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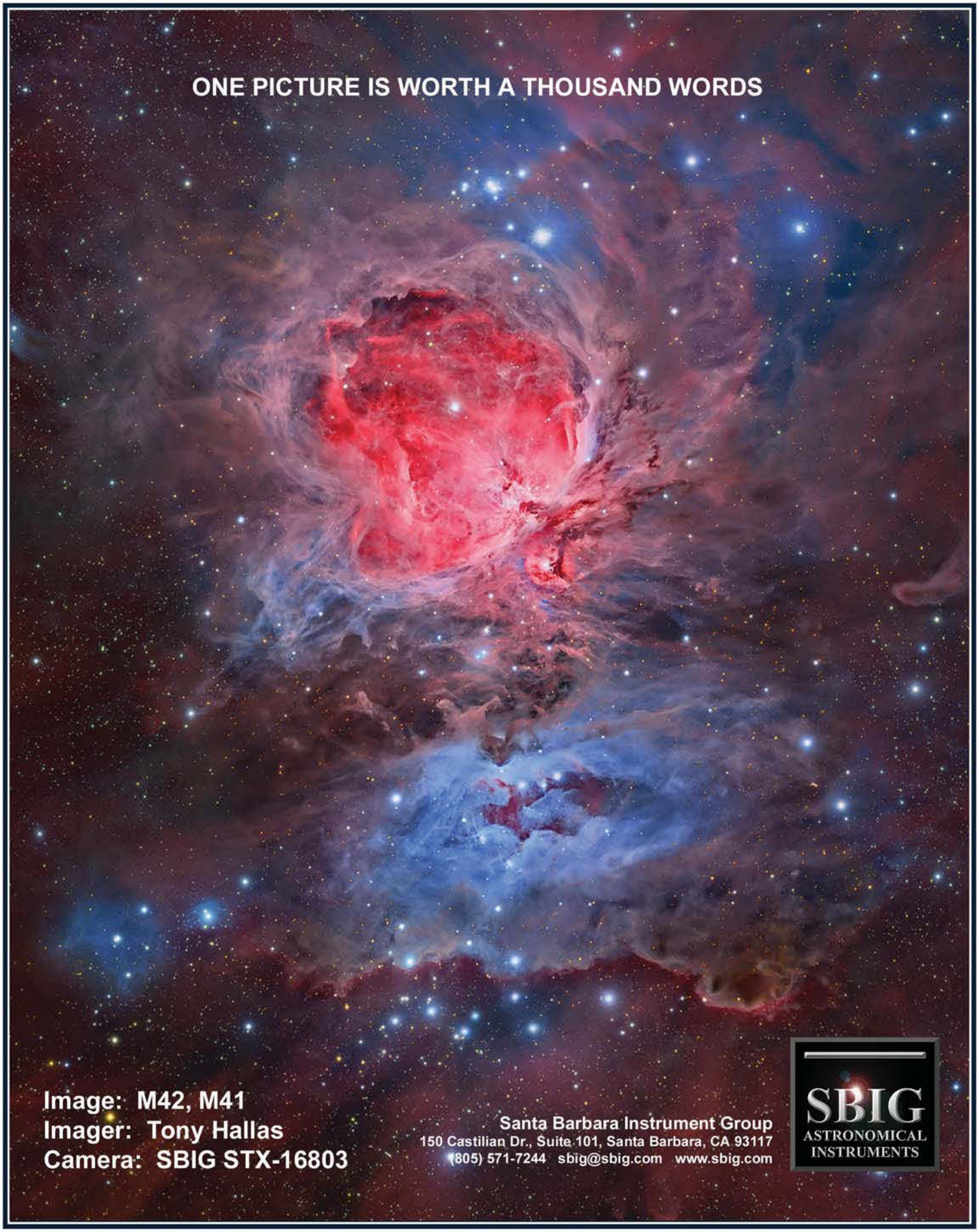
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July 2014 VOL. 128, NO. 1

On the cover: How did the universe blow up from nothing into everything? Now we might know.

S&T ILLUSTRATION: GREGG DINDERMAN

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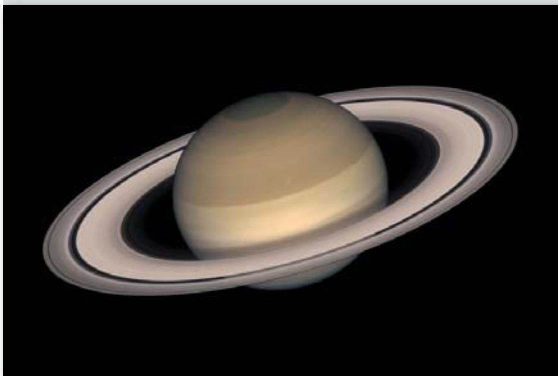

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Out with the Old - In with the New

Nagasaki is a 400 year-old port city on the southern Japanese island of Kyushu. For centuries, it was one of the principal cities where Japanese culture interacted with European and other Asian cultures. As such, it has always been a city that is curious, and eager for learning and new ideas.

The Nagasaki Science Museum now continues that eagerness for education with a total renovation of its planetarium. In March of 2014 the planetarium re-opened after removing an older, larger system from another company, and installing a new, smaller, brighter, state of the art GOTO CHIRON II HYBRID Planetarium™ system. This new projector uses extremely bright LED's to produce more, and smaller stars than ever before. In fact, the CHIRON II projects a Milky Way that is made up of 140,000,000 micro-stars!

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South America Adventures

S&T: ROBERT NAEYE

I WRITE THESE WORDS in mid-April, a few days after returning from an eventful trip to South America. The first week involved a fabulous *S&T* tour of Chile with Spears Travel. Besides daytime sightseeing, our group (*above*) went out five evenings to observe pristine Southern skies with local astronomers. As I expected, every night was clear. Many of my fellow travelers had never had the opportunity to enjoy Southern showpieces such as 47 Tucanae, the Tarantula Nebula, and the Jewel Box cluster. And even a grizzled veteran such as me never gets tired of these spectacles, especially when I view them through large scopes under truly dark skies.

Among the tour's many memorable moments were the two powerful earthquakes that struck northern Chile on April 1st and 2nd. Our group was in San Pedro de Atacama, an oasis town about 280 miles (450 km) east of the epicenters. I had previously experienced quakes in California, but none as powerful as these. I literally felt seismic waves raising and lowering the floor of my hotel room under my feet. Fortunately, we were far enough from the epicenters that we were in no danger. Thanks to Chile's well-enforced building codes and tsunami drills, the death toll was in the single digits — an amazingly low number given that both quakes registered around magnitude 8. Preparation saves lives.

I later flew to Brazil, and spent a few days in Campos dos Goytacazes, a bustling city of nearly half a million located 180 miles northeast of Rio de Janeiro. I attended an annual space-science conference organized by physicist Marcelo de Oliveira Souza and held at a local technical school. I participated in this same conference in 2010 (*S&T:* Aug. 2010, p. 6). Luminaries at this year's meeting included astrophotographer David Malin and ESA astronaut Paolo Nespoli.

Every year Marcelo puts in a Herculean effort to organize this conference. His goal is to stimulate a passion in science among the youth of Campos, and at least a dozen students in his school's astronomy club helped run the show with a high level of enthusiasm. Just like 2010, I came away inspired by Marcelo's incredible dedication to serving his nation, young people, and science. The conference left me feeling energized about the future of astronomy in developing nations. ✦

Robert Naeye
Editor in Chief

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The creation of the remarkable feats in mirror engineering Robert Zimmerman describes in "How to Build a Giant Telescope" (*S&T*: Mar. 2014, p. 24) take place in the massive laboratory directly under the grounds of the University of Arizona's football stadium. To a point, one could say that during a televised game some Arizona Wildcat fans may be cheering the football team while others cheer the engineering machinations occurring under the field of play.

Jerry Fontes, class of 1982
Chatham, New Jersey

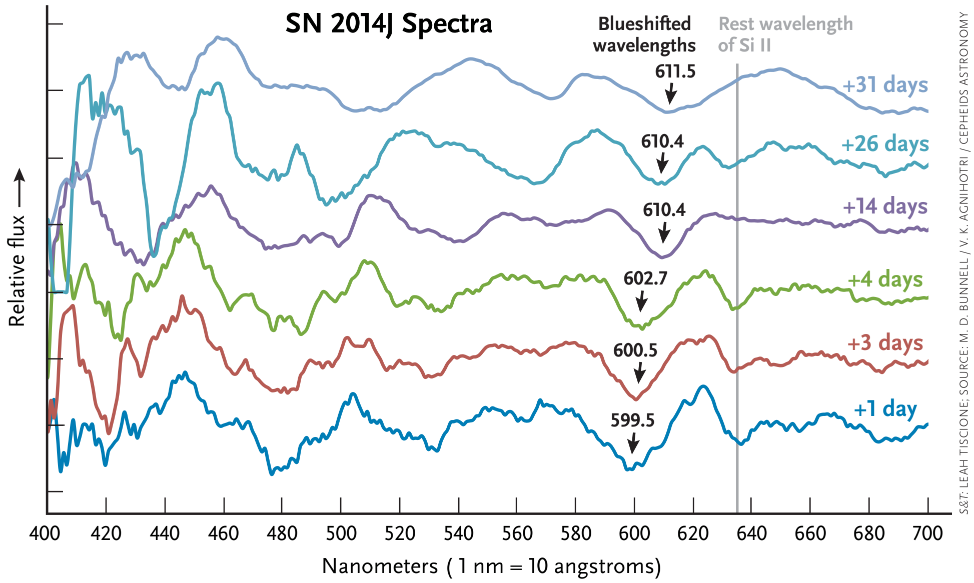
Amateur Spectra of SN 2014J

We obtained spectra of the recent supernova SN 2014J in M82 (*S&T*: Apr. 2014, p. 14) on six dates during the month following its discovery. Each had a total exposure time of 1 hour and was made with an Orion ED 102-mm f/7 refractor, a 200 line/mm diffraction grating, and an SBIG ST402 CCD, yielding a spectral dispersion of 1.09 nanometers/pixel. We then processed the spectra with *RSpec* software, adjusted the spectral flux data for instrument response, and normalized them.

Several of our fellow members in the Cepheids Astronomy Facebook group, as well as the RSpec Yahoo! Group, helped us interpret the data. Our spectra show the prominent, singly ionized silicon (Si II) absorption feature that is used to identify Type Ia supernovae. One day after the supernova, the feature was blueshifted from its normal wavelength of 635.5 nm by 36.0 nm. The shift decreased during the 30 days of observation, allowing us to estimate changes in the expanding shell's velocity over time. Day 1's expansion velocity was 16,995 kilometers/second (38,017,000 mph). By day 31, the Si II line had shifted to 611.5 nm, indicating that over 4 weeks, the expansion velocity had slowed by 5,700 km/sec to 11,300 km/sec.

Mark D. Bunnell
Price, Utah
Vikrant K. Agnihotri
Kota, Rajasthan, India

Editor's Note: *These velocities are consistent with those reported by Ariel Goobar (Stockholm University, Sweden) and colleagues in the March 20th* Astrophysical Journal Letters. *That team used several different professional instruments, including a spectrograph on the 3.5-meter scope at Apache Point Observatory in New Mexico.*



From January 22nd to February 21st, an amateur team obtained low-resolution spectra of the M82 supernova and calculated the changing velocity of the expanding shell based on the changing blueshift of an absorption line of ionized silicon. Days are measured from the supernova's appearance on January 21st, and each spectral profile is a stack of sixty 1-minute exposures.

Cat Chuckles

The Focal Point article about Edwin Hubble and his cat was great! (*S&T*: Feb. 2014, p. 86.) As cat lovers, my brother and I found it wonderful that such an outstanding astronomer had such a love for his cat. It was funny to read that Copernicus the cat didn't like Aldous Huxley very much. We've read this article many times over.

Liede-Marie Haitsma
Walnut Creek, California

Inspiring the Next Generation

You never know what a view through a telescope might do for a person. In the late 1970s, I was on the faculty of the biological sciences department at Loyola University in New Orleans. My wife and I often had students come over to the house to eat supper with us. One night I pulled out my 5-inch reflector and showed them what I could. New Orleans is not the ideal place to observe: light pollution is a real problem and the skies are usually hazy. This particular night was clearer than most, and I managed to show them the thin crescent Moon, Jupiter, Saturn, and one or two deep-sky objects. I explained to them what they were seeing and told them about *Sky & Telescope* and showed them some of my copies.

One young man, Frank, was especially interested. He later graduated and became a dentist in New Orleans, and I moved to North Carolina to take a faculty position. Several years later I returned to New Orleans for a conference and called Frank. He told me that the one evening at my telescope had engendered in him a love for astronomy. He had bought a very nice telescope, was an avid observer, and subscribed to *S&T*. He also made it a point to share the sky with his children and had gotten them interested as well.

I never knew that one evening could do so much to pique one's interest in astronomy. We owe it to our friends, young and old, to show them the wonders of the night sky.

J. Kenneth Shull, Jr.
Boone, North Carolina

Many thanks to Tom Field for his excellent article on Piper Reid and her scientific accomplishments (*S&T*: Feb. 2014, p. 66). It's incredibly important to the advancement of science and technology that we encourage all young people who show an interest in STEM and reinforce in them that it's okay to be smart. They need to know that they have important ideas and capabilities that can contribute to our body of knowledge.

When I was a kid I didn't have the kind of skilled mentoring at home that Reid has in her dad. Instead, I found my mentors in my neighborhood, in college, and at work. As an adult and professional engineer, I have looked for ways I could support kids in STEM activities, and currently I volunteer with those who participate in The Aerospace Corporation's annual science competition. The competition gives minority middle- and high-school students an opportunity to perform research, work as a team, and get familiar with being in a competitive environment — and to have some fun in the process. I've worked with kids who have never operated a microscope to kids who understand robotics and programming, and I'm proud of all of them. (You can watch a video following three teams in the 2013 competition at **skypub.com/aero2013**.)

The group I work in at the corporation has created a mobile mission-control system that we bring to local schools so that students learn how important space is, what satellites do, and what's involved in launching those payloads. We then give the students an opportunity to man their consoles, give us the "go for launch," and enjoy the fruits of their labor with a simulated countdown and blast off! We are so excited when kids "get it." Our nation has an aging population of engineers and scientists; these kids are the ones whom we'll count on to carry us into the future.

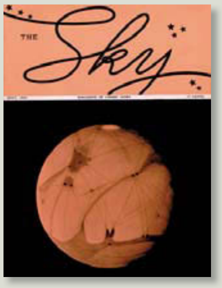
Piper Reid is an extraordinary person and a model for kids all over the world who have a spark for STEM. We as mentors must make absolutely sure that these young people are heard, encouraged, and supported so that the spark in them grows to burn brightly.

Blake Bartosh
Rancho Palos Verdes, California

Write to Letters to the Editor, *Sky & Telescope*, 90 Sherman St., Cambridge, MA 02140-3264, or send e-mail to letters@SkyandTelescope.com. Please limit your comments to 300 words.

75, 50 & 25 Years Ago

Roger W. Sinnott



July 1939

White Dwarfs "One of [the known] white dwarfs is . . . about twice as massive as the sun but no larger than the planet Mars. . . . The stuff weighs 620 tons per cubic inch! If a 150-pound man should be so unfortunate as to be transported to the surface of that star he would find to his great dismay that he weighed 250,000 tons! Aside from the fact that he would encounter a temperature of 18,000° Fahrenheit, he would . . . immediately fall down under his own weight and spread out over the surface like a very thin griddle cake. . . . "

Ernest Cherrington, Jr. was describing the densest matter then known. The existence of white dwarfs stimulated efforts to understand how they had formed. Eventually, neutron stars and black holes joined the ranks of "compact objects."

July 1964

Changes on the Moon "Just after the sun rises there, for an hour or so the convex floor of [Alphonsus] crater resembles a luminous cloud. It is a trap for the unwary beginner, who is apt to believe he has seen volcanic activity. . . . Apart from these [illumination effects], is anything happening on the moon?

"At the symposium on problems of lunar geology, held this May in New York City, Patrick Moore presented a paper 'An Evaluation of Reported Lunar Changes.' Mr. Moore is a British amateur widely known in this country as a skillful visual observer. . . .

"There are no convincing cases of structural change during the century or so that the moon has been carefully studied, Mr. Moore believes. [But l]ocal obscurations of the lunar surface are supported by reasonably strong evidence. Mr. Moore has seen one example himself, inside the crater Plato. . . ."

"Among color changes, Mr. Moore described the tiny red spot seen by some observers near the central peak of Alphonsus, where N. A. Kozyrev had noted an outbreak on November 3, 1958."

Although Moore's mostly negative assessment still holds, we can now add impact flashes of meteoroids on the Moon's nightside to the list of real lunar changes. Astronomers caught one of these impacts on video for the first time during the Leonid meteor storm of 1999.

July 1989

Black Ops "Ever since construction of the [U. S. Naval Observatory's] Black Birch station began in 1982, New Zealand antinuclear activists have voiced suspicion that the Navy funds the program to help target 'first-strike' missiles — those requiring high accuracy to destroy enemy missile silos. . . . James Hughes, the USNO's director of astrometry programs, assured New Zealanders that Black Birch was built for scientific and civilian goals and that the resulting star catalogues will be available to anyone. Any military uses of the data, he said, are incidental to the program's purpose."

The military later cited the importance of USNO data for missile navigation during a dispute with a city zoning commission, inciting more outcry. But New Zealand officials declared Black Birch to be within their nuclear-free law. Ah, the Cold War.

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

ASTEROIDS | Chariklo: An Asteroid with Rings

ESO / LUÍS CALÇADA / NICK RISINGER

Astronomers have discovered two dense, narrow rings around the asteroid Chariklo, the smallest object yet found to host a ring system. This illustration gives a fanciful look at the rings from the asteroid's surface.

An international team of observers has made the surprising discovery that a distant asteroid has two distinct, dense rings. The body, 10199 Chariklo, orbits between Saturn and Uranus as the largest Centaur and is the first small solar-system body found to have rings.

Astronomers detected the features when the asteroid occulted a star as seen from South America. In addition to the telltale dip in the star's brightness as the asteroid crossed in front of it, observers in Brazil, Argentina, Uruguay, and Chile also saw an unexpected bonus: secondary dips in brightness before and after the main event.

Felipe Braga-Ribas (National Observatory/MCTI, Brazil) and colleagues analyzed the wacky signature, ruling out expanding jets of dust and orbiting moons as possible scenarios. The only logical explanation is two narrow, confined rings, they report in the March 27th *Nature*.

The first ring is about 265 km (165 miles) from Chariklo's surface and only 7 km wide. There's a 9-km gap before reaching the outer ring, which is just 3 km wide. Chariklo itself is about 248 km across.

The new discovery resolves previously puzzling observations. In 2008, Chariklo mysteriously dimmed to nearly half its brightness, and its spectral signature due to water gradually disappeared. Now it's clear why: the ice-rich ring system became edge-on during that time, disappearing almost entirely from view. Although significantly darker than most of Saturn's rings (but brighter than those around Uranus), Chariklo's ring particles must therefore constitute a substantial fraction of the system's total light.

The rings might be the remains of a disk of debris created from a relatively low-speed collision that the asteroid suffered before being gravitationally scattered from the Kuiper Belt into its current orbit. If so, the rings have been around for perhaps millions of years and likely remain confined by at least one small shepherd moon.
■ **SHANNON HALL**

SOLAR SYSTEM | Sedna-like Object Found

Astronomers have discovered a small object in the outer solar system that might be a member of the inner Oort Cloud.

The object, 2012 VP$_{113}$, is an estimated 450 km wide and follows a highly elongated orbit, which brings it 80 astronomical units from the Sun at its closest and a whopping 472 a.u. away at its farthest. The body takes 4,600 years to loop around the Sun. Another such object, 90377 Sedna, is likewise distantly adrift. Both lie well outside the classical Kuiper Belt, which ends around 50 a.u. (*S&T*: Feb. 2014, p. 18).

Chadwick Trujillo (Gemini Observatory) and Scott Sheppard (Carnegie Institution) report the discovery in the March 27th *Nature*.

What has dynamicists buzzing is not so much the object's distance, but instead what its orbit has in common with Sedna's. Both have perihelia near the ecliptic plane. So do 10 other far-out objects whose distances from the Sun average at least 150 a.u. But Sedna and 2012 VP$_{113}$ are too far away to have been flung out to their orbits by a close pass with, say, Neptune. Nor could a star that passed very close to our solar system in primordial times explain these dozen objects: the orbits' orientations would have become randomized in the eons since by gravitational nudges from the outer planets.

Instead, the team's computer simulations suggest this all might be the handiwork of a super-Earth-mass planet roughly 250 a.u. from the Sun, hiding in what's considered the inner Oort Cloud of comets. This rogue world would have enough mass to perturb objects such as 2012 VP$_{113}$ and Sedna inward from the cloud.

"This is at the suggestive stage," Trujillo cautions. "There are many possible configurations of perturber(s) that could cause the effect."

"If you're asking me whether they've found a planet, the answer is no," says dynamicist Hal Levison (Southwest Research Institute). But the observational data look sound to him. "I'm uncertain about what it means."

Observations from NASA's Wide-Field Infrared Survey Explorer (WISE) rule out a gas giant in the outer solar system, but smaller objects are too faint for WISE to spot them.
■ **J. KELLY BEATTY**

MISSIONS | LADEE Skims, Crashes into Moon

On April 17th, NASA's Lunar Atmosphere Dust Environment Explorer (LADEE) crashed into the farside of the Moon — but it was on purpose.

LADEE launched last year on September 6th (*S&T*: Dec. 2013, p. 14) and settled into lunar orbit in October to observe the gas and dust hovering over the Moon's surface.

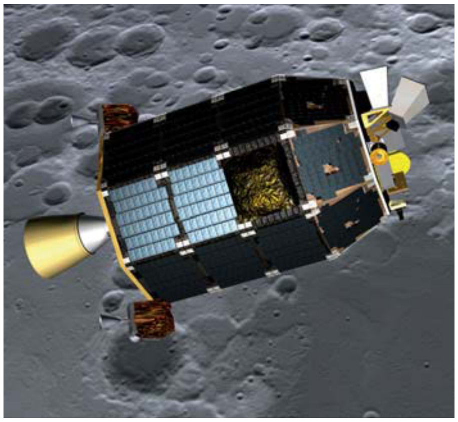
The craft's orbit was relatively snug, ranging from 20 to 50 km altitude at its low point to as high as 75 to 150 km. Science observations were only expected to last 100 days. But flight controllers were so frugal with fuel reserves that the mission received an extension.

"LADEE's science cup really overfloweth," said project scientist Rick Elphic (NASA Ames Research Center) during an April 3rd teleconference. One discovery is that a veil of micron-size dust particles continuously encases the Moon, kicked up by the rain of meteoritic matter onto its surface. The spacecraft picked up helium, neon, and argon right away in the Moon's ultra-tenuous, transient atmosphere (called an *exosphere*), and it detected atoms of magnesium, aluminum, titanium, and oxygen — the remnants of rocky minerals blasted upward from the lunar surface.

Every time LADEE flew lower over the Moon, it discovered something new. So the mission team decided to use the extra fuel to pursue some bonus (and daring) science objectives.

First, LADEE's close point was dropped to a very low altitude — just 2 km — as it passed over the Apennine Mountains. Flying this close to the surface is risky: the Moon's gravity is uneven, and at such low altitudes an unforeseen perturbation could have caused the spacecraft to plunge into a fatal trajectory. (In fact, the craft did crash 4 days before predicted for this reason.)

Second, LADEE braved the April 15th total lunar eclipse. The orbiter's systems weren't designed to be out of sunlight for long, so the eclipse offered NASA engineers a way to test how the spacecraft and its instruments responded to roughly 4 hours of darkness and deep cold.



DANA BERRY / NASA AMES

Artist's concept of NASA's LADEE spacecraft, which crashed into the Moon in April.

LADEE smacked into the farside at 1.6 km per second (3,600 miles per hour). The precise time and location of the crash won't be known until the team identifies the impact site and reconstructs the craft's final moments using high-resolution images from NASA's Lunar Reconnaissance Orbiter.

■ **EMILY POORE**

DARK MATTER | Spotted in the Milky Way?

A team of astronomers claims to have the most compelling case yet for annihilating dark matter.

Theoretically, dark matter particles act as their own antiparticles, meaning they should annihilate one another to produce a cascade of familiar particles (including electrons and positrons) as well as gamma rays. Astronomers have debated whether a haze that NASA's Fermi Gamma-ray Space Telescope detects around the center of our galaxy is due to dark matter annihilation or undetected pulsars, which beam from their poles huge amounts of energy that include matter-antimatter pairs. (This haze is distinct from the Fermi bubbles; *S&T*: Apr. 2014, p. 26.)

Tansu Daylan (Harvard) and colleagues now say they've ruled out pulsars as the cause. The team carefully combed through Fermi's data and subtracted known sources of gamma rays, producing a sharp map that extends nearly 5,000 light-years in all directions from the galactic center. Few pulsars show up in this region, suggesting the excess gamma rays must be due to dark matter annihilation alone.

"If our interpretation is correct, this signal would constitute the discovery of an entirely new particle that makes up the majority of the mass found in the universe," says coauthor Dan Hooper (Fermilab). "I can't find words that are strong enough to capture the significance of such a discovery."

The energy levels favor a mass range for dark matter particles of 31 to 40 GeV.

But others remain skeptical. Kevork Abazajian (University of California, Irvine), whose team also investigates this gamma-ray feature, cautions that extraordinary claims require extraordinary evidence. The population of pulsars located in the galactic center might be different than pulsars in the spiral arm near us, perhaps too dim for us to pick them up as point sources — unexpected, yes, but an alternative worth considering.

"It's a basic principle of science," he says. "If you have something extremely novel you have to make sure you've taken into account every other possibility."

To verify the gamma-ray excess, astronomers are pointing their instruments at relatively nearby dwarf galaxies. Such dim sources are expected to be rich in dark matter but not in other natural particle accelerators, such as pulsars. However, there is currently too little data to determine whether there is a similar excess emanating from these dwarf galaxies.

Many scientists argue that the most convincing evidence for dark matter will come from mine shafts deep underground or giant particle accelerators. No direct detection has been made yet, but a particle mass of 31 to 40 GeV could be seen with the Large Hadron Collider.

■ **SHANNON HALL**

IN BRIEF

Historic Occultation Goes Unseen. Would-be observers of Regulus's occultation by asteroid 163 Erigone on March 20th were clouded out — everywhere. Read more about why no one saw Regulus wink out at skypub.com/regulusflop.

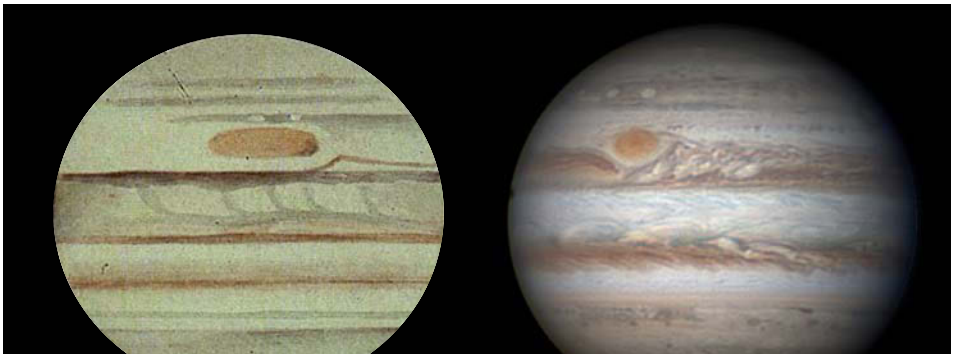
Mercury Really Did Shrink. Geophysicists using images from NASA's Messenger spacecraft have updated estimates of how much the Iron Planet shrank as it cooled after forming 4½ billion years ago. The newly calculated shrinkage — between 3.7 and 7.1 km — matches theoretical predictions and resolves a decades-old disagreement between previous estimates and theory. Interestingly, the widespread volcanic plains near Mercury's north pole bear a disproportionate share of the wrinkle ridges and thrust faults. These plains cover only 6% of the planet, yet 28% of the counted features are found there, and they account for 19% of the total shrinkage, report Paul Byrne (Carnegie Institution) and colleagues March 16th in *Nature Geoscience*. The team also found several instances where the regional topography slowly undulates, as if the crust buckled on larger scales.

■ J. KELLY BEATTY

Subsurface Ocean Confirmed. Long-sought evidence of a subsurface ocean on Saturn's moon Enceladus has finally solidified. Scientists suspected that a reservoir of liquid water feeds the vapor and water-ice crystals that the little moon spews from its south pole, creating Saturn's delicate E ring. Using the changes in Enceladus's gravitational tug on NASA's Cassini spacecraft as the orbiter flew by the moon, Luciano Iess (Sapienza University of Rome, Italy) and colleagues suggest a body larger than Lake Superior lies 30 to 40 km beneath the moon's icy south pole. The subsurface ocean might exist thanks to tidal stresses from Saturn, the team reports in the April 4th *Science*. Jupiter's Europa likely has a subsurface ocean for similar reasons.

■ SHANNON HALL

JUPITER | Not-So-Great Red Spot



Jupiter's Great Red Spot appears much larger in this drawing from 1881 by Thomas Gwyn Elger (left) than it does in this photo from 2014 by Christopher Go. South is up.

Astronomers have known for more than a century that Jupiter's signature feature, its Great Red Spot, has been shrinking. In the late 19th century the spot was nearly 35° wide, which corresponds to about 40,000 kilometers, or more than three times Earth's diameter. By 1979, when Voyagers 1 and 2 flew past Jupiter at close range, the longitudinal extent had shrunk to 21° (25,000 km), though its top-bottom width (12,000 km) was essentially unchanged.

This contraction has continued, and now the iconic vortex is smaller than ever before. According to John Rogers (British Astronomical Association), during the planet's recent apparition in 2013–14 the Red Spot spanned just 13.6° in latitude, a length of only 15,900 km.

Meanwhile, the spot's rotation continues to vary a lot. The Voyagers found a period of 6 to 8 days, corresponding to mean wind velocities around the rim of 120 meters per second (270 mph). In 2000, NASA's Galileo orbiter looked on as the Great Red Spot raced around at a record-setting 165 m/sec. This past year observers found a period of just 3.6 days, and the outer winds clocked at 144 m/sec.

No one knows what's causing these changes, but Rogers suspects the storm is gaining rotational energy as it feeds on smaller spots swept along by the northern jet stream of the South Temperate Belt.

■ J. KELLY BEATTY

PLANETS | Volcanoes on Venus?

New images from ESA's Venus Express orbiter show three transient bright spots at the edge of a young rift zone, hinting there might be active volcanoes on Venus today. Estimates based on the new data suggest the spots are 980° to 1520°F (527° to 827°C), well above the planet's typical balmy temperature of about 870°F, Eugene Shalygin (Max Planck Institute for Solar System Research, Germany) and colleagues reported March 17th at the Lunar and Planetary Science Conference in The Woodlands, Texas.

The team analyzed images from 36 spacecraft passes over a region surrounding Maat Mons, a giant shield volcano that scientists think erupted 10 to 20 million years ago. After considering whether they were seeing image artifacts or holes in the clouds, they rejected both theories. Instead, the researchers think the bright spots could be ongoing lava flows stretching 25 km or so, a chain of cinder cones, or volcanic hot spots — any of which would provide proof that Venus is active today.

So far the claim has not been confirmed. There's no evidence of past lava flows in this area, and there's a 3-month gap in coverage after the features were spotted. Shalygin's team plans to sift through archived radar images from NASA's Magellan spacecraft (which visited the planet from 1990 to 1994) and also to look for similar hot spots in other rift zones using Venus Express. ✦

■ SHANNON HALL

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MICROWAVE EYES The BICEP2 telescope (foreground, inside large shield) with the South Pole Telescope in the background. Both are in walking distance of the South Pole Station.

BICEP CONSORTIUM

What's Next for Inflation Cosmology

ALAN MacROBERT

A new window has opened on what made the Big Bang. A new branch of astronomy is beginning to peer through it.

Hold your thumb up to the blue sky of day, or to the starry sky of night. Your thumb on the sky is about the size and shape of the history-making polarization swirls newly discovered in the sky's microwave background.

Scientists with the BICEP2 project in Antarctica announced the patterns in March, to worldwide fanfare. The swirls were long predicted by inflation theory, which holds that the early universe emerged from an extraordinary, exponential growth spurt. The patterns are the greatest discovery in cosmology this century. They seem to be the super-magnified, flash-frozen images of microscopic gravitational waves, quantum fluctuations of spacetime itself — the long-theorized *graviton* particles that convey gravity — seen before a trillionth of a trillionth of a trillionth of second in the inflating pre-existence that set the Big Bang going. Marveled MIT physicist Frank Wilczek, "We're seeing gravitons imprinted on the sky."

One of them is a clockwise swirl a little north of the star Achernar in Eridanus. Another left a counterclockwise swirl a couple of finger-widths at arm's length to the west, in the constellation Phoenix. BICEP's map on the next page shows more. Their discovery appears to be the triumphant confirmation of the inflationary-physics theory of what made our universe — if the other teams now racing to confirm the find succeed, and if theorists have not somehow been wildly misled.

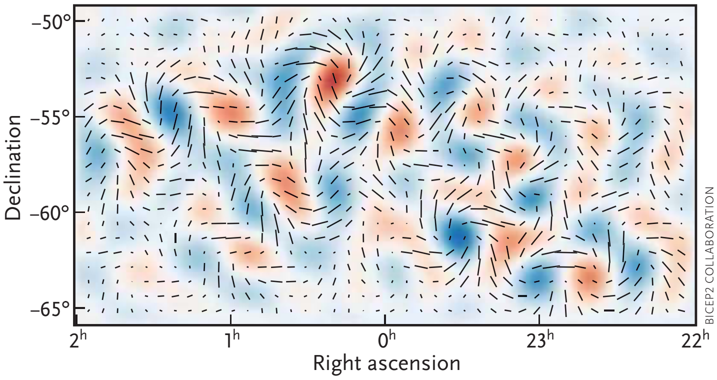
A larger issue is now in play too. The discovery drags to the forefront of science an even more radical prediction that inflation makes: that there exists a hierarchy of at least two kinds of infinite multiverses, thereby posing deep paradoxes of physical infinities. This prediction from inflation will be less easy to test. But BICEP's discovery opens a new branch of observational astronomy that will at least move in that direction.

Triumphant Announcement

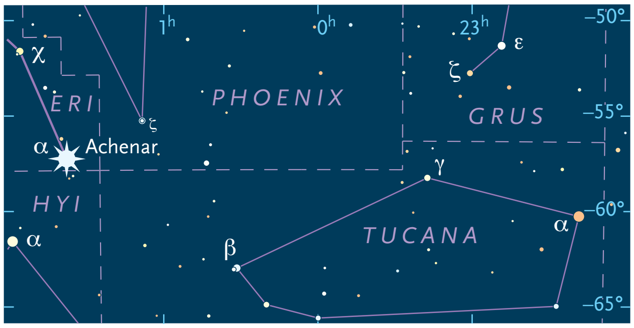
Not that the discovery was easy. The 47-member team that did it, led by John M. Kovac of the Harvard-Smithsonian Center for Astrophysics, has been working since 2006 to measure polarization patterns in the cosmic microwave background using a succession of instruments in the high-elevation dryness of the South Pole. After more than a year of analysis and checking, the team announced its finding on March 17th at Harvard Observatory, a mile up the street from *Sky & Telescope*.

THE ANNOUNCEMENT Marc Kamionkowski (left) and BICEP leaders Clem Pryke, Jamie Bock, Chao-Lin Kuo, and John Kovac tell the world about finding their primordial treasure. Previously, the earliest direct observation we had of events in the Big Bang was the nucleosynthesis of light elements dating from the first few minutes. BICEP's gravitational waves appear to come from the first 10^{-38} second, arguably the biggest leap of observational improvement in history.

RICK FRIEDMAN



BICEP2 COLLABORATION



GRAVITONS BEHIND THE SKY ***Top:*** **This sky map of the cosmic B-mode polarization patterns was drawn from three years of BICEP2 data. Each black dash shows the strength and direction of the B-mode polarization at a point on the sky. Orange highlights the clockwise curls, blue the counterclockwise ones.** ***Above:*** **A constellation map shows the same area of sky. Your fist held at arm's length (10°) is about ⅔ the height of each map.**

The observatory's historic Phillips Auditorium was packed with scientists, reporters, and TV crews. As the BICEP project's co-leaders ended more than two hours of presentations, MIT cosmologist Max Tegmark (who was not involved in the project) couldn't contain himself. "This is one of the greatest discoveries of all time," he declared. Marc Kamionkowski, a cosmologist at Johns Hopkins University, assured the media that the finding "is as Nobel-Prize-worthy as it gets." Alan Guth and Andrei Linde, who originated and developed inflation physics more than 30 years ago, basked for reporters in what appeared to be the triumphant confirmation of their life work.

The polarization patterns had turned out to be unexpectedly strong. Their strength, and their average angular size on the sky, pin down for the first time when inflation occurred and at what temperature: at 10^{-38} second after the theoretical time zero and at 2×10^{29} °C, meaning an energy of 2×10^{16} GeV — a few trillion times more energy per particle than the Large Hadron Collider can achieve. That's a little earlier and hotter than theorists expected.

The signal's strength means that other teams will have an easier time following up than anyone hoped. It also means opportunities for studying it in finer detail. In this new kind of astronomy, we peer back through what we normally call the Big Bang into a truly alien time of extreme physics beyond anything otherwise possible to test experimentally — perhaps getting a glance into much wider realms that exist before and outside of our universe.

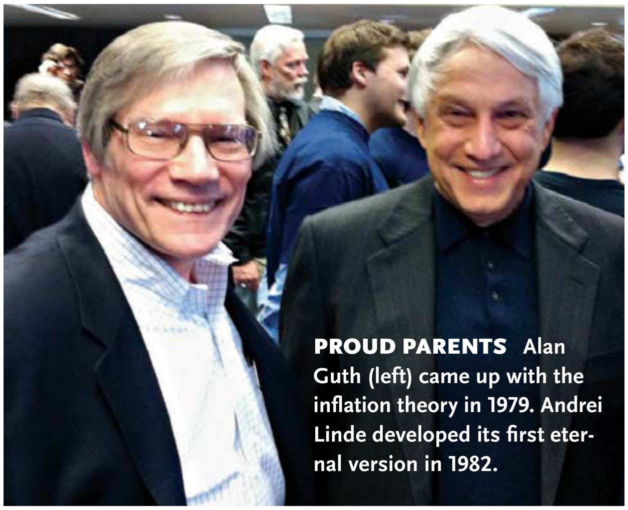
Nearly a dozen groups were hoping to get there first, operating receivers in Antarctica, the Chilean Andes, the upper atmosphere, and in space (*S&T:* Oct. 2013, p. 22). Several should soon confirm or contradict BICEP's findings. The science team for the European Space Agency's Planck probe plans to announce results from its full-sky cosmic-background polarization maps in October or November. The South Pole Telescope, located next to the BICEP installation, should also have something to say by the end of 2014. The Atacama B-Mode Search in Chile, which covers three times BICEP2's sky area, should "be able to weigh in on the matter within the year," says its leader Suzanne Staggs of Princeton. The BICEP team, for its part, is now running a new, five-times-faster instrument called the Keck Array and is preparing BICEP3.

And a much wider, more sensitive, much sharper-seeing polarization mapper that U.S. astronomers were already planning out — the next generation of this new astronomy — now seems sure to be funded and built.

Pulling Up the Picture

All these projects are designed to tease out subtle, second-level features of the Big Bang's dim microwave afterglow that wallpapers the sky. The microwave background comes from long after the cosmic-origin process: 380,000 years after the Big Bang. But its subtle patterns of warm and cool spots carry rich statistical information about the universe in its earlier phases. Ever-improving measurements of these patterns for the last 22 years have been the foundation of modern precision cosmology.

The new wave of experiments goes further to extract not patterns of temperature, but polarization. Like the light blocked by polarizing sunglasses, microwaves can have their electric-field components oriented a particular



PROUD PARENTS **Alan Guth (left) came up with the inflation theory in 1979. Andrei Linde developed its first eternal version in 1982.**

S&T: CAMILLE CARLISLE

way rather than randomly. Many things can polarize the cosmic microwaves, from Earth's atmosphere to dust in the Milky Way to gravitational lensing by distant irregularities in the early universe. But most of this shows up as radial polarization patterns known as *E-modes*. Some of these had already been detected by other experiments.

The gravitational waves predicted to result from exponentially inflating space would result in different, pinwheel-shaped patterns called *B-modes*. These were predicted to be far weaker, perhaps so weak that they could never be detected at all. Moreover, later foreground effects should add B-modes of their own to confuse the picture.

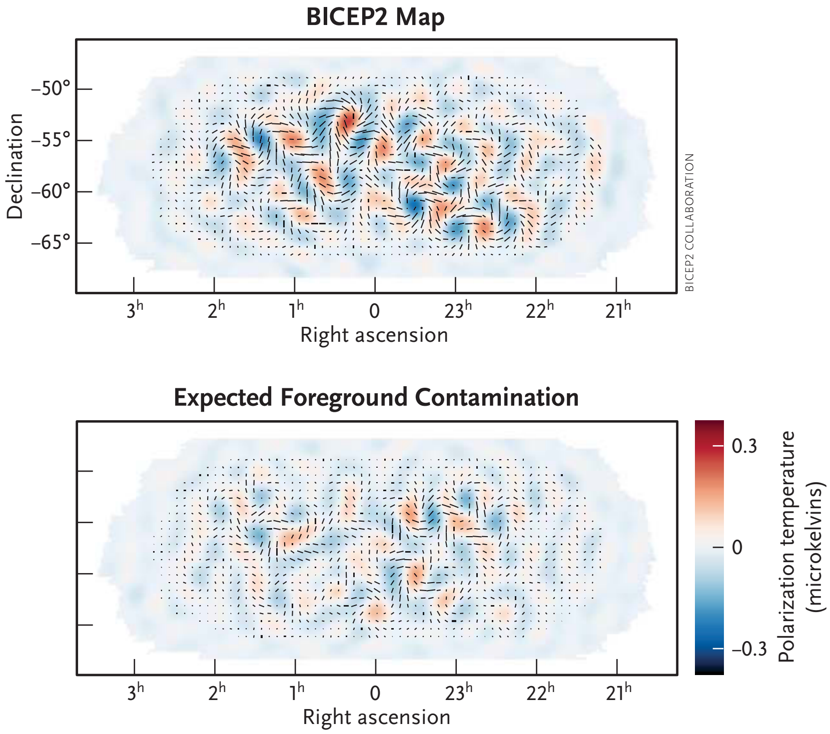
The BICEP team chose a swath of sky in a region known as the Southern Hole for its near total lack of interstellar dust. They succeeded in mapping and removing the E-modes across the field of view. Remaining were B-mode patterns about a tenth as strong, and only a hundredth as strong as the familiar warm and cool patches in the microwave background — which themselves differ in temperature by only a few parts per hundred thousand.

But the B-mode swirls were clear nonetheless. They overpowered the expected B-mode contamination from foreground gravitational lensing (as shown in the map and simulation at right) with a statistical significance of 5.3 sigmas. That means there's only a 1-in-10-million chance that the strong patterns in the map are a statistical fluke. And the swirls are strongest at an apparent width of a couple degrees on the sky, just about what inflation theory predicted.

The strength of the early gravitational waves themselves is denoted by a single number, called *r*. It stands for ratio. It's the ratio of the gravitational-wave distortions *of space itself* to fluctuations of the material *in* the space. It's also called the tensor-to-scalar ratio, for the two types of distortions that these two different effects create. Expect to hear a lot about *r*. It bodes to become as big a deal in the 21st century as the Hubble constant was for much of the 20th.

The BICEP team announced that r is 0.2 ± 0.06, which is staggeringly large. "This has been like looking for a needle in a haystack, but instead we found a crowbar," said co-leader Clem Pryke (University of Minnesota). By comparison, the next-generation project that is being planned was intended to detect an r as small as 0.001, two hundred times weaker.

But already there are signs of complications — maybe problems, or maybe breakthroughs. The Planck science team had already announced finding an upper limit to r of 0.11, working instead from the temperature fluctuations and on smaller angular scales. The apparent conflict could be a statistical fluke. Or maybe r itself changed as inflation progressed, due to an effect that theorists call "running." In fact, the inflationary paradigm *requires* something like this. Something had to make inflation slow and stop, leaving our bubble of ordinary space-time expanding with the fixed quota of matter and energy we



STANDING OUT **The complete BICEP2 polarization map (*top*) shows much stronger B-mode patterns on the sky than could be created by noise and the expected foreground contamination, shown in the simulation below it. The signal stands out with a statistical significance of 10 million to one.**

More Physics Firsts

In the excitement over cosmic inflation, several other big physics firsts in the BICEP discovery went less noticed.

• If the discoverers are right, the BICEP2 map is the first direct observation of **gravitational waves.** Albert Einstein predicted them in 1916 from his general theory of relativity, but until now we've only had indirect evidence for them, in the energy they steal from orbiting pulsars.

• This is the first confirmation that **gravity is quantized.** Physicists assumed it must be, but no one has seen gravitons before. "I think this is the only observational evidence we have that actually shows that gravity is quantized," says cosmologist Ken Olum (Tufts University). "It's probably the only evidence we will ever have."

• This is a detection of **Hawking radiation,** which Stephen Hawking predicted in 1974. Hawking radiation is usually associated with the evaporation of black holes, in the form of particles emitted at a hole's event horizon. But ordinary space also has horizons, a different one centered on each point. These horizons are everywhere, so Hawking radiation should come from every point in space. Today the cosmic horizons are huge and their Hawking radiation is utterly insignificant. But in the universe's first instants, the horizons were tiny and sharply curved. The gravitational waves seen by BICEP are their Hawking radiation.

see in the universe today. But it's still early days, and the BICEP team members, when asked at the press conference, said they do not claim to have discovered running.

From a Series of Successes. . .

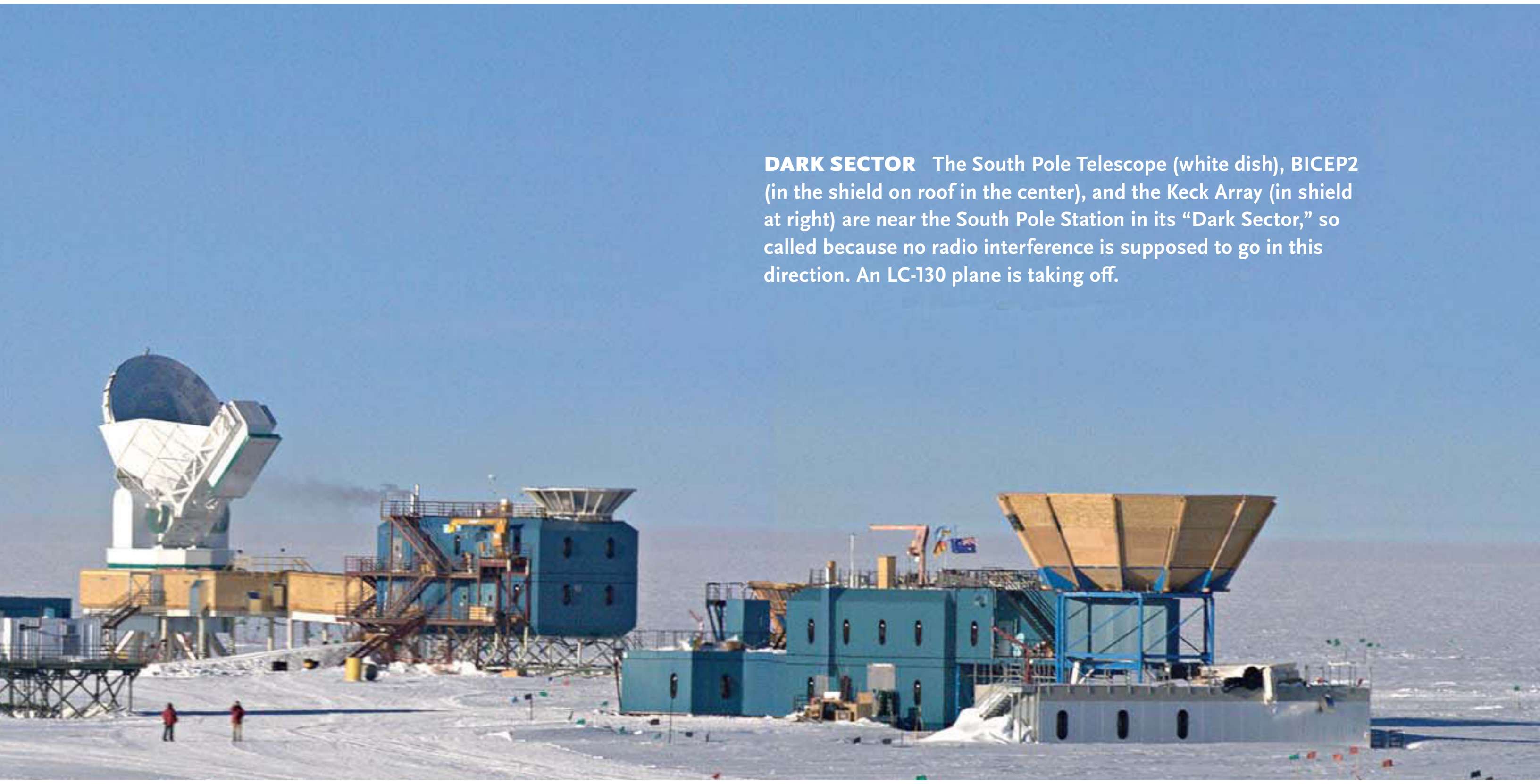
In the 34 years since Alan Guth proposed it, inflation has been a classic example of the scientific process at work. Puzzling observations led to a theory, which made testable new predictions, which proved to be true, which led to refinements of the theory and further predictions.

Guth announced the theory in 1980 as the first physically detailed, by-the-bootstraps mechanism for producing an entire universe from practically nothing. Guth drew upon the idea of a Grand Unified Field breaking apart very early into the strong and weak nuclear forces and electromagnetism. He found that a tiny bit of space could self-expand by at least a factor of 10^{24} in 10^{-32} second or less, while filling with ultradense material drawing on the Grand Unified Field's decay. The regular Big Bang takes over after that. Interestingly, the BICEP2 discovery puts the energy scale of inflation well into the Grand Unified Field range. That may not be a coincidence.

This scenario solved other crucial paradoxes of the original Big Bang. One was the *flatness problem,* or why the cosmic allotment of matter and energy was fine-tuned with fantastic precision to balance between a fast early recollapse (a "Big Crunch") and a fast early expansion away to practically nothing (a "Big Chill"). Inflation also solved the *horizon problem,* or how very distant regions on opposite sides of the sky today can look nearly alike even though in an uninflated Big Bang, nothing can ever have had any common influence on them at all.

Then, starting in 1982, inflation scored perhaps the grandest scientific home run of our time. Cosmologists had long struggled to find a way that today's lumpy, web-like cosmic structure — galaxies, galaxy clusters — could arise from the extremely smooth material that emerged from the Big Bang. What were the gravitational seeds that grew to become today's lumps? Nothing worked. Inflation, physicists realized, gave the stunning answer. Inflation took the microscopic, purely random quantum fluctuations in the smooth material very early and blew them up almost instantly to nearly the masses of galaxies. The normal workings of gravity took over from there, giving us the universe we see today. The numbers worked perfectly. In the subsequent 22 years, virtually every new cosmic discovery has confirmed this picture to greater and greater precision.

Inflation also predicts that the early quantum seeds should have had a size distribution that was nearly equal at all scales, but not quite. The "running" effect required by inflation coming to a halt should have given a slight tilt to the quantum seeds' spectrum of sizes. Theorists predicted that the "spectral index" of this tilt, a value



DARK SECTOR The South Pole Telescope (white dish), BICEP2 (in the shield on roof in the center), and the Keck Array (in shield at right) are near the South Pole Station in its "Dark Sector," so called because no radio interference is supposed to go in this direction. An LC-130 plane is taking off.

STEFFEN RICHTER / HARVARD UNIVERSITY

called n_s, should be just a few percent less than 1.0. In the simplest version of inflation, it should be between 0.92 and 0.98. Last year, the Planck team succeeded in accurately measuring the spectral index from the microwave temperature patches. It is 0.96.

That convinced most wavering physicists that inflation really created the universe. Then came the B-mode discovery. It put an abrupt end to a competing proposal offered by Paul Steinhardt of Princeton. Called the ekpyrotic theory, this had the Big Bang arising from the collision of two 3-D spaces inside a larger superspace. No gravitational waves would have resulted. Steinhardt admits that the ekpyrotic theory is now dead, at least in its original form.

Andrei Linde notes that the high temperature that the BICEP2 team measured for inflation also rules out 90% of the theory's variants that have been proposed in the last 34 years, while leaving his own simpler version standing. But already there are signs of new complications with this. Theorists are furiously at work to find alternatives, and new papers appear almost daily.

. . .to the Multiverse and the Peril of Infinities

The B-mode patterns on the sky represent a look out of our normal space-time into a profoundly alien pre-existence. If inflation's further predictions prove correct, this is a glimpse not into a moment just after a "time zero," but into an opening on vastly older, wider realms.

Most theorists assert that once inflation starts, it must keep expanding overall. It should continue spawning unimaginable numbers of other Big Bangs, creating endless bubble universes as if it were an eternally growing ocean of foaming champaign. This is the *multiverse*.

Says Andrei Linde, "If inflation is there, the multiverse is there. Each observation that brings better credence to inflation brings us closer to establishing that the multiverse is real."

An inflationary multiverse would neatly solve yet another mysterious problem. If you posit that a vast number of big-bang universes exist, perhaps embodying all the possible laws and constants of physics allowed by string theory, you solve the "fine-tuning paradox" that we see in physics itself. This is the mystery of why many physical relations and fundamental constants are adjusted amazingly well to allow any complex organized matter to exist at all, and therefore living observers such as ourselves. If many different universes exist, this mystery goes away. We will necessarily find ourselves living in one of the rare ones that happens to be fine-tuned to allow for life, no matter how infrequent such universes may be.

Some scientists see this anthropic, or self-selection, argument as a cop-out that will sap our motivation to hunt for more direct explanations of various phenomena. Some call the whole multiverse a betrayal of the scientific principle that good ideas should be testable. But there's no reason the cosmos has to be arranged for the benefit of this generation of scientists and their testing capabilities. And as Max Tegmark says, "Parallel universes are not a theory — they're predictions of certain theories."

A bigger problem comes from the idea that if inflation goes on forever, it spawns not just a very large number of big bangs, but an infinite number of them. Nowhere in the real world has any physical infinity ever before appeared. Infinities come up all the time in math that usefully describes the world (that's why calculus was invented). But no measurable physical quantity, such as mass or distance, ever has an infinite value. Unless inflation forces the issue.

And in fact, inflation predicts a second, different kind of infinity closer to home. Even if there is only a single bang and nothing but our own bubble universe (theorists are trying to find a way to make this work), inflation still requires our *own* universe to be infinite in extent. We can't see farther than our 13.8-billion-year horizon, but endless farther reaches must exist beyond it, filled with stars and galaxies pretty much like those nearby. Go far enough, and every possible finite arrangement of atoms, each acting out every quantum event available to it — including perfect, atom-by-atom copies of Earth and its people — not only repeat, but repeat an infinite number of times. Tegmark calls this more immediate version of infinity the "Level I multiverse," and the infinity of other infinite big-bang universes spawned by eternal inflation the "Level II multiverse."

The crisis posed by infinite space is a paradox called the "measure problem." If infinite copies of you exist, for instance, it becomes impossible to assign any probability at all to anything that might happen to you (or to anything else) — because all things happen an infinite number of times, and infinities of this class are necessarily identical. One such infinity can't be larger than another.

The naïve idea that you can just pick a "large enough" finite region, and compare the numbers of things within that, fails to work. In an infinite context, every finite region is itself duplicated an infinite number of times, with an infinite occurrence of all possible outcomes.

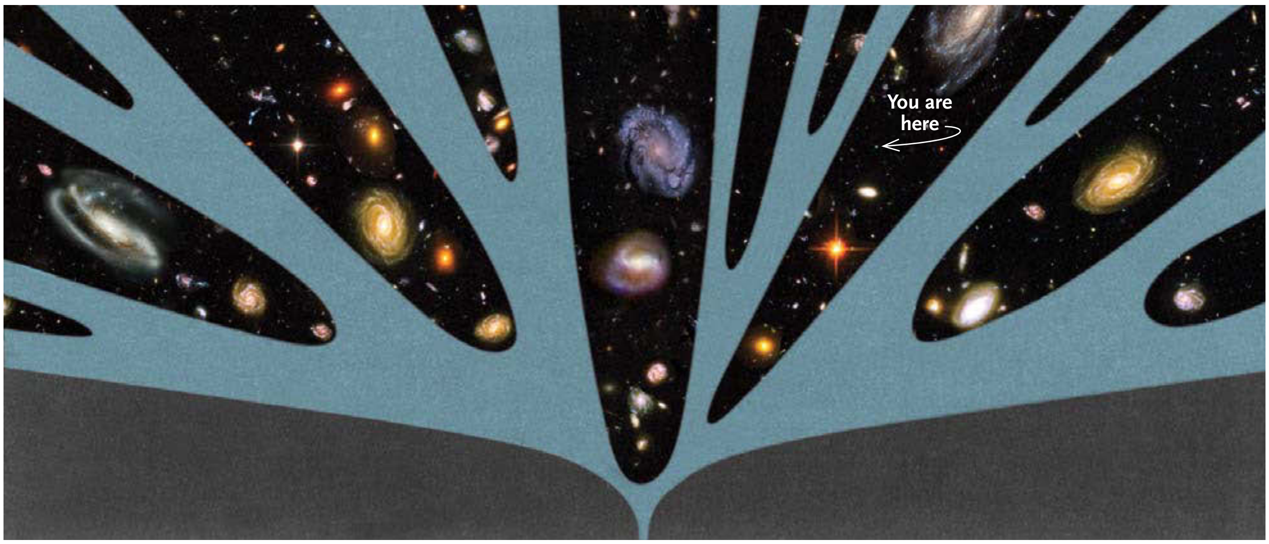
This was just a matter of armchair philosophy before the predictions of inflation started making it pressingly real. Alan Guth, for one, is not very concerned. At the March 17th BICEP press conference, he said that he thinks the measure problem can ultimately be resolved and will go away. Tegmark, on the other hand, says "The measure problem is a terrible embarrassment for modern cosmology. . . . Inflation is saying, hey, there's something totally screwed up with what we're doing. There's something very basic we've assumed that's just wrong. . . . It's telling us that things aren't just a little wrong, but terribly wrong." He predicts that, with the inflationary universe becoming more and more inescapable, coping with the infinities it requires will become the central problem in cosmology and physics going forward.

Stay tuned. ✦

FURTHER READING

More news of cosmology's "spring cleaning" after the BICEP2 announcement keeps appearing. See our choice of links, including the BICEP team's original discovery papers, at **skypub.com/july2014inflation**.

S&T *senior editor* ***Alan M. MacRobert*** *has been following quantum proposals for the Big Bang's origin, and their suggestions of a multiverse, since the first was published by Edward Tryon in 1973.*



ETERNAL INFLATION **In this symbolic representation, separate big-bang universes (black) begin and expand forever in an eternally inflating outer matrix of superdense "false vacuum" (blue). Time runs from bottom to top. There may or may not be a particular start, but once the process gets going, it never ends.**

SOURCE: MAX TEGMARK, *OUR MATHEMATICAL UNIVERSE*

CITIES from Space

Images taken from space can tell us a lot about light pollution.

Scott Kardel

In 1962, as NASA astronaut John Glenn made his historic orbit around Earth and crossed into darkness, residents of Perth, Australia vied for his attention by leaving their lights on. The city's mayor argued that it was "morally wrong for public money to be wasted" in lighting the night, but he was overruled. Glenn easily spotted them on his Mercury flight and again years later during his 1998 Space Shuttle flight.

These days, no one is leaving their lights on just for the astronauts, yet the crews of the International Space Station (ISS) have plenty of lights to see. Their photography is documenting our cities in ways that Glenn never could.

ALL IMAGES COURTESY OF EARTH SCIENCE AND REMOTE SENSING UNIT / NASA-JOHNSON SPACE CENTER

LAS VEGAS, PHOENIX & TUCSON ESA's Cupola module was added to the ISS in 2010. It greatly expanded the station's window space and enabled wide-field photography. This shot shows the Baja Peninsula, coastal cities of Southern California, and cities in Nevada and Arizona. Compare the intensity of the lights of Las Vegas, Phoenix, and Tucson. Over-the-top lighting is embraced in Las Vegas, so its glow can be seen on the ground from hundreds of miles away. The illumination of Vegas does not stay in Vegas. In contrast, Tucson has nearby observatories. The city adopted its first outdoor lighting ordinance in 1972. The need for dark-sky-friendly lighting is part of the community's ethos. Tucson has a similar population to Las Vegas, but their difference in lighting intensity stunningly shows that outdoor lighting controls make a huge difference.

Pointing a camera at Earth's night side from within the space station, which orbits Earth at 17,500 miles (28,000 km) per hour, isn't easy. Astronauts must compensate for the station's orbital motion to avoid trailed images of city lights. NASA astronaut Don Pettit introduced a barn-door tracker on board the ISS to cancel the orbital motion. This enabled him to take long-exposure photos of Earth's city lights and capture details as fine as individual city blocks without blurring

In 2012, European Space Agency astronaut André Kuipers installed NightPod, a device that automatically tracks individual objects on Earth. As a result, ISS images are much more detailed than the famous Earth at Night photos from the Defense Meteorological Satellite Program (DMSP) or even the new "black marble" images from the Suomi National Polar-orbiting Partnership (Suomi NPP) satellite.

Although the astronauts generally don't take photos with scientific rigor, their images document the misdirected light responsible for light pollution. More thoughtful use of nighttime lighting would significantly diminish the view of city lights from space and make our night skies dark again. To minimize light pollution at night, outdoor lights should be pointed downward, used only when needed, and used only in the amount that's needed.

You can download images of individual cities from NASA's Gateway to Astronaut Photography of Earth website (**http://eol.jsc.nasa.gov**). You can even stack frames of nighttime images together much in the same way you'd combine images of the Sun, Moon, or planets to create more detailed pictures. The results reveal the stunning fact that city lights vastly outshine the stars even when viewed from space. It doesn't have to be that way. With more responsible policies, we can limit the footprint of our lighting, and make the stars easier to see from the ground and from space. ✦

*Scott Kardel defends the night as the managing director of the International Dark-Sky Association (**http://darksky.org**). Follow him on Twitter **@darkskyscott**.*

WASHINGTON, D.C. Many would agree that a lot of things need to be fixed in Washington, D.C. Outdoor lighting might not be at the top of the list, but it's so poorly executed that the city's borders are visible at night from space. Although the intense monument lighting on the National Mall illuminates the night, ISS images show that area to be the darkest in D.C. aside from the region's waterways. Washington's borders are visible because there is essentially no unshielded lighting in the city, yet shielded lighting is used literally across the street in the suburbs. The post-top acorn lamps that dominate the D.C. landscape scatter their light in every direction, making them wasteful and bad sources of glare and skyglow.

THE TWO KOREAS *Left:* This dramatic image highlights the role of economic development. At the lower right, most of South Korea is brilliantly illuminated, with Seoul being the most conspicuous city. In contrast, North Korea is almost totally dark, with only a patch of light marking the capital Pyongyang. The demilitarized zone separating the two Koreas is easily seen from space. The gross domestic product of South Korea is about 100 times that of its northern neighbor. Although North Korea's night sky must be exceptionally dark, very few light-pollution-control advocates would call for such extreme levels of darkness in populated areas.

BEIJING *Below:* The Chinese capital is home to 21.2 million people. The image from ISS shows that it's laid out in an efficient grid system. Like most cities, the orange glow comes from high-pressure sodium lighting, one of the worst sources of light pollution. Beijing is also peppered with bright, unshielded light sources of various colors atop its many high-rise buildings. The bright area at right is the Beijing Capital International Airport, one of the busiest airports in the world. *Right:* This wide-field image shows Beijing (upper left) along with two other large cities: Tianjin (population 14 million) at the lower right and Lanfang (4 million) between them.

TOKYO Tokyo spreads outward from Tokyo Bay. The city is dotted with intense white light set on a background of bluish-green. White lights come from a variety of sources, whereas the bluish-green color comes from mercury-vapor lamps, which were once common in the U.S. It's now illegal to buy these lamps in the U.S. and they will soon be banned in the European Union. Traditionally, they have been used in unshielded fixtures. Their old, unshielded design, along with their bluish cast, make them inefficient sources that contribute greatly to light pollution. LEDs are the wave of the future for Tokyo and most cities as they replace older lighting sources. LEDs save energy and are highly directional, keeping their light pointed downward. The best LED streetlight conversions use only the proper amount of illumination, have light that is low in color temperature (3100K, around 5100°F or 2800°C), and incorporate after-hours dimming.

EL PASO & CIUDAD JUÁREZ The differences in lighting between the city of El Paso, Texas (right) and the Mexican city of Ciudad Juárez (left) are striking from space. El Paso uses mostly full-cutoff lighting whereas Ciudad Juárez does not. Historically, the two cities have been divided by the Rio Grande. Now, the international border is illuminated and easily visible from space. El Paso has a population of about 700,000 and Ciudad Juárez has about twice as many people.

BERLIN Some 80% of Berlin's streetlights were destroyed during World War II. The city was divided after the war and lighting was rebuilt under different governments. Berlin was reunited in 1989, but this photo shows that the former East Berlin (right) and West Berlin (left) are still marked by their differing streetlights. Orange high-pressure sodium lights dominate in the East whereas gas lamps are found in the West. The old-style gas lamps may soon be gone because the city is planning major changes to its lighting.

The Case for Structured Observing

Tristan J. Schwartz

ILLUSTRATION BY LEAH TISCIONE

Rigorous goals and methods can enhance your stargazing experience greatly.

In my 20 years of experience in the hobby of amateur astronomy, I have seen almost as many ideas of what it means to be an astronomer as there are participants in the pastime. Some hobbyists focus on the technical artistry of capturing extraordinary astrophotos. Others favor participation in citizen-science projects. I have learned, however, that most visual observers, regardless of the kinds of objects they like to observe, can be classified either as *freeform observers* or as *structured observers*.

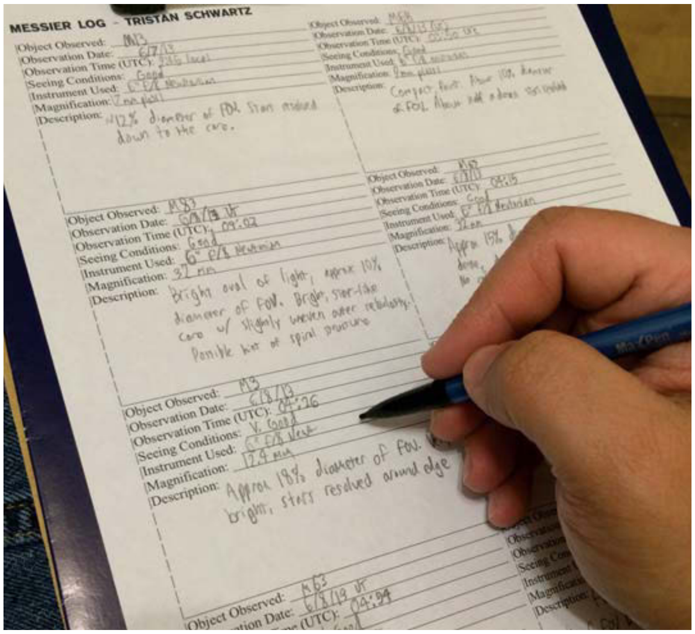
Freeform observers typically haul out their telescopes when the mood strikes them. They don't adhere to a specific schedule or plan, don't set particular observing goals, and rarely keep observing logs. Freeform observers are compelled by the Zenlike relaxation of the hobby and the majesty of the night sky, eschewing rigid goals. Freeform observing can be extremely relaxing, and there's a lot to be said for it.

Structured observers, by contrast, are astronomers with a plan. They set specific goals with elaborate accompanying checklists. They keep extensive logs documenting the objects observed, equipment used, atmospheric conditions, and other minutiae. Frequently these logs include sketches of the views they see in the eyepiece. Every facet of the experience is cataloged and archived.

For my first 18 years as an amateur astronomer, I had my flag planted firmly in the former camp. I wasn't out to impress anybody; I preferred to open my star atlas at random and let the chips fall where they may. In the last two years, however, my approach to the hobby has changed, shifting further and further into structured pursuits. I have come to appreciate the advantages of setting concrete personal goals and adopting detailed observing plans. As a result, I have gotten more out of my observing sessions in the last two years than I did during the previous decade.

The reason for this late conversion seems almost silly in retrospect. Last year I entered into an informal game of one-upmanship against some members of my astronomy club over who could rack up the most Astronomical League observing awards (see page 38). Regardless of my initial reasons, this exercise resulted in more and more of my leisure observing becoming structured. I began to see the benefits of goal-oriented plans, and I doubt my observing routines will ever be the same.

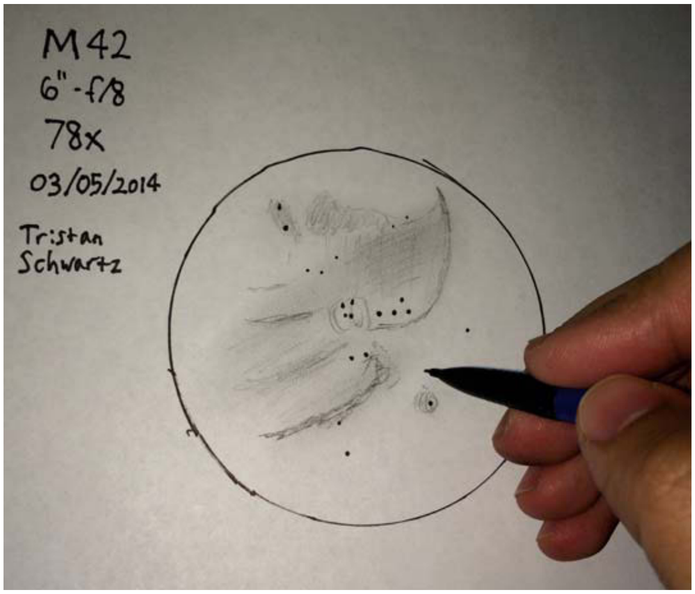
Even if it ultimately isn't for you, I think that every amateur astronomer needs to give rigorous planning and log-keeping the old college try. It might just enrich your experience more than you ever thought possible. Accordingly, I have prepared a list of the top six arguments in favor of structured observing.



The author fills in an entry in his logbook for the Messier Program.

Motivation

I sometimes have a hard time mustering the energy to haul out my telescopes and drive to a dark-sky site, or even to set up in my own backyard — and I know I'm not the only amateur astronomer who feels this way. Having a busy personal and professional life makes it difficult to devote time and energy to your hobby. Setting personal goals such as creating detailed eyepiece sketches of the entire Messier catalog or observing all planetary nebulae visible within your telescope's theoretical magnitude limit can provide the impetus you need to get out there more often. The sense of accomplishment from completing observing goals like these is enormous; it makes you feel like you can conquer the universe.



TRISTAN J. SCHWARTZ (2)

The author tries his hand at sketching Messier 42, the Great Orion Nebula.

Expanding Your Horizons

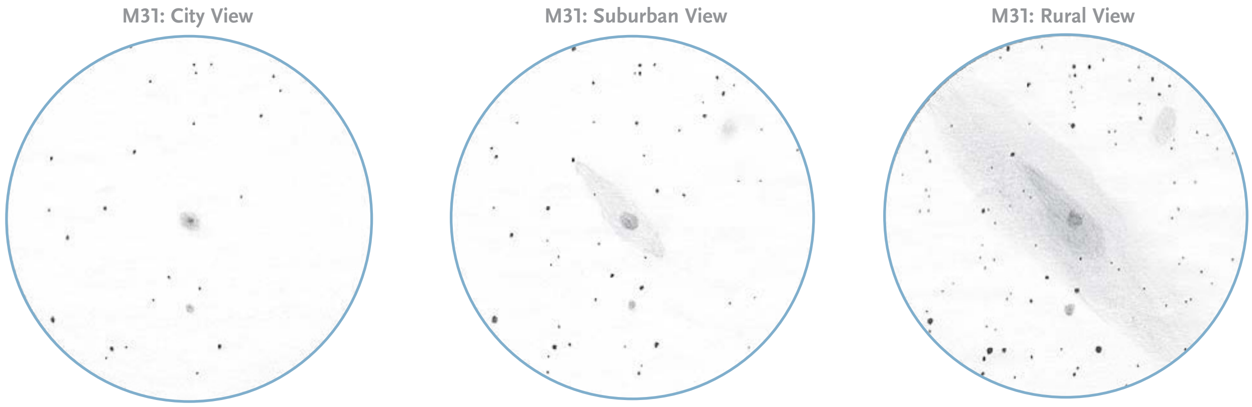
An observing program forces you outside your comfort zone. Instead of observing the same objects over and over, you'll track down things you would have never otherwise considered. For instance, if you set out to observe all planetary nebulae within your telescope's theoretical magnitude limit, you wind up seeing many nebulae that are rarely mentioned in observing books. The sky is full of surprising, hidden gems that aren't part of the prominent Messier or Caldwell lists. Diving deeper into the NGC (*New General Catalogue*) or IC (*Index Catalogue*) can reap surprising rewards.

Deeper Appreciation

Although you see will more objects in the long run if you adopt an observing program, you will probably take a slower pace on a nightly basis. When you're exploring new territory, you're not likely to rush from object to object, as everybody tends to do when running through old familiars. You can devote more attention to the object in front of you, teasing out finer and finer details. You will often discover that your equipment is far more capable than you ever thought.

Improving Your Skills

Taking the time to write detailed notes and sketch an object yields dividends by training your eye to pull in subtleties you otherwise wouldn't have seen. It also leads to a more systematic experimental approach. For instance, if you're studying nebulae, you will probably find yourself using filters more often, and using several different filters



S&T: TONY FLANDERS (3)

***S&T* associate editor Tony Flanders decided to make the best of his urban location by comparing the views of all the Messier objects through two telescopes at different levels of light pollution. This project led directly to his job at *S&T*. His logbook remains one of his most precious resources when editing other observers' articles. These sketches show three views of the Andromeda Galaxy (M31).**

to discern contrast between regions of an otherwise featureless nebula. Likewise, planetary observers will have more reasons to use color filters, which turn out to be very useful once you try sketching fine details on the planets. Have you been looking for an excuse to drop money on one of those fancy filter slides? You may have found it!

Awards and Bragging Rights

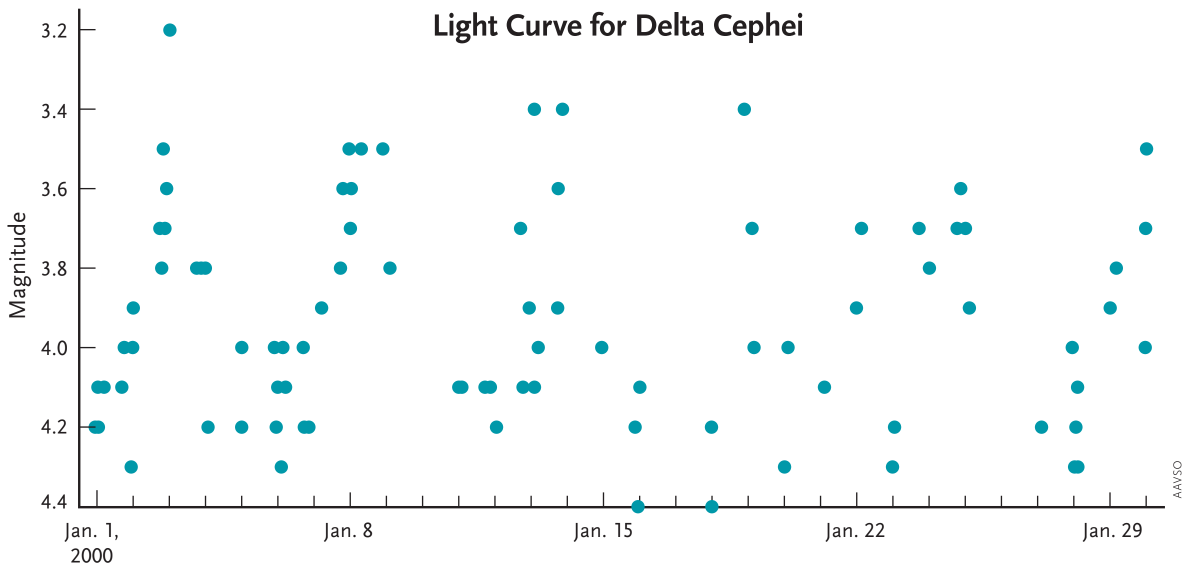
Whether you know it or not, you're probably already a member of the Astronomical League (AL). Membership in most local astronomy clubs includes automatic membership in the AL. Think of it as an organizational body for astronomical societies across the U.S.

The AL has dozens of observing programs dedicated to building structured observing practices and honing observing skills. You're free to participate in them when you're a dues-paying member of the AL or an affiliated society. These observing programs vary in skill level from beginner to advanced, and include projects and object lists to suit a huge range of interests, as described on page 36. Completion of each program results in a certificate signed by the AL president suitable for framing, having your name listed in the awardees archive and published in *The Reflector* (the League's quarterly magazine), as well as a really snazzy lapel pin exclusive to recipients of that award. Collecting AL awards is a lot of fun, and serves a greater purpose of getting you out observing with greater frequency and honing your skills. It also fosters healthy, friendly competition within astronomy clubs.

The Astronomical League's variable-star observation program is even used for data gathering by the American Association of Variable Star Observers (AAVSO), which leads to the big one . . .

A Steppingstone to Citizen Science

Crowdsourcing is a modern buzzword frequently used in venture capitalism and research. In a nutshell, it means outsourcing a task to the willing masses. Crowdsourced



AAVSO

Want to know how the famous variable star Delta Cephei behaved in January 2000? This light curve from the American Association of Variable Star Observers represents the combined data from 21 dedicated skywatchers worldwide.

entrepreneurship is prominent in the public sphere due to websites such as Kickstarter and Indiegogo, which enable inventors and creative professionals to get their ideas off the ground without the traditional system of loans and venture capital. Crowdsourced research finds its expression in campaigns such as Galaxy Zoo, SETI@home, and PlanetHunters.org (March issue, p. 18).

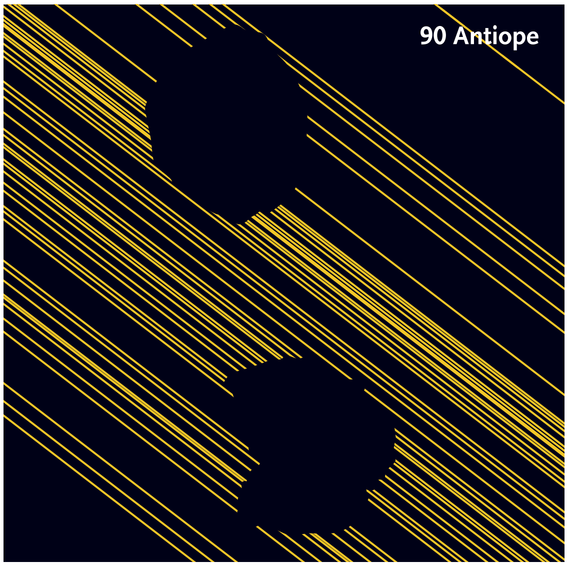
Crowdsourcing, however, is nothing new to amateur astronomy. ALPO (the Association of Lunar and Planetary Observers) has been crowdsourcing scientific data gathering to the amateur community since shortly after World War II, and the AAVSO has been doing the same for more than a century! This tradition of crowdsourced citizen science has continued through a variety of amateur research projects devoted to photometric light curve analysis of asteroids and comets, a pursuit that may even have the long-term potential to help save our species from catastrophic impacts.

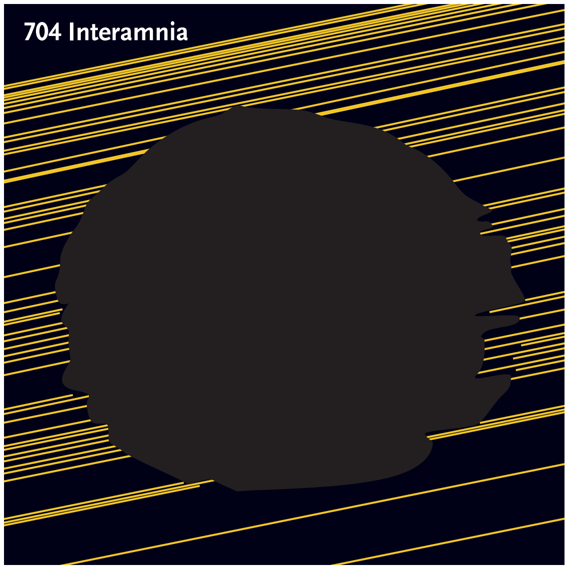
The most important trait for successfully contributing to citizen research is discipline and well-developed organizational and observing skills. Learning to structure your observing pursuits is critical to gathering good, usable data, and participating in the Astronomical League's observing award programs is a great way to learn this.

Citizen research is perhaps the most rewarding pursuit in all of amateur astronomy; it gives an intoxicating sense of pride and accomplishment. Contributing to real, ongoing scientific data gathering allows you to blur the line between "amateur" and "astronomer," giving you a footing one step closer to legendary observers such as William Herschel, Edward Emerson Barnard, and Clyde Tombaugh, all of whom started simply as deeply devoted enthusiasts. Citizen science is proof that fanatical amateurs pooling their research and resources are collectively capable of greatness.

Do I still sometimes go out without a plan, opening my atlas at random and letting the chips fall where they may? Of course I do! But I have found that my forays into structured observing have enhanced even my freeform sessions enormously. I take things at a slower pace, taking more time to soak up the view. I also find myself returning to familiar celestial haunts far less often, instead choosing to seek out unexplored territory. All told, dipping my toe into a more clinical, scientific approach to the hobby has enriched every aspect of my observing experience. I strongly encourage all of my fellow freeform observers to give it a try. It may change the way you look at the sky forever. ✦

***Tristan J. Schwartz** is a current member of the Colorado Springs Astronomical Society and was a guest lecturer at the 2013 Rocky Mountain Star Stare. Tristan is one of the chief designers of "Origins," a space-science exhibit at the Arizona Museum of Natural History in Mesa, where he formerly conducted a number of astronomy outreach programs.*





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

Timing occultations is one of the simplest and most effective ways to contribute to astronomical science. The shapes of these asteroids (one of them double) were determined by multiple observers with video cameras or stopwatches.

Are Observing Programs for You?

Ted Forte

The Astronomical League has a project for every taste and skill level.

IT'S A CLEAR NIGHT. Your scope is set up and pointed skyward. You're ready to start your observing session. And then comes that moment of indecision: What am I going to observe tonight?

If you have ever asked yourself that question and found that the answer was "the usual things" — or worse, "I don't know" — then let me suggest tackling an Astronomical League observing program.

If you're a member of an astronomy club, there's a good chance that you are also a member of the Astronomical League; more than 240 astronomy clubs are member societies. Individuals, too, can join the League as members at large. The forty-plus observing programs (formerly known as observing clubs) are one of the great benefits of membership in the League.

More than just a list of objects to observe, an observing program offers a specific goal to work toward and comes complete with some well-earned bragging rights. The recognition of your fellow hobbyists is marked with a certificate, a lapel pin, and a spot on the awards list published in the League's quarterly newsletter, *The Reflector*, as well as permanent honors on **www.astroleague.org**. A great many observers find a source of pride and accomplishment in earning these awards.

There are a host of benefits to be gained by working the programs. They will help you develop new observing skills and introduce you to objects that you might otherwise never encounter. The logging requirements will foster better note taking. The requirement to describe or sketch objects will improve your eye for detail and make you more observant. And in addition to improving your observing skills, these programs may introduce you to aspects of astronomy that you had not previously encountered, sparking new interests and greater understanding of the science behind the hobby.

There seems to be a program for almost any observing interest, skill level, or degree of commitment. The observing lists are themed. They're typically comprised

The author displays an impressive collection of pins for the Astronomical League observing programs that he has completed. See the key chart below to identify each program. Some have been renamed or reorganized since he received the pin.

TED FORTE

of objects that are either of similar type: globular clusters, open clusters, or planetary nebulae, for example, or that have some historical association, such as the Messier, Galileo, and Herschel programs. There are programs designed specifically for novices, such as the Constellation Hunter and Universe Sampler programs. Children under 10 can complete the Sky Puppy Program. At the other extreme are the Flat Galaxies Program and the Galaxy Groups & Clusters Program, advanced target lists that will challenge even the most experienced observers.

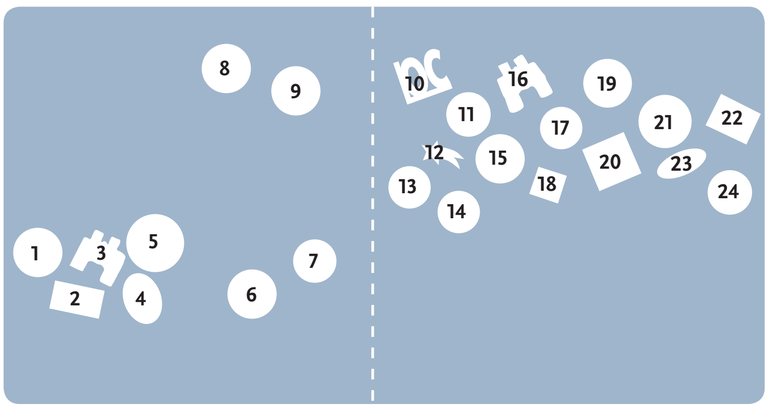
The requirements vary considerably. The Messier and Caldwell programs are designed to encourage observers to learn their way around the sky. As such, they require that traditional star-hopping methods be used to find the targets. Most of the programs, however, allow the use of Push To or Go To device-aided technology to locate objects. Star-hopping is still generally encouraged — nearly all the programs acknowledge manual location as a particularly noteworthy accomplishment. But the emphasis is more on observing objects than on finding them.

Several of the programs encourage observers to sketch what they see, but only a few actually require sketches. You shouldn't be put off by a sketching requirement, because no matter how hopeless your artistic talent, your sketches will be accepted.

Imagers aren't left out either. Several of the programs can be completed by imaging the objects rather than observing them visually. Indeed, a few of the programs were designed specifically with astrophotographers in mind.

Completing the program means observing the required objects and recording those observations in a rather specific way. Again, the requirements vary, but there are some universal aspects to the logs. The date and time of the observation and an estimate of the seeing and transparency for the session are pretty standard requirements. Customary, too, are the aperture of the telescope, the magnifications employed, and a description of the object.

1. **Planetary Nebula Program**
2. **Urban Observing Program**
3. **Binocular Messier Program**
4. **Outreach Award**
5. **Arp Peculiar Galaxies Program**
6. **Comet Observers Program**
7. **Lunar Program**
8. **Double Star Program**
9. **Sunspotter Program**
10. **Open Cluster Program**
11. **Carbon Star Program**
12. **Master Outreach Award**
13. **Planetary Transit Special Award**
14. **Lunar II Observing Program**
15. **Messier Program**
16. **Deep Sky Binocular Program**
17. **Planetary Program**
18. **Herschel II Program**
19. **Herschel 400 Program**
20. **Globular Cluster Program**
21. **Caldwell Observing Program**
22. **Local Galaxy Group & Neighborhood**
23. **Galaxy Groups & Clusters Program**
24. **Flat Galaxies Program**



The A.L. programs are serious, but some are also whimsical. Items 5 – 8 in the popular Lunar Program are observing and sketching the Man, Woman, Cow, and Rabbit on the Moon. Program coordinator Steve Nathan provided the sample sketches shown here and on the A.L. website.

STEPHEN A. NATHAN / ASTRONOMICAL LEAGUE

Beyond that, many programs require the observer to classify the object by some specific scheme: estimating the Trumpler class of an open cluster is an example. All of the requirements are designed to improve the observer's skill, encourage careful observation, and promote meticulous note taking.

The most popular observing program, by far, is the Messier Program. In fact this has become almost a rite of passage in some astronomy clubs and is, more often than not, the first program attempted. Observers are expected to star-hop to any 70 of the objects from Charles Messier's catalog to earn a certificate. The rules make it quite clear that no object-locating devices are allowed. Finderscopes and unit-power finders such as Telrads are fine, of course. But Go To, Push To, and setting circles (both mechanical and electronic) are forbidden. Smartphones and tablets are fine if you just use them to display star charts, but not if you use their built-in compasses and accelerometers to locate objects. The intent is to encourage and reward the effort of learning the night sky.

To earn an Honorary Certificate and an attractive lapel pin that depicts Messier's own signature monogram, the observer must locate and observe all of the Messier objects. For a novice observer, retracing the discoveries of Messier and his contemporaries using nothing more than a star chart and a finderscope is a significant accomplishment, and it's accompanied by a remarkable transformation. One cannot help but learn to recognize the constellations and the brightest stars of the Northern Hemisphere while seeking out the 110 objects. By the time the logs are submitted for the award, the sky has become a familiar place, and the observer has become a confident member of an exclusive circle of sky-savvy observers.

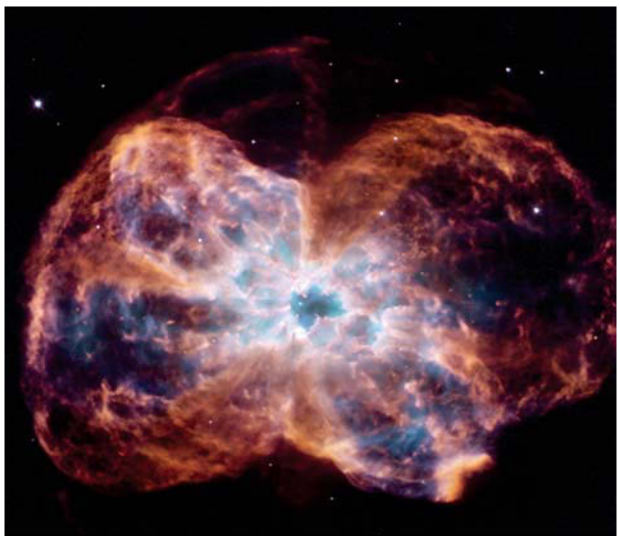
The late British astronomy icon, Sir Patrick Caldwell Moore, inspired another popular observing program by authoring a list of objects that appeared in a December 1995 *Sky & Telescope* article. The Caldwell Catalog, as that list has come to be known, comprises the target list for the only other A.L. observing program that must be accomplished in the traditional way.

League members who complete five required observing programs (the five most popular ones) and five more programs of their choice earn special bragging rights in the guise of the Master Observer Award. As I write this, fewer than 135 observers have earned the master observer designation.

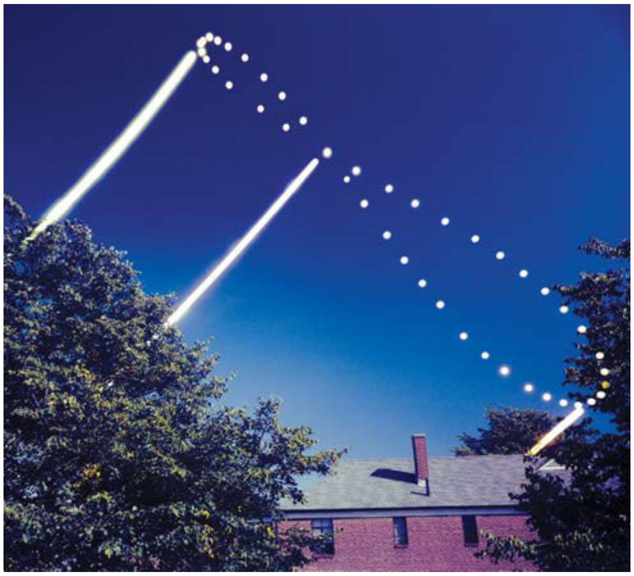
The value of these observing programs and awards as a motivational tool to re-energize your astronomy club should not be overlooked. They can enliven your club's observing sessions by serving as frameworks for group projects and training venues for novice observers.

A little more than a decade ago, I was witness to

The Planetary Nebula Program, which is coordinated by the author, includes many favorites such as the Ring, Dumbbell, and Helix, which is shown at near right. It also includes little-known gems such as NGC 2440 in Puppis, shown at far right.



NASA / NOAO / ESA / STSCI / M. MEIXNER AND T. RECTOR (HELIX) / K. NOLL (NGC 2440)



The Analemma Program requires you to observe the Sun's position at the same time of day over the course of a year, and use the information to calculate various orbital data. But you're not required to capture each of the Sun's positions on a single piece of film, as in this image by *S&T* senior editor Dennis di Cicco.

an utter makeover of my own southeastern Virginia astronomy club created by a concentrated focus on these observing programs. Once a few prominent members of the Back Bay Amateur Astronomers started earning these awards, with a suitable fuss and ceremony accompanying their presentation, more and more members started to try their hand at them. They became the hub of our observing sessions, and attendance at our monthly Skywatch star parties spiked, as members were eager to work on their awards. The best part was that new members — novice observers — were getting out under the stars with ambitions to find and observe lists of objects and were being given expert guidance by other members, who a short time before had been novices themselves.

The motivational impact didn't stop at just completing existing programs. Creating a new program became a stimulating club project. All of the Astronomical League observing programs start as the brainchild of a League member or member society. In my own case, it was disappointment over not having a program dedicated to my favorite type of object, planetary nebulae, that impelled me to inquire of Bob Gent, then League president, why there wasn't a Planetary Nebula Program. His answer — that it didn't exist because I hadn't created it yet — was both a revelation and a challenge. After that challenge was relayed to my astronomy club, we were able to motivate a considerable portion of our membership toward building the observing program. Each observing program in the League's repertoire, no doubt, has a similar story.

KEN CRAWFORD

NGC 4565 is the brightest and best-known of the 200+ galaxies in the challenging Flat Galaxies Program.

S&T: SEAN WALKER

Most of the A.L. programs have canned target lists, but some, such as the Comet Observers and Asteroid programs, encourage you to select your own targets.

Whereas most of these observing programs require that you be a member of the Astronomical League to earn an award, the Herschel 400 Program is an exception. So if you're not currently a member of the League, you can start there. The idea for a Herschel program was inspired by a letter written to *Sky & Telescope* by the prolific astronomy writer James Mullaney. He suggested that the objects in Sir William Herschel's original catalog would provide a challenging and worthy observing project. Members of the Ancient City Astronomers in St. Augustine, Florida, agreed. They selected what they considered to be the 400 best objects out of Herschel's 2,500-object catalog to create the program that has become a traditional "next step" after the Messier list.

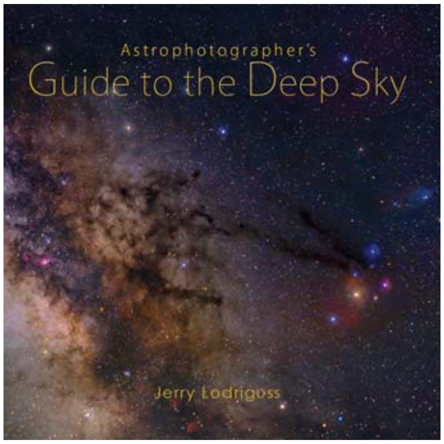
I opened this commentary with a question, asking if you ever experience that bit of trepidation at the start of your observing sessions — that nagging remorse that a clear night might not be put to its best use for want of an exciting observing plan. I think that beginners and experts alike can find inspiration and a renewed sense of purpose in these observing programs. More important, you just might find that they're a lot of fun. ✦

Contributing editor ***Ted Forte*** *works on completing observing programs from his backyard observatory near Sierra Vista, Arizona. He is the coordinator of the Astronomical League's Planetary Nebula Program.*

New Product Showcase

▸ **COMA FIX** Explore Scientific unveils its new HR Coma Corrector ($299.99) for visual and photographic use. This 2-inch unit inserts into your Newtonian telescope's focuser in front of the eyepiece or camera, correcting distorted stars near the edge of the field due to coma and field curvature. Its four-element apochromatic design produces pinpoint, color-free stars in short-focal-ratio Newtonian reflectors as fast as f/3. Users can fine-tune the corrector position with its integrated helical focuser to get the best performance for their equipment. The HR Coma Corrector accepts 2-inch eyepieces, and comes with additional T-Thread and 48-mm threaded adapters to firmly attach heavy cameras.

Explore Scientific
621 Madison Street, Springdale, AR 72762;
1-866-252-3811; www.explorescientific.com



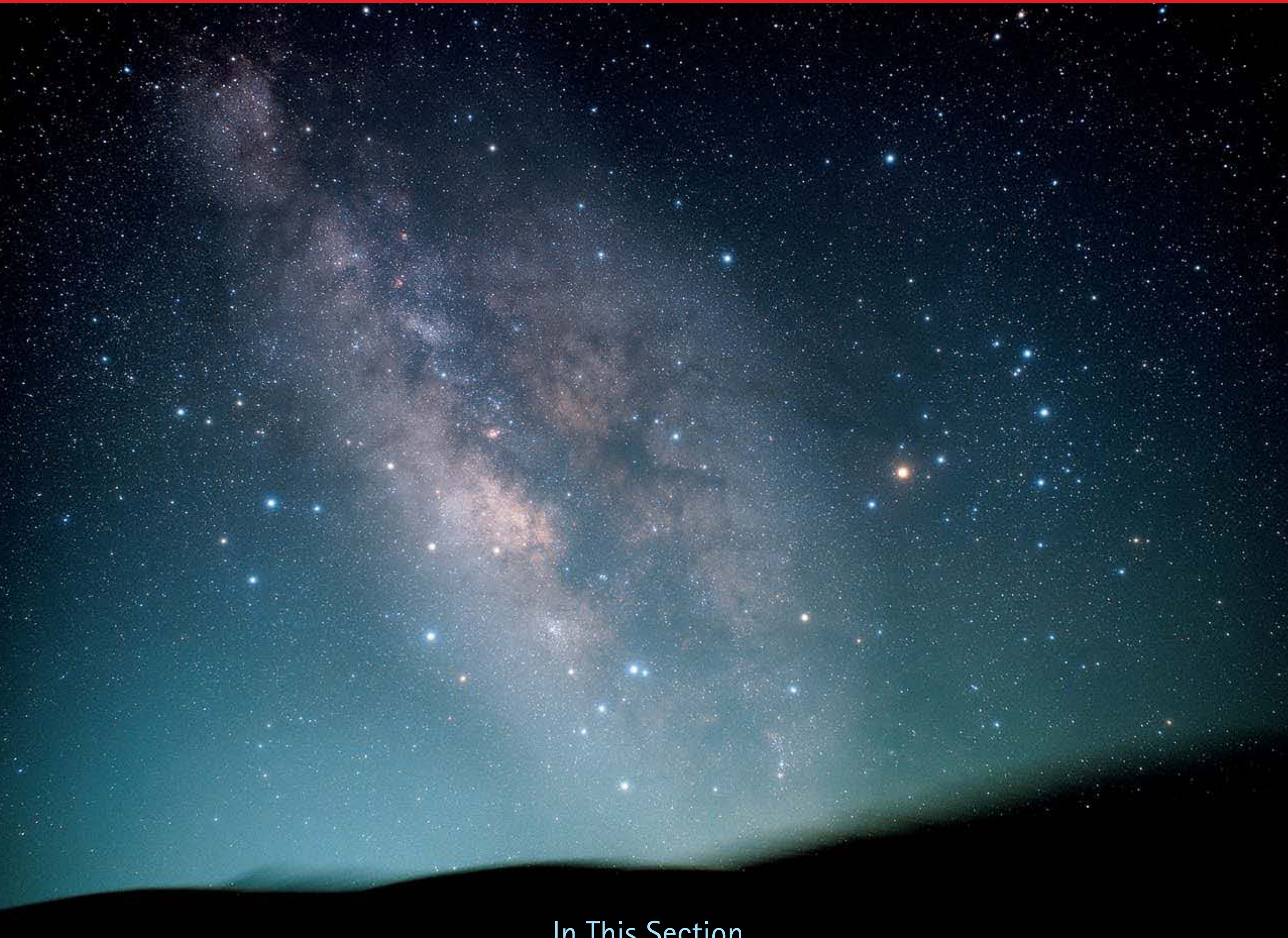
◂ **IMAGING PLANNER** Looking for something to shoot tonight? Astrophotography expert Jerry Lodriguss's new e-book, *Astrophotographer's Guide to the Deep Sky*, can help you choose your targets wisely. Available for $39.95 on CD-ROM, it provides you with detailed information and examples of the many beautiful objects in the sky that you can photograph with your own equipment, from the most interesting wide-angle vistas to close-ups of galaxies, nebulae, and star clusters. *Astrophotographer's Guide to the Deep Sky* contains an all-sky constellation chart with clickable links to each individual constellation and the most interesting objects within them. A master list of objects includes 500 of the most photogenic galaxies, nebulae, supernova remnants, star clusters, and constellations. This list can be sorted by season, object name, type, constellation, right ascension, and focal length. Further information is available for more than 275 select objects visible from the Northern Hemisphere. These targets are displayed on individual pages with added photographic information and details.

Catching the Light
http://www.astropix.com/AGDS/INTRO.HTM

DEEP IMAGER Atik Cameras unveils the Atik One 6.0 CCD camera ($3,295). This compact camera design features the exceptionally sensitive 6-megapixel Sony ICX694AL monochrome CCD of 4.54-square-micron pixels in a 2,750 × 2,200 array. The camera's sealed chamber is purged with high-purity argon to ensure a dry, condensation-free environment. Its thermoelectric cooling is capable of stable operating temperatures to –38°C, helping to limit additional noise in your CCD images. The Atik One 6.0 also includes an internal 5-position filter wheel with a mechanical shutter installed as close as possible to the CCD detector, reducing back focus requirements. Each purchase comes with a 3-meter USB 2.0 cable, 1.8-meter power connector, and CD-ROM with control software, drivers, and PDF manual. See the manufacturer's website for additional options.

Artemis CCD Limited
Unit 8 Lodge Farm Barns New Rd., Norwich, NR9 3LZ, UK
www.atik-cameras.com

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



In This Section

PHOTOGRAPH: AKIRA FUJII

The dark Prancing Horse Nebula, discussed on page 60, floats near the center of the Milky Way's Ophiuchus Bulge, across the Great Rift from the Great Sagittarius Star Cloud.

Additional Observing Articles:

OBSERVING

Sky at a Glance

JULY 2014

3 **Earth** is at aphelion, farthest from the Sun for 2014.

4, 5 **Evening:** Ceres and Vesta appear just 10′ apart in the sky; see page 50.

5 **Evening:** The half-lit Moon is very close to Mars as seen from North America; see page 48. The Moon occults (hides) Mars during daylight in Hawaii and at dusk or night in parts of Latin America.

7 **Evening:** The waxing gibbous Moon is very close to Saturn for North Americans. It occults Saturn for the southern part of South America.

12–24 **Dawn:** Mercury shines 6° to 8° lower left of Venus.

13 **Evening:** Mars shines just 1.3° north of fainter Spica.

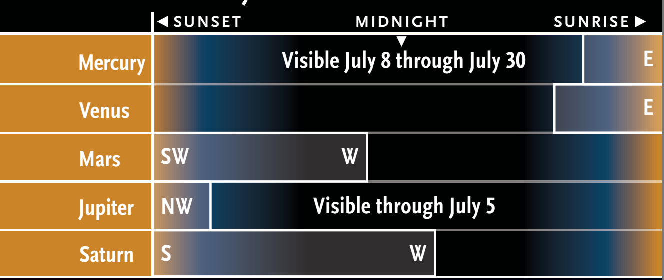
22 **Dawn:** The waning crescent Moon appears very close to Aldebaran (for North America).

24 **Dawn:** The crescent Moon floats about 5° right of Venus. Look for Mercury to their lower left.

25 **Dawn:** A very thin crescent Moon may be visible almost directly below Venus and lower right of Mercury starting 45 minutes before sunrise, as shown on page 49.

28 **Night:** The modest, long-lasting Delta Aquarid meteor shower peaks around this date. It's best at southerly latitudes.

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



Moon Phases

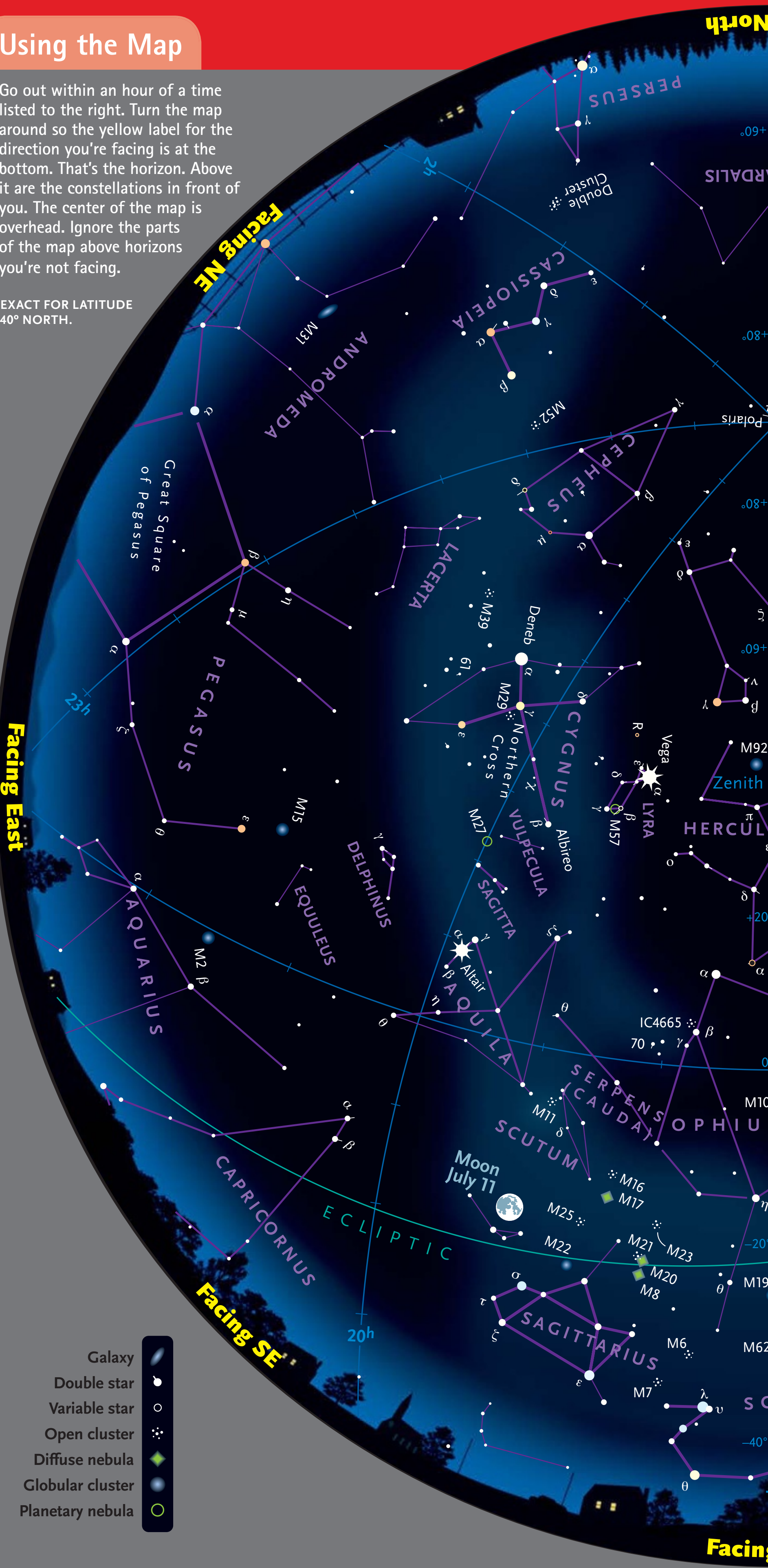
First Qtr July 5 7:59 a.m. EDT
Full July 12 7:25 a.m. EDT
Last Qtr July 18 10:08 p.m. EDT
New July 26 6:42 p.m. EDT

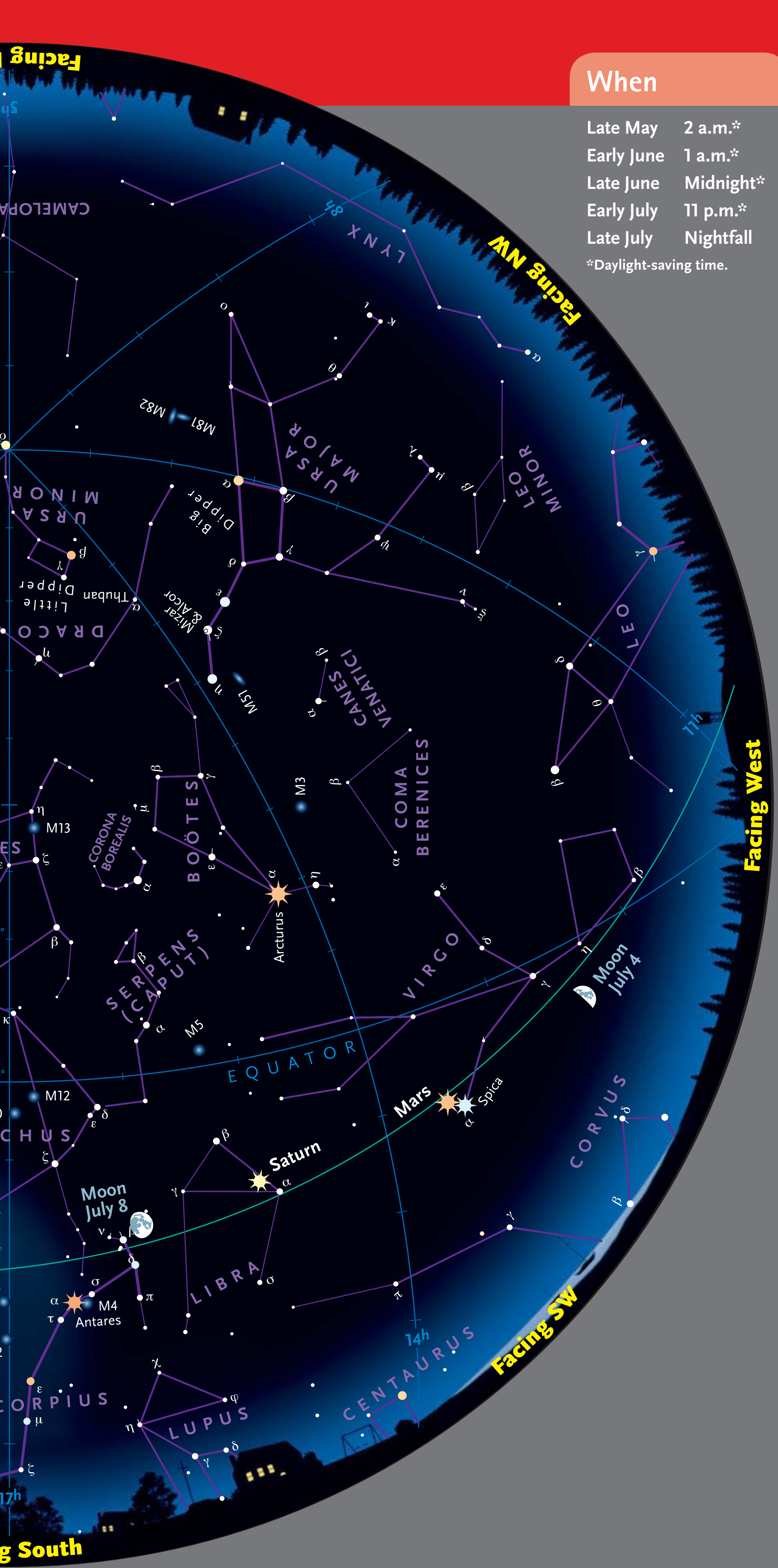
SUN	MON	TUE	WED	THU	FRI	SAT
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

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 May	2 a.m.*
Early June	1 a.m.*
Late June	Midnight*
Early July	11 p.m.*
Late July	Nightfall

*Daylight-saving time.

Gary Seronik

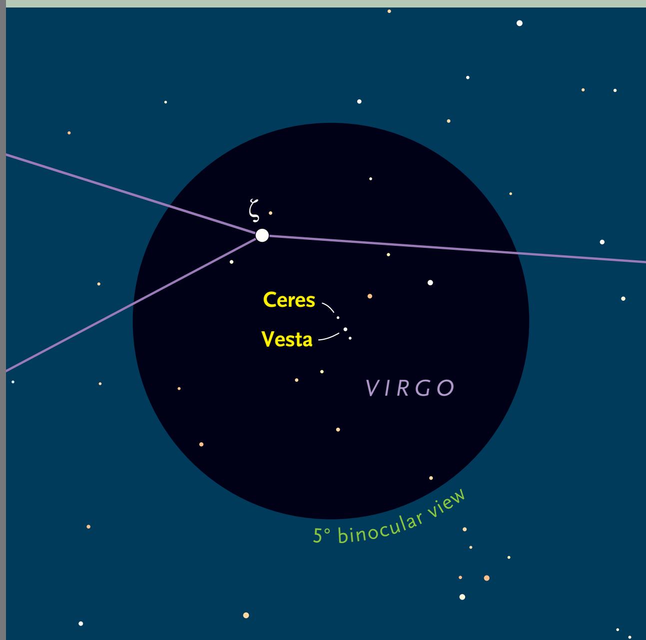
Ceres and Vesta Together

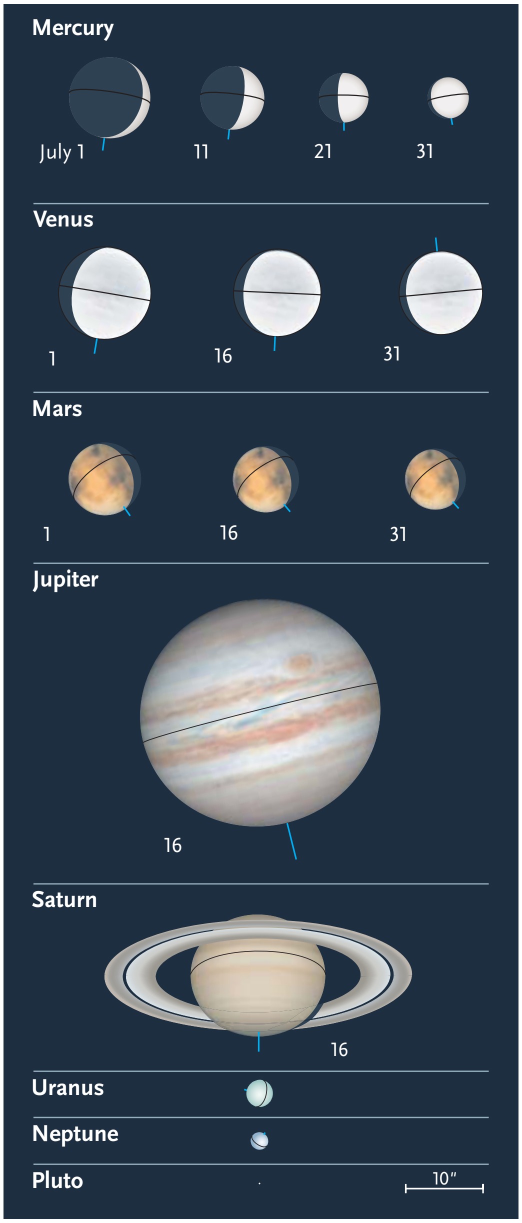
Most objects we view in binoculars lie far beyond the solar system — and sometimes outside our Milky Way Galaxy. Clusters, nebulae, and galaxies are all rewarding in their own ways, but their appeal is largely static. They're attractive but unchanging. Once in a while it's nice to see the celestial machinery in action. Luckily, the asteroids **Ceres** and **Vesta** are putting on a fine demonstration right now.

Asteroids appear as mere points of light, but it's fascinating to watch them move night by night against the background stars — and in this case, relative to each other. Of the two, Vesta is brighter, shining at magnitude 7.1 at the beginning of July versus 8.4 for Ceres. That means that both objects are binocular targets, even under suburban skies. But they're in Virgo, which is sinking low in the west, so make sure you look for them as soon as the sky grows fully dark.

The asteroids have been within the same binocular field for months. But on the American evenings of July 4th (shown below) and 5th, they will be at their very closest — just 10′ apart. That's still a large enough gap that steadily held binos will be able to show both objects as distinct dots. The pair is situated near a handy reference point, 3.4-magnitude Zeta (ζ) Virginis. The star lies in the same binocular field as Ceres and Vesta and makes tracking their changing positions much easier. If you're clouded out on July 4th, the chart on page 50 shows where to find them later in the month.

Don't pass up this rare chance to see the wheels of the celestial machinery in motion! ✦



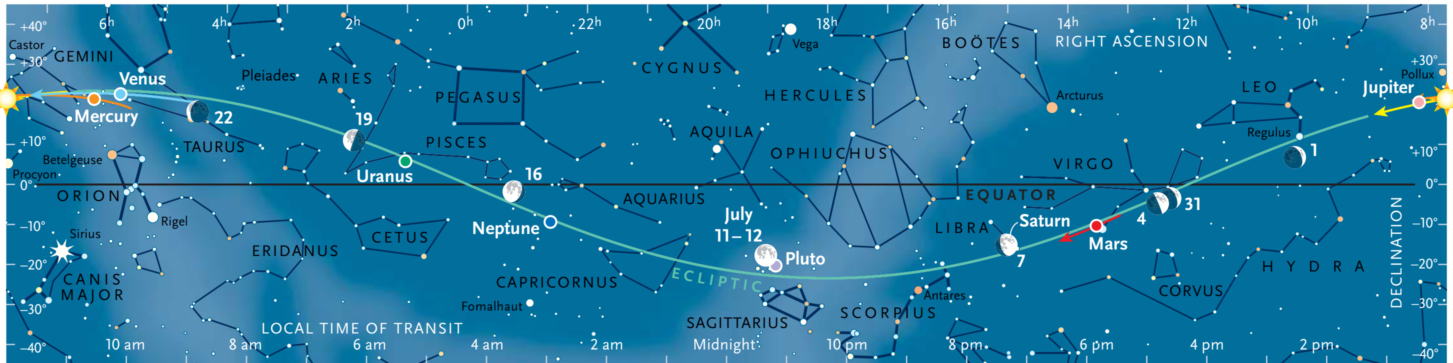


Sun and Planets, July 2014

	July	Right Ascension	Declination	Elongation	Magnitude	Diameter	Illumination	Distance
Sun	1	6^h 38.8^m	+23° 08′	—	–26.8	31′ 28″	—	1.017
	31	8^h 39.8^m	+18° 23′	—	–26.8	31′ 31″	—	1.015
Mercury	1	5^h 35.5^m	+18° 45′	15° Mo	+2.5	10.5″	11%	0.638
	11	5^h 51.0^m	+20° 16′	21° Mo	+0.5	8.3″	32%	0.813
	21	6^h 41.6^m	+22° 10′	18° Mo	–0.6	6.4″	62%	1.045
	31	8^h 00.6^m	+21° 34′	10° Mo	–1.4	5.3″	92%	1.256
Venus	1	4^h 28.9^m	+20° 22′	30° Mo	–3.9	12.0″	85%	1.392
	11	5^h 19.7^m	+22° 06′	28° Mo	–3.8	11.5″	88%	1.446
	21	6^h 11.8^m	+22° 50′	25° Mo	–3.8	11.1″	90%	1.496
	31	7^h 04.3^m	+22° 29′	23° Mo	–3.8	10.8″	92%	1.541
Mars	1	13^h 06.2^m	–7° 34′	99° Ev	0.0	9.5″	88%	0.988
	16	13^h 30.5^m	–10° 18′	92° Ev	+0.2	8.6″	87%	1.087
	31	13^h 59.4^m	–13° 15′	85° Ev	+0.4	7.9″	87%	1.183
Jupiter	1	7^h 54.0^m	+21° 14′	18° Ev	–1.8	31.7″	100%	6.219
	31	8^h 21.7^m	+19° 52′	5° Mo	–1.8	31.4″	100%	6.280
Saturn	1	14^h 59.9^m	–14° 35′	128° Ev	+0.4	17.9″	100%	9.263
	31	14^h 58.9^m	–14° 38′	99° Ev	+0.5	17.1″	100%	9.716
Uranus	16	1^h 01.1^m	+5° 47′	97° Mo	+5.8	3.5″	100%	19.872
Neptune	16	22^h 36.2^m	–9° 36′	136° Mo	+7.8	2.3″	100%	29.232
Pluto	16	18^h 50.3^m	–20° 21′	168° Ev	+14.1	0.1″	100%	31.692

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

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



The Sun and planets are positioned for mid-July; 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 Fabulous Five

The globular clusters of summer are amazing to view.

It has always seemed to the author of this book that J. R. R. Tolkien, in his delightful fantasy The Hobbit, *unwittingly created an exquisite description of M22 when he spoke of the fabulous jewel called "The Arkenstone of Thrain": "It was as if a globe had been filled with moonlight and hung before them in a net woven of the glint of frosty stars."*

— Robert Burnham, Jr.,
Burnham's Celestial Handbook

The summer sky is where you'll find M22 — and almost all the other bright globular star clusters visible from the Northern Hemisphere. Space is short here, so we'll tour just a few of these globular clusters. Let's concentrate on what we might call the Fabulous Five.

Prepare for the Fabulous Five. Our galaxy's globular clusters form a vast spherical halo centered on the galactic core, which lies in the summer constellation Sagittarius. So we see most globulars in the span of sky that stretches from M3, in the late spring constellation Canes Venatici, to M2 and M15 in the early autumn constellations Aquarius and (westernmost) Pegasus.

Only the brightest globular clusters are visible to the naked eye, and even those are mostly borderline-visible blurs seen with averted vision in dark skies. But it doesn't take a very large telescope to start transforming these fuzzy glows into the celestial showpieces they really are.

Famous M13. For many amateur telescopic observers, summer is virtually synonymous with M13. This cluster passes almost overhead at 40° north latitude and is easily found with binoculars and finderscopes along the western side of the Keystone asterism of Hercules. Look for the Keystone about ⅔ of the way between spring's brightest star, Arcturus, and summer's brightest, Vega. Once there, you'll see the fuzzy spot of M13, flanked by two lesser stars, about ⅓ of the way between Eta Herculis (the northwest corner of the Keystone) and Zeta Herculis (the southwest corner). If your skies are dark and M13 is high, you will probably be able to see it with your unaided eyes; some observers estimate it as bright as magnitude 5.3.

But it takes a 6- to 10-inch telescope to resolve large numbers of stars in M13, making the cluster jaw-droppingly magnificent. Note the long strands or arms of stars that seem to radiate out from M13 more than from almost any other globular cluster. While in Hercules, compare M13 to the smaller but differently impressive M92.

DOUG MATTHEWS / ADAM BLOCK / NOAO / AURA / NSF

Messier 22 is a swarm of multicolored stars when viewed through a large telescope at high magnification.

M3 and M5. Glorious as it is, not everyone thinks M13 is the most splendid globular cluster north of the celestial equator. Its competitors are M3 in Canes Venatici and M5 in Serpens. M3 has no even moderately bright stars nearby to use as guides — so look for it about halfway along the long line between Cor Caroli (Alpha Canum Venaticorum) and Arcturus. M5 shines just 20′ from the golden 5th-magnitude star 5 Serpentis and may appear almost a half degree wide to viewers with 10-inch telescopes.

M22 and M4. M22 and M4 are low in the sky for observers at mid-northern latitudes, so haze often dulls their grandeur. But M22 takes your breath away on a truly transparent dark night. It is significantly brighter and bigger than M13 and, being closer to us, has more individually resolvable stars. M22 also lies just 2½° northeast of Lambda Sagittarii, the star that marks the top of the Teapot of Sagittarius. And M22 is less than 1° south of the ecliptic, so it receives frequent visits from planets.

M4, which glows just 1½° west of Antares, is fainter than M22, M5, and M13. But it's one of the three closest globular clusters, so its stars are especially easy to resolve. A large amateur telescope reveals M4's full majesty, including a multitude of individual pinpricks of light and a peculiar bar of stars stretching across it from north to south. ✦

Two Close Conjunctions

The Moon passes very close to Mars and Saturn in July's evening sky.

Shortly after sunset on the first few evenings in July, you may still glimpse Jupiter low in the Sun's afterglow. All month, Mars and Spica shine together in the southwest or west in the evening. Saturn, to their left, shines a little higher and sets a little later.

As July's very early dawns begin to brighten, first Venus and then Mercury nudge up low in the east.

DUSK

Jupiter begins July setting about an hour after the Sun for observers at mid-northern latitudes. But Jupiter appears a half degree lower each evening, so it's lost from view early in the month. The giant planet reaches conjunction with the Sun on July 24th.

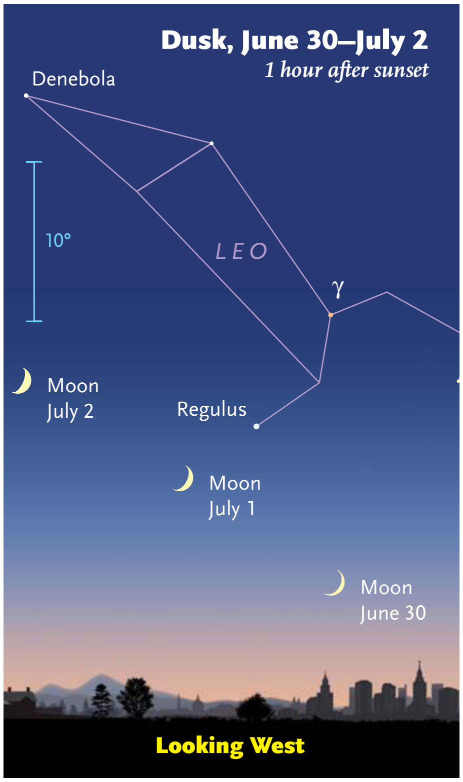
EVENING

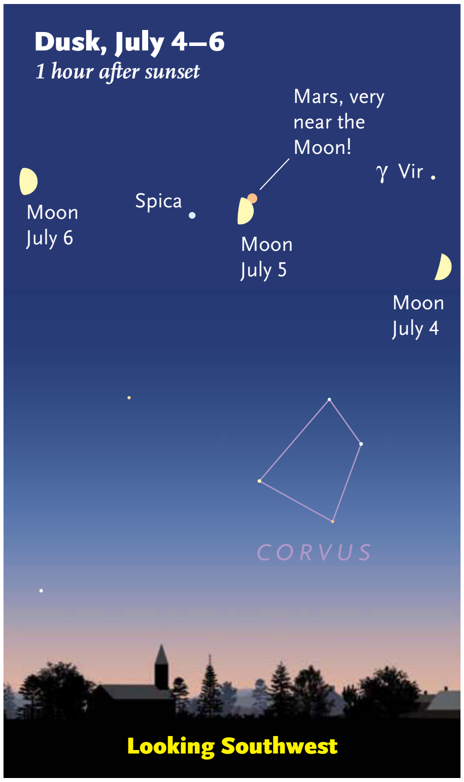
Mars fades from magnitude 0.0 to +0.4 in July but still easily outshines nearby 1.0-magnitude Spica. Orange-yellow Mars is moving eastward with direct motion in July. On the American evening of July 13th it has its third and final conjunction of the year with bluish-white Spica. This conjunction is much tighter than the first two, with Mars passing just 1.3° to Spica's north-northeast.

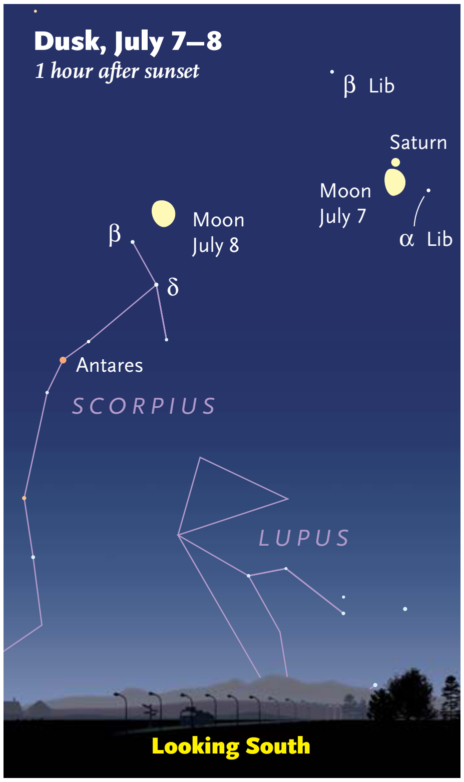
Mars shrinks from 9.5″ to 7.9″ in angular equatorial diameter this month, too small to glimpse more than a few surface features through a telescope. Mars comes to eastern quadrature, 90° east of the Sun, on July 19th, so it shows a slight gibbous phase this month. The planet is already past its highest point in the sky at sunset, so it's best observed while still relatively high in late twilight. Mars starts setting before midnight (daylight-saving time) around mid-month.

Saturn lingers in western Libra near the wide double star Alpha Librae (Zubenelgenubi) this month, dimming a bit from +0.4 to +0.5. The rings are at this year's minimum tilt of 21°, but that's still rather large. On July 21st Saturn halts retrograde motion and resumes direct (eastward) motion against the background of stars. But much faster Mars, though still over in Virgo, continues to close the gap between itself and Saturn: from 28° to 14° in July. Mars will catch up to Saturn on August 25th.

The 7th-magnitude asteroid **Vesta** passes an amazingly small 0.17° south-

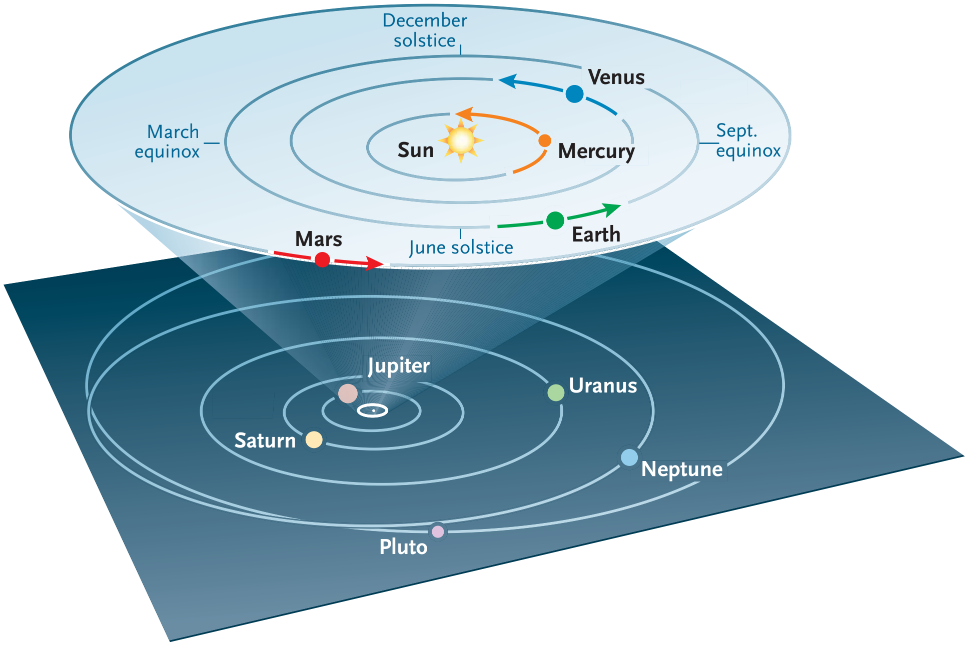






ORBITS OF THE PLANETS

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



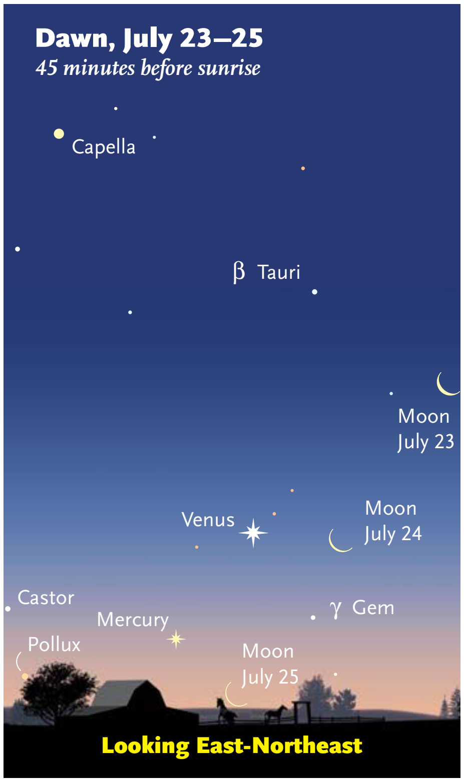
southwest of 8th-magnitude **Ceres** in Virgo around 15^h UT on July 5th; see page 50 for details.

ALL NIGHT

Pluto reaches opposition on July 4th and therefore is highest in the south in the middle of the night. Even at opposition, distant Pluto shines only about magnitude 14.1 this year. Observing Pluto requires dark skies, usually a 10-inch or larger telescope, and a deep finder chart such as the one on page 50 of the June issue. Pluto passes near the 5th-magnitude orange star 29 Sagittarii this month.

DAWN

Neptune, in Aquarius, transits the meridian around the start of morning twilight this month. **Uranus**, in Pisces, transits around sunrise or later. So the best time to see both of the ice giants is at dawn's first gleaming, when they're as high as possible. See **skypub.com/urnep** for finder charts.



Venus rises in the east-northeast right around the start of astronomical twilight throughout July. From June 29th through July 3rd, Venus is less than 5° above or upper left of Aldebaran. July is also when the brightest planet dims to its faintest for the year: –3.8. Its diameter shrinks slightly, from 12″ to 11″, and its phase grows from 85% to 92% lit, making the out-of-roundness of the planet's lit part harder to detect — especially in the unsteady air low in the sky. Even by sunrise Venus is only 20° high for observers around 40° north latitude. And next month its altitude begins to decline.

Mercury puts in a good appearance to Venus's lower left for much of July. Mercury is too faint to find early in the month, but it brightens rapidly and soon moves higher in morning twilight. The little planet reaches a greatest western elongation of 21° on July 12th, but on that date it's less than half lit in the telescope and shines at only magnitude +0.4.

On July 16th Mercury comes closest in the sky to Venus for this apparition, just over 6° away. This is an appulse but not a conjunction — Mercury approaches Venus and then pulls away again, but never passes north or south of it. Mercury appears noticeably lower late in the month but continues to brighten, up to magnitude –1.4 at month's end.

MOON PASSAGES

The **Moon** is a waxing crescent lower left of Regulus on July 1st. On the 5th, the first-quarter Moon hangs close to Spica and Mars for North American observers. It actually occults Mars as seen from much of Latin America at night or dusk, and in Hawaii during daylight. On July 7th the Moon occults Saturn for southernmost South America and appears close to Saturn for North American observers. The waning crescent is very near Aldebaran on July 22nd, and it's rather close to the right of Venus and Mercury on July 24th and 25th, respectively.

EARTH

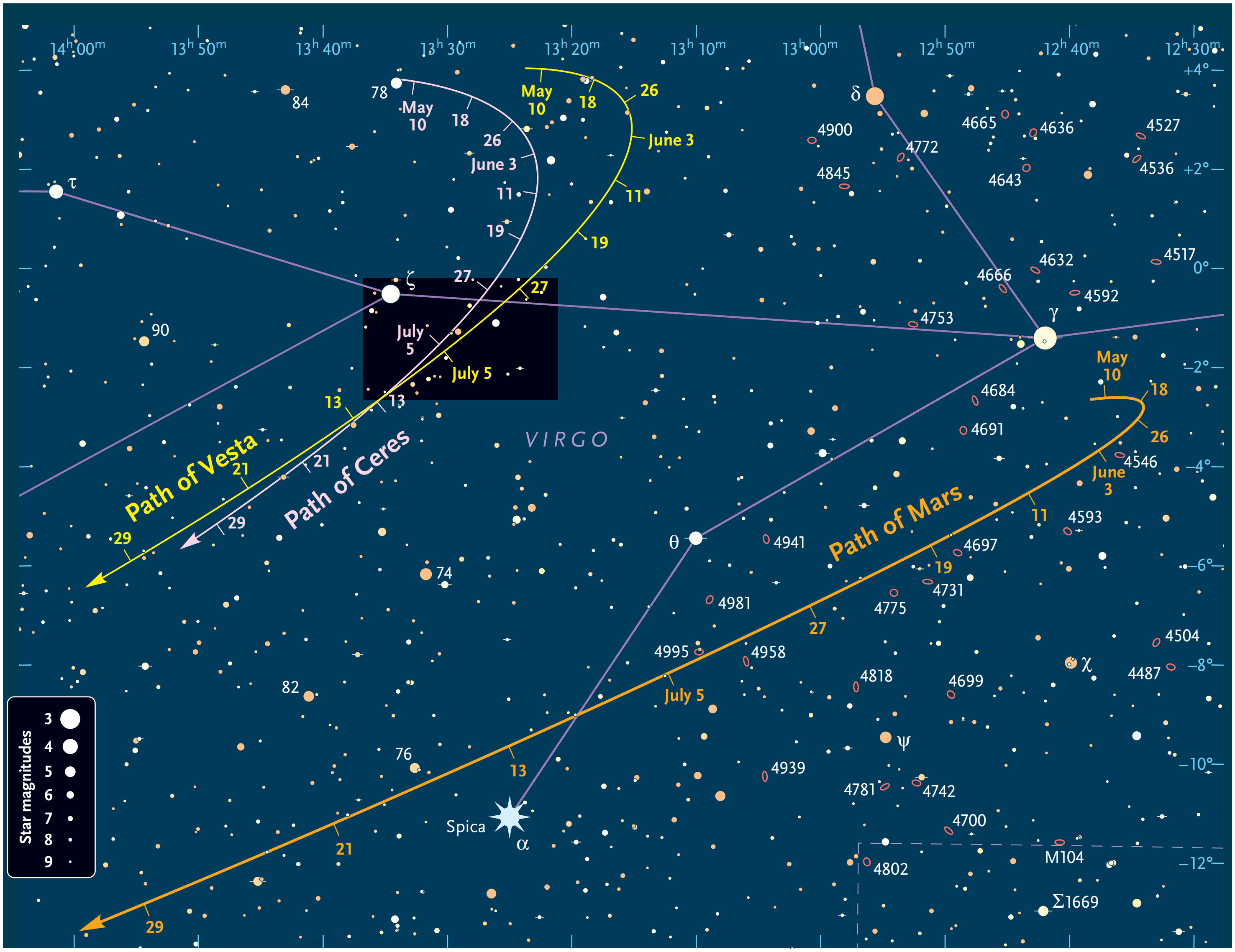
Earth is at aphelion (farthest from the Sun in space for the year, 94,506,000 miles) at 8 p.m. EDT on July 3rd. ✦

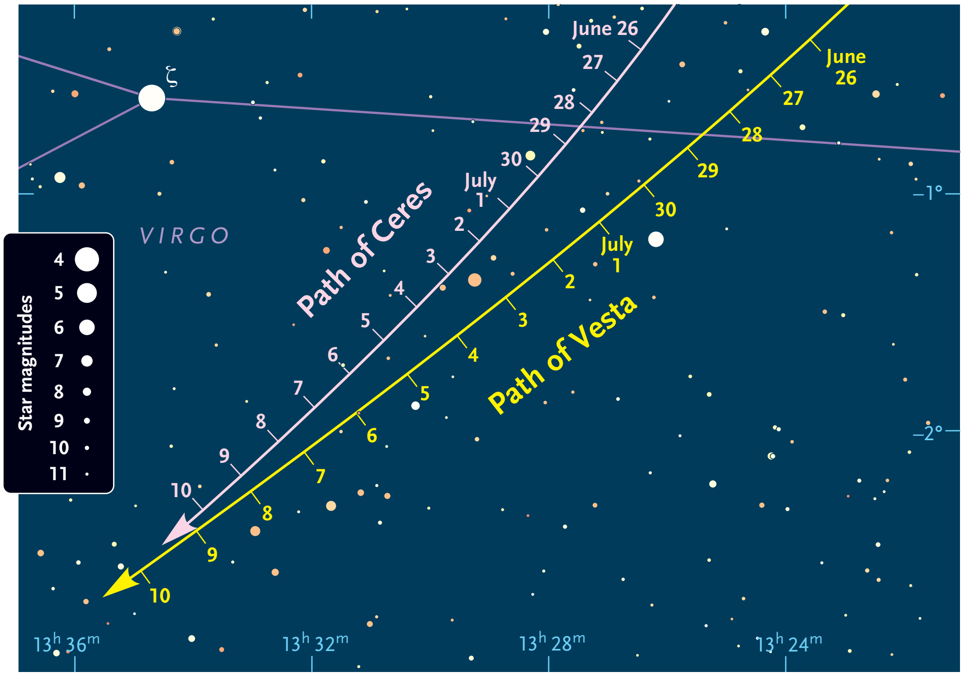
Ceres, Meet Vesta!

The two leading asteroids pair up closer than anyone has ever seen.

Have you looked in on Ceres and Vesta in the last few months? The king and queen of the asteroid belt have been flying in parallel just 2° or 3° apart since the beginning of spring, looping through eastern Virgo. They were at opposition in mid-April, as told in the February issue, page 50 (the names of Ceres and Vesta were swapped on the chart there), and they remain in binocular view.

Now they'll pull much closer together as they fade. They're already in the same wide-field telescopic view, and in early July they come into the same *high-power* view. They'll appear closest, 10 arcminutes apart, on the evenings of July 4th and 5th in the Americas (July 5th and 6th Universal Time), while cruising 1½° southwest of 3rd-magnitude Zeta (ζ) Virginis. Ceres is magnitude 8.5 and Vesta is 7.2 around that date. They're still moderately high in the southwest at nightfall: 30° high if you





Vesta is 7th magnitude and Ceres is 8th as they swing together near Mars and Spica. The date ticks are plotted for 0:00 Universal Time. Interpolate to put a pencil mark on each of the paths for the date and time you plan to look. *Opposite page:* Stars are plotted to magnitude 9.0 and galaxies (in the Virgo Cluster) to 11.5. Third-magnitude Gamma (γ) Virginis is an equal double star with a current separation of 2.1″. The black rectangle shows the area of the close-up chart on this page.

Ceres and Vesta Paired

Date (0^h UT)	Ceres mag.	Vesta mag.	Separation
May 1	7.2	6.0	2.6°
June 1	7.8	6.6	2.1°
July 1	8.4	7.1	0.4°
Aug. 1	8.8	7.4	2.2°
Sept. 1	9.0	7.7	5.0°

live near 40° north latitude.

Mars and Spica are your naked-eye starting points, as shown on the wide-field chart at left. Mars and Spica are 14° apart on American evening of June 1st, 5½° on July 1st, and 1.3° on July 13th, their own date of least angular separation (appulse).

Quite near the two asteroids on the sky, though utterly invisible from Earth, is NASA's Dawn spacecraft. It's en route from its successful 2011–12 mission at Vesta to its next mapping project at Ceres, where it will take up permanent orbit in spring 2015.

Although the two asteroids look close together, they are not. Ceres is a good 46 million miles (74 million km) in the background of Vesta around their appulse date. That's part of the reason why Ceres looks fainter. Ceres, with a diameter of 585 miles (940 km), is actually almost twice as large as Vesta. But it's farther from the Sun as well as from Earth, and it has much darker surface material. Vesta is medium-gray, reflecting 42% of the sunlight striking it (a high albedo for an asteroid), whereas Ceres is a more typical dark gray-brown with an albedo of only 9%. But patchy brighter and darker markings on Ceres, revealed in Hubble images, hint of interesting landscapes awaiting Dawn.

JULY METEORS

Several minor, long-lasting meteor showers with radiants in the southern sky are active in July, including the Alpha Capricornids, Piscis Austrinids, and Delta Aquariids. Together they increase the chance that a meteor you see late on a July night will be flying out of the south.

DAVID MAYHEW

Asteroid Occultation

On the morning of July 19th, the faint asteroid 611 Valeria will black out an 8.7-magnitude star in Pisces for up to 4 seconds as seen from a track predicted to cross northern Mexico, Texas, the Deep South (including the Atlanta area), and the Carolinas. The occultation will happen within a couple minutes of 9:10 UT in Texas and 9:12 UT in the Carolinas, where dawn will be getting under way.

For a map, finder charts, more about asteroid occultations, and additional predictions, see skypub.com/july2014asteroidoccultation.

For the Moon's librations in July, see: skypub.com/july2014librations.

The Closing of 44 Boötis

Can your scope separate a double star 1 arcsecond wide? At high power, a 4-inch scope with excellent optics ought to do it during excellent seeing. A lovely test pair this year is 44 Boötis, an interesting 5th-magnitude binary off the handle-end of the Big Dipper.

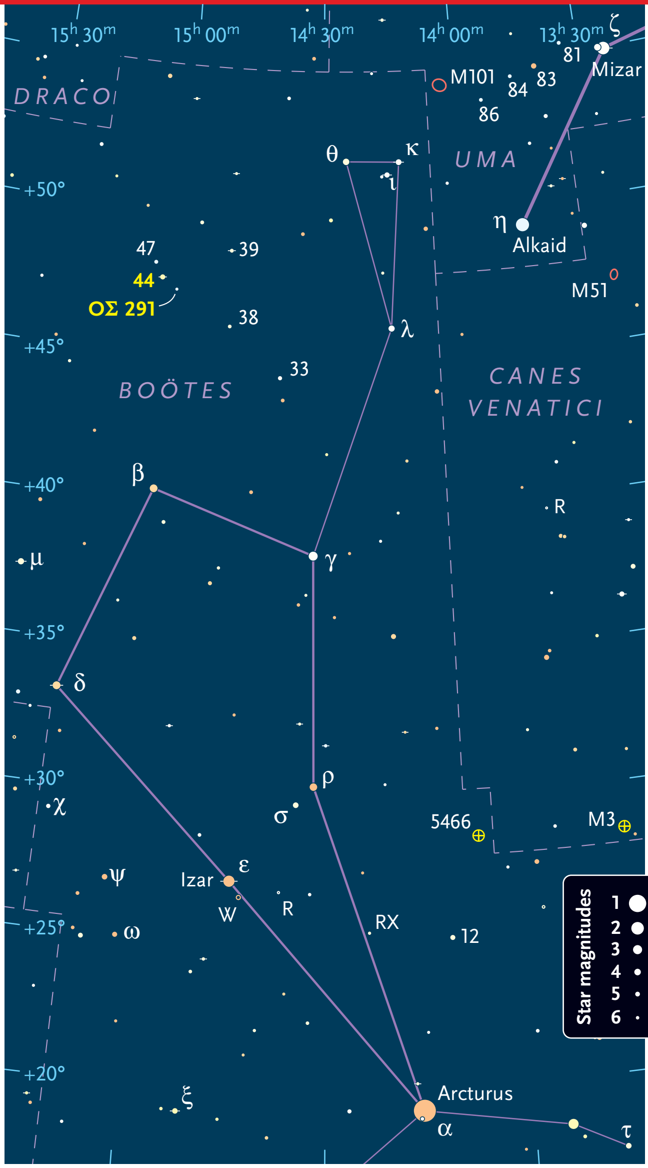
The brighter of 44 Boo's two components is a very Sun-like star of magnitude 5.3, spectral type G0V. The secondary star is an eclipsing binary of the W Ursae Majoris type: a peanut-shaped *contact binary* that varies continuously from about magnitude 5.8 to 6.4, with two almost-equal eclipses during each 6.427-hour orbital cycle. That's fast enough to create a subtle change in the binary's appearance in the course of an observing session if your timing is lucky. At a distance of 42 light-years, 44 Boo B is the nearest contact binary star to the solar system.

The A-B pair is currently passing through an exciting part of its 210-year orbit: the stars are rapidly closing year by year. A recent orbit calculation by Henry Zirm in Jena, Germany, puts the stars' separation at 1.06″ this July 1st and 1.03″ by September 15th. They'll reach a minimum separation of 0.23″ in 2020.

The secondary is currently east-northeast of the primary (at position angle 66°) but will swing around to the primary's southwest in the next decade. The table below gives the pair's predicted separation and position angle, according to Zirm's orbit, around the beginning and end of summer for the next 10 years. Position angle is counted from north (0°) through east (90°), south (180°), and west (270°).

Keep the table handy as 44 Boo becomes a challenge object for bigger and bigger telescopes.

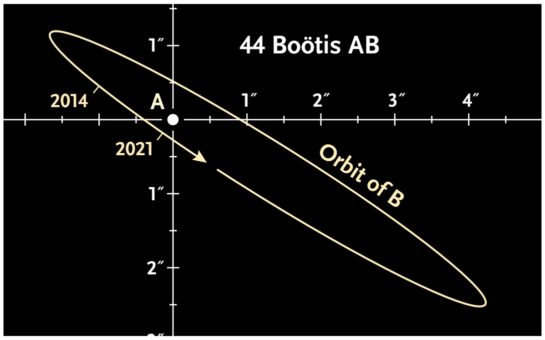
Bonus binary: OΣ 291. The asterism to catch for finding 44 Boo is a little arc of three stars, 1.2° long, with 44 Boo in the middle, as shown on the map. The star southwest of 44 Boo (by ⅔°) is an utterly different visual double, much wider. It's OΣ 291, separation 35″, magnitudes 6.3 and 9.6, with a slight color contrast. ✦



44 Boötis AB

Year	July 1 Sep.	July 1 P.A.	Sept. 15 Sep.	Sept. 15 P.A.
2014	1.06″	66°	1.03″	67°
2015	0.91″	68°	0.88″	69°
2016	0.76″	72°	0.73″	73°
2017	0.61″	77°	0.58″	79°
2018	0.46″	84°	0.43″	87°
2019	0.33″	100°	0.30″	104°
2020	0.24″	130°	0.23″	138°
2021	0.25″	170°	0.27″	176°
2022	0.36″	196°	0.38″	199°
2023	0.50″	208°	0.53″	210°
2024	0.65″	215°	0.68″	216°

Above: **North of the head of Boötes, east of Alkaid at the end of the Big Dipper's handle, lies a little curved row of three stars, including the doubles 44 Boötis and OΣ 291, tight and wide, respectively. This chart shows stars to magnitude 6.5. *Below left:* Double-star enthusiast John Nanson of Oregon drew 44 Boo as seen with a 4-inch f/13 refractor at 173×, when the pair's separation was 1.35″ in April 2012. At 250× he could make out a thread of black sky between the two. *Below right:* The apparent orbit 44 Boötis B relative to the brighter component A, as seen projected on the sky. The true orbit is tipped far out of the paper, only 6° from our line of sight.**

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Illuminating Earthshine

The pale glow on the Moon can teach us about Earth's changing climate.

After a long, snowy winter in New England, early April brought the first pleasant evening for stargazing. A delicate waxing-crescent Moon hovered over the western horizon, and even a quick glance showed there was more to see than just a delicate swoosh of lunar light. In fact, it was easy to make out the entire lunar disk, even the bloated lion's share hidden in shadow, thanks to the ghostly phenomenon known as *earthshine*.

The cause is, by now, well known: whenever the Moon presents a thin crescent to us, in the days before or after new Moon, sunlight reflecting off our planet brightens the lunar night like a giant flashlight. At these times, a hypothetical lunar astronaut would see a brilliant, nearly full Earth hanging in the sky. This mirrored sunlight is enough to make the Moon's darkened, desolate landscape plainly visible to us.

The crescent Moon awash with earthshine (reflected light from Earth on its night side) is one of the most splendid scenes in nature.

P.-M. HEDÉN

Leonardo da Vinci described the phenomenon at some length 500 years ago. The great Renaissance master correctly reasoned that the unlit portion of the Moon is reflecting light shining on it from Earth, though he imagined the lunar surface to be covered with liquid seas. But, remarkably, da Vinci's keen celestial insight wasn't appreciated for nearly two centuries, when a collection of his writings known as the *Codex Leicester* was rediscovered at the end of the 17th century.

Earthshine can be startlingly obvious. One of the most vivid descriptions of this "ashen light," as it's sometimes called, comes from J. F. J. Schmidt, a German-born astronomer who served as director of Athens Observatory from 1859 to 1884. Schmidt was mesmerized by the appearance of a two-day-old Moon in January 1867. Scanning the glowing lunar night through a 6-inch refractor, he could trace many large craters and maria, mountain peaks, and the long rays of Tycho.

Notably, the lunar features seen when bathed in Earth's pale light are the same ones you see well during times near full Moon — splashes of rays, for instance, rather than jagged rims and mountain chains — because in both cases the illumination is coming directly from our line of sight (or nearly so). The crater Aristarchus and the prominent rays emanating from Tycho, Copernicus, and Kepler are easy to spot with optical aid.

You've probably encountered earthshine most often when a thin lunar crescent hangs low in the evening sky — romantically termed "the old moon in the new moon's arms" — or in the predawn sky a few days before new Moon. But various observers have spotted it well after the waning crescent has fattened to first quarter and beyond. In 1949, Audouin Dollfus reported seeing a sliver of earthlight's glow just 38 hours before full Moon. The renowned French observer had some help, though — he used a coronagraph at Pic du Midi Observatory to mask out the bright lunar disk.

If you've noticed that earthshine can vary in intensity from night to night, your eyes aren't playing tricks on you. Clouds cover about 60% of Earth's surface on average, and the ashen glow can appear stronger or weaker depending on the cloud cover across the hemisphere of Earth that's facing the Moon at that moment.

The first useful measurements of earthshine's varying intensity came from André-Louis Danjon (1890–1967), well known to skygazers for his gauge of umbral darkness during total lunar eclipses. He concluded that the *albedo* (reflectivity) of a "full Earth" could vary from a low of 32% in July to a peak of 52% in October.

Danjon's pioneering work has been continued and expanded thanks to Project Earthshine, coordinated by Philip Goode of Big Bear Solar Observatory in southern California and Enric Pallé of Instituto de Astrofísica de Canarias on the island of Tenerife. Since 1999 their small team has used dedicated telescopes to monitor the brightness of earthshine and then to compare those results with satellite imagery of Earth's daylit hemisphere.

You might think that the advent of weather satellites would make measurements of Earth's cloudiness routine. But reliably accurate satellite readings have only been possible in the past two decades. Initially, Goode and Pallé couldn't reconcile their Project Earthshine observations with the weather imagery, but better analysis and techniques (such as using robotic telescopes) have finally brought convergence.

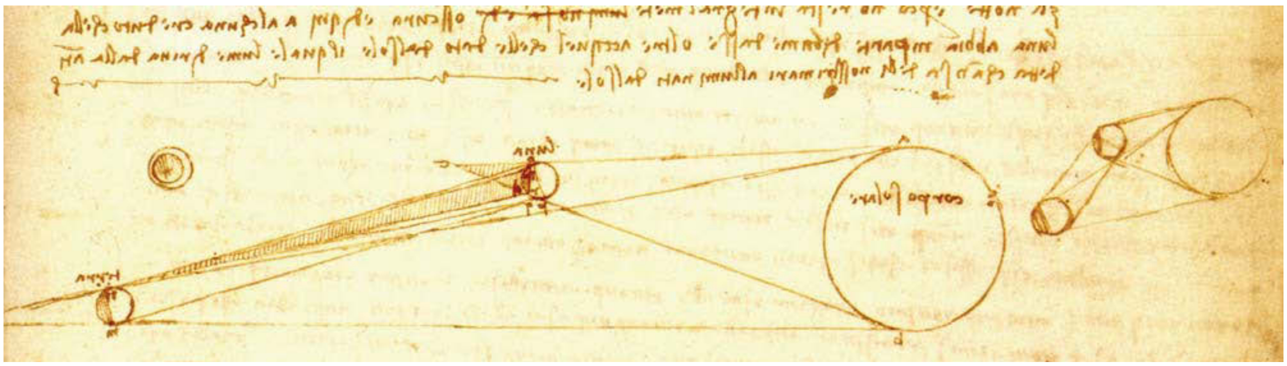
These reflectivity data have become increasingly important in the ongoing debate over global climate change. For example, the Project Earthshine work shows that Earth's albedo made a distinct jump (by roughly 0.5%) from late 1998 through mid-2000, and then afterward it largely leveled off. By comparison, the Sun's output varies only by about 0.1% over an 11-year-long solar cycle. So if Earth has become 0.5% more reflective, then the amount of sunlight reaching the ground has been reduced by about 2 watts per square meter.

This change can't be explained by an increase in greenhouse gases — in fact, this increasing albedo trend, if sustained over time, would tend to make Earth *cooler,* not warmer. Goode says that more observations, covering the period since 2007, should be published soon.

Earthshine is obvious in this view of a two-day-old waxing crescent Moon. Features most visible in the lunar night, such as the rayed crater Tycho, are the same ones seen during a full Moon. Jerry Lodriguss combined eight different exposures to capture both the Moon's sunlit crescent and its dimly lit dark side.

Meanwhile, exoplanet specialists are excited about how earthshine can be used to "detect" our planet's abundant plant life. Leafy plants exhibit a sharp increase in reflectivity at wavelengths longer than about 700 nm. So when sunlight reflects off a particularly verdant continent (South America, for example), the spectrum of earthshine mirrored in the Moon gains a near-infrared enhancement that's very distinctive. Researchers think this "red edge" might become a crucial spectral fingerprint in the search for habitable worlds.

So the next time you're greeted with a Moon grinning at you like a celestial Cheshire Cat, smile back with a knowing nod — and enjoy the wonder of it. ✦



CODEX LEICESTER

In the early 1500s, Leonardo da Vinci deduced that the ghostly glow seen on the night side of the Moon is due to reflected light shining on it from Earth. The backwards writing in his drawing is not a mistake; Leonardo wrote all his personal notes in mirror writing.

Betwixt the Bears

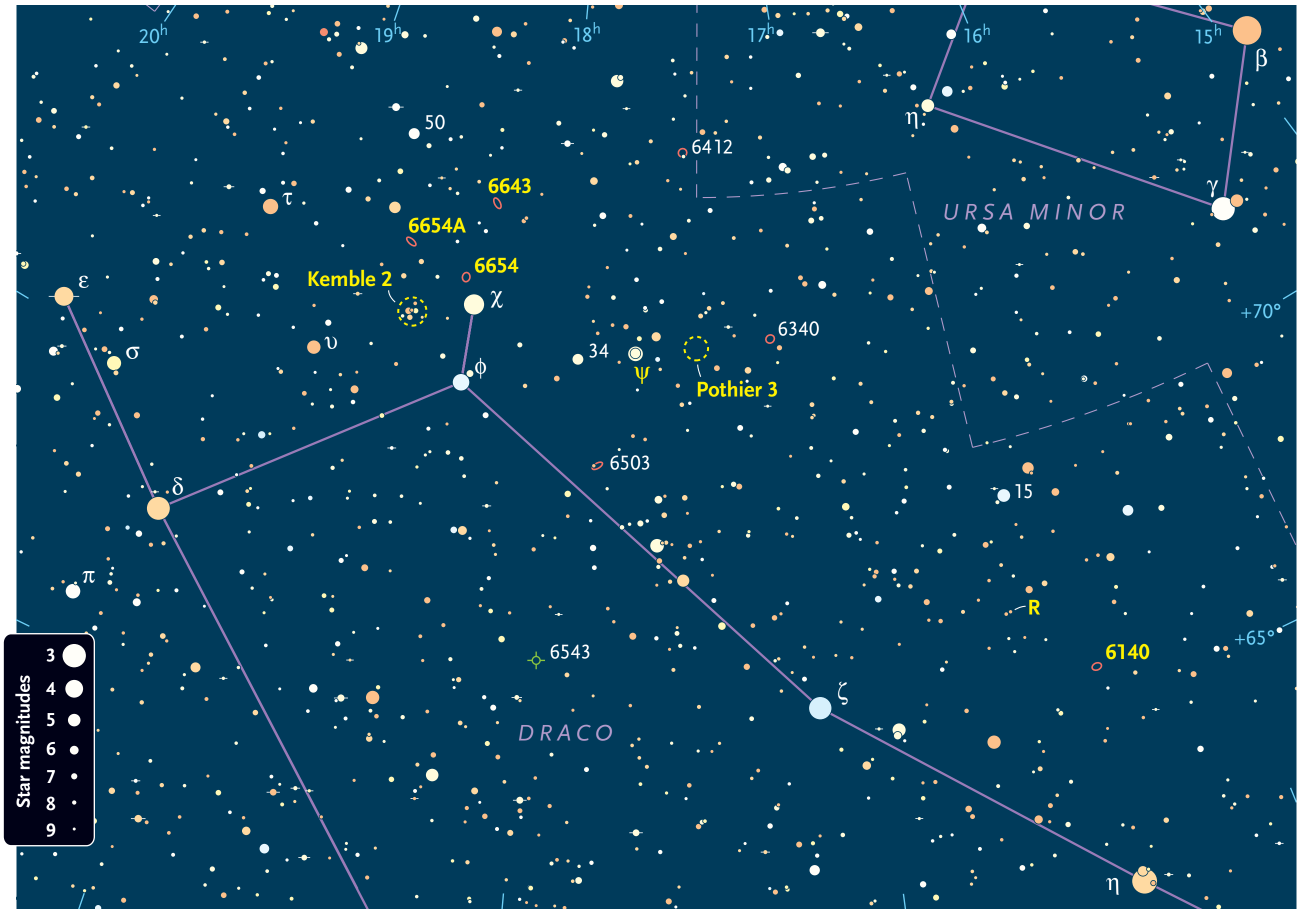
Draco's eastern loop is highest on warm summer nights.

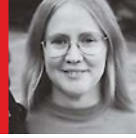
Betwixt the Bears, like foaming river's tide,
The horrid Dragon twists his scaly hide.
To distant Helice his tail extends,
In glittering folds round Cynosyra bends.
Swoln is his neck — eyes charg'd with sparkling fire
His crested head illume. As if in ire
To Helice he turns his foaming jaw,
And darts his tongue barb'd with a blazing star.
— Aratus, *Phaenomena*, translated by John Lamb 1847

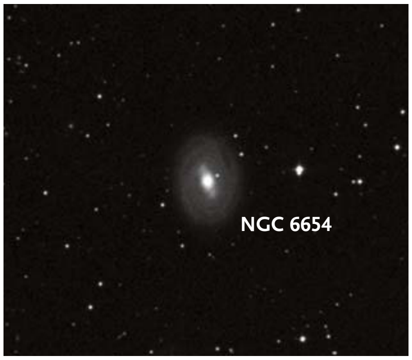
This charming verse teaches us how to find the sky's enormous dragon, Draco. His tail lies betwixt the bears Ursa Major (Helice) and Ursa Minor (Cynosyra), whose brightest stars form the familiar patterns of the Big Dipper and Little Dipper. Look between the bowls of the dippers to spot the tail, and then follow Draco's serpentine chain of stars as he bends around the Little Dipper and then folds back on himself as if trying to sneak up on Ursa Major from behind.

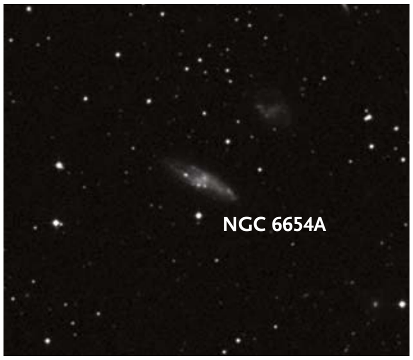
Draco's hairpin turn enfolds one of my favorite asterisms, **Kemble 2**. The late Canadian amateur and Franciscan friar Lucian Kemble found this delightful group in 1994. In an unpublished paper the following year, Father Kemble wrote, "While browsing through *Uranometria* one day I came across a most unusual bright asterism in Draco." His interest piqued, Kemble took up binoculars for an eyes-on view of this copycat asterism.

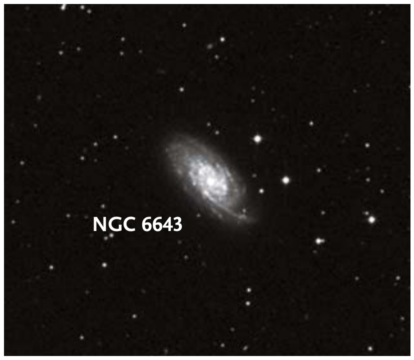
Kemble's Norwegian friend Arild Moland says that "it bears an almost scary resemblance to Cassiopeia." Others noticed the likeness as well, thus the asterism is











POSS-II / CALTECH / PALOMAR OBSERVATORY (3)

nicknamed Mini-Cassiopeia. In his book *The Deep Sky: An Introduction*, Philip S. Harrington calls this striking bunch the Little Queen.

Kemble 2 sits 1.1° east-southeast of Chi (χ) Draconis. Its five brightest stars form a pattern very similar to the familiar W shape of Cassiopeia, the Queen. There's even a sixth star corresponding to Eta (η) Cassiopeiae, albeit slightly out of place. Kemble 2 is quite colorful through my 130-mm refractor at 37×. Starting at the northernmost star and working my way along the W shape, the six stars appear orange, gold, orange, gold, gold, and yellow-white.

The barred galaxy **NGC 6654** dwells 30′ north-northeast of Chi Draconis. My 130-mm scope at 37× shows a small hazy patch enshrouding an elongated bar and is accompanied by an 11th-magnitude star 2.4′ to its west. At 63× the haze is a north-south oval, while the bar tips east of north and hosts a tiny, bright center. With a magnification of 117×, the galaxy's oval profile looks about 1¾′ tall. My 10-inch reflector at 115× discloses a starlike nucleus nested within the little, round core at the bar's center.

NGC 6654A lies 1.2° east-northeast of NGC 6654. Galaxy expert Harold Corwin told me that the object's designation comes from a 1935 paper by Philip C. Keenan in the *Astrophysical Journal*. Keenan discussed Yerkes Observatory's method for determining galaxy magnitudes from photographic plates. Any previously uncataloged galaxy discovered on a plate was assigned the name of the nearest NGC object on the plate, with a capital letter appended. Although Keenan intended these designations to be temporary, the name NGC 6654A has become popular with amateur and professional astronomers.

NGC 6654A is barely visible with averted vision through my 130-mm refractor at 63×. It's just a ghostly little smudge hovering over the western point of a 3.7′-long triangle of three dim stars. I still need averted vision at 91× but suspect the galaxy is slightly elongated.

NGC 6654A is still very faint in my 10-inch scope at 166×. At 213× the galaxy looks a bit oval and 1¼′ long, but the center is a skosh brighter and roundish. I thought I saw an extremely faint star at the galaxy's visible eastern end, which is actually well within NGC 6654A on images. I used the Aladin Sky Atlas (**http://aladin.u-strasbg.fr/aladin.gml**) to check it out.

Although visible-light images that I accessed via Aladin confirmed an object at this spot, it was difficult to tell if it was a foreground star or an H II region within NGC 6654A. To identify the object, I overlaid catalogs on an image and was astonished to see that it's classified as a galaxy in some of them. I didn't believe it. Astronomer Brian Skiff helped me out by examining the object in mid-ultraviolet, far-red, near-infrared, and thermal infrared images. He concludes that this spot is probably an immense cluster of *O*-type stars inside a giant H II region, something like the Tarantula Nebula in the Large Magellanic Cloud. Harold Corwin concurs. If anyone with a very large telescope can detect a contrast enhancement of this star-forming complex when blinking with a nebula filter, I'd love to hear about it.

The fleecy-armed spiral galaxy **NGC 6643** hovers 1.8° north of Chi Draconis. My 130-mm scope at 63× displays

Stars and Galaxies in the Celestial Dragon

Object	Type	Mag(v)	Size/Sep	RA	Dec.
Kemble 2	Asterism	5.6	30′	18^h 35.0^m	+72° 23′
NGC 6654	Galaxy	12.0	2.6′ × 2.1′	18^h 24.1^m	+73° 11′
NGC 6654A	Galaxy	12.9	2.6′ × 0.8′	18^h 39.4^m	+73° 35′
NGC 6643	Galaxy	11.1	3.8 × 1.9′	18^h 19.8^m	+74° 34′
Psi (ψ) Dra	Double star	4.6, 5.6	30′	17^h 41.9^m	+72° 09′
Pothier 3	Asterism	—	25′	17^h 27.8^m	+72° 14′
R Dra	Variable star	6.7 – 13.2	—	16^h 32.7^m	+66° 45′
NGC 6140	Galaxy	11.3	6.3′ × 4.6′	16^h 21.0^m	+65° 23′

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.

JOSEF PÖPSEL / STEFAN BINNEWIES / STEFAN HEUTZ

The spiral galaxy NGC 6140 has an unusually small but bright central bar and intriguingly asymmetric arms. North is to the upper right in this image.

an oval glow with a pair of 12th-magnitude stars off its northwestern flank. The galaxy looks about twice as long as the distance between these two stars, which yields a length of 2.6′. At 117× these stars are joined by two more to their southwest. The foursome makes an L shape that appears backward in my refractor's mirror-reversed view. NGC 6643 grows gently brighter toward the center and appears half as wide as it is long. The galaxy is quite pretty through my 10-inch reflector at 213×. Its inner halo and broadly brighter, oval core are highly mottled. A dim star sits between the edge of NGC 6643 and the middle star in the L's back.

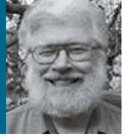
Let's pop in on **Psi (ψ) Draconis**, which appears double even in my 9×50 finderscope. Through a small telescope at low power, the 4.6-magnitude primary star looks yellow-white to me, whereas its 5.6-magnitude companion shines a slightly deeper shade of yellow. Despite their wide separation, the stars are thought to form a mutually orbiting pair. The online *Sixth Catalog of Orbits of Visual Binary Stars* (William I. Hartkopf and Brian D. Mason) lists an orbital period of 3,817 ± 500 years. But the orbit is coded as indeterminate, which means that the orbital elements may not be even approximately correct.

The asterism **Pothier 3** is 1.1° west of Psi. Together they make a lovely duo in the field of my 105-mm refractor at 28×. Pothier 3 is a somewhat butterfly-shaped group of 30 stars flitting across the sky with a wingspan of nearly ½°. The group was noted by French amateur Yann Pothier and later determined to be a chance alignment of stars rather than a true cluster.

R Draconis is a Mira-type variable star, an unstable giant star whose outer layers periodically expand and contract. It reached maximum brightness early this June, and we can follow the star as it falls to its minimum in mid-October. Its listed range is magnitude 6.7 to 13.2, but the extremes can differ by as much as a full magnitude.

NGC 6140 is an intriguing galaxy 1.8° southwest of R Draconis. My 105-mm scope at 87× only shows a very small, diaphanous spot when I use averted vision. At first glance, it's nothing to rave about even through my 10-inch reflector, but careful study discloses subtle features. At 68× the galaxy's low-surface-brightness glow has a 11.5-magnitude star near its northwestern border and a small, elongated, slightly brighter center. At 115× the galaxy reveals a short, slender bar running northeast to southwest, which spans a fainter area elongated east-west, all enclosed in a much larger, gauzy halo. What details can you glean from this peculiar galaxy?

I think it's fitting to wrap up our sky tour with the closing words from Lucian Kemble's paper. "Our charming Dragon, then, while guarding his jeweled treasure trove and overlooking the wheeling disk of our Sun and his family, opens to our gaze his bright gems and the dim cloud of fuzzy galaxies that surround him." ✦



The Snake and Its Eggs

Southernmost Ophiuchus contains some of the sky's best dark nebulae.

I WAS THRILLED when I got my first naked-eye view of the 7°-long **Pipe Nebula** (LDN 1773) at the 1983 Texas Star Party. This nebula is in southern Ophiuchus, around declination –25°, so it's never far above the horizon in my native Canada. But the Pipe was clearly etched against the bright Milky Way background high in the clear, dark skies of West Texas.

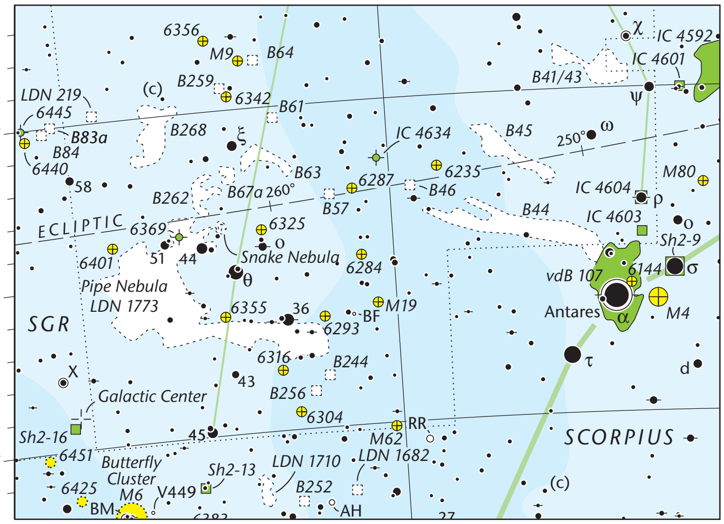
The next year I was surprised to see the Pipe Nebula from latitude 50° north on some dark acreage in the mountains of southern British Columbia. The view pleased me so much that we soon purchased the land as an astronomy-suitable home site. These days I use the Pipe's naked-eye visibility as a test for good summer skies — I don't attempt to view difficult deep-sky objects unless I can see it.

The Pipe lies midway between Antares and the lid of the Sagittarius Teapot, just below an arc of four stars — the only obvious ones in that part of the sky. The brightest, 3.3-magnitude Theta (θ) Ophiuchi, is in the center of the arc. At the southwestern end of the arc, right on the pipe-stem's northern edge, lies the constellation's finest double star: **36 Ophiuchi**. It's a pair of essentially identical stars that appear deep yellow to my eyes, though most guidebooks call them orange. The binary is very close to Earth, just 19.5 light-years distant, and its 5″ separation makes it suitable for small scopes.

On a trip home to Canada's Atlantic coast, I viewed the Pipe Nebula from my sister's pasture overlooking the Bay of Fundy. From this thinly populated area, my 7×50 binoculars revealed the individual but connected dust clouds that the unaided eye strings together to make the pipe stem. The huge **Prancing Horse Dark Nebula** was also easily visible to the unaided eye — the Pipe Nebula forms the Dark Horse's rear legs and hindquarters.

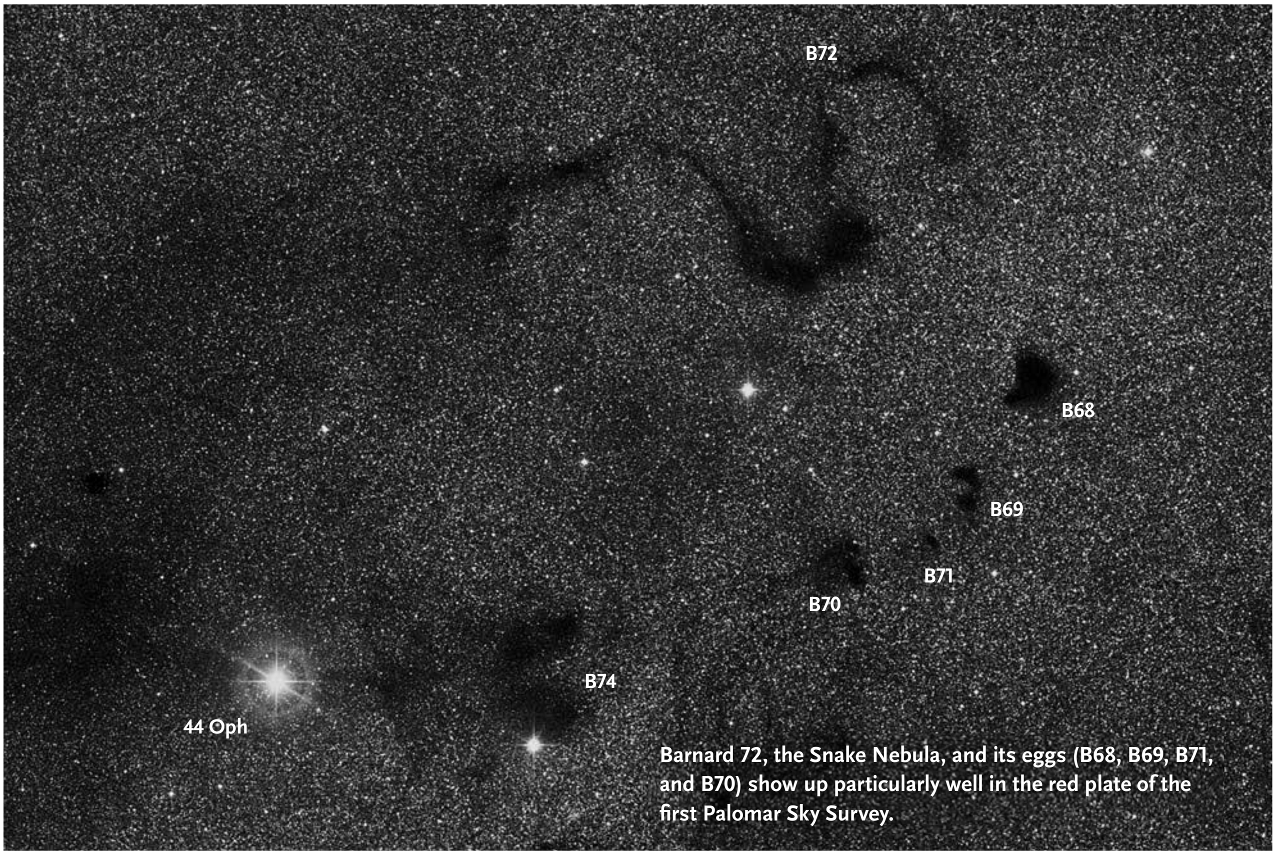
One March morning at Organ Pipe Cactus National Monument in southern Arizona, the Horse pranced high in the south-southeast, and with naked-eye averted vision I could discern the challenging dark lane that runs from the horse's foreleg (**Barnard 63**) to just northeast of Antares. This lane includes **B51/B47** and 5½°-long **B44**.

While observing the globular cluster NGC 6401 in Australia from the darker and drier side of the Blue Mountains with Tony Buckley's 14.5-inch Dobsonian, I noted that the sharp border of the Pipe Nebula's bowl (B78) was well within the same 81× field as the globular.



JIM WINDLINGER

The chart at left is an excerpt from page 56 of *Sky & Telescope's Pocket Sky Atlas*. It shows almost exactly the same section of sky as the photograph at right; see how many of the dark nebulae you can match up. The Dark Horse (sitting on its haunches, also known as the Pipe Nebula) occupies much of the left side of the photo. Antares, M4, and the colorful Rho Ophiuchi Nebula are on the right.



POSS-I / CALTECH / PALOMAR OBSERVATORY

Barnard 72, the Snake Nebula, and its eggs (B68, B69, B71, and B70) show up particularly well in the red plate of the first Palomar Sky Survey.

Two degrees southwest, in the center of the bowl, I noted "opacity 6/6, only 13 mostly faint stars in the entire low power field." The only comparably star-poor area that I have seen within the entire Milky Way is the one that runs eastward from the fine binocular trio **Rho Ophiuchi**, 3° north of Antares.

The ½°-long **Snake Nebula**, Barnard 72, resembles a wisp of smoke wafting from the bowl of the much larger Pipe on wide-field images. Ernst Johannes Hartung's classic guidebook, *Astronomical Objects for Southern Telescopes*, considers B72 to be fairly challenging even from the Southern Hemisphere. Yet superb transparency behind a cold front at the 1996 Mount Kobau Star Party, which is held near Osoyoos, British Columbia, allowed my 16-inch Dob to reveal the entire Snake Nebula. The easier southeastern loop of the S has opacity 6/6, but the middle of the northwestern loop is ill-defined visually.

Expert observer Chris Beckett saw parts of B72 with his 125-mm f/6 apochromatic refractor at 53× from Grasslands National Park on the Saskatchewan-Montana border on a memorable night when the limiting visual magnitude was 7.2. He writes: "Having failed to observe it on two previous excellent nights, I finally made the observation on the 29th of July 2011. B72 was seen as a U followed by a comma, not a continuous S shape. The trick for me was using the reprinted Barnard & Dobek *A Photographic Atlas of Selected Regions of the Milky Way*."

On a night of excellent transparency in northern New Mexico, I aimed Chaco Observatory's 25-inch Dobsonian at B72. At 113× I went after the four adjacent small dark nebulae immediately south of the Snake. They had been on my observing list as the Snake's Eggs for years, and I decided to attempt them while I was in the high desert. The small oval vacancy **B68**, opacity 6/6, was black and obvious — more so than the Snake itself. An 11th-magnitude star lies just outside the dark nebula's western edge. Adjacent **B69** appeared subtle but definite. I finally detected **B71**, but this one was tough — a tiny pore, just a fraction of B69's size. **B70**, elongated north-northeast to south-southwest, was the second-easiest of the Eggs — I swept it up without a detailed star-hop. B70's southern end is darker and more obvious than the northern. The glaring 6.7-magnitude star that lies between the Snake and B70 doesn't help when hunting the Snake's Eggs!

If you don't succeed with the Snake, be sure to give B68 a try before leaving the field. Here at latitude 49° north, on a night when I had failed on both the Snake and the rest of its Eggs, my 8-inch Dob working at 51× managed to barely show B68. It appeared about the same size as in the photograph above. ✦

__Alan Whitman__ thanks Australian Tony Buckley for making large telescopes available to scores of Northern Hemisphere amateurs so they can explore the wondrous Southern skies.

A Dob by Any Other Name

With so many variations, you might wonder when a Dob is really a Dob.

Two events recently prompted me to reflect on the current state of the Dobsonian telescope. The first was the publication of this magazine's February issue with my review of the OneSky telescope from Astronomers Without Borders. Soon afterwards, I was saddened to learn that John Dobson had died (*S&T:* April 2014, p. 71). My path crossed John's many times, and I fondly remember serving as a telescope-making judge with him one year at the Mount Kobau Star Party in British Columbia.

While considering John's contributions to our hobby, I couldn't help but think about how the Dobsonian name now applies to all kinds of scopes, including the OneSky. If, however, the term were to refer to telescopes like those John actually made (or at least those that reflect his views on telescope making), then the OneSky and many other instruments wouldn't qualify as Dobsonians. Why? First, in the case of the OneSky and others of its ilk, it's too small. John felt that the size of instruments commonly used in the 1960s and '70s contributed to a kind of "delinquency" and observing paralysis. He thought that most people back then looked endlessly at the same things because they were aperture-limited. The bigger the better, so far as John was concerned.

GARY SERONIK

At Canada's Mount Kobau Star Party, John Dobson (right) and Lance Olkovick discuss Lance's newly completed 16-inch truss-tube Dobsonian.

Second, John never built anything that didn't have a conventional, solid tube. I remember walking the hill at Kobau with him when we came upon a nice 16-inch truss-tube Dob that my friend Lance Olkovick had built. John was impressed with the scope's portability, and though he didn't express disapproval of the truss design, he never made one himself.

Third, hands up — how many people think that short-focal-ratio mirrors are a Dobsonian innovation? If you raised your arm, you're not alone. Instruments with focal ratios around f/4.5 are commonly called Dobsonians. Yet John never liked fast scopes. His scopes were usually never faster than f/6. The f/4.5 variation originated with the long-defunct Coulter Optical Company. Its f/4.5 Dobsonians were so popular that the focal ratio became regarded as one of the Dobsonian's defining characteristics!

In its original form, the Dobsonian was a Newtonian reflector made with inexpensive materials; it moved on an alt-azimuth mount made of wood with Teflon-and-Formica bearings; and it sported a big, thin primary mirror. John's entire reason for building telescopes was to get as many people as possible to see the universe firsthand. He didn't want expense, aperture, or utility to be barriers.

Of course, there's no putting the genie back in the bottle. Today, the term Dobsonian is attached to all manner of scopes, regardless of what John himself built or blessed. And as ATMs continue to push the limits of what a big-aperture, alt-azimuth Newtonian looks like, so will the range of instruments bearing the Dob descriptor.

In spite of the Dobsonian design's popularity, John was never publicly comfortable taking credit for it. He used to say that he didn't like it when telescopes were named after their inventors. He'd joke, "Maksutov Schmaksutov, Newtonian Schnewtonian, Dobsonian Schmobsonian, Schmidt, Schmidt!" He always laughed at that one. ✦

*Contributing editor **Gary Seronik** is an experienced telescope maker who has built a few "real" Dobsonians, some of which can be seen on his website, **www.garyseronik.com**.*

Sean Walker

The ASI120MM Camera from ZW Optical

This highly versatile camera was made for planetary imaging.

ALL PHOTOS BY THE AUTHOR

ZW Optical ASI120MM

U.S. price: from $328

zwoptical.com

The company's website includes a list of worldwide dealers, including High Point Scientific and OPT Telescopes in the United States.

The ZWO ASI120MM camera is sold as a complete package, including USB and autoguiding cables, software, telescope and lens adapters, and a fisheye lens. The 2-meter (6½-foot) USB cable provides the camera's power as well as its communication with a host computer running 32- or 64-bit Windows XP or higher software.

It's been more than a decade since digital imaging became amateur astronomy's preferred method for monitoring the planets. And each passing year brings more advances in the form of new cameras and new or updated image-processing software. One of the newest cameras is from ZW Optical, a company founded by amateur astronomers in 2011 that specializes in making astronomical imaging equipment.

Unlike "planetary" cameras appropriated from the machine-vision industry, ZW Optical's ASI120MM was designed for planetary imagers from the get-go. Its compact, round body is only 62 millimeters (about 2⅜ inches) in diameter, and its primary mounting is a female T thread, making it readily compatible with filter wheels and other astronomical accessories. The front of the camera is 2 inches in diameter, albeit only 5⁄16 inch long, so it can fit directly into 2-inch focusers. The camera comes with a T-to-1¼-inch nosepiece as well as an adapter that steps the T thread down to a C thread for use with conventional video lenses. Also included is a CCTV lens with a 2.1-mm focal length that allows recording an extremely wide, 150° field of view and is useful for all-sky photography. The rear of the camera body has a ¼-20 threaded socket for attaching the unit to any standard photographic tripod.

At the heart of the ASI120MM is an Aptina MT9M034 CMOS sensor with 1.2 megapixels in a 1,280-by-960-pixel array. This chip is currently the most sensitive camera on the market for planetary imaging at visual wavelengths, especially at the blue and green end of the spectrum. This short-wavelength sensitivity is noteworthy because blue light is particularly affected by atmospheric seeing, leading to more blur when shooting planetary videos. But the chip's high blue sensitivity enables imagers to use shorter exposures and faster frame rates than other chips are capable of achieving, giving us a better chance of beating the seeing with more frames. I found this to be particularly useful when imaging Saturn, the dimmest of the easily visible planets, or when recording fine structure in the thin clouds on Mars.

The camera I tested has a USB 2.0 interface with its host PC, but in mid-April the company announced that a USB 3.0 version is in the works and will have up to double the full-frame rates of the model I tested. The USB 2.0 model has a maximum download speed of 30 frames per second (FPS) for full frames at full resolution. This is more than adequate for wonderful, high-resolution captures of the Sun and Moon. When imaging the planets, the camera supports on-chip, region-of-interest (ROI) cropping, which enables users to download only the portion of the detector recording the planet. This

With the included *FireCapture* program or appropriate third-party software such as *MaxIm DL* or *PHD Guiding*, the ASI120MM will function as an autoguider. The modular ST-4 port on the camera body allows a convenient connection between the camera and a telescope mount's autoguiding input.

allows much higher frame rates, up to a blazing 215 FPS, depending on the crop you choose.

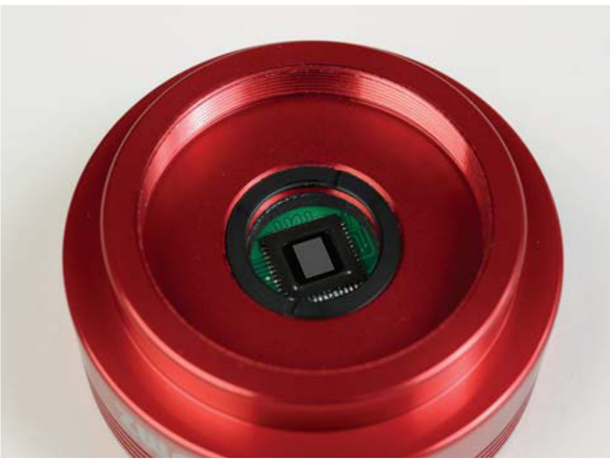
Although the camera is shipped with a mini CD-ROM disk that includes device drivers, operating software, and a manual, it's best to check the manufacturer's website and download the latest drivers. Installation is quick and easy, and my colleague Dennis di Cicco and I tried the camera on half a dozen different desktop and laptop machines running versions of Windows software from XP up through Windows 8. For unknown reasons, it would not work with one laptop running Windows 7 despite working fine on other Windows 7 computers. We assume that the computer is the problem.

Operating *FireCapture*

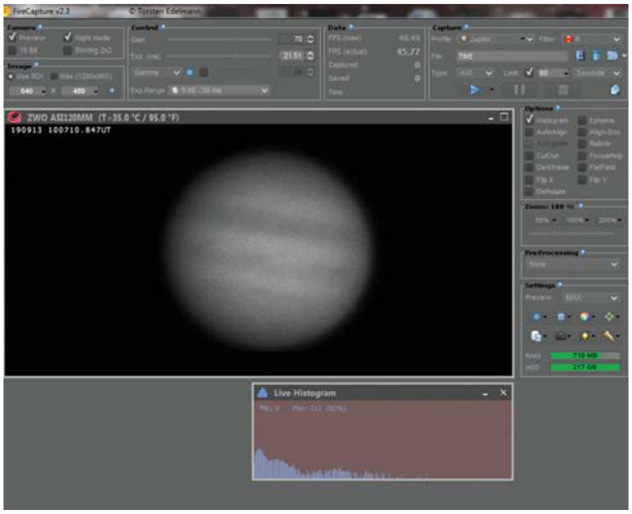
The ASI120MM is supplied with *FireCapture,* a camera-control program written by planetary imager Torsten Edelmann. It is hands down the most well-thought-out camera-control software I've used for planetary imaging. It supports many popular camera models, including ones manufactured by The Imaging Source, Celestron (including the Skyris series reviewed in last April's issue, page 62), Basler, Point Grey Research, and QHY.

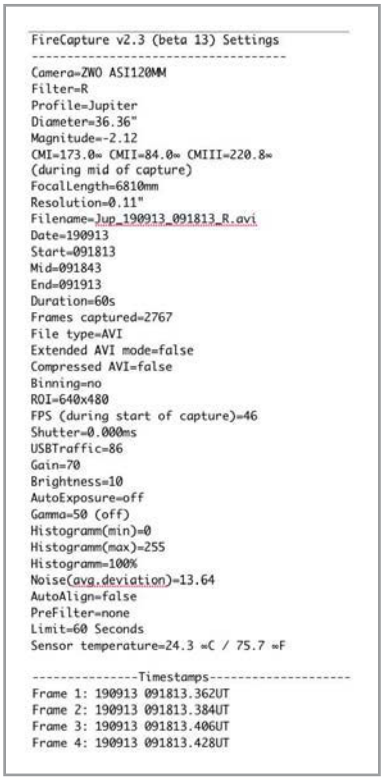
FireCapture includes helpful features that enable you to minimize the settings you have to change for different tasks (such as focusing or shooting with various filters). It also automatically creates a log of all your settings that is recorded along with each video. Thus, it's really worth the time to familiarize yourself with the program before heading out to your telescope on the first night. This is especially true because some of the features aren't particularly intuitive at the outset.

Among the software's best features are shooting profiles that include user-defined presets for the gain,



A glass window seals the camera body and prevents dust from settling on the CMOS sensor.





```
FireCapture v2.3 (beta 13) Settings
------------------------------------
Camera=ZWO ASI120MM
Filter=R
Profile=Jupiter
Diameter=36.36"
Magnitude=-2.12
CMI=173.0∞ CMII=84.0∞ CMIII=220.8∞
(during mid of capture)
FocalLength=6810mm
Resolution=0.11"
Filename=Jup_190913_091813_R.avi
Date=190913
Start=091813
Mid=091843
End=091913
Duration=60s
Frames captured=2767
File type=AVI
Extended AVI mode=false
Compressed AVI=false
Binning=no
ROI=640x480
FPS (during start of capture)=46
Shutter=0.000ms
USBTraffic=86
Gain=70
Brightness=10
AutoExposure=off
Gamma=50 (off)
Histogramm(min)=0
Histogramm(max)=255
Histogramm=100%
Noise(avg.deviation)=13.64
AutoAlign=false
PreFilter=none
Limit=60 Seconds
Sensor temperature=24.3 ∞C / 75.7 ∞F

---------------Timestamps--------------------
Frame 1: 190913 091813.362UT
Frame 2: 190913 091813.384UT
Frame 3: 190913 091813.406UT
Frame 4: 190913 091813.428UT
```

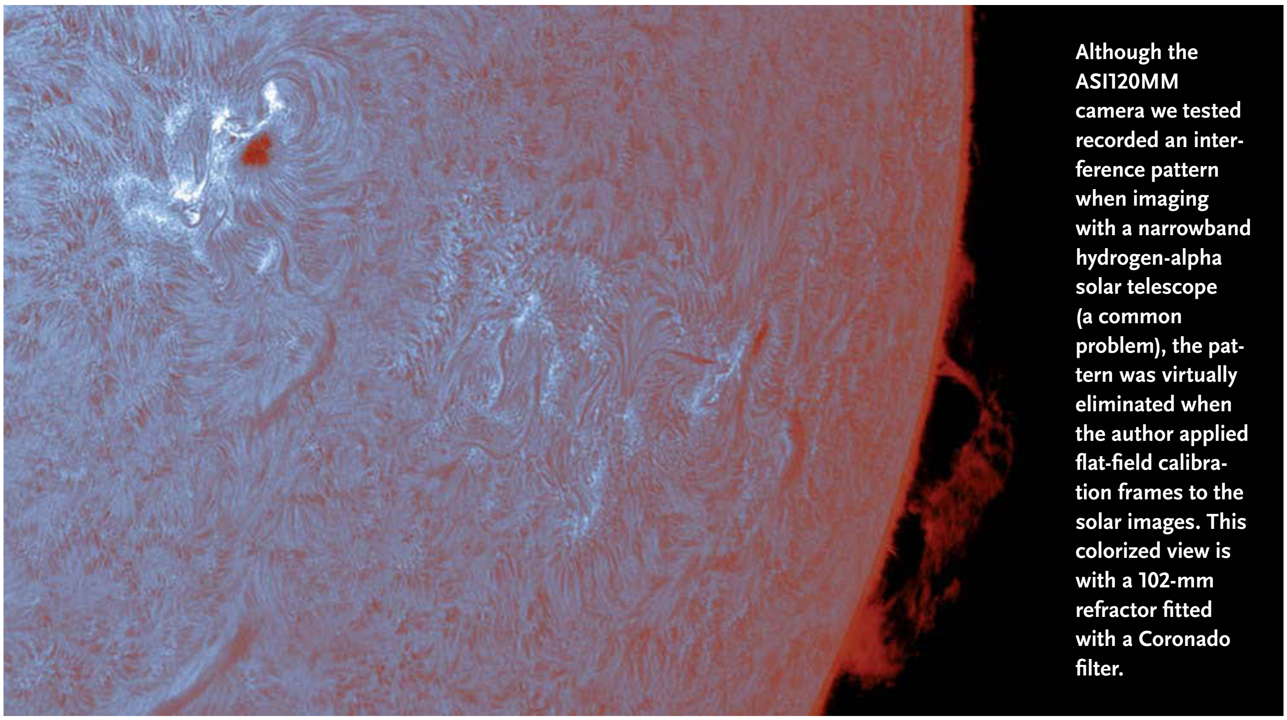
Far Left: **Described in the accompanying text, the *FireCapture* camera-control program supplied with the ASI120MM is the best planetary-imaging software the author has ever used. Especially noteworthy are its user-defined presets for shooting the Sun, Moon, and planets through various filters.**

Near left: **In addition to video clips, *FireCapture* records a detailed log with the settings used for the video as well as information about the target and a separate time stamp for each frame in the recorded video.**

exposure, and length of your capture for each video based on your target. There are built-in profiles for all the bright planets (except Mercury), as well as the Sun and Moon. You can also define the individual settings for each filter you shoot with (Edelmann has listed all the commonly used filters for planetary imaging from ultraviolet through infrared, including a methane filter).

Other *FireCapture* features include a graphical display of the video's real-time histogram, which helps you set the gain and exposure. The program can display an ephemeris for each of the major planets, giving you precise information about your target's apparent diameter, magnitude, and the central meridian visible when you're shooting. If you input your telescope's focal length, *FireCapture* will calculate the exact image scale recorded by your videos. All of this information is included in the log file that's created for each video. This material is particularly helpful if you record a transient event in your video, such as a rare impact flash on Jupiter.

To reduce noise in your videos, *FireCapture* lets you



Although the ASI120MM camera we tested recorded an interference pattern when imaging with a narrowband hydrogen-alpha solar telescope (a common problem), the pattern was virtually eliminated when the author applied flat-field calibration frames to the solar images. This colorized view is with a 102-mm refractor fitted with a Coronado filter.

record a dark frame just before you begin shooting a video clip. This dark frame is then automatically subtracted from every frame in the video.

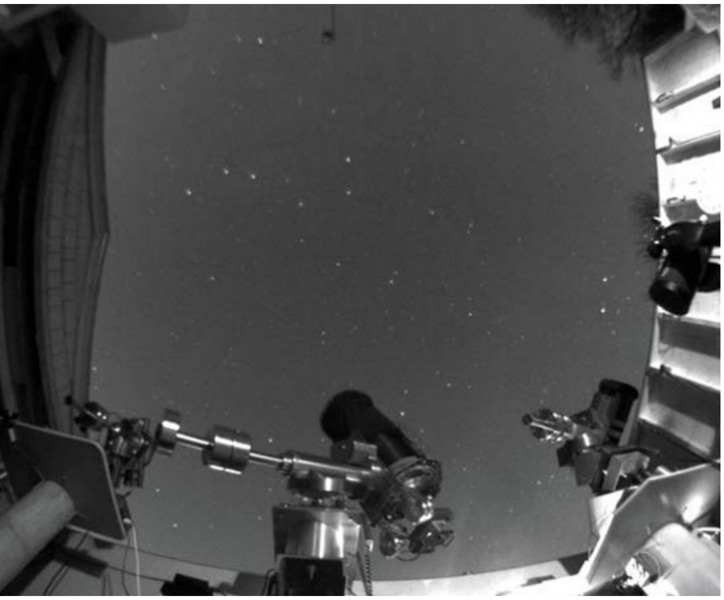
In the Field

Once at the telescope, I found the ASI120MM to be a bit different to use than other video cameras. Its tiny, 3.75-micron-square pixels were roughly half the size of those in other cameras I've tested. This required a weaker Barlow lens than I typically use for matching the pixel scale to my target. Planetary imagers often aim for images scales of 0.25 to 0.1 arcsecond per pixel, depending on the seeing conditions. I settled on an image scale of 0.12 arcsecond per pixel for the Jupiter image on this page.

Using *FireCapture*'s histogram display in conjunction with the user-defined exposure settings for each filter, I could set independent exposure levels for my red, green, and blue videos. This led to an aesthetically pleasing color balance in my images after stacking. The software's FocusHelp feature was useful for quickly establishing sharp focus in my videos when the seeing conditions were at least average. It matched the focus that I could achieve by eyeballing small planetary features such as white ovals on Jupiter, or the sunward limb on Mars.

Using an ROI of 640 by 480 pixels, I managed to record Jupiter videos at 46 FPS when the planet was far from opposition, and upwards of 70 FPS when it was closest to Earth last January. After stacking and sharpening the images, I was quite pleased with the results, which held up to the quality of the other cameras I've used.

The only minor issue I noted was that the background



The fisheye lens supplied with the camera can be used for meteor photography. This 10-second exposure with the camera sitting on the floor of senior editor Dennis di Cicco's observatory records all the naked-eye stars visible in his suburban-Boston sky.

WHAT WE LIKE:

- High sensitivity
- Small and lightweight
- Designed for astronomical imaging

WHAT WE DON'T LIKE:

- Problems running with some PC processors
- Videos have a slightly noisy background

Jupiter presents many small white and reddish storms, bluish festoons, and other subtle color contrasts in this image captured with the author's 12½-inch Newtonian reflector on the morning of September 19, 2013.

sky in each video had a small, though detectable noise level. Later analysis suggests that it might be a fixed structure in the camera's dark signal. If so, I might have mitigated it by using *FireCapture*'s automatic dark-frame subtraction mentioned above, but I didn't do so at the time.

Whereas the ASI120MM is more sensitive than other planetary cameras in visible wavelengths, its sensitivity drops off at the red end of the spectrum, particularly at near-infrared wavelengths. This isn't a major problem, but if you image Jupiter with a methane filter, you'll need longer exposures than you would with cameras that have chips with higher red sensitivity.

One feature that sets this camera apart from other planetary video cameras is its ability to be used for long-exposure astrophotography. Although I had fun playing with this aspect of the ASI120MM, the chip is very small compared with today's DSLRs or CCD cameras made specifically for deep-sky imaging. Moreover, the chip is not cooled, so getting decent deep-sky results could be tricky.

Dennis enjoyed using the camera with its fisheye lens as an all-sky imager for recording meteors. The camera's high sensitivity limited exposures to about 15 to 20 seconds under his suburban skies, but these were long enough to capture all the naked-eye stars. As is typical with this class of fisheye video lens, the quality of star images falls off as they approach the edge of the field.

The ASI120MM has a modular jack wired with the de facto industry standard ST-4 configuration, thus enabling the camera to be used as an autoguider. Although we didn't test this feature, others have reported that it performs well. Users must install ASCOM drivers for the camera to work as an autoguider with the popular software programs *MaxIm DL* and *PHD Guiding*.

Overall, ZWO's ASI120MM is a champion performer, especially considering its very attractive price. Users will get a lot of bang for the buck. ✦

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*An avid planetary photographer, imaging editor **Sean Walker** is also an accomplished painter in his free time.*

Slightly Out of Focus:

Star-Testing Your Telescope

The stars that entice us can also help us optimize our telescopes.

Alan French

Most of us have limited time to observe the night sky. As such we crave the best views through our telescopes when opportunity allows. Fortunately, the stars that entice us can also help optimize our telescopes. Star-testing reveals atmospheric steadiness, how well our optics are aligned, thermal issues, and our instrument's overall optical quality. Acquiring skill as a star-tester lets you see and handle problems that can detract from your eyepiece time.

Under steady skies and using high magnification (25× or more per inch of telescope aperture), we will see a star's image as a tiny disk (called the Airy disk) surrounded by a bull's-eye pattern of faint diffraction rings. The rings grow increasingly dimmer farther out from the center, and you'll probably see only one or two. This image is a consequence of the wave nature of light. (For an interesting, readable discussion of light's nature, I recommend Richard Feynman's 1985 book *QED: The Strange Theory of Light and Matter*.)

Requiring only a high-power eyepiece and a clear sky, a simple star-test can quickly reveal a wealth of information about a telescope's optical performance, including if the optics are properly aligned and acclimated to the ambient temperature. A star-test also lets you assess atmospheric seeing conditions. With experience, star-testers can determine if a telescope's optics suffer from astigmatism, spherical aberration, and stress caused by improper mounting.

ALL *S&T* IMAGES BY DENNIS DI CICCO

The Basics

The size of the Airy disk is determined by the telescope's aperture and the light's wavelength. With green light (555-nanometer wavelength) and aperture (D) measured in millimeters, the angular diameter of the dark ring just outside the Airy disk is 280/D arcseconds. In an optically perfect, unobstructed telescope, 84% of a star's light gathered by the telescope objective is concentrated in the Airy disk, with the rest distributed in the diffraction rings.

This simple mathematical formula easily shows why larger apertures have an advantage. Double the aperture's diameter and your telescope collects four times as much light. But the Airy disk's angular diameter is halved, so the light is now concentrated in one quarter the area. The result is an Airy disk that is 16 times brighter. Illustrations comparing the light distribution for star images in different-sized telescopes are often normalized (portrayed with the same height), which obscures this advantage of a larger aperture. Smaller Airy disks are also the reason why larger telescopes have better resolution, which translates into better views of double stars and lunar and planetary detail.

The diffraction pattern of a flawless in-focus star image is lovely, but atmospheric turbulence (seeing) often conceals it, especially when we're observing with large-aperture telescopes. Luckily, a star's image slightly inside and outside focus more readily helps us diagnose problems, and it's easier to discern details blurred by poor seeing in this larger image.

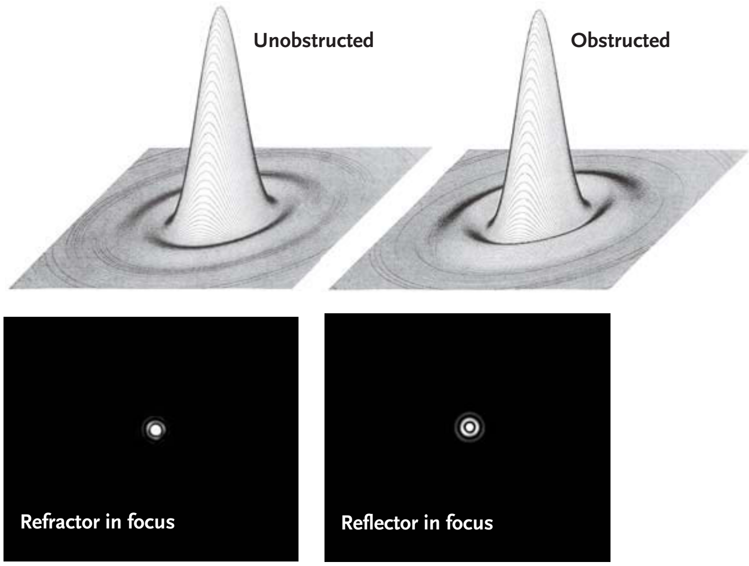
In a telescope free of optical faults, with its optics properly aligned, and at thermal equilibrium, a star's diffraction pattern just inside of focus will be identical to the pattern at the same distance outside of focus. This is true of any telescope design.

In a fine, unobstructed telescope, the expanded diffraction pattern seen just inside or outside of focus is a set of concentric rings, with the outermost ring slightly brighter and broader than the rest. The pattern is different in a telescope with a central obstruction. Other than the very center, the area in the middle is quite dark, the ring structure is coarser, and the inner rings are no longer of uniform brightness. Nevertheless, the patterns at equal distances inside and outside of focus are identical.

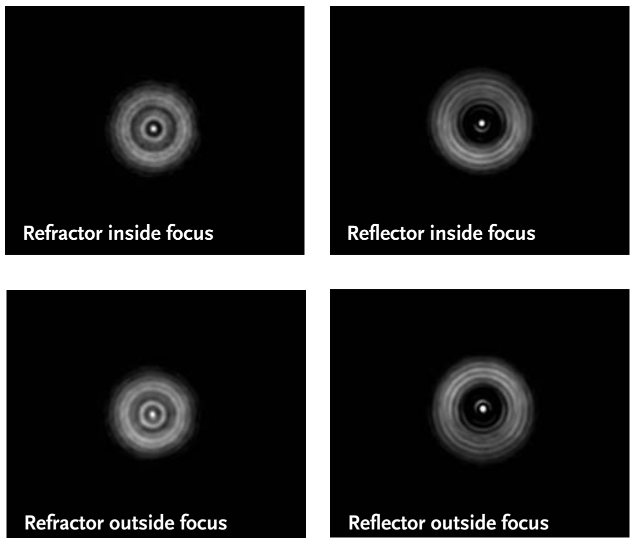
Preparing for a Star-Test

For star-testing, you should set your telescope outside early and allow an hour or more for it to acclimate to the ambient temperature. Although a star-test will quickly reveal if your optics are out of alignment, it's best to start out with the telescope as well collimated as you can make it ahead of time.

For moderate apertures, say 6 to 10 inches, select a 1st- or 2nd-magnitude star. With smaller instruments use a



Stars seem like perfect points of light to our eyes, but they have complex intensity profiles at the focal plane of a telescope. The 3-D plots above by David E. Stolzmann are from this magazine's February 1983 issue and show the intensity profiles for the diffraction patterns created by theoretically perfect optical systems. Brighter parts of the profiles are indicated by increased height of the plots above the base. A star's profile consists of a sharply peaked central Airy disk surrounded by a series of diffraction rings that fade outward from the center. Introducing a central obstruction to an optical system (such as the secondary mirror in a Newtonian or Cassegrain telescope) increases the brightness of these rings relative to those formed by an unobstructed system.



In an optically perfect telescope, the diffraction patterns for a star seen the same amount inside and outside of focus will appear identical. This is true even though the patterns will differ for unobstructed (refractors) and obstructed (most reflectors) telescopes. To a skilled eye, the distribution of light in the diffraction rings can reveal a variety of common optical problems. The setup used to capture these images (see box on page 71) introduced some spherical aberration that is seen as a slight difference between the inside- and outside-of-focus images for both telescopes.

brighter star, and with larger ones, go fainter. Select a star high in the sky where the atmospheric seeing is better. Pick an eyepiece giving an exit pupil of 1 mm or slightly smaller. A simple way to determine the exit pupil of a telescope setup is to divide the eyepiece's focal length in millimeters by your telescope's focal ratio. Thus, an eyepiece with a focal length of 5 mm will yield a 1-mm exit pupil with an f/5 telescope. For large-aperture telescopes, seeing may require you to use lower magnifications — longer focal-length eyepieces and larger exit pupils.

Star-testing is easier with a tracking telescope. Otherwise you have to continuously nudge the telescope along to keep the star closely centered in the eyepiece field while watching for moments of good seeing. For those of us in the northern seats, Polaris is a good target for modest-aperture telescopes that lack motorized tracking.

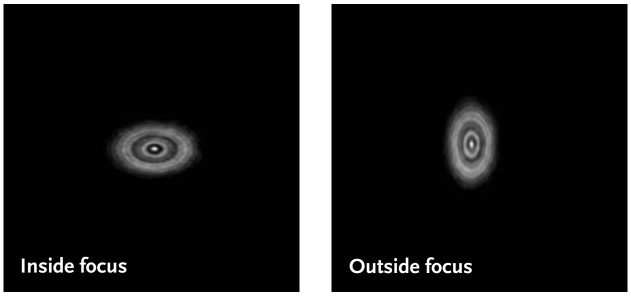
If you're testing a refractor, try adding a green or yellow filter to the eyepiece. Even the best apochromats may have some color artifacts visible on out-of-focus star images that veil the diffraction patterns. Reflective optics do not require a filter, but they can sometimes help you see what's going on. Experiment.

For most testing, defocus the star image enough to see four to eight rings. Move quickly between the view inside and outside of focus, and carefully compare their appearances. This is a very sensitive test of optical quality and you will likely see some differences, but minor ones will not have a noticeable effect on the telescope's performance for in-focus observing.

Interpreting What You See

Artifacts in a diffraction image can arise if your telescope is not at thermal equilibrium. As a telescope with a solid tube cools, the colder, denser air slides down the lower side of the tube while warmer, lighter air rises along the upper side. This variation in air density can alter the out-of-focus patterns. The effects of large temperature differences are blatant, appearing as amorphous blobs moving slowly across the out-of-focus patterns. A nearly cooled scope will show a dent in one side of the pattern well inside focus, and a bulge on the opposite side of it when well outside of focus. Thermal effects are oriented vertically. If you change the tube's orientation, you'll disturb them briefly, but they'll soon reorient themselves.

A quick glance at an out-of-focus star image is all that's needed to tell if a telescope's optics are properly aligned (collimated), since optics that aren't aligned, such as those in the 6-inch Newtonian reflector used for this image, will show eccentric diffraction rings.



Astigmatism causes the diffraction patterns of out-of-focus star images to appear as ovals with an orientation that "turns" by 90° when the eyepiece is racked from one side of focus to the other. The accompanying text explains how to quickly determine if any visible astigmatism is introduced by the telescope optics, the eyepiece, or your eye.

If your optics are not quite aligned, the rings in the out-of-focus pattern will be eccentric and the shadow of any central obstruction will appear off-center. The in-focus image will have incomplete diffraction rings squeezed off to one side. Gary Seronik's column "No-Tools Collimation" (*S&T:* Oct. 2013, p. 64) describes a very easy way for collimating a reflector with a star-test.

Bad seeing often blurs the planets and hides fine detail. It can also make star-testing difficult. In his highly recommended book, *Star Testing Astronomical Telescopes* (Willmann-Bell, 2008), Harold Richard Suiter explains that poor seeing makes the outside-focus star image look as if the dappling of sunlight on the bottom of a pool is washing across the aperture. Under these conditions you'll need to wait for moments when you can separate the true, unchanging features of the pattern from the effects of seeing. On some nights it may be a hopeless task, but on most nights patience will prevail.

Inside- and outside-focus patterns that don't appear round are signs of astigmatism. A small amount of astigmatism results in oval rings, and moving the eyepiece from one side of focus to the other will change their orientation by 90° in the field of view. But astigmatism may not mean a problem with the telescope's optics. Turn your head. If the oval pattern also turns, the astigmatism is in your eye. You should also rotate your eyepiece to see if it is a source of astigmatism. In a Newtonian, note the orientation of the oval pattern and rotate the primary mirror 45°. If the oval also rotates, then the primary is the problem. In a Newtonian reflector, a slightly concave or convex secondary mirror may cause images to appear astigmatic.

If the pattern shows rings that are irregular, especially if they show sharp points, you may have some stress in the way the telescope optics are mounted. Make sure any clips holding a mirror in place or retaining rings securing lens elements are not overly tight.

A common and significant problem with Newtonian mirrors is what opticians call a turned-down edge, meaning that the very outer part of the mirror is too flat. In

Notes on the Diffraction Images with this Article

Except where noted, the images of diffraction patterns appearing with this article were made with high-quality telescopes — an 85-mm refractor and a 90-mm Maksutov-Cassegrain. Both were fitted with appropriate Barlow lenses to yield effective focal lengths of approximately 3,000 mm. In order to enlarge the in-focus appearance of the Airy disk and improve its visibility in the images, each scope was stopped down to a 50-mm aperture. This also enhanced the brightness of the diffraction rings in the Maksutov's images because the scope's central obstruction now represented 55% of the aperture's diameter, transferring more light from the Airy disk into the rings.

An artificial star was created by reflecting the beam of a helium-neon laser located near the telescopes off a small, convex mirror located about 50 feet (15 meters) away. As noted in Alan French's accompanying text, because this artificial star was relatively close to the telescopes, it introduced a small amount of spherical aberration in the images — something that would not have occurred if the telescopes had been focused for infinity.

such cases, inside focus the rings appear washed out and there's a wide, diffuse glow beyond them. Outside focus the contrast of the rings is increased. As a reality check, you can make a circular mask that covers the very outer part of the mirror and repeat the star-test. If you verify that your mirror has a turned-down edge, the telescope's optical performance will be improved by permanently masking the mirror's outer edge.

If a scope's primary mirror or lens has a hill or a trough in the form of a circular band around its center, this "zone" will create a brightened ring on one side of focus that becomes a darkened ring on the other side.

Often a consequence of fast polishing, surface roughness on a lens or mirror causes the rings to appear uneven in brightness, with blotches of light and dark that remain at fixed locations within the rings and gaps. Seeing can produce similar effects, but the positions of the blotches are ever changing.

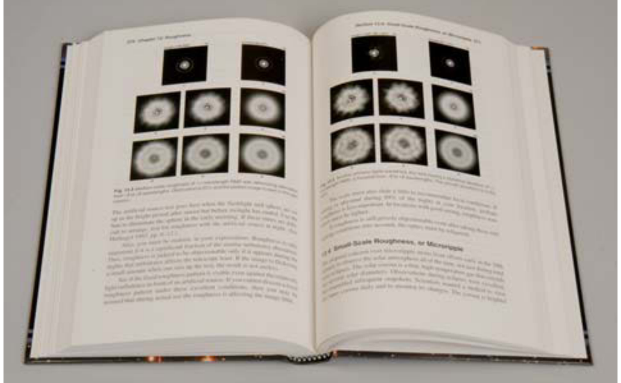
There's a fair chance your telescope will show some spherical aberration, which is a smooth variation of focus depending on where the incoming light falls on the radius of the scope's objective. A common form of spherical aberration comes from a mirror being undercorrected, where the light from the center of the mirror focuses slightly long relative to light reflected from the edge. The opposite is true in the case of an overcorrected mirror.

Ideally, the outer diffraction ring should appear equally bright inside and outside of focus. If the optics are undercorrected, inside focus the outer ring will brighten and light will be lost in the inner part of the pattern. Outside focus the outer ring will darken and the inside will brighten. With overcorrection the reverse happens. A mirror's correction can change as it cools during the night.

For most of us, the biggest hindrance to star-testing is bad seeing. To avoid it, you can star-test early in the day using the Sun's reflection off a distant, shiny sphere. Early in the day, the air is often still over long stretches of lawn. You can also buy or make a portable artificial star for use at night. If you use the Sun's reflection or an artificial star, it must be sufficiently far from the telescope. (In the May 1991 issue, page 528, Roger Sinnott detailed the aberrations caused by focusing a scope closer than infinity.)

Star-testing is often described as easy. The basics are certainly simple, but it takes time to become a proficient tester, especially given the vagaries of seeing and a telescope's thermal behavior. Spend time learning the nuances of being a tad "out of focus," and you'll know how and when you'll get your finest in-focus views. ✦

*Telescope maker and observer **Alan French** wrote about eyepieces in our September 2013 issue, page 68. His wife, Sue, authors our monthly Deep-Sky Wonders column.*

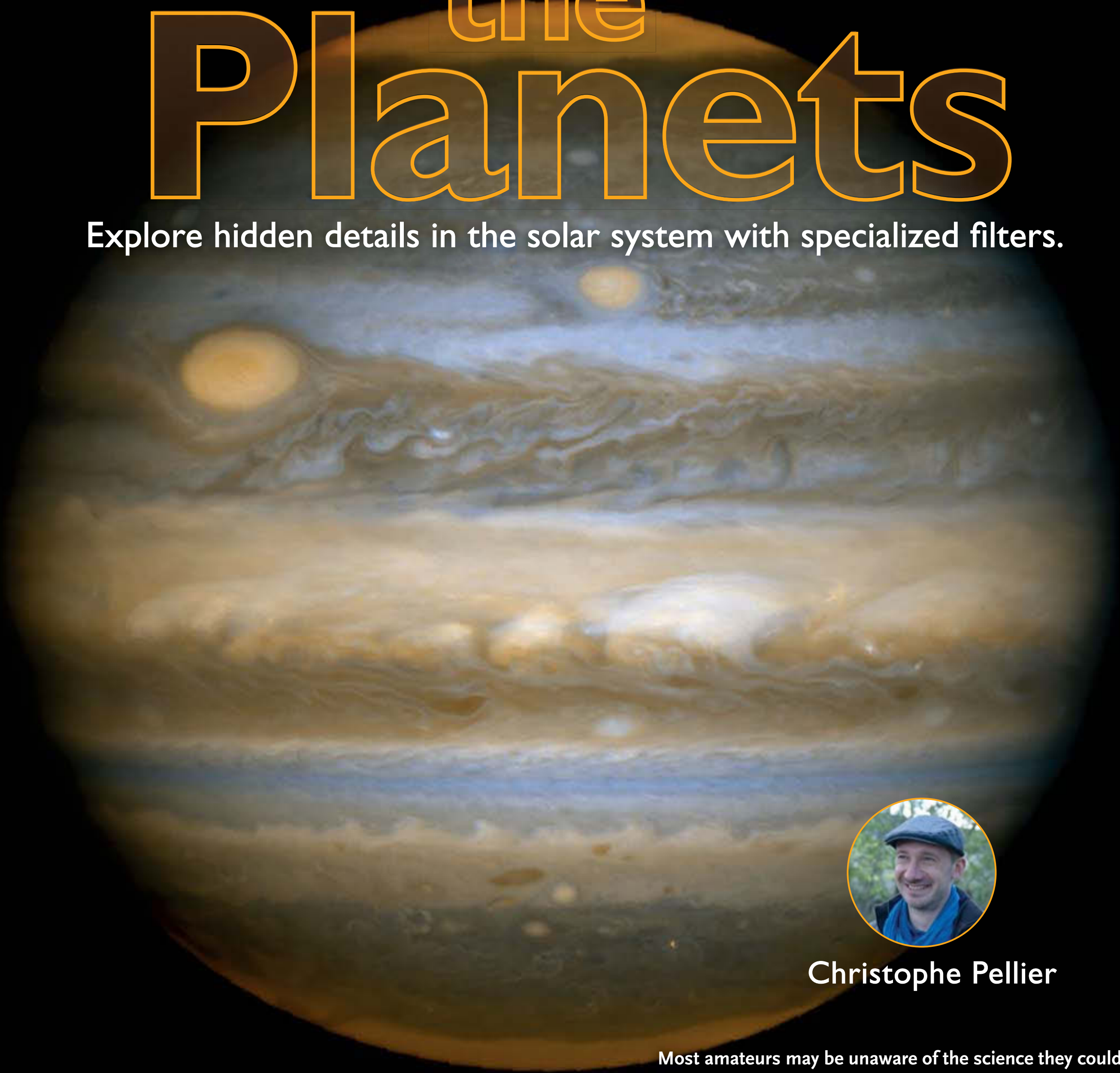


It's in the Book

There's one-stop-shopping for anyone wanting to learn all the nuances that can be gleaned from a star-test — the second edition of Harold Richard Suiter's *Star Testing Astronomical Telescopes* (Willmann-Bell, 2008). An applied physicist, Suiter gives detailed theory and background on star-testing amateur telescopes. A highlight of the book, however, is the computer-generated diffraction images that will help you determine what level of errors exist in an optical system. Subtitled "A Manual for Optical Evaluation and Adjustment," the book is a proverbial gold mine of material for extracting the most information from a star-test. A copy belongs on every serious telescope-user's bookshelf.

Probing the Planets

Explore hidden details in the solar system with specialized filters.



Christophe Pellier

Most amateurs may be unaware of the science they could do by imaging planets through specialized filters. This highly detailed false-color Hubble Space Telescope image of Jupiter was recorded through near-infrared and methane filters, which highlight the altitude of cloud features. Amateurs can take similar filtered images to help determine the origin of transient phenomena.

NASA / ESA / I. DE PATER AND M. WONG (UNIVERSITY OF CALIFORNIA, BERKELEY)

CAPTURING COLOR, high-resolution planetary images has become nearly commonplace. Today's sensitive, high-speed video cameras, coupled with excellent optics, enable subarcsecond detail to routinely appear in amateur images. But amateurs are capable of much more than "pretty pictures." Monochrome cameras combined with specialized filters can deliver a wealth of information about planetary activity. Exploring our solar system beyond the visible spectrum allows amateurs to produce scientifically useful data. And because few professional observatories are dedicated to planetary study, amateur observations are extremely useful. So let's explore what's within our grasp.

Look Deeper with Near-Infrared

Filters that block visual wavelengths and allow near-infrared (near-IR) light to pass through have been popular for many years. CCD cameras are sensitive to light beyond 700 nm — the limit of the human eye's sensitivity to light. Companies including Astronomik, Astrodon, Baader Planetarium, Chroma Technology, and others offer a range of filters passing light longer than 685 nm suitable for astronomy.

Under our often-turbulent skies, images captured in visible wavelengths are sometimes soft and blurry. But due to the nature of light, longer wavelengths in red to near-IR wavelengths are less affected by atmospheric turbulence. Near-IR images are also less affected by dust scattering within our atmosphere, which is one reason why near-IR images have higher contrast than their visible-light counterparts. But near-IR imaging does have one significant drawback: these longer wavelengths are inherently lower resolution than light in the visible spectrum. In many instances though, the benefits outweigh this shortcoming.

Because near-IR light penetrates the upper-atmosphere hazes on all the gas giants, giving us a clearer view to the layers below, astronomers use these images to study features partially obscured in visible wavelengths. This effect is particularly visible on Jupiter. The planet's main cloud deck contains almost all the active structures of its upper atmosphere: high- and low-pressure systems, eruptive plumes, and large swirling storms.

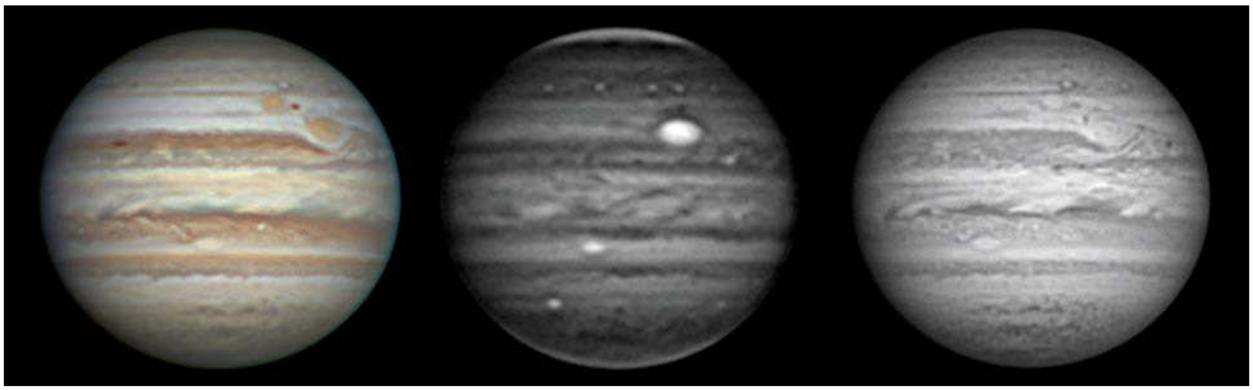
Saturn is a similar case, though imaging the Ringed Planet through near-IR is even more revealing than it is for Jupiter. The planet's colder temperatures produce thicker hazes above its cloud belts, so standard color filters yield low-contrast images compared to near-IR pictures. High-resolution near-IR images often record small storms barely visible in standard visible wavelengths.

Perhaps the most interesting features we can record with a near-IR filter are the atmospheric belts and occasional bright spots on Uranus. These tiny details are beyond even the Hubble Space Telescope's reach in visible wavelengths. Uranus has in recent years displayed a faint equatorial belt as well as a brighter belt near the boundary of its northern polar region. On Neptune, amateurs have detected a bright near-IR spot in its southern hemisphere as recently as 2013.

So what about the rocky planets? Mars displays very-high-contrast albedo features in near-IR light, though these same details are better resolved in red light. During the onset of large dust storms, the haze-penetrating characteristic of a near-IR filter is useful for increasing the visibility of the boundaries of these dust clouds in relation to the known albedo features.

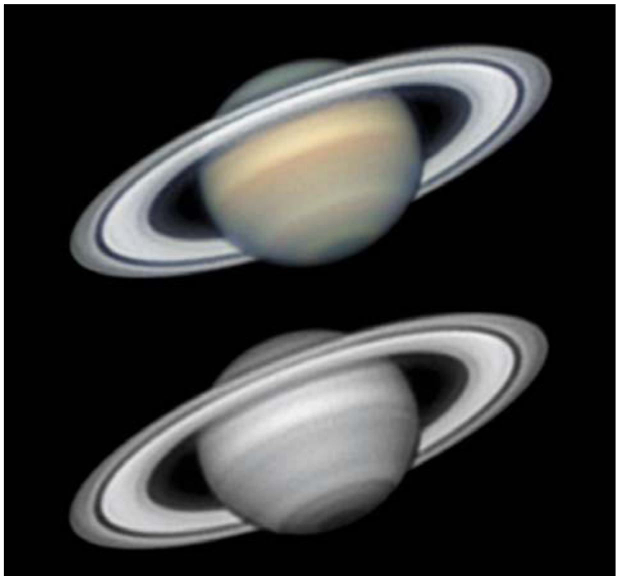
Venus presents faint, grayish atmospheric banding localized at a level too deep to be detected visually (roughly 10 km lower in the atmosphere). Such banding is interesting to follow day to day, as these cloud movements are studied less than in other wavelengths.

Imaging Mercury through near-IR filters is most beneficial due to the planet's close proximity to the Sun, making it impractical to image at night (*S&T:* Oct. 2009, p. 70). Near-IR filters slightly improve the contrast between the planet and the bright daylight sky when Mercury is



CHRISTOPHE PELLIER (3)

Although a wealth of detail can be captured in visual wavelengths (left), shooting Jupiter through a methane filter (center) reveals that certain storms, particularly the large Great Red Spot, reside high above the surrounding atmosphere. Images recorded through a near-infrared filter (right) show details near the limb and poles of the planet that are otherwise hidden by high-altitude haze.



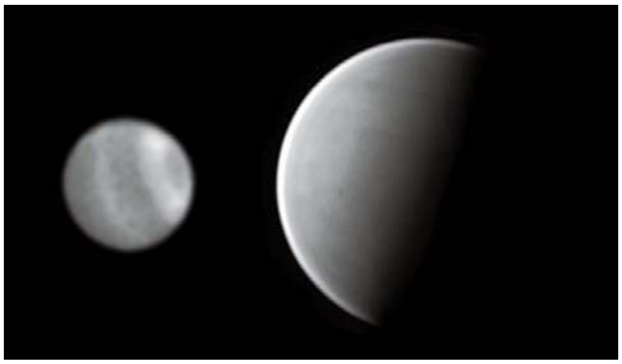
Saturn captured through a 742-nm near-IR filter (bottom) displays atmospheric banding in higher contrast than in the visible wavelength image at top. Notice the planet's hexagonal polar vortex is easier to see in the near-IR.

WAYNE JAESCHKE

highest, and because daytime seeing conditions are often more turbulent than they are at night due to solar heating of the surrounding terrain, the tradeoff of reduced resolution is offset by the steadier seeing in longer wavelengths.

Methane: Seeing the Altitude of Clouds

When imaging the planets, the primary information recorded is the albedo (or reflectivity) information of the target's atmosphere or rocky surface. From ultraviolet (UV) through near-IR, the information that you glean about a planet comes from the color contrast of its details; you see the Great Red Spot (GRS) on Jupiter as a reddish color because it reflects red light and absorbs blue wavelengths. However, there are two notable exceptions to this rule.



URANUS: DAMIAN PEACH; VENUS: SEAN WALKER

Left: **Uranus currently displays atmospheric banding when imaged in near-IR wavelengths.** ***Right:*** **Faint markings are sometimes visible in near-IR images of Venus.**

The first exception is methane (CH_4) imaging using a highly specialized (and often expensive) CH_4 passband filter. A methane filter passes a very narrow range of near-IR light centered at 890 nm. This wavelength corresponds to the strongest *absorption* band in the spectrum of methane gas. The atmosphere of each gas giant contains a small portion of methane. When imaged through a methane-band filter, the planets appear very dark, because their atmospheres are absorbing (rather than reflecting) that wavelength of light. But not all cloud features appear the same. Storms that reside in the highest altitudes have less CH_4 above them, so they appear brighter than their surroundings. Images recorded through a methane filter thus help astronomers study cloud stratigraphy in the gas giants' atmospheres.

Jupiter responds best to a CH_4 filter; most anticyclonic structures, such as the white ovals and particularly the GRS and Oval BA (Red Jr.), appear bright in methane images due to their positions high above the surrounding atmosphere. The planet's South Polar Hood, which is practically invisible at other wavelengths, also appears bright in CH_4. The primary North and South Equatorial Belts are revealed to be lower-altitude clouds and white zones of bright, higher hazes. But most interesting of all, you can detect temporarily bright features, which are rapidly ascending convective clouds — a sign of the onset of a strong disturbance. As such, the revival of faded belts (such as the South Equatorial Belt in 2010) begins with the sudden appearance of bright cumulonimbus clouds, and a CH_4 filter will confirm its altitude.

Due to the poor sensitivity of imaging detectors at 890 nm, combined with the nature of the information recorded, the other gas giants respond rather poorly to imaging through a methane filter. Saturn displays a brighter Equatorial Zone but not much else; even its storms don't appear bright in CH_4 because the atmosphere's upper layers are quite thick. Uranus and Neptune would show very interesting features in methane, but their disks are tiny as seen from Earth, and the absorption of methane in their atmospheres makes the signal too faint to record with amateur equipment.

Thermal Emissions in IR

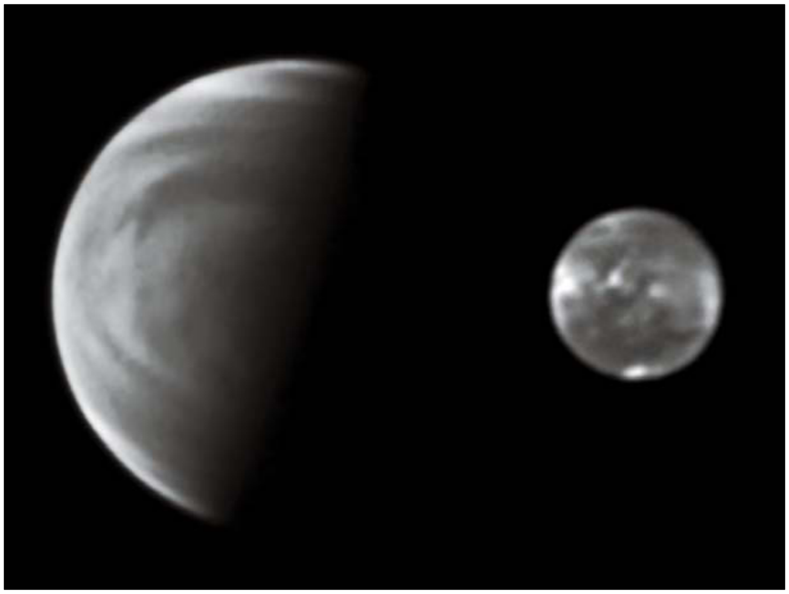
Beyond the methane band, there is one other spectral region at the red end of the spectrum that is of interest to enterprising amateurs. This second exception to the albedo rule serves to reveal what is completely unseen at visual wavelengths: the surface of Venus. Earth's "sister" is permanently hidden beneath a thick and opaque layer of sulfuric-acid clouds. Due to an extreme greenhouse effect, ground temperatures average a hellish 460°C (860 °F). When a body is heated to this temperature, it literally glows at a wavelength of around 1 micron (1,000 nm) in the near-IR, a band of light just barely visible to amateur CCD cameras. And by lucky coincidence, the primary component of the Venusian atmosphere is carbon dioxide, which is translucent at the same wavelength, allowing the thermal emission from the surface to escape into space.

Thermal emissions from the Venusian surface are very weak in comparison to the blinding glare of sunlight reflected by its daytime clouds. For this reason, they can only be observed on the night side of the planet, when Venus is visible from Earth as a razor-thin crescent shortly before and after inferior conjunction. To image this thermal signal you'll need a 1-micron IR filter and you'll have to take exposures several seconds long, deliberately overexposing the dayside crescent (*S&T:* Oct. 2010, p. 72). Some darker regions can be seen on the glowing night side: these are the mountaintops and other highlands, which appear darker due to the lower temperatures found at their higher altitudes.

Ultraviolet Light

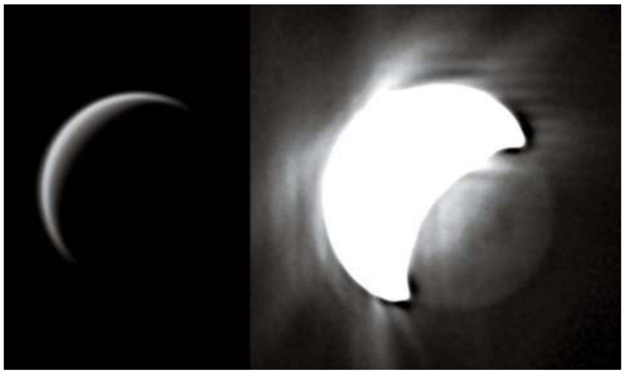
The one other wavelength region useful for studying our solar system's planets resides at the opposite end of the spectrum. These are UV wavelengths, from 300 to 400 nm. Invisible to our eyes, UV light is greatly affected by our atmosphere; short wavelengths are blurred by our turbulent atmosphere and scattered by water vapor and thin clouds. Even our telescope optics block some UV light — glass components from Barlow lenses or corrector plates in Schmidt-Cassegrain telescopes absorb some UV, and the sensitivity of CCD detectors is very low in this region of the spectrum. The UV light accessible to amateurs corresponds to the bands between 300 to 400 nm, also known as UVC, the only one of the three UV bands that manages to penetrate Earth's ozone layer.

Imaging through a UV filter enhances details in the upper cloud layers of the terrestrial planets. Venus particularly benefits from the use of a UV filter (*S&T:* Oct., 2007, p. 96). Its upper atmosphere contains a still-unidentified compound that strongly absorbs light at the UV wavelength centered at 365 nm. The distribution of this compound isn't uniform in the Venusian atmosphere, so UV-filtered images reveal the presence of large vortices above the planet's polar regions, often appearing as bright cusps, while atmospheric waves near the equator form features that resemble a Y or Psi (Ψ) shape. Following these features for a number of consecutive days enabled French amateur Charles Boyer in 1957 to determine the rotation rate of the Venusian atmosphere to be around four terrestrial days (*S&T:* June 1999, p. 56).



VENUS: SEAN WALKER; MARS: CHRISTOPHE PELLIER

Left: **Venus presents swirls and banding in ultraviolet light, whereas it has a mostly bland appearance in other wavelengths.** ***Right:*** **UV images of Mars reveal the planet's water vapor clouds.**



CHRISTOPHE PELLIER (2)

Right: **While imaging Venus with a 1,000-nm filter shortly before the planet's inferior conjunction in 2004, the author was the first to record thermal emissions from the planet's surface. The faint darker markings in the bottom-right of the globe are cooler mountaintops.** ***Left:*** **This image was taken prior to the overexposed version at right, demonstrating the visual appearance of the planet on the same evening.**

Images of the other planets through UV filters show many of the same features recorded through blue and violet visual filters, except Jupiter. Reddish storms in the Jovian atmosphere appear particularly dark in UV wavelengths, and transient coloration events in the belts and storms are easier to detect than at longer wavelengths.

In this recent golden age of planetary imaging, the quality data amateurs routinely produce has led to some exciting discoveries. And with the limited resources dedicated to solar system studies at NASA, ESO, and other professional observatories, amateur observations beyond the visible spectrum are more valuable than at any time in the past. So consider broadening your spectral range to participate in this growing field of pro-am collaboration. You could provide valuable data that unlocks new discoveries in our knowledge of the solar system. ✦

Christophe Pellier *is a long-time planetary imager and observer. Follow his imaging adventures at* ***www.planetary-astronomy-and-imaging.com****.*

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GHOSTLY NEBULAE
Frank Sackenheim
Bluish reflection nebula van den Bergh 152 at right adds color to this otherwise faint column of dust in Cepheus, while the crimson-pink area to the upper left is planetary nebula LBN 538.
Details: *TMB 80-mm refractor with SBIG ST8300M CCD camera. Total exposure was $24\frac{2}{3}$ hours through Astrodon color and Hα filters.*

▲ **ECLIPSE AMONGST THE STARS**

Eric and Josephine Africa

Warm orange and yellow tones color the Moon during April's total lunar eclipse as seen among the fainter stars of Virgo.

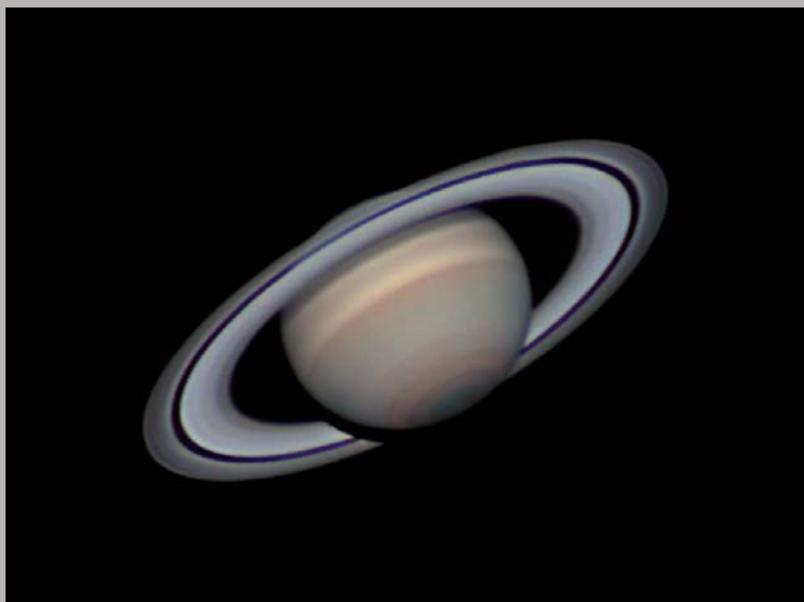
Details: *Takahashi FSQ-106N astrograph with an SBIG STL-11000M CCD camera. Total exposure was just over 3 minutes through color filters.*

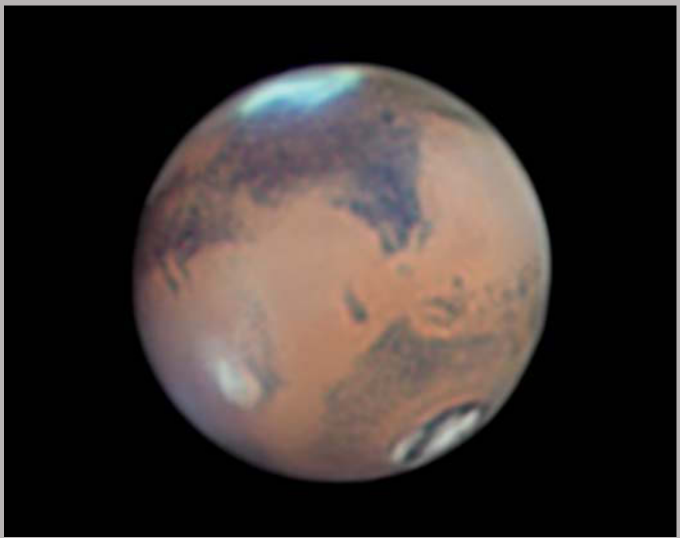
► **BELTS, RINGS, AND GAPS**

Fabio and Gabriela Carvalho

Saturn's increasing tilt as seen from Earth helps to show off the distinct sections of its resplendent ring system. The planet's disk also displays subtle belts and zones, including the greenish hexagonal cloud pattern surrounding its north pole.

Details: *16-inch Newtonian reflector with QHY5L-II video camera. Stack of multiple exposures recorded through Baader Planetarium color filters.*





▲ **PHILADELPHIA MOONSET**

Jerry Lodriguss

Thin clouds seem to conspire with the young Moon's low altitude, turning it a ruddy color over the skies of Philadelphia, Pennsylvania, shortly before sunset on the evening of April 1st.
Details: *Canon EOS Rebel T3i DSLR camera with Nikkor 180mm f/2.8 ED lens. HDR composite combining multiple exposures ranging from 1/15th- to- 2 seconds at ISO 400.*

◄ **CLOUDY ON MARS**

Glenn Jolly

The dark albedo feature Syrtis Major is crowned by the cloud-filled Hellas impact basin in the Martian southern hemisphere (top) while more clouds cling to the flanks of Elysium Mons (left).
Details: *Celestron EdgeHD 14 Schmidt-Cassegrain telescope with ZWO ASI120MM video camera. Stack of multiple exposures recorded through color filters.* ✦

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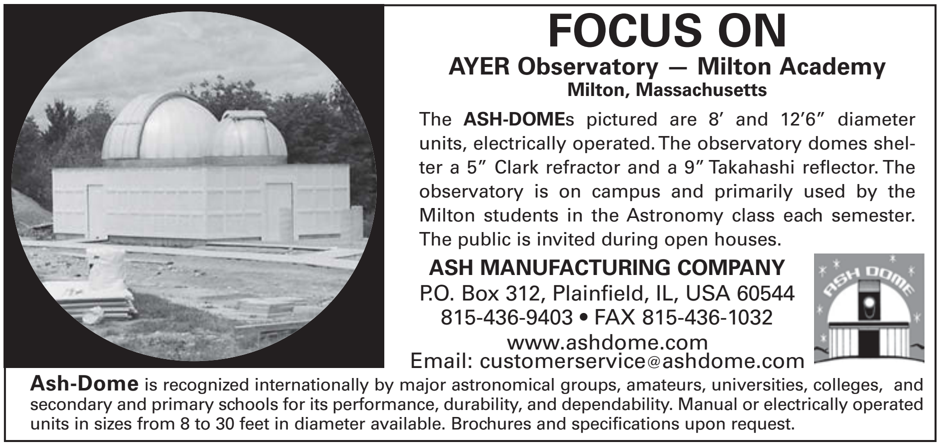

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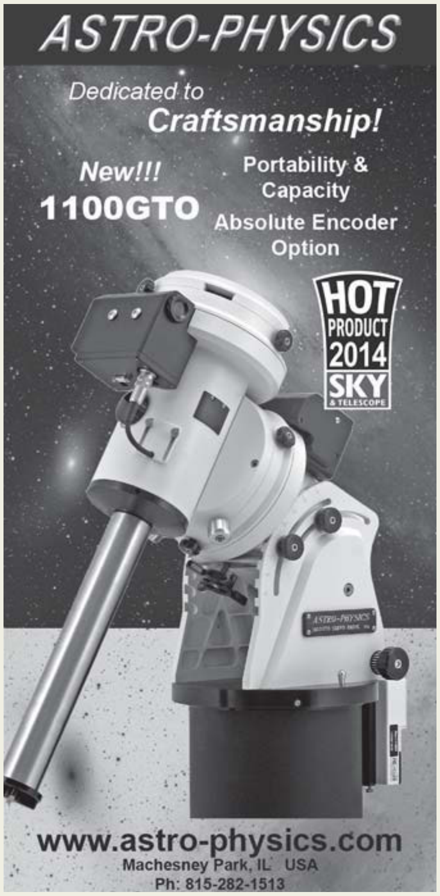

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Michael Deneen

You and the Universe

At the eyepiece, there's a difference between beauty and the sublime.

Perhaps you have noticed the difference. We've all shown Saturn to someone, or perhaps you've shared a clear view of a bright star cluster with someone who hasn't seen such a thing before. In these and similar cases, the sheer beauty of the object is the whole point; any impressive facts are secondary. It doesn't really matter how big or far away it is. When someone sees Saturn for the first time we hear a shout of surprise, a shared experience of joy at seeing something wonderful.

Now think about one of those other sights — the ones that make your gut tighten up, that stop your mind for a few seconds until you recover and are able to take it all in. You probably know the essential facts about this object, but it still baffles you. Chances are that you're looking at something faint, perhaps a very distant galaxy cluster, or perhaps you targeted a quasar. But in each case you're seeing something that is best appreciated when you know how unimaginably far away or immense it actually is.

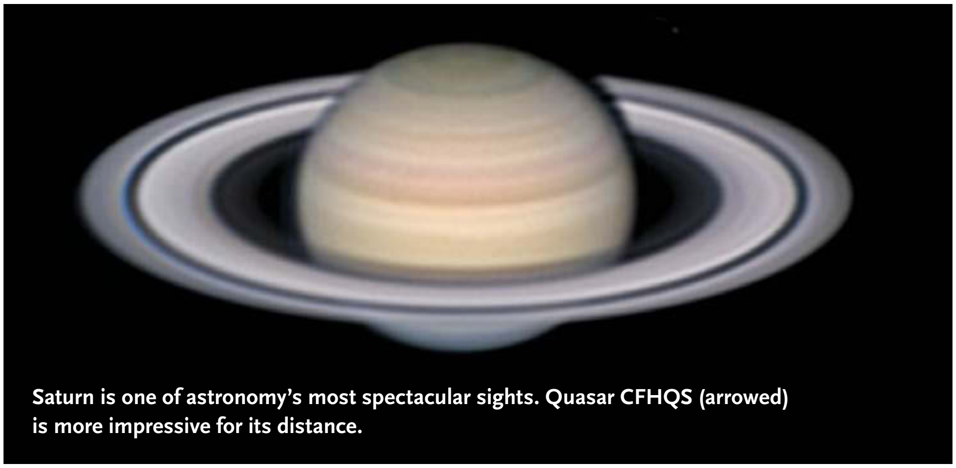
You are probably not going to call a stranger over to see this. What you know you're seeing overwhelms you, sets you back on your heels, but you don't know if the person next to you can appreciate that gray spot in the same heart-stopping way that you do. It's not because the image in your eyepiece is indistinct or faint, it's because you've encountered the sublime.

The difference between these two kinds of experiences is not unique to astronomy. In fact, philosophers no less distinguished than Edmund Burke and Immanuel Kant have pondered the different emotional experiences. They and other intellectual luminaries explored what affects us so deeply when we encounter enormous or uncountable things. They came to different conclusions but agreed that the sublime is distinct from mere beauty. So what really happens to us when we encounter something awesome in the eyepiece, and why does it feel so different?

Kant decided that beauty is social, that it can be reasonably summed up as something we share with others. But that is not so with the sublime. The experience of the sublime puts you right up against what you're viewing; it's just you and the universe and at first it seems like there's a bad fit between the two. It's a solitary experience. Kant explained it like this: faced with something that is just too much for us, we are halted in our tracks, unable to imagine or absorb it. But after this initial moment of blockage, our sense of reason comes to the rescue, and we're able to fashion a kind of accommodation between ourselves and whatever is out there.

It's that brief moment of being blocked, and then rescued, that produces the exhilaration of the sublime. What for a moment had seemed an imaginative defeat has become just the opposite, an experience of awe and of participation in wonder. It's what you sometimes feel on the observing field on a good night. You can share the view, but your feelings can only be shared with the universe. ✦

***Michael Deneen** teaches at Endicott College and is a member of the Gloucester Area Astronomy Club on Cape Ann in Massachusetts. He is a guerrilla astronomy enthusiast, and enjoys staring at baffling objects late at night with friends.*



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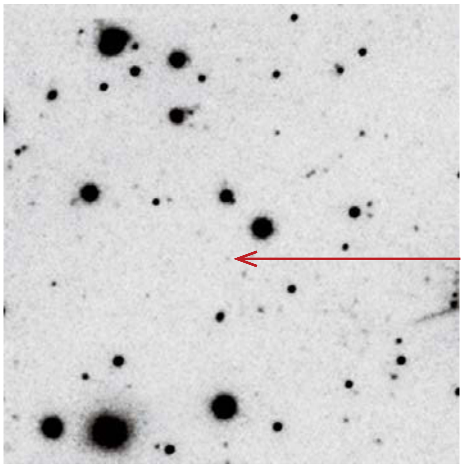

JOHANNES SCHEDLER / KEN CRAWFORD

Saturn is one of astronomy's most spectacular sights. Quasar CFHQS (arrowed) is more impressive for its distance.