BONUS: NEW MERCURY GLOBAL MAP p. 39

BUILDING THE NEXT-GEN SUPERSCOPE p. 24

Mars: GUIDE TO OBSERVING THE RED PLANET p. 50 & 54

THE ESSENTIAL GUIDE TO ASTRONOMY

SKY & TELESCOPE

MARCH 2014

Stellar Blackout over New York p. 30

See Quasars from Your Backyard p. 34

Planet Hunting Goes Public

No scope, no sky, no problem! p. 18

Radically Different Telescope Mount p. 60

How the Web Saved the Webb p. 82

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SKY & TELESCOPE

March 2014 VOL. 127, NO. 3

On the cover: Armchair astronomers can now help find Jupiter-size exoplanets, akin to the one illustrated here.

ESA / NASA / G. TINETTI (UNIVERSITY COLLEGE LONDON, UK & ESA) AND M. KORNMESSER (ESA/HUBBLE)

FEATURES

OBSERVING MARCH

S&T TEST REPORT

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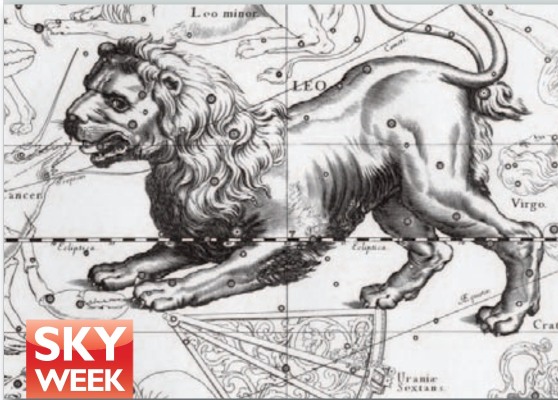

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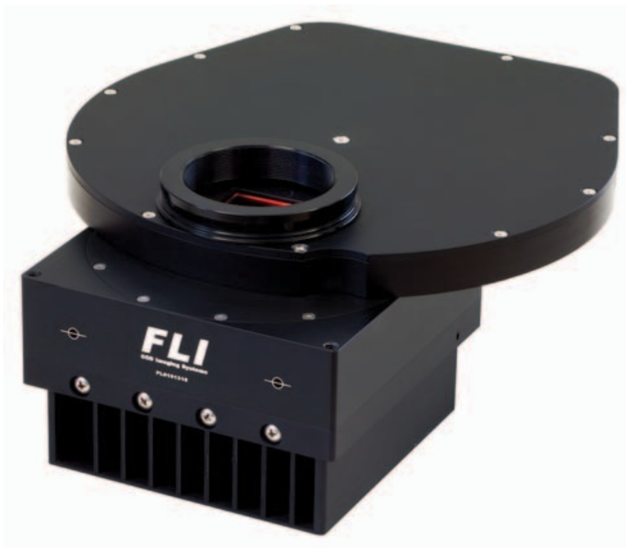
NGC3576. ProLine camera with 2048 x 2048 back-illuminated sensor. Telescope Design: Philipp Keller. Image courtesy of Wolfgang Promper.



March 2014 Digital Extra

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- **Be a Citizen Scientist**
  Learn more about the Mars and Space Warps citizen science projects.
- **The Megatelescopes Are Coming**
  See the progress on three mammoth telescopes currently in development.
- **PlaneWave Products In-Depth**
  Senior editor Dennis di Cicco interviews vendors at the October 2013 AIC conference.

Photo Gallery

Image by Amit Purandare

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Parks Squyres captured Comet Lovejoy with 100 stacked 15-second exposures. See more shots and submit your own at our online photo gallery.

Robert Naeye
Spectrum

Old-School Values

HAVING GROWN UP during the Great Depression, my father, Dr. Richard L. Naeye, was old school. I vividly remember visiting my parents' house in Hershey, Pennsylvania in the late 1990s, just when Google was starting to take off. My mother wanted me to show him how Google worked, so I asked him to name any topic he wanted to search. He spelled out *pneumoconiosis*, the medical term for black lung disease. After he started reading one of the pages that popped up, he retorted, "This isn't right. This Google of yours is no good!" That may have been the last Google search of his life, which ended on December 10, 2013 at age 84.

PENN STATE UNIVERSITY MEDICAL SCHOOL

My dad wasn't always keen on the latest technology, but until he retired in 2008 he was always interested in the latest medical research. As my family reviewed his C.V. a few weeks ago while editing his obituary for the local newspaper, I was astonished to learn that he published at least 270 papers in medical journals, including the *New England Journal of Medicine* and *JAMA*. And as the founding chairman of the Penn State University medical school's department of pathology, he built up a world-class organization from scratch.

Almost everything my father did was motivated by his deep Quaker faith. I have never met anyone who better exemplified the values of patience, frugality, and the desire to serve others. During his career as a medical researcher, he made numerous trips to underdeveloped nations such as Ethiopia and South Africa to improve pregnancy outcomes and reduce infant mortality. As a workaholic, one of his few hobbies was nature photography. He probably could have made a lot of money by selling his pictures, but he was only interested in giving away framed prints for free to family, friends, and local institutions.

Both he and I shared a passion for science, but our specific interests never really converged. He developed only a peripheral interest in astronomy. I fully respected the social importance of his research, but from an early age something from inside me drew me much more strongly to the physical sciences. But my father's influence can be felt in my work at *S&T* in his old-school values of commitment to substance, integrity, and the desire to make the world a better place for others. ✦

Robert Naeye
Editor in Chief

SKY & TELESCOPE

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Mount: Takahashi EM200 Temma2M
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Come on. Admit it. You know you want one. Also, a huge thanks to the folks at Three Rivers Foundation for all of their help with testing our scopes.
As this 100%-sized image from the extreme upper right corner shows, Esprit maintains crisp, pinpoint stars across the entire image plane.

Unclassifiable Comets

Editor's Note: *Comet ISON played it close to the vest right through its perihelion passage on November 28th. As part of Joe Rao's article "How Often Do Bright Comets Appear?" (November issue, page 30), we asked readers which of Rao's three categories they thought ISON would fall into. The poll results were:*

- ***Showstopper:*** *Even a casual observer will stop and say, "Wow, look at that!"* — **15.0%**
- ***Showpiece:*** *It will attract widespread attention or admiration* — **41.1%**
- ***Garden variety:*** *It'll look nice through a telescope, but it wouldn't be considered a "great comet"* — **43.9%**

We now know that a slight plurality had it right: although Comet ISON was a pretty sight with optical aid, it was certainly no showstopper or showpiece. But those who voted "showpiece" were correct in one respect: ISON certainly attracted a lot of attention.

Kudos for Joe Rao's article! I agree that attempting to determine whether a comet is "great" is bound to be subjective. I was pleased to see that Comet Holmes got a mention, although it didn't actually make Rao's list of bright comets. I remember it well — easily visible in Perseus from outside my apartment in urban Oakland, California. It was certainly unusual, with its starlike nucleus and large, fuzzy, and round coma. Its visibility makes me wonder if the 2.5-magnitude rating is a wee bit too conservative.

I had the good luck of seeing Comet Hyakutake in the heavily light-polluted skies of Paris, followed the next year by Hale-Bopp's show in the equally light-polluted skies of Los Angeles. Having seen those, I know that Comet Holmes was no "great" comet, although I would argue that it was more than a garden variety. How about a "What-the-Heck" comet? It certainly deserves more fanfare than that no-show Comet PanSTARRS!

Jeff Rabb
Concord, California


Amateur astronomer George Wilmot captured this shot of Comet Ikeya-Seki in 1965.

I enjoyed Rao's article about bright comets and was interested to see that Comet Ikeya-Seki was included as a "showstopper." My father, George Wilmot, was a chemist by profession but was also an amateur astronomer who sparked my lifelong interest in the sky. On Halloween morning in 1965, he took several photos of Ikeya-Seki using his Kodak Twin-lens Reflex camera. One was published on the front page of a local newspaper. Personally I think that his photo is more impressive than the one you have in the article, but of course, I may be biased. I just wish he would have woken me up that morning to see it!

Greg Wilmot
Laurel, Maryland

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

Illustrating the Heavens

I enjoyed reading about H. A. Rey's *The Stars: A New Way to See Them* (October issue, page 72). When I first started this great hobby I, like many others, had difficulty reconciling star charts with the real night sky. Success in learning the sky always eluded me — that is, until I found

Rey's book. In practically no time at all I could point out the major stars and planets and knew where one constellation ended and the next began. I even had a firm enough grasp of the zodiac that I could explain it to others when they saw me with my telescope at night. I now unhesitatingly recommend this book to anyone who expresses an interest in learning about our heavens. Thank you, Mr. H. A. Rey, and bless you.

William Nopper
Rochester, New York

What a pleasant surprise to find Ann Mulloy Ashmore's article, "The Man Who Illustrated the Heavens," in the October issue. I was fortunate to have a copy of Rey's book when I became a backyard astronomer many years ago. His work made it easy to locate and identify constellations. Later, when I was a university student, I could not help but wonder why the professionals did not use his work to help students find their way around the sky. Today, I recommend *The Stars* to anyone, professional or student, who is interested in astronomy. That the book can still be found in most bookstores today is a testament to Rey's genius. Again, great article and thanks.

Ronnie Whitener
Murphy, North Carolina

My eyes were misty while reading Ashmore's article about H. A. Rey, and not from the drops the eye doctor had recently put in, either: I teared up from the pure joy I felt to see his story told to the world. For me, H. A. Rey was a beloved teacher, and without his book and its sensible drawings, I would never have learned the night sky. Thanks to Rey, I worried for Boötes blowing smoke into the face of the Bear. I located every pair of Ursa Major's paws. In my eyes, Hercules truly held a raised club. When my college studies called for a break, I would step outside clutching my red flashlight and the treasured book to savor the satisfaction of successful searches. Soon, I was teaching friends.

But I disagree that *S&T*'s adjustments added clarity. In these versions Cetus becomes a flyswatter, Hercules a Burmese dancing girl, and Sagittarius a teapot. Although there is a traditional way of visualizing the constellations, those lines made little sense to me when I was trying to learn the sky. I appreciate your monthly charts, but to claim the adjustments added clarity is nonsense. Let's keep things simple for those who will light the future, for they will decide whether to light it with red flashlights or porch lights.

Thanks for telling Rey's story.

Barbara Blanko
Clinton, Connecticut

75, 50 & 25 Years Ago

Roger W. Sinnott

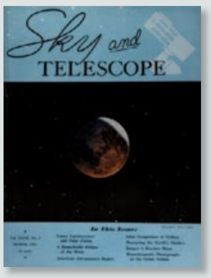
March-April 1939

Invisible Glass "The amount of light reflected from a clean glass surface is small; if the reflected light could be entirely eliminated the glass would become invisible. . . . The trick is accomplished by coating the glass with a thin transparent film about 1⁄200,000 of an inch thick. . . .

"The thickness of the film is critical. By doubling its depth the effect can be completely reversed. The reflections are intensified. Even this result may be of value, by making possible more perfect reflection from a silvered or aluminized mirror surface. . . .

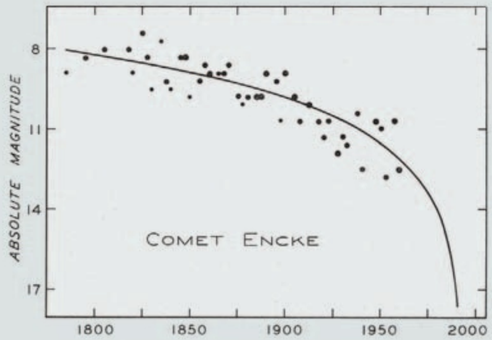
"Astronomers have been struggling for ages to get more of that precious commodity, starlight, into its most useful place, and every increase in efficiency is welcome. . . . How far-reaching the new discovery will be and to what new uses it may be put await for the future to decide."

While still a graduate student, soon-to-be optical guru James G. Baker was reporting a startling discovery just announced by researchers at MIT and General Electric. It led in just a few years to the wide use of anti-reflection coatings on lenses and enhanced reflectivity coatings on mirrors.

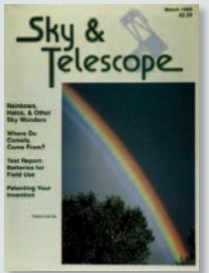


March 1964

Comet's Demise? "Dots [in the accompanying graph] represent absolute magnitudes of Encke's comet at each observed return since 1786. . . . Smaller dots are less accurate values. The curve fitted by F. L. Whipple predicts an increasingly rapid fading, leading to eventual disappearance about the year 1993."



This bold prediction by a noted comet expert did not come to pass. Last November, with Comet ISON in its death dive near the Sun, Comet Encke was a nice binocular target at nearly 7th magnitude.



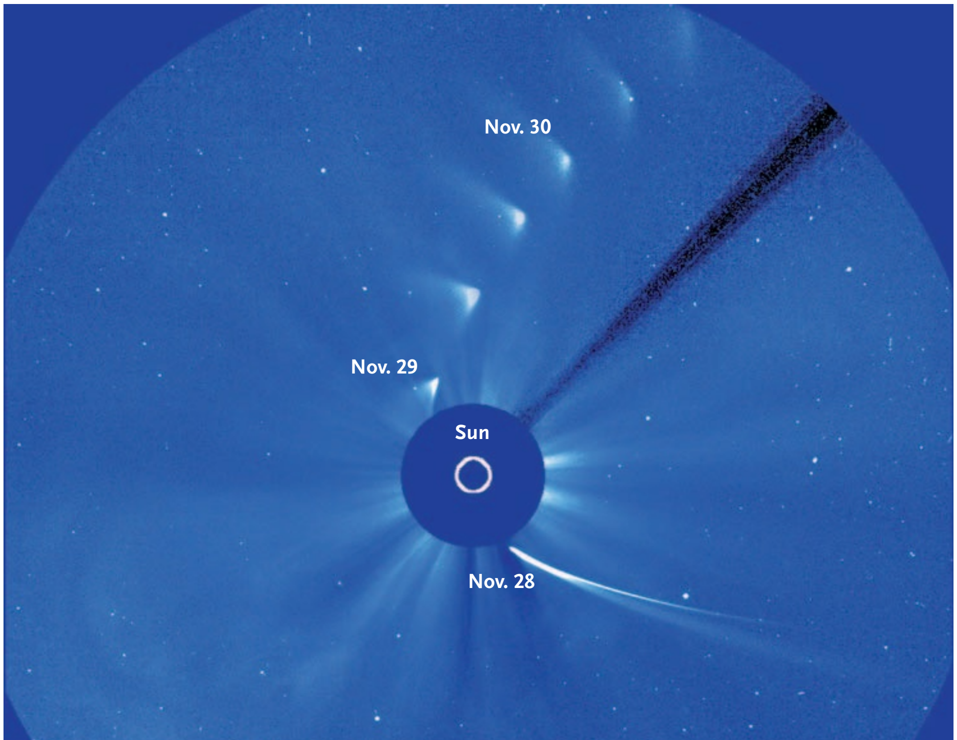
March 1989

Remote Remnant "Robert A. Fesen (University of Colorado) and colleagues have recovered the visible remains of S Andromedae, the first supernova ever recorded in an external galaxy [in 1885]. The CCD image . . . was taken in the light of an iron line at 3860 angstroms with the 4-meter reflector atop Kitt Peak. The long-sought remnant appears as a dark spot . . . *in absorption* against M31's bright central region. . . .

"The 1885 blast was a Type I supernova that left behind an expanding cloud made largely of iron. The debris is now about 0.3 arc second, or about 1 light-year, across, consistent with an expansion speed of 4,000 to 5,000 kilometers per second since 1885."

On August 17, 1885, a bright star appeared in what was then called the Andromeda Nebula. It reached 6th magnitude a few days later and then faded slowly during the next six months. Astronomers would not figure out what a supernova was until the 20th century.

COMETS | ISON's Untimely Demise



Comet ISON plunges sunward toward perihelion, and then its wreckage emerges, in this composite of frames taken by the LASCO C3 instrument on the Solar and Heliospheric Observatory (SOHO). The dark blue disk in the center is a metal mask blocking the Sun's glare; the thick black line (upper right) is the stalk holding the mask.

NASA / ESA / SOHO

As many experts feared, Comet ISON (C/2012 S1) choked. The comet fizzled out as it skimmed the Sun at perihelion on November 28th, despite the spike in its brightness in the preceding weeks that raised observers' hopes. No naked-eye spectacle emerged to light December's dawn, nor did its remains appear in backyard telescopes.

As the comet raced toward its fateful pass, several Sun-watching spacecraft relayed pictures of its progress almost in real time. Excitement peaked in the final 24 hours, when the comet's starlike head brightened to dazzle the SOHO cameras at an estimated magnitude –2. Then, just as rapidly, the head dwindled away.

At the comet's closest approach (less than one solar diameter from the Sun's photosphere), the extreme-ultraviolet cameras on the Solar Dynamics Observatory saw nothing, suggesting the nucleus had ceased to emit gas.

Then out the other side came a headless dust-and-rubble stream. It regrouped somewhat, as expected for a stream decelerating away from the Sun. It gradually expanded and faded to nothing as it left the Sun behind.

Still, astronomers have pulled some scientific results from the comet. Researchers originally estimated the nucleus's diameter was a couple of kilometers wide. But Alfred McEwen (University of Arizona) reported December 10th at the annual American Geophysical Union (AGU) meeting in San Francisco that the nucleus was probably much smaller. Observations by the HiRISE camera on the Mars Reconnaissance Orbiter, taken during the comet's Red Planet flyby at the end of September, suggest that the diameter of the dirty iceball was only between 100 and 1,000 meters (300 to 3,000 feet). Albedo measurements favor the middle of that range, or around 600 meters.

Due to a happy accident, NASA's Messenger spacecraft, currently in orbit around Mercury, was in the right place at the right time to study both ISON and the periodic Comet 2P/Encke as they both passed through the inner solar system. The orbiter's ultraviolet spectrograph performed about 9,000 scans of ISON. As of the AGU meeting, most of those data were still onboard the spacecraft, awaiting download and analysis. But from what scientists have, it looks like the first-timer ISON contained lots of carbon compared with the repeat-visitor Encke. That suggests organic grains might exist on primordial comets but are burned off during solar passages. It's also possible that this "heat treatment" somehow protects periodic comets during subsequent passes.

Scientists think Comet ISON stopped expelling dust at perihelion, even though it briefly brightened a bit right afterward. One theory for this unexpected brightening is that when the comet rounded the Sun it was pulled apart like a Slinky, with its pieces separated but still traveling together as a cloud of debris. That separation would increase the surface area that was reflecting sunlight and would create an illusion of nucleus brightening.

Although it's unclear why some sungrazers survive perihelion and others do not, the consensus is that Comet ISON was too small, too volatile, and too new to survive its close encounter with our star.

Oh well. That's comets for you.

■ **ALAN MACROBERT & EMILY POORE**

Watch video of ISON's demise at skypub.com/ISONdies. We will announce the winners of our Comet ISON photo contest in next month's issue.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MARS | A Habitable Past for a Desert Planet?

NASA / JPL-CALTECH / MSSS

Curiosity's Mast Camera recorded this view of sedimentary deposits inside Gale Crater in February 2013. Wind-driven sandblasting appears to be eating away at the sandstone (rust-colored ledge in the foreground) to expose mudstone below. The sandstone ledge is about 20 cm (8 inches) high.

The researchers coordinating NASA's Mars Science Laboratory have always stressed that their beefy Curiosity rover is *not* searching for life on the Red Planet. Rather, it's designed to find out whether Mars was ever *suitable* for life.

After a year of zapping, sniffing, and tasting rocks and sand, the answer is "yes." A flurry of findings in the December 9th *Science* (and announced simultaneously at the American Geophysical Union meeting) provide the best evidence yet that ancient Mars was indeed habitable.

Curiosity spent many months exploring outcrops in an expanse inside Gale Crater dubbed Yellowknife Bay. Mission scientists soon realized that much of the terrain was covered in mudstone, silty sediments that settled onto the bottom of an ancient lake.

What's now clear, as reported by one team led by project scientist John Grotzinger (Caltech) and a second by David Vaniman (Planetary Science Institute), is that the sediments contain an iron- and sulfur-rich clay called smectite. This clay formed in water with a neutral pH and low salinity — just the kind of benign habitat that primitive life forms called *chemolithoautotrophs* would want. Such microbes derive their energy from the oxidation of inorganic compounds and their carbon from atmospheric carbon dioxide.

A separate analysis by Kenneth Farley (Caltech) and others used isotopic ratios to estimate the age of a mudstone slab nicknamed Cumberland. It's between 3.86 and 4.56 billion years old, confirming that Gale formed very early in Martian history.

But Farley's team also tested for elemental isotopes produced by the potent cosmic rays that bombard the Martian surface. Cumberland's "exposure age" is comparatively young, only 50 to 100 million years. Apparently the sediments in Yellowknife Bay spent eons buried under a protective cover of overlying material, which the planet's incessant winds stripped away in the recent geologic past.

This means the rover could detect any organic matter that might be trapped in these ancient sediments. Not all organics are biogenic, but planets — especially geologically dead ones — are inherently inorganic systems. Douglas Ming (NASA Johnson Space Center) and colleagues report that Curiosity continues to detect simple organics in surface samples, and they can't all be contaminants brought from Earth. They might be indigenous to Mars or introduced by meteorites.

■ **J. KELLY BEATTY**

MISSIONS | China Lands Lunar Rover

In the first non-crash landing on the Moon in the 21st century, Chang'e 3 touched down successfully on the flat volcanic plain of Sinus Iridum at 13:11 Universal Time on December 14th.

Chang'e 3 is the third spacecraft of the China Lunar Exploration Program. Lunar orbiter Chang'e 1 launched in 2007; launched in 2010, Chang'e 2 is traveling through deep space after leaving lunar orbit and encountering asteroid 4179 Toutatis in 2012.

The successful landing marks the first time the Chinese space program has landed anything on an extraterrestrial body. China now joins the select ranks of the U.S. and former Soviet Union as the only countries to set mechanical foot on the Moon.

Chang'e 3 consists of a service module and a landing vehicle. The 1,200-kg (2,600-pound) lander is equipped with an imaging spectrometer, two panoramic cameras, and ground-penetrating radar. It also carries a telescope to observe the dense torus of ionized gas encircling Earth, called the plasmasphere.

Within six hours of landing, mission controllers deployed a solar-powered, six-wheeled rover that is one-tenth the lander's weight and will explore the terrain around the landing site. The rover is aptly named Yutu, for the rabbit companion of Chang'e, a mythological Chinese woman who takes an immortality pill that sends her floating to the Moon.

Although expected to yield new insights into lunar science, Chinese officials also hope that the Chang'e 3 mission will be a precursor to human exploration of Earth's satellite.

■ **EMILY POORE**

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IN BRIEF

Hubble Homes in on Hazy Worlds. Astronomers looking for water in the atmospheres of five hot Jupiters found less water than expected, suggesting these planets are surrounded by a high-altitude haze. Water is a common molecule and had already been detected on the most studied of the five, HD 209458b, which also hosts strong winds and high-altitude clouds. But the researchers had to include similar clouds in their atmospheric models for the other four planets in order to explain why their water signals are less clear, as Drake Deming (University of Maryland) and colleagues report in two papers in the *Astrophysical Journal*.

■ **MONICA YOUNG**

First Noble Gas Molecule in Space. Infrared observations of the Crab Nebula (M1) reveal the presence of argon hydride ions (ArH^+), Michael Barlow (University College London) and colleagues report in the December 13th *Science*. The argon is a special type: it's the isotope argon-36, which astronomers expected to form in supernovae like the one that created the Crab Nebula. Observers first detected knots of ionized argon in the supernova remnant two decades ago, but they haven't known which isotope it is. The new observations show that the strongest emission from both ionized argon and ArH^+ come from the same part of the remnant. On Earth, argon-40 is the dominant isotope. It is released by the radioactive decay of potassium in rocks.

■ **CAMILLE M. CARLISLE**

Piggyback Radio Receivers. NRAO and the Naval Research Laboratory have joined forces to put a system of low-frequency radio receivers on 10 antennas of the Karl G. Jansky Very Large Array (VLA) in New Mexico. The new system, called VLITE (VLA Ionospheric and Transient Experiment), will watch over the dishes' proverbial shoulders during normal research activities, monitoring Earth's ionosphere and looking out for short-lived radio bursts. Because VLITE will be at the whim of where other observers point the antennas, it won't produce a methodical survey. Still, planners expect to see 25% of the observable sky for 100 seconds or longer each year, and 10% for 1 hour or more.

■ **CAMILLE M. CARLISLE**

SOLAR SYSTEM | Plumes on Europa?

Astronomers have detected faint emission above Europa's south pole that might be from spewing water vapor, Lorenz Roth (Southwest Research Institute and University of Cologne, Germany) and colleagues reported December 12th at the American Geophysical Union meeting. The result also appears in *Science*.

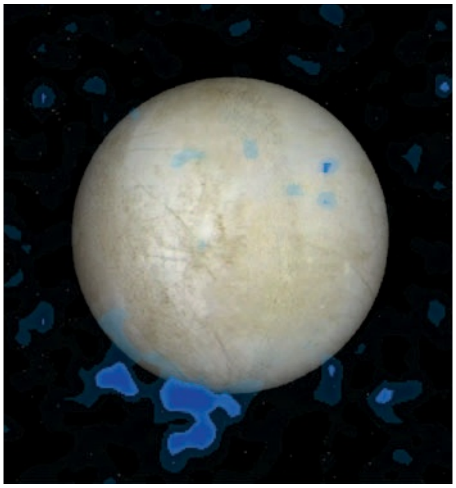
This detection is not the first of potential activity. "The history of apparent plumes on Europa has been somewhat of a sordid one," says planetary scientist Robert Pappalardo (JPL). Both Voyager and Galileo saw hints that were later dismissed, as were thermal observations suggesting an outburst. Roth and colleagues also saw an inconclusive signal from the moon in 2009.

But with a liquid water ocean beneath its icy crust, Europa could have plenty of fuel for eruptions. Features on its surface look akin to those from fissure eruptions on Earth. And there's the parallel with Saturn's satellite Enceladus, which coughs out enough water vapor to form the planet's E ring.

Roth's team used the Hubble Space Telescope to take ultraviolet spectra of the moon's tenuous gas envelope. They focused on two important points in Europa's orbit: its closest and farthest approaches to Jupiter, also known as periapse and apoapse.

Activity on Enceladus suggests that plume outbursts should be stronger at apoapse. When an icy moon like Enceladus or Europa is close to its planet, the tidal forces stretch and squish it, closing up any cracks in its surface, explains Francis Nimmo (University of California, Santa Cruz). But when the moon moves farther away, it becomes "unsquished," opening the cracks. These open cracks could expose liquid water to the vacuum of space, causing it to boil off as temporary plumes.

Roth's team found that at apoapse, emission from oxygen and hydrogen atoms above Europa's south pole was at least three times brighter than the average elsewhere. The signals were absent during two periapse observations.



LORENZ ROTH / SWRI

This composite image combines smoothed Hubble Space Telescope ultraviolet data (blue) with a visible image of the leading hemisphere of Europa. Emission from hydrogen and oxygen suggests that plumes of water vapor are erupting from the moon's south polar region.

The result gives scientists a clear scenario to test: if more observations confirm the uptick in hydrogen and oxygen at apoapse, the detections will be solid evidence for transient plumes on Europa. Until then, both the team and other scientists will remain cautious.

"I'll sleep better knowing that it's been reproduced," Pappalardo admits. Seeing the signal in the same wavelength would be convincing, but it'd be even better if observers could catch infrared emission from warmed material, he adds. "I guess I'm 70-ish percent sure now, based on what I see. I bet if they did it again I'd be 90% sure, and then I'd be up at 100% if I saw the infrared."

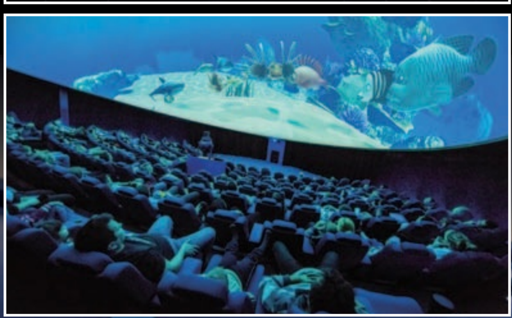
The team thinks the emission could come from plumes 200 km tall, spitting out 7 tons of material each second. That rate is 35 times higher than Enceladus's.

Even though eruption speeds might be about 700 meters per second (1,600 mph), Roth notes that the vapor won't reach escape velocity. Instead, it'll rain back down on the moon, freezing immediately on the cracked, –150°C (–240°F) surface. The whole process would take about 20 minutes.

■ **CAMILLE M. CARLISLE**

GOTO

The HYBRID Revolution in Brno



Photos credit:
Brno Observatory and Planetarium

The city of Brno can be found in the Czech Republic – the heart of Europe – about halfway between Prague and Vienna. A small observatory, used by world famous Czech astronomers was established here in 1954. For example Lubos Kohoutek, the discoverer of the well-known comet, and Lubos Perek, the co-founder of space law concerning satellite traffic were early members. It is also the place where Vladimir Remek, the only Czechoslovak astronaut, started his career in 1962.

Built in 1991 by the City of Brno, the Brno Observatory and Planetarium underwent substantial reconstruction in 2010 and 2011, and in 2013 installed a new GOTO HYBRID Planetarium® as an international joint project of the Czech company Nowatron Elektronik, French RSA Cosmos and Japanese GOTO INC.

Today the Brno Observatory and Planetarium is the largest and most modern institution of this kind in the Czech Republic. It cooperates with local universities and scientific companies, and is a co-founder of the Czech Association of Science Centers. Every year the planetarium has had more than 100,000 visitors who are looked after by 20 employees and about the same number of volunteers.

It reopened on October 31, 2013, with a GOTO Chronos II opto-mechanical planetarium projector synchronized with fulldome video. The reason for choosing the GOTO HYBRID combination was easy: It presents high quality astronomical shows effectively and at the same time can also be used for other educational and cultural activities. Director Jiří Dušek says, “We do not consider the installation to be just a planetarium but a wonderful audiovisual instrument with almost unlimited possibilities.”

The 17-meter dome’s 188 seats have been filled with an incredible 12,000 visitors in the first month of operation. We wish The Brno Observatory and Planetarium even more success in the years to come.

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IN BRIEF

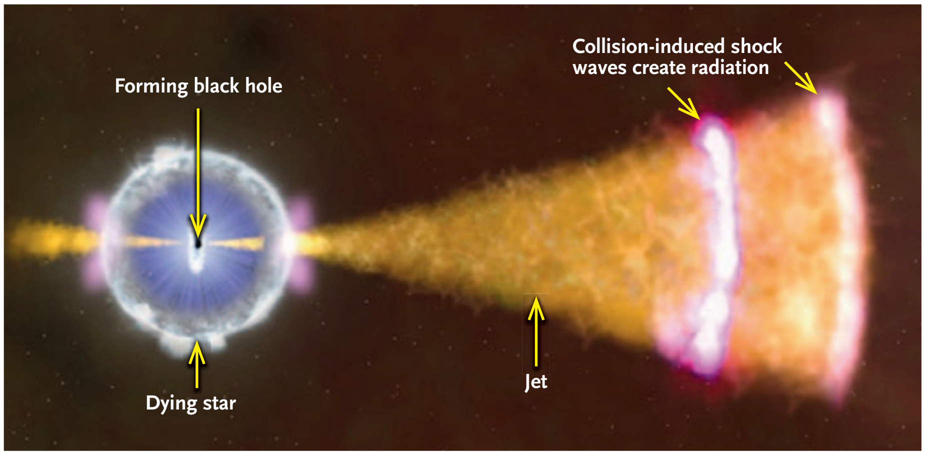
Black Hole Spews Atoms. Astronomers know that black holes launch jets along their twisted magnetic field lines, but they haven't known where that material comes from or, consequently, what it's made of. Now, María Díaz Trigo (ESO) and colleagues report in the December 12th *Nature* that they have detected ionized iron and nickel in the jet from a stellar-mass black hole gobbling material from its companion star. The evidence for atoms strongly favors the idea that the jet material comes from the black hole's accretion disk and is funneled out along magnetic strands that the disk itself has threaded through the black hole. This scenario makes sense: jets usually show up when a sizable corona of ionized gas grows around a black hole's disk. (The alternate explanation is that the material originates from the electrical current generated just outside the black hole, which would instead fill the jet with electrons and their antimatter counterparts, positrons.) The detection is a big deal, but both mechanisms might still ultimately contribute.

■ **CAMILLE M. CARLISLE**

Oddball Pulsar Origin. A few rapidly whirling neutron stars might get their start as white dwarfs, Paulo Freire (Max Planck Institute for Radio Astronomy, Germany) and Thomas Tauris (Argelander Institute for Astronomy, Germany) suggest in the *Monthly Notices of the Royal Astronomical Society*. Millisecond pulsars generally form in binary systems, in which a neutron star spins itself up by siphoning material off its companion star. But in Freire and Tauris's hypothesis, the spun-up stellar corpse is initially a white dwarf. The dwarf spins itself up so fast that, in lieu of collapsing, the object survives beyond its usual mass limit of 1.4 solar masses. When accretion shuts off and the dwarf slows down a bit, the stellar corpse can't delay its death any longer, and it collapses directly into a rapidly spinning pulsar. This scenario might explain two millisecond pulsars found in elongated orbits with their companions, which don't match the circular orbits the neutron star scenario creates.

■ **CAMILLE M. CARLISLE**

STELLAR | Monster Burst Challenges Theories



NASA GSFC

Observations of one of the most powerful exploding stars ever recorded suggest that the standard model for gamma-ray bursts might be missing a piece of the puzzle, scientists report in papers published online November 21st in *Science*.

The gamma-ray burst GRB 130427A set off an alarm on NASA's Fermi Gamma-ray Space Telescope on April 27, 2013. The Swift spacecraft, an array of ground-based robotic telescopes called RAPTOR, the CARMA millimeter-wave observatory, and NASA's NuSTAR X-ray telescope also joined in on the action. In the end, the explosion flooded 58 ground- and space-based observatories with its photons.

These observations show that GRB 130427A is the longest, most energetic such explosion on record. Although the main burst lasted just 20 seconds (a typical duration for this kind of "long" GRB), stray gamma rays kept pouring in for another 20 hours.

Two of the thousands of gamma-ray photons Fermi collected during that time are problematic. The first appeared 19 seconds after the burst began; the next appeared 3¾ minutes later. Both packed a serious punch: 73 and 95 billion electron volts, the highest-energy photons ever recorded from a GRB.

According to the current scenario, these photons shouldn't have existed. In the standard picture, long GRBs like 130427A herald the collapse of very massive stars. As the star's core implodes to create a black hole, a jet forms and burns its way through the star's outer layers in seconds. The jet then rams into the surrounding gas cocoon left behind by the dead star's winds, pushing electrons to relativistic speeds. These electrons race through surrounding magnetic fields, releasing their pent-up energy as synchrotron radiation.

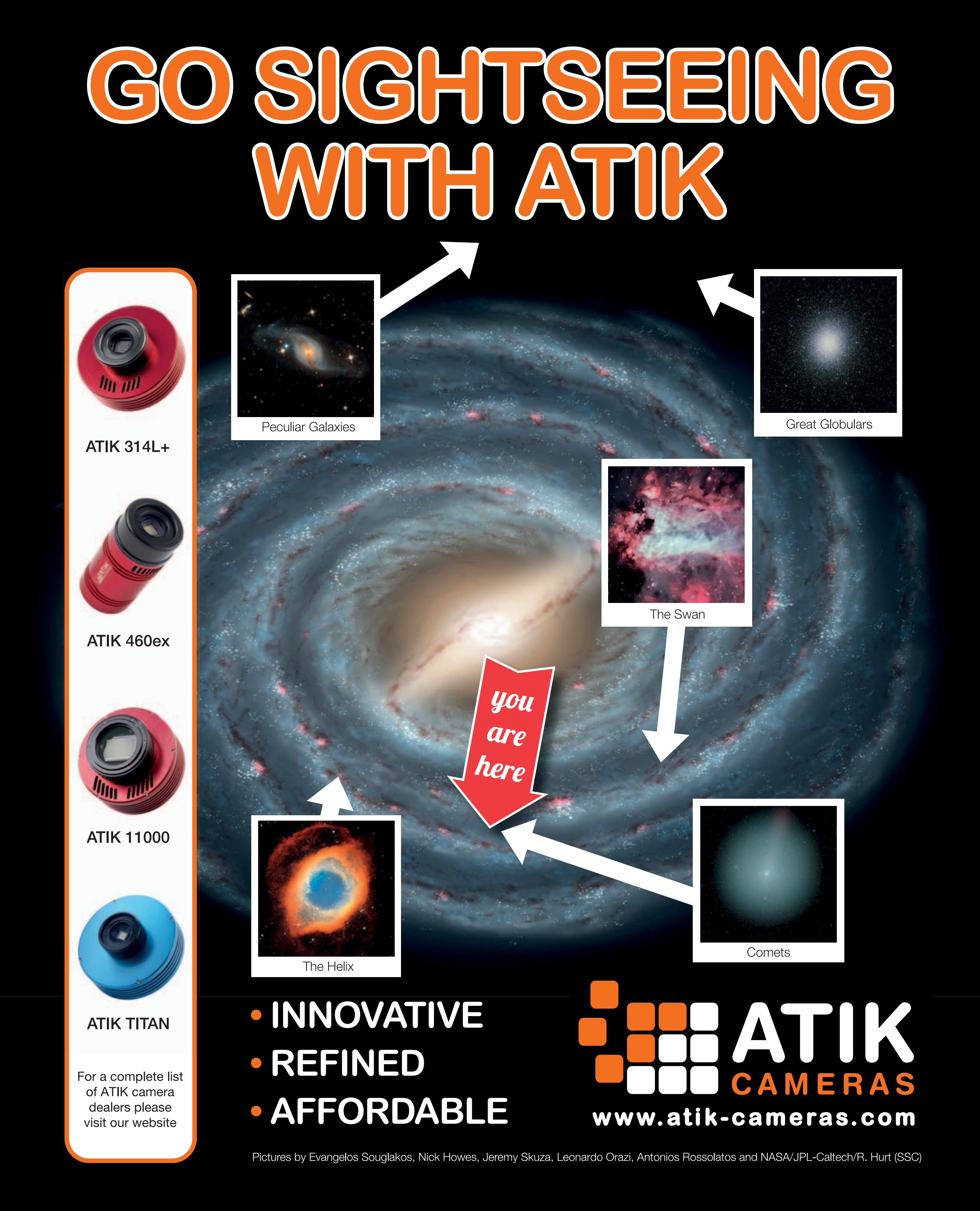
But no matter how fast these electrons spiral, they can't radiate away the 73 billion and 95 billion electron volts the two photons carried.

One study's lead author, Alessandro Maselli (INAF-IASF Palermo, Italy), suggests that the same electrons that created the photons in the first place could pass on an extra punch of energy if they later collide with their progeny.

But a coauthor on another study, Charles Dermer (Naval Research Laboratory), says that if the GRB made its photons in two different ways, we should see a jump in the number created at different energies (for example, many more gamma rays than X-rays). Instead, the whole spectrum from visible light to ultrahigh-energy gamma rays is smooth, suggesting all the photons come from one mechanism.

The teams propose everything from snapping magnetic field lines to scorching-hot gas around the forming black hole as solutions. They haven't ruled out the synchrotron model, but it's clear that something extra is needed. ✦

■ **MONICA YOUNG**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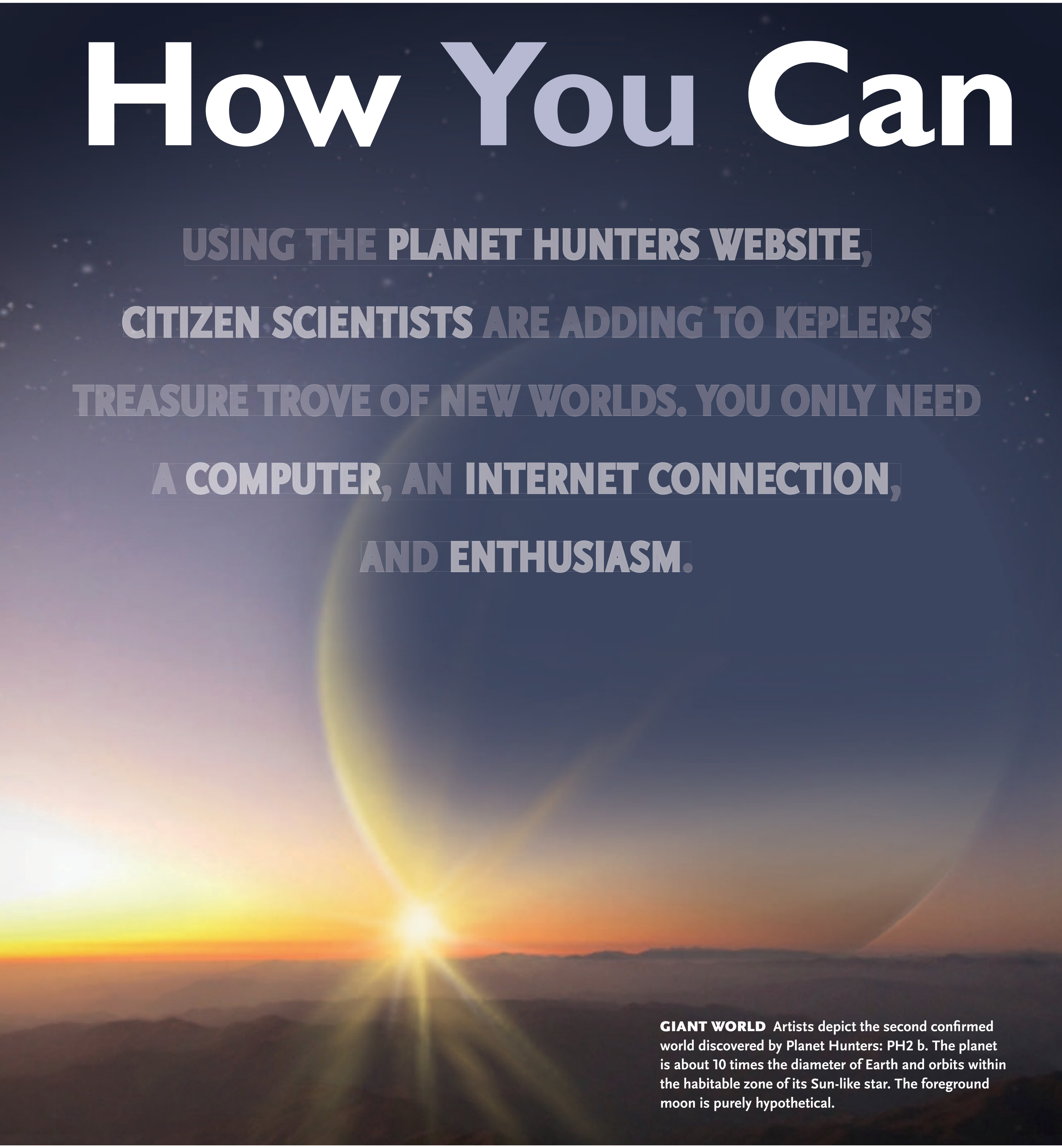
How You Can

USING THE PLANET HUNTERS WEBSITE, CITIZEN SCIENTISTS ARE ADDING TO KEPLER'S TREASURE TROVE OF NEW WORLDS. YOU ONLY NEED A COMPUTER, AN INTERNET CONNECTION, AND ENTHUSIASM.



GIANT WORLD Artists depict the second confirmed world discovered by Planet Hunters: PH2 b. The planet is about 10 times the diameter of Earth and orbits within the habitable zone of its Sun-like star. The foreground moon is purely hypothetical.

HAVEN GIGUERE / MATT GIGUERE / YALE UNIVERSITY

Find an Exoplanet

Meg Schwamb

The rapid rise of computers, smartphones, and the internet has led to a revolution of connectedness across the globe and the nearly instantaneous exchange of information. In this technologically wired age, more than 1 billion people use Facebook, devoting roughly an hour per day on the website, and millions of people spend hours every week flinging birds at chubby pigs in the video game *Angry Birds*. Imagine the science you could accomplish if you could tap into just a fraction of that collective brainpower and apply it toward the unanswered questions about the universe around us. This is exactly what the Zooniverse (**zooniverse.org**) aims to do.

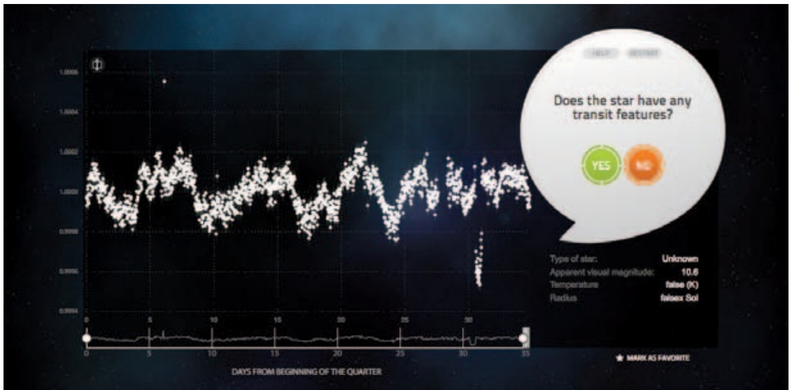
900,000 Heads Are Better than One

The Zooniverse is a menagerie of crowdsourcing or citizen-science projects using the combined power of human pattern recognition via the World Wide Web to tackle some of the most challenging questions in astronomy and planetary science. Humans are well-suited for these tasks because we easily recognize patterns and spot outliers. For example, we instantly identify the faces of our friends and family members in a crowd. But such pattern recognition is still a challenge even for today's most advanced computers.

Citizen science taps into this innate human ability to analyze large datasets for projects that are difficult or nearly impossible for a single scientist. Experiments have shown that by combining the independent assessments of multiple nonexperts, you gain the "wisdom of crowds," where the group opinion can equal or best that of a trained expert, and in many cases, outperform the best machine-learning algorithms. With the internet, scientists can gather multiple volunteer classifications from the hundreds to thousands of people needed to explore large astronomical datasets that have been amassed with the rise of gigabyte and terabyte computer storage.

The Zooniverse, led by Chris Lintott (University of Oxford and Adler Planetarium), started with Galaxy Zoo (**galaxyzoo.org**) to identify the shapes of galaxies (*S&T:* November 2011, page 24). It benefited from the fact that humans are better than computers at distinguishing spiral galaxies from ellipticals and at spotting galaxies with bars. The Zooniverse now hosts the largest collection of online citizen-science projects, with nearly 900,000 volunteers worldwide participating to date. The Zooniverse has grown from just galaxy classification. There are now 23 iterations of online citizen-science projects spanning identification of animals imaged in camera traps in the Serengeti (**snapshotserengeti.org**) to the search for star-formation bubbles in our Milky Way (**milkywayproject.org**).

Each Zooniverse project turns those clicks into science. All you need is a web browser; no special skill or expertise is required. You go to one of the project websites, watch a short tutorial, and then you're off to the races assessing real scientific data and actively contributing to the scientific process.



TRANSIT SIGNAL In this screen shot from planethunters.org, the unambiguous dip near the far right of this Kepler light curve is due to a 3-Earth-diameter planet transiting the star KIC 3425851.

560,000 Eyes Search for Planets

One of the Zooniverse's most successful projects is Planet Hunters (**planethunters.org**), led by Debra Fischer (Yale University). Launched in late 2010, Planet Hunters enlists the public's help in the search for exoplanets.

NASA's Kepler spacecraft spent the past four years staring at the same patch of sky in Cygnus and Lyra, monitoring the brightness of nearly 160,000 stars nearly continuously for the signatures of transiting exoplanets. During a transit, a planet dims a tiny fraction of its host star's light, with the amount enabling astronomers to estimate the planet's diameter. Jupiter-size worlds orbiting a Sun-like star produce whopping transit signals with depths of about 1%. Unlike ground-based telescopes, Kepler could detect the less-than-0.01% transit depth produced by Earth-size planets orbiting Sun-like stars with the sensitivity equivalent to the task of spotting a fruit fly passing in front of a distant stationary car's headlight.

Kepler has truly revolutionized the field, discovering more than 3,500 planet candidates (last month's issue, page 14). It has found Earth-size planets, rocky planets, the first small planets residing in a star's habitable zone, and the first confirmed transiting planets orbiting two stars (circumbinary planets). Despite these impressive "firsts," Kepler is primarily a statistical mission to measure the frequencies of planets around Sun-like stars. With Kepler, we've learned that planets are abundant in our galaxy. Kepler has also revealed a treasure trove of exotic systems, whose architectures and frequencies provide a window into the formation and evolution of planetary systems (August 2013 issue, page 18).

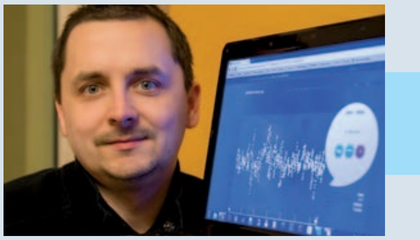
The Kepler science team uses automated detection algorithms to search the Kepler light curves for repeating transit-like features. Planet Hunters complements the machines by utilizing the human brain's innate ability to pick out outliers to identify planet transits that the computers potentially missed. More than 280,000 volunteers worldwide have helped to visually inspect the publicly released Kepler light curves for the signatures of transiting exoplanets, drawing boxes around potential transits spotted in the web interface. Five to 10 people independently review the same 30-day segment of a random Kepler star's light curve. To identify new planet candidates, these multiple responses are assessed and combined. Our volunteers also identify new planet candidates with a companion to the main classification interface known as Talk (**talk.planethunters.org**). With Talk, volunteers can actively discuss the light curves served on the Planet Hunters site with other members of the community and the science team.

Launching Planet Hunters was a bit of gamble. My fellow members of the Planet Hunters team and I didn't know if people would come and review graphs of Kepler light curves, which are not as beautiful as Galaxy Zoo's stunning galaxy images. We wondered if the project would find anything new. The Kepler automated algorithms had a head start and already searched the same observations for planets. But the gamble paid off big time! The response has been overwhelming, with more than 20 million classifications made to date. The project has discovered two confirmed planets and more than 30 unique planet candidates, with potentially many more to come. Our volunteers have also discovered new RR Lyrae variable stars, dwarf novae, and eclipsing binary stars.

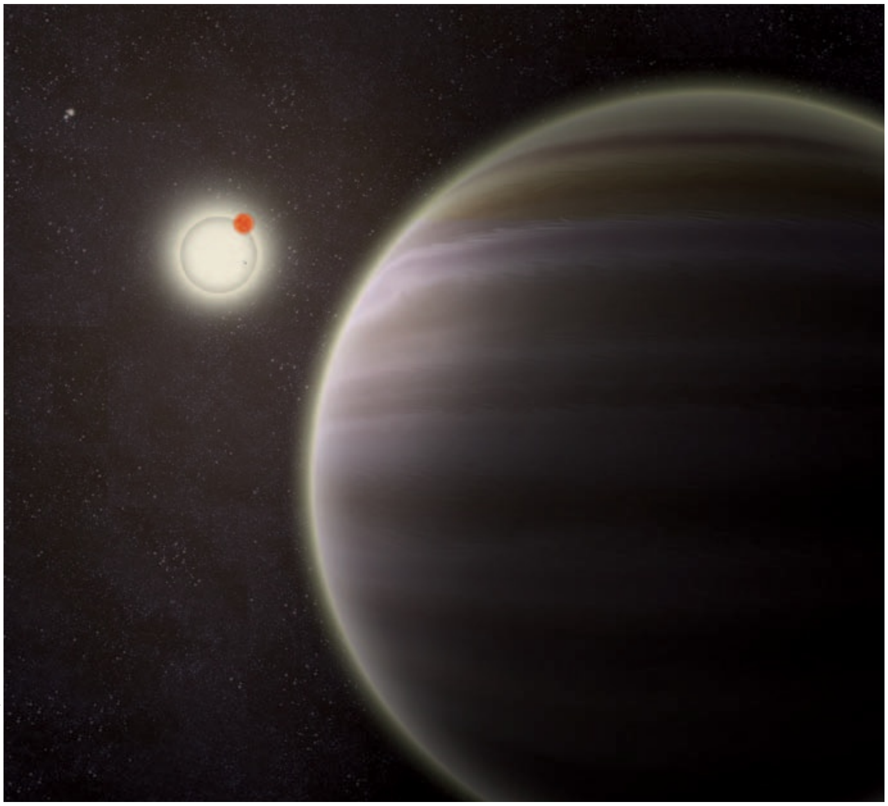
With so many eyes inspecting the light curves with Planet Hunters, there were bound to be surprises, such

COMMUNITY ENGAGEMENT *Left:* Planet Hunters's Talk section enables citizen scientists to converse with one another and with the Planet Hunters science team about light curves and other topics.

PLANET CODISCOVERER Polish citizen scientist Rafał Herszkowicz was one of the first to notice a transit signal from the planet PH2 b.



RAFAŁ HERSZKOWICZ



HAVEN GIGUERE / YALE UNIVERSITY

ROBERT GAGLIANO

KIAN JEK

CIRCUMBINARY PLANET
Far left: **In this illustration, we see a rendition of PH1 b — the first planet discovered by Planet Hunters' citizen scientists and the first planet known to exist in a quadruple-star system. It orbits the two stars to the planet's immediate left. In the far upper left, we see the other two stars in the system.**

CITIZEN SCIENTISTS
Planet Hunters volunteers Robert Gagliano and Kian Jek discovered PH1 b, which turned out to have major scientific importance.

as our first confirmed planet discovery. Planet Hunters volunteers performed their own investigations to look for additional transiting circumbinary planets with our Talk discussion tool. Such planets have proved challenging for automated routines to identify. The planet transits can be easily washed out by the much deeper stellar eclipses, drops in light caused by the two stars passing in front and behind each other. Unlike planets around a single star, the shape and repeat timing of the transits also vary significantly due to the changing velocities and positions of the binary's two stars.

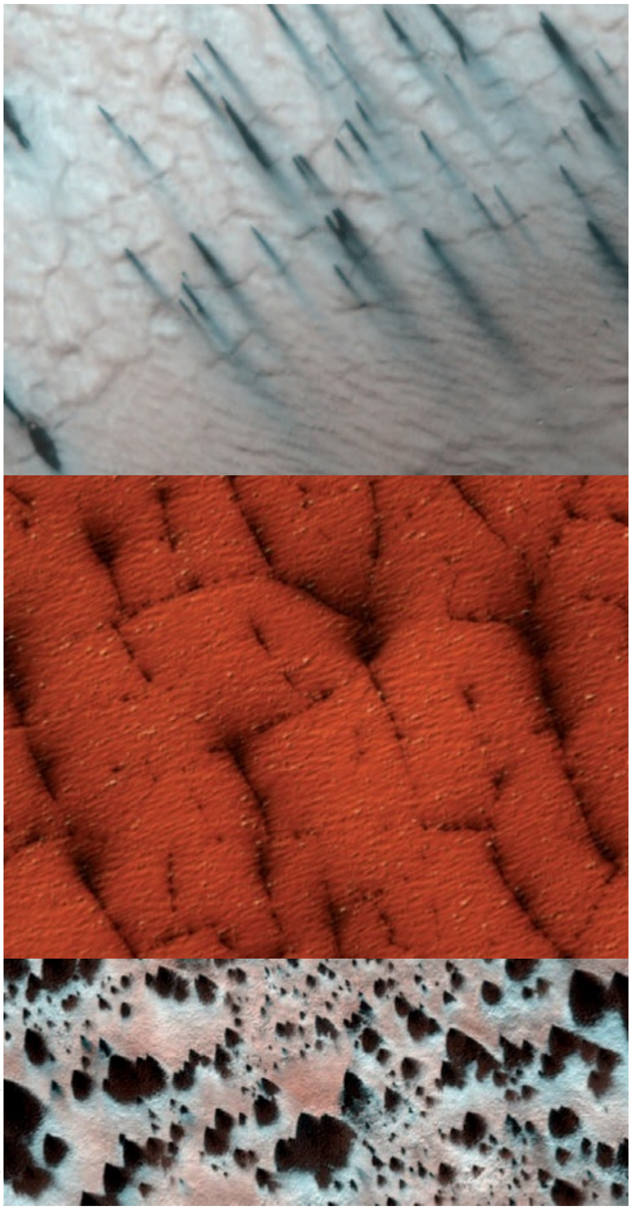
Jackpot!

After careful scrutiny, volunteers Robert Gagliano of Cottonwood, Arizona, and Kian Jek from San Francisco, California, spotted two transit-like features in the light curve of the known eclipsing binary KIC 4862625. From the NASA public archive, they downloaded the light curve for the next three months of Kepler observations, which had not yet been uploaded onto the Planet Hunters site. They found a third transit close to the time they predicted, with a depth similar to the previous two, and then notified the Planet Hunters science team. Analysis of the Kepler light curve, combined with follow-up observations with the 10-meter Keck telescopes and deep optical imaging from the 0.9-meter SARA telescope on Kitt Peak, confirmed the planetary nature of the transiting body. This is only the seventh confirmed circumbinary planet, and as Planet Hunter's first confirmed planet, it's been named PH1 b.

PH1 b is a 6.2-Earth-radii giant (between Uranus and Saturn in size) that resides beyond the 20-day orbit of an eclipsing pair of 1.5- and 0.4-solar-mass stars. The planet transits across the larger star every 138 days. Further observations, including adaptive-optics imaging, revealed another pair of stars about 1,000 astronomical units from the planet. This second binary is almost certainly orbiting the previously known binary, making PH1 the first known quadruple-star system to host a planet. PH1 b's properties will help shed light on how planets form in such dynamically extreme environments.

PH2 b, the project's second confirmed planet, is a 10.1-Earth-radii world orbiting every 282.5 days around Sun-like star KIC 12735740. The planet was discovered during a volunteer-organized search of the Talk tool for new planet candidates. PH2 b's discovery was truly an international effort. Rafał Herszkowicz from Poland was the first person to flag a transit in the main Planet Hunters website. In February 2012, Mike Chopin in the U.K. was the second to flag a transit and the first to post his finding on the discussion tool. Hans Martin Schwengeler in Switzerland then went on to look at the rest of the publicly released Kepler data months later and spotted additional transits, making PH2 b a likely planet candidate. The discovery was then passed onward to the Planet Hunters science team, who subsequently confirmed PH2 b's planetary nature.

The Jupiter-size gas giant resides in the star's habitable zone, the goldilocks region where it is predicted to



NASA / JPL-CALTECH / UNIVERSITY OF ARIZONA (3)

EXPLORE MARS Mars Reconnaissance Orbiter's HiRISE camera captured these images of fans and blotches on the southern polar ice cap. By visiting planetfour.org, you can explore Mars from your home and help scientists monitor these features as the ice cap thaws in the southern spring.

be not too hot and not too cold for water to exist in liquid form. PH2 b is too large to be a rocky world and instead is probably composed mostly of hydrogen and helium, like Jupiter and Saturn. But if the planet has large, rocky moons, they could potentially harbor liquid water on their surfaces. Radial-velocity observations and adaptive-optics imaging from Keck constrain the magnitude of the host star's wobble due to PH2 b's gravitational tug as it orbits. Analysis of these observations rule out the possibility of a star or brown dwarf orbiting KIC 12735740, validating PH2 b as a bona-fide planet.

Last May, Kepler suffered a mechanical failure that has potentially ended its mission (August 2013 issue, page 10). Kepler requires very exact pointing to detect the drop in light due to rocky exoplanets. Kepler uses reaction wheels to carefully nudge the spacecraft to keep the 160,000 stars nearly precisely on the same locations on the imaging plane to achieve the required photometric sensitivity. Kepler needs three reaction wheels to successfully point at its target field, and was launched with one spare. One of the four reaction wheels had previously failed in July 2012. With the malfunction of a second wheel in May 2013, Kepler lost its ability to point.

However, NASA engineers have come up with an ingenious plan for using the Sun to steady the spacecraft, balancing Kepler such that only two reaction wheels are mainly needed. This means Kepler would no longer stare at its original field; it would point to new star fields along the ecliptic that would be observed for shorter durations (40 to 80 days) and with fewer numbers of monitored stars. Engineering tests look promising, and the new mission concept, dubbed K2, recently passed its first hurdle, receiving the go-ahead from NASA to be considered in the Senior Review that will decide if the two-wheeled mission will be funded. NASA will soon make the final decision on whether the K2 mission will proceed.

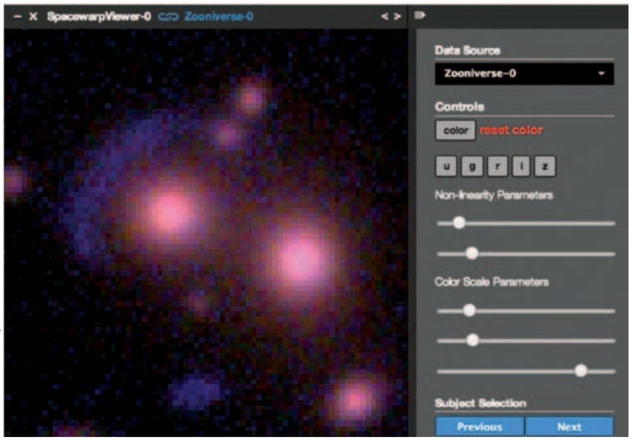
The prospect of a new haul of exoplanets with K2 is exciting, but even if Kepler's exoplanet-hunting days are over, its legacy is far from finished. The Kepler team and the astronomical community are swamped with its exquisite light curves and still has nearly one year of data waiting to be fully analyzed. Planet Hunters has barely scratched the surface of the Kepler data. There will be many more discoveries yet to come with your help.

The Future Is with the Machines

Astronomical surveys in the coming decade will enter the petabyte era with new instruments and observatories currently being planned and built, such as the Large Synoptic Survey Telescope (LSST) and the Square Kilometer Array (SKA). LSST is an 8.4-meter optical telescope currently being constructed in northern Chile that will survey about 18,000 square degrees of the Southern skies in five filters. Once LSST opens its eyes to the sky in around 2022, it will produce the largest public dataset in the world, generating 15 terabytes worth of image data each night!

The SKA will be the largest radio telescope ever built when it comes online in the next decade. Radio dishes will be constructed in Australia and South Africa and combined to produce an effective collecting area of 1 square kilometer. The SKA will generate roughly 11 terabytes of raw data per second with sensitivity unmatched by present-day radio arrays.

Astronomers will use both LSST and the SKA to study everything from dark matter and dark energy to small bod-



SPACEWARPS.ORG / CFHT LEGACY SURVEY

A WARPED PERSPECTIVE Visitors to spacewarps.org can help discover distant galaxies (such as these) that have been gravitationally lensed by foreground clusters of galaxies. This enables scientists to probe the distribution of visible and dark matter in the foreground clusters.

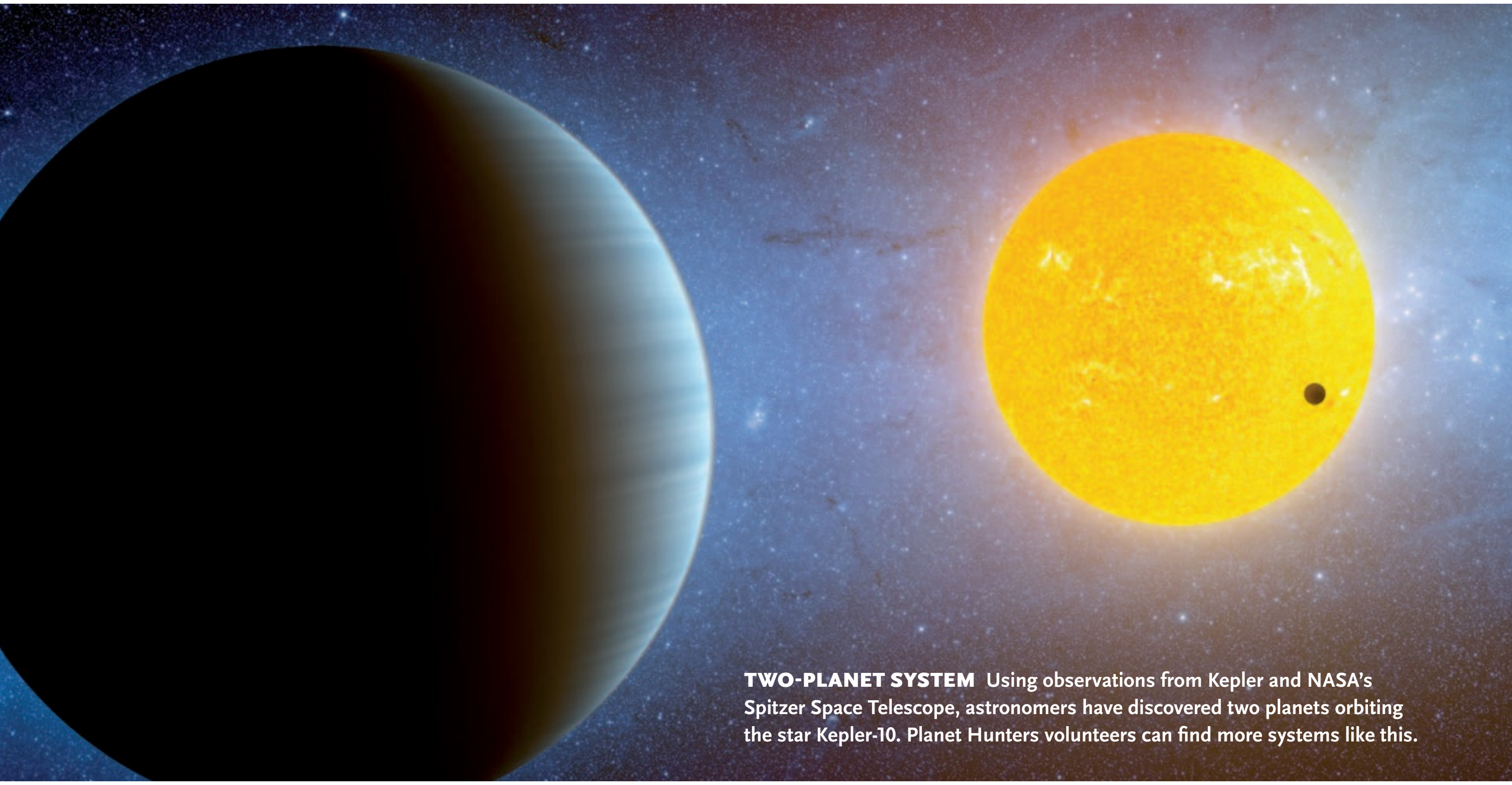
ies in our solar system. These immense datasets will bring new challenges, and citizen science will have to evolve.

It took nearly 14 months for volunteers in the second incarnation of Galaxy Zoo to classify 304,122 galaxies from the Sloan Digital Sky Survey. LSST will provide snapshots of *billions* of new galaxies. That will be far too much data for online citizen science in its current form to take on, even if everyone in the world playing *Angry Birds* spent that time on Galaxy Zoo instead. The solution is to join forces with the machines. The bulk and routine tasks will be given to the computer classifiers, which will likely be trained by human-based classifications. Citizen scientists will be given the more difficult tasks and likely enlisted to review a subset of the images the computers classify to teach and improve the automated algorithms.

In the meantime, while we wait for the arrival of LSST and the SKA, whether it's identifying craters on the Moon (**moonzoo.org**), finding undiscovered gravitational lenses (**spacewarps.org**), or mapping seasonal features on the surface of Mars (**planetfour.org**), why not help astronomers explore our wondrous universe? It's only a click away at the Zooniverse. ✦

Former Yale University astronomer and planetary scientist ***Meg Schwamb*** *is now at the Institute of Astronomy and Astrophysics at Academia Sinica in Taiwan. As a member of the science team for Planet Hunters and Planet Four, she uses citizen-science results to explore how planets form and evolve.*

To learn more about the Mars and Space Warps citizen science projects, visit skypub.com/citizenscience.



TWO-PLANET SYSTEM Using observations from Kepler and NASA's Spitzer Space Telescope, astronomers have discovered two planets orbiting the star Kepler-10. Planet Hunters volunteers can find more systems like this.

NASA/AMES / JPL-CALTECH

How to Build a

GIANT MAGELLAN TELESCOPE / GMTO CORPORATION

Construction of the world's largest ground-based optical telescope takes astronomical engineering to the next level.

Robert Zimmerman

The next generation of megatelescopes took an important step closer to reality on October 23, 2012. That was the day the University of Arizona's Steward Observatory Mirror Laboratory announced it had finished polishing the first mirror of the Giant Magellan Telescope (GMT), to be built at Las Campanas, Chile.

A competitor in the race for the largest ground-based optical telescope, GMT will combine seven 8.4-meter segments into a flower-like primary with the resolving power of a single mirror 24.5 meters (80 feet) wide. The secondary mirror has the same design, with each of its seven segments 3.25 meters wide; they will flex in real time to tune out atmospheric distortions. The behemoth will dwarf the current generation of 8- to 10-meter ground-based optical telescopes, and if its construction beats that of the proposed Thirty Meter Telescope and the 39-meter European Extremely Large Telescope, it will temporarily be the largest in the world. (See the box on page 27 to see how the GMT measures up to its competitors.)

Not only will GMT gather more light than any telescope built so far, its corresponding sensitivity and resolution will result in deep images 10 times sharper than Hubble's. Equipped with this kind of next-generation telescope, astronomers will delve into questions about the formation of the first galaxies and the nature of dark energy and dark matter. They also hope to discover new low-mass exoplanets and might even capture the first direct image of a "wet and warm" rocky planet that orbits in its star's habitable zone.

Though making and combining several smaller mirrors is simpler than building one giant mirror, the concept carries its own set of challenges. Because GMT's seven mirrors combine to form a single parabolic primary, the outer segments cannot be parabolic themselves. Instead, they must be slightly saddle-shaped to match the curve found at the outer edge of the central mirror.

The first completed mirror was one of these outer segments and the first of its kind. A large mirror with such an asymmetric shape had never been built before, says Buddy Martin, a scientist at the Mirror Lab. Its successful completion was proof it could be done.

Attaining that proof was far from simple, demonstrating astronomical engineering of the highest order.

Giant Telescope

Spin Casting Mirrors

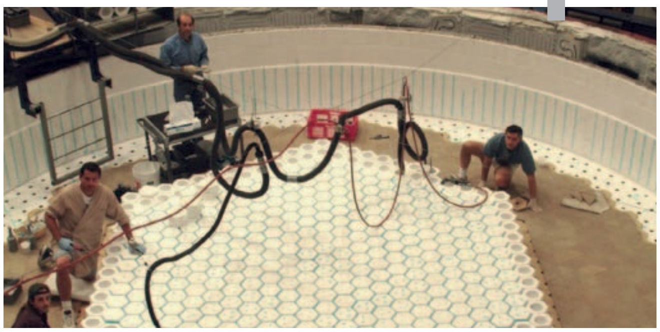
Manufacturing a single 8.4-meter mirror is not easy — in fact, the Mirror Lab is the only place in the world that does it. Yet as high-tech as the business is, it's surprising how much is still done by hand, and in much the same way as first devised decades ago by the Mirror Lab's founder and scientific director, Roger Angel. Angel crafted a technique called spin casting: spinning the molten glass shapes its surface into a paraboloid, reducing the time and energy needed to grind in the curve.

"The reason we are still making the mirrors the same way after 20 years is that it's not possible to make them better," explains Angel. "I believe that if aliens out there are using big telescopes to look at us, they would have had to build them the same way."

The mirror starts with the glass, a high-grade version of what's used in common cookware such as Pyrex. Called E6 low-expansion borosilicate, the glass has a low thermal coefficient, so it holds its painstakingly crafted shape through temperature changes. It also melts at relatively low temperatures, becoming viscous (like cold honey) at 1165°C (2129°F). "There is other glass that is better thermally, but you can't melt it," says Angel.

The glass is manufactured in Japan, forged in clay pots one ton at a time. The pots are cracked off, then the glass is broken into chunks slightly bigger than softballs. The outer chunks that touched the pot are discarded to ensure that the glass used for the mirror has never been in contact with other chemicals and will melt together seamlessly. All told, casting each 8.4-meter mirror requires some 16,000 glass chunks, together weighing 19.2 tons.

Technicians carefully place each piece of glass onto a ceramic mold, which is also largely assembled by hand. Once the glass pieces are in place, a furnace lowers to enclose the mold before heating it to 1165°C. The glass melts over 1,681 hexagonal columns to take on an internal honeycomb structure that maintains stiffness while eliminating 80% of the weight. As the chunks begin to melt and seep into the honeycomb mold, the furnace and mold together spin five times per minute to shape the mirror face into a preliminary paraboloid.



RAY BERTRAM / STEWARD OBSERVATORY MIRROR LAB / UNIVERSITY OF ARIZONA

THE HONEYCOMB MOLD Technicians bolted 1,681 hexagonal columns into place by hand. Molten glass flowed around (not into) the columns to create honeycomb-shaped voids that allowed air circulation, maintained the mirror's stiffness, and lightened its weight.

1

ROBERT ZIMMERMAN

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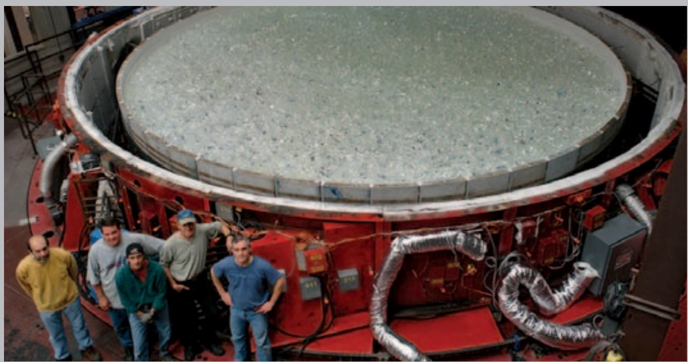

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R. BERTRAM / STEWARD OBS. MIRROR LAB / UNIV. OF ARIZ. (2, 3, 4)

5

PAT MCCARTHY

SPIN CASTING 1. Two sample hexagonal columns are shown. The one on the left has been cut open to show its interior and how it's bolted into place. The glass will melt and solidify around (not inside) these cores. **2.** The crew places 19.2 tons of glass chunks on top of the ceramic mold. **3.** After a long day, they pose in front of their handiwork: a mirror ready for casting. **4.** The furnace lid lowers to enclose the mold. It will take about a week to heat the glass to a maximum temperature of 1165°C. **5.** The furnace and mold together spin at a rate of 5 revolutions per minute to give the mirror surface a preliminary parabolic shape.

The furnace and mold keep spinning as the glass cools rapidly to 650°C. At that point, the glass becomes sufficiently solid that further cooling must be done very carefully to avoid fracturing the glass; the furnace adds heat to gradually cool the glass over the next three months.

Once the glass reaches room temperature, technicians lift the furnace off, remove the top, sides, and floor of the honeycomb mold, and apply a high-pressure water jet to wash out the mold's hexagonal columns. Finally, the mirror blank is ready for polishing.

Polishing the Mirror

Though GMT's first mirror was spun-cast in 2005, the polishing that ground the mirror's surface to its asymmetric shape was not completed until seven years later. That's because even before polishing could begin, the Mirror Lab had to design and build a whole range of new equipment capable of measuring defects in the mirror's surface as small as 5 nanometers high.

The opticians at the Mirror Lab were keenly aware of the spherical aberration that plagued the Hubble Space Telescope, caused by a measuring error during polishing. "Every concern that Hubble had, we have in spades," explains Martin. "We can't rely on just one test."

So, unlike Hubble, they typically have at least two independent measuring devices check a mirror's shape during polishing. For the GMT's unusually shaped mirrors, though, they decided to develop *four* tests. Each test requires technology that is in some manner entirely new.

For example, all telescope mirrors are measured with a *null corrector*, a test that aims a laser beam at the mirror's surface. Engineers compare the reflection's wavefront with the wavefront that would be produced by the ideal mirror; any disagreement between the two tells them where on the mirror they need to polish. But the GMT null corrector is 10 times larger than any built before, and the mirror it must measure is severely asymmetric. To build the test, the lab had to manufacture a 3.75-meter mirror, a major investment in itself, as well as a 28-meter-tall test tower to house the mirror along with other testing equipment.

The team then designed a second *scanning pentaprism* test, to guard against errors in the first test. Also housed high in the test tower, the device beams a laser through a five-sided prism to scan the mirror's face. The laser beam simulates starlight, with all rays parallel as they hit the mirror. If the mirror's curvature is correct, no matter where the beam hits the mirror, its reflection should focus to the same point. A camera records the focused beam, and any deviations it spots indicate polishing errors.

For the third test, the lab built another laser system inside the test tower. This laser beam tracks the position of a small retroreflector that sweeps across the mirror's face. The retroreflector's three mirrors, arranged like the corner of a cube, reflect the laser beam back to its source, so the laser tracker can measure the shape of the surface directly.

R. BERTRAM / STEWARD OBS. MIRROR LAB / UNIV. OF ARIZONA

POLISHING An engineer monitors the Large Polishing Machine as it shapes the first GMT mirror. Tests are performed throughout polishing to ensure the mirror's face has the correct shape.

Finally, a fourth test involves projecting a simple pattern of lines at the mirror and comparing the reflected result with a reference pattern.

Tracking Down Mysterious Errors

The polishing of the first GMT mirror did not go as smoothly as anyone would have liked. The first two devices, the asymmetric null corrector and the scanning pentaprism, test for optical defects such as spherical aberration. And to the scientists' chagrin, the results from these two tests did not agree. Something was wrong with at least one of the tests, and the mirror might have had more optical defects than anticipated.

"We looked for a lot of potential sources of error," Martin explains. "We kept finding that one error after another was not there."

After months of tests and experimentation, they finally found it: a small error in the pentaprism test. The camera used in the device is no ordinary camera — it contains an array of microscopic lenses, one for each of its detector's pixels. Unbeknownst to the scientists, the lenslets had displaced the pentaprism's focused beam by a tiny amount that depended on the beam's direction. A small-scale lab test showed that the displacement caused by the lenslets mimicked spherical aberration almost exactly.

Correcting for this effect brought the two tests into much better agreement. Now the scientists knew that the mirror's spherical aberration was small enough that they could easily correct for it using the 165 active supports that control the mirror's large-scale shape. These supports bend the mirror based on feedback from sensors within the telescope because, as with all large mirrors, the GMT mirrors will flex under their own sizable weight.

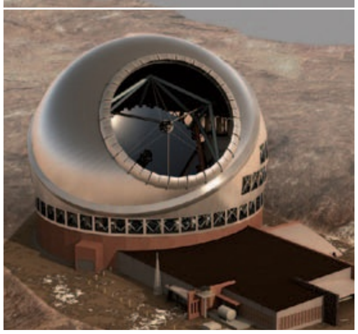
The Megatelescopes Are Coming

The Giant Magellan Telescope isn't the only behemoth planned for the next decade. The Thirty Meter Telescope (TMT) and the European Extremely Large Telescope (E-ELT) are competing with the GMT for the largest-in-the-world title. The table below summarizes the plan, progress, and schedule for the three megatelescopes.

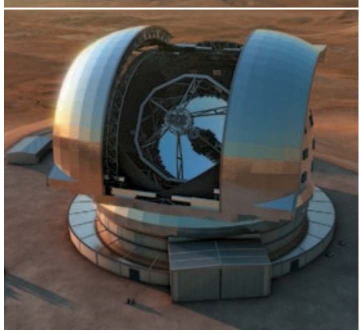
Telescope	GMT	TMT	E-ELT
Location	Las Campanas, Chile	Mauna Kea, Hawaii	Cerro Armazones, Chile
Segments in primary mirror	7 circles	492 hexagons	798 hexagons
Segment size	8.4 meters	1.44 meters (corner to corner)	1.44 meters
Effective diameter of primary	24.5 meters	30 meters	39.3 meters
Construction start	April 2014	April 2014	March 2014
First science	2020*	2022	2024
Projected cost	$800 million	$1.2 billion	$1.5 billion
Funds raised to date	More than half	About 80%	About two-thirds

* Using four of seven mirrors. Installation of remaining mirrors scheduled to complete by 2022.

GIANT MAGELLAN TELESCOPE / GMTO CORPORATION

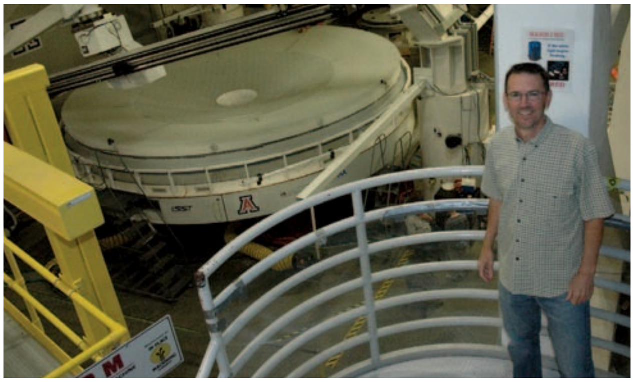


TMT OBSERVATORY CORPORATION



ESO / LUIS CALÇADA

Visit skypub.com/megatelescopes for more information on the three mammoth telescopes' progress.



ROBERT ZIMMERMAN

AT THE MIRROR LAB **Buddy Martin stands in front of the Large Synoptic Survey Telescope's combined primary and tertiary mirror. The unique mirror sits below the nine-story tower that houses four devices for testing surface shape.**

"With this active correction," Martin says, "the first GMT mirror's shape is nearly perfect, with a typical error of only 19 nanometers."

The Giant Magellan Telescope's Future

With the first mirror complete, the plan is to continue grinding out mirrors for the next decade. Two more off-axis mirrors have been cast, one in January 2012 and one in August 2013, and the polishing of their front surfaces should begin in 2015 and 2016, respectively.

The current timetable is a bit delayed because the Mirror Lab has contracts to make mirrors for two other telescopes, including the Large Synoptic Survey Telescope in Chile. Once the Mirror Lab has completed these contracts, it will devote its operations to making GMT's remaining mirrors. By 2017 it should begin churning out mirrors on a 12- to 14-month cycle.

This schedule, of course, assumes that the GMT partnership raises the funds to finish the telescope. The consortium includes the Carnegie Institution for Science, the Smithsonian Institution, and eight other universities and institutions across the U.S., Australia, and South Korea. The group to date has raised more than half of the telescope's projected $800 million cost.

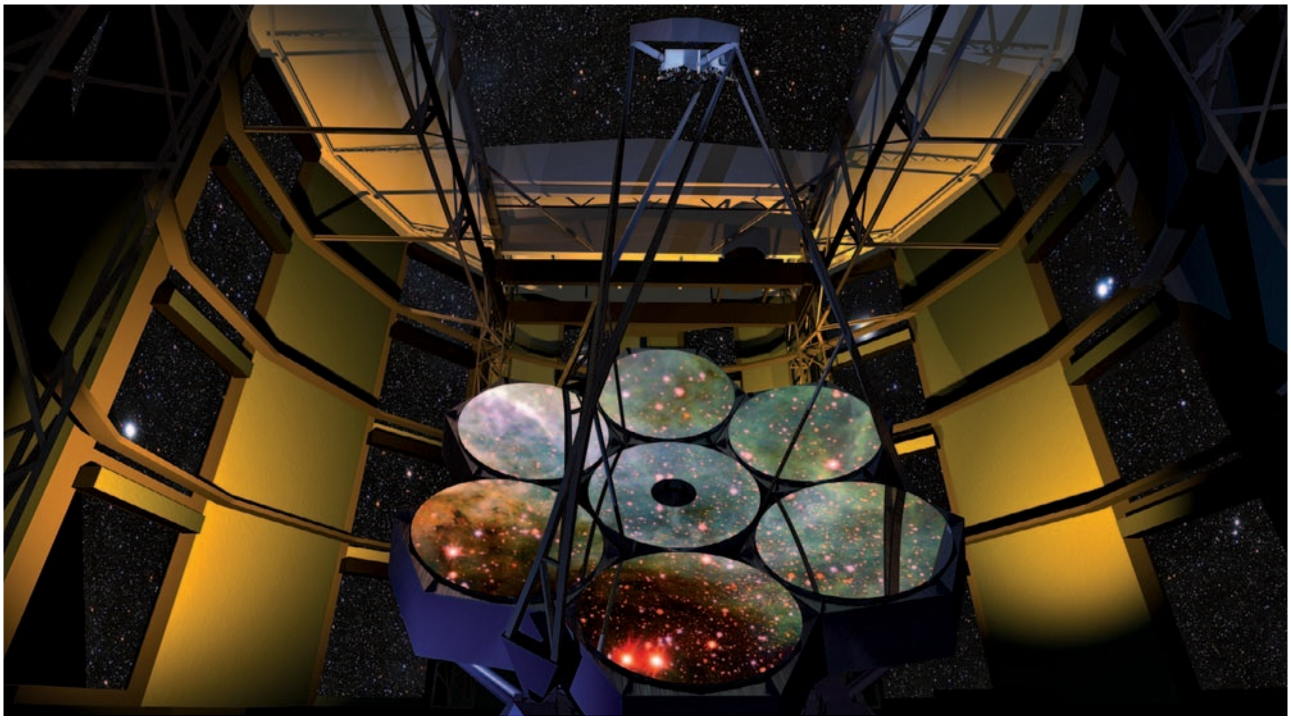
And the partnership is moving forward, buoyed by the first mirror's success. A final design review is planned for January 2014, and construction of the GMT facility should begin later in the year.

The three mirrors cast so far are destined for GMT's outer ring. The Mirror Lab will then cast and polish GMT's central mirror. By 2020, GMT is scheduled to see first light with just these four mirrors installed; if all goes well, all seven mirrors will be installed by 2022.

And the odds are good that all *will* go well. One of the project's themes, Martin notes, is taking something they already know how to do — such as making an 8-meter telescope — and applying it on a larger scale.

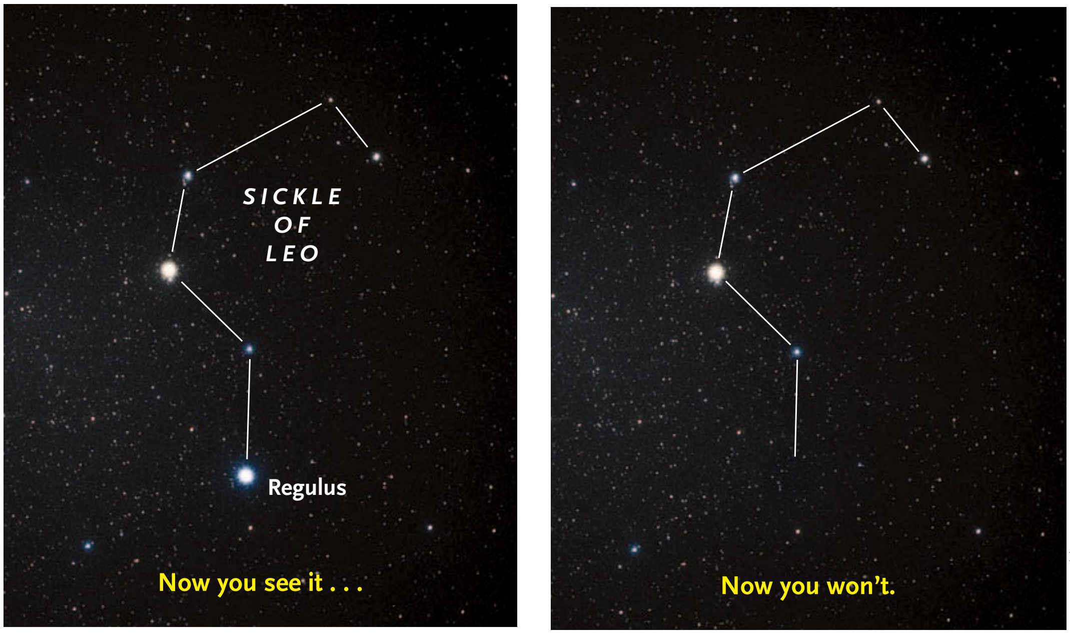
So stay tuned for some spectacularly large-scale ground-based astronomy coming in the next decade. ✦

S&T *contributing editor* ***Robert Zimmerman*** *reports on science, astronomy, culture, and history at his website, Behind the Black, at* **behindtheblack.com**. *A new edition of his first book,* Genesis: The Story of Apollo 8*, is now available as an e-book at all e-book sellers.*



GIANT MAGELLAN TELESCOPE / GMTO CORPORATION

Asteroid to Occult



AKIRA FUJII (2)

Millions of viewers can see one of the brightest stars in the sky black out when an asteroid crosses in front of it.

GET READY for the best and brightest asteroid occultation ever predicted for North America. It will happen late on the night of March 19–20, within a few minutes of 2:07 a.m. Eastern Daylight Time, for more than 20 million people in the New York metropolitan area and parts of Long Island, New Jersey, Connecticut, upstate New York, Ontario, and Quebec. Anyone in the occultation path who looks up should be able to see (weather permitting) the 1st-magnitude star Regulus vanish from the sky for as long as 14 seconds, as the invisibly tiny asteroid 163 Erigone passes in front of it and blocks its light.

Regulus will be about 40° high in the southwest. (On the evening map on page 43, Regulus and its constellation Leo are still high in the southeast). The bright Moon shining above your left shoulder as you face Regulus will hardly matter, nor will most light pollution.

This is the first time in history that such a strikingly obvious asteroid occultation has been predicted to cross such a heavily populated area. But this is more than just a chance to watch a moment of rare celestial drama. We hope to enlist thousands of people in a citizen-science effort to document this event more thoroughly than any asteroid occultation has been up to now. From this, we hope to obtain a very precise picture of the size and shape of Erigone (Eh-RIG-uh-nee), something that cannot be done any other way without sending a spacecraft there.

The International Occultation Timing Association (IOTA) collects observations for about 200 asteroid occultations around the world each year. They come mostly from amateurs, who either make video recordings of the star vanishing and popping back, with a time stamp on each video frame, or who sometimes just make eyeball judgments of the times.

In many cases, only a single observer documents the event. This doesn't tell us much, aside from setting a lower limit on the asteroid's size and perhaps refining its orbit a bit. Two or three successful observers at well-separated sites may produce a fairly good indication of the asteroid's diameter. But if many people make timings from well-spaced locations, we can construct the asteroid's entire irregular silhouette, as in the examples on page 32.

Above: **Late on the night of March 19–20, bright Regulus will briefly go missing for well-positioned skywatchers.**

Regulus *over* New York

STEVE PRESTON

The more good timings we have, the better this is done.

Since the first predicted asteroid occultation was seen in 1961, just one other has involved a 1st-magnitude star: Regulus again, occulted by 166 Rhodope for parts of Europe in 2005.

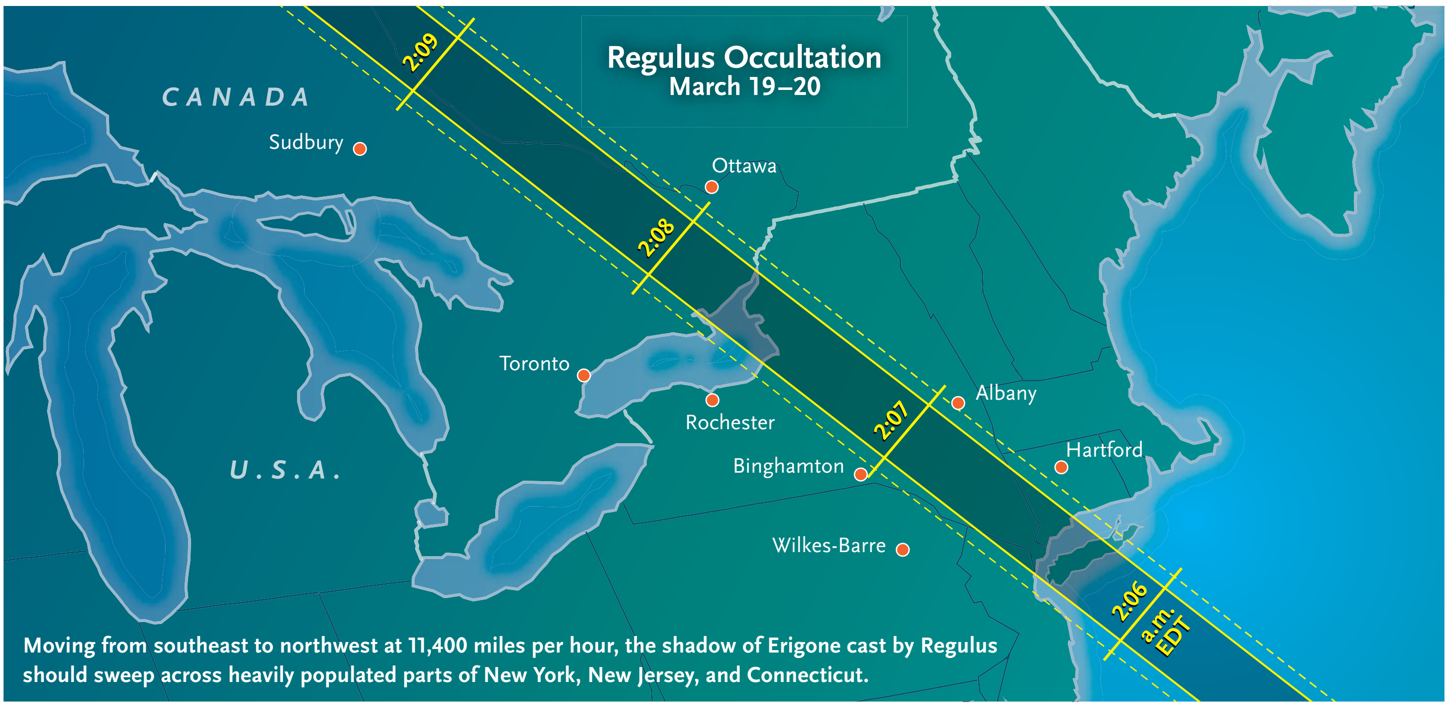
The map below shows where the Regulus-shadow cast by Erigone is predicted to go this March. IOTA encourages everyone anywhere near the path to watch for this striking event and to spread the word to the public in the weeks and days beforehand.

Asteroid occultations are enormously exciting events to watch, and nothing else in amateur astronomy can match the precision that comes from the data collected. We hope to obtain 1-kilometer resolution of Erigone's presumably rugged outline, even from our distance 177 million kilometers (110 million miles) away. What else could most of us ever hope to measure to better than one part in 100 million? To look at it another way, that's a resolution of about 1 milliarcsecond, hundreds of times finer than any amateur telescope could ever resolve directly.

The Odds of Success

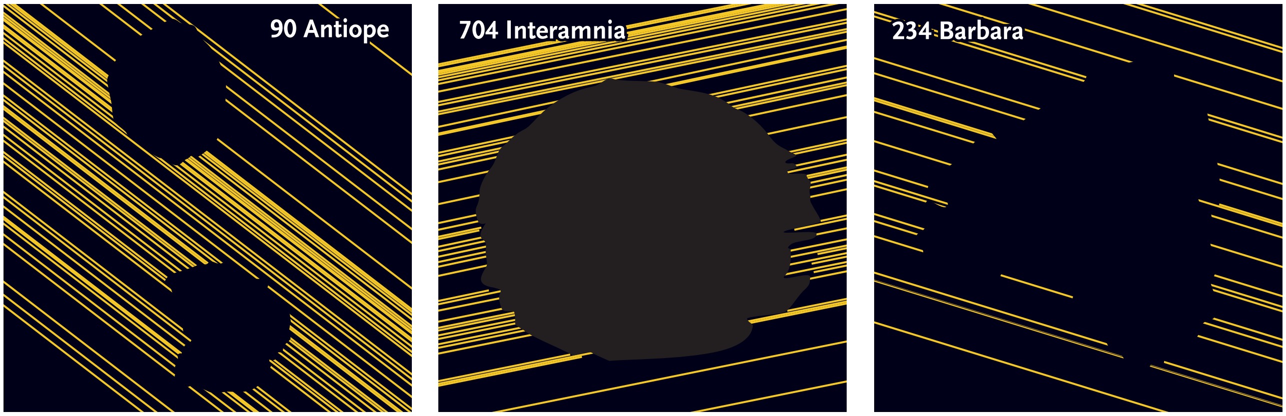
Chasing asteroid occultations is always a game of chance. Predictions are imperfect, and the shadow might miss you completely. But this time your chances look very good.

The shadow path is always as wide as the asteroid or a little wider, depending on the incoming shadow's angle to the ground. Even the best star catalogs and asteroid orbits have uncertainties that are significant compared with most asteroids' tiny angular diameters. In the worst cases, the uncertainty may be several times the path width. But not this time: we're confident that the path below is pretty accurate. The positional data for Regulus (both its position and its proper motion year by year) were confirmed by the 2005 occultation. And Erigone, discovered in 1876, is relatively large and well observed. So the uncertainty this time is relatively small compared with the asteroid's assumed diameter of about 73 kilometers (45 miles). The dotted lines on the map show the remaining position uncertainty of the path edges at the 68% confidence level. That is, the actual path has a 68%



Moving from southeast to northwest at 11,400 miles per hour, the shadow of Erigone cast by Regulus should sweep across heavily populated parts of New York, New Jersey, and Connecticut.

S&T: LEAH TISCIONE



S&T: LEAH TISCIONE; SOURCE: IOTA (3)

Thanks to inexpensive automated video setups, amateurs are accurately timing ever more asteroid occultations from many sites. Each line shows the times when one observer saw the star present (yellow) and absent (black). Based on your location (GPS accuracy is good enough), your timings can be aligned with those from other observers to reveal the asteroid's silhouette, as above. Antiope proved to be double!

chance of falling entirely between the dotted lines.

Similarly, the predicted times on the map should be off by no more than a fraction of a minute. But check for late refinements on IOTA's web page, listed below, as the date draws near.

Of course, we need negative observations from just outside the path too, to determine where the asteroid's edges *don't* extend! And if by chance Erigone has a small moon, observers far from the path could catch it.

Don't expect to observe Erigone directly near the time of the event. At magnitude 12.4, it will be hopelessly lost in the glare of Regulus, which is 26,000 times brighter.

How to Time

The goal of observing an asteroid occultation may be simple, but achieving it can be challenging. The challenge is to determine when the star disappears and reappears very accurately — ideally to 0.1 second or better. Most experienced IOTA observers now record asteroid occultations with a video camera and use a GPS-based video time inserter, which places a very accurate time stamp into every video frame. This equipment is fairly inexpensive.

You can also collect useful data with less specialized equipment. Most of today's DSLR cameras have a video mode that should record Regulus at a reasonably high frame rate. Test this in advance. You can establish an accurate time base for each frame by recording the shortwave-radio time signals broadcast by WWV (at 2.5, 5, and/or 10 MHz) on the audio track of the DSLR.

And it's still worthwhile to make old-fashioned visual timings. Play WWV while holding an audio recorder, and shout when you see the star disappear and reappear. You can later extract the times of your shouts amid the time ticks, then apply a correction for your estimated reaction time. With care, this method can be good to a few tenths of a second. But video is much better.

The Size of Regulus Too?

Most asteroid occultations happen instantaneously as far as the eye can tell. But maybe not this time! Regulus is close (79 light-years) compared with most occulted stars and presents a bigger apparent disk. Like many hot, blue-white stars it's a fast rotator, spinning once every 16 hours (compared with about 27 days for our Sun). That's fast enough to spin it into an ellipsoidal shape. Using interferometry, astronomers have measured Regulus's ellipsoid as presented to Earth: It's 1.25 by 1.65 milliarcseconds in size, with the long axis oriented north-south.

Erigone will be moving across the sky by 6 milliarcseconds per second of time, so the disappearance and reappearance may appear not quite instantaneous, especially when seen from near the edges of the path, where the asteroid's limb will graze the star at an angle. In fact, you can see this happening in a video of the 2005 Regulus occultation made in Italy near the path edge; watch it at **youtu.be/7BXpK5sbOGY**. The larger your telescope, the higher your frame rate can be, so the more useful your video could be for profiling the disk of Regulus itself.

On the ground, the shadow will be moving northwest at 5.1 km (3.2 miles) per second, or 11,400 miles per hour.

More Information

IOTA has set up a dedicated web page with much more information, at **www.occultations.org/Regulus2014.** Check there for news, details of everything you'll need to time the event visually or by video, and where to report your results. The site also contains introductory material for the public, where you can point friends, relatives, news media, science teachers, and anyone else who wants to learn more about what promises to become an exciting public happening. ✦

__Steve Preston__ has long been a key player in the asteroid occultation world, supplying comprehensive predictions and maps at __asteroidoccultation.com__.

New Jersey Quasar Quest

BOB CAVA


BOB CAVA

Observing these exotic objects is easier than most people think.

Let's face it — "dark-sky paradise" isn't the first phrase that comes to mind when you think of New Jersey. So a program to observe quasars visually from New Jersey might seem like a bad idea. Nonetheless, I've had a bug about seeing quasars with my own eyes since the first time I saw a photo of gravitationally lensed quasars 20 years ago. This article describes what happened when I finally got around to trying.

At 13th to 14th magnitude, even the brightest quasars are barely visible specks, but there's something appealing about the fact that old photons, crossing space over unimaginable distances and times, can end their long journey in my eye. And then there's the challenge of the hunt and the thrill of victory, as weird as that may sound when the victory consists of seeing a tiny speck of light.

A few years ago I got serious about making up a quasar observing program. The perfect starting point is 3C 273, some 2 billion light-years distant in the constellation Virgo. It's the brightest true quasar in the sky, varying slightly around magnitude 12.8. I saw it from light-polluted Princeton in my 10-inch Maksutov after a night or two, without much effort or suffering.

That whetted my appetite, and I began my program. Most of the others turned out to be much more challenging.

Making a List

The first step was to make a bright quasar observing list — which turned out to be much more difficult than I expected. Many online resources are available, but it's quite a challenge to sort through them. The same object may be listed under many different names, so it's wisest to identify quasars by their coordinates rather than their names. But even the coordinates vary slightly between sources, and one catalog may list an object as a quasar while another calls it a Seyfert galaxy (see the box on page 37).

I decided to start with the East Valley Astronomy Club (EVAC) online *Quasar Observing Program*. (The URL for this and all other online sources mentioned in this article can be found at **skypub.com/quasarhunt**.) It lists 48 quasars down to magnitude 14.99. I eliminated all entries fainter than magnitude 14.6 or south of declination 0° on the grounds that they're too low and/or faint to view easily from New Jersey.

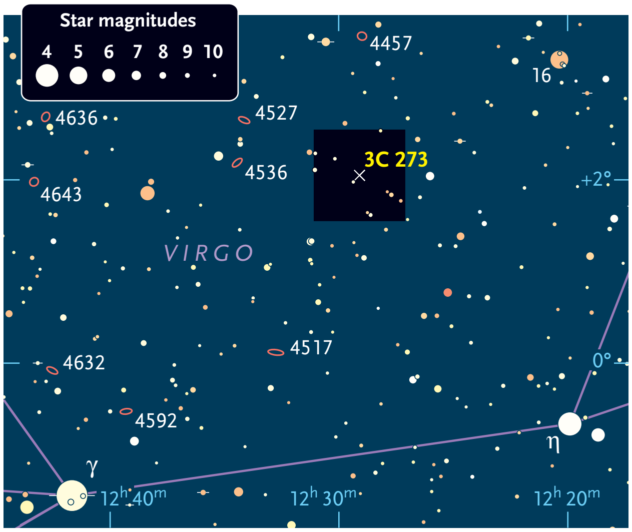
I crossed-checked this with Wolfgang Steinicke's *Catalogue of Bright Quasars and BL Lacertae Objects* and investigated problematic entries with the SIMBAD Astronomical Database and the NASA/IPAC Extragalactic Database. I ended up eliminating some objects that are clearly not quasars at all, plus a few that turned out to be much fainter than the magnitudes listed on the EVAC website. That left 12 objects, which are listed on page 36. I have now successfully observed nine of those.

Photos and Maps

Many amateurs who are interested in trying this kind of project will have Go To mounts or computerized setting circles that will get them to the right general area in the sky, but that's just the first step when searching for a quasar. The problem is that almost all quasars look exactly like stars, and 14th-magnitude stars are so abundant that there are likely to be several near the center of your field of view.

To identify your target quasar, you need images that are centered precisely on the correct coordinates. The ones in this article were generated by combining the red and blue POSS-II plates from the Digitized Sky Survey (DSS); similar results can be obtained from WikiSky or the Aladin Sky Atlas.

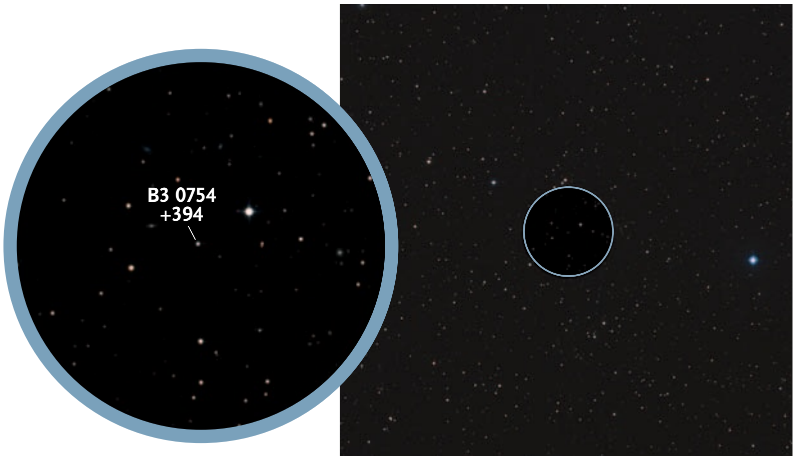
I will admit to being a dinosaur — I found the quasars by star-hopping, using DSS images and detailed maps. I started with the *Uranometria 2000.0 Deep Sky Atlas*, but that only shows stars down to 9th magnitude, so I supplemented it with detailed maps from a planetarium program. I included circles for the fields of the eyepieces I expected to use, and I printed the magnitudes of some of the stars on the maps so I could tell which star patterns I was looking at. (This is also useful because if you can't see nearby 13th-magnitude stars easily, then your quest for the quasar is doomed.) My highest-magnification maps typically show two to four times the field of view of my highest-power eyepiece.

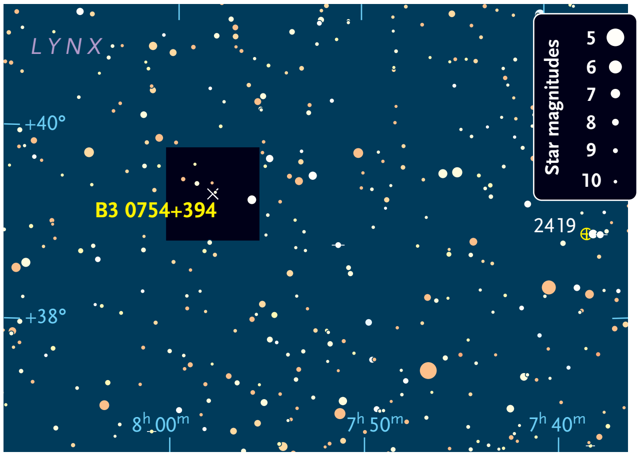


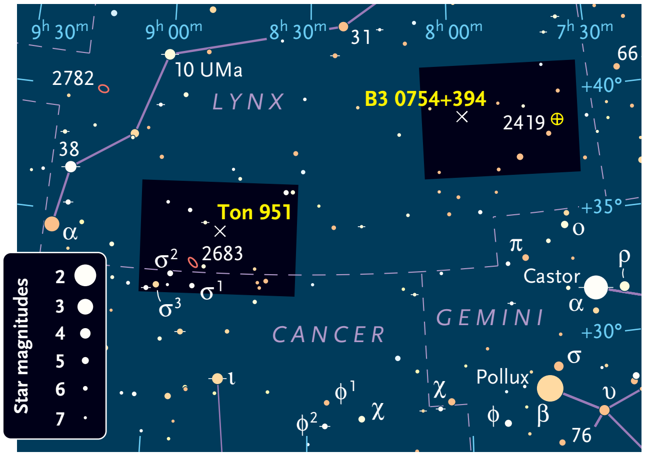
To find 3C 273, the brightest true quasar, use the map at top to point your telescope to the right part of the sky, then navigate to the exact location using your lowest-power eyepiece and the first image, which is 1° square. The circular image shows the central 12′ of the square image. Follow the same protocol for the other charted quasars. All sky images in this article are from the Second Palomar Observatory Sky Survey (POSS-II), courtesy Caltech and Palomar Observatory.

Locations and Equipment

I looked for the quasars from my home in Princeton, New Jersey, and from the New Jersey Astronomical Association observatory site in Vorhees State Park, which is barely 50 miles west of New York City. According to the Clear Sky Chart website, these are in the red and orange light-pollution zones, respectively. (White is brightest, red next, and orange third on an 8-level scale.) I did see some of the quasars from Princeton, but I had better luck from Vorhees State Park.







I used two telescopes: a 10-inch f/20 Telescope Engineering Company (TEC) Maksutov, and a homemade 16-inch f/4.5 Dobsonian with a Meade mirror. Due to its tight star images, the 10-inch didn't do badly at all — I observed several of the quasars with it, even from Princeton. The 16-inch at the darker observing site was definitely better, though. Finder scopes were useful to get to the general area, but I usually used the main scope at its lowest possible magnification to narrow in on the location before switching to higher power. I needed at least 150× to see any of the quasars on the list, and I often used magnifications of 250× or even higher.

Wide-field eyepieces helped me identify the patterns of the field stars when observing at high power. For example, I used 12-mm and 7-mm Naglers in the 16-inch scope. My Maksutov has a drive, which was extremely helpful for this activity, but my 16-inch Dob does not. That made

Bright Quasars in the Northern Sky

Object	RA	Dec.	Const.	Mag (v)	Redshift	Distance	Notes
UGC 545	$0^h 53^m 35.1^s$	+12° 41′ 34″	Psc	14.1	0.061	830 ml-y	Not yet attempted
HS 0624+6907	$6^h 30^m 02.6^s$	+69° 05′ 03″	Cam	14.2	0.370	4,100 m-ly	H, P, 16-inch
B3 0754+394	$7^h 58^m 00.1^s$	+39° 20′ 29″	Lyn	14.4	0.096	1,300 ml-y	M, V, 16-inch
Ton 951	$8^h 47^m 42.5^s$	+34° 45′ 05″	Lyn	14.5	0.064	860 ml-y	E, V, 16-inch
4C +29.45	$11^h 59^m 31.9^s$	+29° 14′ 44″	UMa	13.7 – 18.5	0.729	6,600 ml-y	F, V, 16-inch
PG 1211+143	$12^h 14^m 17.7^s$	+14° 03′ 13″	Com	14.2	0.085	1,100 ml-y	M, P, 16-inch
3C 273	$12^h 29^m 06.7^s$	+2° 03′ 09″	Vir	12.8	0.158	2,000 ml-y	E, P, 10-inch
PG 1351+640	$13^h 53^m 15.7^s$	+63° 45′ 46″	Dra	14.8	0.088	1,200 ml-y	H, P, 16-inch
Mrk 478	$14^h 42^m 07.4^s$	+35° 26′ 22″	Boo	14.6	0.077	1,000 ml-y	H, V, 16-inch
IRAS 17596+4221	$18^h 01^m 09.1^s$	+42° 21′ 44″	Her	14.5	0.054	740 ml-y	Not yet attempted
KUV 18217+6419	$18^h 21^m 57.2^s$	+64° 20′ 36″	Dra	13.8	0.297	3,400 ml-y	M, P, 10-inch
RX J23273+1524	$23^h 27^m 22.2^s$	+15° 24′ 36″	Peg	12.6	0.044	600 ml-y	E, P, 10-inch

Observing notes: E = easy, M = medium, H = hard, F = failed.

Locations: P = Princeton, V = Vorhees.

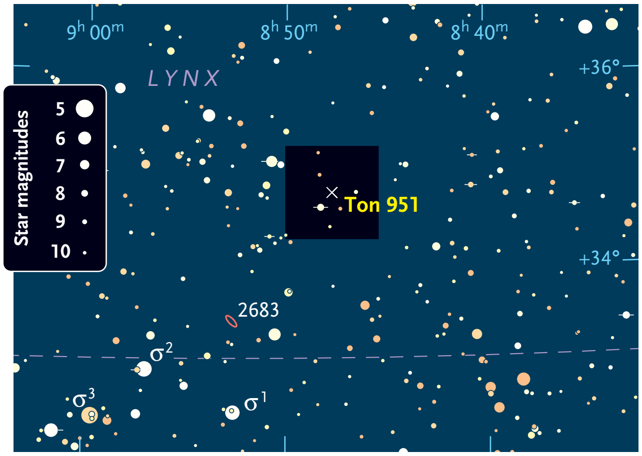
Instruments: 10-inch Maksutov, 16-inch Dobsonian.

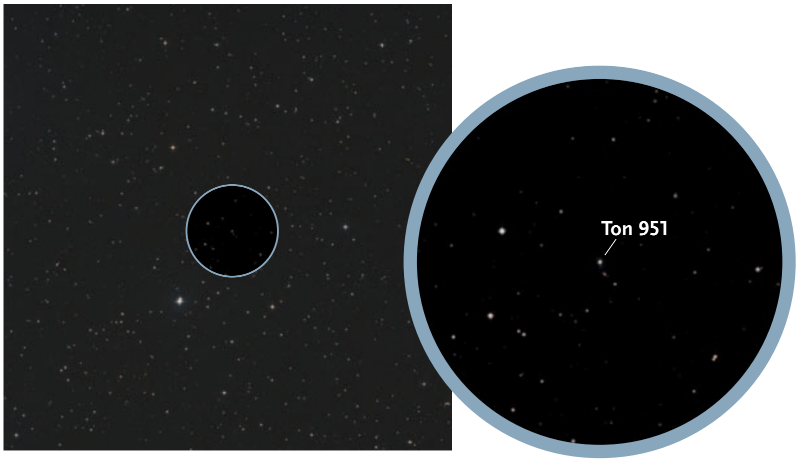
Magnitudes are from various sources; see skypub.com/quasarhunt.

Most of the objects are variable, but they're usually within 0.2 magnitude of the stated values.

Light travel-time distances in megalight-years were computed with Ned Wright's online Cosmology Calculator, assuming H_0 = 69 and $Omega_M$ = 0.29.

Visit skypub.com/quasarhunt for more information about the objects described in this article.





it very difficult to star-hop at 250× while referring back and forth to maps — I sometimes had to retrace my steps several times. It typically took at least an hour to get to the right spot and find the quasar, and sometimes even longer. I often spent several nights recording, sketching, and confirming an observation. Refusing to succumb to frustration was part of the "fun" of it.

The list on the facing page includes very brief observing notes. These may understate how challenging this is from New Jersey, but I'm sure that I saw the ones noted. For many of the quasars, even a small amount of sky haze was enough to kill them, and a quasar could be invisible on one night and then visible on another night.

Toward the end of the project, I realized that while most quasars vary a few tenths of a magnitude in brightness, some vary much more. 4C +29.45 should have been visible at its listed magnitude of 14.4, but I tried it five times without seeing it. Checking the *Frankfurt Quasar Monitoring* website, I discovered that this object (also called Ton 599) varies wildly on time scales ranging from minutes to years. It reaches 14th magnitude fairly often, but it's usually 15th or 16th magnitude, and it has been observed as faint as magnitude 18.5!

I personally plan to try to run through my list again now that I've had the mirror on my 16-inch refigured and I've psychologically recovered from all the fun of the first round of trying. I'll try for some of the quasars I missed, and maybe expand the list to include some fainter quasars. I hope that my experience inspires you to look for a few quasars yourself. Good hunting! ✦

__Bob Cava__ is a professor of chemistry at Princeton University specializing in high-temperature superconductors.

What's a Quasar?

The word "quasar" was coined in 1964 as a shorthand for "quasi-stellar radio source" — a bright, concentrated radio source coinciding with an object that looks like a star but has a very high redshift, indicating that it's moving away from us at a huge speed. Today, the word is usually extended to include quasi-stellar objects (QSOs) that have the same visual properties as quasars, but aren't bright radio sources.

Astronomers soon realized that quasars have many features in common with Seyfert galaxies, which are galaxies that have hyperluminous nuclei with unusual spectral characteristics. According to current theory, Seyferts and quasars are part of the same continuum, members of the broader category of active galactic nuclei (AGNs).

AGNs are supermassive black holes surrounded by disks of matter (September 2013 issue, page 25). These *accretion disks* emit huge amounts of radiation as their material is pulled into the black hole. Many AGNs also shoot out jets at relativistic speeds.

Quasars are probably just like the nuclei of Seyfert galaxies except that they're brighter — often 100 times more luminous than all the host galaxy's stars combined. But the dividing line between quasars and Seyferts is arbitrary. All the objects in our list have been classified as quasars in one or more studies, but if you look at images of UGC 545 and RX J23273+1524, you will see that both of them have prominent galactic disks as well as pointlike nuclei. Most astronomers would probably classify RX J23273+1524 as a Seyfert and UGC 545 as a borderline case.

4C +29.45 (also known as Ton 599) is a *blazar,* a quasar whose jet points straight at us, making it appear much more luminous than it would if the jet were aimed in a different direction. Blazars are characterized by extreme variability, sometimes brightening or dimming by a full magnitude in a single day.

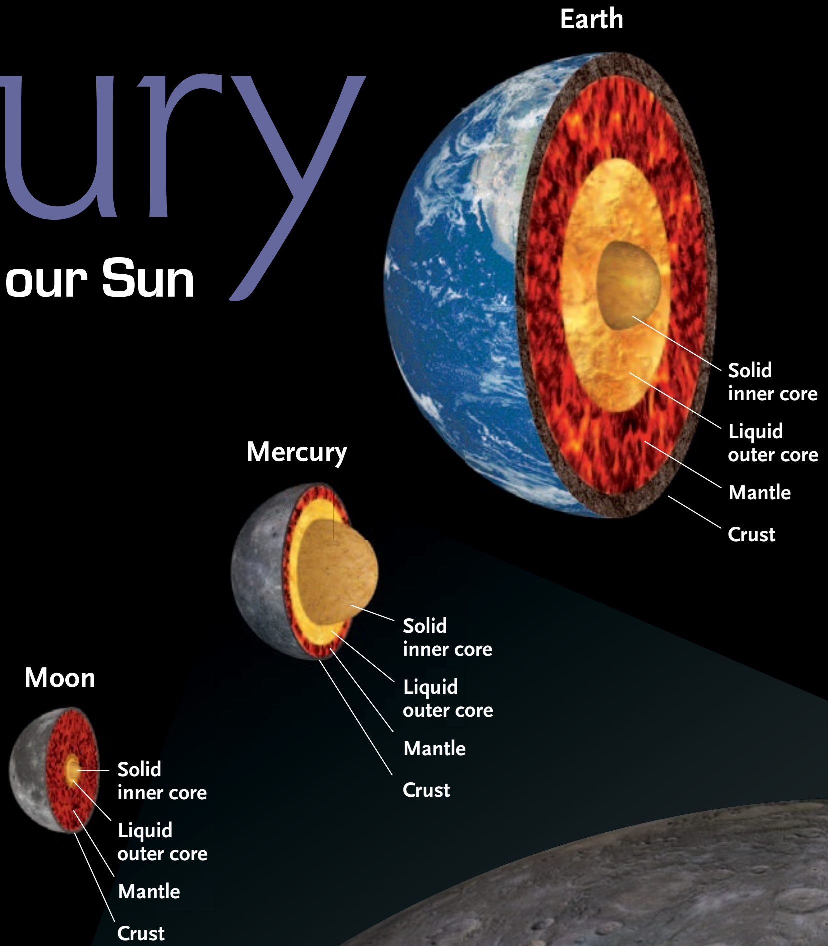
See *S&T* April 2010, page 70, for other blazars observable through backyard telescopes.

— ***Tony Flanders***

ESO / MARTIN KORNMESSER

Mercury

Meet the planet nearest our Sun



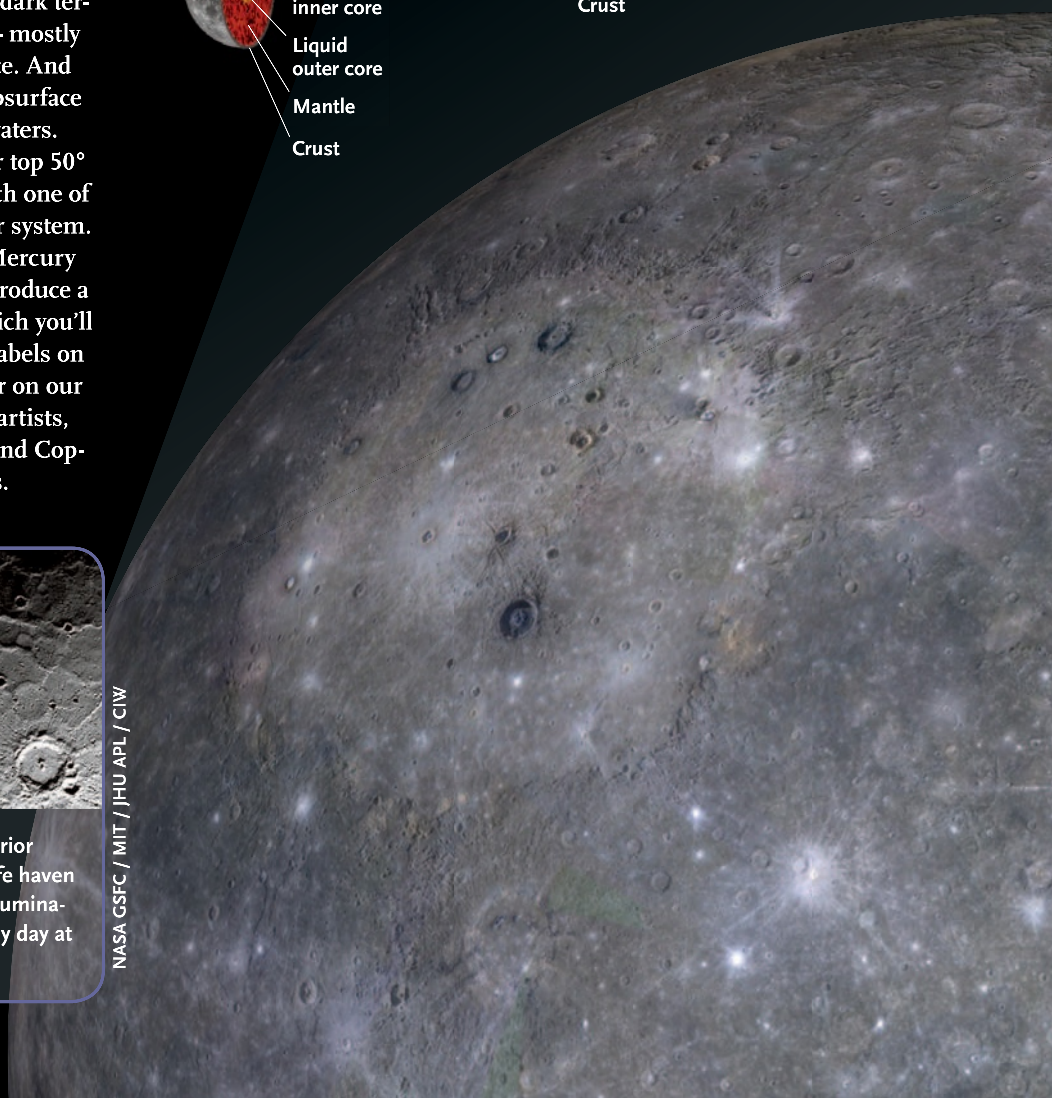
The innermost planet has challenged astronomers for centuries. Its proximity to the Sun limits ground-based telescopic observations, and when NASA's Mariner 10 spacecraft made three close passes during the 1970s, the little planet appeared to have a landscape that strongly resembled the Moon's.

But Mercury is no Moon. NASA's Messenger spacecraft, in orbit around the Iron Planet since March 2011, has recently finished its initial global survey. The work reveals that this wacky world has a unique, complex history all its own.

The survey images show a marvelous world of ancient volcanic floods and mysteriously dark terrain (*S&T*: April 2012, page 26). Plains — mostly volcanic — cover about 30% of the surface. And as radar images have long suggested, subsurface water ice lies tucked inside some polar craters. Temperatures in the coldest craters never top 50° above absolute zero, making Mercury both one of the hottest and coldest bodies in the solar system.

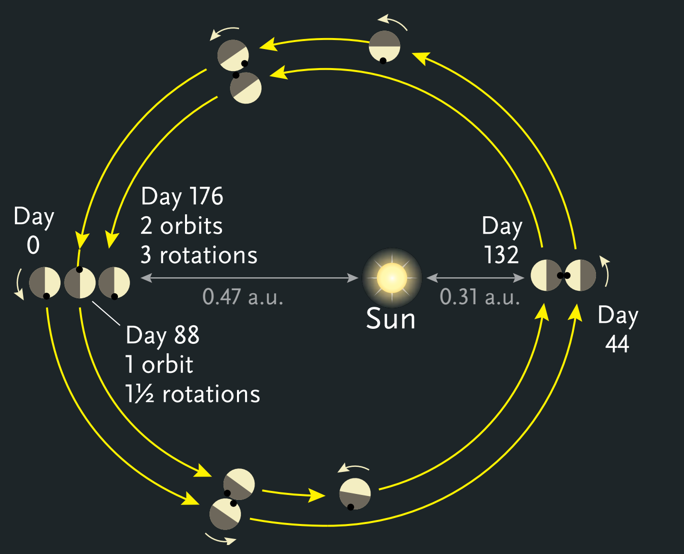
To celebrate Messenger's completed Mercury survey, we've worked with the USGS to produce a labeled map of the innermost planet, which you'll find on the flip side of these pages. The labels on this map are a subset of those that appear on our new Mercury globe. Many names honor artists, writers, and musicians, including Bach and Copland. Even Disney and Seuss have craters.

Prokofiev Crater's north-facing rim and interior remain in perpetual shadow, making it a safe haven for water ice. Watch an animation of how illumination changes over the course of one Mercury day at skypub.com/prokofiev.

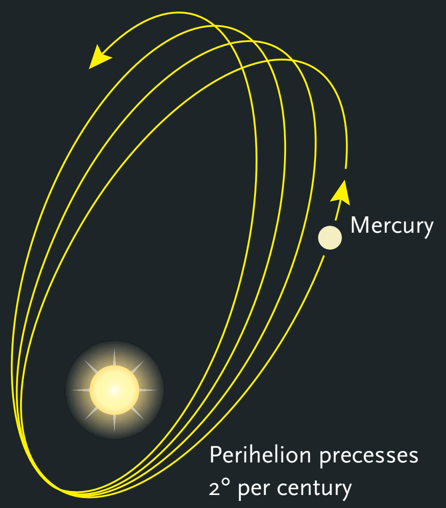


NASA GSFC / MIT / JHU APL / CIW

Mercury's Strange Orbital Dance

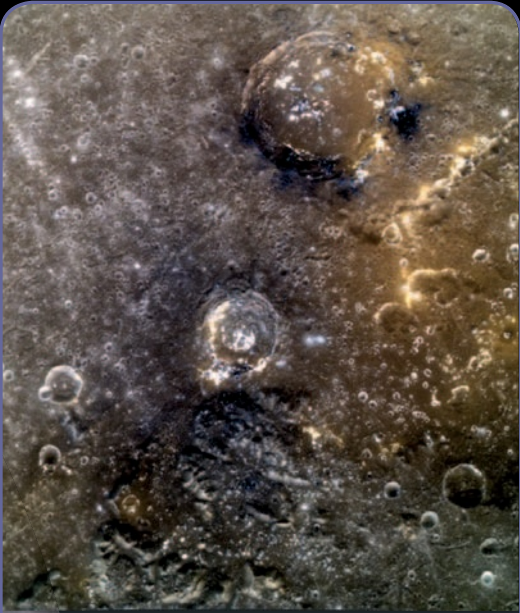


Mercury rotates three times for every two orbits around the Sun. This 3:2 spin-orbit resonance means that for a hypothetical astronaut on the surface (black dot), sunrise comes only once every 176 Earth days. At perihelion, dayside temperatures reach about 700 K; at aphelion, 500 K.



The perihelion of Mercury's orbit precesses 2° per century. Astronomers could explain all but 43″ of that shift with classical mechanics; they needed Einstein's theory of gravity to explain the rest. The orbit's elongation and advance are highly exaggerated to emphasize the effect.

S&T Illustrations: Gregg Dinderman
Globe map: USGS / NASA / JHU APL / CIW



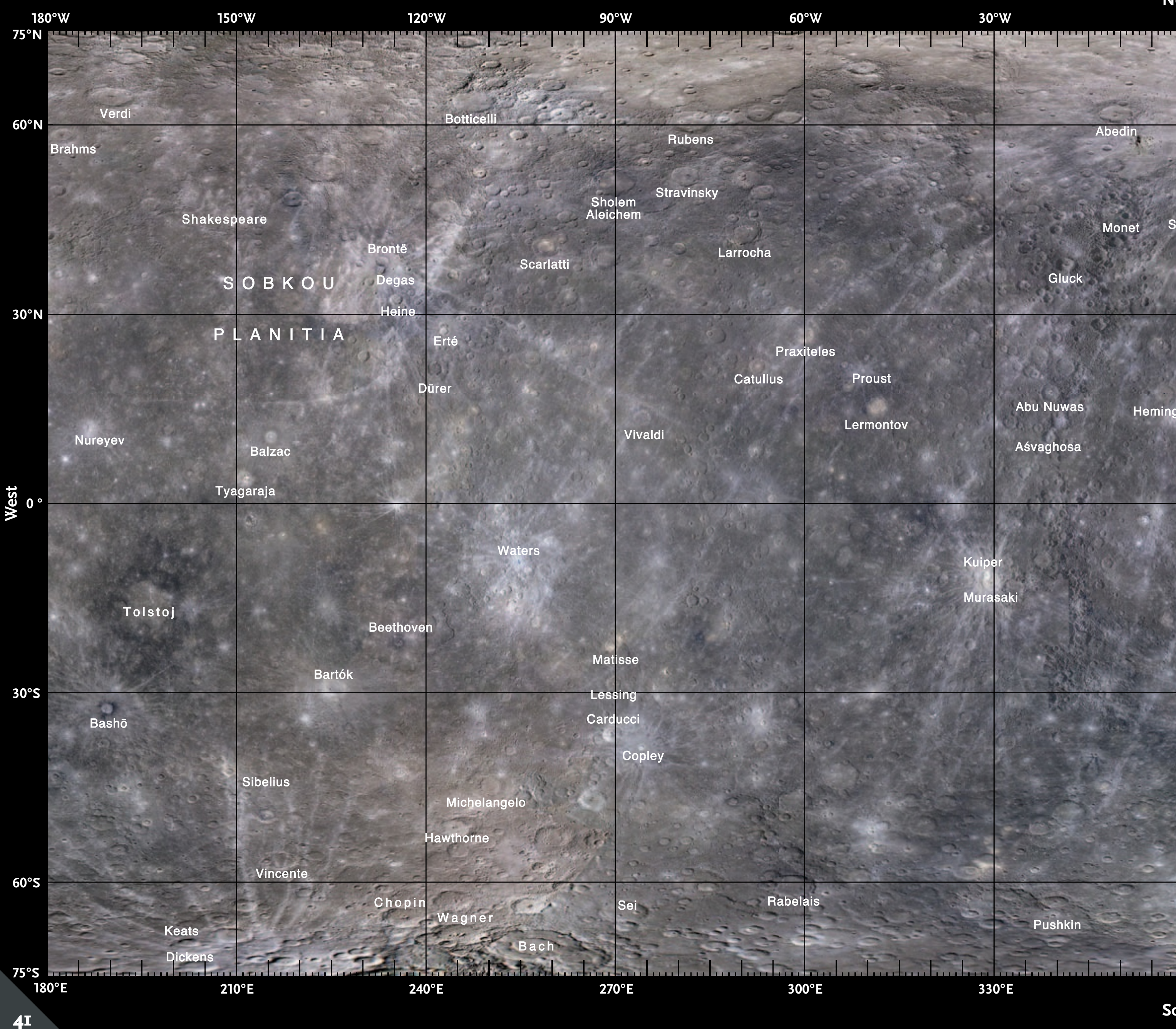
NASA / JHU APL / CIW

This Messenger image shows mysterious "low-reflectance material" excavated by craters near the eastern edge of Caloris Basin. The reddish deposits appear to be volcanic in origin. The orbiter took this composite image using all 11 color filters of its wide-angle camera.

Mercury

North Polar Region

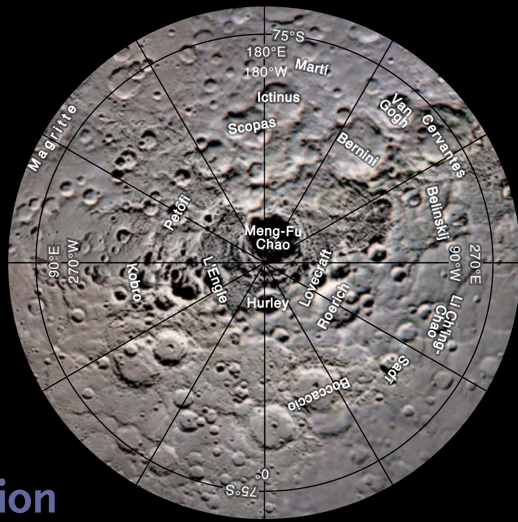
Due to Mercury's unique 3:2 spin-orbit resonance, NASA's entire globe in daylight conditions. Mission scientists comb map with a resolution of roughly 550 feet (170 m) per pixe — consisting of images taken through blue (430 nm), red out subtle color differences. Note: regions poleward of 75°

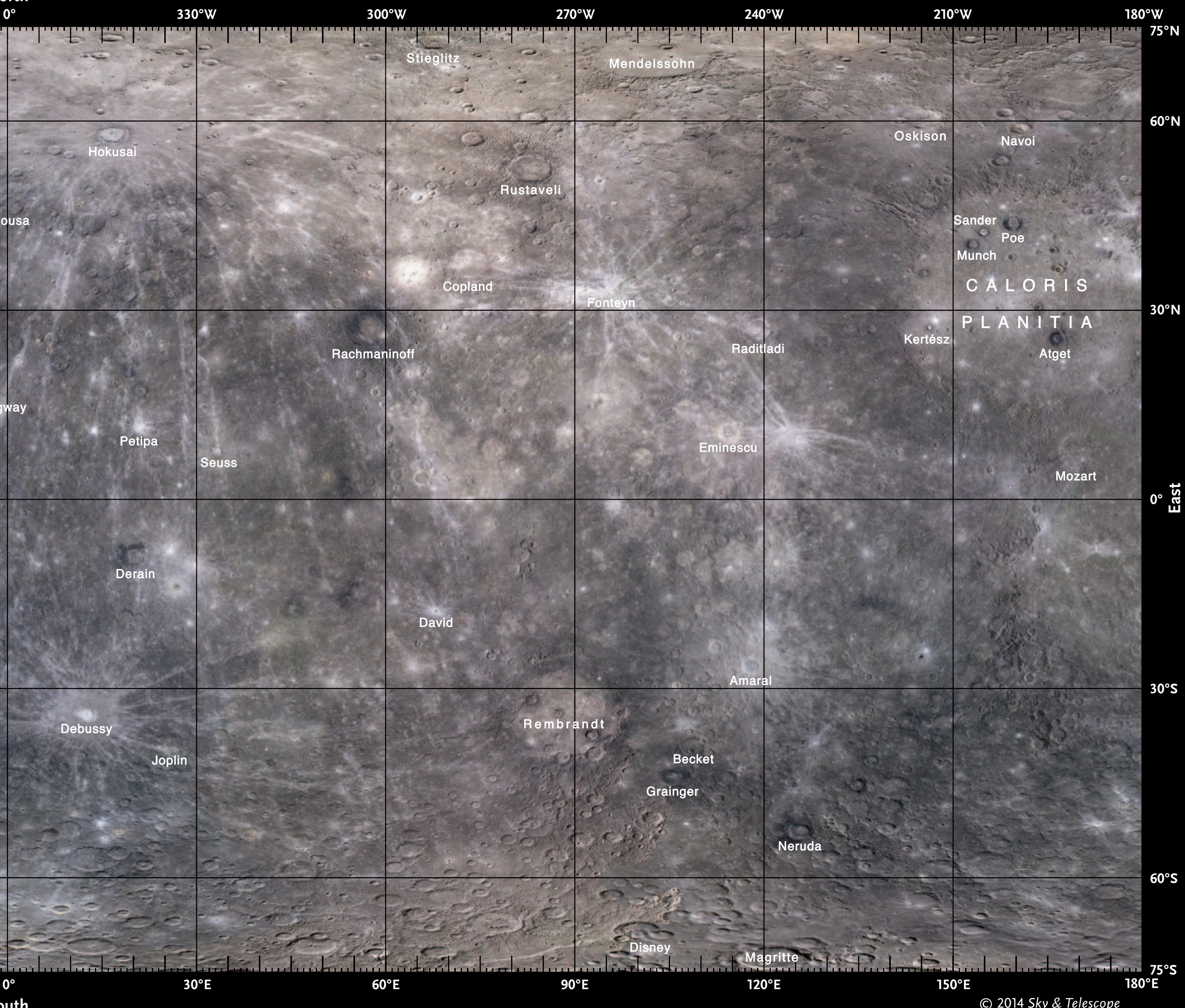


’s Surface

s Messenger spacecraft took nearly two years to record the bined thousands of images to create a monochrome base l. Then they merged it with a second, less detailed mosaic (750 nm), and near-infrared (1000 nm) filters — to bring latitude appear only in the polar maps.

South Polar Region





OBSERVING

Sky at a Glance

MARCH 2014

Feb 16 – Mar 2 **EARLY EVENING:** The zodiacal light shows very well from dark locations at mid-northern latitudes. Look west starting about 80 minutes after sunset for a huge, tall, left-sloping pyramid of light.

Mar 9 **DAYLIGHT SAVING TIME STARTS** at 2 a.m. for most of the U.S. and Canada.

9 **EVENING:** Jupiter shines above the Moon, as shown on page 48. And Algol is at minimum brightness for roughly two hours centered on 11:30 p.m. EDT (8:30 PDT); see page 53.

17, 18 **LATE EVENING:** Spica and much brighter Mars form a changing triangle with the Moon.

18–31 **EARLY EVENING:** The zodiacal light is again on display as described above.

20 **VERY EARLY MORNING:** The asteroid Erigone hides bright Regulus for up to 14 seconds a little after 2 a.m. EDT in a narrow path from the New York City area to eastern Ontario and points north (see page 30).

DAWN: Binoculars show Alpha Librae just left of the Moon, with Saturn well to their left.

SPRING BEGINS in the Northern Hemisphere at the equinox, 12:57 p.m. EDT (9:57 a.m. PDT).

21 **DAWN:** Saturn shines to the right of the Moon.

23 **EVENING:** The shadows of Io and Ganymede fall on Jupiter simultaneously from 10:08 to 10:32 p.m. EDT (9:08 to 9:32 CDT); see page 53.

27 **DAWN:** Venus shines lower right of the thin crescent Moon.

Planet Visibility

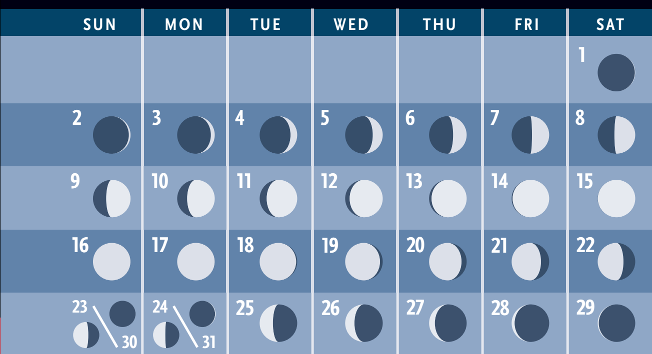
SHOWN FOR LATITUDE 40° NORTH AT MID-MONTH

◀ SUNSET — MIDNIGHT — SUNRISE ▶

Planet	Visibility
Mercury	Visible through March 18; E
Venus	SE
Mars	E, S, SW
Jupiter	S, NW
Saturn	E, S, SW

Moon Phases

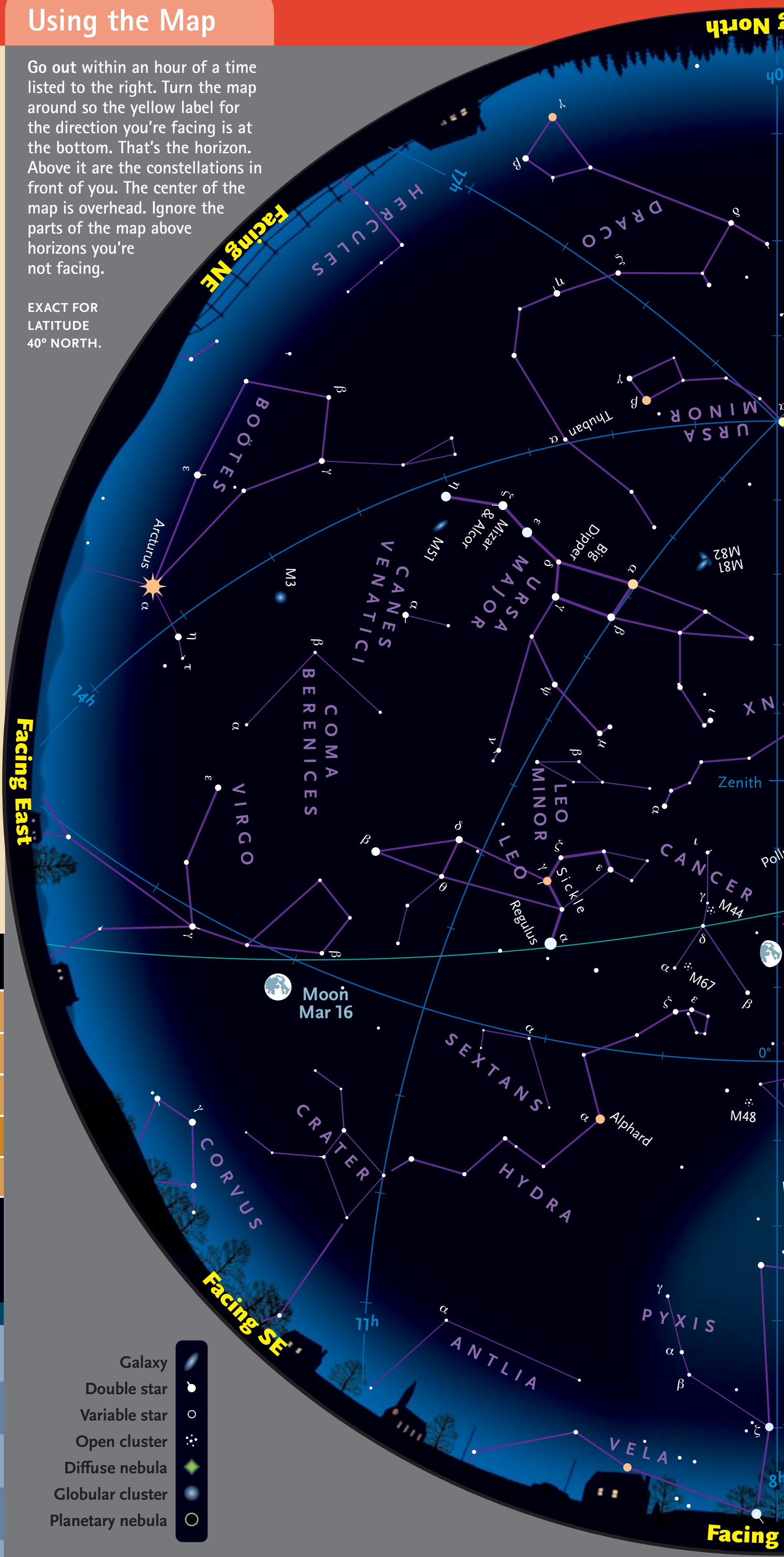
First Qtr	March 8	8:27 a.m. EST	
Last Qtr	March 23	9:46 p.m. EDT	
New	March 1	3:00 a.m. EST	
Full	March 16	1:08 p.m. EDT	
New	March 30	2:45 p.m. EDT	

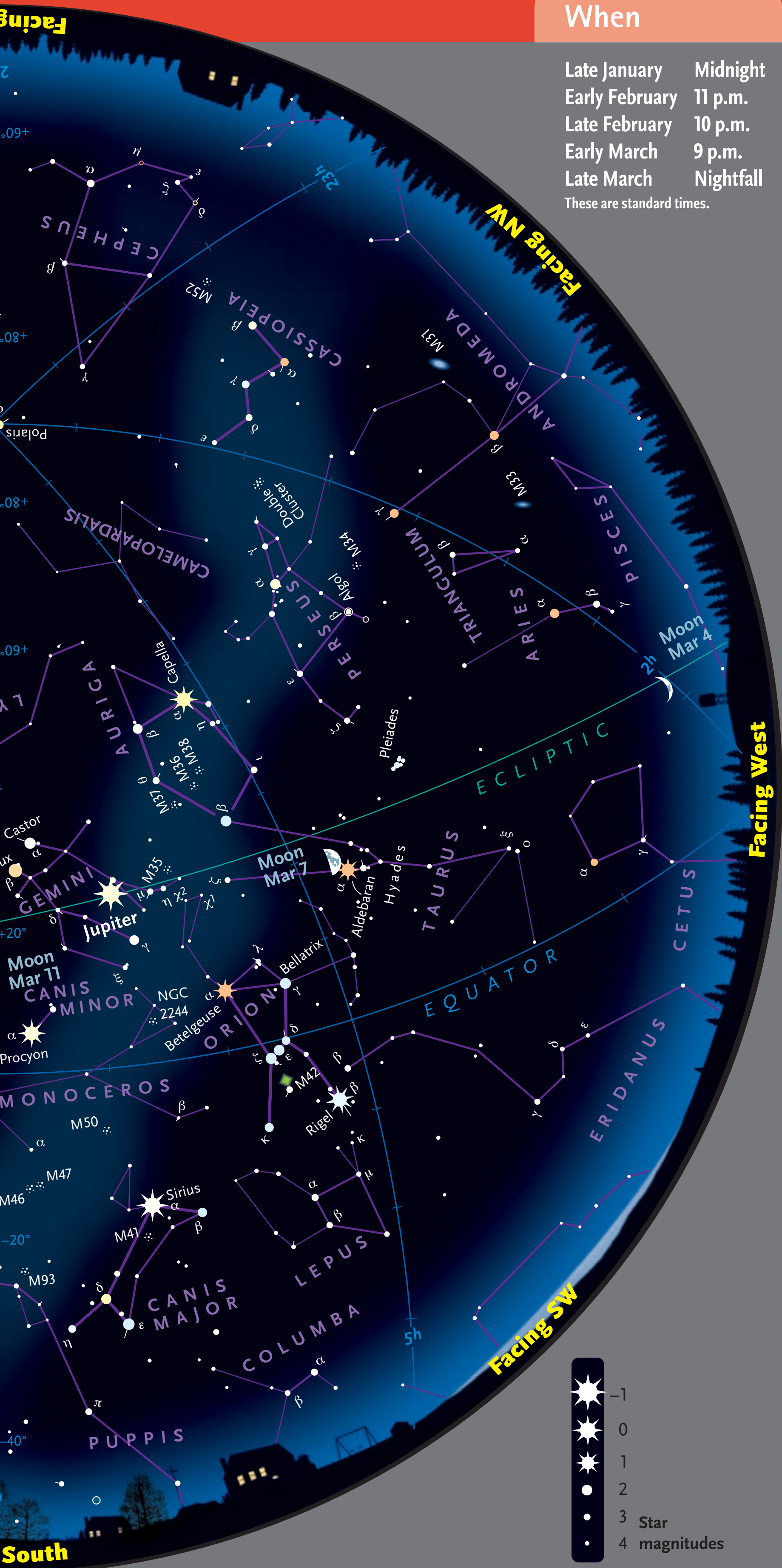


Using the Map

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 January	Midnight
Early February	11 p.m.
Late February	10 p.m.
Early March	9 p.m.
Late March	Nightfall

These are standard times.

Gary Seronik
Binocular Highlight

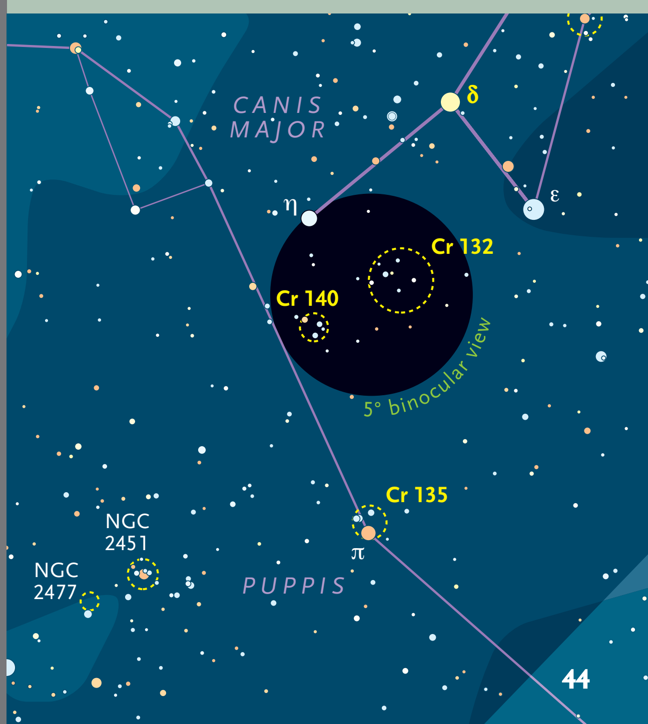
Collinders in Canis Major

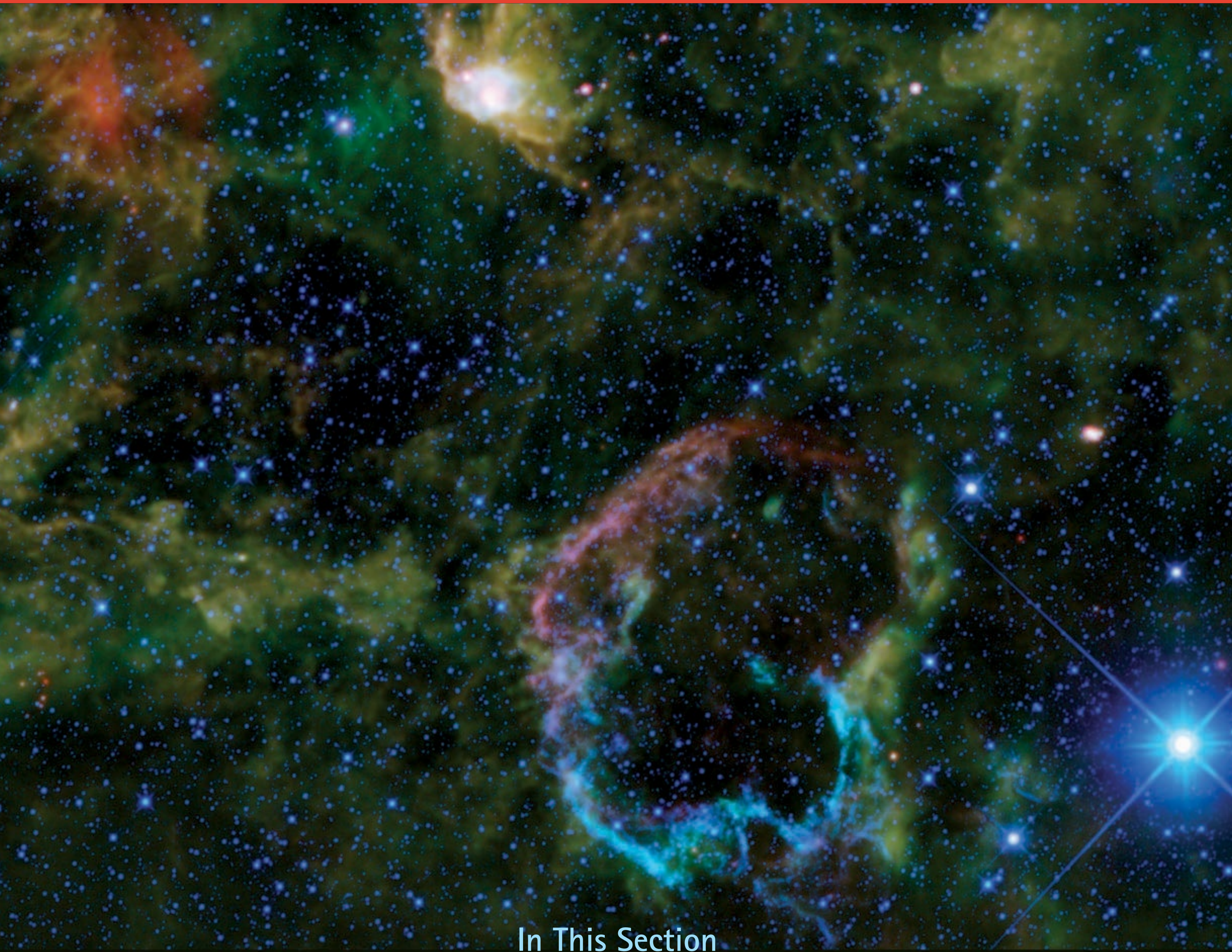
Everyone has heard of the Messier list, Dreyer's NGC, and even the IC, but you might be surprised to find that there are binocular-worthy targets to be found in other, more obscure sources. The Collinder catalog in particular holds a number of interesting objects, several of which reside in southern Canis Major.

Let's begin our Collinder quest at **Delta (δ) Canis Majoris**. Delta is situated in a nice binocular field featuring a curving row of stars that partially encircles it to the southeast. The arc of stars looks like a parachute, and Delta serves as the parachutist. Shift your binocular gaze south by 4° and you come to **Collinder (Cr) 132**. This cluster is very easy to resolve even in my 10×30 image-stabilized binoculars. Its shape resembles a miniature Great Square of Pegasus, but tipped at an odd angle. Cr 132 is sparse with a smattering of reasonably bright stars, but few faint ones.

Next door to Cr 132 is **Cr 140**. It's more obviously a cluster than its neighbor and can even be perceived with the unaided eye under dark skies. My 10×30s show roughly a half-dozen stars arranged like a Greek letter lambda (λ). Within the cluster's core is a haze. My 15×45 image-stabilized binos resolve this into a smattering of faint stars that give the cluster an extra level of richness.

For our final offering, we need to head due south and over the border into neighboring Puppis. There we find **Cr 135**. The field is dominated by 2.7-magnitude Pi (π) Puppis, which forms an isosceles triangle with a pair of nearby 5th-magnitude neighbors. Swarming around Pi is a clutch of dim stars that tantalizingly pop in and out of view in the 10×30s. ✦





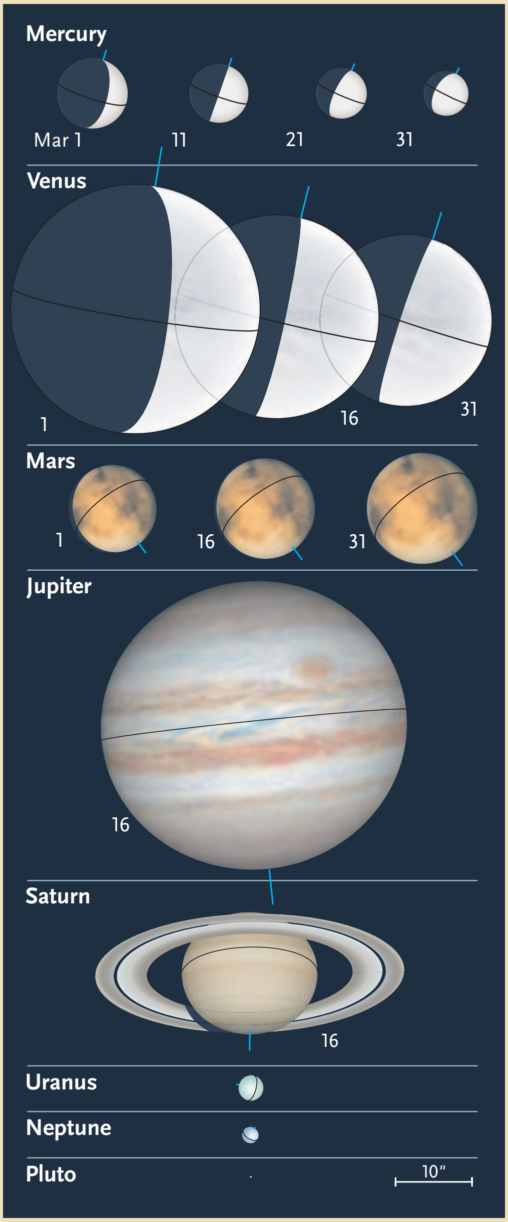
In This Section

Additional Observing Articles:

NASA / JPL-CALTECH / WISE TEAM

The supernova remnant IC 443, immediately east of the bright star Eta Geminorum, looks much more like an expanding shell in this false-color infrared view than in the visible-light image on page 58.

Planetary Almanac

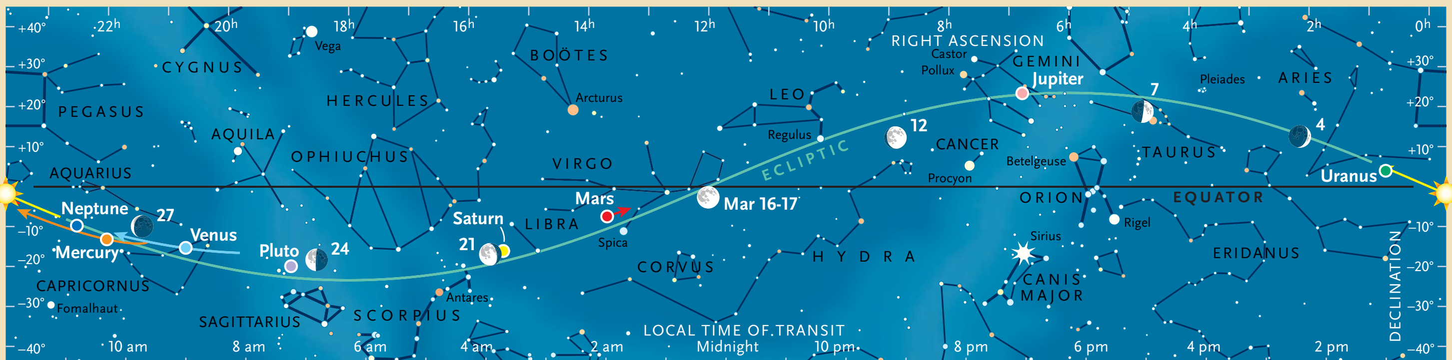


Sun and Planets, March 2014

	March	Right Ascension	Declination	Elongation	Magnitude	Diameter	Illumination	Distance
Sun	1	$22^h 46.6^m$	–7° 46′	—	–26.8	32′ 17″	—	0.991
	31	$0^h 36.8^m$	+3° 58′	—	–26.8	32′ 01″	—	0.999
Mercury	1	$21^h 19.4^m$	–13° 42′	22° Mo	+0.8	9.2″	28%	0.731
	11	$21^h 41.1^m$	–14° 09′	27° Mo	+0.2	7.6″	50%	0.879
	21	$22^h 24.1^m$	–11° 48′	27° Mo	0.0	6.6″	64%	1.024
	31	$23^h 17.5^m$	–7° 09′	23° Mo	–0.2	5.8″	76%	1.154
Venus	1	$19^h 48.1^m$	–16° 38′	44° Mo	–4.8	32.7″	36%	0.511
	11	$20^h 23.0^m$	–16° 03′	46° Mo	–4.7	28.4″	43%	0.587
	21	$21^h 01.7^m$	–14° 43′	47° Mo	–4.5	25.1″	49%	0.664
	31	$21^h 42.5^m$	–12° 37′	46° Mo	–4.4	22.5″	54%	0.742
Mars	1	$13^h 45.5^m$	–7° 53′	133° Mo	–0.5	11.6″	95%	0.809
	16	$13^h 40.7^m$	–7° 24′	149° Mo	–0.9	13.3″	97%	0.706
	31	$13^h 25.4^m$	–6° 04′	168° Mo	–1.3	14.6″	100%	0.640
Jupiter	1	$6^h 44.8^m$	+23° 16′	120° Ev	–2.4	42.4″	99%	4.645
	31	$6^h 48.8^m$	+23° 14′	91° Ev	–2.2	38.6″	99%	5.108
Saturn	1	$15^h 25.3^m$	–16° 16′	107° Mo	+0.4	17.4″	100%	9.559
	31	$15^h 22.8^m$	–16° 01′	137° Mo	+0.3	18.2″	100%	9.141
Uranus	16	$0^h 42.6^m$	+3° 52′	16° Ev	+5.9	3.4″	100%	20.982
Neptune	16	$22^h 30.7^m$	–10° 05′	20° Mo	+8.0	2.2″	100%	30.913
Pluto	16	$18^h 56.0^m$	–20° 07′	72° Mo	+14.2	0.1″	100%	32.909

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 skypub.com/almanac.

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



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

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

Fred Schaaf

The Month Between the Seasons

March separates and unites winter and spring.

When does spring arrive in the Northern Hemisphere? Meteorologists often consider it to start on March 1st, though astronomical spring doesn't start until the equinox, which this year falls on March 20th.

But in much of North America and Europe, even the end of March falls short of most people's conception of spring. The month is famous for some of the biggest snowstorms and blizzards on record — and many a cold night for astronomers.

The season of stirring. I like the way the Eldar (Elves) of Middle Earth divided the year. In *The Lord of the Rings*'s appendix on calendars, J. R. R. Tolkien tells us that they recognized not four but six seasons: spring, summer, autumn, fading, winter, and stirring. For many of us, March is a season of stirring, but not quite spring. The trees won't leaf out for weeks, only the first flowers have bloomed — and the night sky is a strange hybrid of winter constellations, spring constellations, and ones that belong to both seasons.

Constellations on the fence. What season comes to mind when someone mentions Gemini and Canis Minor? I'll bet most of you think first of winter. These constellations are part of Orion's entourage, and Orion epitomizes winter. Canis Minor and its majestic counterpart Canis Major are Orion's dogs, trailing him across the sky. And Gemini is just above or upper left of Orion.

Yet take a look at our all-sky map for March evenings. Castor, Pollux, and Procyon, the brightest stars of Gemini and Canis Minor, have barely passed the sky's meridian. They will be more than halfway up the west sky in April and low but plainly visible at nightfall in May.

What about Cancer the Crab, Gemini's successor in the zodiac? I'd venture to guess that most of us group it with the constellations of spring. Yet it's well up on January evenings, and our March all-sky map shows it and its cluster-filled center barely short of the meridian.

Sights for the season of stirring. Gemini, Canis Minor, and Cancer are at their highest shortly after nightfall in the season of stirring. That's when we can see M44, Cancer's Beehive Cluster, at its most bee-yootifully bright and prominent; appreciate Procyon in its own right, divorced from Sirius, the greater Dog Star; and, with a telescope, split Castor cleanly into two bright bluish stars and one faint red dwarf.

IRIS WIJNGAARDEN / WIKIMEDIA COMMONS

Snowdrops often bloom before the snow has melted, embodying the transition from winter to spring.

Our all-sky map shows that this is also a great time to observe the open star clusters M48, M50, and the wonderfully mismatched pair M46 and M47. There's also M67, Cancer's other great cluster, conveniently close to Alpha Cancri (Acubens). It appears much dimmer and smaller than M44, but it's rich in telescopes and visible to the naked eye in truly dark skies.

Now is also a wonderful time to admire the front, upright third of long, long Hydra, the Water Snake. Hydra's head isn't very bright, but it's compact and therefore rather prominent in reasonably dark skies — a lovely pattern to admire. This mythic creature seems to stick its head and neck up just above the celestial equator as if from out of a lake. Below the celestial equator is Hydra's heart, orange-colored 2nd-magnitude Alphard.

Looking east to spring. If you start getting cold while observing all these wonders on the fence between winter and spring, there's a remedy: take a look at the eastern and northeastern sky. Leo has sprung halfway up the eastern heavens. The Big Dipper has wheeled surprisingly high in the northeast. And bright Arcturus, the great glad star of spring and early summer, has just cleared the east-northeastern horizon. ✦

The Red Planet Approaches

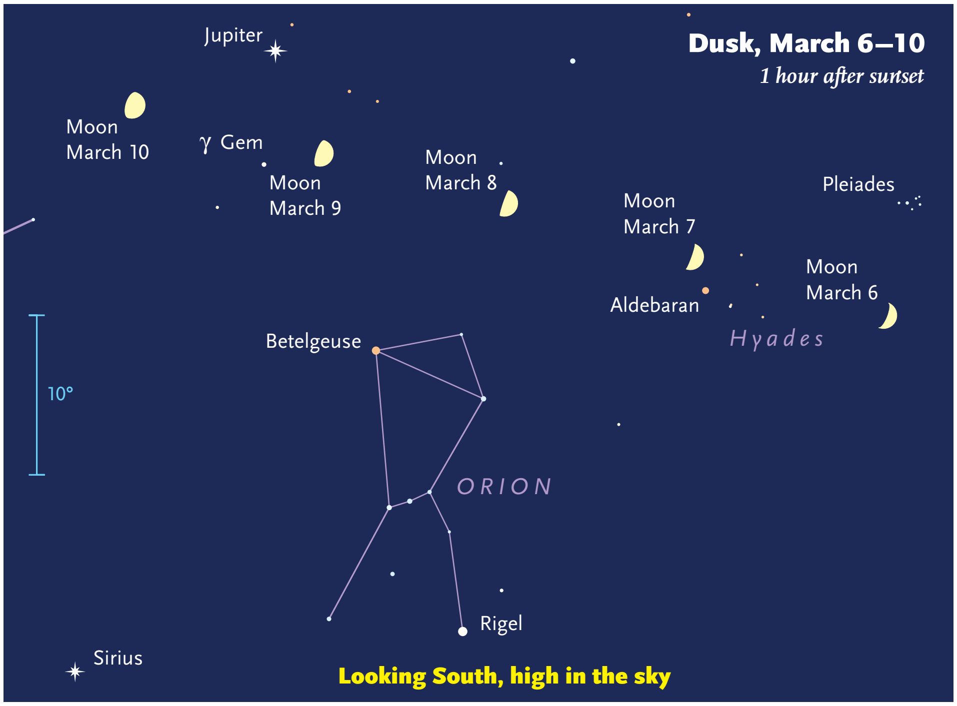
Mars doubles in brightness during the month of March.

The amazing, rare occultation of Regulus by the minor planet 163 Erigone is visible only along a narrow path from the New York City area through eastern Ontario and points north; see page 30. But everyone in the Northern Hemisphere can enjoy fine views of the *major* planets in March. Jupiter is near its highest in the south at dusk. Mars becomes very bright and starts to rise in the early evening. Saturn rises about 2 hours after Mars. And, last of all, Venus and Mercury appear low in morning twilight.

DUSK

Jupiter is best viewed this month at nightfall, when it's near the meridian. Although it fades a bit (from magnitude –2.4 to –2.2) and shrinks a bit (from 42″ to 39″ wide), Jupiter at dusk is just about as high as it can ever be for observers at mid-northern latitudes — and it remains quite high throughout the evening. Jupiter is stationary in right ascension on March 6th and then slowly resumes direct (eastward) motion relative to the stars. So it spends the entire month about 2° south or south-southeast of the 3.0-magnitude supergiant star Epsilon Geminorum (Mebsuta).

Uranus, in Pisces, will reach conjunction with the Sun on April 2nd. It can be glimpsed in evening twilight in early March but is soon lost to view.



EVENING TO DAWN

Mars becomes dramatically bright during March, its magnitude improving from –0.5 to –1.3 on its way to an April 8th opposition. The "Red Planet" rises about 3½ hours after sunset as March opens, but it comes up in bright twilight by the time the month closes. Mars begins to retrograde (move westward against the stars) on March 1st, when it's 6° northeast of Spica. It begins to pick up speed in its westward trek through Virgo, ending March 5° to Spica's north.

In telescopes Mars's globe increases from 11.6″ to 14.6″ wide, offering telescopic views of its surface features when the seeing is good. See the guide on page 50.

Saturn rises in Libra before midnight and shines highest 2 to 3 hours before sunrise. Saturn brightens from magnitude +0.4 to +0.3, and its equatorial diameter nudges over 18″. Saturn's rings remain generously tilted 22° from edge-on.

Saturn reaches its stationary point and begins retrograde motion on March 3rd — just two days after Mars. In fact, by an odd coincidence, four planets and the two brightest asteroids, Ceres and Vesta, all halt their motion in right ascension during a period of 8 days: Mercury (February 27th), Ceres and Mars (March 1st), Saturn (March 3rd), Vesta (March 5th), and Jupiter (March 6th). Ceres and Vesta spend the spring just a few degrees apart and will have a marvelous close encounter in the sky in early summer, as described in the February issue, page 50.

DAWN

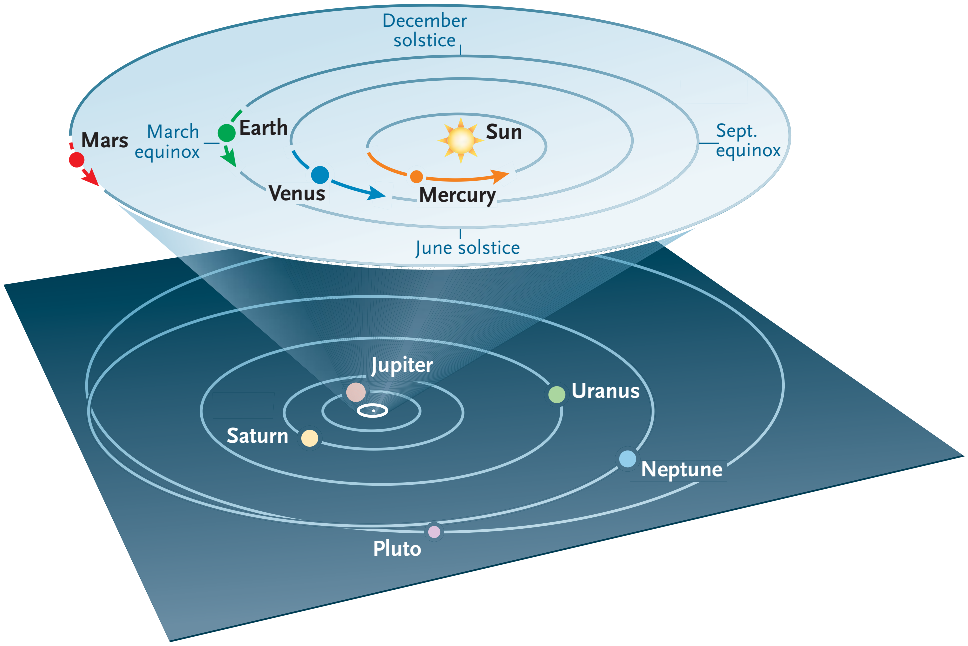
Venus and **Mercury** shine low in the east at dawn in March. Venus is bright and easy to spot. Mercury is far to Venus's lower left — tricky to spot early in the month and probably impossible without optical aid after March 18th.

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

Fred Schaaf

ORBITS OF THE PLANETS

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



Mercury and Venus are at greatest elongation west of the Sun on March 14th and 22nd, respectively. But at mid-northern latitudes the angle of the ecliptic is very shallow at dawn in March, so both planets are still quite low a half hour before sunrise on those dates — about 16° for Venus and just 6° for Mercury (for skywatchers near 40° north latitude).

Venus dims from a stunning magnitude –4.8 to –4.4 during March. Its globe shrinks from 33″ to 22″ wide, and its phase increases from 36% to 54% lit. Mercury starts the month at magnitude +0.8 and brightens only to –0.1 at month's end.

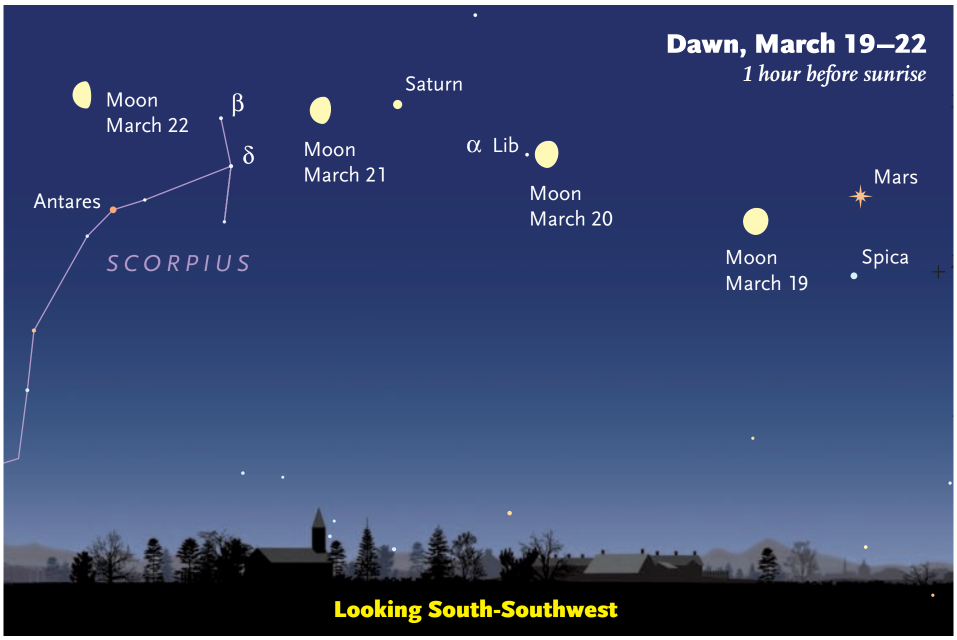
Neptune and **Pluto** were at conjunction with the Sun on February 23rd and January 1st, respectively. Throughout March, they are both too low in morning twilight to view without great effort.

MOON AND SUN

The first-quarter **Moon** is close above Aldebaran at nightfall on March 7th. The waxing gibbous Moon passes below Jupiter on the 9th and 10th and below Regulus on the 13th and 14th.

The waning gibbous Moon rises to the upper right of Mars and Spica late on the evening of the 17th, and it rises below them on the 18th. The Moon shines quite close to Saturn when they rise around midnight on the night of March 20th. Finally, the lunar crescent hangs close to the left of Venus in a spectacular pairing at dawn on March 27th.

The **Sun** reaches the March equinox at 12:57 p.m. EDT on March 20th, starting spring in the Northern Hemisphere and autumn in the Southern Hemisphere. ✦



Mars in Your Telescope

As Curiosity roams its desert landscape, watch Mars from your own backyard.

We're entering the best season we've had for observing Mars in seven years. That's not saying much. Mars comes to opposition every two years and two months, and the oppositions themselves go through a 15-year cycle of close and distant ones. This year the planet is at opposition on April 8th. In the middle two weeks of April, when it's closest to Earth, it will appear 15.1 arcseconds wide. That's bigger than it became during its last two apparitions, but far short of the 24.3″ we can expect in July 2018.

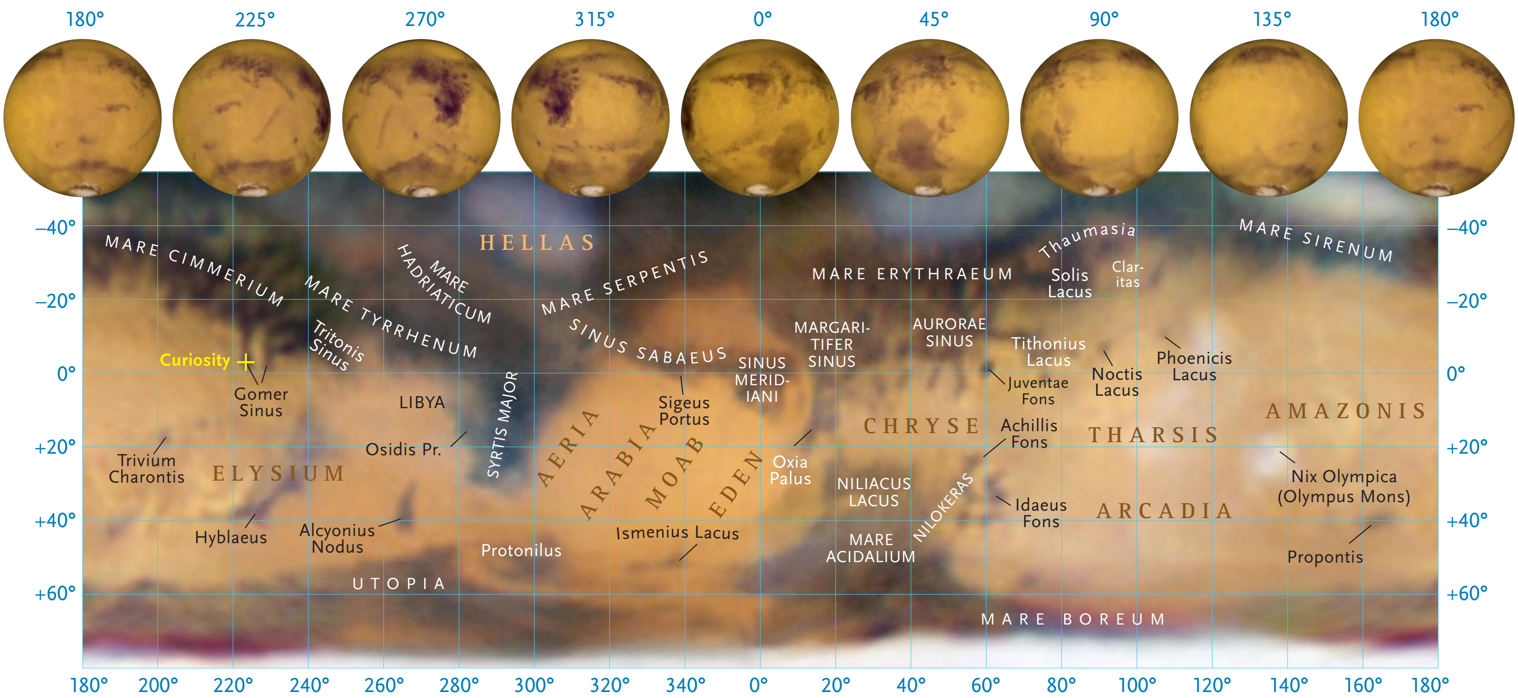
Mars is still just south of the celestial equator, in Virgo near Spica. During its closest oppositions it's always low in the south for mid-northerners. When it's highest it's always small. As if to spite us northerners, Mars, like Mercury, plays favorites with the Southern Hemisphere.

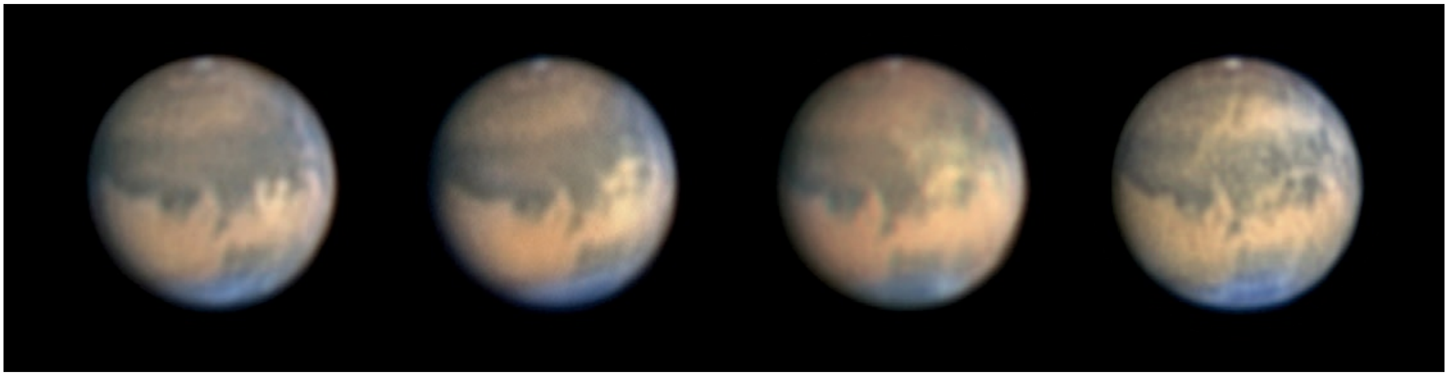
But it can't hide. In February Mars enlarges from 9.0″ to 11.6″, then to 14.7″ by the end of March. Already a good 6-inch telescope during good seeing will show Mars's North Polar Cap, some of its surface markings, and perhaps white clouds. The Martian northern hemisphere is tipped far toward Earth this season, so we'll have a good view of the cap shrinking away to its minimum size as Martian northern summer advances. Watch the dark ring that comes into better view around the cap as it retreats. See page 54 for more on watching for changes on Mars, including clouds, features in the shrinking cap, and possible dust storms.

The map below names many of the main *albedo features,* the dark and light surface markings. An albedo map of Mars, though, is never quite to be trusted. Many albedo features have changed in the decades since they were named, and sometimes they change from one Martian year to the next as windblown dust covers and uncovers parts of the underlying surface. A striking example is on page 54.

But most persist. The barely detectable smudges you detect at the eyepiece take on meaning and excitement if you can identify and name them and mark their rotation around the planet on subsequent nights. Mars spins just a little slower than Earth, once in 24 hours 37 minutes. So if you observe it at the same time each night, you'll see it making one slow, retrograde rotation in about 38 days.

Use this map to find the names of surface features you see. Most telescopes on most nights will show only the largest dark regions. South is up, and Martian west longitude is labeled along the bottom. Damian Peach assembled this map from many images he took in 2009–10. The globes, from *WinJupos*, are tipped correctly for the current apparition. Each globe displays the central-meridian longitude that is directly below it on the map.



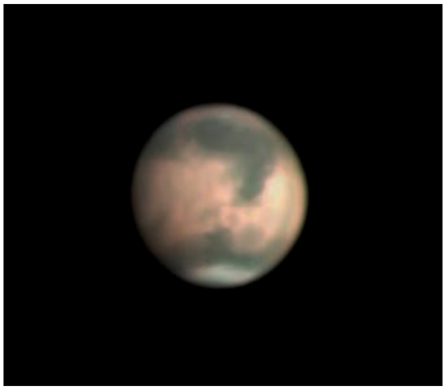


To find which side of Mars is facing Earth at the time and date you observe, you can use our Mars Profiler at **skypub .com/marsprofiler**. Match the central-meridian longitude it gives with the longitudes at the bottom of the map and above the globes. It also tells you Mars's magnitude, angular diameter, and more.

If you haven't yet tried your hand at modern planetary imaging, now's a fine time. Planetary video cameras have become cheap, and the software (such as *RegiStax*) can be found for free.

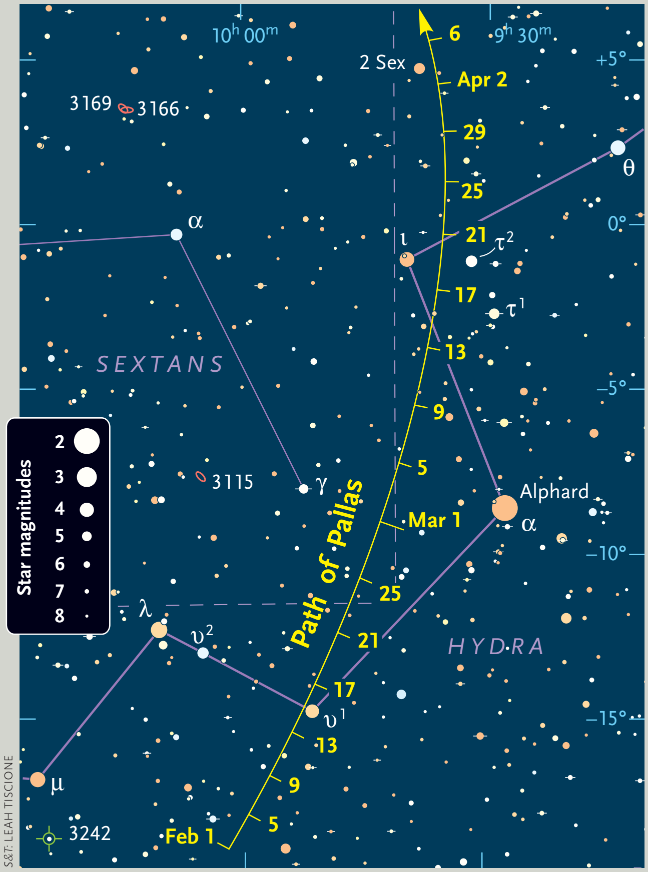
The International Society of the Mars Observers (**www.mars.dti.ne.jp/~cmo/ ISMO.html**) receives many amateur observations and images. Also check the Mars Section of the Association of Lunar and Planetary Observers (**alpo-astronomy .org**) and the International MarsWatch (**elvis.rowan.edu/marswatch**). These websites have more information on observing the planet, what's happening as the apparition proceeds, recent images, and instructions for uploading your own.

Above: **Big dust storms aren't very likely during the Martian northern hemisphere summer, but stacked-video imaging brings even small ones into view. These 2005 images from Sean Walker record spotty yellow dust clouds moving and changing from one night to the next.**



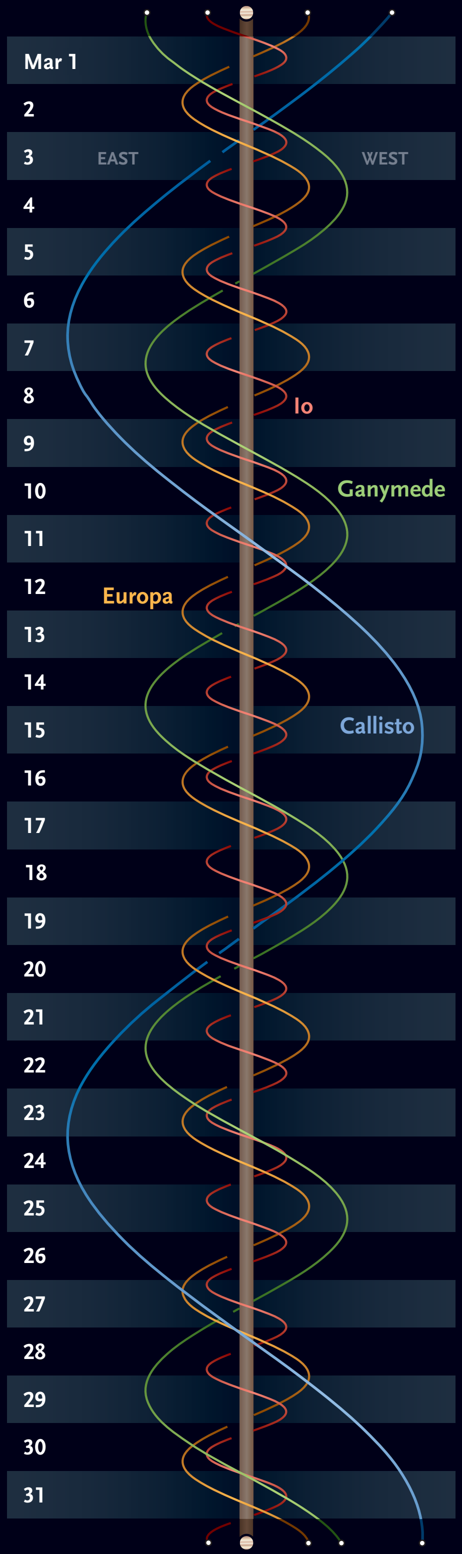
Stacked-video imaging blows past anything you can see by eye. Mars was a tiny blob just 4.3″ wide last September 26th when Don Parker in Florida took this image with a 16-inch reflector. This is the "interesting" side of Mars, with dark Syrtis Major pointing down to Utopia. South is up.

Asteroid Number Two Rides Hydra



Left: **The big asteroid 2 Pallas is sweeping north along the body of Hydra near 2nd-magnitude Alphard. It's magnitude 7.3 on February 1st, 7.0 for 10 days before and after its February 22nd opposition, and 7.6 by April 1st. Watch it creeping north from night to night. (The date ticks are for 0:00 Universal Time.)** ***Above:*** **Pallas shows a slightly flattened profile in this ultraviolet Hubble image. It's about 550 km (340 miles) wide, essentially tying 4 Vesta for second place in size after 1 Ceres. It was the second asteroid discovered.**

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

Christopher Go took this fine image of Jupiter on December 11th with a Celestron-14 scope from his balcony in Cebu City, the Philippines. South is up. Europa is visible on the right end of the Great Red Spot. More obvious is Europa's black shadow, being cast toward celestial west ("preceding") because Jupiter had not yet reached its January 5th opposition. Now Jupiter's moons cast their shadows eastward ("following"). The System II longitude at the time of this picture was 199°; the Red Spot was just about to transit.

In March Jupiter shrinks from 42″ to 38″ across its equator. But it's still at its very highest, almost overhead, around the end of twilight when the atmospheric seeing can be especially good. In the following months Jupiter will continue to shrink, as Earth pulls farther away from it in our faster orbit around the Sun, and it will begin to lose altitude westward.

Any telescope shows Jupiter's four big Galilean moons. Binoculars usually show two or three of them, and occasionally all four. Identify them with the diagram at left.

The table on the facing page lists all of the interactions in March between Jupiter, its shadow, and the satellites and their shadows. A 3-inch telescope is often enough for watching these interesting events.

Here are the times, in Universal Time, when Jupiter's Great Red Spot — currently a relatively strong shade of orange — should cross Jupiter's central meridian, the line down the center of the disk from pole to pole. The dates, also in UT, are in bold:

February 1, 8:57, 18:53; **2**, 4:48, 14:44; **3**, 0:40, 10:35, 20:31; **4**, 6:26, 16:22; **5**, 2:18, 12:13, 22:09; **6**, 8:05, 18:00; **7**, 3:56, 13:52, 23:47; **8**, 9:43, 19:39; **9**, 5:34, 15:30; **10**, 1:26, 11:21, 21:17; **11**, 7:13, 17:08; **12**, 3:04, 13:00, 22:55; **13**, 8:51, 18:47; **14**, 4:42, 14:38; **15**, 0:34, 10:29, 20:25; **16**, 6:21, 16:16; **17**, 2:12, 12:08, 22:03; **18**, 7:59, 17:55; **19**, 3:50, 13:46, 23:42; **20**, 9:37, 19:33; **21**, 5:29, 15:25; **22**, 1:20, 11:16, 21:12; **23**, 7:07, 17:03; **24**, 2:59, 12:54, 22:50; **25**, 8:46, 18:42; **26**, 4:37, 14:33; **27**, 0:29, 10:24, 20:20; **28**, 6:16, 16:11.

March 1, 2:09, 12:05, 22:00; **2**, 7:56, 17:52; **3**, 3:47, 13:43, 23:39; **4**, 9:35, 19:30; **5**, 5:26, 15:22; **6**, 1:18, 11:13, 21:09; **7**, 7:05, 17:00; **8**, 2:56, 12:52, 22:48; **9**, 8:43, 18:39; **10**, 4:35, 14:31; **11**, 0:26, 10:22, 20:18; **12**, 6:14, 16:09; **13**, 2:05, 12:01, 21:57; **14**, 7:52, 17:48; **15**, 3:44, 13:40, 23:35; **16**, 9:31, 19:27; **17**, 5:23, 15:18; **18**, 1:14, 11:10, 21:06; **19**, 7:01, 16:57; **20**, 2:53, 12:49, 22:44; **21**, 8:40, 18:36; **22**, 4:32, 14:27; **23**, 0:23, 10:19, 20:15;

LUNAR OCCULTATION

On the night of March 10–11, telescope users across the U.S. and Canada can watch the dark limb of the waxing gibbous Moon occult the magnitude-3.6 star Lambda Geminorum. Find the times for your location at **lunar-occultations .com/iota/bstar/bstar.htm**.

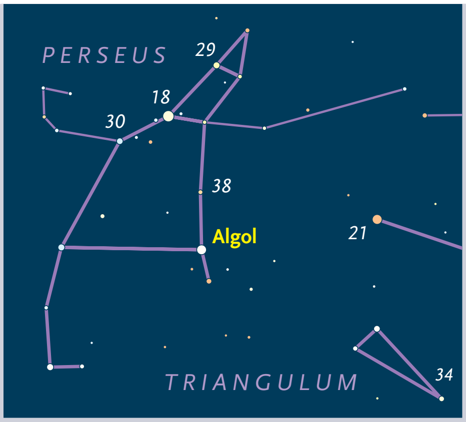
Glance at Algol at any random time, and you have a 1 in 30 chance of catching it at least a magnitude fainter than normal.

24, 6:11, 16:06; **25**, 2:02, 11:58, 21:54; **26**, 7:49, 17:45; **27**, 3:41, 13:37, 23:32; **28**, 9:28, 19:24; **29**, 5:20, 15:16; **30**, 1:11, 11:07, 21:03; **31**, 6:59, 16:55.

These times assume that the Red Spot is centered at about System II longitude 208°. If it's elsewhere, it will transit 1⅔ minutes early for every degree of longitude less, or 1⅔ minutes later for every degree more.

Features on Jupiter appear closer to the central meridian than to the limb for 50 minutes before and after transiting. A blue or green filter helps the contrast of Jupiter's reddish and brownish markings.

Read more about Jupiter and how to make the most of it in our January issue, pages 30, 50, 54, and 72. ✦



Every 3.87 days, the eclipsing variable star Algol fades from its usual magnitude of 2.1 to 3.4 and back. Check it against these comparison stars (their magnitudes have decimal points omitted). Predictions courtesy Gerry Samolyk (AAVSO).

Minima of Algol

Feb.	UT	Mar.	UT
3	17:37	1	13:02
6	14:27	4	9:51
9	11:16	7	6:41
12	8:06	10	3:30
15	4:55	13	0:19
18	1:44	15	21:09
20	22:34	18	17:58
23	19:23	21	14:47
26	16:12	24	11:37
		27	8:26
		30	5:15

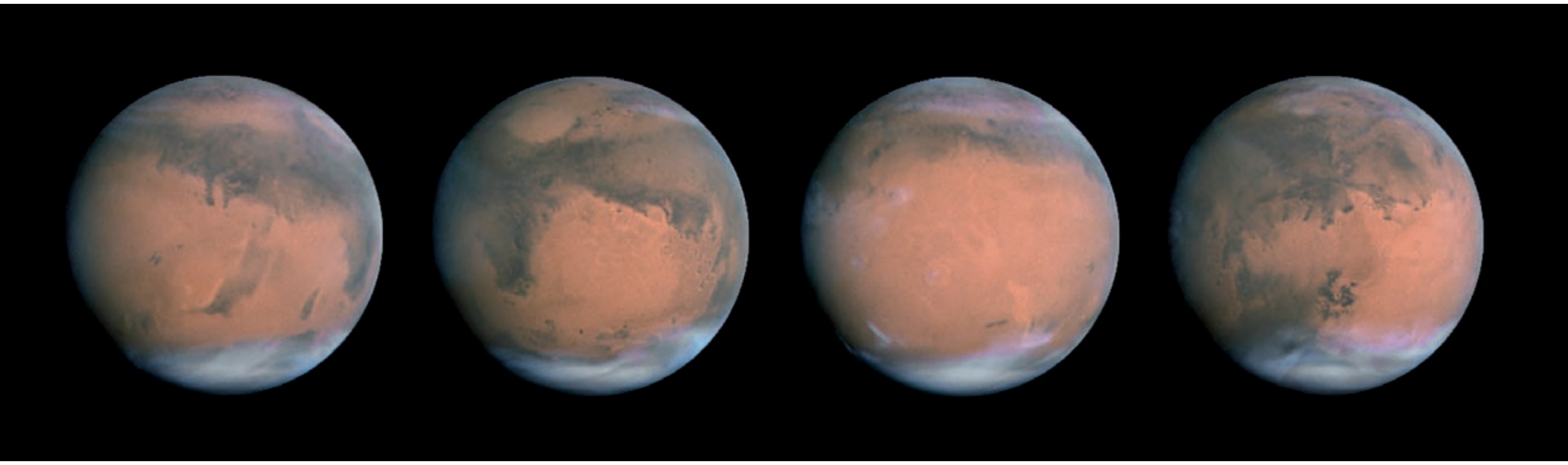
Phenomena of Jupiter's Moons, March 2014

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

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

Changes on Mars

The nearby Red Planet displays remarkable changes every apparition.



NASA / ESA / THE HUBBLE HERITAGE TEAM (STSCI / AURA) / J. BELL / M. WOLFF

Though a predominately dry, desert planet, Mars presents a changing appearance to patient observers. The Hubble Space Telescope captured this series of images in late 2007 showing the entire surface of the planet, including the North Polar Hood enshrouding the polar cap underneath. South is up.

Ever since early 2013, Earth has been steadily closing in on Mars. The approach culminates April 8th in opposition. As the closest rocky planet to Earth whose surface is visible in modest telescopes, Mars easily garners the most attention of all the inner planets. The Red Planet often reveals subtle changes from year to year that stand out to the patient observer. But occasionally, big changes can occur from one apparition to the next.

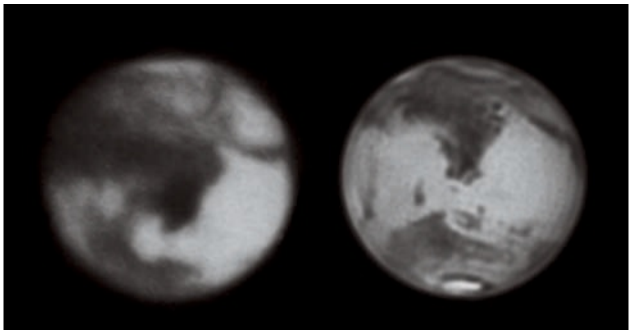
Part of the great attraction Mars has for observers is that the planet once looked more like Earth. Even today, with white cirrus clouds, dust storms, and ice caps that grow and shrink with the seasons, Mars is the most Earthlike of any planet in our solar system. Although the planet's thin atmosphere and dry environment make it look desolate, Mars is far from an unchanging, dead world.

As the planet approaches opposition, keep an eye out for some of these differences. A guide to observing Mars, as well as a map, can be found on page 50.

The Shrinking North Polar Cap

Among the first features even a beginning planetary observer will notice are the Red Planet's bright polar caps. This year, Mars near opposition presents its northern hemisphere to Earth, giving us a nightly view of the rapidly receding North Polar Cap (NPC). At opposition in April, the planet will be well into its long summer season, so the cap should be at its smallest as seen from Earth. That said, the NPC is substantially larger than the SPC and presents many interesting rifts and other features.

As the NPC shrinks, it will unveil what looks like a dark ring encircling the pole. In addition, shortly after New Year's a large, dark rift known as Chasma Boreale should begin to form around 300°W. And at roughly the same time on the NPC's opposite side, a dark swath known as Rima Tenuis will seem to cut off a large, crescent-shaped section of the bright ice cap from the rest of the pole. This



One vivid example of albedo changes occurred sometime in the mid-20th century, when the well-known feature Thoth-Nepenthes vanished. *Left:* This 1956 image shows this curved feature (the middle of the dark, thick C at bottom). *Right:* The author's 2012 image shows only the dark remnant known today as Alcyonius Nodus.

LEFT: E. C. SLIPHER / LOWELL OBSERVATORY; *RIGHT:* S&T: SEAN WALKER

rift should be visible in telescopes 6 inches or larger and will look like a dark inner ring dividing the icy crescent from the main NPC.

Partly Cloudy

Clouds have been prevalent throughout the last several apparitions, and although they are most easily detected by planetary imagers using color filters, observers can enjoy them too. As the NPC recedes, its ices sublimate into the planet's tenuous atmosphere, producing thin clouds that are often visible above the planet's equatorial regions. About this time, the well-known "W" cloud formation often clings to the flanks of the large volcanoes in the Tharsis-Amazonis region. These clouds can sometimes appear so bright that you might have difficulty determining which white spot is the NPC and which is the cloud complex.

Morning clouds and frost can sometimes settle in the broad, low plains of this region, making the giant Tharsis volcanoes Arsia Mons, Pavonis Mons, and Ascraeus Mons, as well as nearby Olympus Mons, appear as dark spots above the bright plains.

In the southern hemisphere, a bright cloud often fills the great Hellas impact basin; don't mistake this for a glimpse of the South Polar Cap.

Dust Storms

In the months leading up to opposition, there's always the chance that changing weather patterns will kick up large dust storms and block parts of the surface from view. Dust storms can spring up overnight and often appear as small, brightish, yellow clouds. They are most prominent when hovering over dark albedo features.

Historically, dust storms have often been spotted in Hellas, Elysium, Chryse, and Solis Lacus. During late October 2005, a large dust storm sprang up in Chryse and then spilled into the deep chasms within Aurorae Sinus. Because of its high albedo compared with the terrain, this storm had the rare effect of making parts of gigantic Valles Marineris visible for a few weeks from Earth in amateur telescopes.

Dust storms can arise almost anywhere on Mars and occasionally encircle the entire globe, obscuring the whole surface. Although global dust events can put a damper on observations, it's exciting to watch these massive wind-driven storms envelop the planet within a few days.

Changing Albedo Features

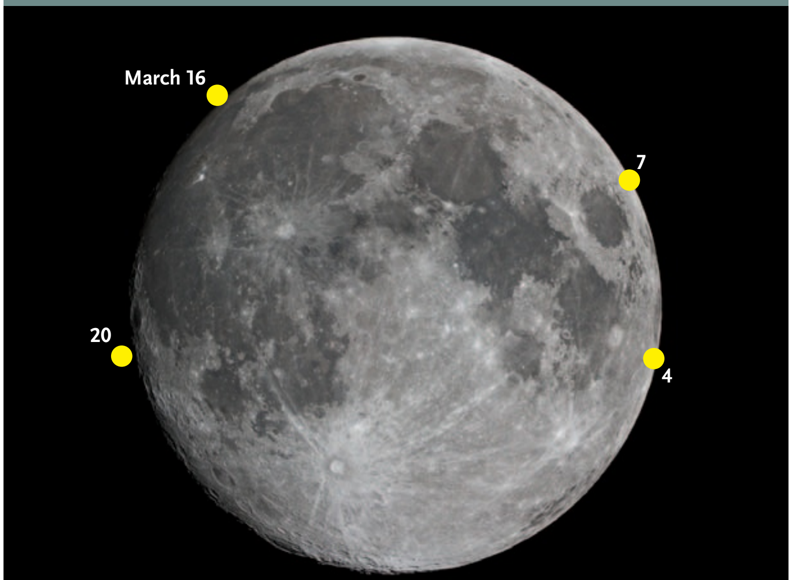
The dark albedo features of Mars have also experienced long-term changes over the years. Dark markings within Solis Lacus have come and gone within the last decade. Additionally, a dark feature at roughly 230°W known as Hyblaeus has also expanded and receded throughout the past quarter century.

Perhaps the largest recent albedo change occurred in the 1960s. Around that time, a large complex of albedo features connecting Syrtis Major to Utopia, located at about 270°W and known as Thoth-Nepenthes, literally disappeared. Today, only the small dark feature known as Alcyonius Nodus remains.

At about the same time as the disappearance of Thoth-Nepenthes, the northernmost tip of Syrtis Major changed from a distinctly pointed feature to the rounded end that today resembles the southern tip of Africa.

Assuming the Red Planet isn't immersed in a globe-spanning dust storm, a dynamic, changing world beckons observers as it draws relatively close for a few brief months every 26 months. Let's see what surprises it has in store for us this year. ✦

The Moon • March 2014



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

S&T: DENNIS DI CICCO

Phases

NEW MOON	March 1, 8:00 UT
FIRST QUARTER	March 8, 13:27 UT
FULL MOON	March 16, 17:08 UT
LAST QUARTER	March 24, 1:46 UT
NEW MOON	March 30, 18:45 UT

Distances

Apogee 251,882 miles	March 11, 20h UT diam. 29′ 29″
Perigee 227,238 miles	March 27, 19h UT diam. 32′ 41″

Librations

Mare Smythii	March 4
Rayleigh (crater)	March 7
Repsold (crater)	March 16
Lacus Veris	March 20

The Twins of Jove

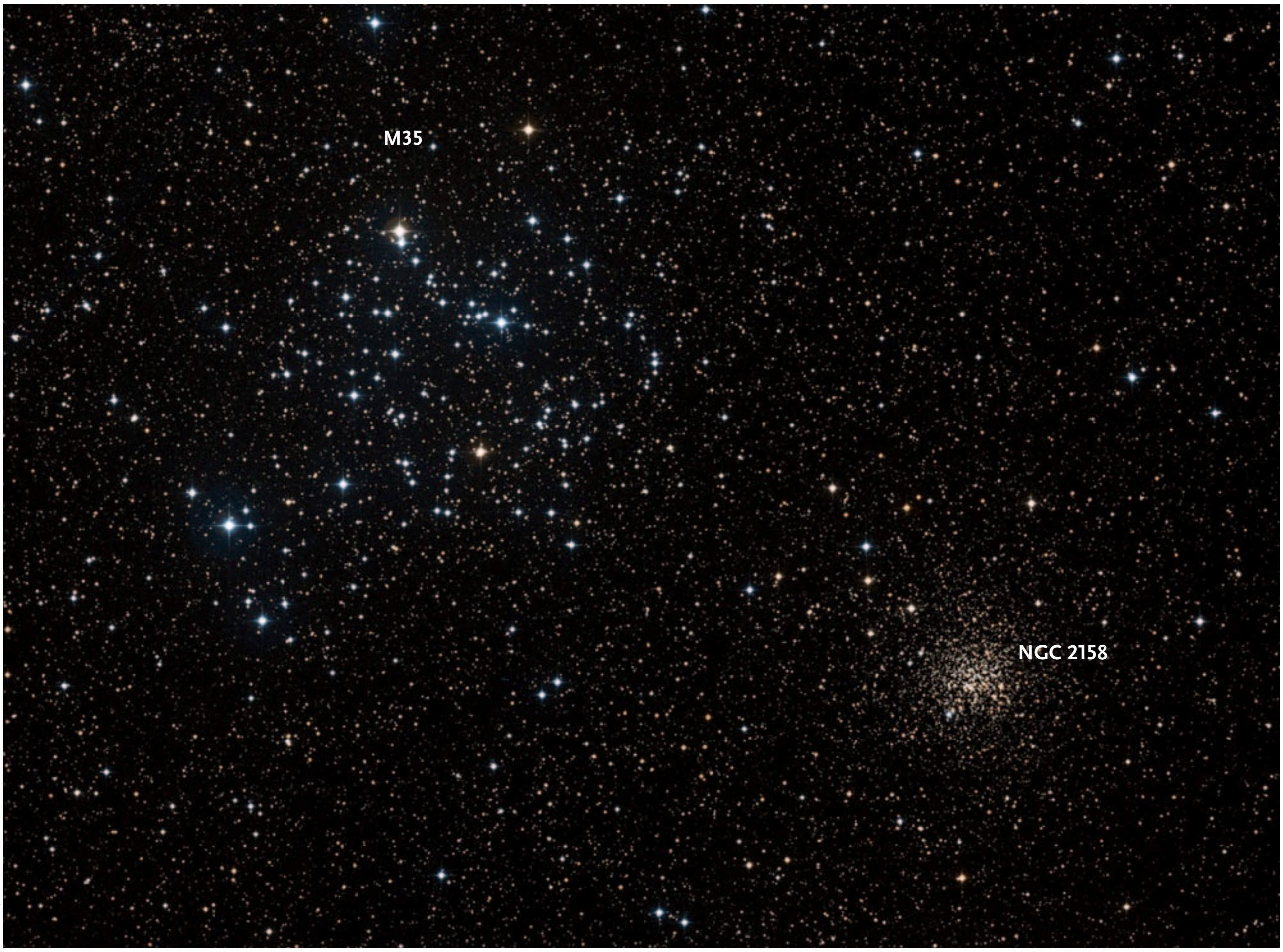
Westernmost Gemini harbors a great variety of nebulae and clusters.

Ye wild-eyed Muses, sing the Twins of Jove,
Whom the fair-ankled Leda, mixed in love
With mighty Saturn's Heaven-obscuring Child,
On Taygetus, that lofty mountain wild,
Brought forth in joy: mild Pollux, void of blame,
And steed-subduing Castor, heirs of fame.

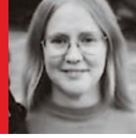
— Percy Bysshe Shelley
Homer's Hymn to Castor and Pollux, 1818

According to some tales, Leda had two mortal children with her husband King Tyndareus and two immortal children with the Greek god Zeus (Jove), who came to her in the form of a swan. Although the original is lost, copies of Leonardo da Vinci's painting *Leda and the Swan* show brothers being hatched from one swan's egg and sisters from another. The girls are Clytemnestra and the beautiful immortal later known as Helen of Troy, "the face that launched a thousand ships." The boys are Castor and immortal Pollux, who grace the sky as the bright winter constellation Gemini, the Twins.

The splashiest deep-sky wonder in Gemini is the breathtaking open cluster **Messier 35**. Even through 15×45 image-stabilized binoculars, M35 is big, bright, and beautiful, with many fairly bright to very faint stars. A zigzag line of field stars makes it look like a pointy-capped mushroom growing up out of Castor's foot. The little, fuzzy ball of nearby NGC 2158 marks the southwestern edge of the cap.



POSS-II / CALTECH / PALOMAR OBSERVATORY



In my 130-mm refractor at 37×, M35 shows about 65 mixed bright and faint stars in the core group, which has ragged edges and spans roughly 25′. I can imagine yet another mushroom, with its cap pointing west, formed from the brightest stars of the core. Outliers stretch the cluster to 40′ and extend as far as NGC 2158. M35's brightest gem is the topaz primary of the double star OΣ 134, while the companion star to the south is a pale sapphire. Although M35 is mainly adorned with blue-white stars, a few shine golden yellow, as does the lovely beacon off the cluster's eastern side. With a wide-field eyepiece giving a true field of 58′ and magnification of 102×, M35 is a stunning jewel box.

NGC 2158 shares the field of view with its flashy cousin, but it's much farther from us — and certainly looks it! In the 37× view described above, NGC 2158 is merely an 8′-wide glow with three superimposed stars: a pair northeast and a brighter star south-southeast of the cluster's center. The cluster is very pretty at 102×, showing perhaps a dozen members stippling the haze. The faintness of the stars is testament to their distance of 16,500 light-years, six times farther away than the suns of M35.

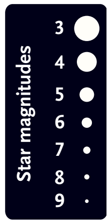
Philippe Loys de Chéseaux is generally credited with the discovery of M35. He included it in a list of 20 nebulae and star clusters that he compiled in the years 1745 and 1746. Among the objects that de Chéseaux deemed ordinary star clusters, it was simply listed as the one above the northern feet of Gemini. Despite its proximity to such a well-known object, NGC 2158 wasn't found until 1784. Discoverer William Herschel called the cluster a miniature of M35 in his *Catalogue of One Thousand New Nebulae and Clusters of Stars*.

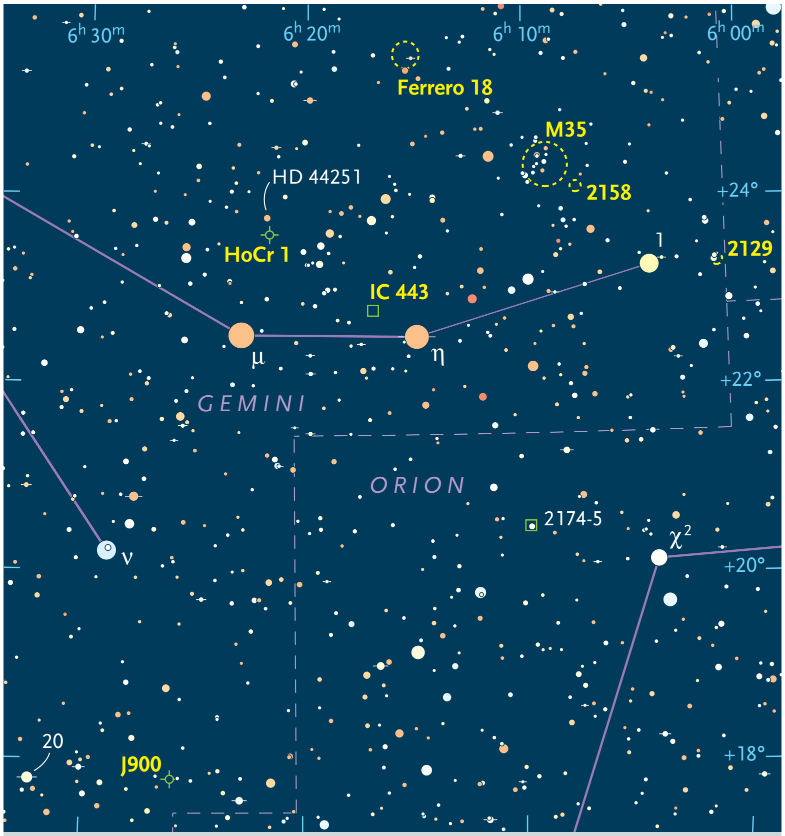
Other enticing objects surround M35, among them **NGC 2129**. This cluster is an easy find 42′ east of the yellow, 4th-magnitude star 1 Geminorum in Castor's northwestern foot. Through my 105-mm refractor at 127×, it packs two bright and about 20 faint to very faint stars into a parcel of sky 7′ across. The cluster is very pretty in my 10-inch reflector, which shows half again as many stars. William Herschel discovered NGC 2129 just before NGC 2158 on the same night.

A nice asterism known as **Ferrero 18** sits 1.9° northeast of M35. In my 130-mm scope at 63×, the group includes the northeastern corner of a prominent square outlined by several field stars. The square's southeastern corner is occupied by a yellow-orange, 7th-magnitude star at the asterism's southern edge. I count 24 stars loosely scattered within 18′. In the view through his 8-inch reflector at 71×, Finnish observer Jaakko Saloranta thinks the group looks a bit like the constellation Scorpius.

Ferrero 18 was found by French amateur Laurent Ferrero during his search for uncataloged star clusters.

Our next target is the elusive supernova remnant **IC 443**. Its position is easy to pinpoint, because the bright star Eta (η) Geminorum marks its western edge. With my 130-mm refractor, I've only seen the nebula's brightest arc, which lies 45′ east-northeast of the star. Its gauzy profile is faintly visible at 37× with an O III filter or at 63× without the filter. It gently curves through a shallow pan outlined by six stars. A seventh star off the pan's south-





Star Groups and Nebulae in the Celestial Twins

Object	Type	Mag(v)	Size	RA	Dec.
M35	Open cluster	5.1	28′	6^h 09.0^m	+24° 21′
NGC 2158	Open cluster	8.6	8′	6^h 07.4^m	+24° 06′
NGC 2129	Open cluster	6.7	7′	6^h 01.1^m	+23° 19′
Ferrero 18	Asterism	—	17′	6^h 15.4^m	+25° 30′
IC 443	Supernova remnant	9	50′ × 40′	6^h 16.8^m	+22° 31′
HoCr 1	Probable planetary nebula	—	73″ × 59″	6^h 21.7^m	+23° 35′
J900	Planetary nebula	11.7	9″	6^h 26.0^m	+17° 47′

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.

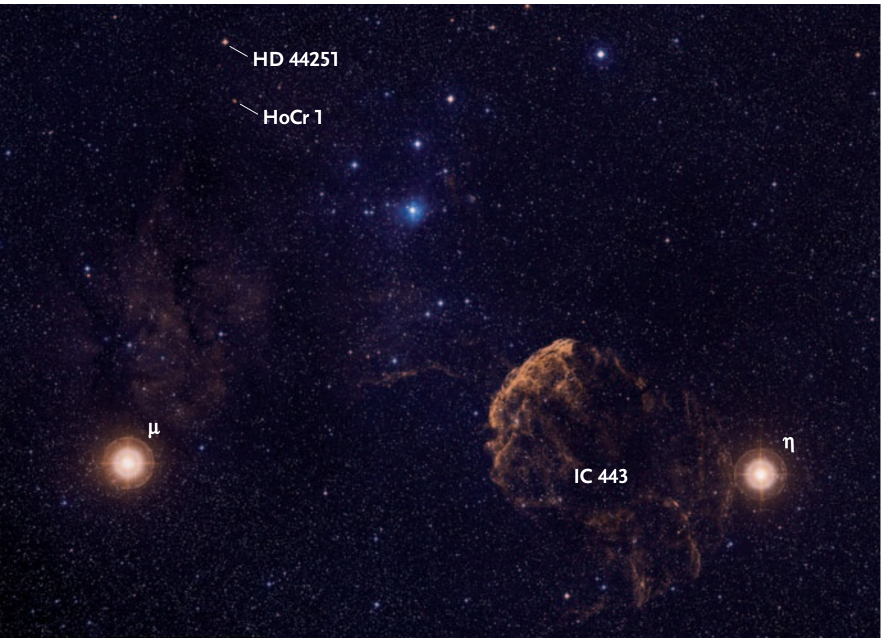
eastern end adds a very short handle. This part of IC 433 is called the Jellyfish Nebula, because in images it looks like a jellyfish bell and has tentacles of nebulosity trailing southwest.

IC 443 displays two sections when viewed in my 10-inch scope at 44×, with either a narrowband or an O III filter. The northeastern arc appears brightest. It's shaped like a fat parenthesis mark nearly ½° long, one-third as wide, and concave toward the southwest. The section near Eta is much more difficult — I can only detect it as an amorphous patch of light southeast of the star and perhaps 12′ across.

German astronomer Max Wolf discovered IC 443 and dimmer IC 444 to its east-northeast with a 2¼-inch, portrait-lens astrograph in 1892.

Not far from IC 443, the probable planetary nebula **Howell-Crisp 1** dwells 1.1° north-northwest of Mu (μ) Geminorum and only 11′ south of the 7.3-magnitude star HD 44251. I couldn't spot it with my 14.5-inch reflector at 276× — until I added a narrowband filter. Then, a little touch of mist made its debut, resting on the northeastern wing of a 10′ asterism that resembles a butterfly. HoCr 1 seems slightly elongated and about 35″-long, with a very faint star nuzzling the northeastern end. Knowing what to expect, I could then detect the nebula using averted vision with the filter removed. In many images, the nebula looks rather blocky.

Michael Howell discovered HoCr 1 on an image he made in early 2006. Later that year, he began a collaboration with fellow narrowband-imager Richard Crisp to identify it. Astronomer George Jacoby provided high-resolution images and is listed as the primary investigator in a 2010 paper in *Publications of the Astronomical Society of Australia* that includes this object. Spectral data support its classification as a planetary nebula.



POSS-I / CALTECH / PALOMAR OBSERVATORY

ESA / HUBBLE / JOSH BARRINGTON

Finally, we'll visit the planetary nebula **Jonckheere 900**. You'll find it 1.5° due west of the pretty, low-power double 20 Geminorum, whose components shine yellow and yellow-white. J900 is easy to see through my 105-mm refractor at 47×, but it appears stellar. At 122× it becomes a tiny nebula with a star on its south-southwestern edge. I tried some intermediate magnifications, but star and nebula blended together as one little blob.

Robert Jonckheere was one of the leading double-star discoverers of the 20th century. Among his finds were some nebulae and galaxies masquerading as double stars. In 1912 Jonckheere announced that J900 is a 3″ planetary nebula showing two stellar points within. In 1917 Edward Emerson Barnard wrote that with the 40-inch Yerkes Observatory refractor, the nebula spanned 7.9″ and was possibly a little brighter in the east, but he saw no central condensation or stars. Jonckheere replied that he'd seen three condensations in 1915, and he attributes the difference in the nebula's apparent size to the aperture of the telescopes. His original estimate of 3″ was made with a 12.8-inch refractor, and his 1915 estimate with a 28-inch refractor was 6.1″. The presence of knots in J900's structure was later confirmed photographically. What do you see through the eyepiece of your telescope? ✦

Dennis di Cicco

iOptron's New ZEQ25GT Mount

There's more to this equatorial Go To mount than just a radical new design.

ZEQ25GT

U.S. price: from $799 (as tested: $937, including tripod, polar-alignment scope, carrying case, and tripod bag)

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

Tipping the scales at only 10½ pounds (4¾ kg) without the counterweight shaft, the ZEQ25GT is compact and very portable. The pivoting counterweight shaft clears the tripod legs when the mount is set for low latitudes all the way to the equator.

ALL PHOTOS BY THE AUTHOR UNLESS OTHERWISE CREDITED

Someone can correct me if I'm wrong, but I can't recall a company ever offering a wider variety of telescope mounts than iOptron currently does. From small and midweight alt-azimuth designs to a range of German equatorials, the company has the biggest selection of Go To mounts available today. Although iOptron's lineup stops short of the massive "observatory" equatorials used by elite astrophotographers, its offerings fully cover the workhorse needs of amateur astronomy. I've spent decades using portable equipment everywhere from my driveway to the Australian Outback, and there's never been an occasion when I wouldn't have been well served by one of the mounts currently available from iOptron.

One of the company's newest Go To equatorials is the ZEQ25GT. It is touted as a "Z balanced" design because it has the telescope and the counterweights at opposite ends of the polar axis. Compared to a traditional German equatorial mount, the ZEQ25GT's center of gravity is closer to the middle of the equatorial head, leading to better inherent stability. As such, the mount's designers could keep the ZEQ25GT's weight low relative to its specified 27-pound (12¼-kg) telescope load capacity. Indeed, without the counterweight shaft attached, the whole equatorial head weighs only 10½ pounds.

The ZEQ25GT proved to be remarkably stable for its small size and light weight, but initially I had to wonder why iOptron's engineers in China undertook such a radical redesign to shave what would have been only a few pounds from a traditional German equatorial of the same load capacity. An answer to this question may have come last November with the unveiling of iOptron's CEM60 at the Arizona Science & Astronomy Expo in Tucson. A variant of the ZEQ25GT's design, the CEM60 also offsets the telescope from the end of the polar axis, keeping the center of gravity near the middle of the mount. It appears

S&T: SEAN WALKER

***Above:* Mentioned in the text, iOptron's CEM60 (seen here at its unveiling last November at the Arizona Science & Astronomy Expo) is another equatorial mount with a "balanced" design. *Below:* A bubble level and latitude scale aid in setting up the ZEQ25GT quickly in the field. Care is needed when attaching cables to their respective ports because many use identical modular jacks.**

that iOptron is making a concentrated effort to increase the load capacity and performance of portable equatorial mounts. It's an admirable accomplishment that helps the majority of amateur astronomers who, like me, frequently set up and break down equipment when they observe.

Take one look at the ZEQ25GT's profile from the side and you immediately see where the "Z" in the mount's name comes from. But I also sense a bit of nationalistic pride in the moniker, since Mandarin-speaking Chinese call their country Zhongguo. And speaking of names, one might ponder whether this design is a significant enough departure from the traditional German equatorial mount to be called something entirely new. That's for the astronomical community to decide, but for me the "Z" in the name serves as a nice reminder that this is a Chinese-designed equatorial mount.

WHAT WE LIKE:

Excellent Go To and tracking performance

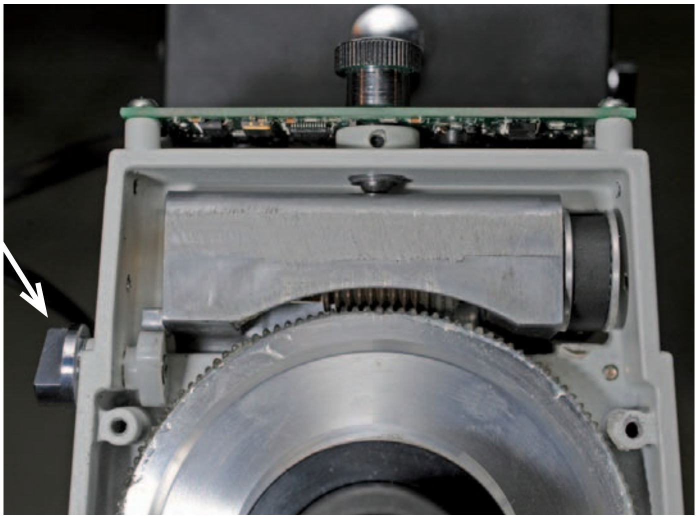
Highly portable with good load capacity for its size and weight

Quiet operation, especially when slewing

WHAT WE DON'T LIKE:

Obstructed GPS antenna (see text)

Limited astronomical information for objects in database



Far left: **To help with balancing the mount, the right ascension and declination drives have gear switches (arrowed) that release the worms from their worm wheels.** ***Near left:*** **The hand control has variable-brightness illumination for the display and buttons. The illumination automatically turns off during periods of inactivity, but returns the moment any button is pressed.**

Notes from the Field

Despite its unusual design, the ZEQ25GT sets up and operates just the same as a conventional German equatorial, and anyone familiar with a traditional equatorial mount will have no problems using this one. Furthermore, the heavily illustrated Quick Start Guide clearly explains the basics as well as features specific to the ZEQ25GT, such as the quick-release "gear switch" that disengages the worm gears from the worm wheels on the right ascension and declinations axes. When the gears are disengaged, the axes swing freely, making it very easy for you to precisely balance the mount on both axes.

The mount is available with an optional hard-sided carrying case and soft-padded tripod bag with shoulder straps.

The mount we borrowed from iOptron for this review came with an optional polar alignment scope. As I've mentioned in previous reviews of iOptron equipment, I'm very impressed with this alignment system for its simplicity and accuracy. The scope's illuminated reticle has two sets of concentric rings graduated into 12 hours. They are for use with Polaris in the Northern Hemisphere and Sigma Octantis in the Southern. Based on the date, time, and location stored in the mount's electronics (more about this in a moment), the hand control graphically displays where you need to position either of these stars on the reticle to achieve accurate polar alignment. There are no calculations necessary on the user's part.

For example, let's say the hand control indicates putting Polaris at the 7^h 30^m mark. You just view through the polar scope and use the fine-motion screws on the mount's azimuth and altitude adjustments to move Polaris in the field of view until it's at the reticle's 7^h 30^m mark and you're done. If you own an Apple mobile device running iOS 6.0 or later, I highly recommend you purchase iOptron's *Polar Scope* app ($1.99 from the iTunes App Store — search for "iOptron"). I find the app visually easier to use for determining the alignment star's correct position on the reticle.

The ZEQ25GT has a built-in GPS receiver for automatically setting the mount's date, time, and geographical coordinates. But there's a caveat. The receiver's antenna is located in the mount's main electronics module, which is attached to the top of the polar-axis housing. As such, it does not have a clear view of the sky when the mount is set up in its initial "home" position with the telescope above the polar axis and pointed toward the celestial pole. In this position, the declination drive blocks the antenna's sky access, which is needed to get a fix from the GPS sat-

The ZEQ25GT is lightweight enough to carry around with a telescope attached. The author did most of his testing with a pair of 4-inch refractors, including the Tele Vue NP101 pictured here.

ellites. Indeed, I was never able to achieve a GPS fix with the mount in the home position.

The simple solution is to swing the polar axis until the declination drive is far to the east or west side of the mount before powering up the electronics (an easy task thanks to the gear switch mentioned earlier). After a minute or two an audible beep and a message briefly appearing on the hand-control's display will alert you to the mount achieving its GPS fix (assuming there aren't other significant sky obstructions due to trees or buildings). You can then swing the polar axis back to the home position and proceed with the initialization of the Go To pointing using any of several alignment methods involving stars or solar system objects.

Of course, you can dispense with the GPS altogether and manually input the data. Whether you or the GPS enters the data, the electronics retain the information and the correct time when the mount is powered off thanks to a user-replaceable button battery in the hand control. Thus, unless you move to a significantly different location that warrants new geographic coordinates (think tens of miles), the electronics will be immediately ready to use on subsequent nights.

Lasting Impressions

The take-away feeling I got from using the ZEQ25GT for several months last summer, fall, and winter is that it's a very good performer for its compact size and light weight. I spent most of my time using it with a pair of 4-inch refractors, but I also tried it with an 8-inch Schmidt-Cassegrain tube assembly. Although these scopes were all well within the mount's specified weight capacity, I don't think the mount would be a good match for apertures larger than the 8-inch, at least not with the standard tripod supplied with the mount. There is, however, an optional tripod available that has 2-inch-diameter legs, rather than the 1½-inch legs on the standard model.

The ZEQ25GT made a superb platform for camera-only astrophotography. Although Comet ISON's post-perihelion apparition was a bust (page 10), my advanced preparations included testing the mount with a pair of heavy DSLR bodies and a variety of lenses. The whole kit was relatively lightweight and highly portable. And even speedy setup in the field using just the polar-alignment scope was more than adequate for 5- to 10-minute unguided exposures with lenses up to 180-mm focal length.

Having the telescope mounted on the south end of the polar axis didn't cause any unusual problems. As with conventional German equatorial mounts, there are parts of the sky where you have to be careful to avoid having the telescope run into the tripod legs. In general, the ZEQ25GT offered a little more "open" access to the northern part of the sky, whereas a conventional German equatorial gives the nod to the southern part. The only time I really noticed a difference between the two styles of mounts was when I observed around the southern meridian with the ZEQ25GT and Schmidt-Cassegrain, since I found myself shouldering up to the equatorial head and straddling the northern tripod legs.

The Go To pointing of the ZEQ25GT was well above average. Most nights I'd use a "one-star alignment" to initialize the pointing after adjusting the mount on the celestial pole with only the polar-alignment scope. With the telescope set in the home position, selecting the one-star alignment automatically sends the scope to the approximate location of a bright star you pick from a list displayed on the hand control. You use the control's push buttons to move the scope until the star is centered in the field of view, press the "enter" key, and your Go To slewing is ready to use. I could send the scope to targets across the entire sky and always have them appear in the field of a low-power eyepiece.

There was one other aspect of the ZEQ25GT that I really liked — the way it sounds when slewing. I find the typical howling motors of most Go To scopes really annoying. But the new iOptron drive was not only far quieter than most Go To scopes, its sound was much more pleasant. It didn't intrude on the serenity of the night sky nearly as much as most other Go To mounts do.

Overall the ZEQ25GT proved to be a very capable equatorial mount. It was an ideal companion for the 4-inch refractors, since I could leave these scopes on the mount and carry the whole setup into the yard in one trip. Polar alignment is fast and the Go To pointing accurate, making spur-of-the-moment observing a breeze. ✦

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*Senior editor **Dennis di Cicco** has been gazing skyward since the dawn of the Space Age.*

▲ **MOTOFOCUS** Jim's Mobile Incorporated releases its MOTOFOCUS for William Optics DDG focusers ($179). The unit attaches to William Optics telescopes with the Digital Display Gauge and comes with all the required hardware to attach directly to your focuser. This enables you to precisely and repeatedly adjust focus in tiny, 0.01-mm increments for visual or imaging applications. Each purchase contains the mounting bracket, screws, a coiled 1/8 jack cable, and a MOTOFOCUS hand paddle. Specify at the time of ordering whether you own a William Optics telescope or use their replacement focusers for Synta telescopes.

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▼ **IMPROVED MARS** The Red Planet really hasn't been improved, but our 12-inch-wide globe has. *Sky & Telescope's* Mars Globe ($99.99) is assembled from more than 6,000 images captured by NASA's Viking orbiters and has been tweaked to better approximate the planet's natural color appearance. Produced in cooperation with NASA and the U.S. Geological Survey, the globe includes official names for 140 features, as well as the positions of all past and current surface science missions, including NASA's newest lander and rover, Phoenix and Curiosity. Each purchase comes with a clear plastic stand and a 16-page booklet about the planet, which describes recent scientific discoveries involving Mars's evolution from a warm-and-wet world that may have supported life to the planet-wide desert that we see today.

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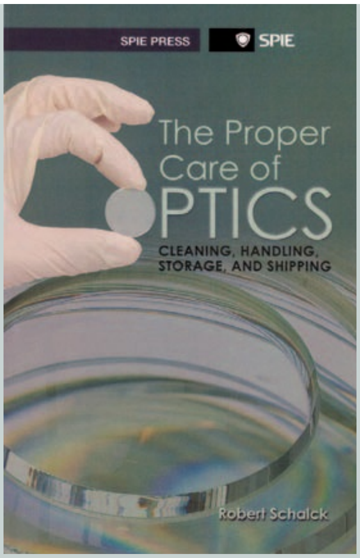

OPTICAL CARE To get the best performance from your optics, you need to properly maintain them. The new book by Robert Schalck, *The Proper Care of Optics* ($43), details the best techniques used by professional opticians to clean, handle, and store precision optics. Written for a diverse audience, Schalck explores many ways to clean optics from a variety of time-tested sources and learned by trial and error. Topics include assembling your cleaning tools and preparing your work area; popular solvents and cleansing agents for restoring any optical element to its peak performance, including mirrors, lenses, and anti-reflection coatings; and proper cleaning methods for removing contaminants from CCD and CMOS sensors. SPIE Press, ISBN 978-0-8194-9457-3, paperback, 236 pages.

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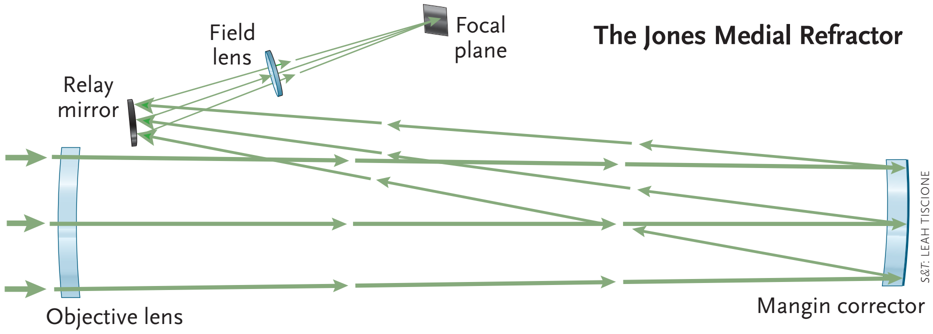
New Product Showcase is a reader service featuring innovative equipment and software of interest to amateur astronomers. The descriptions are based largely on information supplied by the manufacturers or distributors. *Sky & Telescope* assumes no responsibility for the accuracy of vendors' statements.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

The Jones Medial Refractor

This optical design builds on the strengths of several previous ones.



TELESCOPE MAKING IS a hobby with many facets. Some people enjoy assembling scopes with commercial parts, whereas others want to make everything from scratch. And there are also the adventurous ones such as Ed Jones of Ohio who enjoy creating new designs.

I featured Ed's Chiefspiegler reflector in the November 2008 issue, page 87. His newest effort is a high-performance design that he calls the Jones Medial Refractor. It builds on some of his previous scopes, including the Chiefspiegler, and it also shares DNA with exotic designs such as the Schupmann and Honders/Busack Medial refractors. "When developing this design," Ed says, "I started with the Honders/Busack Medial, but I tilted the lenses to avoid an obstruction, and I used Chiefspiegler-type correctors."


ED JONES

Ed Jones shows off his 7-inch Medial refractor that features apochromatic performance.

Ed's scope has a single-element, 7-inch objective (made from BK7 or K5 optical glass). The next element in the optical path is a 6.66-inch diameter Mangin corrector — a lens whose back surface is aluminized (or chemically silvered in Ed's case) to reflect light back through the lens a second time. As such, it functions as both a lens and a mirror. The Mangin corrects for the chromatic aberration of the single-element objective.

In Ed's design, the Mangin is tilted to divert the light cone toward the side of the tube, thus avoiding the need for an obstructing secondary mirror. But, as is typical in the optical-design game, the solution to one problem often creates a new one. In this case, the new problem is a tilted field. "To correct for this, I changed the folding element from a 2.19-inch flat mirror to one with a very weak convex curve," Ed says. "The result is a telescope that is highly corrected, like the Honders, but unobstructed." Light from the convex mirror is fed through a 2-inch-diameter plano-convex field lens that corrects for lateral color error and astigmatism. This is an off-the-shelf component (part number 011-4660) from OptoSigma (**optosigma.com**)

Ed's scope has five optical surfaces (excluding the field lens), each of which must be generated, polished, and tested. That sounds like a lot of work, but all the surfaces are spherical, which makes the task considerably easier. The extra effort does, however, pay off. The resulting telescope is compact, features a convenient eyepiece position, and most importantly is a superb performer. "The scope works very well at high magnification with no hint of color error," Ed reports. "It puts a lot of dark sky between all four of the components in Lyra's famed Double Double. I also enjoy using a low-power eyepiece and seeing perfect star points all the way out to the edge of the field."

Ed's 7-inch is just one possible variant of the design; his recipe can be modified to produce other examples that retain its excellent performance. For instance, Ed says that with some changes to the focal ratio and the spacing of elements, the design can be scaled up to a 40-inch scope and still be diffraction limited across the entire visible spectrum!

Readers interested in exploring the Jones Medial Refractor further can obtain detailed information by e-mailing Ed at opticsed@gmail.com. ✦

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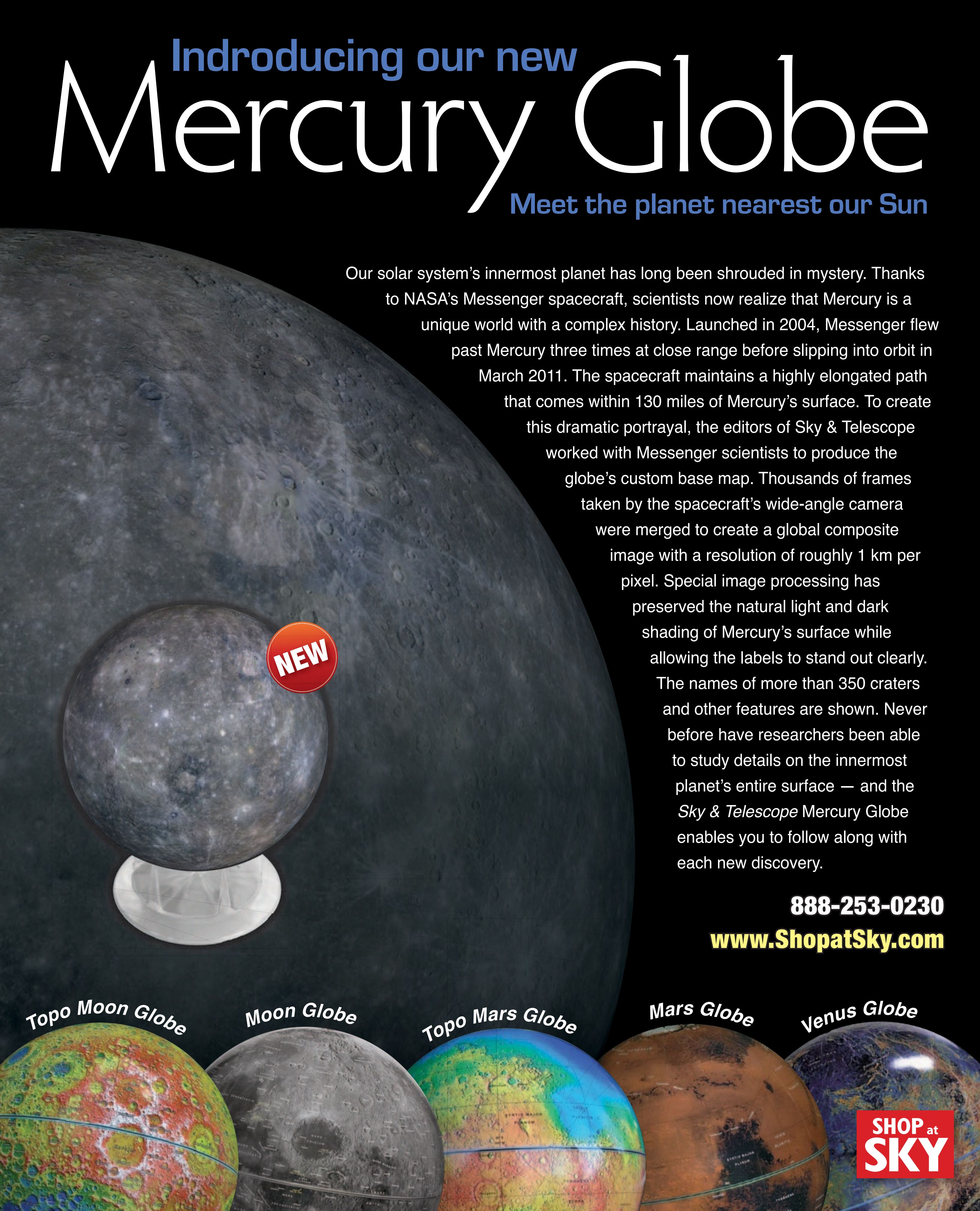
*Contributing editor Gary Seronik is an experienced telescope maker and observer. He can be contacted through his website, **www.garyseronik.com**.*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Meet the planet nearest our Sun
Our solar system's innermost planet has long been shrouded in mystery. Thanks to NASA's Messenger spacecraft, scientists now realize that Mercury is a unique world with a complex history. Launched in 2004, Messenger flew past Mercury three times at close range before slipping into orbit in March 2011. The spacecraft maintains a highly elongated path that comes within 130 miles of Mercury's surface. To create this dramatic portrayal, the editors of Sky & Telescope worked with Messenger scientists to produce the globe's custom base map. Thousands of frames taken by the spacecraft's wide-angle camera were merged to create a global composite image with a resolution of roughly 1 km per pixel. Special image processing has preserved the natural light and dark shading of Mercury's surface while allowing the labels to stand out clearly. The names of more than 350 craters and other features are shown. Never before have researchers been able to study details on the innermost planet's entire surface — and the Sky & Telescope Mercury Globe enables you to follow along with each new discovery.
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The Origin of Stacking

Modern astroimagers owe a debt to the pioneers at Lowell Observatory.

Klaus Brasch

Those of us old enough to have cut our teeth on film-based astrophotography can't help but feel a twinge of envy at how easy it has become to capture impressive images of the Sun, Moon, and bright planets. These days, people can do it by simply holding a smartphone to the eyepiece of a telescope and snapping a few pictures. Likewise, thanks to ever more sophisticated and easy-to-use digital technology, amateurs now routinely capture deep-sky and solar system images that not only rival those taken by professional astronomers but can actually make valuable scientific contributions.

Astrophotographers today regularly capture multiple images of the Sun, Moon, and planets in rapid sequence with video or DSLR cameras, then "stack" them together

Stacking multiple exposures to increase the signal-to-noise ratio in astrophotos today requires nothing more than a few clicks of a mouse, but the fundamentals of the method owe a large debt to the darkroom work of two pioneers of astronomy: Earl C. Slipher (*left*) and Harold L. Johnson (*right*). Unless otherwise noted, all images are courtesy of Lowell Observatory.

with dedicated software. Likewise, deep-sky enthusiasts take many CCD or DSLR images of a single object and combine them using any number of special software applications. The goal in all this is to produce composite images with less noise, higher contrast, and better resolution than a single exposure can provide. Yet as accustomed as we are to stacking images using digital technology and software, it's perhaps surprising to learn that image stacking isn't a recent innovation — it has been around for close to a century.

Two pioneers in composite image stacking (known then as *integration printing*) were famed Lowell Observatory astronomers Earl C. Slipher (1883–1964) and Harold L. Johnson (1921–1980). Together they developed improved astronomical photographic techniques that later became standard throughout the age of film, and even made the transition into the digital age.

Planetary Pioneer

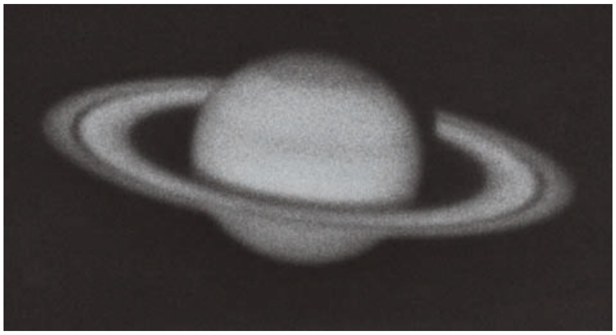
Earl C. Slipher, or "E. C." as he was known, was an extraordinary planetary photographer. He was the brother of renowned astronomer Vesto M. Slipher (1875–1969), who was best known for his discovery of galactic redshifts and the subsequent realization that many of these "nebulae" are moving away from us (September 2009 issue, page 30).

Earl Slipher began systematic photography of Mars with Lowell's famed 24-inch Clark refractor in 1907, and he continued photographing it and other planets into the early 1960s. Many of his finest images were published in two classic books: *Mars, the Photographic Story* (1962) and *A Photographic Study of the Brighter Planets* (1964).

A life-long adherent of Percival Lowell's belief in Martian "canals," Slipher was determined to demonstrate their reality photographically. This proved a near-impossible task, and not just because of their dubious nature: the extremely slow and grainy emulsions available to him at the time made the work daunting. In an effort to circumvent both the technical limitations inherent in black-and-white photography and the relatively low contrast of emulsion-based images, he experimented with various color filters, telescopes, focal lengths, exposures, and types of emulsions.

Although most of Slipher's experiments with photography did little to improve the quality of his early planetary pictures, his methodical experimentation in 1918 led to the standardization of photographic plates for astronomical photometry, which were used until the advent of digital photography.

Sometime around 1930, Slipher became aware of a new photographic technique known as integration printing. The method consisted of capturing several photos of a stationary subject and then meticulously aligning and exposing these plates on a single print. Due to the random distribution of the emulsion grain on each individual negative, combining precisely registered (aligned) negatives into one photographic print resulted in a photo with much less film grain than a single negative could produce, increasing the signal-to-noise ratio in the image.

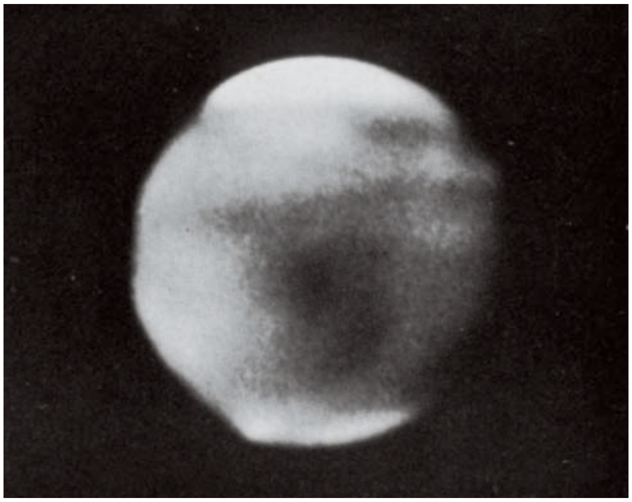


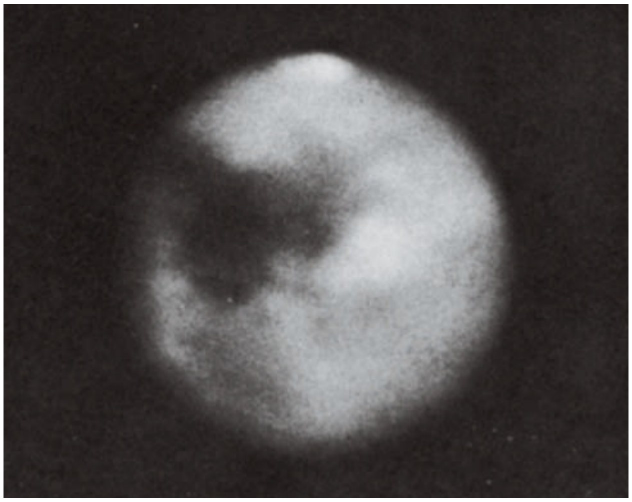
During the early 20th century, the technique of "integration printing" became the standard method used for photographing the planets. A single exposure produced a grainy image with the film available at the time (*top*). But by combining multiple exposures together in a single print, the random grain distribution on each negative would be reduced while details recorded in every negative, such as the atmospheric bands on Saturn (*bottom*), would be enhanced.

Producing an integrated print required dividing the total printing exposure needed for a single negative among the number of negatives used. Unfortunately, photographic paper doesn't respond to light in a linear fashion, so each successive negative would have to be exposed for a shorter duration to contribute equally to the final image. For example, one study recommended combining three negatives by exposing the first for 59% of the total time, the next for 23%, and the final negative for 18%.

Slipher quickly adapted this technique to planetary photography. He took many sequential exposures of a planet on a single photographic plate in rapid succession, and then he combined the images into a composite print using a specially constructed apparatus that precisely adjusted the paper's position to register each negative. The resulting images exhibited higher contrast and markedly reduced graininess compared with single exposures.

Using this complex technique, Slipher was able to produce some of the most detailed images at the time of Mars, Jupiter, and Saturn during favorable apparitions. His images of Mars show hints of what he continued





Using the integration printing technique, Slipher documented Mars for more than five decades. Over that period he recorded changes in albedo features (see page 50), captured atmospheric belts for the first time (*left*), as well as numerous dust storms (*right*).

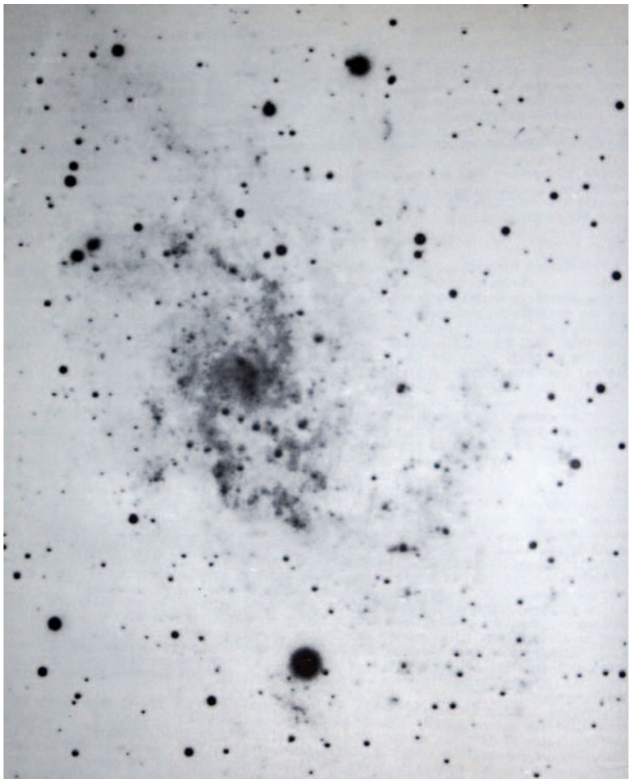
to refer to as canals throughout his long career. Slipher never realized that he was in fact recording subtle contrast and color differences between adjacent albedo features: only a few of his photographs were combined into color prints during his lifetime. One year after Slipher died in 1964, NASA's Mariner 4 spacecraft photographed parts of Mars and conclusively showed that the canals were in fact wind-driven streaks of sand and dust. Slipher might have reached the same conclusion if he had had access to the ultrafine-grained film that became available later.

Fortunately for us, Slipher passed along his integration printing technique to his eventual successors at Lowell Observatory, including Charles F. "Chick" Capen. Capen shared the information with members of the Association of Lunar and Planetary Observers (ALPO).

Deep-Sky Improvements

Although integration printing led to advances in planetary photography, the technique was slower to enter the realm of deep-sky astrophotography. During his seven-year tenure at Lowell Observatory (1952–1959), Harold L. Johnson devoted almost all his efforts to perfecting photoelectric photometry, ultimately leading to the Johnson-Morgan UBV (ultraviolet, blue, and visible) system of stellar observing that is still in use today.

Almost forgotten amid his many other achievements is a 1958 paper coauthored by Johnson with R. de F. Neville and Braulio Iriarte in the *Lowell Observatory Bulletin* (Vol. IV, No. 93), modestly titled "A method of increasing the photographic limiting magnitude of an astronomical telescope." Directly influenced by Earl Slipher's planetary work, the team used the 13-inch photographic refractor (the same used to discover Pluto nearly three decades earlier) to take several identically developed 45-minute exposures of the galaxy M33 on the widely used Eastman 103a-0 plates. Prints were then made from a single plate and compared with a composite image generated by combining 10 plates with the same superpositioning apparatus developed by Slipher.



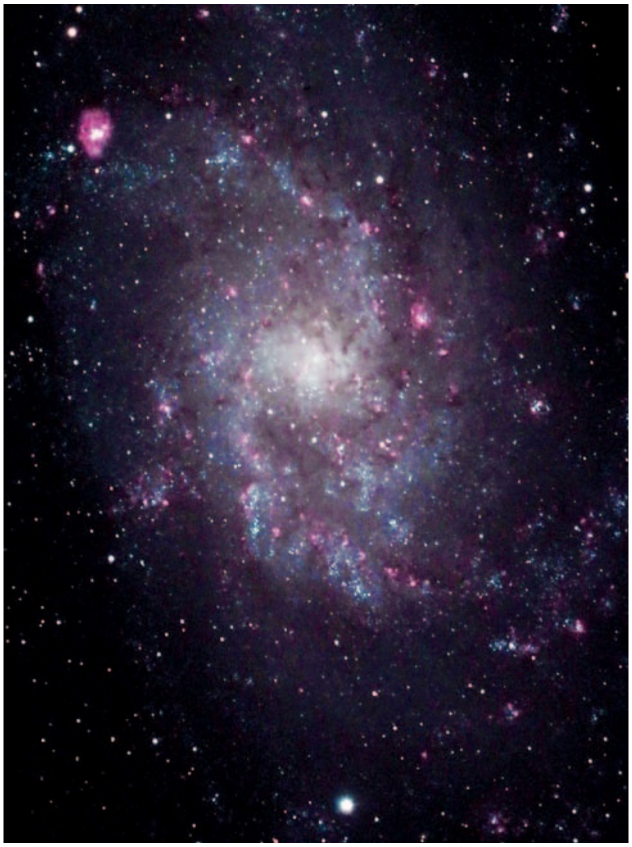
While working at Lowell Observatory, Harold L. Johnson published a short paper on integration stacking of deep-sky images. *Near right:* This is a single negative of M33 taken through a 13-inch refractor. *Far right:* By integrating ten 45-minute negatives of M33, he increased the limiting magnitude of the image. Note the increased visibility of stars and the spiral arms.

The final composite print reveals an impressive gain of 1.2 magnitudes over the single exposure, from 18.5 to 19.7. This tour de force is doubly impressive, because all 7½ hours of exposures were manually guided, requiring constant, careful hand-guided corrections at the telescope, followed by equally intensive work in the darkroom to develop, mechanically align, and print each negative to produce the final result.

From Film to Bytes

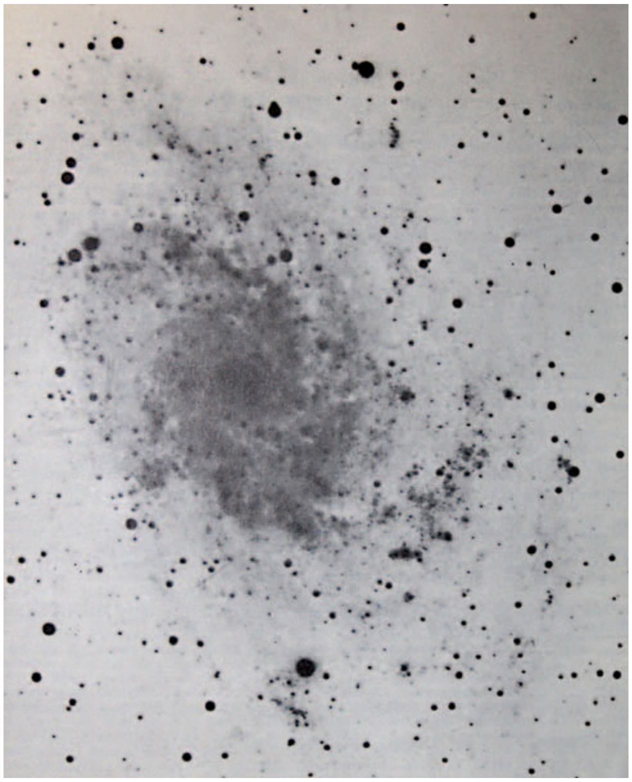
So how do Johnson and Slipher's laborious efforts measure up against today's digital technology? It wouldn't be fair to compare their results with the images that are produced by modern professional observatories. Even amateurs using relatively modest equipment routinely produce higher-resolution images of the bright planets and much deeper images of deep-sky targets than anything that was possible a half century ago. But the process of integration printing (now known as stacking) has become a fundamental principle in nearly all astrophotography done today.

In planetary imaging, software programs automatically sort and stack thousands of images to produce composites. These images are so free of noise that aggressive sharpening techniques can be applied to reveal details only hinted at in the best images of the film era. Additionally, these programs take stacking to a higher level by monitoring hundreds of points in a video and then stacking the sharpest *portions* of each image.



KLAUS BRASCH

Today, consumer DSLR cameras and amateur telescopes easily top the overall quality of the best film astrophotographs of the mid-20th century by relying on the integration principle. The above image of M33 was recorded by the author using a modified Canon EOS 6D DSLR with a Celestron EdgeHD 11 Schmidt-Cassegrain telescope. He stacked five 5-minute exposures to record considerably fainter stars.



Every deep-sky photo-processing program uses a stacking algorithm to increase the signal-to-noise ratio — much as Johnson and his colleagues describe in their 1958 paper — while also removing additional unwanted signals, including satellite and airplane trails. With electronic autoguiding and automated imaging programs, professionals and amateurs alike can shoot as deep as their skies will allow by shooting dozens of hours of exposures over multiple nights. And you can combine the exposures nearly automatically on your computer, without the need for a custom mechanical apparatus or photographic developing chemicals.

Although we have come a very long way since the age of emulsion-based astrophotography, the ingenuity of these pioneers shines through in nearly every planetary and deep-sky image you see today. ✦

*Astrophotographer **Klaus Brasch** wishes to thank Lowell Observatory librarian and archivist Lauren Amundson for her invaluable assistance in researching this article.*

▶ **A COLORFUL ROSE**
Fred Herrmann
The open cluster NGC 2244 nestles in the Rosette Nebula of Monoceros, surrounded by extended nebulosity.
Details: *Takahashi FSQ-106N astrograph with SBIG STL-11000M CCD camera. Total exposure was 4⅞ hours through narrowband and color filters.*

▼ **LOVEJOY SURPRISE**
P-M Hedén
Comet Lovejoy (C/2013 R1) puts on a wonderful display among the stars of Canes Venatici on the evening of November 27, 2013.
Details: *Canon EOS 6D DSLR camera with Pentax 105-mm lens. Total exposure was 15 seconds at ISO 8000.*

HIDDEN GEM OF CYGNUS

André van der Hoeven

This nebulous region in Cygnus lies roughly 1½° southwest of Gamma Cygni. It includes (top to bottom) the reflection nebula vdB 130, the emission nebula LBN 234, and the shapely dark nebula Barnard 344. South is up.

Details: *Telescope Engineering Company APO140ED refractor with QSI 583wsg CCD camera. Total exposure was 32 hours through Astrodon narrowband and color filters.*

▲ **ORION CLOUD COMPLEX**
Gerald Rhemann
The brilliant nebulous complex in Orion includes M42 and the bluish Running Man Nebula (NGC 1977), with pink M43 sandwiched between them. North is to the right.
Details: *ASA Astrograph H f/2.8 with Finger Lakes Instrumentation FLI PL16803 CCD camera. Total exposure was nearly 18 hours through color filters.*

▶ **DUSTY TADPOLES**
Steve Coates
Within the faint nebula IC 410 in Auriga are two dense knots of cooler gas and dust known informally as "the tadpoles." Each tadpole is about 10 light-years long.
Details: *Astro-Tech AT8RC Ritchey-Chrétien reflector with QSI 683wsg CCD camera. Total exposure was 8⅔ hours through narrowband filters.*

◄ **TWILIGHT COMET**
Barry Burgess
Comet ISON C/2012 S1 is seen over Port Medway, Nova Scotia, shortly before dawn on the morning of November 22, 2013.
Details: *Canon EOS 5D Mark III DSLR with 70-to-300-mm zoom lens at 300 mm. Total exposure was 4 seconds.*

▲ **LAKELAND SKIES**
Tunç Tezel
The pinkish color of the Eta Carinae Nebula is visible just above the Southern Cross as seen from Lakeland in Queensland, Australia.
Details: *Hutech modified Canon EOS 5D DSLR camera with 24-mm lens. Total exposure was 25 seconds.*

◄ **CLUSTER EFFECT**
Jim Collins
Winds and radiation from the hot young stars of NGC 6823 near the center of this photo are slowly dispersing the dark nebulous towers of NGC 6820 in Vulpecula. North is to the left.
Details: *Deep Sky Instruments RC10C Ritchey-Chrétien reflector with Finger Lakes Instrumentation ML11002 CCD camera. Total exposure was 45 hours through narrowband filters.* ✦

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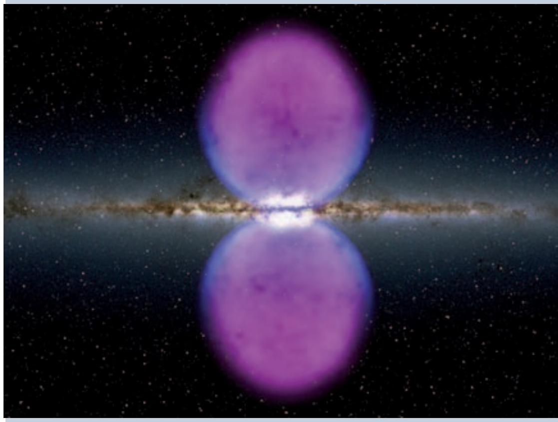
The Return of *Cosmos*

TV viewers will soon retrace Carl Sagan's epic space-time odyssey with new host Neil deGrasse Tyson.



Milky Way Bubbles

Discovered by an astronomer looking for something else, a mysterious haze has proved to be one of the Milky Way's largest structures.

Space Station Telescope

An instrument developed for amateur astronomers is now flying on the International Space Station.

The April 14-15 Lunar Eclipse

For the first time since 2010, all of North America will experience a total lunar eclipse.

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How the Web Saved the Webb

A group of enthusiasts helped rescue an $8 billion national treasure.

NASA / MSFC / DAVID HIGGINBOTHAM / EMMETT GIVEN

At the Northeast Astronomy Forum in 2011, I listened to astronomer Heidi Hammel enthusiastically describe the wonders of the James Webb Space Telescope. Toward the end of her talk, she put out a plea for the audience to write to their Congressional representatives because there was a very real possibility that telescope funding could be cut. The political forces in Congress, even before the current sequestration, had found the JWST program's budget overruns and mismanagement a little too much to swallow. In July 2011, with budget cuts looming at NASA, a House committee recommended culling the so-called "successor to Hubble."

The James Webb Space Telescope — named after NASA's second administrator, a seminal leader who was not averse to fighting for ambitious endeavors in science and technology — was already $3.5 billion into development. Moreover, this is an international project, and a European instrument was at the testing stage.

Comparisons of JWST's plight to that of the fight to save Hubble rippled across the internet. Everyone from science buffs to the engineers building JWST were reminding people that Hubble had been the most successful science instrument in history, and that it was unthinkable to scrap NASA's next great space observatory. It was time to act.

The campaign kicked off with Twitter. Hashtags relating to the scope permeated the social network, encouraging others to read the news that Congress might scrap NASA's ultimate eye on the universe. Raphael Perrino, who had previous experience with saving science projects, picked up the tweets, and after a brief e-mail exchange, he and a small team of enthusiasts set up a "Save the Webb" Facebook page, which went viral, rapidly attracting thousands of passionate followers.

Concurrently, Kyle Sullivan and Blair Schumacher launched an online petition, and within days, joined efforts with me and Raphael. Over the next few weeks, a group of 10 science advocates, web and graphic designers, bloggers, and outreach specialists did everything from lobbying Congress to designing bumper stickers. We all played a major role in getting the message out: this telescope had to be saved. U.S. team members encouraged everyone to sign petitions, write their Congressmen, and spread the word. Video competitions saw some epic film entries, indicative of the level of passion people felt to save the scope.

After four months of rallying support for JWST, supporters breathed a collective sigh of relief when news came that Congress had agreed to fund the scope for launch later this decade. But had the team really made a difference? The small core group of people, spread over two continents and multiple states, had never even met in person. All had regular day jobs, but we all put our heart and soul into the campaign.

Then the letters arrived, from Congressmen, lobbyists, policy analysts, scientists, and Capitol Hill staffers, expressing their sincere gratitude for our efforts and saying how our team's passion had made a difference. So when people voice skepticism about "social not-working" websites, think of what they can do, when, toward the end of this decade, if everything goes well, the most astonishing images and scientific discoveries of our age are beamed back to us from a tennis-court-sized infrared telescope, which a small group of social media space activists helped rescue from the brink. ✦

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