating the dark half of Saturn's moon Iapetus.

Fifth, the surface is a wonderland of weird landforms. The OSIRIS team has subdivided Comet 67P into 19 regions (all named for ancient Egyptian deities) that correspond to five distinct terrain types: smooth, brittle with pits and circular structures, large depressions, dust covered, and consolidated ("rock-like"). For example, Hapi (the god who made the Nile River flood each year) is the smooth terrain in the neck that has dominated the comet's outgassing. Gas-spewing pits dot the region called Seth (a violent god associated with storms and disorder). Elsewhere the camera recorded enigmatic mounds, about 3 meters (10 feet) across, which the team calls "goosebumps." ✦

■ J. KELLY BEATTY

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

Old Glass, New Insights

Mary Alexandra Agner

Astronomers working with historic photographic plates are making novel discoveries.

HARVARD PUBLIC AFFAIRS & COMMUNICATIONS / KRIS SNIBBE (HARVARD STAFF PHOTOGRAPHER)

How many black holes are in our galaxy? Do novae hibernate? What happens to stars before they become planetary nebulae?

These are just some of the questions astronomers are currently working to answer using more than 500,000 glass plates, some of which are more than 100 years old.

It's not the individual plates themselves as much as the years they span — from 1885 to 1992 — that make the Harvard College Observatory's photographic plate collection valuable for insights into novae, black holes, and planetary nebulae. These phenomena can take 50 to 100 years, or longer, to transition between their different phases, making the plate collection one of the few sources of data available that track these objects across their life cycles. Bradley Schaefer (Louisiana State University), one of the collection's most vocal advocates, calls the plate collection "a time machine" and "completely unique. You can't get this sort of thing anywhere else."

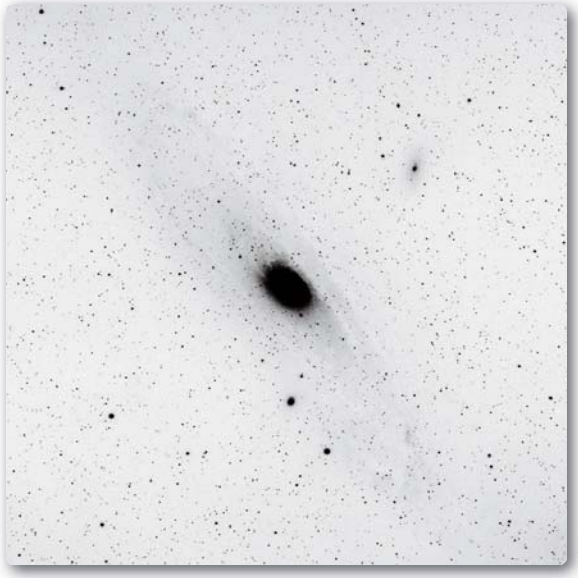
Diving into the Past

The 170 tons of glass are stored in a specially designed building in Cambridge, Massachusetts, on the grounds of the observatory. The building was constructed in 1930 to protect the plates from damage by fire, with a unique metal shelving and support system that stores the plates on three (rather crowded) floors: it is nearly divorced from the brick and mortar of the building, connected only beneath the basement floor.

The majority of the individual plates are 8 inches by 14 inches, with some 14-by-17 plates and a few daguerreotypes. They are stored in nondescript beige sleeves, a blandness belying the wealth of information they hold. Combined, they cover the entire sky for over a century, excepting 1953 to 1973. (During this period, known as the Menzel Gap, director Donald Menzel halted the plate-taking project to save money.)

Alison Doane (Harvard College Observatory), curator of the collection, slides a plate out for inspection, showing off the Andromeda Galaxy, a crisp swirl of grey and black dots. She explains that the plates are like film negatives, turning black where photons have interacted with their emulsion coating. She points to the handwriting on the sleeve: *1897, Andromeda Neb.* This notation shows that the plate was taken before astronomers knew M31 was a separate island of stars from the Milky Way (hence "nebula") and so preserves a bit of the history of astronomical understanding in addition to its scientific data.

FROM THE PAST TO THE PRESENT Astronomers are working to scan the more than 500,000 glass plates sitting in the Harvard archives. Shown left to right are project director Jonathan Grindlay, archive curator Alison Doane, software engineer Edward Los, and research assistant Sumin Tang.



DASCH

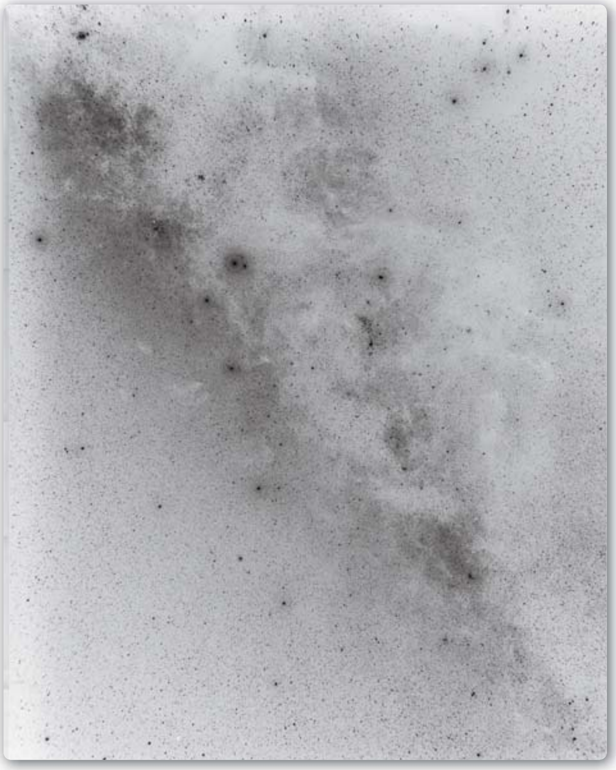
FROM NEBULA TO GALAXY This plate from September 1926 reveals details in the Andromeda Galaxy's disk. It was taken on the 16-inch Metcalf refractor when it was in Cambridge, Massachusetts. (Harvard College Observatory moved the scope to Oak Ridge Observatory in Harvard in 1932 when Cambridge's light pollution grew problematic.)

The plates have a limiting magnitude in the blue filter of approximately 18, making them rich mines for astronomical investigation. One topic astronomers are investigating with the plates is novae. Schaefer is using the Harvard plates' time machine to test the *hibernation scenario*, a current — and contested — hypothesis for explaining the behavior of novae.

Novae eruptions occur in binary systems consisting of a low-mass "donor" star and a white dwarf. With a density approaching 1 million times that of water, the white dwarf gravitationally siphons mass from the donor. At a critical density, the transferred hydrogen begins fusing unstably on the white dwarf's surface, releasing an enormous amount of energy and light in an eruption.

Hibernation proposes that, after eruption, the pair remains bright because material that didn't escape during the eruption falls back onto the white dwarf's surface, emitting extreme ultraviolet radiation. This radiation heats up the companion star, which swells and loses its hold on its outer layers. So mass transfer doesn't

Explore the Harvard plate data on the DASCH website: dasch.rc.fas.harvard.edu/project.php.



DASCH

SOUTHERN SIGHTS The collection houses plates from around the world. One of the observatory's patrol telescopes in Bloemfontein, South Africa, took this 90-minute exposure of the Southern Milky Way on the night of July 21–22, 1928.

TIMELESS SCIENCE For decades astronomers have consulted and cared for the Harvard plate collection. Shown at left is an undated shot from the *S&T* archives (likely from the early 20th century); at right is a former DASCH team member filing a plate.

stop after the eruption, as expected; instead, it continues, keeping the system bright until the white dwarf cools sufficiently to stop stimulating it.

This cooling process takes about a century. After the low-mass companion cools off, mass transfer becomes negligible and the pair "hibernates" in a low-luminosity state until eventually the white dwarf again begins to attract mass from the donor star.

Hibernation theory predicts that novae fade on the time scale of roughly a hundred years, so Schaefer went looking for a record of this behavior in the Harvard plate collection. He has calculated brightness curves for many different novae, including the famous Q Cygni, a nova discovered in 1876.

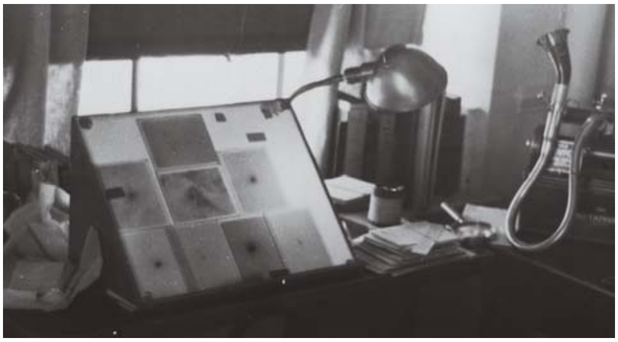
But instead of fading per the hibernation theory, Q Cygni seems to have *brightened* by approximately 0.5 magnitude between 1890 and 2014. Schaefer's research shows nine novae that exhibit behavior contrary to hibernation's predictions. He's not sure yet what's going on, or what it means for the physics of novae.

Black Hole Biographies

Another researcher using the plates is Jonathan Grindlay (Harvard). Part of his work is estimating the number of stellar-mass black holes in our galaxy. Many such black holes have a low-mass companion star that, like the donor star in novae, transfers mass to an accretion disk around the black hole. The disk brightens as matter falls into the black hole and, when this happens, astronomers say that the black hole is *active*.

However, the companion star doesn't donate continuously to the black hole. Activity generally persists only a few weeks at most and occurs every 50 to 100 years. "If you only get to see something for a month every 75 years, you'd better be very patient or be looking all the time, everywhere," says Grindlay. So he turns to the 107 years

20TH CENTURY: *S&T* ARCHIVES; 21ST CENTURY: HARVARD COLLEGE OBSERVATORY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ENDURING TECHNIQUES Astronomers today sometimes still use light tables like those used in decades past to read photographic plates. Shown at left is a setup from circa the 1920s; at right, curator Alison Doane studies the Small Magellanic Cloud.

of all-sky data in the Harvard plate collection.

Grindlay and his team use the plate data to determine the number of active black holes and the duration of their activity. Because some of the galaxy's black holes may not have been active during the century that the plates record, the team calculates the fraction of time that the black holes the plates *do* record are active over this span. The astronomers use that information, together with the duration of activity, to estimate how many black holes they would expect to observe. By comparing the expected value with the observed one, they can estimate the total number of black holes in the Milky Way. Grindlay and his colleagues plan to publish their results in the next few years.

On the more extreme end of the spectrum, Grindlay has also been investigating supermassive black holes that weigh in at millions or billions of times the mass of the Sun. The emission from these black holes isn't constant; instead, the objects vary randomly in brightness. But when Grindlay took a look at the first known quasar, 3C 273, he found something surprising — its supposedly random variations have a long-term, quasi-periodic pulse of about 16 years.

Long-term investigations of another quasar, named OJ 287, turned up a second surprise. This quasar's light is dominated by its jet, which can vary in brightness by a couple of magnitudes. Yet the plate archive shows that in 1918, this quasar jumped an unprecedented 6 magnitudes in brightness.

Both of these phenomena remain unexplained for now, though additional data from the Harvard collection might help shed light on these discoveries.

Grindlay's research is the fruit of another plate project, an engineering endeavor he directs: the digitization of the more than half a million Harvard photographic plates. In the basement of the building that houses the plates, Grindlay has set up the hardware for the Digital Access to a Sky Century at Harvard, or DASCH: a plate-cleaning machine, a custom-designed scanner, the

HARVARD DOMES The plate collection lives in Harvard College Observatory's Building D (left, behind foreground dome), tucked inside the wing to the left of what's shown. The right-hand dome houses the 15-inch Great Refractor, installed in 1847.


JOHN PHELAN

computer to run it, and hard drives to store the data.

The project is more than simply making digital copies of the plates. The software processing provides photometric data for all resolved stars, and astronomers can access the resulting light curves from the DASCH project webpage by entering either an object name or right ascension and declination coordinates. The digitized images of the plates are also available for download.

The project is on track to finish digitizing the plates in 2017, an effort spanning more than ten years.

Unsolved Stellar Cases

Although some of the digital data are already online, Schaefer prefers to use the plates the way Henrietta Leavitt and associates did: in person, in the collection, putting the plates on light tables, and estimating the photometry by eye. And while the Stingray Nebula, a planetary nebula in the constellation Ara, has a lot of eye appeal, it was the behavior of its progenitor star that brought Schaefer to the plates for another of his projects.

In 1967, the Stingray Nebula was a star, Henize 3-1357, identified by its spectrum as a *B*-type supergiant. In 1989, the spectrum changed, showing planetary nebula emission lines and indicating Hen 3-1357 had thrown off its outer layers and was ionizing them, resulting in the boxy shape later imaged by the Hubble Space Telescope.

"The Stingray Nebula is the only case of humanity seeing a planetary nebula birth," Schaefer says. Because of the Harvard plates, astronomers have a photometric history that tracks the star's conversion to a planetary nebula, for use in tandem with spectral data.

Schaefer's results from the plate collection are baffling: Hen 3-1357 dimmed by nearly one magnitude from 1885 to 1992. Furthermore, the rate of dimming *increased* in the late 1970s, speeding up to approximately 0.2 magnitude per year.

Although existing theory can explain Hen 3-1357's fade after its emission lines appeared, the dimming it exhibited before that is a mystery: the star's luminosity dropped by an unprecedented 40% in that time period, corresponding to a roughly 20% shrink in radius. Depending on a star's mass and how fast the star loses its outer layers, it can take a few years to a few decades to transition to a planetary nebula. But astronomers don't understand the details, and it's unclear what Hen 3-1357's prolonged fading means. One possibility Schaefer raises is that this object somehow "anticipated" it was about to become a planetary nebula and started dimming in advance, a transition recorded in the plates.

Although digitization might soon make photographic plate technology obsolete, the detailed information on the plates won't go stale. Their timespan, while short compared to some astronomical events, enables investigations into some of the most interesting and explosive astronomical phenomena. ✦

***Mary Alexandra Agner** writes science nonfiction, fiction, and poetry in Somerville, Massachusetts.*

DASCH

Call for Volunteers: DASCH Project

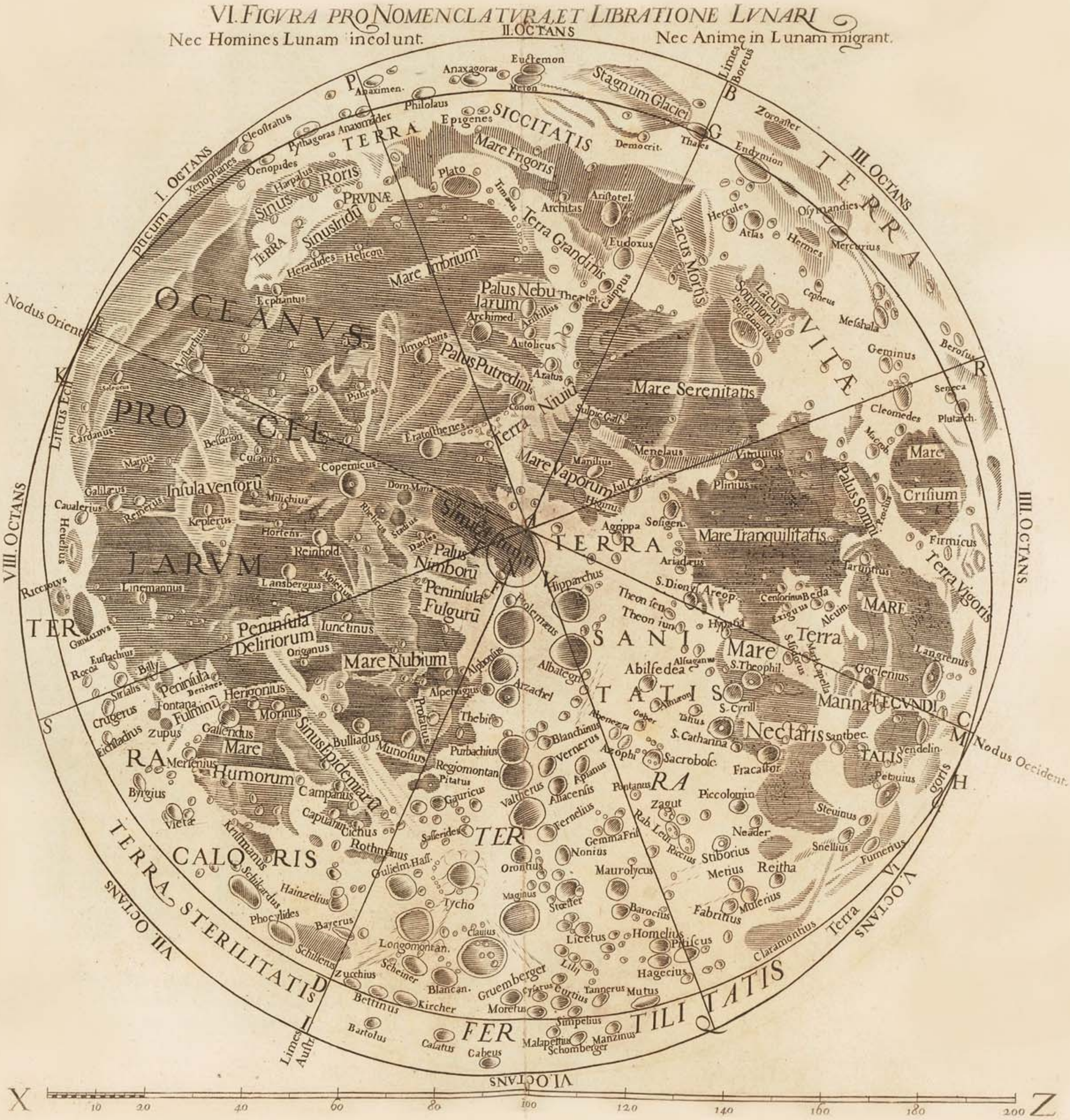
We are looking for help transcribing observing logbooks and other historic astronomical documents as part of the Digital Access to a Sky Century at Harvard (DASCH) project. The project aims to digitize and make available online fully processed digital images and data from the Harvard College Observatory's roughly 500,000 plates.

The Harvard-Smithsonian Center for Astrophysics (CfA), the Astrophysics Data System (ADS), the CfA's John G. Wolbach Library, and the Smithsonian Transcription Center have banded together to recruit volunteers to help transcribe the associated logbooks. Thanks to help from volunteers, staff, and others, we've already transcribed 700 of the 800 books, which have enabled the digitization of 95,000 glass plates. Using both the transcribed logbook entries and the plates, the DASCH team has already discovered new types of variable stars and novae, explored the long-term stability of exoplanet host stars, and identified historic outbursts from black hole X-ray binaries.

We still need help transcribing the last 100 of the 800 logbooks. We have posted high-resolution scans of all the pages of these final logbooks at **http://transcription.si.edu/** (look for the Harvard-Smithsonian Center for Astrophysics project). We will also add materials from other HCO records, which include details of the first observations of Saturn's moon Hyperion in 1848, the discovery of the Horsehead Nebula in 1888, and correspondence between the women working as "computers" during the Edward Pickering era at the observatory.

We ask amateur and professional astronomers from around the world to visit the site and help expedite the transcription process. Scientifically speaking, this archive is the only repository of astronomical data of its kind, and digitizing it will enable astronomers to probe longstanding astrophysical puzzles and make exciting new discoveries. Please lend a hand and help us complete this important work!

Telescope engineer **David Sliski** *(University of Pennsylvania) initiated DASCH's transcription project.* **Jonathan Grindlay** *directs DASCH.*


VI. FIGVRA PRO NOMENCLATVRA, ET LIBRATIONE LVNARI
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Nodus Orient.
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Limes Austr.
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TERRA SICCITATIS
Mare Frigoris
Stagnum Glaciei
Mare Imbrium
Palus Nebularum
Palus Putredinis
Mare Serenitatis
Mare Tranquillitatis
Mare Crisium
Mare Vaporum
Mare Nubium
Mare Humorum
Mare Nectaris
Sinus Iridum
Insula ventorū
Palus Nimborū
Peninsula Fulgurū
Peninsula Deliriorum
Sinus Epidemiarum
TERRA STERILITATIS
TERRA CALORIS
TERRA SANITATIS
TERRA VITÆ
Terra Vigoris
Terra Grandinis
Lacus Mortis
Palus Somnii
Plato
Aristotel.
Eudoxus
Archimed.
Copernicus
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Tycho
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Theophil.
Fracastor
Piccolomin.
Langrenus
Endymion
Hercules
Atlas
Posidonius
Cleomedes
Schikardus
Longomontan.
Gassendus
Bulliadus
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The Man Who Put the Names on the Moon

Giambattista Riccioli had a grander plan than meets the eye — and perhaps a secret agenda.

Andrew Livingston

One benefit of binoculars is their big-picture view. Take the Moon. Looking at it with only 8 or 10 power makes you focus on larger issues, such as why did the second-quarter (waxing gibbous) Moon get the oceans with the ominous names? And what's that gulag of ancient Greek astronomers doing, shivering on the shores of the Sea of Cold? Why are the crater names beginning with *Al-* so concentrated in the south? And why was the great Galileo assigned such an insignificant little out-of-the-way crater that you need 20× to spot it?

The man to ask, the man with the plan, the man who named all the major features on the Moon, was the Italian Jesuit astronomer Giambattista Riccioli (1598–1671).

Riccioli published his landmark Moon map in 1651, just 42 years after Galileo first turned a telescope to the heavens and saw that the Moon was rough and mountainous — and 18 years after the Inquisition sentenced him for advocating the Copernican system of the Earth and planets revolving around the Sun. Riccioli's map of the Moon was the best one yet. Its detail and accuracy are impressive considering the small, primitive, hard-to-use telescopes of the time.

And all those features on the map needed names.

NAMING OF PARTS Riccioli's Moon map, from his *Almagestum Novum* (1651). The subhead says, "Men neither live on the Moon. Nor do their souls go there." Riccioli's rebuke of those popular fancies is ironic — thanks to him the Moon is full of famous men. And a few women.

ALMAGESTUM NOVUM

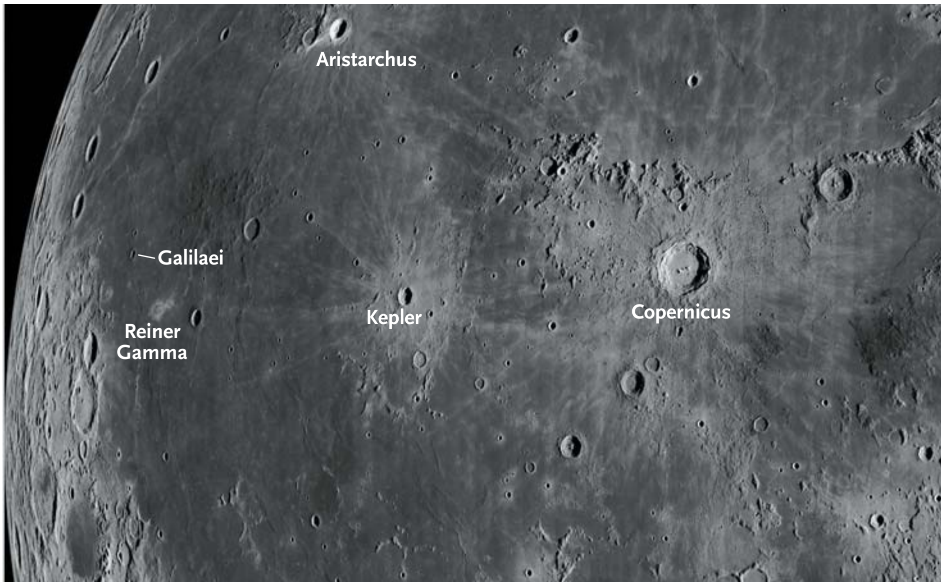
Look at the Moon's celestial eastern limb (on the left) just south of the equator — there Riccioli named a modest crater for himself, giving him the easternmost ringside seat on his handiwork. Next to him is his assistant Francesco Grimaldi, who drew the map. Then comes the Polish astronomer Johannes Hevelius, who had recently published his own Moon map, in 1647, featuring a grab bag of royals, religious figures, scientists, and explorers. Finally, on the opposite side sits Langrenus, whose earlier (1645) map had used neutral but head-scratchingly obscure names from Greek and Latin geographies. Riccioli left him in his own chosen place on the shores of Mare Fecunditatis. There they are, the three pioneers of selenography, except it was pretty much winner-take-all for Riccioli.

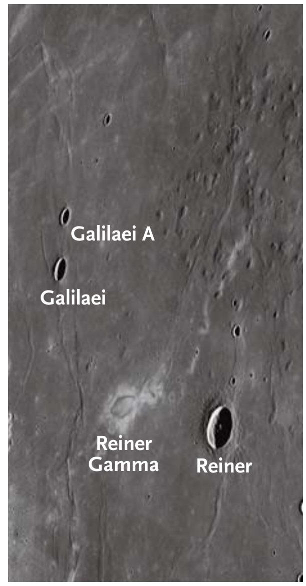
What made his names such a success? Why do we use most of them today?

The Moon's Eight Octants

Riccioli divided the Moon into eight slices like a pizza, drawn on his map and labeled around the edges as seen on the facing page. They start in the celestial northeast with "I Octans": upper left on the map and on the Moon as seen with the naked eye. An odd place to start? Watch what happens. Working around clockwise in a historical timeline, Riccioli sprinkles the Moon with ancient Greeks, followed by Romans and early Christians, then medieval scholars both Christian and Muslim, to end with a grand finale of his fellow moderns in VIII Octans, the easternmost and last to be well revealed as the Moon waxes to full.

Riccioli didn't always follow this design strictly. Some eras spill out of their octants, and along the southern





NASA / LRO (2)

THE COPERNICANS Aristarchus, "the Greek Copernicus," is placed above Galileo, Kepler, and prominent Copernicus himself. *Right*: Riccioli didn't intend Galileo to end up with the tiny crater so named today. He applied the name to what's now called Reiner Gamma: an odd, flat, light marking, part of a streamer with unusual magnetism that may have been left by a comet's ion tail.

limb from Langrenus onward are more of Riccioli's contemporaries — new authorities taking their seats opposite the ancients.

Hold the Latin!

Sorry, not an option. In Riccioli's day, scientists not only published in Latin (Galileo was an exception) but were usually known by Latinized names. Which gives the moderns on the Moon a deceptively antique flavor. Regiomontanus in VI Octans, for example, was born Johannes Müller von Königsberg ("Regent's Mount") in 1436. A Johnny-come-lately by lunar standards, he was the assistant of Purbachius, the crater above. After Purbachius's sudden death in 1461, Regiomontanus found himself finishing off his master's update of Ptolemy's *Almagest*. They had been in Italy, invited by the scholar Cardinal Bessarion, who'd gotten his hands on an *Almagest* in the original Greek; you'll find Bessarion north of Kepler (note that Riccioli often used the obsolete long *s*, which looks almost like an *f*). Regiomontanus ended up in Nuremberg, a scientific center where the wealthy Bernhard Walther helped him build the first scientific printing press. Valtherus, now Walter, is positioned just below Regiomontanus as if to support him. Walther's house, later bought by Albrecht Dürer, is a Nuremberg landmark to this day.

A Quick Tour of the Octants

I and II Octans: Ancient Astronomers On Ice. The north polar region glitters with ancient Greeks. Plato, Aristoteles, Archimedes, and Eratosthenes are the leading lights, but who outshines them all? For Riccioli it was evidently Aristarchus of Samos (circa 310–230 BC), Copernicus's predecessor who first proposed a Sun-centered solar system with the planets in the right order and the stars far away. Riccioli assigned him the brightest marking on the Moon. After he had been ignored in favor of Aristotle and Ptolemy for almost two thousand years, Riccioli's map brings things literally full circle — Aristarchus's neighbors to the south at the end of the timeline are the Copernican astronomers of VIII Octans.

But here Riccioli, a Jesuit priest, was treading on politically risky ground — just 18 years after Galileo had been forced to denounce Copernicanism and was dealt a life sentence of house arrest. Elsewhere, in public, Riccioli was quite the orthodox anti-Copernican, as displayed on his book's frontispiece (see page 31). But did he harbor secret Copernican sympathies? More on this later.

III Octans, outer: Sunset Myth. Shortly after new Moon, when the crescent hangs in the west after sunset, the legendary Greek strongmen Hercules and Atlas stand boldly on the terminator. Hercules's second-to-last labor was to retrieve the Golden Apples of the Sun, apples that gave you immortality. Guarded by a serpent, they grew in the Garden of the Hesperides, the Sunset goddesses, at the western end of the world where Atlas stood holding up the heavens. Since the Hesperides were Atlas's daughters, he agreed to fetch the apples if Hercules relieved him of his burden. Note how Hercules, of mixed birth, gets the smaller crater while Atlas, the 100% god with the full-time job, gets the larger.

III Octans (inner) and IIII: Rome. Julius Caesar earns his place here thanks to the Julian calendar, which brought the dates back in line with the seasons for centuries to come. (When the calendar needed another tune-up by 1582, Pope Gregory turned to Aloysius Lilius and Christopher Clavius, duly cratered in VI Octans.) Manilius is next door for his epic poem *Astronomica*. Agrippa to his south wasn't the famous martial son-in-law of Augustus, but a later Greco-Roman astronomer about whom we know next to nothing except that Ptolemy mentioned him observing an occultation of the Pleiades in AD 92.

IIII Octans raises the question: What's a Sea of Crises (Mare Crisium) doing among the serene, tranquil seas of the first quarter? Riccioli followed a separate scheme for naming the maria; they seem to follow contemporary popular ideas about the influence of the Moon's phases on moods and weather. New Moon, for instance, was a time of changes — times of crises. But there may be a Roman connection here too. Perhaps Riccioli was referring to the persecution of the early Christians by ruthless emperors such as Nero, who was quite unimproved by the philosopher Seneca being his tutor. Seneca, held in high regard by the Church, got a crater for his efforts.

Later we move down to Firmicus, astrologer-polemicist to the first Christian emperor, Constantine. The now defunct Terra Mannae, Land of Manna, is populated by early Catholic scholars such as Dionysius Exiguus, the 6th-century monk who devised our AD chronology of years, and Abbot Alcuin of York, advisor to Charlemagne. Alcuin's gone from modern maps; his dubious astronomical credentials got him swapped out for a more recent Englishman, Sir John Lubbock.

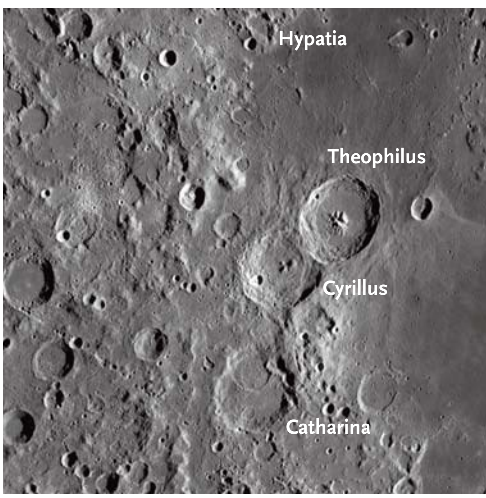
V Octans: Christianity Triumphant. The prominent crater trio Theophilus, Cyrillus, and Catharina lived in Alexandria, which got them seaside locations on Mare Nectaris. Fourth-century Alexandria was the New York of its time, and Saint Theophilus was its crusading bishop. His destruction of the famous temple of Serapis symbolized the final triumph of Christianity over paganism. His nephew Saint Cyrillus followed in his footsteps by banishing the Jews.

Hypatia, above them, is the only astronomer here, with a crater nearby for her father, Theon Junior. (His neighboring senior namesake lived three centuries earlier.) The pagan Hypatia, a remarkable scholar, Neoplatonist philosopher, and mathematician, came to a sticky end thanks to Saint Cyrillus. Her gruesome death at the hands of Cyrillus's agents in AD 415 could be said to mark the end of the classical world.

Saint Catherine's martyrdom parallels Hypatia's; she is said to have been a brilliant Christian philosopher condemned to death by the last pagan emperor, Maxentius, who didn't appreciate her attempt to convert him. No record of her exists until 500 years later; some historians believe she was invented to be a counter-martyr to Hypatia. Both are among the very few women on the Moon.

And how does astronomy fit into this business? Hardly at all. Saint Catherine was highly venerated in the Middle Ages; let's guess that Riccioli, with an eye to any criticism that might come for including the Copernicans on the other side of the Moon, was banking a few points with the Church.

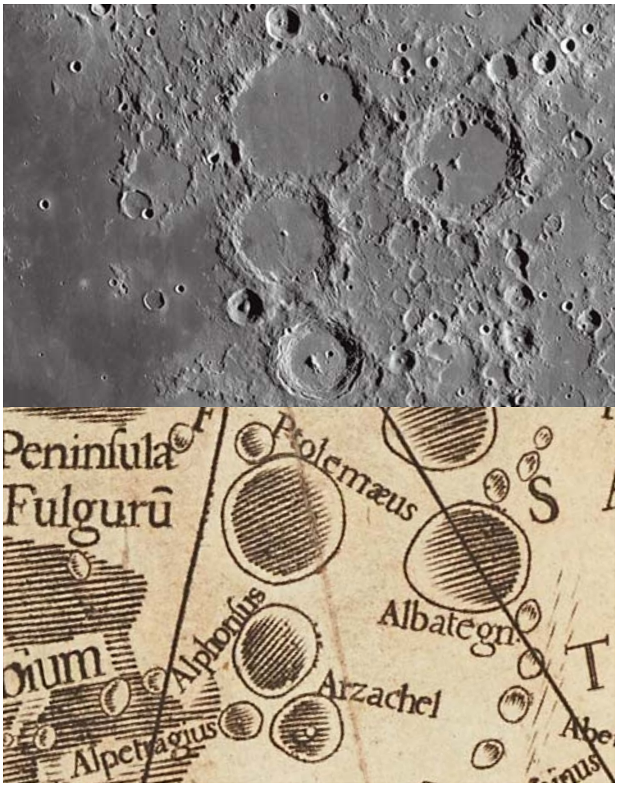
VI Octans. Arab Astronomy Takes a Bow. European astronomers knew how indebted they were to the Arab world. The highlight of the terminator at half Moon is the grand Ptolemaeus-Albategnius-Alphonsus-Arzachel group, with Hipparchus, the greatest of the ancient observers, presiding. Ptolemaeus (Claudius Ptolemy,



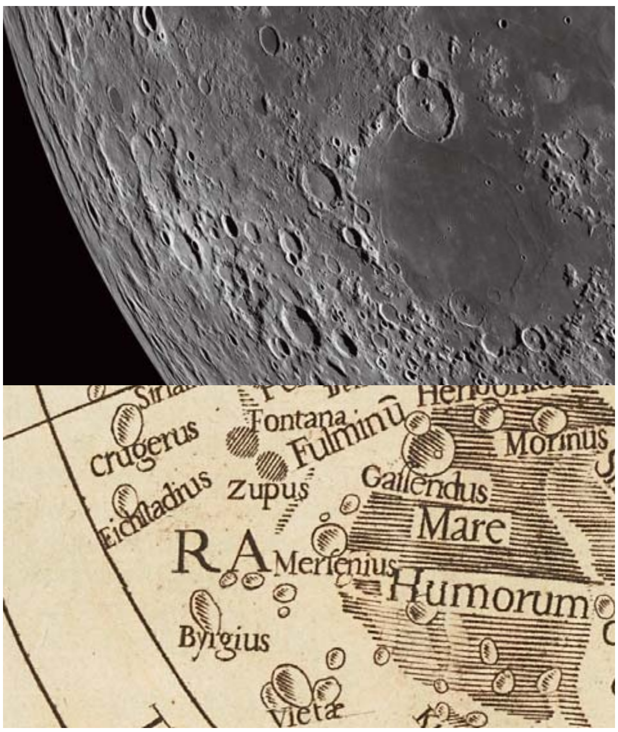
NASA / LRO


FOCUS FEATURES / NEWMARKET FILMS

OPPOSITE MARTYRS The prominent twin craters of the Mare Nectaris region went to the Christians of the Hypatia episode; Hypatia just received a little one. What's interesting is that she's here at all. She and Catharina, two of the Moon's very few women, both died for their beliefs and were placed on opposite sides of Theophilus and Cyrillus. ***Right*****:** Mathematician or witch? Rachel Weisz played Hypatia in the movie ***Agora*** (2009). Two centuries after Hypatia's death, the Coptic bishop John of Nikiû described her as a pagan "devoted at all times to magic, astrolabes, and instruments of music, and she beguiled many people through her Satanic wiles."



SHOULDERS OF GIANTS Ptolemy got pride of place with a grand walled plain near the Moon's center. Below him gather some of his astronomical descendants, the Arabs who laid the foundation for European astronomy.



NAME-DROPPING Riccioli honored some of his own contemporaries in the final octants of his map, no doubt helping to ensure its acceptance.

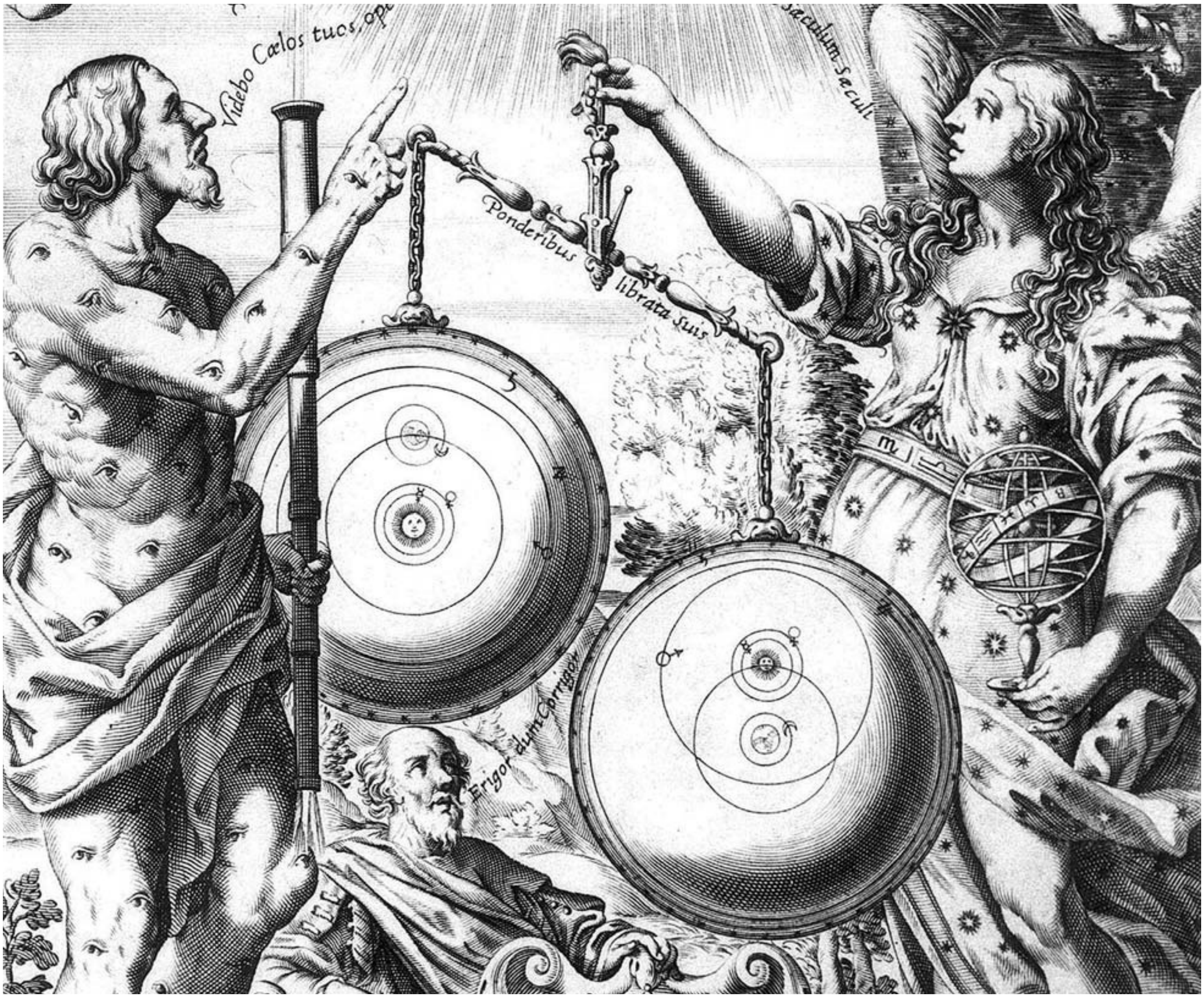
an Alexandrian Greek c. AD 90–160) gets the biggest crater. Throughout the Middle Ages his *Almagest* (from *al-majisti,* "Great Treatise") was *the* astronomy textbook. (Thebit, aka Thabit ibn Qurra of Harran and Baghdad, was a notable translator). Ptolemy's heliocentric model of the solar system, with its awkward circling circles, did a respectable job of predicting the motions of the planets. Albategnius was the 9th-century Syrian al-Battani, whose extremely accurate trigonometry tables were used by Copernicus and Tycho. Alphonsus (Alfonso X "the Wise," King of Castile, 1221–1284) bankrolled the Alfonsine Tables of planetary positions based on the calculations of Arzachel (al-Zarqali, "the Engraver") in Muslim Spain. Arzachel (1029–1087) was a leading astronomer and instrument maker, and perfector of that medieval multi-tool, the astrolabe.

VII Octans. Sunrise on European Science. Philosopher-priest Pierre Gassendi (1592–1655, France) gets the top spot on Mare Humorum, perhaps for being the first to observe a transit of Mercury in 1631, perhaps for trying to reconcile religious belief with a skeptical, scientific outlook, a problem that never goes away. His seaside neighbor Mersenius (Marin Mersenne, 1588–1648, France) was a sort of Jesuit Robert Hooke, who in addition to his own research — he was a forerunner of Cassegrain in reflecting-telescope optics — acted as a clearinghouse for all the latest developments.

Byrgius (Jost Bürgi, 1552–1632) was a super-skillful Swiss instrument maker and unlettered genius who invented logarithms, though by the time Kepler convinced him to publish (Bürgi didn't know Latin), he had been scooped by the Scot John Napier.

Viete (François Viète, 1540–1603), lawyer and mathematician, was involved in the reform of the calendar until he had a falling out with Clavius, Pope Gregory's scientific advisor. And finally there's Peter Cruger (1580–1639, Germany and Poland), who published many scientific papers and was Hevelius's teacher, appealing to him from his deathbed to pursue astronomy. Which Hevelius did in a big way, using fantastically long-focus telescopes. These were a solution to the severe chromatic aberration of the increasingly large single-element lenses that astronomers were trying to use. Hevelius's beer brewery, which no doubt financed such projects, went out of business only recently.

VIII Octans. Galileo, what were you thinking?! Galileo Galilei (Italy, 1564–1642) is still a delight to read (try *The Starry Messenger*), and not just for his scorched-earth rebuttals of other scientists, many of whom were unfortunately Jesuits. With *Dialogue Concerning the Two Chief World Systems* he really burned his bridges with the Church. Comparing Copernicus's model of the solar system with Ptolemy's, he couldn't resist giving the name Simplicio to the hapless defender of the geocentric camp. The name was supposedly "after Simplicius



ALMAGESTUM NOVUM

ANTI-COPERNICUS **On the frontispiece of his great *Almagestum Novum*, Riccioli displays the Muse of Astronomy judging Copernicus's Sun-centered solar system against Tycho's Earth-centered version. The balance beam says, "Their weights assessed." Tycho wins and Copernicus loses, the only safe way Riccioli could rule on the question nine years after the passing of Galileo. Below, old Ptolemy says "I stand corrected."**

the Aristotelian" of the 6th century, called by some the last great philosopher of pagan antiquity and perhaps a suitable representative for Aristotelianism. But was anybody fooled? The word can also mean "dunce." Into Simplicio's mouth Galileo put the arguments of his old friend Cardinal Barberini, now the Pope! The trial of 1633 followed shortly.

This made things awkward for Riccioli when it came to putting Galileo on the Moon. The Church was not in a forgiving mood; the ban on Galileo's books wouldn't be lifted until the next century. So what was Riccioli to do?

He had already assigned Copernicus, Tycho, and Kepler to the splashiest craters, which luckily were all on the waxing-gibbous quarter, the side popularly associated with storms, damp, and misery. Tycho on the Southern Highlands was happily high and dry — Tycho's geo-heliocentric model, with the Sun and Moon orbiting the Earth while the other planets orbited the Sun, did not contradict the Bible.

But Copernicus and Kepler? They were tossed on the Sea of Storms (Oceanus Procellarum), with marshes of fogs and putrefaction to the north (Palus Nebularum and Palus Putredinis), twin threats of disease and insanity to the south (Palus Epidemiarum and Peninsula Deliriorum), and a thunder-and-lightning battering from peninsulas Fulminum and Fulgurum to top things off.

Gothic excess? Not for an audience with fresh memories of the Thirty Years' War. A religious war turned political, it had drawn in mercenary armies from across Europe and killed a quarter to a third of the population of the German states. The German Kepler had danced around disaster while he lived; not so his grave, destroyed by the Swedes in the sack of Regensburg. If

"THE MONSTROUS BEAST OF WAR," detail from a typical flysheet of the time, shows the Thirty Years' War laying waste to the land, pillaging churches and towns, and slaughtering their inhabitants. Were Riccioli's grim waxing-gibbous names a reflection?

Riccioli was using hellish surroundings to launder the Copernicans, perhaps he'd be less likely to get called out for memorializing them so prominently.

Riccioli a Closet Copernican?

Next up in the Tycho-Copernicus-Kepler progression was Galileo. But try to spot Galileo's pinprick of a crater! It's invisible in most binoculars unless you catch it, and its later-named satellite Galilaei A, as twin sparks of light on the terminator.

So what happened? Don't blame Riccioli; only later was Galileo relocated to the insignificant crater that bears the name today. (Beer and Mädler's 1836 map seems to be the culprit.) Riccioli gave Galileo's name to the last bright splash left in VIII Octans: the flat albedo feature Reiner Gamma, which Grimaldi had mistakenly drawn as a largish crater.

Riccioli published his Moon map in his great encyclopedic work the *Almagestum Novum,* a book "no serious seventeenth century astronomer could do without," as John Flamsteed, England's first Astronomer Royal, put it around the 17th century's end. As its frontispiece illustrates dramatically (see previous page), Riccioli held in public that the Copernicans got it wrong. He discusses 77 objections to a moving Earth. Most were variations on "where's the big wind?", but a couple he thought were legitimate. Where were the Coriolis effects if Earth was spinning? Falling objects and flying cannonballs didn't seem to be deflected. And if the Earth circled the Sun without the stars showing parallax motion, the stars would have to be extremely far away. But the small telescopes of his day showed them as little disks (now known to be illusory diffraction disks), which at such a distance would make the stars huge beyond belief.

As for the first objection, and as the Jesuit in Riccioli might have suspected, absence of evidence was not evidence of absence. Coriolis effects are significant only on large scales, because Earth is large; they would be demonstrated in the 19th century. So would the stars' parallaxes. Against these objections was the Copernican system's seductive simplicity. So did Riccioli have his doubts? We'll never know, but it's telling that he gave Aristarchus, the Greek Copernicus, such a blazing beacon unifying the ancient and modern octants, and Copernicus himself a crater second only to Tycho.

The practical purpose for mapping the Moon — so that terminator timings could be used to determine longitude on ocean voyages — turned out to be impractical. But that didn't stop Riccioli's map from becoming a hit with astronomers from Rome to Greenwich. Who could argue with a Hall of Fame, especially if it included them? And hats off to the way Riccioli handled the Copernicans. But the map's enduring appeal was poetic. The Moon, its gaze fixed upon Earth, had seen a lot of history. Riccioli made it bear witness to all those centuries of observation, speculation and calculation.

As for Galileo getting short-changed, there's a postscript. In the far-off future, a spacecraft orbiting the Moon would discover something unusual — that the Reiner Gamma marking is a magnetic anomaly whose mini-magnetosphere may be shielding it from the darkening effect of the solar wind. Left where Riccioli put him, Galileo would have kept his name in lights, and in binoculars, for millennia to come. ✦

In all his years in advertising, ***Andrew Livingston*** *has never seen such an action-packed layout as Riccioli's map of the Moon. As for Galileo, when binoculars show the Sun rising on his crater, he gets an honorary visit with a 13-inch Dob.*

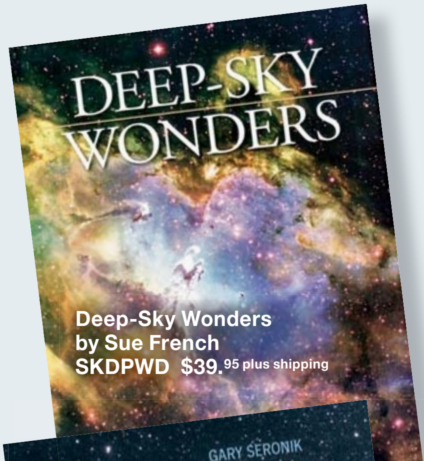
Further Reading

• Antonín Rükl's indispensable *Lunar Atlas* (edited by *S&T*'s Gary Seronik) is a labor of love deserving a crater of its own. It includes a wealth of lunar information as well as a who's who on our side of the Moon.

• Ewan Whitaker, *Mapping and Naming the Moon.* This is the Almagest on the topic, by someone who had a hand in directing the International Astronomical Union's lunar nomenclature and in preparing the map used by the Apollo missions.

• C. M. Graney, *Teaching Galileo? Get To Know Riccioli!,* available at arxiv.org/abs/1107.3483.

• Also by Graney: *Giovanni Battista Riccioli's Seventy-Seven Arguments Against the Motion of the Earth,* arxiv.org/abs/1011.3778.



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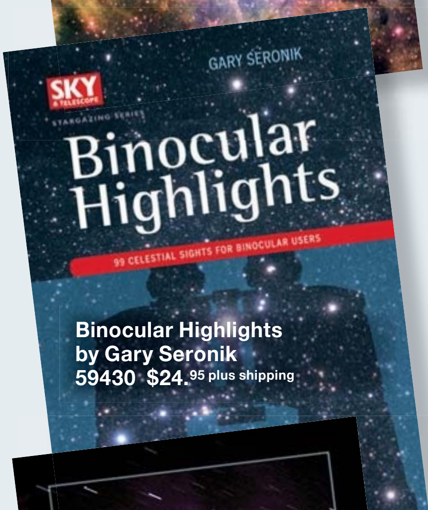

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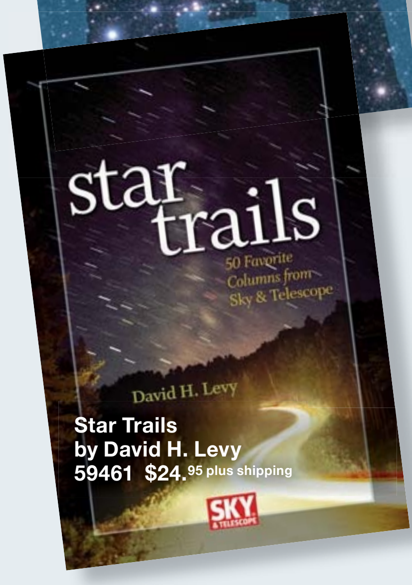

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Surveying Skyglow

Jan Hattenbach

Satellite images don't tell the whole story — measurements by amateur astronomers are needed.

Anyone who observes the night sky knows all too well the telltale signs of light pollution. It might start as an isolated, bubble-shaped glow along the horizon — a "light dome" from some nearby town — that gradually and inexorably swells, broadens, and intensifies. In the worst cases, the pall of skyglow completely overwhelms the celestial scenery overhead.

Unfortunately, light pollution always seems to win. Or does it? Can anyone claim that the nighttime skyglow is actually lessening? Even if true, how could you tell?

Just recently, for the first time, I was able to spot the weak glow of *gegenschein* on a very clear night at my observing site in western Germany, one of the most light-polluted regions of the world. Other stargazers report seeing the Milky Way clearer than it appeared years ago. Are these improvements illusory, wishful thinking — or an attestable trend?

"Concerning worldwide changes of skyglow, there are large uncertainties on which direction we're moving," says Christopher Kyba (German Research Center for Geoscience), who has been studying light pollution as part of an interdisciplinary project called Loss of the Night. In fact, satellite images *do* suggest my observing site has gotten a little darker, but that's only locally.

Looking at the entire European continent from space, the changes are striking. With satellite data gathered over 15 years, Jonathan Bennie (University of Exeter, United Kingdom) and his colleagues recently found that although night brightness has grown significantly in most places, some large areas — and even entire countries — appear to be darker now than they were in the mid-1990s.

Meanwhile, a comparable study led by Christopher D. Elvidge of NOAA's Earth Observation Group seems to confirm this for other parts of the globe as well. His team finds that in some parts of the most developed countries, including the U.S., Canada, and Japan, night lighting overall either declined or remained stable between 1992 and 2012 — despite growth in their respective populations and economies.

While these results raise hope for stargazers, Bennie cautions that apparent changes in brightness from satellite data (see the box on page 39) don't necessarily correlate with changes in ground-level light pollution. Still, if real, what causes these decreasing trends? And do they really bring back the stars?

The View From Orbit

Kyba's research involves quantifying and measuring light at night, and Germany's capital is an excellent place to do that. "Berlin is a large city surrounded by relatively dark countryside," he explains. "Compared to other metropolitan areas, you find all levels of illumination in a relatively constrained territory here." For example, just two hours' drive to the west is Westhavelland Nature Park, which in February 2014 became the first German dark-sky reserve recognized by the International Dark-Sky Association.

A Canadian physicist who gained experience taking extremely low-illumination images in particle physics and radiology before turning to light pollution, Kyba uses aerial photographs and satellite images to assess which types of lighting are best for preventing skyglow. He con-

BIG BLACK MARBLE The glow of civilization across Europe and Africa, as seen by the Suomi NPP satellite in 2012. This global map took 312 orbits to get clear shots of all of Earth's land surface and islands.

NASA / NOAA / NGDC

A CITY'S PALL Chicago ranks among the most overlit cities in the world. Here its streets and buildings burn brightly under blankets of clouds.

© JIM RICHARDSON

curs with Bennie and Elvidge that some of the decreases measured by satellites result from better-shielded lamps that direct their light onto the ground and not into the sky. Less light is getting beamed into the sky.

However, looking down from space alone doesn't tell us the whole story, Kyba says. One limitation of satellites is that they measure light streaming directly upward, whether beamed in that direction or reflected off the ground. But this light is not what contributes most to skyglow. Rather, as shown in the simulation on page 38, worst is the light emitted just above horizontal, which can be scattered by air molecules, airborne dust, and water vapor for hundreds of kilometers in all directions.

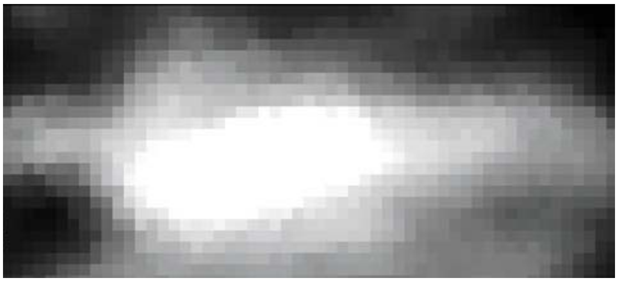
CHRISTOPHER KYBA

BAD TO WORSE The spotlights illuminating Berlin's main television tower (left in photo) are far less obvious from the air than those lighting up the hotel at right. Upward-pointing lights are the type most easily detected from orbit.

For years researchers have struggled to calculate skyglow indirectly using the upward-directed lighting levels measured by relatively crude images from Defense Meteorological Satellite Program (DMSP) satellites. In 2001, Italian astronomers Pierantonio Cinzano and Fabio Falchi published a highly useful global atlas of artificial night-sky brightness (**is.gd/DMSP_atlas**) — but those maps plot the satellite-derived (not directly measured) skyglow intensities seen at ground level.

Newer spacecraft like the Suomi NPP and its visible-infrared imager (VIIRS) provide improved sensitivity and resolution, but there's a catch. Hundreds of millions of streetlights and security lights worldwide utilize high-pressure-sodium (HPS) bulbs, which emit a peach-colored light that's skewed toward red wavelengths. Future installations, both new and as HPS replacements, will be dominated by smaller, cheaper, and more energy-efficient light-emitting diodes (LEDs).

For astronomers, this could become a worrisome development. Most LEDs emit a large amount of blue light, which scatters much more readily than red light does and thus causes more skyglow. "To make things worse," Kyba explains, "both DMSP and VIIRS are not sensitive to blue


NOAA / NGDC


NASA


CHRISTOPHER KYBA

VIEWS FROM ABOVE Compare these three images of Berlin at night. The top view shows the relatively crude resolution of the line-scan camera on a DMSP satellite. In the middle is a 2013 image taken from the International Space Station; note the color difference between West and East Berlin. The map at bottom, created for the Loss of the Night project, is part of a composite of 2,647 aerial photos taken on September 11, 2010.

wavelengths shorter than 500 nm. That's where LEDs have a big peak." (See the box on page 40.) In the worst case, these satellites might indicate decreased light pollution where there's actually been an *increase*.

Color photographs taken by astronauts aboard the International Space Station partly sidestep this wavelength blind spot, but those snapshots do not cover larger areas and are not taken consistently. "We need to do both," says Kyba. "Then we can get some ideas about how the ground illuminance is changing from the space perspective."

Here's Where You Come In

To really understand skyglow, we need to look not down but up. That's where amateur astronomers can play a crucial role. Instead of just guessing how bright (or less bright) their sky is, Kyba hopes more of them will actually measure it, helping him and other scientists get a grip on skyglow where it happens.

For example, Kyba's team has installed a small network of automated night-sky brightness meters around Berlin, but these cover a relatively small area. Similar detectors now continually measure the night sky over a handful of observatories and national parks in the United States. To increase the number of measurements, Kyba has launched a crowd-funded campaign to supply schools with portable, easy-to-use Sky Quality Meters (SQMs), converting schoolchildren to "citizen scientists."

But to acquire enough ground-level measurements to be scientifically useful, many more volunteers are needed — not just in Berlin but worldwide.

Fortunately, becoming a light-pollution scientist has never been easier. Over the past decade, thousands of amateur astronomers and other citizen scientists have submitted sky-brightness measurements to various projects worldwide. Three groups teamed up during 2009's International Year of Astronomy: "Globe at Night" (now managed by National Optical Astronomy Observatory, or NOAO), "Great World Wide Star Count" (National Earth Science Teachers Association), and "How Many Stars?" (started by Kuffner Observatory in Vienna, Austria).

All three efforts ask participants to do much the same activity: determine their sky's limiting visual magnitude


LETTHEREBENIGHT.COM

HOW TO GET INVOLVED

If you're interested in making light-pollution measurements, here are links to key citizen-science efforts:

Globe at Night: **globeatnight.org**

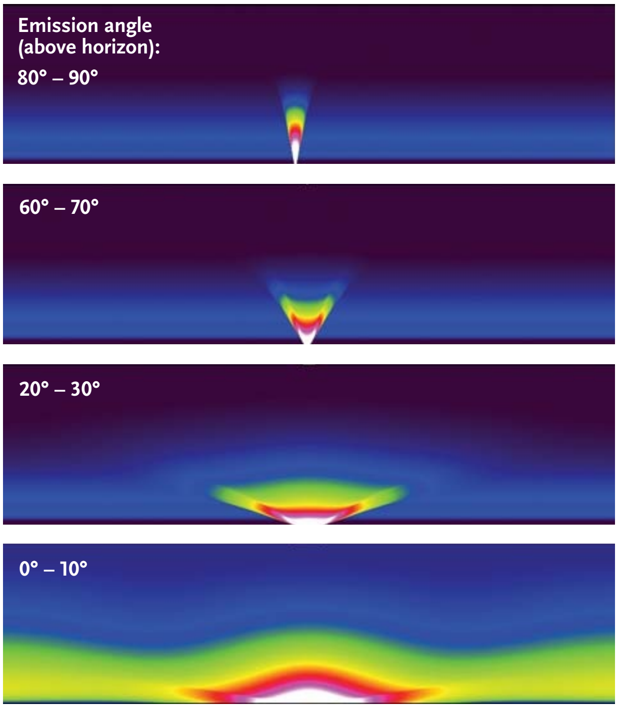
Great World Wide Star Count: **starcount.org**

How Many Stars?: **hms.sternhell.at**

Dark Sky Meter (iPhone): **darkskymeter.com**

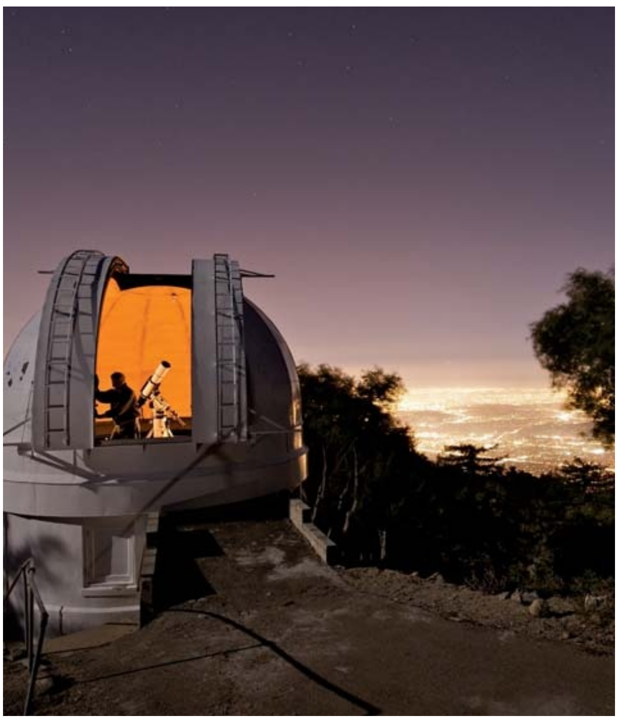
Loss of the Night App: **is.gd/darksky_app**

TEAM EFFORT More than 3,400 Indiana students participated in the Let There Be Night project, which yielded a light-pollution "map" consisting of 35,000 Lego blocks.



CHRISTIAN B. LUGINBUHL / DARK SKY PARTNERS LLC

LIGHT'S LONG REACH A computer simulates the skyglow visible at a mountaintop observatory 50 km away from (and 2 km above) a strong light source. Light directed straight up escapes to space with little atmospheric interaction. However, light emitted just above horizontal scatters strongly and creates the most skyglow. Blue light is scattered far more strongly than red light.



© JIM RICHARDSON

DODGING URBAN LIGHT Amateur astronomer Dave Jurasevich works inside a small dome at Mount Wilson Observatory, fighting to collect cosmic photons that compete with the light pollution from the sprawling Los Angeles metropolitan area.

by comparing a chart of certain constellations visible in the evening sky with the actual sky. The loss of limiting magnitude is still the best indicator for skyglow, especially if augmented with direct measurements acquired by digital light meters like SQMs.

With nearly 100,000 measurements from people in 115 countries during the last nine years, Globe at Night is the most successful of these projects — and these data are now being used for scientific studies. Students have produced four research papers as part of the NSF's Research Experiences for Undergraduates program, explains NOAO coordinator Connie Walker. These examined the effects of light pollution on the nocturnal flight routes of the lesser long-nosed bat (an endangered species) over Tucson, Arizona, and measurements of light over time above various local areas such as the region's mountaintop observatories.

Since 2014, Globe at Night has accepted observations year-round. The more who participate, the better. "To be most useful," Walker explains, "measurements should be taken from the widest possible range of locations — and also taken from the same location both seasonally and yearly."

To boost submissions, the Loss of the Night team created an app for iPhones and Android phones that guides observers to stars of descending magnitude visible at a specified time and place. It then asks whether each star can be seen. This app works best in bright settings where glare from the phone's display isn't a distraction.

Meanwhile, the Dark Sky Meter app, developed by Norbert Schmidt and colleagues at a Dutch software company in cooperation with the International Dark-Sky Association, uses an iPhone's camera to measure the sky brightness more objectively. The results are almost as good as those from SQMs. Finally, Globe at Night has developed an app that allows observers to submit naked-eye measurements in real time.

All these measurements get downloaded into the GaN database once each night, explains Walker, after which you can access the results using a regional map generated by the website. The regional-map function is extremely easy to use, and you can download the tabulated data for whatever area in the world you want.

These digital aids, in the hands of capable amateur astronomers, should help provide ample data for light-pollution research. Quantity is not quality, however — scientists need reliable data. Experienced amateur astronomers know that apparent skyglow depends strongly on cloud cover, dust and smog, atmospheric humidity, and of course moonlight. These factors are accounted for, but measurements are still done by untrained people with very different levels of experience.

In 2013, Kyba and colleagues from Italy and the U.S. published a paper demonstrating that the Globe at Night effort indeed provides useful data for tracking skyglow. However, they found that the range of individual observations is enormous — an average spread of 1.2 magnitudes — and that the spatial distribution of participants is far from ideal (most submissions come from densely populated areas). Still, thanks to Globe at Night's voluminous database, mean values of naked-eye limiting magnitude strongly correlate with both DMSP satellite values and the skyglow atlas by Cinzano and Falchi.

Conversely, of the more than 11,000 observations harvested by the Loss of the Night app in its first year, only 1,500 were suitable for analysis. Kyba explains that most participants did not know how to properly use the app or took their measurements under moonlit or cloudy skies.

This is why Kyba hopes to motivate amateur astronomers to participate. Although scientists are grateful for every observation submitted, those done by frequent stargazers — thanks to their familiarity with the night sky — offer the best quality. Besides, citizen scientists typically live in *very* light-polluted places, and most of them do their measurements only in the evening. "To find dark places in the countryside, it makes no sense to locate people only in city centers," says Kyba.

By contrast, amateur astronomers frequently observe from such dark places — and they're often out long enough to monitor skyglow throughout the night. (Sky brightness usually decreases after midnight, when most

JEREMY WHITE / NPS; METER: UNIHEDRON.COM

DECEPTIVELY SIMPLE ***Above:*** **Unihedron's Sky Quality Meter ($120) measures the sky brightness using a calibrated light sensor. The SQM-L model has a narrower field of view for use in city environments.** ***Left:*** **Volunteers use a Sky Quality Meter to measure the darkness at Saguaro National Park in southern Arizona.**

DARKSKYMETER.COM / VERLUSTDERNACHT.DE

CHEAP DATA **Your smartphone can help you assess the sky's darkness. The Dark Sky Meter app converts your iPhone into a low-cost SQM, whereas the Loss of the Night app asks you to confirm the visibility of a sequence of particular stars, each one with decreasing magnitude.**

Measuring Trends in Europe's Light Pollution

Virtually everyone in the United States and Europe lives with some degree of light pollution, but some have it worse than others. Satellite imagery shows that truly dark skies are challenging to find in Europe.

More interesting is the map below, which shows how Europe's night sky has changed over time. To derive the changes, University of Exeter's Jonathan Bennie and others compared two 5-year compilations (1995–2000 and 2005–10) of DMSP images, which record light sent upward into space. Red hues denote increases in brightness and blue ones decreases.

For calibration, the researchers used a predominantly rural region in southwest England, where they found 111 isolated patches that have increased in brightness and 98 that had gotten darker. Among the latter, 15% were attributed to areas associated with industrial decline, while 45% were urban areas where streetlighting has been modernized.

"The decrease in lighting in urban areas is due to a combination of better shielding, more focused lighting, and some limited shutting off of lights," explains Bennie. "There may be some minor effects due to changes in lighting type, but LEDs have not been adopted on a large scale in the UK."

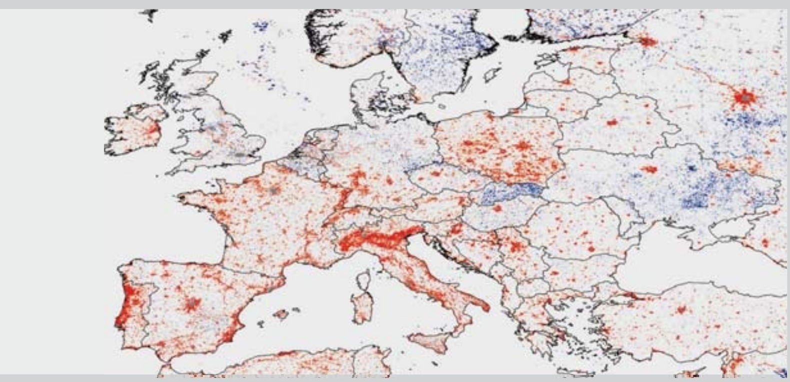
More generally, the United Kingdom shows mixed light-pollution trends, whereas Ireland, Portugal, and northern Italy have gotten considerably brighter.

Norway, Sweden, Denmark, Finland, and Belgium generally seem to emit *less* light now than they did in the 1990s. So do some Eastern European countries, most notably Ukraine and Slovakia. However, Bennie and his team suggest the underlying reasons have less to do with dark-sky awareness and more with industrial decline in the wake of the collapse of Communism.

Decreases in northwestern Europe call for other explanations. "In Scandinavia, a high degree of modernization of lighting has occurred recently," Bennie notes. But since LEDs have not been widely adopted, "my guess is that the decrease here is largely due to better shielding."

If there's a "loser" in the fight against light pollution, it's Spain, which generally has the most illuminated streets in Europe. According to a study of DMSP and Suomi-NPP satellite imagery by Alejandro Sánchez and colleagues from Universidad Complutense in Madrid, electrical consumption in public streetlighting almost doubled since 1990.

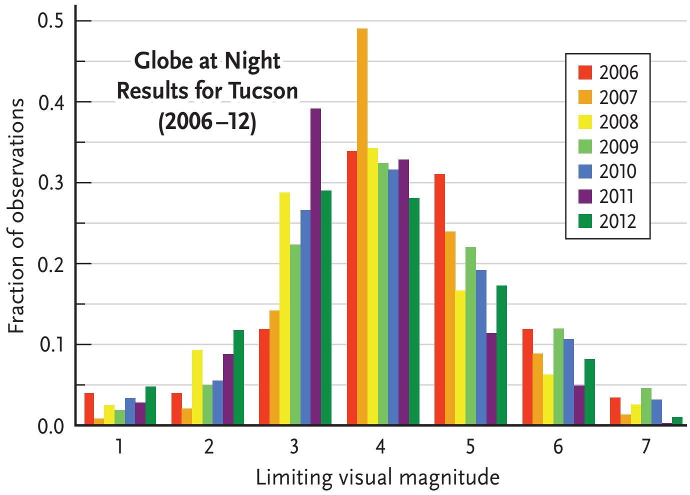
— Jan Hattenbach



J. BENNIE ET. AL. / *NATURE*

Change in brightness (calibrated digital number) between 1995–2000 and 2005–10

■ <–5 ■ –5 to –3 ■ –3 to +3 ■ +3 to +5 ■ >+5



CITIZEN-SCIENCE RESULTS Observations from past Globe at Night campaigns show that participants' evening skies seem to be getting brighter. However, as this plot for Tucson, Arizona, shows, results vary considerably due to the changing locations and conditions when each year's measurements were made.

C. WALKER / GLOBE AT NIGHT / NOAO

people are sleeping.) Amateur astronomers can help fill these gaps by providing measurements from times and places missed in current datasets, thus making them much more useful.

So the next time you're at your preferred stargazing site — whether it's your backyard or a remote park — why not take a few minutes to measure the sky's brightness? Whether you use an app, a light meter, or a tried-and-true "star count" doesn't matter, but your contribution is needed more than ever. It's especially important to get involved during the ongoing transition to LEDs, since backyard observers can provide crucial data that satellites will miss.

Who knows? Along the way you might find a new dark-sky oasis for your own enjoyment, even as you help to ensure that recent progress in the fight against light pollution has not been in vain. ✦

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*A physicist, passionate amateur astronomer, photographer, freelance writer, and newlywed, **Jan Hattenbach** is in the midst of moving from Germany to Chile.*

LED Streetlighting: Promise and Pitfalls

We are on the cusp of a once-in-a-lifetime revolution in the way we illuminate our nighttime environment. Light-emitting diodes, or LEDs, are rapidly replacing any and all light sources used at night — from flashlights to headlights to streetlights.

There's much to like about LEDs. They are mechanically uncomplicated, produce a great deal of light from very little electricity, have extremely long lifetimes (up to 100,000 hours), and can be dimmed or cycled on and off instantly. Illumination technology has not taken such a dramatic step forward since the introduction of high-pressure sodium (HPS) bulbs in the 1960s.

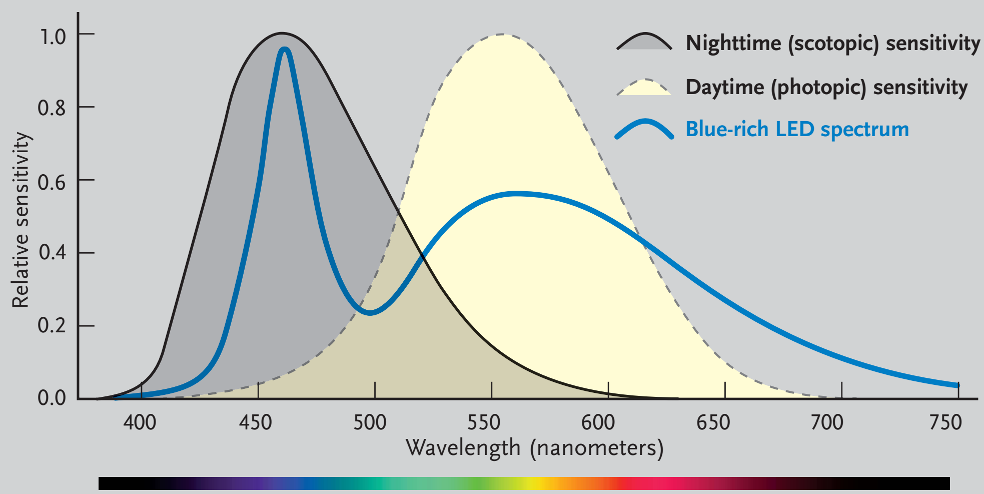
However, white LEDs are strong sources of blue-rich light, which has several negative side effects. For example, blue-rich light is more disruptive to the circadian activity of nocturnal wildlife, including humans. As the graph shows, our eyes are much more sensitive to blue light at night than they are in daylight. Blue-rich light can create strong, often disabling glare within the eyes of elderly people. Most critically for astronomers, blue-rich light scatters readily in the atmosphere (which is why our daytime skies are blue). This means blue light creates far more skyglow at night than a similarly bright "warm" source such as HPS.

One easy way to determine an LED's apparent color is to note its *correlated color temperature,* or CCT. Very high values, 5000 kelvin or above, have the harshest, bluest light; those with CCTs of 3000 K or lower have a "warmer," more environmentally benign output. A 2010 analysis by the International Dark-Sky Association (IDA) addresses these problems in detail; see **is.gd/IDA_white_paper**.

The odds are high that your town or city is planning to convert its streetlight to LEDs, if it hasn't already. The same prospect applies to businesses near you. If so, the IDA makes the following recommendations:

- Always choose fully shielded fixtures that emit no light upward.
- Use "warm-white" or filtered LEDs with a CCT no higher than 3000 K.
- Choose models with adaptive controls like dimmers, timers, and motion sensors.
- Consider dimming or turning off the lights during overnight hours.
- Do not overlight just because LEDs have high luminous efficiency.

—***J. Kelly Beatty***



INTERNATIONAL DARK-SKY ASSOCIATION

New Product Showcase

▸ **ASTRO NIKON** Nikon announces its long-awaited DSLR camera designed exclusively for astrophotography. The Nikon D810A ($3,800) features an expansive 36.3-megapixel full-frame CMOS detector with 4.88-micron-square pixels and an improved infrared-blocking filter that transmits 4× more hydrogen-alpha light than standard DSLR cameras. This modification enables users to record the reddish hydrogen-alpha nebulosity prevalent in the night sky. The camera incorporates an electronic shutter mode to eliminate vibrations, and special long-exposure M modes of up to 15 minutes without the need of a cable release. The D810A includes a special low-light live preview function with exposures of up to 30 seconds to aid focusing and composing your images. Additional features include increased ISO speeds up to 12,800 (expandable to ISO 51,200), and a 23× live focus zoom feature. See the manufacturer's website for additional details.

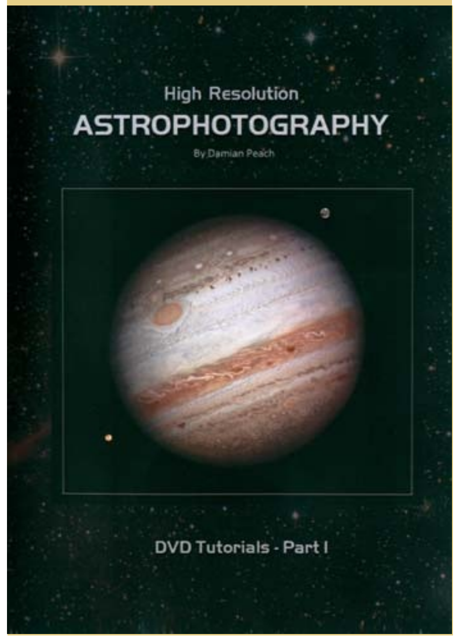
Nikon
1-800-645-6687
www.nikon.com

▾ **PLANETARY CAMERA** Celestron continues its partnership with high-end video camera manufacturer The Imaging Source, releasing the Skyris 132M and 132C (monochrome and color) cameras for $369.95 each. Both cameras feature the state-of-the-art Aptina AR0132AT CMOS sensor with a 1,280 × 960 array of 3.75-micron-square pixels. Each unit's high-speed USB 3.0 data transfer allows users to record up to 60 full-resolution frames per second (fps), or up to 200 fps when using a region-of-interest subframe, which is particularly useful when imaging the planets. Skyris incorporates a rolling electronic shutter and weighs only 3.6 ounces (102 grams). The camera is also capable of recording in 12-bit mode and comes with a C-to-1¼-inch nosepiece, a 10-foot USB 3.0 cable, and Celestron's *iCap* PC camera-control software.

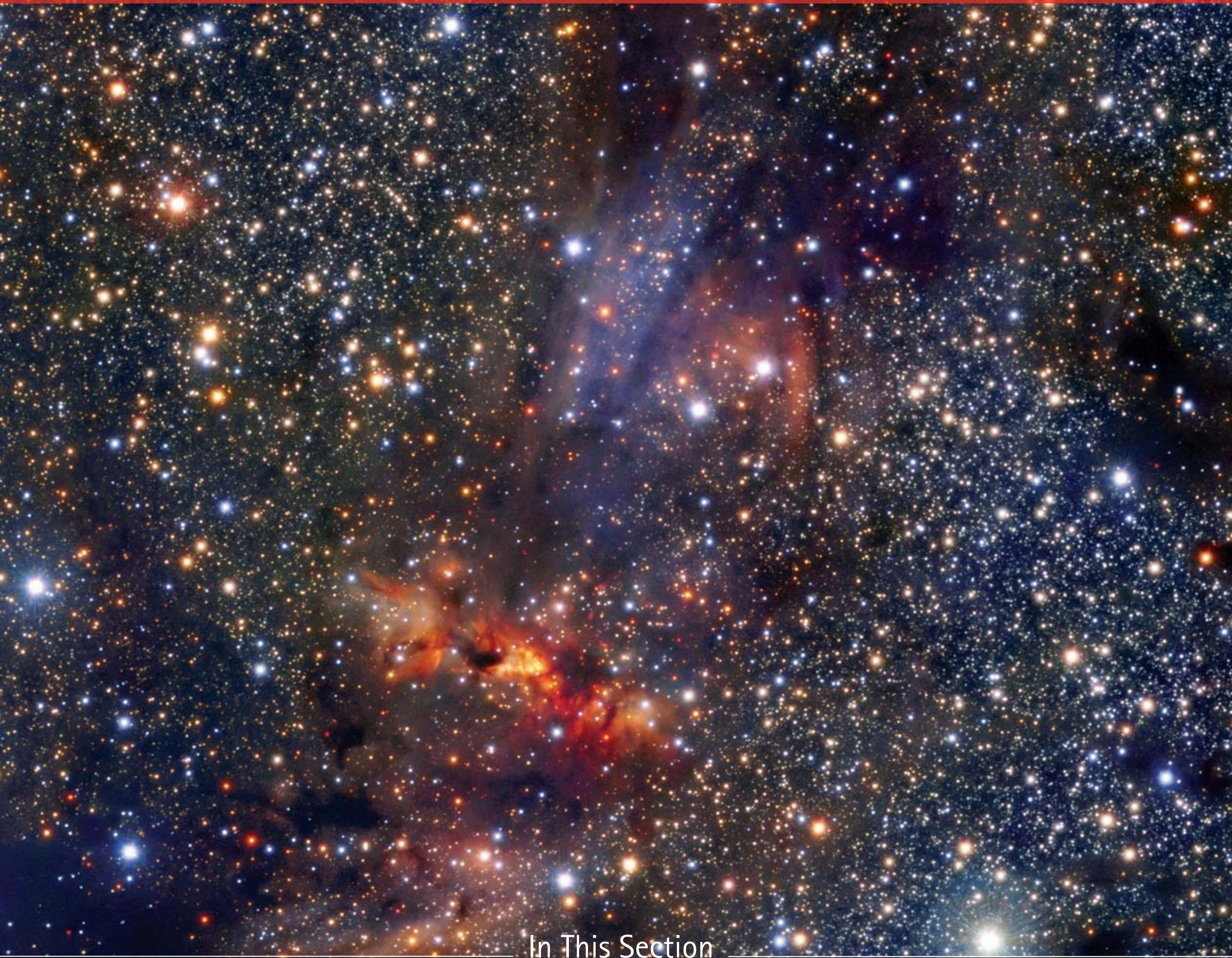
Celestron
2835 Columbia St., Torrance, CA 90503
310-328-9560; www.celestron.com

IMAGING TUTORIAL World-renowned planetary imager Damian Peach releases the first of his new DVD tutorial series *High Resolution Astrophotography*. Within you'll find more than 2½ hours of detailed video guides on how to photograph the Sun, Moon, and planets. Peach walks you through useful features in popular image-processing programs including *RegiStax 6*, *Autostakkert!2*, *WinJUPOS*, and *Adobe Photoshop* to maximize the potential of your own images. He also discusses considerations for choosing the right telescope and camera for planetary photography, and provides a detailed analysis of astronomical seeing conditions and modern forecasting tools.

Damian Peach
www.damianpeach.com



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



In This Section

PHOTOGRAPH: ESO / VVV TEAM / A. GUZMAN

The dust and gas of IRAS 16562-3959 in the constellation Scorpius serves as a breeding ground for new stars.

Sky at a Glance

MAY 2015

1 **DUSK:** Mercury shines high above the west-northwest horizon for the next two weeks. Look for it to the lower right of Venus about an hour after sunset. Tonight it's just left of the Pleiades.

NIGHT: Spica gleams less than 6° from the nearly full Moon.

4 **NIGHT:** The waning gibbous Moon appears about 5° from Saturn near the head of Scorpius in the southeast.

6 **MORNING:** The Eta Aquariid meteors peak before dawn. The gibbous moon makes observing this shower a challenge.

10 **MORNING:** The last quarter Moon is about 3° from 3rd-magnitude Beta (β) Capricorni.

21 **EVENING:** Look west to spot Venus in Gemini about 9° to the upper right of the waxing crescent Moon.

23 **NIGHT:** Jupiter blazes about 6° north of the Moon, which sets around midnight.

25 **NIGHT:** Look for Regulus about 5° above the first quarter Moon.

27 **NIGHT:** A double shadow transit occurs on Jupiter from 10:01 p.m. to 12:18 a.m. EDT; see page 52.

30 **NIGHT:** Look for Spica to the lower left of the gibbous Moon at dusk. Watch the Moon draw closer to it all night.

Planet Visibility

SHOWN FOR LATITUDE 40° NORTH AT MID-MONTH

	◀ SUNSET	MIDNIGHT	SUNRISE ▶
Mercury	NW	Visible April 18 through May 17	
Venus	W	NW	
Mars		Hidden in the Sun's glare all month	
Jupiter	SW	NW	
Saturn	SE	S	SW

Moon Phases

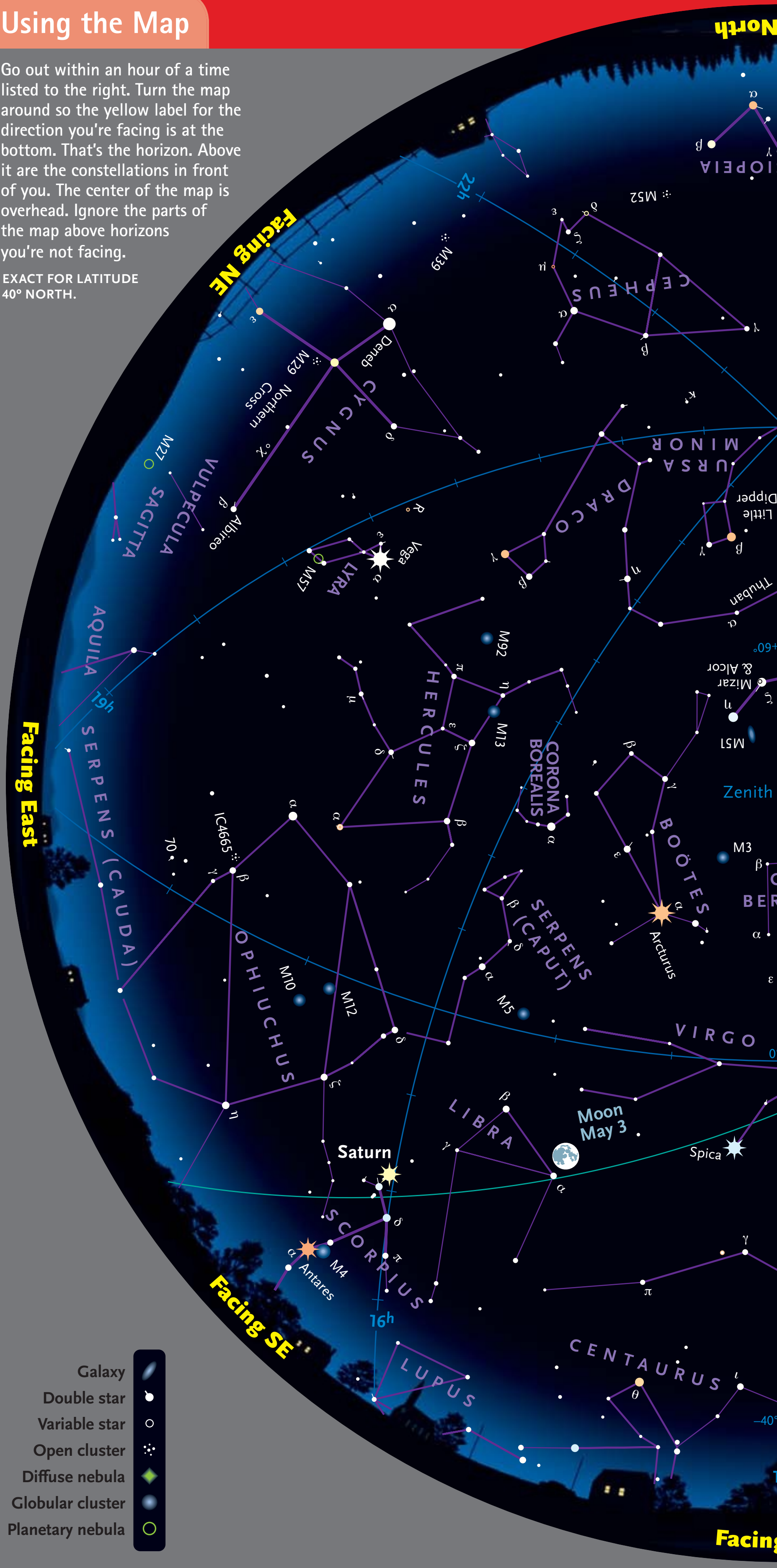
○ Full	May 3	11:42 p.m. EDT	
● New	May 18	12:13 a.m. EDT	
◑ Last Qtr	May 11	6:36 a.m. EDT	
◐ First Qtr	May 25	1:19 p.m. EDT	

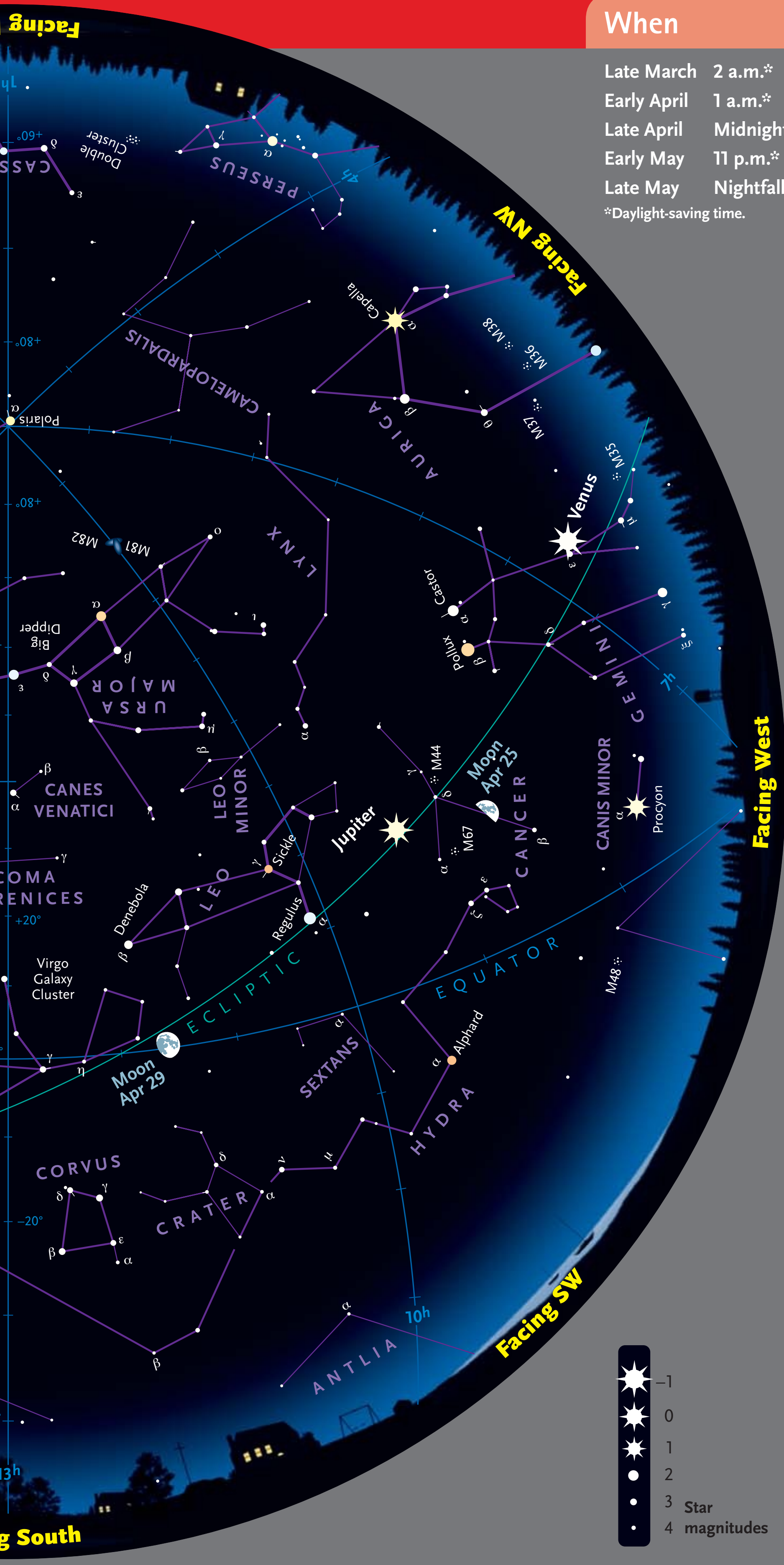
SUN	MON	TUE	WED	THU	FRI	SAT
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24 / 31	25	26	27	28	29	30

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 March	2 a.m.*
Early April	1 a.m.*
Late April	Midnight*
Early May	11 p.m.*
Late May	Nightfall

*Daylight-saving time.

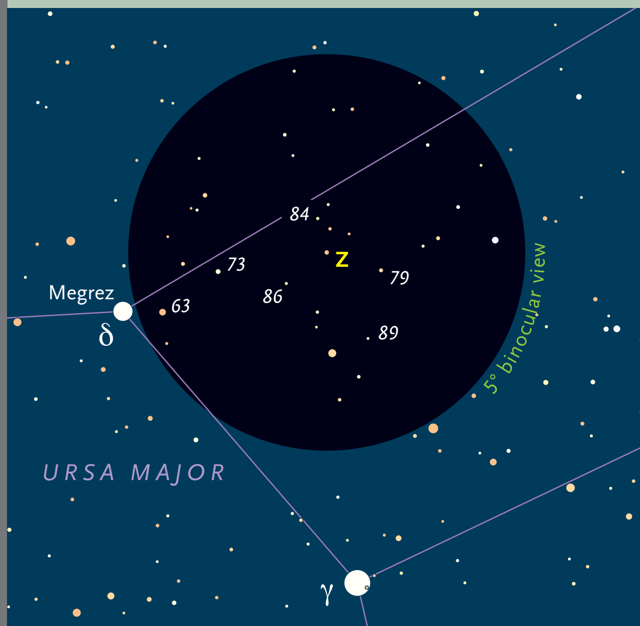
Z Marks the Spot

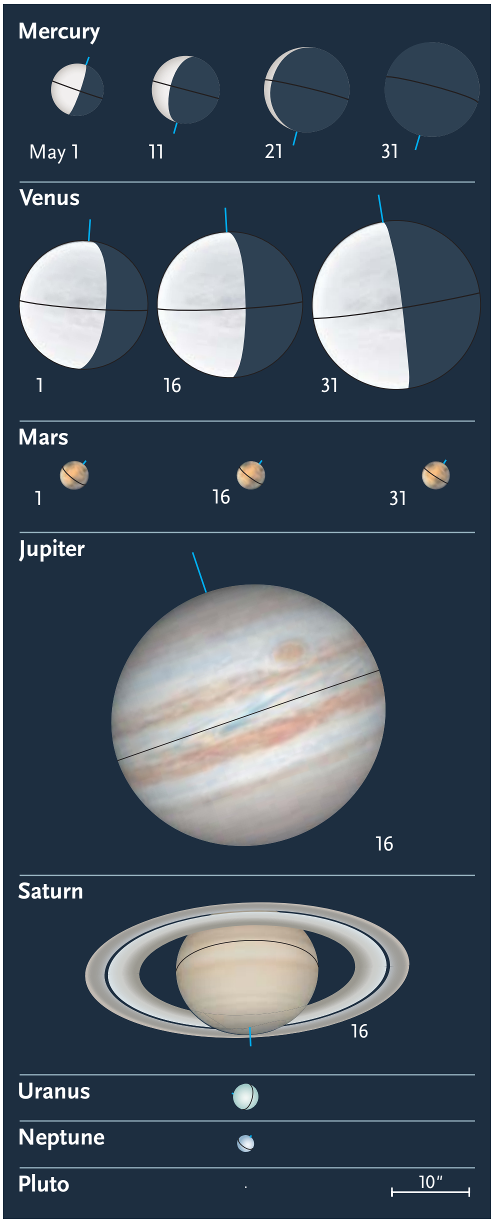
If you've never dipped a toe into the waters of variable star observing, you've been missing out on a fascinating part of the hobby accessible to anyone with a clear sky. And though you can enjoy some bright variables with your eyes alone, binoculars open up a huge range of potential targets. May evenings are an ideal time to begin by seeking out Z Ursae Majoris, a particularly interesting variable star situated near Megrez, the star at the base of the Big Dipper's handle.

You can locate Z UMa quite easily. First center Megrez in your view, then shift roughly half a binocular field toward Dubhe (α Ursae Majoris). Since variable star observing involves consulting star charts frequently to check comparison-star magnitudes, I recommend using a binocular mount, at least initially. That way, you don't have to relocate your target every time you look away.

For most readers of this magazine, Z UMa is circumpolar, which means you can look in on it any night of the year. It normally ranges in brightness from magnitude 7.2 to 8.9. But not always. It's been as bright as magnitude 6.2 and as faint as 9.4. The time between maximum and minimum brightness also changes unpredictably. Typically, the star reaches minima in 196 days, but that's an average — minima can arrive earlier, or later. But this unpredictability is part of the fun. When you check up on Z UMa, you're never entirely sure what you'll find.

Z UMa is classified as a semi-regular variable star. It's a cool red giant that's old enough to have moved off the main sequence to a region of the Hertzsprung-Russell diagram known as the Asymptotic Giant Branch — a collection of stars important to our understanding of stellar evolution. ✦



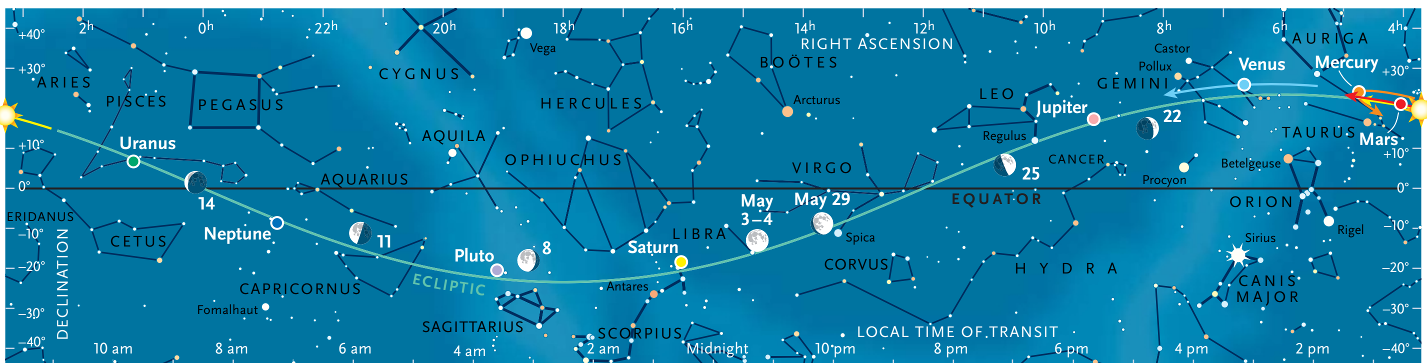


Sun and Planets, May 2015

	May	Right Ascension	Declination	Elongation	Magnitude	Diameter	Illumination	Distance
Sun	1	$2^h\ 30.8^m$	+14° 51′	—	–26.8	31′ 45″	—	1.007
	31	$4^h\ 29.4^m$	+21° 48′	—	–26.8	31′ 33″	—	1.014
Mercury	1	$3^h\ 47.7^m$	+22° 26′	20° Ev	–0.4	6.8″	56%	0.988
	11	$4^h\ 33.0^m$	+24° 21′	21° Ev	+0.8	8.8″	27%	0.764
	21	$4^h\ 45.0^m$	+22° 59′	13° Ev	+3.0	11.1″	7%	0.607
	31	$4^h\ 28.9^m$	+19° 36′	2° Mo	—	12.2″	0%	0.549
Venus	1	$5^h\ 24.7^m$	+25° 33′	42° Ev	–4.2	16.7″	67%	0.999
	11	$6^h\ 14.0^m$	+26° 03′	43° Ev	–4.2	18.1″	63%	0.923
	21	$7^h\ 01.7^m$	+25° 27′	45° Ev	–4.3	19.8″	59%	0.844
	31	$7^h\ 46.5^m$	+23° 54′	45° Ev	–4.4	21.8″	53%	0.764
Mars	1	$3^h\ 17.6^m$	+18° 26′	12° Ev	+1.4	3.8″	100%	2.467
	16	$4^h\ 01.6^m$	+21° 01′	8° Ev	+1.5	3.7″	100%	2.510
	31	$4^h\ 46.0^m$	+22° 51′	4° Ev	+1.5	3.7″	100%	2.544
Jupiter	1	$9^h\ 03.5^m$	+17° 45′	93° Ev	–2.1	37.9″	99%	5.208
	31	$9^h\ 16.0^m$	+16° 48′	67° Ev	–1.9	34.7″	99%	5.676
Saturn	1	$16^h\ 05.6^m$	–18° 37′	157° Mo	+0.1	18.4″	100%	9.040
	31	$15^h\ 56.6^m$	–18° 12′	172° Ev	+0.1	18.5″	100%	8.976
Uranus	16	$1^h\ 08.8^m$	+6° 38′	36° Mo	+5.9	3.4″	100%	20.802
Neptune	16	$22^h\ 45.1^m$	–8° 45′	75° Mo	+7.9	2.3″	100%	30.207
Pluto	16	$19^h\ 04.7^m$	–20° 33′	129° Mo	+14.1	0.1″	100%	32.220

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

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

Fred Schaaf

The Spica Hour

Three bright stars and a celestial arch mark the month of May.

AKIRA FUJII

Last May's installment of this column was devoted to just one object — the star Spica. But this year, we're going to look at the entire sky at the hour when Spica is near the sky's central meridian. Following an idea originated by astronomy writer Guy Ottewell, we can call this time the Spica Hour.

Observing at the Spica Hour. When is Spica near its highest? Our Northern Hemisphere Sky Chart for May is drawn for that time (page 44). The chart shows the state of the sky when the 13^h line of right ascension is on the central (north-south) meridian. We formally call this 13:00 sidereal time, but Ottewell suggested giving to each sidereal hour a name that makes it more memorable and easier to distinguish from the others. In this case, an appropriate name is the Spica Hour.

Brightest stars at the Spica Hour. Zero-magnitude orange Arcturus is not far behind Spica in the trek to the meridian. The third of the three really bright stars in the spring constellations is Regulus, at the heart of Leo the Lion. Regulus still shines high at the Spica Hour but is starting its descent in the west.

Very much lower in the west is what has been called "the arch of spring." It's visible in late spring but is composed of brilliant stars usually considered to belong to winter or early spring. At the Spica Hour for observers around latitude 40° north, the arch stretches from Procyon very low in the west, up to Pollux and Castor, then down to Capella in the northwest. Last May, Jupiter became part of the arch, passing near Pollux and Castor. This May, Jupiter is already well to the upper left and out of the arch, but blazing Venus is in the act of climbing up to and then beyond its curve.

The last very bright stars of the hour are Antares, just rising in the southeast and this year accompanied by much brighter Saturn, plus Vega and Deneb, twinkling low in the northeast. Did you know that around latitude 40° north, Antares rises before Altair, Vega and Deneb's partner in the Summer Triangle?

Star patterns at the Spica Hour. At the Spica Hour, the pattern of Gemini the Twins stands upright on the west-northwest horizon. Cygnus the Swan flies low in the northeast, parallel to the horizon. Two starry beasts — Leo and Ursa Major — descend parallel to each other in the west and northwest sky. Scorpius is only half-risen in the southeast at the Spica Hour.

Of course, the middle of the sky now features the arc (from the Big Dipper's handle) to Arcturus and the spike (straight line) onward to Spica. An extra curve from Spica brings us to the compact pattern of Corvus the Crow. The bright handle of the Big Dipper is at its highest at the Spica Hour and the pattern of Cassiopeia is lowest in the north. The pattern of Hydra now stretches from west to south-southeast, and only around this time is all of Hydra at nearly the same altitude.

The nearly straight line in the Big Dipper. It's been about 40 years since Guy Ottewell came up with the idea of giving the hours of sidereal time more memorable appellations. But Ottewell is still doing interesting new things. He's recently published a greatly expanded edition of *To Know the Stars*, his astronomical guide for beginners, and is now writing a mostly astronomical blog at **universalworkshop.com/guysblog**.

In *To Know the Stars*, Ottewell challenges his readers to draw the Big Dipper from memory and see if they've got it right. He points out that there's a long, nearly straight line connecting four stars within the asterism, but they may not be the four you think they should be. Check this out for yourself on the next clear night. ✦

Good Things Come in Threes

Venus, Mercury, and Saturn dazzle in the month of May.

During May, three planets — Venus, Mercury, and Saturn — all put in what are in some ways their best appearances of the year. At dusk, Venus blazes high in the west all month, with Mercury visible far to its lower right for about the first 10 days of May. The initially huge gap between Venus and Jupiter, far to Venus's upper left, closes dramatically over the course of the month. And Saturn climbs low in the southeast as darkness deepens, achieving all-night visibility as it goes through opposition.

DUSK

Observers at mid-northern latitudes who go out about an hour after sunset on May 1st will find magnitude –0.4 **Mercury** shining about 8° above the west-northwest horizon. This is the highest it's been all spring. Look for it a few degrees left of the Pleiades, and almost directly between the Pleiades and Aldebaran. **Mars** is finally disappearing into the sunset. To glimpse it on May 1st, bring out binoculars or a wide-field telescope about 45 minutes after sunset. You'll find the red planet a few degrees above the west-northwest horizon and about 9° directly below the Pleiades. Mars then becomes lost in the Sun's afterglow for the remainder of the month.

Initially very much higher and brighter than Mars, Mercury nevertheless fades and falls as May progresses. It reaches a greatest elongation from the Sun of 21° E on the evening of May 6th in the Americas, when it's a little dimmer than zero magnitude and less than 40% illuminated. By May 13th, the little planet still sets more than an hour and a half after the Sun, but has faded to magnitude +1.3, with a disk 9½″ wide and only 20% illuminated. Mercury goes through inferior conjunction with the Sun on May 30th.

DUSK TO LATE NIGHT

Venus doesn't reach greatest elongation from the Sun until June 6th, but observers around latitude 40° north see it attain its highest altitude around May 8th. At sunset that evening, the intensely bright planet is visible to the naked eye a full 38° above the horizon in a clear sky.

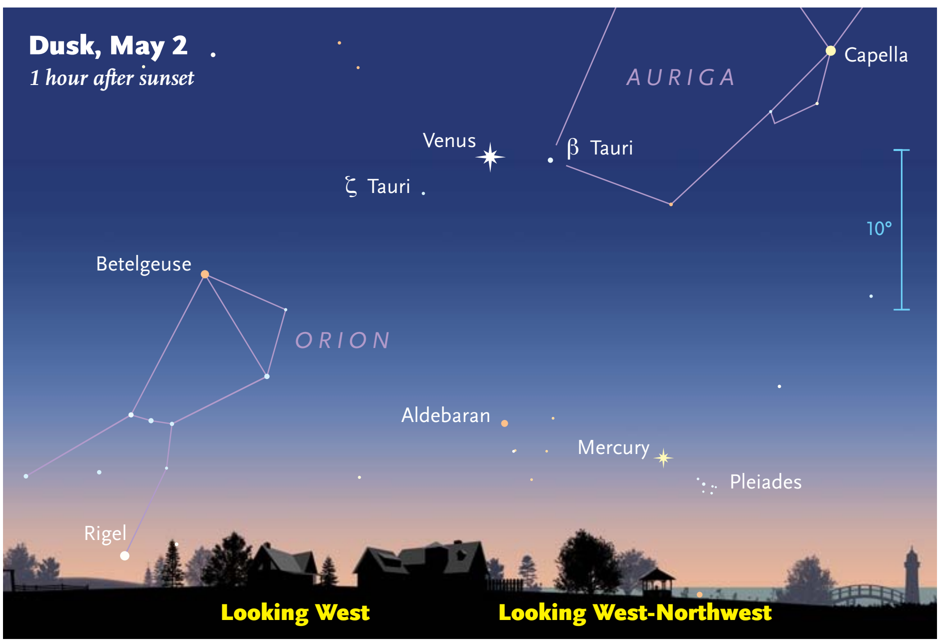
Venus brightens from magnitude –4.2 to –4.4 this month. The interval between sunset and Venus-set decreases bit by bit, shortening to 3⅓ hours by month's end. This still leaves Venus shining in the west-northwest long after dark. Telescopes show the disk of Venus growing from less than 16″ to 22″ wide; its illuminated fraction slims from about ⅔ to just over ½ lit during May.

But, like last month, the most exciting thing to see is Venus passing through patterns of stars and star clusters — and rapidly closing the gap with Jupiter.

Venus opens the month right between Beta (β) and Zeta (ζ) Tauri, the stars that mark the horn-tips of the Bull. From May 8th through 10th, optical aid shows Gemini's big open cluster M35 just a few degrees from the dazzling planet. Around mid-May, Venus stands at about the same height as Capella (far to its right) and Procyon (equally far to its left).

By May 21st, when the crescent Moon approaches, Venus poses almost equidistant below Pollux and Castor, forming a tall V with them. As the month ends, Venus shines just below what would be a horizontal line with Castor and Pollux, with the three almost equally spaced along its length. Venus ends May just on the verge of leaving Gemini — having raced to within 21° (about two fist-widths at arm's length) of Jupiter.

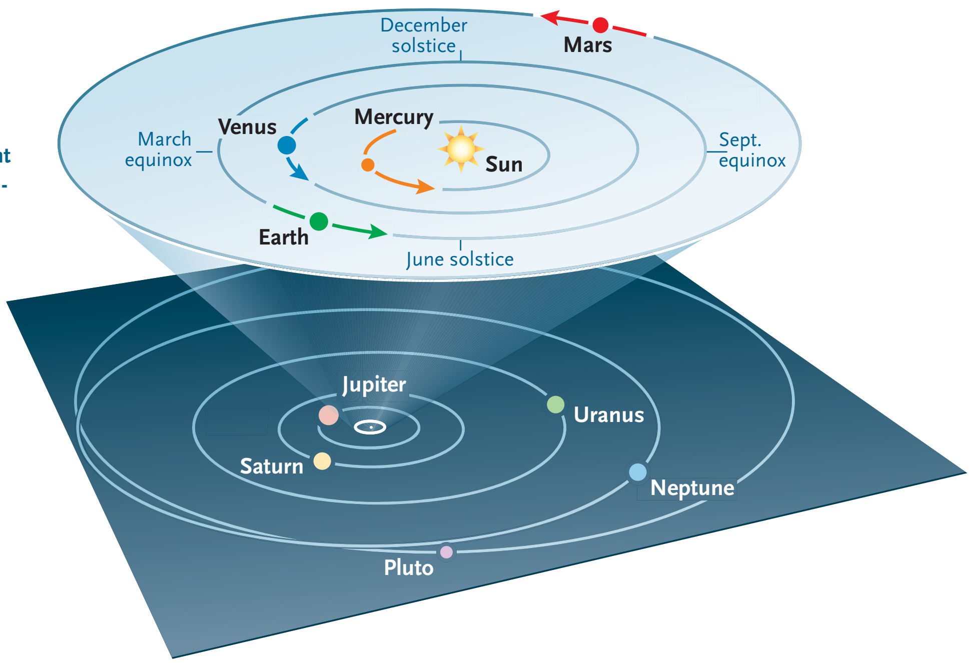
Jupiter dims from magnitude –2.1 to –1.9 in May — over two magnitudes dimmer than Venus — but still stands out majestically in the south-southwest to southwest at nightfall. The two planets are an enormous 50° apart on May 1st,



Fred Schaaf

ORBITS OF THE PLANETS

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



but watch the gap shrink. The gas giant is now trudging slowly east against the stars, away from M44, the Beehive Star Cluster, approaching the eastern border of Cancer the Crab by month's end. It reaches eastern quadrature (90° east of the Sun) on May 4th, creating especially excellent views of the eclipses of the Galilean satellites all April and May. Jupiter's globe shrinks from 38″ to 35″ wide this month.

NIGHT

Saturn reaches opposition on the night of May 22nd, so is visible virtually all night long this month. The ringed planet brightens a bit to a wonderful magnitude 0.0 for part of May, the brightest it's been for eight years. Most of the reason for Saturn's brightness is its rings, which are tilted more than 24° from edgewise.

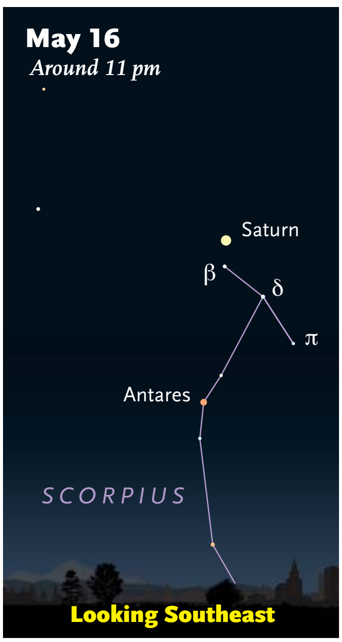
Saturn's globe is 18½″ in diameter this month; its rings span 42″. Saturn retrogrades away from the double star Beta (β) Scorpii, creeping west back into Libra.

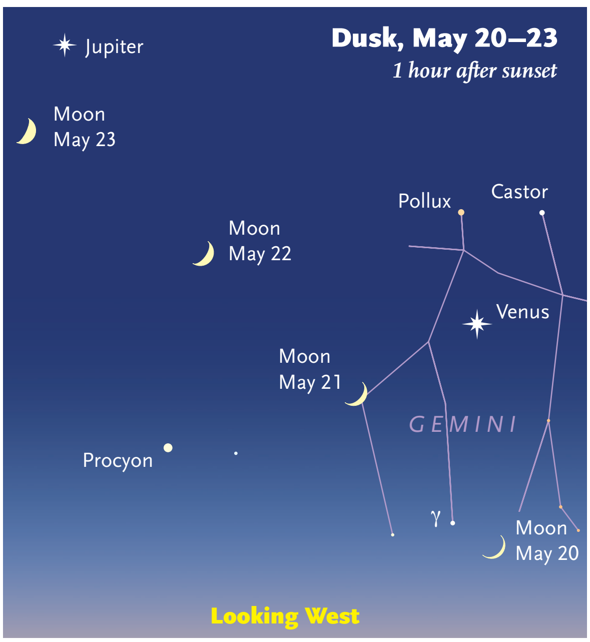
DAWN

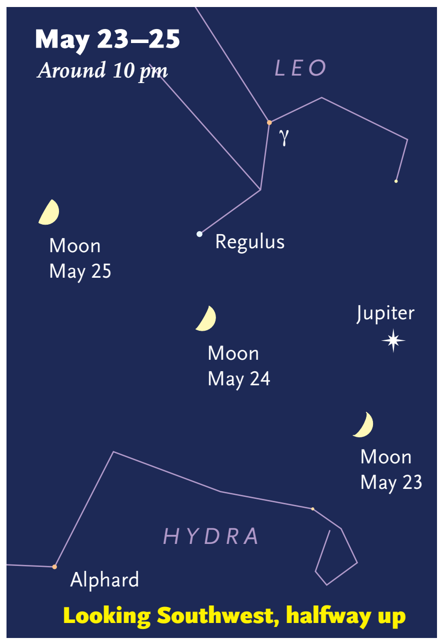
Pluto is high in the sky after midnight but is best observed closer to its opposition in July. **Neptune** rises an hour or two before dawn, **Uranus** in morning twilight.

MOON PASSAGES

The **Moon** is almost full when it's above Spica on the evening of May 1st and lower left of Spica on the 2nd. The waning gibbous Moon is some 5° or 6° above Saturn as they rise in the late evening on the 4th. After sunset on May 20th, the slim waxing crescent is far — but directly — below the brilliant Venus. The next night, the Moon appears closer (though still not very close) to the same planet. The thickening Moon shines well to the lower left of Jupiter in Cancer on May 23rd, below Regulus the next night, left of Spica on the 29th, and to the upper right of Saturn again on the 31st. ✦







Naked-Eye Lunar Details

Copernicus? Kepler? What's the smallest thing you can see on the Moon?

Newcomers to astronomy are often surprised to hear that they can see more on the Moon with the naked eye than they'll be able to see on the planets with a large telescope. But it's true. The naked-eye Moon is a rich target.

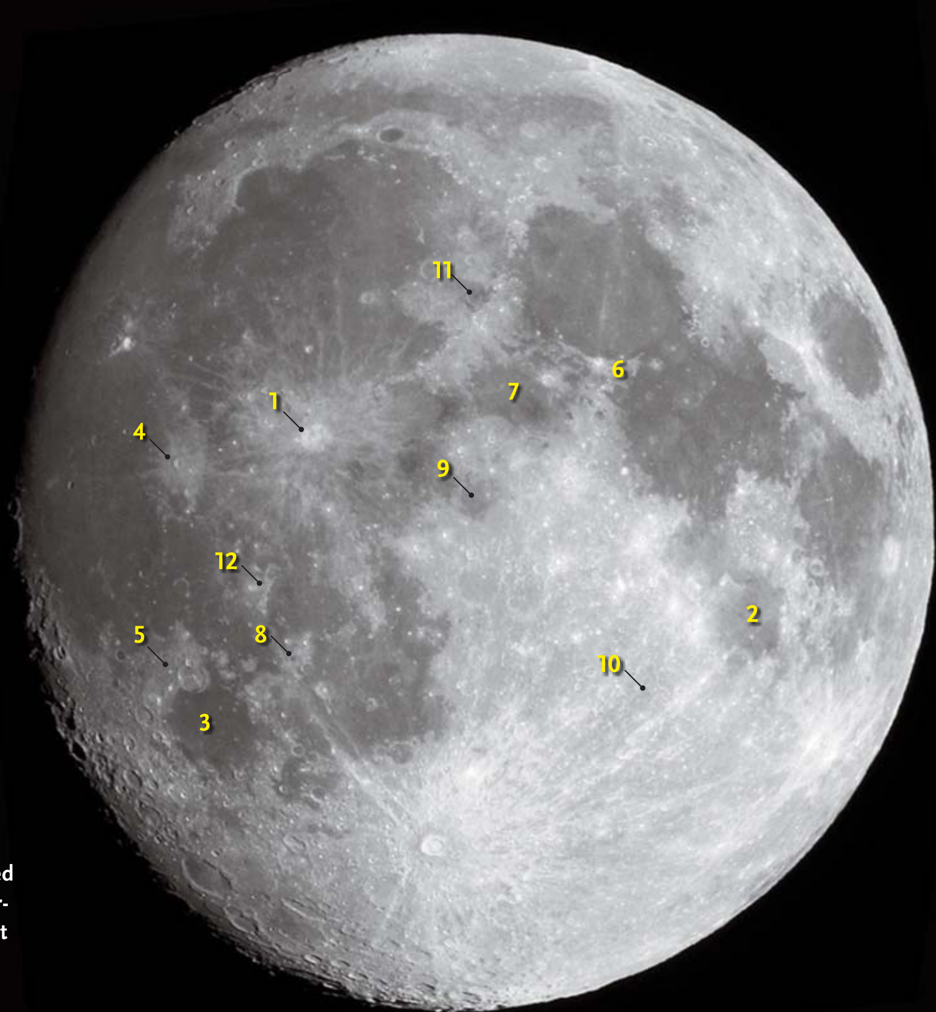
So it's remarkable that pre-telescopic astronomers took almost no interest in what they could see right in front of them on moonlit nights.

After all, Aristotle had said that heavenly bodies were perfect crystalline spheres. That pretty much settled the matter for Western philosophy and religion for the next 1,900 years, until Galileo. The Moon's gray spots and finely detailed white markings had to be some insignificant illusion — Earthly atmospheric effects, perhaps, or maybe reflections of the Earth's own lands and seas. Nothing worth paying attention to, anyway.

A few dissenting voices are known from those 1,900 years. In 1st-century Rome, Plutarch easily refuted the notions that the atmosphere or reflections were at fault. He then reasoned out that the Moon was like another Earth. It reflected sunlight as a rough surface would,

Moon Tests for Sharp Eyes

1 Bright surroundings of Copernicus
2 Mare Nectaris
3 Mare Humorum
4 Bright surroundings of Kepler
5 Gassendi region
6 Plinius region
7 Mare Vaporum
8 Lubiniezky region
9 Sinus Medii
10 Faint shading near Sacrobosco
11 Dark spot at foot of Apennines
12 Riphaeus Mountains



To test your Moon vision, find the highest-numbered of W. H. Pickering's 12 features that you can distinguish with your unaided eyes. The labels above are Pickering's descriptions. The areas that he called "regions" are bright. You'll probably see naked-eye details best in twilight.

S&T: GARY SERONIK

whereas a polished crystal ball would show a small, bright specular reflection of the Sun. He correctly attributed slight irregularities on the Moon's terminator to mountains casting long shadows. As an analogy, he described how Mount Athos in northern Greece casts a shadow near sunset that extends 50 miles across the Aegean Sea to the island of Lemnos. Plutarch may have observed the shadow of the lunar Apennines, the 19th-century lunar astronomer J. H. Mädler suggested. The Apennines briefly produce a definite naked-eye irregularity in the terminator around first and last quarter.

Then in the 11th century, the Arab astronomer al-Haitham, better known as Alhazen, argued that because the Moon's markings never changed shape, position, or size, they were permanent areas of different materials. He wrote that the darker ones should be denser rock. But Plutarch and Alhazen were almost completely ignored despite their renown for their other writings. Not until the century before Galileo did the idea of the Moon having actual blemishes start gaining traction. (See "Lunar Studies Before the Invention of the Telescope" by Joseph Ashbrook, *S&T:* June 1962, p. 322.)

Meanwhile, anyone with eyes could see that the Man in the Moon never changed, regardless of the weather or the Moon's position in the sky.

Visual Tests

What's the smallest lunar feature you can see with the naked eye? Look carefully, and you may be amazed.

About a century ago William H. Pickering, the brother of Harvard Observatory director Edward C. Pickering, drew up a list of 12 test features in order of increasing difficulty. They're marked on the photo at left.

The large gray *maria* are easy for anyone with fairly good (or corrected) vision. The easiest feature in Pickering's list is the bright splash of rays surrounding the crater Copernicus. As Ashbrook wrote in his 1962 article,

> Reasonably good eyes should be able to see No. 7, Mare Vaporum, as a very dark spot, while really good vision can reach No. 10, the faintly shaded area near Sacrobosco.
>
> Persons with exceptional visual acuity might distinguish the 11th feature, a dark patch at the edge of Mare Imbrium, just across the Apennine Mountains from Mare Vaporum. But Pickering thought that his No. 12, the Riphaeus Mountains, might be beyond even the keenest naked-eye vision.
>
> Careful experiments of this kind reveal a surprising amount of lunar surface pattern. The best results, I have found, are obtained by viewing the waning gibbous moon during the latter part of morning twilight. Much less is visible by night, when glare hampers, or in full daylight, when contrasts are diluted.

The waxing gibbous Moon early in evening twilight should be equally favorable, though the air then is less often crystal clear.

It also matters whether the Moon is near perigee or apogee. The size difference between a "supermoon" and a "mini-moon," as they've recently come to be called, is not obvious to the naked eye. But for detecting limit-of-vision details, I've found that features that are normally borderline definitely become easier around perigee.

What else in our everyday lives, we may wonder, has gone unnoticed for centuries because we assume there's no reason to look at it critically?

No Alpha Comae Eclipse!

It was an epic goof. The 4th-magnitude visual double star Alpha Comae Berenices, with a 26-year period and an orbit almost exactly edge-on to us, was supposed to undergo its first observed self-eclipse around January 23rd, as told in the January *S&T,* page 50.

But just days beforehand, as photometrists around the world monitored the star, lead investigator Matthew Muterspaugh announced that his prediction was mistaken. The eclipse had already probably happened a couple months earlier, if it happened at all.

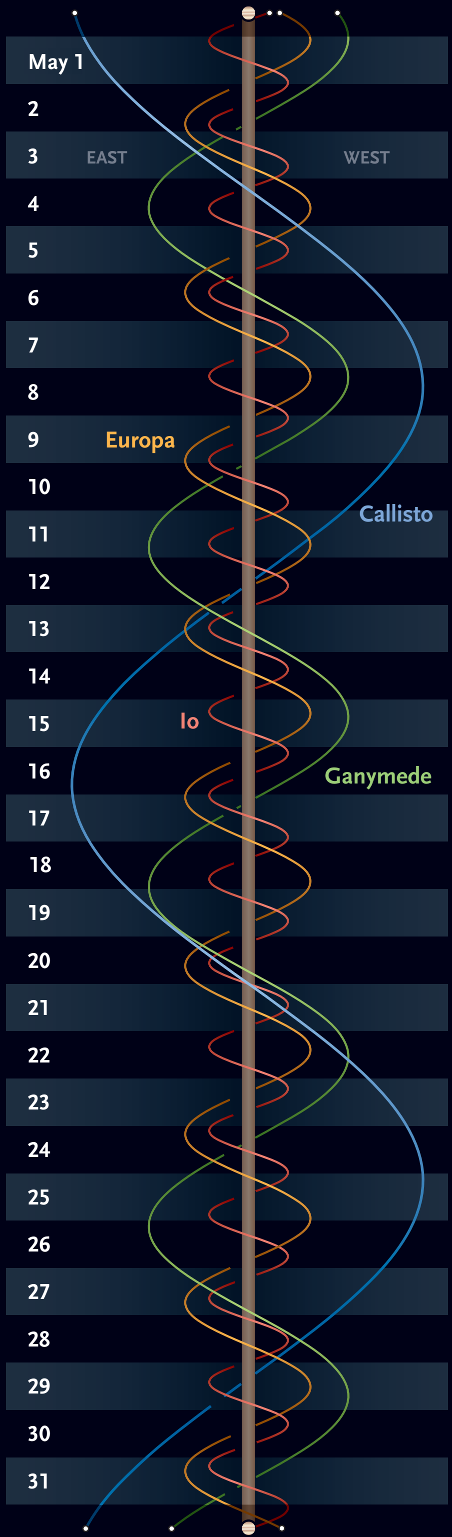
The mistake wasn't exactly his. His calculated orbit was based on 609 measurements of the binary pair that astronomers had made across more than a century. For three of these measurements, made in 1896, 1911, and 1937, the observers accidentally swapped the primary and secondary components of the pair, which are nearly the same brightness. These were enough to throw off the timing for the predicted eclipse. See the full story at **arxiv.org/pdf/1501.05639v1**.

If there's an upside to the story, it's that the corrected orbit opens a slim chance that Earth will see a *secondary* eclipse of the pair: around January 11, 2026. The next primary eclipse should come in late September 2040, when Alpha Comae will be unobservably close to the Sun. So mark your calendar for the next one, in July 2066.

MAY METEORS

The waning gibbous Moon on the morning of May 6th will make this year's Eta Aquariid meteor shower a challenge to observe, even from the southern latitudes where its radiant is highest before dawn and the most meteors therefore appear in the sky.

Jupiter's Moons



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

Action at Jupiter

Jupiter's Red Spot. These are the dates and times, in Universal Time, when the Great Red Spot should cross Jupiter's central meridian in May.

May 1, 5:19, 15:14; **2,** 1:10, 11:06, 21:02; **3,** 6:58, 16:53; **4,** 2:49, 12:45, 22:41; **5,** 8:36, 18:32; **6,** 4:28, 14:24; **7,** 0:20, 10:15, 20:11; **8,** 6:07, 16:03; **9,** 1:59, 11:54, 21:50; **10,** 7:46, 17:42; **11,** 3:38, 13:33, 23:29; **12,** 9:25, 19:21; **13,** 5:17, 15:12; **14,** 1:08, 11:04, 21:00; **15,** 6:56, 16:51; **16,** 2:47, 12:43, 22:39; **17,** 8:35, 18:30; **18,** 4:26, 14:22; **19,** 0:18, 10:14, 20:09; **20,** 6:05, 16:01; **21,** 1:57, 11:53, 21:48; **22,** 7:44, 17:40; **23,** 3:36, 13:32, 23:28; **24,** 9:23, 19:19; **25,** 5:15, 15:11; **26,** 1:07, 11:02, 20:58; **27,** 6:54, 16:50; **28,** 2:46, 12:42, 22:37; **29,** 8:33, 18:29; **30,** 4:25, 14:21; **31,** 0:16, 10:12, 20:08. ✦

Phenomena of Jupiter's Moons, May 2015

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

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

Saturn's Elusive D Ring

Photos and sketches show this ultra-faint band — but we were fooled.

Amateur astronomers of the baby-boomer generation learned long ago that Saturn has four rings: the bright A and B rings, the much fainter C ring inside them, and an even fainter D ring hugging the planet. Yet the last of these is so elusive that for a time astronomers debated whether it even existed.

In 1915 Johns Hopkins University astronomer R. W. Wood photographed Saturn using four filters through the 60-inch reflector at Mount Wilson Observatory. The planet's Equatorial Zone appeared bright in his infrared and yellow images, but in the violet and ultraviolet images it was covered by a broad dusky band. Wood speculated that this "band" wasn't an atmospheric feature but rather a fine haze of particles extending from the inner edge of C ring down to the planet's cloud tops.

As further evidence, he noted that at the shorter wavelengths the space between the planet and the inner edge of C in the rings' ansae ("handles") appeared slightly brighter than the background sky just outside ring A — though he warned that "this luminosity is much too feeble to show in the prints." Wood, a cautious man, made no announcement about his tentative discovery.

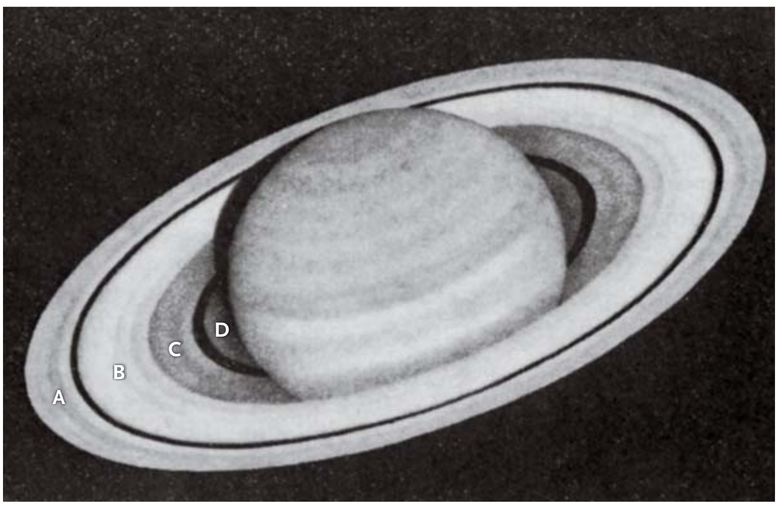
Yet, more than a half century later, photographs of Saturn seemed to vindicate Wood's suggestion of a tenuous fourth ring. French astronomer Pierre Guérin recorded Saturn in 1969 through the 1.07-meter (42-inch) reflector at Pic du Midi Observatory. His negatives appeared to show a faint, diffuse glow that extended outward from the planet's cloud tops and was separated from the inner edge of ring C by a distinct gap. Hints of this feature later appeared in photographs taken at New Mexico State University and University of Arizona, though its "signal" was feeble and embedded in the "noise" of scattered light from Saturn's globe. Despite the lingering doubts about its reality, this feature was provisionally designated "Ring D."

Surprisingly, a confirming visual observation of Guérin's ghostly ring soon followed. After several unsuccessful attempts, J. B. Murray (University of London Observatory) reported that he had managed not only to glimpse the D ring but even to make micrometer measurements of it on four nights during a "remarkable observing run" in September 1973 using Pic du Midi's big reflector. He reported that in near-perfect seeing ring D "was immediately obvious" at a magnification of 725×:

> It has a well-defined outer edge, separated from the inner edge of the Crepe [C] Ring by a division similar in appearance to Cassini's Division. It is extremely faint, much fainter than the Crepe Ring, which shines brightly in the 1.07 m, and its inner edge is undetectable, being lost in the strong contrast effect caused by the comparatively brilliant limb of Saturn.

Murray's account failed to convince the skeptics. An exhaustive 150-page report entitled "The D Ring — Fact or Fiction?", issued in 1975 by the Jet Propulsion Laboratory's Saturn Ring Study Team, concluded that the Earth-based results were inconclusive and that a definitive answer would have to await the results of the upcoming Pioneer and Voyager flybys of Saturn.

In 1979 Pioneer 11's crude spin-scan imager failed to detect so much as a hint of ring D, whose purported brightness should have made it a rather easy target. Two years later, views of the rings captured by the far more sensitive camera aboard Voyager 2 did record an exceedingly rarefied haze of fine particles containing a few narrow ringlets where the D ring had been seen. But this material had just 1/10,000 the optical density of ring C — making it far beyond the grasp of any Earth-based telescope. Moreover, there wasn't any trace of the reputed gap between the C and D rings.

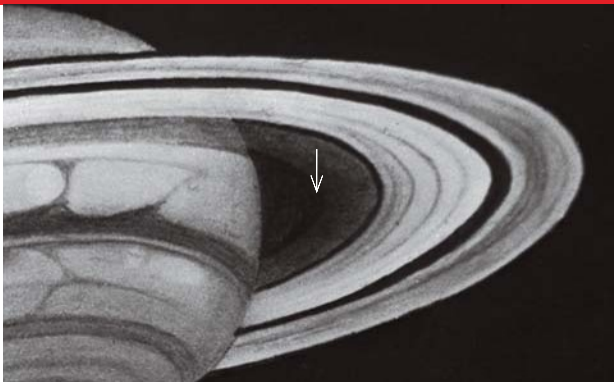


BRITISH ASTRONOMICAL ASSOCIATION

J. B. Murray's 1973 drawing of Saturn, sketched while observing at a magnification of 725× through Pic du Midi's 1.07-m reflector, shows the D ring quite clearly. Note the dark gap that Murray indicates between the C and D rings.

Thomas Dobbins *has contributed articles on observing solar system objects to* Sky & Telescope *since 1987.*

Thomas A. Dobbins



S&T ARCHIVES

Charles H. Giffen's exceptionally detailed drawing of Saturn, made on June 14, 1962, shows a faint glow inside ring C and hints of a gap (arrowed) between them.

The Camera *Does* Lie

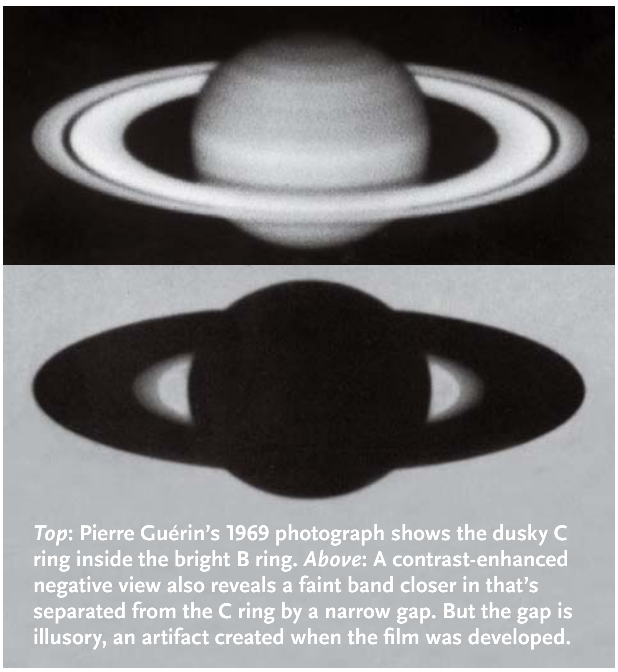
In light of the negative Pioneer 11 observations, Tom Gehrels (who led the mission's camera team) concluded the gap recorded by Guérin must have been a "Mackie line," a darkroom artifact caused by the localized exhaustion of chemical developer in silver-halide photographs. This can make the edges of real features (in this case the inner edge of ring C) appear as spurious dark outlines. Absent the contrasting gap in Guérin's negatives, the feeble glow of ring D would have been immediately recognized as light from Saturn's globe scattered within the photographic emulsion.

But what about Murray's persuasive visual observations? Those were later attributed to expectation and the power of suggestion — but this explanation might be a bit oversimplified. While casually perusing the October 1962 issue of *Sky & Telescope,* my eye was drawn to a striking drawing of Saturn made in June of that year by Charles Giffen, a Princeton University mathematician who was a prominent contributor to the Association of Lunar and Planetary Observers during the early 1960s. Using the 15.6-inch Clark refractor at the University of Wisconsin's Washburn Observatory on a night of excellent seeing, Giffen recorded the minor divisions in the A and B rings with remarkable accuracy. To my amazement, he also took pains to depict a faint glow inside ring C, replete with hints of a gap.

Giffen's observation predated the publication of Guérin's photographs by almost eight years and Murray's visual sighting by 11 years. So expectation and the power of suggestion could not have played any role.

Nonetheless, the explanation for Giffen's eyepiece impressions undoubtedly lies in a phenomenon first described by the Austrian physicist Ernst Mach in 1865 (*S&T:* May 2014, p.54). He noted that the human eye-brain combination is hard-wired to introduce narrow, contrasting bands at the borders of adjacent extended surfaces of differing brightness. Today these illusory features are known as "Mach bands," and they compellingly explain why Giffen saw a gap at the inner edge of ring C that uncannily — and insidiously — affirmed the artifact in Guérin's photographs.

The prominent but nonexistent gap thought to separate Saturn's C and B rings, as reported by generations of visual observers, no doubt arose from the same cause. While Saturn is the most beautiful target for planetary observers, it has proven to be one of the most deceptive. ✦



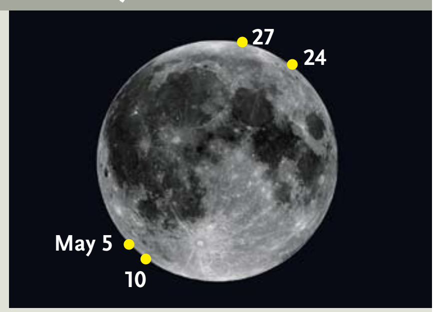
INSTITUT D'ASTROPHYSIQUE, PARIS

Top: Pierre Guérin's 1969 photograph shows the dusky C ring inside the bright B ring. *Above*: A contrast-enhanced negative view also reveals a faint band closer in that's separated from the C ring by a narrow gap. But the gap is illusory, an artifact created when the film was developed.

The Moon • May 2015

Phases

FULL MOON	May 4, 3:42 UT
LAST QUARTER	May 11, 10:36 UT
NEW MOON	May 18, 4:13 UT
FIRST QUARTER	May 25, 17:19 UT



NASA / LRO

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

Librations

Lacus Autumni	May 5
Montes Rook	May 10
Hubble (crater)	May 24
Scoresby (crater)	May 27

Distances

Perigee 227,437 miles	May 15, 0h UT diam. 32′ 19″
Apogee 251,186 miles	May 26, 22h UT diam. 29′ 53″

The Hunting Dogs

Track treasure with the beasts of Canes Venatici.

Spring has come, and a chorus of peepers welcomes twilight as I set out a scope to let it cool. Deepening night brings coyote song, but coyotes aren't the only hunting dogs who keep me company. Those symbolized by the constellation Canes Venatici quietly shine down from the sky.

Although the celestial hunters are seldom referred to by these names today, the northern dog is Asterion (Starry) and the southern one is Chara (Joy). The starting point for our deep-sky tour is Beta (β) Canum Venaticorum, the twinkle in Chara's eye on some old pictorial star atlases.

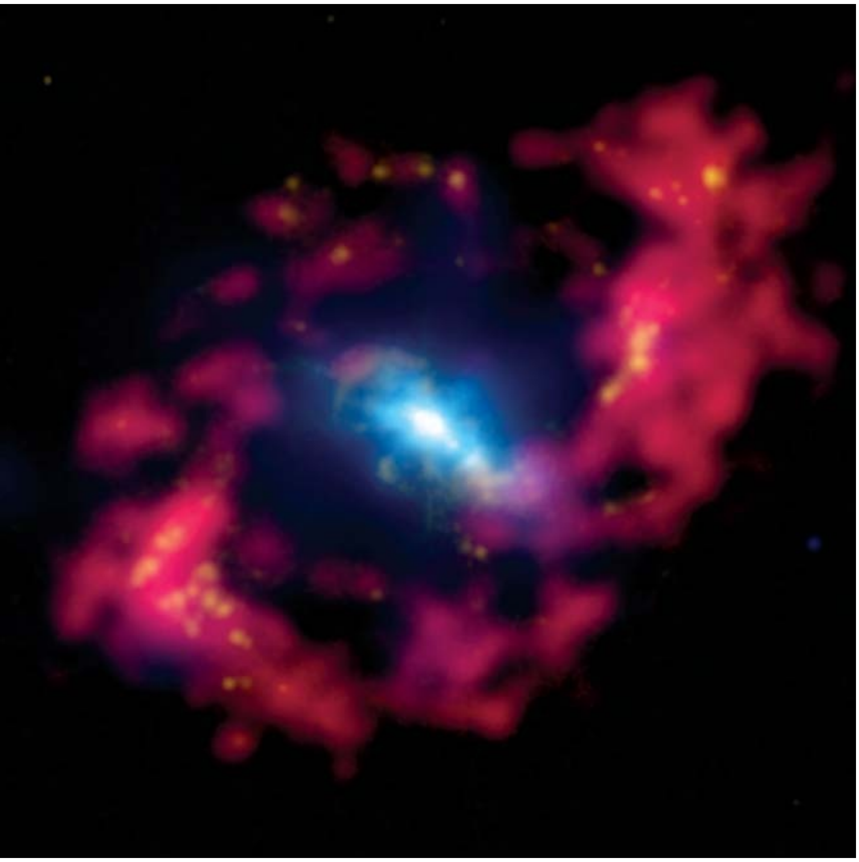
Beta fits within the field of view of a finderscope with orange **2 Canum Venaticorum**, a fetching double star. You may be able to detect 2 CVn's orange tint through a finder, but you'll need a telescope to spot its much fainter companion. Through my 105-mm refractor at a magnification of 28×, the stars are close together, with the companion west and a bit south of the primary star. The companion has a spectral type of F8, which would color it yellow-white. Can you detect its hue?

The hunting dogs lay claim to many quirky galaxies that are fun to observe, and our first will be **NGC 4151**. Pushing the refractor 1.5° west-southwest from 2 CVn, I come to a pentagon of five 7th- to 9th-magnitude stars that's 37′ tall. Two misty ovals greet me, one within the pentagon and a brighter one outside the southeastern corner. The latter is NGC 4151, which harbors a bright center and has a faint star near its northern edge. Inside the pentagon, **NGC 4145** is a low surface brightness galaxy that shows up better at 47×. Its long axis runs east-west, and it has a slightly brighter center. At 87× I see a bright, starlike nucleus within NGC 4151's core, while its halo is aligned northwest-southeast.

With my 130-mm refractor at 91×, **NGC 4156** joins the scene, but it's just a small smudge seen only with averted vision. Look for it 5.2′ northeast of NGC 4151's bright nucleus.

Although NGC 4151 has a large diffuse halo, even my 10-inch scope at 118× only shows the 3′ × 2′ interior. Astronomers dubbed this region "The Eye of Sauron." Its appearance on a composite of X-ray (Chandra X-ray Observatory), optical (Jacobus Kapteyn Telescope), and radio (NRAO Very Large Array) images resembles the eye that blazed over the Dark Tower in the movie adaptation of J. R. R. Tolkien's *Lord of the Rings*. The X-ray emission that dominates the center of the eye is likely due to an outburst caused by the supermassive black hole at the galaxy's heart. In a 2012 *Astrophysical Journal* paper, Edi Bon (Astronomical Observatory, Belgrade) and colleagues suggest that the galaxy's engine may be a binary black hole, which would explain the observed periodic variations in brightness and radial velocity. The authors propose components less than one light-year apart with 44 million and 12 million times the mass of our Sun.

Our next oddball galaxy is **NGC 4244**, which is a simple star-hop from 6 Canum Venaticorum. First drop 42′ south to a pair of widely separated 8th-magnitude



NASA / CXC / CFA / J. WANG ET AL. / ISSAC NEWTON GROUP OF TELESCOPES, LA PALMA / JACOBUS KAPTEYN TELESCOPE / NSF / NRAO / VLA

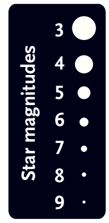
EYE OF SAURON Composite images of NGC 4151 bear a resemblance to the Eye of the Dark Lord of Mordor in the movie adaptation of J. R. R. Tolkien's *Lord of the Rings*.

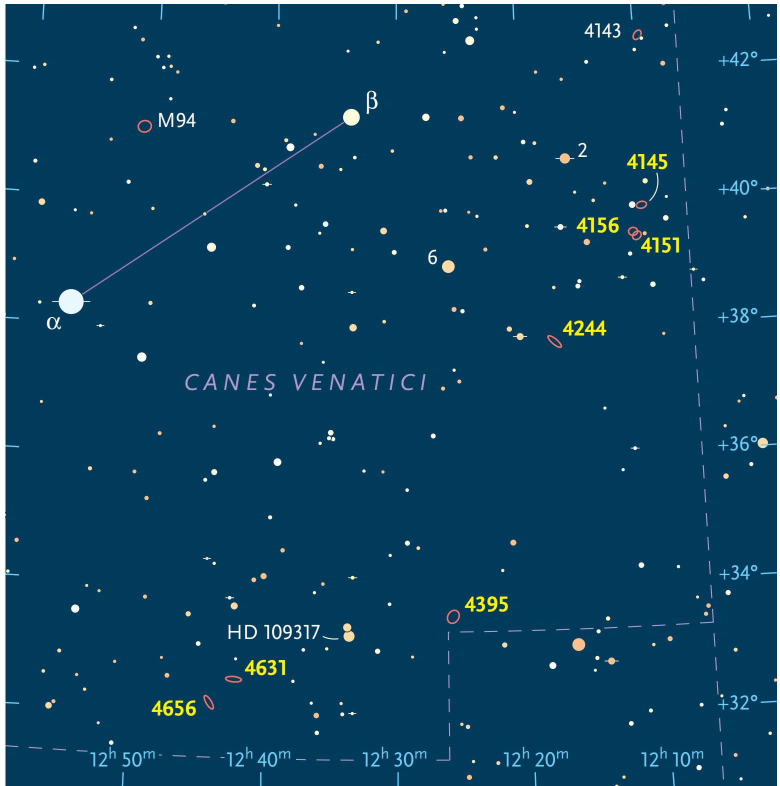
stars, and then slip 57′ west-southwest to a wider pair of 7th-magnitude stars. The northern tip of NGC 4244 is 26′ west of the second pair's southwestern star. At 23× through my 130-mm scope, the galaxy is a ghostly, but quite lovely, thin slash of light that lives up to its nickname, the Silver Needle. At 63× NGC 4244 brightens toward the long axis and the center. It appears about 10½′ long with a faint star snugged alongside its northeastern tip. At 91× the galaxy seems subtly mottled, and there's an elusive brighter spot on the southwestern tip. The brighter part of the galaxy spans about 6′. Through my 10-inch scope at 115×, NGC 4244 attains an impressive length of 15′, and its width at the center is about 1½′. A slightly curved line of three faint stars drips off the galaxy's southwestern tip, which is much fainter than the northeastern tip.

As you might suspect from its apparent size, NGC 4244 is a nearby galaxy, only 13 million light-years away from us — close enough for astronomers to resolve stars within the galaxy. We owe its needle-like profile to the fact that this spiral galaxy is seen very nearly edge-on to our line of sight. Yet few edge-on spirals appear as flat as NGC 4244, because their cores bulge out in the middle. So close to us and lacking a substantial core, NGC 4244 is exceptional among the "flat" galaxies.

Now we'll move on to **NGC 4395**, a challenging galaxy to find because of its low surface brightness. If you have an equatorial telescope, you can drop 8° due south from Beta CVn to a 5th- and 6th-magnitude pair of deep yellow stars. The brighter star is HD 109317 (SAO 63070). Putting the pair in the southern part of a low-power field of view and sweeping 1.6° west will take you to this diaphanous galaxy, which sits between a 9th-magnitude star to its west and a 10th-magnitude star to its east-northeast. Knowing just where to look, I was pleased to discover that NGC 4395 wasn't particularly difficult to spot through my 130-mm refractor at 23×. I can thank the galaxy's large apparent size for this good fortune, because it's much easier to spot a large object with low surface brightness than a small one. From a dark site, Arizona astronomer Brian Skiff has even been able to see it with his 70-mm refractor at 30×. Boosting my magnification to 63×, I find NGC 4395 rather pretty, in an understated way. It looks softly patchy and vaguely oval, spanning roughly 8′ northwest-southeast.

NGC 4395 surrenders some detail when viewed through my 10-inch reflector. At 88× the core is elongated and barely brighter than its surroundings. A smaller but brighter patch rests about 2′ east-southeast of the core. This has its own entry in the *New General Catalogue of Nebulae and Clusters of Stars*, NGC 4401. At 115× I can also detect two very small, very faint spots that also have NGC designations. NGC 4400 lies 1′ south-southwest of NGC 4401, and even dimmer NGC 4399 is 2¼′ south-southwest of the core. One superimposed star is reasonably easy to see 1¾′ northeast of the core. As a whole, NGC 4395 appears very irregular, teas-





The Hunting Dogs

Object	Type	Mag(v)	Size/Sep	RA	Dec.
2 CVn	Double Star	5.9, 8.7	11.9″	12h 16.1m	+40° 40′
NGC 4151	Galaxy	10.8	6.3′ × 4.5′	12h 10.5m	+39° 24′
NGC 4145	Galaxy	11.3	5.9′ × 4.3′	12h 10.0m	+39° 53′
NGC 4156	Galaxy	13.2	1.4′ × 1.1′	12h 10.8m	+39° 28′
NGC 4244	Galaxy	10.4	19.4′ × 2.1′	12h 17.5m	+37° 48′
NGC 4395	Galaxy	10.2	13.2′ × 11.0′	12h 25.8m	+33° 33′
NGC 4631	Galaxy	9.2	15.5′ × 2.7′	12h 42.1m	+32° 32′
NGC 4656	Galaxy	10.5	12.9′ × 1.9′	12h 44.0m	+32° 10′

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.

JIM MISTI / ROBERT GENDLER

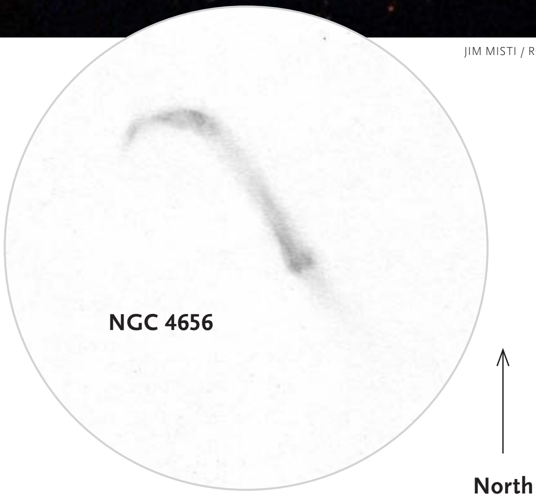
WHALE AND CALF NGC 4631 and companion galaxy NGC 4627.

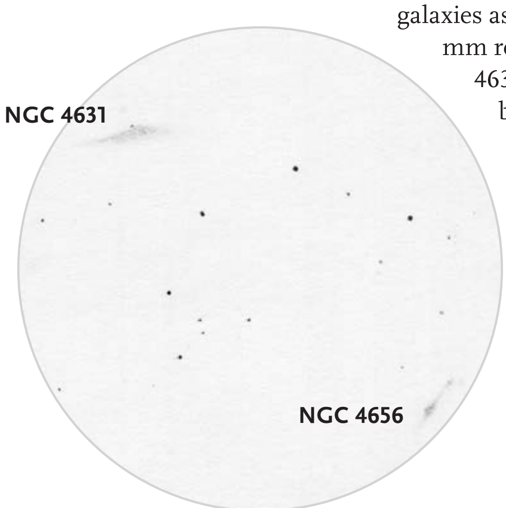
ingly patchy, and curiously amorphous.

NGC 4395 is a Seyfert galaxy, a type of galaxy bearing a highly luminous, point-like nucleus powered by a black hole. But NGC 4395 has the least-massive Seyfert nucleus known, weighing in at approximately 360,000 times our Sun's mass. Most Seyfert nuclei have between a million and a billion solar masses.

No tour of this area of the sky is complete without a visit to the remarkable galaxy pair **NGC 4631** and **NGC 4656**, located 2.2° east-southeast of the star pair we used to find NGC 4395. Sometimes a picture is worth a thousand words. My first sketch shows the galaxies as seen through my 130-mm refractor at 117×. NGC 4631 is known as the Whale because of its humped profile, while the little companion hovering north, NGC 4627, is sometimes called the Calf. NGC 4656 is nicknamed the Hockey Stick because of the distinctive bend at its northeastern end. The close-up sketch shows the view of NGC 4656 through my 10-inch reflector at 171×. William Herschel discovered this galaxy and described it as two objects whose nebulosity joins. He gave the end of the hook a separate designation, and it's now known as NGC 4657. NGC 4656's warped disk is most likely the result of interactions with NGC 4631. Deep images reveal faint extensions that stretch the galaxy to 20′.

With modern astronomical equipment, most galaxies seem to be revealing interesting peculiarities. Maybe quirky is the new normal. ✦





Left: The author sketched NGC 4631 and 4656 with her 130-mm refractor at 117×. ***Above, right***: Viewed through a 10-inch reflector at 171×, the hooked nebulosity of NGC 4656 becomes more evident.

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

Steve Gottlieb

Seeing Triple

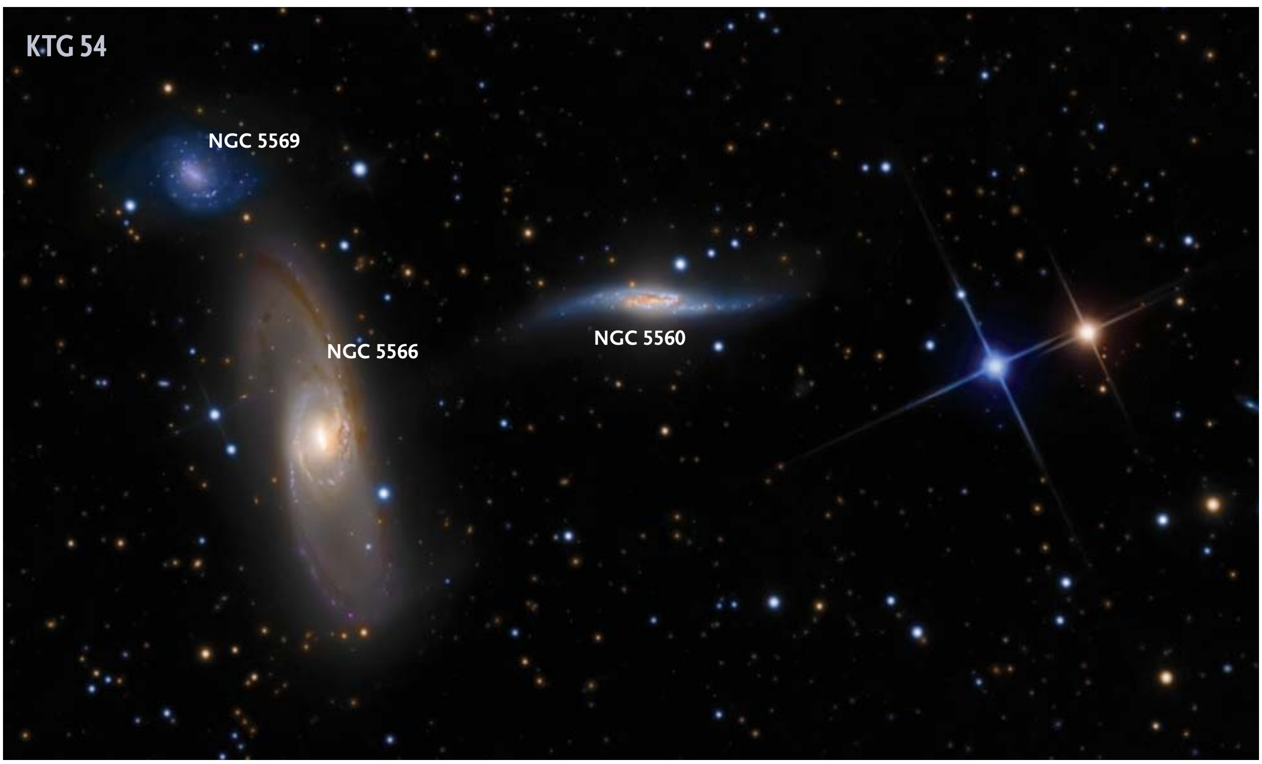
Take a tour in Virgo with the Isolated Triplets of Galaxies.

Galaxies are social creatures — they'll congregate in groups of any size from pairs and threesomes, to clusters and superclusters. Dedicated observers of galaxy groups are familiar with Paul Hickson's *Compact Groups of Galaxies* (*S&T*: Mar. 1999, p. 110) and George Abell's *Rich Clusters of Galaxies*. If these match your observing interests, let me introduce you to the 1979 catalogue of *Isolated Triplets of Galaxies* by principal investigators Valentina Karachentseva (Astronomical Observatory of University of Kiev, Ukraine) and Igor Karachentsev (Special Astrophysical Observatory, Russia).

This catalogue contains 84 northern hemisphere trios (often called the *KTG* or *K-triplets*) found by visual inspection of the Palomar Observatory Sky Survey plates. A group was considered isolated if the nearest "significant" neighbor was at least three times as far away as the separations of the components. A 1998 follow-up study using the Russian 6-meter Large Altazimuth Telescope found magnitudes, diameters, separations, morphological types, configurations, and radial velocities. The study revealed 25% of the K-triplets are chance alignments and not true physical systems.

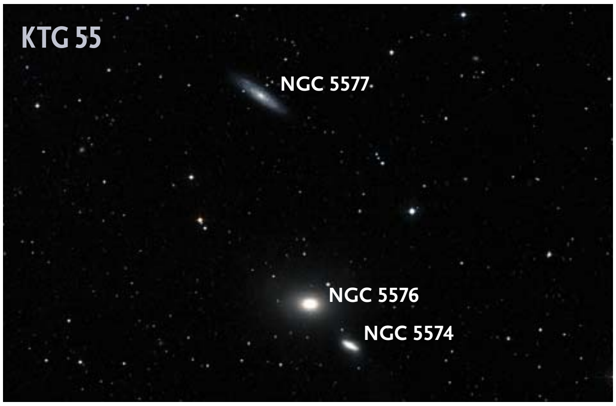
Individual galaxies are generally 15th magnitude or brighter and form a challenging observing project for 12- to 18-inch scopes under dark skies. But not all Karachentseva galaxies require a large aperture — the brightest members of several groups can be viewed in 8-inch and smaller scopes. Follow along for a KTG sampler of three trios in northeast Virgo. Let's head 15° due south of Arcturus or 5° northeast of 4.2-magnitude Tau (τ) Virginis.

KTG 54 is a physical, interacting trio also catalogued as Arp 286 in the 1966 *Atlas of Peculiar Galaxies*. William Herschel swept up the group's two brightest members, NGC 5566 and 5560, with his 18.7-inch speculum reflector



STEPHEN LESHIN

KTG 54. The extended arms of NGC 5560, 5566, and 5569 prompted Halton Arp to include them in his *Atlas of Peculiar Galaxies*.



POSS-II / STSCI / CALTECH / PALOMAR OBSERVATORY

KTG 55. William Herschel noted that NGC 5574 was "pretty bright, pretty large, extended." He described the more prominent NGC 5576 as "considerably bright, round, pretty large."

in April 1786, placing NGC 5566 in his Class I of Bright Nebulae. Today you'll find NGC 5566 included in the Astronomical League's *Herschel 400 Observing Program*.

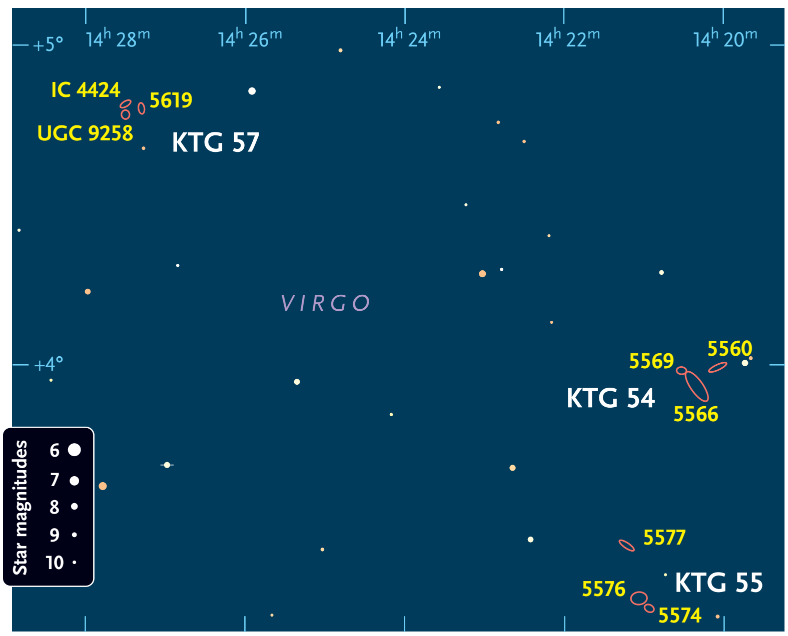
NGC 5566 is easily visible in a 6-inch scope as a 2′ oval with a strong core. Through my 24-inch reflector at 200×, the low surface brightness outer halo is very diffuse, but expands beyond 4′ in length with averted vision, sloping from northeast to southwest in a 3:1 ratio. A strongly condensed oval core harbors an intense, elongated nucleus or bar that angles nearly north and south. Two 12th- and 14th-magnitude stars bracket the core to the east and west. Images reveal NGC 5566 as a double-barred spiral, with an inner nuclear ring or spiral.

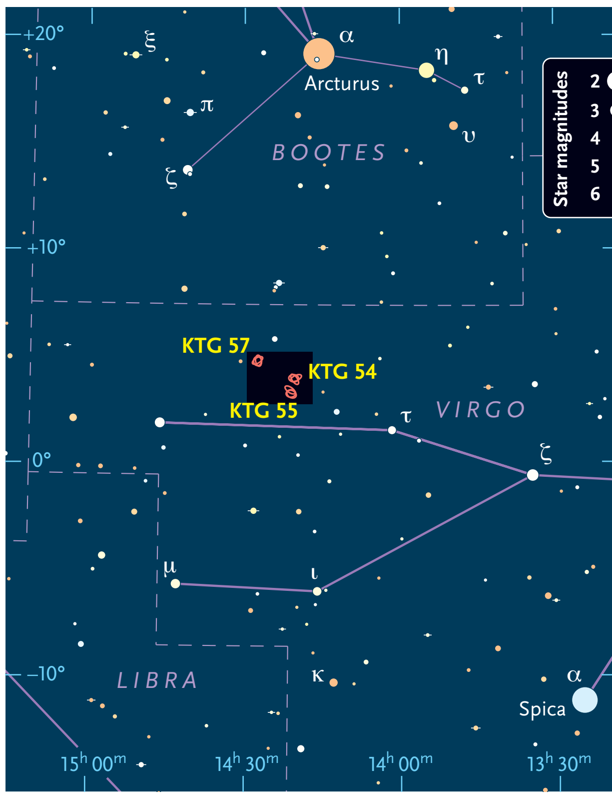
NGC 5560, 5′ to the northwest, is a fairly bright slender streak with a relatively large, elongated core. A 14th-magnitude star perches just north of the bright center. The arms extend 2.0′ long and are one-third as wide, tapering towards the tips, with the major axis perpendicular to NGC 5566. NGC 5560's warped arms are likely due to the gravitational interaction with NGC 5566.

NGC 5569 is an anemic, low surface brightness spiral off the northeast end of NGC 5566; it may require a 12-inch or larger aperture to get a good look at this one. Through my 18-inch scope at 220×, the spiral galaxy is a tenuous, very diffuse glow, perhaps 1′ in diameter, with only a weakly enhanced core. George Johnstone Stoney, the observing assistant on William Parsons's (3rd Earl of Rosse) mammoth 72-inch reflector, discovered NGC 5569 in April 1849 while examining the brighter pair nearby.

Next stop on our tour is **KTG 55**, a mere 40′ south-southeast of KTG 54. These neighbors have similar redshifts, implying a common distance of 70-80 million light-years. Together they form a chummy sextet in the relatively local universe.

NGC 5576, the brightest of the trio, is also in Herschel's Class I and on the *400 Program*. Through a 6-inch at 100×, NGC 5576 is a moderately faint oval, 1.5′ long and two-thirds as wide, with a slightly brighter core. With my 24-inch, the halo swells to 2.0′ × 1.6′ and fades imperceptibly into the background. A prominent core that brightens to a stellar nucleus dominates the galaxy. A 13th-magnitude star brushes against the halo on the northwest side.



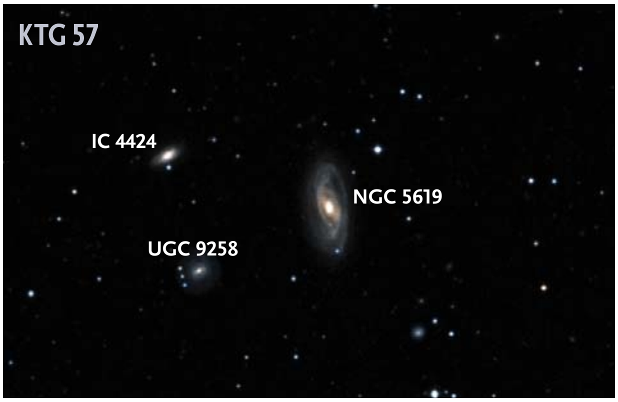


NGC 5574, just 2.8′ southwest of NGC 5576, shines with a visual magnitude of 12.4. In my 18-inch reflector the halo stretches 1.2′ × 0.6′ northwest to southeast and is sharply concentrated with a vivid, elongated core that increases to the center.

NGC 5577 is the northernmost and largest member of this triplet, but with a low surface brightness, it's also the least prominent. NGC 5577 escaped detection in Herschel's sweeps, but was picked up in Stoney's 1849 observations. The halo stretches 3.0′ × 0.9′ northeast to southwest and is flanked by a 15.5-magnitude star at the east edge and two similar stars off the west side. Although the central region is slightly brighter, no distinct core or nucleus stood out when viewed through my 18-inch.

Now sweep 2° to the northeast and you'll arrive at **KTG 57**. This tough threesome resides at a distance of roughly 380 million light-years, 5 times as far as our previous two groups. **NGC 5619** is an enormous spiral with a diameter of about 250,000 light-years. Using 280× in my 24-inch, the galaxy extends 1.6′ × 0.7′ in a north-south orientation. A well-defined core is sharply concentrated with a small, intense nucleus.

IC 4424, only 3.7′ east-northeast, is a much dimmer 14th-magnitude oval glow, perhaps 0.4′ in length. A feeble 16th-magnitude star rests just beyond the south edge. Also catalogued as IC 1016, this subtle galaxy was discovered in 1891 by American astronomer Lewis Swift. **UGC 9258** is a weakly concentrated, low surface brightness patch, requiring averted vision in my 18-inch. Although visually unassuming, this face-on spiral harbors an active nucleus, a feature often seen in interacting galactic systems.



POSS-II / STSCI / CALTECH / PALOMAR OBSERVATORY

KTG 57. Discovered by John Herschel in 1828, NGC 5619 shines the brightest of the three interacting galaxies in the cluster.

If this sampler has whet your interest to tackle the KTG catalogue, Alvin Huey offers a downloadable guide, *Galaxy Trios and Triple Systems*, with finder charts and data on all the K-triplets at **faintfuzzies.com**. Another excellent resource is the Astronomical League's "Galaxy Groups and Clusters Program," which includes 50 targets from the *Atlas of Compact Galaxy Trios* compiled by British Columbia amateur Miles Paul. ✦

Karachentseva Triplets in Virgo

	Object	Mag(v)	Position Angle	Size/Sep	RA	Dec.	
KTG 54				7′	14^h 20.3^m	+03° 58′	(central position)
KTG 54A	NGC 5560	12.4	115°	3.7′ × 0.7′	14^h 20.1^m	+04° 00′	
KTG 54B	NGC 5566	10.6	35°	6.6′ × 2.2′	14^h 20.3^m	+03° 56′	
KTG 54C	NGC 5569	14.5	56°	1.7′ × 1.4′	14^h 20.5^m	+03° 59′	
KTG 55				12.7′	14^h 21.1^m	+03° 20′	(central position)
KTG 55A	NGC 5574	12.4	63°	1.6′ × 1.0′	14^h 20.9^m	+03° 14′	
KTG 55B	NGC 5576	11.0	95°	3.5′ × 2.2′	14^h 21.2^m	+03° 16′	
KTG 55C	NGC 5577	12.3	56°	3.4′ × 1.0′	14^h 21.2^m	+03° 26′	
KTG 57				3.7′	14^h 27.5^m	+04° 48′	(central position)
KTG 57A	NGC 5619	12.6	8°	2.2′ × 1.2′	14^h 27.3^m	+04° 48′	
KTG 57B	UGC 9258	14.4	3°	0.9′ × 0.8′	14^h 27.5^m	+04° 47′	
KTG 57C	IC 4424	14.1	121°	0.9′ × 0.3′	14^h 27.5^m	+04° 49′	

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.

A Comet to Capture the Heart

The newest Comet Lovejoy never cracked naked-eye visibility for most people. But that hardly seemed to matter.

Alan MacRobert

When Australian amateur Terry Lovejoy discovered his fifth comet heading our way last August, it didn't look like it would amount to much. But by December the new Comet Lovejoy (designated C/2014 Q2) was brightening unexpectedly fast. It ended up glowing at 4th magnitude during its moonless best two weeks in January. Under dark enough skies, many amateur astronomers detected it fairly easily with their naked eyes. But most people live where they couldn't.

So why did Comet Lovejoy become a public sensation, headlined in media worldwide? It had to be the pictures, like the ones on these pages. Astrophotographers with modest imaging equipment and dark skies can do wonders these days.

Damian Peach, Jan. 12

In dim light, digital imaging reveals colors vastly better than the eye can. This comet shed very little dust, so practically all we saw was fluorescing gases: neutral diatomic carbon (C_2) making a vivid green coma, and ionized carbon monoxide (CO^+) glowing blue as it became entrained in the magnetic fields of the solar wind to form a tail rapidly streaming away from the Sun. The green of the coma was obvious in telescopes, but the dim tail was more subtle to the human retina.

The tail changed constantly. In December it was lumpy and puffy, as gusty solar wind buffeted and pinched it. Then as the comet drew nearer to the Sun in January, most of the tail smoothed into a bundle of thin striations. For a while it was dominated by two thin, ribbon-like streamers that seemed to rotate around the tail's axis. At times the two ribbons presented themselves edge-on, looking bright, sharp, and separate. Then the tail rotated to show the ribbons broadside and superimposed. "I have viewed and imaged hundreds of comets," wrote Chris Schur, "but none quite like this one!"

The comet came to perihelion on January 30th at a rather distant 1.29 a.u. from the Sun. During the moonless nights of March (roughly the 8th through 24th), it should dim from 7th to 8th or 9th magnitude, still within good telescopic reach as it crosses Cassiopeia. (See our finder chart at **is.gd/zhGzqR**; scroll to bottom.) In the moonless nights of April (about the 7th to 23rd), expect it to be magnitude 9 or 10. The comet will pass very close by Polaris in the last few days of May at about magnitude 12. It won't be back for 8,000 years. ✦

Gerald Rhemann, Jan. 21


Christopher Cook, Jan. 19


Alson Wong, Jan. 16


Mike Keith, Jan. 10


Sean Walker, Jan. 19


Ehsan Rostamizadeh, Jan. 15


Ian Sharp, Jan. 19

Robotic

Increase your productivity with today's off-the-shelf automation.

Robert Capon

Every clear evening, my observatory wakes itself an hour before sunset. After checking weather and seeing conditions, it powers up my equipment, launches control software, opens the dome shutter, and begins cooling the CCD camera. It calculates the precise time of sunset and then slews to an optimal part of the sky for recording flat-field calibration frames. Precisely 15 minutes before sunset, it begins taking test images every 15 seconds to measure the sky brightness. When exposure levels fall within a specified range, it creates file folders for the night's observing run on the computer and begins to record the flats, saving the files to the proper location and writing a detailed log of each event.

When the Sun reaches the position of 12° below the horizon, the system focuses the telescope then reviews a portfolio of projects and selects the best ones for the night. At the appointed hour, the observatory begins its imaging run. If weather conditions deteriorate, it stops imaging and closes the observatory shutter. But if the weather clears up for 15 minutes, the observatory gets right back to work. At sunrise the observatory completes its imaging run, captures dawn flats (if necessary), and safely shuts down for the night, parking the telescope and powering off all of the equipment.

This isn't a passage out of a science fiction story; it's a typical description of hundreds of robotic observatories operating all over the world today using off-the-shelf

While owning an observatory allows you to use your telescopes much more frequently, adding an internet connection, a computer, and automation accessories can greatly increase your science and imaging output. All photos are courtesy of the author.

Astronomy

hardware and software that don't require you to be a computer hacker or electrical engineer to use.

Since the turn of this century, there have been many technological developments that have made robotic observatories an affordable reality for amateurs wanting to increase our productivity. Rapid improvements in computer processing speed and high-speed networks allow massive amounts of data to be transmitted virtually anywhere in the world today. Sophisticated CCD cameras and computerized telescope mounts, combined with in-depth planetarium programs, give amateurs access to a practically limitless number of targets to image and study.

But two developments have been particularly critical to the popularity of the autonomous observatory: the creation of ASCOM Standards for Astronomy (programming standards that allow many different software programs to work together) and the development of the software package *ACP* (Astronomer's Control Panel) by DC-3 Dreams (**acp.dc3.com**).

ASCOM stands for the Astronomy Common Object Model. According to the ASCOM website:

> The ASCOM Initiative is a loosely-knit group of developers and astronomical instrument makers that work together to bring vendor-independent and language-independent plug-and-play compatibility between astronomy software and astronomical instruments on Windows computers.

These standards allow various software and hardware products to communicate and work together, seamlessly integrating technology from more than 40 vendors.

ACP is the brainchild of software developer Robert Denny, the owner of DC-3 Dreams and one of the leaders in the ASCOM project. The software orchestrates and manages the activities of the numerous systems and subsystems within the observatory. *ACP* resides on the computer within your observatory, and it includes a web browser with a dazzling assortment of scripts and tools to control your observatory from anywhere in the world over the internet. In my case, I'm able to operate my observatory from my iPhone, and I have been known to check on the status of an observing run or adjust the temperature of my CCD camera before a movie starts at the local theater.

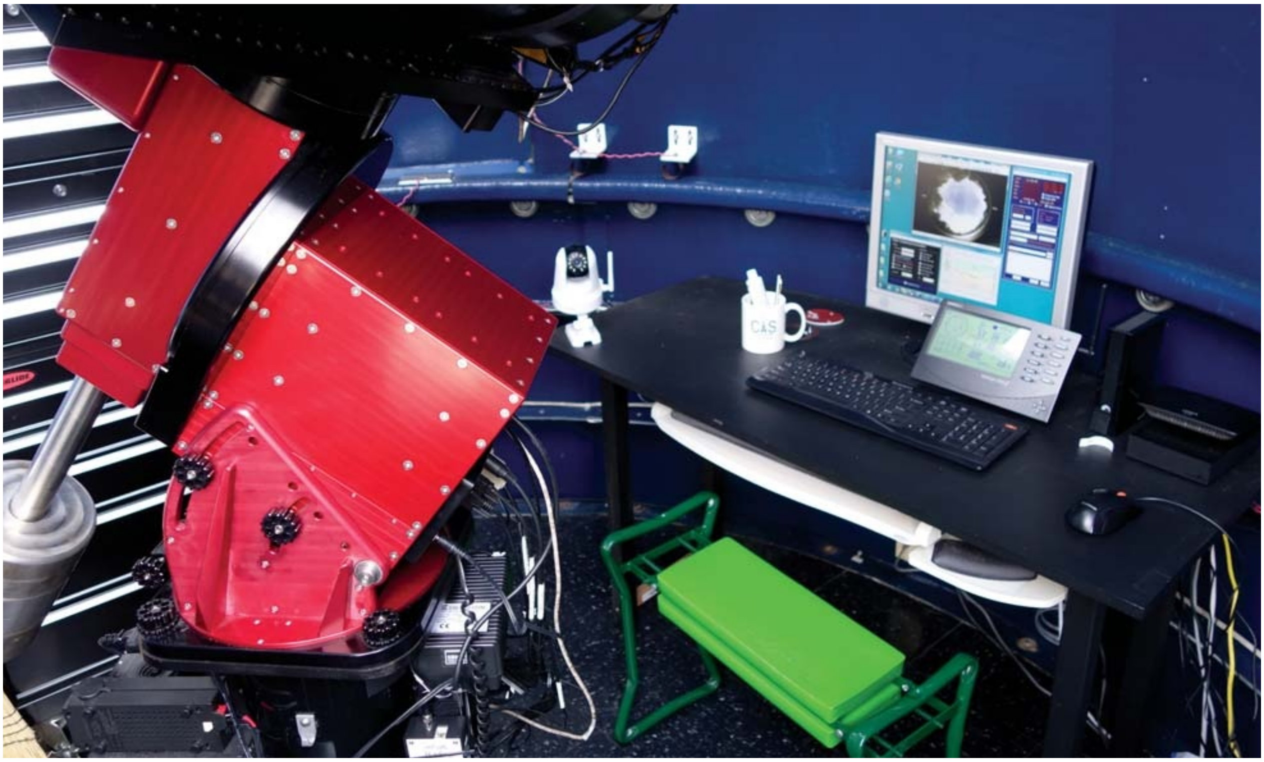
DC-3 Dreams also produces *ACP Expert*, a companion to *ACP* that operates the observatory autonomously and schedules multiple projects throughout the night, for projects lasting many months into the future.

Automation in Action

Operating an automated observatory is surprisingly easy to do. I begin by planning an observing project with a robust planetarium program to help determine when a chosen target is best placed in the sky, or if it's even visible from my observatory's location. Some targets may get above the horizon but do not rise high enough to fall within the limits of how low I can point my telescope. I use Software Bisque's *TheSkyX* or *TheSky HD* (for Apple iOS devices), which have the advantage of being seamlessly integrated with *ACP*.

Once I've chosen my target, I need to translate the imaging objectives into a "project" that *ACP* can execute. *ACP* includes user-friendly web forms to create projects that can then be sent directly from within *ACP Expert* or over the internet through its web-browser interface. *ACP* will receive the projects when the observatory is operating and will undertake them whenever conditions permit. For example, you can set up an imaging project of LRGB images of M33 totaling 24 hours of exposure, and *ACP Expert* will take the images over time and report the percentage of data accumulated in the browser as it goes.

To the left of the author's 10-foot Technical Innovations PD10 Pro-Dome is an SBIG seeing monitor used to determine whether the atmosphere is steady enough for high-resolution imaging with his RCOS 12.5-inch Ritchey-Chrétien or better suited to wide-field photography.



Every robotic observatory requires a robust computer workstation on location to run the control software and connect to the internet. At left is the author's Software Bisque Paramount ME robotic telescope mount, a staple for many robotic amateur observatories for more than a decade.

Advanced users of *ACP Expert* can import entire deep-sky catalogs at once. I recently decided to image the entire Herschel 400 and the *Arp Catalog of Peculiar Galaxies*, so I imported two spreadsheets to create a pair of projects with more than 700 targets. The planning effort took a couple of hours but will keep my observatory busy for more than a year without requiring any additional input.

Once a project has been received, *ACP* orchestrates the activities of the many devices such as the CCD camera, the telescope focuser (to refocus periodically as the temperature changes throughout the night), and my dome's rotation. This is where automation presents utter simplicity for the user. Once you have *ACP* set up, a few minutes' planning and a few mouse clicks result in a sequence of extraordinary complexity, with hundreds of commands executed by the automation software. For example, on a recent evening my observatory took more than 100 images of five objects. The projects each took a few minutes to write, but the observatory ran unattended for eight hours, and the resulting log recorded over 3,000 different actions executed from dusk until dawn.

The web interface is the primary user interface for robotic observatories controlled using *ACP* and doesn't require any programming skills to set up. The web interface includes an entire tool chest of standard scripts for typical actions, such as capturing calibration and light images and controlling dome shutters or roll-off roofs, focusers, filter wheels, and weather stations. These abilities come standard with *ACP* and can be used right out of the box, or you can customize them with a number of user preferences in just a few minutes.

Other Automation Resources

While *ACP* is at the heart of my particular robotic observatory, there are many other capable programs and tools that can help you automate your own equipment. Here

The power hub of Stillhouse Mountain Robotic Observatory is built around a Digital Loggers Web Power Switch 7, enabling the author to turn each piece of equipment on and off through a web browser. The power hub's LCD panel is covered with a black flap to reduce stray light while imaging.

are many of the other factors to consider when assembling your own automated observatory.

• **Automation Software.** CCDWare (**ccdware.com**) offers *CCDAutoPilot5*, a full-featured and capable program to automate observing runs. The software is compatible with a wide range of camera and focuser software programs. The company also publishes a host of related tools, including *CCDNavigator* to plan observing runs and *CCDInspector* to optimize optical systems.

• **Planetarium Programs.** Many excellent planetarium programs are available today that can help you plan your observing sessions. While I primarily use Software Bisque's *TheSkyX* and *TheSky HD* (**bisque.com**) for planning purposes, other options include Simulation Curriculum's *SkySafari 4 Pro* (**simulationcurriculum.com**) and Imaginova's *Starry Night 7 Pro* and *Starry Night 7 Pro Plus* (**starrynight.com**).

• **Robotic Mounts.** Automation necessitates a robotic telescope mount with excellent pointing accuracy and extremely low periodic error. Many manufacturers today offer excellent mounts and integrated telescope/mount combinations that meet the needs of a robotic observatory. It's best to check the features available before making your final decision. I use a Paramount ME by Software Bisque.

• **Robotic Focusers.** An automated observatory requires every moving part to be able to be motorized, including your telescope focusers. Many companies today offer the option to motorize your focuser, but make sure it can be performed remotely you can focus without physically being at the telescope. The ASCOM website includes a list of ASCOM-compliant motorized focusers (**ascom-standards.org/Support/Index.htm**).

• **Focusing Software.** When using a robotic focuser, you'll also need a program that can precisely and repeatedly focus your telescope over the internet, as well as work within your observatory control software. *ACP* is tightly integrated with the program *FocusMax* (sold by CCDWare) and is compatible with a wide array of ASCOM-compliant focusers. *FocusMax* also works seamlessly with *CCDAutoPilot*. Other remote-focusing programs include *@Focus2* by Software Bisque and the focus tab within the popular imaging program *MaxIm DL*.

• **Camera Control.** Your choice of observatory-automating software may dictate which camera-control program you need to use in your robotic observatory. *ACP* requires *MaxIm DL* by Diffraction Limited (**cyanogen.com**). This richly featured camera-control and image-processing program includes a comprehensive array of tools for all types of astrophotography. *CCDAutoPilot5* offers compatibility with multiple camera-control programs, including *Maxim DL* and Software Bisque's *CCDSoft*, as well as the camera add-on for *TheSkyX*.

• **Dome and Roof Control.** Domes and roll-off-roof observatories require different controls. A roll-off roof simply needs to open or shut without hitting your telescope, but a dome requires keeping the slit of the observatory aligned with the direction your telescope is pointing. I control my Technical Innovations Pro-Dome with ASCOM-compliant Digital Dome Works hardware (**homedome.com**). Other options include MaxDome II by Diffraction Limited. Foster Systems (**fostersystems.com**) also produces automation hardware for domes or roll-off-roof observatories alike.

• **Weather Monitors.** Another essential component to a robotic observatory is some form of weather monitoring, so that the observatory will close up when weather conditions are unsafe for your equipment. Diffraction Limited distributes the Boltwood Cloud Sensor, while both Tech-

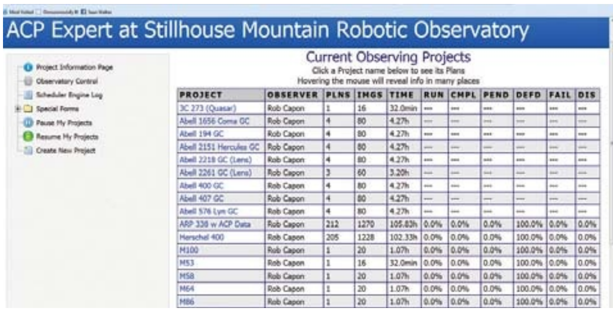
Left: **Another crucial element to a robotic observatory is the ability to monitor the weather. The author uses an AAG CloudWatcher and a Moonlight Technologies AllSky camera (top post) to monitor for rapidly changing conditions. The spikes are used to dissuade birds from perching on the equipment.**

Above: **DC-3 Dreams' *ACP* control software allows users to monitor their observatory and send projects to image at any time, even when the equipment is in use.**

nical Innovations and Foster Systems also carry weather monitors for remote observatories.

• **Computer-controlled Power Switches.** These switches allow you to execute scripts over the internet to turn devices on and off during observatory startup and shutdown, or force a reboot of a locked-up computer. This significantly reduces your electricity usage and protects your equipment from power surges. One manufacturer, Digital Loggers, Inc. (**digital-loggers.com**), produces the Web Power Switch 7, which provides eight programmable power outlets that can be individually controlled. Another option is the NP netBooter product line by Synaccess (**synaccess-net.com**).

• **Observatory Hosting.** Finally, unless your automated observatory is in your own backyard, you'll need a backup plan in case something fails and the observatory needs hands-on attention. This has given rise to professional hosting services at dark-sky sites in both the Northern and Southern hemispheres. Leasing space at one of these facilities enables you to have your observatory at a truly dark site with a local support staff to maintain the observatory hardware. Simply perform a web search for "observatory hosting" to get a current list of companies that provide this service.



PROJECT	OBSERVER	PLNS	IMGS	TIME	RUN	CMPL	PEND	DEFD	FAIL	DIS
3C 273 (Quasar)	Rob Capon	1	16	32.0min	---	---	---	---	---	---
Abell 1656 Coma GC	Rob Capon	4	80	4.27h	---	---	---	---	---	---
Abell 194 GC	Rob Capon	4	80	4.27h	---	---	---	---	---	---
Abell 2151 Hercules GC	Rob Capon	4	80	4.27h	---	---	---	---	---	---
Abell 2218 GC (Lens)	Rob Capon	4	80	4.27h	---	---	---	---	---	---
Abell 2261 GC (Lens)	Rob Capon	3	60	3.20h	---	---	---	---	---	---
Abell 400 GC	Rob Capon	4	80	4.27h	---	---	---	---	---	---
Abell 407 GC	Rob Capon	4	80	4.27h	---	---	---	---	---	---
Abell 576 Lyn GC	Rob Capon	4	80	4.27h	---	---	---	---	---	---
ARP 338 w ACP Data	Rob Capon	212	1270	105.83h	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%
Herschel 400	Rob Capon	205	1228	102.33h	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%
M100	Rob Capon	1	20	1.07h	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%
M53	Rob Capon	1	16	32.0min	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%
M58	Rob Capon	1	20	1.07h	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%
M64	Rob Capon	1	20	1.07h	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%
M86	Rob Capon	1	20	1.07h	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%

***Above*: Autonomous imaging is performed by uploading projects with *ACP*. Projects can be scheduled well in advance, and *ACP* will determine the best times to record data, often dividing each clear night into segments to work on each project when the targets are best placed in the sky.**

Taking deep, high-resolution images such as this example of the Lagoon Nebula, M8, is standard fare for a remote observatory. Automation allows imagers to concentrate more on producing a great result and less on the acquisition of data.

Is It Worth It?

So which software and hardware solutions are right for you? It all depends on your goals and what equipment you may already own or have experience with. You can also give some of these programs a test run — the makers of *ACP*, *CCDAutoPilot*, and other software vendors offer limited trial periods. I tried a number of products before settling on the solution that was right for me. When I decided to automate my observatory, I already owned everything I needed except *ACP*, *MaxIm DL*, *FocusMax*, and a few other devices. An additional investment of roughly $5,000 was required to completely automate my observatory. This additional cost represents about 1⁄10 of the total cost of my observatory, yet it enabled me to achieve a quantum leap in productivity. On many nights my observatory awakens to record images after I'm asleep, particularly when conditions clear long after I would have given up and closed down for the night.

Since automating my observatory, astronomy as a nocturnal activity for me has changed forever. My nights are freed up to do other non-imaging pursuits again, including observing. I can prepare projects in only a few minutes during the day and load them into the observatory, often months in advance because the observatory works on the backlog of pending projects.

Off-the-shelf automation is unleashing unprecedented gains in productivity from amateur observatories worldwide. The ability to record valuable data throughout the night whenever sky conditions permit is a relatively low-cost upgrade that can benefit most any type of astronomical imaging pursuit, and the best part is you'll no longer have to lose any sleep over it! ✦

***Robert Capon** has been a dedicated amateur astronomer for 40 years. He can be contacted at w3dx@aol.com.*

 Johnny Horne

The Atik One CCD Camera

This all-in-one CCD imaging package targets the budding astrophotographer.

Atik One 6.0 Integrated Kit

US price: $3,185.
Available from **atik-cameras.com** and through dealers worldwide.

ASTROPHOTOGRAPHERS today suffer from an embarrassment of riches. A steady stream of mid-sized CCD cameras keeps appearing on the market to appeal to the DSLR astrophotographer ready to step up to a astronomical CCD camera. So how does a manufacturer break away from the pack and get noticed? One manufacturer is betting on bundling to be its solution.

Atik Cameras, based out of Norwich, England, has cultivated a reputation for producing a wide range of high-quality CCD cameras for any experience level and at affordable prices. So when the company announced its Atik One integrated guider and imager kits, *Sky & Telescope* decided to get one into my hands so I could run it through its paces.

The Atik One Integrated Kit combines a 6-megapixel (mp) CCD chip with a built-in filter wheel, off-axis guider, and an additional autoguiding camera in one convenient package. A 9-mp model is also available. Both image acquisition (*Artemis*) and a processing program (*Dawn*) are supplied with the camera.

The camera is built around a Sony ICX694ALG CCD detector with 4.54-micron pixels in a 2,750 × 2,200 array. Its body is manufactured from CNC-machined aluminum measuring 5-by-4¼-by-2½ inches. The complete package weighs just 2½ pounds, which should be light enough for most robust telescope focusers.

WHAT WE LIKE:

Capture software

Requires little back focus

WHAT WE DON'T LIKE:

Requires additional autoguider to mount interface

No mechanical shutter

The Atik One Integrated Kit includes the main camera with internal filter wheel plus an additional camera used as an autoguider, an off-axis guider, as well as all cables. Some assembly is required, particularly when attaching the off-axis guider. All photos are courtesy of the author.

Two small fans dissipate heat from its regulated cooling system, providing stable cooling down to 38°C below ambient. An internal USB hub allows the auto-guiding camera, called the Atik GP, to be plugged into a USB port on the camera housing with a short USB mini cable. This reduces the number of long cables dangling from the camera: a USB 2.0 line connected to your computer, and the camera's 6-foot-long, 12-volt DC power cable terminating in a cigarette lighter-style plug. Atik One's five-position filter wheel is completely internal and requires no additional power or connecting cables.

The Atik One has no mechanical shutter, so users are required to cover their telescope when recording dark and bias calibration frames, which can limit its use as a remote imager. However, if the camera's fifth filter wheel position isn't needed for a filter in your imaging plans, filling that position with an opaque filter would provide an improvised internal shutter for dark frames. Because of its regulated cooling, a dark-frame library can be created for use on future nights.

Two ¼×20 threaded tripod mounts are located on opposite sides of the camera, providing users the ability to mount the unit when using camera lenses with a third-party lens adapter. I used one of these tripod sockets to secure a makeshift "safety line" to the camera to ensure it wouldn't fall to the floor if it slipped from my telescope's focuser.

Out of the box, the Atik One comes with an adapter plate with a standard female T-thread held by three screws to the camera's front housing. A supplied 2-inch nosepiece screws into this adapter plate. This front plate needs to be removed to install the off-axis guider.

Atik provides separate manuals for the main camera, the off-axis guider, and the GP guide camera, and a PDF document is available on the company's website with instructions describing how to assemble the entire system. While assembling the off-axis guider, I ran into my first minor hurdle to surmount — the supplied screws were too short!

After rounding up some metric M3 screws of sufficient length to attach the guider to the camera body, I then attached the GP camera with its T-threads onto the off-axis guider and connected the unit to the main body using the supplied short USB mini cable.

Imagers familiar with autoguiding should note that the Atik GP camera includes no direct connection to your telescope mount, such as an industry standard ST-4 compatible port, to allow guiding commands to be sent directly to your mount's drive motors. An additional interface device is required, or you'll need to use a third-party control software such as *MaxIm DL* that has an option to send guiding commands to your mount through the main camera interface. I used a Shoestring Astronomy GPUSB adapter (**shoestringastronomy.com**) that I had on hand.

Under the Stars

Once I finally had everything configured, "first light" with the system went very well. I began by testing the camera on my 12½-inch f/4 Newtonian reflector fitted with a Baader MPCC coma corrector. The Atik One's short 47-mm back focus with its off-axis guider easily reached focus in my telescope's low-profile Crayford-style focuser, with room to spare. I was concerned that the 1¼-inch color filters might cause some vignetting with such a fast telescope, but the camera's integrated filter wheel places the filters so close to the main detector that this was never a problem.

Even with the off-axis guider's small pick-off prism, finding a suitable guide star was never a problem, owing to both the sensitivity of the Atik GP guider camera and the fast f/4 system I was using. The off-axis guider uses a large knurled wheel that allows quick and precise focusing of the guide camera without rotating the GP camera, a well-thought-out feature for off-axis guiders.

Using the supplied *Artemis* software to operate the

Left: The camera housing contains a slim, internal filter wheel that accepts standard 1¼-inch color filters (not included), though the camera does not incorporate an internal shutter. Users may want to consider filling the 5th filter slot with an opaque filter to use when recording dark and bias calibration frames.

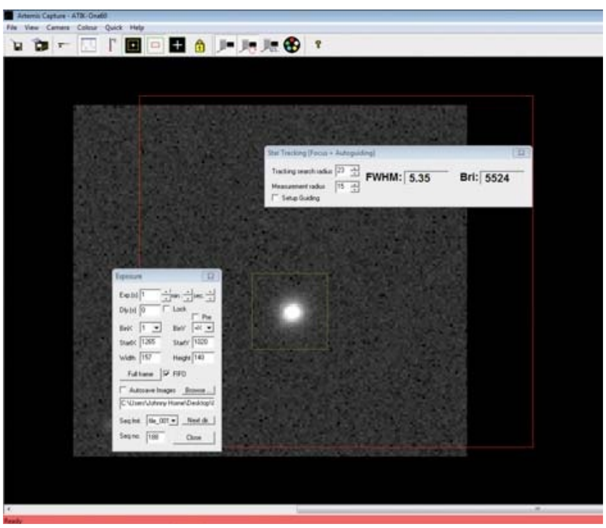
Bottom: Even with its off-axis guider and internal filter wheel, the Atik One takes up very little focus travel (requiring a total of 47 mm of additional focus travel), allowing it to be used with fast Newtonian reflectors such as the author's 12½-inch f/4 with a Baader coma corrector.

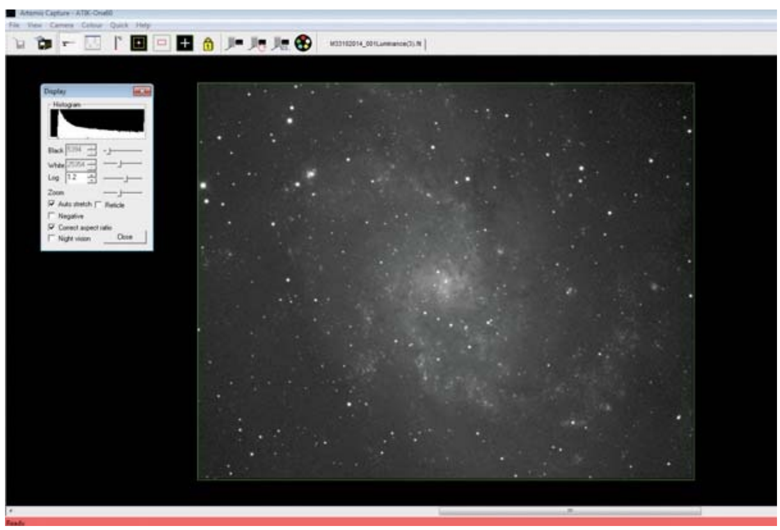
Images with the Atik One were smooth and extremely noise-free. This vibrant color image of M33 was captured through the author's Newtonian with 80 minutes of images through each color and luminance filter using 10-minute individual exposures.

main camera was easy even though it was my first time using the software. *Artemis* is very simple and intuitive, with useful features for focusing, guiding, and image capture that were easy to find and utilize. The software allows users to focus using only a portion of the CCD or up to 8 × 8 pixel binning that provides a low-resolution capture to be updated very quickly. This was useful in targeting and composing an image before switching back to high-resolution settings. The Atik One is ASCOM-compliant and can be controlled using popular camera control software including *MaxIm DL* (**cyanogen.com**) or Stark Lab's *Nebulosity* (**stark-labs.com**), though I used the camera exclusively with the supplied software for this review.

Using *Artemis* to control autoguiding was slightly more challenging. There's no option within the program to connect a second camera while operating the main camera. The solution to this is simply to open a second instance of *Artemis,* as noted in the online PDF document. One window of *Artemis* is set to control the main camera while the second operates the guide camera. With both cameras operating, first focus the main camera, then the GP autoguider. Once the guide star image is focused, *Artemis* then drives the mount in all four directions to measure your mount's response and determine if any backlash compensation is necessary. After it's complete, you can begin guiding.

During my tests with the camera in the early winter, I operated the camera with a cooler set point of 20°C below ambient. Images with its low-noise Sony chip only resulted in a smattering of hot pixels that disappeared when dark frames were applied. In fact, when I was focusing the camera during my first sessions with the Atik One, I forgot to enable the cooling. The





Left: Using the supplied *Artemis* software was intuitive and straightforward. Focusing is done by monitoring a chosen star's full-width half-maximum (FWHM) value, with users trying to achieve the smallest consistent value. *Right:* Imaging was also easy with *Artemis*, although autoguiding requires opening a second copy of the program to control the Atik GP camera simultaneously with the main camera.

ambient temperature images were surprisingly smooth and lacked the typical "static" appearance of other uncalibrated CCD images. I suspect some imagers could dispense with dark calibration altogether and remove any remaining hot pixels using outlier pixel-rejection algorithms when stacking images.

A Welcome Surprise

While using the Atik One, I got to thinking about the close proximity of the detector to the front of the camera. Even with the camera's internal filter wheel, the focus point is only 27 mm from the front flange, according to the camera specs. I wondered if this would allow the use of a third-party Nikon lens adapter with the Atik One. With the off-axis guider attached to the camera housing, the back focus is 47 mm, which put it beyond the point of reaching focus with the third-party Nikon lens adapter I had on hand.

But once I removed the off-axis guider and replaced it with the original T-thread adapter plate, not only would my Nikon lenses reach focus, but the focus setting was very near its "infinity" position, meaning the lens was very close to its optimal spacing. Offering an optional camera lens adapter would be a natural accessory for the Atik One.

With the addition of my Nikon adapter, I used the Atik One on several nights with a Nikon 300mm f/2.8 lens mounted piggyback on my telescope, which produced a generous 143-by-155 arc minute field. The camera's small 4.54-micron pixels make it ideal for use with short-focus telescopes and camera lenses. The camera's tripod sockets can be used to mount the camera when imaging with short, wide-angle lenses.

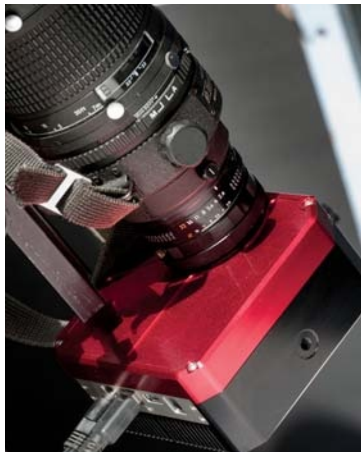
Processing with Dawn

An image-processing software program is also supplied with the Atik One Integrated Kit. *Dawn* works by dragging up to six icons representing image processing workflow steps into a work area. Images to be processed are then loaded into a series of folders, and the processed image appears in an output folder.

Though still under development, *Dawn* is capable of performing some calibration and other processing routines, but it falls short of the automated features in more conventional image-processing programs. For instance, the program can assemble a color image from red-, green-, and blue-filtered images but cannot assemble a color image with additional luminance data, commonly referred to as an LRGB image.

The Atik One Integrated Kit is a solid competitor for budding astrophotographers looking to upgrade to a low-noise, monochrome CCD detector. Its internal filter wheel and intuitive control software make it easy to use, and it provides automated, temperature-regulated imaging of deep-sky objects with only minimal hurdles to surmount. The accurate guiding provided by the off-axis guider and GP camera combination help insure that a night of imaging will produce a fine set of well-guided images ready for processing. ✦

North Carolina newspaper photographer Johnny Horne has reviewed products for Sky & Telescope *since 1987.*



Without the off-axis guider attached, the Atik One is able to accommodate the use of Nikon camera lenses with the appropriate lens adapter, making extremely wide-angle imaging easy. The image of M31 seen below was captured through a Nikon 300mm f/2.8 ED lens stopped down to f/4.

From Truss to Solid Tube

Sometimes sturdy and heavy is better than light and portable.

I HAVE A SUBSTANTIAL contrarian streak in me, so maybe that's why I found Petaluma, California ATM George Golitzin's 12½-inch telescope so appealing. Bucking the trend of converting a regular Dobsonian into a truss-tube model, George went the other way, transforming his truss-tube Dob into one with a conventional tube. Having performed the same operation myself, I had a pretty good idea why he did it.

There's no denying the virtues of a well-made truss-tube Dobsonian. Such instruments combine big-aperture performance with lightweight portability. And yet, for all their virtues, truss scopes do have disadvantages. They can be fussy to balance, a chore to assemble in the field, and often suffer from poor baffling. And I've seen more than a few that sacrificed rigidity for reduced weight. In general, unless you need the portability, a conventional solid-tube Dobsonian is usually a much better choice.

GEORGE GOLITZIN

George Golitzin's 12½-inch f/6 Dobsonian is purpose-built for high-quality views and is a distinct improvement over its previous truss-tube incarnation. The "wheel-barrow handles" make moving the scope from his shed to his observing site quick and effortless.

In George's case, he grew dissatisfied with the performance of his scope's original configuration. "The structure was pretty shaky, mainly because the truss tubes were made from exceptionally thin sheet metal," he says. "The scope tended to shake even with the minimal vibration generated by my cooling fan." So he set to work reconfiguring the scope for better performance, inspired by the acquisition of a 12½-inch f/6 mirror made by the skilled hands of Carl Zambuto. "This was going to be my main planetary and lunar instrument, so now that I had a first-class primary, I wanted a design that was both very stable and with good thermal properties," George says.

"I decided to replace the trusses with a middle section consisting of a large cardboard tube reinforced by aluminum struts." Going this route meant that he could reuse the existing secondary cage and mirror box. The scope's new "mid-cage" is a length of 3⁄16-inch-thick concrete form tube with an inside diameter of 14 inches. The bottom of the tube is affixed to a flange, which attaches to the mirror box with four ¼-20 bolts. The top of the tube has a ring for attaching the secondary cage, and a second ring positioned midway along the tube provides reinforcement. The mid-ring and flange are made with ¾-inch plywood, while the upper ring is ½-inch plywood. In addition, George used four, 1-inch-diameter aluminum tubes to give the tube extra rigidity. Bolts pass from inside the tube through the middle ring and struts, while the rear flange and upper ring are affixed with screws that thread into short lengths of wooden dowel epoxied inside the poles.

Naturally, the addition of the new mid-tube is noticeably heavier than the previous truss system, which means the balance point is shifted forward slightly. To compensate, George added some plywood reinforcement panels to the mirror box, as well as a couple of small counterweights. "The scope is eight or nine pounds heavier than before, and a bit harder to transport," he


GEORGE GOLITZIN

The main components of the optical tube assembly are (from left to right): the mirror box, mid-tube section, and secondary cage. While the mirror box and secondary cage were used in the original version of the scope, the mid-tube is new.

notes. "But it's primarily meant to be used at home, so it only needs to roll about 15 feet from my shed for use."

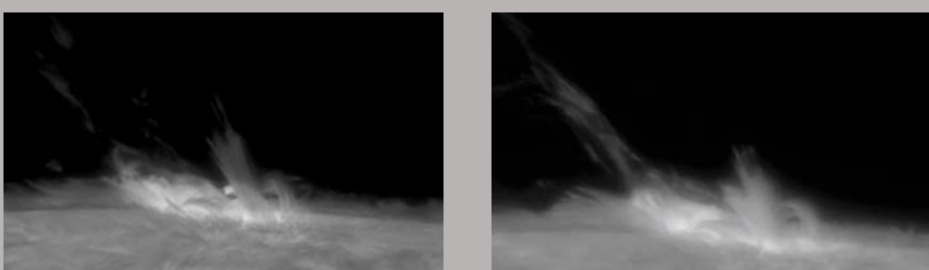
The scope now delivers views that meet George's expectations — and then some. "Last winter the scope gave me a series of mind-blowing views of Jupiter with intense color saturation and intricate belt detail that was far beyond my ability to describe or sketch," he reports. "There were tiny ovals, the turbulent wake of the Great Red Spot, blue festoons — you name it." He has also seen Sirius B, the "Pup," on several occasions. In addition to rigidity, good thermal management is another reason for the scope's fine performance. As George notes, "the scope's closed tube keeps my body heat out of the optical path, which makes thermal management easier."

"This one's a keeper," he says. Readers wishing to learn more about George's converted Dobsonian can contact him at ggolitzin@comcast.net. And if you'd like to see a detailed nuts-and-bolts account of how I converted my own 12¾-inch truss-tube scope to a traditional Dobsonian, stop by the ATM section of my web page and have a look at my Telescope Making Diary series of articles. This collection is also helpful if you're simply interested in making a Dob from scratch and want to know what's involved. ✦

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

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

MEET THE NEIGHBORS
David Mittelman
Little more than a hazy patch when seen by eye, the Andromeda Galaxy (M31) shows intricate details in photographs. Companions M32 (below the nucleus) and M110 (upper right) float nearby.
Details: *Takahashi FSQ-106ED refractor with SBIG STX-16803 CCD. Total exposure was 17.7 hours through Astrodon color filters.*



◂ **FEATHERY FLARE**
Paolo Porcellana
Active region 12161 put on a show along the solar limb on September 13, 2014, just before rolling out of view.
Details: *150-mm homemade refractor, used at f/20, with Point Grey Research Chameleon video camera and DayStar Quantum 0.5-angstrom hydrogen-alpha filter.*

◂ **SISTERS DRESSED IN LACE**
Kim Quick & Terry Hancock
The eye-catching Pleiades open cluster (Messier 45) is embedded in nebulosity.
Details: *Combination of 13 hours' total exposure with Takahashi E-180 astrograph (and QHY11S CCD camera), Takahashi FSQ-106 refractor (SBIG STM-11000), and TMB-92ss refractor (QHY9M).*

▾ **ORION'S BEJEWELED BELT**
Robert Fields
The trio of Alnitak, Alnilam, and Mintaka always grab attention — as do the Flame and Horsehead nebulae (lower left) and bluish NGC 1990 (center).
Details: *Takahashi FSQ-106N refractor and SBIG STL-11000 CCD camera. Total exposure was 3 hours through color filters.*

SOULMATES: IC 1805 AND IC 1848
Terry Hancock
The emission nebulae known as the Heart (at upper right) and Soul are situated about 2° apart in Cassiopeia. They adorn the Milky Way's Perseus arm 6,150 and 6,530 light-years away.
Details: *Four-panel mosaic using Takahashi E-180 astrograph with QHY11 CCD camera and TMB-92ss refractor with QHY9 CCD camera. Total exposure was 56.5 hours, acquired in 2012 and 2014.*

▶ **JUPITER RIDES HIGH**
Fernando Rodriquez
The giant planet's bright zones and dark belts rippled with detail — including the Great Red Spot at lower left — when captured on December 19, 2014.
Details: *Celestron C11 SCT at f/20 and ZWO ASI120MM video camera. Stack of 14,000 LRGB images.*

▶ ▶ **LUNAR ECLIPSE**
Howard L. Ritter, Jr.
The total lunar eclipse of October 8, 2014, maxed near dawn as seen from Maumee, Ohio, creating a deep blue background around the Moon's copper-colored orb.
Details: *Nikon D800 DSLR camera with Nikkor 80-400 zoom lens at 400 mm, ISO 6400, 1½-second exposure.*

◄ **PERFECT PAIRING**

Richard Bloch

With Ursa Major riding high, now is the best time to spot the easily seen Bode's Galaxy (M81, at left) and Cigar Galaxy (M82).

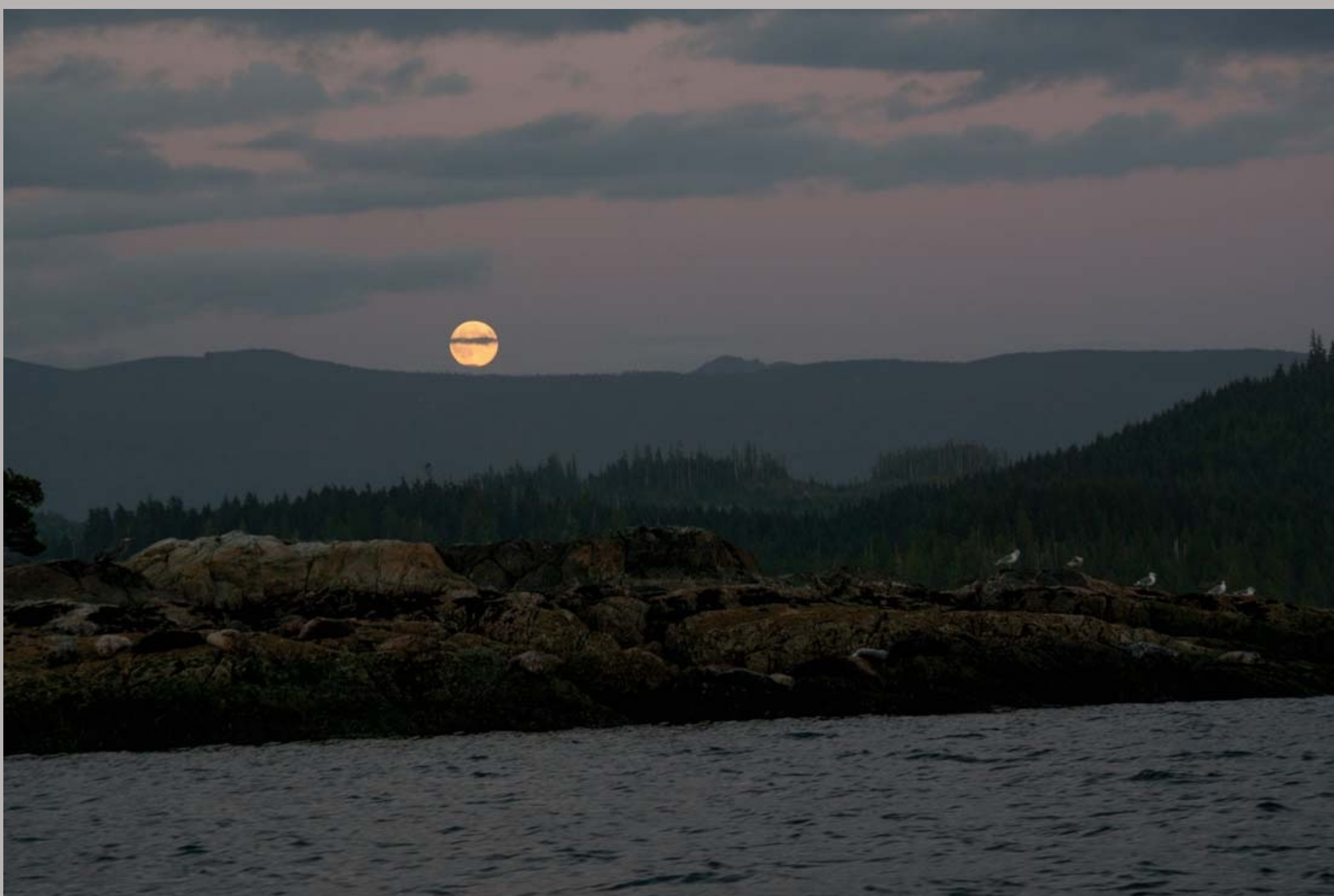
Details: *SkyWatcher ED80 f/7.5 refractor and Canon 600D/T3i DSLR camera. Total exposure was 3 hours.*

▼ **HARVEST MOON**

Gerardo Deman

A full Moon, bathed in sunset's deep colors, rises over hills on the western shore of Vancouver Island on September 9, 2014.

Details: *Pentax K-7 DSLR camera with Pentax 55-300 zoom lens at 78 mm. Exposure: 1⁄50 second at ISO 400.* ✦



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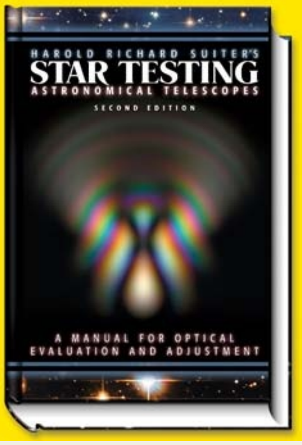

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Climbing Mt. Sharp

Reforging a path for human space travel

On a whim one morning, I showed my 3-year-old son *S&T*'s 2014 special issue on Mars. The content was way above Liam, of course, but the breathtaking illustrations were right at his level. I paged through the issue, pointing at pictures and explaining little things as I went.

Then I showed him the mosaic of photos Curiosity shot of Mount Sharp. "That is a big, big mountain!" Liam exclaimed. I told him that a robot named Curiosity was climbing all the way to the top of that mountain. Maybe he didn't understand the part about the robot, or maybe he just got caught up in the idea of climbing. But he turned to me with big round eyes, pointed a hesitant finger to his chest, and said, "Me?!"

That, right there, is all the argument I'll ever need for a human-crewed space program.

Don't get me wrong: robots are super cool. They explore new vistas, perform chemistry experiments, and relay data we can't get by ourselves just yet. The images captured by rovers and orbiters alike inspire the imagination. Still, there's nothing quite like climbing that mountain yourself.

The question is, how do we get to that mountain? A 3-year-old can lend you unbridled optimism for the future, but reality always intrudes. After all, NASA has struggled for a clear goal ever since it reached the Moon. In a recent presentation to the American Astronomical Society, space historian and policy expert John Logsdon pondered that sense of drift as he described our current position between a rock and a hard place.

First, there's the question of resources. President Kennedy's 1961 directive to land a man on the Moon "before the decade is out" came with an immediate 89% increase in NASA's budget. In the mid-1960s, the agency's funding peaked at roughly 20% of all non-defense, discretionary spending. But during Nixon's tenure, that percentage plummeted to 6%, and in this century it has remained between 3% and 5%.

BACKGROUND ILLUSTRATION: NASA / PAT RAWLINS

Then there's the question of destination. Low-Earth orbit was the only place humans went post-Apollo, though many hoped to press on to Mars sometime in the future. Presidents have also issued directives to establish a Moon colony or visit a near-Earth asteroid. But their budgets never backed those grand visions.

So there's our rock and our hard place: nobody wants to give up our ambitious goals, but we don't have the financing to achieve them.

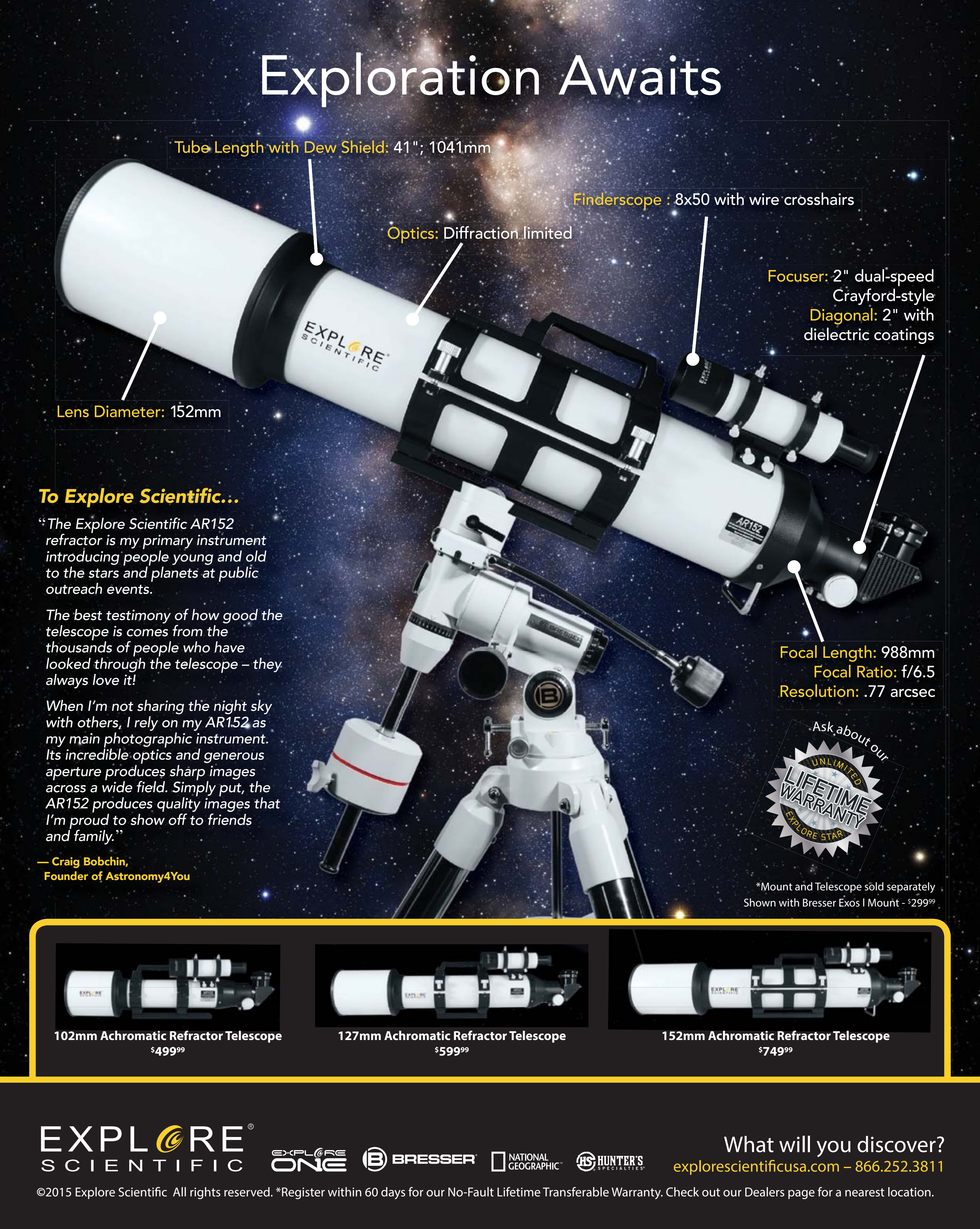
There are potential ways out of this tight spot, however. Logsdon argued that NASA, as a source of alternative funding, should refocus on international coalitions, challenging as they may be to establish and manage.

Another solution might be to combine NASA's vision and technical prowess with commercial sensibilities. In the discussion following Logsdon's talk, Martin Elvis (Harvard-Smithsonian Center for Astrophysics) suggested that private ventures such as those trying to develop space tourism or asteroid mining should help slash launch costs, a major expense of spaceflight, while NASA continues to reduce the technical risks.

My money's on the latter option (and not because Elvis was my doctoral advisor). Commercial spaceflight offers the first spark of hope that human space travel has seen in decades.

Regardless, no solution will happen overnight, and a human trip to Mars is more likely to happen in Liam's lifetime than in my own. But who knows? Maybe he'll be the one leading the expedition. ✦

***Monica Young** is S&T's web editor.*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