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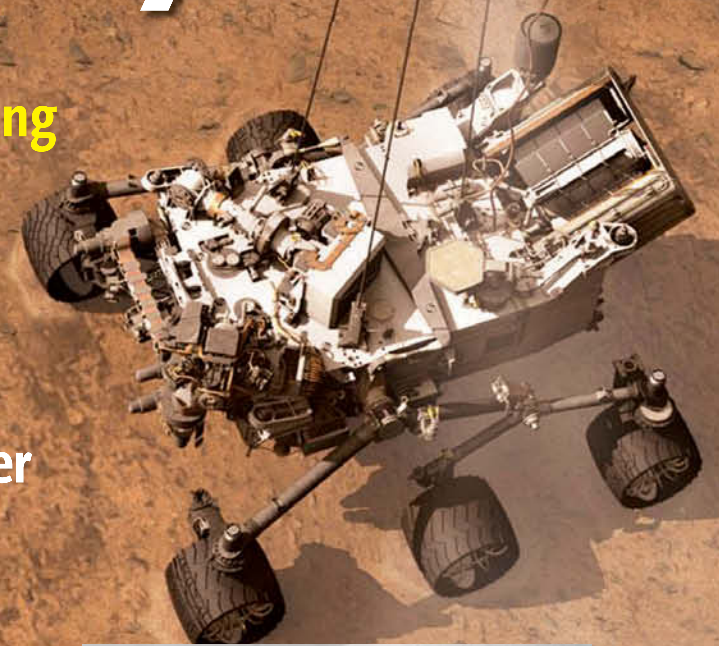

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SKY & TELESCOPE

# November 2012

VOL. 124, NO. 5


**On the cover:**
NASA's rover Curiosity landed safely after a descent plan nicknamed the "7 Minutes of Terror."

**COVER:** NASA / JPL-CALTECH
**INSETS:** EARTH-SKY PHOTO: BABAK TAFRESHI; JUPITER: HUBBLE HERITAGE TEAM; ECLIPSE MAP: MICHAEL ZEILER

## FEATURES




NASA / JOHNS HOPKINS UNIV. APPLIED PHYSICS LAB. / CARNEGIE INST. OF WASHINGTON

## OBSERVING NOVEMBER



## S&T TEST REPORT



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Robert Naeye
**Spectrum**

# 7 Minutes of Triumph

I'M WRITING THESE WORDS on the morning of August 6th, just hours after hearing the news that Curiosity is nestled safely on Mars. I woke up at 5:00 a.m. and after clearing my groggy head, I fired up my iPad and read the news of the successful landing. What a great way to start the day!

As my *S&T* colleagues would attest, I was highly confident of a safe landing. Despite all we heard about the Martian ghoul or gremlin, NASA's track record for landing heavy science packages on the Red Planet was six successes in seven attempts prior to Curiosity (not counting the two failed Deep Space 2 probes, which were very small surface penetrators built on a shoestring budget). With an 85.7% success rate (and now 87.5%), NASA's Earth invaders have clearly gained the upper hand on the Martian ghoul.

Landing heavy loads on Mars is particularly challenging because the planet's atmosphere is so thin that it doesn't provide enough drag for deceleration, but it's thick enough that a spacecraft will burn up if it enters at the wrong angle or is improperly shielded. The engineers who designed Curiosity's entry, descent, and landing (EDL) system had to figure out an entirely novel method to land a 1-ton behemoth. Never before had anyone attempted to land such a large and heavy vehicle on Mars. But trying new and exciting things is what space exploration *should* be all about.

The engineers' bold solution, "sky crane" (*S&T*: December 2011, page 28), looked so scary in a NASA animation that people called its EDL sequence "7 minutes of terror." But I thought sky crane was fundamentally sound, and I was a lot more worried about bad luck than bad engineering. As NASA official and former astronaut John Grunsfeld eloquently stated, "The 7 minutes of terror has turned into 7 minutes of triumph." Now that we know sky crane works, I'd love to see more heavy landers sent to Mars.

NASA's triumph rekindled fond childhood memories from July 20, 1976, when my eyes remained glued to the TV as Viking 1 beamed back the first pictures from the surface of Mars. Being age 13 and a space junkie, I could appreciate that this was a historic moment. Congratulations to the engineers and scientists who have made all these historic moments possible. We can look forward to years of great science and exploration from Curiosity, which we'll be covering in *S&T*.

Robert Naeye
*Editor in Chief*


NASA / JPL-CALTECH


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# Really Big Gets Even Better!

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To fill this huge dome, the CHIRON II is paired with not two, but four ultra-high resolution JVC 4K video projectors for bright fulldome video scenes showing more than 13 million pixels of colorful, animated imagery. These fulldome video images are synchronized to move precisely with the motions of the CHIRON II starball, sun, moon, and planets projectors, for the ultimate planetarium experience.

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S&T: LEAH TISCIONE

## Modified Gravity?

I am thoroughly confused by the conclusion reached in the August News Notes article on the BOSS survey (page 14). Monica Young states that the examination of the galaxies' gravitational motion as they fall toward one another matches the predictions of Einstein's general theory of relativity without a need for modification. The article then concludes, "It appears that dark matter and dark energy are both here to stay." Aren't dark matter and dark energy modifications of Einstein's theory of gravity?

***Frank Kulczak***
*Hanover, Pennsylvania*

***Editor's note:*** *By "modified theory of gravity" we mean changing the actual equations of gravity so that gravity no longer works the way Einstein proposed in his general theory of relativity. Adding dark energy and dark matter to the universe doesn't change how gravity operates; in fact, Einstein's theory of gravity only explains what we see on large scales when we add both of these to the picture. (For example, dark matter explains why galaxies' outer regions rotate so fast, dark energy explains the acceleration of cosmic expansion.) A "modified" (that is, new) theory of gravity would change gravity's strength over large distances. The galaxy motions measured by the BOSS team show that such a modification doesn't make sense: gravity as we understand it works just fine. If we find a galaxy cluster where gravity doesn't behave as it's supposed to, then we'd need modified physics. For now, we don't.*

## Televisions of the Future

I enjoyed Roger Sinnott's August 1962 note in his "75, 50 & 25 Years Ago" column (page 10) about the Telstar satellite and its capabilities. It reminded me of some comments my late father made in *Peon*, a sci-fi fanzine that he wrote, edited, and published from about 1948 through 1957. In his May 1953 editorial, he talks about the problems of TV reception and then describes the "ideal television receiver" as having multiple buttons for choosing stations, each of which would come in as clearly "as if you were right under the transmission tower," regardless of distance from the broadcast source. He describes other features but concludes such a device "is something that will probably never come to pass, for I understand that t.v. transmission is very limited in distance." Fortunately, he lived to see such long-range broadcasts become a reality.

You can read the rest of his comments online or by downloading that issue or other issues of *Peon* from **http://peon.currentsky.com**.

***Bob Riddle***
*Lee's Summit, Missouri*

## What's with Those Martian Dunes?

On page 16 of the September issue, you wrote that the Martian dunes "moved with an average speed of 0.1 meter per Earth year," but the image caption with the story says that "[r]ipples on dunes . . . moved as much as several meters over 105 Earth days." Which figure is correct?

***Jörg Michael***
*Hannover, Germany*

***Editor's note:*** *Both figures are actually correct. The distinction is that the "0.1 meter per Earth year" rate is for the big mounds of sand (the dunes), and the "several meters over 105 Earth days" is for the ripples* on top of *the dunes. The ripples are the little ridges in the dunes' sand and are just visible in the Mars Reconnaissance Orbiter image the caption accompanies. Individual ripples move much faster than the big mounds of sand they adorn. The researchers detected the ripples in Nili Patera moving as much as several meters over 105 Earth days. From these ripple measurements, the team then calculated the movement of the dunes overall — the 0.1 meter per Earth year figure.*

## Expand the Camera Appeal

I'm glad people are pointing out that the Canon 60Da is good for daytime photography (September issue, page 38). Its spectral response is similar to the now-discontinued Kodak Ektachrome film, which was also strong in H-alpha and a favorite of nature photographers. In the long run, the way to keep astronomy-friendly cameras on the market is to promote them for daytime as well as nighttime photography. So tell your nature-photographer friends that this camera is the way to get the Ektachrome look.

***Michael A. Covington***
*Athens, Georgia*

## Stubborn Screws

That tip about using Chap Stick as a lubricant was terrific (*S&T:* December 2011, page 66). It reminded me of a trick that I learned four years ago, suggested by my late brother-in-law, Pat Nocera, who was a materials expert.

I mount my 60-mm Celestron zoom spotting scope on a wooden tripod topped with a cast-iron alt-az fork mount. The mount uses two thumb screws to lock the scope in place, but the azimuth screw was always either totally loose or totally tight. Since I often use this scope at the Jersey shore to follow ships on the horizon, I wanted the scope to remain stable in a stiff, ocean breeze yet still be able to pan left and right without my needing to constantly loosen and tighten the screw.

I planned to put a pencil eraser into the

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screw hole, which I knew *should* work, but Pat pointed out that it would soon shred and gum up the works. He suggested I try a piece of solid polyethylene, like the "cork" found in some wine bottles. This material has a rubbery consistency but never shreds (in fact, I had a devil of a time just cutting off a small piece with a very sharp knife). I eventually fashioned a small, cylindrical plug, inserted it into the thumbscrew hole, put the screw back in, and tightened it down snugly until the friction felt right.

Four years later it still works flawlessly, with no sign of any wear on the plug. I never need to touch the azimuth screw now. The scope is always stable, yet turns smoothly with just moderate hand pressure. If I want a stiffer feel, I just tighten the screw some more. The hand pressure required goes up, but the smoothness never varies. The same solution worked with the altitude screw, too, although the plug falls out if I remove the scope from the mount. I remember Pat fondly every time I use this scope.

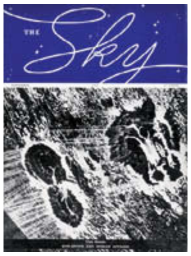
***Tom Sales***
*Somerset, New Jersey*

## For the Record

✹ *In the table that begins on page 70 of the September 2012 issue, the double star Struve 2303 was erroneously listed in Scutum. It is located just across the border in Serpens. A few lines below that, Struve 1181 should say 1881.*

# 75, 50 & 25 Years Ago

*Roger W. Sinnott*




**November 1937**

**Leonid Meteor Storms** "It seems as if the days of 1833 and 1866 are gone forever. . . . During the great showers of 1799, 1833 and 1866, the Leonids seemed to be giant sparks from a celestial blast furnace, pouring down to wipe humanity off the globe. However, if any real damage was done, it has not been discovered to this day. . . .

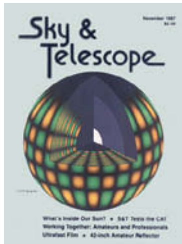
"A maximum for these meteors was expected about 1932. It did appear, but in 1931 there were twice as many Leonids as in 1932. Even then, they could not compare with the shower of one hundred years ago. . . ."

*Assistant editor Charles A. Federer, Jr., who went on to be editor in chief of* Sky & Telescope, *had to eat his words when another Leonid storm, caused by dust streams from Comet 55P/Tempel-Tuttle, roared back on cue in 1966. Another storm followed in 1999, but by the time that storm hit, Charlie had passed away.*


**November 1962**

**Heat from Jupiter** "[Armagh Observatory astronomer Ernst] Öpik offered the very interesting result, derived from radiometric measurements and from the cloud temperature, that the outward heat flux from Jupiter is about 60 percent greater than the incoming solar radiation."

*Marcel Minnaert reported Öpik's finding while covering a planetary colloquium held in Liège, Belgium, in July 1962. The discovery of Jupiter's glow is often attributed to infrared astronomer Frank J. Low in 1966.*




**November 1987**

**Tide at Tarawa** "The morning of November 14, 1987, will not be a good time to try to land a boat on the beach of Betio Island, Tarawa Atoll, if your boat draws more than four feet of water. It will ground on the coral reef about 600 yards from the beach, forcing you to wade ashore. A configuration of the Earth, Moon, and Sun will prevent the midday high water from rising more than 3.7 feet over the reef for the next two days, just as it did 44 years ago this month during one of the most famous battles of World War II."

*Donald W. Olson's detailed tide analysis explained why the 1943 amphibious landing at Tarawa was a near-disaster for the U.S. Marines. Before Olson's article, military strategists and historians had been baffled by the "laggard tide" or "the tide that failed" at Tarawa. This article set the stage for roughly three dozen pieces Olson has written for S&T that use astronomy to clarify not just historical events but the works of well-known artists and writers.*

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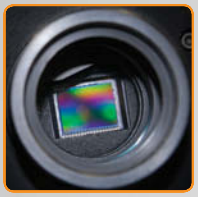

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*– SKY & TELESCOPE MAY 2012*


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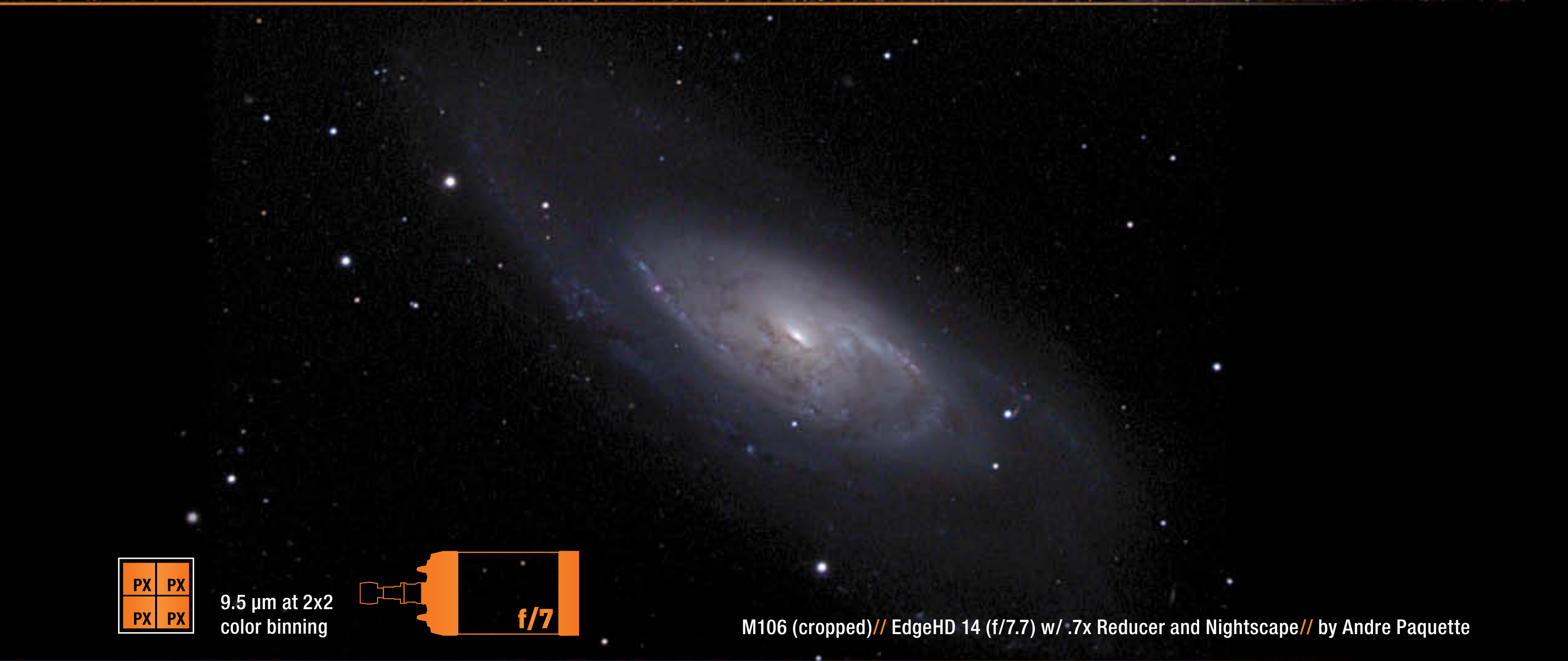
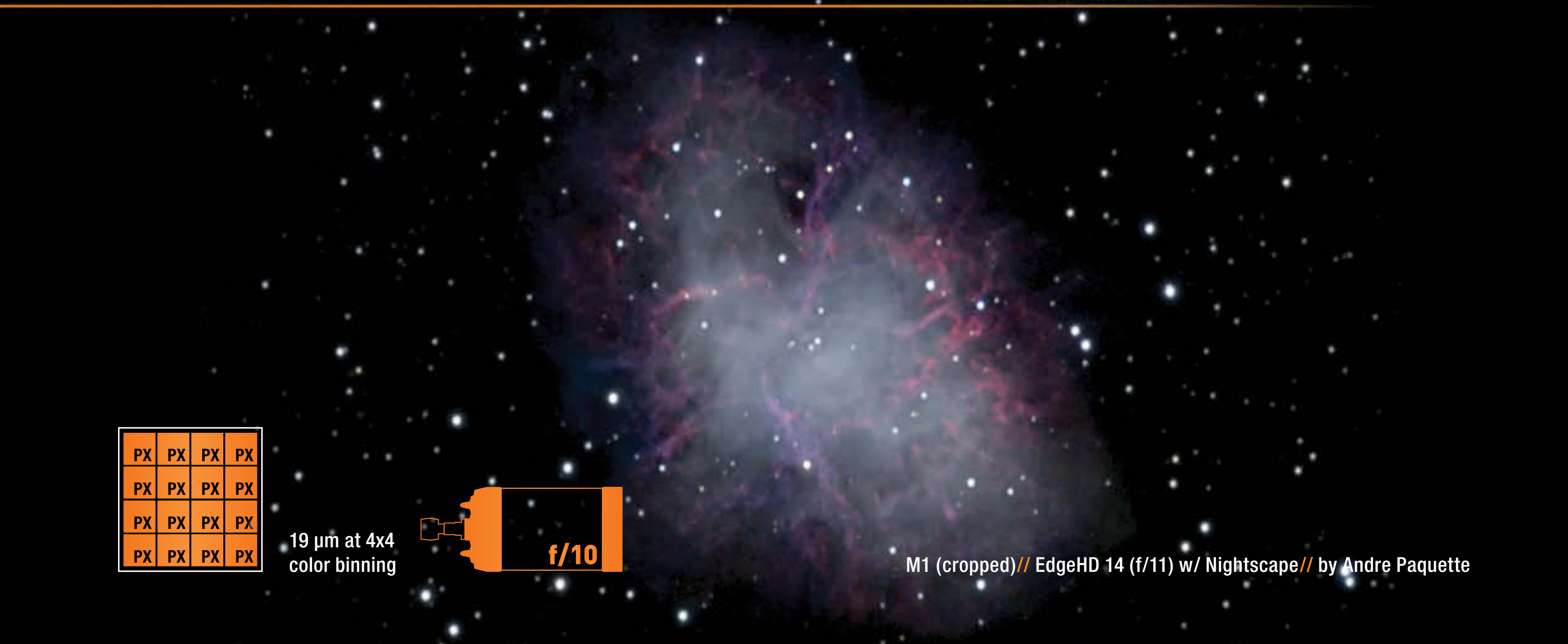


M106 (cropped)// EdgeHD 14 (f/7.7) w/ .7x Reducer and Nightscape// by Andre Paquette



M1 (cropped)// EdgeHD 14 (f/11) w/ Nightscape// by Andre Paquette

# BLACK HOLES | Star Shredder Sings Telltale Note

AURORE SIMONNET (SONOMA STATE UNIVERSITY)

In this artist's concept, the tidal force of a supermassive black hole pulls apart a star as it passes too close. Some of the debris will swirl down to form a disk of accreting material, from which a fraction shoots out as a powerful jet.

**Last year,** astronomers spotted a flare from a distant supermassive black hole that suggested the leviathan had torn a star apart, then gobbled some of it and spat the crumbs out in a relativistic jet. Researchers now report in the August 3rd *Science* that follow-up X-ray observations with the space telescopes Suzaku and XMM-Newton also recorded a short-lived, beat-like signal in this flare with a period of 3.3 minutes. Although many stellar-mass black holes produce such signals, this marks only the second time that astronomers have seen one from a supermassive black hole.

These signals, called *quasi-periodic oscillations* (QPOs), are semi-regular beats that sometimes appear in the X-ray emission from black holes and neutron stars when they're furiously accreting material. Astronomers don't agree on what causes QPOs or why they switch on and off, although they do know that the pulses arise during specific accretion states, detectable in the overall X-ray spectrum.

In the case of the flare-up known as Swift J164449.3+573451, the accreted material came from the shredded star.

"One of my collaborators very imaginatively described this as being able to hear the star screaming as it gets devoured," says study coauthor Rubens Reis (University of Michigan, Ann Arbor). "I think that sounds a little bit dark."

Although there's no unified QPO theory, Reis explains that most researchers think that the signal's frequency relates to how long it takes material to whip around the accretion disk's inner edge. This *innermost stable circular orbit* depends on the black hole's mass and also its spin, which affects how far outside the hole's event horizon the orbit lies (*S&T:* May 2011, page 20). Inside this orbit, general relativity predicts that material will dive into the abyss.

Astronomers hope that with the right QPO theory, they could determine both the hole's mass and spin from these beating X-ray signatures, says Alexander Tchekhovskoy (Princeton University), who was not involved with the study. And mass and spin are basically all you need to know about a black hole.

In the case of the star-swallowing event, Reis's team calculates that if the innermost stable orbit set the QPO's frequency, the black hole weighs between 450,000 and 5 million Suns, depending on how fast it spins. This range roughly agrees with previous estimates based on other methods.

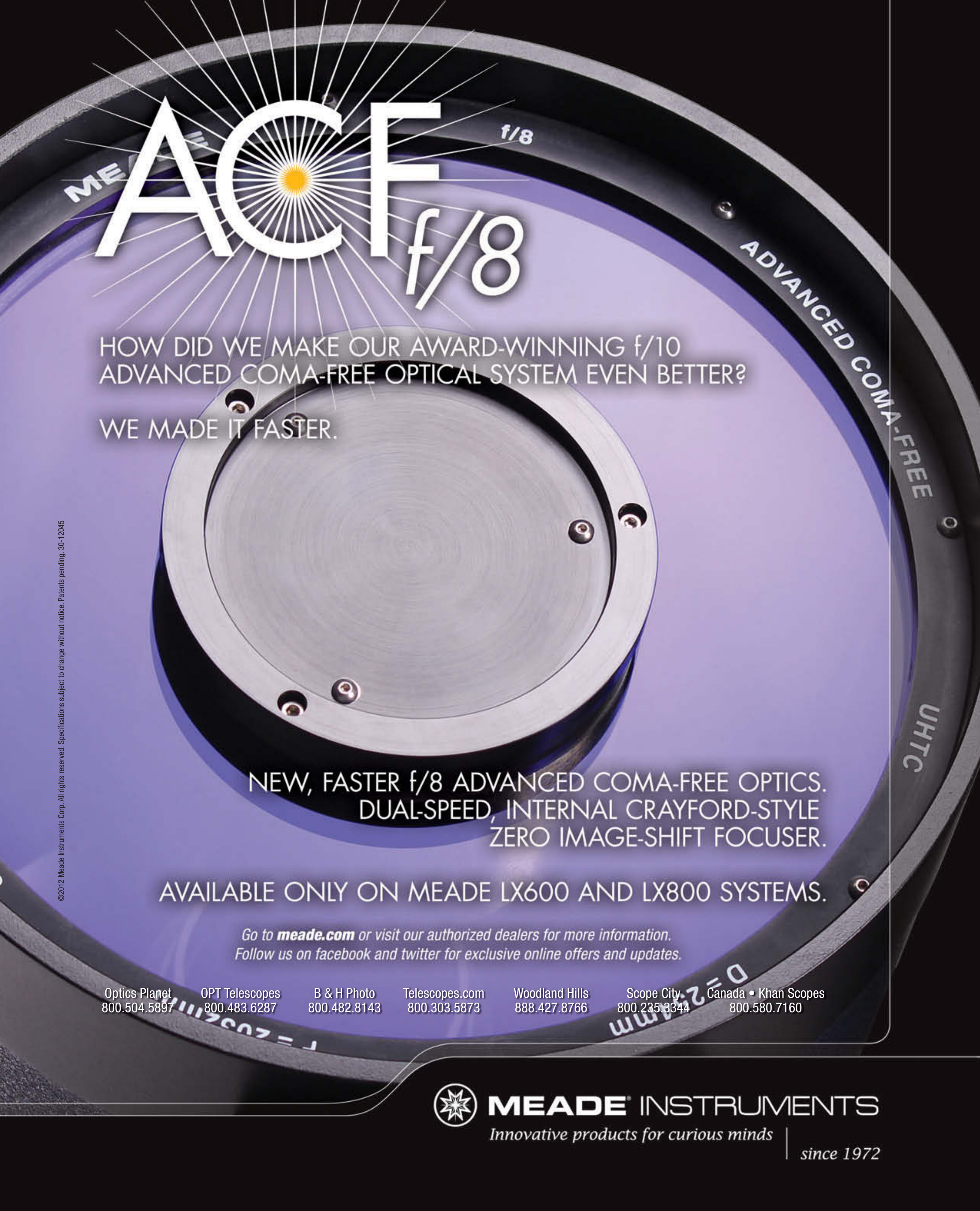
The team doesn't know exactly how long the QPO lasted: the astronomers detected it both nine days and 19 days after NASA's Swift satellite first spotted the flare, but the signal didn't reappear over the six months they watched for it.

Andrew Levan (University of Warwick, England), who was on one of the teams that first reported the flare, says what's exciting about the new QPO is that it confirms that black holes of very different sizes accrete in similar ways, even when the source of material is different. He also notes that such signals could help test aspects of general relativity.

Reis agrees that the chance to probe general relativity, especially at large distances — Sw J1644+57 lies roughly 6 billion light-years away — puts him in a tizzy. "I cannot convey the enthusiasm I have for this result," he says. "It's a beautiful thing."

■ CAMILLE M. CARLISLE

Watch a black hole devour a star at **skypub.com/bheatsstar.**



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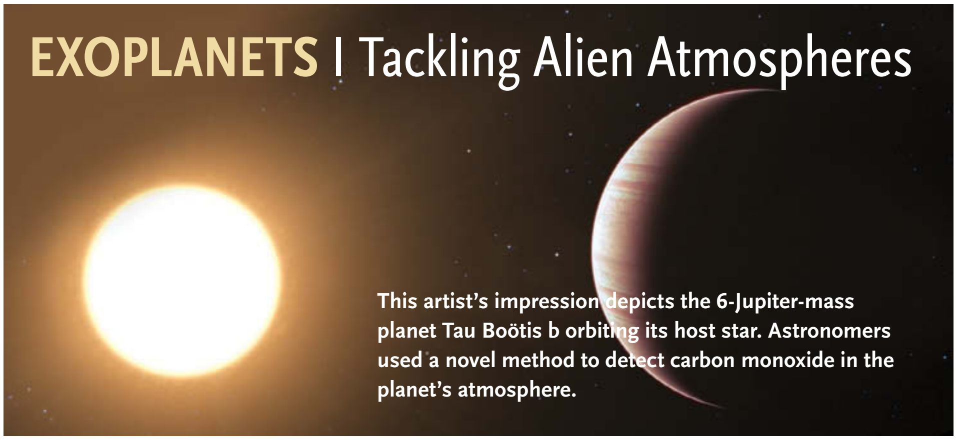
# IN BRIEF

**The three planets** orbiting the young Sun-like star Kepler-30 circle it in almost exactly the same plane. This plane also lines up with the star's equator, just as in our own solar system. Astronomers discovered the system's close alignment by watching the tiny dip in light created as each planet crossed the same starspot on Kepler-30. Some planets, particularly those called hot Jupiters, orbit at tilted inclinations to one another and out of line with the star's equator, but if more systems exist like Kepler-30, our own solar system's orderly configuration might be common. The result could also support the long-standing idea that off-kilter orbits arise not during planetary formation but rather from interactions after planets are born, the authors suggest in their July 26th *Nature* paper.
■ **CAMILLE M. CARLISLE**

**High-resolution images** from NASA's Lunar Reconnaissance Orbiter reveal that five of the six flags erected by Apollo astronauts are still standing. The flags are probably bleached white after being exposed to 40 years of harsh, unfiltered sunlight and space radiation — which actually makes them easier to spot. Their shadows are evident, too. The downed flag is from Apollo 11 and was the first one planted. It blew down in the departing module's rocket exhaust, astronaut Buzz Aldrin reported at the time.
■ **J. KELLY BEATTY**

**Astronomers have used** a distant quasar as a cosmic searchlight to illuminate dark, primeval gas clouds thought to be galaxies' building blocks. Reporting in an upcoming *Monthly Notices of the Royal Astronomical Society*, Sebastiano Cantalupo (University of California, Santa Cruz) and his colleagues observed 12 of these clouds dimly fluorescing due to the nearby quasar's ultraviolet light. Because these blobs contain no stars or ionized gas, astronomers hadn't been able to see them directly. By themselves such clouds are too small and diffuse to effectively form stars, but by clumping together they could grow into galaxies. The new technique should help with studies of galaxies' origins, notes Paul Francis (Australian National University), who was not involved with the study.
■ **MONICA YOUNG**

# EXOPLANETS | Tackling Alien Atmospheres



This artist's impression depicts the 6-Jupiter-mass planet Tau Boötis b orbiting its host star. Astronomers used a novel method to detect carbon monoxide in the planet's atmosphere.

ESO / LUÍS CALÇADA

**Trying to study** the atmosphere of a planet around another star is like trying to see a pea-sized pebble near a light bulb 3,000 miles away — and then analyzing what it's made of. But two teams of resourceful astronomers have dreamed up ways to make the job doable.

The first team, led by astronomers at Leiden University in the Netherlands, developed a method to detect the atmosphere of an exoplanet without the need to block out the star's overwhelming light. Most studies of exoplanet atmospheres have depended on the brief hours a planet passes in front of its star, when a sliver of starlight skimming through the planet's upper atmosphere takes on the atmosphere's spectral imprint. But such observations are fantastically delicate, and only 30% of the nearly 800 confirmed alien worlds transit their suns from our point of view.

So the Leiden University team devised a way to study the atmospheres of non-transiting exoplanets that tightly circle their host stars. Such planets are roasted to high temperatures and glow in the infrared. This glow is buried in the star's much stronger infrared light, but spectral lines in the planet's glow can subtly shift back and forth between redder and bluer wavelengths as the planet orbits the star.

The astronomers managed to tease out these radial-velocity signals in the light from Tau Boötis, which hosts a non-transiting gas giant that orbits at just one-seventh Mercury's separation from the Sun. The planet sizzles at roughly 1500°C (2700°F). The astronomers confirmed the presence of carbon monoxide in its atmosphere, a compound that imposes a strong spectroscopic footprint in the infrared, the team reported in the June 28th *Nature*.

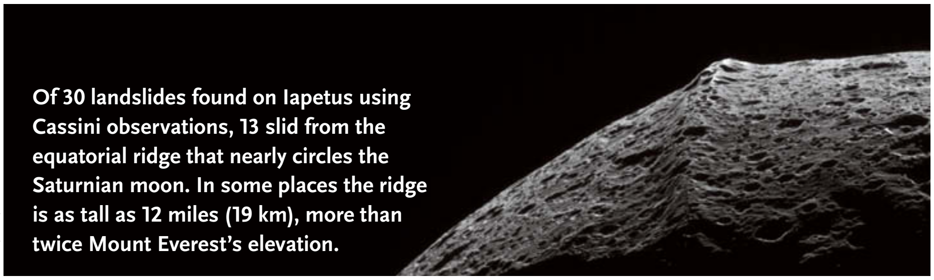
Other teams have used exoplanets' brightnesses at certain wavelengths to discern atmospheric composition (July issue, page 18), but no one has measured a spectral signature for a non-transiting planet before. Team member Ignas Snellen (Leiden University) says the method should also be able to find other compounds, such as methane and water vapor, which the group is looking for now.

Another team is trying to obtain spectra of hot giant exoplanets that can actually be imaged. Only a few confirmed exoplanets have been directly seen, because a star's incredible brilliance overwhelms anything nearby. But a team working with the 200-inch (5.1-meter) Hale telescope at Palomar has built a cutting-edge system that both sharpens and darkens a star's light, which they expect will give them unprecedented chances to catch views of planets.

The system, called Project 1640, is an adaptive optics (AO) package that can make millions of tiny adjustments to the device's two 6-inch (152-mm) mirrors every second. Project 1640's sensors can distinguish between the residual starlight that sneaks through the coronograph and the light from planets, allowing astronomers to filter out background starlight more effectively and tease out exoplanet glows.

Principal investigator Ben Oppenheimer (American Museum of Natural History) says the team plans to investigate some 250 young, nearby stars over the next three years. If successful, he says, the direct imaging could reveal a planet's atmospheric makeup.
■ **STEPHEN P. CRAFT**

## SOLAR SYSTEM | Odd Iapetus Avalanches



Of 30 landslides found on Iapetus using Cassini observations, 13 slid from the equatorial ridge that nearly circles the Saturnian moon. In some places the ridge is as tall as 12 miles (19 km), more than twice Mount Everest's elevation.

NASA / JPL / SPACE SCIENCE INSTITUTE

**Saturn's walnut-shaped moon** Iapetus hosts extraordinary avalanches that slide horizontally much farther than they should, planetary scientists report in the August *Nature Geoscience*. Figuring out what makes these icy landslides flow so far might help scientists better understand similar slides on Earth.

As a rockslide roars to the bottom of a slope, friction typically halts the flow before it can cover more than twice as much horizontal distance as the height it fell. But in *sturzstroms* (German for "falling stream"), a landslide becomes nearly unstoppable, flowing rather than sliding, sometimes along nearly horizontal surfaces or even uphill. Sturzstroms on Earth can travel horizontally greater than 10 times their vertical drop height.

Geologists have developed at least nine theories over the years for how sturzstroms stream along with reduced friction. One leading theory proposes that the avalanching material generates powerful sound vibrations inside the flow that keep the rubble from sticking together.

The new Iapetus study, by Kelsi Singer (Washington University in St. Louis) and her colleagues, looked at the debris of 30 avalanches on the funny-shaped ice moon that all behaved like sturzstroms. Iapetus's average subsurface temperature is about –280° Fahrenheit (–170°C) on its dark half, and at such low temperatures ice is no more slippery than pulverized rock. After analyzing the avalanches, the team decided on a simpler explanation than sound waves: "flash heating."

As the ice pieces rub against one another and the mountainside, friction can heat their surfaces enough to make them slippery without melting. Even mildly heating the ice would transform its frigid, sand-like surface into the slippery stuff we're more familiar with, the team suggests. A similar flash-heating mechanism might explain terrestrial sturzstroms, a claim supported by the discovery of melted rock near landslide sites on Earth imaginatively named "frictionite."

Singer emphasizes that no consensus has been reached, and that more observations will help clear up the mystery.

■ **MONICA YOUNG**

## GALAXIES | Ancient Spiral Galaxy Discovered

**An unexpectedly** early spiral galaxy seen in the universe's first 3 billion years offers another tantalizing clue to how nature creates these iconic designs.

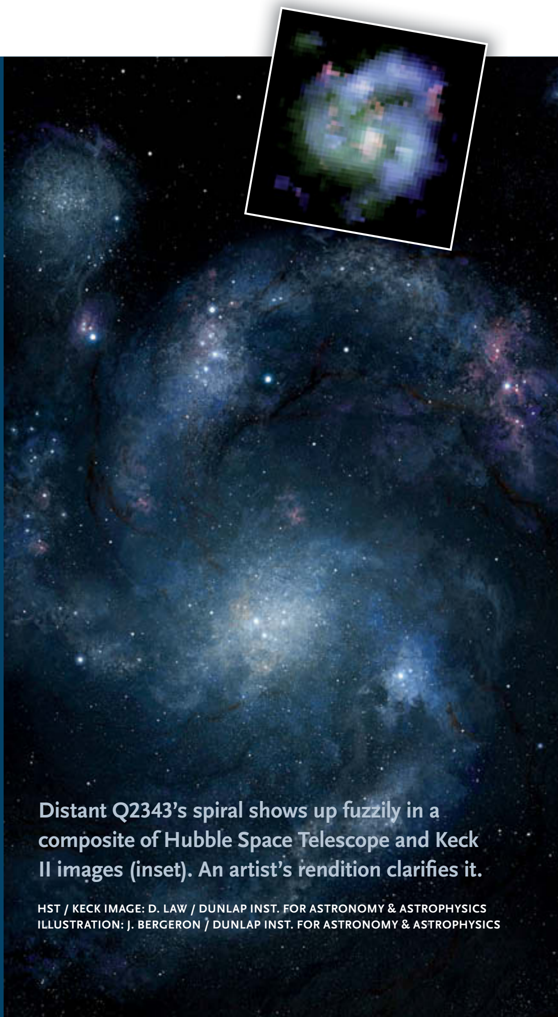
By all appearances, Q2343-BX442 is a normal spiral galaxy. Except for the fact that it exists at such a young cosmic age. When astronomers peer far back into the universe's past, such elegant, "grand-design" spirals give way to clumpy, irregularly shaped galaxies.

Astronomers think spiral patterns were rare in the early universe because young galaxies tend to be turbulent and therefore unfriendly to organized structure. Many stars will circle a galaxy's nucleus in well-behaved orbits, but others will follow random paths that don't match the galaxy's overall rotation. As a result, the galaxy becomes "puffy," making it difficult for gravity and other processes to shepherd the stars and gas into a spiral pattern.

Yet Q2343 is both puffy and spiral. Its design shows clearly in observations by the Hubble Space Telescope and the Keck II Telescope in Hawaii. Measurements made with Keck's OSIRIS spectrograph confirm that the arms are rotating around a central bulge, the study's authors conclude in the July 19th *Nature*. The galaxy is the only one with a regular spiral shape of 306 at a similar distance that the team examined with Hubble.

Based on computer simulations, the authors suggest that the gravitational pull of a passing dwarf galaxy (seen to the upper left of Q2343 in the images) might have tugged in just the right way to trigger the pattern. Some astronomers suspect that grand-design spirals are created through such tugs; a team last year suggested that the Milky Way's spiral structure might result from its interaction with the Sagittarius dwarf galaxy, which it's currently tearing apart. Grand-design spirality would therefore be short-lived — in Q2343, it might last less than 100 million years. ✦

■ **MONICA YOUNG**



Distant Q2343's spiral shows up fuzzily in a composite of Hubble Space Telescope and Keck II images (inset). An artist's rendition clarifies it.

HST / KECK IMAGE: D. LAW / DUNLAP INST. FOR ASTRONOMY & ASTROPHYSICS
ILLUSTRATION: J. BERGERON / DUNLAP INST. FOR ASTRONOMY & ASTROPHYSICS











# Touchdown on

## Curiosity's spectacular landing paves the way for new discoveries about Mars's ability to support life.

Emily Lakdawalla

**On August 6th,** an alien invader jettisoned a flying saucer and rappelled from a hovering rocket-powered craft into a swirling cloud of dust. As retrorockets kicked up gravel and dust, pebbles rattled down onto the deck of the spaceship as its landing gear touched solid ground. The surprising twist to this big-budget summer blockbuster: the alien in the flying saucer came from Earth, and its mission was to invade Mars.

The action-packed last few minutes of the descent of NASA's Curiosity rover to the surface of Mars were captured in high-definition video, thanks to the Mars Descent Imager, or MARDI. The dramatic video shows the heat shield falling away from the rover toward the dark sand dunes on the floor of Gale Crater. The rover rotates 180° before the scene suddenly veers sharply as Curiosity ejects its parachute and back shell and fires its descent rockets sideways to carry it out of the way of the falling hardware.

As Curiosity approaches the surface, the rocket plumes kick up dust and a wheel intrudes into the field of view. After a soft landing, a sequence of more than 800 MARDI images show the ground darkening and brightening as billowing clouds of dust roil before dissipating.

The Rube-Goldbergian chain of events required to bring Curiosity to a soft landing within Gale Crater succeeded brilliantly, turning a pressure-packed control room at the Jet Propulsion Laboratory into a scene of euphoria. It seemed so unlikely that it could all work so perfectly. That's why project scientist John Grotzinger (Caltech) requested that the first image returned from Mars be one that contained a rover wheel in contact with the ground.

**THE VIEW FROM CURIOSITY** Amateur astronomer Damien Bouic assembled this 360° panorama from thumbnail images taken by the rover's Mast Camera. The gray splotches are areas blasted by the descent stage's rockets. Some of the areas of sky had not been imaged when Bouic produced this mosaic, so he added synthetic sky. The rover's ultimate destination, Mount Sharp, is in the center.

# the Red Planet

"Seeing the wheel on the ground was the moment when you know your spacecraft is sitting on the surface of Mars," Grotzinger said in an interview a week after the landing. "When you finally see it down on the ground, it becomes real ... it just sinks in what an awesome place this really is."

## Drilling into Mars's Past

Curiosity's mission to Mars is the logical next step in a 15-year international program of Mars exploration that previously included four orbiters and four landers. Those prior missions surveyed the globe for evidence of past water. The program culminated in two orbiters (Mars Express and Mars Reconnaissance Orbiter, or MRO) that discovered places where enough water might have flowed for enough time for life to have gained a foothold.

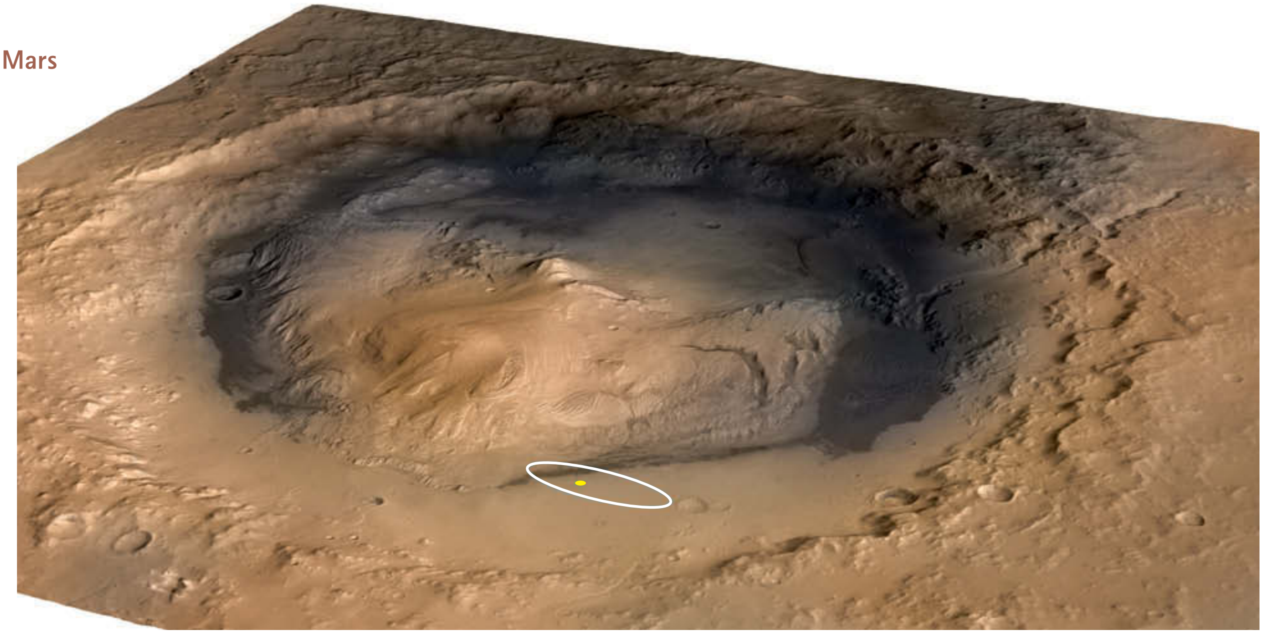
The $2.5-billion Curiosity rover was sent to follow up those discoveries, examining a location containing rocks more ancient than any previously studied by a Mars lander. With a suite of 11 science instruments, aided by a dozen engineering cameras, and with a total size twice that of Spirit and Opportunity combined, Curiosity will investigate whether those ancient rocks preserve evidence for habitable environments that contained liquid water, sources of energy, and organic (carbon-rich) material (*S&T:* December 2011, page 22).


NASA / JPL-CALTECH

**JUBILATION** **Mission personnel at JPL celebrate moments after Curiosity's safe landing was confirmed at about 1:35 a.m. EDT on August 6th. The team had cause for celebration: there were no bugs in the 500,000 lines of computer code, and the 76 pyrotechnical devices fired perfectly in sequence.**

Like Spirit and Opportunity, Curiosity will explore its landing site using a six-wheeled mobility system, mast- and body-mounted cameras, and a multi-tooled robotic arm. But to understand the past chemical and climatic environment of Gale's ancient rocks, Curiosity carries

NASA / JPL-CALTECH / MSSS / DAMIEN BOUIC




**GALE CRATER** We're looking toward the southeast in this oblique view of 154-km-wide Gale Crater. The near-true-color image combines data from NASA's Mars Reconnaissance Orbiter (MRO) and Viking orbiters, and the European Space Agency's Mars Express orbiter. The targeted landing ellipse is white, and Curiosity's actual landing spot at the foot of Mount Sharp is marked yellow. Mount Sharp rises 5.5 km (3.4 miles) above the floor of Gale. There is no vertical exaggeration in this image.

the most sophisticated set of scientific instruments ever landed on another planet.

Curiosity's mast-mounted Chemistry and Camera instrument (ChemCam) shoots laser pulses at rock targets and uses a telescopic spectrometer to determine their elemental compositions from the resulting hot plasma. ChemCam's laser zapped its first rock on August 19th, revealing a typical Martian basalt (volcanic rock).

Inside Curiosity's body are two laboratory instruments. The Chemistry and Mineralogy experiment (CheMin) will perform the first direct identification of mineral species on Mars. The other, the Sample Analysis at Mars (SAM), will sniff out the compositions of light-element-bearing chemicals, such as organics, in the soil and atmosphere. The 30-kilogram (66-pound) turret at the end of the robotic arm includes a percussive drill and a complex sample-handling mechanism that can sieve and portion rock and soil powders for delivery to CheMin and SAM.

The rover is powered by a radioisotope thermoelectric generator (RTG) that is now producing 115 watts of power (more than the planned-for 105 watts). The RTG power source means that Curiosity's mission duration will not be limited by dust settling on solar panels; the RTG's 14-Earth-year nominal lifetime is far longer than Curiosity's baseline 2-year mission.

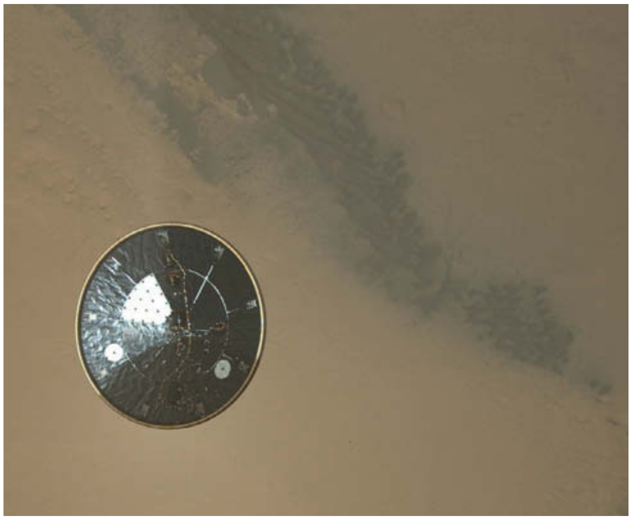
Curiosity landed less than 2 kilometers (1.2 miles) downrange from the center of its 7-by-20-km landing zone in a flat part of the floor of 154-km-wide Gale Crater. Engineers deemed the flat area a safe place to land, but it's not what Curiosity was sent to explore. The rover's ultimate goal is a pile of layered sedimentary rock that forms a 5.5-kilometer-high mountain in the crater's center, formally named Aeolis Mons.

As expected, the early color images reveal topography more dramatic than any ever before seen by a Mars lander. "The rim of the crater looks like a terrestrial mountain range," says Grotzinger, likening the scenery to that of the Mojave Desert. As for the mountain, which the science team informally refers to as Mount Sharp for the late Caltech geologist Robert P. Sharp, "We knew it would be spectacular when we saw it from the ground. All those little buttes and mesas — you realize just how spectacular it's going to be driving through those valleys, just like cruising around mesas in Arizona."

## Gale's Mysterious Mound

It took years of work by hundreds of Mars scientists poring over data from all four of the recent Mars orbiters — Mars Global Surveyor, Mars Odyssey, Mars Express, and Mars Reconnaissance Orbiter (MRO) — to find just the right landing site for Curiosity. At one point in the selection process, Gale actually dropped off the list because it lacked strong evidence for minerals that had formed in the presence of water. The science team returned it to the list amid worry that there weren't enough low-elevation candidate sites, and Gale was the lowest of them all. Still, it was less popular than other sites.

That picture changed when a young JPL spectroscopist, Ralph Milliken, found evidence in MRO data for a clay mineral called nontronite in Gale. One of Gale's earliest advocates, planetary geologist Jim Bell (then at Cornell University), gave his graduate student Ryan Anderson the task of examining MRO's high-resolution images of Gale Crater to begin piecing together the crater's geologic history. Anderson delved into the rich trove of data, and the more he looked, the more interesting Gale's story became.

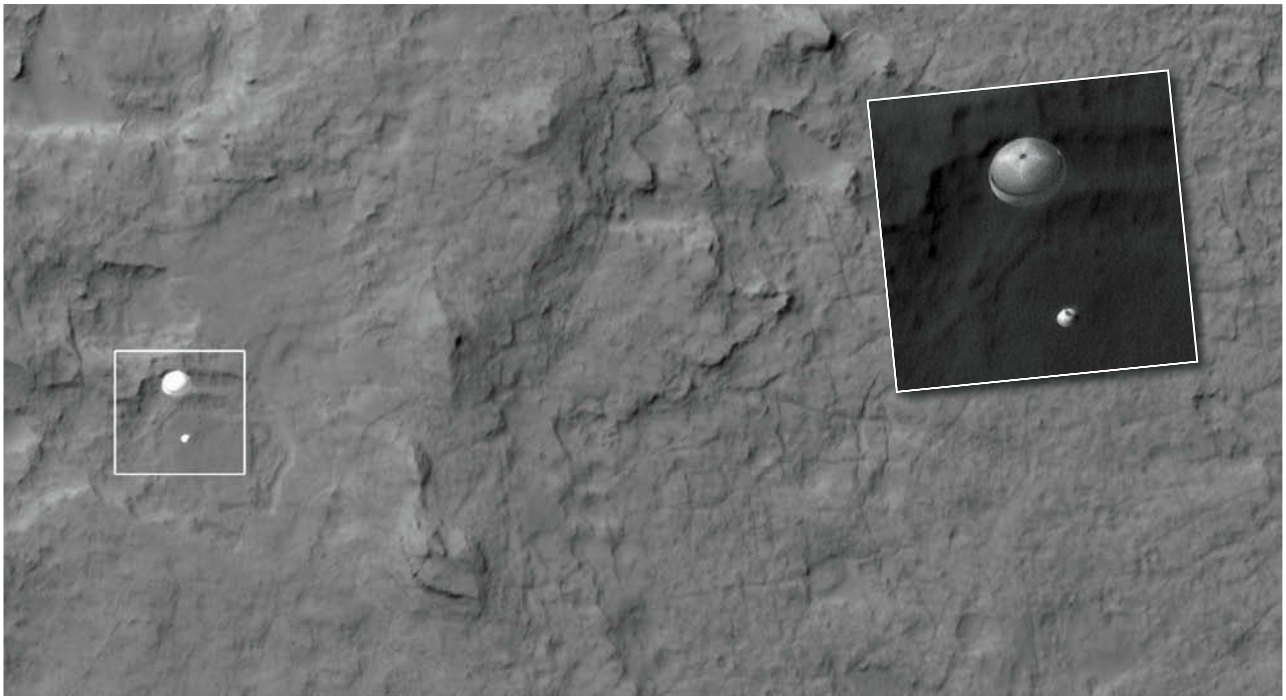


NASA / JPL-CALTECH / MSSS (2)

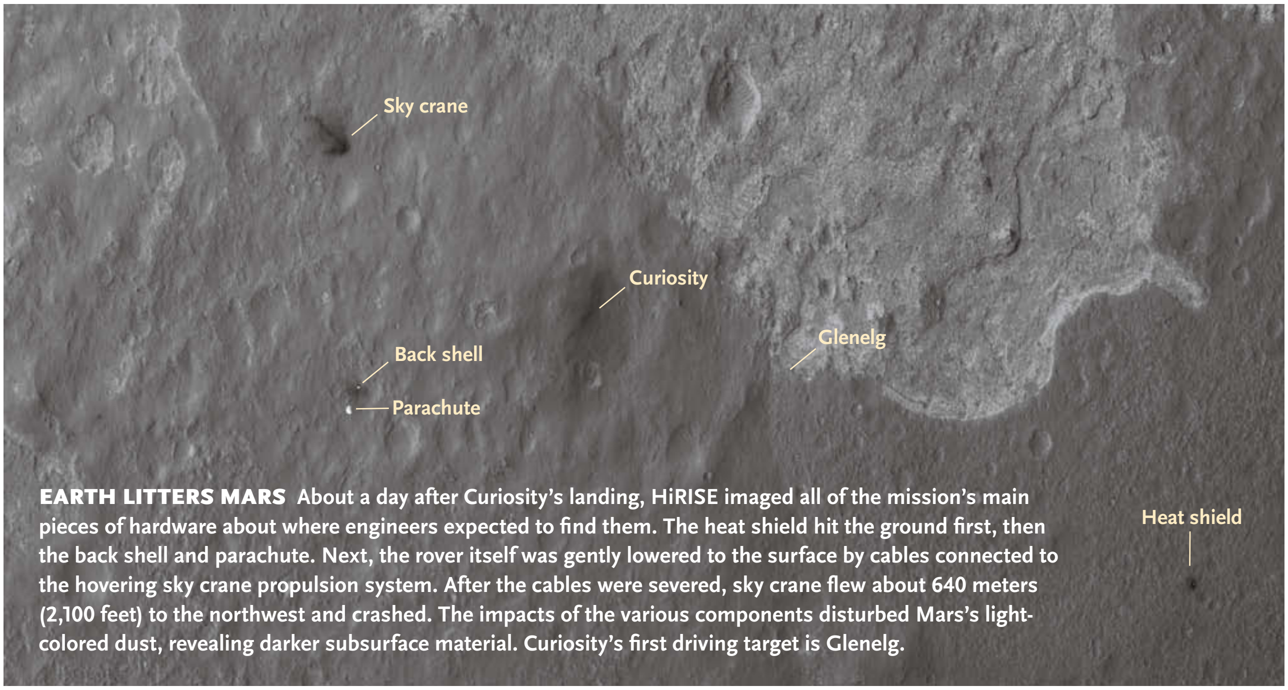
"There are a few places on Mars that are deeper, but Gale is an extremely deep hole in the ground," says Anderson. But Gale is an unusual sort of hole in the ground: it contains a central mountain whose peak now stands higher than the crater rim. The most popular hypothesis explaining this state of affairs holds that the peak is all that remains of a massive pile of sediment that once filled the crater completely. Having no outlet, Gale trapped all the sediment that flowed with water into the crater from the outside. Later, wind erosion removed much of that fill, leaving a remnant mound in the crater's center. The mound's layered rocks appear to preserve a record of Mars's varying chemical history, a history that has only recently been revealed through analysis of spectral data from the orbiters.

**APPROACHING THE SURFACE** ***Above left:*** **Curiosity's descent camera captured this image of the heat shield about 3 seconds after it separated from the mother ship and about 2.5 minutes before touchdown. The 4.5-meter-wide heat shield is about 15 meters (50 feet) below the rover.** ***Above right:*** **This descent-camera image shows swirls of dust being kicked up by the rocket motor exhaust as Curiosity was being lowered to the surface by tethers connected to the hovering sky-crane system. The rover was about 20 meters above the surface at the time this image was taken, about 30 seconds before touchdown.**

**GENTLE DESCENT** **MRO's high-resolution camera (HiRISE) took this remarkable image of Curiosity as it parachuted to the surface, about a minute before landing. The targeting of the camera was so precise that if the picture had been taken a few seconds earlier or later, it would have missed Curiosity.**



NASA / JPL-CALTECH / UNIVERSITY OF ARIZONA (2)




NASA / JPL-CALTECH / UNIVERSITY OF ARIZONA

**EARTH LITTERS MARS** About a day after Curiosity's landing, HiRISE imaged all of the mission's main pieces of hardware about where engineers expected to find them. The heat shield hit the ground first, then the back shell and parachute. Next, the rover itself was gently lowered to the surface by cables connected to the hovering sky crane propulsion system. After the cables were severed, sky crane flew about 640 meters (2,100 feet) to the northwest and crashed. The impacts of the various components disturbed Mars's light-colored dust, revealing darker subsurface material. Curiosity's first driving target is Glenelg.

According to the current picture, early Mars had a lot more water at or near the surface than it does now, and this water had a relatively neutral pH. Over millions of years the water reacted with surface rocks to form clays. But as Mars's original carbon-dioxide-rich atmosphere thinned, the surface dried out and the giant Tharsis volcanoes pumped huge quantities of sulfur into the atmosphere. Mars's water acidified and chemically attacked Martian rocks, creating acid brines that left behind sulfate-rich evaporites and altered bedrock (*S&T:* July 2009, page 22). Both Spirit and Opportunity explored sulfate-rich rocks. If this chemical history of Mars is true, the kindest environments for ancient life should be preserved in clay deposits buried below the sulfates.

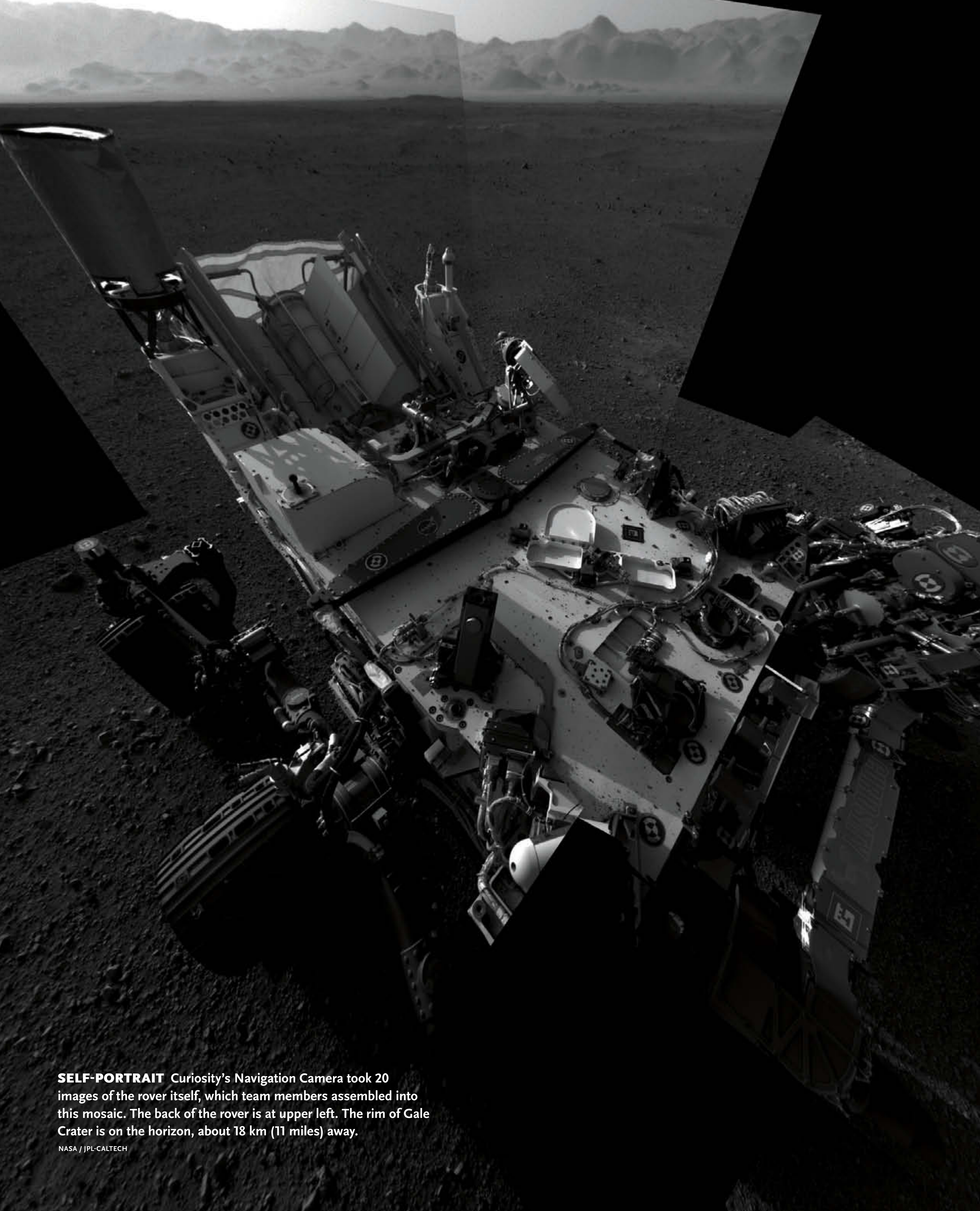
Clay-bearing rocks at the base of Mount Sharp transition to sulfate-bearing rocks higher up, which is consistent with this story. In detail, though, Gale's unique history might be considerably more complicated, which is where the rover comes in. "We're going to be looking at the layers in the mound, because layers only form when conditions change somehow," says Anderson. "We have this giant three-mile-high stack of layers, and that records a lot of changes in conditions. By traversing across those transitions we can understand how those environments change and what that says about habitability."

Gale belongs to a family of impact craters in its region of Mars. The craters range from being more or less completely filled — with only a few rim remnants — to more well-defined impact features such as Gale, which may have been filled with sediment that was later exhumed. In fact, Grotzinger points out, Opportunity has been roving on similar material on the flank of a large, filled crater named Miyamoto. Most of the craters Opportunity has examined are just tiny windows into the uppermost layer of Miyamoto's fill.

Anderson points closer to home for a terrestrial example of how a similar process has operated. On Earth, we know where all the eroded cover goes: into sea and ocean

NASA / JPL-CALTECH

**LONG SHADOW** Curiosity's left-front Hazard-Avoidance Camera took this shot through a fisheye lens about a day after landing. Mount Sharp looms in the distance, though the summit of the giant mound of sediment is not visible from this vantage point.



**SELF-PORTRAIT** Curiosity's Navigation Camera took 20 images of the rover itself, which team members assembled into this mosaic. The back of the rover is at upper left. The rim of Gale Crater is on the horizon, about 18 km (11 miles) away.
NASA / JPL-CALTECH

basins. But it's not so obvious what happened at Mars. "Where did all the stuff in Gale go? That's one of the big mysteries," he says. Since orbital images do not reveal any valleys indicating that water ever flowed out of the crater, Anderson thinks that a combination of chemical weathering and physical erosion broke down the mound materials into particles small enough to be carried out of the crater by Martian winds. "It's important to remember that the wind has had billions of years to eat away at Mount Sharp," he adds.

Grotzinger maintains that the question of how the mound formed doesn't need to be solved yet. "The great thing is that we're there. We don't have to decide now. We can just continue to collect observations and do detailed observations that will hopefully constrain the mechanism of how the layers built up."

## Driving Directions

To reach the ancient clays exposed at the foot of the mound, Curiosity will first have to traverse 8 km of crater floor, skirting the tips of giant crescent-shape dunes made of black sand. Orbiters have actually observed these dunes moving from year to Martian year. Where the black sand originates, nobody knows. In the dune-filled regions, the moving sand scours the crater floor free of dust, leaving flat, inter-dune exposures of bedrock that will provide Curiosity's first glimpse of the earliest part of Martian history chronicled in Mount Sharp's layers.

But that bedrock will not be Curiosity's first roving target. Just a day after the landing, MRO's high-resolution camera captured an oblique view of the rover (and all its landing hardware) resting on the surface. It was immediately obvious that the rover had landed only 400 meters from a junction of three different rock types informally named Glenelg. One of Glenelg's light-colored areas of hard rock has increasingly intrigued Anderson, Grotzinger, and other mission geologists becomes it seems out of place on a planet where rocks are typically darker in color.

Although Glenelg lies only a short distance from Curiosity, it's in precisely the *opposite* direction to the path through the dunes that leads to the clays at the foot of Mount Sharp, so it was a difficult decision to go there first. "Every minute we spend here is a minute we don't spend over there," says Grotzinger. Curiosity landed at the toe of an alluvial fan, and as Grotzinger explains, alluvial fans are deposits made by liquid water. In other words, Curiosity will barely have to travel at all to analyze the finest sediments that are most likely to preserve ancient organics.

Grotzinger's internal mental battle whether to visit Glenelg first was mirrored in the arguments among the more than 400 members of the Curiosity science team. It's a much larger team than Spirit and Opportunity ever had, and it's difficult to imagine that so many scientists will come to a consensus every day about what Curiosity should do next on Mars. But Grotzinger is unconcerned about the team's ability to cohere and make decisions on where to send Curiosity. The crater's collection of layered rocks and wind-blasted landscapes is so diverse that he says, "There's something for everybody here."

There is certainly plenty to satisfy Anderson, who

NASA / JPL-CALTECH / MSSS

**LAYERED FLANK After exploring Glenelg, Curiosity will head toward Mount Sharp to explore its layered terrain. This mosaic of the western flank was assembled from images taken by the 100-mm Mast Camera. The rover team processed this picture for terrestrial lighting conditions to make the terrain easier to analyze. The image only gives a taste of the beautiful mesas and buttes Curiosity will encounter.**

NASA / JPL-CALTECH / MSSS (2)

**CRATER RIM** ***Top:*** **Curiosity's Mast Camera was looking north when it obtained this image of Gale Crater's wall. This part of the rim was cut eons ago by water flowing into the crater.** ***Above:*** **The top image was processed to show what this scene would look like under terrestrial lighting and atmospheric-filtering conditions.**

has seen the field site of his graduate work become the landing site of the most sophisticated robot ever to touch down on another planet. "Most of the time you study Mars, you do the best you can with orbital data, and that's it. You're left wondering a lot of times what's really there. Being able to land on the stuff you've been looking at from orbit, and drive around on it, and shoot it with a laser, and drill holes in it, is really great. Nobody deserves to be this lucky."

Of course, the scrutiny of 400 other, more senior scientists will undoubtedly turn up problems in his dissertation work. About that, Anderson is philosophical. "I'm fully expecting that I'll be wrong. I think it'll be nice to have gotten close on some of it. But being wrong is part of how science works. I'm looking forward to seeing why I was wrong." ✦

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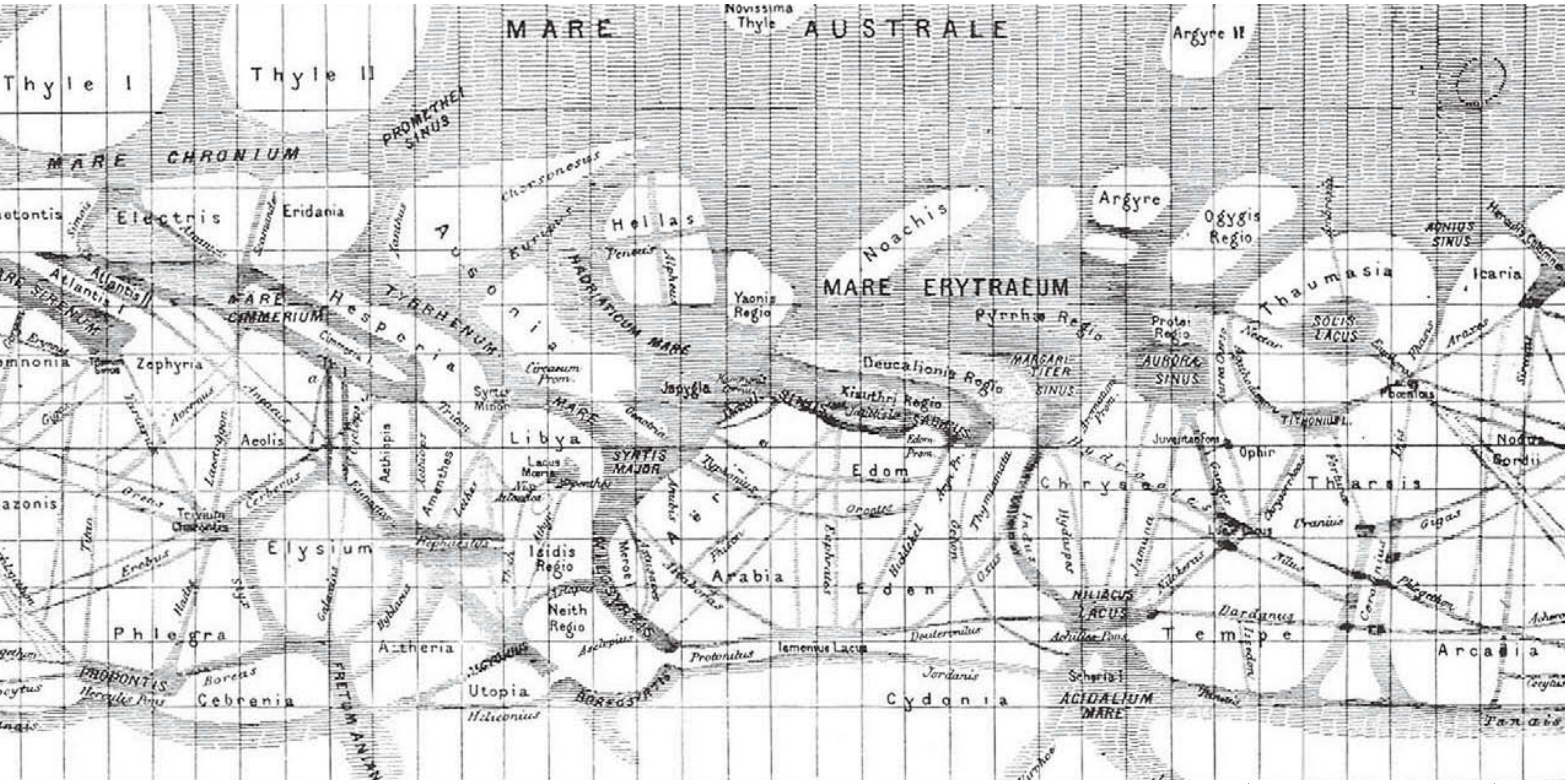
*S&T contributing editor and Planetary Society senior editor* ***Emily Lakdawalla*** *is the 2011 recipient of the Jonathan Eberhart Planetary Sciences Journalism Award. She blogs daily at* ***planetary.org/blog****.*

**For more images and updates about Curiosity, visit skypub.com/Curiosity.**

# From Handel to Hydra: Naming Planets, Moons & Craters




FLAMMARION, *LA PLANÈTE MARS ET SES CONDITIONS D'HABITABILITÉ*

**MARS MAP** Italian astronomer Giovanni Schiaparelli explored the Martian surface through his telescope in the latter decades of the 1800s, naming "continents," "seas" and other features.

"Naming a thing is man's nearest approach to creating it." – Percival Lowell

**NAMES HOLD POWER.** They help us sort and make sense of our world. Perhaps that's why, since the earliest days of civilization, we have felt the need to name the town we live in, the lake we swim in, or the mountains we see in the distance. Names may give honor to a notable person, such as Italian navigator and explorer Amerigo Vespucci, who inspired the names of the American continents. Other times, the history of a place name is lost — scholars still debate the origin of Mount Kilimanjaro, the name of Africa's highest mountain.


Names of Earth's features evolved over thousands of years, but in only a few decades, space exploration has introduced myriad new worlds. The question of nomenclature has never been more complex. What should we call newly discovered moons and rings? How should we name craters on Mars or volcanoes on Io?

And, more importantly, who should decide?

## A Brief History of Nomenclature

When the ancients looked skyward, they saw the planets move against a background of fixed stars. The Greeks and Romans named these "wandering stars" after their gods. It was all quite logical: swift Mercury was named after the messenger god, brilliant Venus after the goddess of beauty and love, and red Mars after the god of war. Bright Jupiter reigned as the king of gods, and dimmer Saturn was named after Jupiter's father. The mythological trend continued as additional planets were discovered; Uranus is a Greek exception in the otherwise Roman planetary pantheon.

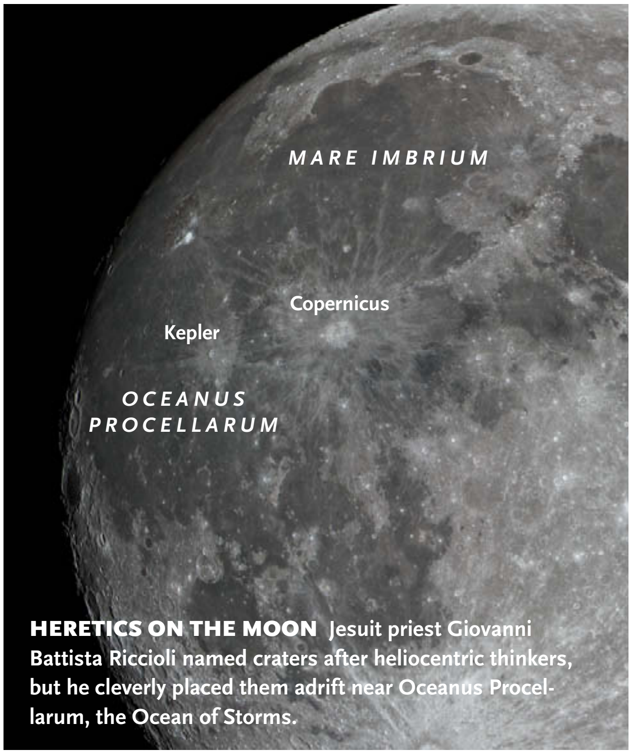
But naming became a more contentious exercise with the advent of the telescope. When Galileo spotted Jupiter's four largest moons, he originally sought to name them "Medicean stars" in an attempt to please his patron-to-be. But German astronomer Simon Marius discovered the Galilean satellites independently and, in a somewhat heated affair, bestowed the names that survived. At Johannes Kepler's suggestion, Marius named the moons after the lovers of Zeus, Jupiter's Greek equivalent, writing, "Io, Europa, the boy Ganymede, and Callisto greatly pleased the lustful Jupiter."

Galileo refused to use these names and instead invented a numbering scheme that is still used today. But Marius's names again became widely used as the number of Jovian moons climbed in the 20th century. The legendary king of gods had a variety of lovers who inspired names for additional moons. But the discovery of dozens more (67 in total as of August 2012) forced the theme to expand, including daughters of Jupiter and even his nurse Adrastea. It seems that Jupiter was not sufficiently lustful.

By the early 20th century, planetary nomenclature was unregulated and downright chaotic, not only for Jupiter's moons but also for features on the Moon and Mars. During the International Astronomical Union's (IAU) founding meeting in 1919, members appointed a committee to arbitrate planetary and satellite nomenclature. Now known as the Working Group for Planetary System Nomenclature, this committee has bestowed more than 15,000 names to date.

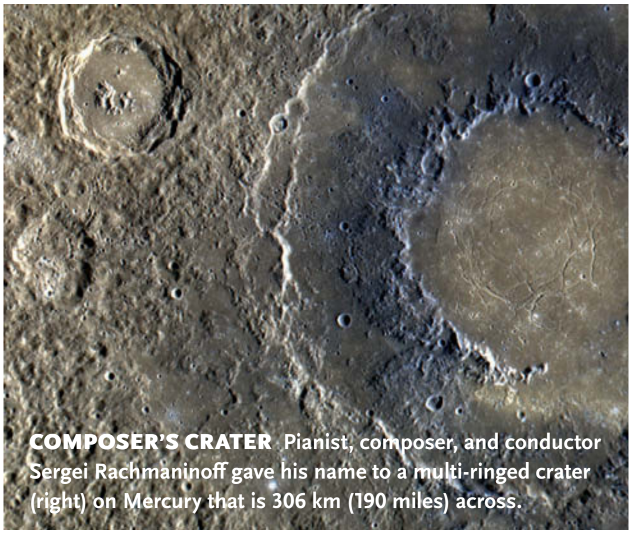
The committee's first priority was to standardize lunar nomenclature. The first report was published in 1935, and it was later updated throughout the mid-1960s. The catalogs list the names and coordinates of features, and they became the recognized source for lunar nomenclature.

The committee kept and standardized many names given by Giovanni Battista Riccioli, a Jesuit priest who published the *Almagestum Novum* in 1651. Even though Riccioli rejected the heliocentric theory, he named several craters after prominent Copernicans, including Galileo, Kepler, and Copernicus himself. He cleverly placed the heretic names on craters adrift near the dark plain he called Oceanus Procellarum ("Ocean of Storms"). He also

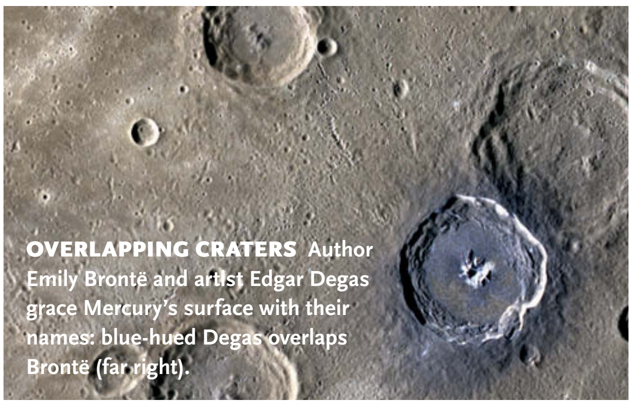



**HERETICS ON THE MOON** Jesuit priest Giovanni Battista Riccioli named craters after heliocentric thinkers, but he cleverly placed them adrift near Oceanus Procellarum, the Ocean of Storms.

S&T: DENNIS DI CICCO

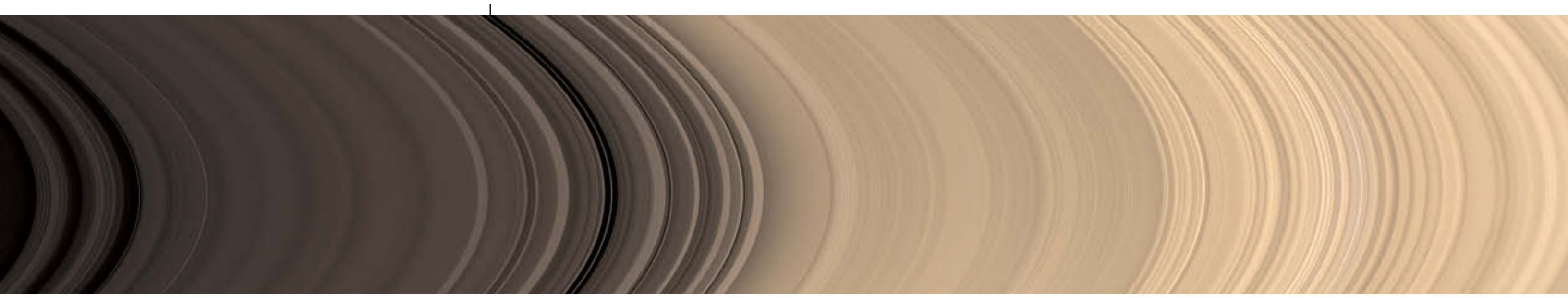


**COMPOSER'S CRATER** Pianist, composer, and conductor Sergei Rachmaninoff gave his name to a multi-ringed crater (right) on Mercury that is 306 km (190 miles) across.



**OVERLAPPING CRATERS** Author Emily Brontë and artist Edgar Degas grace Mercury's surface with their names: blue-hued Degas overlaps Brontë (far right).

NASA / JOHNS HOPKINS UNIV. APPLIED PHYSICS LAB. / CARNEGIE INST. OF WASHINGTON (2)




**SATURN'S RINGS** Cassini returned this sunlit panorama, seen in natural color. The rings are named in the order of their discovery.


NASA / JPL-CALTECH / UNIV. OF ARIZONA

gave the other basaltic plains their names, calling them "seas" (maria): the Seas of Crises (Mare Crisium), Serenity (Mare Serenitatis), Fertility (Mare Fecunditatis), Rains (Mare Imbrium), Clouds (Mare Nubium), and Cold (Mare Frigoris). Of course, by the time the IAU reports were published, scientists knew there were no real seas on the Moon, but the designations stuck.

The committee's next priority was to clarify Martian nomenclature, which had developed over the years as observers saw and mapped surface features. A 1958 ad hoc committee recommended the names of 128 albedo

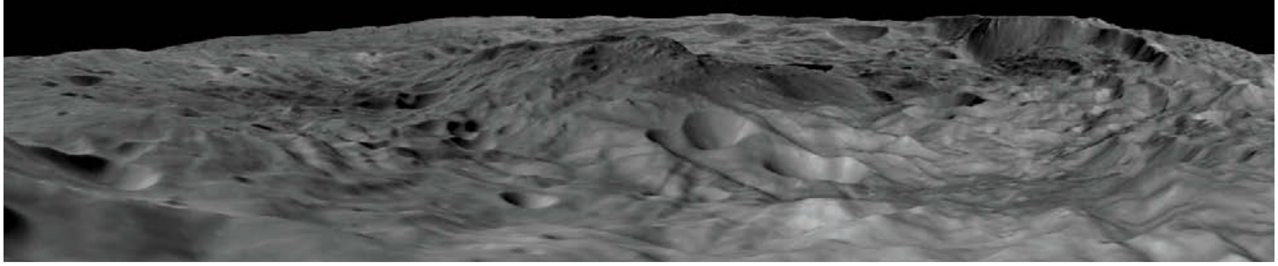
**VICTORIA** The name for this half-mile-wide Martian crater comes from the capital city of the Republic of Seychelles, an archipelago nation off the coast of eastern Africa.

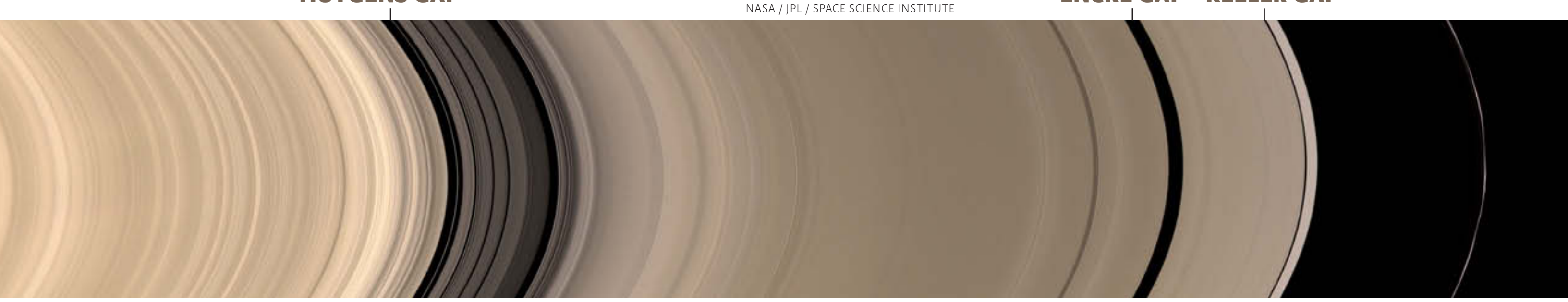
## Naming Vesta

**For more than a year**, NASA's Dawn spacecraft circled an asteroid named after the Roman goddess Vesta, revealing dozens of surface features in high-resolution images (September issue, page 32). The craters that cover much of the surface take their names from the vestal virgins, priestesses of the goddess, as well as from famous Roman women. Minor vestal virgins such as Caparronia, Minucia, and Scantia lend their names to craters, as do the legendary vestal virgins Claudia, Marcia, and Rhea Silvia, the mother of the twins Romulus and Remus who founded Rome. Other craters are named Antonia (after the daughter of Marcus Antonius and Octavia), Serena (after a Roman noblewoman), and Helena (after the mother of Constantine the Great).

Roman festivals and places associated with the vestal virgins inspire the names of other features. Two small mountains (tholi) are named Aricia Tholus, after a once-powerful city, and Lucaria Tholus, after an ancient Roman feast in July. A plain is called Feralia Planitia after the Roman All Souls Day in February.

**RHEASILVIA CRATER** The vast impact basin that covers much of Vesta's south polar region is named after Rhea Silvia, a legendary vestal virgin and the mother of the founders of Rome. This oblique view of the basin comes from Dawn images.


NASA / JPL-CALTECH / UCLA / MPS / DLR / IDA / PSI




features (bright, dark, or colored areas) observed through ground-based telescopes. The IAU committee based many of the names on a system developed in the late 19th century by Italian astronomer Giovanni Schiaparelli and expanded in 1929 by Eugène M. Antoniadi.

As space exploration opened new frontiers, the task of naming them expanded. The IAU formed a Mars working group to name new features discovered by the three Mariner space probes that flew by the Red Planet in the 1960s. Mariner 9 settled into orbit around Mars in 1971 to map its surface, contributing still more features to the list. Around the same time, another ad hoc committee suggested names for lunar features found by the Soviet Zond and NASA's Lunar Orbiter and Apollo programs.

During the 1973 General Assembly, the IAU reorganized the committees responsible for nomenclature, forming separate task groups for the Moon, Mercury, Venus, Mars, and the outer solar system. The Committee on Small Body Nomenclature was formed in 1984 to name surface features on asteroids and comets; it was later tasked to establish names for Kuiper Belt objects and Pluto's newfound moons.

Early astronomers could only have dreamed about the wealth of features and bodies that now need names. The newest of these are features on the asteroid Vesta. As the chair of the Task Group for Outer Solar System Nomenclature, I reviewed name proposals for dozens of surface features revealed by the Dawn spacecraft (see "Naming Vesta" on the facing page). Our group anticipated the rush — we had already prepared and approved a list of potential names before the spacecraft even went into orbit.

After a task group assesses a name proposal, the feature name or theme goes to the Working Group for Planetary System Nomenclature for formal approval. After a name is official, it's published in the *Gazetteer of Planetary Nomenclature*. To maximize international participation and to achieve the right mix of expertise, membership in the task groups is granted by invitation only.

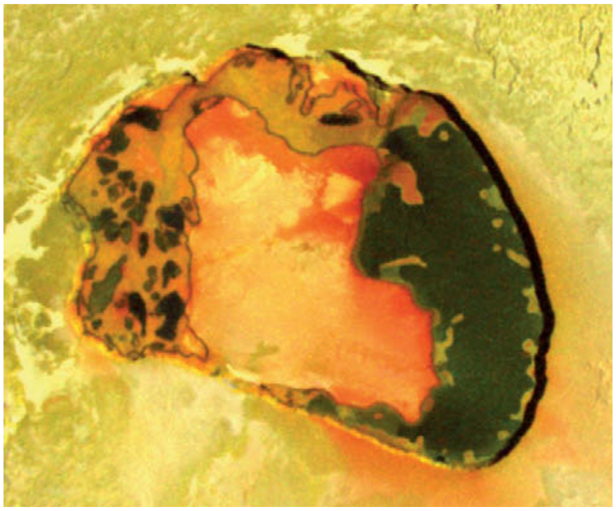
## A System for Names

Why is a crater on Mercury called Handel, after the German-British composer, while another on Mars is called Bigbee, after a town in Mississippi, and yet another Asimov, after science-fiction writer Isaac Asimov? It all starts with the theme.

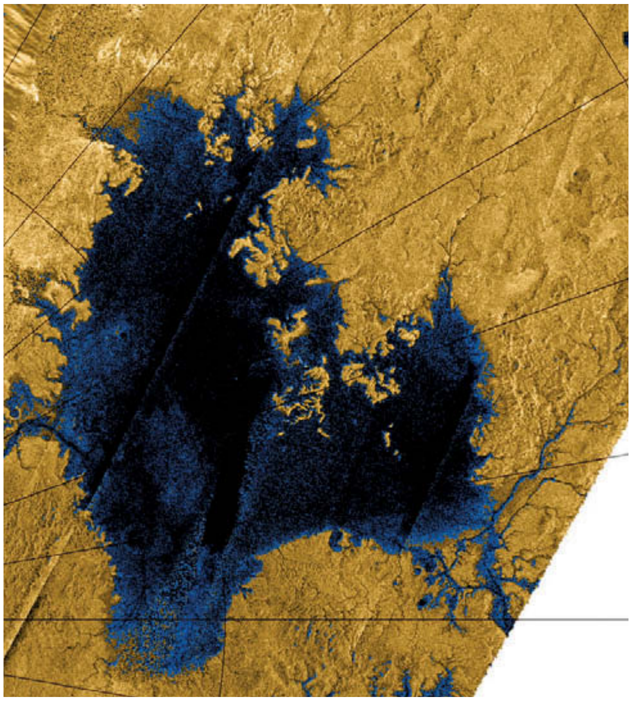
On Mercury, the IAU names craters after artists, musicians, painters, and authors — figures who were historically significant for more than 50 years and who made fundamental contributions to their field. One caveat: they must be dead for at least three years. On Mars, craters receive different themes depending on size. Craters larger than 60 km in diameter (an admittedly arbitrary distinction) are named after deceased scientists and explorers, especially those who had contributed to the study of Mars, as well as writers who added to Martian lore. Meanwhile, cities across the world with populations less than roughly 100,000 inspire the names of the smaller craters.

Craters are generally easy to name because they're easy to recognize. Other features are less obvious. So before we name a feature, we must first label the type of feature,

**Find out the names and protocols for features and bodies throughout the solar system at www.skypub.com/nomenclature.**


NASA / JPL / UNIV. OF ARIZONA

**TUPAN PATERA** This irregularly shaped volcanic crater takes its name from a thunder god of Brazilian indigenous people. The colors are slightly enhanced from what the human eye would see.



NASA / JPL-CALTECH / USGS

**LIGEIA MARE** Liquid ethane, methane, and dissolved nitrogen likely fill Titan's largest lake, tinted blue in this radar image.

usually using Latin. The label, also called a descriptor term, must be distinct from a feature's origin, since geological interpretations of particular features might change over the years. A flow-like feature is thus designated *fluctus* (Latin for "flow"), regardless of whether the feature has volcanic or fluvial origins. Descriptor terms should describe a feature, not interpret it. For example, scientists interpret a *patera* as a volcanic crater or caldera, but the descriptor term simply means "an irregular crater, or a complex one with scalloped edges." If the scientific interpretation ever has to be revised, the descriptor term will still apply.

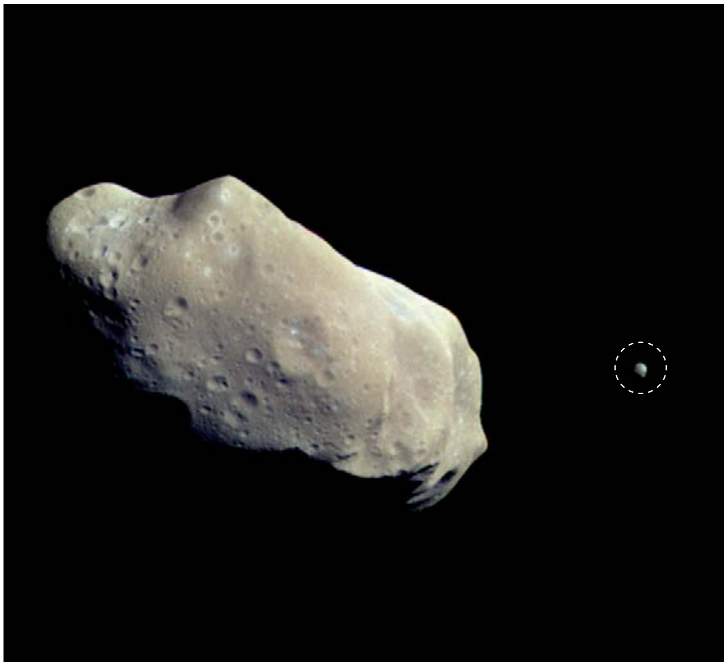
High-resolution images such as those from the Cassini mission only complicate nomenclature. Consider Saturn with its myriad rings and ringlets. Letters A through G label the main rings, but in order of their discovery, not their distance from Saturn. Divisions, such as the famous Cassini Division, separate the main rings. Smaller gaps within named rings take their names from deceased scientists, such as Maxwell, Huygens, Encke, and Keeler.

Other ringed planets have their own naming conventions. For example, Neptune's rings take their names from astronomers who contributed to scientific understanding of the planet, such as William Lassell and John Couch Adams. Very dark particles, probably a mix of ices and radiation-processed organic materials, compose the rings. But in the Adams ring, the material clusters together to form bright arcs dubbed Liberté, Egalité, Fraternité, and Courage.

The outer solar system contains a good deal more than gas giants: a plethora of moons, asteroids, and dwarf planets need names, too. History dictated the theme for many moons, as they follow or expand on tradition. Neptune's moons are named after characters from Greek or Roman mythology associated with the sea god and his oceans. Saturn's satellites are named after the grandfather god's brothers and sisters, the Titans and Titanesses (such as Iapetus, Titan itself, and Phoebe), as well as their descendants (such as Calypso). Other Saturn moons take their names from giants of various mythologies, including Albiorix (Gallic), Paaliaq (Inuit), and Ymir (Norse).

The moons of Uranus, the god of the sky, follow a different convention. Discoverer William Herschel turned to literature rather than mythology, taking his names from sprites of the air. He called the first two moons Titania and Oberon from Shakespeare's A *Midsummer Night's Dream*. The next two, Ariel and Umbriel, took their names from Alexander Pope's *The Rape of the Lock*. Shakespeare and Pope serve as the inspiration for the other moons as well.

Of all the features and objects in the solar system, only comets and asteroids may receive the name of a living person. Comets are traditionally named after their discoverers, whereas asteroid discoverers can suggest a name within certain guidelines. For example, asteroids can be named after friends or family members, except when they are modern-day politicians. Luckily, no relative of a modern-day politician I know of has ever discovered an asteroid; I can imagine the lively debate that would follow.



**NOT IDA-HO** Flight team members initially wanted to name the object orbiting potato-shaped Ida "Ho," but IAU's nomenclature committee eventually named the moonlet Dactyl.

NASA / JPL

## Call Me Clever

Tradition plays a large role in nomenclature, but that doesn't mean there isn't room for creativity. James W. Christy discovered the first moon of Pluto in 1978. He wanted to name it after his wife Charlene (nicknamed Char), but moons cannot take their names from people. Christy snuck her name in anyway when he proposed the name Charon, after the boatman in Greek mythology who ferried souls across the river Styx to the underworld. In 2005 a team of scientists associated with NASA's New Horizons mission (due to arrive at Pluto in 2015) discovered two more moons around Pluto. The team proposed the names Nix, the mother of Charon, and Hydra, a monstrous guardian of the underworld. Cleverly, the initials "N" and "H" also stand for New Horizons. The Hubble Space Telescope has since detected two more moons (October issue, page 14), but these have yet to be named.

Another moon took the IAU by surprise. The Galileo mission flew by the asteroid Ida and saw the first moon of an asteroid — a new type of body requiring a new theme. Since Ida's shape looks remarkably like that of an Idaho potato, flight team members started looking for reasons to name the moon "Ho." Alas, a good joke does not necessarily meet nomenclature criteria. The moonlet was officially named Dactyl, after the Dactyl beings who guarded the infant Zeus on Mount Ida in Greek mythology.

Dwarf planets in the Kuiper Belt are the newest additions to the world of nomenclature. Only a few dwarf planets have received names so far. One object in particular, discovered by Mike Brown in 2005, will stand out in history. Roughly the same size as Pluto, this object began the debate that led to the IAU vote to demote Pluto from planet status, possibly the most contentious IAU vote to date. As the discoverer of the dwarf planet, Brown suggested the name Eris, for the Greek goddess of discord and strife who instigated the Trojan War. I thought it was just perfect and was the first to vote yes. ✦

*__Rosaly Lopes__ is a Senior Research Scientist at the Jet Propulsion Laboratory. She is also the Chair of the International Astronomical Union's Outer Solar System Task Group.*

### Titan's Maria

***Mare*** **is a familiar term used on the Moon to designate large expanses of lava flows. The IAU debated whether to use the same designation to name large bodies of liquid methane and ethane on Titan, discovered with Cassini data. Titan's smaller lakes were named after lakes on Earth with similar shapes. But many scientists felt the largest lakes deserved to be distinguished, so the designation "mare" was proposed and accepted.**

**The theme for Titan's maria comes from mythology and literature. The three discovered so far have taken the names Kraken (a sea monster in Norwegian lore), Ligeia (a siren in Greek mythology), and Punga (a supernatural being in Maori mythology).**

**A NON-VOLCANIC PATERA** Many irregularly shaped craters known as *paterae* are thought to be volcanic in origin, but Orcus Patera on Mars is probably an exception.

ESA / DLR / FU BERLIN (GERHARD NEUKUM)

# The Evolving Eclipse Map

SHEILA TERRY / PHOTO RESEARCHERS, INC.

Nearly 400 years of fine-tuning have turned today's eclipse maps into works of art that predict cosmic alignments with exquisite precision.

MICHAEL ZEILER

**Eclipse maps tell amazing stories.** They combine space and time to instruct us how to station ourselves to observe a total eclipse of the Sun. Eclipse maps also weave together exploration, mathematics, astronomy, geography, culture, and artistry.

Eclipse maps arose four centuries ago and progressed in synchrony with advancements in scientific knowledge, eclipse calculations, and cartography. Today's eclipse maps present an audacious degree of precision, predicting where and when the Moon's shadow will fall on Earth with accuracies of tens of meters and tenths of seconds. With modern technology, we can predict the syzygies of the Sun, Earth, and Moon with such confidence that our current eclipse maps will still be reasonably accurate for centuries into the future. As eclipse chasers gather in Australia and the Pacific this November (see page 52), we'll know *exactly* where and when to go to witness the greatest show on Earth — a total eclipse of the Sun.

## Origins

Historians have traced the origin of eclipse maps back to the ancient Greeks and Claudius Ptolemy, who made rough eclipse predictions and diagrams. But mapping an eclipse's path on Earth required more detailed knowledge of the motions of the Earth, Sun, and Moon than these past astronomers possessed. The ancients found rhythms of the Moon and Sun (such as the saros cycle, see page 37) that they used to make predictions of when an eclipse might happen, but this knowledge was insufficient to predict the path of a solar eclipse on Earth.

It was not until the scientific revolution in Europe that eclipse predictions improved to a point when astronomers could produce the first true eclipse maps. The modern conception of the motions of solar system bodies arose in the 16th and 17th centuries, marked by Copernicus's heliocentric model, Kepler's laws of planetary motions, and Newton's theory of gravitation.

This scientific milieu was the setting for the earliest known eclipse map, created in 1654 by German mathematician, astronomer, and philosopher Erhard Weigel. Weigel was a key figure in the German Enlightenment, a mentor to Gottfried Liebniz, and a leader of calendar reform in Germany. Weigel's eclipse map had been long forgotten until its recent recognition by German historian of astronomy Klaus-Dieter Herbst.

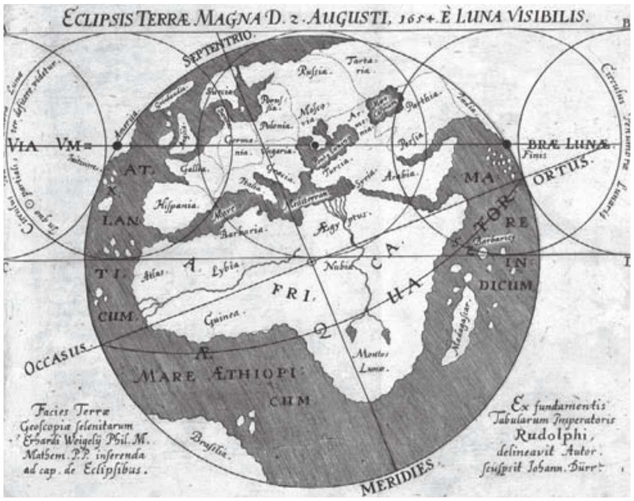
Weigel's calculations were based on the *Rudolphine Tables*, an early ephemeris calculated by Johannes Kepler, who applied his discovery of elliptical planetary orbits to Tycho Brahe's extensive observations of planetary motions. Remarkably, Weigel prepared his eclipse map on the day before the total solar eclipse of August 12, 1654. Weigel's map is fairly accurate and compares reasonably well with a reconstructed map of this eclipse. The point of greatest eclipse on Weigel's map matches the modern calculated position to an accuracy of about 100 kilometers (60 miles), quite impressive for the earliest effort!

More eclipse maps followed. In 1676 Johann Christoph Sturm, professor of astronomy, mathematics, and physics at Altdorf University in Bavaria, published a 34-page almanac. In a similar fashion to Weigel's map, he also depicted eclipses as a series of circles representing the Moon's outer (penumbral) shadow. But unlike Weigel, Sturm more accurately portrays the eclipse path as curved rather than as a straight line, which results from the combination of the passage of the Moon's inner (umbral) shadow, Earth's rotation, and the tilt of Earth's axis.

While at the Paris Observatory, Jean Dominique Cassini created a map for the path of the annular-total solar eclipse of September 23, 1699. Cassini's map is significant not for its greater accuracy but because it begins to resemble modern eclipse maps with features such as curves representing the maximum magnitudes of eclipse. At Denmark, the eclipse path on Cassini's map is about 150 km south of the true location and at the Crimean Peninsula, it improves to about 50 km south of the true path.

The May 12, 1706, solar eclipse crossed Europe and motivated many observations by astronomers of the day. Historian Robert van Gent has documented several maps produced in the Netherlands and Germany for this eclipse. In Amsterdam, Symon van de Moolen published a predictive eclipse map in 1705, and in Rotterdam, Andreas van Lugtenburg published a map in 1705 or 1706 with a rough path for the eclipse and detailed descriptions of eclipse circumstances for various places in Europe. Van Lugtenburg's map shows only three points with two connecting lines. The three points each seem to be accurate to within 300 km, but it's difficult to judge this map because the eclipse's path could be determined to a greater accuracy than the location of the continents on maps of this era.

Edmond Halley made a famous map for the total solar eclipse of May 3, 1715. Although not the earliest eclipse map as is often believed, Halley's map was nonetheless a significant advance. He applied Newton's laws of motion to create a map that predicted the eclipse path with an accuracy of about 30 km. Moreover, Halley solicited observations from the interested public to note where totality was actually observed, along with eclipse durations. Using reports from observers, he made a post-eclipse

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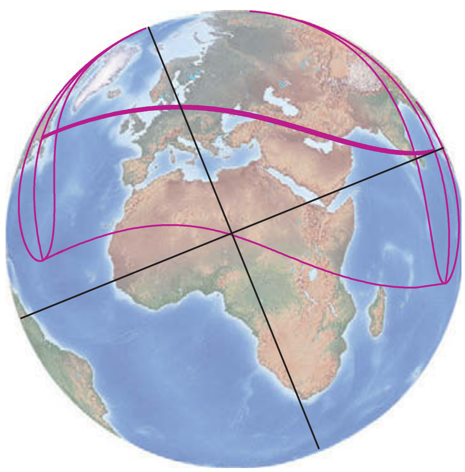

**IMPRESSIVE START** German astronomer Erhard Weigel produced the first known eclipse map in 1654 (*near right*). Though his map of the August 12, 1654, total solar eclipse seems crude, the eclipse track was remarkably accurate when compared to a modern map (*far right*). Weigel's map shows Earth from the Sun's perspective at the moment of greatest eclipse. The point of greatest eclipse is correctly shown as being within the Crimean Peninsula.

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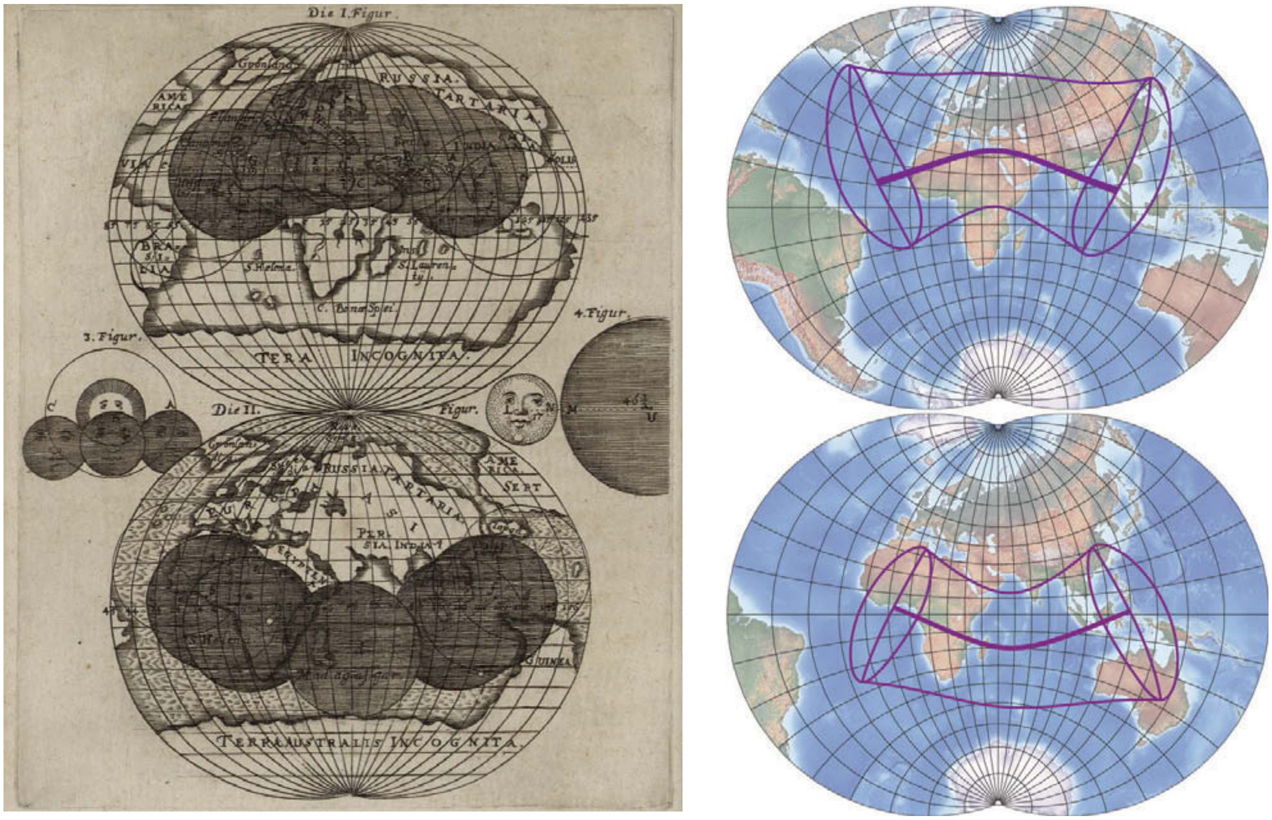


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**THE NEXT STEP** **German astronomer Johann Christoph Sturm produced these impressive maps *(left)* of the June 11, 1676, annular solar eclipse and the December 5, 1676, total solar eclipse. Like Weigel, he depicted an eclipse as a series of circles for the Moon's outer (penumbral) shadow. Improving upon Weigel, he realized that an eclipse's path would follow a curved path due to the inclined passage of the Moon's shadow over the rotating Earth with its axial tilt. Modern maps of these eclipses are shown on the right.**

map with a corrected path that had an accuracy of about 3 km. Halley created additional maps with similar accuracy for the total solar eclipse of May 11, 1724.

Several British cartographers published maps for the solar eclipses of 1715, 1724, 1737, 1748, and 1764, a rare and fortuitous series of eclipses crisscrossing the British Isles within a relatively short time span. This was a golden era of eclipse mapping because of innovations such as the inclusion of the northern and southern limits of totality, lines of equal eclipse magnitude, and ovals representing the Moon's shadow at an instant of time.

## The Next Step

A major breakthrough came in 1824, when German astronomer Friedrich Wilhelm Bessel developed an improved theory that simplified eclipse-path calculations. Bessel selected a frame of reference (the fundamental plane) through the center of Earth facing the Sun. This simplified the number of values needed to calculate the motion of the Moon's shadow and enabled faster computations of an eclipse path, which was advantageous in an era when calculations were done manually. Bessel's approach proved so successful that it remains the standard method of computing eclipse predictions today.

Around 1830 eclipse maps started to appear in three of the main annual ephemerides of the 19th century: the French nautical almanac *Connaissance des Temps*, the British *Nautical Almanac and Astronomical Ephemeris*, and the *American Ephemeris and Nautical Almanac*. Eclipse maps are just about the only illustrations that appear within these ephemerides, each of which contain hundreds of pages of numerical tables for the motions of the Sun, Moon, and planets, along with star positions.

Early ephemeris eclipse maps began as half-page graphics, then expanded to full-page maps, then as maps across a two-page spread, and finally as fold-out maps at the dawn of the 20th century. The map projections began with ill-considered choices such as the Mercator projection and were later replaced by map projections better suited for eclipses, such as the stereographic and orthographic projections. Early maps were spare in eclipse details, meaning they did not include features such as curves of equal magnitude or contact times. But more of this information appeared over the next several decades.

Although eclipse maps still appear in national ephemerides, most eclipse chasers turn to the NASA eclipse bulletins produced by Fred Espenak and Jay Anderson as the authoritative reference for eclipse predictions and maps. This series has been recently concluded, but Espenak and Anderson are launching a series of privately published eclipse bulletins, and Espenak provides many detailed predictions at his website, **MrEclipse.com**.

## Canons of Solar Eclipses

Eclipse canons are collections of eclipse maps and tables spanning many years. Franz Ignatz Cassian Hallaschka published the first substantial canon of eclipses in Prague in 1816. The first volume of his book *Elementa eclipsium* contained eclipse maps from 1816 to 1860, and a second volume followed with eclipse maps through 1900. Hallaschka made a careful study of eclipse calculation techniques by luminaries such as Leonhard Euler, Joseph-Jérôme LeFrançais de Lalande, and Joseph Louis Lagrange and developed a new method that anticipated Bessel's standard theory of eclipses.

In 1868 Austrian astronomer and mathematician Theodor von Oppolzer observed a total solar eclipse, and like many first-time eclipse observers, was deeply moved by the experience. He was inspired to organize a team to calculate the circumstances for a prodigious series of solar and lunar eclipses from 1200 BC to 2161 AD. These results were published in 1887 as the *Canon der Finsternisse* ("Canon of Eclipses"), which contained tables and maps of 8,000 solar and 5,200 lunar eclipses.

For each solar eclipse, von Oppolzer's team of 10 people calculated three points; the beginning, middle, and ending. Since each eclipse was mapped as an arc through these three points, the paths are not very accurate. Errors in estimates of the Moon's motion created inaccuracies for eclipse paths in the distant past. Still, the *Canon* was a groundbreaking feat of computation, and it became a vital resource for astronomers studying eclipse cycles and for historians identifying eclipses recorded in historical chronicles.

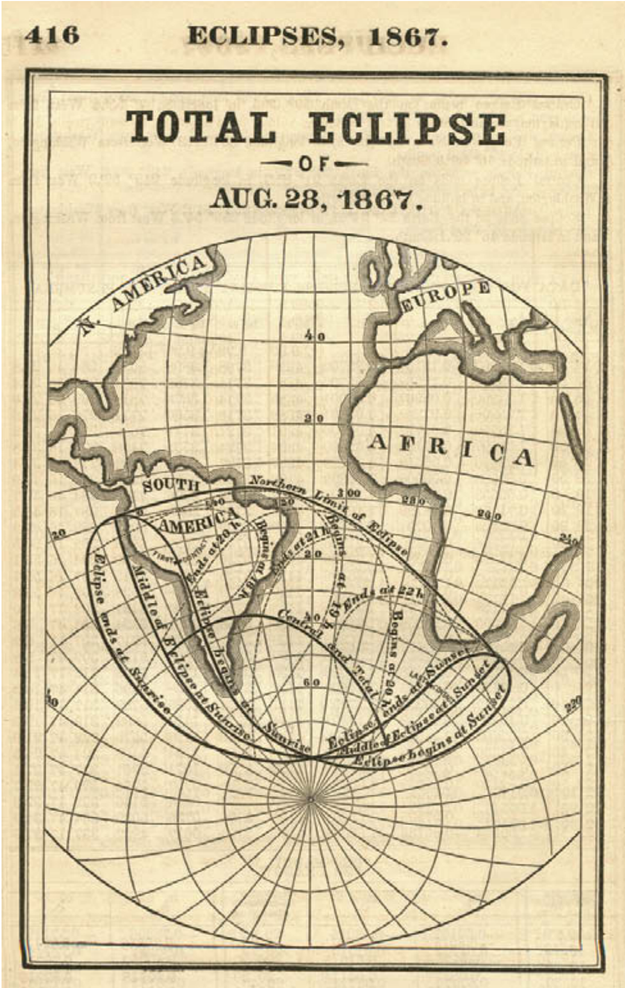
In the 20th century, several eclipse canons were built on improved methods of calculation and on computer technology. Jean Meeus, Carl Grosjean, and Willy Vanderleen published the *Canon of Solar Eclipses* in 1966 using IBM computers. In 1987 Fred Espenak produced the *Fifty-Year Canon of Solar Eclipses: 1986–2035*, which is still widely used by today's eclipse chasers. Canons have recently become available on the internet, such as Meeus and Espenak's *Five Millennium Canon of Solar Eclipses*.

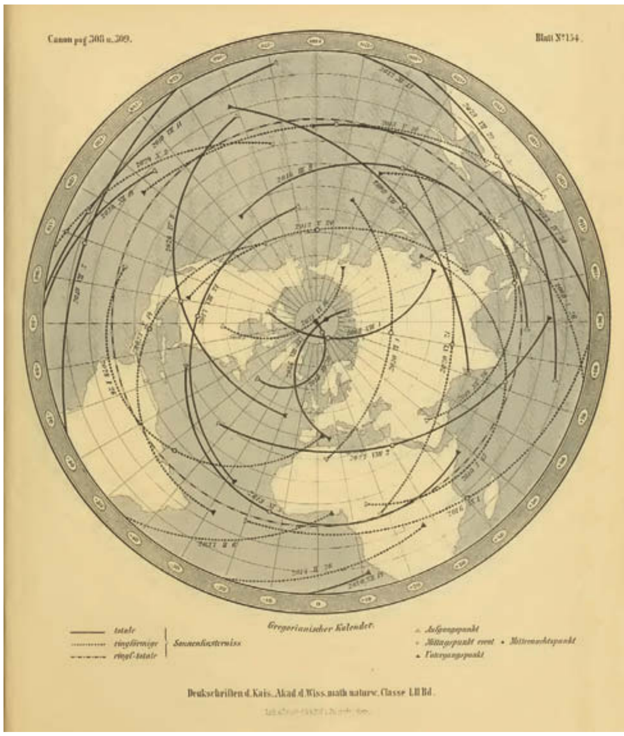
Once you catch the eclipse bug, a canon becomes an essential expedition-planning guide for the remainder of your life. Eclipse chasing is a fascinating interest because

### SAROS CYCLES

Astronomers as far back as about 600 BCE could predict lunar eclipses with at least crude precision because of their knowledge that eclipses repeat themselves with a periodicity known as the *saros cycle*. In more recent times, Edmond Halley discovered that solar eclipses also follow saros cycles. This is a cycle that repeats every 6,585.33 days (about 18 years, 11 days). It's governed by three elements of the Moon's orbit: its 29.53-day period from New Moon to New Moon, its 27.55-day period from perigee to perigee, and its 27.21-day period from a node to the same node (a node is one of two points where the plane of the Moon's orbit around Earth intersects Earth's orbit around the Sun). Two consecutive eclipses belonging to the same saros sequence will occur 18 years apart, on the same calendar date plus 10 or 11 days, when the Moon is at the same node and at the same distance from Earth.


**ENGLISH ECLIPSE** ***Left:*** **Edmond Halley's detailed predictive map of the May 3, 1715, total eclipse was accurate to about 30 kilometers. The dark oval represents the Moon's inner shadow (umbra).** ***Center:*** **After compiling reports from observers, Halley produced an even better map that was accurate to within 3 km.** ***Right:*** **Author Michael Zeiler produced this modern map of the 1715 eclipse, which helps demonstrate the brilliance of Halley's achievements. British cartographers of this era clearly had a sophisticated knowledge of the sizes and shapes of the various landmasses in their region.**



you will visit distant and exotic places that you would probably never otherwise consider, and the journeys can be as remarkable as the eclipses themselves (July issue, page 36).

## Extreme Precision

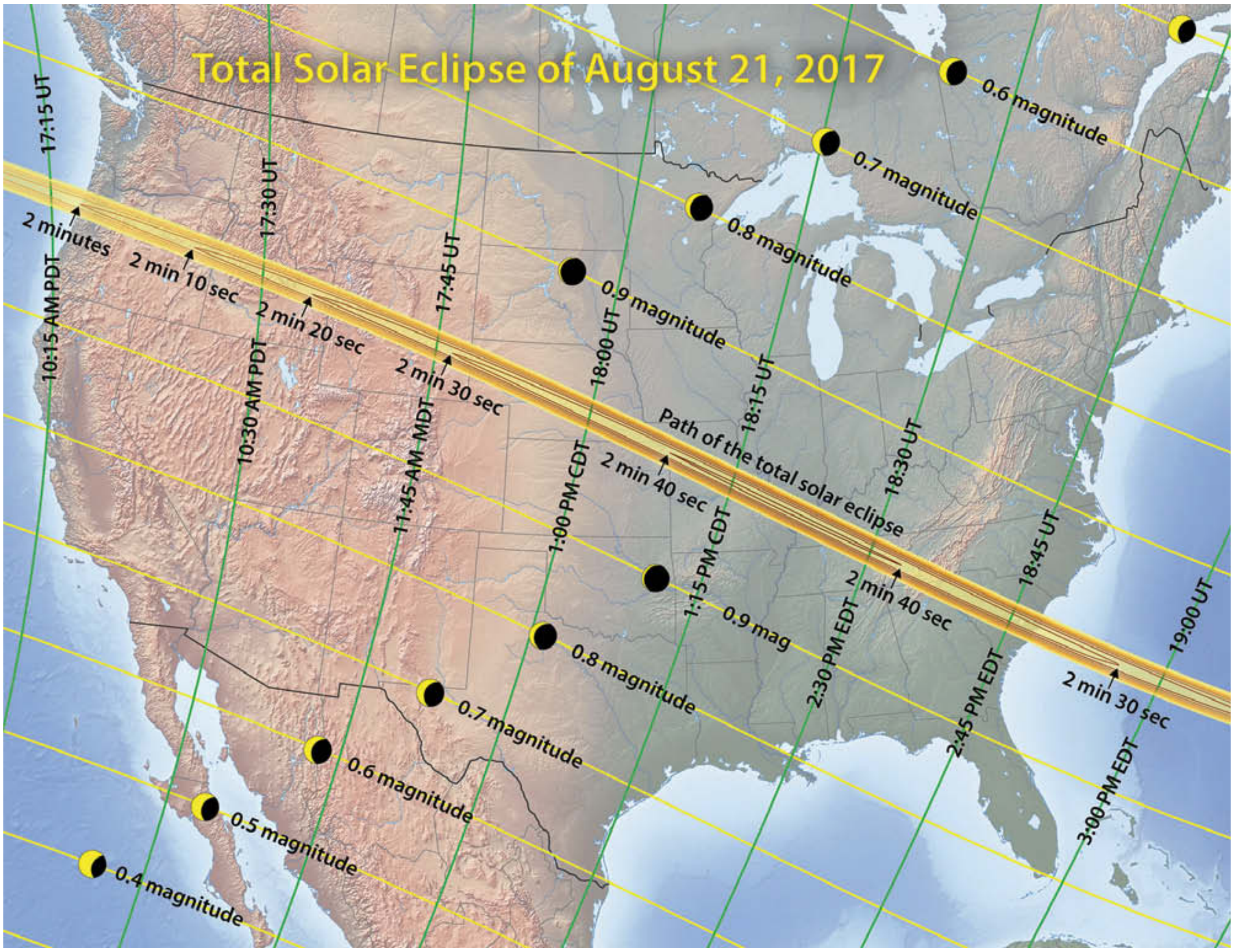
Eclipse maps are currently being produced with even higher levels of accuracy and cartographic quality. I'm developing new maps by integrating eclipse calculations into geographic information systems (GIS) using calculations by Bill Kramer and Xavier Jubier and eclipse elements from Espenak and Meeus (a GIS performs sophisticated spatial analysis on a mapping database). I'm applying detailed base-map layers such as satellite imagery, terrain relief, and street networks within the GIS software. I use state-of-the-art cartographic techniques so that the eclipse maps are not only precise, but also display the appropriate level of geographic detail.

The mathematical models for each eclipse (the Besselian elements) are based on extremely accurate measurements of the motions of the Sun, Earth, and Moon. For example, the Moon's distance is now known to a precision of several centimeters due to measurements made from laser reflectors left by the Apollo astronauts. Using customized eclipse calculators, I process several tens of millions of gridded points within the path of each eclipse. I input these points with eclipse circumstances into a geographic model to derive eclipse features such as lines of equal eclipse duration. In 1887 von Oppolzer had to rely on the efforts of his team of 10 human calculators to find three points for each eclipse; we can exploit today's computer technology to quickly calculate many millions of data points.

Previous eclipse maps assumed a perfectly round shape for the Moon. In 2009 I collaborated with Kramer to make the first maps that account for the Moon's irregular profile due to lunar mountains and valleys. We used lunar profiles derived by David Herald from digital elevation models captured by the altimeter on Japan's Kaguya lunar orbiter. By comparing our prediction with a

**NAUTICAL ALMANAC** ***Top left:*** **By the mid-1800s, eclipse maps had reached a level of sophistication and accuracy approaching modern standards. This map of the August 28, 1867, total solar eclipse appeared in the** ***American Ephemeris and Nautical Almanac*****, published by the U.S. Naval Observatory. These maps were prepared several years in advance, so the U.S. government continued their publication during the Civil War.**

**ECLIPSE MAP CANON** ***Left:*** **In 1887 Austrian astronomer Theodor von Oppolzer published a groundbreaking canon (compilation) of eclipse paths for eclipses dating from 1200 BC to AD 2161. This page shows tracks for solar eclipses from 2008 to 2030. For nearly a century, scholars referred to von Oppolzer's canon to better understand eclipse cycles and eclipses recorded in history.**




**MODERN MAP** Author Michael Zeiler produced this map of the August 21, 2017, total solar eclipse. Modern maps include a level of astronomical precision and cartographic detail that would have astonished the great astronomers of yesteryear.

timing derived from a video recording of the July 22, 2009 eclipse, we estimate that our eclipse predictions and maps now have an accuracy of about 0.1 second.

Recently, I began to apply calculations by Jubier to take into account the effects of atmospheric refraction. This correction is important if you plan to witness an eclipse at sunrise or sunset because the refraction of the Sun's apparent disk will extend the eclipse path by several tens of kilometers. Jubier and I are currently working on incorporating surface elevations for every point on Earth for even higher accuracy. We are truly in the era of high-precision eclipse predictions and mapping.

We're also starting to see dynamic eclipse maps on smartphones and tablets. I envision this scenario for the August 21, 2017, total solar eclipse in the U.S.: It's two hours before the eclipse and you're driving in Wyoming to intercept totality. Because of widespread thunderstorms in the area, you abandon your planned viewing location. Your phone displays a map showing the eclipse path, topography, roads, and real-time traffic and weather data.

**To view more eclipse maps and to learn more about this fascinating topic in astronomical history, visit skypub.com/eclipsemaps.**

Through a voice interface, you'll ask your map to provide an optimized driving route to dodge the predicted clouds at eclipse time as well as to avoid traffic congestion caused by other eclipse chasers. When you arrive at your destination near the centerline, you'll view a glorious total eclipse, upload the video you made with your phone, and then watch pictures and videos from others by tapping icons overlaid on the map. ✦

*Michael Zeiler (**michael.zeiler@yahoo.com**) sits on the International Astronomical Union's Working Group on Solar Eclipses. He is an author of several books on geographic data modeling for his employer, Esri (**www.esri.com**). Zeiler operates **www.eclipse-maps.com**, which contains more than 1,500 historical eclipse maps and hundreds of new eclipse maps.*

 *Johnny Horne*

# Orion's StarShoot G3 Cameras


*Beginning astrophotographers have two new astronomical CCD cameras to consider.*

ALL PHOTOGRAPHS BY THE AUTHOR

THE COST OF OWNING an astronomical CCD camera continues to fall. As the "price per pixel" drops and manufacturers add advanced features such as regulated cooling, investing in a high-quality CCD camera has become a lot less painful now than it was just a few years ago. An excellent example of this trend is a new contender in the beginner CCD market from Orion Telescopes & Binoculars. The StarShoot G3 Deep Space Camera doesn't require deep pockets to purchase, and it's also small enough to fit into those same pockets.

The StarShoot G3 is available in two models. The monochrome version has a 752-by-582-pixel Sony ICX-419ALL CCD chip with an active imaging area measuring 7.40 by 5.95 millimeters. The other model is a "one-shot" color camera with Sony's ICX419AKL chip that has the same array size. Both cameras have very slightly rectangular 8.6-by-8.3-micron pixels. And both G3 cameras feature regulated thermoelectric cooling (TEC) that can chill the CCD as much as 10°C below ambient air temperature and help reduce noise in the images.

The two G3 models look identical, measuring a bit more than 1 inch (2½ cm) thick and 3½ inches in diameter. Each one weighs 12 ounces (340 grams) — I own eyepieces that are heavier — so the cameras will not impose excessive loads on your telescope's focuser.

You can connect the StarShoot G3 to a telescope in several ways. The body's integral 2-inch-diameter "snout" will slide directly into a 2-inch focuser without the need for additional attachments. Doing this places the CCD's surface only 3½ mm beyond the end of the focuser's drawtube, meaning that the camera can reach focus with virtually any telescope that works with an eyepiece. The G3 body also has female T threads that accept an included 1¼-inch nosepiece for use with smaller focusers. In this configuration, the CCD is 23 mm beyond the drawtube. Lastly, the camera can also be attached to any telescope adapter that has male T threads.

Both cameras are powered and controlled via a single USB 2.0 connection to a PC computer running Windows XP, Vista, or 7. There's a separate 12-volt DC jack for powering the single-stage TEC, and the camera comes with a 10-foot power cord fitted with a cigarette-lighter plug.

## Orion StarShoot G3 Cameras

**U.S. price:** $499.99 (monochrome or one-shot color)
Orion Telescopes & Binoculars
89 Hangar Way, Watsonville, CA 95076
800-676-1343, oriontelescopes.com

***Above:*** **The only difference between the monochrome and one-shot color G3 cameras is the Sony 0.44-megapixel CCD detector.** ***Right:*** **The G3 camera body is designed to fit directly into a 2-inch focuser.**

A small fan runs from the same 12-volt source to dissipate heat from the cooler, which draws about 1 ampere of power.

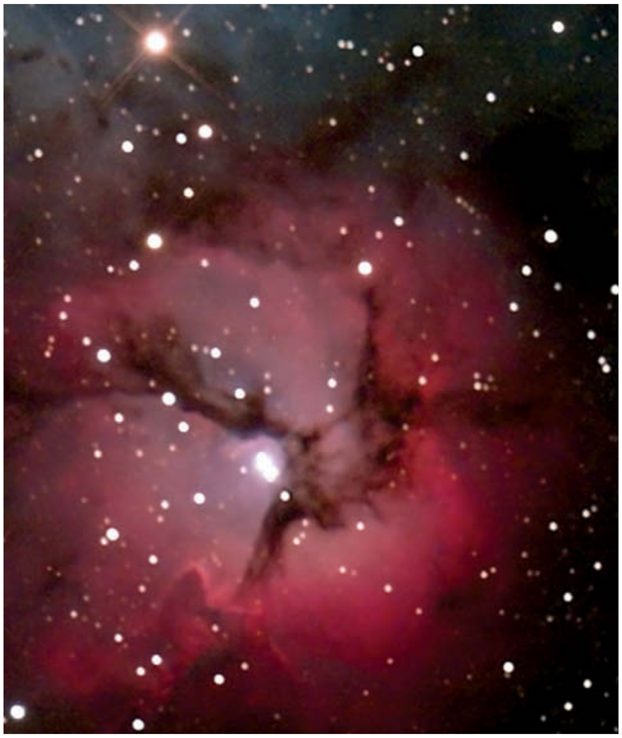
The G3 cameras are supplied with *Orion Camera Studio* software. Along with its easy-to-understand, 23-page manual, this program will have you up and running quickly. The software is certainly no-frills, but it is fully functional, allowing the automated shooting of sequences of light, dark, flat, and bias frames. The software also displays the CCD's temperature and lets you adjust the settings for the TEC.

In addition to controlling the cameras and performing basic image calibration with dark, bias, and flat-field frames, *Orion Camera Studio* can register G3 images for stacking. These processing steps are detailed in the camera's manual, which can be downloaded for free from the product information page on Orion's website.

The cameras also come with the software drivers that are needed to operate them with ASCOM-compatible programs. Although I acquired all of the images appearing here with *Orion Camera Studio,* I also successfully operated the G3s with the popular programs *Nebulosity* (**www.stark-labs.com**) and *Images Plus* (**www.mlunsold.com**).

Neither of the G3 cameras liked the powered USB hub that I use to keep cables on my observatory's fork-mounted 12½-inch classical Cassegrain telescope more manageable. The first image I took when the cameras were connected through the hub resulted in a readout error, after which the software wouldn't recognize the camera. Plugging the cameras directly into a USB port on my Dell desktop computer solved this problem.

As mentioned above, the TEC cooling only reduces the CCD's temperature by a modest 10°C, but the key here is the G3's temperature regulation. I found that the camera's gentle but stable cooling allowed me to make very effective dark frames for image calibration, even on hot North Carolina nights. The temperature readout in the software indicated that the temperature held stable to within 1°C. Because of this stability, I could take dark frames during dusk at the same temperature used later in the evening for my deep-sky images. This is much more efficient than having to make dark frames along with each regular exposure and it allowed me more time under a dark sky



**This view of the Trifid Nebula, M20 in Sagittarius, was made by stacking 14 200-second exposures taken with the G3 color camera and the author's 12½-inch f/4 reflector.**

for actual imaging. The G3 cameras lack a mechanical shutter, so you will need to cap the front of your telescope to make dark frames.

## Which Camera Is for You?

The G3 cameras worked as I expected, with the monochrome camera producing images that have higher resolution than the color camera. That's because of the latter's Bayer filter array on the CCD. It's also possible to do color imaging with the monochrome camera using Orion's optional filter wheel and LRGB filters ($349.99). Both cameras have high sensitivity, but the monochrome camera is the champ. Many of the popular deep-sky objects I imaged were visible with exposures of only a second or two at the f/4 focus of my scope, making it easy to compose the shots quickly. The speedy readout of the G3 images makes focusing easier, too.

The G3 cameras are not equipped with infrared-blocking filters. This was fine for me, because I tested the cameras with telescopes that have all-mirror optics. But purchasing an infrared-blocking filter is a good idea if you're using either G3 camera with a refractor or camera lens that doesn't focus infrared light along with the visible spectrum. An infrared filter can be threaded into the front of the G3's 1¼-inch nosepiece, or into another set of threads on the G3 body just ahead of the optical window in front of the CCD.

Both G3 cameras can be used as sensitive autoguiders without an additional interface device between the camera and compatible telescope mount. (Neither camera can


**What we liked:**

Attractive price

Regulated cooling

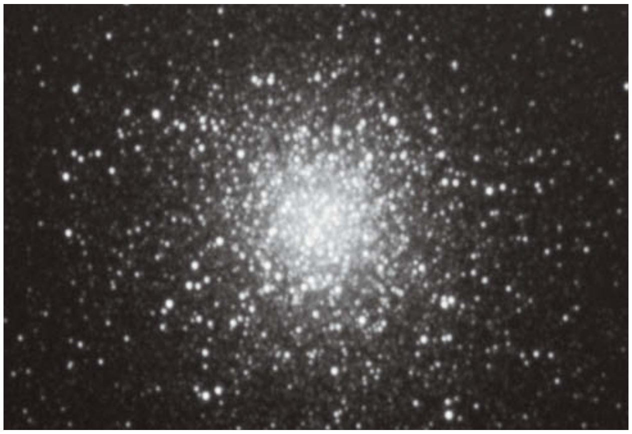
Doubles as a high-performance autoguider

**What we didn't like:**

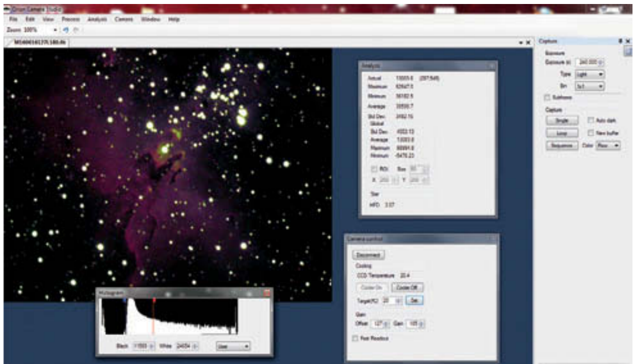
Difficulty using with USB hub

guide and image at the same time.) I frequently made deep-sky exposures with the G3 color camera while using the monochrome G3 as an autoguider. As expected, the monochrome camera can guide on fainter stars better than the color camera can due to its higher sensitivity. Both cameras have an industry-standard ST-4 jack for direct hookup of a (supplied) cable between the camera and the autoguider input on the mount. The G3 doesn't need its TEC when used as an autoguider, which is a benefit for those using battery power in the field. I did my autoguiding with the program *PHD Guiding* (also from **www.stark-labs.com**).

If you image with fast Newtonian scopes, you'll find the G3's chip a close match to the size of the relatively coma-free area of the telescope's focal plane. I used a Baader MPCC coma corrector at my classical Cassegrain's f/4 Newtonian focus, but found this unnecessary when I used the G3 cameras with my 8-inch f/5 Newtonian.



**The G3 cameras will record bright Messier objects with very brief exposures. This image of globular cluster M13 is a stack of 120-second exposures with the 12½-inch scope.**



**The *Orion Camera Studio* software supplied with the G3 cameras offers basic camera control and image-processing functions that are easy to use.**

I found both StarShoot G3 cameras to be exciting additions to the beginner CCD camera market. Their decent-sized chip, small physical size, and regulated cooling rolled into a package costing $500 are clearly milestones in the continually evolving amateur imaging field. In the early 1990s, the ST-4 from Santa Barbara Instrument's Group was the introductory CCD camera for many amateurs, including me. Today's beginning CCD astrophotographers have a far superior and less expensive first step available to them in the Orion StarShoot G3 cameras. ✦

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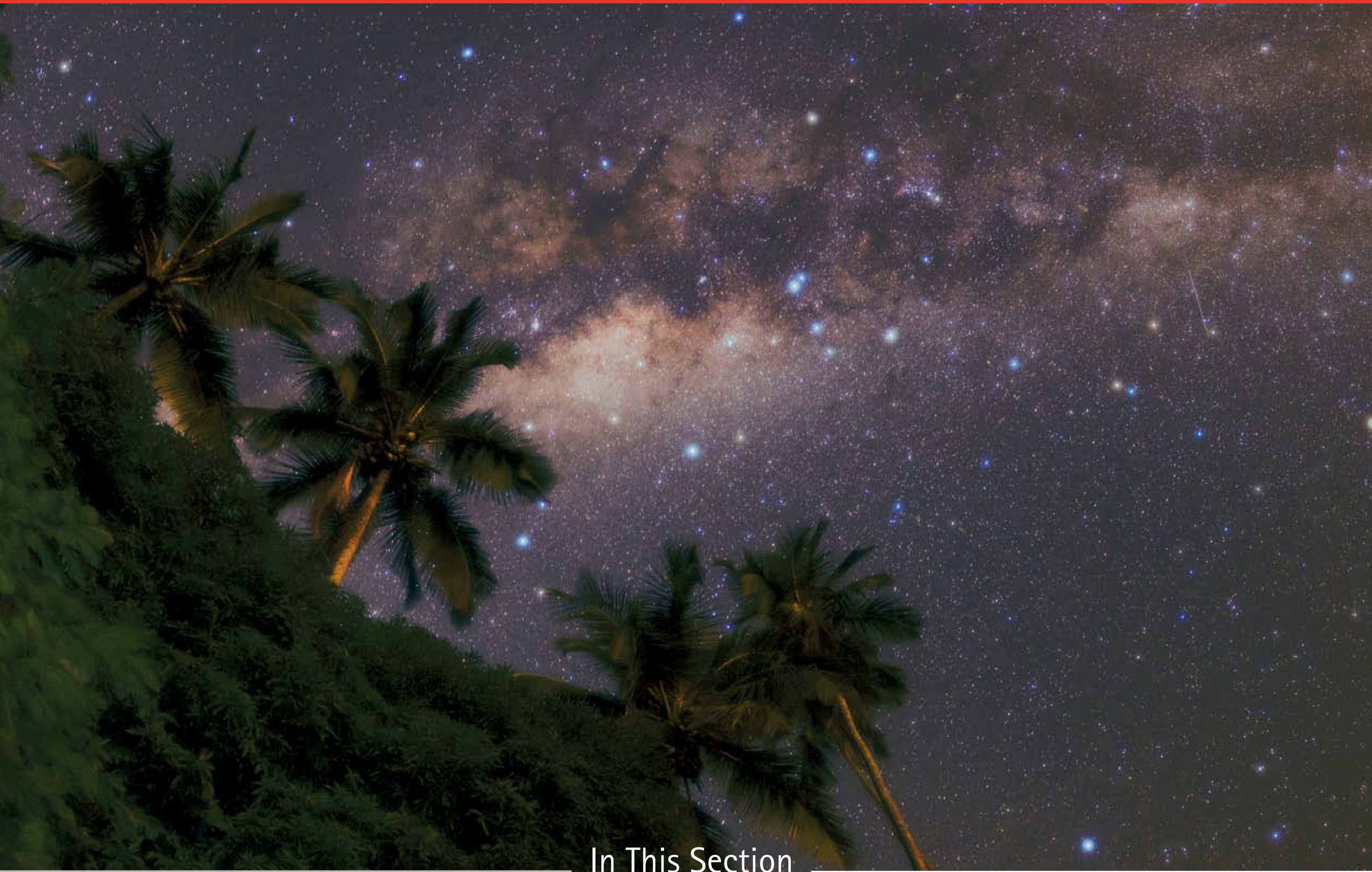
*Newspaper photo editor* ***Johnny Horne*** *has viewed numerous comets, deep-sky objects, and historic astronomical events from his 34-year-old backyard observatory in North Carolina.*

**These images of the Eagle Nebula, M16 in Serpens Cauda, were made with the color (*left*) and monochrome G3 cameras. Although the imaging area and pixel size of both cameras are identical, the filter array built into the color CCD reduces the inherent resolution and sensitivity of the color camera. The exposures and telescope for these views are the same as for the M20 shot on the previous page.**



## In This Section



**Additional Observing Article**



*Top*: Babak Tafreshi photographed the Milky Way framed by trees on an island off the coast of Brazil. See page 49 for a discussion of trees and the night sky and page 70 for Tafreshi's tips on nightscape photography.

## NOVEMBER 2012

**1 EVENING:** Jupiter shines close above the waning gibbous Moon; see page 50.

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

**11 DAWN:** Venus blazes well to the left of the waning crescent Moon from predawn to sunrise.

**12 DAWN:** Saturn shines to the lower left of the thin crescent Moon very low in the east-southeast starting around an hour before sunrise. Binoculars help.

**13–14 A total solar eclipse** crosses northernmost Australia and the South Pacific; see page 52.

**15, 16 DUSK:** The waxing crescent Moon passes dim Mars low in the southwest.

**17 PREDAWN:** The normally weak but occasionally surprising Leonid meteor shower should be strongest (perhaps 20 meteors per hour under a dark sky) in the small hours until the sky starts to brighten. The Moon is absent.

**26, 27 DAWN:** Venus and Saturn are less than 1° apart, with Mercury well to their lower left.

**28 PREDAWN:** The Moon experiences a penumbral eclipse for western North America; see page 52.

**28 EVENING:** Jupiter is very close to the upper left of the just-past-full Moon.

## Planet Visibility

| | ◀SUNSET | MIDNIGHT | SUNRISE▶ |
|---|---|---|---|
| Mercury | Visible November 24 through December 24 | | SE |
| Venus | | | SE |
| Mars | SW | | |
| Jupiter | NE | S | W |
| Saturn | Visible starting November 8 | | SE |

PLANET VISIBILITY SHOWN FOR LATITUDE 40° NORTH AT MID-MONTH

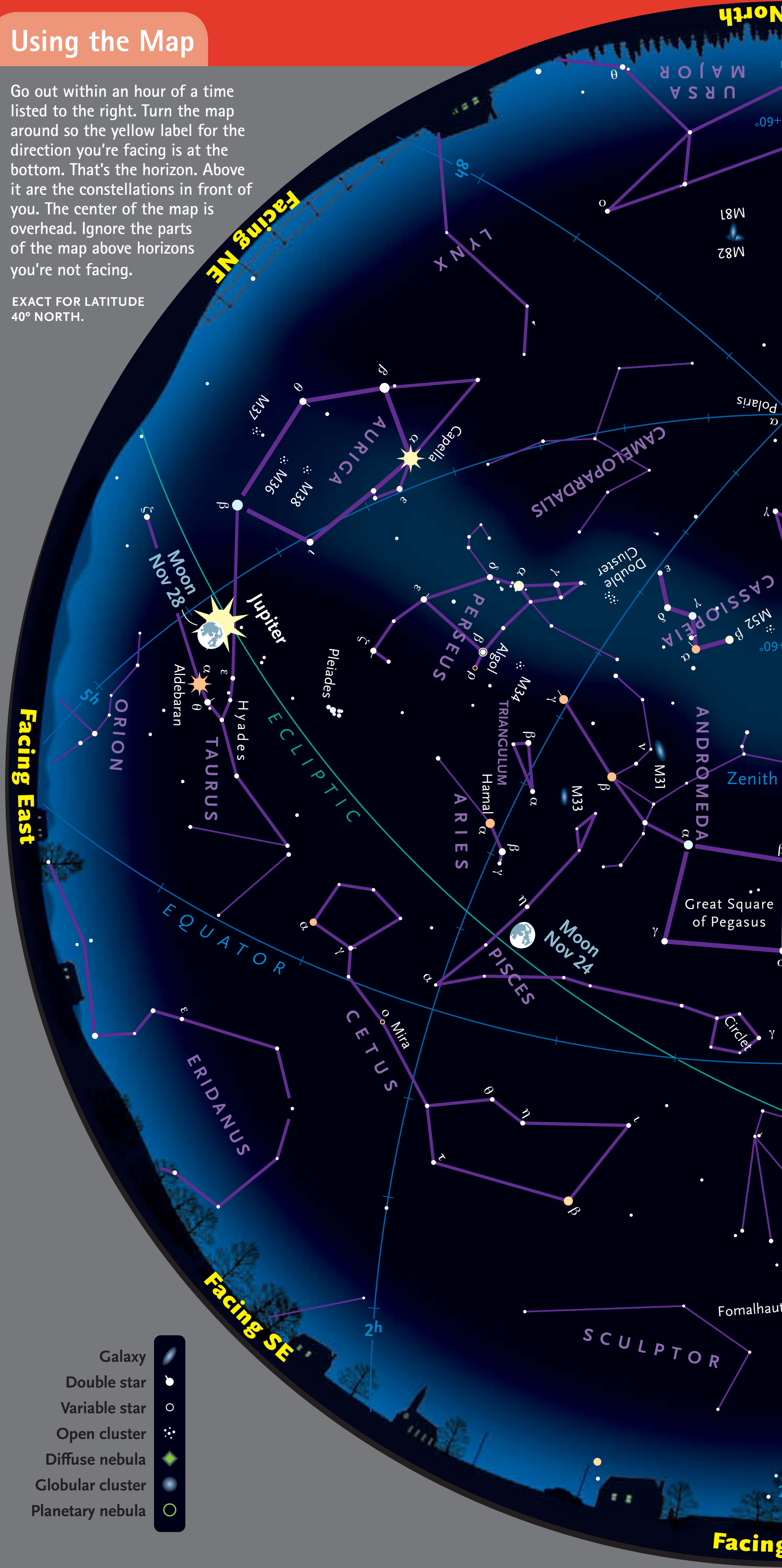
## Moon Phases

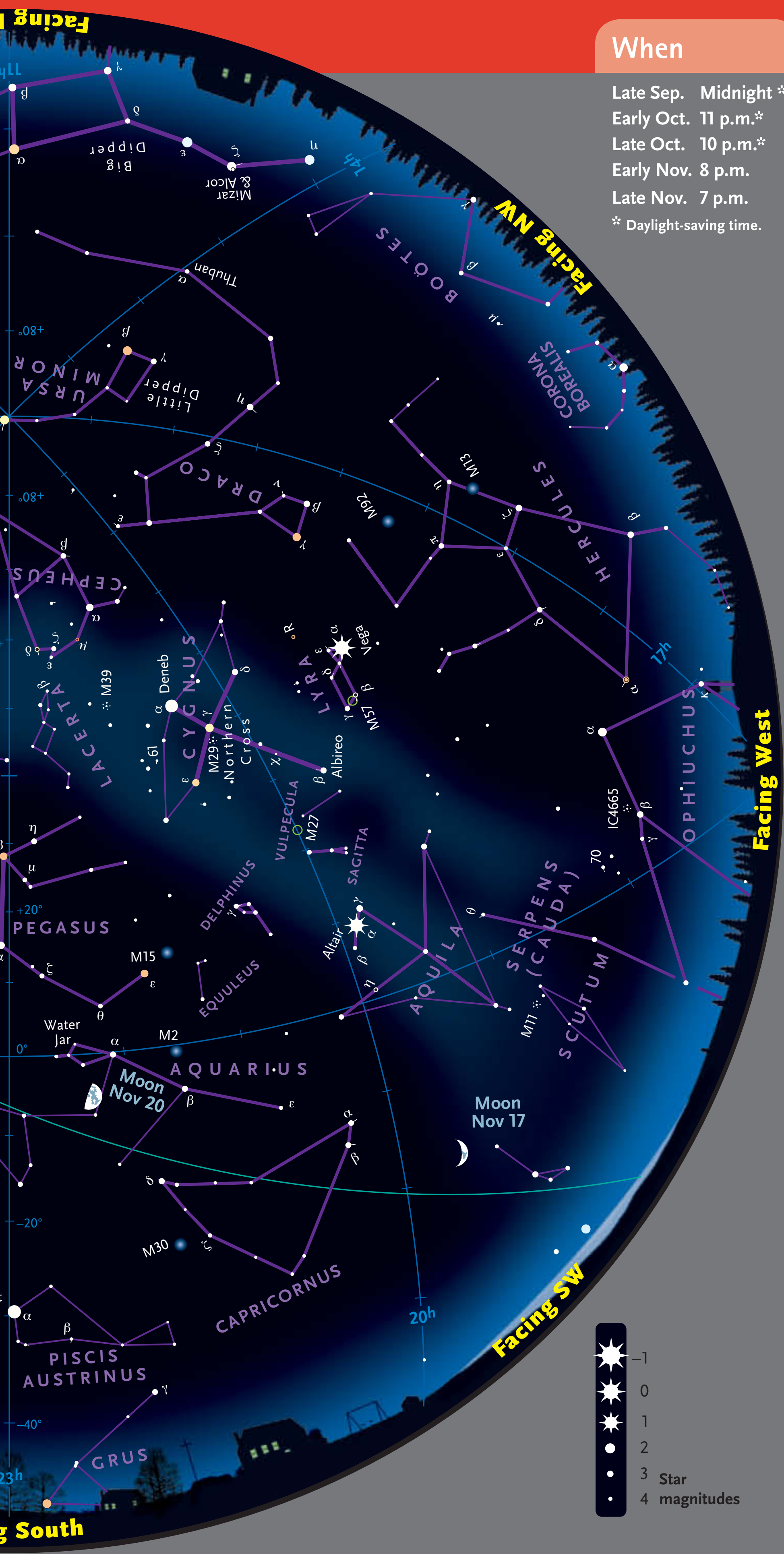
| SUN | MON | TUE | WED | THU | FRI | SAT |
|---|---|---|---|---|---|---|
| | | | | 1 | 2 | 3 |
| 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| 25 | 26 | 27 | 28 | 29 | 30 | |

## Using the Map

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

EXACT FOR LATITUDE 40° NORTH.






## When

| | |
|---|---|
| Late Sep. | Midnight* |
| Early Oct. | 11 p.m.* |
| Late Oct. | 10 p.m.* |
| Early Nov. | 8 p.m. |
| Late Nov. | 7 p.m. |

* Daylight-saving time.

Gary Seronik

Binocular Highlight

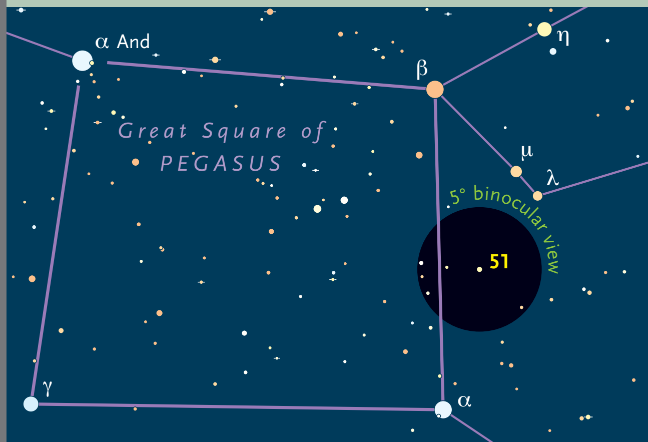
# Revisiting 51 Pegasi

**Binocular highlights** generally come in two varieties. First there are objects that are interesting for what they look like; second there are objects that are interesting for what they *are*. This month's highlight definitely falls into the latter category. In binoculars, **51 Pegasi** is a nondescript 5.5-magnitude point of light situated in an unremarkable field in western Pegasus. Yet it's worth visiting because it's one of the most historically significant stars in the sky.

Among astronomy's greatest quests is the search for new planetary systems. There's something about the idea that excites the imagination — perhaps it was all that *Star Trek* we watched as kids. But before you can seriously contemplate the possibility of "new life and new civilizations," you have to find the "strange new worlds" such creatures might call home. In 1992 radio astronomers Alex Wolszczan and Dale Frail detected the first exoplanets, which orbit a pulsar. Three years later, Swiss astronomers Michel Mayor and Didier Queloz struck cosmic gold when they discovered the first planet orbiting another Sun-like star. That star is 51 Pegasi. In spite of the star's similarities to our Sun, its planet is distinctly unlike Earth. It's a massive world that orbits at the breakneck speed of one revolution every 4¼ days!

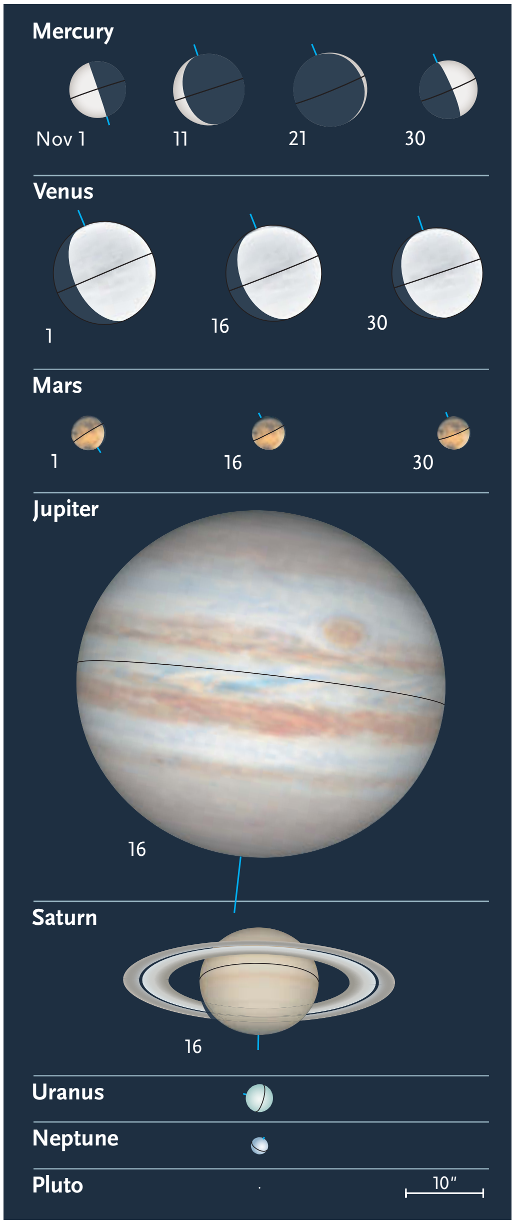
To locate 51 Pegasi, sweep midway and slightly west of a line drawn from Alpha (α) to Beta (β) Pegasi. The star also completes a tilted right triangle with Mu (μ) and Lambda (λ) Pegasi. Given that the exoplanet tally now exceeds 600 systems, the excitement over 51 Pegasi has understandably faded. But take a moment to locate this distant Sun with your binoculars and appreciate it for its impact on modern astronomy and our exploration of the universe beyond our own celestial backyard. ✦

— ***Gary Seronik***




## Watch a SPECIAL VIDEO

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

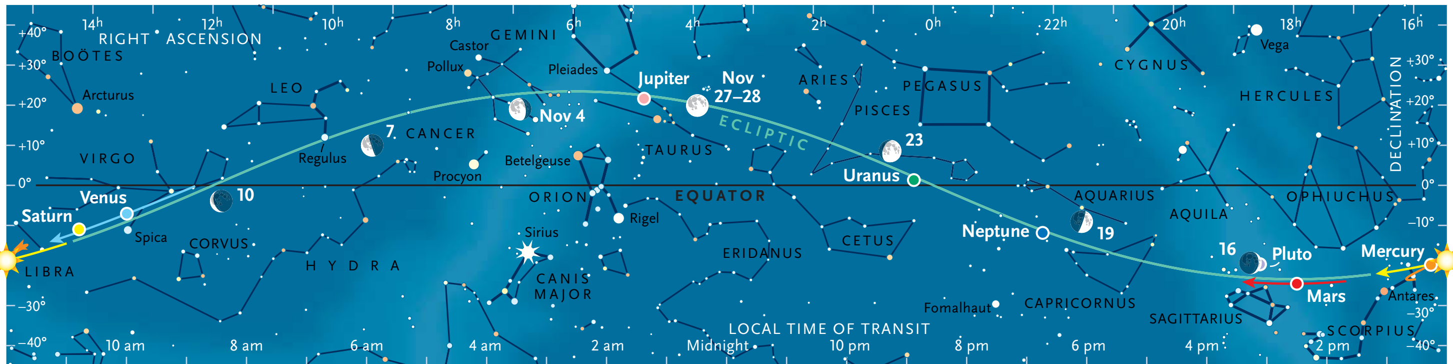



## Sun and Planets, November 2012

| | May | Right Ascension | Declination | Elongation | Magnitude | Diameter | Illumination | Distance |
|---|---|---|---|---|---|---|---|---|
| Sun | 1 | $14^h\ 25.6^m$ | –14° 26′ | — | –26.8 | 32′ 14″ | — | 0.992 |
| | 30 | $16^h\ 25.0^m$ | –21° 38′ | — | –26.8 | 32′ 26″ | — | 0.986 |
| Mercury | 1 | $15^h\ 56.8^m$ | –23° 24′ | 23° Ev | –0.1 | 7.3″ | 51% | 0.915 |
| | 11 | $16^h\ 01.8^m$ | –22° 23′ | 14° Ev | +1.5 | 9.3″ | 15% | 0.726 |
| | 21 | $15^h\ 17.2^m$ | –16° 41′ | 8° Mo | +3.2 | 9.6″ | 5% | 0.702 |
| | 30 | $15^h\ 08.2^m$ | –14° 55′ | 19° Mo | –0.3 | 7.6″ | 44% | 0.888 |
| Venus | 1 | $12^h\ 17.2^m$ | –0° 08′ | 35° Mo | –4.0 | 13.3″ | 81% | 1.257 |
| | 11 | $13^h\ 02.5^m$ | –4° 45′ | 33° Mo | –4.0 | 12.7″ | 83% | 1.314 |
| | 21 | $13^h\ 48.6^m$ | –9° 17′ | 30° Mo | –3.9 | 12.2″ | 86% | 1.368 |
| | 30 | $14^h\ 31.2^m$ | –13° 06′ | 28° Mo | –3.9 | 11.8″ | 88% | 1.414 |
| Mars | 1 | $17^h\ 06.5^m$ | –23° 55′ | 39° Ev | +1.2 | 4.6″ | 95% | 2.056 |
| | 16 | $17^h\ 55.5^m$ | –24° 33′ | 35° Ev | +1.2 | 4.4″ | 96% | 2.103 |
| | 30 | $18^h\ 42.3^m$ | –24° 14′ | 32° Ev | +1.2 | 4.4″ | 96% | 2.143 |
| Jupiter | 1 | $4^h\ 55.1^m$ | +21° 46′ | 144° Mo | –2.7 | 46.8″ | 100% | 4.209 |
| | 30 | $4^h\ 40.4^m$ | +21° 22′ | 176° Mo | –2.8 | 48.4″ | 100% | 4.069 |
| Saturn | 1 | $14^h\ 06.1^m$ | –10° 24′ | 6° Mo | +0.6 | 15.4″ | 100% | 10.762 |
| | 30 | $14^h\ 19.1^m$ | –11° 30′ | 32° Mo | +0.7 | 15.7″ | 100% | 10.609 |
| Uranus | 16 | $0^h\ 18.6^m$ | +1° 13′ | 131° Ev | +5.8 | 3.6″ | 100% | 19.399 |
| Neptune | 16 | $22^h\ 09.9^m$ | –11° 59′ | 96° Ev | +7.9 | 2.3″ | 100% | 29.867 |
| Pluto | 16 | $18^h\ 32.4^m$ | –19° 48′ | 44° Ev | +14.1 | 0.1″ | 100% | 33.039 |

**The table above** gives each object's right ascension and declination (equinox 2000.0) at 0h Universal Time on selected dates, and its elongation from the Sun in the morning (Mo) or evening (Ev) sky. Next are the visual magnitude and equatorial diameter. (Saturn's ring extent is 2.27 times its equatorial diameter.) Last are the percentage of a planet's disk illuminated by the Sun and the distance from Earth in astronomical units. (Based on the mean Earth–Sun distance, 1 a.u. is 149,597,871 kilometers, or 92,955,807 international miles.) For other dates, see SkyandTelescope.com/almanac.

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




**The Sun and planets** are positioned for mid-November; 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 Marriage of Earth and Sky

## Mundane and celestial objects enrich each other where they mingle.

**In last month's column**, I began to discuss why trees and buildings that partly block our sky have some virtues that we should appreciate. I noted that we can benefit from having the lower, more light-polluted parts of our sky shielded from view.

There are, however, even more profound reasons to appreciate trees, buildings, and mountains that hide parts of the sky from us.

**Connecting sky and earth.** If you most often observe from a site where you live, you may already connect certain trees or buildings with important stars and constellations that come up or go down behind them. When I was a child I first learned the bright star Arcturus from its rising at the tip-top of a particular tree. When my father had to cut down the tree, it was a real loss. Even today, 50 years later, the Arcturus Tree stands in my memory, invisibly greeting the great glad star of spring when it returns to the evening sky.

Particularizing parts of the landscape with the positions of stars and constellations isn't just sentimental, it can also be very useful. Waiting for specific objects to appear above a building, or emerge into certain breaks between the trees, can help organize and focus our efforts. When, on a November evening, does low Fomalhaut or the beautiful spiral galaxy NGC 253 appear over or between the trees to your south? A forest can help you plan your observing schedule.

Perhaps you desire complete freedom to observe what you want, when you want. But both visually and photographically, sights of the stars can be more interesting when they're framed by objects in the landscape. Back in March I was struck by how relatively uninteresting many photos of the Venus-Jupiter conjunction were. The exciting and beautiful ones were mostly those where the planets hung near trees or buildings, linking them to our landscape and lives.

The classic *Burnham's Celestial Handbook* includes many photos of stars and star clusters over a tree or even among its branches. The Pleiades cluster is a beautiful adornment at our current time of year. There's a magic about having this cluster growing like fruit on a tree in your yard or elsewhere. The experience connects you with those stars closely and personally.

Stars among the bare branches of trees at this time of year are especially wonderful. The 20th-century naturalist Edwin Way Teale, a good friend of the famed amateur astronomer Leslie Peltier, wrote a book titled *A Walk Through the Year*. In his entry for November 30th, Teale states: "The glory of the autumn leaves is gone. But now, through the months of winter, we will have trees filled with stars."


French astrophotographer Laurent Laveder captured the March 12, 2012, conjunction of Jupiter (left) and Venus over a pair of twin trees.

**Twigs and galaxies.** In his cover essay to the *Astronomical Calendar 1976*, Guy Ottewell wrote: "You wake at night, perhaps camping in a wood near a shore, with a rent of sky above; what time is it? It is the *Andromeda Hour*." That's close to the time our all-sky map is drawn for, with the Andromeda group of constellations high. Ottewell writes that at our imagined camping spot, it happens that these constellations "have all at this moment moved into the interstices between the boughs." His conclusion? "Such miraculous moments, when human pattern-making for a moment fuses with the pattern-making of inert matter in its twigs and galaxies, do happen, if you lie out often enough under the stars." ✦

# The Planets of Love and Time

Venus pairs spectacularly with Saturn in the morning sky.

**Earth's first total** solar eclipse in almost 2½ years occurs on November 13–14, and there's a large penumbral lunar eclipse on November 28th (see page 52).

Mars lingers low in the southwest at dusk in November, as it has all fall. Regal Jupiter rises increasingly early in evening twilight as it nears opposition. Venus comes up well before dawn and passes Spica in mid-November. Saturn lifts out of the sunrise glow as the month progresses and meets Venus for a beautiful, very close conjunction on November 26th and 27th. And on the final mornings of the month, rapidly brightening Mercury becomes visible below them.

## DUSK

**Mars** continues to appear a little more than 10° high in the southwest 45 minutes after sunset for viewers around 40° north latitude. It shines at only magnitude +1.2 and appears only 4½″ wide in telescopes. Binoculars show the big Teapot of Sagittarius left of Mars for much of November, then setting below it by month's end. On November 18th, a telescope might show M8, the Lagoon Nebula, very near Mars extremely low in the sky 60 to 90 minutes after sunset.

## EVENING AND NIGHT

**Jupiter** rises about two hours after sunset on November 1st, but by month's end it's already glaring in the east as twilight fades. It's quite high by mid- to late evening all month long.

Jupiter is the only bright planet above the horizon for most of the night, so we have to rely on it for our planetary thrills — and the giant world does not disappoint. Its brightness increases to magnitude –2.8 and its angular diameter to 48″ as it approaches opposition to the Sun on the American evening of December 2nd.

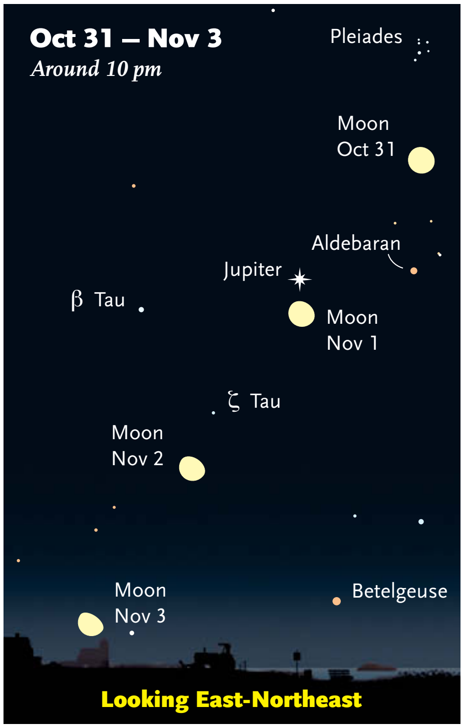
Jupiter is moving retrograde (westward with respect to the stars) toward Aldebaran and the Hyades. Its distance from Aldebaran decreases from about 7° to 5° during November.

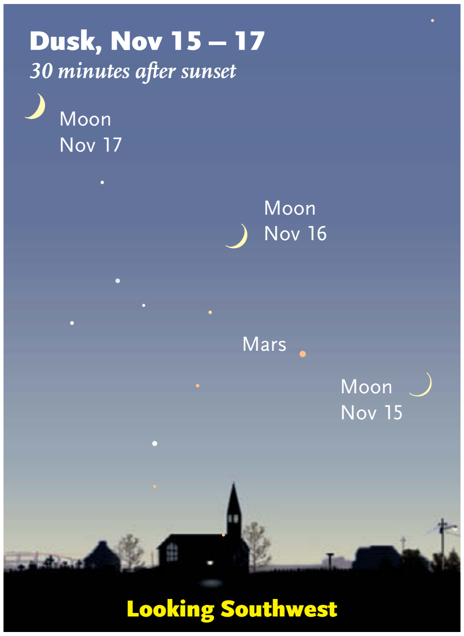
**Neptune,** the eighth planet, is highest in the south as evening twilight fades, and **Uranus** is highest around 8 or 9 p.m. standard time. For finder charts, see **skypub.com/urnep** or page 50 of the September 2012 issue.

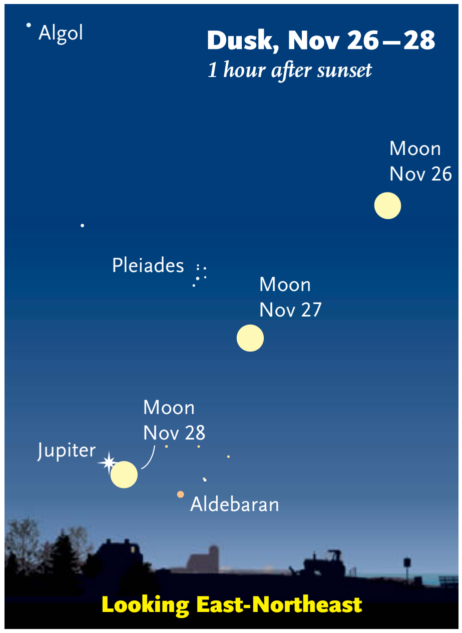
**Pluto** remains observable at nightfall in the Southern Hemisphere, but it's too low for northern observers.

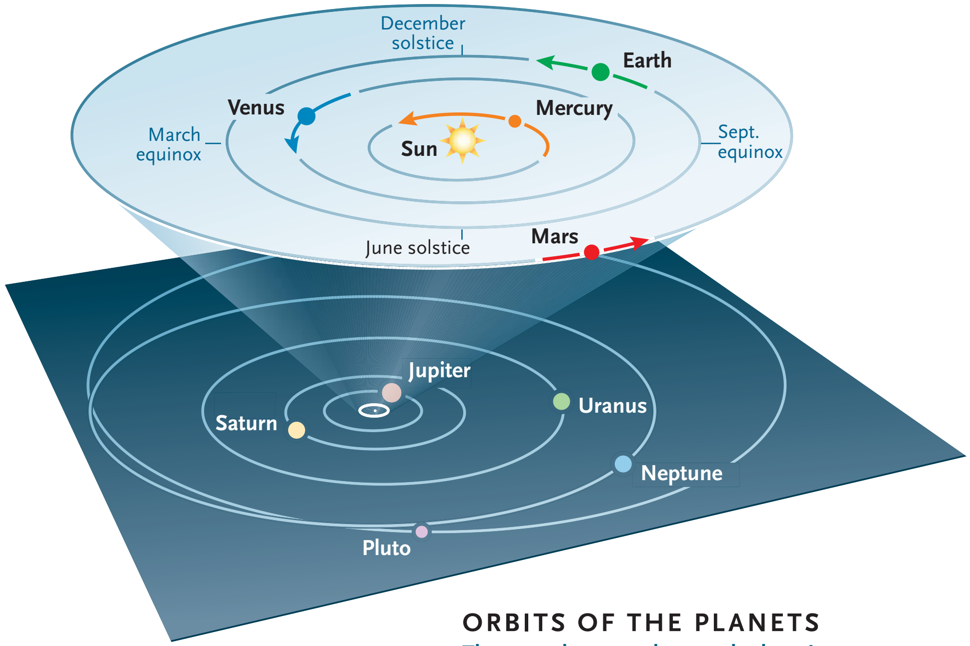
## PREDAWN AND DAWN

**Venus** rises about 3 hours before the Sun as November opens, but only 2½ hours as the month closes. Its altitude 45 minutes before sunrise drops from roughly 25° to 17° during November. Venus also dims to –3.9 (still spectacularly bright) and shrinks to less than 12″ wide — almost its minimum values for both.






**ORBITS OF THE PLANETS**
**The curved arrows show each planet's movement during November. The outer planets don't change position enough in a month to notice at this scale.**

Venus begins November a big 20° upper right of 1.0-magnitude Spica as that star rises in bright morning twilight. But each morning Spica appears higher and Venus lower, and on November 17th Venus passes less than 4° to Spica's upper left. That's not very close. But Venus has one more glorious trick to play this year: an excitingly close conjunction with one of its fellow planets.

**Saturn** is the planet that pairs with Venus this month. At the start of November Saturn rises in bright dawn, visible only in binoculars. But by the 15th it's in good view above the east-southeast horizon an hour before sunrise.

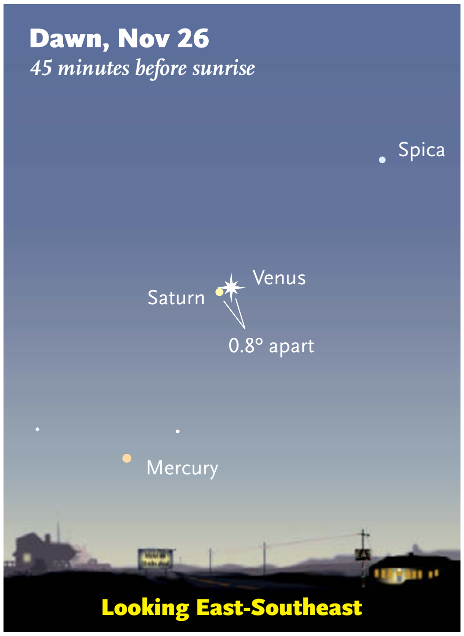
Saturn and Venus are within 4° of each other November 23–30, and they're less than 1° apart at dawn in the Americas on November 26th and 27th. Those two mornings, many telescopes will show Venus's dazzling, slightly out-of-round disk in the same field as Saturn's slightly larger (15½″) but vastly dimmer (magnitude +0.7) globe. Saturn's rings span 35″, and they have opened to appear 18° from edgewise, their most tilted in six years.

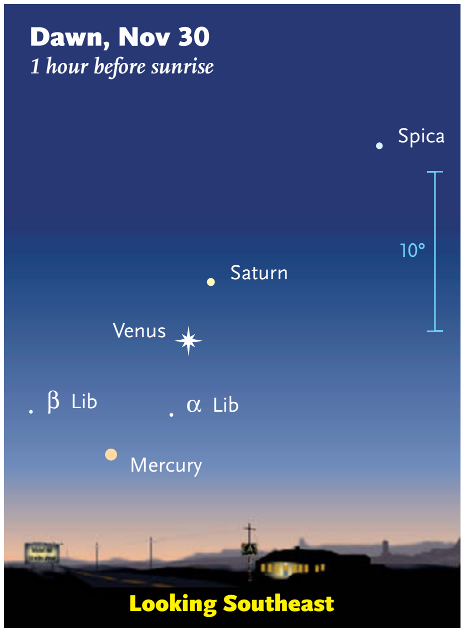
**Mercury** leaps up from inferior conjunction with the Sun on November 17th to rise more than 90 minutes before the Sun by November 27th. It brightens rapidly in the last week of the month, from magnitude +1.6 on November 23rd to –0.3 on November 30th. Look for it far to the lower left of Saturn and Venus.

## MOON PASSAGES

The **Moon** is waning gibbous with brilliant Jupiter just above it on the American evening of November 1st. The waning lunar crescent is right of Venus and Saturn at dawn on November 11th and 12th, respectively. Reappearing in the evening sky, the waxing lunar crescent passes Mars at dusk on the 15th and 16th.

On the evening of November 28th the just-past-full Moon repeats its November 1st alignment with Jupiter, but this time it appears very close to Jupiter's lower right. The Moon occults (hides) Jupiter in much of South America and southern Africa. ✦

# The Moons of Uranus & Neptune

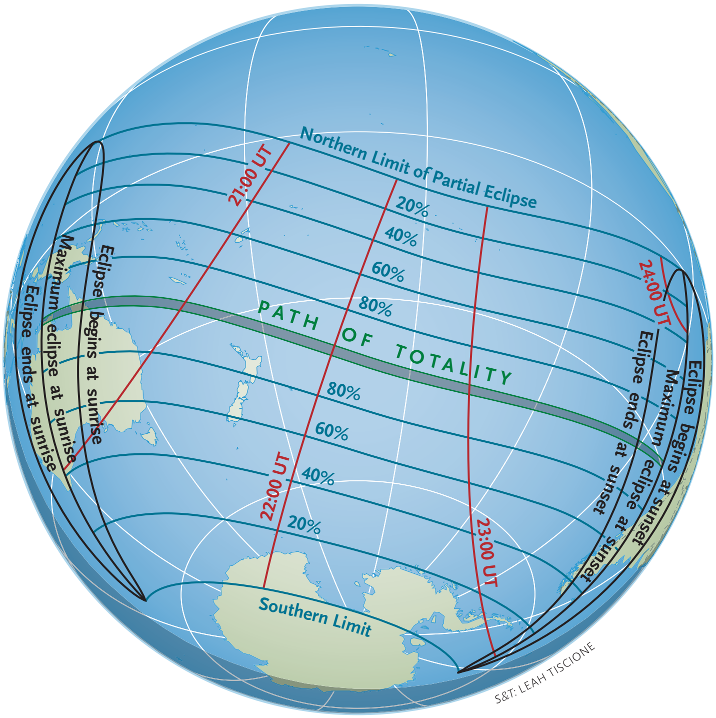
**Uranus and Neptune** are invitingly high in the south these evenings, shining at magnitudes 5.8 and 7.9 in Pisces and Aquarius, respectively. Find them with the charts in the September issue, page 50, or at **skypub.com/urnep.**

Much more challenging are their faint satellites. Triton, Neptune's one big moon, is magnitude 13.5. But if you've ever found Pluto, you'll find Pluto-like Triton more easily. It's higher and slightly brighter, and it never strays more than 17″ from much more easily found Neptune.

The brightest moons of Uranus — Titania, Oberon, and Umbriel — are about a match for Triton, but Uranus's brighter glare make them tougher to see. In all cases, use your highest power.

The trick to finding any faint, difficult target is knowing *exactly* where to look. To print custom finder charts for the date and time when you plan to observe, go to **skypub.com/triton** and **skypub.com/uranusmoons**.

Or for Triton, the least difficult of the batch, you can




## Pacific Solar Eclipse November 13–14

The first total eclipse of the Sun in 2½ years skims northern Australia just after sunrise on November 14th local date, then spends the rest of the day crossing the South Pacific (and the International Date Line) with no further landfall. A much wider region sees a partial eclipse, including southern Chile at sunset on the 13th local date. Above, red lines indicate the time of deepest eclipse, in UT November 13th. The blue lines tell the maximum percentage of the Sun's diameter covered.

# Penumbral Lunar Eclipse

**On the morning of November 28th**, skywatchers in western North America can watch the full Moon skim through the pale outer fringe — the *penumbra* — of Earth's shadow.

The effect will be fairly subtle. The Moon will miss the shadow's dark umbra completely: by a fifth of a lunar diameter.

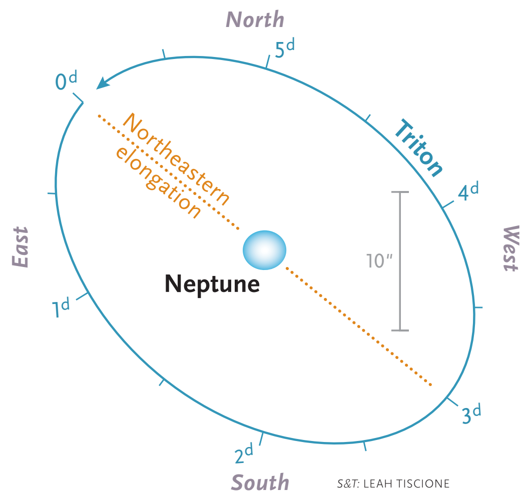
You might begin to detect the pale penumbral shading on the Moon's upper (celestial north-northeastern) edge as early as 5:45 a.m. Pacific Standard Time (13:45 UT), when morning twilight will already be underway for most of the West Coast and the Moon will be sinking low in the west-northwestern sky (with Jupiter above it). The Moon will pass deepest through the penumbra at 6:33 a.m. PST, when the shading will be more obvious. But by then twilight will be brighter and the Moon lower, and for Southern California it will already be around moonset and sunrise.

The event takes place high in the dark middle of the night (of November 28–29) for Australia and Japan, in late evening of the 28th local date for China and Southeast Asia, and early that evening for India with the rising Moon still low in the east.

use the diagram at right with a calculator as follows. Convert the time and date you'll observe into a decimal date in Universal Time (for example, 12:00 UT November 9th is "November 9.50"). Next, find how long this has been, in days, since the most recent of these dates of Triton's northeastern elongation: September 24.42, October 6.18, November 4.58, December 3.96.

Divide this difference by 5.877 (Triton's orbital period in days). Drop anything left of the decimal point. Multiply the remainder by 5.877. The result tells how many days (*d*) Triton has moved counterclockwise along its orbit since northeastern elongation.

For instance, at 5:30 UT October 20th, Triton turns out to be 2.3 days past northeastern elongation — putting it south-southwest of the planet.



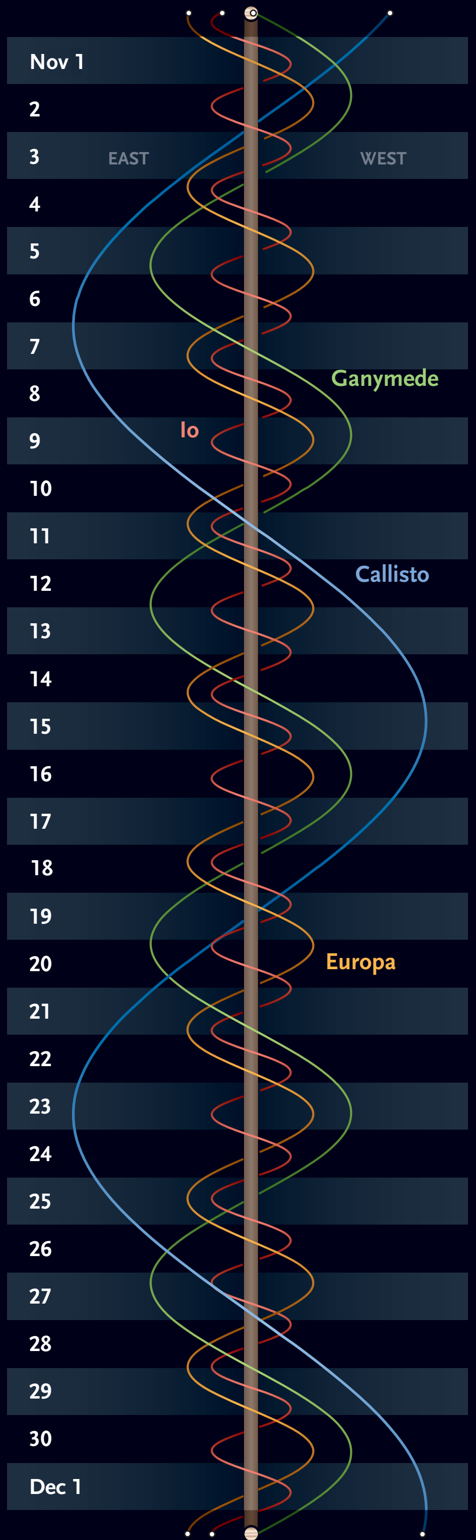

S&T: LEAH TISCIONE

## Phenomena of Jupiter's Moons, November 2012

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

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

## Jupiter's Moons




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

# Action at Jupiter

**Jupiter in November** climbs to an excellent high view by late evening, shining in Taurus near Aldebaran as it nears its December 2nd opposition.

Even the smallest telescope shows Jupiter's four big Galilean moons. Binoculars usually reveal at least two or three of them. Identify them with the diagram at left. Or you can see the moons' precise positions at any time using **skypub.com/jupsats**.

Listed on the previous page are all of the moons' many interactions with Jupiter's disk and shadow in November, fascinating events to watch in a telescope.

Following are the times, in Universal Time, when Jupiter's Great Red Spot should cross the planet's central meridian: the imaginary line down the center of Jupiter from pole to pole. The dates (also in UT) are in bold. The Red Spot appears closer to Jupiter's central meridian than to the limb for 50 minutes before and after these times:

**October 1,** 4:39, 14:35; **2,** 0:30, 10:26, 20:22; **3,** 6:17, 16:13; **4,** 2:09, 12:04, 22:00; **5,** 7:55, 17:51; **6,** 3:47, 13:42, 23:38; **7,** 9:34, 19:29; **8,** 5:25, 15:21; **9,** 1:16, 11:12, 21:07; **10,** 7:03, 16:59; **11,** 2:54, 12:50, 22:45; **12,** 8:41, 18:37; **13,** 4:32, 14:28; **14,** 0:24, 10:19, 20:15; **15,** 6:10, 16:06; **16,** 2:02, 11:57, 21:53; **17,** 7:48, 17:44; **18,** 3:40, 13:35, 23:31; **19,** 9:26, 19:22; **20,** 5:18, 15:13; **21,** 1:09, 11:04, 21:00; **22,** 6:56, 16:51; **23,** 2:47, 12:42, 22:38; **24,** 8:34, 18:29; **25,** 4:25, 14:20; **26,** 0:16, 10:12, 20:07; **27,** 6:03, 15:58; **28,** 1:54, 11:50, 21:45; **29,** 7:41, 17:36; **30,** 3:32, 13:28, 23:23; **31,** 9:19, 19:14.

**November 1,** 5:10, 15:05; **2,** 1:01, 10:57, 20:52; **3,** 6:48, 16:43; **4,** 2:39, 12:35, 22:30; **5,** 8:26, 18:21; **6,** 4:17, 14:12; **7,** 0:08, 10:04, 19:59; **8,** 5:55, 15:50; **9,** 1:46, 11:42, 21:37; **10,** 7:33, 17:28; **11,** 3:24, 13:19, 23:15; **12,** 9:11, 19:06; **13,** 5:02, 14:57; **14,** 0:53, 10:48, 20:44; **15,** 6:40, 16:35; **16,** 2:31, 12:26, 22:22; **17,** 8:17, 18:13; **18,** 4:09, 14:04; **19,** 0:00, 9:55, 19:51; **20,** 5:47, 15:42; **21,** 1:38, 11:33, 21:29; **22,** 7:24, 17:20; **23,** 3:16, 13:11, 23:07; **24,** 9:02, 18:58; **25,** 4:53, 14:49; **26,** 0:45, 10:40, 20:36; **27,** 6:31, 16:27; **28,** 2:23, 12:18, 22:14; **29,** 8:09, 18:05; **30,** 4:00, 13:56, 23:52.

To get Eastern Daylight Time from UT, subtract 4 hours; for Pacific Daylight Time subtract 7. After standard time returns (on the morning of November 4th for North America), the corrections are EST = UT – 5 and PST = UT – 8.

The times listed assume that the spot is centered at System II longitude 184°. If it's elsewhere, it will transit 1⅔ minutes late for every 1° of longitude greater than 184°, or 1⅔ minutes early for every 1° less than 184°.

Markings on Jupiter appear a little more contrasty through a blue or green eyepiece filter. The larger your scope, the darker the blue or green can be; you want enough light to see fine details clearly, so for small apertures that means light tints.

Try several magnifications to find one that shows the most given the current seeing. Too high a power and you'll lose things in the overmagnified blurring.

And keep looking! More and more flickers of features come out with protracted scrutiny. ✦

## Minima of Algol

| Oct. | UT | Nov. | UT |
|---|---|---|---|
| 1 | 9:55 | 1 | 22:51 |
| 4 | 6:43 | 4 | 19:40 |
| 7 | 3:32 | 7 | 16:29 |
| 10 | 0:21 | 10 | 13:18 |
| 12 | 21:10 | 13 | 10:07 |
| 15 | 17:58 | 16 | 6:56 |
| 18 | 14:47 | 19 | 3:45 |
| 21 | 11:36 | 22 | 0:34 |
| 24 | 8:25 | 24 | 21:23 |
| 27 | 5:14 | 27 | 18:12 |
| 30 | 2:03 | 30 | 15:01 |

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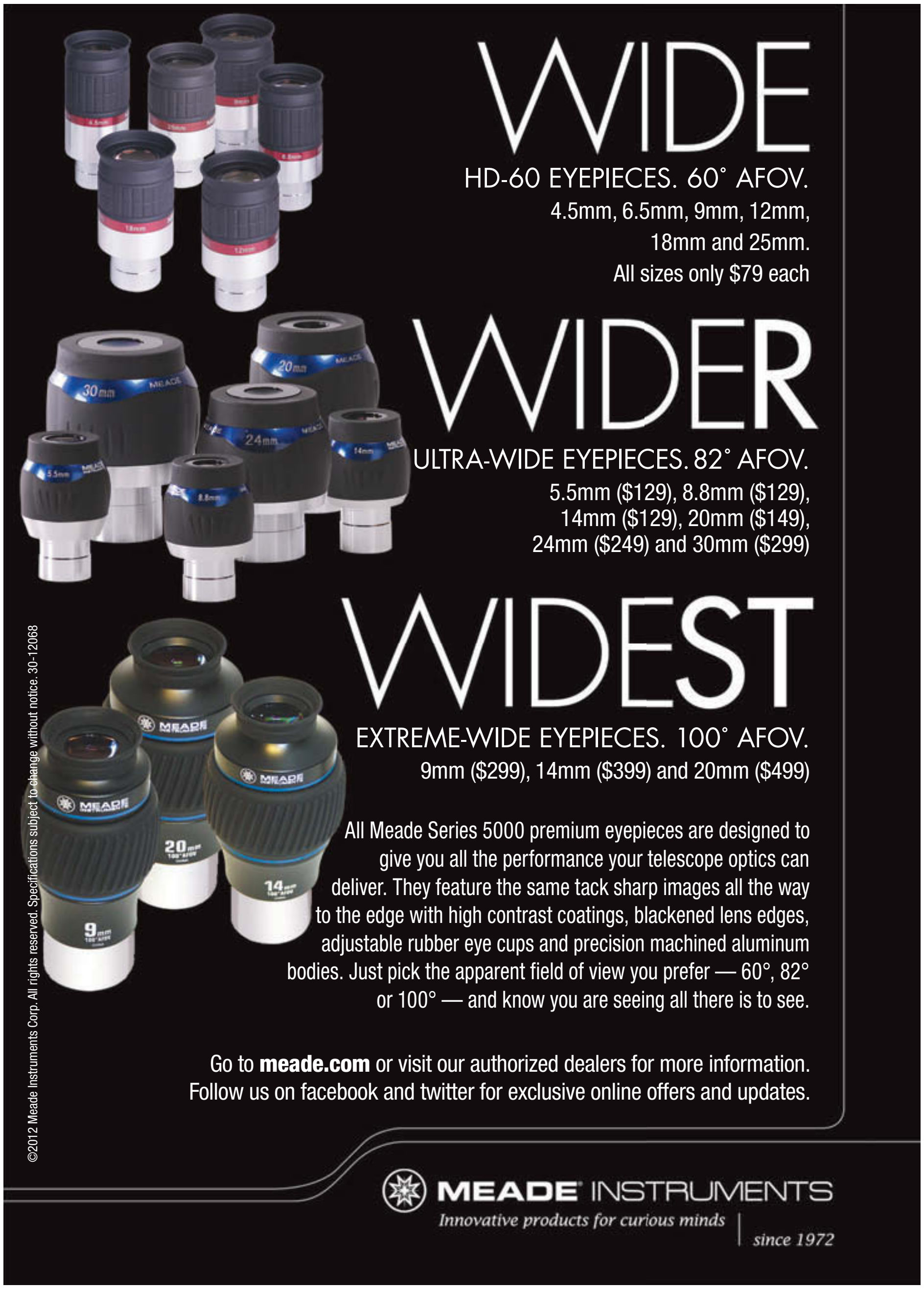
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# Turmoil on Jupiter

## The King of the Planets reappears with chaos in its northern hemisphere.

**As you aim** your telescope at Jupiter this fall, you'll immediately notice that the planet appears markedly different than it has in years past. Great climatic upheavals are currently restoring two of the most prominent dark belts, accompanied by the first widespread episode of reddening in more than 20 years.

Historically, Jupiter has periodically undergone large-scale disturbances, including belt revivals, jet-stream outbreaks, and coloration events. These disturbances tend to come together. For example, the revival of a major dark belt, after it has faded and narrowed, often occurs alongside unusually vigorous activity in an adjacent jet stream. This revival is sometimes then followed by a reddish coloration outbreak in the belt that can spread to other regions. Scientists still don't understand the reasons why these phenomena are linked.

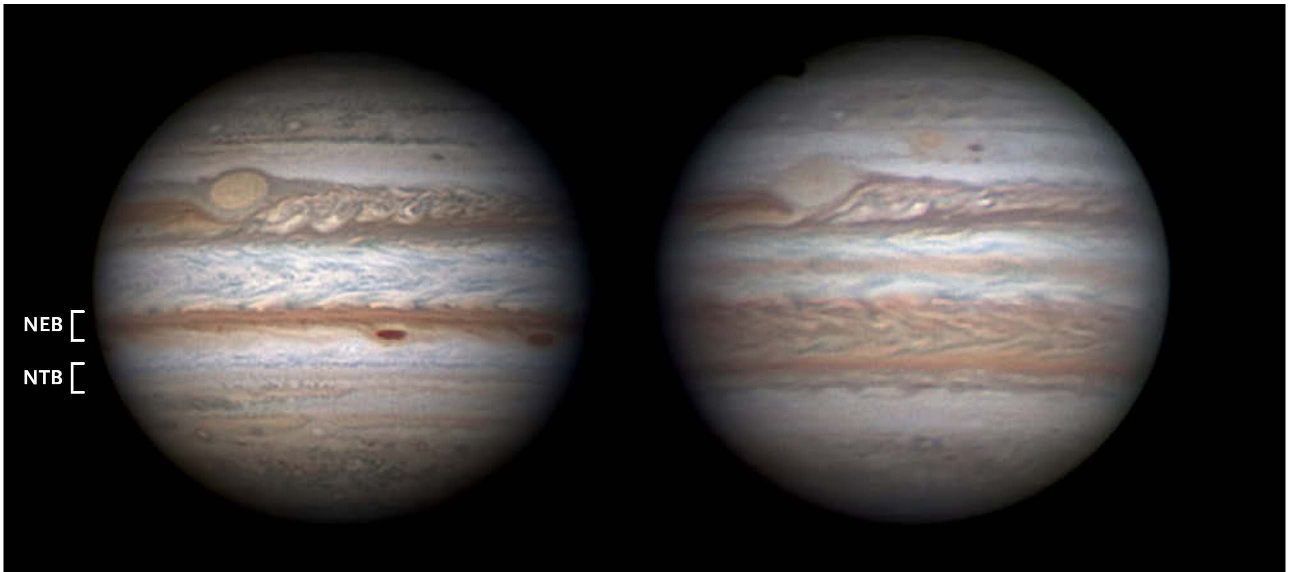
But since the great global upheaval of 1990-91, there was only one isolated belt revival until 2007. In that year imagers recorded energetic revivals of the South Equatorial Belt (SEB) and the North Temperate Belt (NTB). In 2010 observers caught an even more vigorous revival of the SEB in revelatory detail (*S&T:* September 2010, page 50). Still, contemporary observers have not yet seen all the variety that the King of the Planets can display.

This year we finally have our chance. Another NTB resurgence and major coloration event began this April, which was paired with the first revival in nearly a century of the neighboring North Equatorial Belt (NEB).

An NTB revival is typically initiated by a brilliant plume erupting in the adjacent super-fast jet stream. When NASA's New Horizons spacecraft passed Jupiter in 2007 on its way to Pluto, it found that the NTB jet stream was blowing with the maximum wind speed that Jupiter ever sustains. That uptick in speed presaged the 2007 disturbance, which started shortly after the New Horizons flyby.

Hints of an imminent disturbance again appeared when Grischa Hahn of the JUPOS project (**http://jupos.privat.t-online.de/index.htm**) found that the jet stream had regained the same impressive speed from his analysis of amateur images taken through 2010. Based upon the pattern noted in previous eras, astronomers suspected that an NTB outbreak would soon follow, possibly five years after the 2007 one.

Last April 19th, only a week before Jupiter disappeared into the evening twilight, Greek observer Manos Kardasis captured an image in which he identified the brilliant white spot and dark streak that typically initiate such out-




CHRISTOPHER GO (2)

**Comparing these images taken December 14, 2011 (left), and July 15, 2012 (right), reveals big changes on Jupiter. The North Equatorial Belt (NEB) greatly expanded and the North Temperate Belt (NTB) experienced a resurgence. South is up in both images.**

*John H. Rogers is director of the British Astronomical Association's Jupiter section (http://britastro.org/baa).*

John H. Rogers

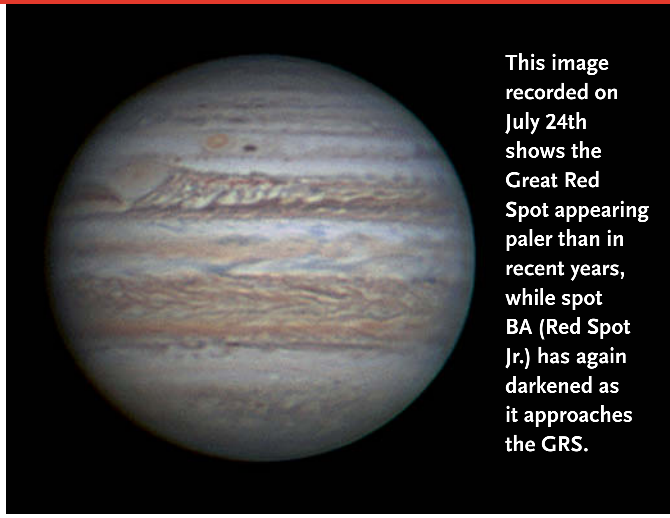
breaks. Two days later, Italian observer Gianluigi Adamoli also managed to detect these features and confirmed their rapid drift rate. The planet then became unobservable as it passed behind the Sun.

As the planet re-emerged in the morning sky following solar conjunction, the NTB's impressively dark orange appearance and the chaotic disturbance surrounding it left no doubt that the predicted outbreak had indeed begun.

Meanwhile, the adjacent NEB had also been fading and narrowing, to an extent unseen in living memory. The usual large, dark "projections" on its equatorial edge had disappeared, and the smaller, remaining projections were all moving with an unprecedentedly rapid speed. All these changes suggested that the belt had reverted to a state similar to that depicted in drawings from more than a century ago, when the NEB often lacked large features and underwent cyclic narrowing and broadening every three years, up to 1915. (There was a final, isolated revival in 1926.)

On March 18th of this year, Wayne Jaeschke in Pennsylvania noticed a new outbreak in the NEB (which had actually begun 10 days earlier) consisting of a bright streak of convective clouds with two very dark bluish spots on the south edge. This disturbance persisted over the next month. It evidently continued developing throughout solar conjunction, too, because when the planet reappeared in June the NEB was in an amazingly turbulent state, with dark formations spread all around its southern edge.

Let's hope that Jupiter will continue to display its complex turbulence, which spans the entire region stretching from the newly revived NTB to the equatorial zone. The "icing on the cake" is the dull reddish color that has



This image recorded on July 24th shows the Great Red Spot appearing paler than in recent years, while spot BA (Red Spot Jr.) has again darkened as it approaches the GRS.

DAVID TYLER

spread all over this disturbed region, including over what is usually a white zone. Similar reddish coloring has also appeared in a band along the equator. This is the first chance that we've had to observe the reddening and belt revival process with modern imaging equipment, so seize this opportunity while we have it.

Observers can now follow these disturbances to their completion over the coming months and be on watch for whatever happens next. In some eras, NTB outbreaks have recurred at 5-year intervals, with NEB revivals recurring at 3-year intervals, so we could see these disturbances again with the same periodicities. On the other hand, outbreaks can also occur in isolation or even cease for decades, so we can never predict future Jupiter events with any certainty. Whatever happens, it will be fascinating to watch and to study. ✦

## The Moon • November 2012

### Phases

| | | | |
|---|---|---|---|
| November 7 | November 13 | November 20 | November 28 |
| **LAST QTR MOON** | **NEW MOON** | **FIRST QTR MOON** | **FULL MOON** |
| 0:36 UT | 22:08 UT | 14:31 UT | 14:46 UT |

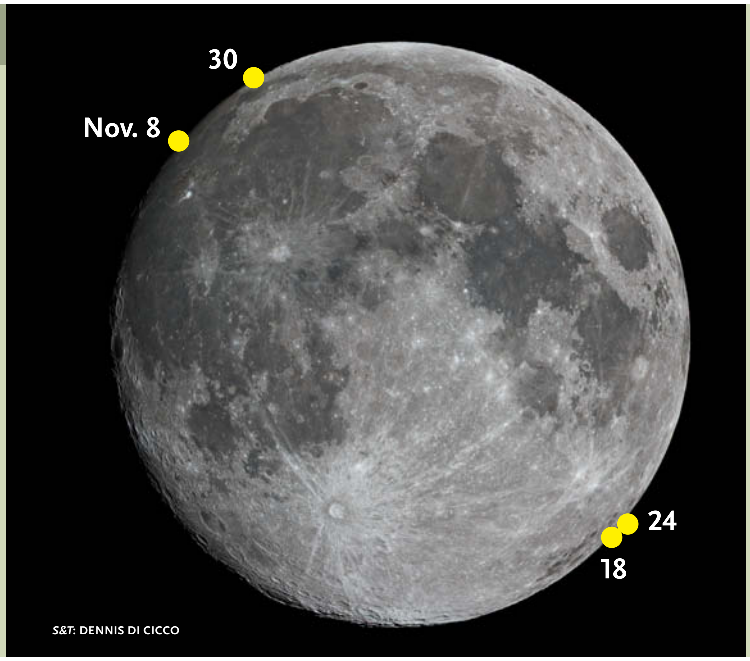
### Distances

| | |
|---|---|
| **Apogee** 253,017 miles | **Nov. 1, 15ʰ UT** diam. 29′ 21″ |
| **Perigee** 223,670 miles | **Nov. 14, 10ʰ UT** diam. 33′ 33″ |
| **Apogee** 253,360 miles | **Nov. 28, 20ʰ UT** diam. 29′ 19″ |

### Librations

| | |
|---|---|
| Galvani (crater) | Nov. 8 |
| Jenner (crater) | Nov. 18 |
| Mare Australe | Nov. 24 |
| Xenophanes (crater) | Nov. 30 |

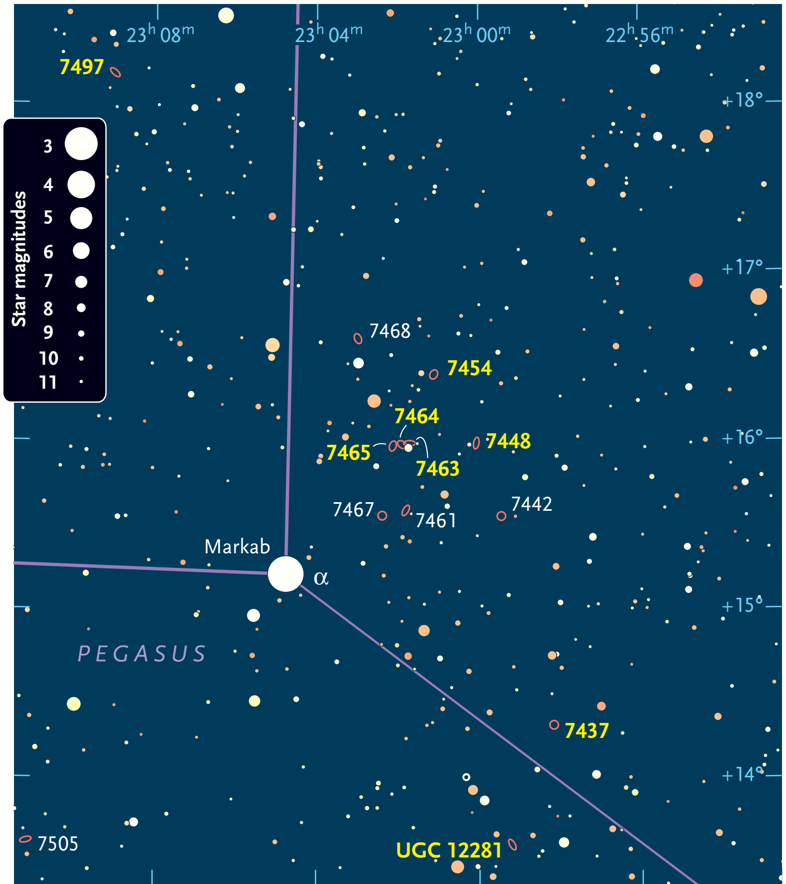
For key dates, yellow dots indicate which part of the Moon's limb is tipped the most toward Earth by libration under favorable illumination.




S&T: DENNIS DI CICCO

# By Telescopic Glass

The southwest corner of the Great Square hosts a fascinating variety of galaxies.




## Galaxies near the Southwest Corner of the Great Square of Pegasus

| Object | Mag(v) | SB | Size | RA | Dec. |
|---|---|---|---|---|---|
| NGC 7497 | 12.2 | 13.9 | 4.9′ × 1.1′ | $23^h$ $09.1^m$ | +18° 11′ |
| NGC 7454 | 11.8 | 13.2 | 2.2′ × 1.6′ | $23^h$ $01.1^m$ | +16° 23′ |
| NGC 7465 | 12.6 | 13.9 | 2.2′ × 1.8′ | $23^h$ $02.0^m$ | +15° 58′ |
| NGC 7463 | 13.2 | 13.6 | 2.6′ × 0.6′ | $23^h$ $01.9^m$ | +15° 59′ |
| NGC 7464 | 13.3 | 11.8 | 0.5′ × 0.5′ | $23^h$ $01.9^m$ | +15° 58′ |
| NGC 7448 | 11.7 | 12.8 | 2.7′ × 1.2′ | $23^h$ $00.1^m$ | +15° 59′ |
| NGC 7437 | 13.3 | 14.4 | 1.8′ × 1.8′ | $22^h$ $58.2^m$ | +14° 19′ |
| UGC 12281 | 14.2 | 13.6 | 3.2′ × 0.2′ | $22^h$ $59.2^m$ | +13° 36′ |

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.

*'Tis evening, and night closes all about,*
*The stars in countless numbers coming out,—*
*In countless numbers, clustering all the skies,*
*A joy and wonder unto human eyes.*

*But how can human eye unaided know*
*The countless galaxies of stars that glow*
*In boundless space, unseen, unnamed, unknown,*
*Until by Telescopic glass they're shown:*
*Worlds upon worlds, and still new worlds arise,*
*Tenants of the illimitable skies*

— Richard Tonson Evanson, *Nature and Art, 1868*

**Faint fuzzies** — that's what many observers call the distant galaxies. Sometimes we forget what a marvel it is to behold them, each one a shining metropolis of billions of suns millions of light-years away. Yet a backyard telescope can place thousands of galaxies before our wondering eyes. Many are faint, and folks with large scopes often push their limits by looking for the dimmest ones they can see. But there's no reason the rest of us can't have fun testing our abilities as well.

A nice collection of galaxies with which to while away a night inhabits the sky near Alpha (α) Pegasi, also known as Markab. We'll begin north-northeast of Markab with **NGC 7497**. Markab sits at the base of a 3°-tall Y that it makes with three 6th-magnitude stars. Look for the galaxy halfway along and a little north of an imaginary line connecting the stars that end the Y's tines.

In my 130-mm refractor at 63×, NGC 7497 is a ghostly finger that points northeast to the eastern corner of a triangle of 9th-magnitude stars. The galaxy is more obvious at 117×, though still diaphanous. Its slim profile is about 3¼′ long, and a faint star sits 2.2′ northwest of the galaxy's center. My 10-inch reflector at 166× shows an elongated core with dimmer extensions. At 213× the core looks irregular in brightness, an effect that may be augmented by an extremely faint star on its northeastern end.

NGC 7497 has a total magnitude of 12.2. In other words, the galaxy would shine as brightly as a 12.2-magnitude star if its light were gathered into a single point. But with its light spread out into a 4.9′ × 1.1′ oval, the galaxy's average magnitude per square arcminute, known as surface brightness (SB), is only 13.9. Luckily, the galaxy's inner regions are brighter and therefore easier to see. This is true of most galaxies and explains why their observed sizes are usually smaller than the cataloged values.

Deep, wide-field images of NGC 7497 are spectacular. The galaxy seems to be entangled in a wonderfully complex ribbon of nebulosity. In reality, NGC 7497 is about 60 million light-years away from us, while the shadowy veil resides within our own galaxy. Known as MBM 54, the nebula is a cool, dense cloud of hydrogen molecules with a dash of cosmic dust.

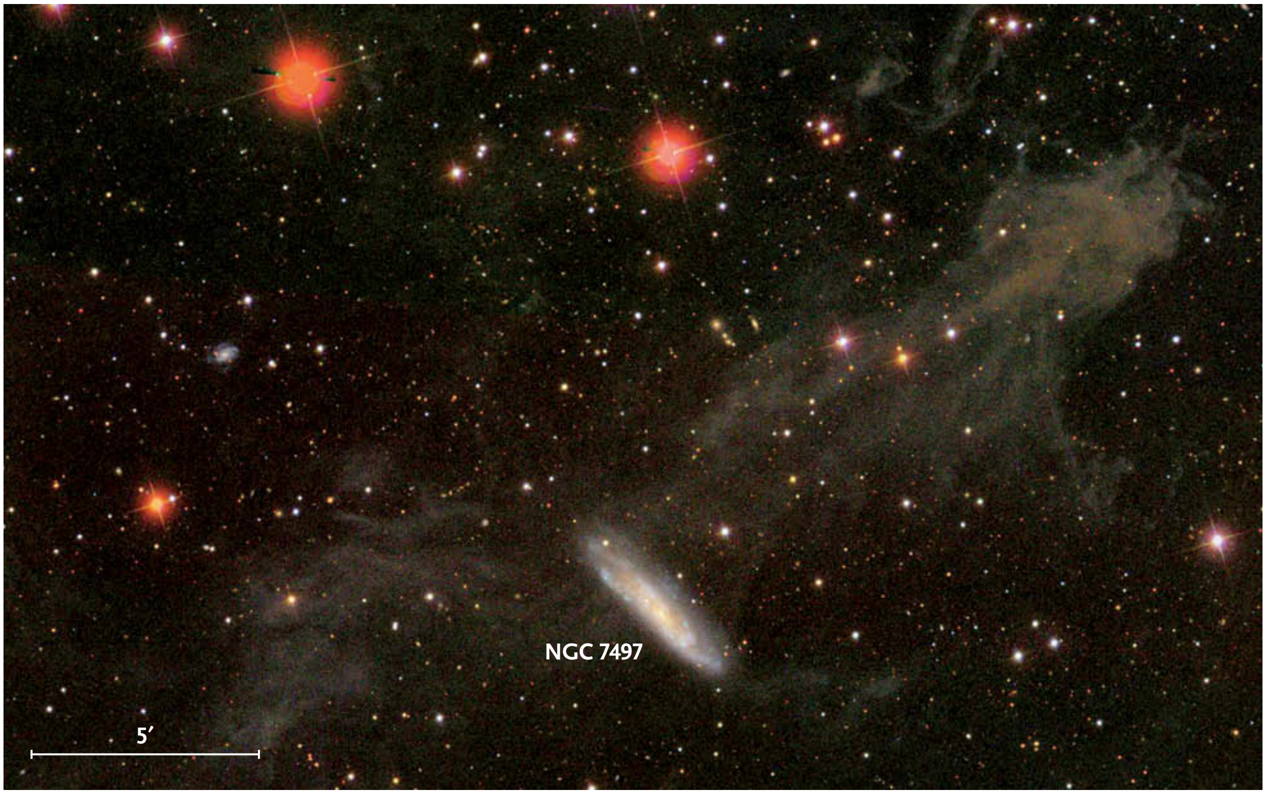
Next we'll visit the NGC 7448 Group, a physically related collection of galaxies roughly 90 million light-years distant. Several of its probable members share the field of view through my 130-mm scope. To locate them, note that Markab marks the bottom of a 1.3°-tall, lopsided kite that it makes with three 6th- and 7th-magnitude stars to the north. The eastern and middle stars at the top of the kite point to **NGC 7454**, the middle and western stars point to the **NGC 7465**, **NGC 7463**, **NGC 7464** galaxy trio, and **NGC 7448** is 27′ due west of the trio. Together, these galaxies anchor the points of a nearly equilateral triangle.

Only three of the galaxies make their appearance at 63×. Leaning a little west of north, NGC 7448 is a fairly bright oval that's twice as long as wide. A 10th-magnitude star lies 2.5′ east. NGC 7454 looks dimmer and could easily be overlooked because of the distracting 11½-magnitude star nudging it from the west-northwest. The galaxy is oval and grows brighter toward the center. A yellow, 9th-magnitude star 4.5′ east helps pinpoint its position. NGC 7465 is just a very faint little smudge 4.1′ east of an 8th-magnitude star.

The galaxies still share the field of view through a wide-angle eyepiece at 117×, but it's a tight fit. NGC 7448 is about 4¾′ long and half as wide, and it grows gradually brighter toward the center. NGC 7454 is 1.1′ long and two-thirds as wide. It brightens toward the center, and a second guard star appears, this one near the north-northwestern tip. NGC 7465 is still small, but more readily visible. The galaxy is slightly elongated north-northwest to south-southeast and harbors a fairly bright, starlike nucleus. Just 2.4′ to the west-northwest, NGC 7463 becomes visible with averted vision as a small faint glow elongated nearly east-west.

I need my 10-inch reflector to glimpse NGC 7464, the final member of the closely knit galaxy trio. At 299× with averted vision, I catch repeated glimpses of a small round spot pressing the southern flank of NGC 7463, but I can't hold the little galaxy steadily in view. NGC 7464 has a rather high surface brightness, but the close proximity of its neighbor and light from the nearby 8th-magnitude star hinder the view.

Although much farther south, **NGC 7437** is also a likely member of the NGC 7448 Group. A finderscope shows a




**This photo of NGC 7497, like all the others in this article, comes from the Sloan Digital Sky Survey. This image was enhanced to show the faint foreground nebulosity better; all the other images are shown as they appeared when downloaded from the SDSS website.**

small, distinctive, slightly curved line of three 8th-magnitude stars southwest of Markab. Through a low-power eyepiece, the middle star is yellow orange, and the arc makes a skinny pizza slice with a 9th-magnitude star to the west-northwest. NGC 7437 is 17′ north-northwest of this star.

Seen with averted vision in my 130-mm scope at 102×, NGC 7437 is an ashen specter that's easier to spot when I slowly sweep my telescope across it. This face-on spiral appears round, and its pallid light makes its size difficult to judge. By comparing the galaxy with the distance between two field stars, I estimated a 1½′ diameter. I get a better measure of 1¼′ with my 10-inch scope at 187×, and the galaxy gains a very small, brighter core.

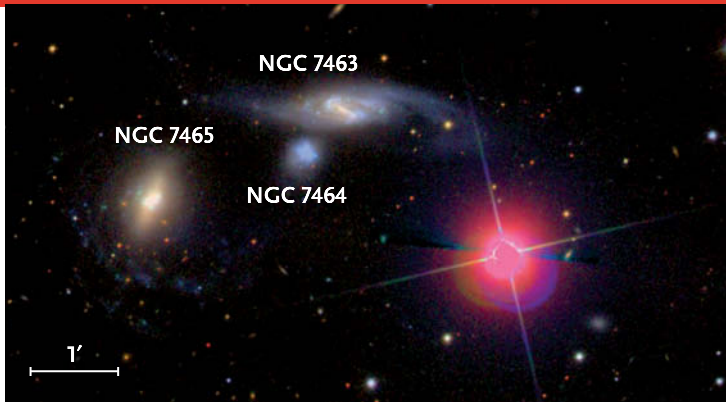
Spiral galaxies tipped to our line of sight have their light bundled into a smaller area than face-on spirals do, so the latter often have low surface brightness. The total magnitude of NGC 7437 is 13.3 while it surface brightness is a teasingly feeble 14.4.

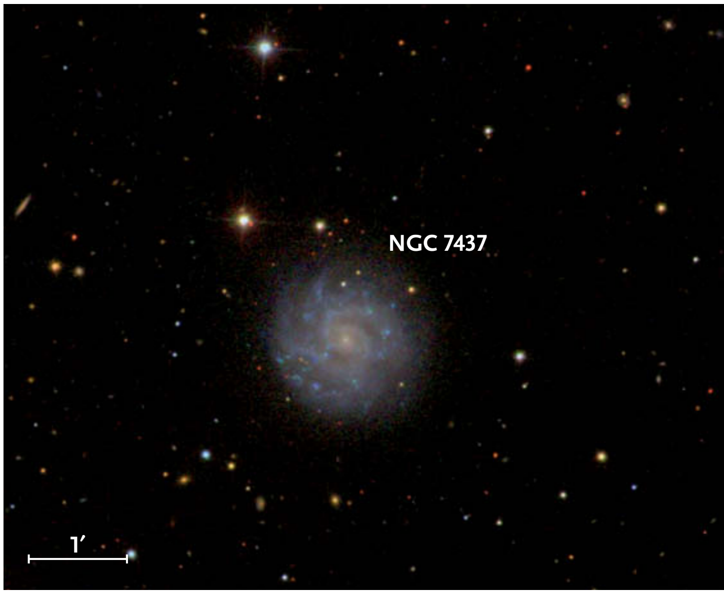
If you have a large telescope and don't feel tested by any of these galaxies, try superthin **UGC 12281**, found 18′ south-southwest of the southernmost star in our pizza crust. Superthin galaxies are edge-on spirals that look exceptionally slender and have little or no central bulge. Measured on blue-light images, UGC 12281 is 17 times longer than wide.

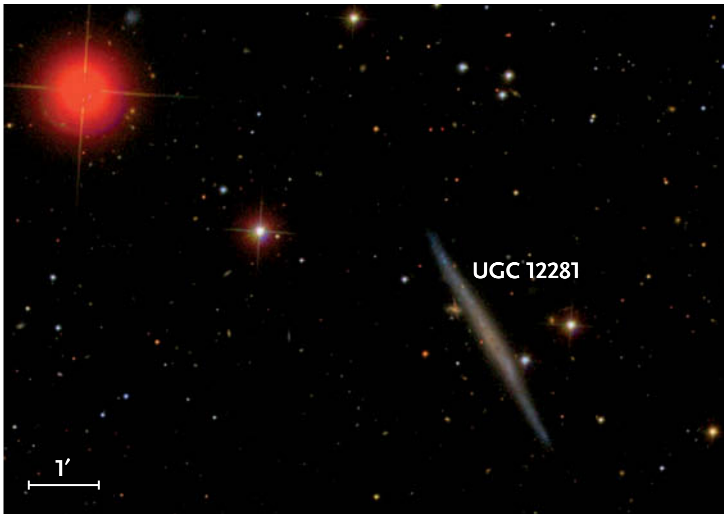
The position of UGC 12281 is easy to determine, because it's nearly perpendicular to two faint stars to the west, one just off its flank. With my 10-inch reflector at 166×, I can barely tell that something elongated dwells there. I had better luck with my 15-inch reflector at 247×. A section 1′ to 1¼′ long is steadily visible, and with careful study, faint extensions stretch this needle-like galaxy to a length of perhaps 2½′.

With his 48-inch reflector at very high magnifications, Texan Jimi Lowrey saw mottling in the brighter regions of UGC 12281. This patchiness is due to a significant amount of recent star formation, which is unusual for a superthin galaxy. Impressively, Lowrey could also see the little 18th-magnitude background galaxy nuzzling the southeastern flank of UGC 12281, ½′ northeast of the galaxy's center. Can anyone snare this with a smaller scope?

The table for this article lists the total magnitude (Mag) and surface brightness (SB) for each galaxy so that you can see how they, along with their environments, affect what your telescopic glass will show. Be patient, and enjoy! ✦






***DID YOU KNOW?***

*Sky & Telescope's online Photo Gallery is one of the most popular sections of our website. It includes more than 4,000 images submitted by contributors worldwide. They range from beginners' efforts to masterpieces by some of the world's best known astrophotographers. You can browse the Gallery at skypub.com/gallery.*



# A Peculiar Pair by the Pole

*These dissimilar galaxies are always well placed for scrutiny.*

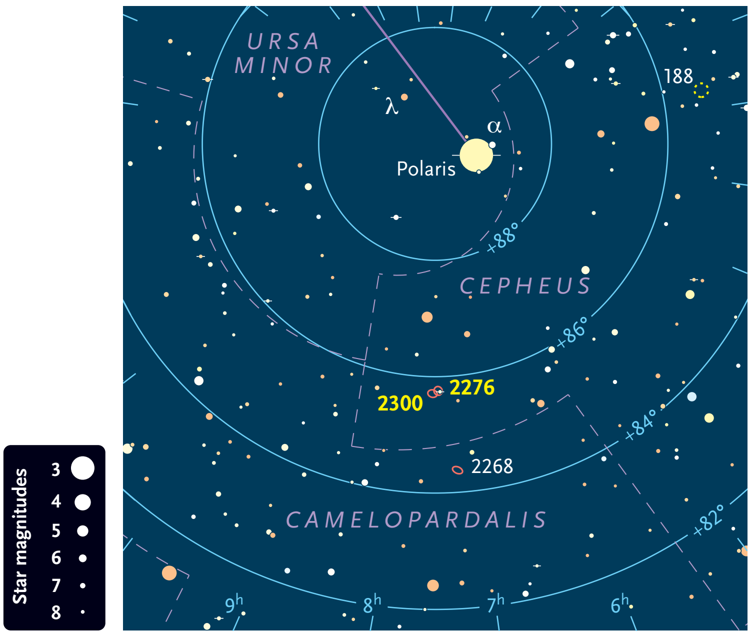
I GENERALLY IGNORE the region around the north celestial pole. However, I recently spent some time studying **NGC 2276** and **NGC 2300**, which lie in Cepheus just 4.1° from Polaris and 6.4′ from each other.

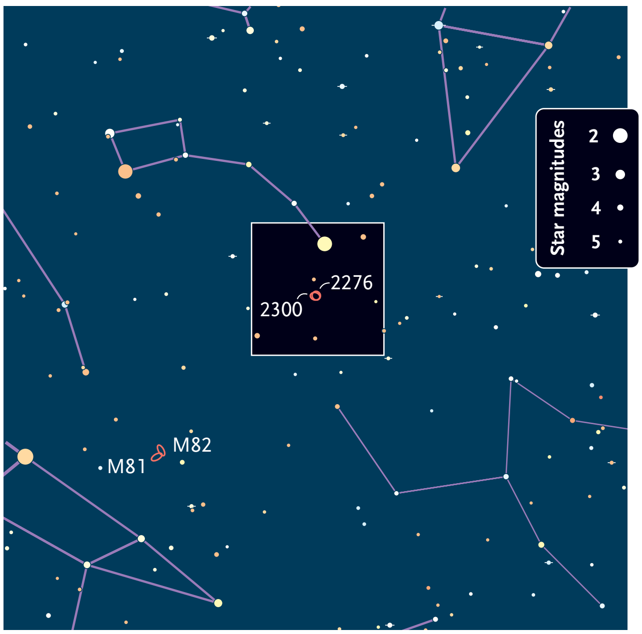
These galaxies form a true physical pair, lying about 120 million light-years from Earth, but they're not alike. At magnitude 11.1, NGC 2300 is almost twice as bright as 11.8-magnitude NGC 2276, and its surface brightness is a full magnitude lower (better). NGC 2300 is usually classified as an elliptical, though images suggest that it might be a tightly wound spiral with a bright center and a diffuse disk. NGC 2276 is loosely wound, with a muted core, and it's asymmetric in shape.

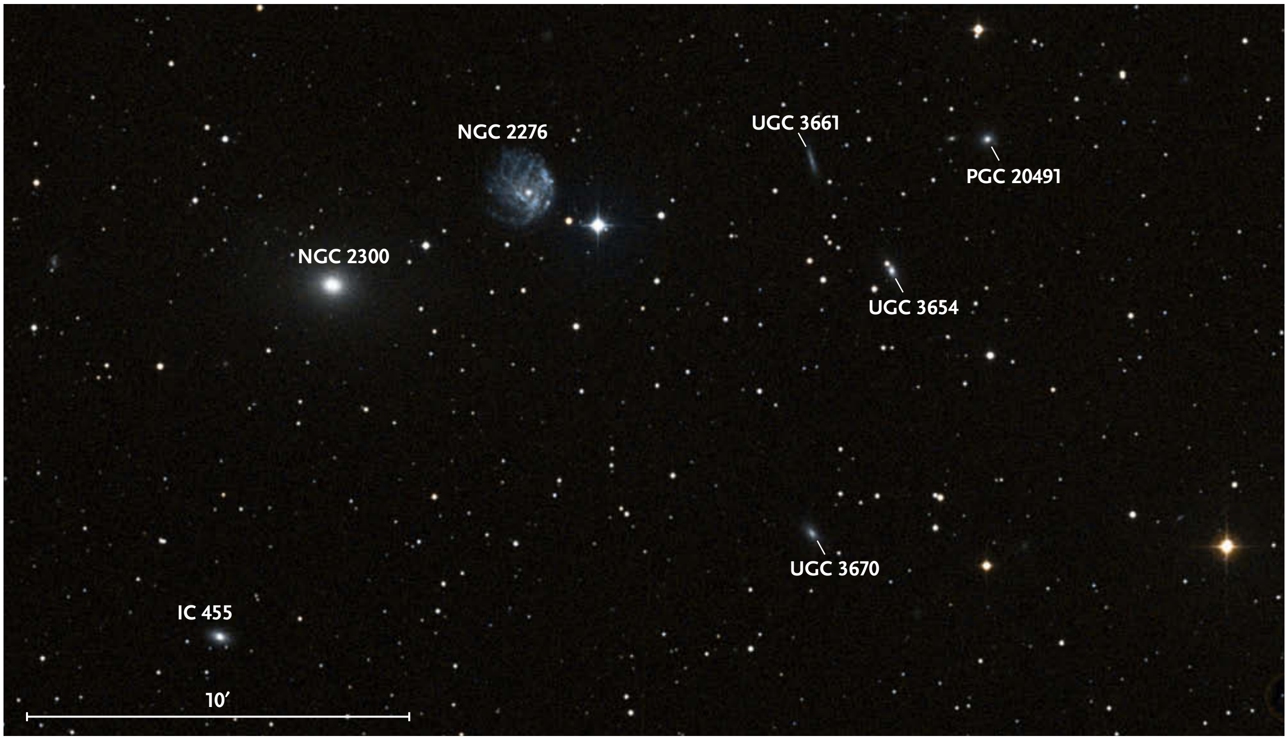
Halton C. Arp made this odd couple the 114th entry in his *Atlas of Peculiar Galaxies*, published in 1966. Arp felt that NGC 2276, identified on its own as Arp 25, "may be perturbed," and cited as evidence a "tubular arm, straight at first, then bent." An image of NGC 2276 by the Hubble Space Telescope shows a long, cluster-rich arm (of which Arp's tubular feature is a part) west and south of the nucleus. Shorter arms spread like fingers across the fan-like portion east and north of the nucleus.

I became interested in this field a year ago while thumbing through the superb *Arp Atlas of Peculiar Galaxies: A Chronicle and Observer's Guide* by Jeff Kanipe and Dennis Webb. On page 125 the authors challenge readers to detect the "mottling and tubular arm" in Arp 25, and I wondered if my 17.5-inch Dobsonian might succeed. Locating the target was easy enough. From Polaris, I hopped 3° to the 5th-magnitude variable OV Cephei, then drifted another 1¼° southward until my finderscope swept up the 8th-magnitude star HD 51141, which glares 2′ southwest of NGC 2276. An 83× eyepiece revealed both galaxies instantly. An 11.2-magnitude star shines midway between them, and an 11.7-magnitude star glimmers between HD 51141 and NGC 2276 — the unassuming but intriguing Arp 25.

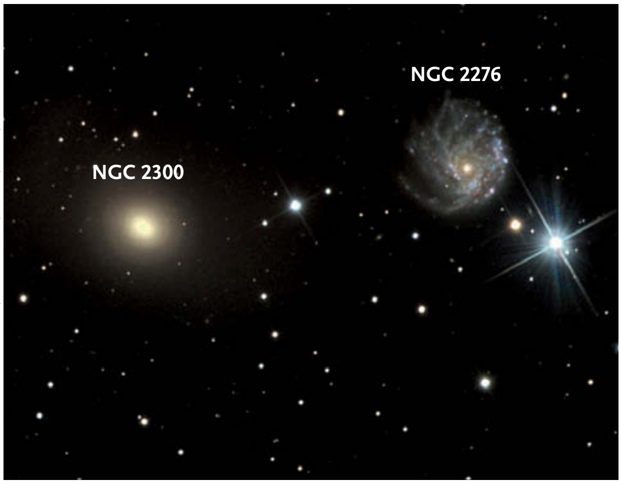
Less than 3′ wide and low in surface brightness (magnitude 13.8 per square arcminute), NGC 2276 is hardly eye-catching. But patient staring at 83× confirmed that while the galaxy's broad northeast side is pale and misty, the squashed southwest side (facing the 8th-magnitude star) is bright and contrasty. At 222× I saw a tiny core offset toward the southwest. The fuzz around it appeared






POSS-II / CALTECH / PALOMAR OBSERVATORY




CARLOS AND CRYSTAL ACOSTA / ADAM BLOCK / NOAO / AURA / NSF

granular. Bumping up to 285× did not produce any additional structure — the mottled mass remained unorganized — but the core was distinct, as was the compressed edge southwest of it. I compared my impression with that of Minnesota amateur David Tosteson quoted in the *Observer's Guide*. Working with a 25-inch Dob at 160×, Tosteson described Arp 25 as "Fairly smooth, not brighter toward the middle. Some mottling, flattened on southwest." Except for our impressions of the middle, that's pretty good agreement.

NGC 2300 appeared noticeably brighter and smaller than NGC 2276 in my 17.5-inch Dob. Despite listed dimensions of 2.8′ × 2.0′, NGC 2300 looked essentially circular, diffuse in the periphery, and very bright toward the middle. In fact, at 222× the center was nearly pinpoint sharp. It looks to me like a featureless face-on spiral masquerading as an elliptical galaxy.

For extra fun, I identified five obscure galaxies scattered south and west of the Arp objects. The least difficult one, 13.3-magnitude **IC 455**, lies less than 11′ south-southeast of NGC 2300. Although a minuscule 1.1′ × 0.7′ in extent, the galaxy was an easy catch. At 222× it was an oval patch that seemed almost stellar in the middle.

The other four galaxies were quite challenging, but I glimpsed all of them at magnifications of 222× or 285×. I found 14.3-magnitude **UGC 3654** almost 9′ west and slightly south of the glaring star HD 51141. Although teensy, the galaxy stood out right next to a 14th-magnitude star. This binary-like "star 'n gal" became a handy reference point that I nicknamed The Combo.

I nudged my scope nearly 4′ northwest of The Combo to pick up tiny **PGC 20491**. It sported decent contrast. Pushing 3′ north and slightly east of The Combo uncovered the edge-on **UGC 3661**. Diminutive and barely perceptible, it nonetheless yielded an elongated form. Finally, I swept 7′ south of The Combo to snare **UGC 3670**. It was extremely faint and diffuse.

I enjoyed working this far-northern field with my Dobsonian. The alt-azimuth light-bucket was easy to aim near the celestial pole, and I needed little effort to keep the objects centered at high magnification. Try this Arp expedition yourself! ✦

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*Long-time deep-sky observer and* S&T *contributing editor* ***Ken Hewitt-White*** *lives in southern British Columbia, where Polaris hovers almost 50° above the horizon.*

# The Delmarva Pipe Mount

*This update of a classic design combines smooth performance and stability.*

In the pre-Dobsonian era, many homebuilt telescopes ended up riding on a mount made from galvanized-steel plumbing parts. “Pipe mounts,” as they are collectively known, have many virtues. They’re simple, inexpensive, and easy to make. But there are a couple of reasons you don’t see too many of them on observing fields these days. First, they generally only work well with small or mid-sized telescopes, and second, they are prone to binding and play. These shortcomings are mainly due to the simple pipe-thread bearings.

Some ATM’s have improved the pipe mount’s performance by “lapping” the threads with grit and grease. Although this creates a significantly smoother motion for the mount’s axes, you’re still dealing with bearings that tighten when you turn them in one direction, and loosen in the other direction. One solution is to incorporate ball bearings into the design, but this sacrifices the mount’s greatest selling feature: its simplicity. And so the pipe mount languishes as an artifact from a bygone era. But thanks to Delaware ATM David Groski, it may see a resurgence in popularity.

“A few years ago I decided to see if I could come up with a design that overcame the problems of pipe-thread bearings and could still be fabricated with tools found in the average ATM’s workshop,” Dave explains. His result is both simple and effective — the Delmarva pipe mount.

The right ascension and declination shafts of the Delmarva mount are made from ¾-inch galvanized steel pipe, which Dave sanded smooth with 220- and 400-grit wet/dry sandpaper. As with many traditional pipe-mount designs, the shafts are housed within a pair of metal pipe tees. But it’s the bearings that make the Delmarva version different.

There are four bearings, one at each end of the two tees where the shafts pass through, as shown in the photographs here. The heart of each bearing is a 1¼- to ¾-inch PVC reducing bushing that is modified in three steps. First, Dave bores out the bushing’s interior threads with a 1-inch Forstner bit in a drill press. Because the outside diameter of ¾-inch galvanized pipe is a little greater than 1 inch, he enlarges the hole a little bit with a drum sander. “The hole doesn’t need to be a precision fit for the pipe because it’s not the bearing surface,” Dave notes. Next, he cuts two perpendicular slots into the bushing. This forms a kind of ferrule with four tabs. Finally, he seats a 2¾-inch-long, ½-inch-wide strip of 3⁄32-inch-thick Teflon inside the bushing — this forms the actual bearing surface that the shafts ride on.

“As you screw the PVC bushing into the metal tee,” Dave explains, “the fours tabs bend inward slightly to compress the Teflon strip around the shaft. This lets you set the amount of friction in each axis until you get the

S&T: DENNIS DI CICCO

**David Groski’s 4-inch f/12 Newtonian rides on his new mount design, which features simple-to-make Teflon bearings. The telescope won several awards at this year’s annual Stellafane convention in Springfield, Vermont, where this photograph was taken.**

ALL IMAGES BY DAVID GROSKI UNLESS OTHERWISE STATED.

***Above left:*** **The heart of the Delmarva mount's bearing system is a PVC reducer bushing.** ***Center:*** **Two perpendicular cuts in the reducer allow the Teflon strip to be squeezed against a shaft when the reducer is threaded into a galvanized tee fitting.** ***Right:*** **The fully assembled bearing shows that the Teflon strip is kept short enough to prevent its ends from meeting when the bushing is threaded into the mount.**

***Left:*** **Another refinement to the mount is its fine-latitude adjustment, which is described in the accompanying text.**

***Below*****: Four bushings are used in the Delmarva pipe mount: two per axis (a coating of Hammertone gray paint gives the mount a uniform appearance). Thin Teflon washers (white) are used as thrust bearings on both ends of the declination axis and at the top of the polar axis.**

feel you want. The motion is very smooth, with no play, and no worries about the fittings unthreading as you swing the telescope around."

Another very nice feature of Dave's mount is a fine latitude adjustment, which cures one of the classic pipe mount's ills — its imprecise polar alignment. Typically the polar axis is fixed at the angle of a street elbow, usually 45°. The adjuster on the Delmarva mount consists of two wooden disks, each with a pipe flange attached to the outward-facing surface. Sandwiched between the disks is a hard plastic track ball salvaged from an old computer mouse, seated in beveled, undersized holes drilled through the disks. Adjustment is accomplished by loosening and tightening wing nuts on three bolts that pass through both disks near their outer edge. It is similar to the arrangement found in a double-plate primary-mirror cell. "This ball joint allows about 10° of tilt adjustment," Dave explains. "To make the part look nicer, I concealed the upper flange under a decorative oak disk."

I like the way Dave's Delmarva equatorial mount combines old-school construction and functionality with Dobsonian technology. It should appeal to anyone looking for something more sophisticated than a basic alt-azimuth mount, but who doesn't want to go overboard with a difficult project. For complete instructions on building pipe mounts, there is no better source than Sam Brown's classic *All About Telescopes* (available from various used-book sources, such as **www.abebooks.com**). "I hope my ideas allow ATMs without access to machining equipment to make nice mounts," Dave concludes. "One could easily upgrade many of the pipe-mount designs featured in Brown's book with these modifications."

Readers with questions about the Delmarva pipe mount can contact Dave at groski@udel.edu. ✦

*One of contributing editor **Gary Seronik's** first ATM projects was an alt-azimuth pipe mount. He can be contacted through his website, **www.garyseronik.com**.*

Shooting the splendors of the night sky above storybook landscapes, such as this scene in Iran's Alborz Mountains, is a relatively easy way to get started in astrophotography. What appears to be a river of glowing red water is actually a person walking with a red flashlight and pointing it toward the ground.

# Tips for Shooting Great Nightscapes

Capturing the Earth and sky in one great composition is surprisingly easy.

Babak A. Tafreshi

**Seen from a little island** off the coast of Brazil, the Milky Way hangs above coconut palms. Gentle waves break the island silence, softly washing the shore's tiny grains of sand. Millions of those grains are under my feet as I stand next to my camera, trying to capture both the boundless cosmic ocean above and the quiet terrestrial one below.

This attempt to capture the beauty of the Earth and sky is known as landscape astrophotography. The resulting nightscapes made using off-the-shelf cameras and lenses are immensely successful in astronomy outreach. Picturesque terrestrial landmarks crowned with the stars above allow viewers to relate to otherwise abstract celestial sights. These wide-field photos often reveal surprising astronomical and atmospheric phenomena impossible to record through a telescope's narrow field of view. We often think of the universe as an astronomer's laboratory, but these celestial portraits remind us that the night sky is also an essential part of nature — and therefore of us.

Striking this balance between art and science in nightscapes is one of the more challenging aspects of landscape astrophotography, but if done properly, these images can revitalize the sublime experience of naked-eye observing.

## Right Place, Right Time

Today's nightscape astrophotographers are pursuing the hobby at the right time. When I began photographing the night sky in the early 1990s, photography was a complex and fickle endeavor. My first successful sky image came after months of trial and error with a single-lens reflex camera. I had to figure out the best films and exposures, as well as find a reliable photo lab. Today, thanks to digital technology, delicate Earth and sky images appear on my camera's LCD screen as soon as the exposure is complete.

Compared with telescopic astrophotography, nightscape imaging is a low-gear endeavor; you don't need a vast array of high-tech equipment. A single camera, tripod, and a shutter-release cable will not only get you started, they are almost all you need as a nightscape astrophotographer. Post-processing of your images is also minimal, because you're aiming to create an image resembling what an observer might see with the unaided eye.

Keeping your equipment as compact as possible also helps you tackle the real challenge of landscape astrophotography — getting to the right location at the right time. Much of your setup time will involve traveling to remote locations, searching for picturesque landscapes, and waiting for the right moment. Unless you're particularly fortunate, you'll never take the best nightscapes in your backyard. The view down your street with electricity wires, streetlights, and other signs of urban life will often

ALL PHOTOGRAPHS BY THE AUTHOR

Perhaps the biggest challenge to nightscape photography is traveling to picturesque locations. Here the author prepares for a night of imaging in the foothills below Mount Damavand in Iran.


*Above:* Besides a tripod, the only equipment necessary to capture wonderful nightscapes is a DSLR camera, high-quality lenses, a heavy-duty battery, and a programmable intervalometer that allows you to take hundreds of continuous photos. *Left:* Nearly all current DSLR cameras feature Live View, a video readout of the camera's field of view that enables you to focus on bright stars quickly and easily.

degrade an otherwise wonderful nightscape. Being at the right place at the right time usually comes with careful planning, which includes knowledge of the night sky.

Having the minimal amount of equipment not only helps you move around during the night to find the best compositions, it also allows you to enjoy your time under the starry sky. My usual imaging gear consists of two cameras: one used to capture still images that I move to different positions throughout the night, and another to record time-lapse sequences. Everything fits conveniently inside a backpack.

Also consider the size of your team. I tend to avoid doing night photo sessions when I'm alone, and I always let someone know where I'm going when I shoot from a remote location. On the other hand, larger groups cause their own issues, including too many tripods to trip over and sometimes too many flashlights in my photos. Astrophotography in small teams of two or three people is often the most comfortable.

## Choosing Your Gear

The most important tool for taking world-class nightscapes is obviously your camera. Although some great twilight photos can be taken with pocket digital cameras, serious landscape astrophotography is impractical with compact digital cameras. Their average nighttime sensitivity is mediocre at best. The newest point-and-shoot cameras use small detectors boasting a dozen megapixels or more, which may sound wonderful at first. But these detectors incorporate extremely small pixels that aren't well suited for nightscapes, as I'll explain in a moment. Additionally, compact point-and-shoot cameras come with a single zoom lens, which more often than not is both photographically slow and often has poor edge quality that reveals itself as distorted stars near the corners of the image.

The best choice for nightscape photography is a digital single-lens-reflex camera (DSLR). These cameras feature dozens of advantages over point-and-shoot cameras, including high sensitivity, interchangeable lenses, manual exposure and aperture settings, bulb exposure mode (which enables practically unlimited exposure lengths), and a RAW file mode that preserves the dynamic range of your image (June issue, page 68). Most recent DSLR models utilize "live view," which provides on-screen focusing and can display the brightest stars at night, greatly simplifying the process of achieving proper focus.

DSLRs are very sensitive to light, much more so than even the best films of the past. And while you can adjust the ISO setting to achieve "faster" performance than point-and-shoot cameras, the latest models offer much lower noise at the same ISO settings than cameras manufactured just a few years ago. Changing the ISO setting of your camera doesn't truly increase its sensitivity to light, but rather electronically amplifies the signal readout from your camera's CMOS detector. This amplification has the cost of producing more noise in the image.

A DSLR's true sensitivity depends on a number of factors, such as the sensor's quantum efficiency, or QE. This is the percentage of usefully recorded photons compared to the total that strikes the detector. The QE of a human eye ranges from 1 to 5%. A rough estimate for the peak QE of current DSLR cameras ranges from 30 to 40%. Note that the QE changes across the spectrum and thus depends on the wavelength of the light striking the detec-

In nightscape astrophotography, unexpected occurrences can often enhance a composition. Broken clouds add to the beauty of this photo of Venus over Dasht-e Kavir in central Iran.

When shooting nightscapes from remote locations such as this site in the Semnan Desert in northeastern Iran, it's best not to go alone, and to always let someone know where you're going. But don't take too many people along on an imaging trip, either.

tor. A camera's QE also varies in each of the RGB color filters incorporated in the camera's Bayer matrix.

Under a dark, moonless sky, current DSLRs perform well at ISO 1600. This is a good compromise between photographic speed and noise in the resulting images. A goal in nightscape astrophotography is to capture a sharp landscape and pinpoint stars. You can often avoid tracking if you limit your exposure to roughly 30 seconds with a 15-millimeter lens, or up to a minute with very wide-angle or fisheye lenses. Beyond that, the stars will trail noticeably. Some new camera mounts, such as Vixen's Polarie (reviewed in the March issue, page 58), compromise between the stars and foreground image by tracking at half the normal rate. This speed allows you to shoot longer exposures before stars become objectionably long trails while also not contributing much blur to the foreground.

Slower ISOs of 200 to 800 work well at twilight, in bright moonlight, or in considerable light pollution, and when shooting star trails. Slower ISOs record fewer stars and won't capture fainter objects such as the Milky Way

When shooting a brilliant aurora, it's easy to point the camera up and snap away. Don't forget to include some foreground to help give your audience some visual cues to the scale of the display. This composition from northern Sweden includes a small cabin that helps to connect the viewer with the events in the scene.

in short exposures of the sky, but they have the benefit of lower noise, better dynamic range, and they produce more saturated star colors.

## The Multi-Megapixel Lure

Another important factor that determines a camera's sensitivity is the size of the individual pixels in the camera's sensor. These tiny, photon-collecting wells are like buckets collecting raindrops. The larger a pixel is, the more photons it can collect before it gets full, or saturated. Although new cameras that boast small pixels provide higher resolution and capture sharper details (particularly in telescopic planetary imaging), they lack the sensitivity of sensors with larger pixels, and the small pixels quickly saturate during long exposures. Rapid saturation results in colorless white stars across the field and low dynamic range when using high ISOs.

Another consideration when choosing a camera for nightscape astrophotography is determining if you want a full-frame sensor or one of the smaller APS-format cameras. A full-frame sensor requires lenses that can illuminate the whole detector. This is an important consideration, because most camera manufacturers offer lenses specifically for their APS cameras, and these will seriously vignette the corners of the full-frame camera.

While some of the best choices for nightscape photography are full-frame cameras such as the Canon 5D Mark II and the Nikon D3, they aren't absolutely necessary. Under a dark sky and using a good wide-angle lens, you can make a 30-second exposure at ISO 1600 on most current APS-format cameras and still record a surprisingly glorious view of the Milky Way. When choosing an APS-format DSLR for nighttime imaging, remember to avoid budget models with high megapixel counts, because their super-sharp daytime performance won't last when the Sun sets.

## Lenses as Your Telescopes

Even the best DSLR cameras produce mediocre images when coupled with a cheap lens. Consider investing in high-quality lenses with fixed focal lengths. Zoom lenses are often inadequate for any kind of low-light photography. The wide-range zoom lenses such as the standard 18-to-200-mm zoom that comes with many camera packages offer you both wide views of constellations and close-up Moon shots. But these complex lenses use many optical elements and offer slow photographic f/ratios that limit how deep you can go in short, untracked exposures.

The basic lens for nightscape photography is a wide-angle lens ranging from roughly 15 to 35 mm for full-frame cameras, ideally f/2.8 or faster. An APS-format camera lens equivalent would range from 10 to 24 mm. These fast, fixed-focal-length lenses are the key to success in low-light photography. With a fast 15-mm f/2.8 lens, a 30-second exposure at ISO 1600 will reveal faint nebulae

and star clusters within the Milky Way.

When shooting with lenses faster than f/2.8, stop the aperture down one or two f/stops to achieve the sharpest focus and to reduce coma at the corners. For example, a good 24-mm f/1.4 lens should be stopped down to at least f/2 to produce good star images across the entire image.

For close-up views of celestial events such as conjunctions or eclipses, a telephoto lens in the range of 85 to 200 mm is required. Longer, fast telephoto lenses (500 mm and more) are quite expensive, and small apochromatic refractors with similar focal lengths are usually much better optically and less costly.

## Shooting Old School

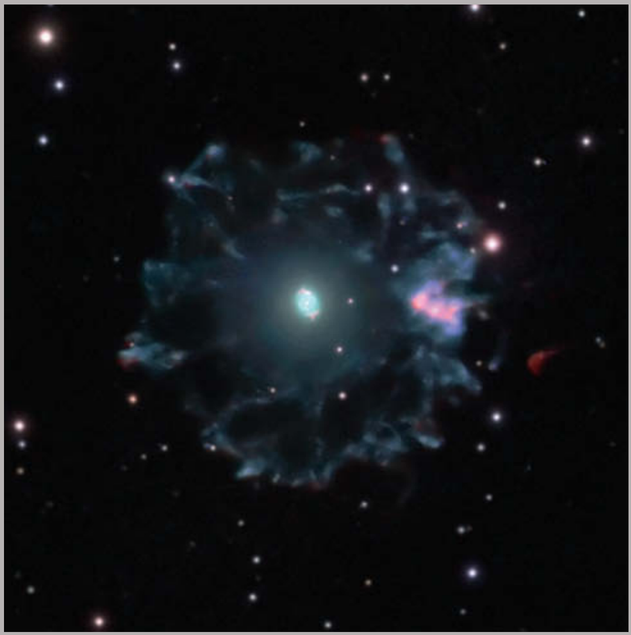
Finally, what about film cameras? Film nightscape astrophotography is still alive (see images by The World at Night photographer Oshin Zakarian at **www.twanight.org/zakarian)**. Film cameras are very affordable and still a perfect supplement to your digital equipment. Available films today are relatively slow but work fine for imaging at twilight, under bright moonlight, and for long-exposure star trails. Film cameras with manual shutters don't require electricity to function in bulb mode. Medium-format film cameras are available on the used market often at bargain prices and produce wonderful nightscape photographs. You can still find medium-format films of ISO 800 in many professional photo stores, or online.

These tips should get you well on your way to capturing wonderful scenes of conjunctions, meteor showers, and the resplendent Milky Way above the most beautiful locations in the world. Nightscape astrophotography is among the easiest and most enjoyable pursuits for amateurs today, and is by far the most accessible to everyone. ✦

**Cities can also offer a great setting for wonderful nightscapes. Here the author calculated where to set up in Paris to catch the setting Moon next to the famous Arc de Triomphe using a long telephoto lens.**

---

S&T *contributing photographer* ***Babak A. Tafreshi*** *is the founder of TWAN (**www.twanight.org**) and is the 2009 co-recipient of the Lennart Nilsson Award for scientific photography. See more of his nightscapes at **www.dreamview.net**.*



◄ **CAT'S HALO**
Derek Santiago
The popular planetary nebula NGC 6543, the Cat's Eye, displays a large outer halo in extremely deep photographs.
**Details:** *Meade 10-inch LX200R Schmidt-Cassegrain telescope with a QSI 540wsg CCD camera. Total exposure was 17 hours through color and narrowband Astrodon filters.*

▼ **ANTARES' DIVERSE NEIGHBORS**
Iván Éder
The massive red giant star Antares, embedded in yellowish dust at left, is accompanied by the bright globular cluster M4 (middle), and the reddish emission nebula Sharpless 2-9 at right.
**Details:** *8-inch Newtonian astrograph with Canon EOS 5D Mark II DSLR camera. Total exposure was 2 hours and 5 minutes.*

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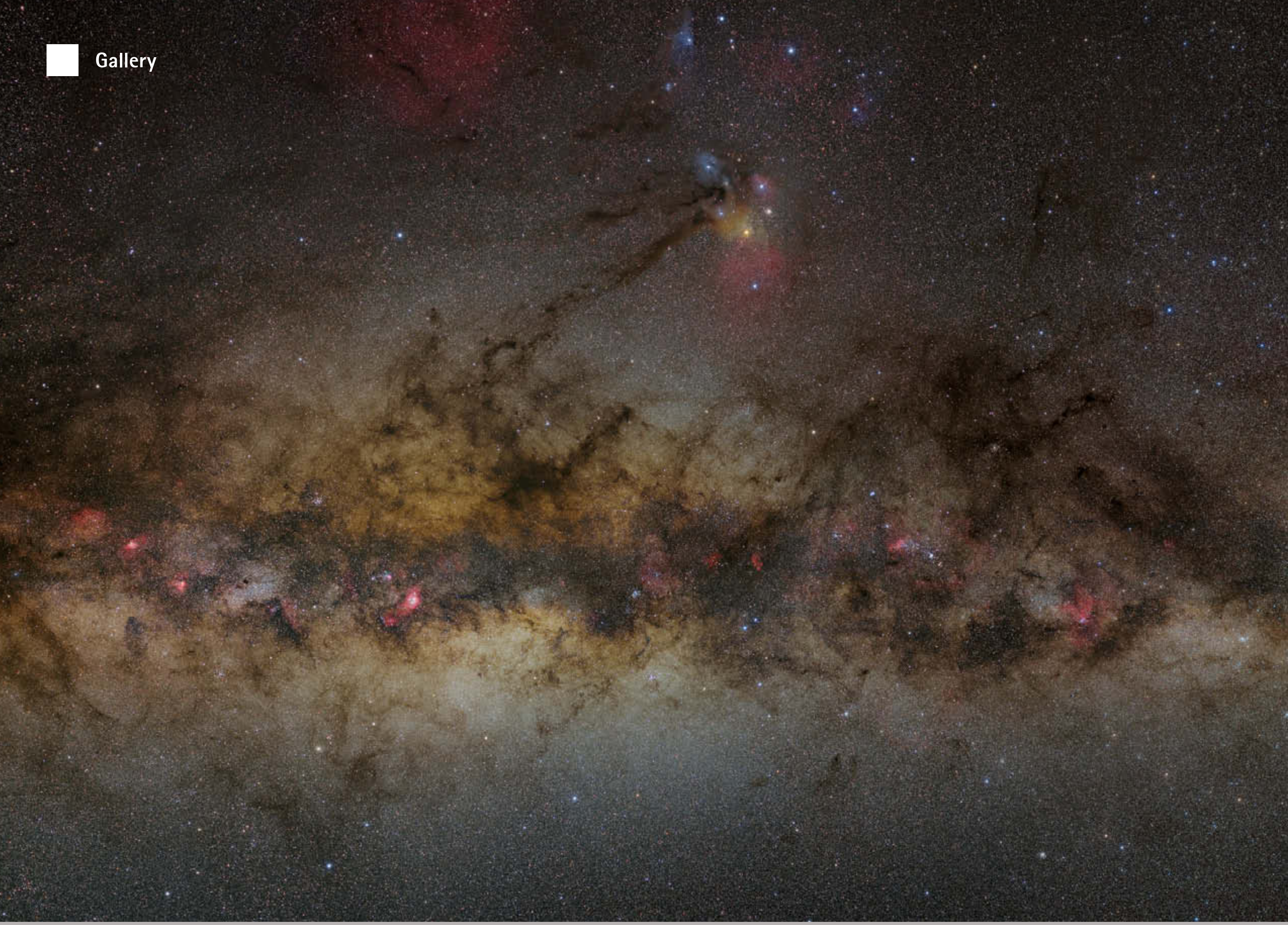
**MORNING GLORIES**

**Richard Steeg**

Early risers were treated to a wonderful pairing of Jupiter (higher) and Venus (lower) last July as they converged in the morning sky near the Hyades star cluster in Taurus.

**Details:** *Canon EOS XSi DSLR camera with a 50-mm lens. Two-frame mosaic, each consisting of 45-second exposures recorded at ISO 1600.*



▲ **MILKY WAY CENTRAL**

Fabian Nayer

The central region of the Milky Way is revealed in exquisite detail in this deep mosaic. Many pinkish emission nebulae are seen from left to right: M16, M17, M8, NGC 6357, and NGC 6334.

**Details:** *Modified Canon EOS 40D DSLR camera with a 50-mm lens. Mosaic of 16 frames totaling 17½ hours of exposure.*

▶ **KNIFE-EDGE GALAXY**

Al Kelly

The nearly edge-on spiral galaxy NGC 5907 in Draco displays a thin dust lane and a slight warp, hinting at past interactions with other galaxies in its vicinity.

**Details:** *Celestron CGE 1400 Schmidt-Cassegrain telescope with an Orion Parsec 8300C CCD camera. Total exposure was 4½ hours.* ✦

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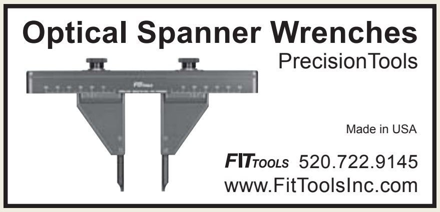
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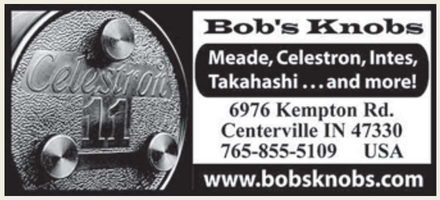
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# See the Sky with a Different Eye

*Native peoples of the American Great Plains developed their own concepts of the sky.*

Much of modern astronomical lore is based on ancient Greek and Roman mythology, and many star names come from Arabic. We have become so accustomed to these cultural perspectives that different views often don't enter into our imaginations. But other peoples also looked up at night and wondered.

Consider the Lakota, who lived in the Great Plains of what is now the north-central U.S. For the Lakota, the circle was sacred. They drew the four winds, the four seasons, and the four cardinal directions as a cross within a circle. It thus makes sense that they would look to the sky to seek a circle. Around midnight on the winter solstice, *Ki Inyanka Ochanku*, the Great Sacred Circle, is visible in the southern sky extending up to the zenith. It's drawn from Capella, clockwise through the Pleiades, then to Rigel, Sirius, Procyon, Castor, and Pollux. Orion is within the circle, but it's only part of a much larger animal, perhaps a bird, which extends lengthwise from the Pleiades to Sirius and extends side to side from Betelgeuse to Rigel.

In Lakota lore, Polaris (*Wichapi Owanjila*) has great importance because it appears to remain stationary. The Lakota considered the circle to be sacred, so this implied that *Wichapi Owanjila* was superior to the other stars that circle around it.


S&T: LEAH TISCIONE

The planets also disregarded the predictable motion of the stars. This made them "Contraries." To the Lakota, animals, people, and other living things that defied conformity were thought to have special power.

These nomadic people saw constellations that were quite different from those familiar to Northern Hemisphere stargazers today. For example, they saw a snake (*Zuzuecha*) slithering along from Puppis through the hindquarters of Canis Major to Columba. They called the Hyades cluster *Hehaka*, the Elk, because they saw the head and antlers of an elk. They saw Leo's head as a dome-shaped oven or fire pit. Gemini was not a constellation of twins, but *Mato-tipila*, the lodge of a Great Bear. They recognized the Pleiades as the *Wincinchala Sakowin*, the Seven Little Girls. *Chanshasha Ipusye*, the Dried Willow, is seen in the stars of Triangulum and includes Alpha and Beta Arietis. The Great Square of Pegasus is *Keya* the Turtle.

The Lakota understood the Milky Way to be "the Spirit's Road" on which the souls of the dead traveled to the afterlife. Where the Spirit's Road splits, a spirit directs the souls of the good and the evil. Evil souls follow the path that ends in eternal peril at the end of the "short, narrow path," possibly in the area of Sagittarius or Scorpius. Virtuous souls follow the wider path, which continues unending to paradise.

For one clear night, leave your scope at home and with just your eyes, see the sky in a different way. ✦

***Karl Matz** teaches social studies in the Department of Elementary and Early Childhood Education at Minnesota State University, Mankato. He explores the dark skies of southern Minnesota through his handmade 8-inch Dob.*