Bob Berman on the SMELL OF SPACE p. 12

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THE GREATEST GALAXY SHOW

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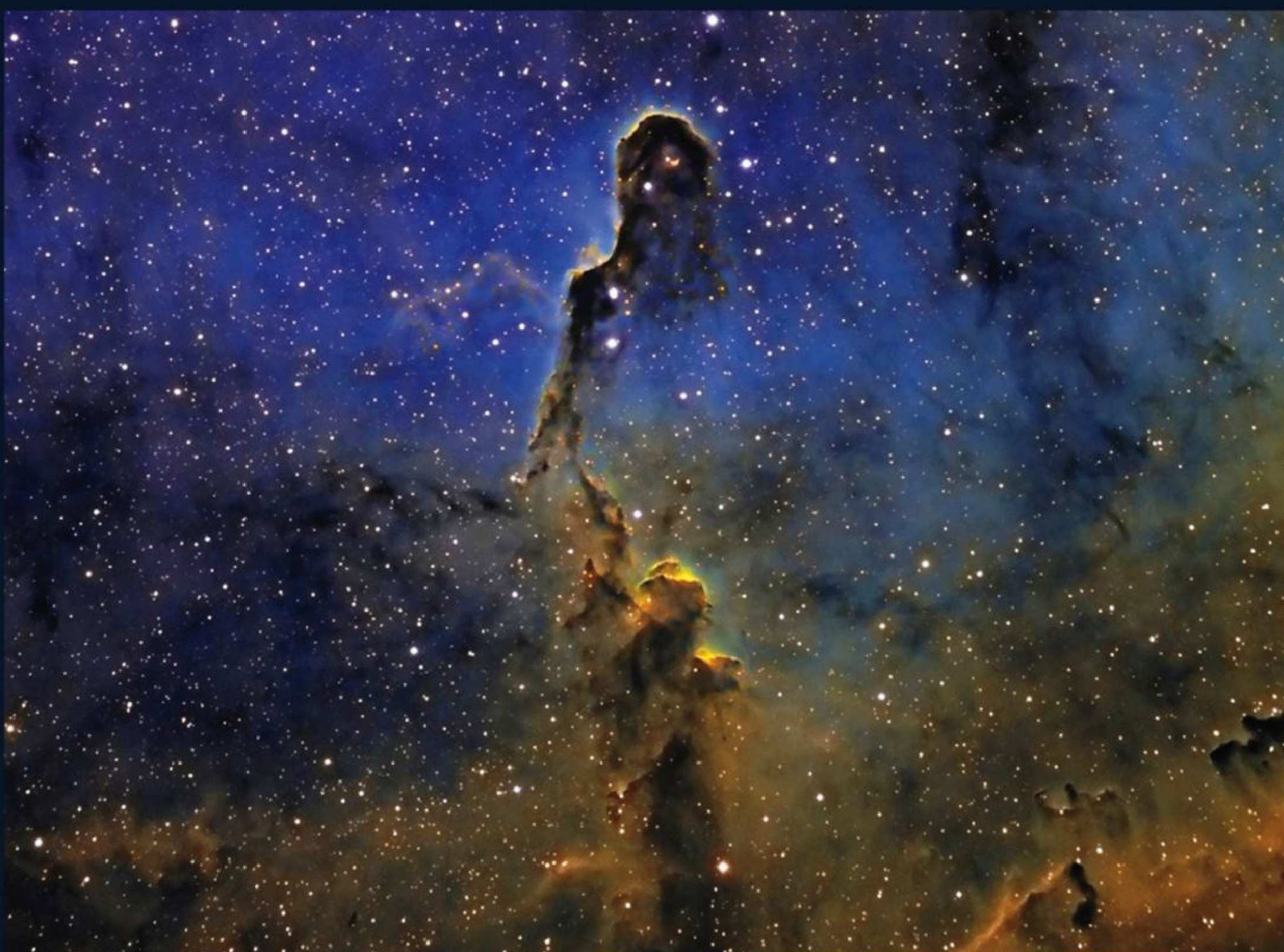

This beautiful image of Vdb 142 was taken by Peter Clausen using an SBIG ST-8300M camera and narrowband filters.

VOL. 39, NO. 7

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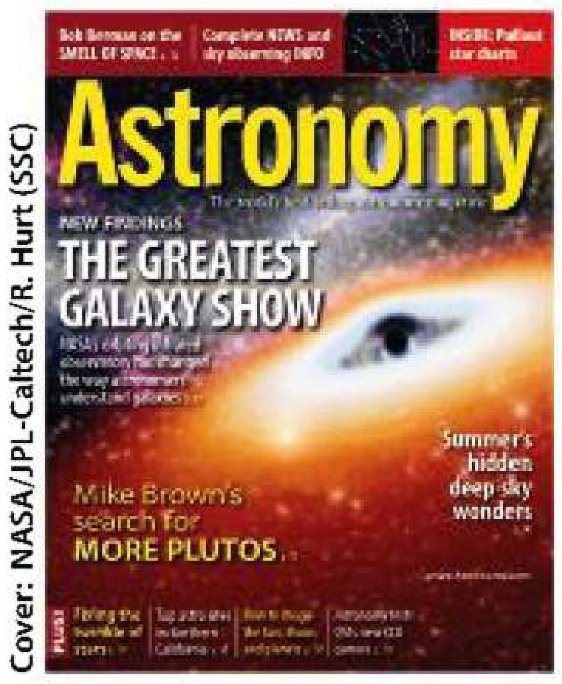

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ON THE COVER

In just 6 years, NASA's Spitzer Space Telescope radically changed how astronomers understand galaxies, black holes, and more.

July 2011

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Astronomy (ISSN 0091-6358, USPS 531-350) is published monthly by Kalmbach Publishing Co., 21027 Crossroads Circle, P. O. Box 1612, Waukesha, WI 53187–1612. Periodicals postage paid at Waukesha, WI, and additional offices. POSTMASTER: Send address changes to *Astronomy*, 21027 Crossroads Circle, P. O. Box 1612, Waukesha, WI 53187–1612. Canada Publication Mail Agreement #40010760.

Congratulations to our youth essay winner

by David J. Eicher

This March, the editors of *Astronomy* chose the winner of our second annual Youth Essay Contest. Sixteen-year-old Benjamin Palmer of Queensbury, New York, won a trip to the Northeast Astronomy Forum and Telescope Show (NEAF). More than 50 enthusiasts submitted essays detailing what they love best about astronomy.

As I write this, NEAF is going on — and by the time you read this, it will have happened. Senior Editor Michael Bakich and I attended and reported on the meeting on our website, www.Astronomy.com, in our blogs.

Benjamin caught the *Astronomy* staff's attention with a thoughtful essay in which he showed his passion for both the hobby and the science as he explained how astronomy has touched his life. "Astronomy is revolutionary because it changes the way we think about the world and ourselves," he wrote. "It encourages me to think outside the box — the box of self, the box of finite knowledge, the box of known commodities. In the truest sense, astronomy opens up the physical world of possibility."

Benjamin first became interested in astronomy at age 9 when he attended an open house at the Eileen Collins Observatory in Corning, New York. There, he heard two astronomy professors talk about the Big Bang and listened to an audio clip of the interstellar static produced by the cosmic microwave background radiation. Soon after, he acquired his first telescope. Since then, Benjamin has spent many nights detailing his adventures at the telescope. And for the past 2 years, he has interned at Dudley Observatory in Schenectady, New York, where he's learning astrophotography and honing his skills as an observer.

It thrills Benjamin to attend the show April 16 and 17, having wanted to do so for the past 5 years. "I'm absolutely

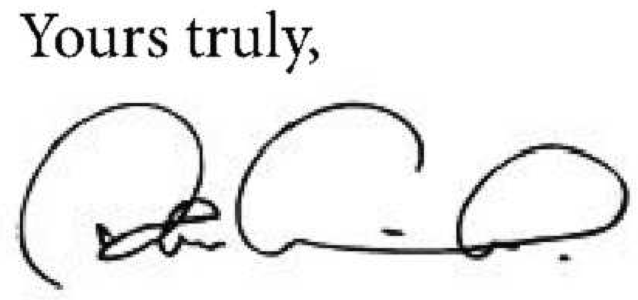
Nancy Palmer

ecstatic to be attending NEAF," Benjamin says. "It's really a dream come true. This will give me a unique opportunity to interact with a wide array of individuals who are dedicated to this field. I'm looking forward to attending some great workshops, exploring state-of-the-art equipment, and participating in the Solar Star Party."

And the Solar Star Party isn't the only exciting thing happening at NEAF's 20th anniversary celebration. NEAF features special guest speakers from the science and hobby, as well as more than 130 vendors showcasing the latest telescopes and accessories. There also are a variety of activities, from astroimaging workshops to STARLAB planetarium shows.

NEAF is just the type of event a young enthusiast should attend. We are excited to have provided him with this opportunity, and I hope it inspires him even more to follow his passion.

Yours truly,



David J. Eicher
Editor

Astronomy

Volume 39, Number 7

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Peeling back the layers

Young stars speckle this tapestry of dark clouds and glowing gas. Cataloged as Monoceros R2, this giant molecular cloud is a hotbed of star formation. But you wouldn't know that by looking at a visible-light image. Interstellar dust blocks most of this radiation from escaping the cloud's interior and ultimately traversing the 2,700 light-years to Earth. But in infrared images like this one, the newborn stars blaze forth and gaseous outflows colored pink and red shoot from still-obscured protostars. Astronomers took this image with the European Southern Observatory's Visible and Infrared Survey Telescope, a 4.1-meter scope located on Cerro Paranal in northern Chile. ESO/J. Emerson/VISTA

Letters

Tricky imaging

I'm new to astronomy, and every night is a fascinating adventure. You'll often find me scanning the heavens with my 8-inch telescope whenever I get the opportunity in the ambient-light-drenched city of Los Angeles, California.

I'm a subscriber to *Astronomy* and am enjoying the magazine and website immensely. It's amazing to me to think that, for the most part, the world's population focuses solely on earth-bound things and is mostly oblivious to the beauty and complexity of what lies just above its heads.

I'd like to reassure fellow readers that they don't need pristine conditions or expensive camera equipment to photograph our celestial neighbors. Recently, I've taken photos of the Moon from Los Angeles using a Meade LX90 ACF 8-inch telescope and my cell phone. I've even snapped an image of Saturn. No f/stops or complicated exposure times to consider — the only requirement is to not use a flash. The outcome isn't as glorious as Hubble's, but the results are still remarkable.

Even with light pollution in Los Angeles, California, a reader was able to capture images of the Moon using his cell phone and his 8-inch telescope. Glenn Holland

— **Glenn Holland**, Marina Del Rey, California

Why we should care

I enjoyed reading Karen Jennings article, "Why Gen X and Y should care about astronomy," in the February 2011 issue. I agree that young adults should care about our hobby. This topic comes up a lot at star parties and club meetings. The gray-haired ones scratch their heads and wonder where the younger folks are. My answer is that they just aren't here ... yet. Many of those gray-haired ones didn't attend amateur astronomy events as young adults either. I believe that astronomy is a hobby that more people come to, or come back to, later in life.

That's my situation. I grew up on ranches in New Mexico and Colorado, where the night sky was always glorious. From an early age, I learned about the stars; I was in my teens during the Mercury, Gemini, and Apollo programs. General interest in space and astronomy was high. But then, as a young adult, I became involved in other things. My life as a young husband and father was oriented differently. I didn't return to astronomy until my late 40s. Until then, I didn't have the time and resources to pursue the hobby at the depth I now enjoy.

So, don't lose heart. Gen X and Y will be just as interested as we are. Perhaps even more so, drawn in by the technological advances available to amateur astronomers. The appeal will be there — they just need to get a little gray hair first.

— **Rick Angell**, Golden, Colorado

I am a 15-year-old girl, and I have been a subscriber to *Astronomy* for a year. When the time comes for a new issue, I check the mailbox with enthusiasm every day. *Astronomy* teaches me all the new details about our solar system and the universe.

I agree with Karen Jennings about how fascination in space and the universe is being lost in those generations. As I was growing up, I never heard my parents or grandparents talk about the stars, the Moon, or the universe. The only astronomy I knew of concerned our solar system, and I learned that information in second grade.

In eighth grade, I became obsessed with space and my interest hasn't lessened since then. I love to stand outside and stare at the night sky to try to view the stars; unfortunately, I can't get a good view because of all the light pollution. I would go to star parties, but no one around me is as interested in astronomy as I am.

Thank you for letting me read and learn about astronomy every month.

— **Devyn Koob**, Wichita, Kansas

Powering future missions

I enjoyed the article "How we'll probe the solar system" (January 2011). Author James Oberg indicated that some future missions (for example, the Curiosity Mars rover) would use a nuclear power system. However, I recently read that a current plutonium shortage requires that future missions find an alternate power source for radioisotope thermoelectric generators. How serious is this problem, and how will it impact future deep-space or long-duration missions?

— **Rob Moore**, Haymarket, Virginia

The plutonium shortage has become a serious design factor for future NASA deep-space probes after the last United States production facility was shut down in 1997, and, later, Russia revoked an agreement to sell the United States some of its own supplies. Restoring U.S. production has been decided on, but even with adequate funding, it could take the rest of this decade. It definitely puts future science probes between a space rock and a radioactive place. — **James Oberg**, contributing author

Correction

On page 22 of the February 2011 issue, in the "Most distant galaxy seen" Briefcase, the text should say "600 million years." We apologize for the confusion. — ***Astronomy* Editors**

We welcome your comments. Send letters to Astronomy Letters, P. O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.

Web Talk

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What's new at Astronomy.com. **by Karri Ferron**

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Strange**Universe**

by Bob Berman

The smell of space

How do our other senses apply to astronomy?

Astronomy is a visual science. All our knowledge begins with photons of light. By stimulating our retinas, they provoke 12 watts of electricity to course through our 1000 cc, motorcycle-cylinder-sized brains. The result: images of various nebulae.

Yet the universe makes us use the poorest facets of our vision. Most backyard astronomers assume the gray galaxies and blurry nebulae they see are due to their modest optics. But as I've pointed out before, "blurry and gray" is simply how our eyes perceive faint objects. Galaxies exhibit a low surface brightness through telescopes. In such dim light, the retina's only tool is its 120 million rod cells, which produce a pathetic 20/200 sharpness and a total absence of color. Observe the Whirlpool Galaxy and you are legally blind — plus as colorblind as an owl. But is vision really our only tool for probing the cosmos? What about our other senses?

Sound: Some folks insist they've heard meteors. And a dozen observers in Alaska emphatically told me the aurora they witnessed was accompanied by hisses and crackles. Yet sensitive microphones set up by University of Alaska researchers in Fairbanks have never detected any sound whatsoever. In truth, the large distances (80 miles [130 kilometers] to meteors and even farther to aurorae), plus the very thin air up there, would make sounds virtually impossible. And even then it would require at least 7 minutes for a noise to reach the surface. That's a far cry from the instantaneous reports.

Call me naïve, but I still believe those people. I think some folks somehow perceive the radio waves generated by meteors as they ionize the air around them. Similarly, aurorae are often accompanied by huge electrical currents on the ground.

Browse the "Strange Universe" archive at www.Astronomy.com/Berman.

Such electromagnetic phenomena move at light-speed, so any noises should indeed be simultaneous. Still, how anyone's senses could perceive this is a mystery.

The biggest boom box in our neck of the woods is the Sun. Its surface has nonstop, complex, up-and-down pulses, like a woofer. Studying those is the province of helioseismology, which is fun to say. It's a powerful tool for probing what's below the solar photosphere, just as earthquakes tell us what's going on beneath our planet's surface. Those pulses definitely create sounds. If the solar system ever passes through an impossibly dense nebula, we might someday hear the music of the Sun.

No, you don't want to go around sniffing the solar system.

Smell: To have any smell at all, atoms must cling to our nasal membranes. This is why large molecules like tetracycline or DNA have no odor — they're too big to stick to our noses. But truly large molecules are rare beyond Earth, so most celestial objects would indeed have some sort of scent. Unfortunately, the universe does not smell like roses. Parts of the solar system generate foul substances. Io's volcanoes spew out putrid sulfur dioxide. Jupiter's environment is worse than a college dorm. Uranus and Neptune are rife with ammonia. No, you don't want to go around sniffing the solar system.

Even the Moon may stink. When Michael Collins received Apollo 11's samples, the containers had lots of lunar dust on them, which wafted into the command module. Collins said it smelled awful. Then again, maybe he was really getting a whiff of Aldrin's socks. Or perhaps the Moon is made of green cheese after all, and a government conspiracy is covering this up.

Lunar regolith (soil) is mostly silicon and oxygen, so in theory the Moon should smell like sand. However, trace materials often impart distinctive odors to things, so compounds like iron oxide, which is 12 percent of the Moon, are what probably give it a foul stench.

Touch: Is this a touchy-feely universe? Maybe a little. In addition to the 842 pounds (382 kilograms) of Moon rocks Apollo astronauts carried back, plus 5 ounces (142 grams) the Soviets scooped up and returned robotically, the Stardust mission captured grains of Comet 81P/Wild, which contained the life-friendly amino acid glycine. The allure of "hands on" explains why meteorites are so popular. For a few hundred dollars, you can buy a gorgeous octahedrite. "Here!" you say to guests, letting them hold a heavy black metallic chunk that a magnet will yank. It's fun to hand someone an asteroid. (Meteor showers are fragile comet ices that never make it to Earth. A meteorite you can touch is an asteroid or a piece of the Moon or Mars.)

You can touch the Moon at Washington's Air and Space Museum, where a lunar rock is set so you can run your fingers over it. If you could leave Earth and briefly remove your gloves, you'd find the Moon's surface as pleasantly fine as baby powder, martian soil much coarser to the touch, and Venus rock-hard and nearly red hot. The outer planets have no surfaces at all, so you'd just be swiping at cold gas.

Bottom line: Our non-visual senses offer slim celestial pickings, and they're not always agreeable. Looks like we'll stick with those photons. Maybe gray is cool, after all. Noticing the transformation of my mustache, I can only hope so.

Contact me about my strange universe by visiting **http://skymanbob.com**.

by Glenn Chaple

Binary stars in action

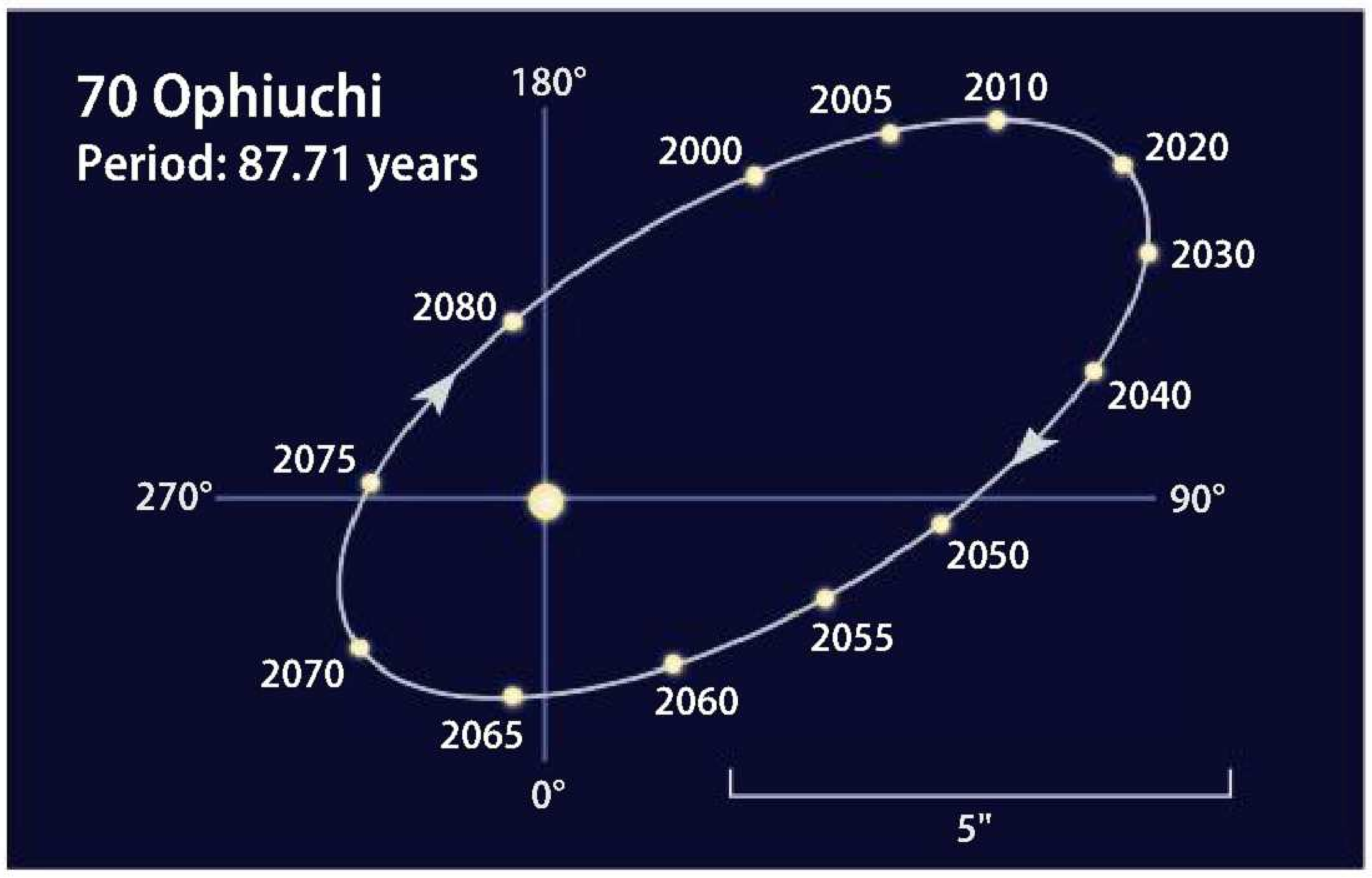
You can witness some visual double stars complete much of their orbits within your lifetime.

Can an amateur astronomer with a backyard telescope perceive the orbital motion of a binary star in a reasonably brief period? Gene Crist of Peoria, Arizona, wants to know. "Are you aware of any visual binaries that are short period?" he e-mailed. "By short period, I mean they have a complete orbit that takes 20 years or less; something I could possibly observe in my lifetime."

That's a tall order. Of the thousands of double stars resolvable in small- to medium-sized telescopes, true binary pairs with orbital periods of 20 years or less are as rare as astronomers at an astrology convention. An unfortunate astronomical fact of life is that the typical short-period binary comprises stars locked in a close gravitational embrace. The result is a subarcsecond angular separation that observers can breach only using large-aperture telescopes. Conversely, a binary star with a wide angular separation is likely composed of physically distant components whose orbital period is measured in centuries.

Twenty years may be a stretch, but a number of visual binaries undergo a large portion of their orbits well within the span of a human lifetime. Using nothing more than my trusted 3-inch f/10 reflecting telescope, I've followed the orbital shift of a trio of binary stars.

The first is Alpha (α) Geminorum, better known as Castor. Attempting to split this magnitude 1.9 and 2.9 pair in 1970 proved marginally successful. At the time, the two were separated by 1.8" — as close to one another as they can get (an orbital position called "periastron"). Six years later, they had widened enough (2.1") to be cleanly split at 120x. At present, half that magnification will reveal both components, now separated by a comfortable 5.0". They will remain an easy small-scope target until their next periastron sometime during the 25th century.



Visual binary star 70 Ophiuchi has an orbital period of nearly 88 years. It's currently approaching "apastron," a position where the two components are as far away from each other as they get. *Astronomy*: Roen Kelly, after Richard Dibon-Smith

Porrima (Gamma [γ] Virginis) presented the opposite set of circumstances. In 1970, this striking set of magnitude 3.5 twins was 4.6" apart — a piece of cake for the 3-inch scope. They were closing rapidly, however, and by the beginning of this century were resolvable only through large telescopes. At periastron in 2005, they were a mere 0.4" apart. The two are now separating, and their current 1.7" gap will more than double in the next 20 years.

Castor and Porrima have orbital periods of 467 and 167 years, respectively. How can such relatively long-period binaries exhibit so much motion in a handful of decades? The answer lies in their orbital speeds at the time of periastron. Just as Earth moves more rapidly when nearest the Sun, so do the components of a binary star when at periastron.

70 Ophiuchi vividly demonstrates this high-gear orbital shift at periastron. When I first observed 70 Ophiuchi in 1970, its component stars were separated by 2.4". Back then, the 5.9-magnitude companion was situated northeast of the magnitude 4.2 primary. Approaching periastron, the companion picked up speed. In less than half of its roughly 88-year cycle, it arced north, west, and south to its present location 6.0" southwest of the primary — an orbital swing of 270°! Now approaching "apastron" (greatest separation), the companion is slowing down. A half-century will pass before it completes the final 90° segment of its orbit.

Perhaps you're not interested in spending 20 to 30 years monitoring the orbital activity of a binary star. How about spending 20 to 30 minutes admiring what is undoubtedly one of the night sky's premium double stars? 70 Ophiuchi is part of a "mini Hyades" — a V-shaped asterism in Ophiuchus called "the Bull of Poniatowski." Composed of K-type dwarfs, 70 Ophiuchi sports colors of golden yellow and orange-red. A few reputable astronomers claim that the companion is violet! Take a good look at 70 Ophiuchi and see if you agree.

70 Ophiuchi has pretty much "done its orbital thing." A frenetic periastron sprint has evolved into a casual apastron stroll. Backyard astronomers eager to document a rapid orbital change in a binary star will have to look elsewhere. Next spring, I'll introduce you to another easily observed, rapidly orbiting binary. Stay tuned!

Psst! Looking for a useful astronomical website to visit on cloudy nights? Try "The Constellations," a site put together by Richard Dibon-Smith, author of the star atlas *StarList 2000* (John Wiley & Sons, 1992). As you explore its many useful items, you'll come across a section containing detailed diagrams of the orbits of 70 Ophiuchi and dozens of other binary stars. Check it out at www.dibonsmith.com/orbits.htm.

Questions, comments, or suggestions? E-mail gchaple@hotmail.com. Next month: A tale of two (star) cities. Clear skies!

See Glenn Chaple's sketches of 70 Ophiuchi at www.Astronomy.com/toc.

SecretSky

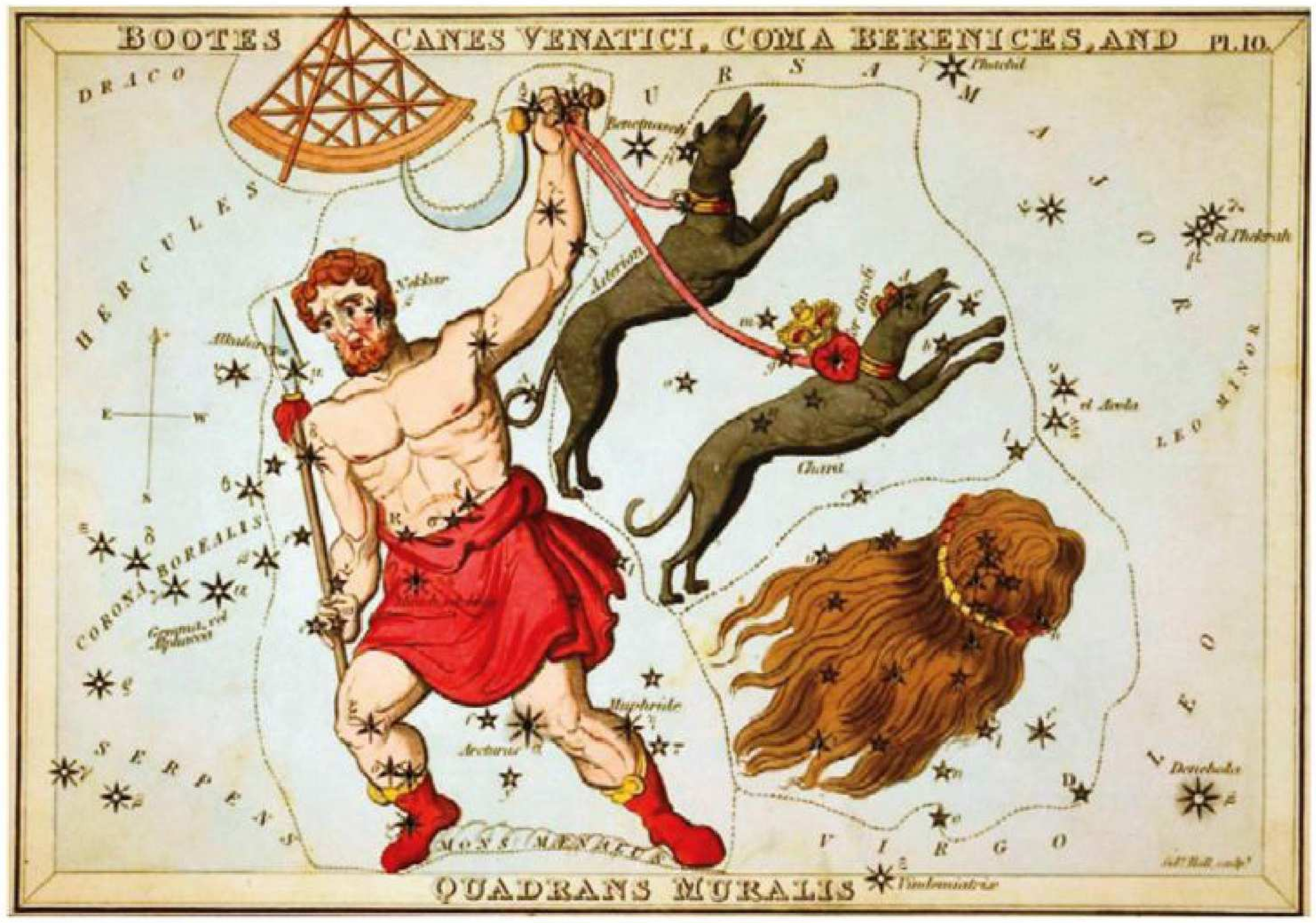
by Stephen James O'Meara

"Pop-up" stars in Boötes

Uncover the sometimes surprising, but always intriguing, stars within the Herdsman.

One night in May 2007, as *Astronomy* Editor David J. Eicher, Contributing Editor Martin Ratcliffe, and I hiked across the barren lava fields of Hawaii's Kilauea Volcano, I looked up at the stars (while trying not to trip) and noticed Boötes. I asked my companions to stop and gaze at magnitude 2.4 Izar (Epsilon [ε] Boötis) — first with direct vision, and then with averted eyes. In concert, both Dave and Martin said they saw a dim star next to Izar "snap" into view with averted vision.

Neither Dave nor Martin had noticed Izar's pop-up neighbor before. In fact, I had stumbled upon it myself only recently. Nevertheless, seeing their surprise comforted me because I had reacted the same way. It helped me realize that without the element of surprise, our hobby would be somewhat mundane. To paraphrase the fictitious FBI Special Agent Fox Mulder in the 1998 movie *The X-Files*: In a universe of infinite possibilities, we should anticipate the unforeseen and expect the unexpected. Perhaps that's why Dave suggested I share this "stellar" surprise — to help you, too, expect the unexpected.



Boötes the Herdsman may be a familiar sight in the sky, but it still can hold a few surprises for even the most seasoned of stargazers. Urania's Mirror/Urania's Muse

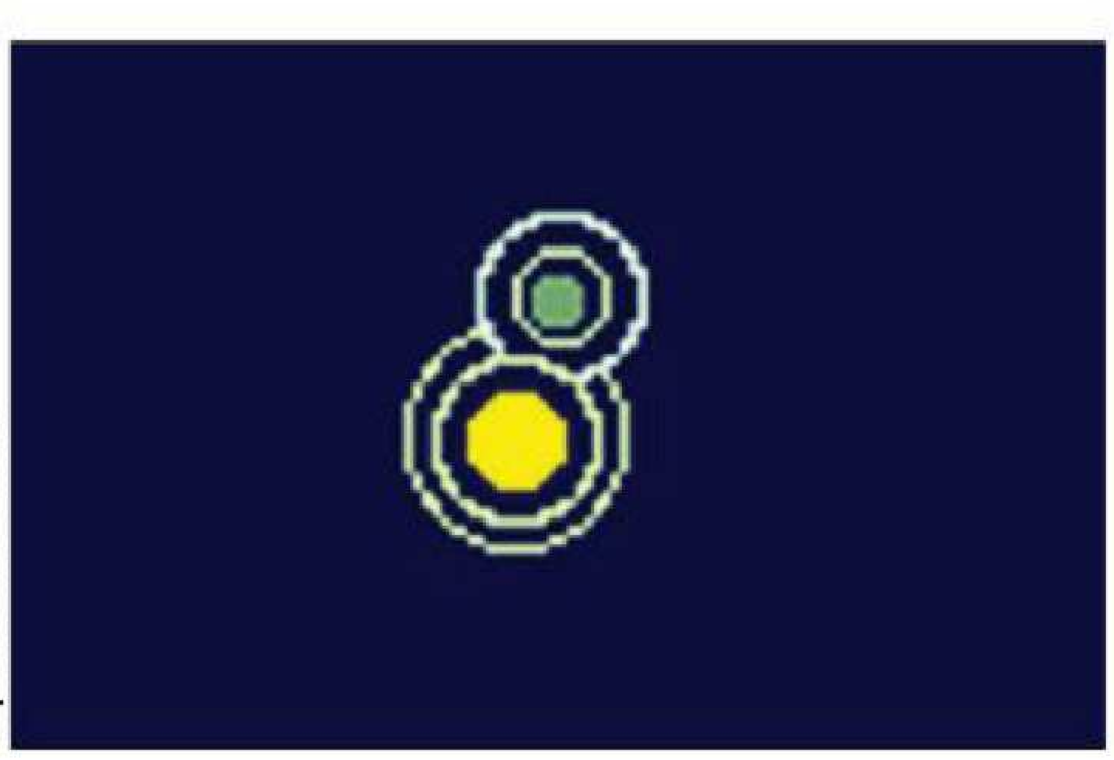
W Boötis

Izar's naked-eye companion is W Boötis (also known as 34 Boötis) — a semiregular variable star whose brightness ranges from magnitude 4.7 to 5.4 over an unpredictable time period. The star, a class M3 red giant, has a diameter some 130 times that of the Sun and a luminosity nearly 3,000 times greater. It's an old star, most likely in a "pre-helium flash" phase, before it evolves into a white dwarf surrounded by a planetary nebula.

From 1966 to 1990, W Boötis pulsed with a period of about 25 days. Then, from 1991 to 1994, its period seemed to change to about 50 days, but these observations became muddled when it turned out the comparison stars were themselves variables! In 1996, new studies suggested staggered periods of 25 and 33 days.

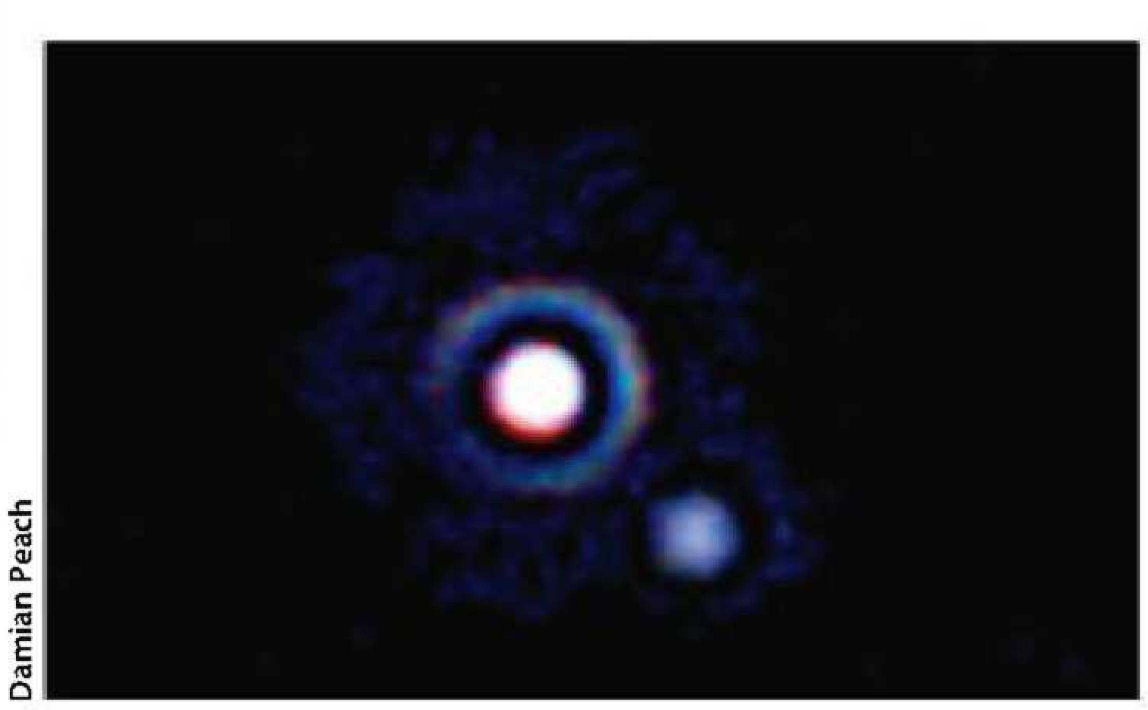
Whatever its period, the good news is that whether the star shines at minimum or maximum light, it stays within naked-eye range. But W Boötis easily escapes notice because it lies only 40' southwest of brighter Izar, which can easily steal our eyes' attention. Besides, the variable comes to "light" only by using averted vision, especially when it's dimmest.

That said, I'd love to learn how many observers can see W Boötis by directly gazing at it (using the eyes' central cone cells rather than their peripheral rod cells). It's an ongoing project of mine to test the limits of stargazing using direct vision. The power of night vision can vary not only with individual eyesight but also with one's observing experience and sky conditions; any light pollution or atmospheric contaminants will diminish your chances.



Stephen James O'Meara

Izar (Epsilon [ε] Boötis) is a fascinating binary star that offers a test for those using small telescopes. In 1829, Friedrich G. W. Struve honored Izar with the title *Pulcherrima* (the most beautiful one), owing to its contrasting colors. The author saw the primary as lemon yellow and its companion as a sooty green.



Damian Peach

Izar appears to have a companion in W Boötis, a semiregular variable star lying only 40' away; in fact, almost 700 light-years separate the two.

Izar, W Boötis, and nearby Arcturus are all relatively prominent within Boötes the Herdsman, given a dark enough sky to serve as a backdrop. Bill and Sally Fletcher

Still, I'd love to hear what you see (or don't see). In January 2008, I detected W Boötis with direct vision when, according to Elizabeth Waagen at the American Association of Variable Star Observers, the star's magnitude was about 5.1.

Izar's other buddy

Although Izar and W Boötis lie close together in our perceived two-dimensional sky, they are not physically related. Izar lies at a distance of about 200 light-years, while W is nearly 4.5 times farther away. Like marigold-colored Arcturus (Alpha [α] Boötis), the brightest star in the north celestial hemisphere, Izar is a full-fledged K-type orange giant. However, I find Izar looks more lemon yellow than golden through my 5-inch f/5.2 Tele Vue refractor; W Boötis, on the other hand, shines like a warm golden flame.

And do turn your telescope to Izar because it has a beautiful telescopic companion: a magnitude 5.1, A-type main-sequence dwarf. The two stars are 2.6" apart, with a position angle of 343°; they orbit one another perhaps once every several thousand years.

Izar was one of many double stars that William Herschel discovered and monitored over the course of some 2 decades. In an 1803 paper, Herschel noted that changes in the relative positions of these pairs (including Izar) proved that many are "not merely double in appearance, but must be allowed to be real binary combinations … held together by the bond of mutual attraction."

John Chumack

Arcturus (Alpha [α] Boötis) is its constellation's (and the north celestial hemisphere's) brightest star. Despite being the same spectral class as Izar (a K-type orange giant), the author perceives the two as noticeably different colors.

Splitting Izar has been considered a "test" for beginners with apertures up to 6 inches. Nevertheless, the experienced 19th-century British observer Rev. Thomas W. Webb saw it "perfectly" with a 2¼-inch refractor. The key to success is to observe on a night of good seeing (one with bright moonlight or in the twilight), exercise patience, and use sufficient magnification.

For instance, on the morning of January 23, 2011, Izar boiled madly when I looked at it through my 5-inch scope. In the turbulent air, the star's disk swelled and contracted so violently that I had difficulty keeping the star in focus. Yet, during fleeting moments of atmospheric stability, Izar's yellow disk suddenly appeared to have a slight discolored bump that popped in and out of view with the seeing at 229x. Although I did not split Izar, I could at least suspect a companion.

As dawn approached and the seeing steadied, Izar's companion revealed itself stunningly at powers of 165x and 330x. Once I knew where to look, I could also separate the two stars at powers as low as 94x. I could not convince myself of the star's duplicity at 60x, however.

Worlds apart

More than 2 centuries ago, Herschel penned that Izar "has much the appearance of a planet and its satellite, both shining with innate but different light." Indeed, my first impression of the pair was one of a distant Sun-like star with a wondrous water-world orbiting it. And I'm not alone: The late astronomy popularizers Agnes Clerke and Camille Flammarion described the primary as "chrome yellow" and "bright yellow," and the secondary as "sea-water blue" and "marine blue," respectively.

Is it surprising then that, in the early 1970s, Scottish science-fiction writer Duncan Lunan caused an international commotion when he claimed to have translated signals from a spacecraft sent to the Moon in the 1920s by the inhabitants of a planet orbiting Izar? Lunan's translation of the alien message begins: "Our home is Epsilon Boötis, which is a double star." Among other media, the story made it to the *CBS Evening News* and *Time* magazine. Although Lunan has since withdrawn most of this idea, it remains a testament to the power and intrigue of this amazing star.

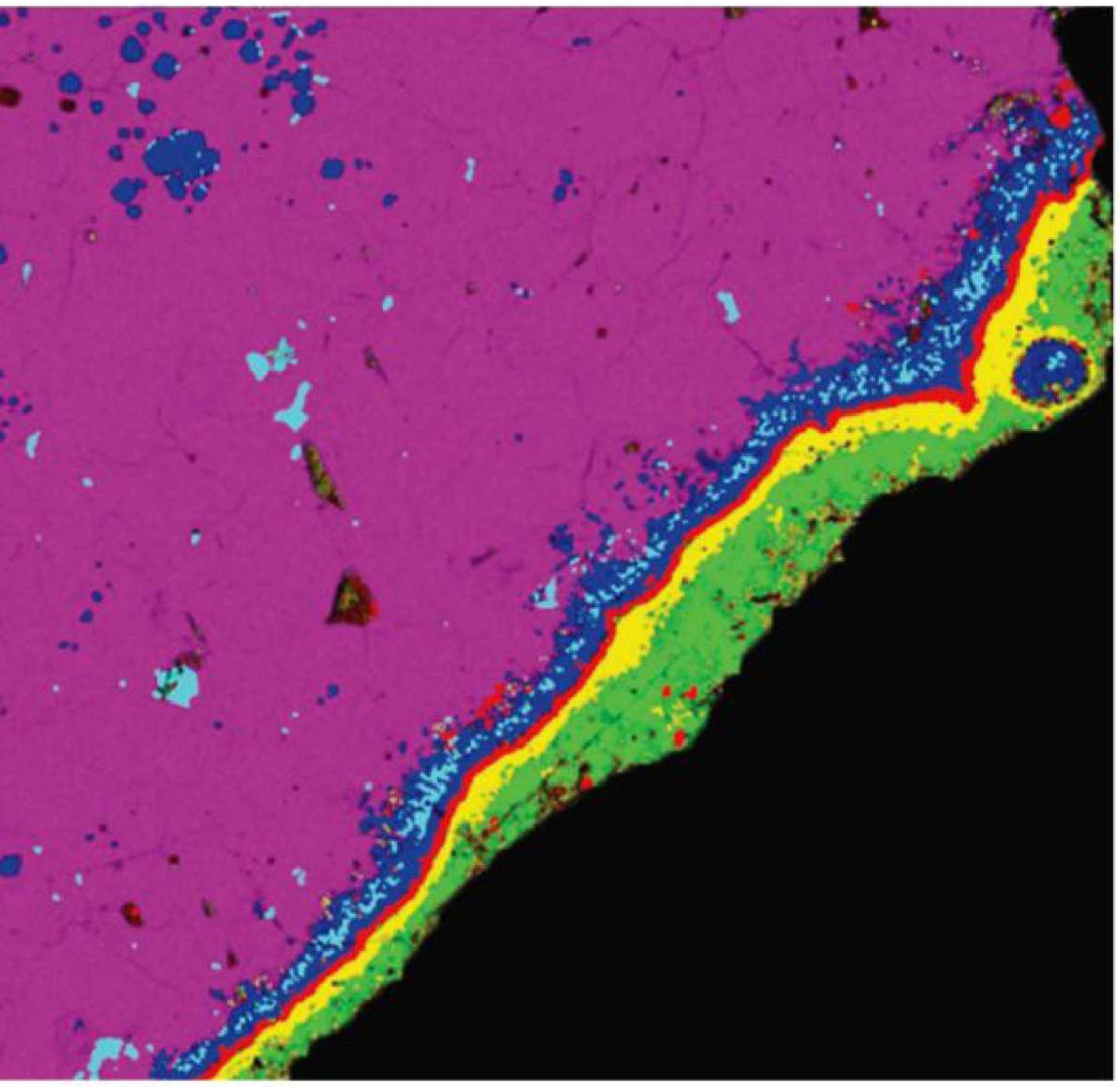
As always, send your thoughts and reports to someara@interpac.net.

Browse the "Secret Sky" archive at www.Astronomy.com/OMeara.

Survey says On March 8, the American Astronomical Society's Division for Planetary Sciences endorsed the decadal survey recommendations outlining the most significant priorities in planetary sciences.

For the latest news on space discoveries, spacecraft missions, and sky events, visit **Astronomy.com/news**

Astronews



Telling rock. You can see different layers of a meteorite in this false-color X-ray image. Scientists probed them to determine oxygen abundances, and thus the locations this meteorite once traveled through. Erick Ramon and Justin Simon

Meteorite holds hints of solar system formation

Planetary scientists say analysis of a pea-sized meteorite reveals that our solar system's formation was complex and small particles likely traveled through varying environments during the planet-forming era. The findings appeared in the March 4 issue of *Science.*

Justin Simon of NASA's Johnson Space Center in Houston, Texas, and colleagues investigated micrometer scales to learn about the oxygen composition of the meteorite. The abundance of oxygen isotopes varied at different locations in the Sun's pre-solar nebula.

In particular, they probed one of the meteorite's inclusions, called a calcium-aluminum inclusion (CAI). Data from the object's core, layers, and rim told the scientists that the grain likely formed near the Sun, was thrown out to the planet-forming region, and then either that region's composition changed or the object was tossed back toward the Sun.

Simon and colleagues plan to study additional CAIs with the same tool (a microprobe) to see if other meteorites show similar oxygen abundances. The grain they analyzed in the *Science* study was a piece of the Allende meteorite, which fell to Earth in February 1969. It broke up in the atmosphere and showered the ground in the state of Chihuahua, Mexico, with thousands of pieces. — **LIZ KRUESI**

Latest Mars images reveal oval-shaped crater

The European Space Agency's Mars Express has again spotted an odd feature on the Red Planet's surface: an elongated impact crater, as yet unnamed, lying south of the southern hemisphere's Huygens Basin.

The odd shape likely results from multiple projectiles impacting the planet at a shallow angle. The presence of smaller craters nearby suggests a relatively old age for the elongated crater; small channels hint at an impact long enough ago to affect a volatile surface (perhaps due to water) that melted because of the projectiles' heat.

The crater measures some 48 miles (78 kilometers) in length, varies in width from 6 miles (10 km) to 16 miles (25 km), and reaches depths of 1.2 miles (2 km). — **BILL ANDREWS**

Elongated excision. A long oval-shaped crater on Mars indicates that multiple impactors hit the Red Planet at a shallow angle. ESA/DLR/FU Berlin (G. Neukum)

Dark energy beats out rival bubble theory

NASA/ESA/A. Riess (STScI/JHU)/L. Macri (Texas A&M University)/Hubble Heritage Team

Space's speedometer. Spiral galaxy NGC 5584, captured in this Hubble image, contains various Cepheid variable stars and a recent type Ia supernova. Using such objects from this galaxy and seven others, astronomers measured the expansion rate of the universe precisely enough to rule out an alternative to dark energy.

A more accurate measurement of the universe's expansion speed has eliminated a possible theoretical alternative to dark energy, according to an April 1 paper in *The Astrophysical Journal.*

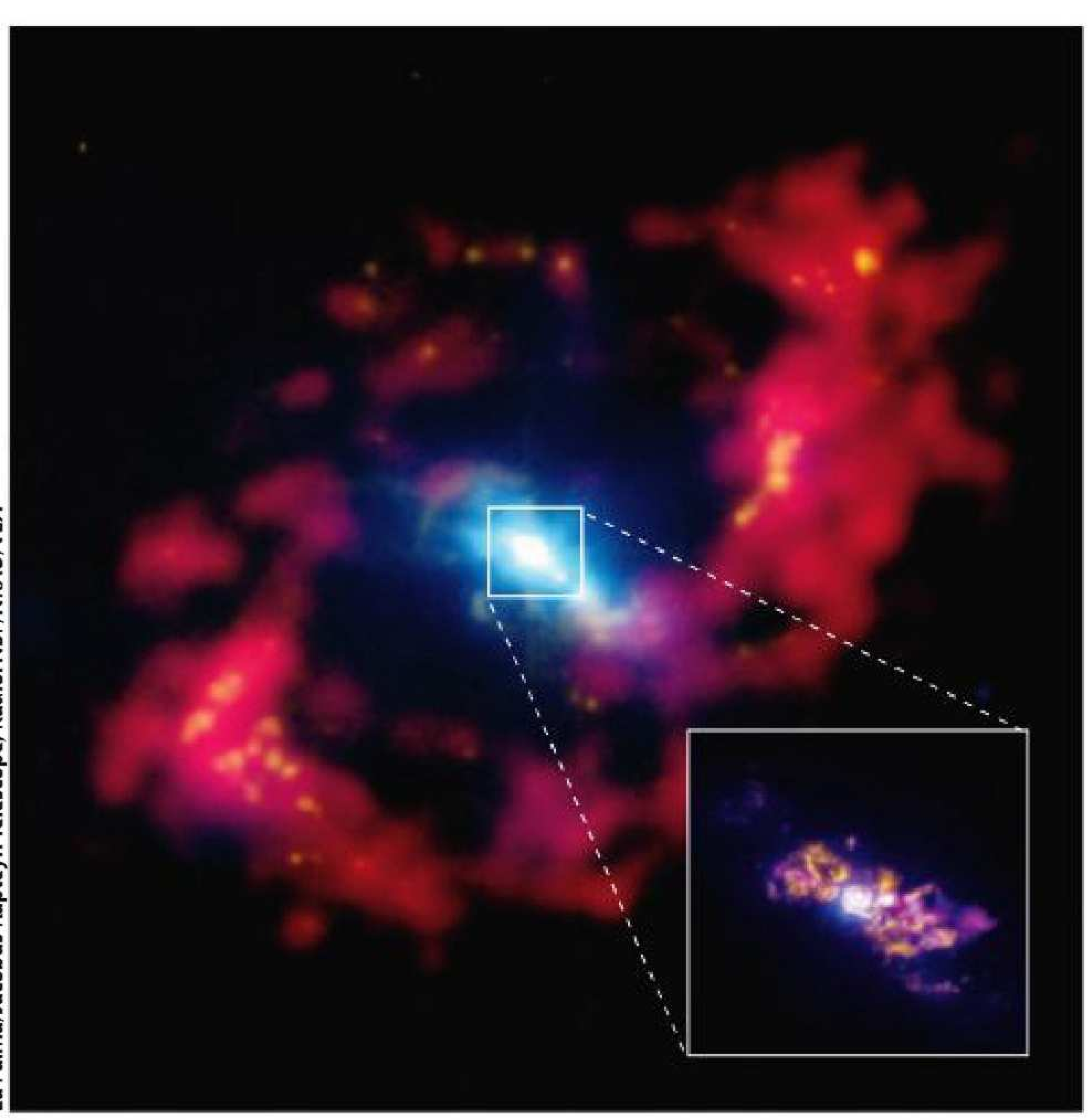
Astronomers realized late last century that the universe's expansion rate was increasing instead of slowing down as they expected. To explain this, they theorized that an unknown force, called dark energy, fills the universe and somehow pushes it apart. An alternative theory suggested that a gigantic bubble of relatively empty space may surround our galactic neighborhood; if this bubble expands faster than the rest of the universe, it would appear to observers on Earth that the entire universe experienced an accelerating expansion.

But the new research, led by Adam Riess of the Space Telescope Science Institute in Baltimore, Maryland, invalidates the bubble theory. Riess' team used Hubble's sharpest cameras to study Cepheid variable stars and type Ia supernovae (two well-known types of objects that allow astronomers to calculate galactic distances); they eventually came up with an expansion rate with an uncertainty of just 3.3 percent.

The new value measuring the universe's expansion is 45.9 miles (73.8 kilometers) per second per megaparsec. This means that for every million parsecs (1 parsec = 3.26 light-years) a galaxy lies away from us, it will appear to be receding 45.9 miles (73.8 km) per second faster. The bubble theory required the expansion rate to be significantly slower, around 37 to 40 miles (60 to 65 km) per second per megaparsec.

"We are using … Hubble like a policeman's radar gun to catch the universe speeding," Riess says. "It looks more like it's dark energy that's pressing the gas pedal." — **B. A.**

A galaxy's black (hole) eye



X-ray: NASA/CXC/CfA/J. Wang, et al.; Optical: Isaac Newton Group of Telescopes, La Palma/Jacobus Kapteyn Telescope; Radio: NSF/NRAO/VLA

Here's looking at you. Spiral galaxy NGC 4151 hosts an actively feeding supermassive black hole at its center. As the black hole's intense gravity draws nearby gas closer, this material forms into a disk. Friction in the disk leads to radiation ranging from radio (in red) to optical (yellow) to high-energy X-rays (blue). The yellow blobs are star-forming regions. This galaxy lies some 43 million light-years from Earth in the constellation Canes Venatici. Astronomers using NASA's Chandra X-ray Observatory released this multiwavelength view of NGC 4151 March 10. — **L. K.**

QUICK TAKES

NO GUTS …
NASA's Glory mission, meant to study Earth's climate, failed to reach orbit after its March 4 launch, for still-unknown reasons.

MRO AND CO_2
NASA announced March 8 that its Mars Reconnaissance Orbiter detected carbonate minerals deep within craters, indicating where the Red Planet's "missing" carbon dioxide may have gone.

WAY TO GO MRO
On March 10, NASA's Mars Reconnaissance Orbiter celebrated its fifth anniversary orbiting the Red Planet.

MANTLE PIECE
Scientists argue that drilling into Earth's mantle may be possible in a paper in the March 24 issue of *Nature*.

COOL STAR
An upcoming paper in *The Astrophysical Journal* will announce that a brown dwarf known as CFBDSIR 1458+10B, whose surface is only about as hot as boiling water, may be the coldest starlike object known.

MAP OF THE MOON
NASA's Lunar Reconnaissance Orbiter team released the fifth and final set of data from the mission's exploration phase March 15, including a global Moon map with a resolution of 100 meters per pixel.

SOLAR SIMULATIONS
Computer simulations indicate that the reason behind the Sun's unexpectedly long quiet spell may be changing flows of hot plasma inside it, according to a March 3 paper in *Nature*.

SENIOR GALAXY CLUSTER
Research in the February issue of *Astronomy & Astrophysics* suggests that the most distant galaxy cluster known, whose light from its early youth only now reaches Earth, seems remarkably developed and mature.

IN MEMORIAM
Leif J. Robinson, former editor in chief of *Sky & Telescope*, passed away February 27 at the age of 71.

IN MEMORIAM
Edward A. Halbach, founding member of the Milwaukee Astronomical Society and first president of the Astronomical League, passed away March 20 at the age of 101.

Jeffrey Bada, Robert Benson (Scripps Institution of Oceanography, University of California, San Diego)

Smelly science. Recent analysis of an old experiment containing the pungent gas hydrogen sulfide reveals how early combinations of primordial gases on Earth may have eventually led to life.

Old experiment leads to new insight into early life

Stanley Miller may not be a household name, but his seminal research in 1953–54 helped show how elements in Earth's primordial atmosphere might combine to form amino acids, precursors of biological material. Now, more than 50 years later, scientists have found even more dramatic results hiding within a forgotten sample of Miller's experiments. The research appeared in the March 21 online early edition of the *Proceedings of the National Academy of Sciences*.

Miller's experiments consisted of sending a jolt of electricity through the most likely gases in Earth's early atmosphere, within sealed containers. In the recently discovered sample, scientists found amino acids containing sulfur for the first time in any such experiment. "Much to our surprise, the yield of amino acids from Miller's [forgotten] experiment is a lot richer than that from any other experiment he had ever conducted," says Jeffrey Bada of the University of California, San Diego, a co-author and former student of Miller.

Unlike most of Miller's known experiments, the recently found sample used hydrogen sulfide, the chemical behind the pungent aroma of rotting eggs. It's unknown why Miller never reported these findings, but perhaps it had to do with the upsetting odor. "Stanley mentioned to several of us that he hated working with hydrogen sulfide because it smelled so bad and tended to make him sick," says Bada. — **B. A.**

SPACE SCIENCE UPDATE

MESSENGER arrives at Mercury

On March 17, the MESSENGER (MErcury Surface, Space ENvironment, GEochemistry, and Ranging) mission entered orbit around Mercury, beginning a yearlong science mission. This is the first spacecraft to orbit our innermost planet, and one of its goals is to gather data about regions not seen by previous flyby missions, specifically the poles.

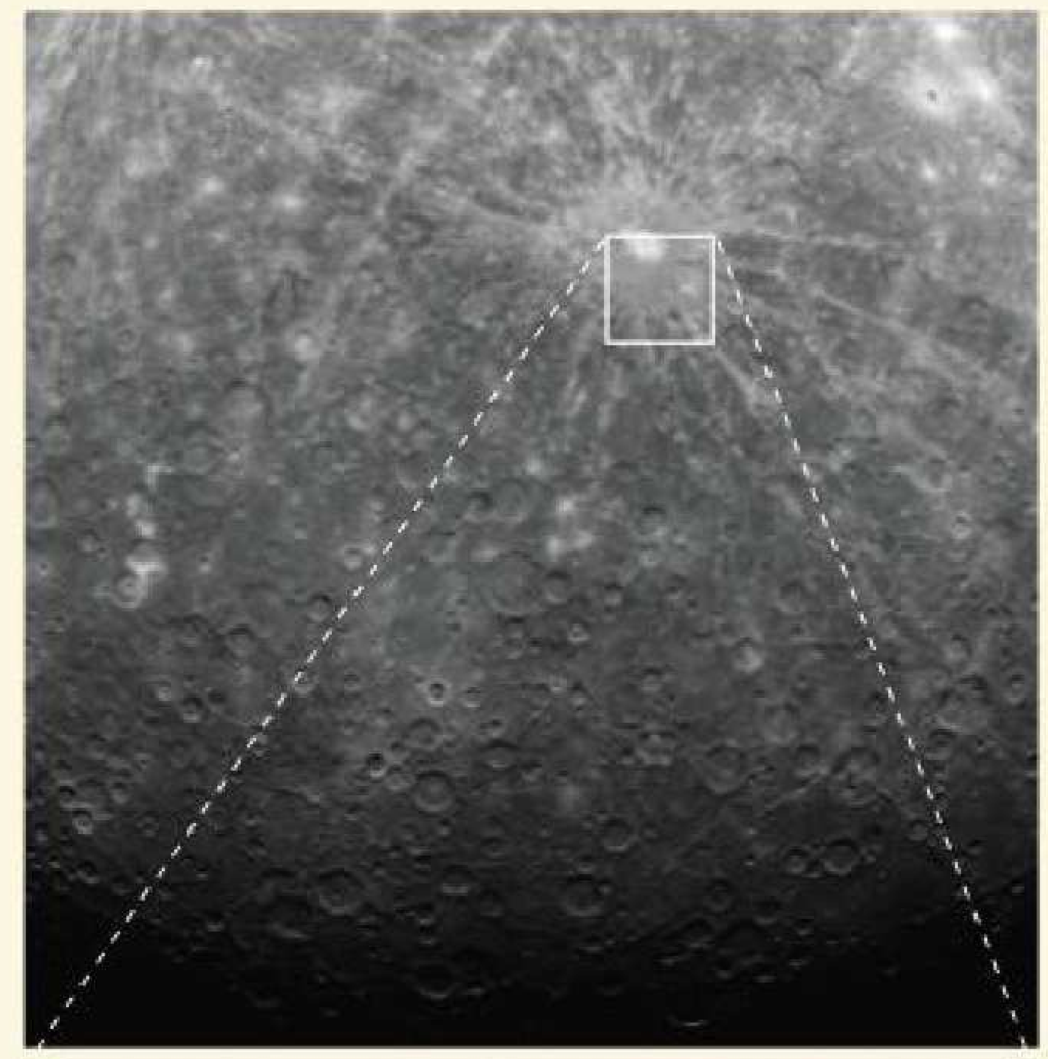
Prior to orbiting Mercury, the craft flew by the planet three times — January and October 2008 and September 2009 — to gather data and tweak its trajectory.

MESSENGER's orbit around the innermost planet is highly elliptical, bringing it just 129 miles (207 kilometers) above the surface at the nearest point and about 9,300 miles (15,000 km) at the farthest point. The spacecraft completes two orbits per Earth day.

Scientists estimate the probe will acquire some 80,000 images over its yearlong mission. They released the first image from MESSENGER's new orbit March 29, and during the first 3 days of data collection (March 29–31), they acquired 1,500 images.

The spacecraft has eight instruments in addition to its imaging system. Scientists have already started acquiring topographic profiles of Mercury, which tell them about geological features at large scales down to individual craters. They've also started to map Mercury's magnetic field. Scientists don't understand why this planet has a magnetic field; it should have disappeared long ago, like that of Mars.

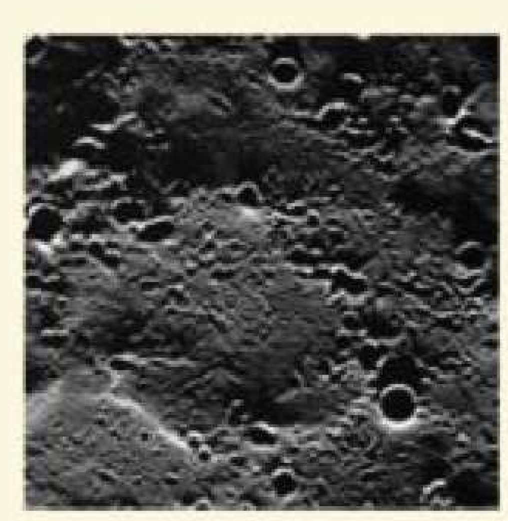
Expect a lot more data — images and otherwise — to come from the MESSENGER mission over the next year. — **L. K.**



All images: NASA/Johns Hopkins University Applied Physics Laboratory/Carnegie Institution of Washington

Mercury first. MESSENGER's wide-field image (top) of Mercury's Debussy Crater is the first obtained from a spacecraft in orbit around the innermost planet. The probe's Narrow Angle Camera captured a more detailed image of the same crater and its emanating rays.

Seeing color. This wide-angle image (spanning 320 miles [510 km]) shows different compositions in Mercury's surface material. The camera used three of its 11 filters to take this image. (The wide-angle camera can image through 11 filters across the range of visible to near-infrared radiation.) Scientists combined data taken at 1,000 nanometers (red), 750nm (green), and 430nm (blue) to create this false-color image.



Cratered world. MESSENGER is the first spacecraft to image this region at Mercury's extreme northern latitudes. The many secondary craters come from ejecta of a large impact (the crater lies out of the field of view). This image spans 52 miles (84 km) across.

Smooth plain. Not all of Mercury is heavily cratered; ridges also run along the surface. This image, which spans about 60 miles (100 km), shows terrain near the planet's north polar region. MESSENGER took this image at 280 miles (450 km) above the surface.

Model black holes

A *Physical Review Letters* paper appearing online March 1 reported how physicists can exploit the oddities of a charged black hole to model the behavior within the latest superconductors.

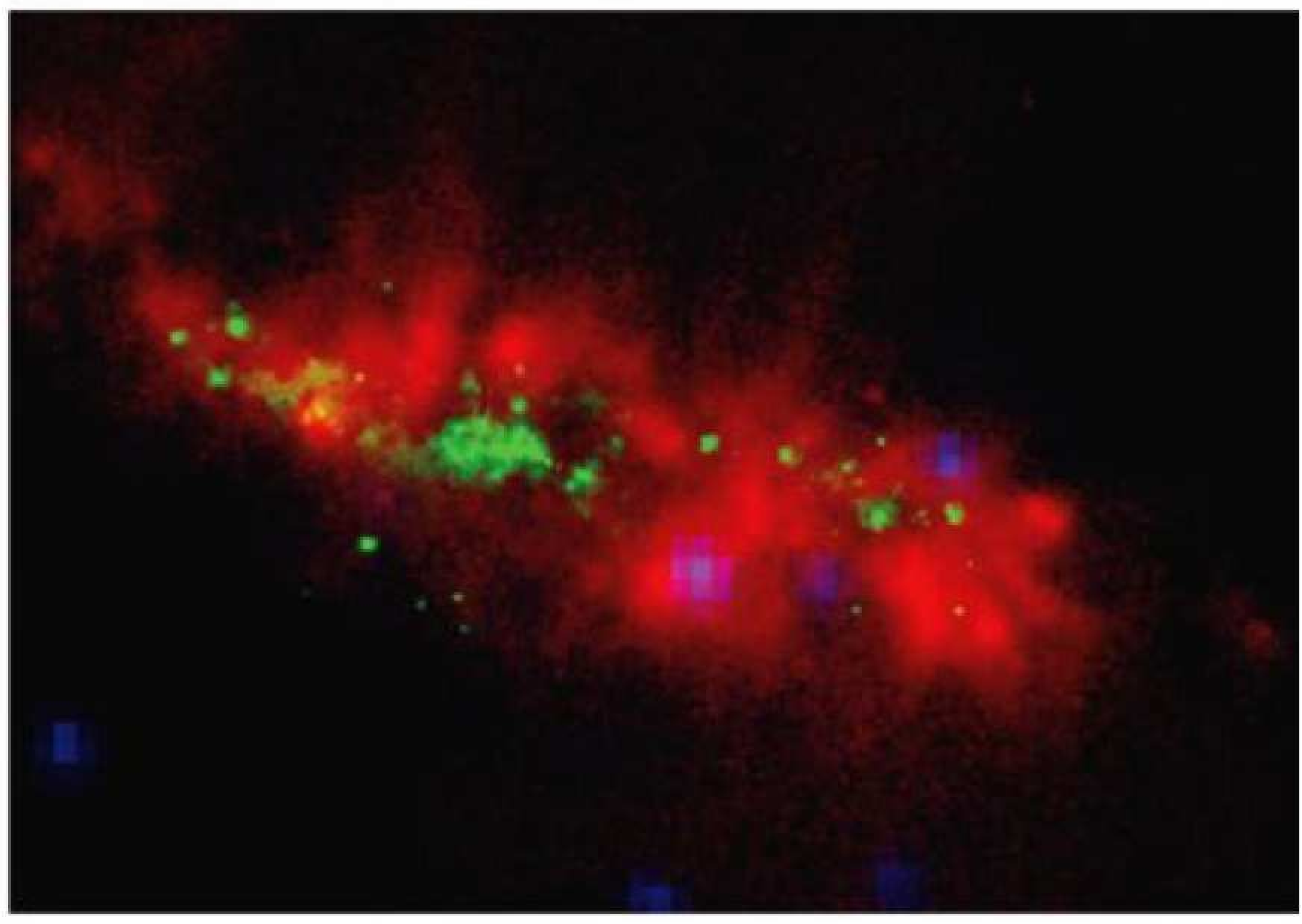
A cosmic-ray surprise

High-energy particles called cosmic rays bombard our planet constantly; most are protons and helium nuclei. Scientists had thought the same process accounted for the high energies of both types of particles, but new findings show these particles' energies differ from each other.

These cosmic rays have a magnetic charge, so magnetic fields can alter their course as they travel through interstellar space. This makes it difficult to track where the particles originated. However, because of their high energies, cosmic rays must result from a powerful event, like a supernova. The leading theory states that shock waves in the supernova accelerate particles to extreme speeds, and then they enter the interstellar medium and eventually end up at detectors.

Astronomers now say, however, that this relatively "simple" method of accelerating cosmic-ray particles can't account for new findings. An international group of scientists using data collected over 3 years from the Payload for Antimatter Matter Exploration and Light-nuclei Astrophysics (PAMELA) has found that protons and helium nuclei have different spectral signatures. Such differences indicate that the same process can't accelerate the particles to observed energies. This result appeared online March 3 in *Science* Express. — **L. K.**

Galactic detail seen in infrared image



Teeming galaxy. Scientists have imaged the inner 2,000 light-years of starburst galaxy M82 in near-infrared wavelengths and discovered sources of M82's superwind. This false-color composite shows the Subaru mid-infrared data (red), near-infrared data from the Hubble Space Telescope (green), and X-ray data from Chandra (blue). Subaru Telescope Facility

Astronomers have used an infrared telescope to peer into the central region of Messier 82 to image young star clusters and the source of the starburst galaxy's superwind. The scientists released images taken with the Subaru Telescope March 7, and the findings appeared in the March 28 issue of the *Publications of the Astronomical Society of Japan*.

M82 forms stars at a much faster rate than typical galaxies (like our Milky Way). Earlier generations of stars have since died, spewing dust and gas into the interstellar medium. This material blocks the view into the galaxy at visible wavelengths, but infrared radiation can penetrate the dust. The superwind also radiates in the infrared. "The wind is found to originate from multiple ejection sites spread over hundreds of light-years rather than emanating from any single cluster of new stars," says lead author Poshak Gandi of the Japan Aerospace Exploration Agency. "We can now distinguish 'pillars' of fast gas, and even a structure resembling the surface of a 'bubble' about 450 light-years wide."

The observations from the Subaru Telescope are the most detailed in infrared wavelengths yet of the starburst galaxy. — **L. K.**

ESO/Sergey Stepanenko

Young stars alter their surroundings

Stellar gusts. Baby stars blow off jets of material and radiation that then interact with nearby gas and dust. The arcs and blobs in this image of a section of the nebula NGC 6729 result from these interactions. Although astronomers can't see the fledgling suns through the interstellar material, they know these objects exist because of the resulting shapes they create. The European Southern Observatory (ESO) released this image from the Very Large Telescope March 16. It combines information from hydrogen (orange) and sulfur (blue) emissions. This image is a result of the "Hidden Treasures" competition, where amateur astronomers scoured ESO's data and compiled and processed files to bring out never-before-seen details. — **L. K.**

Astronews

Methane rain NASA's Cassini probe spied evidence of a spring rain of methane falling on dunes near the equator of the saturnian moon Titan, according to a March 18 paper in *Science*.

BRIEFCASE

Mapping a monster

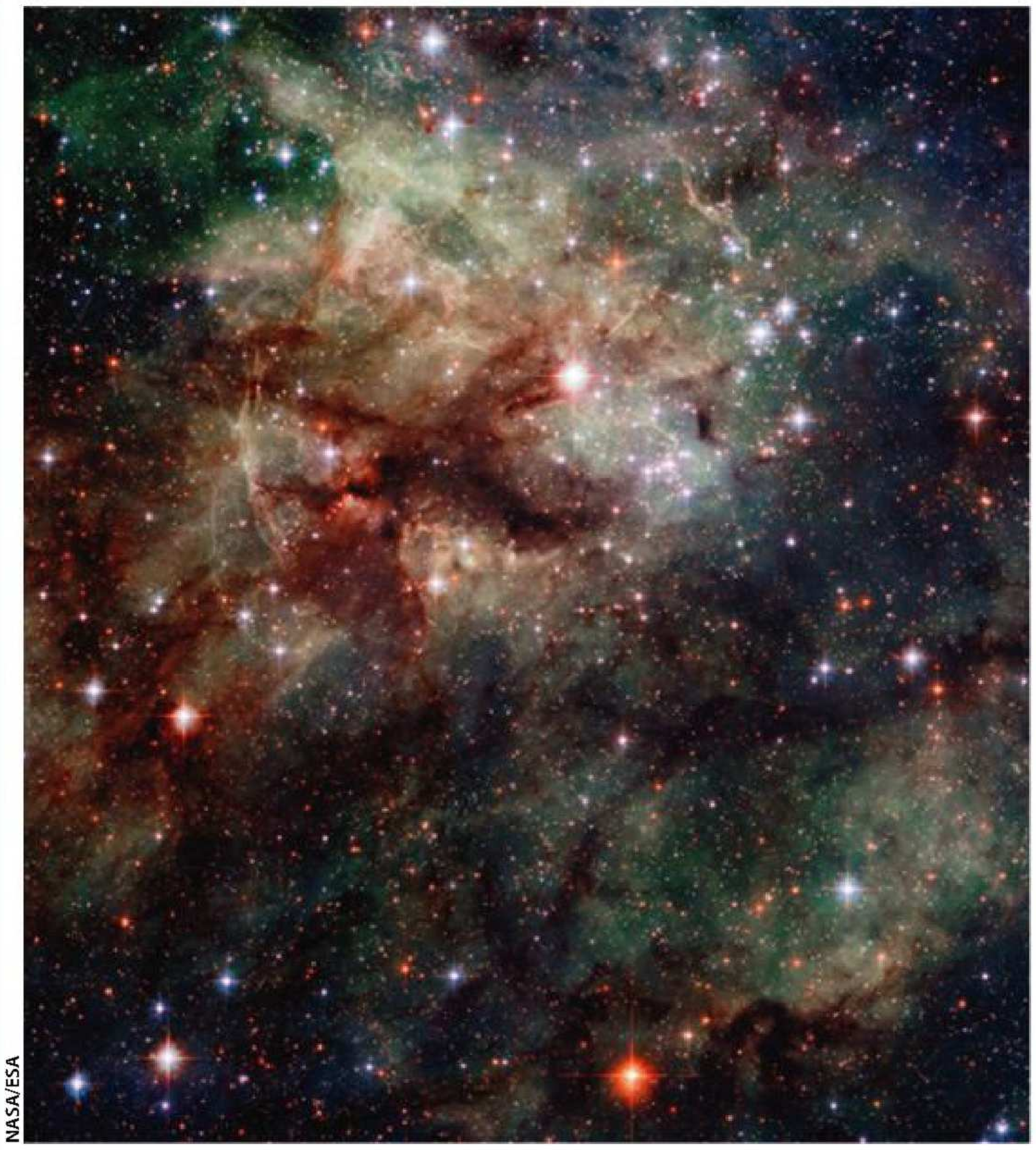
New data from the Suzaku X-ray observatory have allowed scientists to more accurately determine the size, mass, and chemical content of the Perseus galaxy cluster. Located about 250 million light-years from us, this cluster spans some 11.6 million light-years and contains more than 660 trillion solar masses of material. While gas is smooth at the center, it clumps near the cluster's edge. These findings appeared in the March 25 issue of *Science*. — **L. K.**

Stardust-to-dust

NASA's Stardust (and Stardust-NExT [New Exploration of comet Tempel 1]) mission sent its last transmission to scientists and officially ended operations March 24 at 7:33 P.M. EDT. The spacecraft collected and returned to Earth material from Comet 81P/Wild in addition to completing a recent flyby of Comet 9P/Tempel. The craft burned all of its remaining fuel so that mission scientists could assess the accuracy of their fuel-consumption models. Such spacecraft don't have fuel gauges to tell scientists how much remains. Stardust's fuel burn lasted for 146 seconds. — **L. K.**

Red giants sing a new tune

Astronomers can differentiate between red-giant stars using data from the Kepler mission. By analyzing stellar brightness oscillations, scientists learn about a star's density and chemistry. These brightness fluctuations also can show whether the star is burning hydrogen or helium in a shell surrounding the core and, therefore, what evolutionary stage the star is in. These findings appeared in two recent papers: March 17 in *Science* Express and March 31 in *Nature*. — **L. K.**



NASA/ESA

Hubble inspects spacey spider

Terrific Tarantula. Unlike the close-up shots of actual arachnids, which show off details most people would rather forget, this recent Hubble photo scrutinizes a portion of the Tarantula Nebula (NGC 2070) with much more pleasing results. Released March 15, the image homes in on the central area of the nebula, a giant cloud of gas and dust residing within our galactic neighbor the Large Magellanic Cloud. The bright glow comes from ionized gases and young stars in the region. — **B. A.**

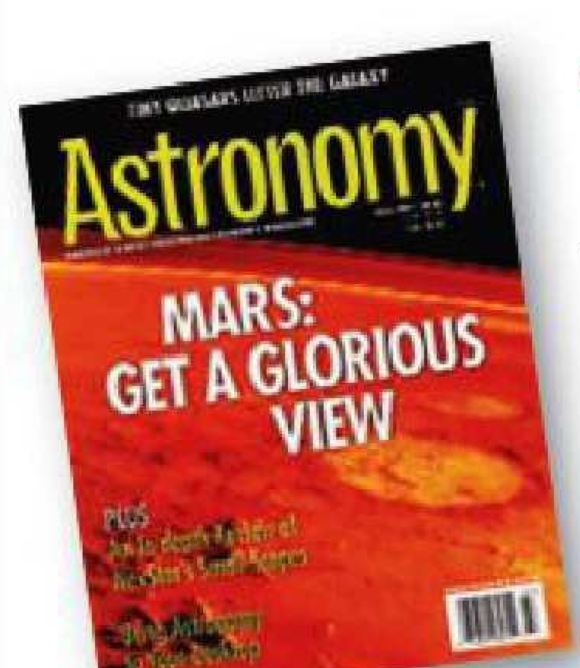
25 years ago in *Astronomy*

July 1986

In the July 1986 issue, science writer Ken Croswell took an in-depth look at what was then the farthest and smallest planet in the solar system in "Pluto: Enigma on the Edge of the Solar System." Taking advantage of the tiny world's temporary closeness to the Sun, and the edge-on orbit of its closest moon, Charon, astronomers were just starting to understand some of the mysterious destination's secrets.

"Imagine a world so far from the Sun that sunlight is nine hundred times fainter than it is on Earth," Croswell began, before describing more of Pluto's most likely attributes. Of course, in 2006 the International Astronomical Union voted to demote Pluto to "dwarf planet" status, a decision that remains controversial today, but which Croswell anticipated. "Is Pluto a Planet?" a subhead asked. Croswell's simple response: "No."

10 years ago in *Astronomy*



July 2001

The July 2001 issue featured astrophysicist Mark Sincell's profile of the latest craze in amateur astronomy: using a personal computer to make discoveries from the image archives of professional observatories. "Cybertrackers" began with the story of Michael Oates, an amateur astronomer from England who'd discovered more than 100 comets, a world record. "Despite his accomplishments, Oates is not paid by ESA or NASA," Sincell wrote. "He doesn't publish his results in scientific journals. He is not even a professional astronomer."

Nowadays, the article's tone of restrained shock may seem quaint. Citizen science projects like Galaxy Zoo and SETI@home have allowed interested amateurs to contribute meaningfully to astronomy from the comfort of their own desktops. But, 10 years ago, in the wild days of the Internet before Facebook and YouTube, and before anyone knew what "citizen science" was, many tech-savvy volunteers began this tradition for no other reason than their love of the science. And, of course, for what Sincell called "the most compelling reason of all": the chance to study the stars indoors. — **B. A.**

2010 Astronomy magazine Out-of-this-world public program

Astronomy announces 2010 Out-of-this-world Award winner

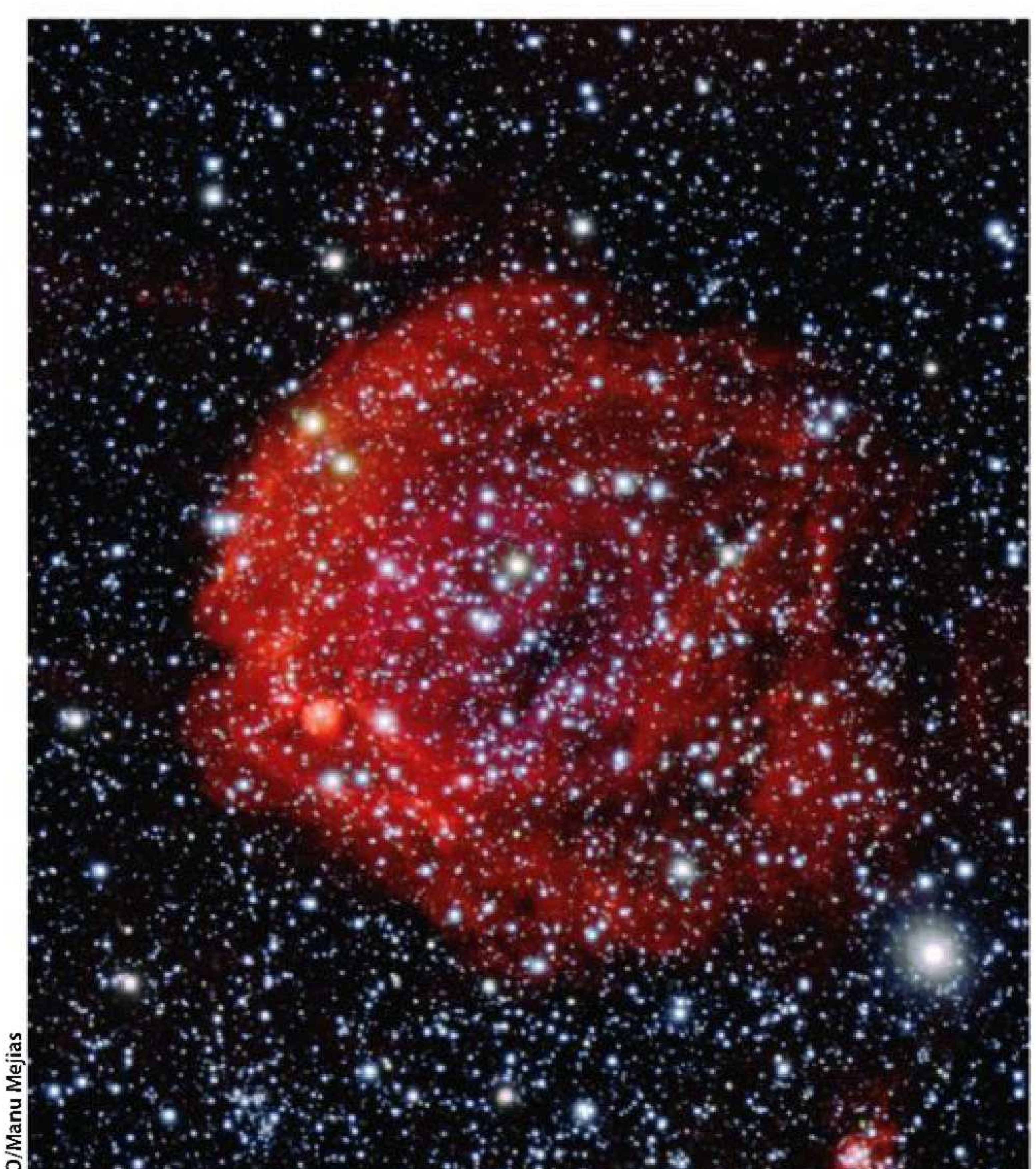
Astronomy magazine has chosen the Santa Barbara Astronomical Unit (SBAU) as the winner of its 2010 Out-of-this-world Award for outstanding programming.

SBAU separated itself from the pack with its extensive, almost prolific, outreach programs, which have provided more than 16,000 individuals personal access to telescopes, information, and friendly, helpful people. Whether through its monthly public star parties, regular visits to schools, or even assisting fledgling astronomy clubs, the group has gone out of its way to inspire everyone with the majesty and promise of the cosmos.

Well, not quite everyone: SBAU plans to use the award money on its "You Can See Too" (UC2) program, which caters specifically to the wheelchair-bound segment of the populace. Construction has already begun on a custom-designed UC2 scope, featuring a portable hydraulic lift system, so the SBAU can use it not only at public star parties, but also on trips to hospitals and nursing homes. Thanks to the $2,500 from *Astronomy* magazine to use toward its outreach activities, SBAU can continue to help more people fall in love with the sky.

Work on the scope is going well thanks to the group's members, according to SBAU President Ruben Gutierrez. "We have some great people here," he says, "and we've been very well received. It really is a cool club."

Astronomy's annual Out-of-this-world Award rewards ongoing programs sponsored by an educational or civic organization. SBAU is the fifth winner since the award debuted in 2006. More than 30 groups entered this year, from almost two dozen states and six countries.



ESO/Manu Mejias

Examining a colorful stellar nursery

Glowing gas. The European Southern Observatory released this image from the Very Large Telescope in Chile March 30. It shows off a breeding ground for young stars: the glowing hydrogen shell surrounding star cluster NGC 371 in the nearby Small Magellanic Cloud. The shell is all that remains of a larger, thicker cloud of hydrogen, from which the cluster's newest members formed. Their energetic emissions of ultraviolet light now hit the gas shell, causing it to light up so strikingly. — **B. A.**

Deep-space science

Spitzer's galaxy show

NASA's orbiting infrared scope has changed our understanding of individual galaxies, galaxy formation, and the universe's evolution.

by Robert Benjamin

If you had just 6 years to live, what would you do? Spend quality time with family and friends? Travel the world to see all that our great, but tiny, planet has to offer? Would you open up a new window to the universe?

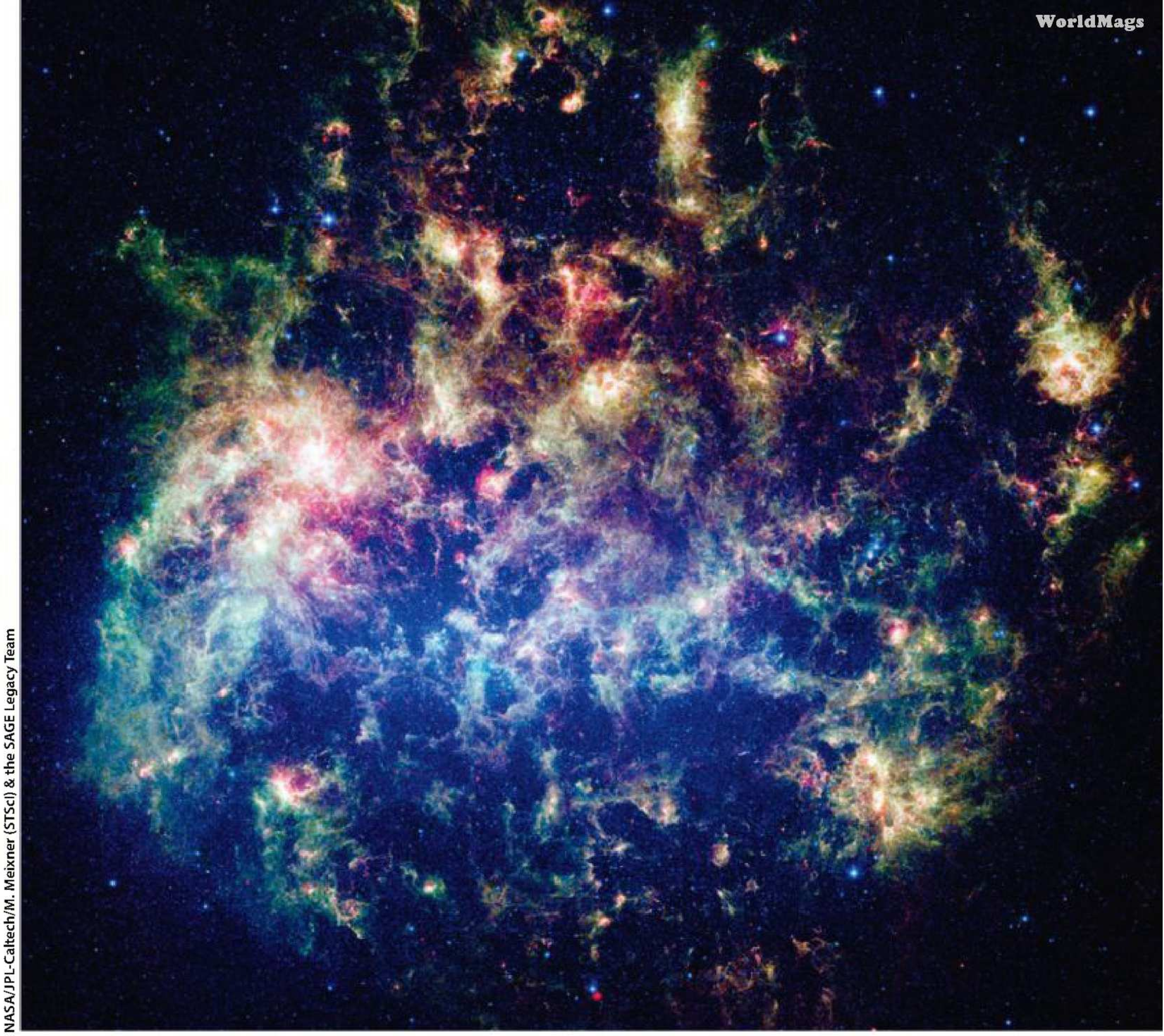
That's just what the Spitzer Space Telescope did from 2003 to 2009. Moreover, during its travels, Spitzer sent back "postcards" by the millions. They depicted all sorts of exotic locations: NGC 891 ("Wish you were here — reminds me of home"), II Zw 096 ("Odd, but exciting!"), M101 ("Harsh here in the outback"), to name a few. Images even arrived from unexpected places, like the Milky Way's center ("Brilliant!"). This correspondence taught us much, particularly about the surprising diversity of galaxies in the universe.

Spitzer is part of a quartet of telescopes in NASA's Great Observatories program, each tuned to see a different wavelength of light. The most well-known of them is the Hubble Space Telescope, which continues to use visible light to produce beautiful images of unparalleled sharpness. Next, the Compton Gamma-ray Observatory sought out the highest-energy emissions from sources across the universe. The Chandra X-ray Observatory probes the high-energy X-ray emission emitted by million-degree plasma from stars, nebulae, and galaxies.

Spitzer's forte is the infrared. The orbiting telescope was built with one detector to obtain precise measurements of light's characteristics, or spectra, called the Infrared Spectrometer (IRS). Two other detectors designed to obtain images joined it: the shorter wavelength Infrared Array Camera (IRAC) and the longer wavelength Multiband Imaging Photometer for Spitzer (MIPS). To function, two of these detectors require liquid helium cooling to minimize the infrared light produced by the telescope and therefore "see" the faintest sources. Launched August 25, 2003, Spitzer's race against time was to observe as much as it could before the liquid helium ran out on May 15, 2009.

◀ **The Spitzer Space Telescope is not only capable of helping create beautiful pictures, like this one of the Whirlpool Galaxy (M51), but it also has provided some of the most important findings in galactic astronomy of the past decade.**

X-ray: NASA/CXC/Wesleyan Univ./R.Kilgard, et al.; UV: NASA/JPL-Caltech; Optical: NASA/ESA/S. Beckwith & Hubble Heritage Team (STScI/AURA); Infrared: NASA/JPL-Caltech/Univ. Arizona/R. Kennicutt



NASA/JPL-Caltech/M. Meixner (STScI) & the SAGE Legacy Team

This Spitzer image of the Large Magellanic Cloud shows off the cycle of star formation; astronomers used this to characterize the rate at which stars both form and die in this galaxy.

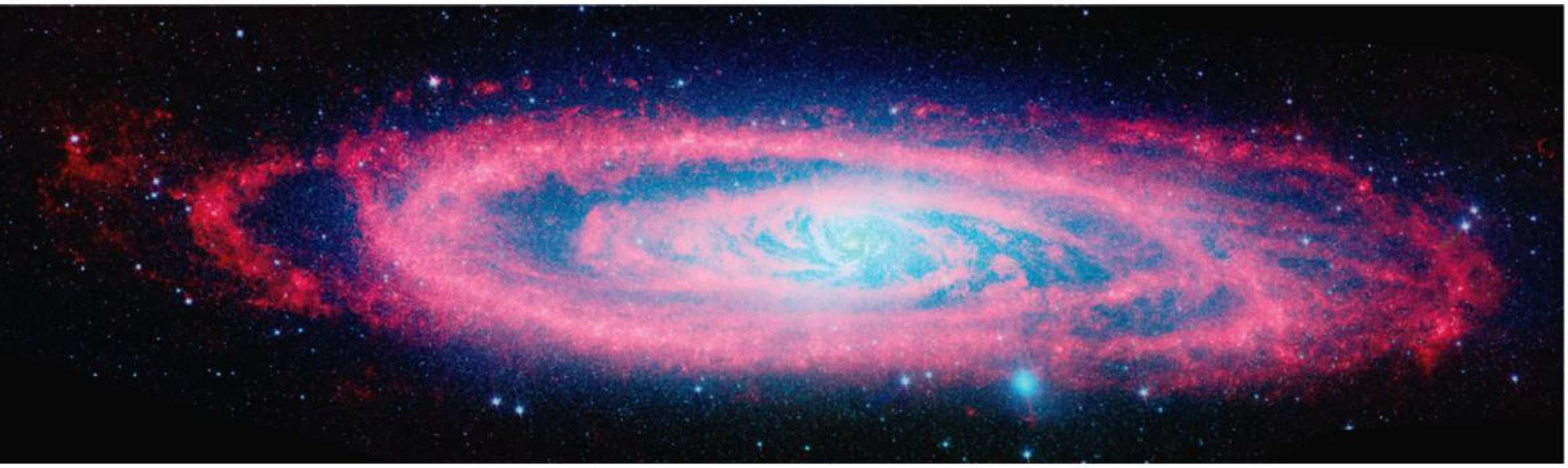
Infrared light and galaxies

Infrared light can loosely be thought of as "heat radiation." Objects that are warm — but not hot enough to glow visibly — will still shine in the infrared. Familiar technologies take advantage of this: TV remote controls send out infrared signals, and the military uses infrared light to search the sky for satellites. (You can paint a satellite black, but you can't hide the dull infrared glow its warm electronic components produce.) Your body also shines in the infrared, peaking in brightness at 10 microns (meaning the light's wavelengths crest ten millionths of a meter apart), with a power of 75 to 100 watts.

The importance of infrared wavelengths to astronomy is threefold. First, objects too cool to be visible in optical light, like certain dust clouds in which stars form, emit a detectable glow in the infrared. Second, when an object lies behind layers of material, it absorbs and scatters the optical light emitted by the object, while the longer infrared waves in this case penetrate through dusty layers. Thus, many objects invisible in optical light show up in infrared radiation. And third, many interesting interstellar atoms and molecules fluoresce (emit previously absorbed light) in the infrared. Detecting these emission lines allows astronomers to learn about the chemistry and velocities of the stars and gas in galaxies.

{ The Spitzer Space Telescope's race against time was to observe as much as it could before the liquid helium ran out on May 15, 2009. }

Most people think of galaxies as "stellar islands," congregations of billions of stars (about 200 billion in the case of the Milky Way) separated by the gulf of intergalactic space. But galaxies are much more than that! In spiral galaxies like ours, about 90 percent of the mass is likely in the form of dark matter, which scatters and absorbs no type of light (that we know of) and is observable only through its gravitational effects. Stars, gas, and dust make up the remainder, and most of the light we see from this component comes from hot young stars and old



NASA/JPL-Caltech/P. Barmby (Harvard-Smithsonian CfA)

Different wavelengths give different views of the Andromeda Galaxy (M31). Light at 3.6 and 4.5 microns (in blue) — where the light's wavelengths crest 3.6 and 4.5 millionths of a meter apart, respectively — shows off the old stars, while the 8.0-micron view (in red) traces a type of organic molecule.

red giants significantly more luminous than our Sun. Spitzer's infrared observations have unveiled the stars, the gas and dust, and even the dark centers of hundreds of galaxies.

Meet the neighbors

The Milky Way and the Andromeda (M31) galaxies are the two big spirals in an otherwise scruffy group of a few dozen galaxies creatively named the Local Group. The proximity of these galaxies to the Milky Way has made it possible for Spitzer to probe their distributions of stars and dust in detail, in order to develop a more complete picture of how these galaxies work.

One notable example is the Large Magellanic Cloud (LMC) — a dwarf galaxy about 160,000 light-years from the Sun. It was the target of a dedicated campaign led by Margaret Meixner of the Space Telescope Science Institute in Baltimore, Maryland. Spitzer observations have detected nearly one million previously hidden stars and show that the total mass of interstellar gas and dust in the LMC is about a billion times the mass of our Sun — almost twice as much material as astronomers had previously detected.

These observations also have allowed astronomers to measure two important rates: how fast gas and dust condense to form new stars (approximately 1 solar mass of material, the equivalent of our Sun, every decade), and how often dying stars feed new chemical elements and dust back into the nearby area (approximately 1 solar mass of material every 10,000 years). Because the LMC is incorporating gas into stars faster than it can replenish the material, the galaxy's star formation "engine" is clearly running down, assuming that no matter is fed into it. So enjoy the beautiful sight of the LMC while it lasts!

More intriguingly, Spitzer's view of the Andromeda Galaxy, about 2.5 million light-years from the Milky Way, is stunningly different depending on the choice of wavelength. At shorter infrared wavelengths, such as 3.6 and 4.5 microns, the IRAC image of Andromeda shows a disk, some spiral arms, and a pronounced central bulge of stars, all appearing smooth and uniform. The longer-wavelength view, at 8 to 24 microns, produces a completely different impression: lumpy, stringy, and filled with a rich variety of structures. Why the difference? The answer highlights one of Spitzer's greatest strengths: different wavelengths trace different components of a galaxy.

At the shorter wavelengths, most of the light comes from stars, principally red giants. Because many of these stars are old, their random motions over time smoothed out their distribution throughout the galaxy. On the other hand, at longer wavelengths, much of the light comes from clouds of gas and dust heated by young stars, showing just how clumpy galactic star formation is. One of Spitzer's greatest contributions is that it can see both the old stars, which trace the stellar mass of a galaxy, and the new regions of star formation at the same time, allowing scientists to more completely assemble the puzzle of how galaxies form.

"Nearby" galaxies

In the 20th century, anyone studying "nearby" galaxies — those beyond the

NASA/JPL-Caltech/STScI/H. Inami (SSC/Caltech)

When galaxies collide, they trigger star formation. Spitzer here captures the infrared light from the dense clouds formed during the collision of merging galaxies II Zw 096.

Robert Benjamin *is a professor of physics at the University of Wisconsin-Whitewater and part of the Spitzer GLIMPSE Legacy team, which provides infrared views of our Milky Way Galaxy.*

Local Group but still close enough to show clear structural details — would have to study a few sample galaxies in depth. But in the fast-paced 21st century, technology has improved considerably. Surveys of hundreds of galaxies have become the norm, and Spitzer was at the leading edge of this trend.

The Spitzer Infrared Nearby Galaxy Survey, headed by Rob Kennicutt of Cambridge University in England, gathered Spitzer observations and supporting data for a sample of 75 galaxies out to a distance of 98 million light-years. Next came the Spitzer Local Volume Legacy Survey, a complete sample of 258 galaxies within 36 million light-years. All told, during its 6-year lifetime, Spitzer observed about 600 nearby galaxies, ranging from small, irregular dwarfs to different classes of spirals, to giant ellipticals.

NASA/JPL-Caltech/K. Gordon (STScI)

This multiwavelength view of spiral galaxy M101 displays a distinct edge to the distribution of its molecules. Dust clouds appear in red, molecules in green, and stars in blue. Clouds in the inner galaxy are red-green, but in the outer galaxy become only red, indicating an end to the molecules.

One of most significant results was a greatly improved method of determining the rate at which stars form in a galaxy, a fundamental figure needed to characterize how a galaxy changes and evolves over time. Unlike with the Milky Way and other Local Group galaxies, it's impossible to resolve the individual stars forming in these galaxies. Instead, astronomers calculate this rate indirectly by measuring the total radiation produced by the brightest and hottest stars. Because stars form in dusty clouds, much of this radiation is not detectable in visible wavelengths.

After measuring the infrared glow from these clouds, and accounting for how much of the starlight the cloud's matter absorbed, astronomers get a much more accurate rate of star formation. Many scientists now research the factors that determine this star formation rate, including gas density, pressure, galactic environment, and other galaxy characteristics.

{ Another important result of Spitzer's observations was the ability to detect previously unexplored forms of interstellar matter. }

Another important result of Spitzer's observations was the ability to detect previously unexplored forms of interstellar matter. Dense, optically dark clouds are pervasive in certain spiral and dwarf galaxies, and many of these clouds actually glow brightly in the infrared due to heating from young stars trapped deep inside. The amount of mass in the form of dust in many of these galaxies saw a sharp upward revision. Images of these galaxies at 8 microns also showed the ubiquity of large molecules called polycylclic aromatic hydrocarbons (PAHs). These molecules, consisting of many carbon rings, are large enough that they straddle the line between large molecules and very small dust grains. When these molecules get close to hot young stars, they fluoresce brightly in the infrared, serving as signposts of star formation.

Studies of the distribution of these dust clouds and PAHs in galaxies raise as many questions as they solve. For example, Spitzer's images of spiral galaxy M101 show that emission from PAHs isn't spread uniformly throughout the galaxy; it traces the arms and spurs of star formation. But then, beyond a certain distance from the center of the galaxy, the PAH emission drops, even where stars are still forming. The distribution of this material in M101 and other galaxies remains mysterious and under investigation.

DID YOU KNOW?

The Spitzer Space Telescope has a mass of **1,900 lbs** (865 kilgrams)

Extreme galaxies

It's clear that Spitzer has given us a marvelous new view of the nearby "ordinary" galaxies: the stately spirals, raggedy dwarfs, and giant ellipticals. But it has also opened a new frontier onto star cities in extreme situations: merging galaxies and galaxies with ravenous central black holes. When this happens, the density of interstellar matter becomes so high, and the gas and dust clouds so opaque, that infrared wavelengths provide our best window into the dark hearts of these galaxies.

Galaxies do not spend their lives in splendid isolation. As they orbit each other, they sometimes pass close enough that the orbits of the gas clouds in the galaxy are strongly disturbed, causing multicloud pileups. Fast enough collisions can create extraordinarily dense regions and star formation. As a result, interacting galaxies put on quite a light show, particularly in the infrared. These collisions can cause an impressive chain reaction.

Spitzer observations of the interacting galaxies named II Zw 096 not only show a burst of star formation far from the center of the galaxies, but also have uncovered

Spitzer can spy what lurks in the dark hearts of galaxies — in this case, a small ring of stars around the central black hole of NGC 1097, as well as material falling into the black hole. NASA/JPL-Caltech/The SINGS Team (SSC/Caltech)

the stellar blast of a supernova! This presumably resulted from the rapid demise of a massive star formed during the interaction. Although the sight of these galaxies interacting can be beautiful in the optical, the infrared view allows astronomers to see the full impact of all of the star formation in the aftermath.

The very centers of galaxies also provide areas of extreme density and energy generation for Spitzer to probe. Astronomers now think most large galaxies harbor supermassive black holes at their centers.

The environs of these black holes shine brightly in the infrared for two reasons. First, for black holes currently devouring streams of interstellar matter and stars, the gravitational energy lost in the death spiral of this material goes into heating the dust, causing it to glow brightly at all wavelengths. Because the infrared radiation can penetrate the dense infalling gas, scientists can detect it with Spitzer. But second, even before this gas makes it to the black hole, some of it can collapse into stars, producing small but intense rings of star formation and infrared emission.

DID YOU KNOW?

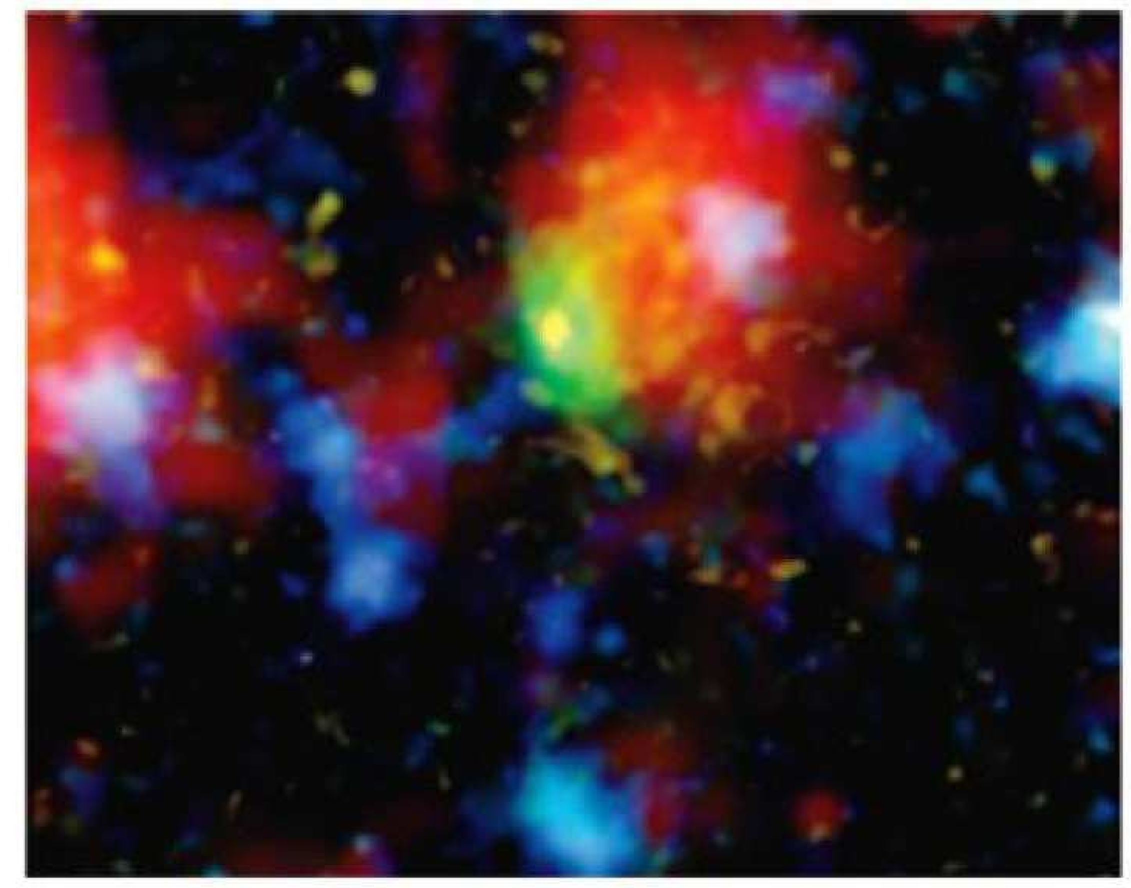
During its 6-year lifetime, Spitzer observed about **600** normal galaxies

The strikingly spooky Spitzer image of NGC 1097 above shows both the aftermath of black hole accretion and a star formation ring peering from the center of this galaxy. This behavior is typical around the active black holes in the centers of galaxies. Spitzer has allowed astronomers to measure the amount of star formation and the energy released in this process.

The first galaxies

All the galaxies in the universe had to form sometime, and Spitzer has played a pivotal role in unveiling them in their infancy. Because of the time it takes their light to reach us, when we view distant galaxies, we are really seeing how they looked billions of years ago. Distant galaxies have been the subject of studies at all wavelengths, but Spitzer's data has been particularly important for determining the mass of stars that formed in these early galaxies.

As you might expect, there have been some surprises. Some of these galaxies are turning out stars at a prodigious rate — more than 400 times that of the Milky Way — and some of these "baby" galaxies turn out to have already formed a puzzlingly large number of stars despite their youth. Did all these stars form in one system, or did many small pieces quickly merge to form the galaxies we see? This question is still hotly debated at astronomy meetings, and it's helped produce a list of questions for NASA's future infrared James Webb Space Telescope to investigate. Despite its many accomplishments, it appeared even Spitzer could not do it all.



Stars form at a fantastic rate in this distant galaxy, whose light traveled for 12.4 billion years (nearly 90 percent the age of the universe) before reaching Earth. NASA/JPL-Caltech/Subaru/STScI

A new lease on life

On Saturday, May 16, 2009, while attending the graduation ceremony at my university, I got the e-mail announcing that Spitzer had run out of liquid helium the previous day. Almost 6 years earlier, on my first day as a physics professor, I had rushed from meetings back to my office to watch its launch. It's been a fun and overwhelming ride, and yet Spitzer's discoveries are still only beginning.

Despite the curtailing of many operations, Spitzer remains capable of collecting 3.6 and 4.5 micron data without liquid helium, so it continues to produce astonishing images. In fact, the limitation in abilities has allowed the telescope to observe with greater focus and completeness. It spotted about 600 normal galaxies at several wavelengths during its cryogenic lifetime, but now the Spitzer Survey of Stellar Structure in Galaxies (S4G), led by Kartik Sheth of the National Radio Astronomical Observatories in Charlottesville, Virginia, is currently surveying 2,331 galaxies within 130 million light-years of the Milky Way.

Clearly, there are many more sights in the universe left for Spitzer to show us.

See more of Spitzer's images online at www.Astronomy.com/toc.

FIXING THE twinkle OF STARS

Adaptive optics helps ground-based telescopes take crystal-clear images. Here's how it works.

by Liz Kruesi; illustrations by Roen Kelly

Creating a "star"

▲ **If the field of view** doesn't contain a star brighter than at least magnitude 13, a telescope with an adaptive optics system "creates" one. Most observatories use a laser with a wavelength of 589 nanometers, which excites sodium atoms in the upper atmosphere — about 60 miles (100 kilometers) above ground. This image shows the European Southern Observatory's Very Large Telescope using a laser to create a guide star. Yuri Beletsky/ESO

Have you ever noticed that stars appear to twinkle in the night sky? This effect results from turbulence in Earth's atmosphere due to temperature differences, wind, or other phenomena. The same effect makes deep-sky objects viewed through a telescope on Earth's surface appear blurry and speckled.

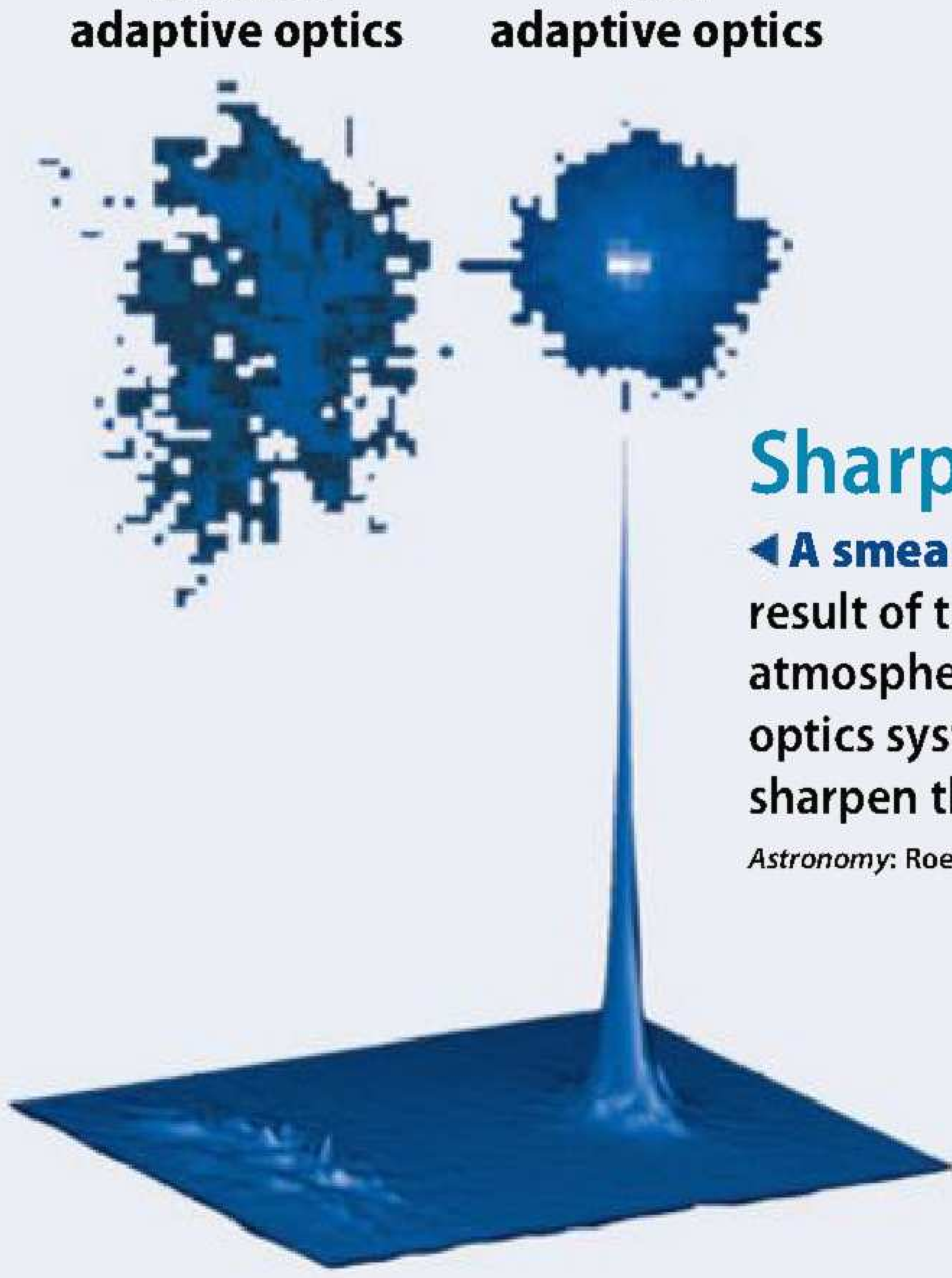
One way to avoid this atmospheric turbulence is to launch telescopes into space. Although the Hubble Space Telescope's mirror is some 4 times smaller in diameter than the biggest ground-based scopes, it sees objects much more clearly because it doesn't have to look through the atmosphere. Some Earth observatories, however, correct for turbulence using a technology called adaptive optics.

Originally created in the 1970s for military purposes, adaptive optics uses actuators connected to a deformable mirror to compensate for the atmosphere's distorting effects. More than a dozen telescopes in the world use the technology, which ensures images taken through the scopes are comparable to (and sometimes better than) what Hubble can produce.

So, how does adaptive optics work? Astronomers use a bright star in the telescope's field of view, or if one isn't available, they create one with a laser. They know the star should appear as a point even though it looks fuzzy. Wavefront analyzers then calculate how actuators must deform a bendable mirror to compensate for the distortion.

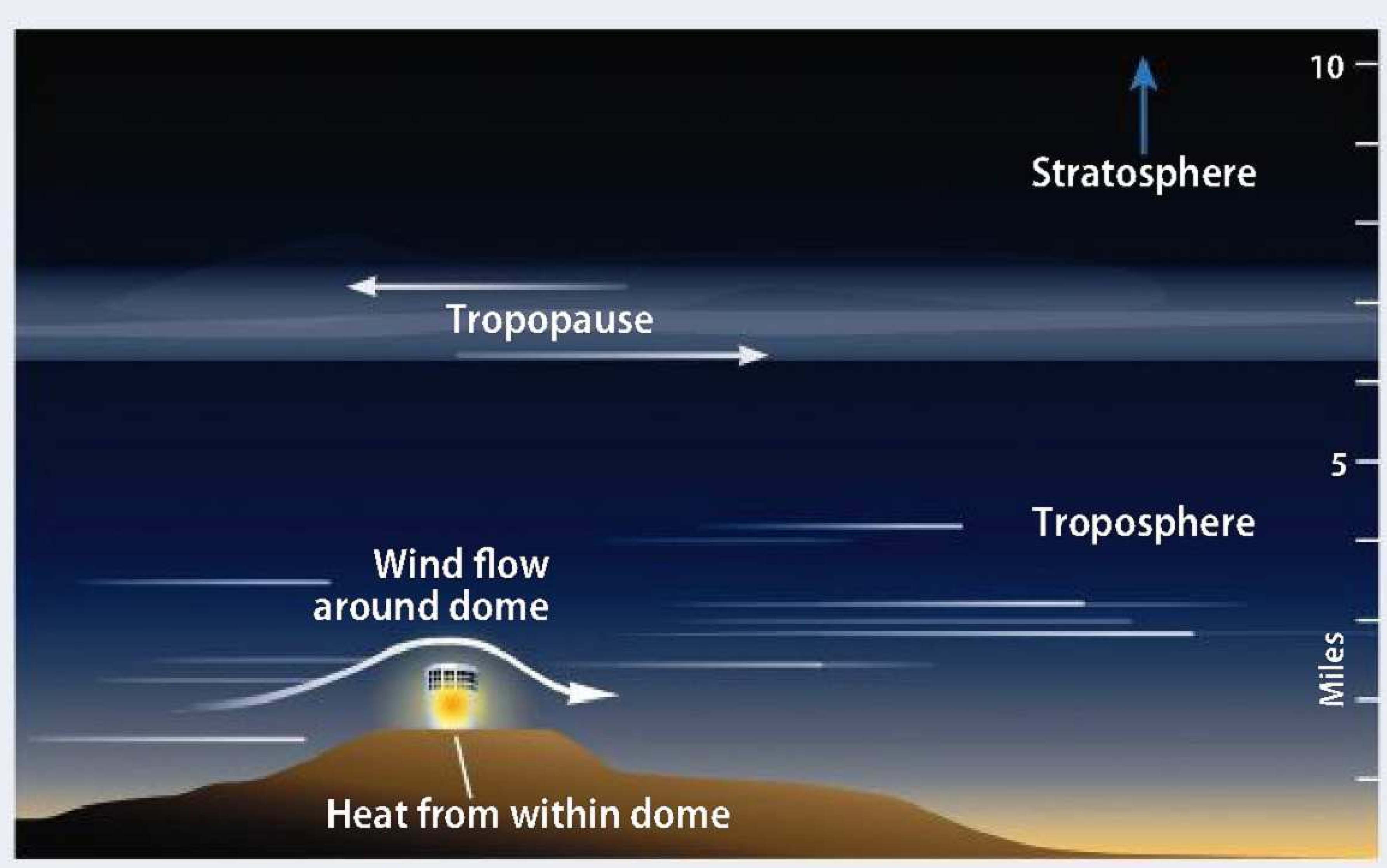
An adaptive optics system *adapts* to changing turbulence in the atmosphere and alters the mirror using real-time data. The result is that stars appear as points of light. There is a tradeoff, however: Such systems have tiny corrected fields of view — around a few arcseconds across. But researchers are slowly creating technologies to increase the sky area that the instruments can capture.

Liz Kruesi, *an associate editor of* Astronomy *magazine, last collaborated with illustrator Roen Kelly in the June 2010 "What makes stars tick?" article.*



Sharper star

◀ **A smeared star image** is a result of turbulence in the atmosphere. An adaptive optics system works to sharpen the star's image.
Astronomy: Roen Kelly, after Lick Observatory

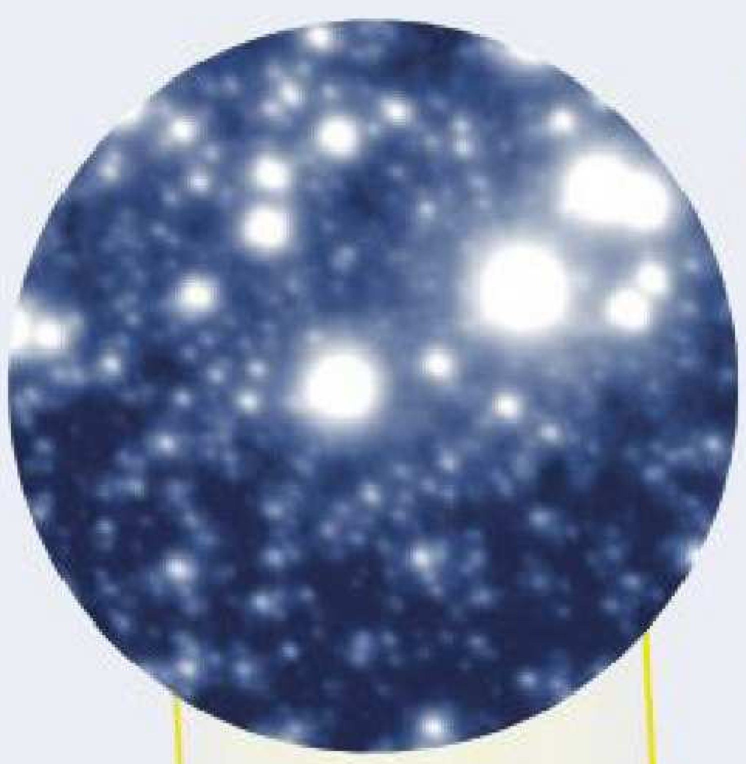


The makeup of Earth's atmosphere

▲ **Light from a distant astronomical object** must penetrate many turbulent layers in Earth's atmosphere, and even pass through heat differences near the observatory dome. These factors distort the light before it enters the telescope.

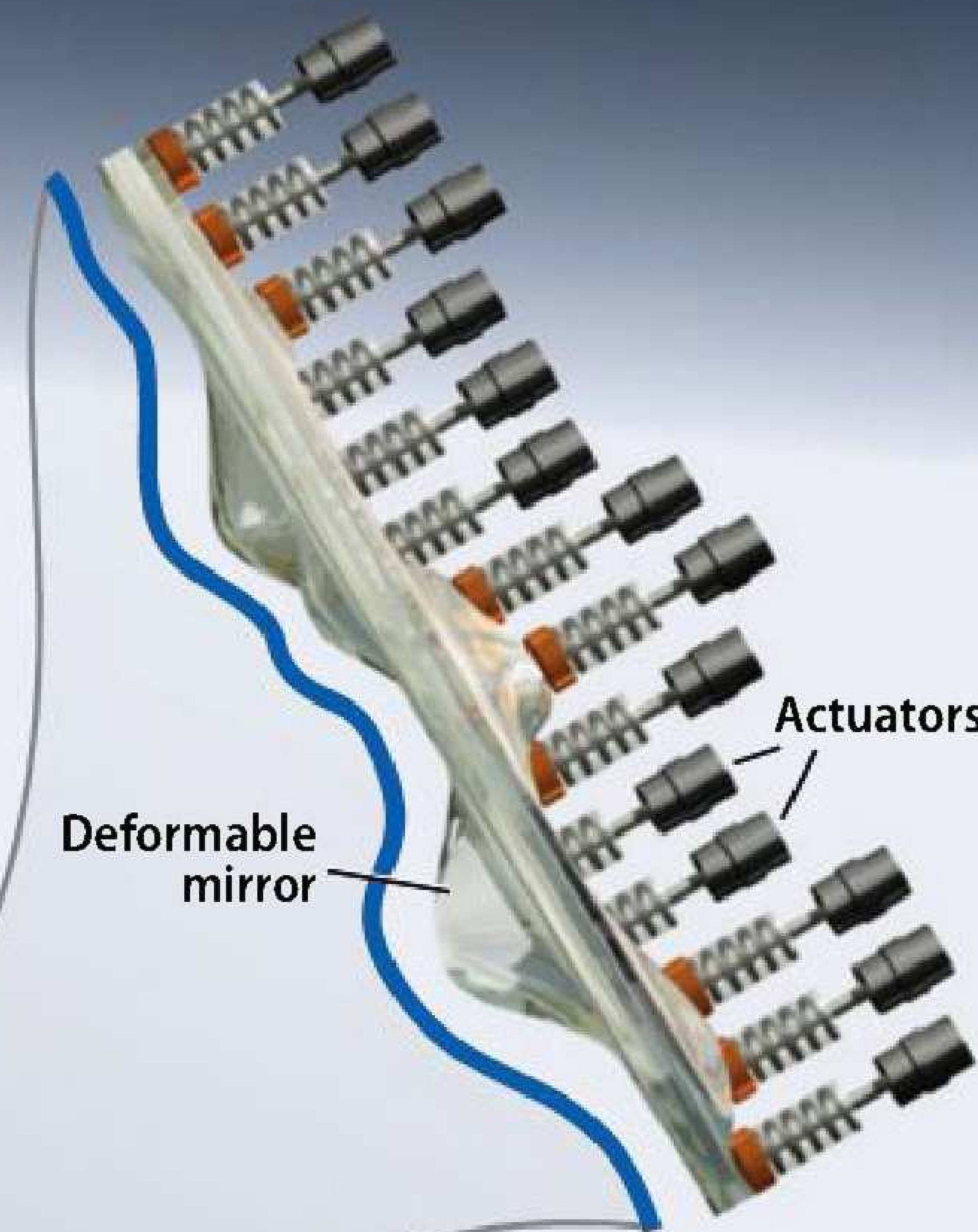
How it works

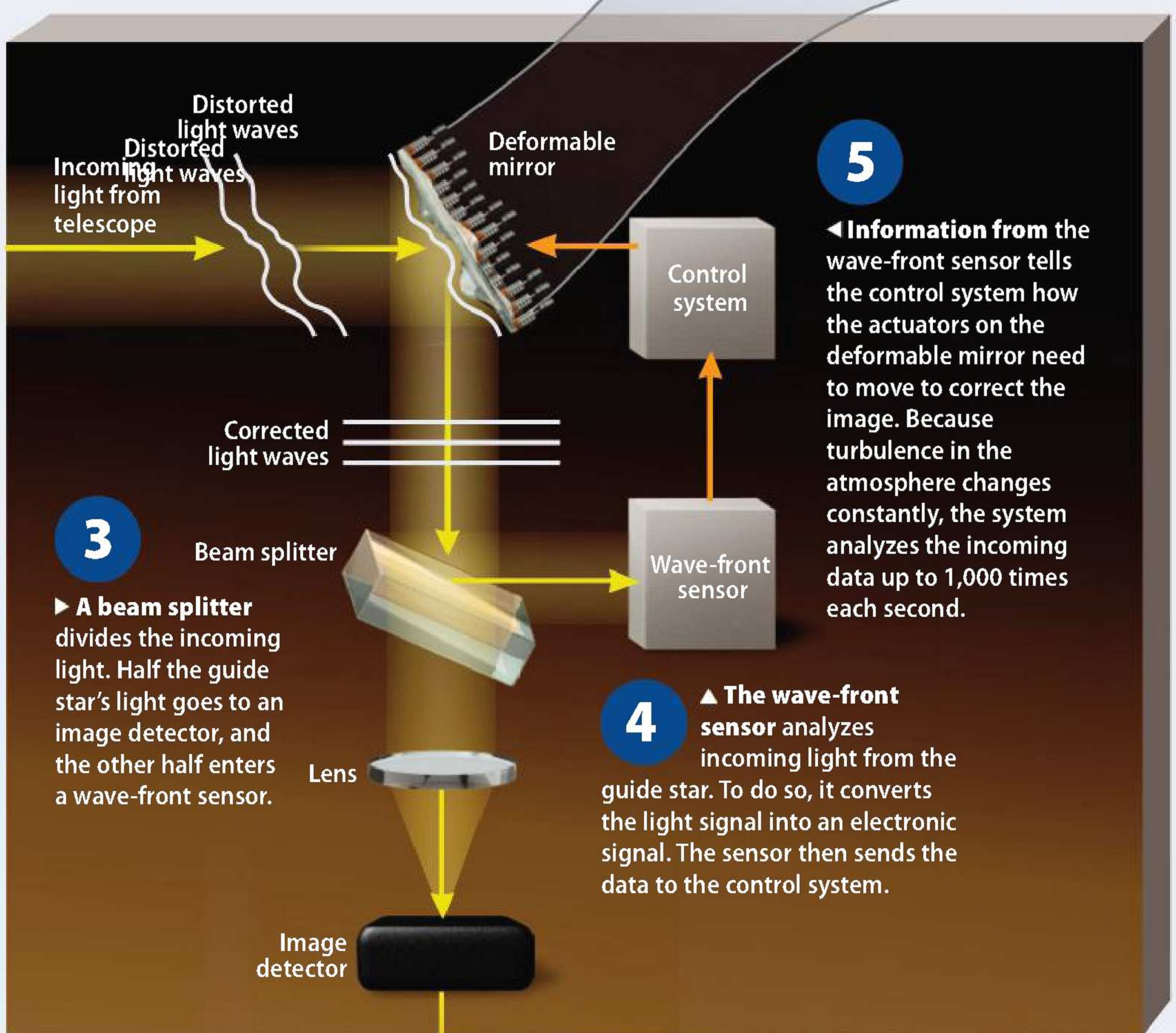
The deformable mirror and all the electronics associated with adaptive optics are in one instrument. Incoming light first reflects off the telescope's primary mirror and secondary mirror before it enters the adaptive optics system, which is housed at one of the telescope's focal points. The system's deformable mirror is a few centimeters in diameter and a few millimeters thick.



1 ◀ **Light from distant stars** appears smeared and distorted to ground-based telescopes due to turbulence in Earth's atmosphere. Gemini Observatory

2 ▶ **Actuators that control** the mirror's shape sit on the back of the deformable mirror. When the wave-front sensor detects turbulence, a change in voltage causes an actuator to expand or contract, similar to a piston in a car's engine. This example shows a single flexible mirror, but some telescopes use segmented adaptive mirrors. Future adaptive optics systems will use larger mirrors with thousands of actuators.

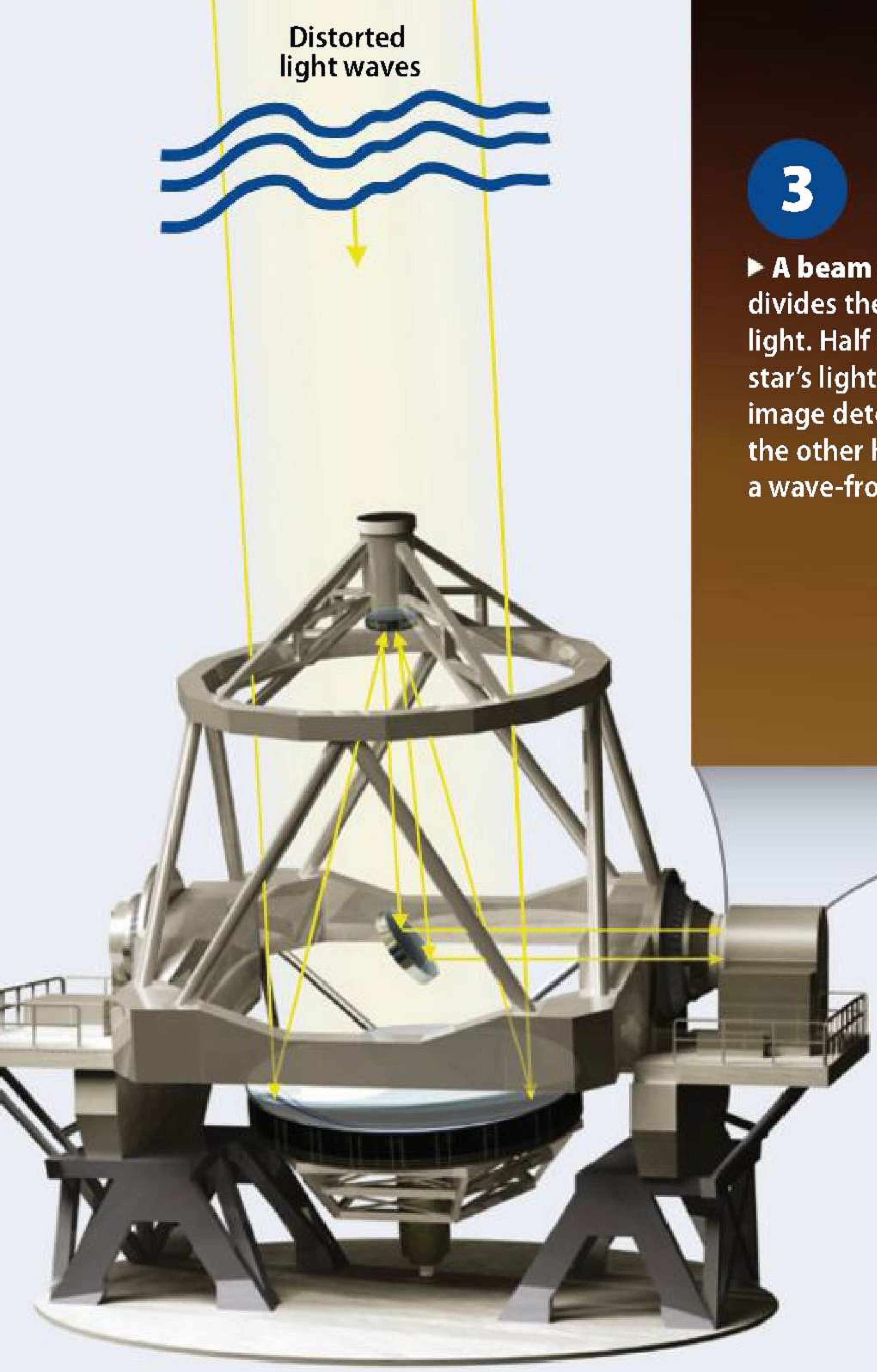


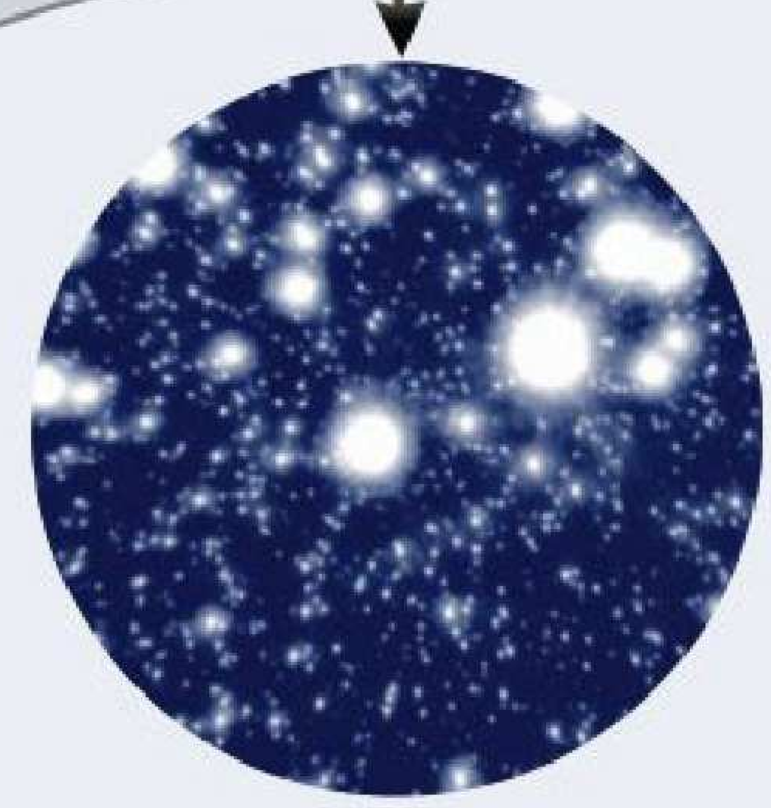


3 ▶ **A beam splitter** divides the incoming light. Half the guide star's light goes to an image detector, and the other half enters a wave-front sensor.

4 ▲ **The wave-front sensor** analyzes incoming light from the guide star. To do so, it converts the light signal into an electronic signal. The sensor then sends the data to the control system.

5 ◀ **Information from** the wave-front sensor tells the control system how the actuators on the deformable mirror need to move to correct the image. Because turbulence in the atmosphere changes constantly, the system analyzes the incoming data up to 1,000 times each second.





6 ◀ **The captured image of stars** is much sharper after the light passes through the adaptive optics system. This technology helps factor out the distortion effects from Earth's atmosphere. Gemini Observatory

The search for more

Astronomer Mike Brown discovered the largest known solar system object beyond Pluto. Now he and his colleagues have expanded their search for distant worlds to the southern sky.

by Dean Regas

Our understanding of the outer solar system has been rocked by an 8-year search started by one man: Caltech astronomer Michael E. Brown. Thanks to his work, Pluto no longer is officially a planet. The object's demotion left many people enraged, but Brown's not sorry. He readily admits his responsibility in his latest book, aptly titled *How I Killed Pluto and Why It Had It Coming* (Spiegel & Grau, 2010).

How did Brown do it? By discovering more than 70 objects beyond Neptune, including Eris, a world as big as Pluto. For decades, Pluto had seemed a small and lonely outpost in the outer solar system. But now it has company: a family of objects far more numerous than the planets themselves.

The solar system's outer frontier is not closed yet. Brown's survey covered only the northern sky and swept up objects glowing at 21st magnitude and brighter. A similar survey of the southern sky has never been attempted, leaving one-third of the celestial sphere untouched. Now, three teams are vying to discover a southern Eris. Brown and two colleagues lead these teams attempting to fill in the missing pieces at the edge of the solar system.

Dean Regas *is the outreach astronomer at the Cincinnati Observatory. Check out his blog about constellation mythology and much more at www.cincinnatiobservatory.org/deanspace.html.*

On the hunt for planets

There has always been glamour and a certain amount of celebrity in the discovery of new worlds. Galileo's observations of Jupiter's moons, William Herschel's sighting of Uranus, and Urbain Leverrier's precise calculations that led Johann Galle to find Neptune were all sensations in their times. But astronomy had never seen anything like Pluto. American astronomer Clyde Tombaugh discovered this alluring oddball in 1930. From the start, it didn't seem to fit with the other planets because it has such a large, eccentric orbit that tilts well out of the plane of other planetary paths. Later on, astronomers learned that the distant world is much smaller than the other planets and has a unique origin and composition.

But Pluto was popular. Never before had the public so embraced an object in space. It was the only substantial thing beyond Neptune, where it roamed as a lone and lonely planet, for 62 years.

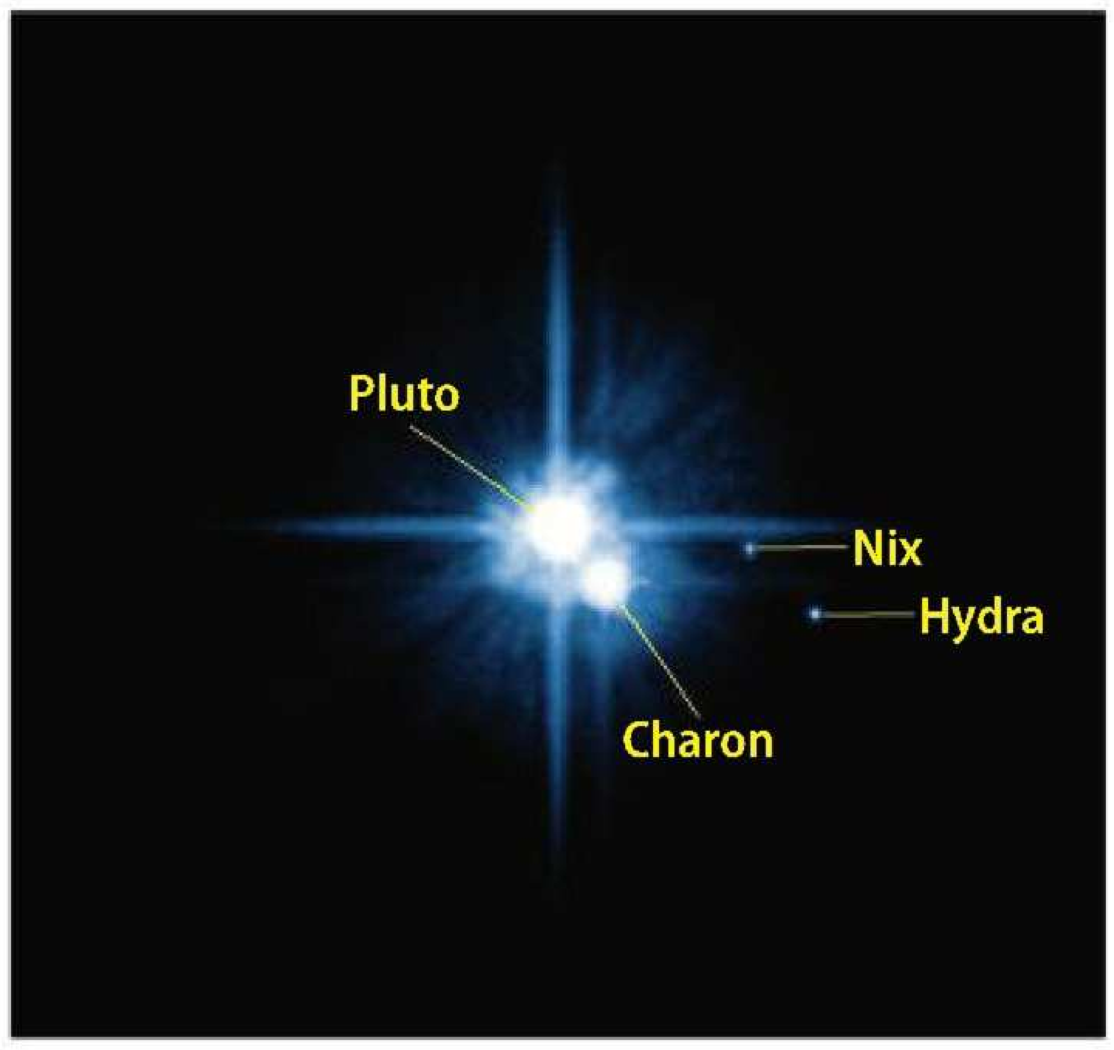
That status changed in 1992 once astronomical tools advanced to the point where they could detect small, faint objects in Pluto's remote neighborhood. In the middle of that year, astronomers David Jewitt and Jane Luu discovered another object, cataloged as 1992 QB$_1$, beyond Neptune's orbit. Soon, researchers started finding more of Pluto's siblings. Scientists now know of more than 1,000 of these so-called trans-Neptunian objects, or TNOs, and they expect to find many more. Pluto simply had too much company to keep its "planet" status.

A new search

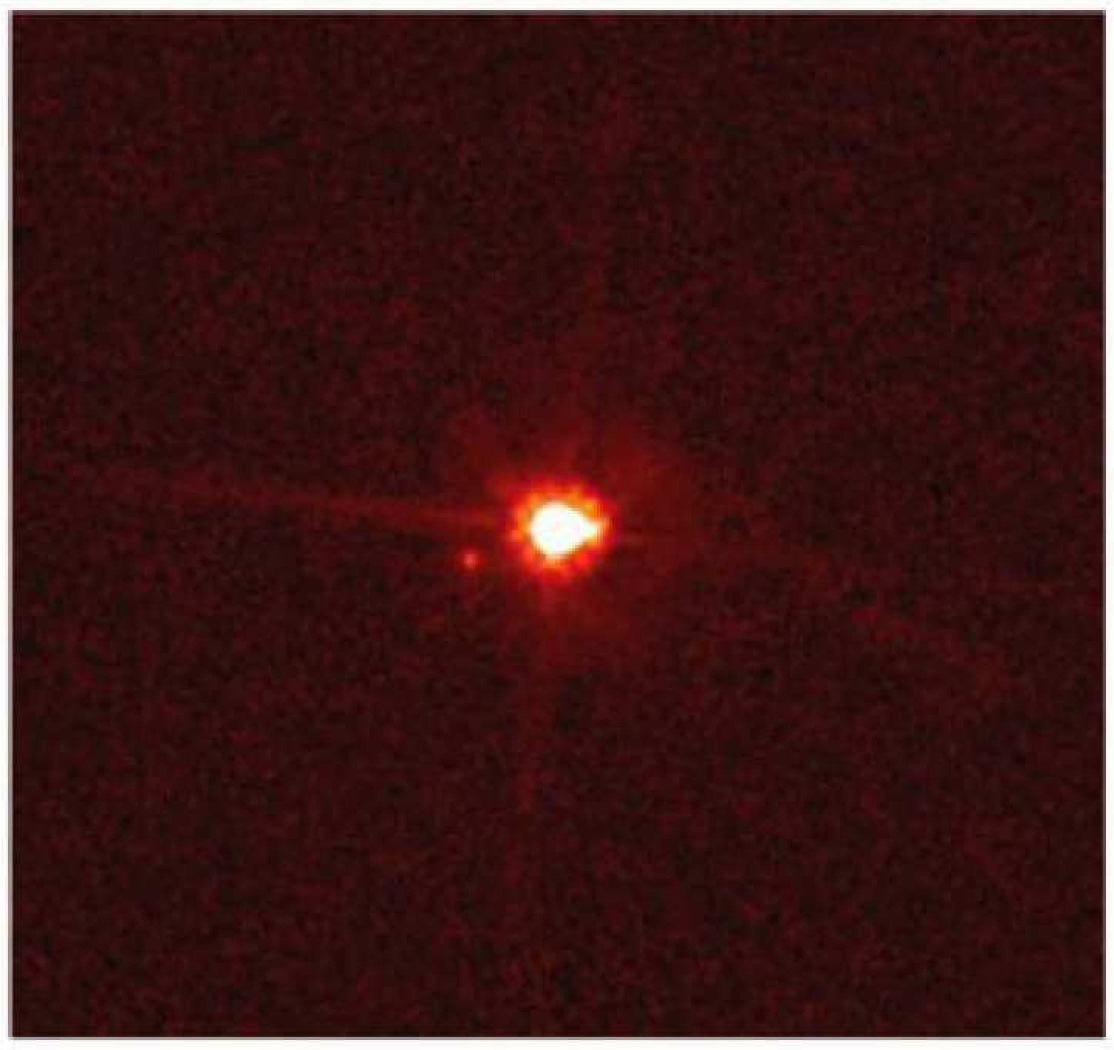
Enter Mike Brown. To conduct his TNO hunt, Brown selected an underutilized telescope at Palomar Observatory outside San Diego, California. Palomar, famous for the massive 200-inch Hale Telescope, had an even better instrument for Brown's purposes. The 48-inch Oschin Schmidt Telescope has a wide field of view ideal for big sky surveys. And Brown's plan was an easy sell. Most observers have to compete for limited

Plutos

Haumea has to be one of the oddest objects beyond Pluto. Its oblong shape, fast rotation, two moons, and widespread debris field set it apart from its cousins. Ron Miller for *Astronomy*



Pluto was the first trans-Neptunian object known. This distant world has at least three moons: giant Charon and diminutive Nix and Hydra. Hal Weaver (JHUAPL)/Alan Stern (SwRI)/NASA/ESA



Giant Eris, seen here with its faint moon Dysnomia (at the 8 o'clock position), currently ranks as the most massive object beyond Neptune. NASA/ESA/Mike Brown (Caltech)

telescope time, but Caltech, Brown's employer, owned the Schmidt — and no one was using it.

The idea was simple. Brown would survey the entire sky within 25° of the celestial equator. This swath brackets the plane of the solar system, where astronomers expect most TNOs to lie. Whereas the Tombaugh survey that led to Pluto's discovery imaged everything brighter than 15th magnitude, Brown's would go down to 21st magnitude — capturing objects more than 100 times fainter.

On a given night, the Schmidt telescope would observe an area of sky about the size of your palm held at arm's length. Brown's team took three photographs of each field 90 minutes apart. If an object moved between the photos, the researchers flagged it. Originally, the survey took photographs on glass plates 14 inches (36 centimeters) across.

Then, in 2003, the scientists installed a new 161-megapixel CCD camera called QUEST (short for Quasar Equatorial Survey Team), and things really started rolling. Yale University researcher David Rabinowitz, who led the group that built the camera, soon joined Brown's team. Although the QUEST camera didn't quite cover the entire field that the previous camera did, no one needed to load, process, transport, and scan the cumbersome glass plates.

In fact, while QUEST scanned the sky for TNOs, the team members were sound asleep in their beds. "I never even had to go up the mountain," says Brown. "Every morning after a clear night, the data came into my computer at home, and I sifted through it."

The QUEST camera not only eased the burden in capturing the sky, but it also took images at a much quicker pace. With a torrent of data flowing in, the team needed a computer program to search the images. Brown turned to Chad Trujillo, an astronomer at Gemini Observatory in Hawaii, to set up an algorithm that could detect any object that shifted position relative to the background stars. It wasn't an easy task because TNOs lie so far from the Sun that they barely crawl across the sky.

Trujillo's program flagged any object that moved during the 3-hour window covered by the three pictures. Brown then reviewed the selected objects, a total of about 100 per clear night, and threw out any that moved too fast (such as asteroids, planes, or random flashes). He then discarded those that matched previously discovered objects. The few that were left became new TNO candidates.

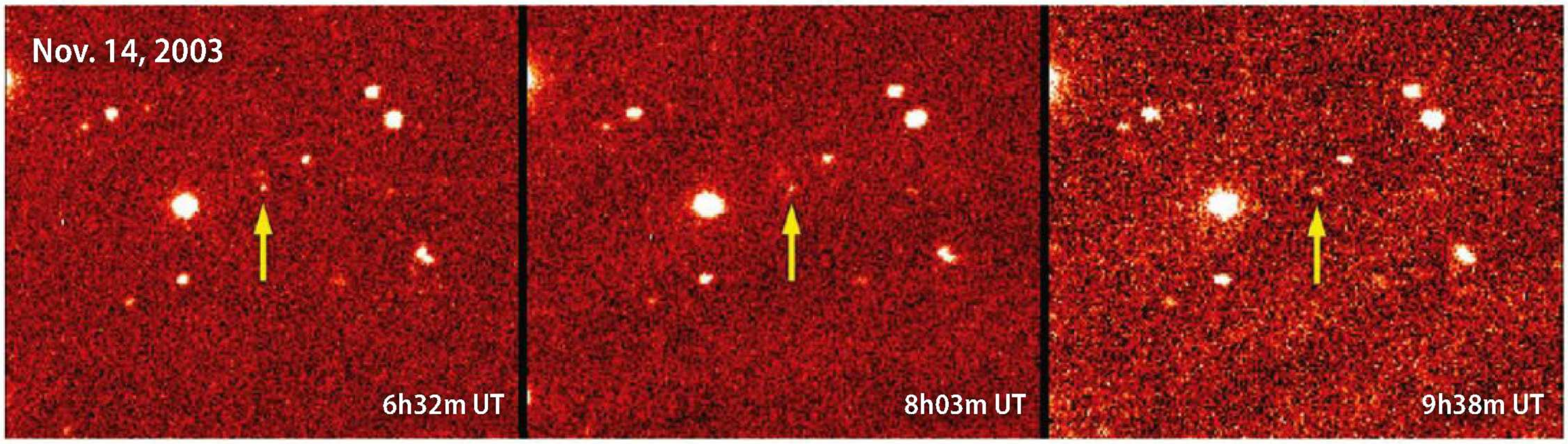
Eureka

January 5, 2005, was the day they found Eris — and it was big. "I knew it within 60 seconds," says Brown. "It was clearly bigger than Pluto." (Brown based this initial assessment on Eris appearing brighter than Pluto would have at the same distance. Observations made in late 2010 show Pluto and Eris have similar diameters, although Eris possesses nearly 30 percent more mass than Pluto.)

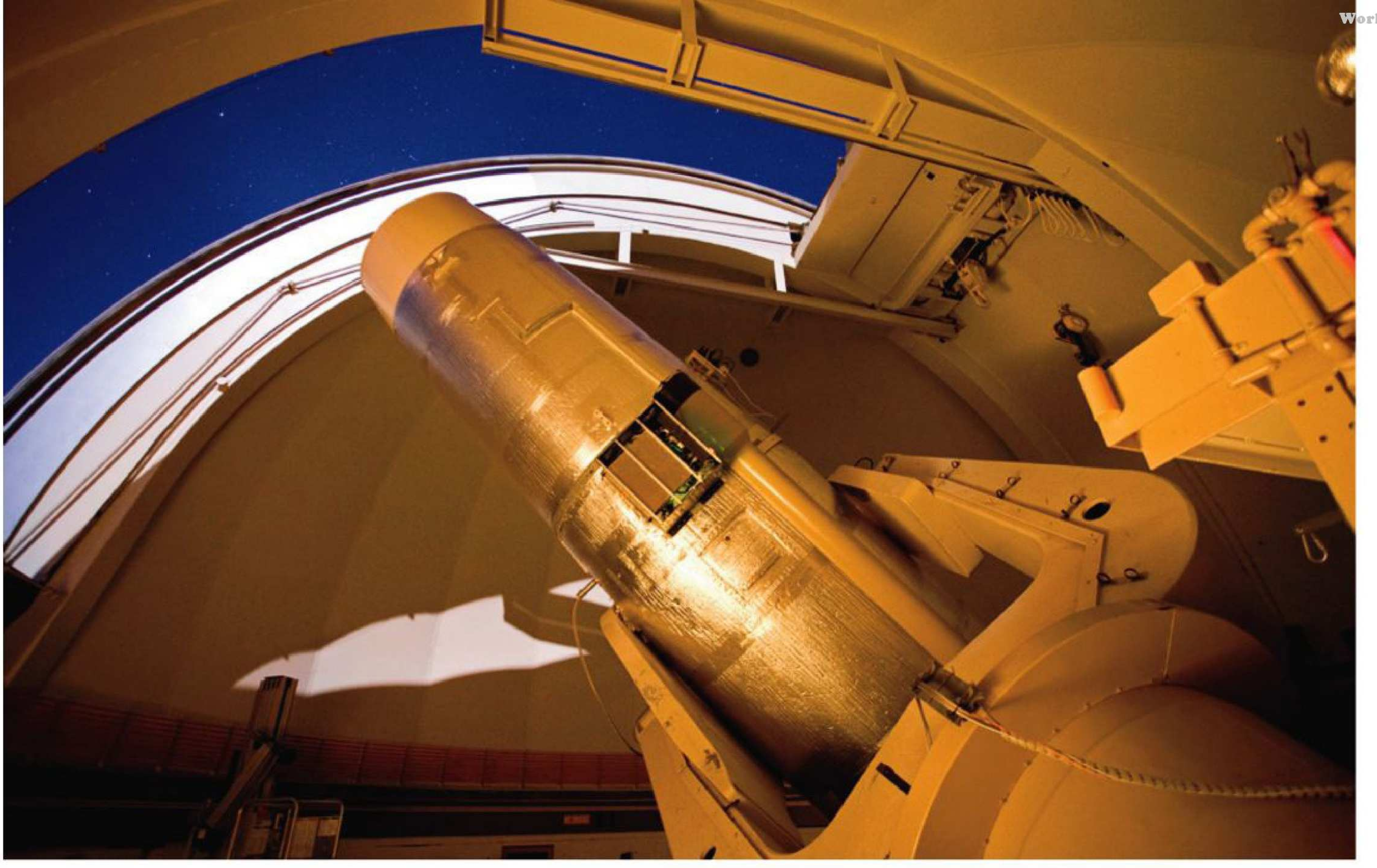
After years of sifting through mounds of data, Brown finally found what he was looking for. And he had a special nickname for it: Xena. Yes, as in *Xena the Warrior Princess*.

"We wanted the name to be female, mythological — even if it was from TV mythology — and start with an 'X,'" explains Brown. The tongue-in-cheek nickname leaked to the media, but Brown soon gave Xena a more appropriate, official name: Eris, the goddess of discord from Greek mythology.

Eris certainly lived up to its name, forcing astronomers to confront head-on the definition of a planet. Eris even has a moon, which Brown named Dysnomia



Distant Sedna turned up during Mike Brown's survey for trans-Neptunian objects (TNOs). This magnitude 20.5 object, the farthest TNO known, moved slightly against the background stars on these three images taken during a 3-hour period. Mike Brown (Caltech)/Palomar Observatory



The 48-inch Oschin Schmidt Telescope at California's Palomar Observatory is blessed with a wide field of view that makes it perfect for sky surveys. It's the instrument Mike Brown and his team used to expand our view of the outer solar system. Scott Kardel (Palomar Observatory)

after the Greek goddess of lawlessness, who happened to be Eris' daughter. "The name's connection to Lucy Lawless, the actress who played Xena, was pure coincidence," says Brown, chuckling.

Lost in the planet debate is what Brown's team actually found — a host of strange and dramatic new worlds. They go by exotic names such as Sedna, Haumea, Quaoar, and Makemake. Of all his discoveries, Brown considers Eris to be the least interesting scientifically. Haumea and Sedna really stand out. "Haumea is the crazy oblong one rotating every 4 hours," says Brown. "Something smacked it a long time ago, creating two moons and a debris field."

Sedna is the new oddball object — the "Pluto II," if you will. Discovered in 2003, Sedna traces out a highly elliptical orbit that takes 12,000 years to complete. Brown was lucky to capture it when it was near its closest point to the Sun. Eventually, it will recede into the depths of the solar system, with only some comets known to be farther out. "Sedna is the most scientifically important," says Brown. "It shouldn't be there." It could be a precursor to even larger objects hiding at the solar system's edge.

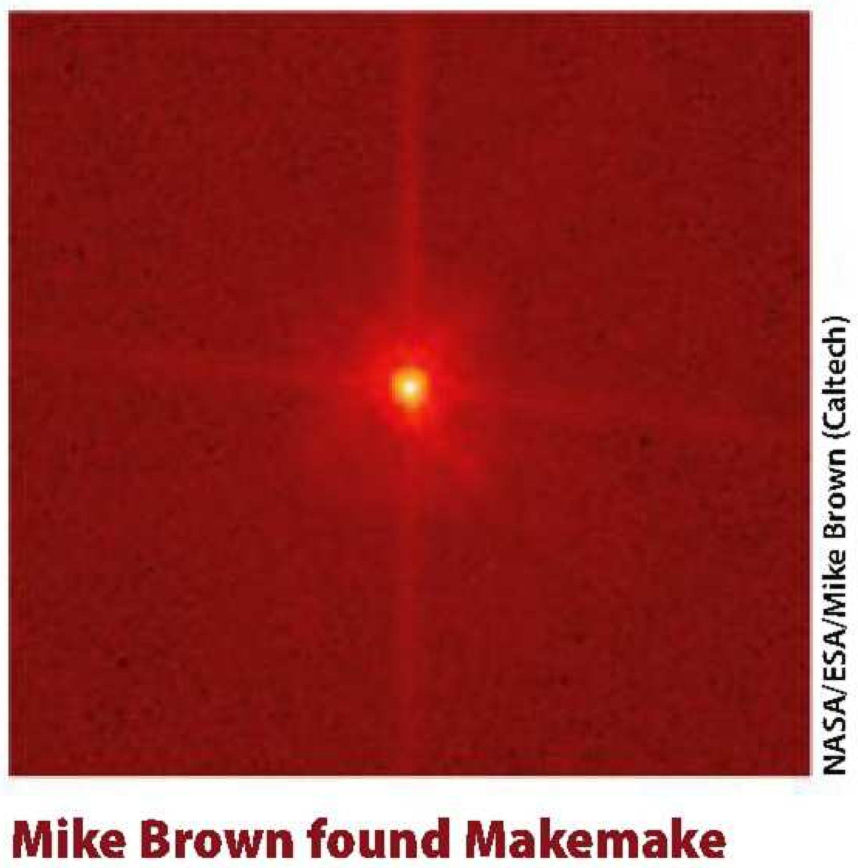
The race for the southern sky

As meticulous as Brown is, he didn't head immediately to the Southern Hemisphere to extend his search. (The Palomar survey went as deep into the southern sky as the telescope could reach effectively from California.) "To be honest," Brown admits, "I was tired." The previous search had occupied almost every day of his life for 8 years. He resurveyed the sky to see if he had missed anything and thoroughly examined the objects he had discovered. "Plus, I wanted to give someone else a chance. If I was a young whippersnapper, I'd have been down there in a second."

But even after challenging colleagues to head south, it looked like no one was going to pick up the torch. "So, I cracked," says Brown. "With a little discussion, I got involved with a group from the Australian National University who were building a new telescope to survey the whole southern sky in what they called the SkyMapper project." The only problem: The telescope and camera are still being built.

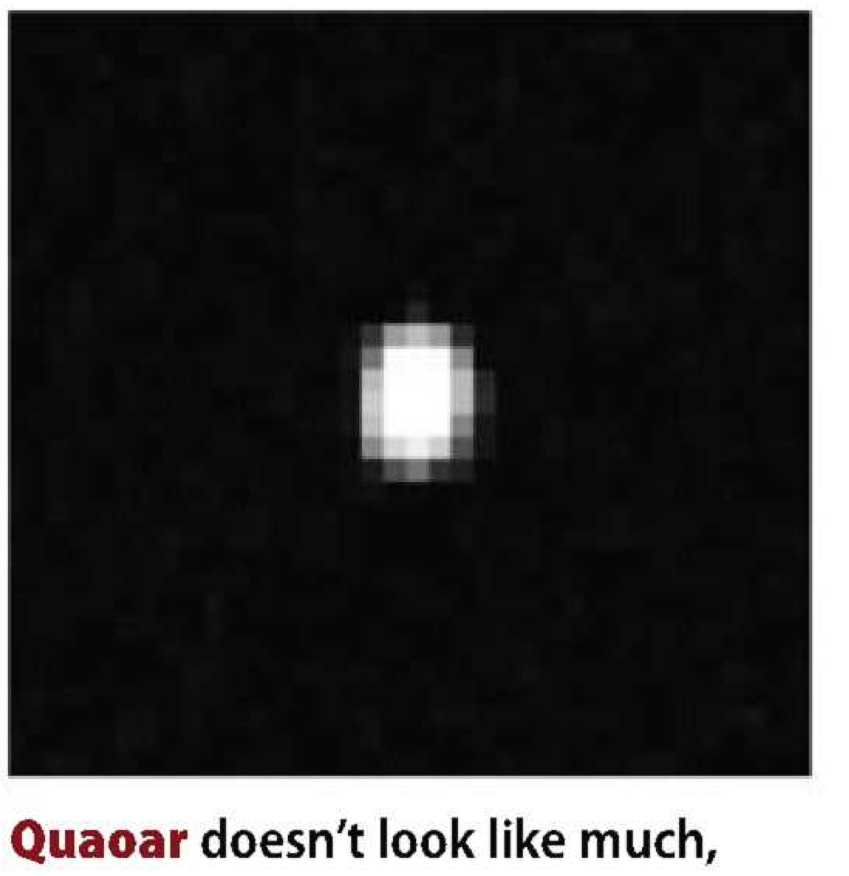
In the race to find the next Eris, Brown considers himself in third place. While he waits for the equipment to be ready, his former planet-hunting mates,

Haumea and its moons, Hi'iaka (top) and Namaka (bottom), posed for this 2005 portrait. Scientists discovered Haumea's oblong shape from its changing brightness as it spins. Keck Observatory



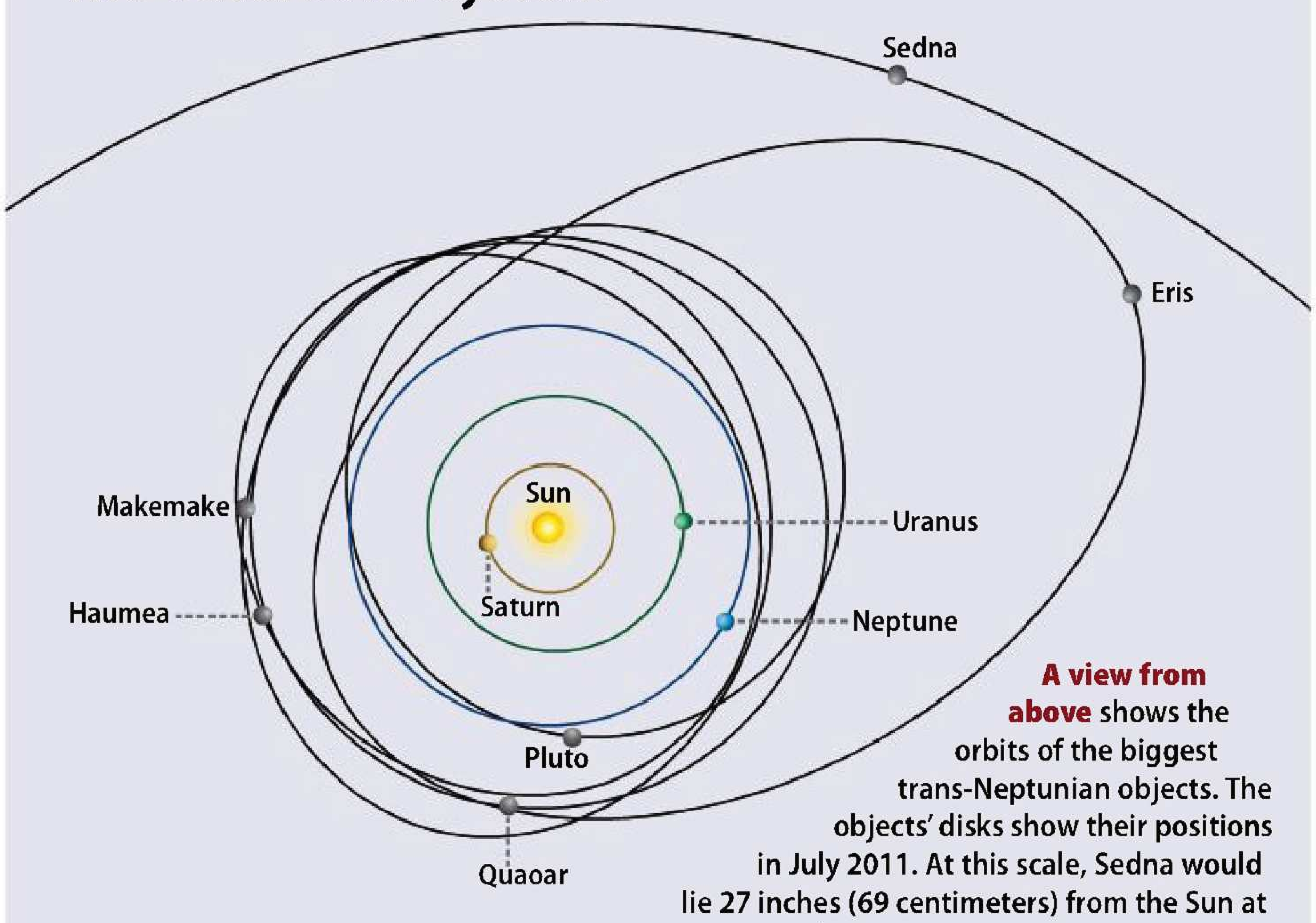
NASA/ESA/Mike Brown (Caltech)

Mike Brown found Makemake in March 2005. It's the brightest trans-Neptunian object after Pluto, and the only other one Clyde Tombaugh could have seen.



Quaoar doesn't look like much, even to Hubble's sharp eyes. The reason: It's half the size of Pluto and lies more than a billion miles farther away. NASA/ESA/Mike Brown (Caltech)

The outer solar system



A view from above shows the orbits of the biggest trans-Neptunian objects. The objects' disks show their positions in July 2011. At this scale, Sedna would lie 27 inches (69 centimeters) from the Sun at its greatest distance. *Astronomy*: Roen Kelly and Richard Talcott

In search of the man

A career in space exploration was almost inevitable for Michael Brown. After all, he grew up in Huntsville, Alabama, America's "Rocket City" and home to NASA's Marshall Space Flight Center. Outer space was such a big part of the culture that his high school was named after Mercury astronaut Gus Grissom. He earned a bachelor's degree in physics from Princeton University in 1987 and ultimately a doctorate in astronomy from the University of California, Berkeley, in 1994.

Planet hunting was not his original passion. "I was interested in galaxies," says Brown. "But one summer, I was forced into doing cometary work at Lick Observatory [in California]." Surprisingly, he found great pleasure viewing Comet Austin not only with the observatory's telescopes but also through binoculars.

This helped him develop an appreciation of objects closer to home, which led to the 8-year survey that uncovered so many trans-Neptunian objects. "I love the field of astronomy," says Brown. "It's still possible for you as an individual to make huge discoveries." He had the right telescope, camera, and disposition for the job. "I had persistence and delusion," says Brown. "I just knew there was something out there."

Brown is humble about his discoveries. He admits that it's hard not to be swayed by fame and notoriety, but considers it unfair. "Look," he says, "I didn't find anything big and important in the solar system. I didn't find Uranus, so I'm not William Herschel. What I did was cool, but let's put this in perspective."

Mike Brown chokes Pluto, the Disney dog, while the author lends a hand. Marsie Newbold

The discovery of Eris even led to a memorable exchange with his wife, Diane. "When I told her that I found something bigger than Pluto but that it was not really a planet," recalls Brown, "she said, 'Not a planet? Don't be an idiot!'" But he's glad Eris is not a planet. "If I was known as the discoverer of a planet, I'd feel like a fraud."

Brown also has a sense of humor about it all. When he visited the Cincinnati Observatory in 2010 as keynote speaker for its annual "ScopeOut" event, he comically strangled a stuffed animal of Pluto, the beloved Disney dog. However, he still has to win over his 6-year-old daughter and successfully explain to her how and why he killed Pluto. — *D. R.*

Trujillo and Rabinowitz, have formed their own observing teams and are already in the game.

After the discoveries at Palomar, Trujillo also bided his time. He continued to study the northern objects until the allure of possible new discoveries proved too much. "You can't just go down there and take over a telescope," says Trujillo. "We went the easiest route by using an existing scope and equipment." He joined a team with Polish astronomer Andrzej Udalski and Scott Sheppard from the Carnegie Institution of Washington's Department of Terrestrial Magnetism that was surveying the galactic plane. The team could use the same data to hunt for TNOs.

The telescope is the 1.3-meter Warsaw University Telescope at Las Campanas Observatory, located in the foothills of the Andes about 350 miles (600 kilometers) north of Santiago, Chile. Udalski had set up the telescope and a 256-megapixel CCD camera for the fourth stage of the Optical Gravitational Lensing Experiment (OGLE). Coincidentally, astronomers with OGLE previously had discovered more than a dozen exoplanets.

The 2010 survey scoured the far southern sky within 20° of the solar system's plane to magnitude 21.5. In Trujillo's mind, this was the most likely location to find distant worlds, and they did — 14 of them never seen before. Unfortunately, none was as big as Eris. The largest is an object dubbed 2010 EK_{139}, which has a diameter between 310 and 620 miles (500 and 1,000 km), or roughly 20 to 40 percent the size of Pluto and Eris.

Although the first stage of Trujillo's search is complete, the survey did not cover the whole southern sky, just the most likely places a large object might hide. Anything big and bright would have to be on a highly inclined orbit and far south. "There could be a Pluto somewhere in there that we missed," muses Trujillo, "but it's pretty unlikely."

Casting a wider net

Rabinowitz has also gone to Chile to probe the uncharted territory. Working with a 1-meter Schmidt telescope at the European Southern Observatory's La Silla site, which lies about 15 miles (25 km) south of Las Campanas, Rabinowitz and his team have been gathering data since August 2009. His advantage: He's using the same QUEST camera used in the Palomar survey.

On a typical night, the team takes a series of images covering a few hundred square degrees. The next morning, Rabinowitz receives the observations over a high-speed data link. Software then picks out moving candidates, a few of which turn out to be outer solar system objects.

"Early on, we were so excited to make a find," says Rabinowitz, "and then we'd discover that it had already been found." By whom? Trujillo's team. But as time went on and Rabinowitz's survey started to cover regions not imaged by Trujillo, TNOs began popping up. To date, he has found nearly 100 distant worlds, half of which are new discoveries. Unfortunately, the largest tops out around 150 miles (250 km) in diameter.

While Trujillo's survey covered the assumed hotbeds, Rabinowitz scans the entire southern sky. "You always think that you're going to find just what you expect," says Rabinowitz. But nature doesn't always oblige. "The most exciting thing we have found so far is 2010 WG_9, which we have nicknamed 'Spike.'" The object's orbit tilts 70° to the plane of the solar system, one of three such objects found so far. Current theories can't explain their formation. "We did not find anything like these objects with our Palomar survey," adds Rabinowitz.

Although no previous southern sky survey expressly targeted TNOs, that doesn't mean there's a lack of useful data. For the past 10 years, astronomers have scanned the sky with the 0.5-meter Uppsala Schmidt Telescope at Australia's Siding Spring Observatory, searching for and tracking near-Earth asteroids.

Although these nearby objects move fast, Brown can go through the archives and flesh out the slower-moving, more-distant TNOs. "This is my secret weapon," says Brown. The telescope and camera are not supersensitive, however, so any TNOs in the data would have to be as big and bright as Eris or Haumea. "If there is something that bright in the south, we should find it first," says Brown.

The first Pan-STARRS telescope sits atop Haleakala on Maui. When completed, Pan-STARRS will extend the search for distant solar system objects down to 24th magnitude. Rob Ratkowski

One southern search for distant worlds uses this 1-meter Schmidt telescope at Chile's La Silla Observatory. From here, David Rabinowitz's team has helped discover a population of objects with high-inclination orbits. ESO

The search will go on

The surveys by Brown, Trujillo, and Rabinowitz have cataloged objects as faint as 21st magnitude. But could there be something significant that's fainter and farther away? Take Sedna as an example. Its orbit brings it as close to the Sun as 76 astronomical units (or AU; 1 AU is the average distance between the Sun and Earth, or about 93 million miles [150 million km]). But at its most distant, Sedna lies 960 AU away — and it spends far more time on the outer part of its orbit than on the inner part.

Luckily, Sedna lies close to us now, less than 100 AU away. Even so, Brown's survey barely detected its magnitude 20.5 glow. "If Sedna was farther away," says Trujillo, "we would never have found it." Perhaps this world is the prototype for a class of objects that spend most of their time at the solar system's edge. If so, thousands of such bodies could be too distant for current techniques to pick out.

The ambitious Panoramic Survey Telescope and Rapid Response System (Pan-STARRS) may be able to help. This project plans to observe the entire sky visible from the summit of Mauna Kea on the Big Island of Hawaii with a 1.4-gigapixel digital camera, the world's largest. When fully operational, Pan-STARRS will accomplish in a month what it took Brown 8 years to complete. And Pan-STARRS will go down to 24th magnitude, more than 10 times fainter than current surveys.

By the end of the decade, astronomers in Chile should be operating the Large Synoptic Survey Telescope (LSST). Still in its design phase, LSST will use a 3.2-gigapixel camera attached to an 8.4-meter telescope. The goal will be to take a 10-year-long "movie" of the night sky and make it available to everyone. If all goes according to plan, LSST will image objects glowing at 27th magnitude, roughly 250 times dimmer than Brown's survey.

New discoveries could reignite the planet debate. "What happens when we find something the size of Mercury or Mars at 100 AU?" asks Brown with a mischievous grin. Always the believer, notice that he said "when," not "if."

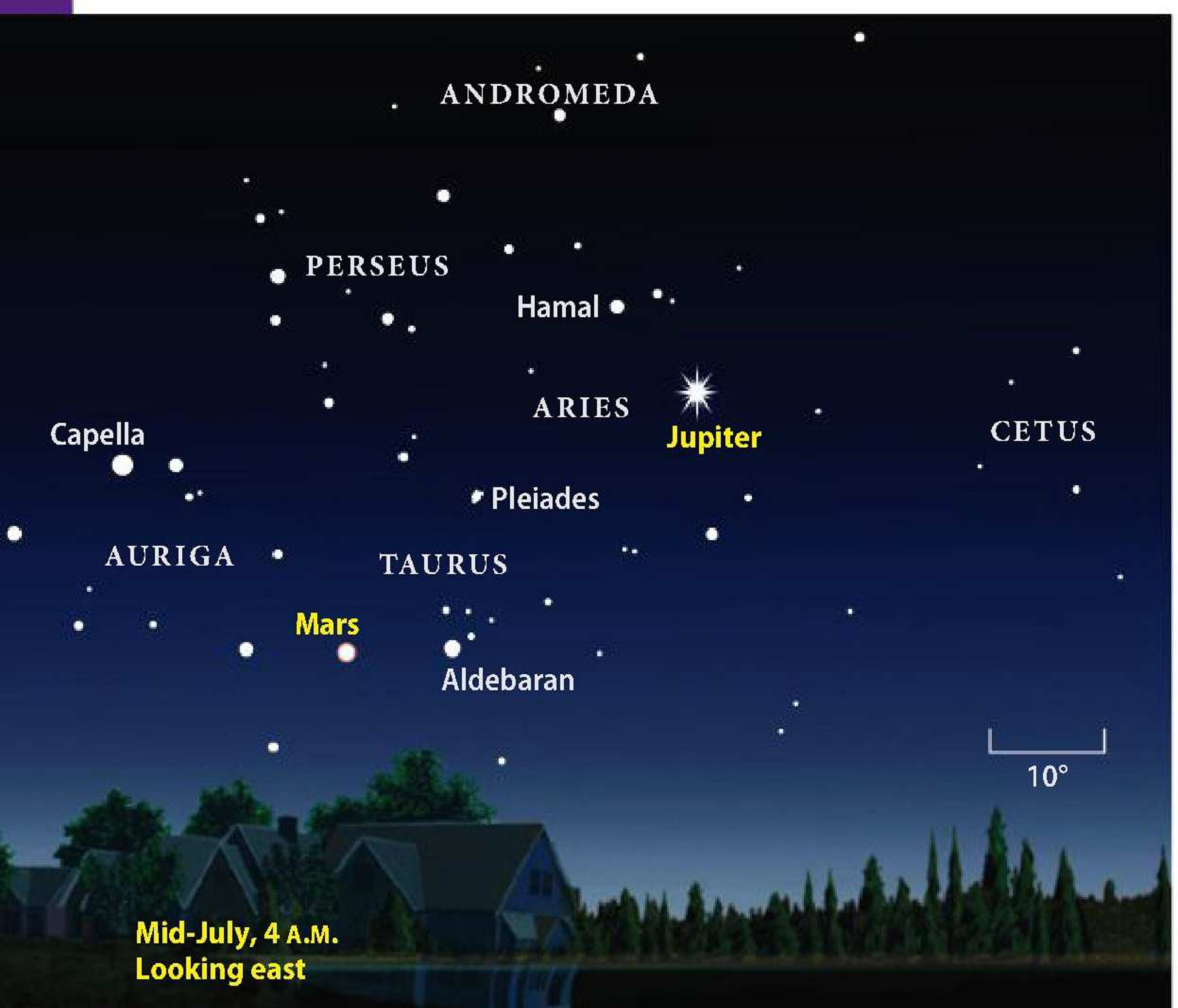
Learn more about the properties of TNOs at www.Astronomy.com/toc.

The Sky this Month

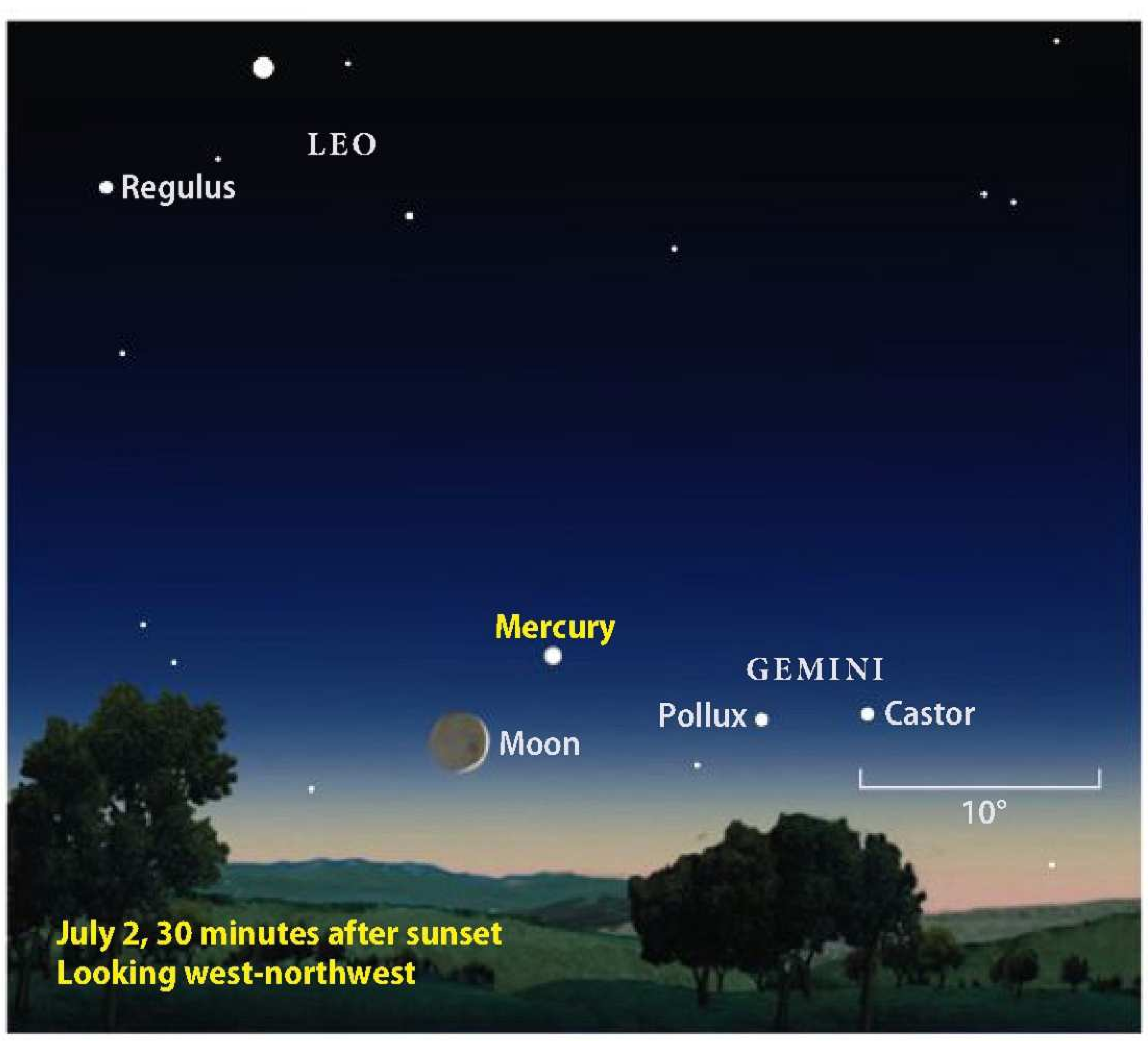
Martin Ratcliffe and Alister Ling describe the solar system's changing landscape as it appears in Earth's sky.

July 2011

Happy birthday, Neptune!



Giant Jupiter climbs high in the east before dawn, when observers can get great views with naked eyes or through any telescope. *Astronomy*: Roen Kelly



Mercury glows low in the west-northwest after sunset this month and puts on a nice display near the Moon July 2. *Astronomy*: Roen Kelly

Although summer nights are the shortest of the year, the solar system provides plenty to see this July. Mercury and Saturn offer tempting targets after sunset. By midnight, Uranus and Neptune become easy objects through binoculars. Jupiter delivers spectacular views in the wee hours, while the predawn sky features the ruddy glow of Mars.

Let's start our tour of solar system delights where we normally do, in the western sky at dusk. Shining at magnitude –0.4, **Mercury** pops out of the twilight glow just as the sky starts to darken. Look for it July 2, when it stands 8° above the horizon 30 minutes after sunset and 5° north of a slender crescent Moon. Our satellite sets around 9:30 P.M. local daylight time and the planet follows some 20 minutes later. Point a telescope at the inner world, and you'll see a gibbous disk spanning 6".

Mercury's next impressive conjunction comes July 6, when it crosses the Beehive star cluster (M44) in Cancer the Crab. The pair's low altitude makes seeing the cluster a challenge even through binoculars. Your chances increase if you live farther south, where the two appear higher and in a darker sky.

Mercury reaches greatest elongation July 19/20, when it lies 27° east of the Sun. It won't be any easier to see from the Northern Hemisphere than it was early in the month, however, because its brightness dips (to magnitude 0.3) and its altitude remains nearly the same. A telescope does reveal a more interesting disk, one that measures 8" across and has a fat crescent shape.

About an hour after sunset, **Saturn** appears as a bright dot one-third of the way from the southwestern horizon to the zenith. The golden-colored planet lies nearly 15° to the right of blue-white Spica, Virgo the Maiden's luminary, and shines a hair brighter than the 1st-magnitude star.

Yet Saturn appears much closer to Virgo's next-brightest

— Continued on page 41

Visible to the naked eye
Visible with binoculars
Visible with a telescope

— Continued from page 36
star, 3rd-magnitude Gamma (γ) Virginis. On July 1, you could fit a single Full Moon between these two objects. By month's close, four Moons would fit between.

The view of Saturn through a telescope is never less than stunning. The planet's disk spans 17", and the ring system stretches 39" from tip to tip. The rings start to become more noticeable this month as they tip more to our line of sight. In June, the tilt slimmed to 7°, its minimum for 2011. The tilt grows to 8° by mid-July and to 15° by year's end.

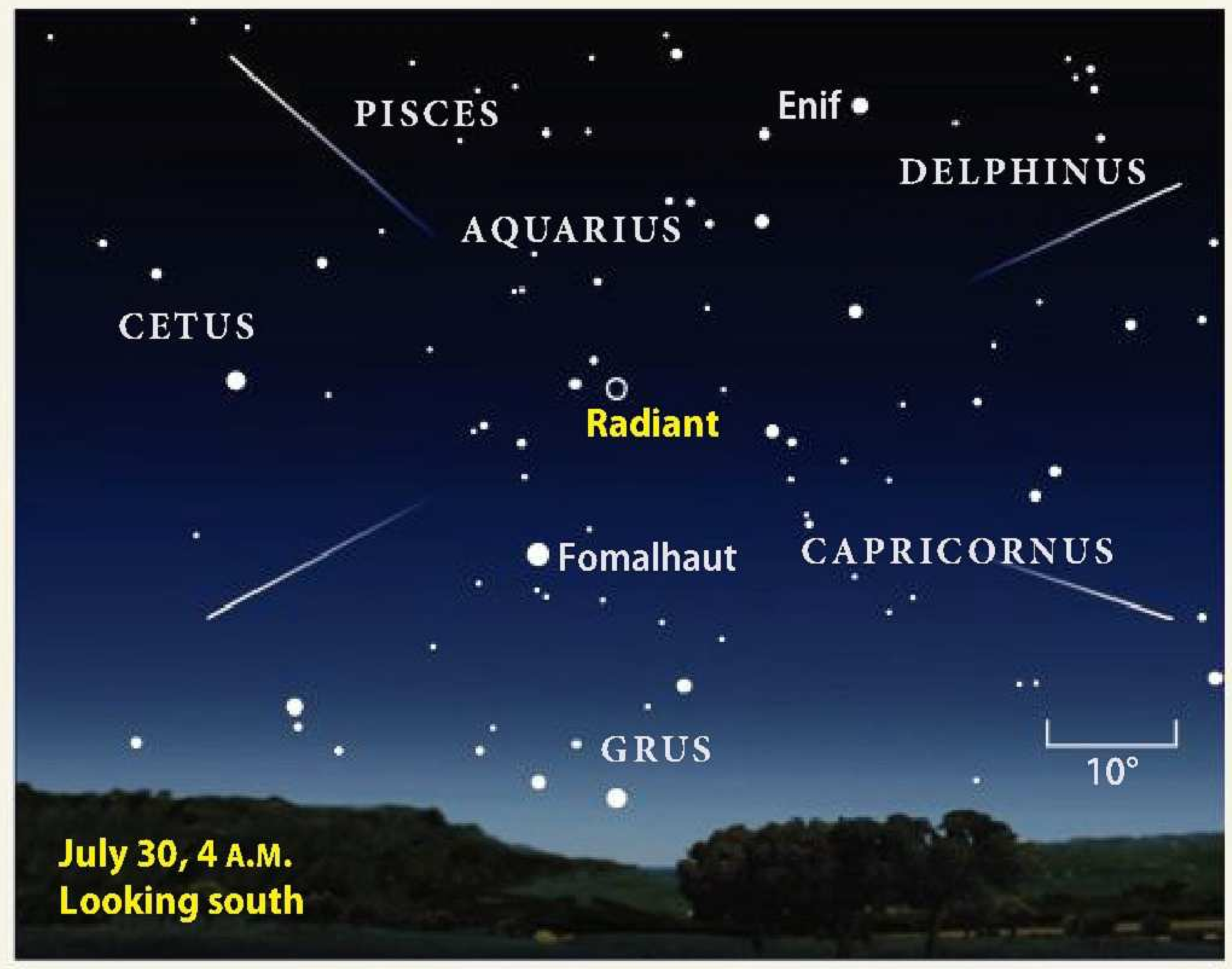
While we're on the subject of interesting angles, Saturn reaches quadrature July 2/3. To understand this configuration, imagine looking down on the solar system from far above. At quadrature, a line drawn from the Sun to Earth and then to Saturn forms a 90° angle. To observers, this means the shadow cast by Saturn falls as far east of the planet as possible and hides a noticeable section of the rings' farside from view.

Any telescope will show you Saturn's largest moon, Titan. The 8th-magnitude satellite orbits the ringed planet once every 16 days. For North American observers, Titan lies farthest east of Saturn July 1 and 17, and farthest west July 9 and 25.

A 4-inch scope reveals a trio of 10th-magnitude moons — Tethys, Dione, and Rhea — with smaller orbits than Titan. Farther out lies two-faced Iapetus. This satellite shines at 10th magnitude when it's farthest west of Saturn, as it was in early June. The moon passed north of the planet June 30 on its way toward greatest eastern elongation, which occurs July 20. Iapetus then glows at 12th magnitude and will be a challenge to see through an 8-inch scope. It lies some 8' from Saturn, 5 times farther east of the planet than Titan.

Martin Ratcliffe *provides professional planetarium development for Sky-Skan, Inc., in Nashua, New Hampshire. Meteorologist* **Alister Ling** *works for Environment Canada in Edmonton, Alberta.*

Meteor watch



Delta Aquarid meteors will grace the skies of late July, offering up to 20 meteors per hour from dark sites. *Astronomy:* Roen Kelly

Fiery streaks radiate from a moist place

One of the year's most prolific meteor showers, the Southern Delta Aquarids, reaches its peak July 30. The Moon obliges observers by reaching its new phase the same day, making for ideal conditions. The meteors appear to radiate from the constellation Aquarius the Water-bearer, which rises in late evening and climbs highest in the hours before dawn.

Although the Delta Aquarids produces a lot of meteors while it's active from July 12 to August 23, it doesn't produce the high peak rates some other showers do. At its best, you can expect to see an average of between 15 and 20 meteors per hour under excellent conditions. Fortunately, those rates remain nearly constant for a day or two on either side of the peak. For the best views, find an observing site far removed from city lights.

Rising Moon

A lunar "X" marks the spot

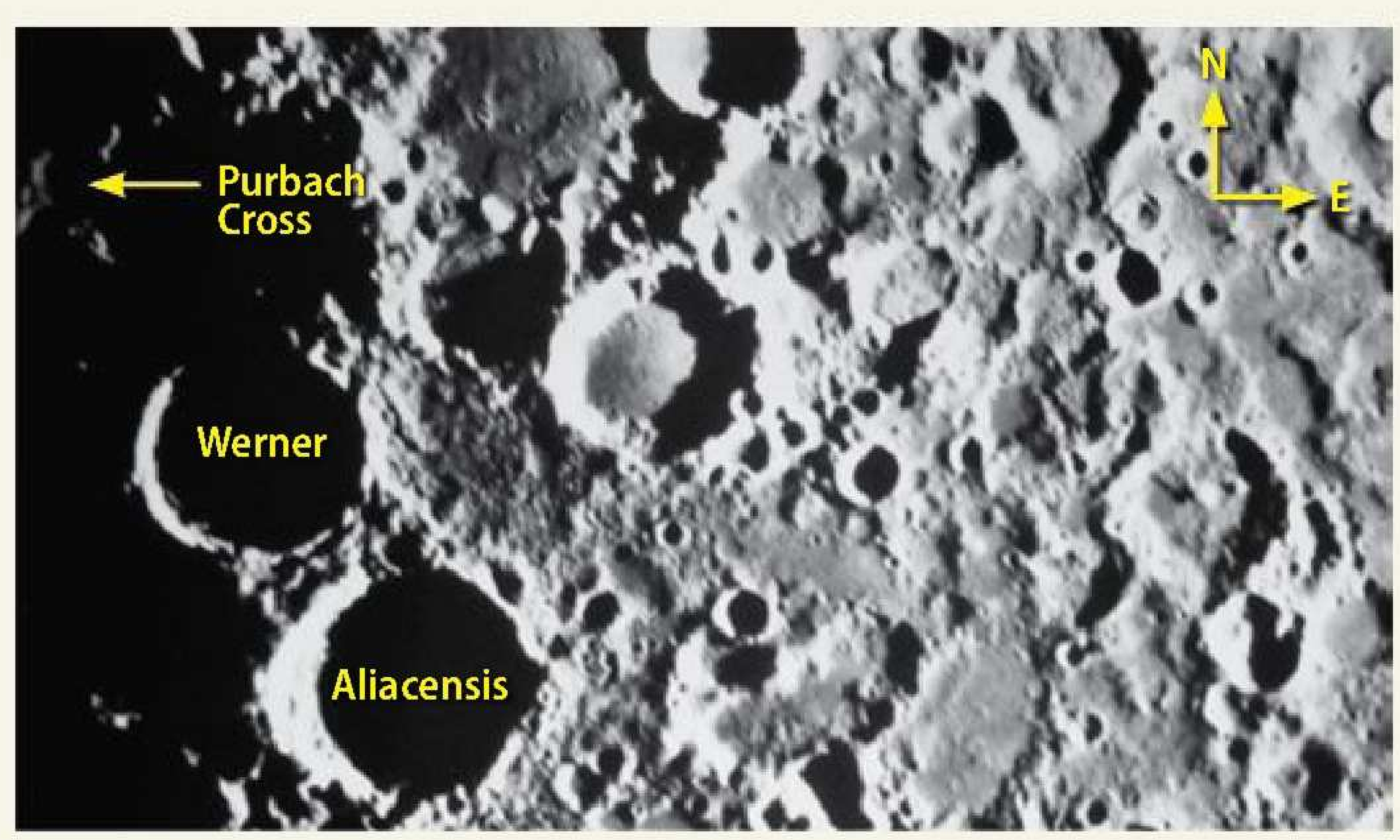
Observers in the western half of North America have a great opportunity this month to watch a few points of light on the Moon's surface evolve into a prominent letter X. This feature carries the unofficial titles of Purbach Cross and Werner X, both of which refer to nearby named craters.

Set up your scope shortly after sunset July 7. As the sky darkens, target a region along the lunar terminator (the dividing line between light and dark) and focus on a spot about halfway between the equator and the south pole. You should have no trouble picking out the craters Aliacensis and Werner. These near twins serve as your guide to the X, which lies just to their northwest.

In just a few hours, you can see the X emerge, peak, and disappear. It's mesmerizing to watch the rising Sun transform the appearance of a group of crater walls. You also might consider taking a series of images with a digital camera or webcam. With one shot every 5 to 10 minutes, you can create a time-lapse movie of the X's evolution.

Oddly enough, the craters that form the X don't show up on a night when the feature is visible. Only their high walls catch the first rays of morning sunlight. The individual craters — Blanchinus, la Caille, and Purbach — don't come into full view until the following night. The photo above shows the region with the X just starting to emerge out of a sea of blackness.

From eastern North America, the X only begins to appear as the Moon sets. Observers there can take solace in enjoying myriad craters on the terminator as they evolve from arcs of light into full circles.



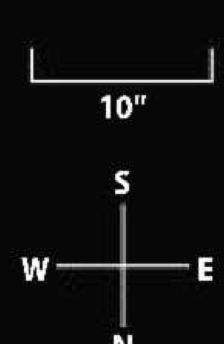
The Purbach Cross, or Werner X, lies just northwest of the crater Werner the evening of July 7. *Consolidated Lunar Atlas*/UA/LPL

Planets in July 2011

This map unfolds the entire night sky from sunset (at right) until sunrise (a
Arrows and colored dots show motions and locations of solar system obje

MOON PHASES

To locate the Moon in the sky, draw a line from the p
Note: Moons vary in size due to distance from Earth

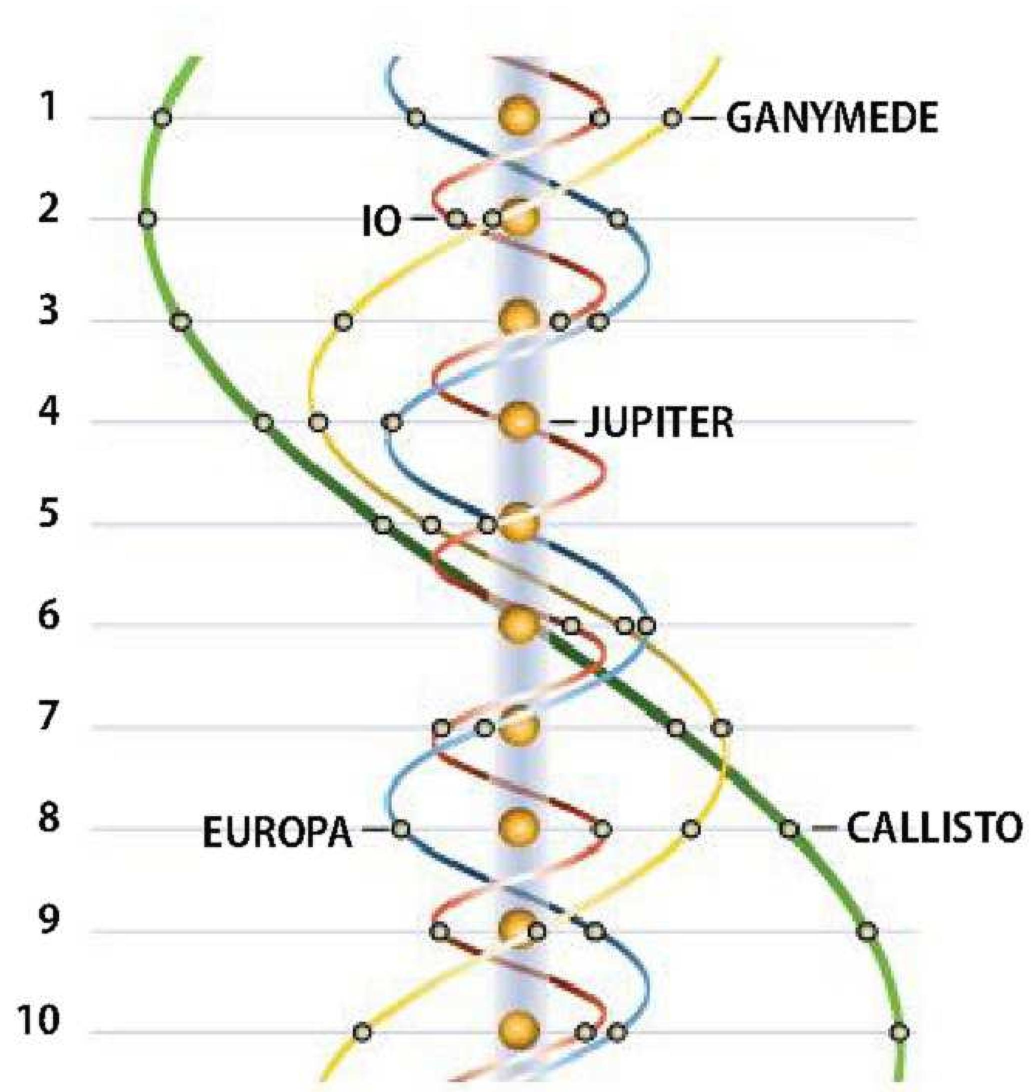


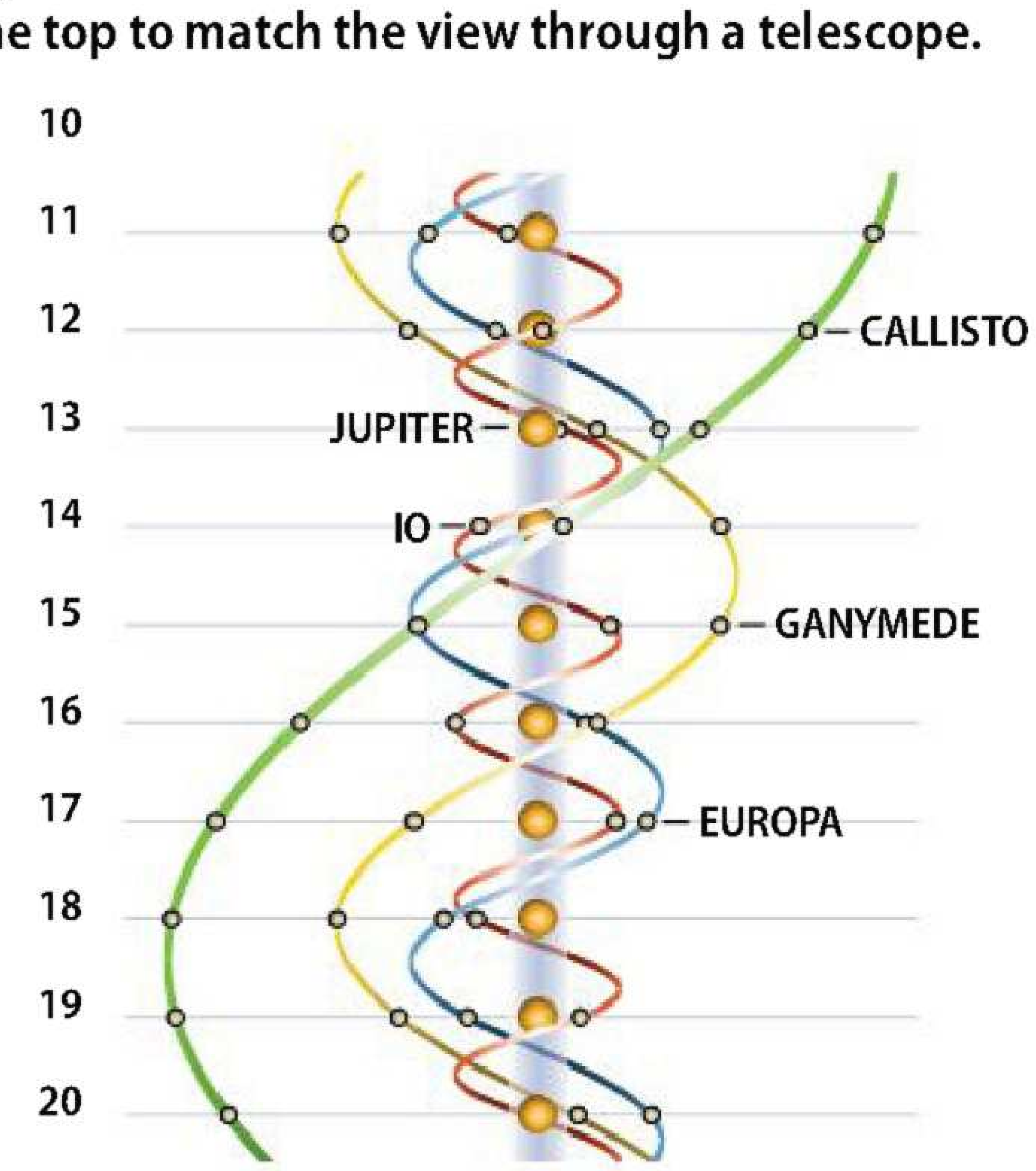


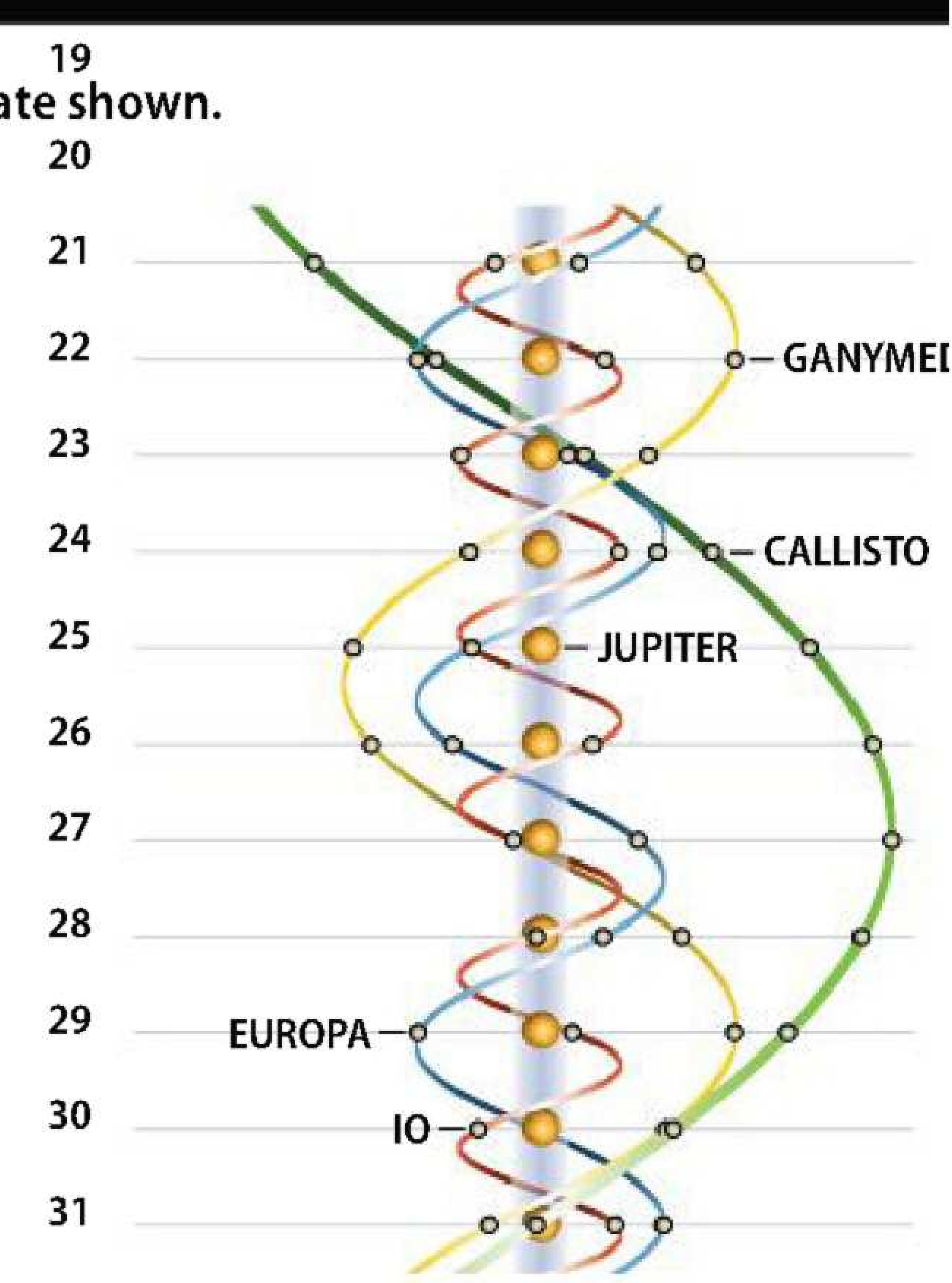

PLANETS	MERCURY	VENUS	MARS	CERES
Date	July 15	July 1	July 15	July 15
Magnitude	0.1	–3.8	1.4	8.7
Angular size	7.2"	10.0"	4.3"	0.5"
Illumination	52%	98%	96%	97%
Distance (AU) from Earth	0.933	1.677	2.186	2.456
Distance (AU) from Sun	0.449	0.721	1.479	2.981
Right ascension (2000.0)	9h22.9m	5h42.4m	5h01.9m	0h20.9m
Declination (2000.0)	15°31'	23°09'	22°51'	–11°37'

Jupiter's moons

Dots display positions of Galilean satellites at 4 A.M. EDT on the date shown.
South is at the top to match the view through a telescope.







Astronomy magazine

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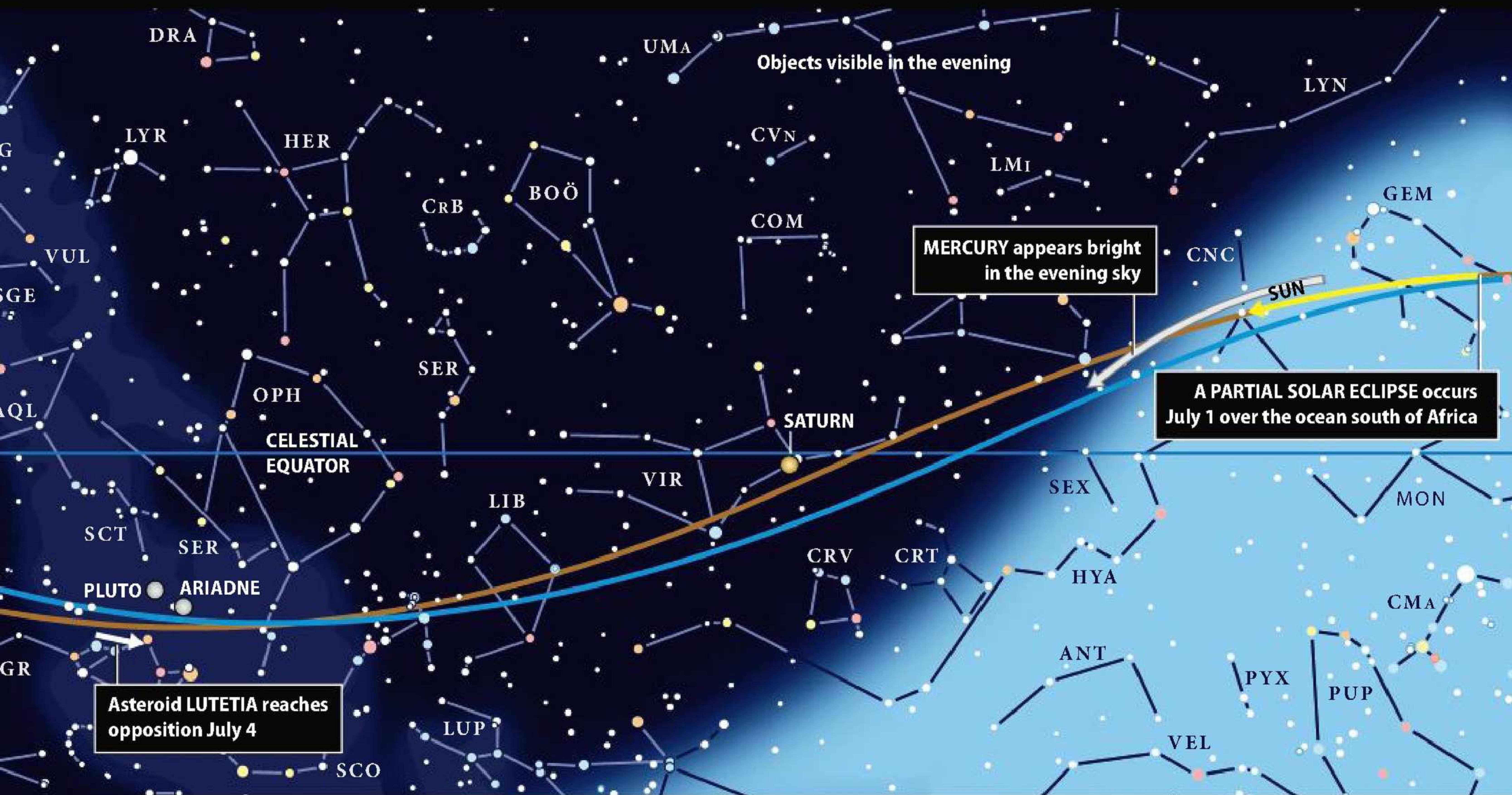
cts during the month.



ight

Early evening

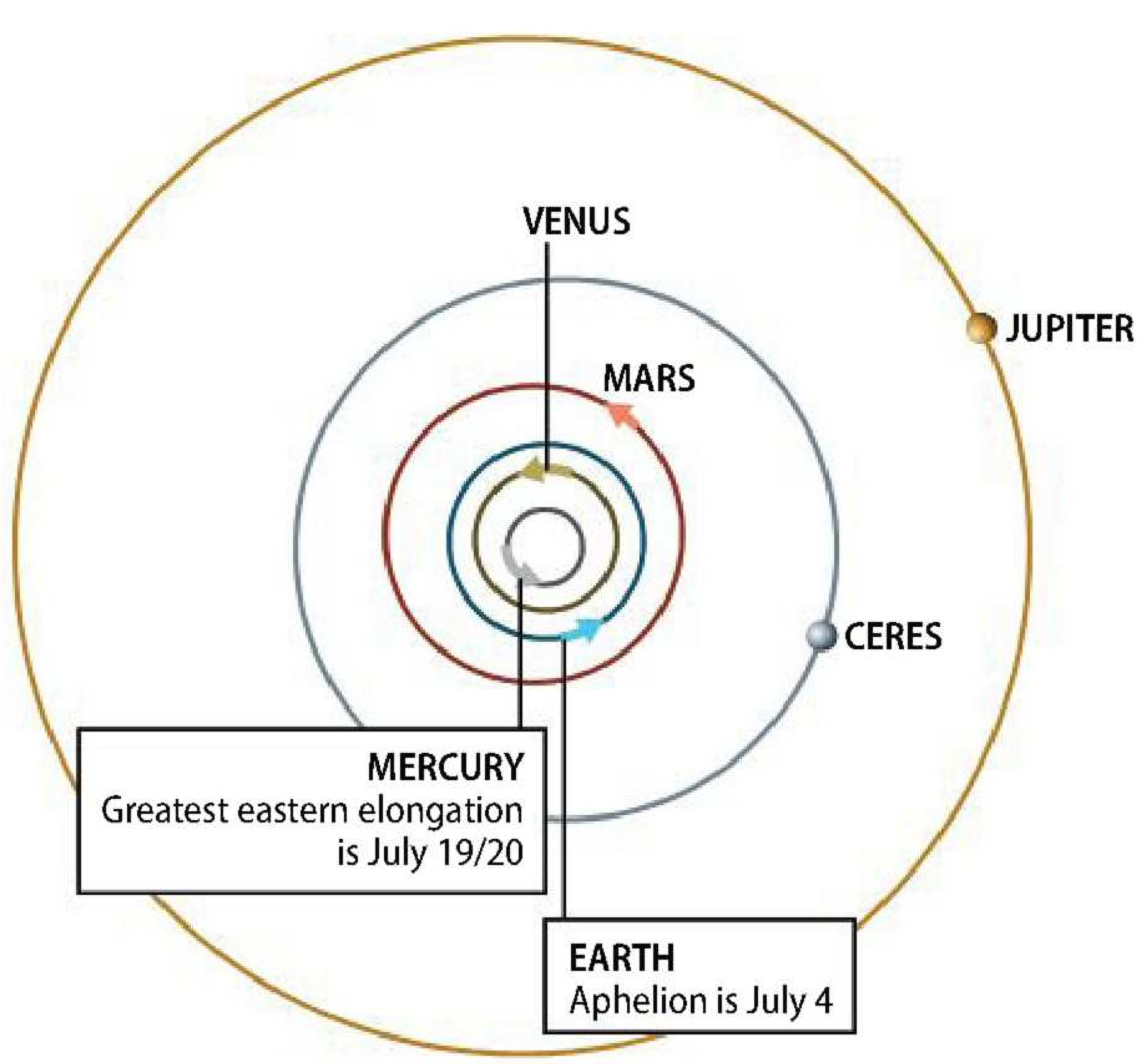
phase shown for the day straight up to the curved blue line.
and are shown at 0h Universal Time.

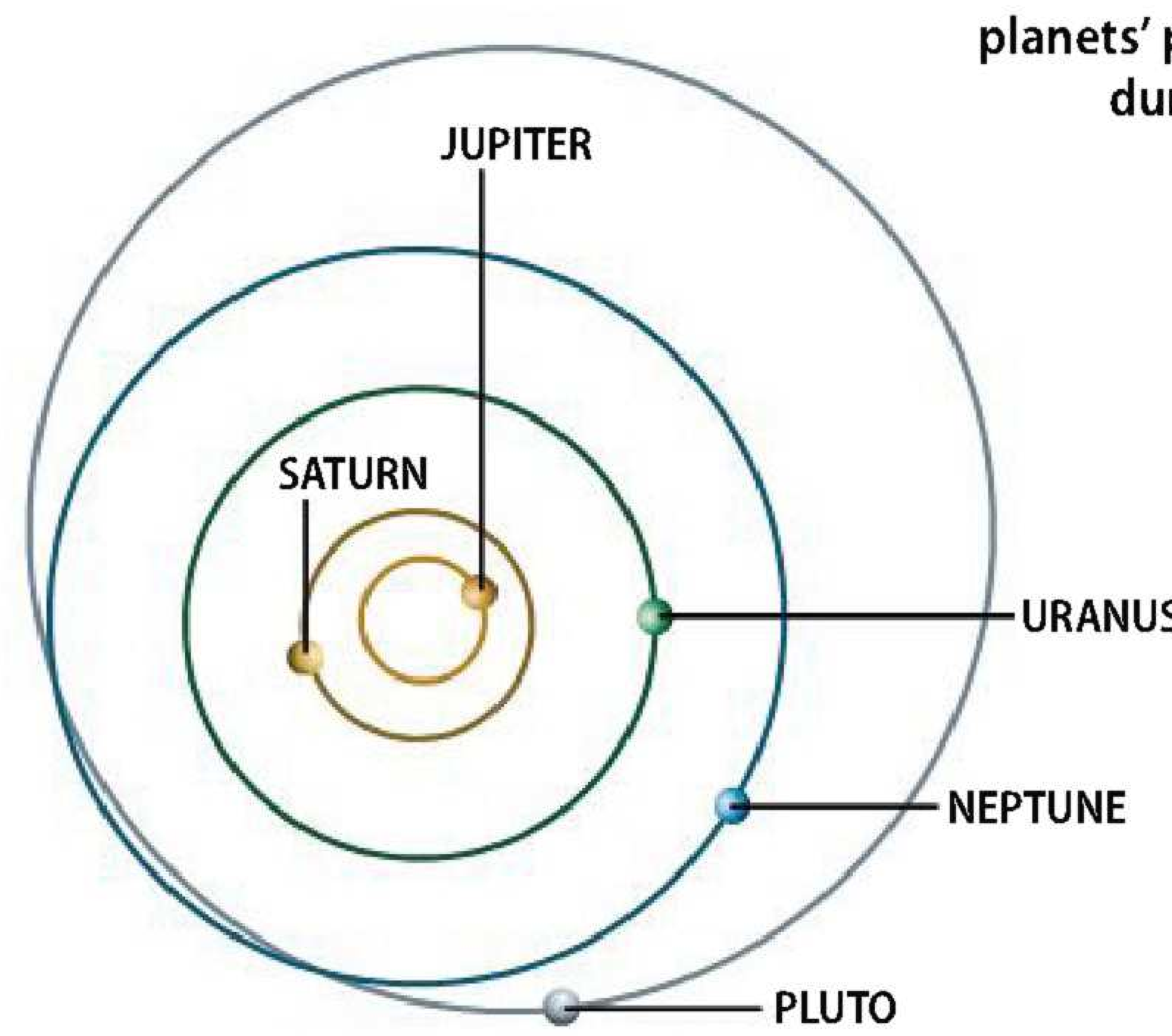
JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
July 15	July 15	July 15	July 15	July 15
−2.3	0.9	5.8	7.8	14.0
38.5"	17.0"	3.6"	2.3"	0.1"
99%	100%	100%	100%	100%
5.114	9.784	19.751	29.203	31.087
4.953	9.643	20.083	30.008	32.061
2h19.7m	12h44.7m	0h17.3m	22h10.3m	18h23.7m
12°39'	−2°09'	1°03'	−11°52'	−18°52'

DE

The planets in their orbits

Arrows and dots show planets' positions during July.





The all-sky map shows how the sky looks at:
midnight July 1
11 P.M. July 15
10 P.M. July 31

Planets are shown at midmonth

How to us **lati**

Magnitudes

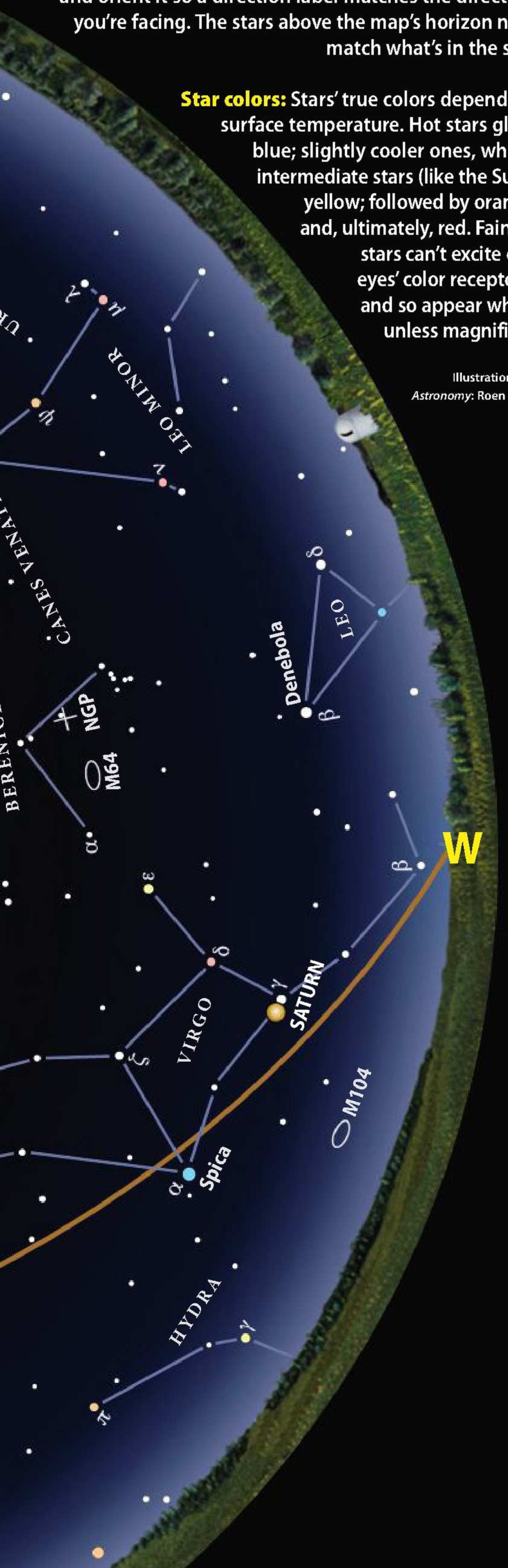
- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

e this map: This map portrays the sky as seen near 35° north tude. Located inside the border are the four directions: north, south, east, and west. To find stars, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

Star colors: Stars' true colors depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white unless magnified.

Illustrations by *Astronomy*: Roen Kelly



Quick fact: This month, Neptune completes its first orbit of the Sun since German astronomer Johann Galle first spotted it in September 1846.

Astronomy magazine

July 2011

Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

SUN.	MON.	TUES.	WED.	THURS.	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						

Calendar of events

1 New Moon occurs at 4:54 A.M. EDT; partial solar eclipse

2 The Moon passes 5° south of Mercury, 10 P.M. EDT

4 Asteroid Lutetia is at opposition, 3 A.M. EDT

Earth is at aphelion (94.5 million miles from the Sun), 11 A.M. EDT

6 Mars passes 5° north of Aldebaran, 3 A.M. EDT

7 The Moon is at perigee (229,640 miles from Earth), 9:53 A.M. EDT

The Moon passes 8° south of Saturn, midnight EDT

8 First Quarter Moon occurs at 2:29 A.M. EDT

10 Uranus is stationary, 4 A.M. EDT

15 Full Moon occurs at 2:40 A.M. EDT

18 The Moon passes 6° north of Neptune, 6 A.M. EDT

20 Mercury is at greatest eastern elongation (27°), 1 A.M. EDT

21 The Moon passes 6° north of Uranus, 3 A.M. EDT

The Moon is at apogee (251,254 miles from Earth), 6:46 P.M. EDT

23 Last Quarter Moon occurs at 1:02 A.M. EDT

The Moon passes 5° north of Jupiter, 9 P.M. EDT

27 Asteroid Metis is at opposition, 11 A.M. EDT

The Moon passes 0.5° south of Mars, 1 P.M. EDT

Special observing date

27 The Moon occults Mars for observers in parts of the South Pacific and southern South America.

29 Asteroid Pallas is at opposition, 10 A.M. EDT

30 Southern Delta Aquarid meteor shower peaks

New Moon occurs at 2:40 P.M. EDT

31 Asteroid Ceres is stationary, 8 P.M. EDT

When to view the planets

EVENING SKY
Mercury (west)
Saturn (southwest)

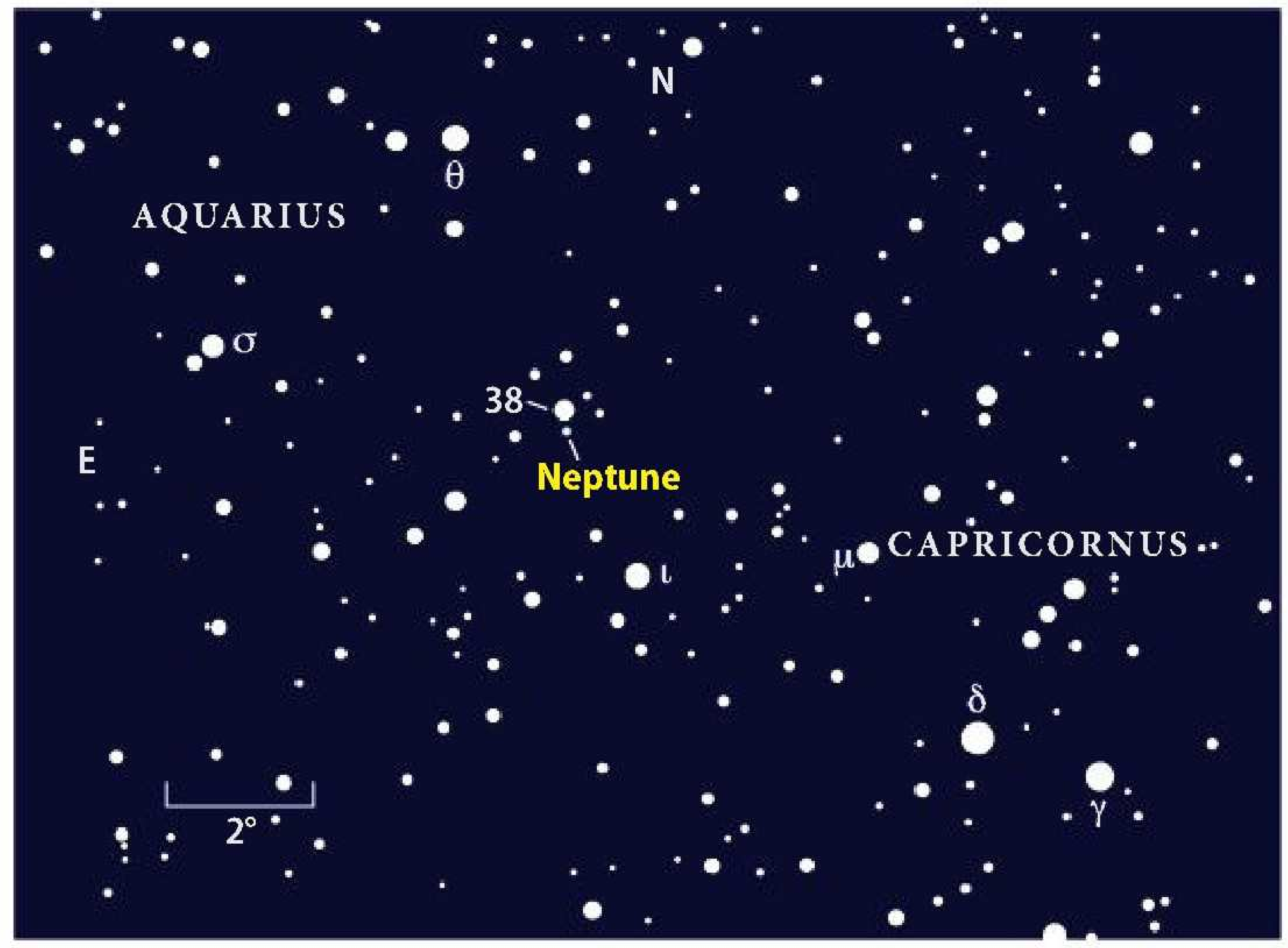
MIDNIGHT
Saturn (west)
Uranus (east)
Neptune (southeast)

MORNING SKY
Venus (northeast)
Mars (east)
Jupiter (east)
Uranus (southeast)
Neptune (south)

Distant **Pluto** reached opposition and peak visibility in late June, so it remains a tempting (although challenging) target in July. It glows at 14th magnitude, which puts it within range of a 10-inch telescope on a clear, dark night. You can find Pluto about 2° west of the bright open star cluster M25 in northern Sagittarius. The best guide star in the planet's immediate vicinity is 9th-magnitude SAO 161442. Pluto slides 0.1° south of this star during July's first week.

On July 12, **Neptune** completes its first orbit of the Sun since its discovery. (German astronomer Johann Galle first spotted the distant world September 23, 1846, by looking in the spot where French astronomer Urbain Leverrier calculated it would be.) What better time to look for the eighth planet?

Neptune glows at magnitude 7.8, so it's easy to pick out through binoculars. First, find 5th-magnitude 38 Aquarii, the brightest star along a line joining 4th-magnitude Theta (θ) and Iota (ι) Aquarii. Neptune passes 0.3° (half of the Full Moon's width) south of 38 Aqr during July's second week. Turn a telescope on Neptune, and you'll see a blue-gray disk that spans 2.3".



Neptune returns to the site where astronomers discovered this distant world 165 years ago. *Astronomy*: Roen Kelly

Uranus lies one constellation east of Neptune in a star-poor region of Pisces the Fish. But you should start your search for Uranus with a more conspicuous asterism: the Great Square of Pegasus. Draw a line from Alpheratz, the square's northeastern corner, to Algenib, the southeastern corner. Then, extend this 14°-long line another 14° to the south. Uranus will be right there. Although this area clears the eastern horizon by midnight local daylight time, you'll get a better view if you wait until dawn approaches.

Although Uranus shows up to naked eyes under a dark sky, binoculars are better for hunting it down. Just don't confuse the planet with a pair of stars less than 1° to its

Comet search

Garradd flies through the Winged Horse

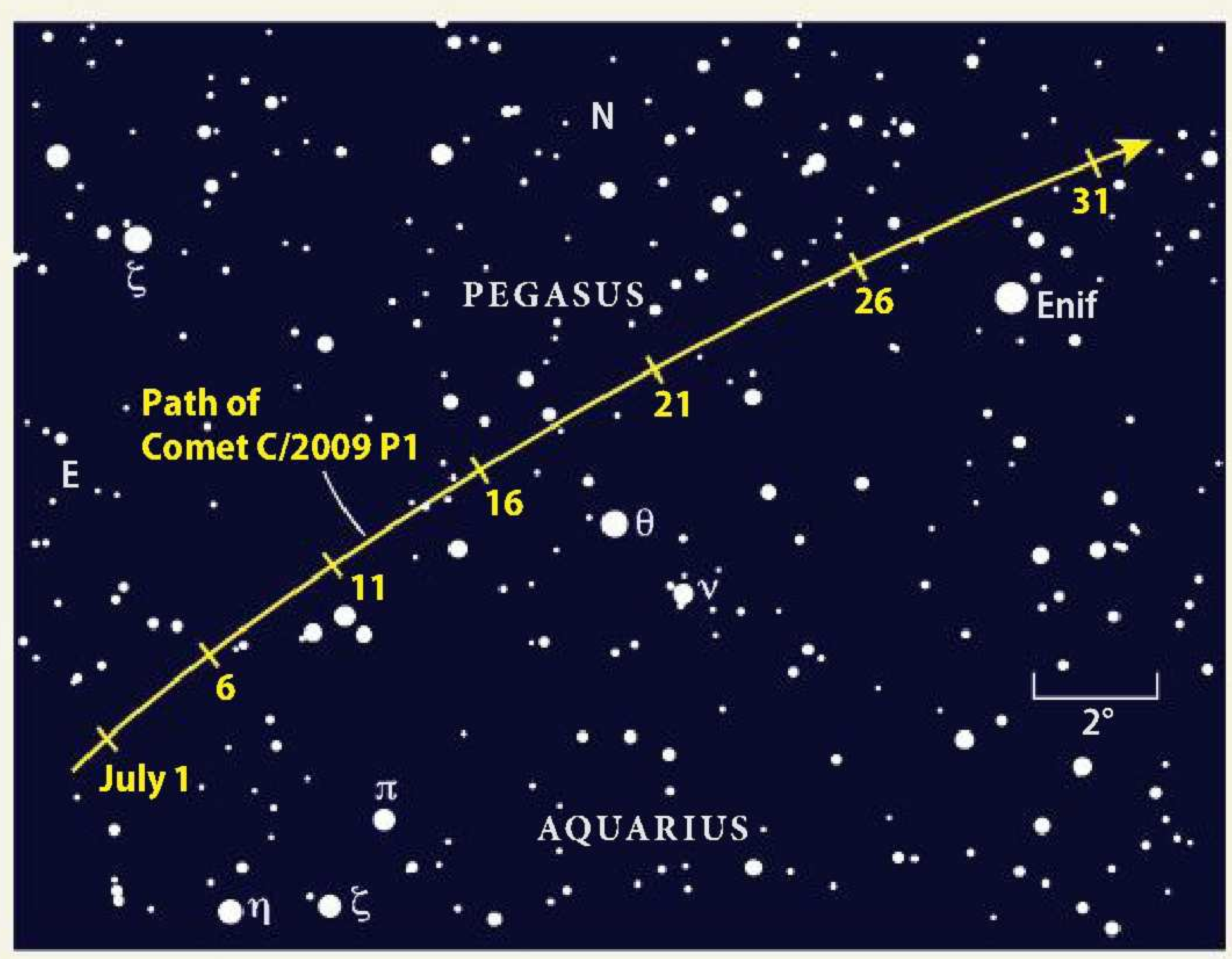
We are entering a long period of comet plenty following spring's drought. Comet C/2009 P1 (Garradd) will take a year to sail through the inner solar system. It should remain a fixture in Northern Hemisphere skies from now until next summer. It currently glows around 8th magnitude and may peak near naked-eye visibility this winter.

You should be able to pick up this visitor from the distant Oort Cloud through a 4-inch telescope under a dark sky. From city suburbs, however, don't expect to see much more than a faint fuzzy ball through an 8-inch scope. Comets making their first trip into the inner solar system are notoriously unpredictable, so don't be surprised if Garradd glows 1 to 2 magnitudes brighter or fainter than expected.

This ancient ball of ice and dust rises in the east during the late evening hours and remains on view the rest of the night. It begins July just a couple of degrees northeast of the Water Jar asterism in the constellation Aquarius the Water-bearer. The two 4th-magnitude stars at the asterism's eastern edge, Eta (η) and Zeta (ζ) Aquarii, appear at the bottom of the finder chart at right.

From there, the comet heads northwest through Pegasus the Winged Horse. It passes 2° north of 4th-magnitude Theta (θ) Pegasi during July's third week and skims a similar distance north of 2nd-magnitude Enif (Epsilon [ε] Peg) at month's end.

Like all comets, Garradd grows brighter as it approaches the Sun. Radiation from our star heats the ices in the comet's nucleus until they turn directly to gas. The liberated molecules carry dust particles with them, which gives rise to a spherical shell around the nucleus that can span a million miles. The Sun's ultraviolet light ionizes the gas molecules, and the solar wind then carries them away, forming a gas tail. Meanwhile, radiation pressure pushes the dust particles away from the Sun, creating a dust tail.



Comet C/2009 P1 (Garradd) continues its northwestward trek during July as it crosses Pegasus the Winged Horse. *Astronomy*: Roen Kelly

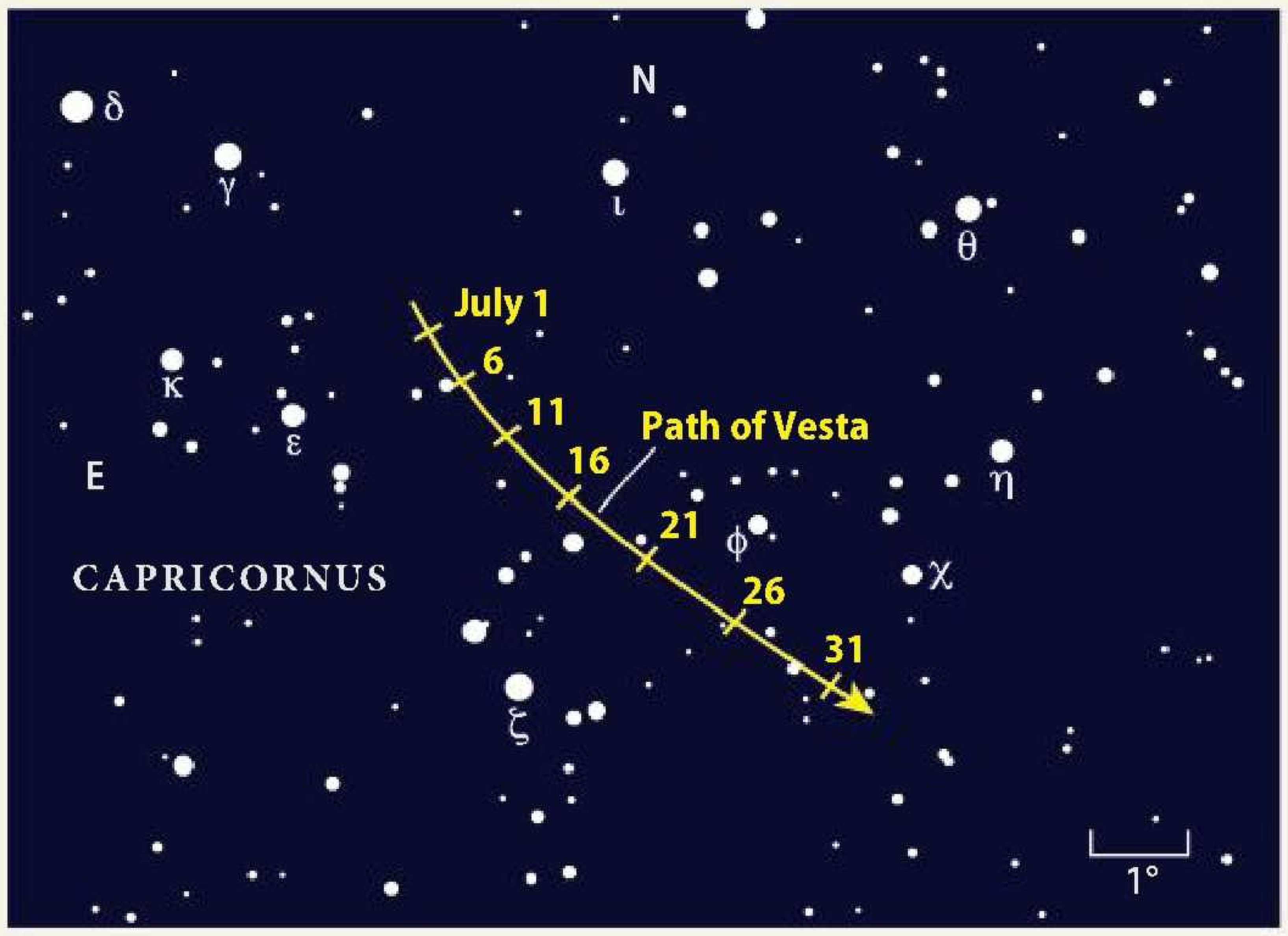
Locating **asteroids**

Vesta awaits its day in the Sun

An asteroid that will be in the news later this summer puts on a nice show in July's night sky. Vesta glows at 6th magnitude among the background stars of Capricornus the Sea Goat and is easy to see through binoculars. Vesta rises in late evening but becomes easier to find once it climbs higher after midnight.

At the beginning of July, Vesta forms the southern tip of an isosceles triangle with the 4th-magnitude stars Gamma (γ) and Iota (ι) Capricorni. It then heads southwest, passing a few modest stars, but not many that surpass the solar system's brightest asteroid. Avoid looking between July 15 and 19, when a bright Moon passes north of Vesta.

Vesta reaches opposition and peak visibility in early August, when it will glow at magnitude 5.6. But the big story next month will be the arrival of NASA's Dawn spacecraft at Vesta. The probe will orbit the third-largest asteroid until next May. Earth-based studies show that frozen lava covers Vesta's surface, and a huge crater lies near the object's south pole. After completing its Vesta reconnaissance, Dawn will fire its engines and head toward Ceres, the largest asteroid.



Asteroid Vesta slides southwestward through the background stars of Capricornus the Sea Goat in July. *Astronomy*: Roen Kelly

north. Uranus glows at magnitude 5.8, slightly brighter than either star. Through a telescope, the planet displays a 3.6"-diameter disk with a distinct blue-green color.

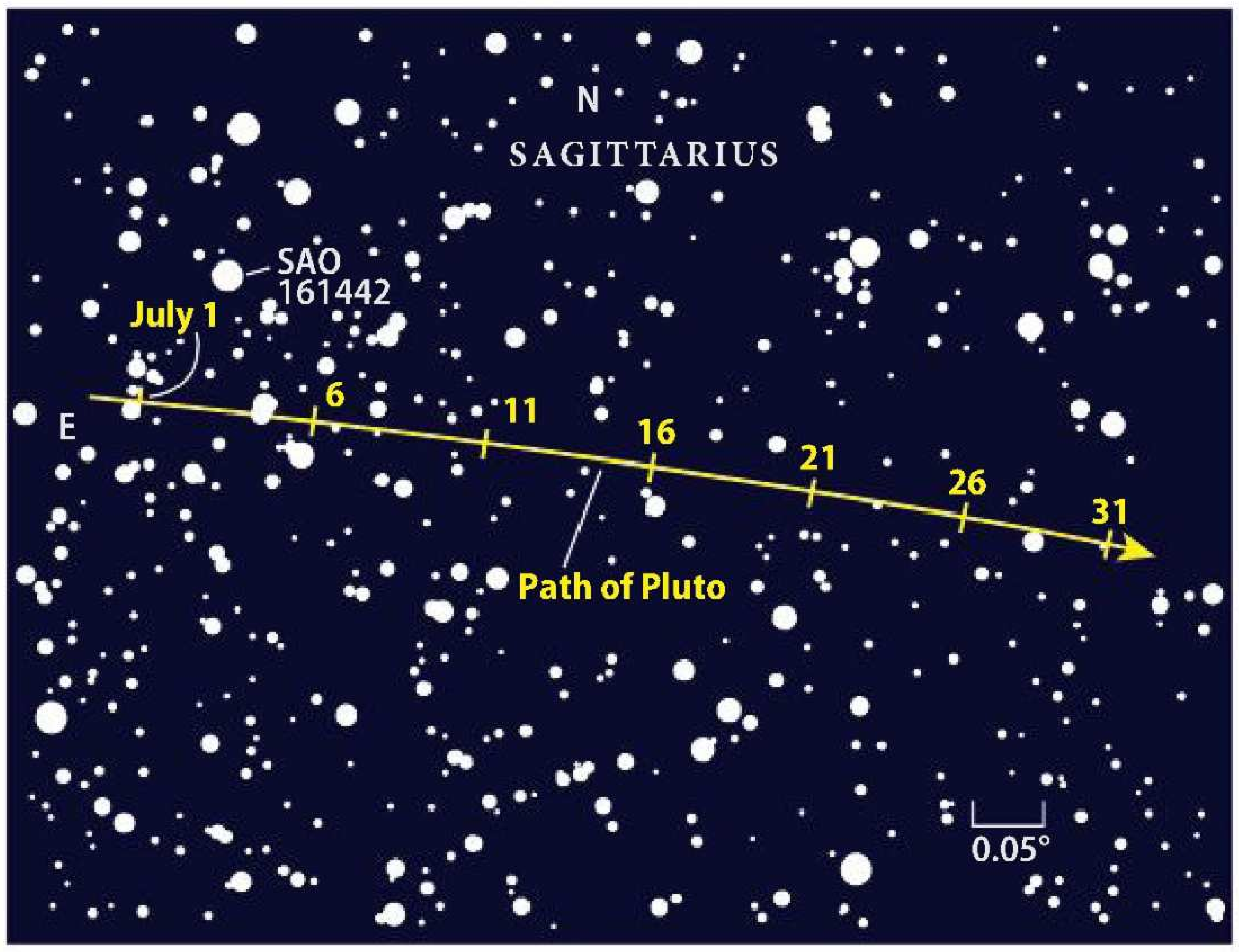
The king of the planets, **Jupiter**, certainly lives up to its name this month — no other world shines as brightly in a dark sky or appears as large through a telescope. The giant planet lies in southern Aries the Ram and rises around 2 A.M. local daylight time July 1 (it peeks above the horizon 2 hours earlier by month's end). The best views come when it climbs higher in the hour or two before twilight begins.

Jupiter shines at magnitude –2.3 at midmonth, nearly 10 times brighter than any star visible before dawn. When viewed through a telescope, this world dazzles. Jupiter's disk grows nearly 10 percent this month, from 37.1" to 40.5" across at the equator. Look for major atmospheric features such as the two dark equatorial belts. But don't let a casual glance cause you to miss fine details. Watch for a few minutes, and you're bound to catch at least one fleeting moment of good seeing, when turbulence in Earth's atmosphere settles down and crisp details pop out.

You can also follow Jupiter's four bright moons through any scope. These worlds constantly change their positions as they circle the planet at different rates. Innermost Io moves fastest, orbiting the planet once every 1.77 days. Europa, which is in an orbital resonance with Io, orbits in twice that period (3.55 days), while Ganymede orbits in twice Europa's period (7.15 days). Outermost Callisto takes 16.7 days to orbit Jupiter, slightly longer than double Ganymede's period.

A Last Quarter Moon stands to Jupiter's upper right July 23. It's a fine sight with naked eyes in the hour before dawn, especially when the stars associated with winter reappear above the eastern horizon. Taurus the Bull reminds us that these balmy summer nights eventually will give way to a harsher season.

Taurus looks different this month because **Mars** is in its midst. On the morning of July 6, Mars lies 5° north of Aldebaran, the Bull's brightest star and a near match to the Red



Distant Pluto crosses northern Sagittarius during July. The 9th-magnitude star SAO 161442 will help guide you to the dim world. *Astronomy*: Roen Kelly

Planet's color. Shining at magnitude 1.4, Mars appears slightly fainter than the star. The planet's disk spans just 4" and shows no detail through a telescope. Still, its trek across Taurus during July will be fun to watch. It passes between the horns of the Bull July 26 and, a day later, teams up with a slim crescent Moon for a nice morning scene.

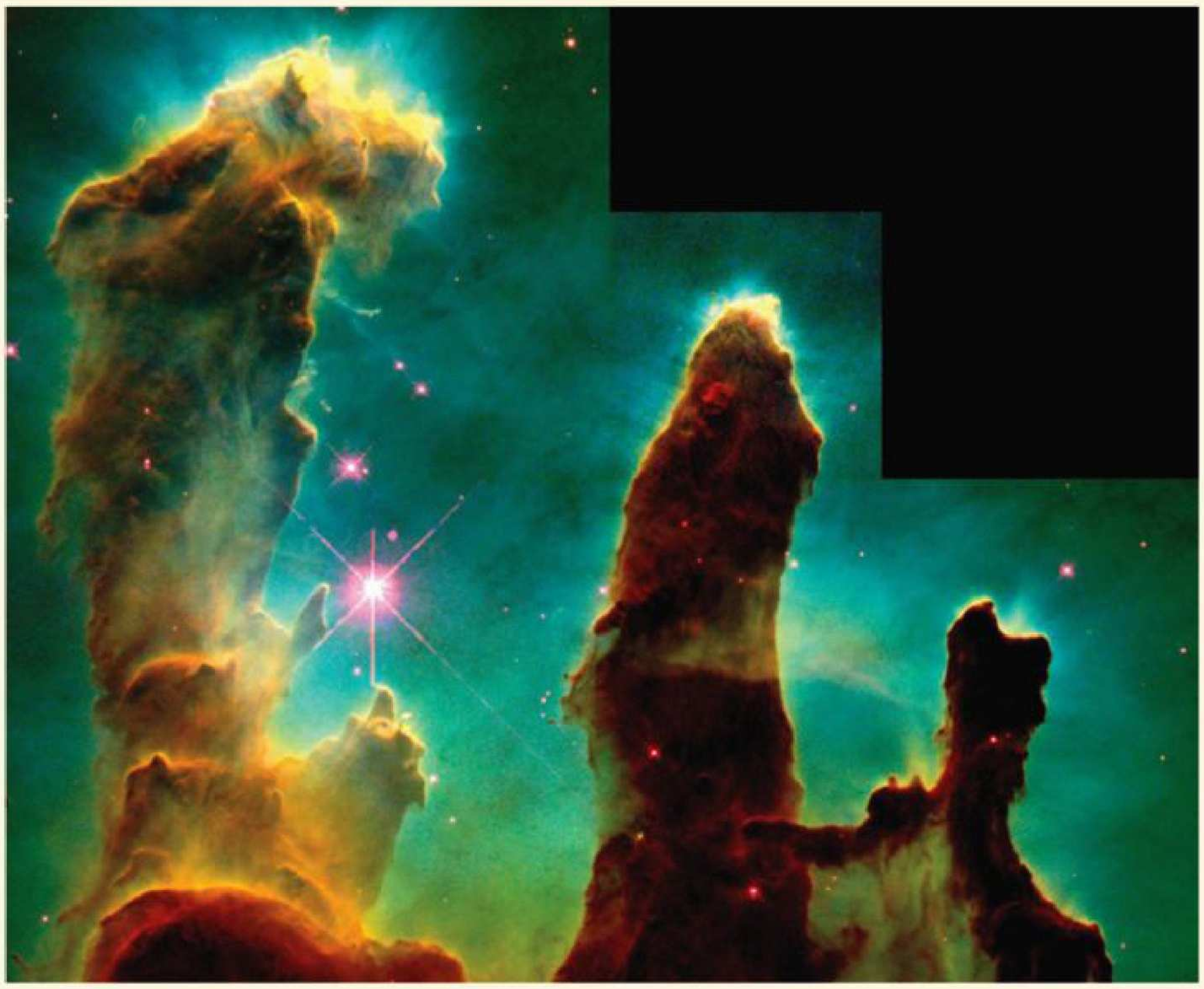
Venus appears low in the east-northeast before dawn in early July. It shines brilliantly at magnitude –3.8, the only reason it shows up in the bright twilight. Venus disappears in the Sun's glow after July's first week, and it will remain out of sight until late September.

A **partial solar eclipse** occurs July 1, but few people are likely to see it. The Moon's shadow touches Earth only in a small region between Antarctica and South Africa. And the eclipsed Sun hovers just above the northern horizon in the Southern Hemisphere's winter sky. The eclipse reaches maximum at 8h40m Universal Time, when the Moon blocks 10 percent of the Sun.

Astronomy's experts from around the globe answer your cosmic questions.

Large scales trick the eyes

Q: How dense are giant gas clouds like the "Pillars of Creation"? — **Dave Sorrell,** Waverly, Iowa



The Eagle Nebula appears to contain nearly solid pillars of gas, but these structures are actually much less dense than air on Earth. NASA/ESA/STScI/J. Hester and P. Scowen (Arizona State University)

A: The biggest pillar in the classic Hubble Space Telescope picture of the Eagle Nebula (also known as the "Pillars of Creation") measures about 3 light-years. The pillars are about half a light-year thick. The image leads us to believe that the contrast between the pillars and the space between them is large — the pillars look almost solid. However, the amount of material we are looking through, rather than the density of the gas, determines this contrast.

The terrestrial analog is looking into a fog bank. What we call "dense fog" is not actually denser; it is just a larger cloud of material — more water droplets suspended in the air along our line of sight obscure our view. And so it is with these types of nebulae. Because we're looking a half light-year through the pillars, we can see sharp edges and apparently dense structures — even though the material is quite tenuous.

In the Eagle Nebula, the density of material within the columns is about 4,000 particles per cubic centimeter. Air density at sea level has more than 10^{19} particles per cubic centimeter — that's a factor of 10 million billion times more dense than in the pillars. The 4,000 particles per cubic centimeter density is far lower than that of the best vacuum we can achieve on Earth. So, it is the vast scales of these nebulae that give them the appearance of solid structures. — **Paul Scowen,** Arizona State University, Tempe

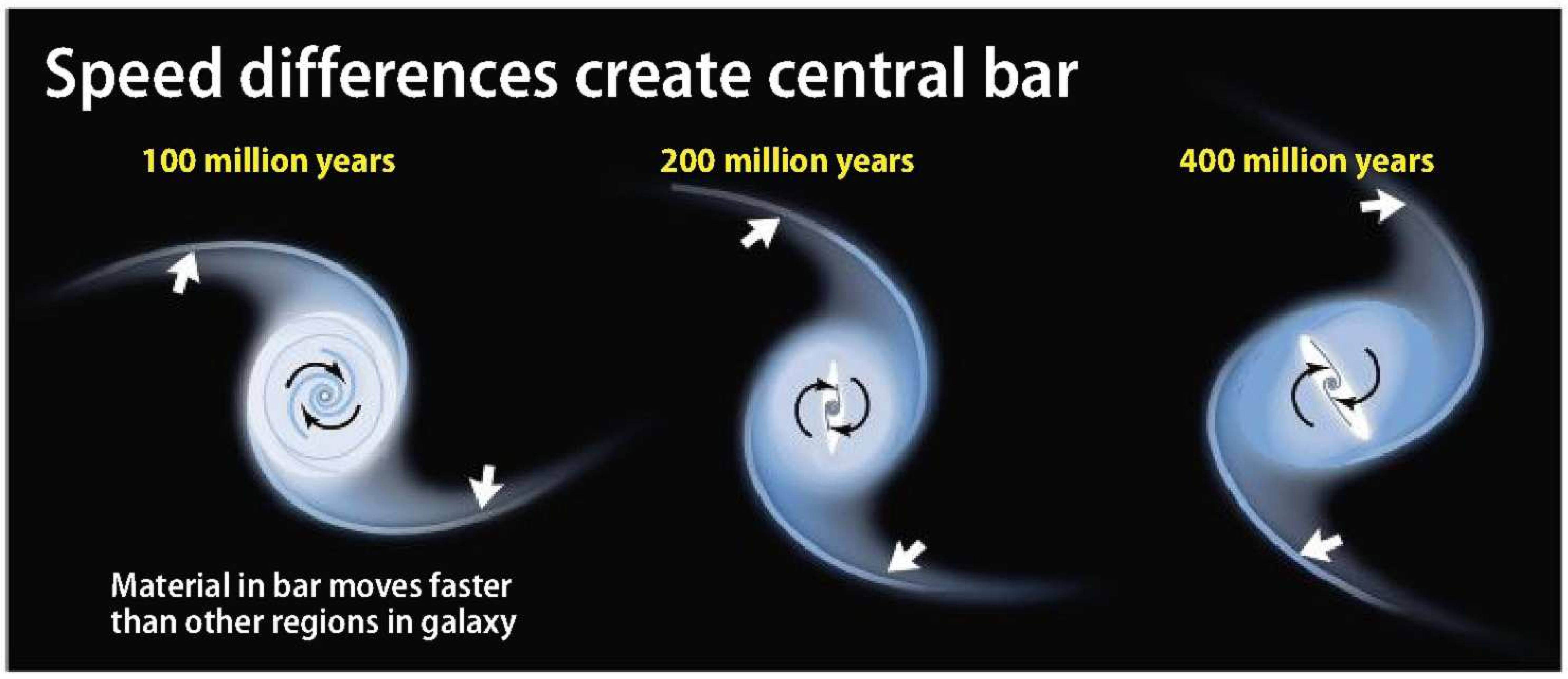
IS TITAN FLAMMABLE?

Q: On Earth, methane is a flammable fuel. If you introduced a flame to the methane on Saturn's moon Titan, would it burn? — **Roland Labounty,** Seneca, South Carolina

A: Combustion, or burning, is a process where a fuel such as methane undergoes a sequence of exothermic chemical reactions that release energy when interacting with an oxidizing compound (usually molecular oxygen). In Earth's atmosphere, the overall methane reaction is: methane + 2 molecular hydrogen molecules → carbon dioxide + 2 water molecules + energy.

The main constituents of Titan's atmosphere near the satellite's surface are molecular nitrogen, methane, and molecular hydrogen in approximate ratios of 0.95 to 0.049 to 0.001, respectively. The atmosphere contains no free molecular oxygen. In fact, the most abundant molecule with an oxygen atom is carbon monoxide, at 50 parts per million. Carbon monoxide is an end product of incomplete combustion and has one of the strongest chemical bonds for diatomic molecules. Therefore, it is impossible for methane — with a chemical bond strength less than half that of carbon monoxide's — to interact with carbon monoxide in an exothermic, heat-releasing reaction.

Thus, **methane would not burn in Titan's atmosphere in the normal sense of combustion.** But ultraviolet photons and reactive molecules, such as molecular carbon and methane, can chemically break the carbon-hydrogen bonds in methane to produce more complex hydrocarbons — such as acetylene, ethylene, ethane, propane, benzene, etc. This chemical conversion of methane to more complex hydrocarbons is an irreversible process because the hydrogen atoms and molecules released ultimately escape out the top of Titan's atmosphere. — **Darrell Strobel,** Johns Hopkins University, Baltimore, Maryland



A galaxy's central bar may look like a solid structure, but it's really a dense region that affects the galaxy as it rotates around the core. Gas near the galaxy's center moves at faster speeds than that farther out. This, combined with density waves, helps create the bar. *Astronomy*: Roen Kelly, after Daisuke Namekata, et al.

THE GALACTIC BAR

Q: What causes the central bar in some spiral galaxies? — **Dennis Shingler,** Inverness, Florida

A: Central bars occur in about two-thirds of spiral galaxies. We think they are regions of many overlapping stellar orbits. **Bars are also density waves that rotate around the disk with a speed different from the rotation speed of individual stars, much like the waves that create the spiral structure of these galaxies.**

Gravitational instabilities in the centers of galaxies, or gravitational disturbances from nearby galaxies, can cause density waves. As the waves rotate around the galaxy, they hold their shape like the blades of a fan. When a wave reaches a cloud of cold molecular gas, the density in the cloud may increase enough to cause the cloud to collapse under its own gravity, eventually forming stars.

Bars can also affect star formation by moving large amounts of gas toward (or away from) the galactic center. Gas in the inner region of the galaxy will orbit at a higher speed than the bar. When this gas catches up to the bar and passes through it, the bar's stronger gravity slows it, so the material loses energy. As a result, the gas falls toward the galactic center. If this process funnels enough gas toward the galactic center, a tremendous period of star formation — called a nuclear starburst — follows.

Farther out in the galaxy, the gas moves more slowly than the bar. When the bar overtakes the gas, the bar pulls the material forward, speeding it up. The fast-moving gas will then gain energy and be flung outward, away from the galactic center. — **Bradley W. Peterson,** Iowa State University, Ames

A+ Find out how Earth's radio emission compares to that of the rest of the planets at www.Astronomy.com/toc.

TELESCOPE TALK

Q: What is the benefit of a 2" eyepiece compared to a 1¼" eyepiece? — **Tom Nagy,** North Ridgeville, Ohio

A: A 2" eyepiece delivers a wider true field of view (the actual amount of sky visible) than a 1¼" eyepiece of the same focal length. Two factors determine the true field: the telescope's focal length and the diameter of the eyepiece's field stop. A field stop is a centered, circular opening in front of the eyepiece's front (or field) lens. The bigger the field stop, the more sky you'll see.

The only limit to field stop size is the inside diameter of the eyepiece's barrel. So, for example, a 20mm 2" eyepiece will show more sky than a 20mm 1¼" eyepiece through the same telescope. What's more, the magnification through both eyepieces will be the same.

Most observers prefer a wider field that doesn't sacrifice higher magnification. This really helps skywatchers whose telescopes lack a motorized drive. **A wider true field of view means you have to manually move your scope less often to follow objects as Earth rotates.** — **Michael E. Bakich,** Senior Editor

AN ODD FORCE

Q: Gravity decreases with distance. Could the repulsive force of dark energy increase with distance, causing the universe's expansion to accelerate? — **Jim Hartsell,** Sunnyvale, California

A: Every fundamental force in nature that acts on astronomical scales must decrease with distance. Otherwise, for example, a distant planet or star would exert a stronger pull on us than Earth does. **Life as we know it would be impossible if a force actually increased with distance.**

However, it could be that there exists a new force that decreases with distance, but does so at a rate slower than that of gravity. In other words, this hypothetical force would fall off slower than the inverse square of the distance. It would thus become more important than gravity when calculating the gravitational pull from objects that are extremely far away. In fact, cosmologists have speculated that gravity itself may have such a property — that its force may fall off slower than what Isaac Newton calculated and Albert Einstein generalized — when the distance is billions of light-years. Observations have not yet ruled out such a modification to the law of gravity.

However, replacing one curious finding (the acceleration of the universe's expansion) with a somewhat bizarre theory (an ad hoc change in the well-established law of gravity) does not explain the accelerating universe in a convincing way. More measurements and deep new insights will be necessary to understand the physical mechanism behind dark energy. — **Dragan Huterer,** University of Michigan, Ann Arbor

Send your questions via e-mail to: **askastro@astronomy.com**; or write to **Ask Astro, P. O. Box 1612, Waukesha, WI 53187.** Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

Discover summer's hidden deep-sky wonders

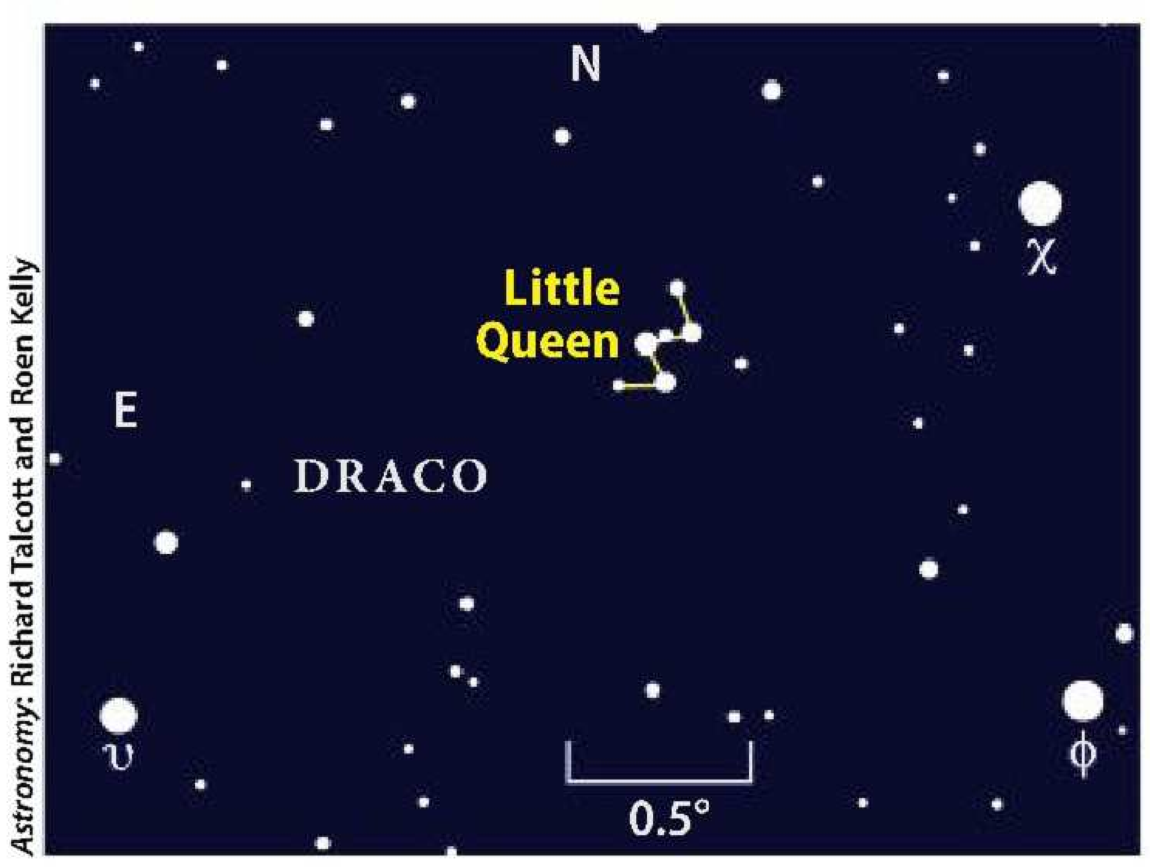
This select group of 10 summer gems boasts everything from colorful nebulae to ultra-faint galaxies. **by Michael E. Bakich**

When I head out to observe, I target faint or little-known objects. I reserve views of easier targets like the Andromeda Galaxy (M31) and the Orion Nebula (M42) for relatives and public star parties. Bright celestial targets have the greatest impact on those not familiar with the sky. But experienced amateur astronomers, or those wanting to see more than just the highlight objects, quickly point their telescopes to more elusive targets.

The 10 objects in this article all lie in the summer sky but well off the beaten path taken by beginners. Each of them is a worthwhile target you'll be happy to view. I've organized the list starting with the easiest to see and proceeding to the most difficult. An 8-inch telescope will reveal all but the last two of these gems. If you're up to the challenge, read on.

A low-power start

I'll start the tour with an easy-to-see binocular asterism called the **Little Queen** because of its resemblance to the "W" figure within the constellation Cassiopeia. *Astronomy* Contributing Editor Phil Harrington first popularized this group in the late 1990s.



To find the Little Queen, look in Draco for a tiny asterism that resembles the "W" figure of Cassiopeia. This star pattern sits between Chi (χ) and Upsilon (υ) Draconis.

The Little Queen lies 1.2° east-southeast of magnitude 3.6 Chi (χ) Draconis. If you draw a line from Chi to magnitude 4.8 Upsilon (υ) Draconis, the asterism lies just north of the halfway point between the two stars.

The Little Queen's stars from north to south are SAO 9173, SAO 9169, SAO 9181, SAO 9176, and SAO 9189. SAO 9181 shines brightest at magnitude 6.8. The faintest, SAO 9189, glows at magnitude 8.6.

It's OK if you've never observed (or even heard of) **IC 4665**. Although it's a relatively bright open cluster at magnitude 4.2, it won't look that bright to you because its light spreads out over a diameter of 70'. That's more than 5 times the area covered by a Full Moon.

IC 4665 lies in northern Ophiuchus, 1.3° north-northeast of magnitude 2.8 Beta (β) Ophiuchi. To observe the cluster, use a low-power eyepiece that will give you at least a 1° field of view. You'll see several dozen 7th- to 9th-magnitude stars and another 20 stars around magnitude 10 set against a rich background haze of fainter points.

My best view of IC 4665 came through an 8-inch f/4.5 Newtonian reflector equipped with a binoviewer. Using a magnification of around 45x, the cluster took on a layered 3-D appearance.

You want obscure? For our next object, the **Mu Normae Cluster** (NGC 6169), North American observers will have to scrape the southern horizon. This hidden gem lies 4° west-southwest of magnitude 3.6 Zeta (ζ) Scorpii. The open cluster shines at magnitude 6.6 and spans 12'. It lies in our line of sight with the magnitude 4.9 star Mu (μ) Normae, thus the cluster's common name.

The Emerald Nebula (NGC 6572) in Ophiuchus is easy to spot because it has a high surface brightness. Most observers see a greenish hue, but you may see blue because the eye's color receptors differ from one person to the next. Bruce Bodner/Adam Block/NOAO/AURA/NSF

I take one of two approaches to observing this cluster through an 8-inch or larger telescope. Sometimes I use low power, around 50x, and just try to ignore the star Mu Normae. That's tough to do because Mu lies pretty much dead center.

My other approach is to use high magnification, say 250x, and observe each half separately. Place Mu just outside the field of view twice, in opposite directions. That way, you can observe half of the 10th-magnitude and fainter cluster stars when Mu lies outside the field of view to the east and the other half when you've moved Mu out to the west.

Planetary overload

Even a small telescope will reveal the next object. It's the **Emerald Nebula** (NGC 6572) in Ophiuchus, 2.2° south-southeast of the magnitude 4.6 star

Michael E. Bakich *is a senior editor of* Astronomy. *His latest book is* 1,001 Celestial Wonders to See Before You Die *(Springer, 2010).*

71 Ophiuchi. This planetary nebula is small, only 18" across, but it has a high surface brightness, and it's colorful.

Through an 8-inch telescope, you'll see the Emerald Nebula's oval shape and a bright central region. The observing strategy I suggest to pull out NGC 6572's color is to keep the magnification low, but I've had good results from 100x to 400x through a 12-inch telescope.

Another planetary nebula worth lengthy observation is the **Little Ghost** (NGC 6369) in southern Ophiuchus. It lies 0.5° west-northwest of the magnitude 4.8 star 51 Ophiuchi.

The Little Ghost measures about 30" across and glows at magnitude 11.4. Through an 8-inch telescope at 200x, you'll see a circular ring with a slightly brighter northern half. Although the central star shows up well in astroimages, you'll need at least 14 inches of aperture to spot this magnitude 16 specter. Through even larger instruments, the bright northern rim turns into a vivid streak buried in the ring's nebulosity.

What could be better to follow the Little Ghost than the **Little Gem** (NGC 6818) in Sagittarius? This treat sits in a no man's land bereft of bright stars near the Archer's northern border with Aquila. Look for this small planetary nebula 9° due west of 3rd-magnitude Dabih (Beta Capricorni). Although stellar luminaries in this part of the sky are scarce, it is a great area for deep-sky treats. The Little Gem lies only 0.7° north-northwest of Barnard's Galaxy (NGC 6822). Talk about two objects that are on the opposite ends of the surface-brightness spectrum!

Luckily for this list, the Little Gem is the bright one. It shines at magnitude 9.3 and measures roughly 40" across from north to south and a bit less from east to west. The combination of brightness and small size means NGC 6818's surface brightness is high, and you can really crank up the magnification.

The greenish-blue color most observers see appears best at around 100x. Above that power, look for this object's ever-so-slightly darker inner half.

Adam Block/NOAO/AURA/NSF

To see details in the Box Nebula (NGC 6309) in Ophiuchus, you'll need an 8-inch scope, a dark site, a nebula filter (such as an Oxygen-III), and an eyepiece that magnifies at least 250x.

The Little Ghost (NGC 6369) lies just 0.5° from the magnitude 4.8 star 51 Ophiuchi. The little-observed planetary nebula displays nearly a perfect ring through an 8-inch telescope. R. Jay GaBany/Adam Block/NOAO/AURA/NSF

The Little Gem (NGC 6818) in Sagittarius isn't easy to star-hop to because of the lack of nearby bright stars. What most observers remember about this object is its greenish-blue color, which is easy to see. Mitch and Michael Dye/Adam Block/NOAO/AURA/NSF

Nearly every dedicated observer has seen the Bug Nebula (NGC 6302) in Scorpius. My next suggested target — also a planetary nebula — isn't as big, bright, or famous. Sound like fun? Well, then, look for the **Box Nebula** (NGC 6309) in Ophiuchus 1.6° west of magnitude 4.3 Nu (ν) Serpentis.

The Box Nebula glows at magnitude 11.5. At least it doesn't spread its light across a large area. NGC 6309 measures only 18" across, and that's a plus in this case because the small size keeps the planetary's surface brightness high.

Through an 8-inch telescope, crank the magnification past 250x to identify the box's shape. A nebula filter such as an Oxygen-III (OIII) will help a lot. Some observers use lower powers and combine NGC 6309 with the 9th-magnitude star 1' to its northwest to form the Exclamation Point Nebula. Try it yourself.

If you're lucky enough to view the Box Nebula through a telescope with 16 inches of aperture or more, you'll see tiny but distinct details at magnifications approaching 500x. For example, the northwest half appears slightly brighter than the southwestern part. Faint nebulous tendrils roughly one-quarter of the Box's length extend outward from the northwestern edge. And the central star will pose no problem. That magnitude 14 point of light lies at the nebula's center.

As planetary nebulae go, the **Retina Nebula** (IC 4406) in Lupus is relatively

Abell 2151, also known as the Hercules Galaxy Cluster, is my all-time favorite deep-sky object. Unfortunately, it's not easy to see. You'll need a 16-inch or larger telescope to discern more than just a few faint smudges. When you see it, however, you're looking at objects 650 million light-years away. Ken Crawford

The Retina Nebula (IC 4406) in Lupus sits low on (or below) the horizon for many Northern Hemisphere observers. Once you locate the magnitude 10.2 glow, look for the object's straight northern and southern edges. Jack Marling

bright, although it measures only 30" across. What makes it obscure for northern observers is its location. It lies at a declination of –44°. My rule of thumb is if you can see Omega Centauri (NGC 5139) from your observing site, you stand a good chance of picking up IC 4406, which lies 3° farther north.

IC 4406 sits a bit more than 3° southwest of magnitude 2.3 Eta (η) Centauri. Through an 8-inch telescope equipped with an OIII filter, the "top" and "bottom" of this nebula orient east to west and appear remarkably straight. The northern edge is brighter than the southern one. At high powers, you'll see that the central region has indentations, lending the whole object the appearance of another dumbbell-shaped nebula.

Go deeper

All the selections on this list qualify as "deep-sky" objects, but galaxy cluster **Abell 2151** in Hercules takes that term to a whole new level. It lies at the astounding distance of 650 million light-years from Earth. Imagine that. The light that you glimpse from any of its galaxies started on its journey toward Earth several hundred million years before the first dinosaurs existed.

If your scope has a go-to drive, its database may not contain Abell galaxy clusters. That's not a problem here. Just target this cluster's brightest member, elliptical galaxy NGC 6041, which glows at magnitude 13.4.

Success observing this galaxy cluster requires at least a 12-inch telescope and eyepieces that give powers in excess of 250x. High magnifications increase the contrast between extended objects such as galaxies and the background sky. Abell 2151 spans more than 1°, so move your scope around a bit to see the maximum number of galaxies.

As if Abell 2151 weren't faint enough, I'll finish this tour with a real challenge object. Those of you with 16-inch or larger telescopes might want to search for the ultra-faint trio of galaxies called **Zwicky's Triplet**, which lies in Hercules. Also known as compact galaxy group Arp 103, it contains three spiral galaxies.

The Triplet's "luminary" is magnitude 15.2 PGC 59061. From there, it's all uphill. PGC 59062 glows at magnitude 15.6 and PGC 59065 (dare I say "shines"?) at magnitude 16.2.

For those observers not familiar with the "PGC" label, it stands for the *Principal Galaxy Catalog*. Astronomers compiled 73,197 galaxies for the 1989 catalog. The 2003 version contains 983,261 galaxies brighter than magnitude 18.

Don't look for details in the members of Zwicky's Triplet. You won't see any. Consider it a badge of honor if you just detect them. Only 8' east-southeast of Zwicky's Triplet, you'll spot another galaxy, NGC 6241. I wish I could tell you it's a good one, but it's only as bright as PGC 59061, which isn't all that bright.

The summer sky is chock-full of terrific deep-sky objects that do not contain "Messier" in their designations. In the Northern Hemisphere, nights are short (but warm), so stay out late and observe sky treats that lie off the beaten path.

Visit Northern California's top astronomy sites

From mountaintop observatories exploring the distant cosmos to long tunnels probing matter's heart, Northern California has sites for any astronomy buff. **by Yvette Cendes**

Nearly every visitor to Northern California comes away impressed with the stunning views. Whether you prefer the elegance of the Golden Gate Bridge in San Francisco, the majestic coastal redwoods, or the granite monolith of El Capitan in Yosemite, the Golden State has sights to satisfy any taste. But California has many world-class astronomical vistas to soak in as well, and many of them lie within an easy drive of the Bay Area. Any visiting astronomy buff should add some of these sites to their itinerary, or see them all and make their California adventure an epic road trip.

The Allen Telescope Array at Hat Creek Radio Observatory currently features 42 radio telescopes looking for signals from alien civilizations. Seth Shostak/SETI Institute

Allen Telescope Array

It's a thrill to stand in the shadow of the Allen Telescope Array (ATA) knowing that someday you might tell your grandchildren you were there. The reason: 42 matching radio telescopes silently scan the sky across millions of radio frequencies in a quest to find signals from civilizations elsewhere in the galaxy. The Search for Extraterrestrial Intelligence (SETI) could finally bear fruit at ATA. Of course, the

The radio dishes of the Owens Valley Radio Observatory stand as sentinels across Klondike Lake at the foot of the Sierra Nevada. David M. Weber

long-awaited signal might be years in the future — if it comes at all — but who's to say E.T. won't phone tomorrow?

Located 5 hours north of San Francisco near Lassen Volcanic National Park, Hat Creek Radio Observatory is home of the ATA, which is named after Microsoft co-founder Paul Allen (who funded the technology development and construction). The current 42-dish array, a joint project of the SETI Institute and the University of California, Berkeley, is just the first phase of a much larger instrument that someday will boast 350 telescopes.

The ATA's design pushes the envelope in new technology. The dishes are only 20 feet (6 meters) in diameter — small for a traditional radio telescope but cheaper to build — and high-performance electronics combine signals from the multiple dishes. Further, the array's unique design allows radio astronomers to conduct wide-field sky surveys and SETI searches simultaneously for the first time.

Walk-in tours are available Monday to Friday from 9 A.M. to 3 P.M. during the summer. Tours include seeing the array and visiting the control room (where, it must be noted, the computers do not run Windows even though Allen is the array's namesake). If you're lucky, you might get to chat with visiting SETI astronomers.

Top astronomy sites of Northern California

The Golden State features spectacular natural scenery along with many science sites guaranteed to excite astronomy enthusiasts. *Astronomy*: Roen Kelly

ADDRESSES AND WEBSITES

For more information, contact the specific sites:

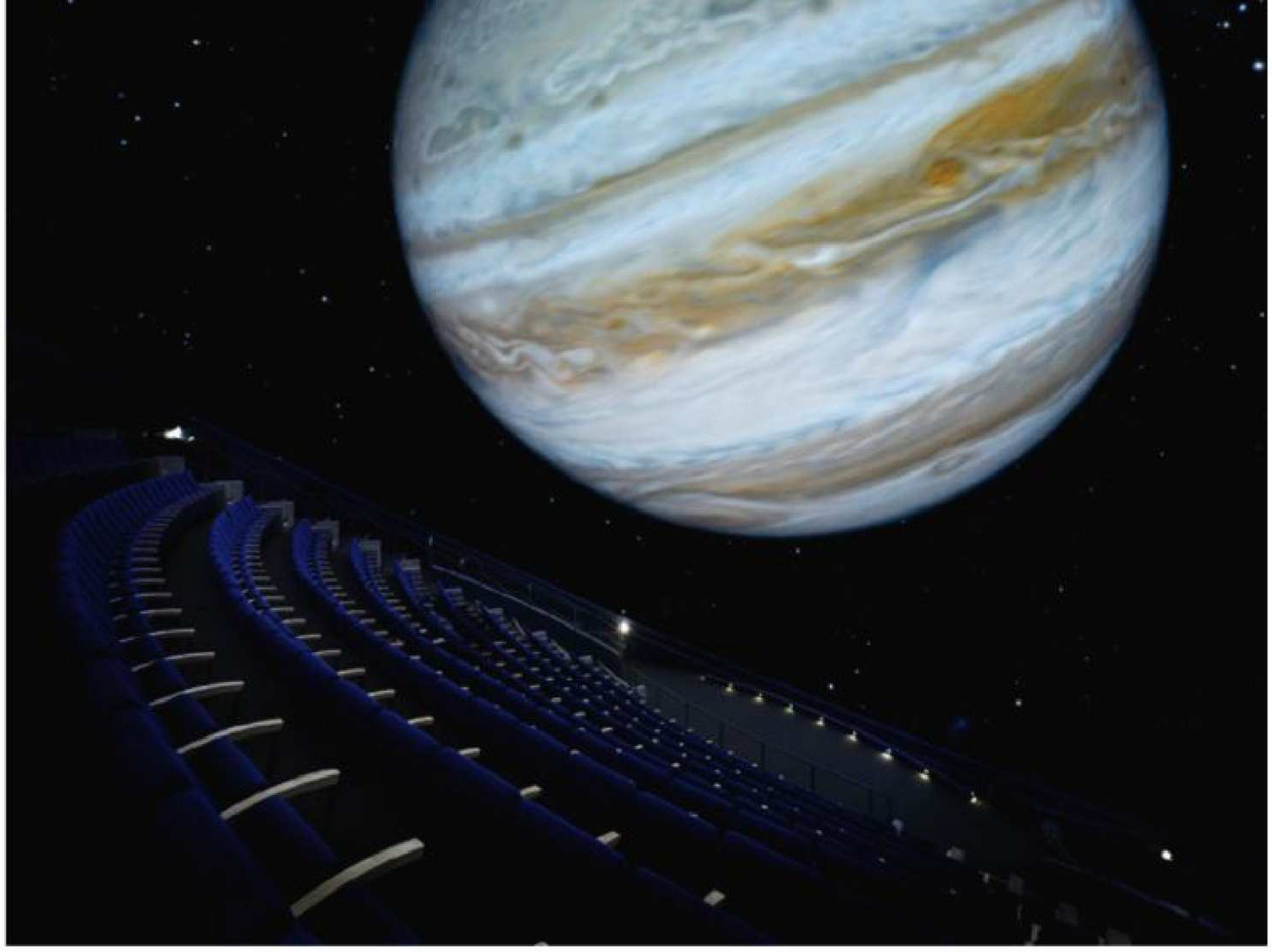
Allen Telescope Array
42231 Bidwell Road
Hat Creek, CA 96040
[t] 530.335.2364
[w] www.seti.org/ata

California Academy of Sciences
55 Music Concourse Drive
Golden Gate Park
San Francisco, CA 94118
[t] 415.379.8000
[w] www.calacademy.org

Lick Observatory
7281 Mount Hamilton Road
Mount Hamilton, CA 95140
[t] 408.274.5061
[w] http://mthamilton.ucolick.org

Owens Valley Radio Observatory
100 Leighton Lane
Big Pine, CA 93513
[t] 760.938.2075
[w] www.ovro.caltech.edu

SLAC National Accelerator Laboratory
2575 Sand Hill Road
Menlo Park, CA 94025
[t] 650.926.3300
[w] http://slac.stanford.edu



The Morrison Planetarium at the California Academy of Sciences in San Francisco features a 90-foot (27 meters) dome tilted at 30° for optimal viewing. Tim Griffith/California Academy of Sciences

California Academy of Sciences

Located in Golden Gate Park in the heart of San Francisco, the California Academy of Sciences boasts itself as "the only place on the planet with an aquarium, a planetarium, a natural history museum, and a 4-story rainforest all under one roof!" If that slogan doesn't impress you, the building's award-winning design will. Opened in 2008, it focuses on sustainability and even sports a "living roof," which features 197,000 square feet of native plants spread across seven hillocks.

Although all of the exhibits are a treat, astronomy buffs will delight in watching a show at the Morrison Planetarium. The world's largest all-digital planetarium, its 90-foot (27 meters) dome tilts 30° for optimal viewing. The shows are crafted with painstaking scientific accuracy.

The academy is extremely popular and tickets are available on a first-come, first-serve basis, so consider purchasing them online before your visit. Regular museum hours run Monday to Saturday from 9:30 A.M. to 5 P.M., and Sunday from 11 A.M. to 5 P.M.

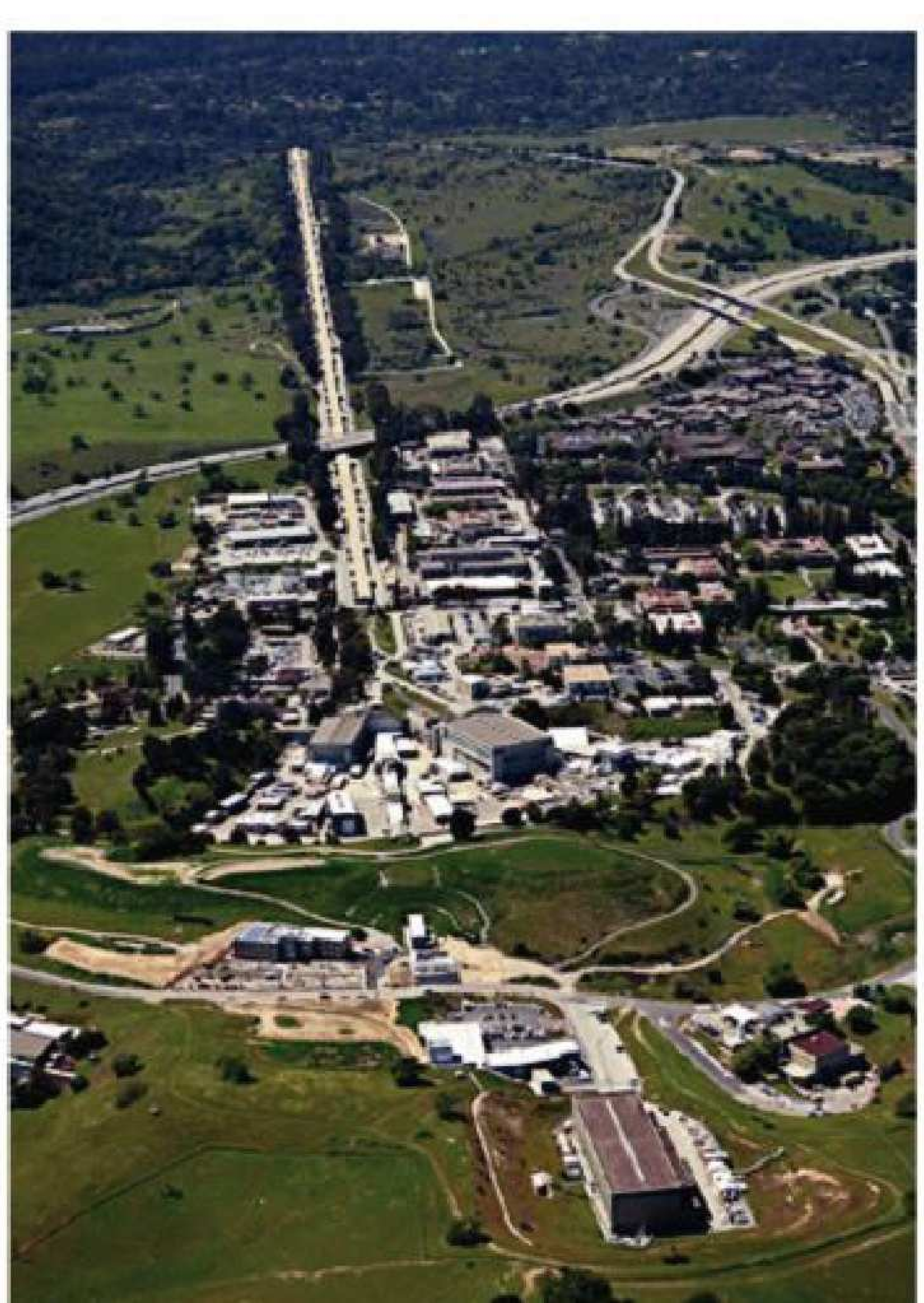
SLAC National Accelerator Laboratory

Here's an interesting thought to distract you as you head toward Silicon Valley on I-280: When you pass Stanford University, you also are driving over the longest linear accelerator in the world. Part of SLAC National Accelerator Laboratory, this science instrument measures 2 miles (3.2 kilometers) long and stakes a claim as "the world's straightest object."

Research at SLAC has produced three Nobel Prizes in physics — for the discovery of the charm quark, the discovery of the tau lepton, and investigations into the quark structure found inside protons and neutrons. All these findings helped scientists better understand the composition of matter in our universe.

The laboratory resides on the campus of Stanford University, a half-hour drive from San Francisco. Free guided tours take place every third Friday of the month and include a visit to the linear accelerator. You can sign up for a tour on the lab's website.

When not globetrotting, **Yvette Cendes** *pursues her astronomy Ph.D.*



The world's longest linear accelerator, located at the SLAC National Accelerator Laboratory, probes subatomic structure. Brad Plummer/SLAC

Lick Observatory

You'll experience no less than 365 turns on the winding road up Mount Hamilton to Lick Observatory — a reminder of the low-grade track needed by the horses and wagons that transported heavy equipment to the summit during the observatory's construction in the late 19th century. Financed by James Lick, then the wealthiest man in California, the scientific site was the world's first permanently occupied mountaintop observatory. At first light in 1888, the impressive 36-inch Lick Telescope was the largest refractor in the world, and it still has the curious feature of having its patron entombed beneath its platform.

Despite the observatory's age and location in the Bay Area, scientific research still goes on. Astronomers have had great success using Lick's telescopes to discover extrasolar planets and nearby supernovae. Visitors can see several of the observatory's telescopes, including the giant 120-inch Shane reflector and 36-inch Lick refractor, during visiting hours from noon to 5 P.M. 7 days a week from Memorial Day to Labor Day.

The observatory normally discourages nighttime visits to minimize stray lights, but it does hold some special events. The Summer Visitors Program involves a lecture by an astronomer and viewing through the 36-inch refractor and 40-inch reflector; the Music of the Spheres concert series includes live music, a talk, and an observing session. You can find the dates and purchase tickets on the observatory's website.

Owens Valley Radio Observatory

Drive about 5 hours southeast from San Francisco, past Yosemite and Mammoth ski resort, and some of the highest peaks in the contiguous United States eventually part to make room for the dusty plains of Owens Valley. The area is nearly empty, but such isolated, dry areas are ideal for radio astronomy. Here's where you'll find the Owens Valley Radio Observatory (OVRO).

Lick Observatory houses the 120-inch Shane reflector (foreground), the 36-inch Lick refractor (back left), and five other telescopes hunting for planets, supernovae, and other cosmic wonders. Laurie Hatch

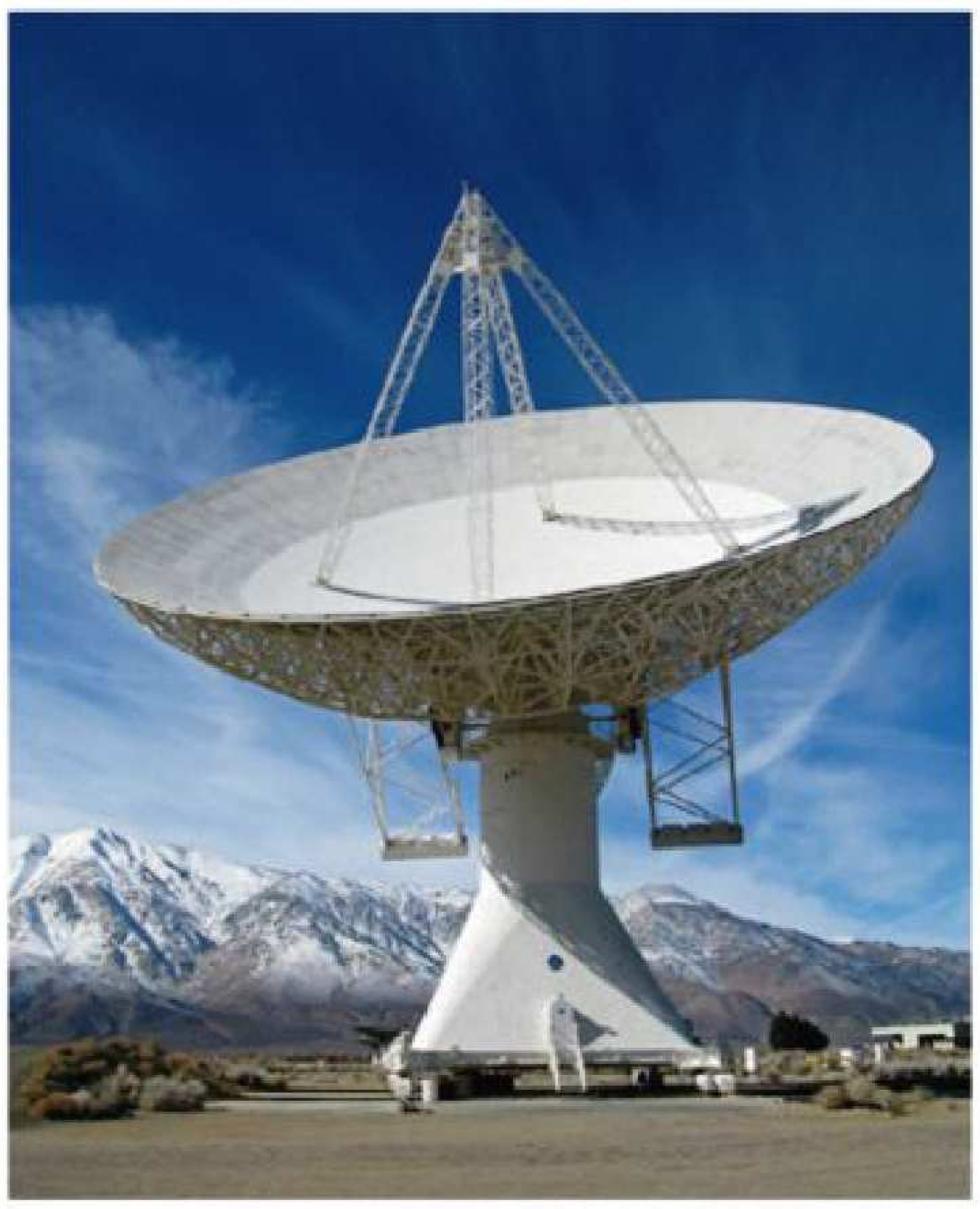
The 36-inch Lick refractor was the largest in the world when it saw first light in 1888. Laurie Hatch

OVRO has several major facilities operating in many radio astronomy subfields. Two of the most notable instruments are the gigantic 40-meter radio telescope that studies a class of active galaxies known as blazars, and the only dedicated solar radio observatory in the United States.

Approximately 20 miles (32 km) east of OVRO lies the Combined Array for Research in Millimeter-wave Astronomy (CARMA). This instrument is one of the most powerful millimeter-wave interferometers in the world. By studying this radiation, astronomers learn about the formation of stars and galaxies, the composition of planets and comets, and even the evolution of the universe.

The observatory conducts tours of both OVRO (November to April) and CARMA (May to October) at 1 P.M. on the first Monday of the month unless it's a holiday. No reservations are required. Look on the website for information about public observing nights with optical telescopes.

When you turn south from OVRO, the open road beckons, and the redwoods of the north give way to the endless desert that stretches into Arizona and beyond. But at the conclusion of this Northern California road trip, you'll think back on not just the beautiful scenery but also the vistas created by those places peering into the universe beyond. From corridors buried under the interstate to mechanical behemoths waiting for messages above, these sights are truly some of the Golden State's greatest treasures.



The 40-meter radio telescope at Owens Valley is the largest at the site. It explores the inner workings of active galaxies known as blazars. Tim Pearson/Owens Valley Radio Observatory

Read about Lick Observatory's history at www.Astronomy.com/toc.

Astrophotography: part five

Shoot the Sun, Moon, and planets

Surprisingly simple cameras will let you capture the solar system. **by Michael A. Covington**

In recent years, high-resolution photography of objects within our solar system has gone through a revolution. Imagers no longer use film and try thousands of times to get one lucky shot. Instead, they shoot streams of video and use software to select, align, and stack the sharpest frames, taking advantage of moments of steady air the way a visual observer does. The resulting amateur images are often as good as those taken from professional observatories.

The camera

The traditional video camera used for astroimaging is a low-end webcam with the lens removed and a telescope adapter fitted in its place. Nowadays, you can buy similar cameras ready-made for astronomy, such as the Meade Lunar Planetary Imager, Orion's StarShoot Solar System Color Imager, and many others. Just like webcams, these cameras do not need cooling or elaborate controls. Their power comes through the USB cable that connects them to the computer.

Amateur astronomers can also choose higher-grade planetary cameras from the Imaging Source, Lumenera, and other vendors. Such units have better sensors, more rugged construction, and more sophisticated control software.

All these cameras fit in a telescope's focuser and record about the same field of view as a 6mm eyepiece. A 640x480 sensor is big enough because planets — even Jupiter — appear small. You might want a slightly larger sensor in your camera if you plan to use it with a 12-inch or larger telescope, but you won't need the multiple-megapixel units that are desirable for deep-sky work.

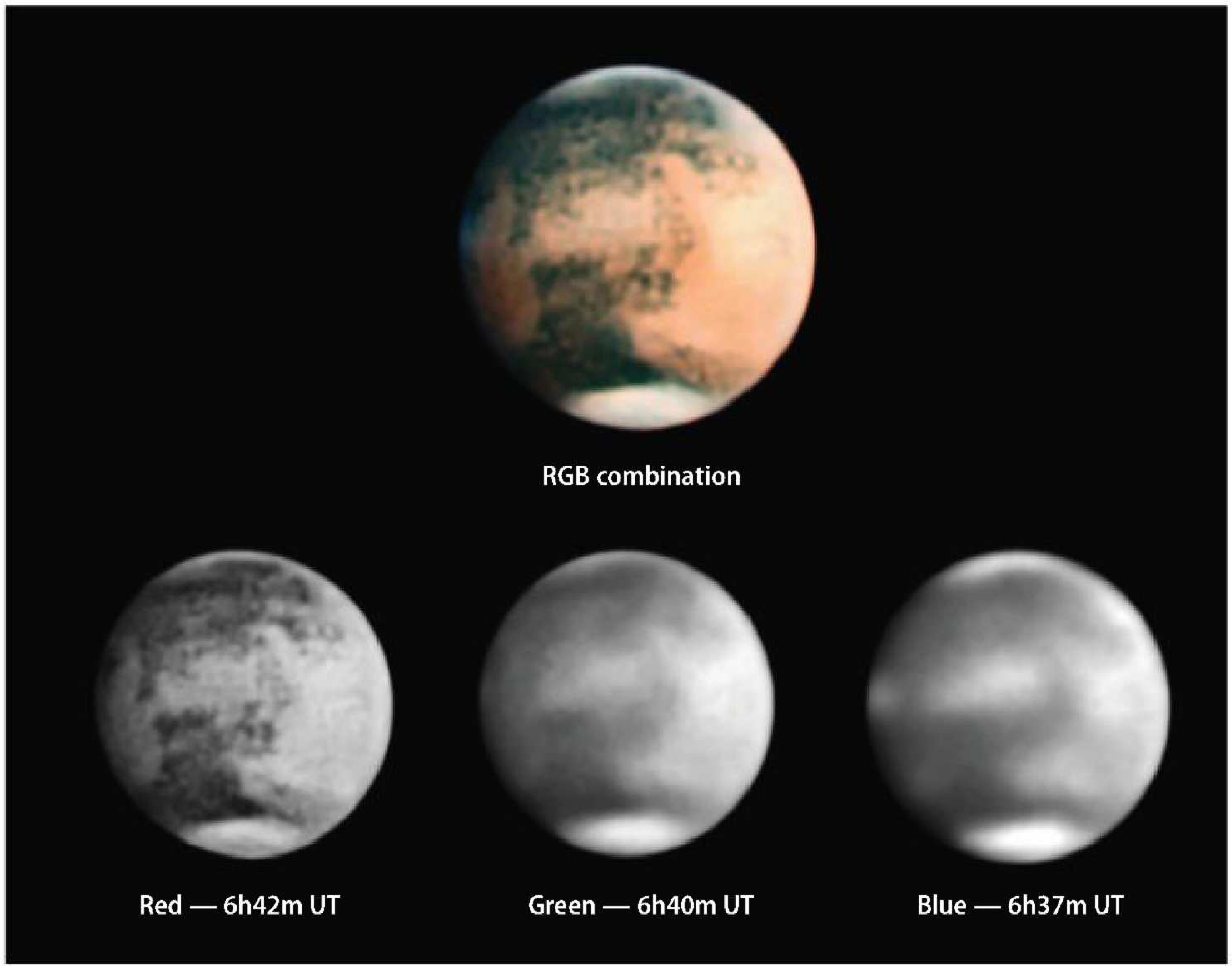
Most of these cameras produce color images the same way a webcam does — using a matrix of pixels sensitive to red, green, and blue light. For higher quality, you can use a monochrome camera and take each picture three times, through red, green, and blue filters.

The Imaging Source offers three lines of cameras: monochrome (DMK), color (DFK), and color without an infrared-blocking filter (DBK). The last of these requires a separate infrared-blocking filter to give realistic color images, but you have the alternative of using a visible-light-blocking, infrared-passing filter (deep-red) to take pictures that record infrared (IR) radiation. Some imagers prefer an IR filter because the "seeing" (a measure of the atmosphere's steadiness above your camera) is often better in infrared than in visible light.

The pixel size of video astrocameras is a good match to the diffraction-limited resolution of a telescope at focal ratios between f/20 and f/30. That means you'll need at least a 2x Barlow lens with an f/8 or f/10 telescope. With my f/10 Schmidt-Cassegrain, I normally use a 3x Barlow to give f/30. When imaging Saturn, which is not as bright as Jupiter or Mars near opposition, I use a 2x Barlow and work at f/20. That combination produces a brighter but smaller image.

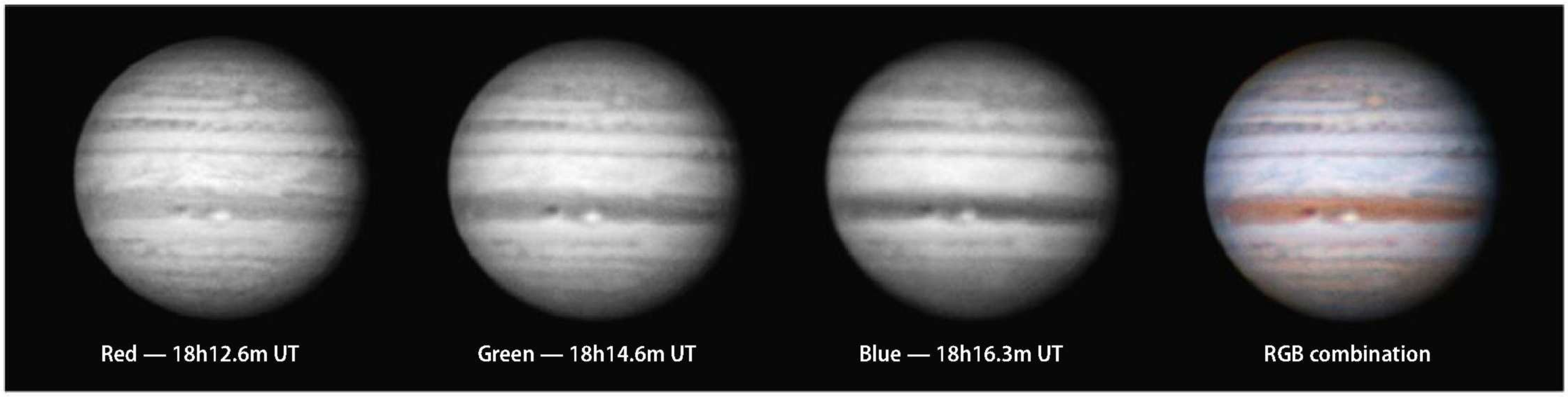
Conditions

The main challenge of planetary observing is atmospheric unsteadiness. Experi-



These images of Mars, taken December 30, 2009, from Coral Gables, Florida, included the description: "Bright terminator cloud south of Meridiani; Clouds over Chryse and Tharsis, S. Limb; 'Lifesaver Effect' in NPC; Possible dust streak along western NPC edge." Such images prove that amateur astronomers using video cameras can record lots of planetary detail. Donald Parker

Longtime astrophotographer **Michael A. Covington** *is a senior research scientist and associate director of the Institute for Artificial Intelligence at the University of Georgia.*



To make the color image of Jupiter, the photographer captured the giant planet through red, green, and blue filters, and then combined them into the single image on the right using software. He shot these through an 8-inch Meade LX200 Schmidt-Cassegrain telescope at f/32 and a Lumenera SKYnyx 2-0M CCD camera January 15, 2011, at the times shown, from Tournefeuille, France. Marc Delcroix

enced visual observers keep staring at a planet, making the most of brief moments of clarity. The trained observer's brain also can reconstruct, at least partly, the sharp image that he or she would see if the air were calmer.

Image-processing software also can do both of these things. By selecting and stacking the best video frames, it simulates good seeing. And with other techniques, it can sharpen the image.

Even so, it's best for the air to be as steady as possible. A slight haze can be good, extremes of hot and cold are bad, and a clear sky is often an unsteady one. Your telescope must be in thermal equilibrium with the air, so leave it outdoors in the shade for a couple of hours before doing critical planetary work.

The immediate surroundings of the telescope also matter. Observing over a cliff is best, over grass is all right, and over hot pavement is unacceptable. Because my permanent pier sits at the end of a driveway, I placed a plastic picnic table just south of it. This blocks the hot air rising from the pavement and improves the view considerably.

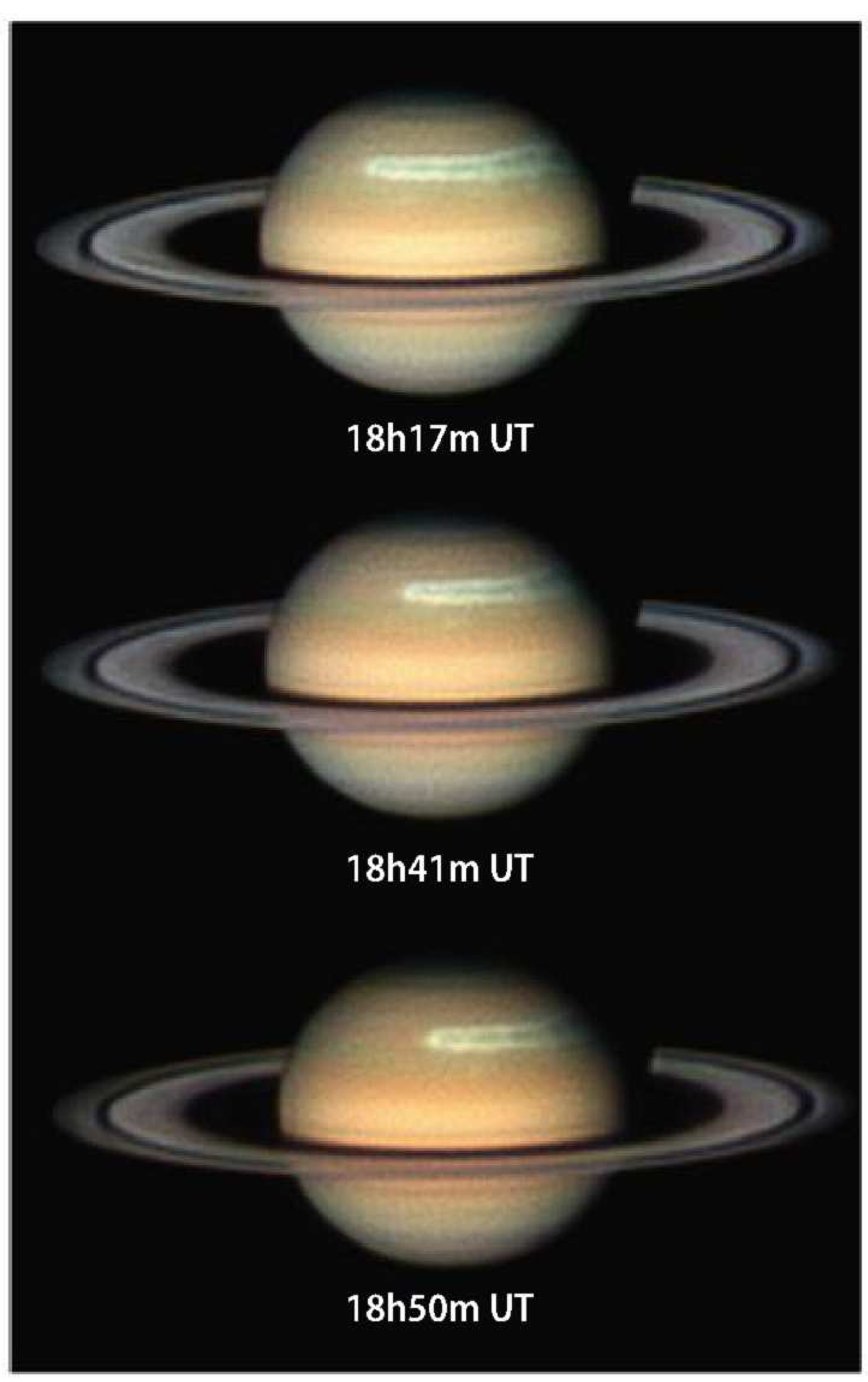
I also find that a Kendrick dew heater running at low power helps maintain a steady view in a refractor, even when there is no dew. The reason is that the front lens of the telescope actually gets colder than the surrounding air because of its low thermal conductivity. It therefore radiates heat faster than it can regain it by conduction. Warming the lens slightly to match the air temperature helps keep the image steadier.

This is the fifth and final part of Michael Covington's imaging series.

Exposures and time limits

To get a properly exposed image, you must have the correct integration time, a setting equivalent to shutter speed except that there is no shutter. You can find this by experimentation. As a starting point, assume your video camera's "speed" is comparable to ISO 400, but expect wide variation. Set the camera's gain and contrast to the middle of its range unless you're imaging a faint planet, for which you'd set it in the upper end of its range.

I often have better luck with slightly longer exposures (like 1/10 second) rather than shorter ones, but this depends on atmospheric conditions. Some software includes an auto-exposure feature that works well with planets. If yours doesn't, set the exposure manually rather than letting the computer take wild guesses. When in doubt, underexpose somewhat because you can restore dim areas by stacking images, but overexposed areas are irrecoverable.



This Saturn series shows what astronomers call the Northern Electrostatic Disturbance, a huge storm in the ringed planet's northern hemisphere. The imager used an 11-inch Celestron Schmidt-Cassegrain telescope and a Point Grey Flea3 FireWire CCD camera February 6, 2011, from Cebu, Philippines. Christopher Go

You must also choose the number of frames per second your camera shoots. Typically it's 15 or 30. Make sure the frames aren't shorter than the exposures. If you select 30 frames per second and each frame is 1/20 of a second, most of them will record more than once, and the duplication does no good.

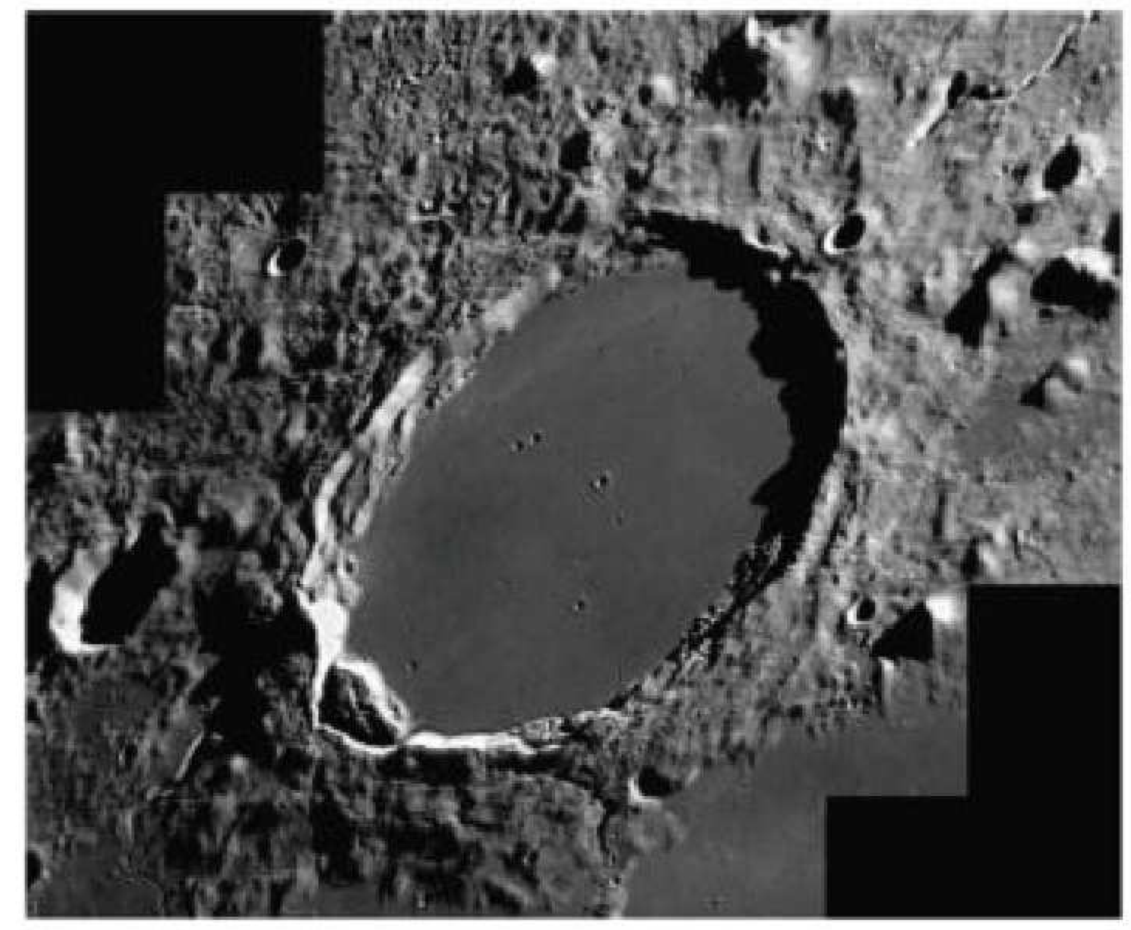
You also get to choose the video format, called the codec. The best choice is to record uncompressed or minimally compressed video rather than using heavy compression. For specifics, consult the documentation for your camera and software. Note that Microsoft AVI is not a video format; it's just a type of "container file" that can contain video encoded many different ways.

The planet's rotational speed limits how much video you can use in your image. A reasonable limit is the time it takes for the planet's rotation to smear central details by half an arcsecond as seen from Earth. The formula for this is: time (in minutes) = the planet's rotational period (in hours) x ($60/\pi$) x apparent diameter of planet (in arcseconds).

That works out to about 2.5 minutes for Jupiter, 5 minutes for Saturn, and 15 minutes for Mars. You can see why multifilter work is popular with Mars but somewhat unfeasible with Jupiter. In practice, you can do a bit better than

David Buchla

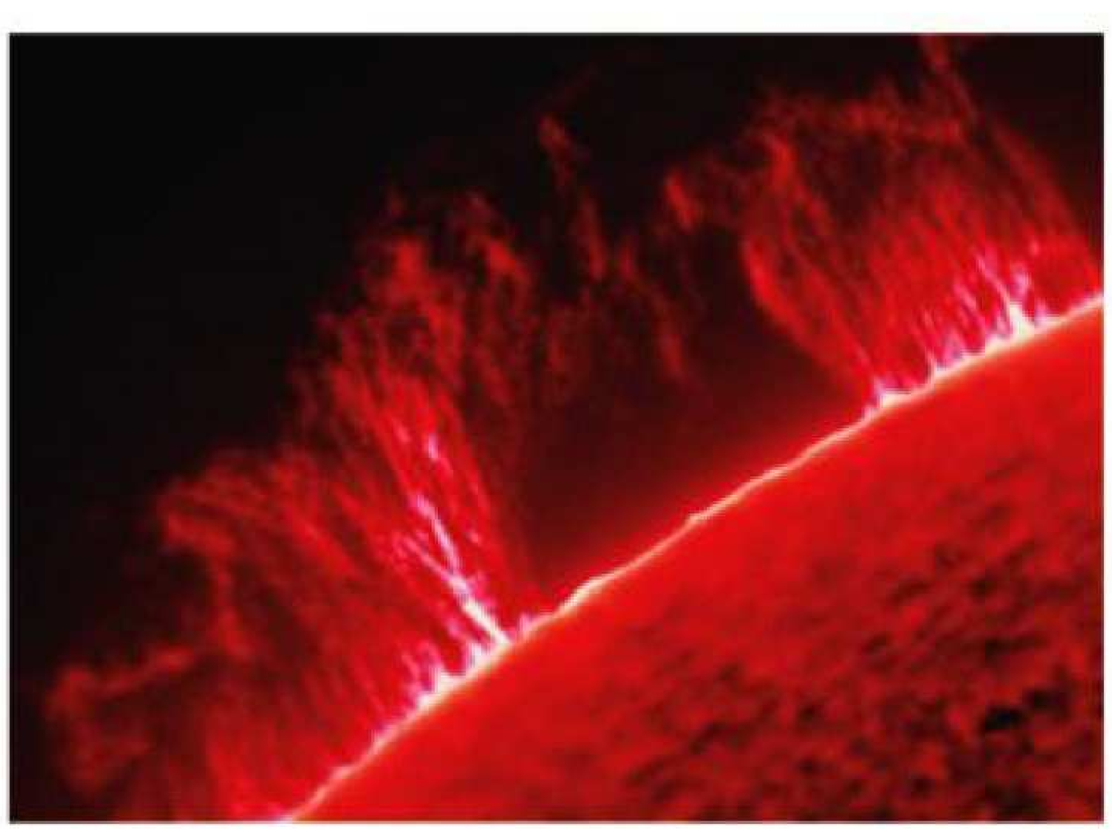
The diamond ring blazed during the July 11, 2010, total solar eclipse. As the author suggests, the imager used a camera that captures a much wider field of view than a video astrocamera. He took this shot through a Canon EOS 5D Mark II DSLR with an EF300mm f/2.8L USM lens and a 1.4x extender for an effective focal length of 420mm. He made a 1⁄1,600-second exposure at f/4.5 and ISO 500.



The Moon's Plato Crater sits on the northern edge of Mare Imbrium. Since its formation some 3.8 billion years ago, meteors have pocked its lava-filled floor with craters. For this shot, the imager used a 14-inch Celestron Schmidt-Cassegrain telescope and a Lumenera SKYnyx 2-0M CCD camera May 26, 2007. Damian Peach

calculated because software like *RegiStax* will favor the sharpest part of the picture (usually the center) and will shift the images to leave the best detail there at the expense of blurring the edges. Under poor conditions, record longer because you have less to lose from blurring and more to gain by having more frames to stack and select.

In any case, your goal should be to record anywhere from 1,000 to 5,000 frames of video. With Jupiter, recording 15 frames per second will create 1,800 frames in 2 minutes. Fainter Saturn will probably limit you to 7.5 or 3.75 frames per second, but you can record longer overall sequences, up to 8 minutes.



A video astrocamera's small field of view can still cover a prominence at the Sun's edge. The imager shot our daytime star through a 14-inch Celestron Schmidt-Cassegrain telescope, a Hydrogen-alpha filter, and a Lumenera SKYnyx 2-0M CCD camera January 19, 2011, at 12h40m UT, from Flackwell Heath, England. David Tyler

Mercury and Venus are special cases because they rotate slowly, so you can record for several minutes. Remember that the visible detail in Venus is mainly an ultraviolet (UV) phenomenon. You'll do best with a monochrome camera and a filter that passes UV light, such as a deep-violet filter.

Processing

Once you have your video, your next task is to process the frames with *RegiStax*. Several detailed *RegiStax* tutorials exist on the Internet, so I'll just summarize the process. The first step is to open the video file and let *RegiStax* align the video frames. *RegiStax* sorts the frames in decreasing order of quality and asks you how many you want to keep. I generally keep the best two-thirds of the total.

Next, *RegiStax* optimizes the alignment by realigning the frames once it has seen the full set. It then stacks them.

Last, you should use the program's wavelet function to bring out detail by selectively enhancing features of a particular size. If you've captured good video, the smallest wavelet filters (1 and 2 pixels wide) will do the most good. You can see the effect of each filter as you adjust it; your goal is to bring out planetary detail but not the camera's electronic noise.

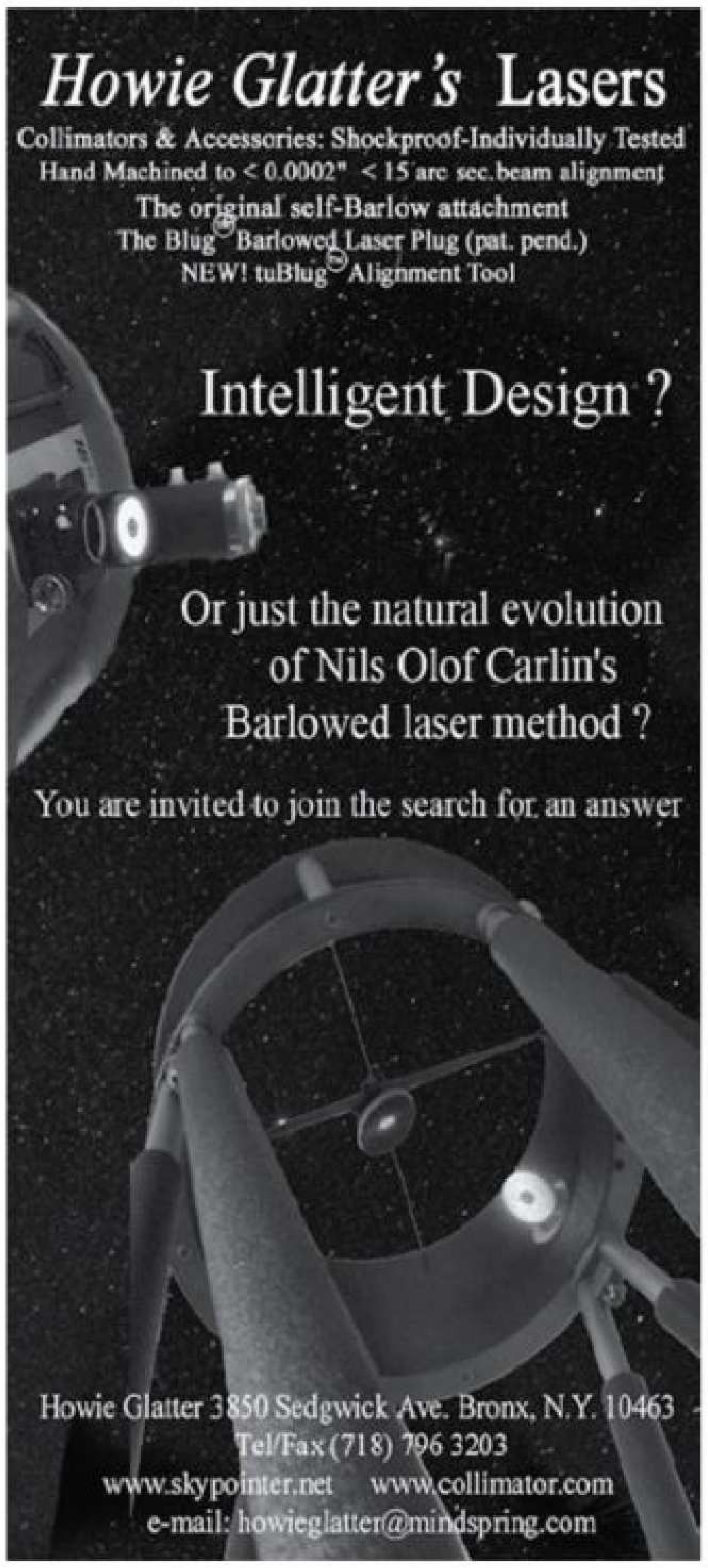
Solar and lunar work

Imaging small areas of the Moon is just like planetary work except that you can use *RegiStax* in multi-point mode to counteract the stretching and distortion caused by bad seeing. Imaging sunspots is like imaging lunar craters except that, of course, you need an approved solar filter in front of the telescope, and lunar-rate tracking is not needed.

Full-face views of the Moon, the Sun, or eclipses of either are an entirely different game. Instead of a video astrocamera, you will want a digital single-lens reflex camera — preferably one that will let you start the exposure electronically during live focusing so there is no shutter vibration. Canon calls this feature "Silent Shooting" during "Live View" and offers it on many newer models. Alternatively, if you have time and patience, you can cover the full face of the Moon using a mosaic of separate video images.

The Sun, the Moon, and the visible planets offer bright, detailed targets for amateur astronomers — in essence, a wonderful and rewarding introduction to astrophotography.

A+ To read the previous four parts of this series, visit www.Astronomy.com/toc.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Astronomy tests QSI's 583 CCD camera

Quantum Scientific Imaging's compact CCD camera produces high-quality images. **by Bob Fera**

During the past several years, astroimagers have seen an unprecedented number of high-quality, innovative cameras come on the market. While many of these products are from manufacturers well-known to seasoned imagers, others originate from companies relatively new to the scene.

One such group is Quantum Scientific Imaging (QSI) with its line of 500-series CCD cameras. Although a fairly recent addition to the amateur astronomy market, QSI actually has been building digital imaging systems for nearly 20 years, and that experience clearly shows here.

It's all in the numbers

QSI has historically targeted its 500-series cameras at entry-level users, but with the introduction of the 583s and the 583ws (which includes an internal filter wheel), the company has ventured boldly into advanced-amateur territory.

Recently, I had an all-too-brief opportunity — thanks to an unforgiving Northern California winter — to test QSI's top-of-the-line camera.

The 583ws utilizes Kodak's popular 8.3-megapixel KAF-8300 sensor, which uses an 18mm by 13.5mm CCD chip and contains a matrix of 5.4-micron-square pixels. The tiny pixels make this detector ideally suited to short-focal-length instruments such as fast refractors, Newtonian astrographs, and camera lenses.

Unfortunately, I did not have such a telescope available at test time, so I attached the camera to my 14-inch Officina Stellare Ritchey-Chrétien reflector, which operates at f/8 and has a 2,845mm focal length. With this camera, it yields an image scale of 0.39"/pixel.

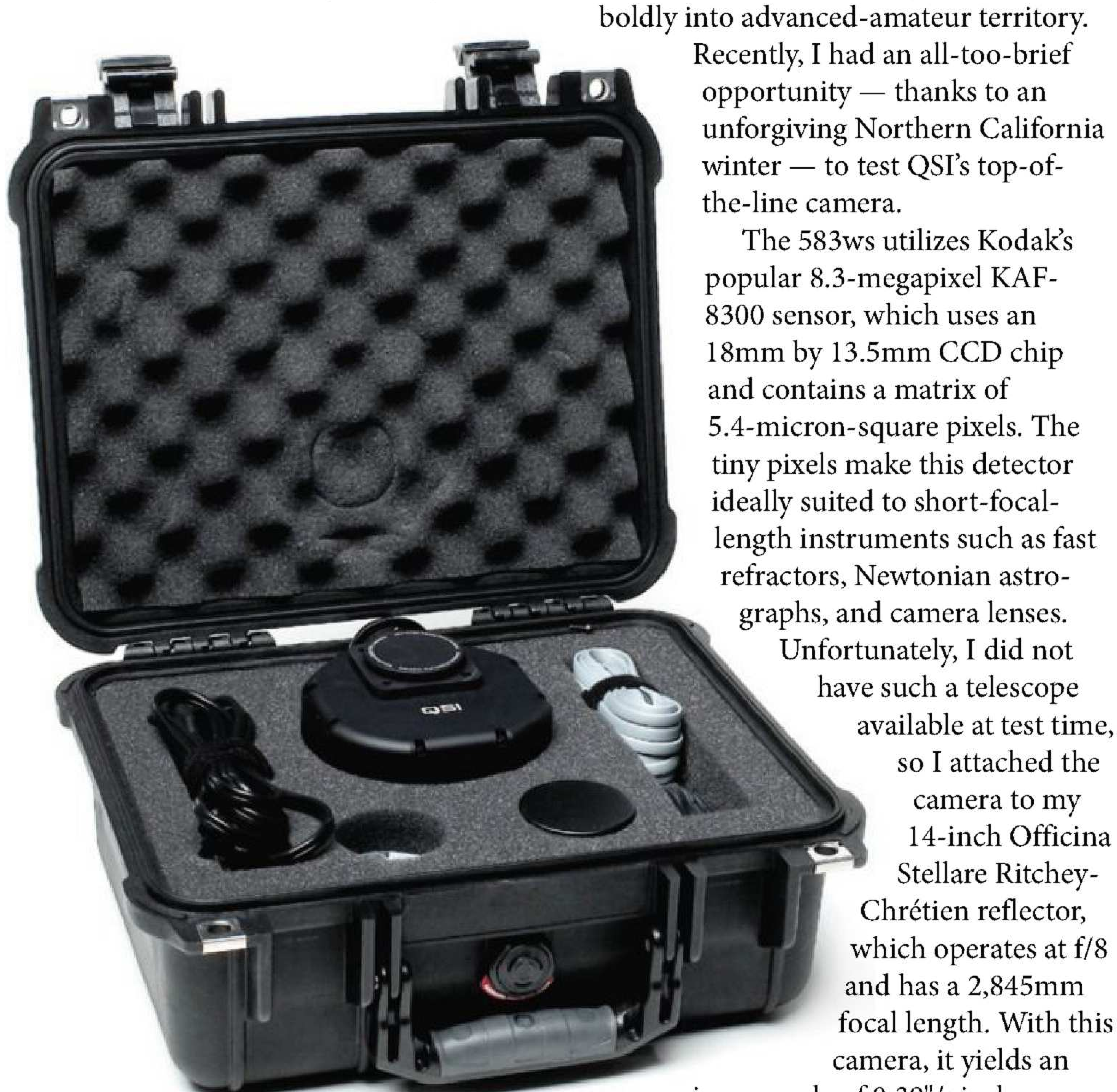
The QSI 583ws features a small lightweight body and includes a 2" nosepiece, making it simple to attach to any telescope with that size focuser. The 583ws also houses an internal five-position filter wheel in which QSI placed the filters close to the CCD. This allows the use of less expensive 1¼" filters — a real plus.

The camera package comes in a sturdy Pelican carrying case and includes a CD with drivers and plugins for *MaxIm/DL* and *CCDSoft* camera-control software, all necessary cables, and a set of Allen wrenches. The initial installation process was painless, and the software has a professional look. The skies didn't cooperate that evening, however, leaving first light for another night.

Problem solved

When a clear evening finally arrived, I fired up *MaxIm/DL* and attempted to connect to the camera. It was at this point I ran into a problem: *MaxIm/DL* locked up, forcing a computer reboot.

The next day, I contacted QSI technical support and described the symptoms. The support technician who answered



Quantum Scientific Imaging's 583 CCD camera series comes with all cords and connectors safely ensconced in a waterproof, custom-fit Pelican case. Equipment photos: *Astronomy*: James Forbes

Contact information

Quantum Scientific Imaging, Inc.
34145 Pacific Coast Highway, #512
Dana Point, CA 92629
[t] 888.774.4223
[w] www.qsimaging.com

◀ **The 583 series** houses Kodak's 8.3-megapixel KAF-8300 CCD chip. QSI electronically cools the chip with air, which reduces the amount of noise in exposures.

▶ **Emission nebula NGC 1931** in Auriga was the author's test image. It demonstrates the QSI 583's wide dynamic range, as well as its ability to record faint detail and register accurate color. Bob Fera

the phone, none other than QSI owner Kevin Nelson, immediately realized that old drivers for a USB-to-serial adapter caused my trouble.

The drivers were from the same company that supplies camera chips to QSI. The quick fix was to make sure I connected the camera to the computer before connecting the USB-to-serial adapter. Once I did that, all was well. QSI is working on the long-term solution, which will involve upgrading the outdated drivers.

Astroimaging

During the next few nights, I learned what a fine instrument the QSI 583ws is.

The QSI 583wsg is available with an Integrated Guider Port. This option allows you to guide using light collected by your main telescope because the mirror picks off the guide star in front of the filters.

The camera quickly cooled to –13° Fahrenheit (–25° Celsius), about 63° F (35° C) below the ambient temperature (50° F [10° C]), and it produced smooth, incredibly low-noise images.

My target was NGC 1931, a small but colorful emission nebula in the constellation Auriga. With exposures totaling just 3 hours of unfiltered luminance and 75 minutes each through red, green, and blue filters, the camera easily recorded both the pink emission and blue reflection nebulosity.

It also picked up the object's faint outer wisps, a testament to the camera's sensitivity. My only complaint is that download times are longer than I expected, between about 30 and 40 seconds per image, which rates slower than comparable cameras I've used.

A worthy option

Any discussion of QSI's 583ws would not be complete without mentioning an optional feature available on the company's 500-series product line — an integrated off-axis guider. With the guider, the 583ws becomes the 583wsg.

For the upgraded model, QSI replaces the camera's faceplate with one that includes a pick-off prism and guide camera port. This arrangement places the guide star image in front of the filters, greatly easing the process of finding such stars. The pick-off prism is comparable in size to that of other popular high-end off-axis guiders. Using the supplied adapters, the guide camera locks solidly onto the 583wsg body, yielding a system with no flexure. The focusing mechanism is a bit awkward, with adjustments that require repeated removal and replacement of the guide camera. QSI describes this procedure clearly in the well-written user manual included on the CD, and you only need to do it once. This is truly a worthwhile option if you don't already own a separate off-axis guider.

Overall, the QSI 583 series impressed me greatly. Its quality construction, excellent performance, lack of electronic noise, innovative features, helpful technical support, and attractive price make it a great choice for beginning and advanced astroimagers alike. ◐

Bob Fera *is a longtime image contributor to* Astronomy *who captures celestial photons falling on Foresthill, California.*

Product specifications

Quantum Scientific Imaging QSI 583
Type: CCD camera
Chip: Kodak KAF-8300
Pixel array: 3348x2574 total
Pixel size: 5.4 microns, square
Exposure range: 0.03 second to 4 hours
Dimensions: 583s: 4.45 by 4.45 by 2 inches (11.3 by 11.3 by 5 cm); 583ws: 4.45 by 4.45 by 2.5 inches (11.3 by 11.3 by 6.4 cm)
Weight: 583s: 34 ounces (950 grams); 583ws: 39.5 ounces (1,120g)
Price: 583s: $2,795; 583ws: $3,190; 583wsg: $3,690

EveningStars

by David H. Levy

The AAVSO turns 100

An astronomical family stays strong after a century's worth of observations.

The American Association of Variable Star Observers (seen here at its seventh annual meeting in 1918) will celebrate its centennial in October, but its work is still vital and it still feels more like a family than anything else. American Association of Variable Star Observers (AAVSO)

Last month's *Astronomy* carried an article I wrote about the American Association of Variable Star Observers (AAVSO), which this fall celebrates the centenary of an idea. The plan, as it stood in 1911, was not to increase the number of scientists, but to organize an observing campaign that followed the changing brightness of variable stars. Ever since, amateur astronomers have contributed millions of such observations.

As the clock turns on the AAVSO's 100th birthday this October, its role has expanded. The group has shown astronomers not just what these stars are doing, but also how to monitor them best, both from the ground and with the Hubble Space Telescope. Yet at its founding, there was no organized way of submitting observations. In fact, the AAVSO's earliest years were devoid of meetings, concentrating instead on adding to the group's series of observations of variable stars, now known as the AAVSO International Database.

In Montreal, Canada, I heard Isabel Williamson first mention the AAVSO in 1961 — I thought she was telling a joke. As we all chuckled, she went on to announce that the AAVSO would be holding their annual meeting in Kalamazoo, Michigan, and that several officers of the Royal Astronomical Society of Canada's Montreal Centre would be representing our active astronomy club there. I soon learned that the AAVSO was a group well worth supporting.

During the summer of 1966, I began observing three stars: the semiregular red supergiants g Herculis, X Herculis (see chart), and RR Coronae Borealis. These huge stars swell and contract, thus altering their brightness, on a not-quite-regular basis. I quickly followed up with other stars, like R Leonis, a long-period variable whose brightness slips from fainter than 10th magnitude up to 5.8 and back again, all in a period of just under a year. Soon, I began using the AAVSO's classic blueprint charts, with white stars painted on a blue background. Nowadays, almost no one uses these charts, but their beautiful design and artwork (by D. F. Brocchi, R. A. Seeley, and R. Newton Mayall) are still a wonder to behold.

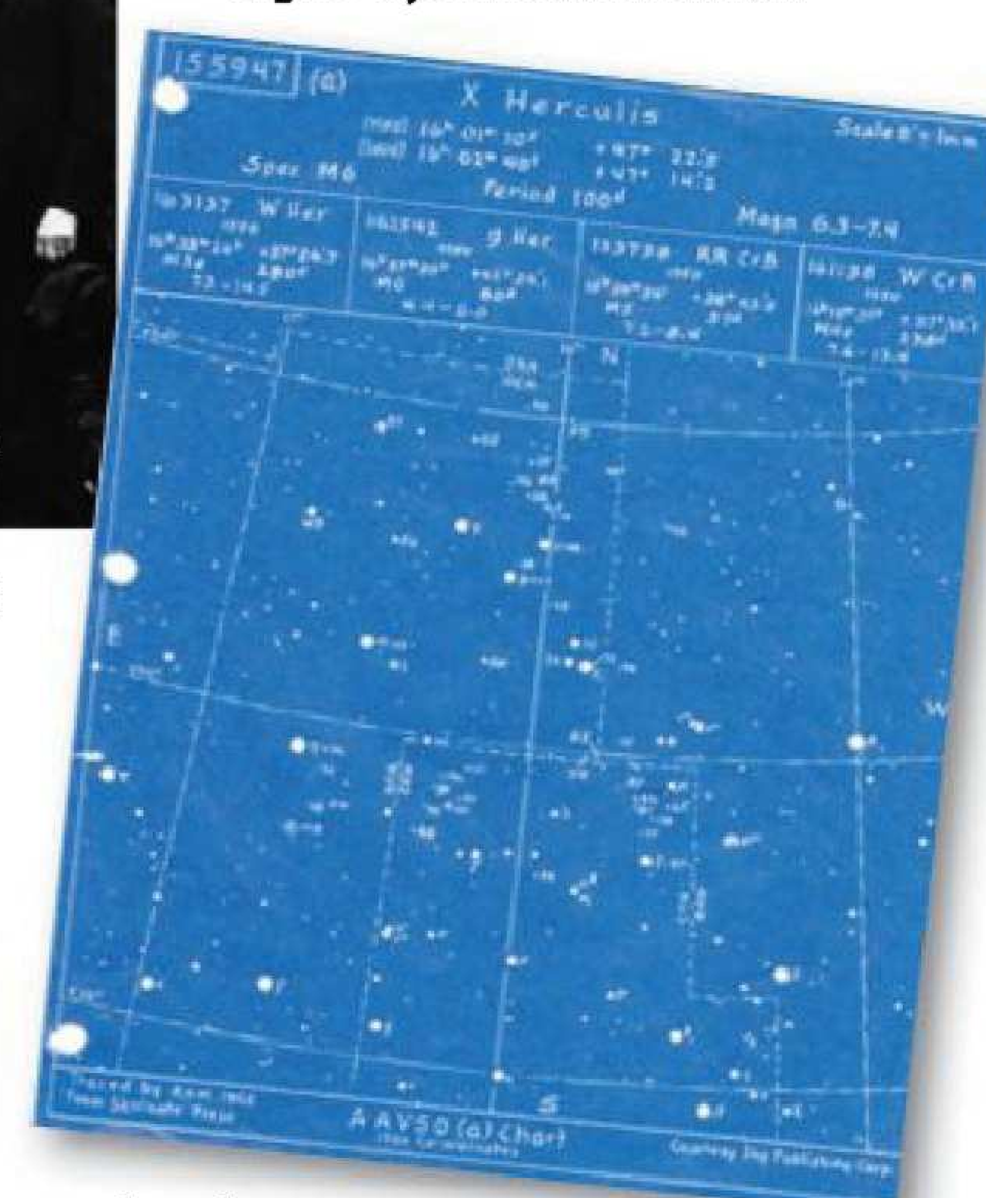
At its simplest level, a variable star is one whose light output changes. Mira-type stars, like R Leonis and its namesake Mira (Omicron [o] Ceti) itself, are Sun-sized objects that have used up their cores' hydrogen; this means our Sun will one day become a Mira-type star. Other stars vary cyclically; eclipsing binary variables, for example, decrease in light output when a fainter companion passes in front of the brighter of the pair. Other stars vary cataclysmically: When a binary system consists of two nearby stars, the less massive one can leak hydrogen to form an accretion disk around the more massive one, and after enough time, this extra hydrogen explodes, resulting in a dramatic rise in the system's brightness.

These are but some of the fantastic tales of variable stars. The science behind them might be interesting, but getting to meet the people who enjoy monitoring these stars can be even more fruitful. For my first meeting, in the fall of 1978, I drove down to Cambridge, Massachusetts, and checked in at the AAVSO's then-headquarters at 187 Concord Avenue. Immediately after walking in the front door, I found myself embraced by director Janet Mattei. From then on, I knew the AAVSO was a family.

Over the next few days, I learned much about the history of this family. I even contributed my own story; during a 10-minute talk about teaching children astronomy, I discussed how stars are like people, with individual behaviors and even moods.

Variable star observing remains as vibrant today as it did a century ago. Its magic lies not just in the stars themselves; it also lies within the academic volumes written on the subject, and in stellar poetry written long ago and in modern times, by amateur astronomers motivated to add rhyme to their lists. And it rests within the senses of all those observers who, on the AAVSO's centennial, relish the hours they spend gazing at these wonderful stars as they parade about the sky.

▼ **The AAVSO's classic** blueprint charts, this one depicting the two bright "semiregular variables" X and g Herculis, remain a testament to the group's devotion to the night sky. AAVSO/R. Newton Mayall



Browse the "Evening Stars" archive at www.Astronomy.com/Levy.

New Products

See reports on 250+ products at www.Astronomy.com/equipment.

Attention manufacturers: To submit a product for this page, e-mail **mbakich@astronomy.com**.

Tripod

Celestron
Torrance, California

Celestron's AstroMaster heavy-duty tripod provides a stable platform for binoculars, small telescopes, and spotting scopes. The unit features steel legs and an accessory tray. Setup requires no tools, and the tripod can support 10 pounds (4.5 kilograms).

Price: $79.95
[t] 310.328.9560
[w] www.celestron.com

Schmidt-Cassegrain system

Celestron
Torrance, California

Celestron's CGEM DX 1400 is a 14-inch f/11 Schmidt-Cassegrain telescope on an equatorial CGEM DX mount. The kit includes NexStar control technology, Starbright XLT coatings, a stainless-steel tripod, and a 9x50 finder scope.

Price: $6,299
[t] 310.328.9560
[w] www.celestron.com

Stargazing poster

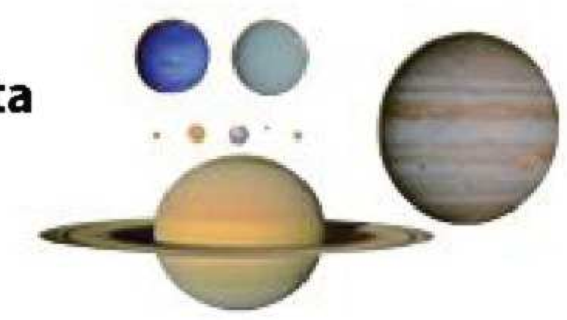
Ashland Astronomy Studio
Ashland, Oregon

Ashland Astronomy Studio's "Stars of the Northern Hemisphere" is a glossy poster showing stars in three panels: circumpolar, winter, and summer constellations. The poster measures 36 by 24 inches (91.4 by 61 centimeters).

Price: $16.95
[t] 541.201.8854
[w] www.astrostudio.org

Scale-model solar system

Proportional Planets
Minnetonka, Minnesota



Proportional Planets' scale model of the solar system features die-cut vinyl images with adhesive backing of the eight major planets and the Moon. Sizes range from 27.4 inches (69.6cm) for Jupiter to 0.7 inch (1.8cm) for the Moon.

Price: $125
[e] peter@proportionalplanets.com
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Observatory dome

Astro Haven Enterprises
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Astro Haven Enterprises uses closed-mold vacuum infusion to create its 18-foot-diameter (5.5 meters) five-shutter fiberglass clamshell dome. The design maximizes the height between the base and the top.

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[t] 949.215.3777
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2.6-inch refractor

BARSKA Optics
La Verne, California

BARSKA Optics' AE11120 Magnus 65ED is an f/6 apochromatic refractor with a fully multicoated triplet lens. The unit includes a 2" Crayford focuser, a 90° erect-image star diagonal, an extendable dew shield, and a hard carrying case.

Price: $1,000
[t] 888.666.6769
[w] www.barska.com

by Tony Hallas

Working with Hydrogen-alpha data, part 1

Great results come to imagers who take the narrow path.

It doesn't take long before an astroimager hears about a seemingly exotic technique called narrowband imaging. These photos are exactly what they sound like — images made from a thin slice of the spectrum centering on specific emission lines. The three most common are Hydrogen-alpha (656.28 nanometers), Oxygen-III (500.7nm), and Sulfur-II (672.4nm).

Hydrogen-alpha, or Hα, emission is abundant in many deep-sky objects such as the Rosette Nebula (NGC 2237–9), Veil Nebula (NGC 6960 and NGC 6992/5), and North America Nebula (NGC 7000), to name a few. Because this wavelength carries high detail, imagers covet it as a source of information to augment their LRGB data.

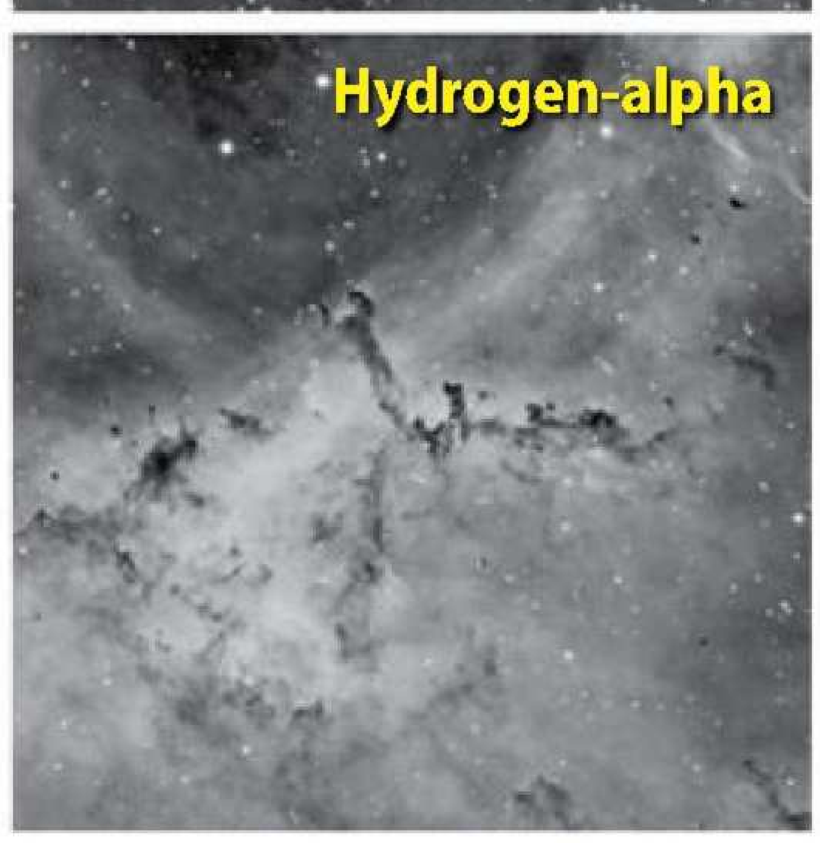
In the next several columns, we will look at various ways to add the Hα information to our color images. First, let's look at a comparison between the luminance and the Hα of NGC 2244, the open cluster associated with the Rosette Nebula, along with NGC 2237–9, the surrounding nebulosity.

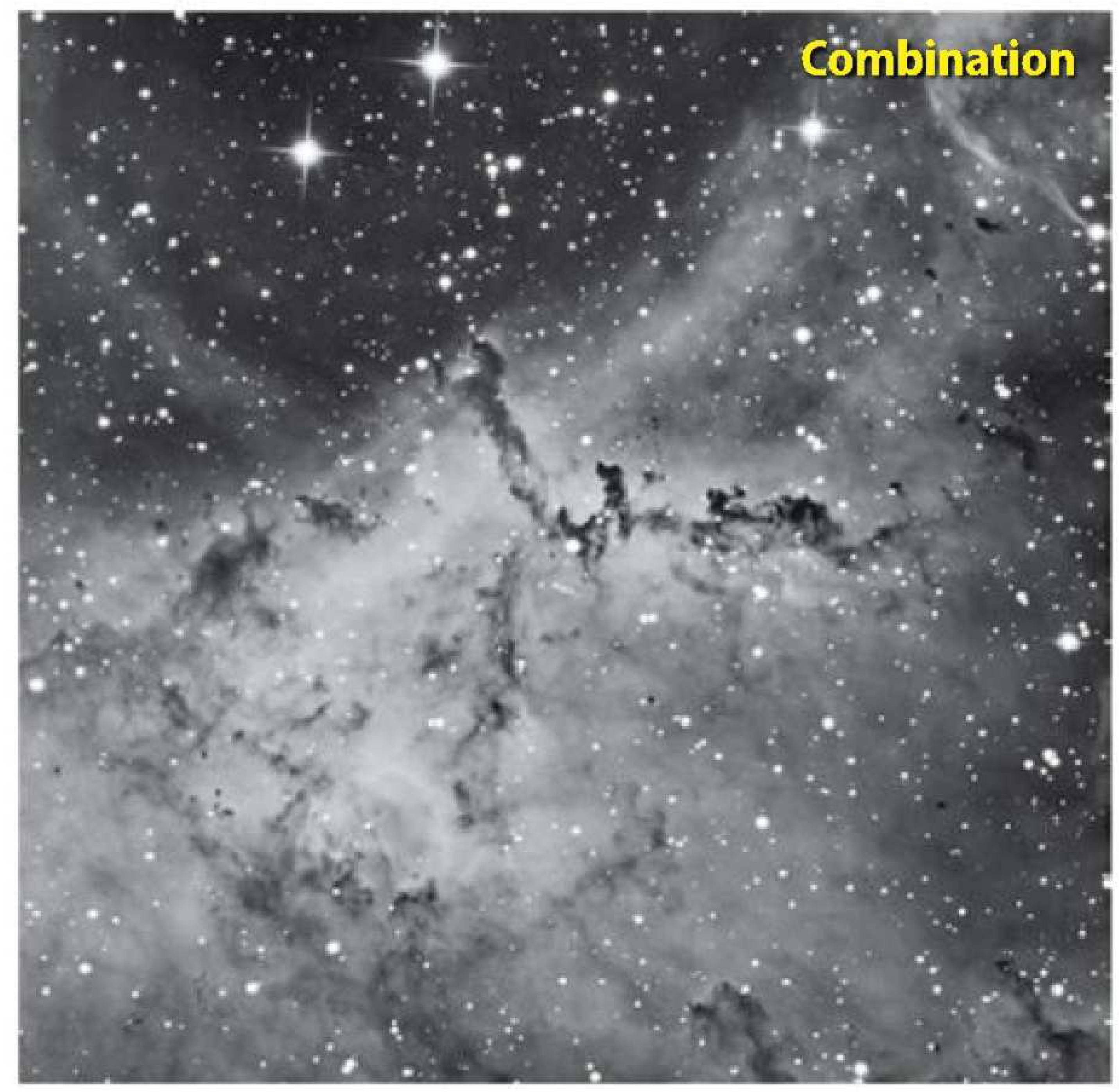
Hα filters are deep red. They pass the Hα spectral line but little else. As a result, stars appear much fainter (and, therefore, smaller) in the Hα exposure because only a small portion of their light hits the CCD chip. Most of the Hα nebula detail comes through, however, and here (as in many other nebula shots) it is spectacular.

Images through the luminance filter favor many other wavelengths over the subtle Hα component. The imager's goal is to blend these two together to create a hybrid luminance with representation from Hα.

Furthermore, it is possible to move one step further and convert the Hα to color and enhance the RGB component with it. Let's first combine the Hα and luminance in black and white to see how that works.

Browse the "Imaging the Cosmos" archive at www.Astronomy.com/Hallas.





Combining a luminance image with one you took through a Hydrogen-alpha filter delivers impressive results, as in this example of NGC 2237–9 and NGC 2244. Tony Hallas

Step 1: Make sure you carefully register the Hα and luminance images. I always use *RegiStar* (which I covered in my May 2011 column) to accomplish this.

Step 2: Open the luminance image in *Photoshop*. This will be the background.

Step 3: Open the Hα image, open the "Layers" palette (F7), and drag the icon of the Hα image on top of the luminance image. This will turn the Hα portion into a layer sitting atop the luminance.

Step 4: Make the "Combine" mode "difference" and, holding down the "control" key and the left mouse button, drag and center the Hα layer over the luminance image. Let go of everything.

Step 5: With the Hα layer active, change the "Combine" mode to "lighten." Here's where the magic happens. *Photoshop* will look at both images, and where the Hα image appears lighter, it will use that data. Note that the stars on the luminance image take priority because they are lighter than the Hα ones. The advantage of the "lighten" method is that by changing the density of the Hα layer, you can adjust how much of that image contributes to the luminance. If you lighten the image, *Photoshop* will add more of it to the final image. By darkening the Hα image, less of it will appear.

There is another way to combine the Hα with the luminance: Use the "screen" mode instead of "difference." This is more of a balanced approach to adding the Hα data. You can also fine-tune this method by adjusting the density of the Hα layer.

Experiment with both methods until you find what works best for you. You can add a little more Hα to your finished image by duplicating the Hα layer and using the "soft light" combine mode for this layer. Best results occur if you make the opacity of that layer between 33 and 50 percent.

In next month's column, I'll show you how to use these techniques to create a color version of your image.

INDEX *of* ADVERTISERS

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2011 Summer Sweepstakes - Official Rules

1. No Purchase Necessary. Official entry forms are bound in the June 2011, July 2011, and August 2011 issues of *Astronomy* magazine, and the June 2011 issue of *Discover* magazine. The 2011 Summer Sweepstakes is open to residents of the United States and Canada (except Quebec) only, 18 years of age or older. Employees (and their dependents and immediate household members) of Kalmbach Publishing Co., their advertising and promotional agencies, and sponsoring companies are not eligible to participate.

2. Sweepstakes Entry. To enter, complete and mail the official entry form or a postcard with your name, address, city, state or province, and ZIP or postal code to: The 2011 Summer Sweepstakes, P.O. Box 378, Waukesha, WI 53187-1199. Or enter online at www.Astronomy.com/sweeps by filling in the Online Entry Form and hitting the SUBMIT ENTRY key. The Online Entry Form must be filled out completely to be eligible. Incomplete or defaced entry forms are void. One entry per household. The official ending date for the 2011 Summer Sweepstakes will be July 22, 2011, and all entries must be transmitted or postmarked no later than that date.

3. Prizes and Odds of Winning. One drawing will be held on or around September 20, 2011, for the following awards: one (1) Grand Prize consisting of a Celestron NexStar 8SE Telescope (retail value $1,199.00); one (1) First Prize consisting of an AstroMaster 70AZ (retail value $139.95); one (1) Second Prize consisting of a SkyMaster 15x70 Binoculars (retail value $89.95); one (1) Third Prize consisting of a Celestron FirstScope (retail value $49.99). Cash equivalents of merchandise will not be awarded. Substituting prizes is not allowed. Any applicable federal, state, and/or local taxes are the responsibility of the winner. Odds of winning depend on the number of entries received. Total circulation of *Astronomy* magazine is 106,131 and total circulation of *Discover* is 701,215. Sweepstakes void in Quebec and void where prohibited.

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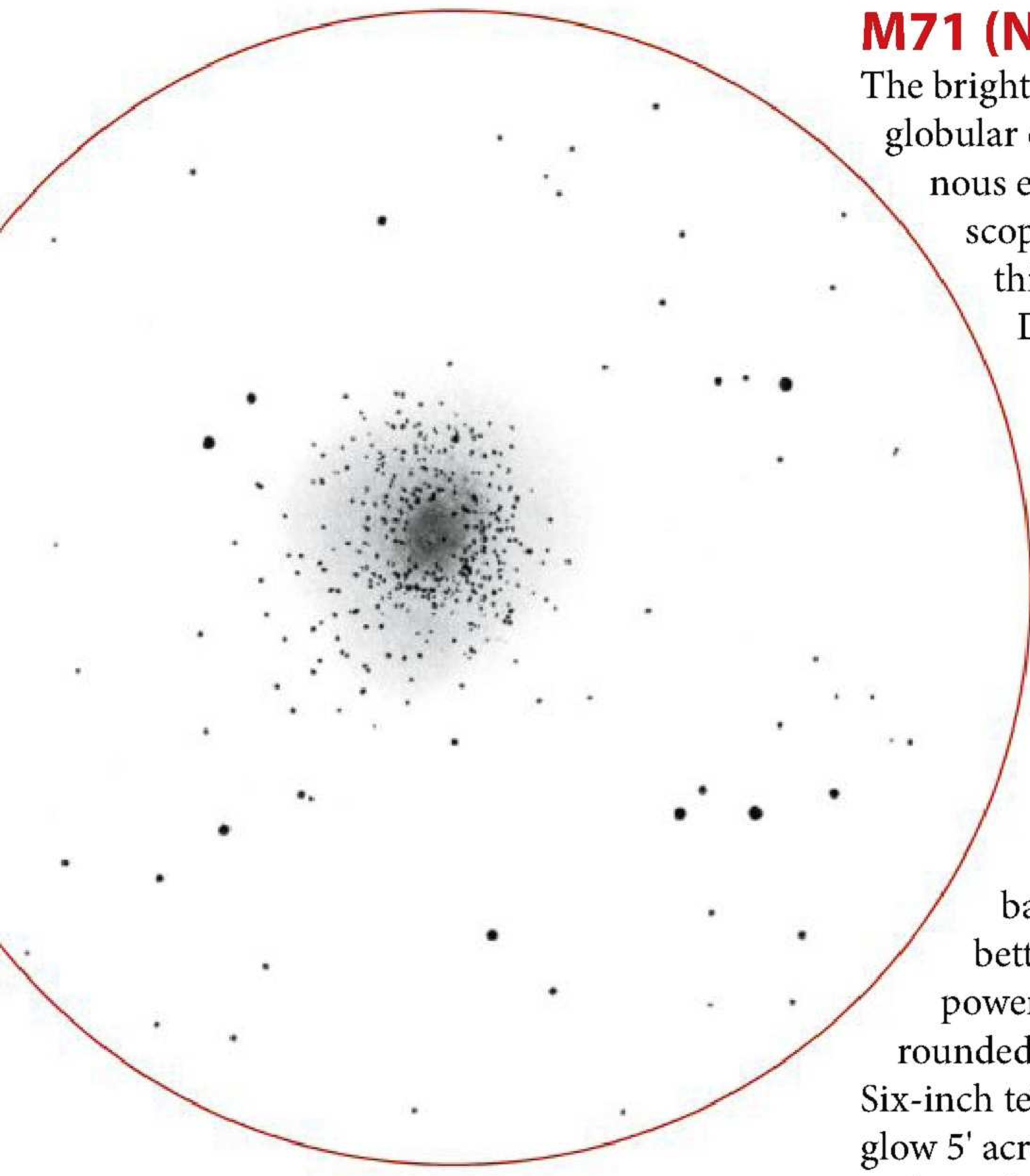
Deep-sky Showcase

Astronomy's editor sketches two of his favorite objects. **by David J. Eicher**

M71 and M92



M71 sketched by David J. Eicher using an 8-inch f/10 Celestron SCT at 50x.

M71 (NGC 6838)

The brightest deep-sky object in Sagitta is globular cluster M71, which is luminous enough to be visible in any telescope or binoculars. Astronomers think Johann G. Koehler of Dresden, Germany, discovered M71 in 1775. However, there is evidence suggesting Jean-Philippe de Chéseaux observed the cluster as early as 1746. The great French observer Charles Messier described the 71st object in his list as "very faint ... it contains no star ... the least light extinguishes it."

The view through modern backyard scopes is considerably better. A 3-inch instrument at low power shows a knot of light surrounded by a rich field of bright stars. Six-inch telescopes reveal M71 as a hazy glow 5' across, peppered by dozens of 11th- and 12th-magnitude stars. The cluster's total magnitude is 8.2, which makes it appear bright through large backyard telescopes. A 12-inch scope resolves more than 100 stars across the cluster's face, demonstrating how M71 is one of the "loosest" globulars in the sky. This looseness makes it fun to observe because of the myriad stars that can be resolved in high-magnification eyepieces.

M71

Anthony Ayiomamitis

Designations: M71, NGC 6838
Position: 19h54m, 18°47' (2000.0)
Constellation: Sagitta
Magnitude: 8.2
Size: 7.2'
Distance: 13,000 light-years

M92

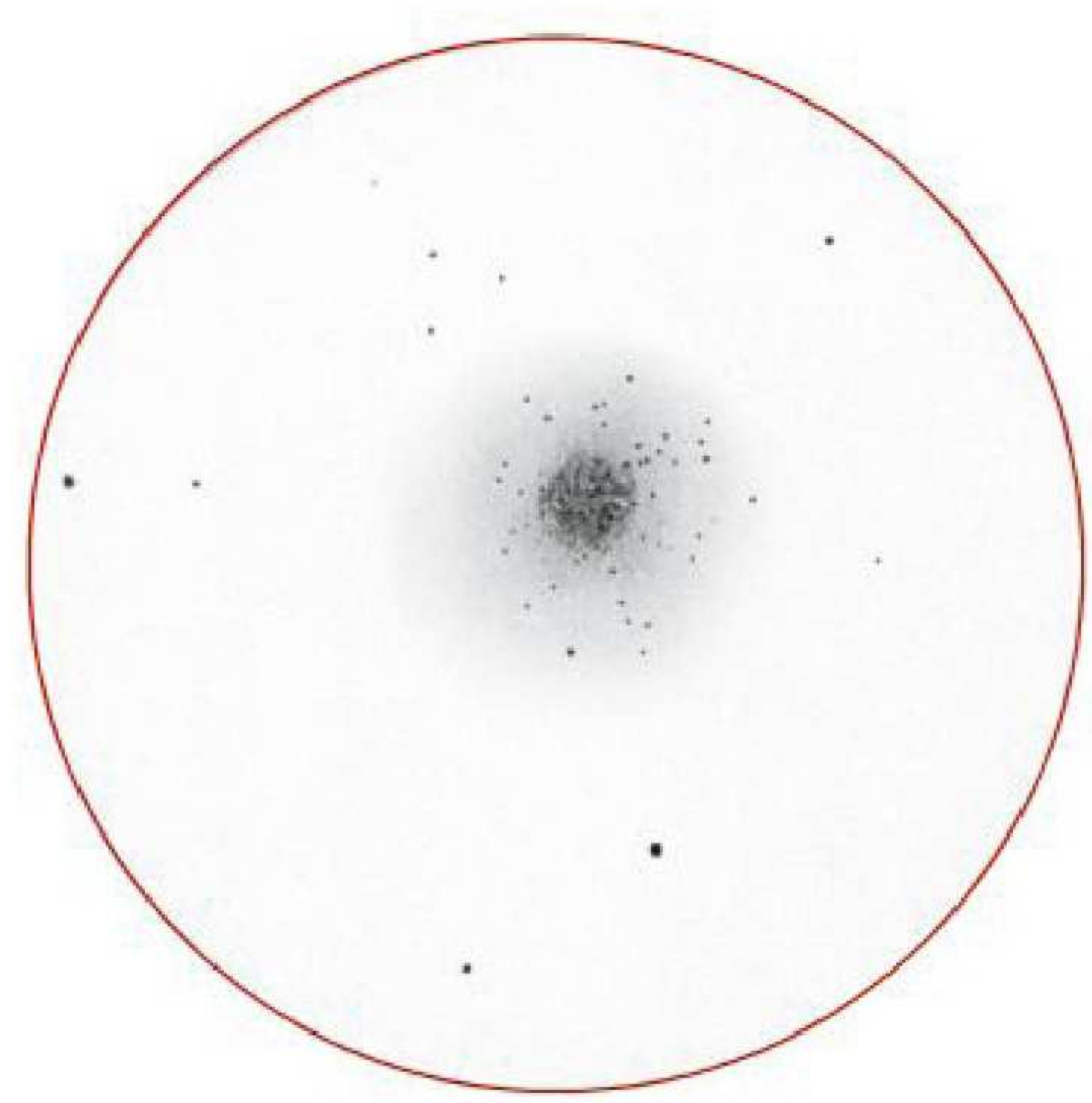
Bob Fera

Designations: M92, NGC 6341
Position: 17h17m, 43°08' (2000.0)
Constellation: Hercules
Magnitude: 6.3
Size: 11.2'
Distance: 30,000 light-years

M92 (NGC 6341)

Nearly 10° northeast of its more celebrated cousin the Hercules Cluster (M13) lies a stellar treat that is often overlooked — globular cluster M92. Shining at magnitude 6.3 and spanning 11.2', M92 is nearly as large and bright as M13, but because it is more compact, it's harder to resolve into kindred stars. A 6-inch scope at high power will show a smattering of suns lining M92's edges; a 12-inch instrument will essentially duplicate the view of M13 through a small scope. M92 is physically smaller and fainter than M13 and lies slightly farther away.

German astronomer Johann E. Bode was first to spot this cluster in 1777, some 63 years after the famous comet observer Edmond Halley became the first to spot M13. Ever since its discovery, M92 has been lying in the shadows of the nearby Hercules Cluster. Give it a try, and I expect you'll find M92 is every bit as alluring, in its own way, as its more celebrated neighbor.



M92 sketched by David J. Eicher using an 8-inch f/10 Celestron SCT at 100x.

David J. Eicher *is the editor of* Astronomy. *He has observed and sketched deep-sky objects for 35 years.*

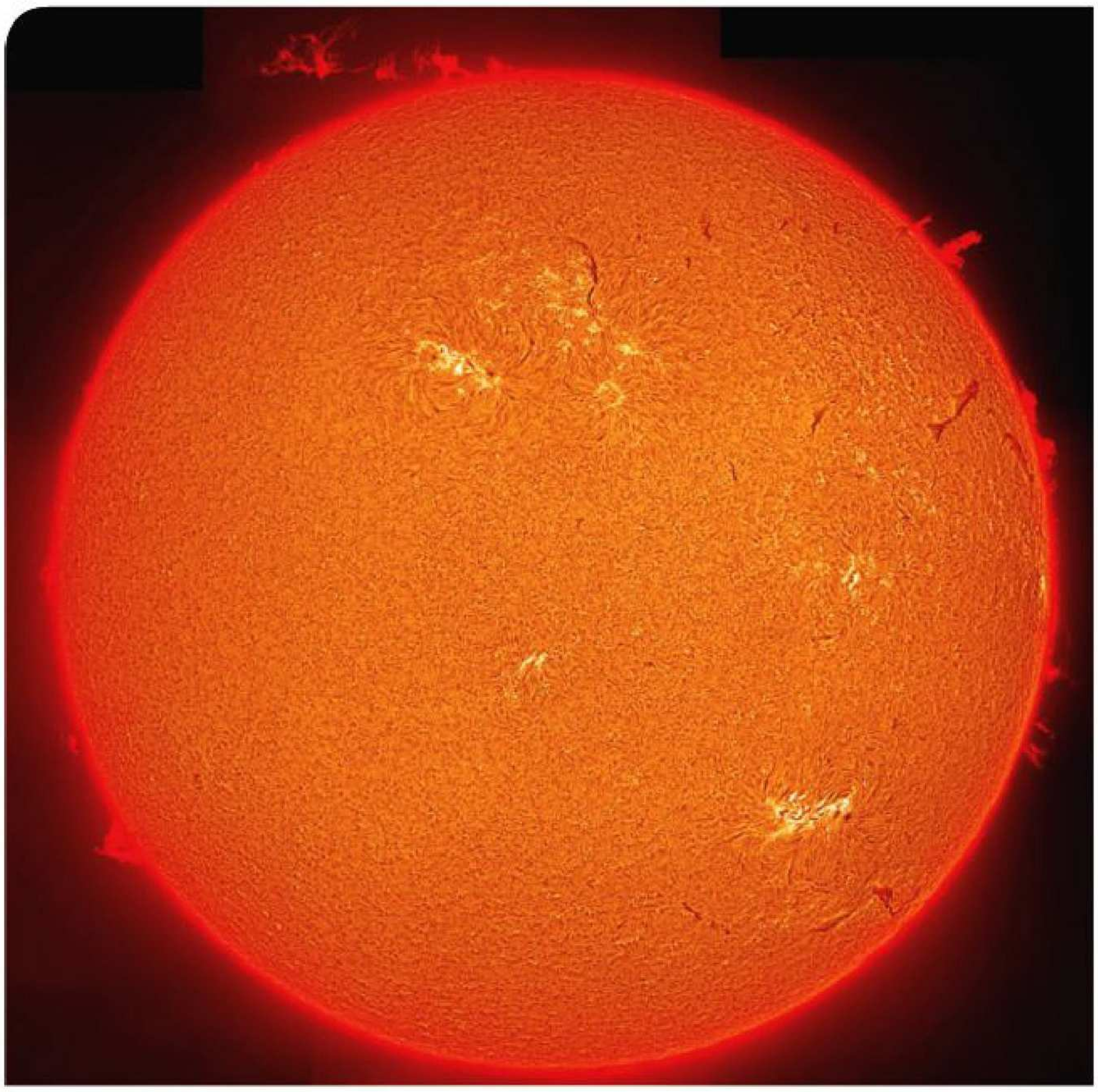
The Tadpole Nebula

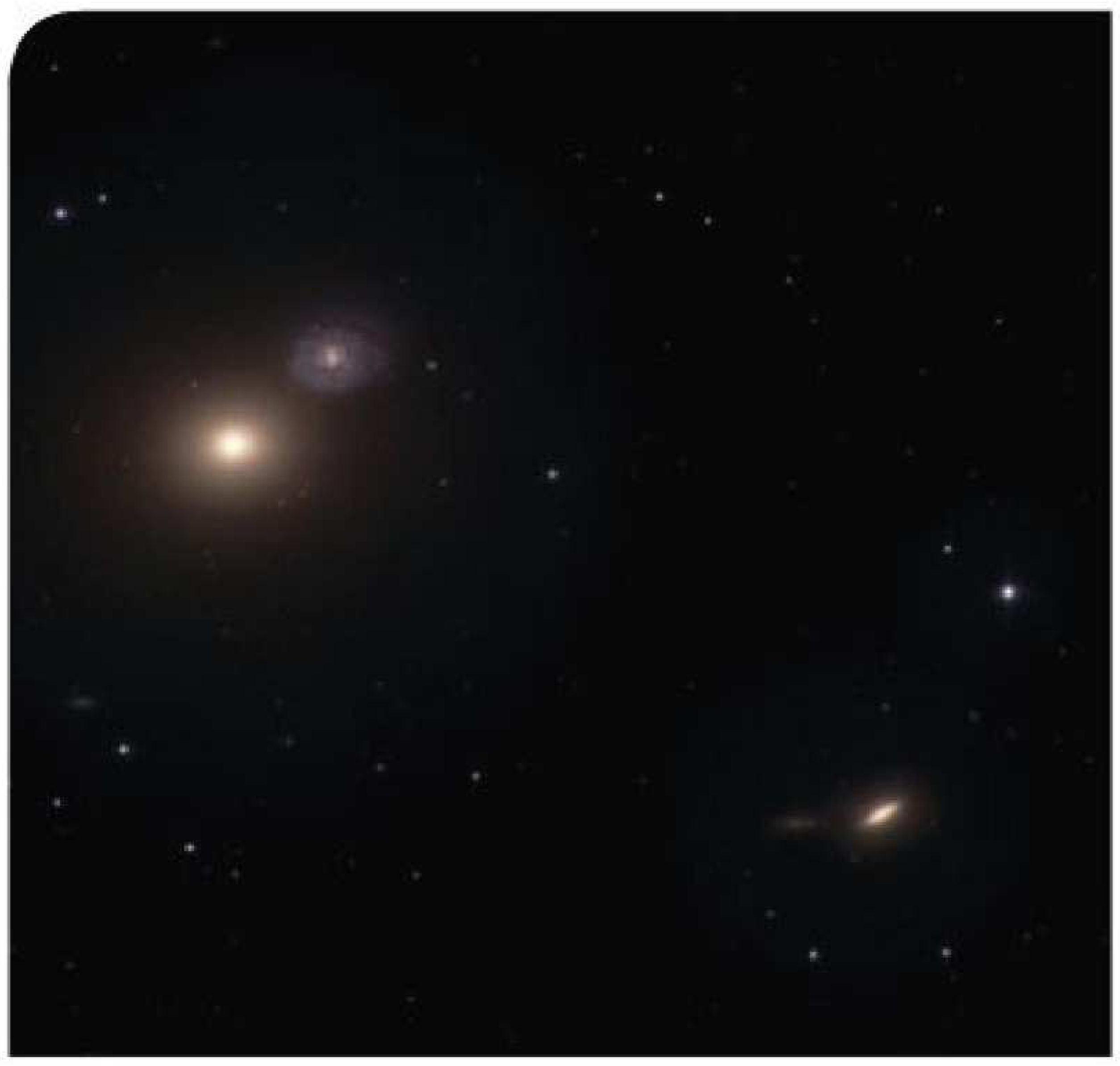
This image of Sharpless 2–236 in Auriga the Charioteer reveals a wide variety of structure: thick (brighter) and thin regions of red emission nebulosity; dark nebulae composed of dust and cold gas; and so-called tadpoles (left of center), clumps of gas whose "tails" arise from the radiation pressure and stellar winds from nearby stars. Those stars belong to open cluster NGC 1893. Its young luminaries emit ultraviolet radiation, which the hydrogen in Sh 2–236 absorbs. When it releases that energy, it shines with the characteristic red color of all such objects.

Sharpless 2–236 (5.2-inch Takahashi TOA-130 apochromatic refractor at f/6, SBIG STL-11000M CCD camera, HαRGB image with exposures of 900, 80, 80, and 80 minutes respectively) • Alistair Symon, Marana, Arizona

The Fox Head Cluster (NGC 6819) in Cygnus received that name because, like a fox's head, this magnitude 7.3 open cluster's brightest stars form a V shape. (14-inch Celestron CGE 1400 Schmidt-Cassegrain telescope at f/6.7, Orion Parsec 8300C CCD camera, ten 5-minute exposures, stacked) • Al Kelly, Friendswood, Texas

NGC 4372 in Musca is one of the sky's least-concentrated globular clusters. It shines at magnitude 7.3 only 0.7° southwest of magnitude 3.8 Gamma (γ) Muscae. (Orion 80ED refractor at f/7.5, Starlight Xpress SXV-H9 CCD camera, LRGB image with exposures of 30, 15, 15, and 15 minutes, respectively) • Michael Sidonio, Kotara, New South Wales, Australia



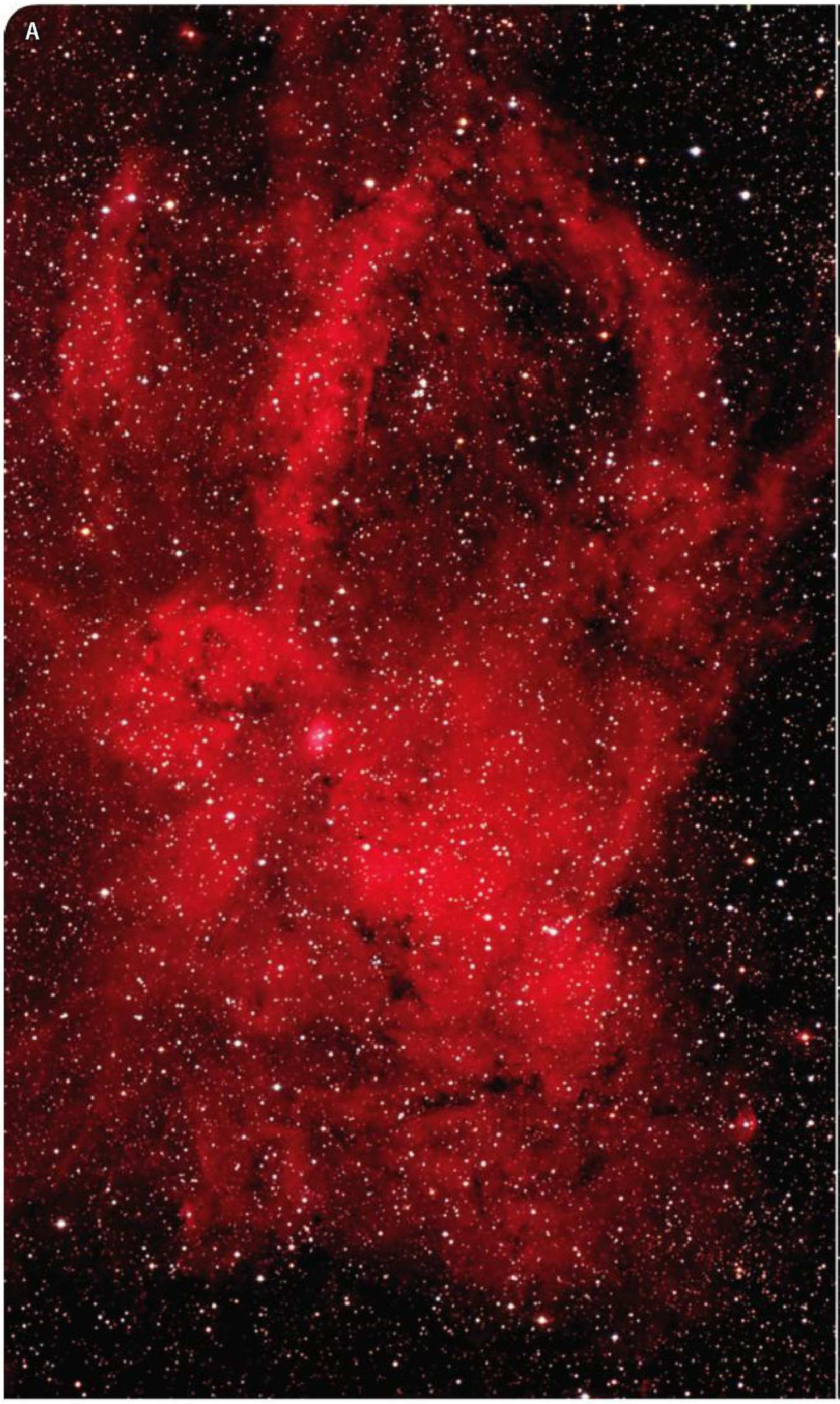


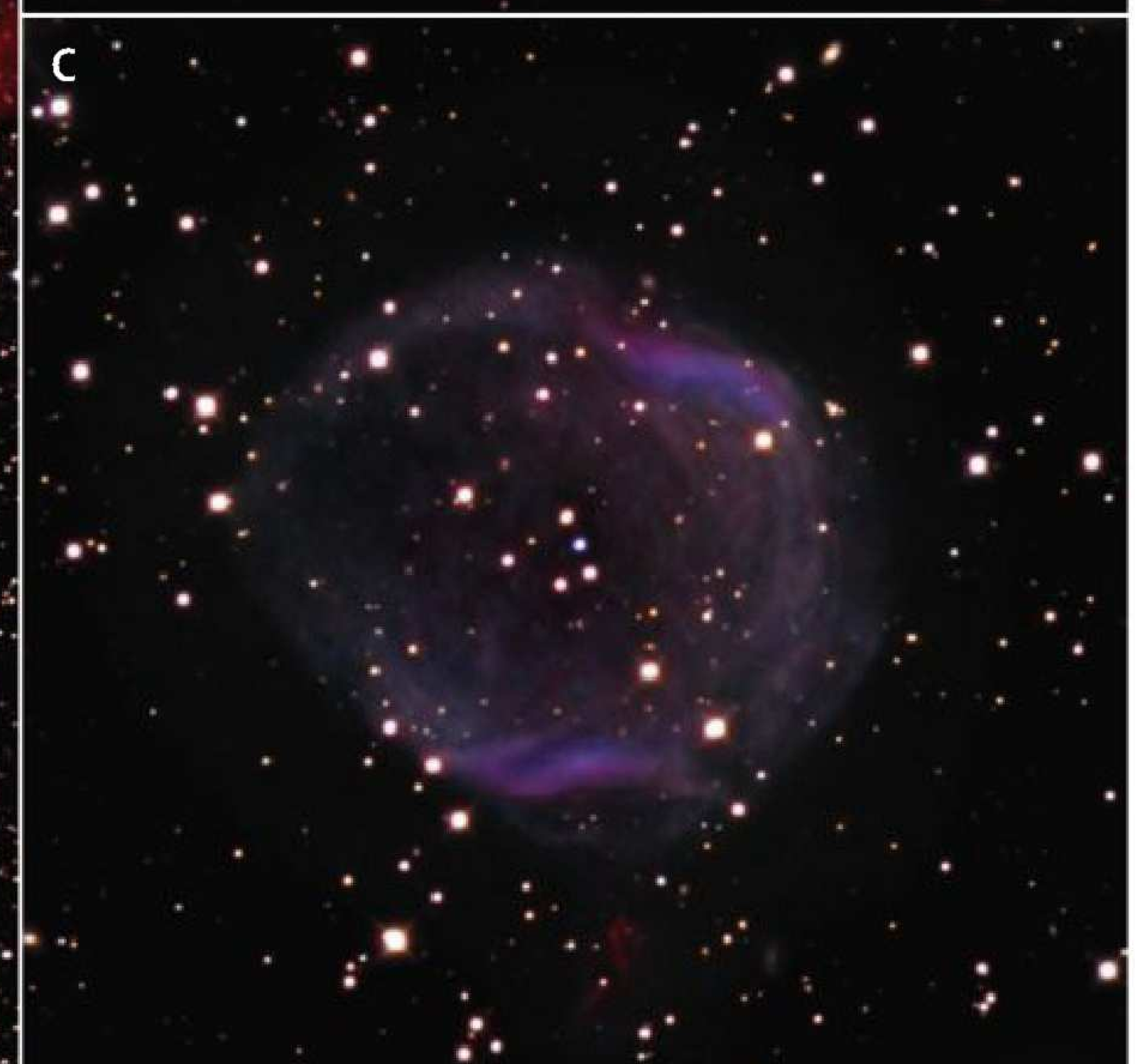
▲ **Elliptical galaxy M60** in Virgo (brightest object on left side of image) shines at magnitude 8.8. It appears as a double galaxy through medium-sized telescopes with its companion, the magnitude 12.3 spiral NGC 4647. (14-inch Astro Optik Philipp Keller Hypergraph at f/3.3, Starlight Xpress SXV-H9 CCD camera, LRGB image with exposures of 78, 28, 30.8, and 39 minutes, respectively) • Harald Strauss, Gahberg, Austria

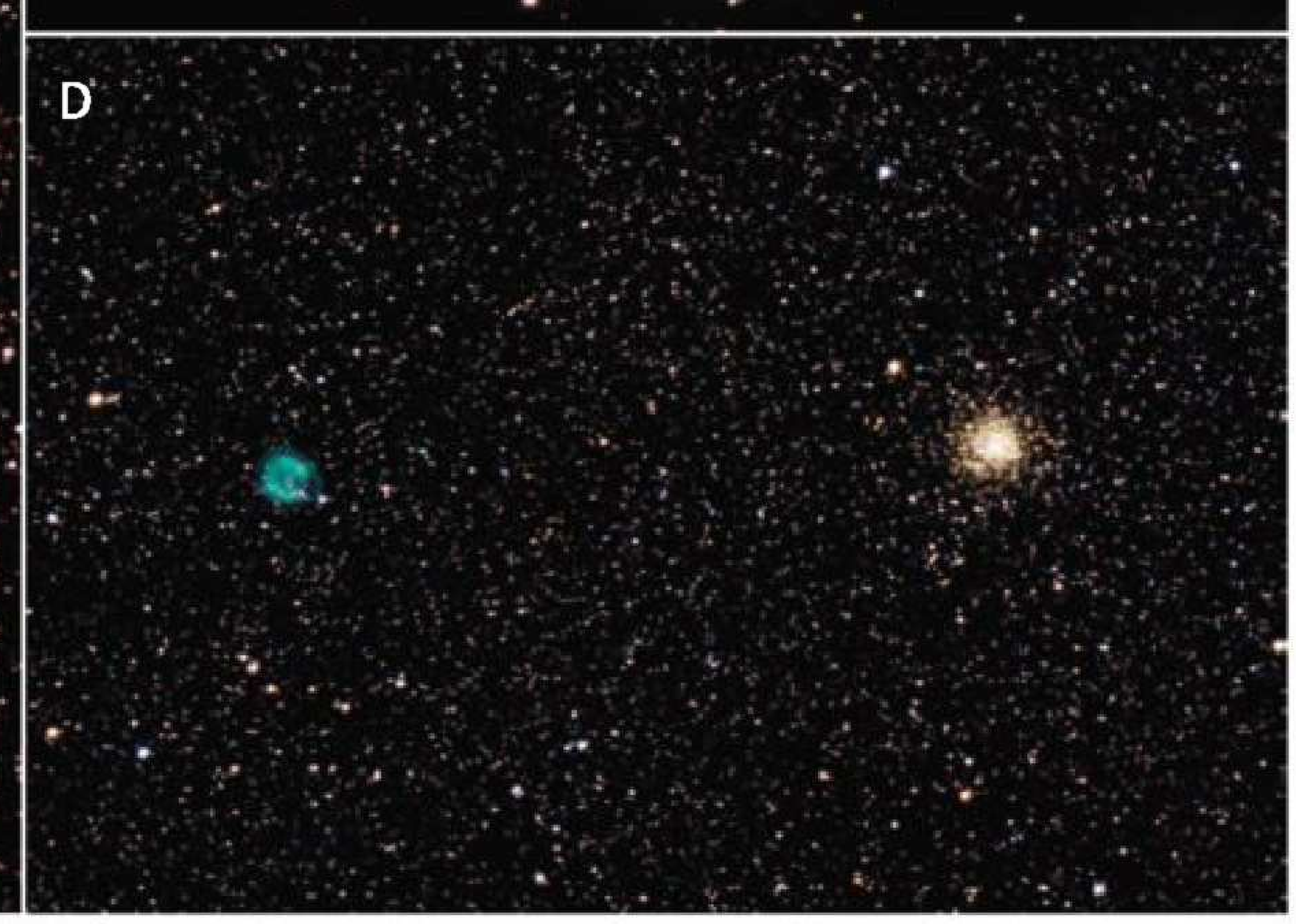
◀ **The Sun's activity** has increased throughout 2011, with more flares (the white surface patches) and prominences (extending from the edge) visible to observers than in any of the past 5 years. (4-inch Vixen FL-102S refractor, SolarScope SF-70 0.7-angstrom Hα filter, Lumenera SKYnyx 2–0M CCD camera, taken February 17, 2011, at 12h23m UT, from Selsey, England) • Pete Lawrence, Selsey, England

Send your images to: *Astronomy* Reader Gallery, P. O. Box 1612, Waukesha, WI 53187. Please include the date and location of the image and complete photo data: telescope, camera, filters, and exposures. Submit images by e-mail to readergallery@astronomy.com.

reader gallery







(A) Emission nebula Sharpless 2–157 in Cassiopeia shrouds planetary nebula Weinberger-Sabbadin 6 (WeSb 6), the small elliptical object in the lower right of this image. (12.5-inch RC Optical Systems Ritchey-Chrétien telescope at f/9, SBIG STL-6303E CCD camera, HαLRGB image with exposures of 240, 160, 90, 90, and 100 minutes, respectively) • Anthony Ayiomamitis, Athens, Greece

(B) The Spare Tire Nebula (IC 5148) in the constellation Grus the Crane appears as a 120"-wide irregular ring with a dark center. Find it 1.3° west of magnitude 4.5 Lambda (λ) Gruis. (12.5-inch RC Optical Systems Ritchey-Chrétien telescope at f/9, SBIG STL-6303E CCD camera, LRGB image with exposures of 200, 100, 100, and 80 minutes, respectively) • Steve Crouch, Tuggeranong, Australia

(C) Planetary nebula Jones 1 (PK104–29.1) in Pegasus the Winged Horse glows softly at magnitude 12.5. Its central star (the blue one) is even fainter at magnitude 15.0. (20-inch RC Optical Systems Ritchey-Chrétien telescope at f/8.3, Trifid II 6303E CCD camera, LRGB image with exposures of 280, 90, 90, and 120 minutes, respectively) • Ken Crawford, Camino, California

(D) Planetary nebula IC 1295 (left) floats 24' east-southeast of the magnitude 8.1 globular cluster NGC 6712 in Scutum. (6-inch Explore Scientific David Levy Comet Hunter Maksutov-Newtonian telescope at f/4.8, Canon 350D DSLR, ISO 800, forty-eight 3-minute color exposures stacked with six 10-minute exposures through an OIII filter) • Chuck Kimball, Julian, California

The Cosmic Grid

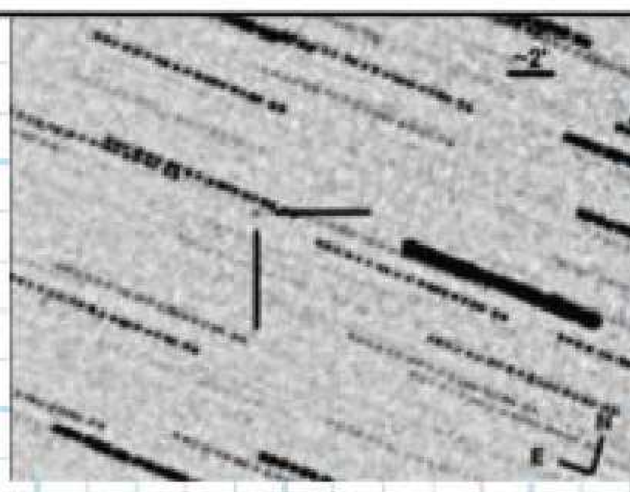
All things high, low, weird, and wonderful in astronomy and space science. **by Bill Andrews**

WEIRD

HOT

NOT

PREDICTABLE

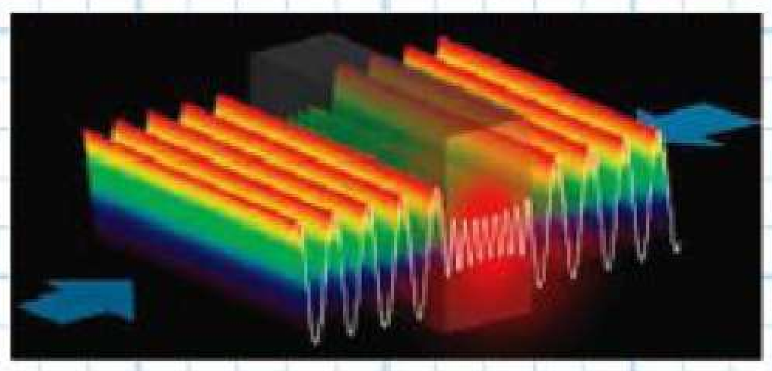


Asteroid alacrity

Two small asteroids, 2011 CQ_1 and 2011 CA_7, whiz closely past Earth, yet no major stories about impending doom sweep the country. Gosh, are you feeling OK, mainstream media?

Lesson plan liftoff

NASA announces it "seeks K-12 educators to defy gravity," apparently targeting instructors who enjoy unorthodox teaching methods. And Broadway musicals.



The laser's nemesis

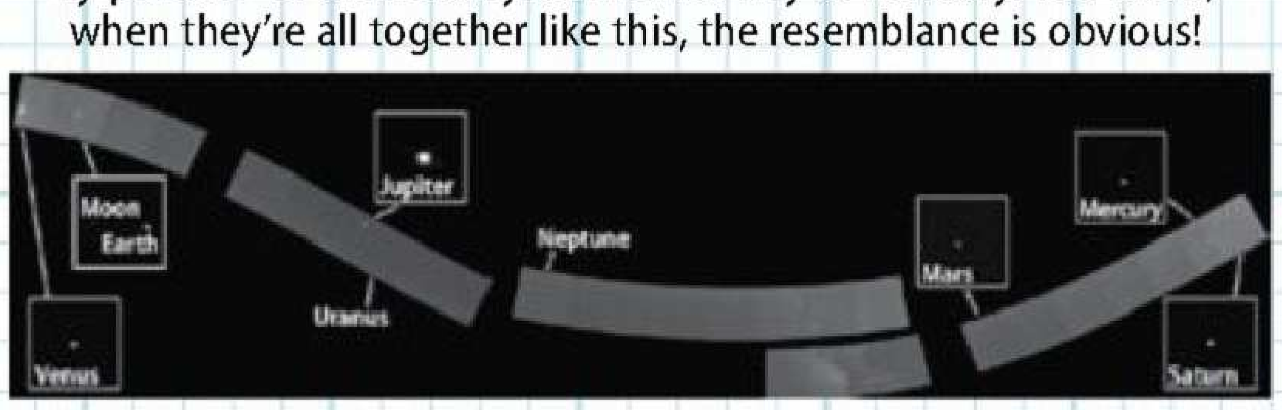
Yale physicists announce the creation of the world's first "anti-laser" — which compresses beams of light perfectly enough to cancel them out — cementing physicists' reputation as the most contrary of scientists.

Habitable heyday

NASA announces its Kepler mission found more than 1,200 candidate planets, with 54 of those in their stars' habitable zone, spurring @Gliese581g to tweet, "KEPLER PROJECT, IT'S LIKE YOU'RE TRYING TO MAKE ME FEEL INSIGNIFICANT!"

Nuclear planetary system

NASA's MESSENGER probe takes the opportunity to snap a "family portrait" of the solar system on its way to Mercury. You know, when they're all together like this, the resemblance is obvious!



Cupid's comet

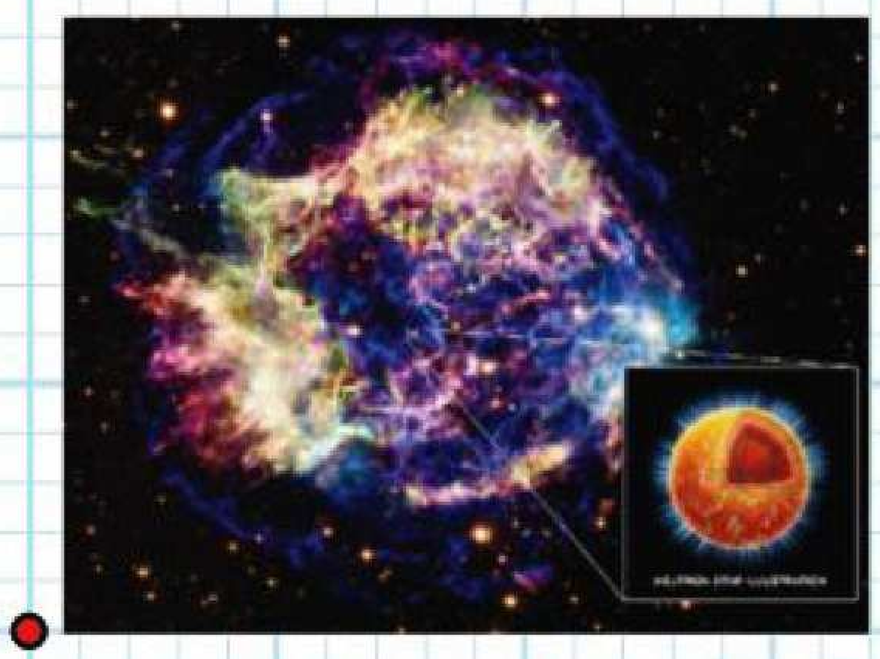
NASA's Stardust-NExT craft probed Comet Tempel 1 on February 14, which the agency referred to as a "Valentine's Day comet rendezvous" and a "celestial date." Is there, uh, more to these missions than you're letting on, NASA?

Facing the heat

Authorities arrest a former NASA worker for allegedly stealing space shuttle heat shield tiles and selling them for $12,000 online. It's bad news for sure, but it looks like we may have figured out a way around NASA's perennial budget troubles!

Planetary house-hunters

Snarky pop-culture site Gawker publishes "Why We Can't Live on the 54 New Possibly-Habitable Planets" that Kepler announced. Top reasons include "Really cold," "Ugly," "Commute would be awful," and "Right near a really loud planet."

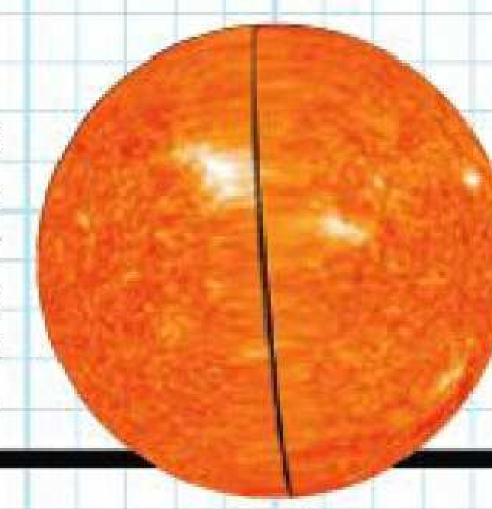


Sickly star

NASA proudly announces its Chandra X-ray Observatory "Finds superfluid in neutron star's core," which is cool even though it sounds like the first stages of pneumonia.

Jocks v. nerds

NASA unveils the first complete view of the Sun's entire surface and atmosphere on Super Bowl Sunday (February 6), rebranding the day "Super Sun-Day." Nice try, NASA, but I think football still won out for most people.

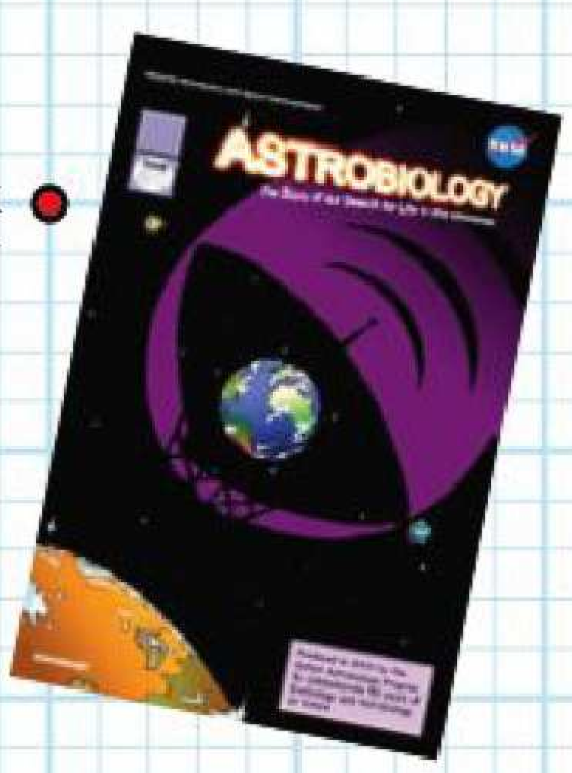


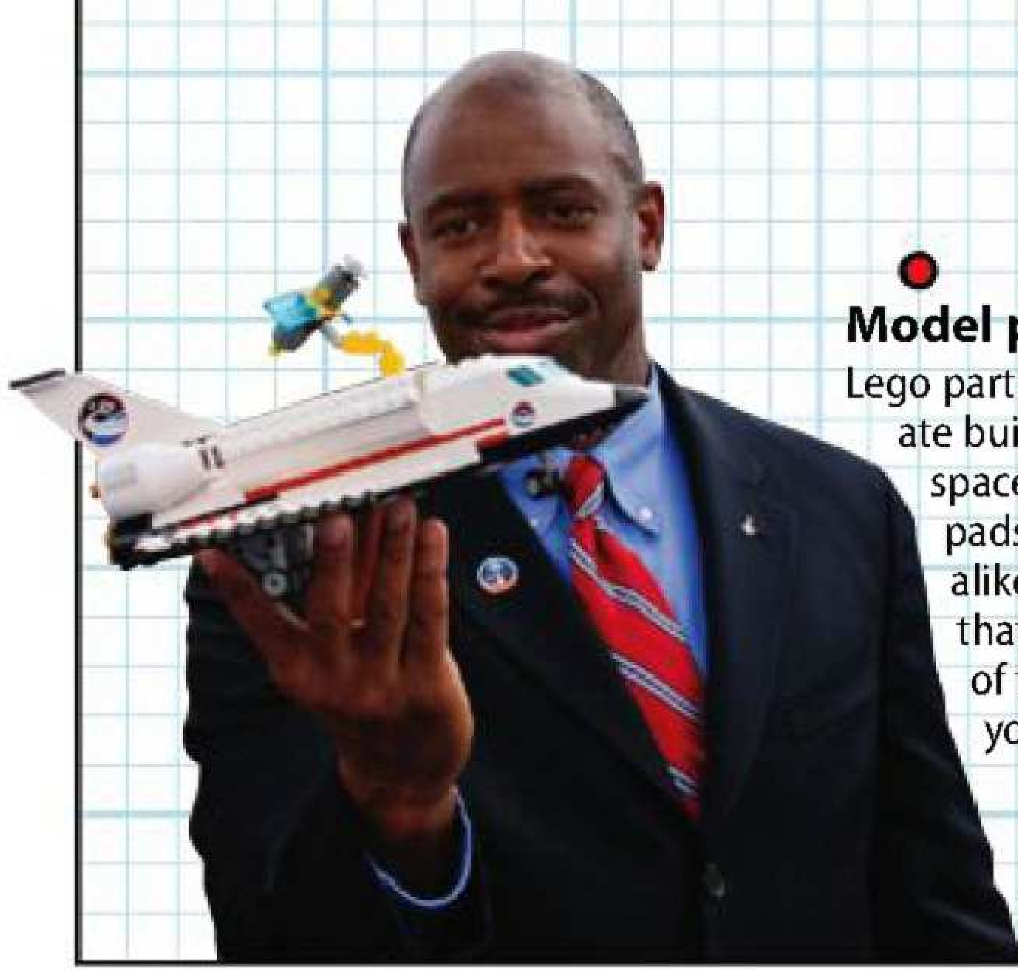
Space science race

Nature's blog "The Great Beyond" announces "Citizen scientists beat Kepler team to candidate planets," which is great. But people please! This isn't a competition — there's enough science to go around!

Cosmic comic book

The NASA Astrobiology Program, in honor of the science's 50th anniversary, debuts the first issue of the *Astrobiology* graphic novel. Because sometimes, science alone isn't geeky enough.





Model partnership

Lego partners with NASA to create buildable space shuttles, space stations, and launch pads for kids and astronauts alike. Guys, it's OK, we get that astronauts do lots of fun things — now you're just rubbing it in.

"Follow that rocket!"

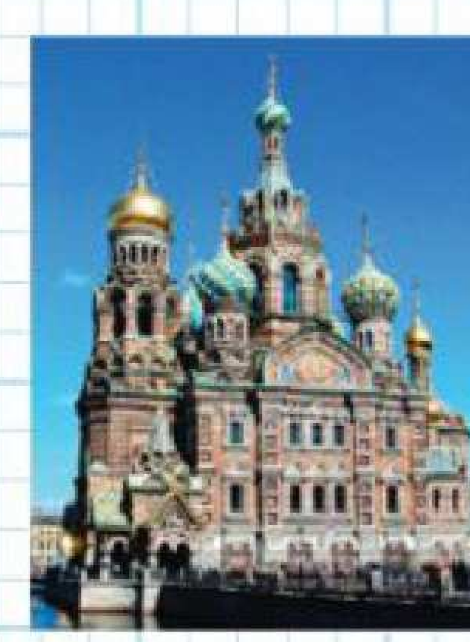
The aerospace companies Alliant Techsystems and Astrium hope to repurpose the canceled NASA Ares I rocket as a kind of "space taxi," a phrase that really turns the promise of the future into the squalor of the present.

Committee on asteroid affairs

Satirical newspaper *The Onion* runs the fake story, "Republicans Vote To Repeal Obama-Backed Bill That Would Destroy Asteroid Headed for Earth." At least, I think it's a fake story …

Out to launch

Sony's PlayStation 3 video game console offers owners the chance to watch space shuttle *Discovery*'s launch and chat via headsets with other PlayStation viewers; let's hope Leeroy Jenkins doesn't ruin it for everybody.

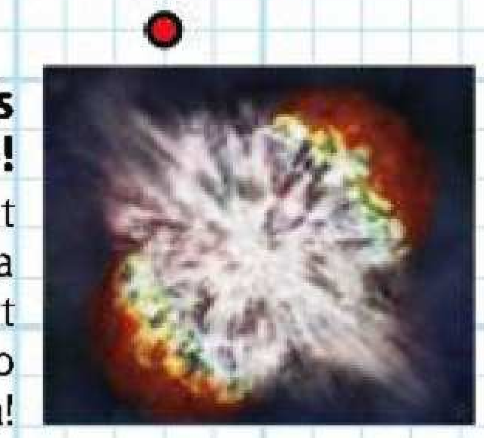


Ptolemaic populace

A poll finds that one-third of Russians think the Sun orbits Earth, proving the old adage that folks are the same no matter where you go. Sadly.

Betelgeuse: It's not showtime!

Stories about Betelgeuse's imminent (and deadly) supernova in 2012, a completely unscientific belief, start making the rounds. Ah, glad to see you're feeling better, media!



PHOTOGRAPHS: G. Sostero & E. Guido/Remanzacco Observatory (Asteroid alacrity); Yidong Chong/Yale University (The laser's nemesis); NASA/ESA (Habitable heyday); NASA/Johns Hopkins University Applied Physics Laboratory/Carnegie Institution of Washington (Parental planetary system); NASA/JPL-Caltech/Cornell (Cupid's comet); NASA (Facing the heat); X-ray: NASA/CXC/UNAM/Ioffe/D.Page, P.Shternin, et al.; Optical: NASA/STScI; Illustration: NASA/CXC/M.Weiss (Sickly star); NASA (Jocks v. nerds); © 2011 Jupiterimages Corporation ("Follow that rocket!"); Lawrence Jackson (Committee on asteroid affairs); Dionysus (Ptolemaic populace); NASA/Tony Gray (Out to launch); NASA/CXC/M.Weiss (Betelgeuse: It's not showtime!); NASA (Space science race); NASA Astrobiology Program (Cosmic comic book); NASA/Jack Pfaller (Model partnership)

Jupiter rules the roost

Only one bright planet graces the early evening sky most of the month. **Saturn** lies about 20° high in the west as the sky darkens September 1. It shines at magnitude 0.9 among the stars of Virgo, nicely placed between 1st-magnitude Spica (which appears above the planet) and 3rd-magnitude Gamma (γ) Virginis.

When viewed through a telescope, Saturn is undeniably beautiful. Even the smallest scope shows the ring system, which currently spans 36" and tilts 10° to our line of sight, wrapped around the planet's 16"-diameter globe. Also look for 8th-magnitude Titan, Saturn's largest moon and second only to Jupiter's Ganymede in the solar system. Titan orbits the ringed planet every 16 days.

Because Saturn appears lower in the twilight sky with each passing night, observe it as often as you can in early September. It disappears during the month's final week, just as **Venus** returns to view. The inner planet gleams at magnitude –3.9, bright enough to pierce the bright twilight when Saturn no longer can. On September 30, look for Venus about 5° high in the west 30 minutes after sunset. Our views of this world will improve noticeably during October.

By late evening, brilliant **Jupiter** rises in the east. The largest planet lies in Aries, roughly 10° southeast of that constellation's stellar trio of Alpha (α), Beta (β), and Gamma Arietis. At magnitude –2.7, however, Jupiter shines nearly 100 times brighter than any of these stars.

To see Jupiter at its best through a telescope, wait until after midnight when it climbs higher in the sky. At your first glance, notice the planet's squashed appearance — its disk spans 47" across the equator but 3" less through the poles. Second, look for features in Jupiter's atmosphere. You should see two dark belts sandwiching a brighter equatorial zone. In moments of good seeing, fine details will pop into view. And finally, search for the four bright Galilean moons, which show up easily whenever they are clear of the jovian disk.

Mars continues its holding pattern in the northeast before sunrise. It rises about 2.5 hours before the Sun all month and maintains a nearly steady altitude in the predawn sky. The reason: Its eastward motion against the background stars almost matches that of the Sun. The Red Planet crosses eastern Gemini in early September, passing 6° south of Pollux on the 10th. (Both star and planet shine at 1st magnitude.) Mars enters Cancer at midmonth and closes September about 1° to the upper left of the Beehive star cluster (M44). The proximity of Mars to the bright cluster will make a nice sight through binoculars. Unfortunately, a telescope shows little on Mars because it appears only 5" in diameter.

September 3 marks the peak of this morning appearance of **Mercury**, but that's not saying much. Although the innermost planet reaches greatest western elongation that day, it lies just 18° from the Sun. From the Southern Hemisphere, Mercury climbs only a few degrees above the horizon in the predawn sky. (It appears a little higher for observers closer to the equator.) Through a telescope at greatest elongation, Mercury appears 7" across and has a fat crescent phase.

The starry sky

Although lots of people have heard of the zodiacal light, few have seen it. This ghostly glow appears in the western sky shortly after evening twilight fades and in the eastern sky just before morning twilight begins. The cone-shaped glow has a broad base at the horizon and a gently tapering peak that can extend halfway to the zenith under favorable circumstances. Although the zodiacal light is tricky to see — it glows a bit fainter than the Milky Way's brightest parts — September evenings are a great time to spot it.

The zodiacal light originates in the countless number of interplanetary dust particles that pervade the inner solar system. We see the sunlight that reflects off these tiny dust grains, most of them apparently debris from comets breaking up or outgassing. This material concentrates in the plane of the solar system, so it appears along the ecliptic, and, therefore, against the backdrop of the zodiacal constellations. That's how the zodiacal light got its name.

Experienced observers know that Earth's atmosphere dims celestial features near the horizon far more than those that lie higher. The Milky Way is a prime example — think of how hard it is to see this glow from the innumerable stars in our galaxy's disk when it skirts the horizon compared with the great views we get when it lies high in the sky.

The zodiacal light is no different. It shows up best when the ecliptic makes a steep angle with the horizon and the cone's apex appears highest. From the Southern Hemisphere, that means evenings during September and mornings in March.

You can give yourself a far better chance of seeing the light by observing under the darkest sky possible. In early September, the Moon interferes. Fortunately, it's a thin crescent during the month's first couple of days, so it still should be possible to see the light. After that, wait until a few days after the September 12 Full Moon. Target the evenings from September 15 onward, when the waning gibbous Moon rises long after twilight fades.

Light pollution is another important consideration. It's impossible to see the zodiacal light from a big city, or even from a relatively small town if street lights get in the way. You'll increase your odds significantly if you make an observing trip out to dark country skies.

StarDome

The all-sky map shows how the sky looks at:
10 P.M. September 1
9 P.M. September 15
8 P.M. September 30

Planets are shown at midmonth

How to use t
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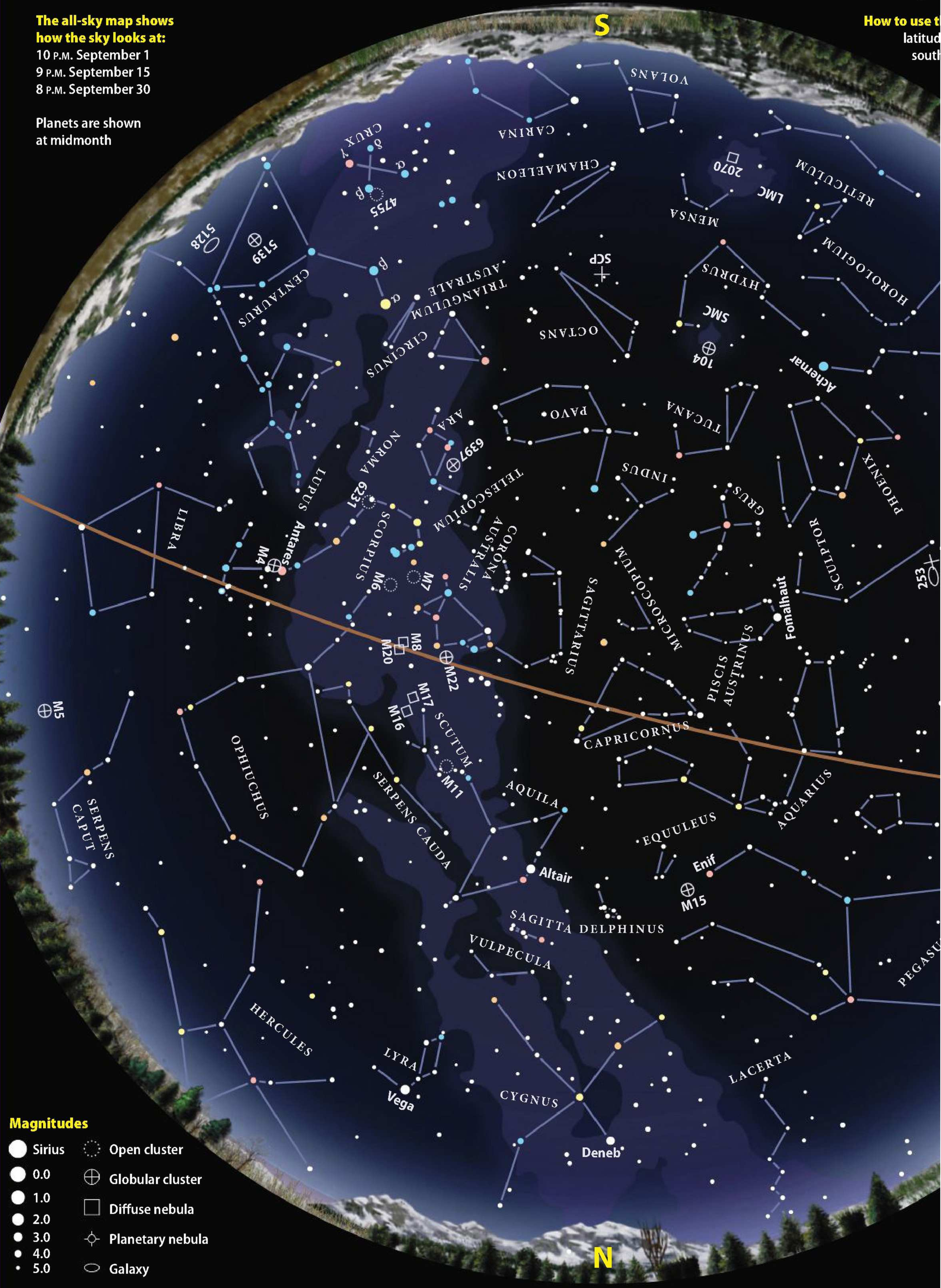
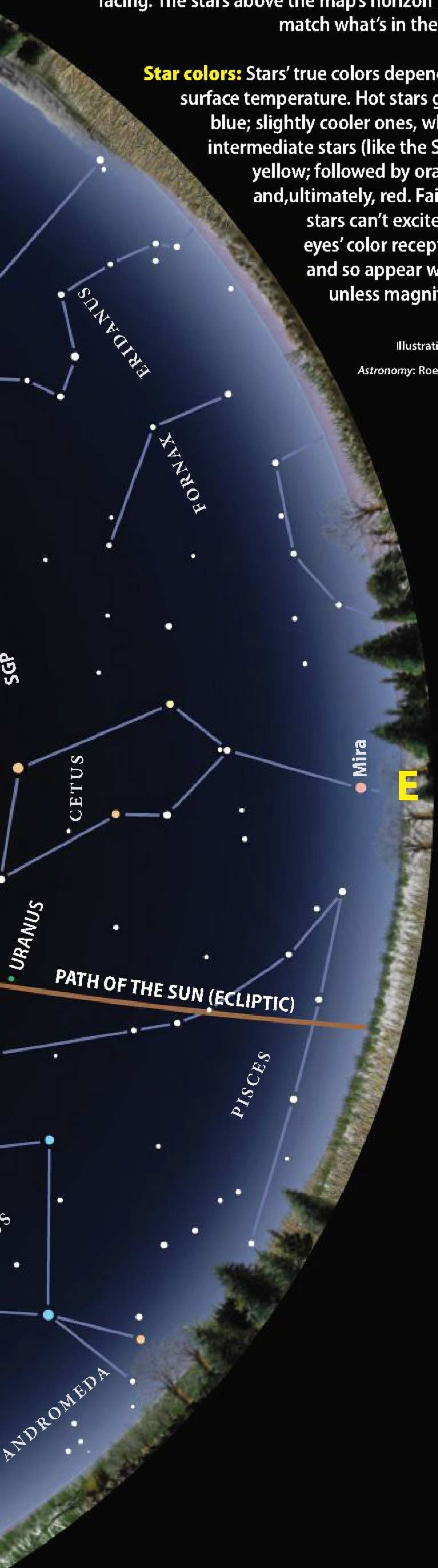
south



his map: This map portrays the sky as seen near 30° south e. Located inside the border are the four directions: north, n, east, and west. To find stars, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

Star colors: Stars' true colors depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white unless magnified.

Illustrations by *Astronomy*: Roen Kelly



September 2011

Calendar of events

3 Mercury is at greatest western elongation (18°), 6h UT

4 First Quarter Moon occurs at 17h39m UT

9 Mercury passes 0.7° north of Regulus, 2h UT

10 Mars passes 6° south of Pollux, 2h UT

The Moon passes 6° north of Neptune, 21h UT

12 Full Moon occurs at 9h27m UT

13 The Moon passes 6° north of Uranus, 18h UT

15 The Moon is at apogee (406,065 kilometers from Earth), 6h24m UT

16 Pluto is stationary, 12h UT

Asteroid Ceres is at opposition, 17h UT

The Moon passes 5° north of Jupiter, 18h UT

Asteroid Pallas is stationary, 22h UT

18 Asteroid Vesta is stationary, 2h UT

20 Last Quarter Moon occurs at 13h39m UT

23 The Moon passes 5° south of Mars, 8h UT

September equinox occurs at 9h05m UT

26 Uranus is at opposition, 0h UT

27 New Moon occurs at 11h09m UT

28 The Moon is at perigee (357,557 kilometers from Earth), 1h03m UT

Mercury is in superior conjunction, 20h UT

For definitions of terms, log onto www.Astronomy.com/glossary.