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SKY & TELESCOPE
October 2013 VOL. 126, NO. 4

On the cover: This multiwavelength composite shows the Crab Nebula, a famous supernova remnant.

COVER IMAGE: STAR FIELD: R. GENDLER; SUPERNOVA: X-RAY: NASA/CXC/SAO/F. SEWARD, OPTICAL: NASA/ESA/ASU/J. HESTER & A. LOLL, INFRARED: NASA/JPL-CALTECH/UNIV. MINN./R. GEHRZ

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OBSERVING OCTOBER

S&T TEST REPORT

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  Watch a total solar eclipse from the stratosphere.

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Image by Ted Rafferty

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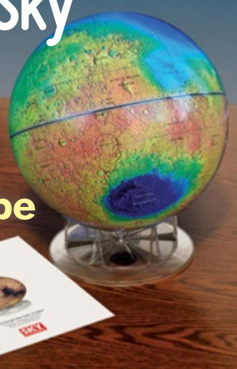

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June, July, August, and September

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ONLINE PHOTO GALLERY

Niels V. Christensen imaged M51 in March and April of this year.
See more beautiful astrophotos, or submit your own, to our online Photo Gallery.

Money Spent Down Here

THIS IS GOING to sound strange, but I had a lot of fun at July's Green Bank Star Quest even though the nights were clouded out. This star party is held at the National Radio Astronomy Observatory in Green Bank, West Virginia. NRAO generously allows GBSQ attendees to tour inside the security gate for close-up views of the antennas. NRAO also permits the use of many of its facilities. GBSQ organizer Roy Jaworski of the Central Appalachian Astronomy Club lined up impressive speakers, including Jimmy Carroll, one of the "Rocket Boys" who inspired the movie *October Sky*. You can watch my talk on amateur contributions to exoplanet research at **skypub.com/gbsq**.

Alas, the weather gods refused to cooperate. During the evenings I hung out with a bunch of organizers and attendees in the Drake Room, located in the dormitory where visiting scientists sleep. This is where Frank Drake unveiled his famous equation in 1961 for estimating the number of communicating civilizations in our galaxy.

S&T: ROBERT NAEYE

Roy Jaworski and Bob Naeye pose in front of the Drake equation plaque.

While bemoaning the clouds, we shot the breeze about a wide range of topics. One night featured a spirited discussion about the lack of direction in the space program, which some felt to be symptomatic of the U.S. losing its edge. As one attendee pointed out, NASA currently relies on Russia to ferry American astronauts to a space station built with billions of American taxpayer dollars.

A lot of frustration was expressed that our nation is being held back by a bitterly partisan Congress and a political system beholden to special interests. Several folks expressed the view that U.S. society has become overly litigious and risk-averse. As an example, one participant excoriated former NASA administrator Sean O'Keefe's decision to cease Hubble servicing missions because of safety concerns.

After discussing private initiatives, there was consensus that we need bold, visionary leadership to outline a compelling long-term plan for both human and robotic spaceflight. But we all recognized that any major expansion in the space program will generate opposition, with the familiar refrain, "Why spend all this money up there when we have all these problems down here?" Retired NASA engineer (and amateur astronomer) Robert Dutilly passionately voiced a response: "All the money is spent *down here*." As he explained, it's spent training scientists and engineers, creating jobs, and developing technologies that eventually filter back into society, for everyone's benefit. If the U.S. is indeed losing its edge, this sounds like a way to reverse course. ✦

Robert Naeye
Editor in Chief

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The Essential Guide to Astronomy

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Milky Way's Makeup

I very much enjoyed Craig Crossen's cover story about the Milky Way in the July issue [Part II is on page 32 of this issue]. However, where he accounts for the various contributions to the galaxy's mass he mentions stars, interstellar gas, and dust, but not dark matter. Please explain. I was under the impression that dark matter makes up a significant fraction of the Milky Way's mass, given that its gravitational contribution affects the speed of stars rotating around the galaxy.

Pedro Lilienfeld
Lexington, Massachusetts

***Editor's Note:** Good point. There is compelling evidence that galaxies are enveloped in halos of dark matter. However, dark matter has been detected only by its gravitational effects, and Crossen's article was concerned with the aspects of the Milky Way Galaxy that can be observed directly and studied in detail — hence the omission of dark matter in his tally.*

S&T: LEAH TISCIONE

Is Cosmic Optimism Realistic?

I agree with David Grinspoon's June column (page 14) that it is time to modify the Drake equation to represent an evolving, not steady-state, galaxy. As he points out, the parameter L is a prime candidate for change. On its website, the SETI Institute defines L as the length of time that technologically advanced civilizations release detectable signals into space. That might be synonymous with Grinspoon's definition: the civilization's average lifetime. Or is L instead the average time during which civilizations *emit* detectable signals? There are subtle and important differences here. For example, a civilization may persist for thousands of years, optimizing its population's distribution and energy production so much that its high efficiency and low heat signature make it inadvertently undetectable (except by choice) over most of its existence.

Thanks for producing such a thought-provoking article.

Mike Mortenson
Port Townsend, Washington

I must disagree with Grinspoon on the odds of there being many advanced civilizations in our universe. Even if our civilization is one of the earliest to develop, it seems to me that there should have been enough successful civilizations arising before us that they would be aware of our existence. If another civilization was aware of us and could travel between stars, and if it thought as we do, it generally would like to (A) conquer us, (B) eat us (or at least take advantage of our resources), or (C) befriend us, if for nothing more than to play interstellar Parcheesi. Yet none of these has occurred. The only other explanation requires conspiracy-type thinking of the sort that suggests there is a pan-universe agreement not to disturb us as we develop. That seems unreasonable: would not other civilizations want to keep a close eye on any people as warlike as we seem to be?

We have produced radio waves for the past century. Even if those other beings have advanced well beyond radio, would they not still listen to it as a sign of advanced development?

So, either it is impossible for a civilization to reach interstellar travel or communication, or there are very few (if any) other civilizations out there. Either way, Grinspoon's optimism is unwarranted.

Chris Marrou
Santa Fe, New Mexico

***Editor's Note:** There are indeed strong deterrents to interstellar travel. Such travel would be fastest if a spacecraft could attain a fair fraction of the speed of light, or circumvent the distance problem in another way (wormholes, for example). However, at 50% light speed the bombardment of particles from the interstellar medium would act as lethal bullets — a 1-milligram particle moving at 150,000 kilometers per second would have the kinetic energy of a 45-kg (100-pound) human traveling at 22 km/s (14 miles per second). On the other hand, if civilizations are truly engaging in interstellar travel, they might move through the galaxy at slower speeds, particularly if they send machines rather than biological creatures. Some scientists have argued that such efforts could enable civilizations to colonize the galaxy in a few million years, a possibility that led physicist Enrico Fermi to ask, "Where is everybody?"*

When I encounter the Drake equation, I often think that there has to be an upper limit on the number of advanced civilizations predicted, based on one fact: we have not heard from any of them yet. And as time goes by without a signal, that upper limit decreases.

We've had radio receivers for roughly 100 years and have (to our knowledge) heard nothing. If we draw a sphere around ourselves with a radius of 100 light-years and assume the population density is even across the Milky Way, the total number of such spheres that fits within the galaxy gives us that upper limit. If the population density is greater than that, we should have picked up a signal by now, intentional or not.

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

A back-of-the-envelope calculation gives an idea of this upper limit. I simplified the galaxy to an ellipsoid 100,000 × 100,000 × 10,000 light-years in size, then subtracted an inner ellipsoid of 20,000 × 20,000 × 5,000 light-years under the (perhaps wild) assumption that the galaxy's center is too crowded with stars and such to be inhabitable. The net volume of the supposed galactic habitable zone is then 51 trillion cubic light-years. Dividing that into spheres of communication 100 light-years in radius yields roughly 12 million such spheres.

Although fraught with assumptions, that number represents the number of civilizations in the galaxy there would have to be in order for us to have heard from them by now.

Now, I'm certainly not saying there is no other intelligent life (however you wish to define it) in the galaxy. I suppose we will hear a signal at some point — say in a few hundred years or so. But I'm betting the message won't be, "We'll get right back to you."

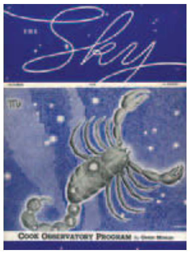
William Shaheen
Gold Canyon, Arizona

For the Record

✷ *The photo of Comet PanSTARRS on the August issue's page 79 was taken by Steve Riegel, not Rigel as stated.*

75, 50 & 25 Years Ago

Roger W. Sinnott

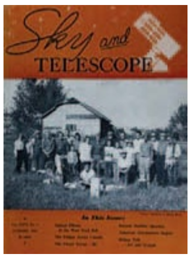


October 1938

Palomar Progress

"Although it is probable that the world's largest telescope, the 200-inch reflector for Palomar Observatory in Southern California, will not be ready for use for another year, . . . the steel horseshoe, in which will swing the 200-inch telescope, is polished. One of the most painstaking jobs ever attempted in steel, . . . [this] required polishing to within 5/1000th of an inch of a perfect circle. One hundred thirty-one days were devoted to the task and more than two tons of steel were ground away."

World War II would delay the telescope's completion for another decade.



October 1963

Weighing a Comet "Hitherto, astronomers have known very little about the masses of comets. In a few instances a comet has passed very close to a planet, without causing any perceptible change in the planet's orbit. . . .

"A more definite answer has been found for Comet 1956c [Wirtanen] by Elizabeth Roemer, at the Flagstaff, Arizona, station of the U.S. Naval Observatory. . . . In May, 1957, the nucleus of Comet Wirtanen was found to be double. . . . During the next 2½ years, observations at Lick, McDonald, and Flagstaff showed a continual gradual separating of the two nuclei. . . .

She made the basic assumption that this rate was equal to the velocity of escape from the comet. From this she calculated that the mass of Comet Wirtanen was 10^{17} grams or somewhat more. (This is . . . equivalent to a gold sphere 1.3 miles in diameter.)"

Roemer's estimate is very much in line with the masses of later comets measured via spacecraft flybys.

October 1988

First Exoplanet "[Bruce Campbell (University of Victoria)] and associates . . . have been making highly precise observations of the radial velocities of 18 bright, nearby stars. By placing a gas cell between their spectrograph and the Canada-France-Hawaii Telescope, they superimpose narrow absorption lines onto the observed stellar spectra. These provide an accurate reference against which to measure the Doppler shifts of the stars' own lines. . . .

"So far only one object, Gamma Cephei, has been observed long enough to detect a full orbital period. This 3.2-magnitude *K*1 subgiant may be circled by a planetlike body only 1.6 times more massive than Jupiter."

Richard Fienberg was reporting from the 1988 meeting of the International Astronomical Union in Baltimore. The Campbell team's discovery of a planet outside our own solar system would not be fully confirmed for another 15 years.

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RADIO | Mystery Signals from Space

SWINBURNE ASTRONOMY PRODUCTIONS; H-ALPHA: DOUGLAS FINKBEINER / APJS 2003

An artist's composite of the 64-meter Parkes radio telescope shows a bright radio burst (upper left) blazing briefly far from the Milky Way's plane (red swath at right). The Milky Way image is from a hydrogen-alpha full-sky map.

An international team of astronomers has detected four powerful radio bursts that appear to come from billions of light-years away. At that distance, the radio pulses would each have put out in a few thousandths of a second the same amount of energy that the Sun would need 10,000 years to emit.

The bizarre signals came to light as part of the High Time Resolution Universe survey, a project using the 64-meter Parkes radio telescope in Australia that searches the sky for pulsars and transient blips. Because the pulsars we detect lie in our own galaxy, astronomers often look near the Milky Way's plane when hunting for these zombie stars. But when Dan Thornton (University of Manchester, UK, and CSIRO, Australia) started digging through normally "boring" data far from the galaxy's dusty gleam, he stumbled across the four enigmatic bursts.

The fast radio bursts (or FRBs) have a distinct look: their lower frequencies arrive noticeably later than their higher ones, spreading out the signal into a unique shape. This spreading happens because the lower radio frequencies are more easily diverted by electrons between us and the source.

The pulse shape encodes how much stuff lies between us and the FRB, and the spread in the arrival times of these milliseconds-long signals implies that they came from far beyond the Milky Way. Throwing some assumptions into the mix, Thornton and his colleagues estimate the four bursts originated at redshifts from 0.45 to 0.96, 4.6 to 7.6 billion years in the past. These distances imply energies between 10^{37} and 10^{39} joules, or between 100 billion and 10 trillion times the energy the Sun puts out in a single second.

These four bursts aren't the first to baffle astronomers. In 2007 Duncan Lorimer (now at West Virginia University) and his colleagues reported a bizarre radio blast so strong that the processing software assumed it couldn't be astrophysical and so deleted part of it from the data. That "Lorimer burst" looks like the new four.

So what are FRBs? "I don't think we have any idea what these are," says radio astronomer Bryan Gaensler (University of Sydney, Australia). "It's a mystery!"

Thornton and his colleagues consider a few ideas in their July 5th *Science* paper, but their favorite is that the bursts are giant flares from a highly magnetized neutron star called a magnetar. That flare could be created by a massive disruption of the magnetic field after a starquake on the magnetar's surface, Thornton says.

Other astronomers have also proposed their own theories, such as the death signal from a too-massive neutron star collapsing to become a black hole when its spin slows enough to let gravity prevail.
■ **CAMILLE M. CARLISLE**

STARS | Taming a Stellar Zoo

Neutron stars seem to come in a menagerie of different species, but an international team thinks it has taken a major step towards unifying this zoo, Daniele Viganò (University of Alicante, Spain) and colleagues report in an upcoming *Monthly Notices of the Royal Astronomical Society*.

The menagerie includes pulsars, which are the galaxy's radio-emitting lighthouses, and magnetars, which flare unpredictably with X-rays and gamma rays and boast the strongest magnetic fields ever detected — up to 10,000 trillion times stronger than Earth's. But there are also high-B pulsars (B is the symbol used for the magnetic field), falling somewhere between those two, and the X-ray Isolated Neutron Stars (XINSs), a mouthful that designates the radio-quiet, oldest, and coolest stellar corpses.

Viganò's team simulated the aging and cooling of neutron stars over time, incorporating an electromagnetic phenomenon called the Hall effect. This effect triggers a complex chain of interactions between the star's magnetic field and the sea of electrons flowing through the star's crust. It's usually ignored, but according to Viganò's team, it's the most important effect in magnetars: it shakes and breaks up their crusts, dissipating their intense magnetic fields in as little as 10,000 years.

By comparing its results with NASA Chandra and ESA XMM-Newton X-ray observations of 40 known neutron stars, the team found that its models produced evolutionary tracks in which young neutron stars begin as magnetars, then age gracefully through the other observed categories, cooling to become high-B pulsars, classic radio pulsars, and finally XINSs.

Sandro Mereghetti (ISAF-Milano, Italy), who was not involved in the study, agrees this picture is a step forward in taming the neutron star zoo, but says, "I think that what we really need are much better data on a larger sample of isolated neutron stars." He adds that the lack of major planned X-ray space telescopes might put that work on hold.

■ **MARK ZASTROW**

EARTH | Faint Young Sun? No Problem

Astrobiologists have long worried about how Earth sustained primitive life 3½ billion years ago when the young Sun was supposedly too faint to keep our planet from freezing over. But new 3-D climate simulations offer a way out of this paradox.

In its infancy, the Sun put out about 70% of the energy it does today. In 1972 Carl Sagan and George Mullen realized that because of this "faint young Sun," the early Earth should have been completely frozen over — but geologic and paleontologic evidence shows it wasn't.

The simplest explanation is that our planet's early atmosphere contained lots of carbon dioxide to trap heat and boost the surface temperature. But the data don't back that explanation up.

A key problem has been the computer simulations, which have used 1-D atmospheric profiles and couldn't account for factors such as clouds or the fact that ice forms first at the poles, rather than everywhere at once.

In July's issue of *Astrobiology*, Eric Wolf and Brian Toon (University of Colorado, Boulder) describe the results of a complex 3-D computer model that suggests that about 2.8 billion years ago, when sunlight was 20% weaker than it is today, an atmosphere with 1.5% carbon dioxide (about 40 times what we have now) and a dash (0.1%) of methane would have produced a virtually ice-free Earth with mean temperatures close to today's. Reducing the CO_2 to just 0.5% and eliminating the CH_4 yielded a subfreezing global mean temperature, but even then about half of the open ocean remained ice free.

■ **J. KELLY BEATTY**

IN BRIEF

Pluto's moons christened. The International Astronomical Union has approved names for the newest of Pluto's five moons, discovered in Hubble images taken in 2011–12 (*S&T*: October 2012, page 14). They are Kerberos (for P4) and Styx (for P5). In Greek mythology, Kerberos is the three-headed guard dog that prevents the dead from escaping the underworld. (The variant spelling Cerberus is an asteroid.) Styx is the river (and the goddess thereof) that separates Earth from the underworld.

■ **J. KELLY BEATTY**

Two spacecraft bite the cosmic dust. In June the French space agency CNES declared that its exoplanet hunter COROT was officially "mission accomplie" within a few days of the Caltech-led GALEX being shut off. COROT stopped sending data last November, and engineers have been looking for a solution since then. The failure's exact cause remains unknown, but it looks like the converter that delivers power to the onboard computer can't give the electrical kick needed to restart, potentially due to a high-energy particle impact. (The electronics were also only certified to last three years, and they've been in space for six.) GALEX's fate is funds-driven. It observed the ultraviolet universe for a decade and was the first NASA spacecraft handed over to a private organization (Caltech), but after extensive fundraising the team finally decided to "end the mission on a high note and move on to other projects." Both satellites will take roughly 50 years to reenter Earth's atmosphere.

■ **CAMILLE M. CARLISLE**

NASA launches new solar mission. The Interface Region Imaging Spectrograph (IRIS) fired off on a Pegasus XL rocket on June 27th for a two-year study of the narrow transition region between the Sun's 10,000-kelvin chromosphere and its blazing 1-million-kelvin corona. Equipped with a 20-cm (8-inch) ultraviolet telescope and better resolution than previous spectrographs, IRIS will stare at just 1% of the Sun's surface to reveal features as small as 240 km across. The spacecraft will study the energetic processes that drive the solar wind and heat the corona.

■ **SHARI BALOUCHI**

IN BRIEF

Disk gaps might not signal planets. Astronomers often suspect that the empty rings in the dusty gas disks encircling young stars are caused by one or more planets. But detailed simulations by Wladimir Lyra (Jet Propulsion Laboratory) and Marc Kuchner (NASA/Goddard) in the July 11th *Nature* show that these gaps might grow on their own thanks to a well-known physical phenomenon. The disk's dust absorbs starlight, making it cast off electrons via the photoelectric effect. These electrons collide with gas molecules, heating the gas and making it expand. This expansion then triggers a change in the gas molecules' orbital speed — an increase for the molecules expanding toward the star, a decrease for those expanding away — which in turn pushes the dust (still moving at its original speed) into a ring. The process reproduces patterns for a range of disk types; however, it can't totally explain gaps in disks with very high or low concentrations of gas, such as the controversial TW Hydrae and Fomalhaut systems.

■ **SHARI BALOUCHI**

Crowded clusters host planets. The discovery of two mini-Neptunes around Sun-like stars in the open cluster NGC 6811 reveals that small planets can arise in more crowded neighborhoods than previously thought. Until now, astronomers had detected only four planets inside open clusters, compared to more than 800 planets found around isolated stars. But in the July 4th *Nature*, Søren Meibom (Harvard-Smithsonian Center for Astrophysics) and colleagues report the detection of Kepler-66b and Kepler-67b, both about three times Earth's radius and situated in a billion-year-old open cluster that was packed with more than 6,000 stars (100 times denser than theorized for the Sun's natal environment) during the era of planet formation. After considering how many planets Kepler should have been able to detect in NGC 6811 if the planet-formation process works as well in these dense regions as it does elsewhere, the team concludes that they observe as many as expected.

■ **SHARI BALOUCHI**

EXOPLANETS | A Glassy Blue Jupiter

NASA / ESA / MARTIN KORNMESSER

This illustration shows the Jupiter-mass exoplanet HD 189733b, which hugs a *K*-type star 63 light-years away. But don't be fooled by the blue hue: it's definitely *not* habitable.

In a first-of-its-kind confirmation, an international team of astronomers has used the Hubble Space Telescope to measure the visible light reflected from an exoplanet, and it's a deep cobalt blue.

"[W]e can actually imagine what this planet would look like if we were able to look at it directly," says the team's leader, Frédéric Pont (University of Exeter, UK).

But lying 10 times closer to its star than Mercury's distance from the Sun, the hot Jupiter HD 189733b would not be a pleasant place to visit. The weather forecast calls for 1200°C (2200°F), raining glass, and up to 15,000-km-per-hour (9,300-mph) winds.

The transiting exoplanet showed its true colors by temporarily disappearing. Using Hubble's STIS spectrograph, the team measured the star-planet system's brightness in bluish and greenish light before, during, and after the planet slipped behind the star. When the planet was visible, a tiny fraction of the detected starlight was reflected off the planet (about 1/10,000 the total brightness). But when the planet hid from view, the blue light dimmed and the green did not — ergo, the planet itself must be bright in blue wavelengths.

Although the team didn't observe in red wavelengths, preliminary measurements of polarized light from the planet had already indicated a surplus of blue light and a deficit of red. The lack of red in the spectrum makes sense: if HD 189733b were reddish, its overall brightness would be higher than most of the hot Jupiters that astronomers have been able to study this way.

The team suspects that silicate particles cause the striking color. These tiny, glassy beads flying through the churning atmosphere would scatter blue light toward us. That's different from Uranus and Neptune, which have a bluish tint because the methane in their atmospheres absorbs red light. Both solar system planets also look far greener than HD 189733b.

■ **MARK ZASTROW**

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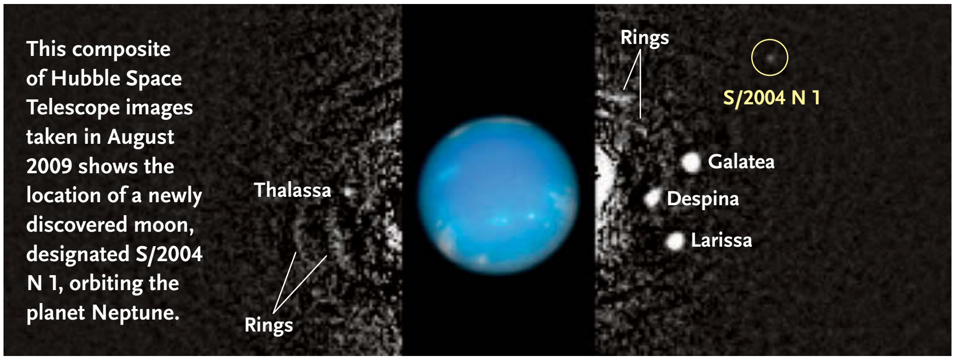
SOLAR SYSTEM | New Neptune Moon Discovered . . .

There's a newfound moon around Neptune, Mark Showalter (SETI Institute) and his team announced July 15th. This find, designated S/2004 N 1, brings the planet's satellite count to 14.

Showalter found the moon by chance while looking through Hubble Space Telescope observations taken from 2004 to 2009. He says the little body has sat unnoticed for years owing to its tiny size and rapid motion around the planet. The moon doesn't appear in images from Voyager 2, which flew past Neptune in 1989. In fact, with an estimated magnitude of 26.5, S/2004 N 1 barely registered in the individual HST images. If its surface is dark like those of other nearby satellites, then the new find has a diameter of no more than 20 km (12 miles) — making it the smallest of Neptune's known moons.

S/2004 N 1 appears to travel in a near-circular orbit very close to Neptune's equatorial plane. Based on its recorded positions, it circles the planet every 22.47 hours, meaning it orbits about 105,000 km from Neptune's center. That puts it between the small inner moons Larissa and Proteus. (Below, Galatea looks farther out than Larissa due to projection.)

■ J. KELLY BEATTY



This composite of Hubble Space Telescope images taken in August 2009 shows the location of a newly discovered moon, designated S/2004 N 1, orbiting the planet Neptune.

NASA / ESA / MARK SHOWALTER (SETI INSTITUTE)

. . . and Sun Sports Windsock in Interstellar Space

Three years of observations from NASA's Interstellar Boundary Explorer (IBEX) mission confirm that charged particles escaping from the Sun form a long tail much like a comet's, IBEX principal investigator David McComas (Southwest Research Institute) announced at a July 9th press briefing. The result also appears in the July 10th *Astrophysical Journal.*

IBEX launched in 2008 to map the turbulent boundary between the realm outside the solar system and the heliosphere, the enormous bubble filled with charged particles and magnetic field lines that stream out from the Sun in all directions as the solar wind. The satellite maps the boundary indirectly by detecting energetic neutral atoms, or ENAs, created when the solar wind's protons steal electrons from slower hydrogen atoms in the interstellar medium.

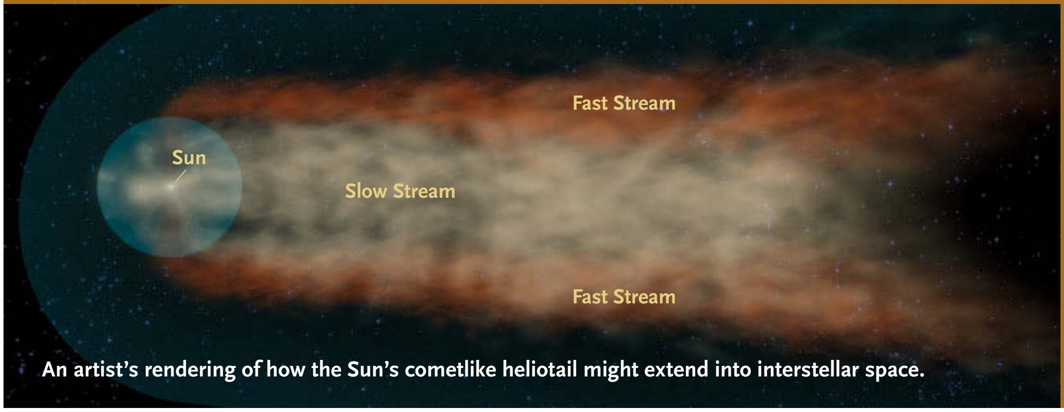
Looking over the calibrated all-sky map of IBEX's cleaned data, mission scientists found that lots of ENAs are arriving directly from the Sun's "downwind" direction, between Betelgeuse and Aldebaran along the Orion-Taurus border. That suggests that the solar wind stretches out into interstellar space as a long tail behind our star as it moves through the galaxy. Although details are still vague, the tail probably resembles the long streamer trailing behind the star Mira (*S&T*: April 2012, page 20).

The concentration of ENAs in this downwind direction suggests that a faster-moving stream lines the top and bottom of a middle layer of slower-moving particles. In hindsight, this makes complete sense: researchers have known for decades that the Sun spits out a much faster solar wind from its polar regions than from its midsection. Still, the structure was a surprise.

"It's very easy to expect the right thing once you've seen it," McComas admits.

Based on its shape, this *heliotail* is squeezed and rotated slightly by the interstellar magnetic field, rather like a beach ball distorted and flattened by bungee cords. ✦

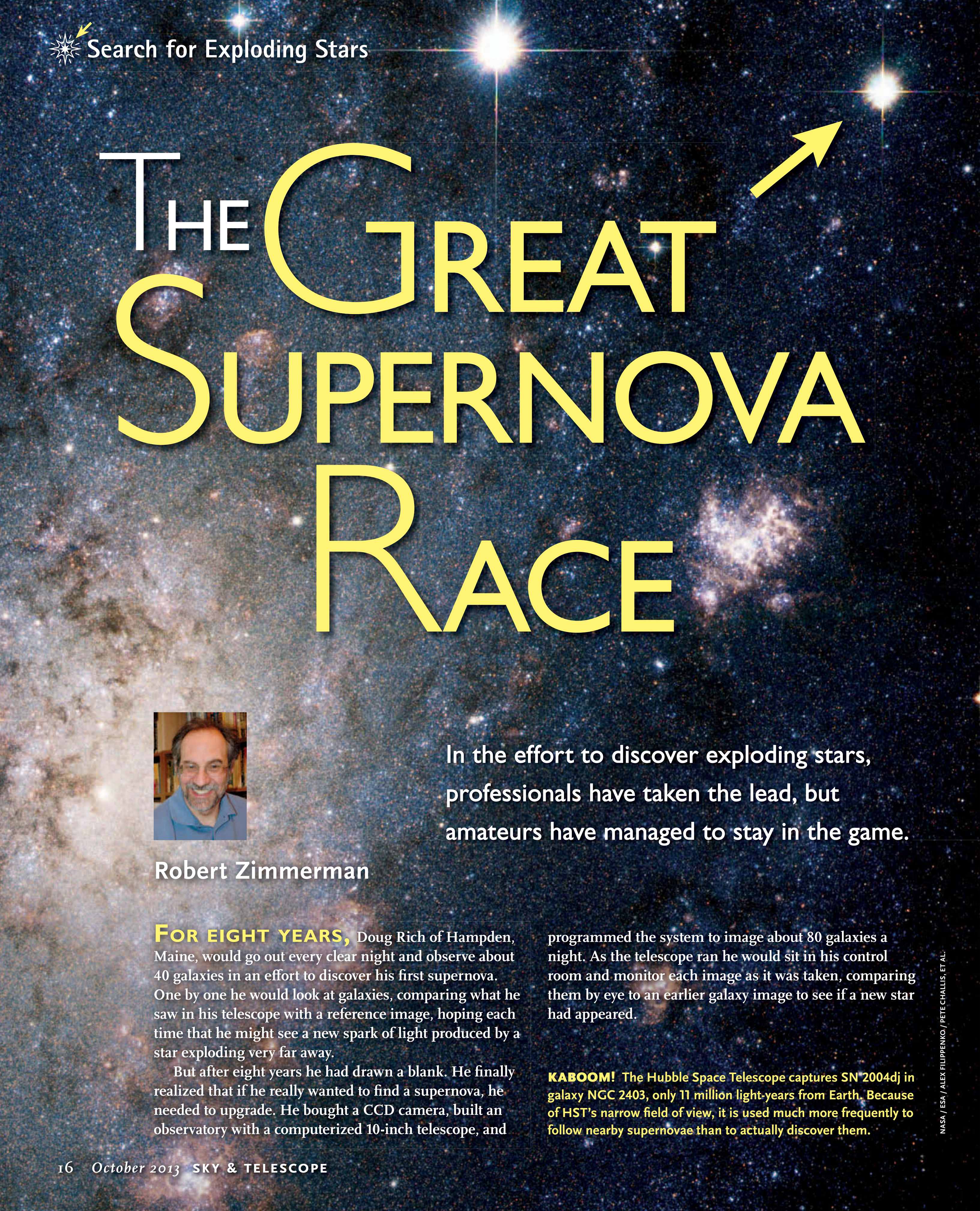
■ J. KELLY BEATTY



An artist's rendering of how the Sun's cometlike heliotail might extend into interstellar space.

NASA

Read more and watch a video explaining the heliotail's shape at skypub.com/heliotail.



The Great Supernova Race

In the effort to discover exploding stars, professionals have taken the lead, but amateurs have managed to stay in the game.

Robert Zimmerman

For eight years, Doug Rich of Hampden, Maine, would go out every clear night and observe about 40 galaxies in an effort to discover his first supernova. One by one he would look at galaxies, comparing what he saw in his telescope with a reference image, hoping each time that he might see a new spark of light produced by a star exploding very far away.

But after eight years he had drawn a blank. He finally realized that if he really wanted to find a supernova, he needed to upgrade. He bought a CCD camera, built an observatory with a computerized 10-inch telescope, and programmed the system to image about 80 galaxies a night. As the telescope ran he would sit in his control room and monitor each image as it was taken, comparing them by eye to an earlier galaxy image to see if a new star had appeared.

KABOOM! The Hubble Space Telescope captures SN 2004dj in galaxy NGC 2403, only 11 million light-years from Earth. Because of HST's narrow field of view, it is used much more frequently to follow nearby supernovae than to actually discover them.

NASA / ESA / ALEX FILIPPENKO / PETE CHALLIS, ET AL.

He repeated this routine for three more years without result. Sometimes he'd see an asteroid. Sometimes a cosmic ray would leave a false positive on his image. What he didn't see was a previously unknown supernova.

Then, on a cold January night in 2003, there was something in one image that was not on the reference image. The galaxy was about 200 million light-years away and on its outer periphery a new star had appeared. It was a new supernova, and Rich was the first to spot it! "It was like you put me on a plane and flew me to heaven," he recalls.

The Race Takes Shape

Since the invention of the telescope, many supernovae had been discovered by dedicated amateur astronomers spending hours at their eyepieces scanning the galaxies looking for tiny changes. Because professionals used big telescopes with very small fields of view and were usually focused on studying specific objects, they were generally poorly positioned to spot new supernovae when they appeared in random galaxies in the sky.

Amateurs, however, looked everywhere, and they did it with binoculars and small telescopes that could look at many galaxies in one night. And with a large amateur community, they covered the sky far more thoroughly. Thus, when a supernova was discovered, it was often an amateur who struck gold. An exception to this trend occurred during the 1950s and 60s, when a group led by Caltech astronomer Fritz Zwicky discovered about 100 supernovae in photographic plates taken with the 48-inch Schmidt telescope at Palomar Observatory in California.

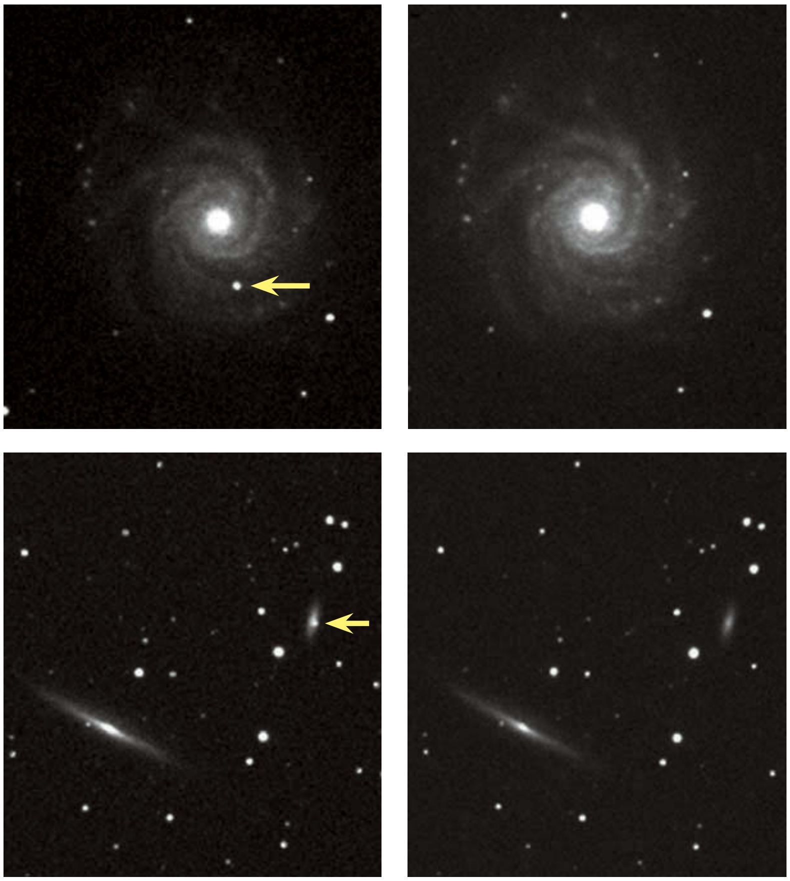
But all this has changed in the past 15 years. Beginning in the late 1990s, professionals stepped in, taking advantage of the advent of automated, computerized, and remotely controlled telescopes to do their own supernova searches. Well funded and equipped with sophisticated software unavailable to amateurs, these professional surveys very quickly began racking up discoveries in numbers far greater than any ever produced by amateurs. Not only was the amateur dominance in the field of supernova discovery over, it seemed they were no longer needed. Professionals could do it all, and far better.

Not so fast. Despite the professionals' advantages, amateurs still have a place in this field. In fact, if done properly, amateurs can even beat the pros at this game. As David Bishop, who maintains the website Latest Supernovae notes, "There are way too many galaxies out there for even the most powerful professional survey to cover."

Eyeball to Automated

In the beginning, amateurs simply used their eyes to hunt for new supernovae. The king of supernova visual searches is Robert Evans of Hazelbrook, Australia (*S&T:*

LAURIE RICH



DOUG RICH (4)

SUPERNOVA HUNTER ***Above:*** **Maine amateur astronomer Doug Rich poses with his 16-inch Meade LX200 telescope, which he has used to discover 16 supernovae since November 2007. The scope rests on a Paramount ME mount and is equipped with an SBIG ST-9XE camera. Rich has since formed a team to help process and analyze his galaxy images.** ***Above right*****: Doug Rich caught SN 2005ay (arrowed) in spiral galaxy NGC 3938. A later image shows the galaxy after the supernova had faded from view.** ***Bottom right*****: These comparison images show the distant galaxy MCG+12-18-22 with and without the very faint SN 2009gh.**

SUPERNOVA TYPES

Supernovae come in many varieties, but most involve either the explosion of a massive star (Types Ib, Ic, and II) or the explosion of a white dwarf pushed to nearly 1.4 solar masses (Type Ia).

January 2007, page 116). Starting in the early 1980s, Evans would go out each clear night with his 10-inch telescope and do a manual sweep of visible galaxies, looking for new objects. On average he would observe between 50 and 100 galaxies per hour, depending on how clustered they were to one another in the sky. Because he would look at the same galaxies repeatedly, he soon memorized each one's appearance, and could then tell instantly if a new object had popped into view.

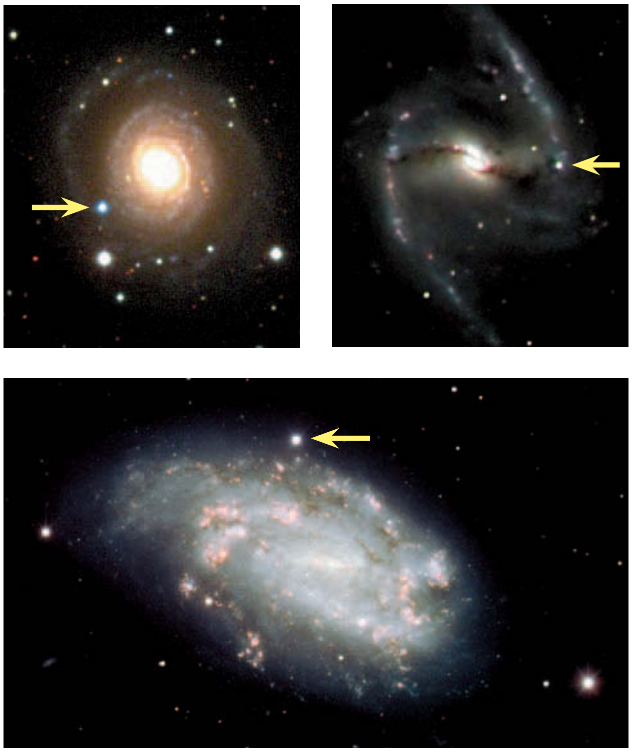
By 1985 Evans had discovered 11 new supernovae, and some of his findings helped lead to the recognition of the new class of Type Ib supernova. He then upgraded to a 16-inch telescope. Over the ensuing years his discoveries mounted, until by 2005 his tally had reached 40.

Evans's visual approach is today somewhat unusual. Since the invention of CCD photography, most amateur supernova hunters have instead followed Doug Rich's technique: they snap images of their galaxies and then compare them with reference images. For example, Wayne Johnson of Benson, Arizona, known among amateurs as "Mr. Galaxy," made his first two supernova discoveries visually, like Evans, but he then switched to CCD imagery for his next four (two of which he found on one night, May 15/16, 1996). "I wasn't doing anything fancy," he explains. "Take the image, blink compare it to a reference image. You could immediately see if there was something new in that image."

In more recent years, the search strategy has been further augmented by computer software that allows amateurs to remotely and automatically operate their telescopes. Rather than stay up all night taking galaxy images, amateurs can program their telescopes to do the work for them. For example, Michael Schwartz would program a telescope at his Tenagra Observatory in Nogales, Arizona, to snap images of 50 to 100 subject galaxies and then review the images in the morning by eye to see if there was anything new. "The introduction of automation is what opens the door," he explains. The result, he adds, is that "I've discovered so many supernovae that the fun of discovery has completely worn off."

The most successful by far of the amateur supernova surveys is led by Tim Puckett of Ellijay, Georgia (*S&T:* October 2009, page 32). Like Schwartz, Puckett has programmed his telescopes to remotely and automatically image a preset list of galaxies each night. But Puckett enlisted the help of other amateurs to make his search a collaborative effort. The group has grown to about two-dozen members, who process and analyze images taken by telescopes in Georgia, Arizona, and British Columbia. By organizing a cadre of amateurs to eliminate false positives — such as cosmic rays, asteroids, and image artifacts — and by then looking for possible supernova

MICHAEL SCHWARTZ



MICHAEL SCHWARTZ / ODD TRONDAL (TENAGRA OBSERVATORIES) (3)

SUPERNOVA SLEUTH By using his vivid memory of galaxy appearances, Australian amateur Robert Evans has discovered 42 supernovae visually, eight with the pictured 12-inch reflector made by local amateur friends. ***Right*: These images of SN 2000cj, SN 2000du, and SN 2005af (clockwise from upper left) were taken after Evans discovered them visually. With the advent of CCD cameras, the era of visual supernova discoveries is nearly over.**

ALEX FILIPPENKO / WEIDONG LI / LICK OBSERVATORY SUPERNOVA SEARCH

LAURIE HATCH

DISCOVERY MACHINE ***Above:*** **The late Weidong Li (left) and Alex Filippenko pose with the Katzman Automatic Imaging Telescope (KAIT), a 30-inch reflector at Lick Observatory. Astronomers using KAIT have discovered nearly 1,000 supernovae since it began operations in 1997.** ***Right:*** **KAIT images about 1,000 galaxies per night, and software automatically identifies potential new objects. Undergraduate students scrutinize these candidates to determine which ones are likely to be real supernovae.**

candidates in the remaining images, Puckett's team efficiently handles the most time-consuming part of any supernova search effort. As of late June, the Puckett World Supernova Search had discovered 280 supernovae, and is looking for more volunteers to operate telescopes with apertures 14 inches or larger.

The Pros Beef Up

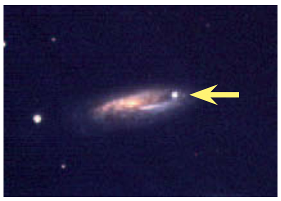
In the past 15 years or so, the hunt for supernovae has been revolutionized by the advent of a host of professional survey telescope projects.

Among the first was the Lick Observatory Supernova Search (LOSS), which uses the 30-inch Katzman Automatic Imaging Telescope (KAIT). Begun in 1997, the equipment is entirely robotic, with the software programmed to check the weather, open the dome, and aim KAIT at its target list of about 1,000 galaxies per night. "Identifying new supernovae as quickly and as frequently as possible is what KAIT was designed to do," explains Brad Cenko (NASA/Goddard Space Flight Center).

In its first three years KAIT found between 20 and 40 supernovae per year. After 2001 those numbers grew, and for the next decade it found nearly 800. In 2007 a similar program, the Chilean Automatic Supernova Search (CHASE), was begun in the Southern Hemisphere.

These surveys can image five to ten times more galaxies per night than any amateur can. They're also well funded and have ample cheap labor in the guise of college students available to look for potential supernovae in the many images produced. These surveys have churned out discoveries at a pace no amateur can match. Then, in the late 2000s, these survey programs were trumped by the Palomar Transient Factory (PTF), which uses the 48-inch Schmidt telescope at Palomar, and the 1.8-meter Panoramic Survey Telescope & Rapid Response System (Pan-STARRS1) instrument in Hawaii. Unlike KAIT, PTF and Pan-STARRS1 do not look at a target list of specific galaxies. Instead, they take a more brute-force approach, using wide-field telescopes to image gigantic swaths of the sky each night, which are then analyzed by computer.

The result of these technological wonders has been a shift in who makes the most discoveries, from amateurs to professionals. In 1999 amateurs discovered about 78% of all new supernovae. But in 2012 that percentage had dropped to 15%. "A lot of amateurs are getting discouraged," says Rich. "The general feeling is that we're looking at a time in the future when we might not be making any supernova discoveries, or very few anyway."



ALEX FILIPPENKO / WEIDONG LI / LOSS (3)

DISTANT SUPERNOVAE
These images show supernovae discovered with KAIT: SN 1998dh ***(top left)*****, SN 1999gi** ***(left)*****, and SN 1999by** ***(above)*****.**

CFA / PS1 SCIENCE CONSORTIUM

NEW SUPERNOVA SLEUTH With its ultra-wide field and ability to go extremely deep, the recently commissioned Pan-STARRS1 telescope on Maui is starting to crank out supernova discoveries. The example above, SN PS1-12sk, is an extremely rare and poorly understood Type Ibn supernova.

ROB RATKOWSKI

The Race Heats Up

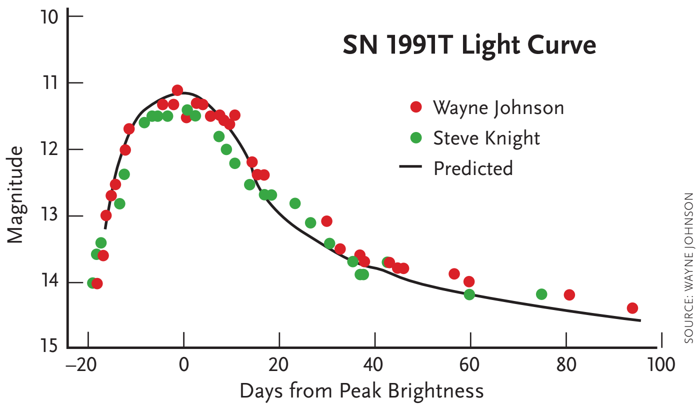
And yet, despite the high-tech competition from professionals, amateurs are still finding it possible to survive in the modern era of supernova searches. For example, though the overall *percentage* of total supernova discoveries by amateurs has plummeted in the past decade, the actual *number* of discoveries by amateurs has not really changed that much. Since 1997 there has been no strong trend, up or down, in the number of amateur supernova discoveries. The annual totals have ranged from 114 to 274, with the average per year during this time period holding steady at around 167. For example, from 2007 to 2012, years when professional dominance in this field was solidified, amateur discoveries each year were 114, 144, 198, 151, 162, and 159 respectively, numbers not much different from the 166 supernovae discovered by amateurs in 1999.

What *has* changed is that the professionals have found a way to discover many more supernovae in fainter, more distant galaxies. In 1999 the total number of supernovae discovered was 216, but in 2012 that number had skyrocketed to more than 1,000, the increase entirely because of the new professional surveys.

Clearly, amateurs still have a place at this table, but to hold it they have adopted several basic strategies. If you want to join the search, here are some simple guidelines:

First, know what your equipment can do. For example, the galaxies you target should not be so far away that any supernovae that appear will be too faint for your telescope to see. "Pay attention to what is physically realistic, based on the limitations of your hardware," explains Schwartz.

Second, image as many of the right kinds of galaxies as you can. "The more images you take, the more discov-



SOURCE: WAYNE JOHNSON

LIGHT CURVE Amateurs do more than discover supernovae. These visual observations of SN 1991T revealed the brightening and fading of a Type Ia supernova with a particularly slow rise.

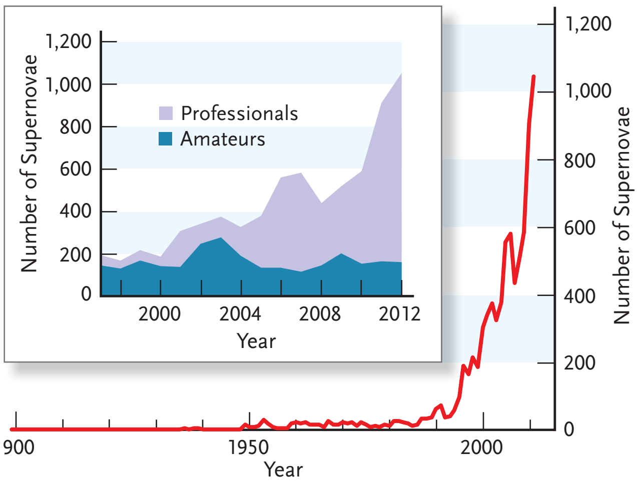
For links to websites associated with professional and amateur supernova searches, visit skypub.com/supernovarace.

eries you make," quips Rich. For example, in 2012 Rich discovered seven supernovae, but to do that he had to image more than 10,000 galaxies.

Third, and perhaps most important, assemble a team, as Tim Puckett did. Today's computerized telescopes can produce a lot of images, but the software that makes it easy to spot new objects in those images is unavailable to amateurs because of cost and difficulty of use. Instead, amateurs still need to look at each image by eye, comparing them one by one with a reference image. This process is time consuming. By assembling a team of eager volunteers to scan the images, amateurs such as Puckett can still keep up with the pros.

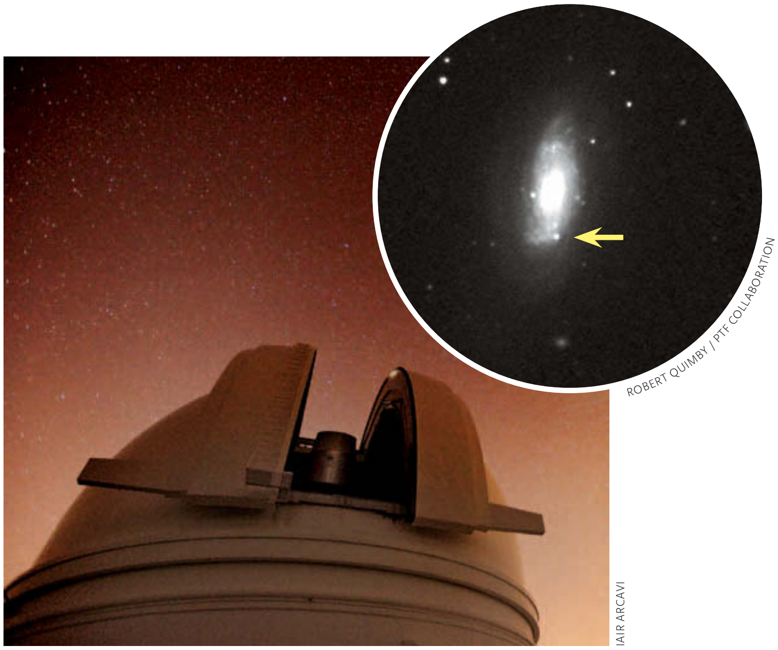
Doug Rich has followed in Puckett's footsteps, and this effort has quickly paid off. It started with the Eagle Hill Institute, located in Steuben, Maine, near Acadia National Park. Eagle Hill had previously focused on Earth sciences, but staffers decided to begin an astronomy initiative. In December 2012 they asked Rich to give a talk on his supernova work. "I got this brainstorm. I've been doing this by myself up until now, and had been fairly successful," he explains. "Why not make it a team thing, like Tim Puckett does, and allow others to experience the satisfaction and excitement of making a discovery?"

He recruited a handful of volunteers after his talk, including some amateur astronomers. After several meetings and the installation of the necessary software



SOURCE: IAU CENTRAL BUREAU FOR ASTRONOMICAL TELEGRAMS / ASTRONOMY SECTION OF THE ROCHESTER ACADEMY OF SCIENCES; INSET: ASTRONOMY SECTION OF THE ROCHESTER ACADEMY OF SCIENCES

DISCOVERY RATES ***Main graph:*** **The red line, based on publicly reported supernova findings, shows how the total supernova discovery rate (amateur and professional combined) has skyrocketed in recent years due to the advent of new professional surveys.** ***Inset*****: As recently as the early 2000s, amateurs usually discovered more than half the total number of new supernovae in a given year. Professionals are now finding the large majority of supernovae, but amateurs continue to crank out 100 to 200 each year. Some of the professional teams are finding so many supernovae that they don't publicly report every discovery, so the number of supernovae detected in the past decade is actually greater than these graphs indicate.**



ROBERT QUIMBY / PTF COLLABORATION

IAIR ARCAVI

SUPERNOVA FACTORY The Palomar Transient Factory team uses the 48-inch Oschin Schmidt telescope at Palomar Observatory. In June 2013, the group discovered a Type Ib supernova (provisionally named iPTF13bvn) in spiral galaxy NGC 5806.

on everyone's computers, the system worked as planned. When he had a clear night — "A rare thing in Maine," Rich notes — he would take about 150 to 300 galaxy images and upload them to a website where his volunteers could download them and compare them to their previously installed reference images.

On April 7, 2013, the group bagged its first supernova discovery. Then, only three weeks later, another one turned up. "It was pretty exciting for these guys," explains Rich. "The fact that we found two in such a short time means I might start getting more volunteers than I need."

And the possibility of many more amateur discoveries continues. Though a survey telescope such as Pan-STARRS1 can look at most of the visible sky with enough detail to see almost any supernova in its view, it generally can scan the entire sky only about once per week.

Thus, the professional survey might spot a supernova, but it would do so relatively late. An amateur looking each night thus has a chance of seeing it first, and by doing so will provide the scientists information about the earliest stages of a stellar explosion. "There just aren't enough professional observatories across the globe to cover nearby galaxies as frequently as we would like," explains Cenko.

Or as Doug Rich points out, "There are so many galaxies out there that it's impossible for the professionals to watch everything." ✦

Contributing editor ***Robert Zimmerman*** *has just released a new electronic edition of his book* Genesis: The Story of Apollo 8, *available at e-book vendors everywhere or on his website* ***http://behindtheblack.com***.

Back to the Big Bang

A faint signal hidden in the universe's earliest light might reveal what happened in the first moment after cosmic birth.

Bruce Lieberman

THE SKY ABOVE CERRO TOCO in Chile's Atacama Desert slides quickly from a crystalline blue to hues of purple and charcoal gray as the western horizon dims like embers in a fading campfire. The southern sky's brightest stars begin to emerge overhead, then the Milky Way and Magellanic Clouds materialize, all three galaxies breathtakingly surreal.

Here, at 17,000 feet above sea level in a desolate, rust-colored landscape evocative of Mars, is where the hunt is on for the signature of inflation — the hypothesized epoch immediately after the Big Bang when the universe expanded exponentially for a tiny fraction of a second. Cosmologists predict that inflation's signature will appear as vanishingly faint patterns of polarized light embedded in the cosmic microwave background (CMB), the radiation released when the universe's primordial soup cooled enough to allow photons to travel freely across the expanding universe. Researchers call these polarization patterns *B-modes*, and many say that finding them would provide "smoking-gun" evidence that inflation actually happened.

For this reason, numerous experiments today are racing to detect these predicted but never-before-seen B-modes. One of them is called Polarbear, which stands for "Polarization of Background Radiation," and it saw first light in early 2012 at this high-altitude site below the peak of Cerro Toco. Its team members hope that their precise observations of the CMB, which fills every cubic centimeter of the cosmos with about 400 microwave photons, will reveal the imprint of inflation's physics.

Looking for Inflation's Signature

Inflation is a pillar of Big Bang cosmology and explains key features of the universe we see today. Among them are the uniform distribution of matter on large scales and the pattern of temperature variations in the CMB. But inflation is still merely a theoretical framework. If it did happen, many cosmologists expect that it should have generated ripples in spacetime called gravitational waves, born from quantum fluctuations in gravity itself that were then stretched during inflation's superluminal cosmic expansion. These waves would have left the B-mode imprint on the CMB.

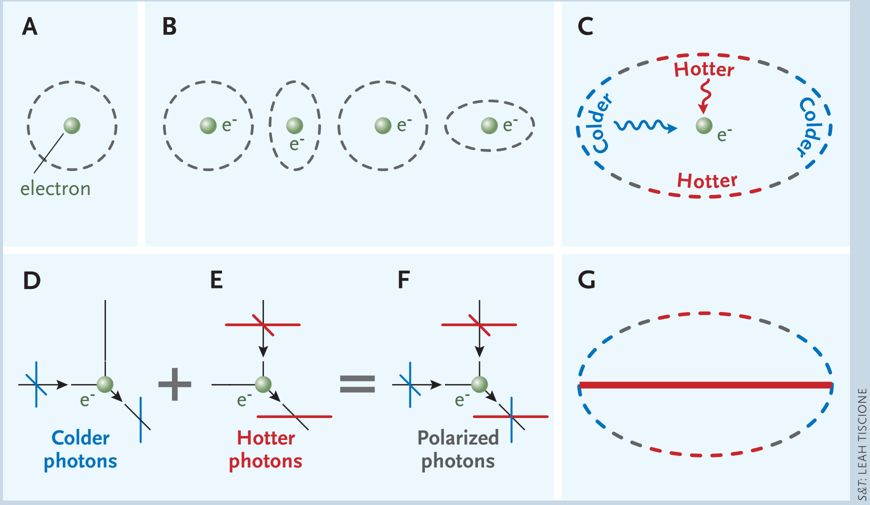
Like all polarization types, B-modes are a particular orientation of light. A wave of light oscillates perpendicular

UPPER LEFT ILLUSTRATION BY PATRICIA GILLIS-COPPOLA, PHOTO BY THE AUTHOR

How Gravitational Waves Create Polarization

Gravitational waves created polarization patterns in the cosmic microwave background (CMB) by stretching and squeezing space — and therefore the plasma soup of primordial photons and electrons — as the waves passed.

(A) Before a wave hits it from behind, a cross-section of space with an electron in the middle looks normal. But when the wave hits, the cross-section stretches and squeezes one way, then another, in an oscillating pattern (B). Instead of a uniform soup, the electron "sees" around it a universe a bit hotter in the squeezed direction and a bit colder in the stretched direction (C). Originally, a photon's wave wiggles in all planes perpendicular to the photon's motion (D and E, incoming crosses). When photons scatter off the electron, they become polarized, wiggling in only one plane (outgoing lines). The resulting pattern (F) is a sum of the cold and hot photons' polarizations. But because photons from hotter regions have more energy, their pattern "wins out," meaning the overall polarization is parallel to the hot regions (G).

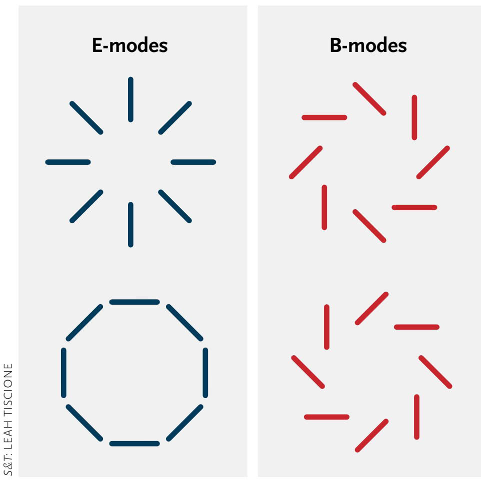


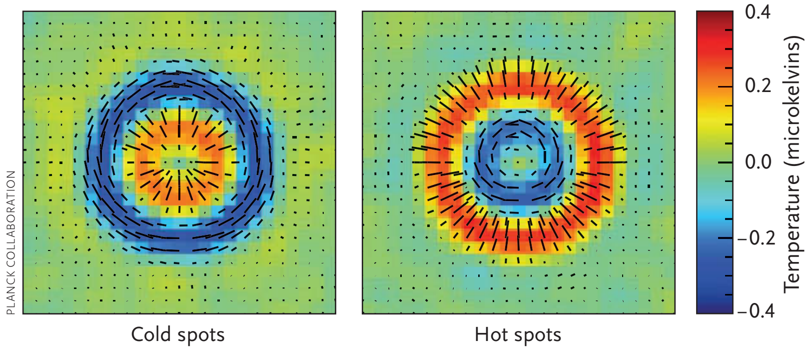
to the direction in which it travels. For a light beam that is unpolarized, there is no preferred angle of vibration — the waves wiggle in random orientations about the axis of motion. For polarized light, the waves collectively have a preferred angle of vibration.

Unpolarized sunlight can become polarized when it reflects off a flat, nonmetallic surface, such as a lake, so that the reflected waves vibrate parallel to that surface as they travel toward our eyes. We see the reflected light as glare. Polarized sunglasses are designed to block that light and thereby reduce the glare.

The CMB's light should be polarized in two different patterns: E-modes and B-modes. Both would have been created 380,000 years after the Big Bang, when the CMB photons were released and scattered off electrons for the last time before flying off freely into space. Scattered photons are generally polarized, but an electron being bombarded by photons of the same energy from all sides will scatter those photons uniformly in all directions, thereby canceling out the polarization signature.

RING AROUND THE ROSIE E- and B-mode polarization patterns look different. E-modes have no "handedness" — if you draw a line down the pattern's center and reflect the pattern, nothing changes. B-modes look like spirals and don't reflect. Although gravitational waves can create both types, primordial B-modes can only be made by gravitational waves.





PLANCK CATCHES E-MODES By stacking maps of more than 11,000 cold and 10,000 hot spots in the CMB, researchers on the science team for the European Space Agency's Planck satellite revealed the related E-mode polarization patterns to high precision. The team is now analyzing Planck's polarization data and hopes to release results for B-modes and the largest angular scales in 2015.

But if a gravitational wave comes by, it will squeeze spacetime in one direction and stretch it in another. That means the electron will see a universe that is a little bit hotter in one direction (where the wave squeezed spacetime) and a little bit colder in the other direction (where the wave stretched spacetime). When photons come at the electron from these different regions, the electron still scatters them all, but it does so with a preferred direction. The polarization pattern of the hotter (and therefore more energetic) photons wins out over that of the cooler ones, leaving a mark in the CMB.

These marks from the universe's many electrons drew both E- and B-mode patterns. E-modes have already been detected and studied. But other mechanisms besides gravitational waves also produced E-modes, such as photons scattering off the early universe's higher-density regions, which later grew into galaxies and clusters. The primordial B-mode pattern, in contrast, only could have originated from the stretching and squeezing of spacetime by gravitational waves, so cosmologists depend on it for evidence of inflation. "It would be a very beautiful confirmation of another important feature that inflation predicts," says inflation architect Alan Guth (MIT).

No Wiggle Room

So, what will each polarization pattern look like? CMB light waves oscillate at distinct angles in the plane perpendicular to the waves' direction of travel. On CMB polarization maps, those angles of vibration can be drawn as line segments angled in a particular direction. As you go from one point in the sky to another, the segments' orientations create collective patterns. E-modes look like rings, or rays on a stick-figure Sun (see facing page). But the B-mode patterns should trace out spirals as you move from one line segment to another. These curls appear to turn either clockwise or counterclockwise.

The B-mode pattern is expected to be incredibly hard to detect. The CMB's temperature varies only a few parts in 100,000; in comparison, to detect primordial B-modes detectors must have a sensitivity equivalent to distinguishing temperature differences that vary only a few hundred parts per billion. E-modes are about 10 times stronger than that.

Despite these hurdles, cosmologists say that they should be able to detect this B-mode imprint in the CMB. The pattern should be most apparent across regions roughly 2° wide on the sky.

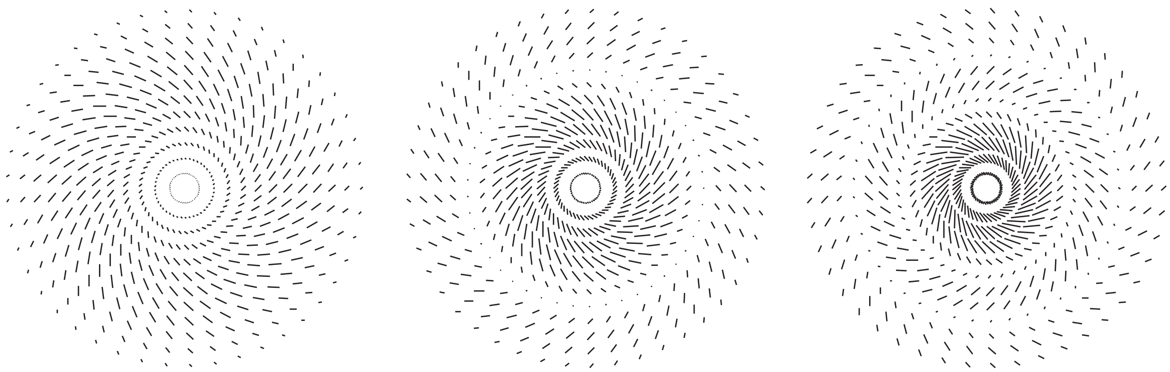
For B-modes to be detectable, they must have been imprinted by gravitational waves whose amplitude corresponds in a specific way to the energy stored in empty space right after the Big Bang, when three of the four fundamental forces — the electromagnetic force, the weak nuclear force, and the strong nuclear force — were joined together. Physicists think this unification of forces existed until about 10^{-35} second after the Big Bang, meaning the forces split right around the time inflation ended.

Measuring the intensity of gravitational waves would essentially be a direct measurement of how much energy was stored in space itself when inflation happened, says Guth. "It would be the first time that we would have an observational handle on that question."

Observing the CMB from Cerro Toco

Polarbear is an international, multi-institution experiment at the eastern fringe of Chile's Atacama Desert near the Bolivian border, where the thin and dry atmosphere above the barren volcanic landscape makes the site one of the premier places on Earth for microwave astronomy. The telescope, which collects microwave light with a 3.5-meter parabolic dish, is situated in the Chajnantor Scientific Reserve, where numerous high-profile astronomical projects are under way. Just a short walk from Polarbear is the 6-meter Atacama Cosmology Telescope (ACT) — which will also hunt for B-modes — and a few miles to the south is the Atacama Large Millimeter/submillimeter Array (ALMA), its dozens of antennas gleaming white in the bright midday Sun.

Polarbear is in its second year of observations. By 2016



SOURCE: ANTONY LEWIS

PEEK AT THE UNSEEN **Three examples of what primordial B-modes might look like. Unlike the E-modes detected by Planck, such B-modes would not be associated with hot and cold spots in the CMB: they're created by gravitational waves (see sidebar "How Gravitational Waves Create Polarization"). Cosmologists expect these patterns to appear in the sky on scales of a few degrees or larger.**

BRUCE LIEBERMAN

ADRIAN LEE

THE WHOLE SHEBANG ***Top:*** **A side view of the Polarbear telescope in Chile. The scope's shield hides the primary mirror, but the receiver box beneath it is visible.**

Bottom: **Hideki Morii (KEK, Japan) and Zigmund Kermish (now at Princeton) fine-tune the Polarbear detectors (see page 28). Notice the oxygen lines to their noses: at 17,000 feet above sea level, the Atacama site can pose a health hazard to the unprepared.**

the single telescope will be joined by two others to create an array of three scopes called the Simons Array that will measure CMB polarization.

"If we can see a signal from this earliest time in the universe . . . we will have a window to high-energy fundamental physics that people don't have on the Earth right now," says principal investigator Adrian Lee (University of California, Berkeley), who proposed the project in 2000. "For me, to have a chance at opening a window on that kind of physics would be a dream come true."

Polarbear faces competition from numerous other endeavors (see sidebar on facing page). Among them is SPTpol, a polarization experiment at the 10-meter South Pole Telescope led by the University of Chicago, and the Columbia University-led EBEX (the "E and B Experiment"), a balloon that was launched in December from McMurdo Station in Antarctica for three weeks of high-altitude observations. Neighboring ACT was outfitted this spring with a new detector called ACTPol so that it can search for B-mode signals in the CMB.

"These projects take a long time, and someone who decides to devote five or 10 years of their lives to this — it means they really think they have a chance to do it," says cosmologist Scott Dodelson (University of Chicago), who has made fundamental contributions to understanding the CMB. "There are probably hundreds of people [working on B-mode search projects], so that is a pretty good indication that it's a big prize."

Back in 2002, when Polarbear scientist Brian Keating (University of California, San Diego) helped propose the BICEP experiment at the South Pole to look for B-modes, scientists thought detections of these signatures in the CMB were improbable, if not impossible. "And they may be," he says. "B-modes from inflation may not exist at the level of detectability, or they may not exist at all. Inflation may not have happened — although that seems unlikely."

B-modes will not readily show themselves: they will only become apparent after much abstract mathematical analysis of the data, which should reveal the patterns in the CMB sky, Lee says. "The real sky maps will largely look like noise, but once separated by mathematical analysis, you can see that there are B-modes."

In addition to detecting primordial B-mode signals, Polarbear, like several other polarization experiments, will also look for "lensed B-modes." These are actually E-modes converted into B-modes through gravitational lensing. During its journey across the cosmos, some of the CMB radiation traveled too close to the universe's cosmic web of dark matter and galaxy clusters, and the gravity of those objects acted as a lens, bending the photons' paths. That distortion converted a fraction of primordial E-modes to B-modes.

Studying lensed B-modes, which were detected for the first time this past July by the South Pole Telescope team, could lead to insights about the large-scale structure of the universe and nearly massless, relativistic particles called neutrinos, Keating says. The lensed polarization signals could help researchers map the predicted cosmic neutrino background, as well as determine the contribution of neutrinos to dark matter. That calculation could help researchers indirectly determine the mass of the neutrino, which has not yet been measured. "It is somewhat of an embarrassment that we physicists do not know the mass of the neutrino — arguably the fourth most important particle after the proton, neutron, and electron!" adds Keating.

Understanding the nature of lensed B-modes also will help researchers distinguish them from primordial B-modes and subtract them out as unwanted noise. Fortunately, lensed B-modes are found on the sky at very small angular scales, on the order of 10 arcminutes, Lee says — one-tenth the size of primordial B-modes. Polarbear's neighbor ACTPol is actually optimized to find lensed B-modes, although it's expected to also look for the primordial ones.

Scanning the Chilean Sky

The Polarbear site is designed as much as possible to be self-contained. It includes a small complex of white shipping containers converted into a lab and control room, equipment storage, several onsite generators, and a toolshed where team members can assemble and repair the telescope's components. Team members almost always carry oxygen tanks in small backpacks, and, like scientists at other high-altitude projects around the world, they wear many different hats: astronomer, physicist, engineer, technician, construction worker, handyman, and tinkerer — frequently in the face of rapidly changing weather conditions. Here at 17,000 feet, there are no Home Depots; scientists must react quickly and resourcefully to the technical glitches that invariably pop up.

B-Mode Search Projects Underway

Ground-Based (Chile):

POLARBEAR: Polarization of Background Radiation

ACTPOL: Atacama Cosmology Telescope – Polarization

ABS: Atacama B-mode Search

Ground-Based (Antarctica):

SPTPOL: South Pole Telescope's polarization-sensitive camera

BICEP2: Background Imaging of Cosmic Extragalactic Polarization (and Keck Array)

QUBIC: Q&U Bolometric Interferometer for Cosmology

Ground-Based (Canary Islands):

QUIJOTE: Q-U-I JOint TEnerife

Balloon Experiments:

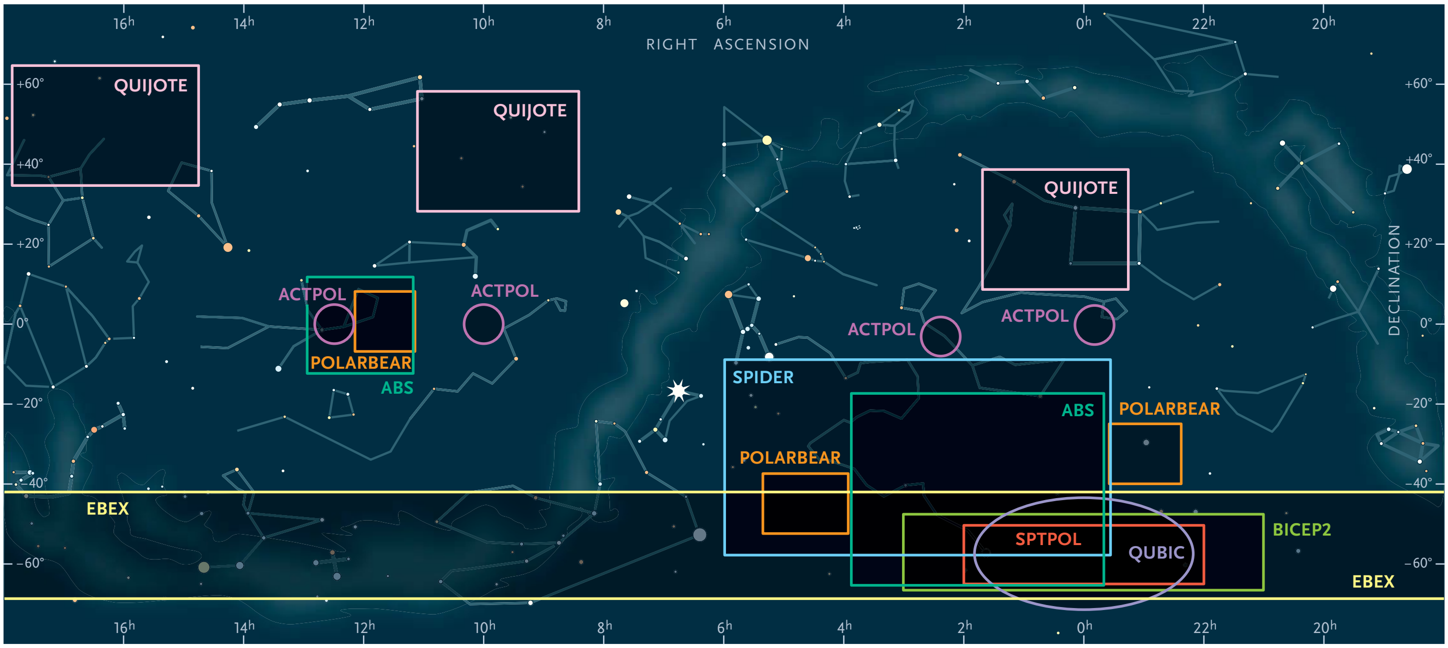
EBEX: E and B Experiment

SPIDER: Suborbital Polarimeter for Inflation

ESA Satellite Mission:

PLANCK

RACE TOWARD THE BIG BANG Several projects are currently hunting for the polarization signature of inflation. Shown below are the fields of view for active projects (except for Planck, which is all-sky). Fields are approximate and distorted by projection at high declinations.



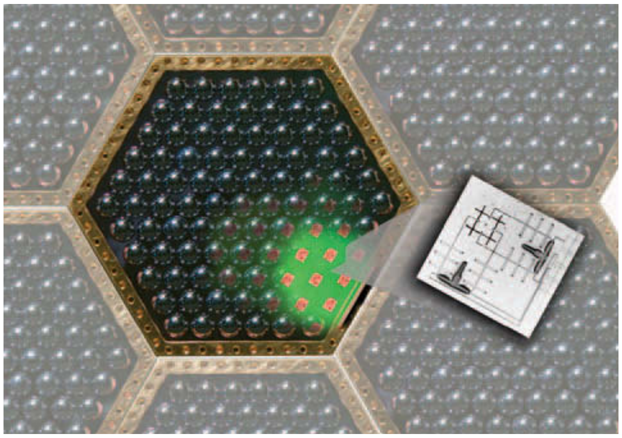
S&T: GEGG DINDERMAN

Right now Polarbear only comprises the Huan Tran Telescope (HTT), an off-axis Gregorian Mizuguchi-Dragone design fabricated in Italy by VertexRSI, now part of General Dynamics. (Huan Tran, the telescope's principal architect, died in an accident in 2010 while on his way to the Polarbear site during its engineering run in the Inyo Mountains of California.) The off-axis HTT telescope has the advantage of having an unobstructed aperture, because it doesn't need the secondary support structures required for on-axis telescopes. HTT's antenna has a 2.5-meter primary mirror precision-machined from a single piece of aluminum and a lower-precision guard ring that extends the dish out to 3.5 meters.

Housed in a 2.1-meter receiver that is anchored below and forward of the primary is a focal plane of 1,274 antenna-coupled, polarization-sensitive bolometers that measure the angle of vibration of incoming light waves (see image at right). Put enough measurements together, and astronomers can determine how the CMB is polarized across that section of sky.

This year Polarbear will move to observing three 15° × 15° patches of the southern sky, carefully chosen to minimize the amount of foreground contamination, primarily by dust from the Milky Way. The telescope currently observes in a single spectral band centered at 148 GHz, but eventually three scopes will work together as the planned Simons Array to observe the sky at multiple frequencies. The second two telescopes will be identical to the first but with improved receivers containing more detectors. An updated receiver will eventually be installed on HTT, too.

The team is analyzing data from the first season's observing run in 2012 and expects to report results this fall. To prevent unsuspected biases from creeping in, the researchers are first working on a small portion of data and analyzing it completely — "*except for looking for the B-modes*," Keating says. "We do every possible test that you can do to ensure that the data have high quality, and we strive to avoid at all costs the spurious effects, the systematic effects." Only then will they look for B-modes.


POLARBEAR TEAM

DETECTING POLARIZATION A single antenna can only pick up light polarized in one direction, so researchers need multiple antennas to detect all polarization angles. In Polarbear's tick-tack-toe arrangement, each antenna is sensitive to polarization perpendicular to the antenna slot, allowing the team to detect both horizontal and vertical polarizations. The bolometers (the T-shapes in the zoom image) act like receivers that convert incoming microwaves into signals. To detect polarization angles between horizontal and vertical, the team subtracts one from the other. Waves polarized at 45° thus disappear, so other antennas in the array are rotated 45° from the one shown to compensate.

Forward, Cautiously

Sitting in the high-altitude lab during a short break from work at the observatory site, Polarbear scientist Hans Paar (University of California, San Diego) says that, like other teams searching for the prized B-mode signal, his team is vigilant about not rushing toward a result.

"We are hemmed in between the desire to be right and the desire to be first," Paar says. "The desire to be first is not a scientific desire; it's a human desire. The desire to be right is a scientific desire. You don't want to mislead your community with something that's incorrect."

And what if there are no B-modes to be found?

"I would say that if we don't find B-modes, it in no way suggests that inflation did not happen," Guth says. "It does mean, of course, that we are not getting the opportunity to see a new piece of evidence that would tell us that inflation did happen." If the current generation of experiments fails to detect B-modes, it could simply mean that the signal is far fainter than cosmologists expect, he says. But that could indicate that inflation occurred at a lower energy level. "So it would have an effect on inflationary theorizing, even if it's a negative result," he adds.

Nobel laureate John Mather (NASA/Goddard Space Flight Center), who worked on the Cosmic Background Explorer (COBE) satellite that revolutionized CMB science in the early 1990s, says the detection of B-modes would be "tremendously important" but that the signal's absence would also be progress.

"For an astronomer, a measurement is a measurement, so we would be thrilled to have a measurement," Mather says. "We don't have a textbook that says it's supposed to be one way or another. We're in the discovery mode here. So, I would be happy to know that it's there or that it's not there. Then we just go on and try to understand it." ✦

Learn more about these projects at skypub.com/CMBpolarization.

***Bruce Lieberman** is a freelance science writer with nearly 25 years' experience in the news business. He has written about astronomy and other space-related subjects for* Air & Space, Scientific American, *and the Kavli Foundation.*

October's Dawn Window for Sirius B

Alan Whitman

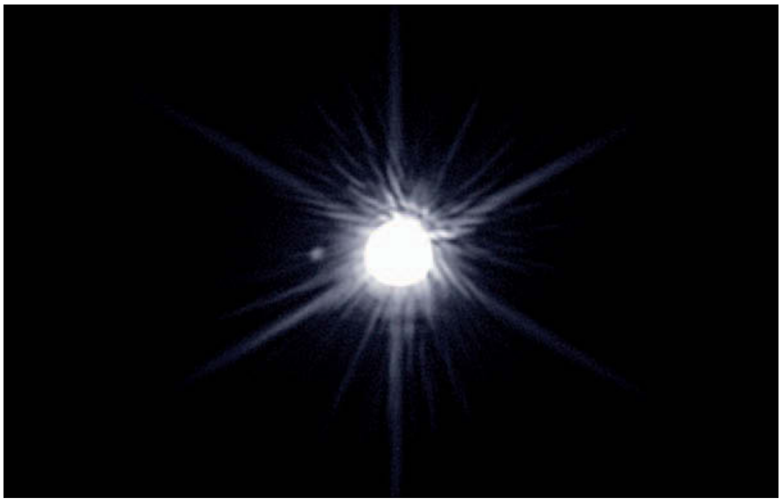
Sirius in October? If you'd like to try for its legendary white dwarf companion — easier to see now than in decades — here's why to set your alarm clock.

Orion's belt stars were fading from view on the October morning 30 years ago when I first collared the Pup — the famous white dwarf that orbits the Dog Star. In addition to observing through a bright dawn sky, I had further dimmed the glare of Sirius A with a Moon filter. Even so, shards of light danced and flickered all around Sirius in my 8-inch f/6 Newtonian. But at 348× one faint spark, only a ten-thousandth as bright as Sirius A, repeatedly held stationary for a few seconds at a time.

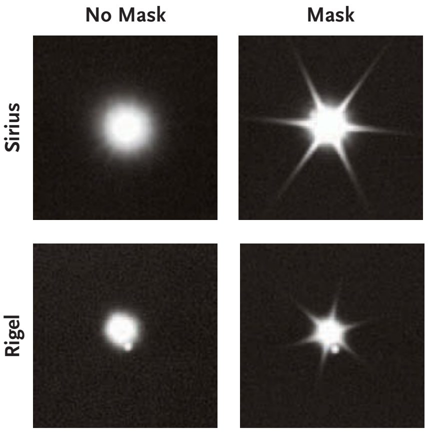
Then as now, Sirius's historic white dwarf companion star was about the same distance from its primary as Rigel's easier companion is, making it easy to compare them and confirm that my sighting of the elusive Pup was at the proper separation. To the unaided eye Sirius was twinkling only slightly, despite culminating a mere 23° above the south horizon of my British Columbia backyard, located at 50° north latitude. The seeing was memorably steady, caused by what meteorologists call an upper ridgeline passing overhead.

Sirius culminates at dawn in early October, near 9 p.m. in mid-February, and around sunset by late March. I have succeeded at all of those times. But calm October dawns, when the seeing is likely to turn particularly stable, offer you perhaps the best chance of bagging Sirius B with your scope, especially if you live in a semi-arid climate as I do. In dry air the temperature usually plummets after sunset if there's no breeze, and it can be difficult to cool your mirror as rapidly as the air temperature falls. But late at night the temperature levels off as it nears or reaches the dewpoint, and after spending hours outdoors, your mirror should reach equilibrium with the air temperature. I enjoy steady seeing during morning twilight more frequently than at any other time.

In 1844 Friedrich Wilhelm Bessel deduced that Sirius had a massive companion, based on careful measurements of the primary's slightly wavy proper motion across the sky. But it was not seen until January 1862, when Alvan G. Clark serendipitously discovered the tiny Pup while testing an 18.5-inch refractor lens that he and his father were making (*S&T:* February 2008, page 30). The



As with planets, stacked-video imaging is the best way to take pictures of close double stars. At the 2008 Winter Star Party in the Florida Keys, Damian Peach used a 10-inch scope and a SKYnyx 2.0 astro video camera to take 1,800 frames (60 per second) stacked here. Sirius A and B were 8.4″ apart, with the Pup almost due east from the bright Dog Star.



In 1975, when Sirius and its companion were 11.3″ apart, Dennis di Cicco used a 14-inch Schmidt-Cassegrain telescope with and without a hexagonal mask to take these photos of Sirius and Rigel. Only with the mask is Sirius B really apparent, just northeast (upper left) of brilliant A.

tiny size of the star, despite its known large mass, set off a revolution in astrophysics. Sirius B is still the closest white dwarf to the solar system. (Though it's not the easiest to view; that's 40 Eridani B).

Of course, once a challenging object has been discovered with a large telescope, it can be detected with a smaller one. You have a huge advantage over the Clarks — you know that Sirius's companion exists, *and* where it is.

Sirius A and B are magnitudes –1.5 and +8.5, and this huge brightness difference causes all the difficulty. The stars are now 10.0″ apart, with B at position angle 81°: just north of due east from A. Their orbital period is 50.2 years, and their maximum separation of 11.3″ is due in 2022.

For weather watchers, a surface high-pressure area under a strong upper ridge or, better yet, a rare upper high, will usually cause excellent telescopic seeing due to light winds at all altitudes and the absence of wind shear. Try to observe over greenery; avoid heat sources such as your neighbor's roof. High-quality optics, clean and well collimated, are essential. On four nights since 2008 I have succeeded with my 16-inch (at 522×) and 8-inch (at 348×). In those cases I used a 7-mm orthoscopic eyepiece with opaque photography tape covering half of its tiny field stop, along with a 2× Barlow. When Sirius A is hidden just behind the tape's sharp edge, Sirius B is easier to spot.

On a fifth night, February 20, 2008, I put my 8-inch on its portable Dob mount to observe a bright orange total eclipse of the Moon low in the east. After totality, noticing that a southing Sirius was barely twinkling, I tried for the Pup at only 244× using a lunar filter and no occulting bar. To my surprise I succeeded, though the separation was only 8.1″ at the time. The seeing was superb that night.

From more southerly latitudes than mine, Sirius's higher altitude will improve your chances. Good hunting! ✦

***Alan Whitman**'s first eyepiece occulting bar was a matchstick that he placed across the field stop of a 10.5-mm ortho. Unfortunately, he often used this eyepiece to project an image of the Sun onto white paper. When he absentmindedly did so weeks later, the Sun was crisp for a few seconds, then dissolved into a blur. Smoke poured from the focuser! The field lens was hopelessly coated with tar, and he eventually had to discard a prized eyepiece.*

Tips for Hunting Sirius B

Observe when Sirius is highest in the south, use your highest magnification, hide Sirius's dazzle behind an occulting bar or the sharp edge of your eyepiece's field stop, and wait patiently for moments of good seeing — but you know that already. The following tips will help further.

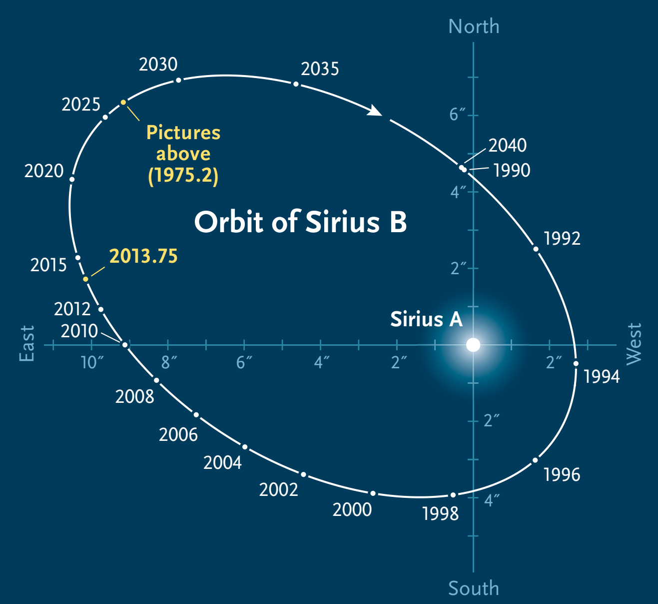
Keep watching as dawn brightens. The reduced glare of Sirius A in a twilight sky may improve the detectability of its 8th-magnitude companion.

Move diffraction aside. Your target is almost due east of the bright star. This puts it almost on a bright diffraction spike in a reflector with a spider vane running north-south. In a scope with spider vanes, rotate the tube (or tilt or turn the whole mount) to move a diffraction spike away from Sirius B. The main source of diffraction in any telescope, however, is the edge of the aperture itself. You can't get rid of this, but you can herd it around. Cut a square or hexagonal hole in a piece of cardboard, sized so opposite corners are the width of the aperture. Tape it over the telescope's front. Bright stars now have four or six diffraction spikes. Rotate the mask so celestial east is between two of them. The photos at left show the improvement.

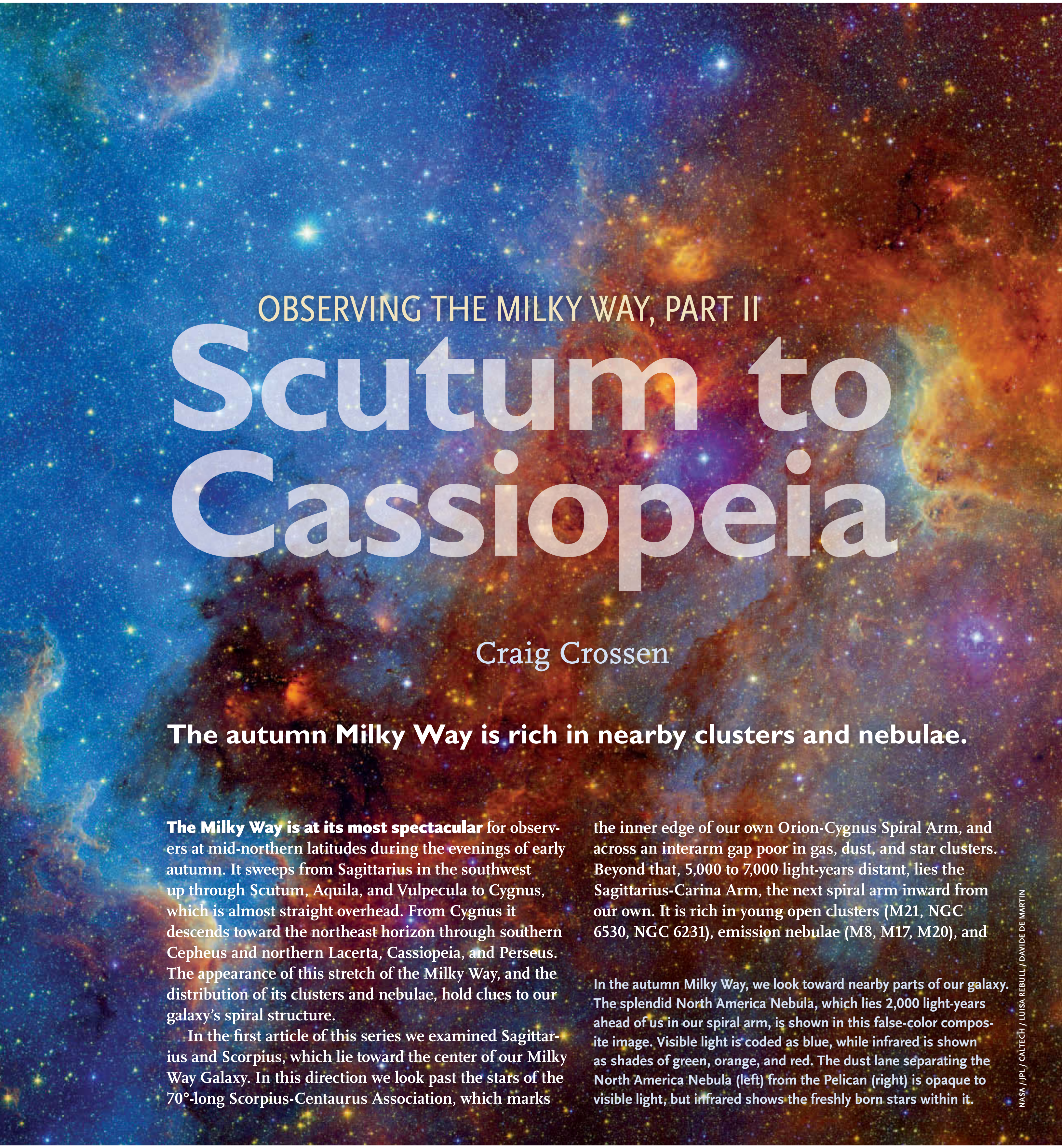
Practice on Rigel. By a wonderful coincidence, Rigel, nearby in Orion's foot, is a similar but easier bright-and-faint double star. Its separation is almost the same, 9.5″, but the brightness difference is 10 times less extreme: magnitudes +0.1 and +7.6 (1 to 1,000 instead of 1 to 10,000). In Rigel's case, the companion (a normal main-sequence star) is south-southwest of the primary. It'll give you an idea of what to look for.

Don't be haunted. Almost one full orbit ago back in 1968, I was amazed at how well I could see Sirius's companion in my new homemade 6-inch reflector. Only after several nights did I notice that it changed position with respect to Sirius when I moved Sirius in the eyepiece! I realized to my horror that I was seeing not the storied white dwarf but a *ghost* — a faint reflection of Sirius itself between eyepiece lens elements. Check for this by moving Sirius around. After bragging about my eagle-eyed sighting to relatives and my high-school science teacher, I had some crow to eat.

— *Alan MacRobert*



The apparent orbit of Sirius B with respect to Sirius A, as projected onto the plane of the sky. The true orbit is inclined 43° to the sky. Dates without decimals are for the beginning of the year.



OBSERVING THE MILKY WAY, PART II

Scutum to Cassiopeia

Craig Crossen

The autumn Milky Way is rich in nearby clusters and nebulae.

The Milky Way is at its most spectacular for observers at mid-northern latitudes during the evenings of early autumn. It sweeps from Sagittarius in the southwest up through Scutum, Aquila, and Vulpecula to Cygnus, which is almost straight overhead. From Cygnus it descends toward the northeast horizon through southern Cepheus and northern Lacerta, Cassiopeia, and Perseus. The appearance of this stretch of the Milky Way, and the distribution of its clusters and nebulae, hold clues to our galaxy's spiral structure.

In the first article of this series we examined Sagittarius and Scorpius, which lie toward the center of our Milky Way Galaxy. In this direction we look past the stars of the 70°-long Scorpius-Centaurus Association, which marks the inner edge of our own Orion-Cygnus Spiral Arm, and across an interarm gap poor in gas, dust, and star clusters. Beyond that, 5,000 to 7,000 light-years distant, lies the Sagittarius-Carina Arm, the next spiral arm inward from our own. It is rich in young open clusters (M21, NGC 6530, NGC 6231), emission nebulae (M8, M17, M20), and

In the autumn Milky Way, we look toward nearby parts of our galaxy. The splendid North America Nebula, which lies 2,000 light-years ahead of us in our spiral arm, is shown in this false-color composite image. Visible light is coded as blue, while infrared is shown as shades of green, orange, and red. The dust lane separating the North America Nebula (left) from the Pelican (right) is opaque to visible light, but infrared shows the freshly born stars within it.

NASA / JPL / CALTECH / LUISA REBULL / DAVIDE DE MARTIN dust clouds. A window through the Sagittarius-Carina Arm dust allows us to see the 10,000- to 16,000-light-year-distant Small Sagittarius Star Cloud (M24), a star-rich stretch of the Norma Spiral Arm of our galaxy's deep interior. Finally, looking "beneath" the dust clouds that lie along the plane of the Milky Way, we see the Great Sagittarius Star Cloud, a section of our galaxy's central bulge.

A quick note on terminology: The names of our galaxy's spiral arms have not been standardized. Many researchers call the Norma Arm the Scutum-Centaurus or Scutum-Crux Arm. And the Orion-Cygnus Arm is often called the Orion Arm, Orion Spur, or Local Arm.

The Scutum Star Cloud

As we shift our gaze up along the Milky Way away from the galactic center (northeastward in terms of celestial coordinates), we start looking toward our galaxy's outer regions. The last deep-interior feature that we see is the impressively bright **Scutum Star Cloud**.

The open clusters **Messier 11** and **Messier 26** appear to be in the Scutum Star Cloud, but they are in fact in the foreground, about 6,000 and 5,000 light-years distant, respectively. In any case, they're too old to be true spiral-arm tracers. Stars and star clusters are born almost exclusively within spiral arms, but they drift far from their spiral-arm birthplaces as they age.

In the Scutum Star Cloud, we appear to be looking along the length of one of the spiral arms as it curves inward around the galactic center, seeing stars at many different distances superposed on each other. This is either the Sagittarius-Carina Arm (the next arm inward from ours), the Norma Arm (the arm inside that), or possibly a place where both arms intersect. This hasn't been proved, but it seems plausible because bridges and branching are common in loose spiral galaxies such as the Milky Way.

Spiral Structure and Galactic Longitude

When we sweep farther northeastward from the Scutum Star Cloud and farther from the galactic center, we shift our gaze away from our galaxy's inner regions and increasingly encounter features in our own spiral arm.

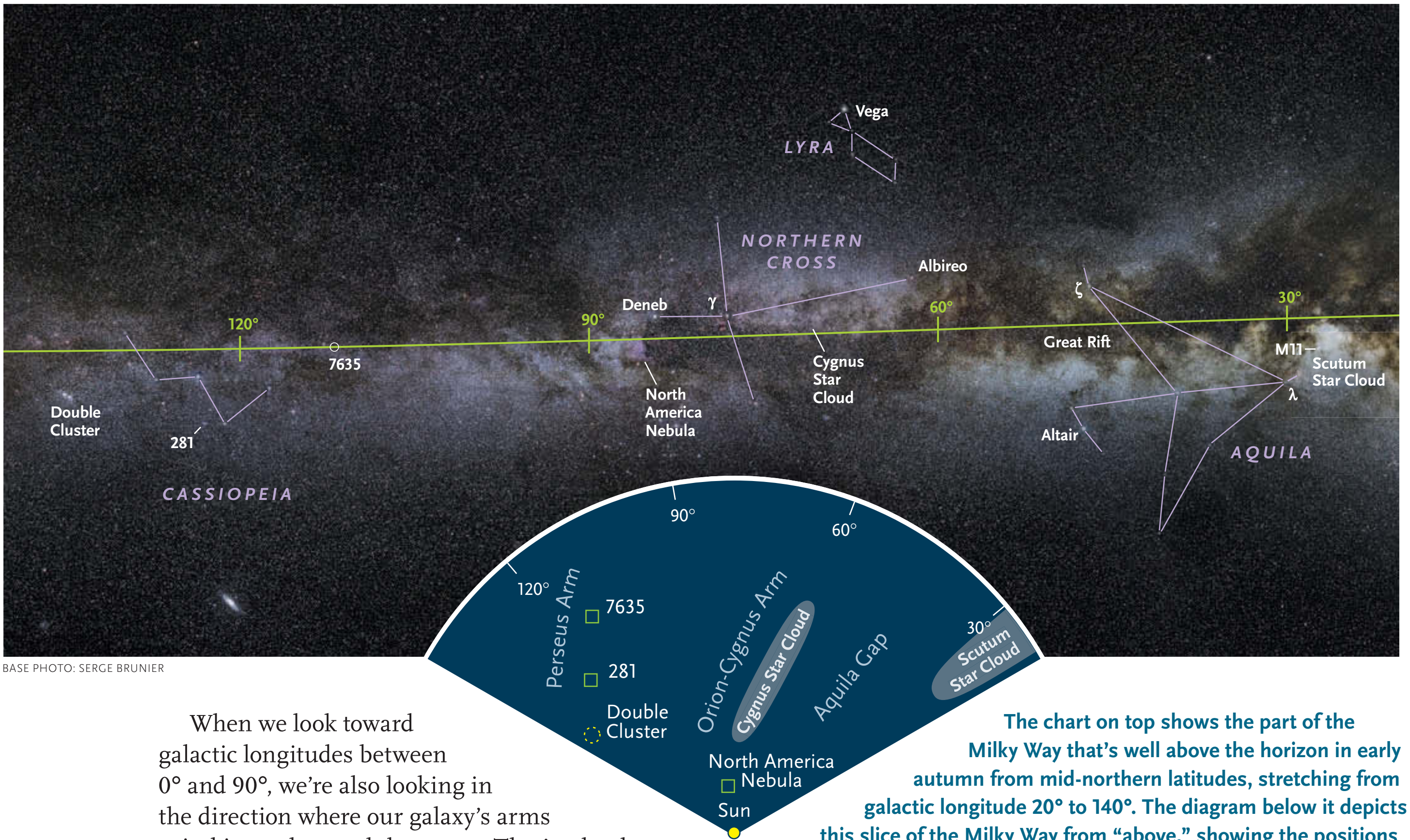
To decipher these features and get a sense of galactic depth perspective on the autumn Milky Way, it's helpful to use the galactic coordinate system. The galactic equator (galactic latitude 0°) is the centerline of the Milky Way, which makes a full 360° circle around the sky. Around this equator are four cardinal points of galactic longitude, starting with 0°, the direction of the galactic center. Galactic longitude 90°, looking forward along our own spiral arm, lies in Cygnus just 5° northeast of Deneb. Longitude 180°, the galactic anticenter, is near Beta (β) Tauri on the Taurus-Auriga border. Finally, galactic longitude 270°, looking backward along our spiral arm, is in the southern constellation of Vela. The part of the Milky Way from there to longitude 340°, in southern Scorpius, is invisible or barely visible from mid-northern latitudes.

When we speak of looking forward and backward along our spiral arm, this isn't just a figure of speech. Most of the stars in our neighborhood are in fact moving toward Cygnus. No two stars move with exactly the same speed and direction; for instance our own Sun is about 9% faster than the average star in its vicinity and is heading slightly inward and "up" (away from the galactic plane). But with few exceptions, the deviations from the average velocity are quite small.

For observers in the North Temperate Zone, galactic longitude 90° is nearly straight overhead during early autumn evenings. Thus when you look straight overhead toward Deneb and longitude 90°, you're looking into the direction of our neighborhood's orbital motion around the galactic center. The center itself is just above the southwest horizon, and the galactic anticenter is just below the northeast horizon.

CANADA-FRANCE-HAWAII TELESCOPE / *COELUM*

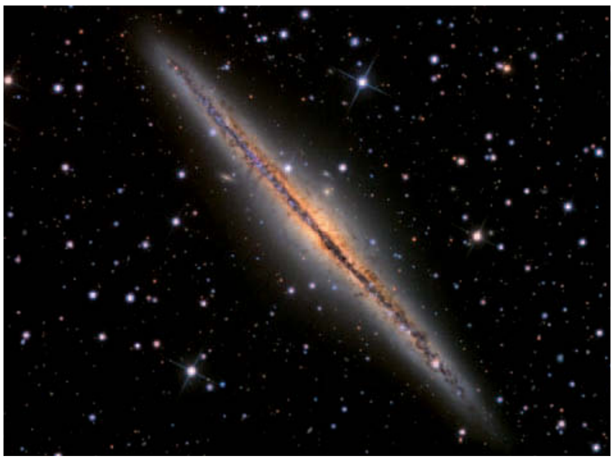
The rich open star cluster Messier 11 appears to lie inside the Scutum Star Cloud, but it's actually a foreground object, some 6,000 light-years distant. M11 is about 250 million years old, ample time to wander far from its birthplace within a spiral arm.



BASE PHOTO: SERGE BRUNIER

The chart on top shows the part of the Milky Way that's well above the horizon in early autumn from mid-northern latitudes, stretching from galactic longitude 20° to 140°. The diagram below it depicts this slice of the Milky Way from "above," showing the positions of selected objects in the galactic plane. The outer edge of the pie slice is 15,000 light-years from the Sun. Distances to some of the objects, notably the star clouds, are not known with high precision.

When we look toward galactic longitudes between 0° and 90°, we're also looking in the direction where our galaxy's arms spiral inward toward the center. That's why the bright nebulae of the Sagittarius-Carina arm such as M16 and M17 stretch only to longitude 17° in this direction, whereas the Eta Carinae Nebula, also in the Sagittarius-Carina arm, lies 72° on the opposite side of the galactic center, at longitude 288°. The Eta Carinae Nebula doesn't just *appear* farther from the galactic center than M16 does — it actually *is* farther, because it lies along the outcurving portion of the spiral arm, whereas M16 lies along the incurving portion.



ADAM BLOCK / MOUNT LEMMON SKYCENTER / UNIVERSITY OF ARIZONA

As this photograph of the edge-on spiral galaxy NGC 891 shows, dust tends to collect near a spiral galaxy's center plane.

The Great Rift

The Milky Way from Sagittarius to Cygnus isn't merely a faint band of featureless haze; it's divided by a long dark rift, smudged by several dark patches, and ornamented by a half-dozen star clouds of different sizes and brightnesses. To the unaided eye, the most striking feature of the early autumn Milky Way is the **Great Rift**, which divides the Milky Way southwest of Deneb into two more-or-less parallel streams.

The western (and mostly fainter) branch of the Milky Way fades out in northern Ophiuchus, obscured by the large dust cloud that covers much of that constellation's eastern section. But it reappears some 20° farther on in the region of Eta (η) Ophiuchi. The Great Rift extends beyond Sagittarius deep into the far southern Milky Way, finally ending at Alpha (α) Centauri.

Wide-angle images of the Milky Way from Cygnus to Centaurus are remarkably like photos of edge-on spiral galaxies such as NGC 891 in Andromeda and NGC 4565 in Coma Berenices. That's because the Great Rift of the Milky Way and the dark lanes of edge-on external galaxies are the same sort of thing: clouds of interstellar dust that obscure the light of the stars of the galaxy's interior.

The true nature of the Great Rift can best be appreciated by sweeping with binoculars between the two streams of the autumn Milky Way. Particularly fine scans across the Great Rift are from the scintillating star clouds around Albireo, at the foot of the Northern Cross, toward the tip of Sagitta, and from the luminous Milky Way glow near Altair and Gamma (γ) Aquilae toward the star pair of Epsilon (ε) and Zeta (ζ) Aquilae.

The dark lanes that we see on photos of edge-on spirals such as NGC 891 and 4565 are composites of all the dust along the planes of such systems. But the Milky Way's Great Rift is basically a single chain of dust clouds. It approaches nearest to us in far southern Ophiuchus, where the dust clouds of the Rho (ρ) Ophiuchi star-formation region north of Antares are less than 700 light-years distant. The Aquila Rift dust clouds west of Gamma Aquilae are about 1,000 light-years away. And the dust clouds at the far northeast end of the Great Rift near Deneb are around 2,200 light-years from us.

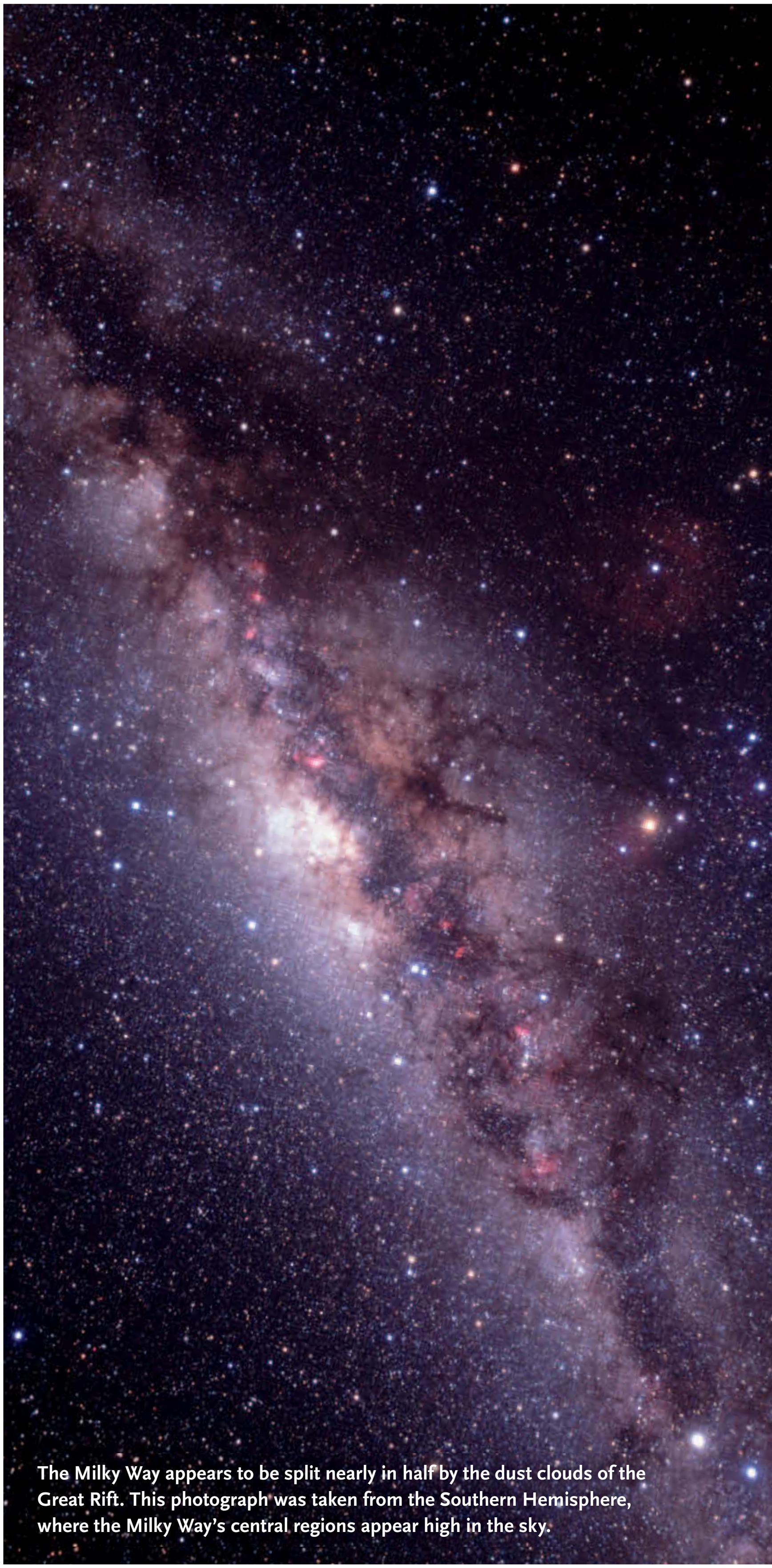
But the Rho Ophiuchi complex is between us and the galactic interior, and Deneb is ahead of us (in terms of galactic rotation). Thus we have to think of the Great Rift as a chain of dust clouds extending from ahead of us in Cygnus to behind us in Centaurus, and lying between us and the galactic interior. Photos of other spiral galaxies show that dust lanes often line the interior edges of spiral arms. The Great Rift marks the interior edge of our spiral feature, the Orion-Cygnus Spiral Arm.

Aquila and the Interarm Gap

Moving up the Milky Way from the Scutum Star Cloud toward higher galactic longitudes, the next bright section that we encounter is the **Cygnus Star Cloud**, a 20°-long oval that lies along the long arm of the Northern Cross, from Albireo to Gamma (γ) Cygni. The Cygnus Star Cloud and neighboring parts of Vulpecula contain an abundance of distant open clusters and stellar associations. However, the Aquila Milky Way between Scutum and Vulpecula is very poor in open clusters: *Burnham's Celestial Handbook* catalogs five open clusters in Scutum and nine in Vulpecula, but only three in the very much larger Aquila.

Toward Aquila lies the interarm gap between the incurving edge of the Sagittarius-Carina Arm and the incurving edge of our own Orion-Cygnus Arm. Thus toward Aquila we look past a sprinkling of foreground stars down a long, relatively empty interarm gap toward very distant star clouds, which are probably the far arc of our Orion-Cygnus Arm. When we sweep up the autumn Milky Way from Scutum to Cygnus, we look first at the edge of the Sagittarius-Carina Arm, then at the interarm gap, and finally along our Orion-Cygnus Arm.

The preceding scenario isn't accepted by all astronomers. Some think that the Sagittarius-Carina Arm extends through Aquila to Vulpecula. But there are some



AKIRA FUJII

The Milky Way appears to be split nearly in half by the dust clouds of the Great Rift. This photograph was taken from the Southern Hemisphere, where the Milky Way's central regions appear high in the sky.

problems with this theory. First, the distant nebulae and clusters in Vulpecula are about as far from the galactic center as are the Sagittarius-Carina Arm objects in Sagittarius itself. So it's unlikely that they're in the Sagittarius-Carina Arm, because the arm should be winding inward in this direction. Second, the brightness of the Aquila Milky Way decreases from northeast, near Gamma Aquilae, to the southwest, near Lambda (λ) Aquilae, just as it would if we're seeing the forward arc of our Orion-Cygnus Arm curving around to the far side of the galactic bulge. Finally, there are no nearby young open clusters or emission nebulae in Aquila that could be tracers of the Sagittarius-Carina Arm.

In fact, Aquila is exceptionally rich in planetary nebulae, which are the remnants of old solar-type stars and are distributed fairly evenly throughout the galaxy's thick disk (though with a bias toward the interior). Planetary nebulae are not very easy to see through interstellar dust, and their abundance in Aquila suggests that there isn't much dust in this direction — except for the sharply delineated Aquila Rift.

Cygnus: the View Down Our Arm

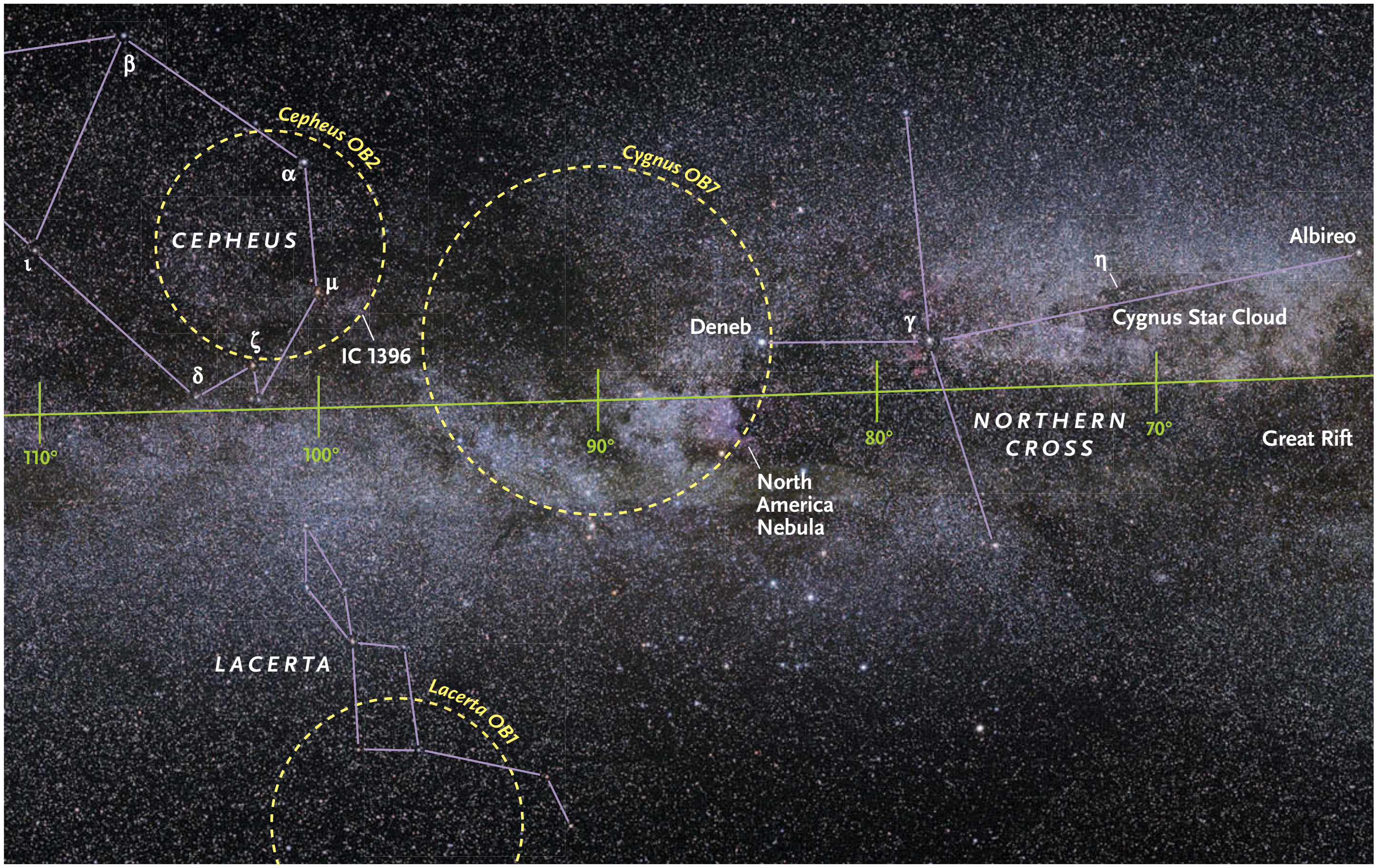
Because we're near the inner edge of our Orion-Cygnus Spiral Arm, we see no nearby young clusters and only one nearby stellar association (Scorpius-Centaurus) until we sweep upward to the Cygnus-Cepheus Milky Way, which in terms of galactic rotation is ahead of us in our orbit around the galactic center.

The most prominent young star grouping in this area is probably the **Cygnus OB7 Association**, which is centered roughly 2,000 light-years distant. It includes Deneb and the **North America Nebula** (NGC 7000), a splendid binocular target. The **Pelican Nebula** (IC 5067) is part of the same complex, but it's separated from the North America by a band of foreground dust.

The extensive and populous **Cepheus OB2 Association** lies slightly farther away. Its brightest star is the red supergiant **Mu (μ) Cephei** (sometimes called Herschel's Garnet Star), and it contains the large emission nebula **IC 1396**, which is surprisingly easy to see through 10×50 binoculars under dark skies.

The **Lacerta OB1 Association**, scattered over the southern half of that constellation, is located just 1,500 light-years from us, and makes a fine 7× binocular field.

Note that these three nearby associations lie at or beyond galactic longitude 90°, the direction of orbital motion of our neighborhood of the galaxy, whereas the more distant Cygnus Star Cloud, where we look down the forward arc of the Orion Cygnus Arm, is between galactic



BASE PHOTO: SERGE BRUNIER

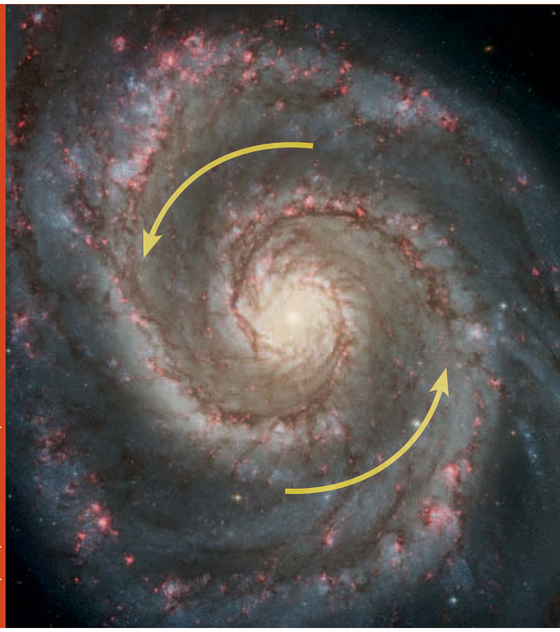
Spiral Arms and Galaxy Rotation

All spiral galaxies rotate; however, the spiral arms don't rotate in lockstep with the material inside them. In fact, spiral arms are much like traffic jams on a crowded highway. Individual cars move through traffic jams and out the other side. Traffic jams do tend to drift down the road, but much more slowly than the cars that pass through them.

Gas and dust pile up on the inside edges of spiral arms, forming dense dust clouds. These give rise to star-forming regions, which in turn give rise to clusters and stellar associations. The hot, bright, bluish stars in these clusters and associations burn out in short order, but the fainter stars and more mature clusters eventually rotate out of the spiral arms and into the gaps between. There's actually almost as much material between the arms as in them, but these areas appear much dimmer because they contain few really bright stars.

The pattern is apparent in this HST image of Messier 51 (whose companion has been cropped off for clarity). Dark clouds line the spiral arm's inside edges, followed by pink star-forming regions, followed in turn by associations of blue-white stars. But there are numerous exceptions; the process isn't as orderly in real life as it sounds on paper.

NASA / ESA / STEVEN BECKWITH / HUBBLE HERITAGE TEAM

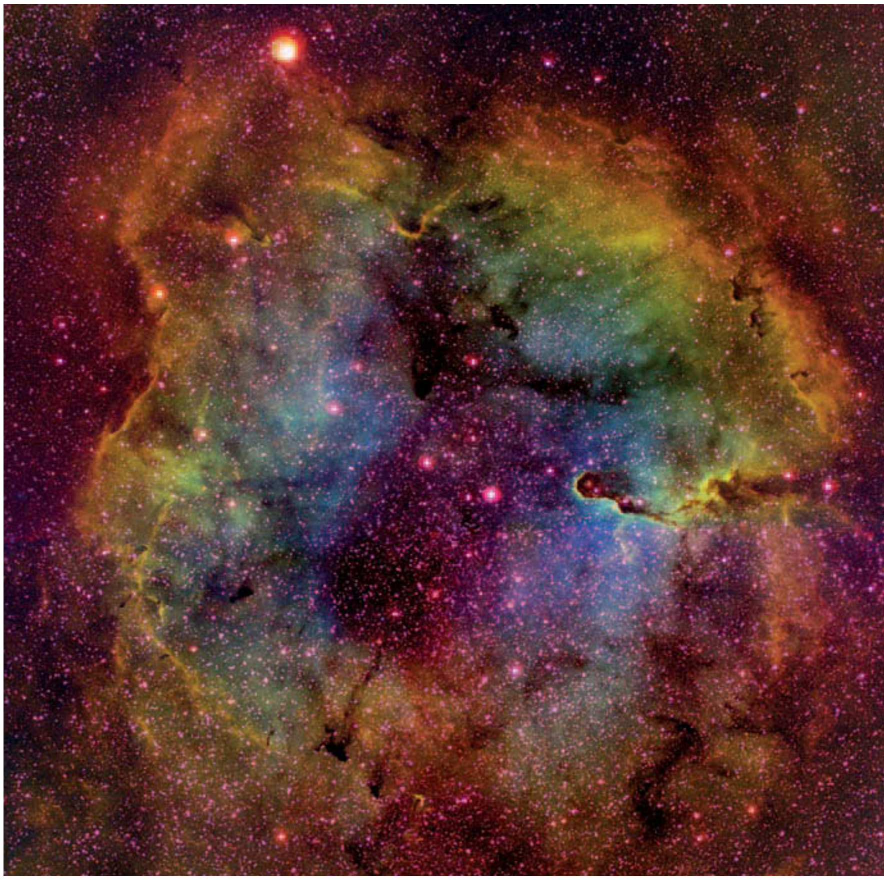


longitudes 80° and 60° — in other words, a bit toward the interior of the galaxy. That's because the spiral arms of galaxies wind up in the direction of rotation, so the forward arc of our spiral arm is somewhat nearer the galactic center than we are.

In the northeast (closer) half of the Cygnus Star Cloud, between Gamma and Eta Cygni, astronomers have identified several extensive and populous stellar associations. But they are rather distant (4,000 to 7,000 light-years). In binoculars this half of the star cloud is rich in stars from magnitude 7 to 10, but its background glow is pale and cut through by narrow, snaking, dark lanes. The stars are the brightest members of the stellar associations, and the dark lanes are the dust involved with these star groups. Binoculars resolve fewer stars in the southwest (more distant) half of the Cygnus Star Cloud, but this region is an impressively bright glow with a myriad of faint and momentarily resolved stars embedded inside it. Interstellar dust must be very thin in this direction out to more than 10,000 light-years.

Other areas in Cygnus with bright Milky Way background glows and multitudes of faint or partially resolved stars (as seen in binoculars) lie north and northeast of the North America Nebula, and in far northeast Cygnus and neighboring northern Lacerta. In these directions we have views thousands of light-years long through relatively dust-free windows.

The Great Rift ends at an impressively dark dust cloud several degrees across between Gamma Cygni and Deneb, but there are additional dust features northeast along the Milky Way. The North America Nebula is shaped by foreground dust clouds to its west, south, and east. And centered midway between Deneb and Alpha Cephei is the large naked-eye dust cloud **Le Gentil 3**.



RICHARD CRISP

The star-forming region IC 1396 is shown here in false color, with red, green, and blue representing emissions from sulfur, hydrogen, and oxygen, respectively. The bright star near the top is the red supergiant Mu Cephei.

The unaided eye also shows that a branch of the Milky Way extends from the star clouds of northeastern Cygnus into central Cepheus, where it dead-ends in the square formed by Alpha, Beta, Iota (ι), and Zeta Cephei. In binoculars this branch of the Milky Way resolves into a rich field of stars ranging from magnitude 5 to 9, most of which are members of the Cepheus OB2 Association.

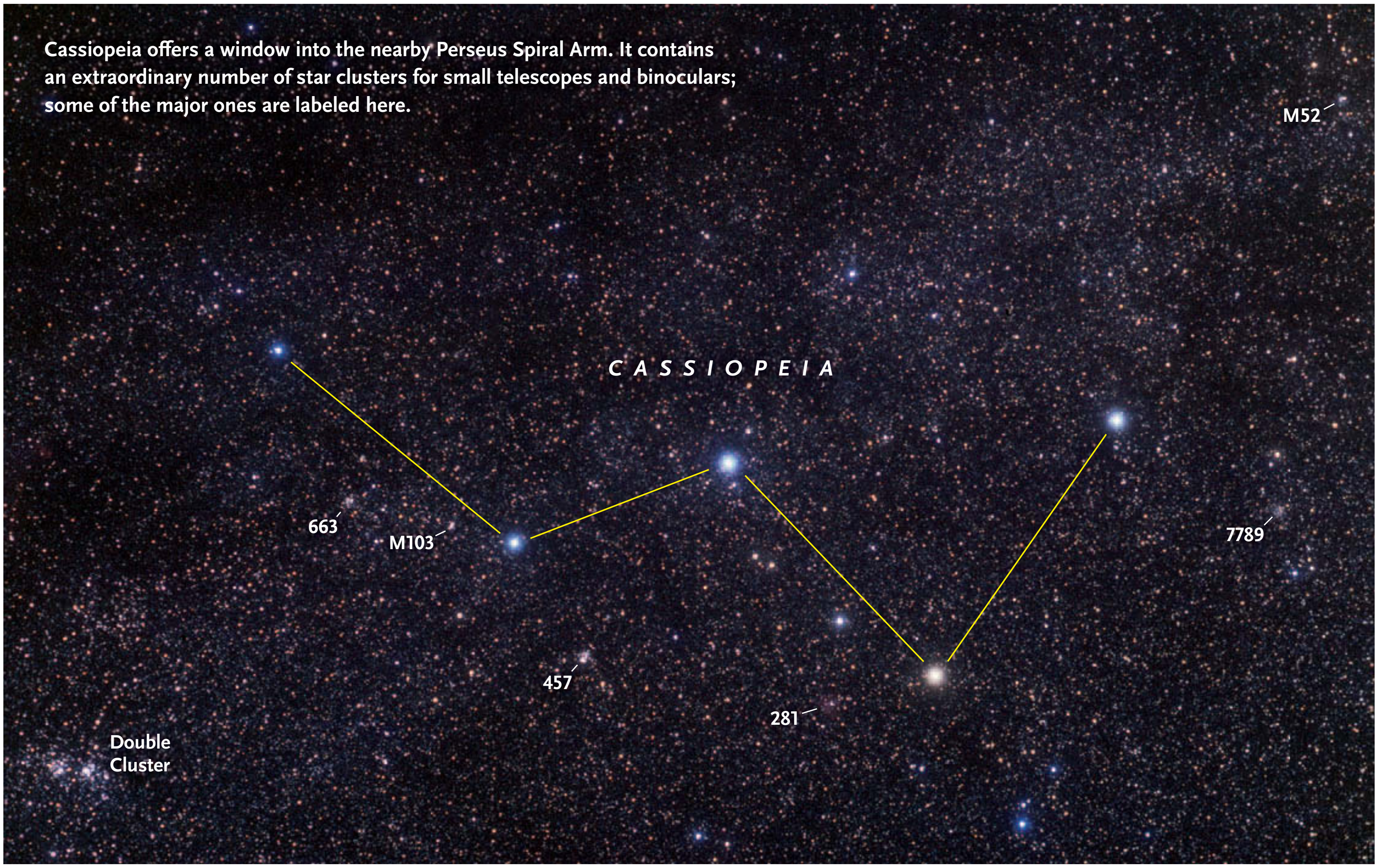
Cassiopeia: a Window to the Perseus Arm

By nightfall in November, or midnight in September, the Milky Way constellations that follow Cepheus — Cassiopeia and Perseus — are high in the east for mid-northern observers. The magnificent **Double Cluster** lies near the border between these constellations; it's technically in Perseus but visually seems more part of Cassiopeia.

The Perseus Milky Way (excluding the Double Cluster) appears much thinner and fainter to the unaided eye than the Milky Way in Cassiopeia. A scan with binoculars shows why: the Cassiopeia star fields are much richer than those of Perseus. Toward Perseus the interstellar dust of our own spiral arm is especially thick, whereas toward Cassiopeia there's a window between the Orion-Cygnus Arm dust clouds of Perseus on the east and those of Cepheus on the west. Through this window we can see the next spiral feature out from ours.

To get a better perspective on this, look up toward Deneb, in the direction of galactic longitude 90°. Stand with the galactic center in Sagittarius on your left and the galactic anticenter (on the Taurus-Auriga border) on your right. You will see that Cassiopeia lies somewhat right of longitude 90°, about a third of the way from Deneb down toward the galactic anticenter. Therefore, toward Cassiopeia we're looking ahead (in the direction of galactic rotation) but at an angle through our own Orion-Cygnus Arm (because we're near its inside edge) out toward the rim of the Milky Way Galaxy. Since there's a window through nearby dust clouds here, what we see in this direction are not the stellar associations, clusters, and nebulae of our own spiral arm, but those of the next spiral feature out: the Perseus Spiral Arm.

The Cassiopeia Window extends from just east of the famous variable star Delta (δ) Cephei all the way through Cassiopeia to the Perseus Double Cluster, which gives the Perseus Arm its name. Most of Cassiopeia's many bright open clusters are in the Perseus Arm, including **M103**, **NGC 457**, and **NGC 663**, as is the bright emission nebula **NGC 281**. The large but faint emission nebulae **IC 1848** and **IC 1805** in extreme southeast Cassiopeia are also tracers of the Perseus Arm. (IC 1848, which measures 2° × 1°, is visible but challenging through 10×50 binoculars.)



Cassiopeia offers a window into the nearby Perseus Spiral Arm. It contains an extraordinary number of star clusters for small telescopes and binoculars; some of the major ones are labeled here.

AKIRA FUJII

The components of the Double Cluster are clearly distinct, but almost certainly related. Like most young open clusters, their stars range greatly in brightness, and many are hot, blue, and extremely luminous.

POSS-II / CALTECH / PALOMAR OBSERVATORY

The IC 1848/1805 complex is at about the same distance (7,500 light-years) as the Perseus Double Cluster, and the line joining the Double Cluster to the nebula complex is perpendicular to the galactic equator. Thus their 4° apparent separation implies that the Perseus Arm is at least 500 light-years thick in the "vertical" direction. The distances to the Perseus Arm clusters and nebulae in Cassiopeia range from roughly 6,000 to 10,000 light-years, suggesting that the arm is some 4,000 light-years deep along the galactic plane. But spiral arms are ragged-edged structures, so this should be understood as an extreme, not an average, width. Much of the dust in this part of the Perseus Arm must be inside the arm or even on its far side, otherwise we would not be able to see so many of its clusters and associations.

Not all of Cassiopeia's open clusters lie in the Perseus Arm. The major cluster **M52** lies about 5,000 light-years away in the gap between our Orion-Cygnus Arm and the Perseus Arm. Evolved clusters such as M52 (which is around 100 million years old), though originally born in spiral arm dust clouds, can be found scattered across interarm gaps.

Other examples of evolved open clusters in interarm gaps are M6 and M7 in the Tail of Scorpius, M23 and M25 in Sagittarius, and M11 and M26 in Scutum.

Sometimes old clusters end up inside spiral arms by accident. At a distance of 7,500 light-years, the star-rich cluster **NGC 7789** lies inside the Perseus Arm, but it's not a true Perseus Arm cluster because it's more than a billion years old. That means that it has completed several orbits around the galactic center, and is probably far from the spiral arm within which it was born.

In the third and final article of this series, which will run early next year, we'll look at the part of the Milky Way that's visible during the Northern Hemisphere's winter, as well as the spectacular section that's visible only from the tropics and the Southern Hemisphere. ✦

POSS-II / CALTECH / PALOMAR OBSERVATORY

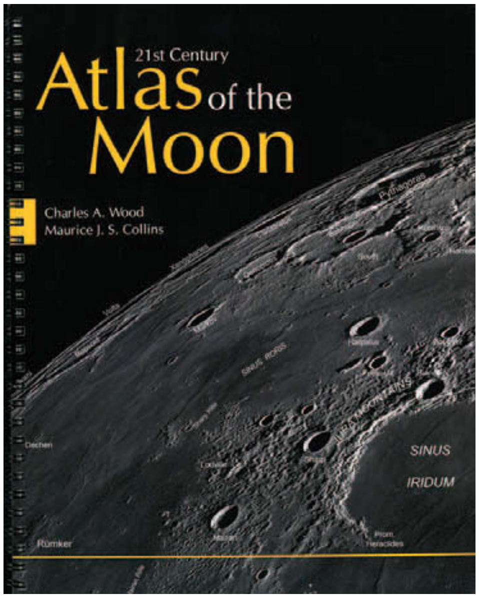
The stars in old open clusters such as NGC 7789 (shown above) tend to appear fairly uniform, because all the really bright ones have burned out. This cluster is now dominated by a few aging red giants. The bright star at right probably lies in the foreground.

Craig Crossen, a native of Minnesota, currently lives in Vienna, Austria. He is researching a book on the ancient Mesopotamian constellations.

A New Lunar Atlas for a New Century

21st Century Atlas of the Moon

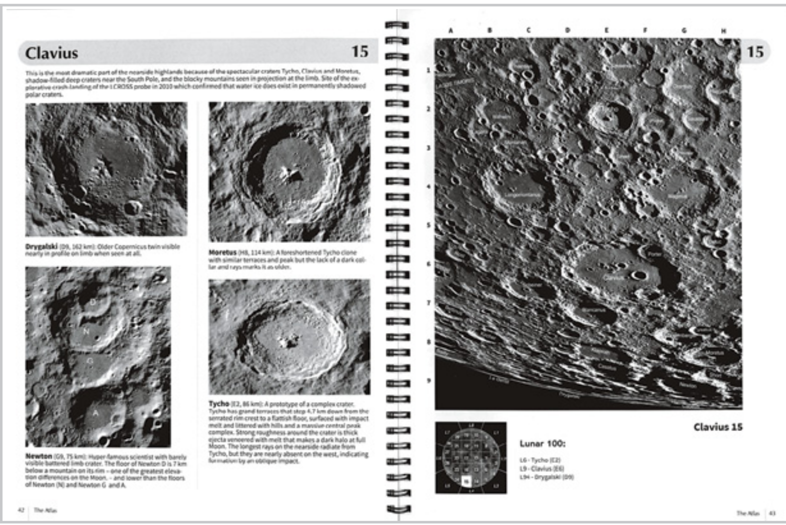
Charles A. Wood and Maurice J. S. Collins
(Lunar Publishing, 2012).
111 pages. ISBN 978-0-9886430-0-0. $29.95, spiralbound.



WITHOUT DOUBT, the reference Moon observers traditionally reach for most often, or covet most strongly, is Antonín Rükl's classic *Atlas of the Moon*. And yet, as wonderful as that work is, its lovingly hand-rendered charts are clearly the product of an earlier era. That it has remained the go-to lunar atlas for so long is a testament to its many virtues.

Most people imagine that with all the spacecraft that have visited our neighboring world since the dawn of the Space Age, a Moon atlas utilizing images from lunar orbit is long overdue. And yet it wasn't until NASA's 2009 Lunar Reconnaissance Orbiter (LRO) mission that a suitable and comprehensive set of image data existed. Now, thanks to the team of *S&T* columnist Charles A. Wood and amateur astronomer Maurice Collins, those data have yielded a "Rükl" for the 21st century.

In many respects, *21st Century Atlas of the Moon* uses the same successful format as its much-lauded predecessor. After a brief introductory section, the reader is presented with a series of detailed charts, each with a selection of highlighted features described on the facing page. This is followed by 8 additional maps depicting the libration zones, charts of the full Moon, and a section illustrating the major basin systems. The black-and-white images used throughout are nicely reproduced and crisply rendered with a good range of tonal values. The exceptions are the set used to depict basins and mare ridges, which appear pixilated compared with the main charts, owing to resolution limits in the source data.



Where Rükl used 76 charts to depict the lunar nearside, Wood and Collins use only 28. This is because the latter presents the Moon at a scale of roughly 3.5 km/mm, versus 2.4 km/mm in Rükl. In spite of this, thanks to its high-resolution LRO images, the *21st Century Atlas* charts are actually more detailed. The reduced scale also allows more of the Moon's surface to be shown on each map, which means you'll have to do less page turning to cover the same amount of lunar real estate.

As good as the atlas is, I have a couple of minor gripes. First, though I really like that the charts are sequenced along lines of lunar longitude (which allows the user to travel the length of the lunar terminator), the alternating north-to-south and south-to-north flow strikes me as an odd, slightly counterintuitive choice. Second, most lettered craters are unlabeled, which means some fairly substantial features (such as 26-km-diameter Reinhold B, for example) go unidentified. In addition, the main charts lack lines of latitude and longitude, which will make cross-referencing with other sources a little difficult. On the plus side, these decisions lead to maps that are refreshingly uncluttered.

Finally, as with most first editions, this one is lightly sprinkled with a number of minor spelling errors. When it comes to books about the Moon, it's a virtual certainty that "Tranquillitatis" will be misspelled at least once, as it is here on page 13.

With its spiral binding and spartan text, this is a volume ideally suited for use at the business end of a telescope. The criticisms I've highlighted don't significantly detract from the book's appeal — Wood and Collins have produced a fantastically useful volume that offers a wonderful alternative to Rükl's famed atlas. As a dedicated lunar observer, I heartily recommend this book and expect it will become my go-to field reference for telescopic lunar exploration. ✦

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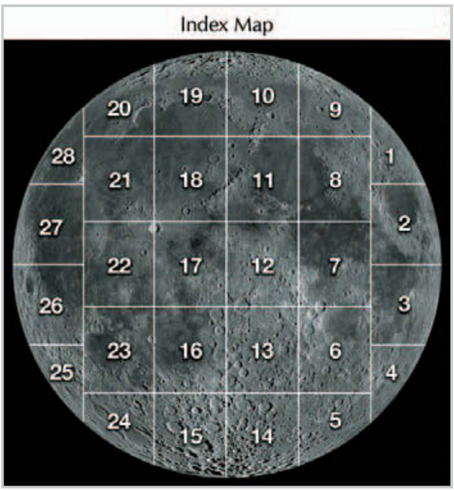
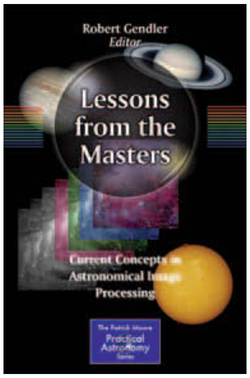
*Contributing editor **Gary Seronik** has been telescoping the Moon for four decades. He served as editor for both Charles A. Wood's* The Modern Moon *and Antonín Rükl's* Atlas of the Moon.



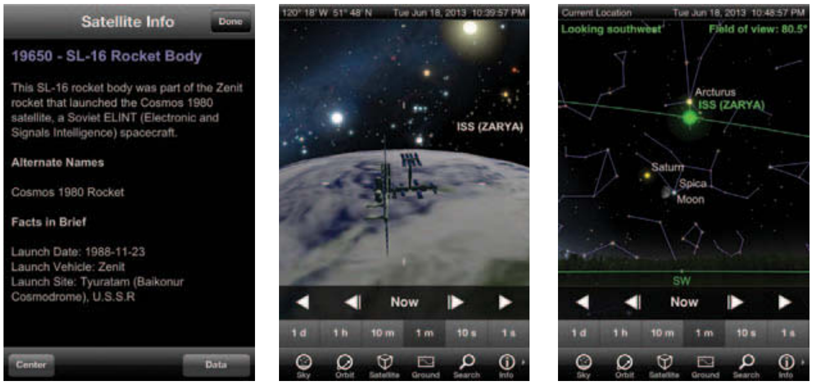


▲ **PROCESSING COMPENDIUM** World-class astrophotographer Robert Gendler has compiled the most up-to-date image-processing tutorials in his new book *Lessons from the Masters: Current Concepts in Astronomical Image Processing* (Springer, $44.99). Gendler has gathered the best astrophotographers from around the world to contribute, and they each share their cutting-edge techniques for processing every genre of astronomical photographs. Imaging luminaries — including Babak Tafreshi, Damian Peach, and R. Jay GaBany — describe in individual chapters their specific workflows using current equipment and processing software. Subjects range from sky-scapes, solar system objects, and deep-sky images captured with DSLRs to CCD cameras to high-speed videos. Springer, ISBN 978-1-4614-7833-1 paperback, 378 pages.

Springer
www.springer.com

▼ **SATELLITE APP** Southern Stars has released its newest astronomy app: *Satellite Safari* ($4.99). This app for Apple and Android mobile devices shows you the positions of hundreds of artificial satellites in real time. The app lets you view the positions of the International Space Station and many other large satellites. It also plots an object's visibility radius as seen from the ground — or you can switch to the satellite's point of view to see a simulation of the sky and Earth as they would appear from the spacecraft's perspective. *Satellite Safari* tells you where bright satellites will appear in your local sky and updates orbital data each day. And when the Southern Stars SkyCube is launched later this year, *Satellite Safari* will allow you to request your own photographs of Earth from space or broadcast radio messages and tweets. *Satellite Safari* is compatible with all iPhone, iPad, and iPod Touch models using iOS 5 or later, and Android devices running 2.2 (Froyo) or later. See the developer's website for more information.

Southern Stars
123 Tenth St., San Francisco, CA 94103
415-671-6254; www.southernstars.com



◄ **DOB RISER** Orion Telescopes & Binoculars announces the Dob Pod ($99.95). This sturdy riser attaches to the base of an Orion 4½- to 10-inch Dobsonian reflector and raises the entire telescope one foot for more convenient and comfortable use while stargazing. Constructed from 1-inch thick melamine-coated particle board, the Dob Pod features built-in handle cutouts on each leg panel, which serve to both decrease the overall weight of the unit and make it easy to grab and transport. The Dob Pod is compatible with all Orion SkyQuest XT Classic, IntelliScope, and Go To Dobsonians from 4½- to 10-inch aperture, and it complements the Dob Dolly (sold separately).

Orion Telescopes & Binoculars
89 Hangar Way, Watsonville, CA 95076
800-676-1343; oriontelescopes.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

In Cygnus, we're looking down the length of our own Milky Way spiral arm.

OCTOBER 2013

1 **DAWN**: The thin waning crescent Moon forms a triangle with Mars and Regulus; see page 48.

3–16 **DAWN**: The zodiacal light is visible in the east 120 to 80 minutes before sunrise from dark locations at mid-northern latitudes. Look for a tall, broad, right-leaning pyramid of light with Jupiter near its apex.

4 **PREDAWN AND DAWN**: The star Delta Geminorum shines just 6′ from Jupiter; best viewed through a telescope or binoculars.

7, 8 **DUSK**: The waxing crescent Moon shines well to Venus's right on the 7th and upper left of Venus on the 8th. Binoculars show Saturn above Mercury well to Venus's lower right.

9 **DUSK**: Look for Delta Scorpii just ¾° above Venus.

12 **EARLY MORNING**: A rare triple shadow transit occurs on Jupiter from 4:32 to 5:37 UT; see page 52. The event is best viewed from Europe and Africa, but may be visible in eastern North America.

15 **DAWN**: Mars passes just 1° upper left of Regulus fairly high in the east.

16, 17 **DUSK**: Antares glows less than 2° below Venus low in the southwest.

18 **EVENING**: A modest penumbral lunar eclipse peaks around 7:50 p.m. EDT; see page 51.

25, 26 **DAWN**: Jupiter shines not far from the Moon.

29 **DAWN**: The crescent Moon forms a triangle with Mars and Regulus for the second time this month.

Planet Visibility

SHOWN FOR LATITUDE 40° NORTH AT MID-MONTH

	◀ SUNSET	MIDNIGHT	SUNRISE ▶
Mercury	W	Visible with binoculars in early October	
Venus	SW		
Mars			E SE
Jupiter		NE	S
Saturn	W	Visible through October 13	

Moon Phases

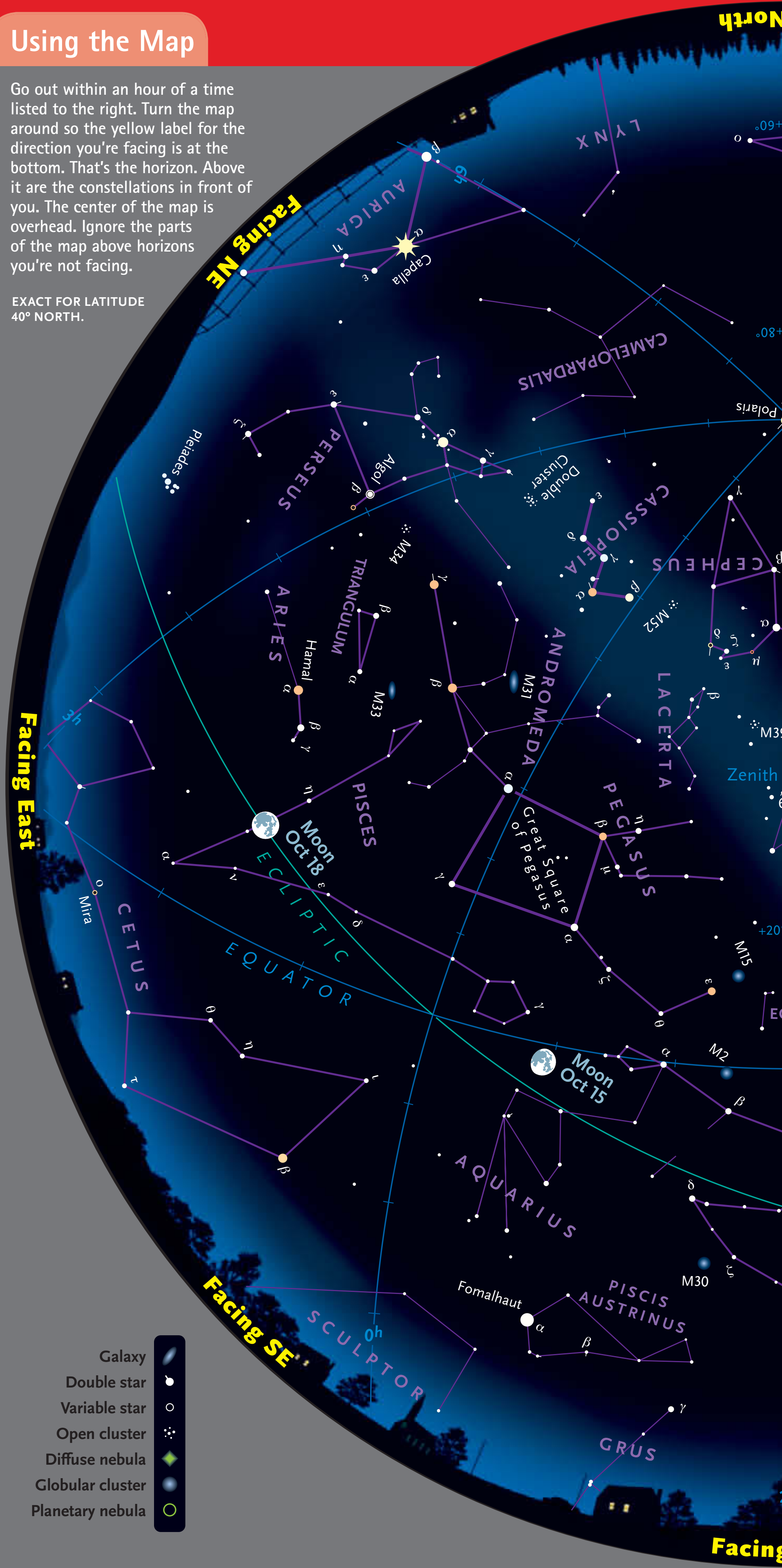
New	October 4	8:35 p.m. EDT	
First Qtr	October 11	7:02 p.m. EDT	
Full	October 18	7:38 p.m. EDT	
Last Qtr	October 26	7:40 p.m. EDT	

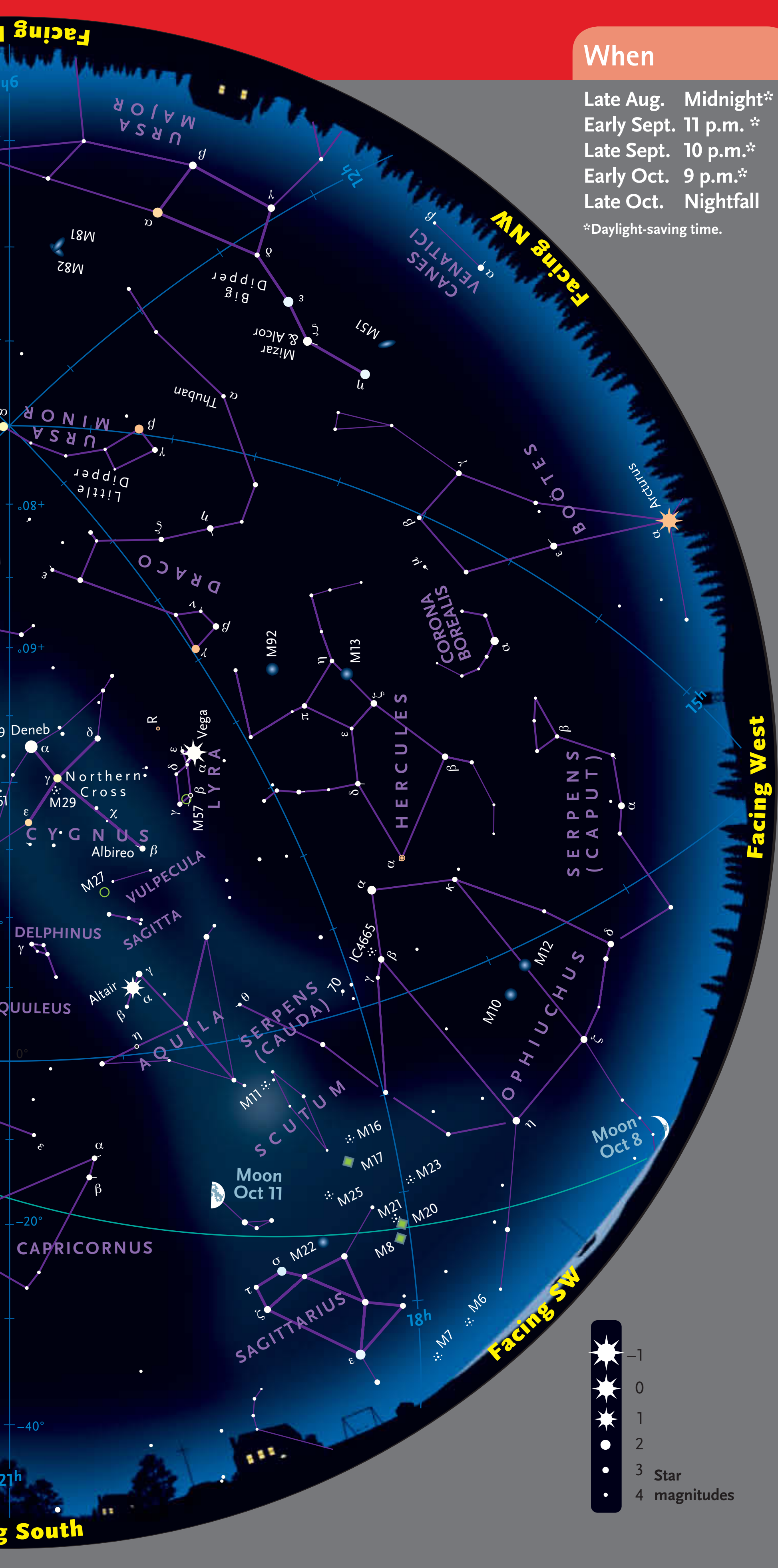
SUN	MON	TUE	WED	THU	FRI	SAT
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

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 Aug.	Midnight*
Early Sept.	11 p.m.*
Late Sept.	10 p.m.*
Early Oct.	9 p.m.*
Late Oct.	Nightfall

*Daylight-saving time.

Gary Seronik

Binocular Highlight

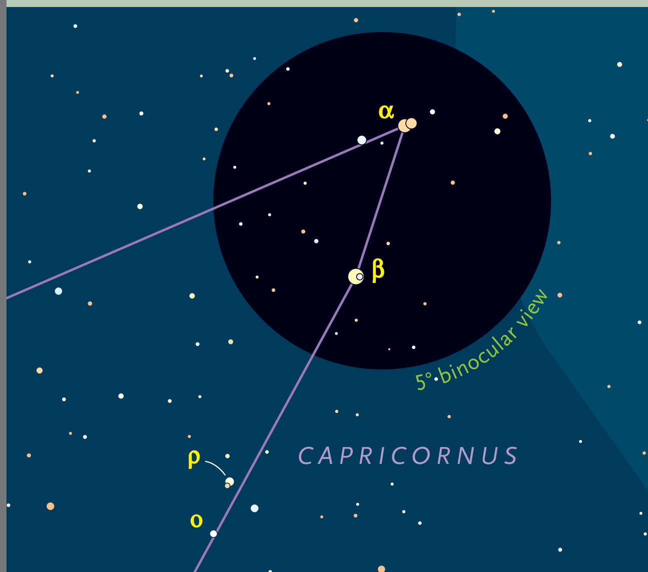
Doubling up in Capricornus

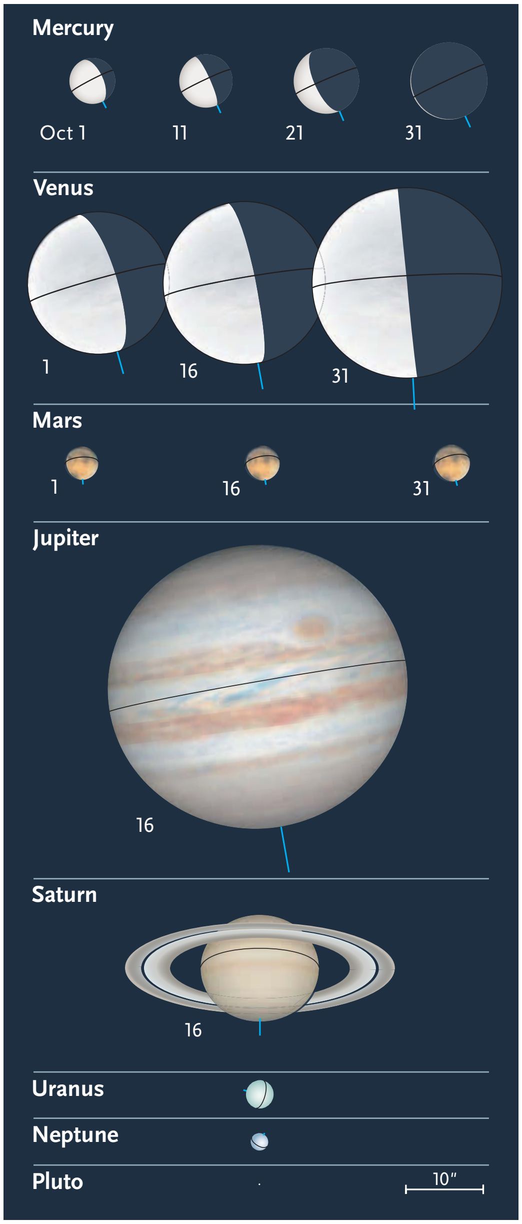
Under light-polluted skies, Capricornus is a big, indistinct constellation. But don't be fooled — there are several nice binocular double stars here that don't require pristine dark skies. And as a bonus, a bunch are located in a small piece of the constellation's northwest corner.

Let's begin with the easiest double first: **Alpha (α) Capricorni**. The Alpha duo consists of the bright middle stars in an attractive, four-in-a-row chain. Separated by 381″, this double is easy to split in any pair of binoculars. But look carefully — do the stars appear equally bright? At first glance they might, but with careful inspection you should be able to detect the ½-magnitude difference between the 3.7-magnitude primary and 4.2-magnitude secondary.

South of Alpha, and in the same field of view, is our next target: **Beta (β) Capricorni**. This is another wide pair (207″ separation), but with a much greater brightness difference, which makes Beta slightly more challenging. The primary star is magnitude 3.2, while its companion is 6.1. Even so, my 10×30 image-stabilized binos make easy work of this double.

Proceeding 3½° south-southeast from Beta brings us to a tilted right triangle of stars, the brightest and most northern of which is **Rho (ρ) Capricorni**. Rho looks a bit like a dimmer version of Beta and features 5.0- and 6.7-magnitude components separated by 259″. It's another easy binocular split. But if you want a challenge, take a look at **Omicron (ο) Capricorni**, the lower left star in the triangle. Omicron is tough because its component stars are close (21.6″ apart) and the 5.9-magnitude primary is twice as bright as its 6.7-magnitude companion. I was able to split Omicron with my 15×45 image-stabilized binoculars, but not easily. How about you? ✦



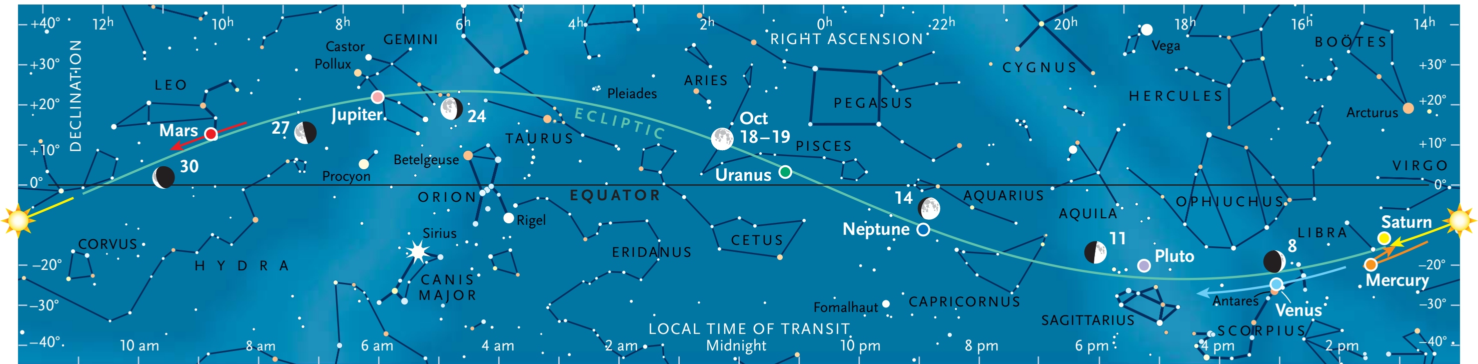


Sun and Planets, October 2013

	October	Right Ascension	Declination	Elongation	Magnitude	Diameter	Illumination	Distance
Sun	1	$12^h\,28.6^m$	–3° 05′	—	–26.8	31′ 57″	—	1.001
	31	$14^h\,20.7^m$	–14° 01′	—	–26.8	32′ 13″	—	0.993
Mercury	1	$13^h\,55.4^m$	–14° 00′	24° Ev	–0.1	5.9″	73%	1.131
	11	$14^h\,37.4^m$	–18° 32′	25° Ev	–0.1	6.9″	58%	0.973
	21	$14^h\,59.2^m$	–20° 15′	21° Ev	+0.5	8.5″	32%	0.791
	31	$14^h\,35.8^m$	–16° 27′	4° Ev	+4.8	10.0″	1%	0.672
Venus	1	$15^h\,17.3^m$	–20° 23′	45° Ev	–4.2	18.4″	63%	0.905
	11	$16^h\,03.2^m$	–23° 30′	46° Ev	–4.3	20.1″	59%	0.830
	21	$16^h\,49.6^m$	–25° 43′	47° Ev	–4.4	22.1″	55%	0.754
	31	$17^h\,35.3^m$	–26° 56′	47° Ev	–4.5	24.6″	50%	0.677
Mars	1	$9^h\,35.5^m$	+15° 41′	47° Mo	+1.6	4.4″	95%	2.137
	16	$10^h\,10.9^m$	+12° 45′	52° Mo	+1.6	4.6″	94%	2.039
	31	$10^h\,44.6^m$	+9° 39′	59° Mo	+1.5	4.9″	93%	1.929
Jupiter	1	$7^h\,18.6^m$	+22° 08′	80° Mo	–2.2	37.6″	99%	5.243
	31	$7^h\,27.5^m$	+21° 54′	107° Mo	–2.4	41.2″	99%	4.786
Saturn	1	$14^h\,32.5^m$	–12° 42′	32° Ev	+0.7	15.5″	100%	10.693
	31	$14^h\,45.9^m$	–13° 48′	6° Ev	+0.5	15.3″	100%	10.853
Uranus	16	$0^h\,37.3^m$	+3° 14′	167° Ev	+5.7	3.7″	100%	19.066
Neptune	16	$22^h\,19.3^m$	–11° 11′	130° Ev	+7.9	2.3″	100%	29.331
Pluto	16	$18^h\,38.2^m$	–20° 13′	76° Ev	+14.1	0.1″	100%	32.747

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

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



The Sun and planets are positioned for mid-October; 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

A Pivotal Month

The celestial glories of summer are replaced by their autumn counterparts.

October brings many major changes in the starry sights that reign in the evening sky.

Bright galactic center to dim galactic pole. In last month's column, we discussed the Sagittarius Milky Way, the bright, broad band between us and our galaxy's center. The all-sky chart on the preceding pages shows that this region is still visible on October evenings, though it's very low in the southwest.

The constellations that are replacing Sagittarius and the bright Milky Way in the south and southeast stand in stark contrast to the departing star-rich realms. To the east of Sagittarius lie three of the zodiac's four dimmest constellations: Capricornus, Aquarius, and Pisces. (Cancer, the only fainter zodiacal constellation, won't appear for several more months.) All three, plus several neighboring constellations, represent mythological figures that are associated with water. So this, the vastest of all dimly starred regions of the heavens, is often called the Great Celestial Sea, or just "The Water."

Capricornus, the first of the three faint zodiacal constellations, now straddles the meridian. It's traditionally considered to be a "Sea-Goat," half goat and half fish, but its main pattern appears more like a misshapen half-sandwich — assuming that your sky is dark enough to see all of its stars.

The second constellation is Aquarius, the Water-Bearer. Its north end features a rather dim but interesting little Y-shape of stars called the Water Jar or Urn, which pours south delicate dim streams of stars.

The third is Pisces, which represents a pair of fish on fishing lines. The head of the westward-facing fish is a dim but very shapely loop of stars called the Circlet. The easterly fish is even fainter. Strings of dim stars connect the imagined fish to 3.8-magnitude Alpha (α) Piscium — also known as Alrescha, which means "the Cord."

South and east of Pisces is one more huge constellation that's faint except for its 2nd-magnitude ends. This is Cetus the Whale. Its head, starring 2.5-magnitude Alpha Ceti (Menkar), is just rising due east on our map. Its tail, tipped with 2.0-magnitude Beta (β) Ceti, also called Deneb Kaitos or Diphda, is still low in the southeast. Almost due south of Beta Ceti is an important coordinate point: the south galactic pole. It's located in a dim area of the constellation Sculptor only 2° from the lovely spiral galaxy NGC 253 and ½° from the globular cluster NGC 288.

UNITED STATES NAVAL OBSERVATORY LIBRARY

Aquarius and Capricornus are beautifully rendered in this 1822 star atlas by Alexander Jamieson.

Old stars make way for new. South of Aquarius, and well west of Beta Ceti, is Fomalhaut, the lone 1st-magnitude star of the traditional autumn constellations. It's the Alpha star of Piscis Austrinus, the Southern Fish. (This is a single fish, not two like Pisces.) Fomalhaut rises at about the same time as Capella, the zero-magnitude stellar gem that's still low in the northeast on our map. Capella won't peak until winter, but it adds it brightness to the sky just as marginally brighter Arcturus sets in the west-northwest.

What other replacements in the heavens do we see brought on by autumn? The Summer Triangle of Vega, Deneb, and Altair is at last wholly past the zenith. Trailing behind it in the east is a pattern that's significantly dimmer (2nd magnitude) but still very striking. This is the largest geometric figure of autumn, the Great Square of Pegasus.

The two 2nd-magnitude stars of Sagittarius, setting low in the southwest, are countered by the two 2nd-magnitude stars of Perseus, rising low in the northeast. And Cassiopeia has finally replaced the Big Dipper as the highest bright pattern in the north circumpolar sky. ✦

More Meetings at Dusk & Dawn

Venus and Mars experience close encounters with bright stars this month.

Brilliant Venus decorates the low southwest dusk throughout October, passing close by Antares at mid-month. Saturn and Mercury start October even lower at dusk and soon disappear from view. Jupiter rises in late evening and shines highest in the south in early dawn. Mars rises around 3 a.m. and has a close, colorful conjunction with Regulus.

DUSK

Venus brightens from –4.2 to –4.5 in October and reaches its greatest elongation from the Sun on November 1st. The interval between sunset and Venus-set grows significantly during October — from about 1¾ to 2½ hours — for viewers around 40° north latitude. But the planet is so far south on the celestial sphere that it remains fairly low, just 10° above the southwest horizon 45 minutes after sunset. So the best time to view Venus through a telescope is around sunset or even earlier. Then you can watch its angular diameter grow from 18″ to 25″, and its phase wane from 63% to 50% illuminated, during the course of October.

On October 9th, binoculars and wide-field telescopes show the 2nd-magnitude star Delta (δ) Scorpii, also called Dschubba, a mere ¾° above Venus. On October 16th, 1st-magnitude Antares is 1½° to Venus's lower left. Venus glides through Libra, Scorpius, and Ophiuchus during October, entering Sagittarius on November 1st.

Saturn should be visible without optical aid in early October, glowing far to Venus's lower right. Saturn appears lower each evening, so observers at mid-northern latitudes will probably need binoculars to see it after mid-month. **Mercury** is twice as bright as Saturn but quite a bit lower, so it will probably require binoculars throughout this apparition.

In bright twilight on October 7th, point your binoculars well to the lower right of the slender crescent Moon for Saturn glowing at magnitude +0.6 with Mercury 5° below it, shining feebly through the thick air and sunset afterglow at magnitude –0.1.

Large backyard telescopes still show **Pluto** in the south or southwest immediately after nightfall. Use the finder charts on page 52 of the June issue.

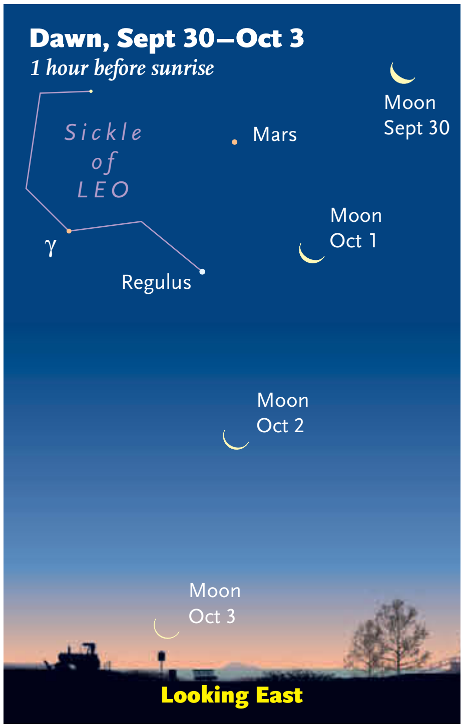
EVENING AND NIGHT

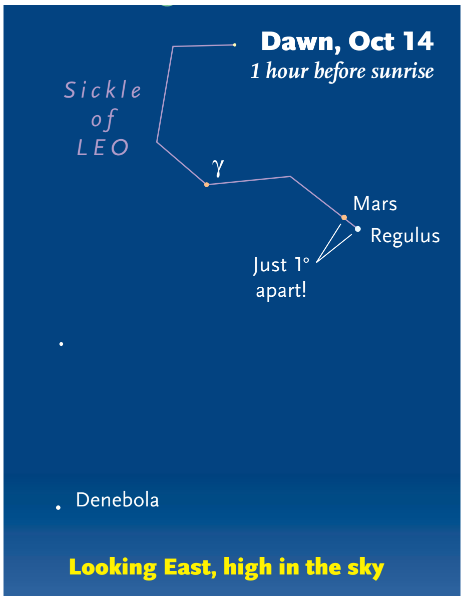
Uranus comes to opposition in Pisces on October 3rd, so this month it's highest around midnight (daylight-saving time). That's the best time to locate the 5.7-magnitude world and study its tiny, 3.7″-wide blue or blue-green disk in your telescope.

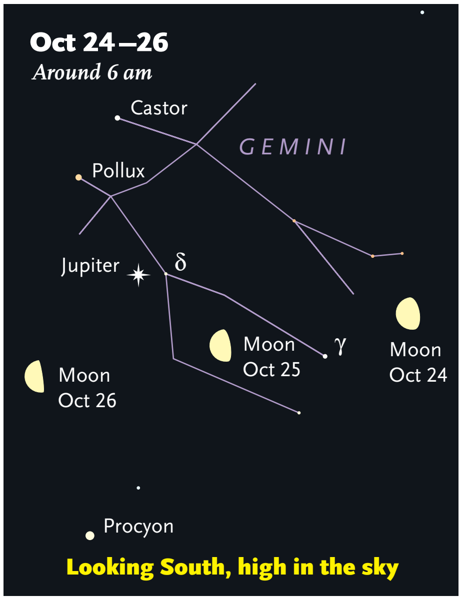
Neptune, in Aquarius, is just one-eighth as bright (magnitude 7.9), less than two-thirds as wide (2.3″), and highest in mid- to late evening. Use the charts on page 50 to locate the two ice giants.

DAWN

Jupiter rises around midnight (daylight-saving time) on October 1st, and two

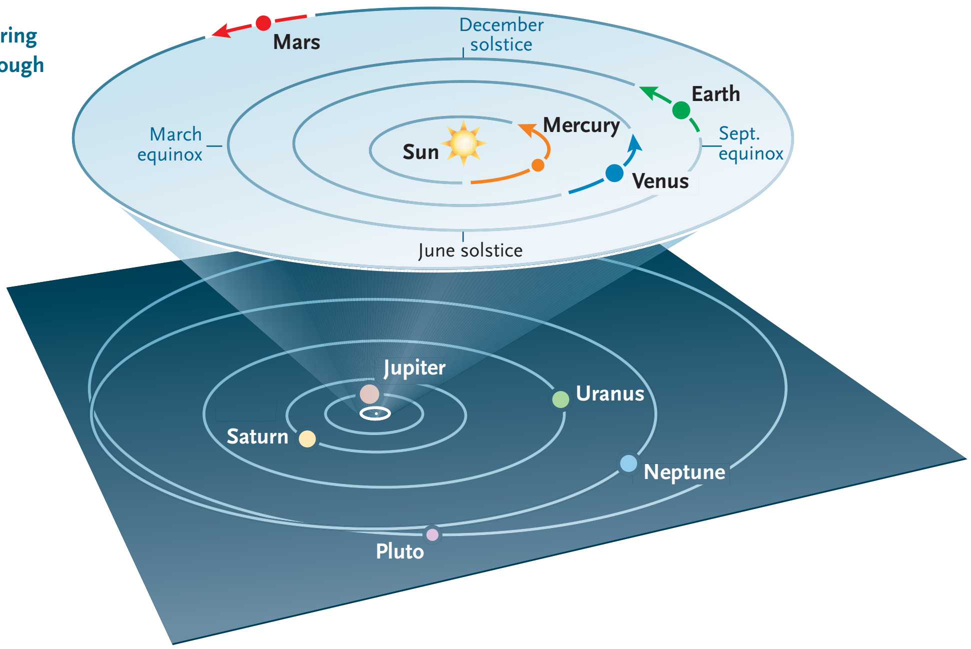






ORBITS OF THE PLANETS

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



hours earlier by the end of the month. It brightens from magnitude –2.2 to –2.4 during October, and its angular diameter increases from about 38″ to 41″. Jupiter reaches western quadrature (90° west of the Sun) on October 12th. That's when we see it at its most side-lit, so this month is especially favorable for viewing eclipses and shadow transits of its Galilean satellites (see page 52). Jupiter is near its highest, and therefore its best in a telescope, early in morning twilight.

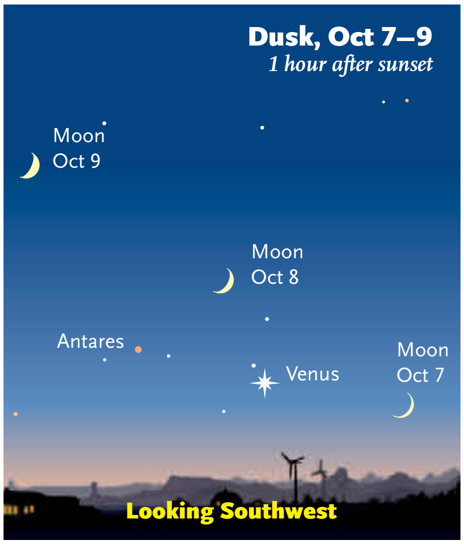
Jupiter is moving slowly east relative to background stars. It has a wonderful conjunction with Delta Geminorum (Wasat) on October 4th, passing little more than 6′ north of the star for the Americas. The star is magnitude 3.5, more than a magnitude brighter than Ganymede, Jupiter's brightest moon. So it will be interesting to test whether you can see Wasat with your naked eyes so near Jupiter's glare. (Ganymede that morning is 3′ to 4′ from Jupiter for the Americas.)

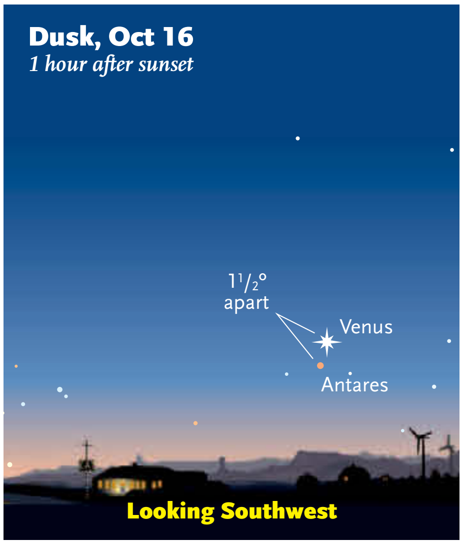
Mars rises 4 to 5 hours before the Sun this month. It's in Leo all month, passing less than 1° from Regulus on the American morning of October 15th. Compare the blue-white of 1.4-magnitude Regulus to the orange-yellow of 1.6-magnitude Mars, and see if the colors are enhanced by contrast when the objects appear especially close to each other. This happens routinely with double stars.

But a third object races in to glide very close to Mars and Regulus — Comet ISON.

Comet C/2012 S1 ISON is now fairly high in the predawn sky, possibly brightening from 10th to 7th magnitude during October. It passes just 0.07 a.u. directly above the orbit of Mars when Mars is there on October 1st — and then takes exactly one month to fly in to a point directly above Earth's orbit.

The comet passes 2° north of Regulus on the 16th. Mars and Comet ISON proceed in tandem through the stars about 1° apart from October 16th to 19th. ISON reaches a greatest elongation of 54° from the Sun on October 23rd. Next month comes its dramatic plunge toward the Sun past another 1st-magnitude star and two planets. It may reach naked-eye visibility in mid-November and might become spectacular in early to mid-December. See **skypub.com/ison** for the latest updates.





MOON EVENTS

The thin waxing crescent **Moon** forms a roughly equilateral triangle with Venus and Antares on October 8th.

The full Moon experiences a penumbral eclipse on October 18th. The eclipse is deepest around 7:50 p.m. EDT (23:50 UT), when the Moon is high in Europe and Africa and well above the horizon in northeastern North America and much of South America. Look for a subtle shading on the Moon's southern third; see page 51 for details.

The last-quarter Moon shines lower right of Jupiter high at dawn on October 25th. The waning crescent makes an approximately equilateral triangle with Mars and Regulus on the morning of October 29th. ✦

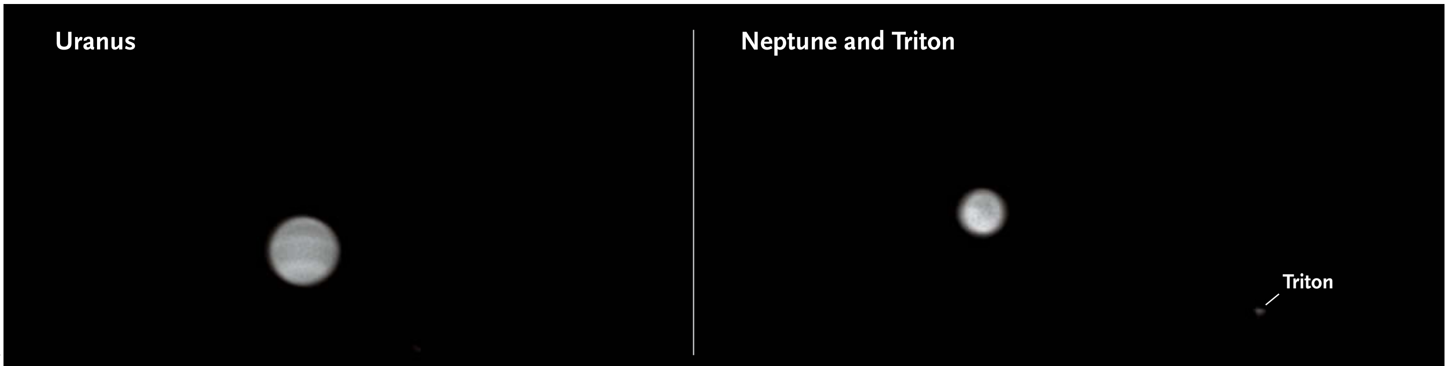
Spotting Uranus and Neptune

In the Great Celestial Sea float the ice-giant twins of autumn evenings.

The dim southern sky of fall is filled with water-themed constellations, so this whole enormous region is sometimes called the Great Celestial Sea. In light-polluted skies it's almost as blank as a real ocean, but the slightest low-power optical aid enables you to work through its ancient and legendary constellations. Here also float the solar system's two "ice giant" planets, Uranus and Neptune.

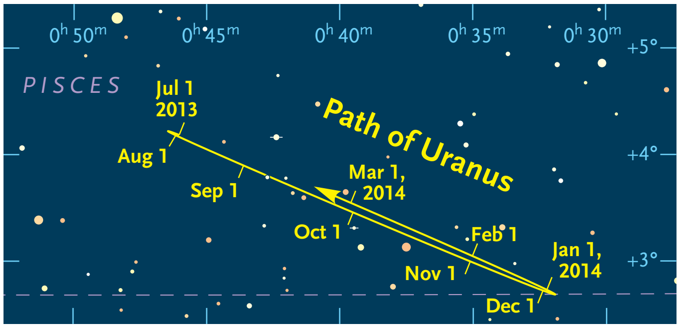
At magnitude 5.7 in September and October, Uranus is actually a naked-eye planet (barely) from a dark wilderness site. It's easy with binoculars from almost anywhere. Neptune is a tougher catch at magnitude 7.8 or 7.9.

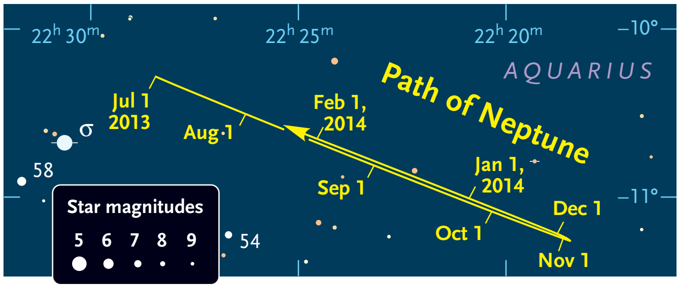
A challenge is detecting their colors — and being sure you're not imagining them. Uranus to me shows a subtle, very pale aquamarine blue-green tint in 10×50 binoculars. This becomes plainer in a telescope, especially if there are contrasting stars in the same field. Neptune is a colorless point to me in binoculars but shows a

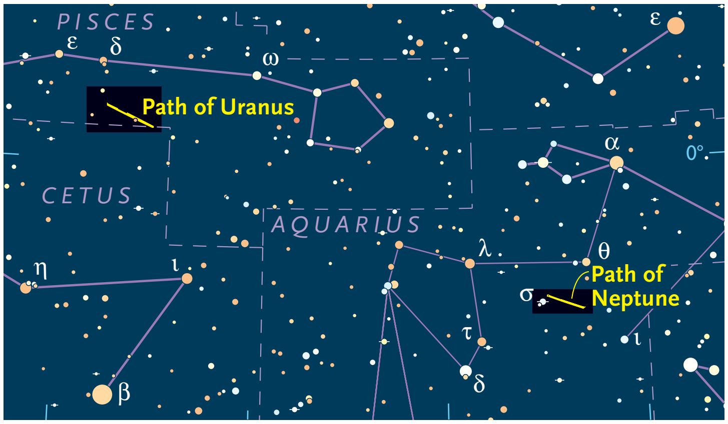


S2P / IMCCE / OMP / F.COLAS / M.DELCROIX (2)

Not often are Uranus and Neptune imaged well enough from the ground to show any markings. Marc Delcroix and François Colas used the 42-inch reflector at Pic du Midi Observatory in the French Pyrenees to obtain these two infrared images on July 1st. An atmospheric-dispersion corrector helped. Uranus is now banded, unlike the blank face it presented during Voyager 2's flyby in 1986. Neptune shows signs of an off-center white spot. Shown here at the same scale, the planets are currently 3.7 and 2.3 arcseconds wide. Triton's visibility has been boosted.







South of the Great Square of Pegasus (see the chart on page 44), star-hop with binoculars or a finderscope to Uranus in Pisces and Neptune in Aquarius. The closeup charts at left enlarge their paths for the next few months. Uranus is about magnitude 5.7, so once you find where on its path it currently lies, the wide-scale chart above will be all you need. Neptune, magnitude 7.9, will require the fainter stars of its closeup chart.

trace of blue through my 6- and 12.5-inch telescopes. The actual colors are weak enough (unlike in garishly contrast-boosted spacecraft images) that even planetary scientists have some trouble distinguishing a difference between the two planets. Moreover, the colors may be slightly variable. (See "The Colors of Uranus and Neptune," *S&T:* September 2010, page 56.)

Uranus and Neptune are called "ice giants" not because they're cold but because much of their bulk is thought to consist of water (H_2O), ammonia (NH_3), and methane (CH_4), compounds that planetary scientists call "ices." Never mind that deep inside the planets, these materials are extremely hot.

Once regarded as oddities, Uranus and Neptune are turning out to represent a class of planets common around other stars wherever exoplanets hunters look — and therefore, presumably, they are abundant throughout the universe.

A Weak Penumbral Lunar Eclipse

On the evening of Friday, October 18th, careful skywatchers in the eastern half of North America can watch the full Moon undergo a slight penumbral eclipse.

The Moon will glide across the pale outer fringe *(penumbra)* of Earth's shadow, never reaching the shadow's dark umbra. Mid-eclipse occurs at 23:50 UT on the 18th (7:50 p.m. Eastern Daylight Time), when the Moon's south-southeastern limb will be a quarter of a lunar diameter away from the unseen edge of Earth's umbra. Unusual shading on that side of the Moon should be fairly plain to see. You may detect lesser traces of penumbral shading for about 45 minutes before and after that time.

The penumbral eclipse will also be visible in the evening from the Caribbean and South America. In Europe and Africa, it happens in the middle of the night with the Moon high in the sky. For observers in western, central, and south Asia, it happens before or during dawn on the 19th (local date).

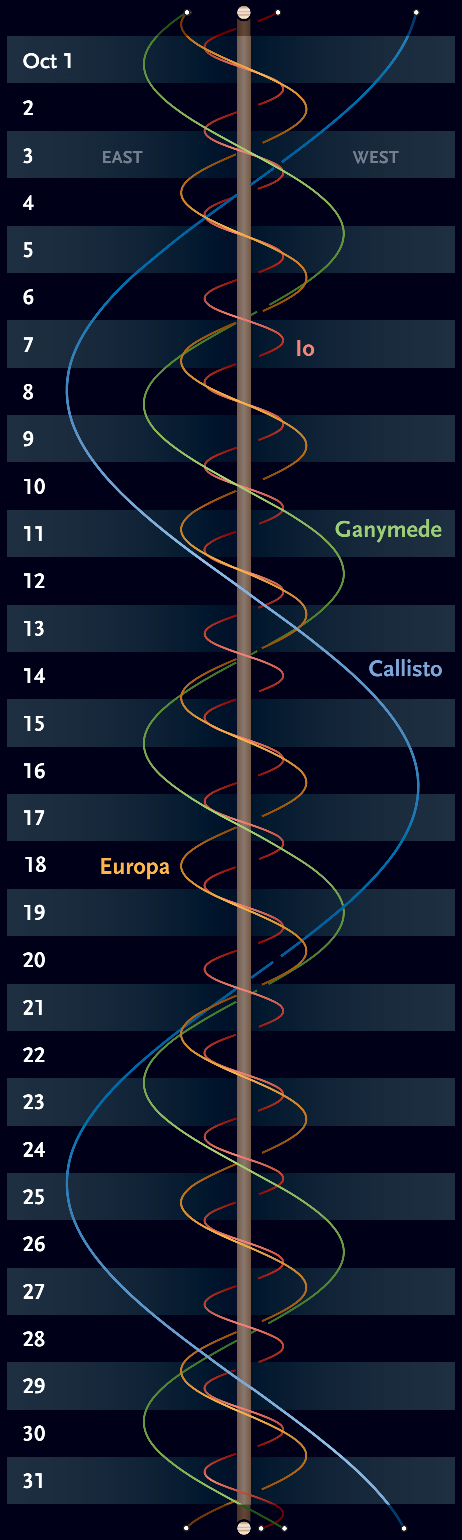
See more at **skypub.com/oct2013eclipse**.

Phenomena of Jupiter's Moons, October 2013

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

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

Jupiter's Moons



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

Action at Jupiter

In October Jupiter rises very late in the evening and shines highest and steadiest around the beginning of dawn — when you may already be out with your scope trying for Sirius B (see page 30).

Any telescope shows Jupiter's four big Galilean moons. Binoculars usually reveal at least two or three, occasionally all four. Identify them with the diagram at left. All of the month's interactions between Jupiter and its satellites are listed in the table on the previous page.

Multi-Shadow Transits

Many *double shadow transits* occur on Jupiter in October, when two of the moons cast their tiny black shadows onto the planet's face at once. In the table, look for two shadow events beginning *(Sh.I)* before one of them ends *(Sh.E)*. The ones with good viewing times for at least part of North America come on the mornings of October 17th (beginning at 11:57 UT), 19th (6:25 UT), and 26th (8:37 UT).

On the morning of October 12th you can watch during a *triple* shadow transit from the longitudes of Europe and eastern North America; it runs from 4:32 to 5:37 UT (12:32 to 1:37 a.m. Eastern Daylight Time, when Jupiter will still be moderately low as seen from the Eastern time zone). The satellites involved are Io, Europa, and Callisto, with Callisto's shadow crossing the planet's south polar region.

Great Red Spot

Jupiter itself enlarges from 38″ to 41″ across its equator in October. Here are the times, in Universal Time, when the Great Red Spot (actually pale orange-tan) should cross Jupiter's central meridian. The dates, also in UT, are in bold:

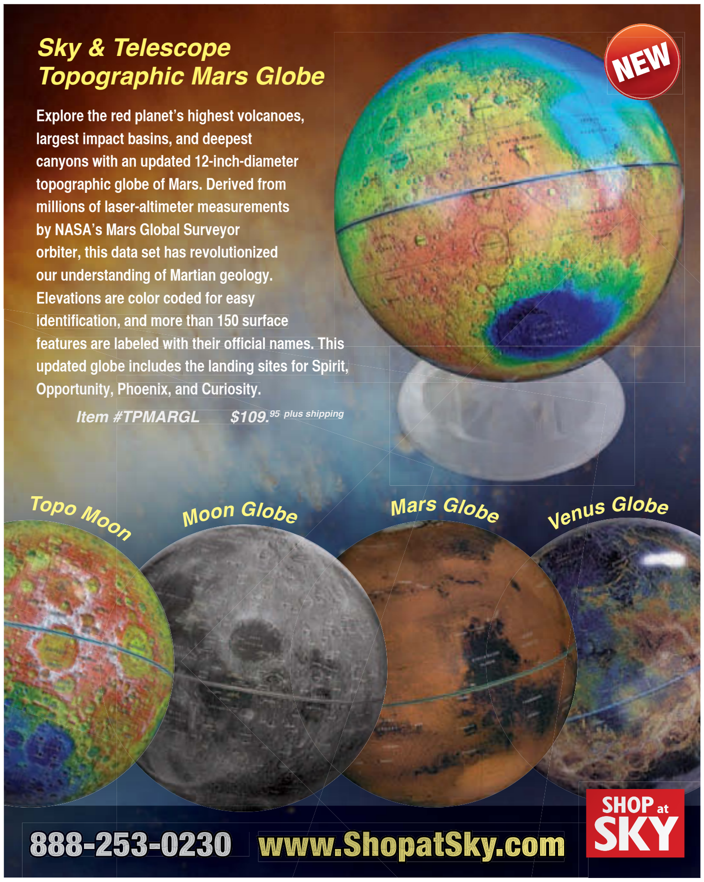
September 1, 7:41, 17:36; **2**, 3:32, 13:28, 23:24; **3**, 9:19, 19:15; **4**, 5:11, 15:07; **5**, 1:02, 10:58, 20:54; **6**, 6:50, 16:45; **7**, 2:41, 12:37, 22:33; **8**, 8:28, 18:24; **9**, 4:20, 14:16; **10**, 0:11, 10:07, 20:03; **11**, 5:59, 15:54; **12**, 1:50, 11:46, 21:41; **13**, 7:37, 17:33; **14**, 3:29, 13:24, 23:20; **15**, 9:16, 19:12; **16**, 5:07, 15:03; **17**, 0:59, 10:55, 20:50; **18**, 6:46, 16:42; **19**, 2:37, 12:33, 22:29; **20**, 8:25, 18:20; **21**, 4:16, 14:12; **22**, 0:07, 10:03, 19:59; **23**, 5:55, 15:50; **24**, 1:46, 11:42, 21:37; **25**, 7:33, 17:29; **26**, 3:25, 13:20, 23:16; **27**, 9:12, 19:07; **28**, 5:03, 14:59; **29**, 0:55, 10:50, 20:46; **30**, 6:42, 16:37.

October 1, 2:35, 12:30, 22:26; **2**, 8:22, 18:18; **3**, 4:13, 14:09; **4**, 0:05, 10:00, 19:56; **5**, 5:52, 15:47; **6**, 1:43, 11:39, 21:34; **7**, 7:30, 17:26; **8**, 3:22, 13:17, 23:13; **9**, 9:09, 19:04; **10**, 5:00, 14:56; **11**, 0:51, 10:47, 20:43; **12**, 6:38, 16:34; **13**, 2:30, 12:25, 22:21; **14**, 8:17, 18:12; **15**, 4:08, 14:04, 23:59; **16**, 9:55, 19:51; **17**, 5:46, 15:42; **18**, 1:38, 11:33, 21:29; **19**, 7:25, 17:20; **20**, 3:16, 13:12, 23:07; **21**, 9:03, 18:59; **22**, 4:54, 14:50; **23**, 0:46, 10:41, 20:37; **24**, 6:33, 16:28; **25**, 2:24, 12:20, 22:15; **26**, 8:11, 18:07; **27**, 4:02, 13:58, 23:54; **28**, 9:49, 19:45; **29**, 5:41, 15:36; **30**, 1:32, 11:27, 21:23; **31**, 7:19, 17:14.

To obtain Eastern Daylight Time from UT, subtract 4 hours. The times above assume that the spot is centered at about System II longitude 202°. The Red Spot appears closer to the central meridian than to the limb for 50 minutes before and after these times. A light blue or green filter will help by boosting the contrast of Jupiter's reddish, orange, and tan markings a bit. ✦

Minima of Algol

Sept.	UT	Oct.	UT
1	21:31	3	10:27
4	18:20	6	7:15
7	15:08	9	4:04
10	11:57	12	0:53
13	8:46	14	21:42
16	5:34	17	18:30
19	2:23	20	15:19
21	23:12	23	12:08
24	20:00	26	8:57
27	16:49	29	5:46
30	13:38		



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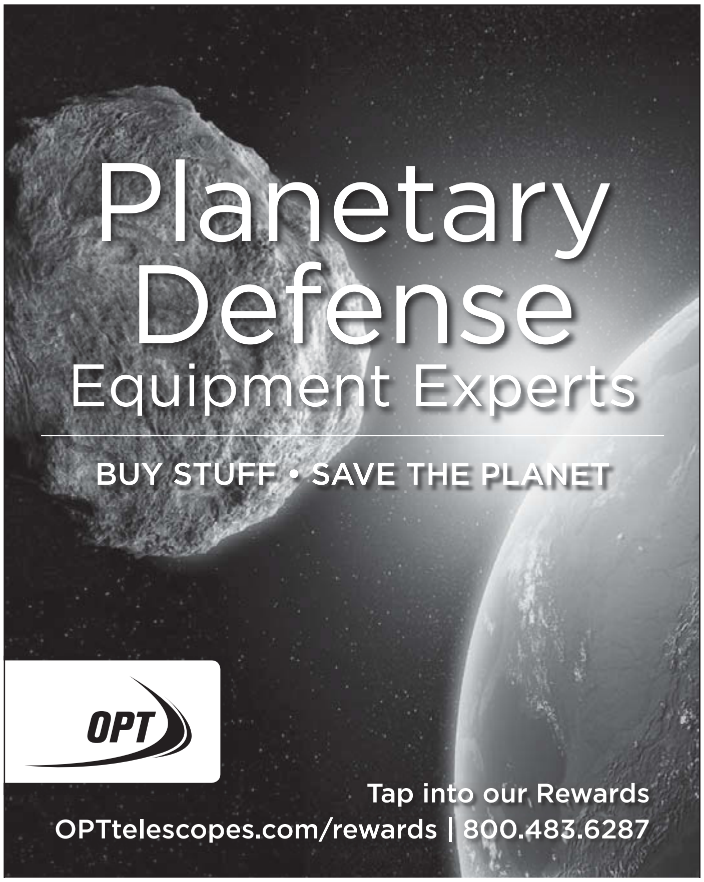

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Drawing the Moon

Sketching lunar features trains you to see more.

Photographic images provide geologists with critical evidence about the structure of craters, lava flows, volcanoes, and other lunar landforms. This evidence leads to interpretations of the processes that formed and modified the lunar surface. In the late 1940s, astronomer Ralph Belknap Baldwin used photographs to measure the diameters and depths of craters. He later used their depth-to-diameter ratios as strong evidence that lunar craters were formed during explosive impact events, rather than by volcanic eruptions.

Today, scientists rely on much higher resolution images from NASA's Lunar Reconnaissance Orbiter to study impact melts and discover small fault scarps and other details important to improving our understanding of the Moon.

THOMAS MCCAGUE

Although photography has long since replaced sketching as the imaging tool of most astronomers, drawings such as this excellent example of craters Mercator and Campanus at sunrise are attractive and informative.

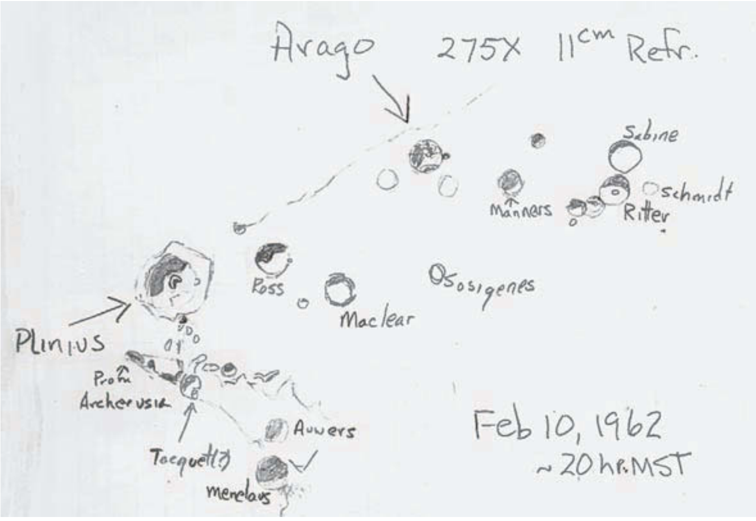
Photographs are required for such work because they are unbiased depictions of the Moon's surface. Drawings of lunar features, dating back to astronomers' first telescopic explorations, cannot be relied on to accurately represent the shapes, sizes, positions, or even the existence of features. And yet, sketching still has plenty to offer amateur observers. Drawing at the eyepiece is perhaps the best way to appreciate what you are looking at.

To take a telescopic image of the Moon today hardly requires more than centering the area of interest on your computer monitor, adjusting focus, and recording some snapshots or videos. Executing a drawing forces you to carefully study every detail of the area of interest. You can't add a line to the sketch without repeatedly looking in the eyepiece to see the shape and brightness of each feature. Drawing also makes you question every detail you see: Is that crater bigger or smaller than the surrounding craters? Does it overlap adjacent landforms, or do other features cross over it? Is its rim sharp and crisp, or rounded with bites taken out? Drawing requires real-time interrogation of every bit of the landscape seen in the eyepiece, which will subconsciously inform your future observations.

Even if you're not artistically inclined, drawing the Moon is relatively easy. My first two sketches (facing page) demonstrate how drawing leads to rapid learning. My first attempt more than 50 years ago produced a simple outline map showing major features over a broad area. I was happy to locate and identify craters at the time, but other than finding my way around the Moon, I didn't learn much about lunar landforms.

My next sketch focused on just one feature, 34-km-wide crater **Davy**. I succeeded in capturing the crater's irregular outline, its small central peaks, and the mounds near its floor that cut into its wall. I also tried to depict shadows, bright walls, and tonal variations. Even today I am satisfied with this drawing, because it marked the beginning of my careful study of crater morphology.

Many amateur astronomers sketch what they see in the eyepiece not only because it's challenging and fun, but also because it's a great learning experience. During the last decades of the 20th century, British amateur Harold Hill created many renditions of lunar features using a technique known as *stippling* — groups of dots whose varied size and spacing create the illusion of volume and



CHARLES A. WOOD (2)

Left: **The author's first lunar drawing captured the general positions of Plinius and its surroundings, but little else.** ***Right:*** **His second attempt concentrated on crater Davy, capturing its unique shape and central peaks. South is up in both sketches.**

light. Phil Morgan is a modern stylistic disciple whose drawings often lead to innovative interpretations of lunar geology and topography. Other drawing techniques are also employed by other artists. Thomas McCague of Illinois and Erika Rix in Texas both use black paper and Conté crayons to produce a "painterly" look to their drawings. There's even a website to share your lunar (and many other astronomical objects) drawings, known as the Astronomy Sketch of the Day (**http://www.asod.info**), where you can explore other amateurs' results.

Try some lunar sketching next time you're at the telescope as a way to learn to look closely when observing, and you'll quickly find yourself noticing more and more subtle details. ✦

S&T: DENNIS DI CICCO

The Moon • October 2013

Phases

NEW MOON	October 5, 0:35 UT
FIRST QUARTER	October 11, 23:02 UT
FULL MOON	October 18, 23:38 UT
LAST QUARTER	October 26, 23:40 UT

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

Distances

Perigee	October 10, 23ʰ UT
229,792 miles	diam. 32′ 19″
Apogee	October 25, 14ʰ UT
251,379 miles	diam. 29′ 32″

Librations

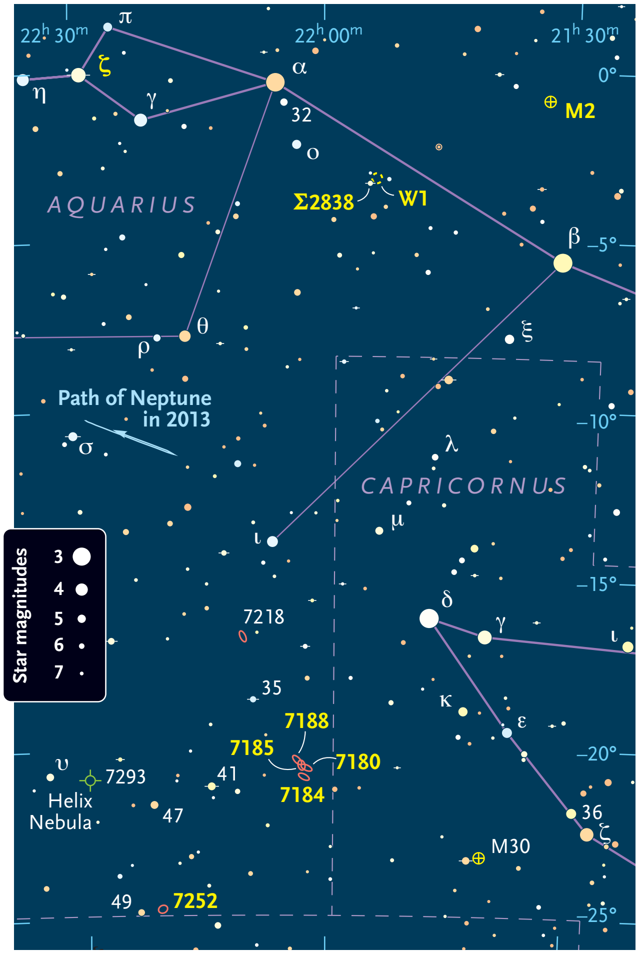
Paneth (crater)	October 1
Demonax (crater)	October 12
Petrov (crater)	October 15
Abel (crater)	October 18

The Age of Aquarius

Explore the delights of the celestial Water Carrier.

The age of Aquarius is said to begin when the March equinox, the spot where the Sun crosses the celestial equator from south to north, moves into Aquarius. Although this may take place in a wide range of centuries according to various precepts of astrology, astronomically it won't occur until the year 2597. But we needn't wait that long to enjoy peace under the stars, love of the night sky, and an understanding of the universe. For stargazers, the age of Aquarius is whenever that constellation is best placed for us to explore.

Our first stop in Aquarius is the beautiful globular cluster **Messier 2**. Italian-French astronomer Giovanni Domenico Maraldi discovered M2 while tracking Comet de Chéseaux of 1746. At first Maraldi mistook this object for the comet, but then he realized that it was another "nebulous star," like the one he'd found four nights before — the globular cluster M15 in Pegasus. Maraldi described his discovery as "round, clearly bounded, and brighter in the middle."



Since M2 is visible in most binoculars and finder-scopes, it's easy to locate by noting the triangle that it makes with the stars Alpha (α) and Beta (β) Aquarii. In my 9×50 finderscope, M2 is a small, glowing ball that grows considerably brighter toward the center. Even when I view the cluster from my home, where it's buried in the glow of nearby Schenectady, M2 shows a faint halo, brighter core, and tiny bright nucleus through 12×36 image-stabilized binoculars.

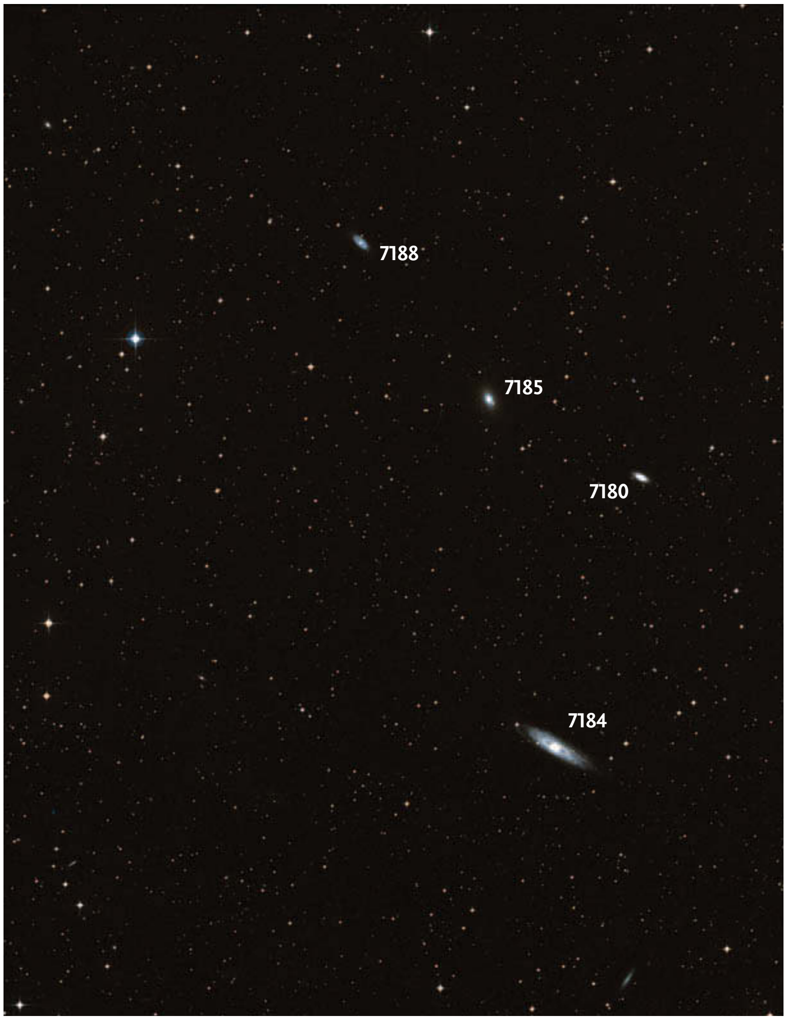
Through my 130-mm (5.1-inch) refractor at 23×, a 10th-magnitude star pinned to the northeastern fringe of M2's halo serves as a handy measuring device. The star is 4.5′ from the M2's center, as measured on a detailed sky atlas, so the cluster's apparent diameter is 9′. At 63× the halo is very granular, and the core grows intensely brighter toward the center. Two prominent stars inhabit the southeastern reaches of the halo, and a few lesser suns dwell farther in. At 117× I see many very faint stars in the halo and outer core. The outer core is about 5½′ long, elongated southeast to northwest, while the bright inner core is rounder. M2 is quite pretty in my 10-inch reflector at 213×. Its fiercely blazing heart is flecked with stars, and the rest of the cluster is a starry blizzard 12′ across.

M2 is a geriatric 12 billion years old, beams at us from a distance of 38,000 light-years, and hosts 350,000 stars.

Let's move on to the double star **Struve 2838** (Σ2838 or STF 2838), stationed 2.5° west-southwest of Omicron (ο) Aquarii. The 6th-magnitude primary is easy to spot as the brightest star in the area. It shines yellow-white in my 130-mm scope at 63×, and a much dimmer companion lies to its south.

Struve 2838 didn't appear in Thomas William Webb's *Celestial Objects for Common Telescopes* until the book's fourth edition (1881). There Webb writes, "Curious and beautiful stream of small stars *n p*," where *n p* means north preceding (northwest of) the double star. Webb's star stream, **W1 Aquarius**, is only 15′ from Σ2838, and they easily share the field of view through my 130-mm scope at 63×. The asterism boasts seven stars from magnitude 9.8 to 12.9 cascading slightly east of south for 11.7′. This glittering

The three northernmost galaxies in this group are physically related, but NGC 7184 is significantly more distant.



POSS-II / CALTECH / PALOMAR OBSERVATORY

tumble of suns courses through a 34′, westward-pointing, isosceles triangle of 6th- and 7th-magnitude stars. The triangle's southeastern corner is claimed by Σ2838, while the very wide double Scardia 104 takes the western point.

The name W1 Aquarius springs from a booklet created by Ohio amateur Daniel M. Hudak, who sketched 128 of Webb's starry fields from the 1962 edition of *Celestial Objects for Common Telescopes*.

The Water Jar of Aquarius is an asterism marked by the stars Gamma(γ), Eta (η), and Pi (π) Aquarii, with **Zeta (ζ) Aquarii** in the center. Zeta is a visual binary whose nicely matched stars, currently 2.2″ apart, make a charming duo in my 130-mm refractor at 117×. Both gleam yellow-white, with the slightly dimmer companion resting south-southeast of its primary.

Now we'll dive down to the galaxy quartet of **NGC 7180**, **NGC 7184**, **NGC 7185**, and **NGC 7188** in southern Aquarius. NGC 7184 is the brightest of the bunch and makes an equilateral triangle with the stars 35 and 41 Aquarii. Through my 105-mm refractor at 36×, NGC 7184 is faint and very elongated east-northeast to west-southwest. The view is much improved at 87×, with the galaxy nearly 4′ long and a little shy of 50″ wide. It holds a brighter oval half as long, and the oval frames a bright, round core half the galaxy's width. A 13th-magnitude star is anchored off the galaxy's east-northeastern tip.

Placing NGC 7184 near the southern edge of the field brings two additional galaxies into view, both very faint. NGC 7185 is a small, plump oval tipped north-northeast,

The string of stars that lies immediately northwest of the bright double star in the lower left corner (Struve 2838) is sometimes called W1 Aquarius.

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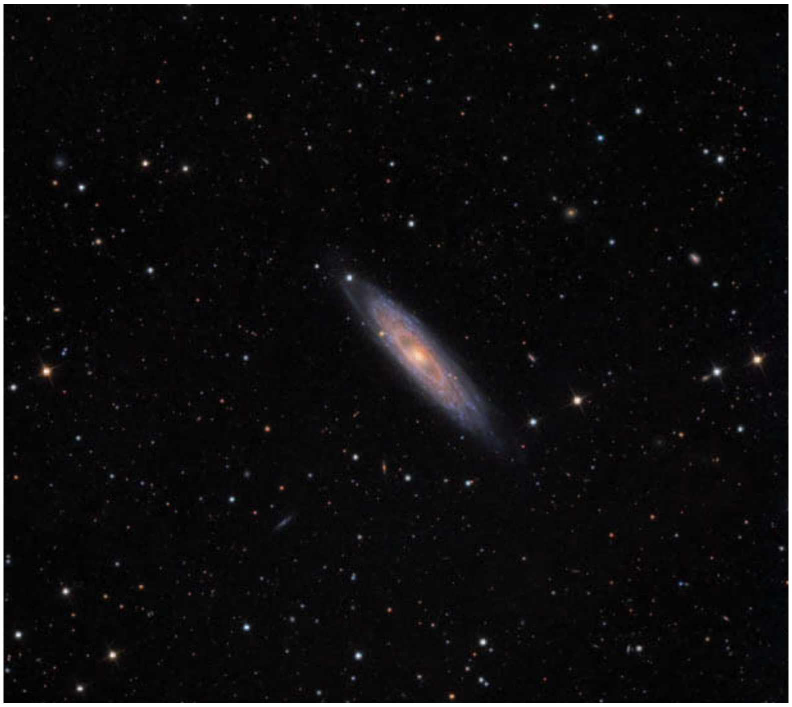
Galaxies, Stars, and One Great Star Cluster in Aquarius

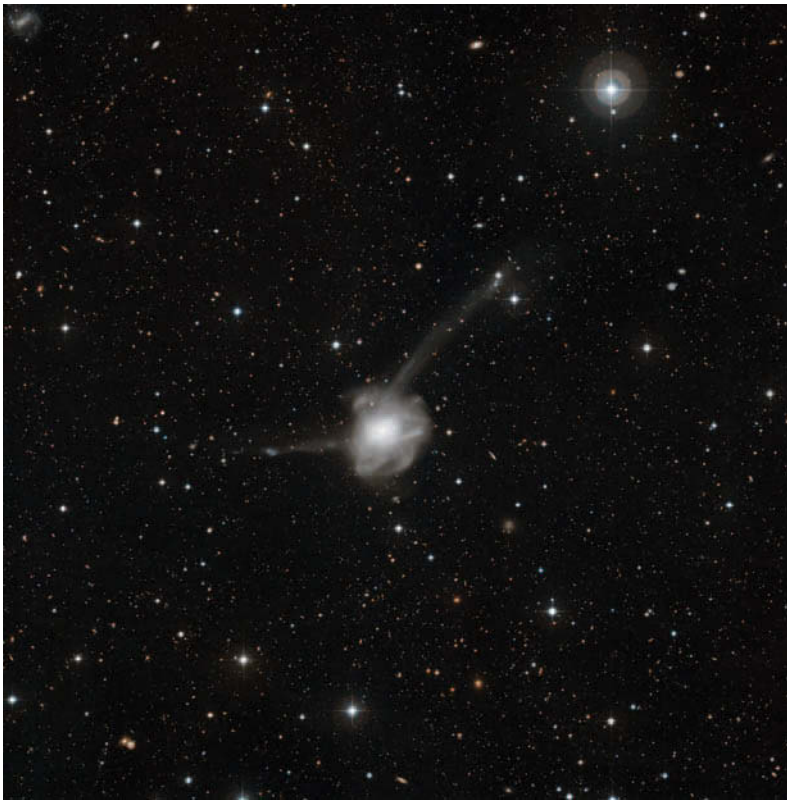
Object	Type	Mag. (v)	Size/Sep.	RA	Dec.
M2	Globular cluster	6.5	16′	21^h 33.5^m	–00° 49′
Σ2838	Double star	6.3, 9.5	16″	21^h 54.6^m	–03° 18′
W1 Aqr	Asterism	8.7	11.7′ × 2.2′	21^h 53.8^m	–03° 09′
ζ Aqr	Double star	4.3, 4.5	2.2″	22^h 28.8^m	–00° 01′
NGC 7180	Galaxy	12.6	1.6′ × 0.7′	22^h 02.3^m	–20° 33′
NGC 7184	Galaxy	10.9	6.0′ × 1.5′	22^h 02.7^m	–20° 49′
NGC 7185	Galaxy	12.6	2.3′ × 1.5′	22^h 02.9^m	–20° 28′
NGC 7188	Galaxy	13.2	1.6′ × 0.7′	22^h 03.5^m	–20° 19′
NGC 7252	Galaxy	12.1	2.2′ × 1.8′	22^h 20.7^m	–24° 41′

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.



ADAM BLOCK / MOUNT LEMMON SKYCENTER / UNIVERSITY OF ARIZONA

This close-up of the giant spiral galaxy NGC 7184 provides a clear view of the star-forming ring surrounding the galaxy's bright core.



ESO

The complex shape of NGC 7252, also known as the Atoms for Peace Galaxy, results from the relatively recent merger of two disk galaxies.

while NGC 7180 is a slightly shorter and more slender oval leaning east-northeast. These three galaxies also share the 32′ field of view through my 10-inch scope with a wide-field eyepiece that gives a magnification of 187×. NGC 7184 is lovely. It covers 5′ × 1′, shelters a starlike nucleus, and wears an extremely faint star on its southern flank, east of the galaxy's nucleus. The relatively large, bright core of NGC 7185 now sports a sizeable halo 1½′ long and two-thirds as wide. NGC 7180 stands out well and appears 1′ long and half as wide. Shoving the scope a bit northeastward takes us to the final member of our quartet, NGC 7188. This galaxy is roughly the same size and shape as NGC 7180, but it leans northeast and has a tiny, bright nucleus.

The quartet's three faintest galaxies are about 60 million light-years away from us and physically related. Despite the fact that NGC 7184 appears larger and brighter, it's actually more distant at 100 million light-years. NGC 7184 is a giant spiral galaxy, substantially larger than our own Milky Way. The oval I saw within NGC 7184 is actually a star-forming ring. Can you distinguish the ring's true shape?

Lastly we'll visit **NGC 7252**. It's fun to observe an object with an unusual name, and you have to love one called the Atoms for Peace Galaxy! In 1953 President Eisenhower gave his famous "Atoms for Peace" speech promoting the peaceful use of nuclear power. The ensuing conference's logo included a diagram of an atomic nucleus surrounded by loops representing orbiting electrons. Reminiscent of that diagram, NGC 7252 displays strange loops of material around its core.

Atoms for Peace is simple to locate. It shares a low-power field with golden 49 Aquarii, which sits 38′ to the east. The galaxy is just a faint smudge that shows better with averted vision through my 10-inch scope at 68×. A 14′-tall, lopsided U of six 10th- to 12th-magnitude stars hangs upside down above (north of) the galaxy. At 88× NGC 7252 is slightly oval, tipped north-northwest, and about 2′ long. It bears a relatively large, slightly brighter core. The galaxy is more fetching at 115×. Its core appears somewhat blocky, and it's adorned with a small, brighter nucleus.

The strange structure of Atoms for Peace is the result of a nearly completed merger of two disk galaxies. Their cores have already combined, but surrounding loops and tails composed of stars, dust, and gas are evidence of the ongoing fray. Some say that the fusion of these galaxies to form something new and grand can be likened to nuclear fusion, making the galaxy's nickname even more appropriate.

Can anyone with a large telescope detect the galaxy's tails or the arrangement of loops in its halo?

This is also the age of Aquarius for the planet Neptune, which is currently near Sigma (σ) Aquarii. Its tiny blue dot won't leave the constellation until 2023. ✦

Sean Walker

The Baader Q-Turret Eyepiece Set

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Described in detail in the accompanying text, the new Baader Classic Q-Turret Eyepiece Set includes four eyepieces, a versatile Barlow, and the eyepiece turret all packaged in an attractive metal container. The items (including the container) can be purchased separately.

Although my astronomical interests focus mainly on astrophotography, when it comes to visual observing I most enjoy solar system objects and the occasional double star. So it piqued my interest when the venerable German firm Baader Planetarium introduced a new observing package geared toward planetary observers.

The Classic Q-Turret Eyepiece Set includes a four-position eyepiece turret, a set of four eyepieces, and a 2.25× convertible Barlow all packaged in an attractive foam-fitted metal container. The turret, eyepieces, and Barlow are standard 1¼-inch format. Each item individually represents a great value, and together they make an excellent observing package.

The idea behind a turret to hold multiple eyepieces dates back to 1863, when the German optics manufacturer Ernst Leitz introduced a turret system for microscope objectives. By the late 19th century, commercial eyepiece turrets were being made for telescopes. These accessories, however, have only been available sporadically in the United States. Several companies advertised them during the 1950s and '60s, but they never became very popular. Perhaps that will change with the introduction of the Baader model, especially since it is of far better quality than any of the ones I've seen going back to the '60s.

The Q-Turret

The Q-Turret, which is available separately for $85, is manufactured from high-density plastic that is lightweight and durable. Its four eyepiece holders are attached to a convex disk carefully designed to require a minimum of additional focus travel. When fitted to a telescope's 1¼-inch focuser, the Q-Turret moves eyepieces just 1½ inches (38 mm) farther out from the focuser.

Although this distance is inconsequential for Schmidt- and Maksutov-Cassegrain telescopes that focus by moving their primary mirrors, it may present a problem for telescopes with fixed focal points. For example, the additional 1½ inches of back focus was just slightly too much for my 12½-inch Newtonian and its low-profile focuser. Fortunately, it was easy for me to move my scope's primary mirror forward in its tube by 1 inch and solve the problem, but this may not be possible with some commercial telescopes. If you have a telescope with a fixed focal point, make sure you can rack your focuser in by at least 1½ inches from the focal point in order to use the Q-Turret in its basic configuration.

Another option for reaching focus with the Q-Turret is to thread the 2.25× Barlow lens into the turret's nosepiece. Doing this will extend the telescope's focal point out from the focuser, but at the cost of increasing the magnification of all the eyepieces.

Once I moved my scope's primary mirror forward, every eyepiece I tried came to focus. The Q-turret uses a nice click-stop mechanism to reliably position each eyepiece holder precisely over the turret's nosepiece when you rotate the unit. This feature works very well. The turret rotates smoothly and easily by hand, and the click stops provide enough tension to prevent it from turning even when you are using moderately heavy eyepieces or planetary cameras.

I certainly enjoyed using the Q-Turret, and I found it particularly nice when used with my Imaging Source video camera. I would center a crater in the field of the 10-mm Classic Ortho eyepiece and then rotate the camera into position. Without fail, the crater would be accurately centered in the camera's frame. This arrangement will also be ideal for planetary imaging, since it can be notoriously difficult to center planets in the small fields of most video cameras.

One drawback I encountered with the Q-Turret was an artifact of our summer climate here in the northeastern U.S. Our nights are generally very humid, and radiational cooling can quickly drop the temperature of exposed optical

***Top:* The author tested the Classic Q-Turret Eyepiece Set with his 12½-inch Newtonian reflector after moving the primary mirror ½ inch forward in its tube to allow for the additional back focus required for the Q-Turret. *Bottom:* The Q-Turret is an ideal accessory for planetary imagers working with compact video cameras. After centering the target in an eyepiece, you can rotate the camera into position and have the target centered in the frame. Note the impromptu lens caps, which keeps dew from forming on the eyepieces. They are described in the text.**

WHAT WE LIKE:

Well made and durable

Precision click stops

Eyepieces have classic Zeiss Jena optical design

WHAT WE DON'T LIKE:

Only available in 1¼-inch format

The Barlow lens provides the same 2.25× magnification increase for eyepieces when it is threaded into its own barrel or when threaded into the Q-Turret's nosepiece.

surfaces below the dew point, causing them to fog up. This frequently happened to all four eyepieces simultaneously, temporarily putting an end to my observing. That was before I discovered an interesting trick. When the rubber eye guard is slipped off each eyepiece, the top rim of the eyepiece is the perfect diameter to snuggly hold the plastic dust caps supplied for the eyepiece barrels. These impromptu lens caps, which were very easy to pop on and off, kept the eyepieces dew free when I wasn't looking through them.

The Baader Classic Eyepieces

The four Baader Classic eyepieces supplied with the set can be purchased individually for $74 each. There are three orthoscopic eyepieces (18-, 10-, and 6-mm) and a 32-mm Plössl. They are claimed to be parfocal, but I found that each required a slight adjustment of the telescope's focus when swapping among them. When used in the Q-Turret, however, it was easy enough to slide each eyepiece back and forth slightly in its holder and lock it into a precise parfocal position. This made switching the eyepieces quick and easy.

With my 12½-inch Newtonian, the eyepieces produced magnifications of 51×, 90×, 162×, and 270×. Adding the Barlow lens to the turret's nosepiece upped the magnifications to 114×, 203×, 365×, and 608×, a range that almost perfectly accommodates my viewing habits when the seeing is very good.

As a set, all four eyepieces worked well. I noticed that I needed to keep my eye carefully centered in the field of the 32-mm Plössl, since the view tended to black out if I didn't. The kit includes a plastic extension piece that fits between the top of the Plössl's barrel and eye guard and help users position their eyes properly. It did help reduce the blackouts slightly.

Overall, the views through the Plössl were pleasant, with good star images nearly to the edge of the field, and only a slight bit of color fringing was apparent when bright

The Q-Turret's compact size makes it an easy-to-use accessory for Cassegrain telescopes.

objects such as the Moon were at the edge of the field.

My best views were with the three orthoscopic eyepieces. Baader states that they are based on the legendary Zeiss Jena orthoscopic design, with a few notable differences. First, as anyone familiar with the views through traditional orthoscopic eyepieces knows, the design has a narrow apparent field of view (AFOV). Baader, however, has used a larger field stop than found in traditional orthoscopics, and this has increased the AFOV to 50°. This was done to help observers find their targets and center them in the field rather than to create a wider field of excellent images. But even a 50° field may seem small in an age when many modern eyepieces have 70°, 80°, and larger fields.

Although I knew that Baader chose a wider field at the expense of what some may consider imperfect stellar images at the edge of the field, I found the drop in performance to be inconsequential. Star images were slightly degraded at the edge of the field; they were more out-of-focus than astigmatic, though it was hard to tell which caused the most distortion. But the Classic Orthos aren't designed for observing extended star fields. Like traditional orthos, their sweet spot is at the center of the field.

One of my test targets for the eyepieces was the famous double star Gamma Virginis, better known as Porrima. This pair of 3.5-magnitude suns is currently widening from a minimum separation about a decade ago, and they now appear almost 2 arcseconds apart. With my 12½-inch reflector and the 2.25× Barlow screwed into the turret's nosepiece, I easily saw Porrima as double with all three Orthos. The components were most cleanly split when I was viewing them with the 6 mm.

Observing Saturn through the Orthos, particularly the 10 mm, was stunning. The planet's muted butterscotch colors and bright ring system were on fine display near opposition when I was testing the Q-Turret set. I routinely spotted five of Saturn's moons even when they were close to the bright rings. Eye relief was tight with the 6-mm eyepiece, but the recessed region around the eye lens's "volcano top" let me to soak in the sharp image without smudging the field lens with errant swipes of my eyelashes.

I was particularly taken by the pure colors seen through all four of the eyepieces. The view was much "whiter" than that in several of my eyepieces made with exotic-glass elements that impart a slight yellow cast to the view. Light scatter and ghosting are also well controlled in the Baader Classic Eyepiece Set; only occasionally did I spot any reflections in the field when I moved the gibbous Moon just outside the field.

The 2.25× Barlow (sold separately for $69) is a versatile accessory. It is designed to avoid duplication of magnifications when used with the Classic Eyepiece Set, and works very well with each eyepiece except for a slight vignetting with the 32-mm Plössl. The Barlow provides the same 2.25× magnification increase when eyepieces are slipped into the Barlow barrel assembly or when the Barlow lens is threaded into the Q-Turret nosepiece. The lens also provides a modest 1.3× magnification increase when it is threaded directly into the barrel of any of the eyepieces in the set.

Top: **Two well-designed detents (arrowed) ensure precise alignment of the four eyepiece ports when each one is rotated into place. The detents also provide enough holding force to keep the Turret from rotating under the load of heavy eyepieces or cameras.** ***Bottom:*** **Little details such as threaded brass inserts molded into the turret's plastic body are an indication that the unit was designed for years of use.**

I found the Barlow to be a perfect accessory for imaging the Sun with my Coronado P.S.T. and the Imaging Source DMK 21AU618.AS video camera. Threaded into the camera's nosepiece, the lens extended the scope's focal point enough for the camera to reach to focus with only a slightly boost in image scale.

The Baader Classic Q-Turret Eyepiece Set, or any of its individual components, can fill voids in any planetary observer's arsenal of tools. ✦

After a slow summer for planetary observers, imaging editor ***Sean Walker*** *is awaiting Jupiter's return to the evening sky.*

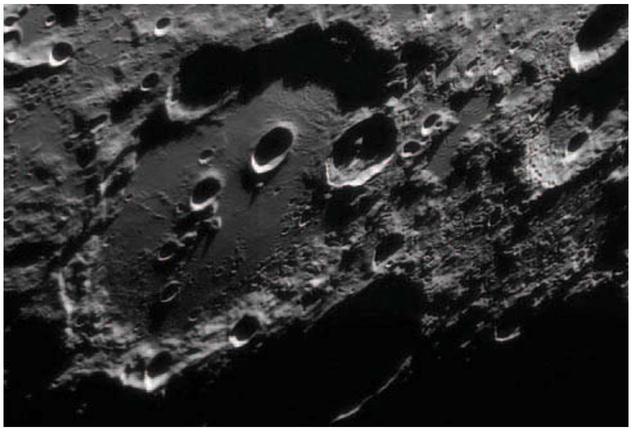
No-Tools Collimation

Here's a simple method for aligning your telescope's optics without lasers or other gadgets.

MOST READERS KNOW that the only way to get every last drop of optical performance from a reflecting telescope is to have the scope in good collimation. When we want to tune up the collimation we usually reach for devices such as a Cheshire eyepiece or laser collimator. But in spite of their utility and usefulness, many of these collimation tools have shortcomings. For example, most collimation devices require that the center of the primary mirror be accurately marked in some way. That's fine for Newtonians, but not for Schmidt-Cassegrains and Maksutovs. Luckily, there's an easy way of achieving optical alignment that doesn't require any of these tools.

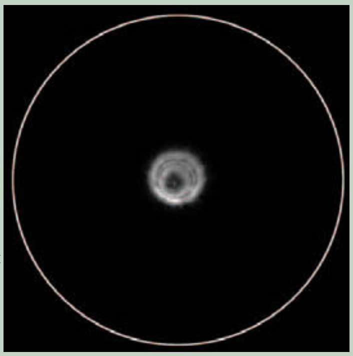
The method outlined here is essentially a star test, but with a twist. It can be performed in the dark and only requires a clear night sky. Begin by centering a star that's around 2nd magnitude in your scope's field of view. For Dobsonian users in the north, Polaris is the ideal choice — it's the right brightness and essentially stationary. If your scope has a tracking mount, you have more options.

Next, choose an eyepiece that provides the right amount of magnification. The ideal power is around 25× per inch of aperture, which is what Dick Suiter recommends in his classic book, *Star Testing Astronomical Telescopes* (Willmann-Bell, 2009). Thus, you should use around 200× for an 8-inch scope. A simple, math-free way



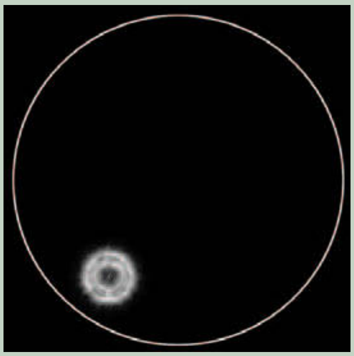
S&T: SEAN WALKER

To enjoy the sharpest views of the Moon, planets, and stars, the optics in your telescope must be accurately collimated.

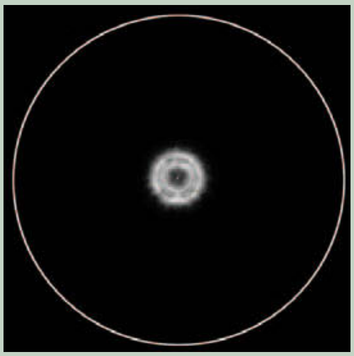


GARY SERONIK (4)

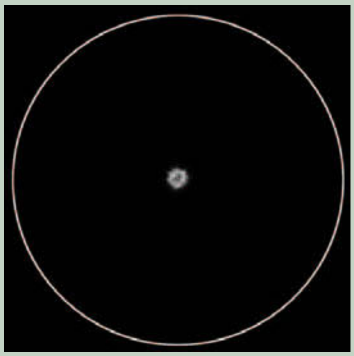
As explained in the accompanying text, the offset central hole in this defocused star image indicates that the reflector is out of collimation.



Step 1: By re-aiming the scope, move the defocused star image around the field until its image appears the most concentric.



Step 2: By adjusting the scope's main collimation screws, move the defocused image to the center of the field.



Step 3: To further refine collimation, adjust the scope's focus to produce a smaller out-of-focus image and repeat steps 1 and 2.

to get 25× per inch of aperture is to choose an eyepiece with a focal length that matches the f/ratio of your scope. For example, if your scope is f/6, use a 6-mm eyepiece. If it's f/10, a 10-mm eyepiece is right.

Begin by adjusting the focus in or out until the star appears as a disk of light with a dark hole near its center (the hole is the secondary mirror's silhouette). If your scope is out of collimation, that hole will not appear centered in the illuminated disk, and thus your primary mirror's zone of optimum performance isn't centered in the eyepiece field. Your collimation task is to move that zone to the center of the field.

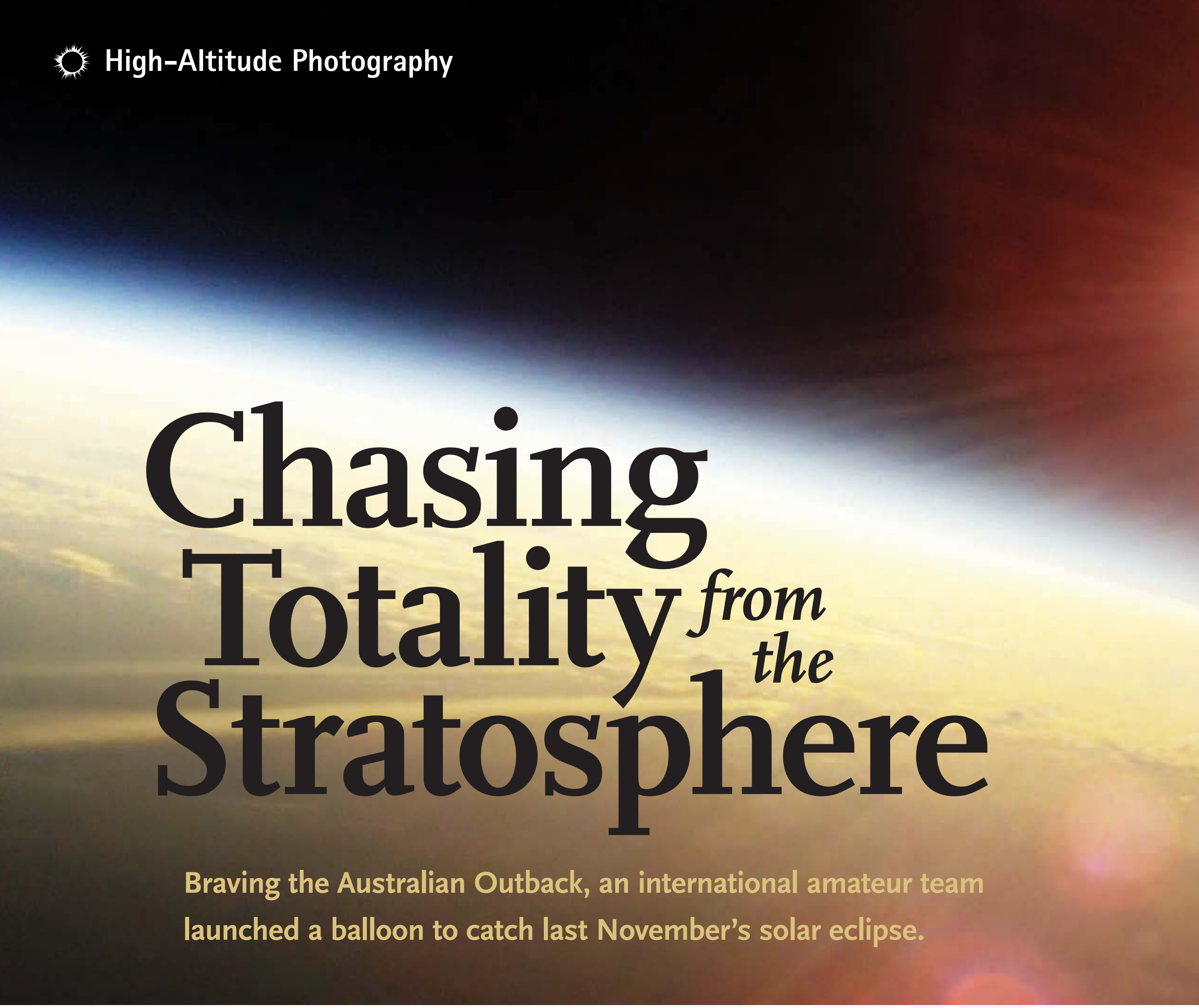
Begin this process by moving the out-of-focus star around the field of view by re-aiming the scope slightly. Eventually you'll find the location where the dark hole in the star image is centered, or most nearly so — that's the sweet spot. Then, by using your scope's collimation screws only, move the defocused star from that position to the center of the eyepiece field.

If you're working with a Newtonian reflector, it helps to have someone else make collimation adjustments to the primary mirror while you look in the eyepiece and give instructions. If you're collimating a Schmidt-Cassegrain, you can probably do the necessary adjustments to the secondary mirror yourself. Proceed slowly and methodically.

Once you've moved the defocused star to the center of the eyepiece field, adjust the scope's focus to shrink the star image down into a smaller circle of light — this ups the collimation sensitivity. Repeat the previous steps, then focus down tighter still, and repeat again. After one or two iterations, you will be looking at a star image that's just slightly out of focus, which is where this method is most accurate. Finally, when you think you're done, center the star, defocus it, then slowly refocus while paying close attention to the dark hole at the center of the star image. If your scope is well collimated, the bright rings in the defocused star image will collapse down concentrically around the shrinking black center.

This method works very well, but there are a couple of provisos. First, if you're collimating a Newtonian, you have to make sure your secondary mirror is already correctly positioned. (See the September 2012 issue, page 72, for details.) Second, collimation accuracy depends on atmospheric seeing conditions, but then too so does your scope's optimum performance. Finally, the star-test collimation method works best for a quick touch-up after the scope has already been roughly aligned — but most of the time that's all the collimation that's needed. Give it a try. I'm confident that with a little practice, it'll take you only a few moments to fine-tune your scope's optical alignment in the field. ✦

*Contributing editor **Gary Seronik** is an experienced telescope maker and observer. He can be contacted through his website, **www.garyseronik.com**.*



Chasing Totality *from the* Stratosphere

Braving the Australian Outback, an international amateur team launched a balloon to catch last November's solar eclipse.

Cătălin Beldea & Joe Cali

For eclipse chasers, 2011 was not a very good year. The Moon's umbral shadow had last crossed Earth's surface in July 2010, and the next total solar eclipse wouldn't come until November 2012. But it occurred to me [coauthor Beldea] that having this much time would give me a chance to prepare something special, something attempted only once before by NASA in 1963: a stratospheric balloon flight into the shadow of the next total eclipse.

The path of the November 2012 eclipse would begin in northeastern Australia, where the Moon's shadow entered the atmosphere at colossal speed before slowing down little by little as it swept across the Pacific Ocean toward its end point near the coast of Chile. Roughly 100 miles (160 km) wide, this eclipse track resembles a fault line in the atmosphere where the shadow's sudden appearance causes a rapid change in local conditions, sending an "atmospheric tsunami" thousands of miles north and south of the track. This phenomenon has not been widely studied, which added to the attractiveness of a balloon flight.

In addition to lofting scientific instruments into the umbral shadow, a balloon flight presented the opportunity to make a video of the eclipse in high definition from the stratosphere, 20 to 25 miles up.

In collaboration with the Romanian science magazine *Stiinta & Tehnica*, my team launched a balloon named Stratospherium 1 on October 15, 2011. It reached an altitude of 22 miles, setting a new altitude record for an "amateur" balloon launch in Eastern Europe and bringing back to Earth the first Romanian-made images from

Just as totality ended, an HD video camera aboard the balloon captured the Moon's shadow racing eastward across the Cape York Peninsula below. Unless otherwise credited, all photographs are by Cătălin Beldea with special processing of the flight's video images by coauthor Joe Cali.

the upper stratosphere. Its success ignited my dream that we could do serious research with a limited budget from the stratosphere during the next total eclipse.

To that end we launched Stratospherium 2 in August 2012. The flight did not lift above 20 miles, hammering home the need for us to be cautious with our preparations and especially with our launch procedures. It did, however, help us train a team for what we knew would be a difficult launch into the lunar umbra three months later.

Reaching for the Stratosphere

How do you send a balloon to the edge of the stratosphere? A helium balloon lifts by displacing heavier air that would normally occupy the same volume as the balloon, similar to the way a boat floats by displacing water.

To see an edited version of the eclipse video made from the balloon, go to www.skypub.com/balloon.

The mass difference between the volume of helium in the balloon and the air it displaces allows us to calculate the buoyancy. Air is only 5.6 times heavier than helium (unlike water, which is 833 times heavier than air), so a balloon needs a lot of helium to lift a relatively small pay-

RAZVAN ANGHELESCU (2)

Romanian members of the eclipse team Florin Mingireanu (left), coauthor Cătălin Beldea (center), and Marc Ulieriu (behind Beldea) prepare for the 2011 balloon launch described in the text. The successful flight achieved many milestones for the team.

load. Hydrogen has about half the density of helium and can therefore lift more for a given volume, but we decided against using it for safety reasons.

A balloon filled with 35.3 cubic feet of helium can hold a 2.2-pound payload neutrally buoyant (no rise or fall). In order to lift a payload, the mass of the air displaced by the helium must be greater than the payload. This difference is called free weight, and the amount of free weight determines the balloon's ascent velocity. This velocity was especially important to us because we wanted our payload to reach the stratosphere just as the eclipse shadow swept by. And with a mere two minutes of totality, the timing of this encounter was critical.

For the eclipse flight our scientific package had to be downsized from those used at our launches in Romania. We made a fiberglass-reinforced polystyrene capsule measuring 11-by-9-by-6 inches, half the size of the previous flights. But we doubled the number of cameras, putting one on every side of the capsule to shoot critical footage toward and away from the Sun during totality. Two of these cameras were HD camcorders and the other two were still cameras. Other equipment included a tracking radio, GPS module, and a science pack with temperature, pressure, and UV- and IR-radiation sensors. The science instruments were powered by a 4 amp-hour Li-Po battery that weighed about 9 ounces (about 0.25 kg).

During the 2011 Romanian balloon flight, a camera captured this stratospheric view of the Danube River and its delta region where it empties into the Black Sea.

One of the most important aspects of the eclipse flight was to obtain the necessary permits to fly a balloon in Australian airspace. Because a careless balloon launch a few months earlier had shut down a large track of airspace, the Australian authorities put us through the wringer. But after long and difficult negotiations, coauthor Cali obtained the permits.

In order for us to "see" the trajectory of the balloon in real time, we had to rely on the experience of Adrian Florescu, the amateur-radio expert on our team. Unfortunately, Adrian's visa application wasn't granted until it was too late to travel to Australia, so he had to coordinate everything from Bucharest. But we were able to team up with an amazing pair of enthusiastic ham-radio specialists, Howard Small and Sam Scafe from Queensland. Along with our aerospace engineer, Florin Mingireanu, they tracked our balloon and transmitted its exact coordinates to Australian air traffic controllers every 15 minutes after the launch. Howard and Sam were also charged with recovering our instrument package after the flight ended and the package parachuted back to Earth.

Lastly, there was our choice of a launch site. In addition to the width and location of the eclipse track, we had to consider the trajectory of the balloon based on wind forecasts, which aren't accurate until 6 to 12 hours before the launch. Clouds were also an issue since our permits only allowed for a balloon launch in clear skies.

Heading for the Launch

At 7 a.m. on November 13th, just 24 hours before totality, our team left Cairns in a convoy of three cars for the wilderness of the Cape York Peninsula. We crossed the Great Dividing Range and passed through some of oldest rain forest on Earth. After the small town of Mount Carbine, the landscape changed dramatically to dry, open eucalyptus forest and savannah grasslands. Soon the GSM cell phone signal faded away and the only hint of civilization was the asphalt road beneath us. If not for the road, we'd have sworn that we'd traveled back to prehistoric times.

At noon, we stopped to refuel in a small village called Lakeland. The Sun was blazing hot, but it cast no shadows — our latitude put the Sun right at the zenith. As we continued on from Lakeland, the paved road soon ended and we entered "no man's land." We stopped to check our maps and test our satellite telephone, watched by two emus and dozens of snakes. We also made one last attempt to get a wind update to forecast the balloon's trajectory. After that, we moved farther into the Outback near the village of Kimba, arriving at King Valley around 6 p.m. We decided to spend the night there and launch Eclipser 1 from that location in the morning. Our station was at east longitude 143° 44.3′ and south latitude 15° 34.9′.

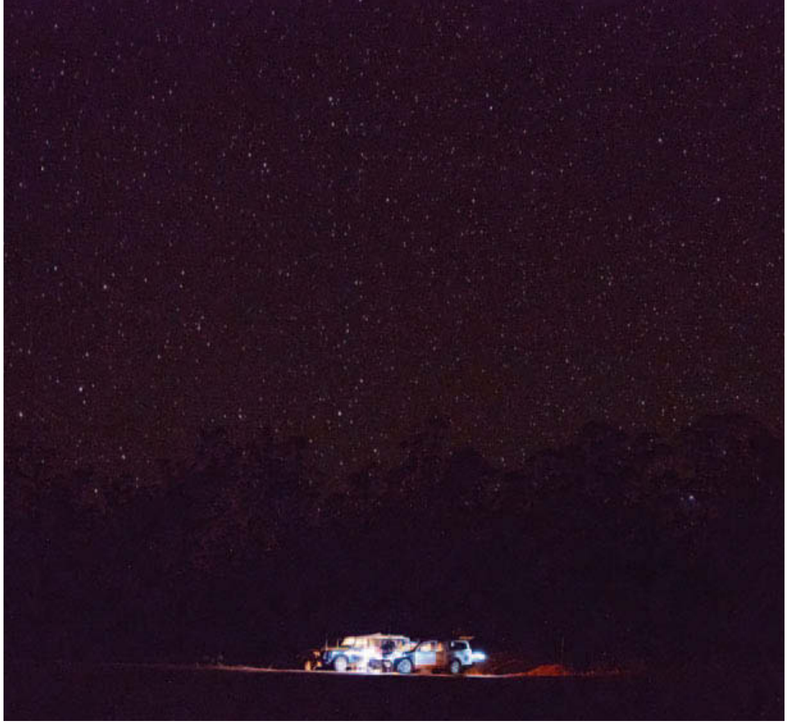
We assembled our science capsule and parachute before midnight. After a final two-hour technical discussion on flight parameters, we agreed to fill the balloon with no more than 215 cubic feet of helium, providing an ascent velocity of 19 feet per second. Our launch had to be at precisely 5:25 a.m. to ensure that the balloon wouldn't reach its bursting altitude before the 6:37 a.m. totality.

Near Disaster

At 3:30 a.m. we began our launch preparations. All went smoothly until the helium flow unexpectedly stopped. After a few agonizing minutes we realized our helium cylinder was empty. Instead of containing 250 cubic feet of gas, the cylinder had only 145, leaving us well short of our planned 215 cubic feet!

With only 20 minutes until the time of launch, we had a major problem. We spent 5 minutes recalculating lift parameters and came to some painful conclusions. In order to achieve the lift velocity of 19 feet per second, we had to remove almost half of the capsule instruments, including several cameras and the precious scientific sensors.

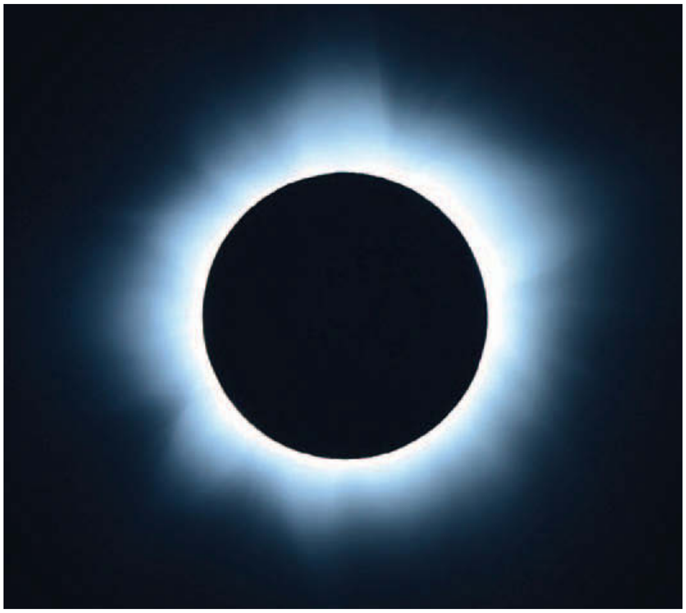
With the stripping down of the capsule completed, we had an otherwise perfect launch at 5:27 a.m. After two minutes of flight we had confirmation that the balloon was ascending at a velocity of 18½ feet per second! It was almost perfect. As planned, we transmitted Eclipser 1's position to air traffic authorities every 15 minutes, and the balloon's position was also uploaded in real time to the ham radio ARPS website for digital communication. (You can see a map of the balloon's trajectory archived on that website at **www.skypub.com/balloontrack**.)



Above: A star-studded sky in the hours before the launch bode well for the team because their flight permit was only valid for clear conditions.

Left: With the science capsule readied, the team began filling the balloon unaware that there wasn't enough helium for the planned flight.

Below: Facing away from the Sun during totality, the HD video camera recorded the Moon's umbral shadow darkening the sky overhead and the ground below. Perspective enhances the shadow's tapered appearance.

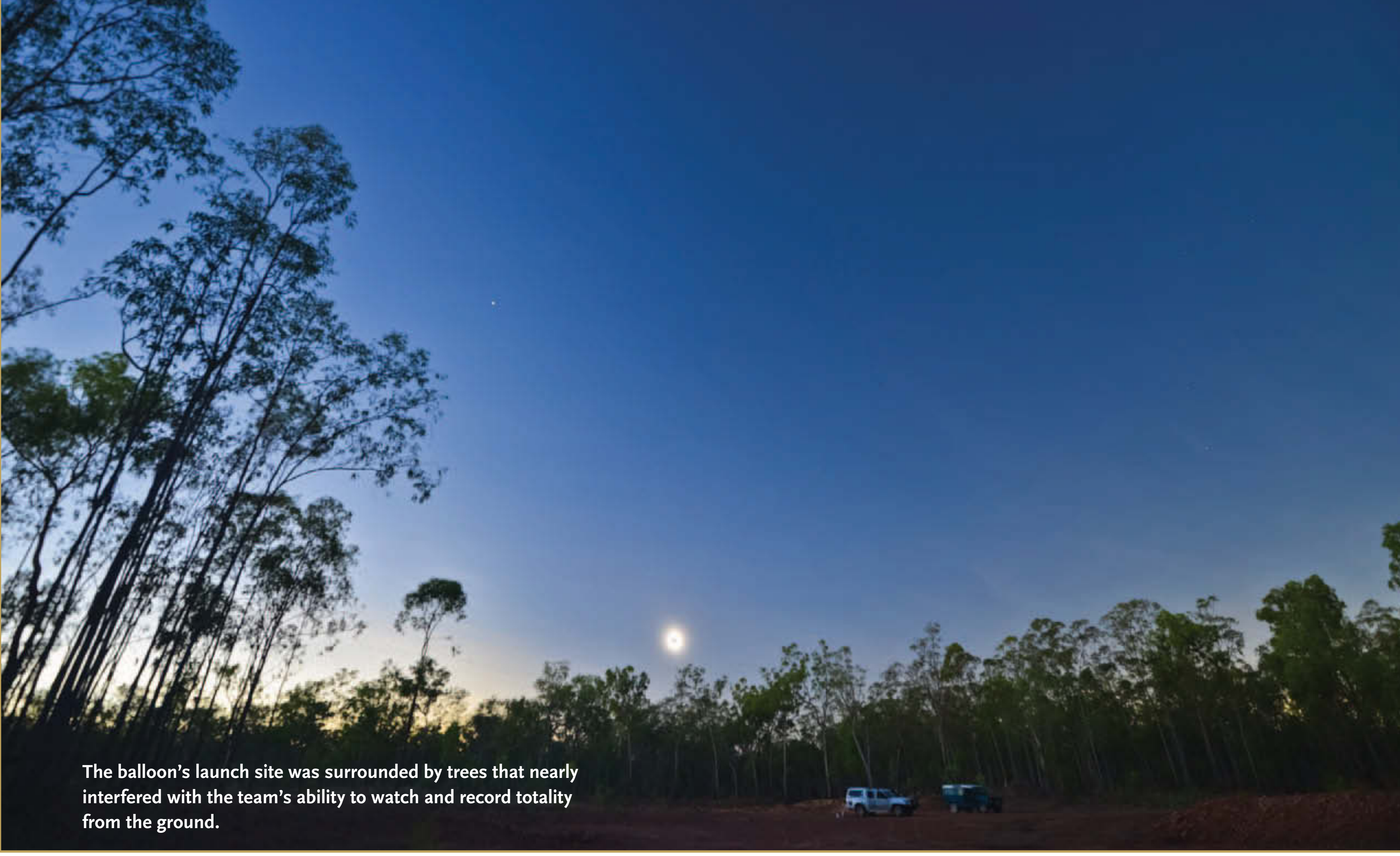


With the balloon climbing toward the stratosphere, we set about documenting the eclipse from the ground. We had an hour to prepare our gear and find a good spot to watch the partial phases. Our launch spot wasn't the ideal observing location. We had chosen the only clearing we found for miles around, and it had trees blocking the horizon in all directions. Fortunately, there was one spot where the eclipsed Sun would appear just 1½° above the forest canopy.

At 6:36:44 a.m., the balloon entered the umbral cone above us. On the ground, however, we had to wait another 25 seconds before totality engulfed us. As the Moon moved in front of the Sun, we experienced a beautiful 2-second-long "diamond ring" followed by the sudden appearance of the solar corona. Unlike my previous four eclipses, this corona was radially symmetrical and shaped very much like the 1999 corona visible during the total eclipse that crossed Europe. This shape is commonly observed near the time of maximum solar activity, and it is very different from the bowtie-shaped coronas seen during minimum activity. Although it might have been an illusion, the corona and its fine radial filaments seemed sharper to the eye than what I recalled from the previous few eclipses, which had broader coronal streamers.

Immediately after totality, our attention turned back to the balloon. Where was it? Was it flying in the right direction? At what altitude did it intercept the eclipse? Howard looked at the tracking coordinates and realized the balloon was right above us. I looked up, and when my eye found infinity focus, there it was! About 60 miles southeast of our location, coauthor Cali was viewing the eclipse near the community of Maitland Downs. He looked for the balloon after totality but could not find it.

Above: **Coauthor Beldea used a William Optics 88-mm f/5.6 Megrez refractor and Nikon D800 camera for his ground-based pictures snapped (*top to bottom*) at the beginning, middle, and end of totality. *Right*: Beldea's composite image of brief exposures, made at the beginning and end of totality, shows the Sun's pink chromosphere on the east (right) and west limbs at the eclipse's contact points.**



The balloon's launch site was surrounded by trees that nearly interfered with the team's ability to watch and record totality from the ground.

***Right*: After a 45-minute parachute descent from the balloon's maximum altitude of 23 miles, the instrument capsule landed 60 feet up in a tree a mere 12 miles east of its launch site.**

MARC ULIERIU

Once we had sight of our balloon perched in the stratosphere, we followed it with our naked eyes and binoculars as it rose from 18 to 23 miles altitude. With binoculars, we could distinguish the entire assembly, especially the balloon, which had expanded to its maximum diameter of 32 feet due to the low air pressure at that altitude. Florin, who has participated in dozens of stratospheric balloon flights launched from U.S., said that it's rare for a ground crew to see a balloon at the top of its flight.

After 108 minutes of ascent, the balloon burst 23 miles above Cape York Peninsula. It took another 45 minutes for the capsule to parachute back to Earth, where it landed some 12 miles east of our position, 60 feet up in a tree flanked by dozens of huge termite nests.

The balloon had documented the eclipse from inside the umbral cone at an altitude of 79,000 to 82,500 feet. The onboard cameras captured the elliptical shape of the umbra as it rushed across the ground from the Gulf of Carpentaria toward us and as it continued onward, disappearing into the vastness of the Pacific Ocean.

Just as with any flight mission into space (or near the edge of space), this was a difficult task. And ours was made more challenging because we couldn't postpone the launch when technical problems arose — the eclipse wasn't going to wait for us. We missed an opportunity to measure key atmospheric parameters, but we succeeded in documenting the event with full HD video. Perhaps our story will inspire future eclipse chasers to launch stratospheric flights into the umbral shadow. ✦

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*Romanian science journalist **Cătălin Beldea** is an avid eclipse chaser. See his work at **www.astrofoto.ro**. Australian **Joe Cali** has visited more than a dozen countries in 20 years of pursuing the Moon's shadow. His work is at **www.joe-cali.com**.*

The Man Who

H. A. Rey, co-creator of *Curious George*, turned his talents skyward to demystify the stars.

Ann Mulloy Ashmore

Hans Rey sat in his Greenwich Village studio in the autumn of 1947, trying to come up with an idea for his family's annual New Year's card. Together with his wife, Margret, Rey had created the popular *Curious George* children's book series in the early 1940s. But the illustrator had always held an interest in the night sky, and he toyed with the idea of a zodiac theme for his holiday card. When he consulted an encyclopedia to aid in the design, he found images that recalled a long-held frustration.

"The constellations were connected with meaningless lines," he said. "I thought there must be a better way."

Rey's experience with traditional astronomical guides began in 1916, when the German army drafted him at age 18 to fight in World War I. "[I was sent] to Russia, Belgium, and France as an involuntary and unwelcome tourist," he recalled. So he passed away the long, dark nights on the front gazing at the heavens with a small astronomy book as his guide.

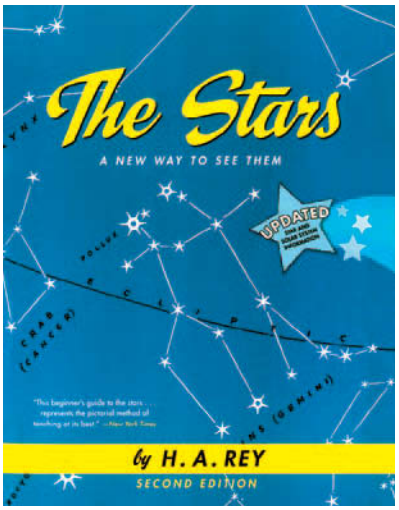
Those long nights, and the New Year's card that recalled them, ultimately led to *The Stars: A New Way to See Them*, a refashioned beginner's guide to the night sky published in 1952. A second book published two years later, *Find the Constellations*, presented a simplified version of the guide for children. Rey explains why he felt compelled to redesign the sky's patterns in *The Stars*:

> There are of course plenty of books about [astronomy], and they do very well in most respects. But in one important point they seem to fail us: *the way they represent the constellations* . . . Some books show, arbitrarily drawn around the stars, elaborate allegorical figures which we cannot trace in the sky. Others, most of the modern ones, show the constellations as involved geometrical shapes, which don't look like anything and have no relation to the names. Both ways are of little help if we want to find the constellations in the sky — yet this is precisely what we are after.

Rey didn't know much about celestial cartography or mechanics when he first decided to write books about the night sky, but he spent the next four years researching the subjects intensively. In 1951 Rey began to redraw the constellations on his own terms, 35 years after his frustrated attempts to find the constellations above the battlefields of Europe. He spoke of his method in a *New Hampshire Times* profile: "I started experimenting, connecting the stars the way children do to make a drawing. I made the constellations clearer. I took exactly the same stars and connected them differently."

Rey drafted *The Stars* at his Greenwich Village studio, using the roof of the six-story building "as an observatory to check my diagrams with the real stars in the sky." (He recommends rooftop observing to all his urban readers too.) To see his diagrams in the dark, Rey painted the glass on his flashlight red, probably borrowing fingernail polish from his wife. But Margret didn't join him on the rooftop. As Rey put it, "You might say we have our books, her books, and my books, the latter being astronomy — a sideline of mine. Margret is allergic to stars."

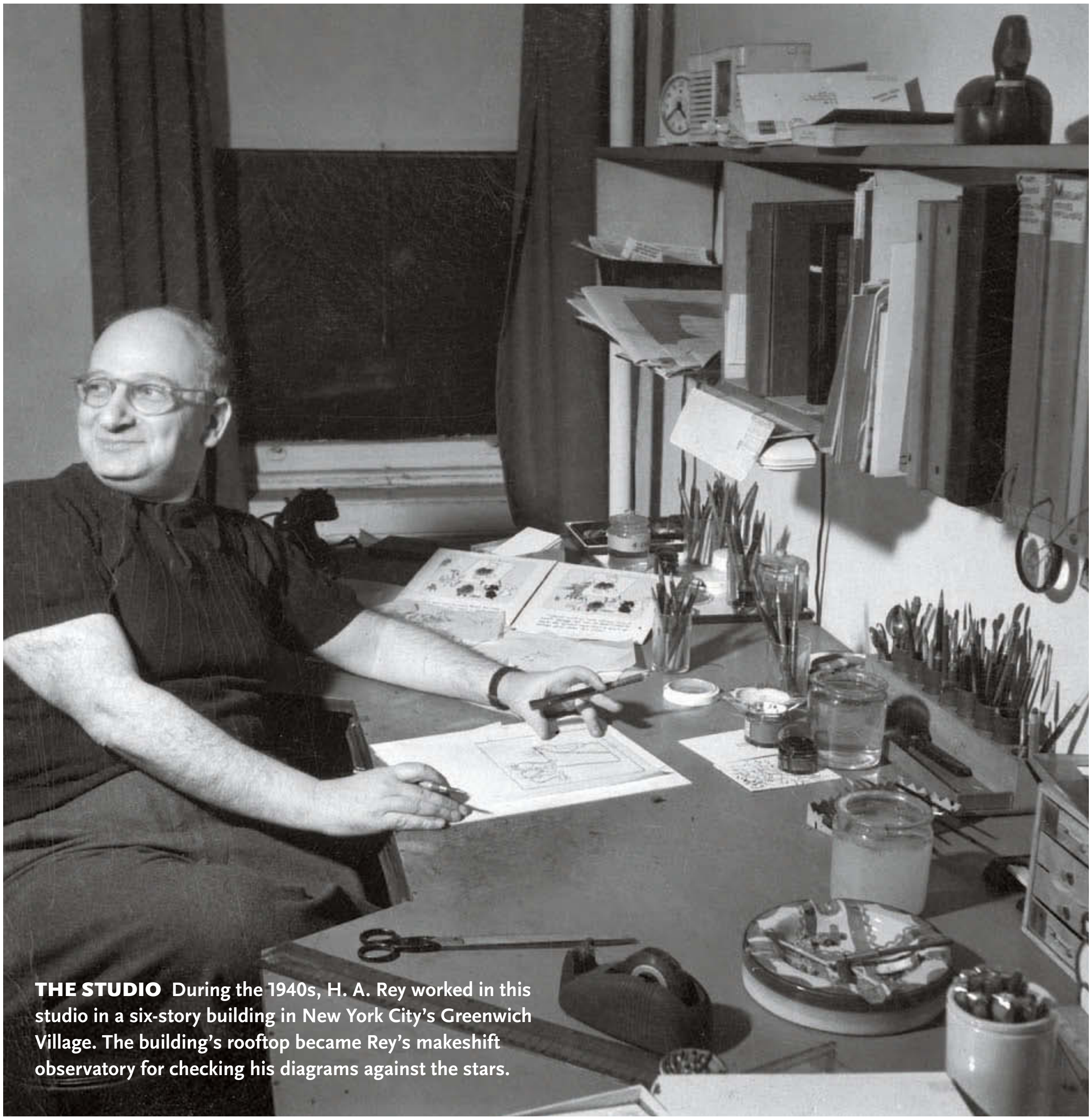
"[Rey] was a man of unusual gifts and interests," said Anita Silvey, one of the editors at his publisher, Houghton Mifflin. "He spoke six languages fluently, and had a work-



A NEW WAY OF SEEING
H. A. Rey's long-standing interest in astronomy led to a refashioned guide to the night sky. He conveyed complex celestial mechanics in a conversational style, but he's best remembered for restyling the constellations.

IMAGE FROM *THE STARS*, BY H.A. REY. COURTESY OF HOUGHTON MIFFLIN HARCOURT

Illustrated the Heavens



THE STUDIO During the 1940s, H. A. Rey worked in this studio in a six-story building in New York City's Greenwich Village. The building's rooftop became Rey's makeshift observatory for checking his diagrams against the stars.

THE DE GRUMMOND COLLECTION / THE UNIVERSITY OF SOUTHERN MISSISSIPPI

THE DE GRUMMOND COLLECTION / THE UNIVERSITY OF SOUTHERN MISSISSIPPI (2)

ing knowledge of at least a half-dozen more. He knew animals so intimately and befriended them so easily that people were constantly bringing him creatures both wild and tame that needed attention and loving care."

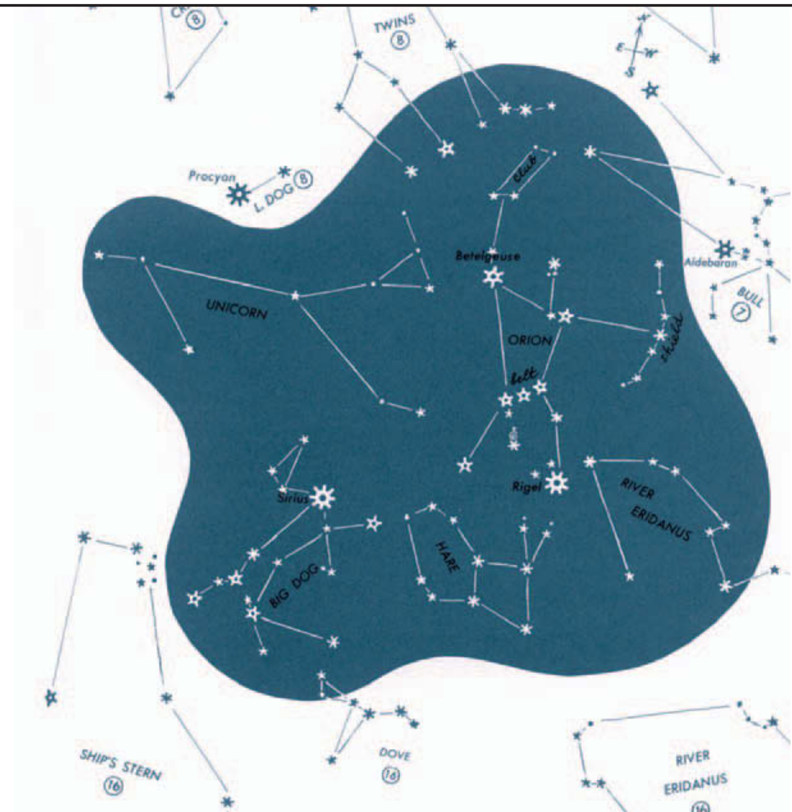
Only a small part of his extensive knowledge of science went into *The Stars*. Though Rey wrote his book for amateur astronomers like himself, he also wanted to make it accessible to those without his background knowledge. Afterwards, he noted how difficult it was to make complex concepts plain using everyday language. "Just as it takes a thief to catch a thief," Rey joked, "so it often takes a layman to write for the layman on a scientific subject." "In my case," he added, "the combination of the gift for graphic presentation combined felicitously with a keen interest in the scientific subject, and with an interest in methods of teaching and learning."

Inspiring Youth

Rey's simple presentation and artistic talent introduced many beginners to the sky through *The Stars*, and the same skills served him well in teaching. By 1953 Rey's research led him to teach a free course on constellations at the American Museum of Natural History for the Amateur Astronomers Association of New York.

Club member Bernie Golub wrote about Rey's popular class in an article for the December 1954 issue of *Skylines*, the association's newsletter:

> Mr. Rey, an AAA'er and no stranger to most of us, delighted his audience of some 250 AAA'ers and guests with his delineations of the constellations. The matchstick configurations created by Mr. Rey sweep away many cob-webby and foggy notions of the constellations and bring a breath of fresh thought to the study



One Curiosity, Two

ONE YEAR AFTER *THE STARS* was published in 1952, one of Rey's friends, sculptor Robert Berks, visited Albert Einstein to design a bronze portrait bust. The project would forge a lasting connection between Rey and the famous scientist.

Einstein and Rey shared strikingly similar backgrounds and personalities, though they lived in different worlds. Both men were German Jews who had sought refuge from Hitler's war machine. Both revered nature, loved animals, and attributed their success to a childlike playfulness and curiosity that neither ever abandoned. And both men — each in his own way — sought to describe the heavens.

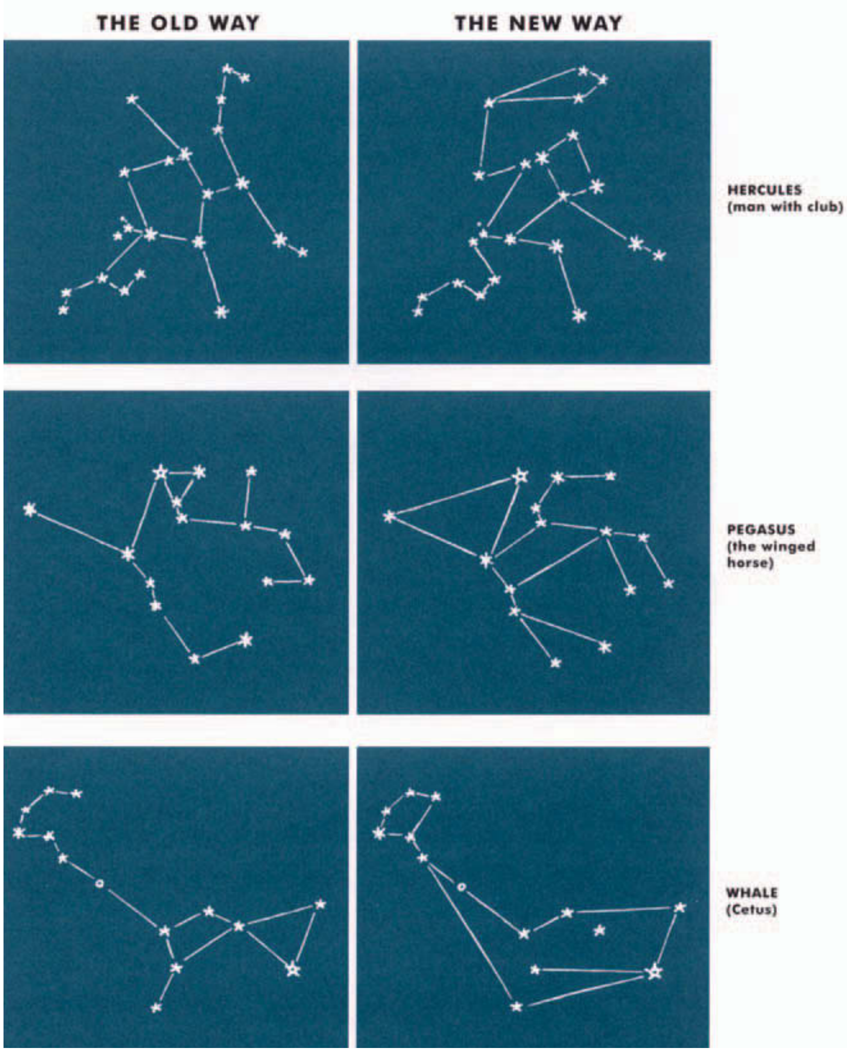
When Berks traveled to Princeton, New Jersey, to visit Einstein's home, he spent a full day getting to know the scientist before he began designing the bust. As they talked in the study, Berks mentioned his astronomically inclined friend. Recounting Rey's dissatisfaction with the constellations depicted in most astronomy books, Berks told Einstein about Rey's new patterns, designed to actually represent the animal or person in the constellation's name.

IMAGE FROM *THE STARS*, BY H.A. REY. COURTESY OF HOUGHTON MIFFLIN HARCOURT

INSPIRING YOUTH ***Facing page, far left:*** **H. A. Rey reads one of his books to a group of children in 1968.**

THE TEACHER ***Facing page, near left:*** **Rey entrusted 14-year-old Harvey Singer to set up his Unitron refractor, "the Cadillac of small telescopes" (pictured here), in Central Park for observing sessions after class.**

OLD VS. NEW ***Right:*** **Rey's diagrams simplified and demystified "modern" constellation lines, which he said, "show the constellations as involved geometrical shapes, which don't look like anything and have no relation to the names."**



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of the sky. Nothing but a clearer understanding of the heavens can possibly evolve from his happy and concise ideas."

Another amateur and one of the association's youngest members, Harvey Singer, attended the constellation classes as a 14-year-old boy. "Mr. Rey's presentations were always interesting," Singer recalled (*S&T*: September 1999, page 10) before he corrected himself. "No, not interesting — they were *exciting*. He knew the secret of making ordinary things interesting and interesting things extraordinary."

Rey brought his Unitron refractor to class every week for an informal observing session in Central Park after class. And every week, Rey asked young Singer, "Would you mind setting up the telescope so that it will be ready for us when we arrive?"

"Would I *mind*?" Singer thought. "I would have done it for him anywhere and at any time . . . He trusted me completely. Of course, I treated his telescope as if it were my own — no, *better* than if it were my own. And I felt incredibly important. And proud."

Visions of the Heavens

Rey's book appealed to Einstein, perhaps in part because he recognized his own nonconformity in the artist's work. As biographer Walter Isaacson wrote, several of Einstein's contemporaries "came close to some of his breakthroughs . . . but [he] alone among them was rebellious enough to throw out conventional thinking that had defined science for centuries."

Rey sent Einstein a copy when Berks told him of the scientist's interest. Addressing the "Sehr verehrter Herr Professor" (very honored professor), he wrote, "This book has no scientific claims, only the presentation method is different."

Einstein replied, "Many thanks for your lucid and stimulating book. I hope it will find the interest it deserves" — words now printed on the back of every copy of *The Stars* — before signing his note, "Freundlich grüsst Sie" (with friendly greetings).

As Berks campaigned to build a memorial to Einstein on the grounds of the National Academy of Sciences in Washington, D.C., he ensured the two men would share a lasting connection. Unveiled in 1979, two years after Rey's death, the memorial serves as a meeting point of two visions of the heavens.

A giant bronze Einstein hunches over in thought, scribbling equations on the pad of paper in his lap as he did the day Berks studied him in 1953. But here his feet rest on a field of stars, planets, and galaxies — 2,700 objects in all, set as metal studs in the emerald pearl granite.

The spray of celestial objects might bewilder visitors if not for the nearby plaque Berks designed, where familiar figures outline the stars beneath Einstein's feet. Just as in Rey's illustration at left, Orion looms above the Hare, his club lifted overhead. The Bull rushes towards the hunter, the Pleiades dangling at the end of one of his long horns. Sirius, the brightest star in the sky, adorns the collar of the Big Dog, who runs at Orion's side. And high above the fray, Rey's Twins march hand in hand across the sky.

— A. M. Ashmore

But it was his mentor's humanity and compassion that Singer appreciated the most. "After the viewing, everyone who wanted to would accompany Mr. Rey to a local cafeteria for coffee and more conversation. Since my budget was limited, I just took the subway home instead. But one evening Mr. Rey asked me to accompany the group to the cafeteria. He wanted to buy me an ice-cream soda . . . I am certain it was the best ice-cream soda I have ever had, bar none."

Wanting to return the favor, the teenager "collected all the spare change I could." The next week at the cafeteria, Singer offered to pay for Rey's coffee. "'Thank you,' Rey responded, 'but, no. Someday, when you are older, you can buy me a beer.' He knew exactly how to say 'no' without hurting a teenager's feelings."

In 1963 the Reys moved to Cambridge, Massachusetts, just over a mile from the offices of *Sky & Telescope*. Rey continued teaching at the Cambridge Center for Adult Education, his passion for sharing the night sky unabated.

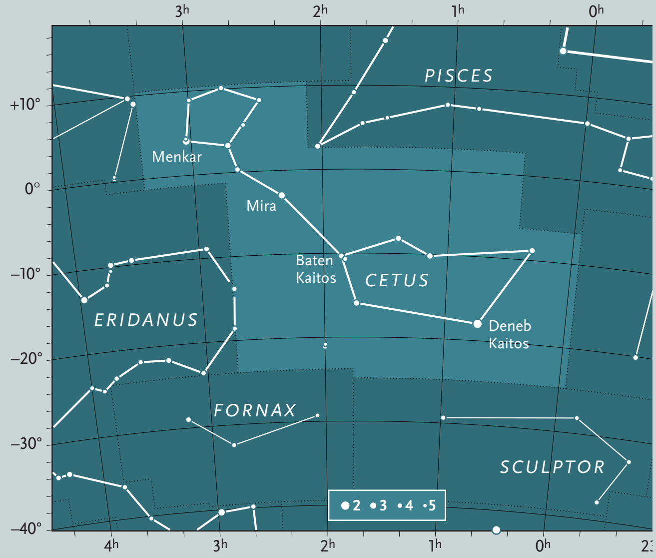
And Rey continued working on a third book about the stars, to be titled *Road Atlas of the Sky*. But diminished eyesight and a failing heart prevented its completion. After Rey's death in 1977 at the age of 78, a letter from a neighbor in Waterville Valley to Margret described what all who knew him and his love of the stars felt about him:

> Hans was such a fine, happy man . . . We will always remember the nights that he came down to our cottage to get the boys to 'come out and see what's happening in the sky!' Andy and I have decided with great certainty that Hans and [Curious] George are right up there in their own twinkling constellation — Hans smiling and watching, and George probably acting out the pictures for a new book, *George and Hans Go to Heaven*!" ✦

***Ann Mulloy Ashmore**, associate professor at Delta State University, was a collection specialist at the de Grummond Children's Literature Collection, which houses the H. A. and Margret Rey Literary Estate.*

IMAGE FROM *THE STARS* BY H.A. REY. COURTESY OF HOUGHTON MIFFLIN HARCOURT

S&T's Constellations



S&T: GREGG DINDERMAN

SEA MONSTER H. A. Rey's patterns influenced *S&T*'s "official" constellations, but many were adjusted for clarity and to preserve traditions. For example, Alan MacRobert changed the shape of Cetus to preserve Deneb Kaitos as the sea monster's tail.

PERUSE THE EVENING SKY CHART at the center of *Sky & Telescope* and you'll see echoes of H. A. Rey's stick figures everywhere. I led the design of *S&T*'s "official" constellations — all 757 line segments! — that appear in every issue since January 1993. But though I grew up dearly devoted to Rey's patterns, I realized early on that we would need to make some changes.

First, his charmingly realistic figures rely heavily on stars that are just too faint for modern, light-polluted skies. Night skies have worsened significantly over the past 60 years. And maybe even back then Rey was pushing a little too hard to find a good cartoon in every constellation.

In pursuit of that goal, he also drew some lines where the eye has a hard time seeing them. In the real sky, your eye infers a line between any two bright stars that are near each other, whether you like it or not. Your eye won't favor lines pointing instead to much fainter stars, even to make a good Sea-Goat or Ram.

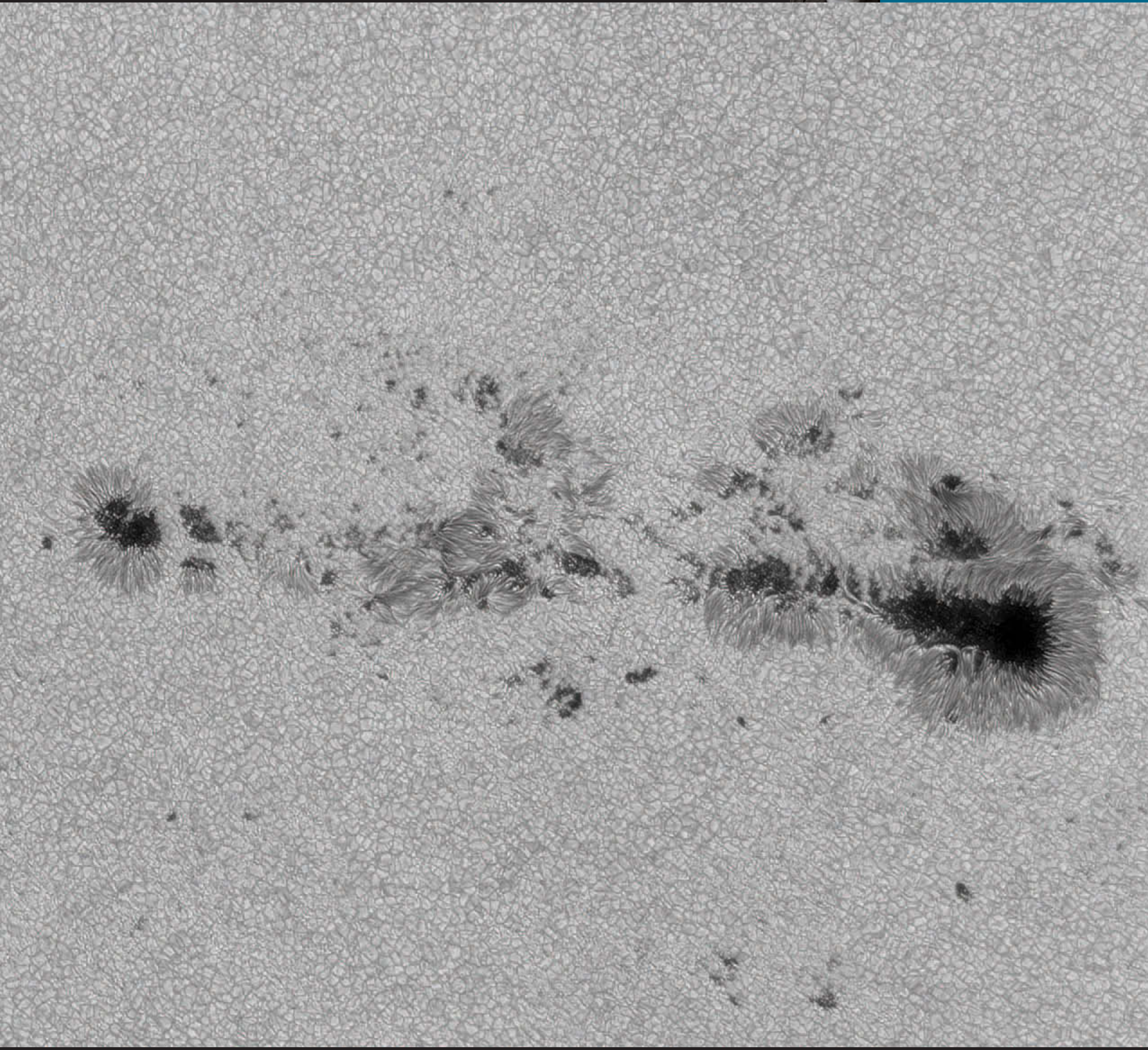
Third, Rey ignored the ancient, millennially accepted constellation figures — which remain on classical maps, in legendry, and in Arabicized star names everywhere: the Head of the Kneeler (Rasalgethi), the Tail of the Sea Monster (Deneb Kaitos).

So I adjusted the beloved but occasionally frustrating stick figures accordingly — compromising between realistic cartoons, clear visibility, and adherence to ancient traditions.

Along the way I came up with a few remarkably suggestive constellation patterns that match the ancients' arrangements spot-on. Virgo, for instance, is not supposed to be carrying Spica on her rump but in one hand, while she sows springtime seeds. Lupus, a pointy-nosed Wolf, is supposed to be recoiling backward as Centaurus spears him in the throat.

So far, this new set seems to be standing the test of time.

— Alan MacRobert

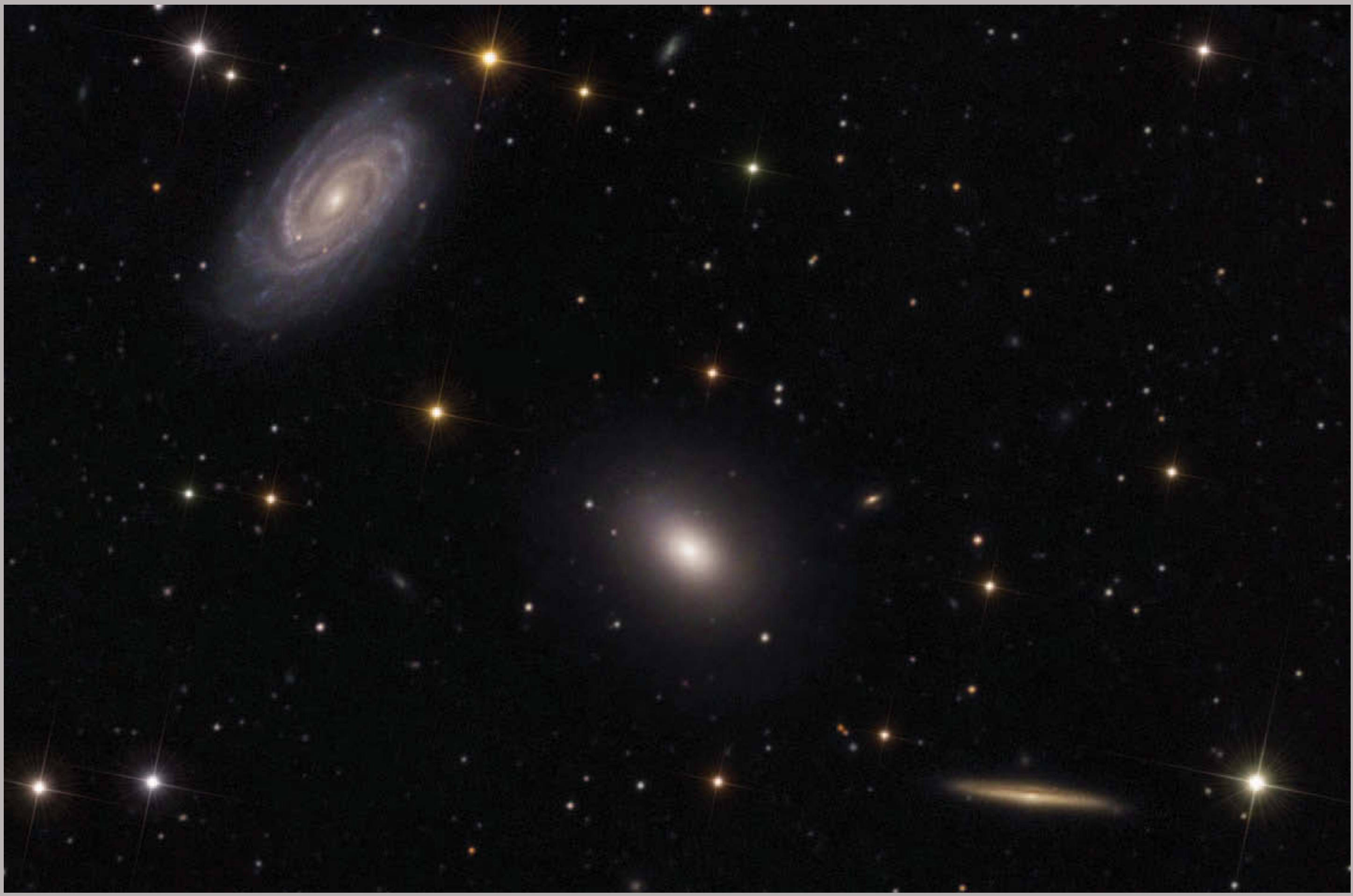


EXPANSIVE SUNSPOTS

Christian Viladrich

Surrounded by the solar surface's complex granulation, sunspot groups AR 1785 (right) and 1788 display thin filaments within their penumbrae in this high-resolution image.

Details: *Celestron C14 Schmidt-Cassegrain with Baader Astrosolar Safety Film and IDS UI-3370CP video camera. Stack of 150 frames captured on July 6th at 11:02 UT.*



▲ **GALACTIC CASCADE**

Terry Hancock and Fred Herrmann

Known as the Draco Trio, galaxies NGC 5985, 5982, and 5981 (from left to right) appear distinctly different in a compact ¼° field.

Details: *Astro-Tech 12-inch f/8 Ritchey-Chrétien astrograph with SBIG STT-8300 and QHY9 CCD cameras. Total exposure was 8 hours through color filters.*

▶ **CHINESE NIGHT**

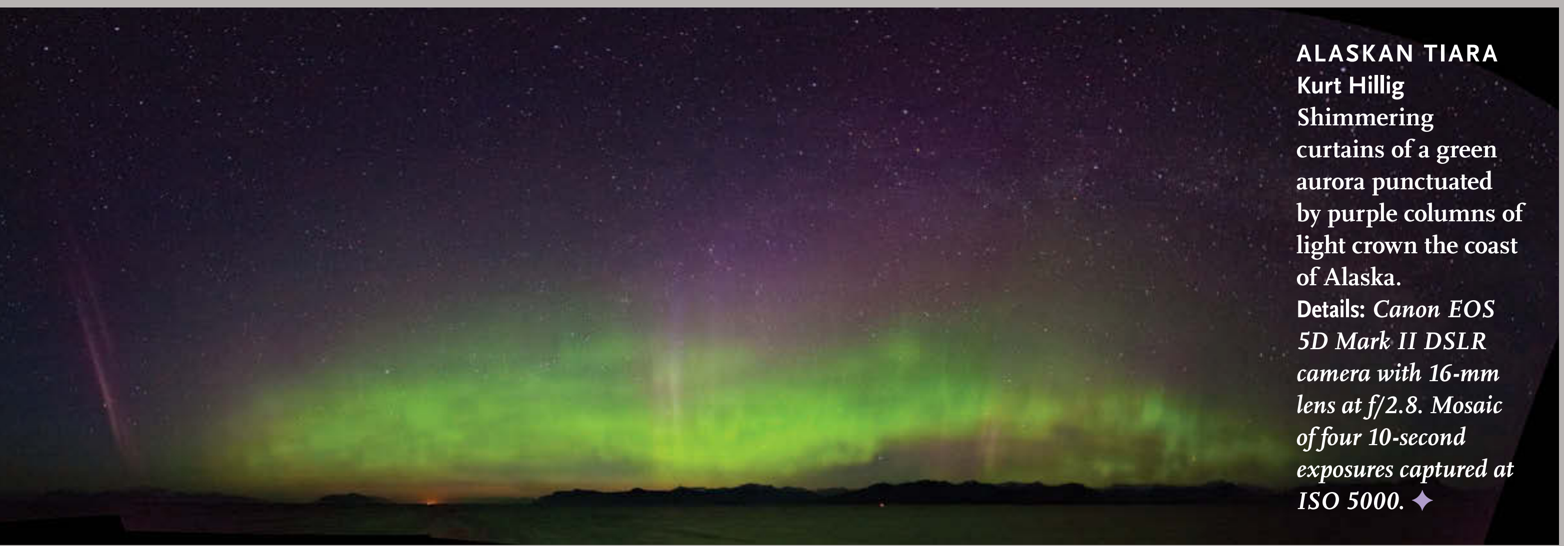
Jeff Dai

The center of the Milky Way shines over the countryside near the village of Bamei in China's Sichuan Province.

Details: *Canon EOS 5D Mark II DSLR camera with 14- to 24-mm zoom lens. Total exposure was 2 minutes at ISO 2500.*

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

REFLECTIONS IN CYGNUS
Harel Boren
NGC 6914's bluish reflection nebula adds a distinct color contrast to clouds of hydrogen gas that permeate Cygnus.
Details: *Boren-Simon f/2.8 Powernewt Astrograph with SBIG ST-8300M CCD camera. Total exposure was 3⅚ hours through Astrodon color and narrowband filters.*



ALASKAN TIARA
Kurt Hillig
Shimmering curtains of a green aurora punctuated by purple columns of light crown the coast of Alaska.
Details: *Canon EOS 5D Mark II DSLR camera with 16-mm lens at f/2.8. Mosaic of four 10-second exposures captured at ISO 5000.* ✦

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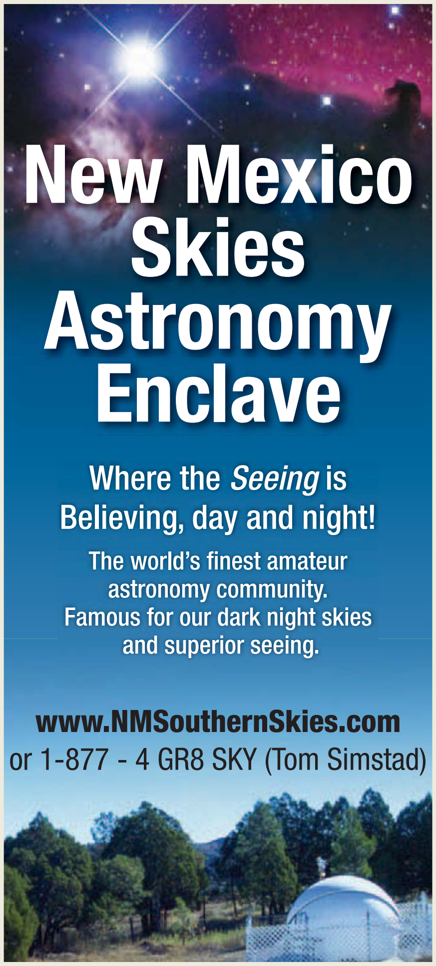

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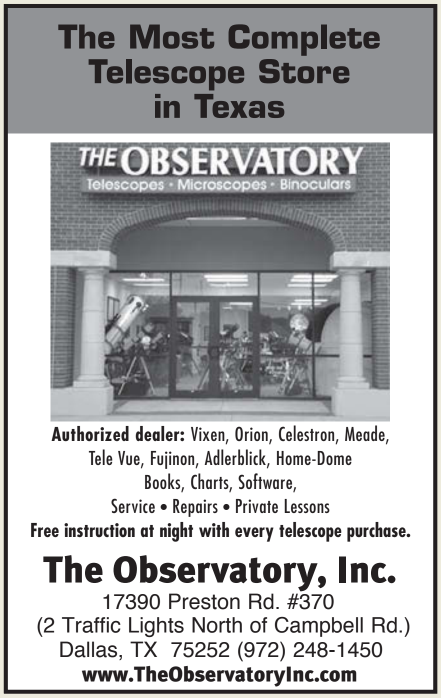

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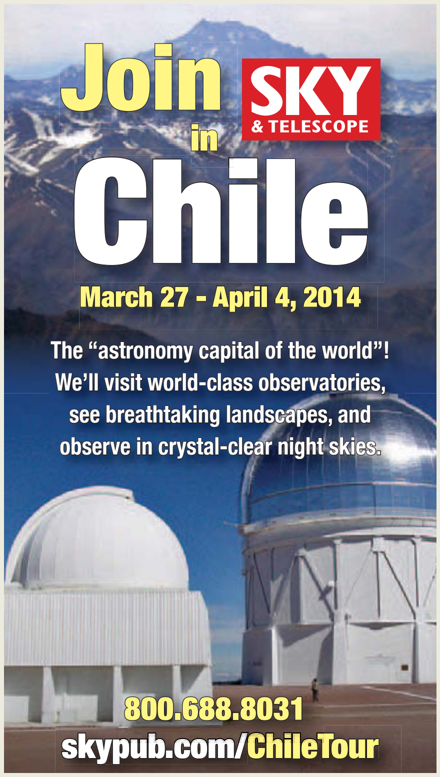

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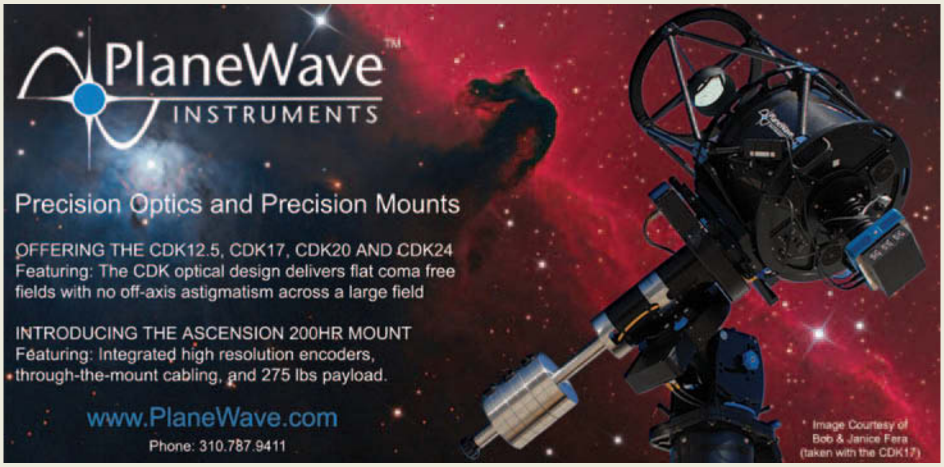

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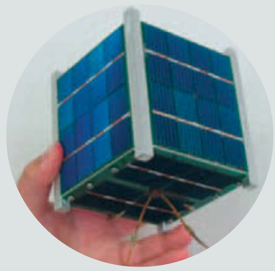

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Henry G. Stratmann

Cat-astrophic Observing Session

A feline "friend" interferes with the author's astronomy plans.

Many observing sessions end prematurely when inquisitive clouds gather above my telescope. I recently discovered another, unexpected hazard for the amateur astronomer.

One clear night I drove my car out of the garage and moved a new astrophotography system into my driveway. After running a long yellow extension cord from an outlet in the garage to power my equipment, I set up a table for my laptop and ran cables from it to my telescope and CCD cameras. While polar aligning my mount, I was startled by something brushing against the back of my ankles.

It was a neighbor's petite gray cat out for a nocturnal stroll. Her eyes glowed in the dark like a golden double star as she scrutinized me and my astronomical paraphernalia.

I continued my work, expecting the furry interloper to lose interest and leave. But whether due to her species' natural nosiness or simply finding me a convenient rubbing post as she intermittently stroked her body against my pant legs, she didn't.

Then I realized the danger she presented. I pictured myself stepping backward in the darkness and falling over my feline "friend" — something that would do neither of us any good. My extension cord still extended through the open garage door. If I ignored her, she might wander into a secluded corner of my cluttered garage and be inadvertently trapped inside when I finished my activities and lowered its door.

Though appreciating her interest in stargazing, I decided it would be best if she left and resumed her neighborhood patrol. "Go away, kitty!" was spectacularly ineffective. Striding toward her in an unconvincingly threatening fashion while making shooing motions with my hands made her retreat momentarily — only to return and sniff my shoes as I resumed my endeavors.

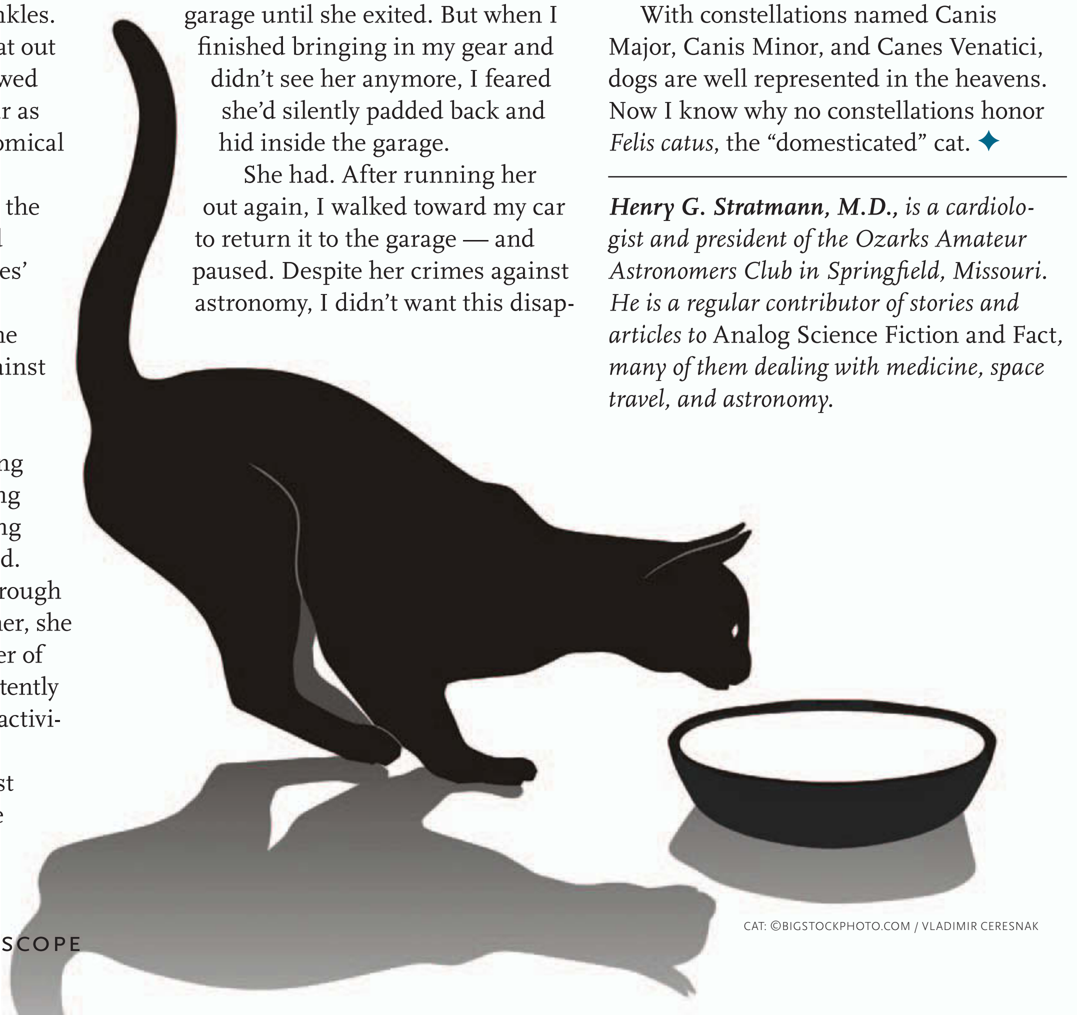
Her persistence finally convinced me that any attempts at observing and imaging that night would be futile. As I returned my equipment to the garage, she followed me there, too. "Out of the garage, kitty!" fell on deaf ears. I resorted to awkwardly chasing her around the garage until she exited. But when I finished bringing in my gear and didn't see her anymore, I feared she'd silently padded back and hid inside the garage.

She had. After running her out again, I walked toward my car to return it to the garage — and paused. Despite her crimes against astronomy, I didn't want this disappointing night to end with the cat's curiosity proving fatal if she darted beneath my moving wheels.

I raced inside my house and returned with a bowl of milk. Setting it a safe distance away on the driveway, I watched her every second as she imbibed that liquid treat, and I made sure she remained far away while I cautiously drove my vehicle back into the garage. As I lowered the garage door, the cat finished her repast and sauntered away — casting me a last look that reminded me of images I have seen of the Cat's Eye Nebula.

With constellations named Canis Major, Canis Minor, and Canes Venatici, dogs are well represented in the heavens. Now I know why no constellations honor *Felis catus*, the "domesticated" cat.

***Henry G. Stratmann, M.D.,** is a cardiologist and president of the Ozarks Amateur Astronomers Club in Springfield, Missouri. He is a regular contributor of stories and articles to* Analog Science Fiction and Fact, *many of them dealing with medicine, space travel, and astronomy.*



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