New Section! 16-Page Guide to April's Sky p. 43

THE ESSENTIAL MAGAZINE OF ASTRONOMY

SKY & TELESCOPE

APRIL 2012

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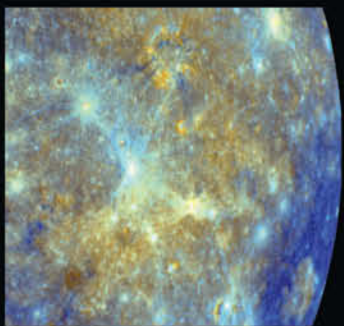

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SKY & TELESCOPE

April 2012

VOL. 123, NO. 4

TITANIC PAINTING: SIMON FISHER

On the cover: An astronomical alignment may have let loose the *Titanic's* fateful iceberg.

FEATURES

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S&T TEST REPORT

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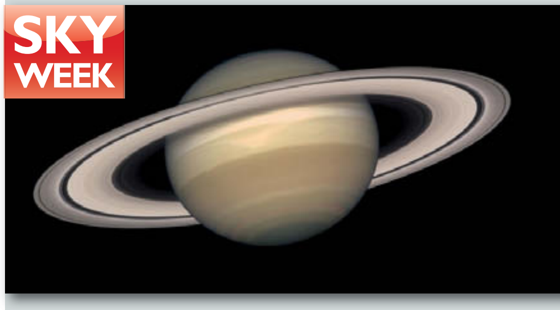

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S&T's New Observing Section

I KEEP A WHITEBOARD in my office where I jot down wise and inspirational quotes. One of the quotes that's been there for quite awhile comes from inventor Charles Kettering: "The world hates change, yet it is the only thing that has brought progress."

I suspect that you have already noticed one big change with this issue. Rather than spreading our monthly observing articles around the magazine, we're running them all together and linking them thematically with a red band across the top of each page. This unified observing section starts off with a table of contents (page 43) and generally goes from our departments that cover naked-eye objects to Sue French's Deep-Sky Wonders column, which mostly describes objects requiring telescopes.

You're undoubtedly wondering what motivated this change. My colleagues and I felt that our readers would appreciate having all of our monthly observing content consolidated in one section, making it easier for you to find what you're looking for. In addition, it showcases the breadth of the observing content we include in each issue. For us, articles about what's up in the night sky are the most important stories in every issue.

S&T: DENNIS DI CICCO

Please note that the actual content has not changed in any substantive manner. Everything that we included in previous issues is still there — it's just that some of it has been moved around and arranged a little bit differently. In fact, this revised section, created by *S&T* design director Pat Coppola (seen at the upper right with her hand extended) and unanimously approved by the editorial staff, gives us more flexibility, which will enable us to increase our monthly observing content. For example, we'll be able to give an extra page or two each month to Alan MacRobert's Celestial Calendar department.

As magazines evolve, so will *S&T*. We're contemplating additional changes to give the magazine a fresher appearance while maintaining our long-held standards of accuracy, quality, and integrity.

Robert Naeye
Editor in Chief

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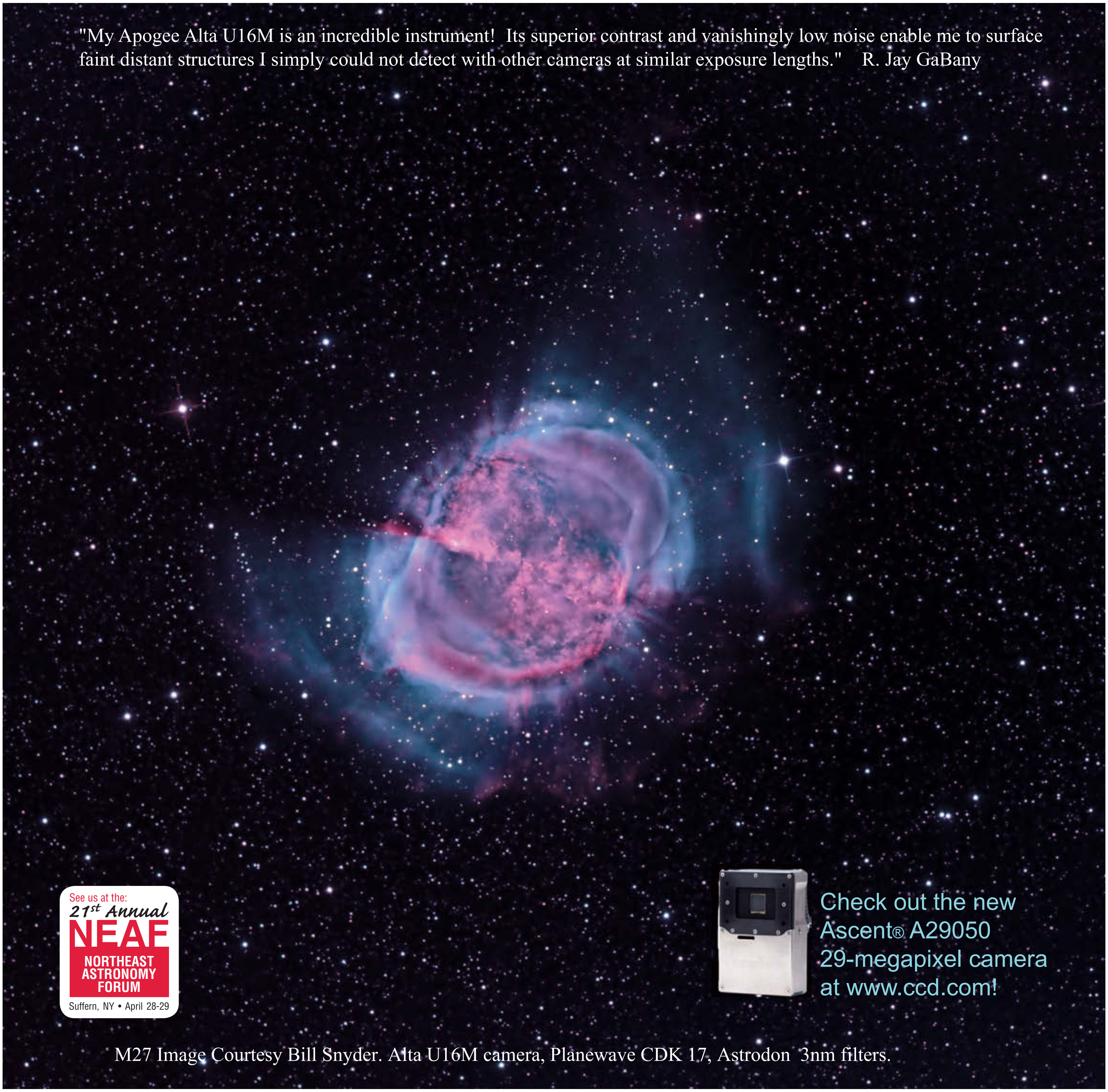

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S&T: LEAH TISCIONE

Interstellar Communication

The article "How Alien Astronomers Could Find Earth" (*S&T*: January 2012, page 24) assumes that if intelligent life exists, it is roughly as intelligent as we are. However, please consider that we live in a 13.75-billion-year-old universe on a 4.5-billion-year-old planet. It is statistically improbable that aliens are near our stage of intelligence.

If there is intelligence out there (which seems likely), it probably discovered Earth hundreds of millions of years ago. They deliberately do not contact us for the same reason that humans increasingly do not disturb wilderness areas: had contact been made 100 million years ago, life on Earth would have evolved much differently.

For these reasons, helping aliens contact us misses the mark. If they wanted to contact us, they would have already.

Phinizy Spalding
McDonough, Georgia

Dr. Lazio outlines the difficulties for generating a recognizable signal with which to communicate our presence to other civilizations. These difficulties doubtless explain the lack of results from the SETI program, since any other advanced civilization would undoubtedly have arrived at the same roadblocks to interstellar communication as we have. Therefore, we and our galactic neighbors all have our SETI earphones on, passively listening for a signal that no one is willing to transmit!

Gene Homme
West Milford, New Jersey

Wonderful article about how alien astronomers could find us on planet Earth. Author Joseph Lazio wonders if such aliens could pick up our light pollution, as well as episodes of *Gilligan's Island*. It turns out that they could — if they set up a gravitational-lens telescope 550 astronomical units from their own Sun-like star and used it to magnify an image of Earth. Such was reported by Seth Shostak (SETI Institute) in a past issue of a British astronomy magazine.

Such a distant observing outpost is beyond our current capabilities (the Voyager spacecraft are only about 100 a.u. away). But if aliens did manage to observe us that way, would they visit us pronto instead of waiting for their signal to reach us? I think they would.

Julian Grajewski
Hamburg, Germany

Author's Note: *The gravitational lens method could technically work but may not be practical. What happens if you want to point the lens telescope in a different direction? The spacecraft has to be moved. How far the spacecraft has to move depends upon how much you want to change the direction in which the telescope is pointing. Changing the pointing direction by only 1° requires moving the spacecraft by about 10 a.u., Saturn's distance from the Sun. In the worst case (looking the opposite direction), the spacecraft has to move more than 1,000 a.u.*

I was disappointed that you spent 7 pages of the January 2012 issue talking about the futility of trying to say "Here we are" to neighboring stellar civilizations when a single paragraph can express that futility quite well. Intelligent beings could hardly be expected to waste the prodigious amounts of energy that Lazio describes, just to signal other star systems. And no intelligent being is likely to use any of the known communication methods to connect with another system's inhabitants. Imagine trying to play chess with someone 50 light-years away. By the time they responded to your move, you'd be long gone. There will be no interstellar "communication" until signals can be exchanged via subspace or some other as-yet-to-be-discovered faster-than-light process.

I'd also like to ask for a clarification: In the sidebar "Could Aliens Listen to Our Radio or Watch Our TV?" (page 30), you said that "any nearby civilization must have telescopes 100 times more sensitive than our current radio telescopes to have any hope of detecting our TV signals." This statement seems rather vague. How close is "nearby?" And how close would a civilization with our current level of technology have to be to listen in on our radio and TV broadcasts?

Jack Ryan
El Dorado, Arkansas

Author's Note: *The short answer is that, with our current level of technology, we could only detect ourselves slightly outside the solar system and certainly not farther than about 1,000 a.u. That estimate is based on a combination of assumed values for things such as the TV channel frequency, transmitter power, and the sensitivity of the radio antenna that's receiving the signal. For example, if we were to use India's Giant Metrewave Radio Telescope to detect a TV broadcast of 600 MHz (about channel 30), the GMRT could be at most about 400 a.u. away. For reference, Alpha Centauri is more than 300,000 a.u. away. Thus, with our current technology one would need a telescope at least 100 times as sensitive*

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as the GMRT, which is among the most sensitive telescopes at the relevant frequencies.

Why is it so hard? For essentially all radio astronomy observations, the amount of power contributed by whatever source we're trying to detect is an incredibly small fraction of the total received power. Competing sources include the Milky Way, other sources in the sky, natural radio emissions from Earth, and even the radio telescope itself (the last two are good examples of radiation emitted because objects have a temperature). Which of these various contributions dominates depends upon the frequency we're observing at. At frequencies relevant for radio and TV broadcasts, the dominant, or nearly dominant, contribution is the radio emission produced by highly relativistic electrons spiraling in the magnetic field of our galaxy.

For the Record

✷ *In the map on page 74 of the January 2012 article previewing Venus's June transit, the region encompassing North America should be labeled "Transit in progress at sunset," not sunrise. The map on page 70 of the article has the correct labels.*

✷ *On page 22 of the February 2012 article "Einstein's Shadow," the labels for the Sgr B1 and Sgr B2 star-forming regions are reversed. Thanks to Dave Mehringer for pointing out the switcheroo.*

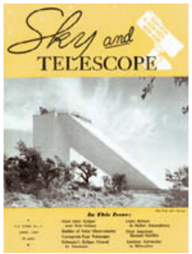
For a list of past errata, please go to **SkyandTelescope.com/Errata**.

75, 50 & 25 Years Ago

Roger W. Sinnott

March–April 1937

The Sun's Artillery "Research has conclusively demonstrated that sun-spots are huge solar cyclones, whirlwinds in the solar atmosphere, accompanied by pronounced magnetic conditions. . . .

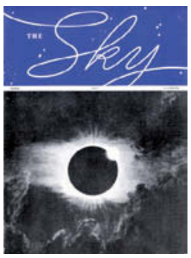


"It has been suggested that the presence of huge magnetic fields in sun-spots results in their acting as howitzers to pour forth charged particles of matter into the interplanetary realm. If the earth is in the range of the howitzer, its atmosphere is the recipient. . . .Such terrestrial phenomena as auroral displays, magnetic storms, and effects on long distance radio reception should then occur."

Since Loring B. Andrews penned these words, astronomers have figured out that flares erupting in association with large sunspots, and not the spots themselves, are the "howitzers" — although the short cannon comparison needs a little stretching now.

April 1962

Cassegrain-Type Telescopes "Recently, the writer decided to compare the performance to be expected of a Cassegrain telescope with those of various other systems . . . evolved from it. The study was made in the course of developing an automatic lens-design program for use on the IBM 7090 computer at United Aircraft Research Laboratories. . . .

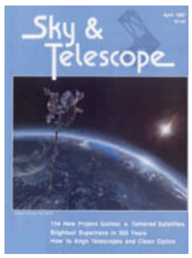


"The last and most complex member of the Cassegrain family that I have examined is the Schmidt-Cassegrain. . . ."

The Schmidt-Cass was then almost unheard-of, but it fared quite well in Ronald R. Willey's ray traces. Willey's S&T article inspired Celestron's founder to switch to the Schmidt-Cass design, ultimately turning the amateur telescope marketplace on its end.

April 1987

Giant Galactic Arcs "Perhaps the most remarkable announcement at the January meeting of the American Astronomical Society concerned the detection of giant arcs encircling at least two distant clusters of galaxies. Their scale is truly staggering. . . . In fact, they are the largest known entities in the universe that shine in visible light."



At the time of Leif Robinson's report, many astronomers didn't yet realize that the arcs were mirages — light from a galaxy far beyond each galaxy cluster, lensed by the cluster's gravity.

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

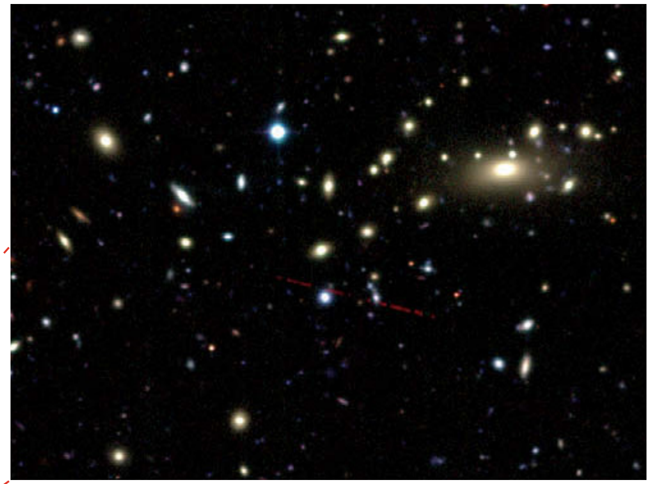
New Maps of Dark Matter

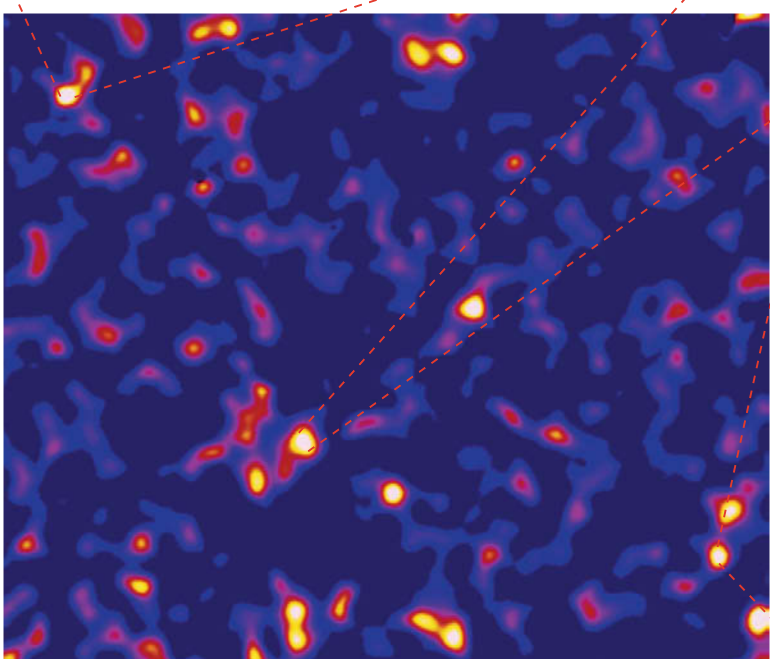
Tiny distortions in the images of more than 10 million distant galaxies are giving astronomers a big-picture view of where the universe's dark matter hangs out — in particular, the ways it clumps together and takes shape on a cosmic scale. The Canada-France-Hawaii Telescope Lensing Survey (CFHTLenS) has produced the largest maps yet of the unseen, mysterious, non-atomic stuff that makes up more than 80% of cosmic matter.

The maps, such as the purple one below, reveal clumpy filaments outlining gigantic empty spaces. The clumps align closely — though perhaps not exactly — with large visible galaxy clusters. This is excellent news for the standard model of cosmology, which accounts for the development of the universe since the earliest moment of the Big Bang. The dark-matter web looks like the detailed theoretical simulations produced a few years ago, based on the standard model, by the Millennium Simulation Project at the Max Planck Institute for Astrophysics in Germany. Except it's real.

CFHTLenS has deeply imaged four large patches of sky covering a total of 155 square degrees. Typical faint galaxies in the images are about 6 billion light-years away. Their light doesn't come to Earth in perfectly straight lines. Instead it is "weakly lensed": distorted slightly as it passes through the gravitational fields of matter

Dark matter shows itself only by its gravity. New maps of its distribution, based on the gravitational bending of light from the far background, reveal a weblike network of gigantic dense and empty regions *(below)*. The largest concentrations match the locations of massive clusters of galaxies.





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concentrations scattered along the way.

Strong lensing turns a background galaxy into an obviously distorted arc, an effect familiar from Hubble images of dramatic cases. But most of the galaxies in the survey are lensed only about 1%, nowhere near enough to be recognizable on a case-by-case basis. With large enough numbers, however, even weak distortions of galaxy shapes show up statistically.

It wasn't easy. Team member Thomas Erben (Bonn University, Germany) says the group originally expected the galaxy-shape analyses to be done in one year. They took four.

Already the project is 100 times larger than any previous deep lensing survey (though not as deeply penetrating as some). The largest of the four sky patches, shown on page 12, is 7° wide. This is 1 billion light-years wide at its typical detection limits. The largest pools of dark matter it shows amount to 100 trillion solar masses.

The project continues. Its sky coverage should increase by 10 times in the next three years, and 3-D maps will become possible.

Smallest Black Hole

No wilder and weirder place is known than the region just outside a black hole. From some of these places, astronomers have rich but puzzling data to sift for clues about the exotic things going on.

As material spirals down toward a black hole it becomes X-ray-hot, and weird effects imprint the X-ray emission. Over the past 35 years, astronomers have found that most accreting holes exhibit four distinct types of X-ray flares and pulsations. These differ in duration and magnitude depending on the hole's size, spin, accretion rate, and perhaps other phenomena.

Then there's GRS 1915+105, also known as the variable star V1487 Aquilae. It consists of an orange *K* giant orbiting a roughly 14-solar-mass black hole. The star is pouring enough gas toward the hole to turn it into a "microquasar"; the hole emits blobby jets from the direction of its poles at 98% of the speed of light. Its immediate surroundings display more than a dozen distinct classes of X-ray signals, typically lasting seconds to hours.

In particular, a pattern dubbed "the heartbeat" seems to flip the entire jet on and off rapidly. Apparently the inner accretion disk grows hot enough to blow a powerful wind, which halts the jet-formation process. The inner disk keeps growing hotter until it disintegrates and collapses into the hole, ending the wind and allowing the jet to restart. This cycle sometimes repeats as fast as every 40 seconds.

This "heartbeat" behavior used to be unique, but now there's a second such system. IGR J17091–3624 in Scorpius shows X-ray signals remarkably similar to those of GRS 1915+105 but consistently speedier. Here the "heartbeat" cycle sometimes happens every 5 seconds. The likeliest explanation is that the black hole has less than 3 times the Sun's mass and everything is scaled down accordingly.

That's just about at the theoretical borderline between black holes of the minimum possible mass and neutron stars that are not quite heavy enough to collapse.

Deep-Fried Exoplanets

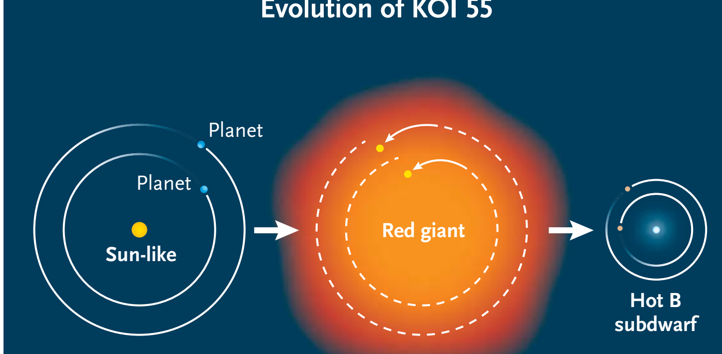
Strange new exoplanets just keep on coming. Scientists working with NASA's Kepler mission have announced two planets that seem to have been deep-fried *inside* a red-giant star that has since evolved on to the next stage of its life.

The star is known as KOI (Kepler Object of Interest) 55. Today it's a very hot, type-*B* subdwarf: the core remaining from a red giant that has lived out its life and shed the bulk of its material back to space. Orbiting this star very closely are two roughly Earth-diameter objects, KOI 55.01 and 55.02. They circle just 750,000 and 1 million km (470,000 and 620,000 miles) from the star's surface. In order to be so close to it, they must have had a remarkable past. "Our two planets were most probably swallowed by their parent star when it became a red giant, a stage that ended only about 18 million years ago," writes a research team led by Stéphane Charpinet (University of Toulouse, France). "They were probably orbiting farther away and may have been dragged deep into the red-giant envelope to their current positions."

Such survivors may be showing us the fate of Earth. Some 7 billion years from now the Sun will swell to a couple hundred times its present size, engulfing Mercury, Venus, and possibly Earth. Astronomers had assumed that such ill-fated worlds would spiral in so deep that they would be vaporized completely. But KOI 55.01 and 55.02 are telling a different story.

There's also another possibility: they could be new objects that, after the star ended its red-giant phase, formed from material left behind.

If the two were in fact engulfed, they may have themselves hastened the giant's disruption by stirring up or flinging off its thin outer layers. Such a process might limit the damage to the planets, allowing the star only to shrink their orbits somewhat and erode them partially. How rare would such a lucky balance be? The fact that even one such a system has already been found suggests that it's not an unlikely fluke. This hints that some self-regulating process was at work.



The star KOI 55 is a hot, blue subdwarf nearly at the end of its life. Its two planets likely formed farther out, were engulfed when the star swelled to become a red giant, eroded and spiraled down through the giant's thin outer layers, then were left hanging when the star blew its outer layers away.

S&T: LEAH TISCIONE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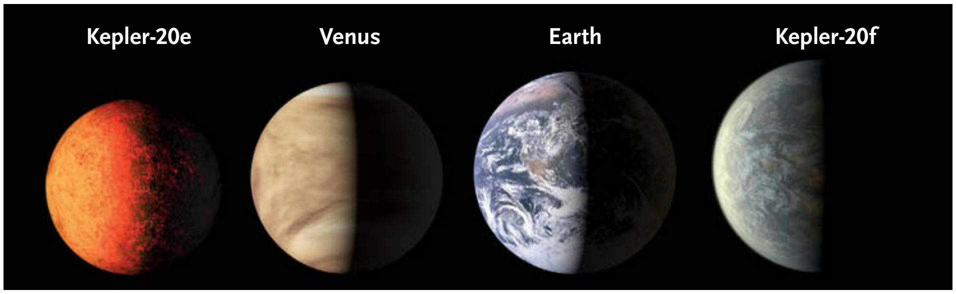

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The sizes of Kepler-22e and f are compared to the sizes of Venus and Earth. The two new planets' actual appearances are unknown, but both are hot roasters close to their star.

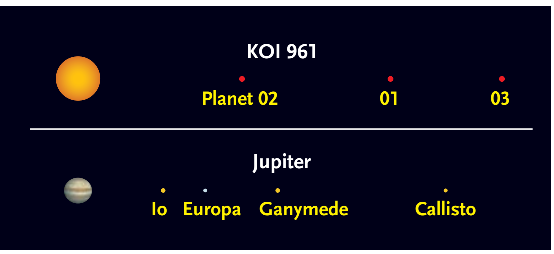
In a remarkable demonstration of the Kepler mission's versatility, KOI 55.01 and 55.02 were not found the way most Kepler planet candidates are, by transiting across a star's face. The star itself was being studied because it exhibits a wide variety of throbbing pulsations that cause its brightness to vary slightly in many complex modes. Kepler excels at measuring these patterns, which lay bare the details of a star's interior structure. Charpinet and his team found two periodic sets of weak brightenings with periods too long to be inherent to the star. After ruling out other possibilities, they concluded that the brightenings must be the star's light being reflecting off the gibbous and full faces of planets that swing behind it every 5.8 and 8.2 hours. Working the numbers, the researchers conclude that the planets, presumably rocky, have diameters just 76% and 87% that of Earth. Some astronomers, however, say more data is needed to confirm this interpretation.

The First Exo-Mars

Pushing discovery limits further, another Kepler group has identified a dim little red-dwarf star with three candidate planets crossing its face, all smaller than Earth. One is only half Earth's diameter: comparable to Mars.

The star (KOI 961) and planets are not only small, they form the most compact system found to date. In fact, the whole array is sized more like Jupiter and its four large satellites than what we'd normally think of as a planetary system, as illustrated below.

An amateur astronomer was key to this find. The diameters of faint red dwarfs are notoriously hard to determine. But British amateur Kevin Apps, who devours research papers and memorizes star-catalog data in his spare time, noticed something. He wrote to the discovery team that the photometric colors of KOI 961 match those of Barnard's Star only 6 light-years away, one of the nearest and best-studied red dwarfs in the sky. "It was as if it was the exact same star," says team member John Johnson (Caltech). Being so close, Barnard's Star has a diameter that's well determined: half what the team had assumed for KOI 961.



S&T: LEAH TISCIONE

The KOI 961 planetary system is compared to the Jupiter system, shown at the same scale.

Using Barnard's Star as a base, the astronomers determined KOI 961's properties to high accuracy. From this information they found sizes for the orbiting bodies: 73%, 78%, and 57% of the diameter of Earth, half what they originally figured. They thanked Apps by making him a coauthor of their paper.

This find raises hopes of detecting more tiny planetary systems around inconspicuous dwarfs. "It's kind of like cockroaches," says Johnson. "If you see one...."

Staggered Planets

The Kepler mission has 207 likely Earth-size planets in its public data set, and many more are about to be announced. Most remain unconfirmed, but the Kepler science team expects 80% to 95% to prove real. The statistics already indicate that Earth-size and smaller planets are even more abundant throughout the universe than the larger worlds that are easier to find. This means that most stars probably have terrestrial-size planets.

Of Kepler's *confirmed* exo-Earths, two reside in a system that defies explanation. They're Kepler-20e and f, two of five worlds closely orbiting a G8 yellow dwarf 950 light-years away and not quite as large and hot as the Sun. The other three are roughly Neptune-like in size and mass. The five show an unexpected arrangement. In our solar system, small, rocky worlds orbit fairly close in and gas giants farther out, where planet-formation models predict each should form. But the planets of Kepler-20 *alternate* in size: big, little, big, little, big. And all are closer to the star than Mercury is to the Sun.

"The architecture of this system is nuts!" says codiscoverer David Charbonneau. "I dare astronomers to explain it."

Norman Edmund, 1916–2012

Amateur science, and especially amateur astronomy, would not have taken root in postwar America quite as they did had it not been for Norman Wilson Edmund, who died on January 16th at age 95.

EDMUND OPTICS

A tinkerer and hobbyist, Edmund started selling government-surplus lenses during World War II from boxes under his bed. His business grew to become Edmund Scientific of Barrington, New Jersey. Its catalog of telescopes, electrostatic generators, chemistry sets, and other fascinating gizmos was thumbed ragged by the science-minded kids of the baby boom. The company's mirror-making kits enabled a generation of amateur telescope makers, and its simple, diagram-filled books on telescopes and the sky formed a major route into amateur astronomy. In 1975 Edmund retired and turned the company over to his son Robert, who continues as CEO. Read more at **skypub.com/normanedmund**. ✦

Days of Powder and Planets

A conference about exoplanet climates reveals our rapidly changing understanding.

I'M WRITING FROM the ExoClimes 2012 Conference in Aspen, Colorado, where astronomers, planetary scientists, and Earth scientists have gathered in early morning and evening sessions to share results and ideas about the climates of extrasolar planets. Our afternoons are free for skiing.

The combination of mental stimulation and physical exhilaration facilitates insight and collaboration among the disparate specialists. Although it's been a bad winter here for skiing, we emerged from the first day of talks to find the valley filled with freshly fallen snow. What a planet! It's large enough for plate tectonics to raise these uppity mountains, and warm enough for water to be at the "triple point" — where it can be liquid for biochemistry, vapor for climate regulation, and solid for skiing. But how rare is this winning combination that supports our biosphere of aspens, archeobacteria, and astrobiologists?

Since the first ExoClimes conference two years ago, Kepler and other telescopes have shown us that planets are common, their sizes range from smaller than Earth to larger than Jupiter, and that some orbit in their host star's habitable zone. It's only a matter of time before Kepler finds its holy grail — an Earth-sized planet in the habitable zone. How many of these might be habitable, and what it really takes for a planet to qualify, are hot topics here. Bright young researchers are applying clever new techniques to glean a surprising amount from the scant signals of distant, modulated starlight.

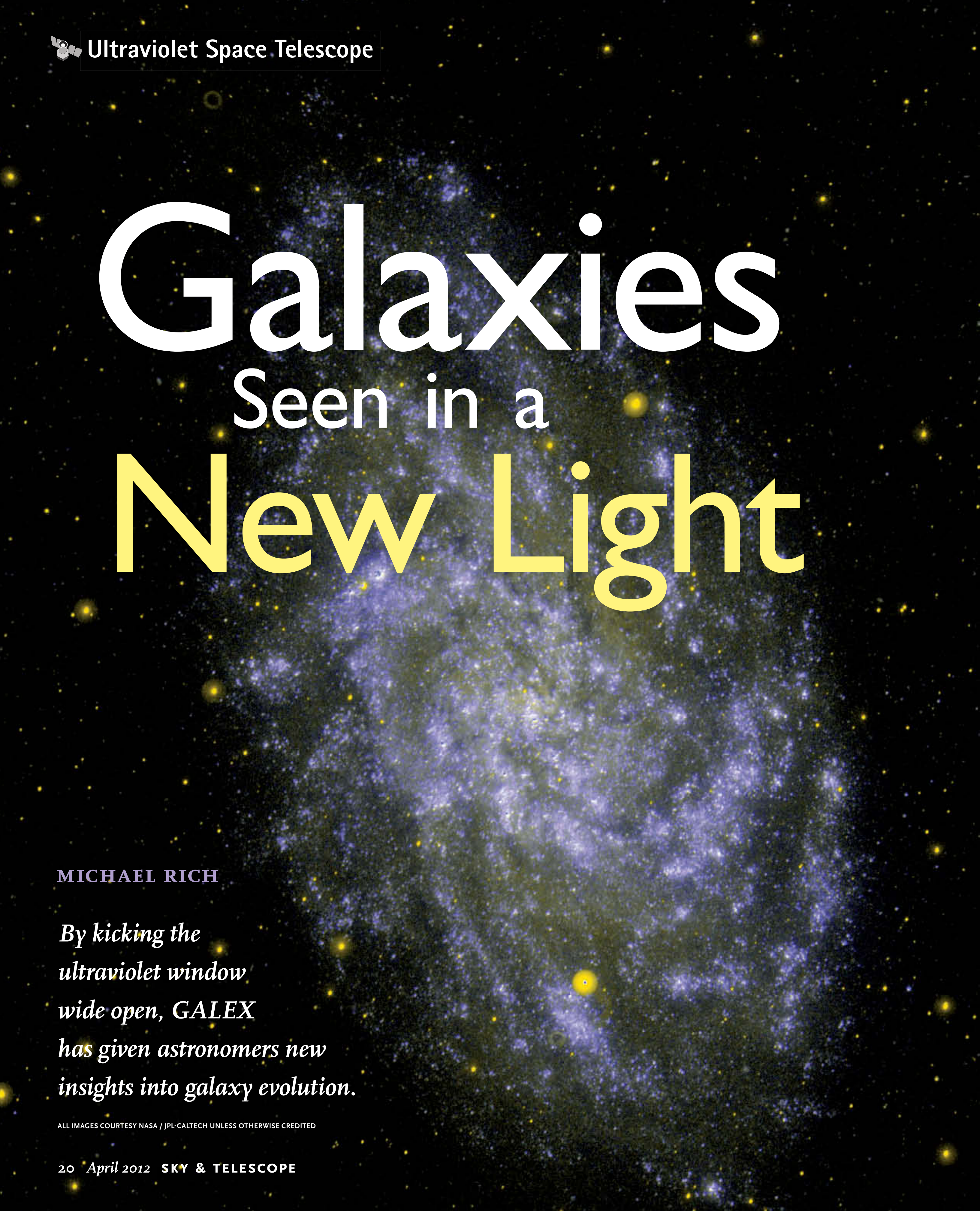
©BIGSTOCK / MAGANN

But what can we really say about the detailed environments of these worlds? How many rocky planets have plate tectonics, which is so important on Earth? Adrian Lenardic (Rice University) presented models suggesting that it's insufficient to know a planet's mass, density, and temperature — two planets with these same parameters may have different global tectonics, depending on their histories. It's difficult to imagine knowing an exoplanet's geologic history when we still don't know Venus's history! But these behaviors would produce different atmospheres, which we might in time be able to predict and observe.

Several researchers describe the role of less obvious gases and parameters in determining planetary climate, suggesting that our standard notion of the habitable zone — having enough greenhouse gases to support liquid water at a certain distance from a star — needs revision. Ray Pierrehumbert (University of Chicago) shows how large amounts of hydrogen might warm climates enough to expand the zone's outer edge, but also how methane-producing organisms on such worlds might eat up the hydrogen and carbon dioxide molecules, collapsing the greenhouse and dooming their own world. As Colin Goldblatt (University of Victoria, Canada) stated, "Habitability and inhabitance are inseparable."

Perhaps our search for "another Earth" is driven by naïve assumptions. But our growing awareness of exoplanets is providing incentive for new models with a much wider range of parameters, such as including less obvious greenhouse gases (like nitrogen) that may be more important than we have realized. And so it goes: the observers give us theorists new puzzles and we provide them with new clues to search for as we strive to understand what kinds of planets are out there. ✦

***David Grinspoon**, a barely competent skier on planets at 1g, is Curator of Astrobiology at the Denver Museum of Nature & Science. His website is **www.funkyscience.net**.*



Galaxies Seen in a New Light

MICHAEL RICH

By kicking the ultraviolet window wide open, GALEX has given astronomers new insights into galaxy evolution.

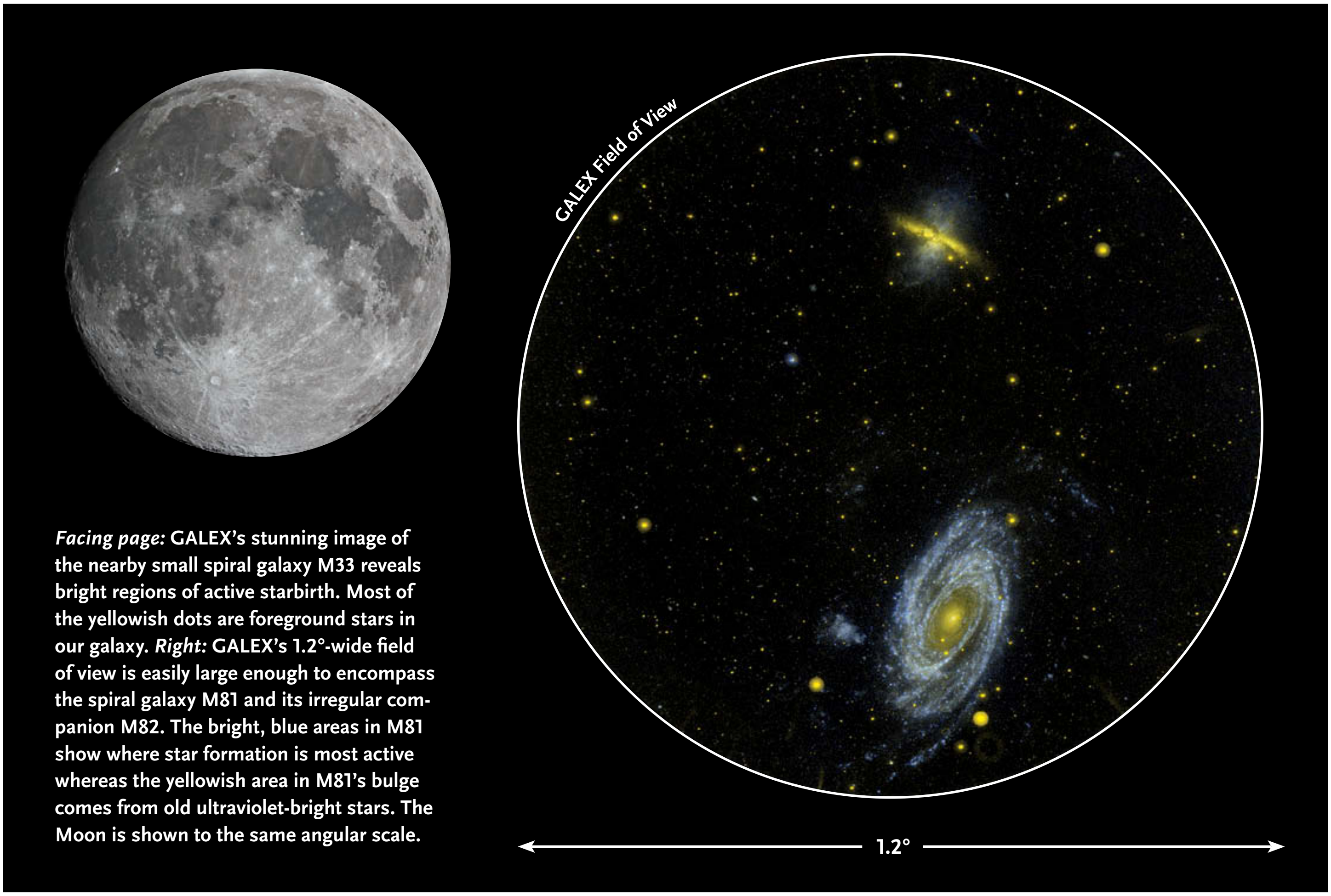
ALL IMAGES COURTESY NASA / JPL-CALTECH UNLESS OTHERWISE CREDITED

On April 28, 2003, an L1011 jet rumbled into the early morning skies of Florida's Cape Canaveral Air Station, carrying a cruise-missile-like Pegasus rocket to an aerial launch. Although the Pegasus vehicle had experienced several prior failures, it was the only option, because its payload, the Galaxy Evolution Explorer (GALEX) satellite, was a small Explorer-class NASA mission with a hard cost cap of $100 million — a bargain in our era of billion-dollar space telescopes. GALEX was NASA's first mission after the tragic loss of Space Shuttle *Columbia*. The successful launch, followed by spectacular ultraviolet images of objects in deep space, gave NASA a much-needed lift.

GALEX's 16-inch telescope has surveyed nearly 80% of the sky at ultraviolet wavelengths ranging from 150 to 280 nanometers — about twice the energy of the ultraviolet-B rays that cause nasty sunburns. No all-sky map of this important spectral region existed before GALEX. Although NASA's Great Observatories had surveyed and examined the sky from gamma rays (Compton) to the infrared (Spitzer), the UV window was virgin territory. GALEX's objective was to discover where stars are forming in the nearby universe, and to shed light on how star formation and its cessation can transform galaxies.

Technicians at Orbital Sciences Corporation test the solar arrays on the 620-pound (281-kg) spacecraft. GALEX is one of the smallest space telescopes launched by NASA in recent years.

In contrast to the Hubble Space Telescope, whose field of view is the size of a small lunar crater, GALEX's 1.2-degree-wide field is large enough to capture the galax-



Facing page: **GALEX's stunning image of the nearby small spiral galaxy M33 reveals bright regions of active starbirth. Most of the yellowish dots are foreground stars in our galaxy. *Right:* GALEX's 1.2°-wide field of view is easily large enough to encompass the spiral galaxy M81 and its irregular companion M82. The bright, blue areas in M81 show where star formation is most active whereas the yellowish area in M81's bulge comes from old ultraviolet-bright stars. The Moon is shown to the same angular scale.**

MOON PHOTO BY *S&T*: DENNIS DI CICCO

RODERIK OVERZIER / ESA / NASA

LIVING DINOSAURS GALEX enabled astronomers to identify rare ultraviolet-luminous galaxies (UVLGs) within 2 billion light-years. UVLGs, which are mere point sources in GALEX images, are compact galaxies more commonly found at much greater distances. These six follow-up Hubble Space Telescope images resolve individual starbirth regions in relatively nearby UVLGs, as well as their nuclei. Some of these nuclei appear to be emitting X-rays and forming supermassive black holes. Each frame is about 5,000 light-years across.

ies M81 and M82 in the same image. GALEX's detectors are extremely sensitive to the ultraviolet light emitted by young stars, which are particularly bright in the UV. So despite GALEX's small aperture, it can detect traces of star formation missed by other telescopes. GALEX can also image starburst galaxies (galaxies that are rapidly forming stars) out to redshifts of nearly 1, corresponding to a look-back time of roughly 6 billion years.

GALEX's main surveys are nearing completion, but the telescope has also notched some unexpected discoveries. These include the discovery of gigantic star-forming disks three times larger than our Milky Way, "living dinosaur" galaxies resembling those from the early universe, a black hole caught in the act of devouring a star, supposedly "dead" galaxies with signs of star formation, and a spectacular comet-like tail associated with the bright variable star Mira.

Living Dinosaurs

GALEX was 10 years in the making, the dream of principal investigator Chris Martin (Caltech). The science team, which includes astronomers from the U.S., France, and South Korea, knew GALEX could be a discovery engine like its visible-light predecessor, the Palomar Sky Survey.

The universe's brightest sources of UV radiation are the youngest stars (10–100 million years old), some of the oldest stars (such as white dwarfs and hot post-red giants), and gas swirling around interacting binary stars and black holes. GALEX is so sensitive that it can also detect UV radiation in unexpected places, such as elliptical galaxies whose light is dominated by red giants, the tidal tails of interacting galaxies, and the outermost disks of spiral galaxies.

One of GALEX's first achievements was to isolate the nearby counterparts of galaxies ordinarily seen in the distant universe: rare ultraviolet-luminous galaxies (UVLGs). These extreme galaxies pack 10 billion Suns of ultraviolet luminosity into a volume only 10% the size of our Milky Way. In 1996 Charles Steidel (Caltech) discovered the faraway versions of UVLGs at redshifts of 3 or greater, corresponding to at least 11.5 billion years of look-back time. GALEX's relatively nearby UVLGs, within 1 to 2 billion light-years, are literally the astronomical equivalent of finding a living dinosaur in the present time.

The UVLGs detected by GALEX are close enough for Hubble follow-up studies. Images taken by Roderik Overzier (European Southern Observatory) reveal spectacular

FAR-OUT STARS This GALEX image clearly shows patches of UV light — the hallmark of star formation — well beyond spiral galaxy M83's visible disk (the bright inner region). This result startled astronomers by informing them that stars can somehow manage to form in gas-poor environments.

ANDROMEDA PORTRAIT GALEX's ultraviolet image of the Andromeda Galaxy (M31) is one of the observatory's iconic images. Nearly concentric rings of bright star-forming regions surround the center. The nucleus's surprising brightness in ultraviolet light is probably due to ancient stars that are fusing helium in their cores as they near the end of their lives.

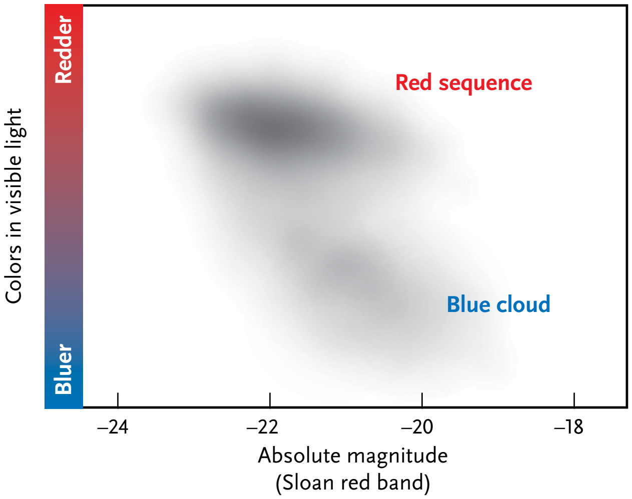
giant star clusters and the occasional galactic nucleus star cluster as the bright sources of UV emission. Intriguingly, some of these galaxies appear to have nuclei that might be on the way to producing a supermassive black hole — but as yet still do not exhibit all of the hallmarks of black-hole formation. These nuclei might contain precursors of the supermassive black holes found in many galactic centers, making them objects of keen interest. Eventually, these galaxies might evolve into giant ellipticals such as M84, M86, and M87 in the Virgo Cluster.

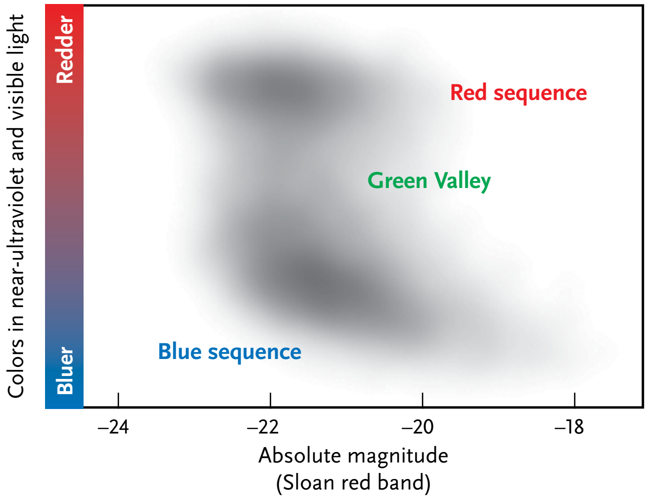
At about the same time, GALEX imaged the nearby spiral galaxy M83 and found star formation way beyond its visible disk, where only hydrogen gas had been detected. This result tells us that it takes far less hydrogen to form stars than we thought; many spirals consequently have much bigger disks of stars than we previously realized.

The Green Valley

GALEX's most fundamental contribution is an improved diagram for galaxies analogous to the Hertzsprung-Russell diagram for stars. When astronomers plot the luminosities of stars against their temperatures in an H-R diagram, they see distinct groups: stable hydrogen-burning stars (the main sequence), red giants, and white dwarfs (*S&T:* December 2010, page 30). A similar diagram for galaxies plots their intrinsic brightness (luminosity, or absolute magnitude) against their "color" — red to blue.

When we do this in optical colors using, for example, the Sloan Digital Sky Survey's huge database, the brightest galaxies, such as Virgo's giant ellipticals, tend to be red. In fact, these galaxies define a "red sequence" of galaxies that have similar populations of older stars. In very dense galaxy clusters such as the Coma Cluster, nearly all





S&T: GREGG DINDERMAN / SOURCE: MICHAEL RICH

THE GALAXY H-R DIAGRAM Astronomers have produced a galaxy version of the famous Hertzsprung-Russell diagram for stars. *Left:* This plot from Sloan Digital Sky Survey data classifies galaxies according to their colors in visible light. Almost all galaxies are members of either the red sequence (old stars) or the blue cloud (young stars). *Right:* This diagram incorporates GALEX ultraviolet data in the color index. Blue galaxies form a more clearly defined sequence rather than an amorphous cloud. In addition, a third region known as the green valley emerges. Galaxies in this class appear to be in transition from the blue sequence to the red sequence.

the galaxies fall on the red sequence. But most galaxies don't reside in very dense clusters; some dwell in small groups and others live in relative isolation, and many of these tend to have young stars and disks. These galaxies are fainter and bluer than the red galaxies, falling in a region of the galaxy H-R diagram called the "blue cloud."

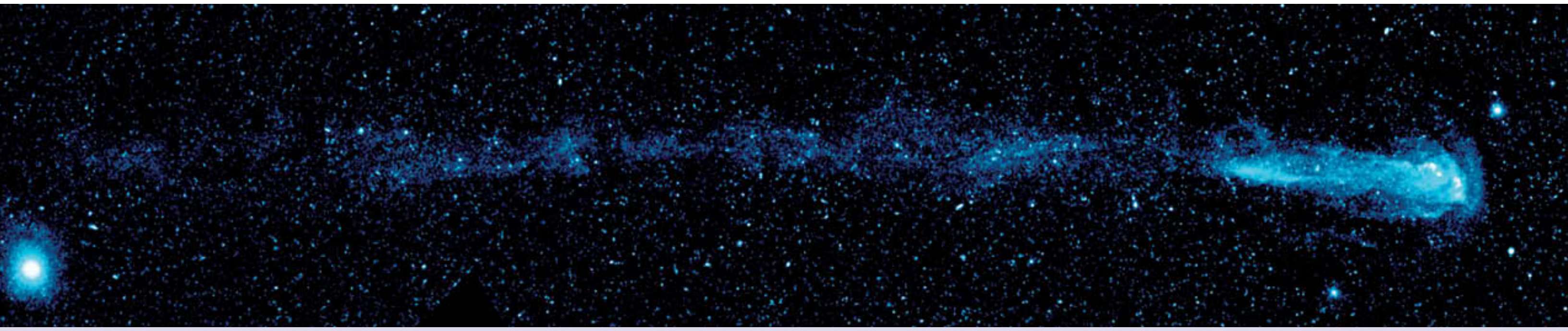
Star-forming galaxies such as M33 and the Magellanic Clouds live in the blue cloud. Surprisingly, even though the Milky Way and Andromeda galaxies are still forming stars, they fall on the red sequence because the old stellar populations of their inner disks and bulges outshine the younger, bluer stars in the spiral arms. If we plot this graph using visible light only, the red galaxies show some sense of a sequence, whereas the blue galaxies fall in the amorphous "blue cloud."

But when astronomers measure galaxy brightnesses in GALEX's near-UV filter, and plot their intrinsic optical magnitudes against an optical–UV color index, the plot becomes more interesting: there's a red sequence of old galaxies and a separate blue sequence of galaxies that are actively forming stars. Falling between the red and blue sequences is a gap christened the "green valley" because it's a region with relatively few galaxies (a "valley") whose members are a kind of hybrid between the red and blue sequences. By applying GALEX's UV data to this plot, astronomers could classify the galaxies in the blue sequence as mostly star forming, those in the red sequence as lacking young stars, and those in the green valley as possibly being in transit to the red sequence.

ULTRAVIOLET LIGHT

Ultraviolet light is a form of radiation sandwiched between the X-ray and visible-light portions of the spectrum. UV wavelengths range from 100 to 400 nanometers, shorter than visible light but longer than X rays. Most UV photons are absorbed by Earth's atmosphere, which is a good thing for us because excessive exposure to this high-energy radiation causes sunburn and skin cancer. But it also means that astronomers must loft telescopes into space to detect cosmic UV sources. Normal CCDs don't work in the UV, so GALEX uses a combination of old and new technology to detect UV photons while rejecting 100% of visible-light photons.

We're interested in the green valley because that's where we can find galaxies on the move, so to speak, thanks to the processes that cause galaxy evolution. Some galaxies in the green valley may have just experienced a "wet merger," in which two gas-rich galaxies merged and converted nearly all their gas into stars, with no gas left to form new stars. Some green-valley residents appear to have been forming stars until an active galactic nucleus turned on, producing radiation and gas outflows that may have quenched their star formation. Other green-valley members appear to be red-sequence galaxies (our "red-and-dead" seniors) that are taking a fling with youth,



NASA / JPL-CALTECH / C. MARTIN / M. SEIBERT

NOT A COMET **Astronomers were stunned when GALEX revealed a 13-light-year-long tail extending from the variable-star Mira (far right). As Mira moves through space, collisions with interstellar material blows off some of the gas in the star's outer atmosphere at a rate of about one Earth mass per decade. In this follow-up GALEX image, the left end of the tail consists of material shed by Mira 30,000 years ago, when our home planet was still caught in the grip of the last Ice Age.**

Mira's Extended Tail

GALEX has made stunning discoveries in our own galaxy. The red-giant star Mira would, it seems, surely be no candidate for an ultraviolet study. Its fame derives from its 900-day period of variability from naked-eye visibility to invisibility. Mira is a huge, cool star that was expected to be invisible in the UV. While inspecting a portion of the All-sky Imaging Survey, GALEX team scientist Karl Forster (Caltech) noted a strange smudge, like a comet. Much to his surprise, the smudge coincided with Mira's coordinates in the constellation Cetus. GALEX principal investigator Chris Martin (Caltech) obtained deeper exposures that revealed a bow shock and a comet-like tail 13 light-years long that results from the erosion of Mira's extended atmosphere as it plows through interstellar gas. Much to everyone's surprise, the tail glowed most brightly in the far-UV, most likely the radiation of excited hydrogen (H_2) molecules.

forming stars from some newly acquired hydrogen gas. We think those galaxies will be back on the red sequence in less than a billion years. Alternatively, they could instead be galaxies that once had massive disks like our Milky Way, and are fading onto the red sequence. We're not completely sure, and that is why the green valley offers a trove of interesting case studies to explore in great depth.

Unexpected Discoveries and the Future

GALEX has made many other discoveries. In March 2004, the satellite serendipitously caught a burst of UV emission from the nucleus of a distant galaxy. Suvi Gezari (Johns Hopkins University) discovered this on a series of GALEX images while she was working at Caltech. The fading of the burst matched nearly exactly the predictions for what we would see if a star was tidally shredded as it fell into a 100-million-solar-mass black hole.

GALEX has even been used to isolate nearby stars that are good candidates to be young enough to host planets still visible by their own radiation. UCLA astronomers David Rodriguez and Ben Zuckerman used the UV properties of nearby stars to winnow through thousands of objects to find just the right candidates that might have young Jupiter-mass planets shining in infrared light from their heat of formation, making them bright enough to be seen with adaptive-optics imaging.

Despite GALEX exploring the ultraviolet sky for nine years, some problems in UV astronomy remain unsolved. Among the enduring mysteries is the exact cause of UV radiation seen in very old red galaxies and bulges. This mysterious light was one of the first important discoveries made by any space satellite (in this case, the Orbiting Astronomical Observatory-2 in the late 1960s). We know that the rising UV flux comes from a population of very old stars that burn helium as their energy source. But the exact stellar population remains a mystery. The Hubble Space Telescope might reveal the individual stars responsible in Andromeda's bulge. But the mystery might persist until an 8-meter UV-optical space telescope can be lofted into orbit.

About two years ago, GALEX's far-UV detector failed, leaving the satellite to undertake its mission with only its near-UV detector. But the near-UV eye is so sensitive that the 16-inch mirror can still image, in only about an hour of integration time, galaxies out to 10 billion years of look-back time, and quasars to even greater distances.

Listen to a BONUS AUDIO INTERVIEW

To see more beautiful GALEX images of galaxies and other objects, and to listen to an interview with author Michael Rich, visit skypub.com/galex.

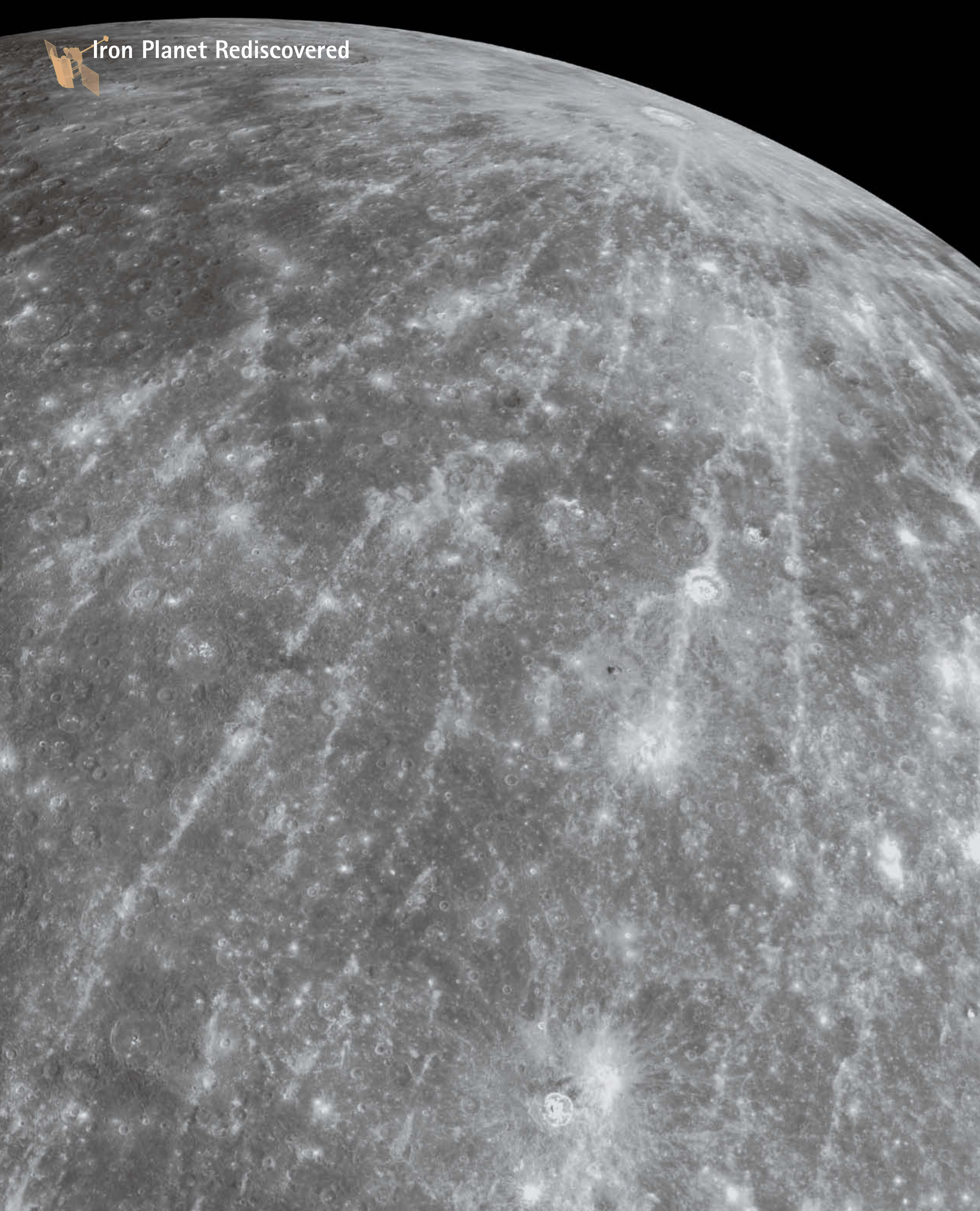
HELIX NEBULA **GALEX turned its eye on the Helix Nebula (NGC 7293), a nearby planetary nebula. The hot central white dwarf is faint in visible light, but is very bright in the UV. GALEX also reveals gas well outside the area of optical emission.**

GALEX had been slated to continue surveying the area of the Sloan Digital Sky Survey to a depth of 23rd magnitude in the near-UV band, and it would have provided critical complementary data to a new generation of surveys, including the 8-meter Large Synoptic Survey Telescope (LSST). Unfortunately, NASA must stop its funding of the GALEX surveys in early 2012, and unless private or international funds can be found to continue the mission, GALEX will be shuttered, detecting its last UV photon.

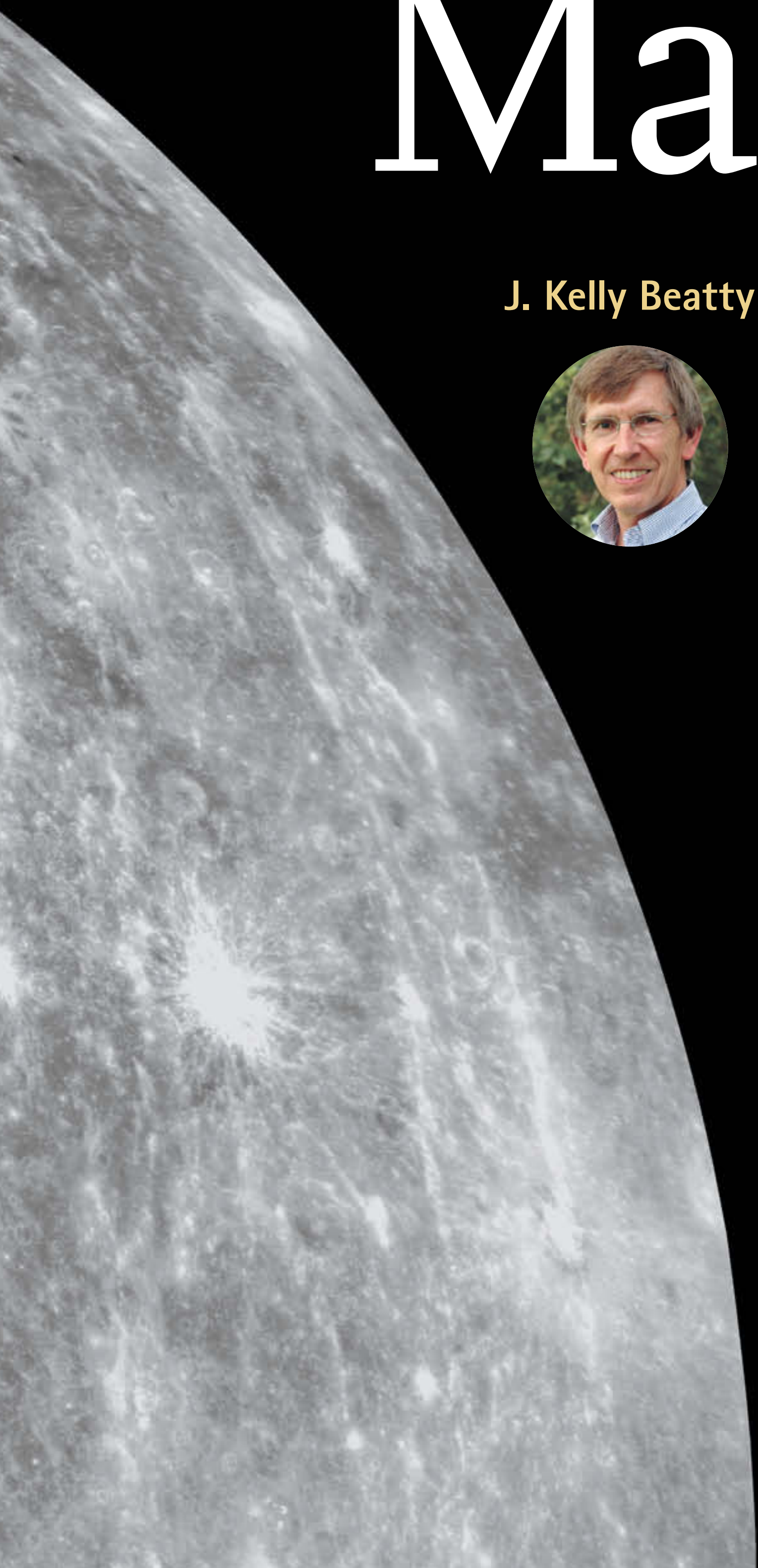
But in what may be its final few months, GALEX has undertaken one of its most exciting missions: mapping the plane of the Milky Way, the bulge, and the Magellanic Clouds — regions once considered too dangerous to point at for fear of damaging sensitive detectors. After GALEX's mission ends, the satellite will continue orbiting but not operating. A deeper survey of the ultraviolet sky will remain a dream for future generations of astronomers.

Even after GALEX ceases operation, team scientist Mark Seibert (Carnegie Observatories) will produce a final catalog from the mission. GALEX data is being combined with those of NASA's Wide-Field Infrared Space Explorer (WISE) mission. The combination of the vast GALEX trove with all of these new data sets has resulted in yet more discoveries and will doubtless spur research for decades to come. Despite its small size and low cost, GALEX has beautifully complemented the missions of the Great Observatories (Compton, Hubble, Chandra, and Spitzer), fueling astronomical discoveries just as effectively as its visible-light cousin, the 48-inch Palomar Schmidt telescope, did a half-century ago. ✦

*GALEX science team member **Michael Rich** is an astronomer at the University of California, Los Angeles.*



Mercury's Marvels



J. Kelly Beatty

Don't let its plain appearance fool you — the innermost planet has an enormous iron core, a surface awash with ancient volcanic flows, and a composition that defies easy explanation.

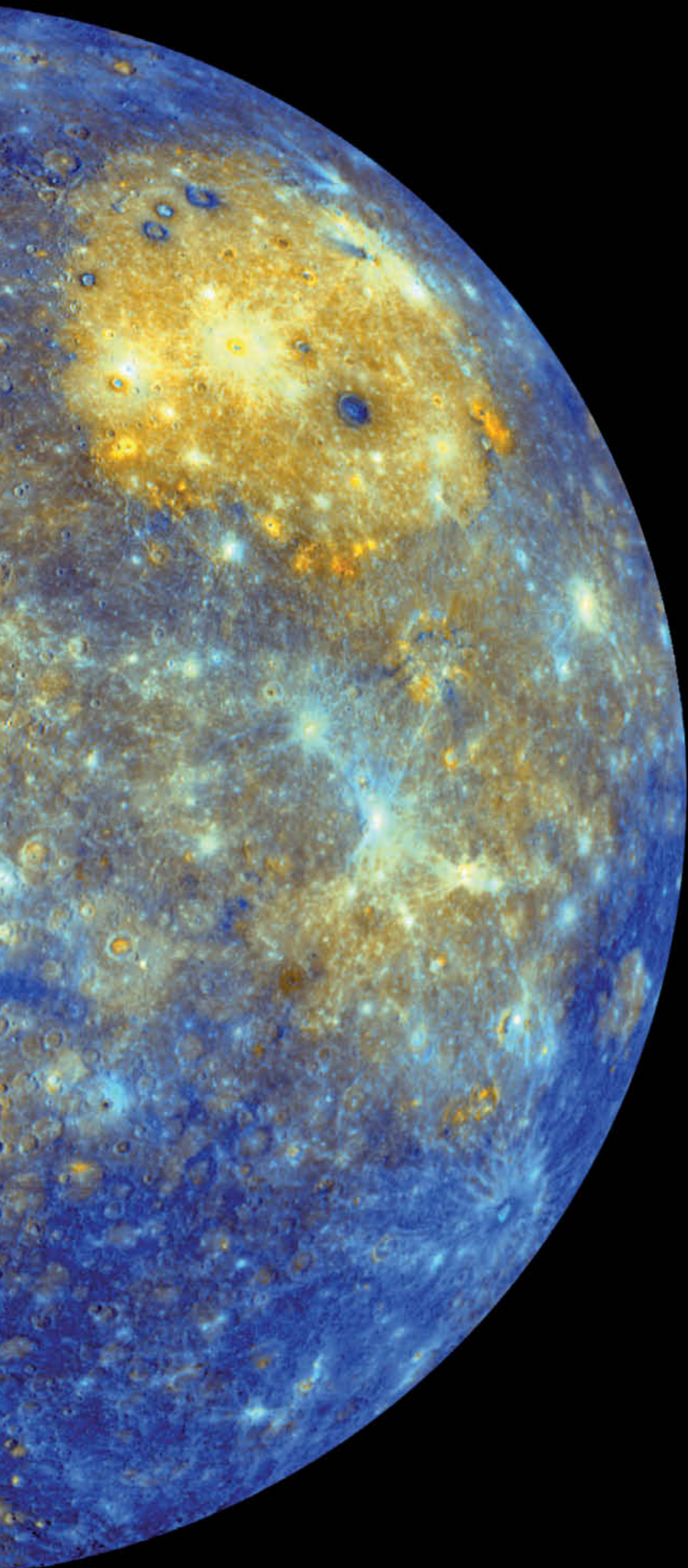
It's hard to believe, but a year has passed since the Messenger spacecraft fired a braking rocket and slipped into orbit around Mercury. In that time the innermost planet has made four orbits of the Sun and twirled around its axis six times, long enough for NASA's robotic emissary to study the entire globe repeatedly at close range. You might think all that scrutiny would have given mission scientists a fairly complete picture of Mercury's past and present — but it hasn't, at least not yet.

"Messenger" stands for MErcury Surface, Space ENvironment, GEochemistry and Ranging, a convoluted acronym that conveys what this mission is all about: revealing the insides and outs of a small planet with big mysteries. And while the list of unknowns still stretches long, even after a year, the spacecraft's eight experiments have unveiled surprising clues to Mercury's strange nature.

Much of the scientific revelation has come from two onboard instruments, a pair of spectrometers that record

Taken during Messenger's second flyby of Mercury in October 2008, this image reveals an extensive and intriguing pattern of bright rays emanating from the fresh crater Hokusai (about 60 miles across) along the upper limb. The crater was first identified in 1991 as a bright spot in radar observations made from Earth.

ALL IMAGES FROM NASA / JHU-APL / CARNEGIE INSTITUTION OF WASHINGTON UNLESS OTHERWISE CREDITED



X-rays, gamma rays, and neutrons emitted by rocks on the planet's hellish surface. These instruments map the abundance of elements with high atomic weights, such as silicon, magnesium, aluminum, and iron — precisely the ones that form rocks — and they've confirmed what ground-based observers have suspected for some time: very little iron exists on the planet's surface. Instead, explains geochemist Larry Nittler (Carnegie Institution of Washington), Mercurian rocks are infused with lots of magnesium, a chemical signature unique among the terrestrial worlds.

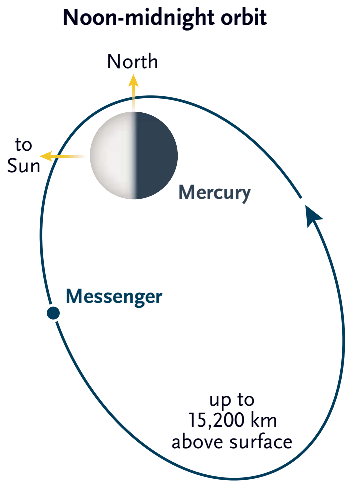
But particularly revealing are unexpectedly high abundances of sulfur, potassium, and sodium mapped by Messenger's spectrometers. These "volatile" elements vaporize at relatively low temperatures, and their ubiquitous presence has immediate consequences for theories of how the innermost planet formed. "The exciting thing about our observation of volatiles on the surface of Mercury is that it rules out most theories for the planet's formation," notes Patrick Peplowski, a Messenger team member from Johns Hopkins University's Applied Physics Laboratory (APL).

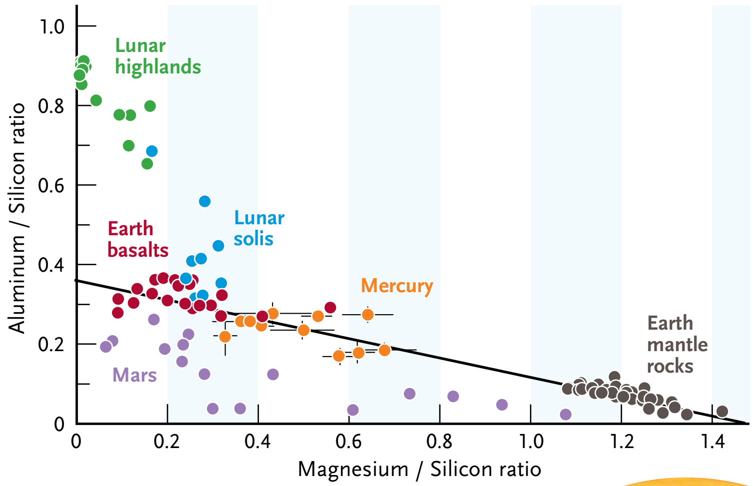
It's the Heart that Counts

Mercury, you might recall, is nicknamed the Iron Planet because its high overall density betrays the presence of a very large metallic core — an iron-rich cannonball that takes up three-fourths of its diameter and half its volume. Ever since Mercury's first and only inspection at close range, by Mariner 10 in the mid-1970s, scientists have wondered how this iron-hearted planet managed to form 4½ billion years ago.

One idea holds that Mercury's initial composition was more Earthlike but, thanks to being blasted by a young and energetic Sun, its outer layers got so hot that they largely vaporized. However, this solar stripping would

Left: **Caloris Basin appears as a stark yellow blotch in this enhanced-color mosaic taken by Messenger at the end of its first flyby. The colors are nothing like what the human eye sees; instead, they indicate different rock types on the planet's surface. The basin is about 960 miles (1,550 km) wide.** ***Above:*** **Although Messenger photographed nearly all of Mercury during its flybys, some of the images were of poor quality** ***(left)*****. Being in orbit has allowed the spacecraft to record the same features** ***(right)*** **with much sharper detail. Completely missing from the left image, the ghostly pockmark (*****circled*****) in the snapshot's lower right hints of a crater buried by the lava flood that created the northern plains.**





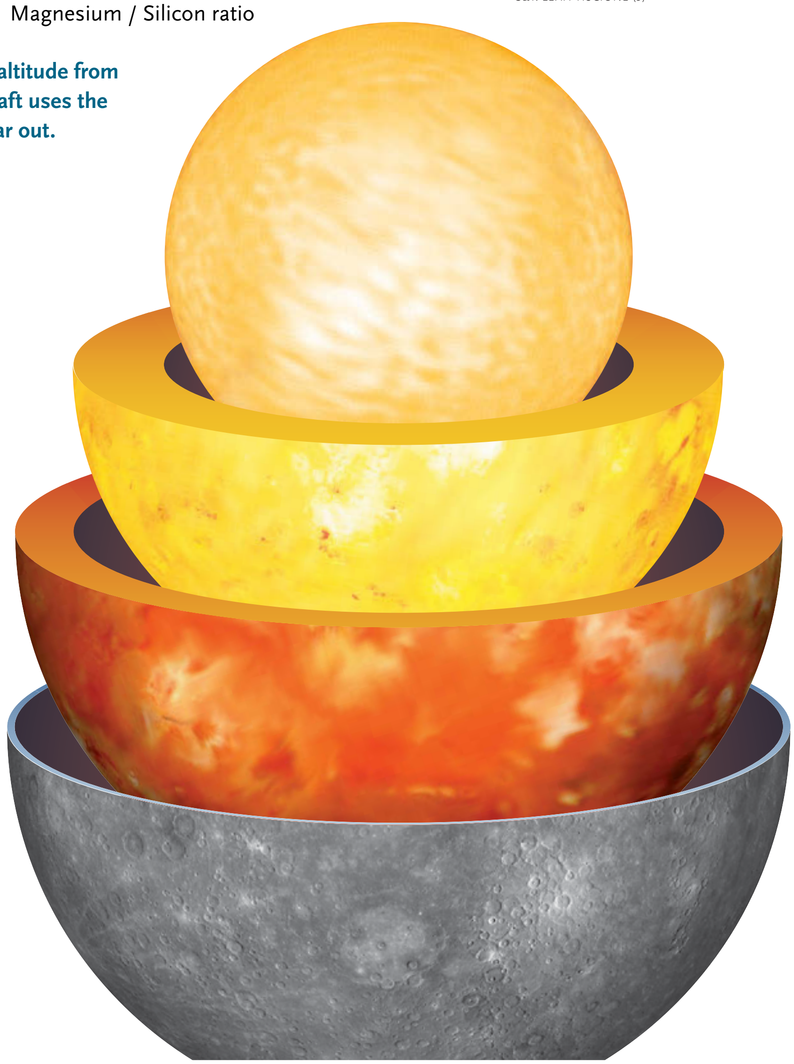
Near left: **The major-element composition of Mercury's surface differs from rocks and soils of Earth, the Moon, and Mars, suggesting it has a different geologic history.**

SOURCE: NASA / JHU-APL / CIW

Below: **Mercury is a cannonball planet. An iron-dominated core (sphere at top) takes up about 80% of its radius and more than half its total volume.**

S&T: LEAH TISCIONE (3)

Above left: **Messenger's looping polar orbit around Mercury ranges in altitude from just 120 miles (200 km) to about 10,000 miles (15,000 km). The spacecraft uses the close-ins for observations and beams its data back to Earth when it's far out.**



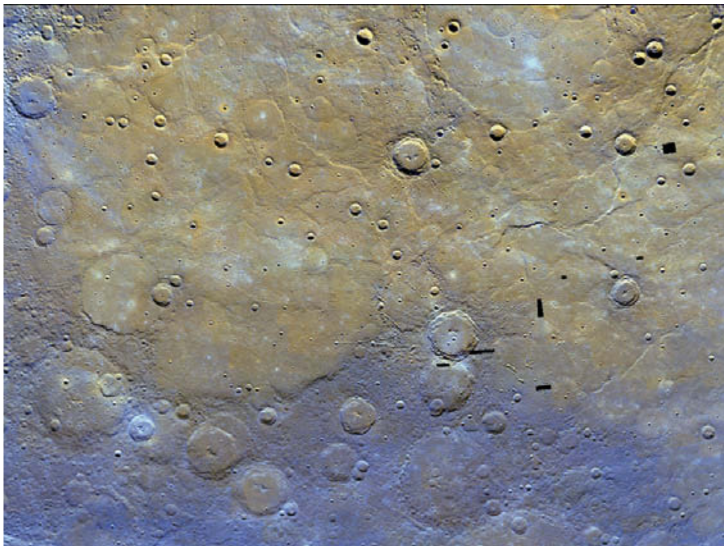
have left the surviving layers with very little sulfur, potassium, and sodium — the same elements Messenger detects in abundance.

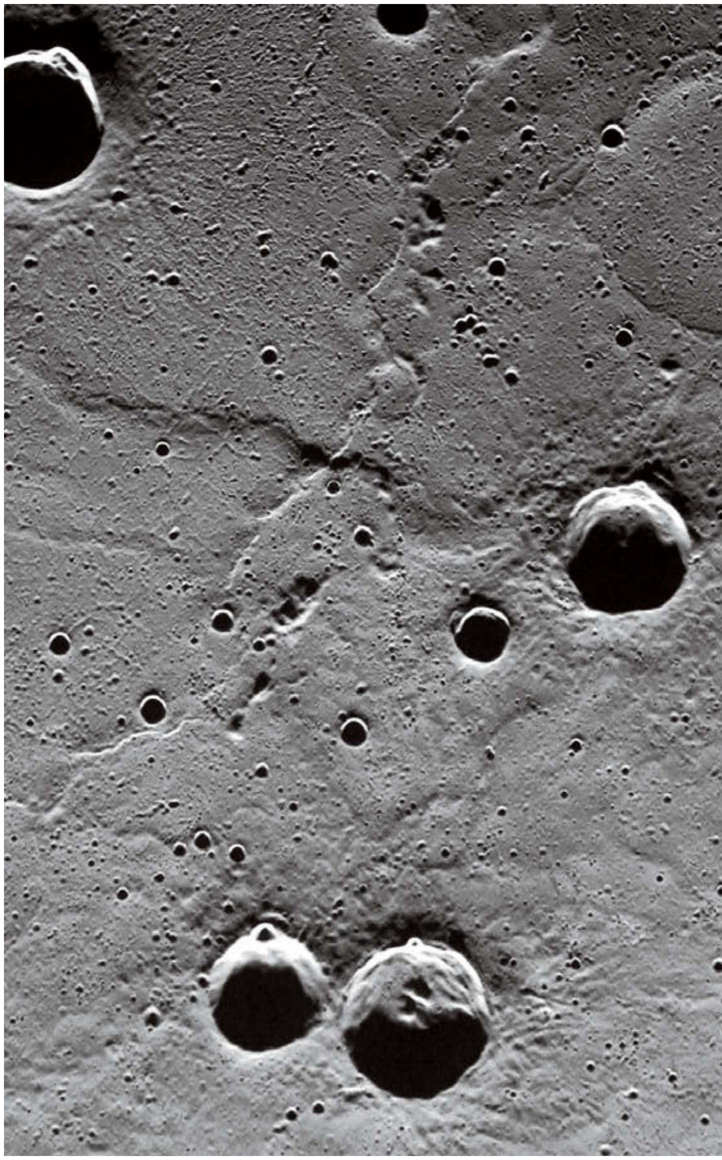
A similar idea, the "big splat," still stands (albeit shakily). In this account, Mercury formed somewhat bigger than it is now but soon suffered a massive hit that stripped away most of its crust and mantle, leaving behind its core and not much else. The hit is similar to the one thought to have created Earth's moon, except that Mercury, being less massive than Earth, should have had more difficulty retaining its volatile elements than Earth did. Some data work with this model, says Nittler, but it doesn't yet explain how surface rocks ended up with roughly 10 times more sulfur than exists on Earth. Being a volatile element, sulfur should have evaporated and escaped during the crash.

A third notion is that, somehow, Mercury was *never* Earthlike but instead assembled from metal-rich building blocks. Such bodies exist: metal-rich meteorites called CV chondrites. But what Messenger is seeing on Mercury isn't a good match to those meteorites' composition. An iron-poor type known as aubrite is a better fit (see the box on page 31). Perhaps the primordial matter floating close to the young Sun was carbon rich and oxygen poor, as proposed recently by geochemists Denton Ebel (American Museum of Natural History) and Conel Alexander (Carnegie Institution of Washington). Planetesimals with such an elemental mix would have delivered plenty of iron to the growing planet but largely prevented it from incorporating that iron into crustal rocks. Instead, essentially all of the iron would have ended up as the massive core.

Curiosities Erupt

Ever since Mariner 10, geologists have suspected that volcanism played an important role in shaping Mercury's surface. Messenger's cameras have confirmed that broad lava plains fill most of the real estate between the planet's abundant craters. Particularly intriguing is a vast expanse surrounding the north pole that covers 6% of the planet's surface. This region, distinctly lower in elevation than elsewhere, was inundated early in Mercurian history by a volcanic outpouring of almost unimaginable size. On Earth, the plain would cap most of the continental U.S. with lava 1 or 2 miles thick. "It's flood volcanism with a vengeance," quips veteran planetary geologist James W.





Wanted: Meteorites from Mercury

During a recent science conference, Messenger investigator Shoshana Weider (Carnegie Institution of Washington) commented, "Short of landing on the surface, picking up a rock, and bringing it home, the instruments on Messenger that characterize chemistry are the best we're going to get."

GARY FUJIHARA

She might still get to hold such a rock. According to a 2009 analysis by Brett Gladman and Jaime Coffey (both then of University of British Columbia), chunks of Mercury should be lying somewhere on Earth right now. The dynamicists conclude that 2% to 5% of the debris blasted by impacts off the surface of Mercury at or above escape velocity (2.6 miles per second) should reach Earth within 30 million years. That translates to at least a half-dozen stones having reached terra firma and been picked up.

A Mercurian meteorite would have a distinctive makeup: an igneous rock — or perhaps a fused *breccia* of different rock types — rich in magnesium and volatile elements but nearly devoid of iron. This closely matches the composition of rare meteorites known as aubrites (an example is on the left).

But a piece of Mercury should be much darker than an aubrite. It might also smell faintly of sulfur, appear heavily shocked, exhibit significant exposure to cosmic rays, and even be slightly magnetic.

Head III (Brown University).

Such massive outflows would be difficult to produce unless the crust were ripped open along extensive, miles-wide fractures that tapped vast sources of magma deep below the surface. On Earth, convective bubbles in the mantle create localized volcanic "hot spots," such as those under Hawaii and Iceland. But with a huge core at the planet's center, Mercury's mantle might be too thin to establish such convection-driven churning. Instead, Head suggests, static slabs of mantle material might have somehow liquefied below the surface, creating enormous reservoirs of molten rock just waiting for a crustal breach to make their escape to the surface.

All that rampant volcanism occurred early in the planet's history, and there's no evidence (yet) for recent or ongoing eruptions. But apparently Mercury isn't geologically dead. Its surface abounds with clusters of small shallow pits, ranging in size from tens of meters to several kilometers across (February issue, page 18). These "hollows," hints of which were spied by Mariner 10, have bright interiors and halos, tend to occur in or near impact craters, and look fresh.

Find more selected Mercurian scenery and the latest Messenger news at www.skypub.com/Messengermission.

So what are they? Investigator David Blewett (APL) thinks the hollows likely result from the loss of some kind of volatile material, something that's unstable in the conditions at or near the surface. Add a source of heat — the pulse from an impact, contact with hot rocks rising from the interior, or just the blistering midday sunlight — and this material could change to a gas and jet into space.

Mars has similar-looking "Swiss cheese" terrain near its south pole, created as the topmost layer of carbon dioxide ice warms in spring and summer's sunlight and sublimates away. But the Mercurian hollows seem to be something entirely different, a unique landform created by material emplaced and buried long ago.

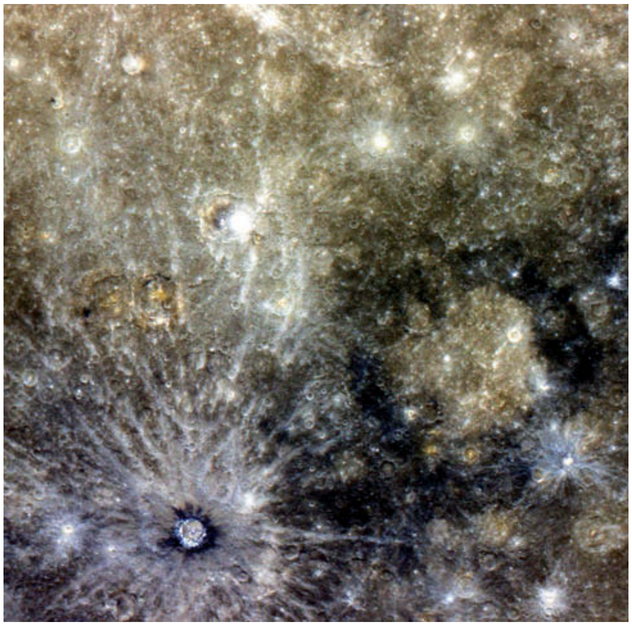
Complicating the search for a cause is the fact that the hollows appear to be associated with some unknown dark material found planetwide. Overall, Mercury reflects less sunlight (has a lower albedo) than the Moon does, and some locations are nearly black. We know why the Moon is dark: over time, bombardment by meteorites and harsh radiation (so-called "space weathering") extracts iron and titanium from lunar rocks and creates somber microscopic flecks of metal or metal-enriched glass that gradually build up in the dusty surface debris.

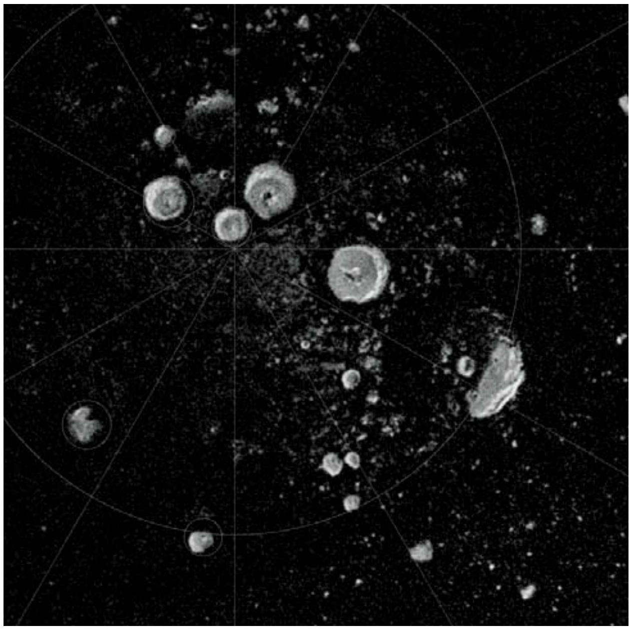
But with little iron or titanium on Mercury's surface, investigators are struggling to find suitable compounds to darken the terrain. "I think we can explain a lot of the low albedo through space weathering," notes Brett Denevi (APL), "but the extremely low albedos that are related to certain geologic units, such as those around Tolstoj basin, really must be due to compositional variation" — a change in the cake recipe, not just the icing.

Far left: **The floor and ringed mountains of the Raditladi impact basin contain dense clusters of shallow irregular depressions, dubbed "hollows" (bright spots), that give the surface an etched appearance. Hollows appear all over Mercury and might be caused by the escape of trapped subsurface gas. This false-color composite is about 25 miles (40 km) long.**

Top left: **A strongly color-enhanced view of Mercury's surface, centered near 73° N, 300° E, brings out compositional differences between old, highly cratered areas (bluish in color) and younger lava-flooded plains (brownish).**

Bottom left: **Vast lava plains, covering nearly 2 million square miles, surround Mercury's north pole. The wrinkle ridge running through this snapshot formed when a massive volcanic outpouring cooled and contracted. Numerous craters in the lava suggest that the material flowed early in Mercury's history.**





JOHN HARMON ET AL.

Left: This false-color image draws attention to the mysterious dark material that surrounds Tolstoj basin (about 250 miles across, at right), Basho crater (at lower left), and many other impact features on Mercury. Tolstoj is ancient and Basho relatively young, so the dark material must be due to Mercury's composition rather than space weathering. *Right*: Does water ice lie at the bottoms of shadowed craters near Mercury's north pole? This radar image of the polar region, obtained at the Arecibo Observatory, shows that some craters are filled with radar-bright material. These deposits might conceivably be water ice, or some other unknown compound.

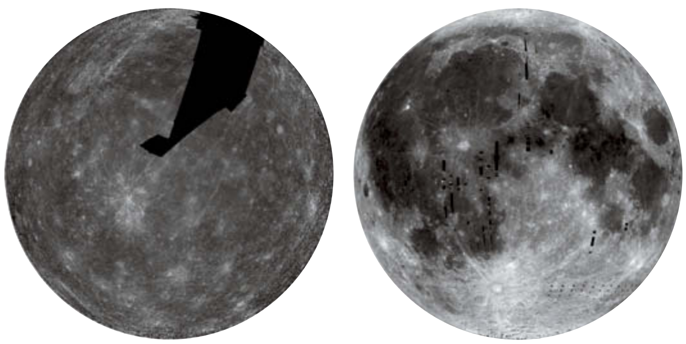
Magnetic Lines of Evidence

Mariner 10 discovered that Mercury is the only terrestrial world (aside from Earth) with a substantial magnetic field. This field suggests that the outer, still-molten portion of the core gurgles enough to create a field-producing dynamo. But Messenger's magnetometer finds that the source of this magnetic field is not dead center in the planet's interior; rather, it's offset toward the north pole by 300 miles (480 km), about 20% of Mercury's radius.

This is interesting for at least two reasons. First, the northward offset leaves the planet's southern hemisphere — particularly the broad region under the magnetic field's southern cusp, where field lines stretch open-endedly into interplanetary space — more vulnerable to bombardment by space radiation. "These open field lines are interstate highways for charged particles," says Sean Solomon (Carnegie Institution of Washington), Messenger's chief scientist. Such magnetic inroads might allow harsher space weathering to alter the surface rocks at far-southern latitudes. Second, the offset suggests that the dynamo originates not in the planet's heart but from somewhere higher up, near its core-mantle boundary.

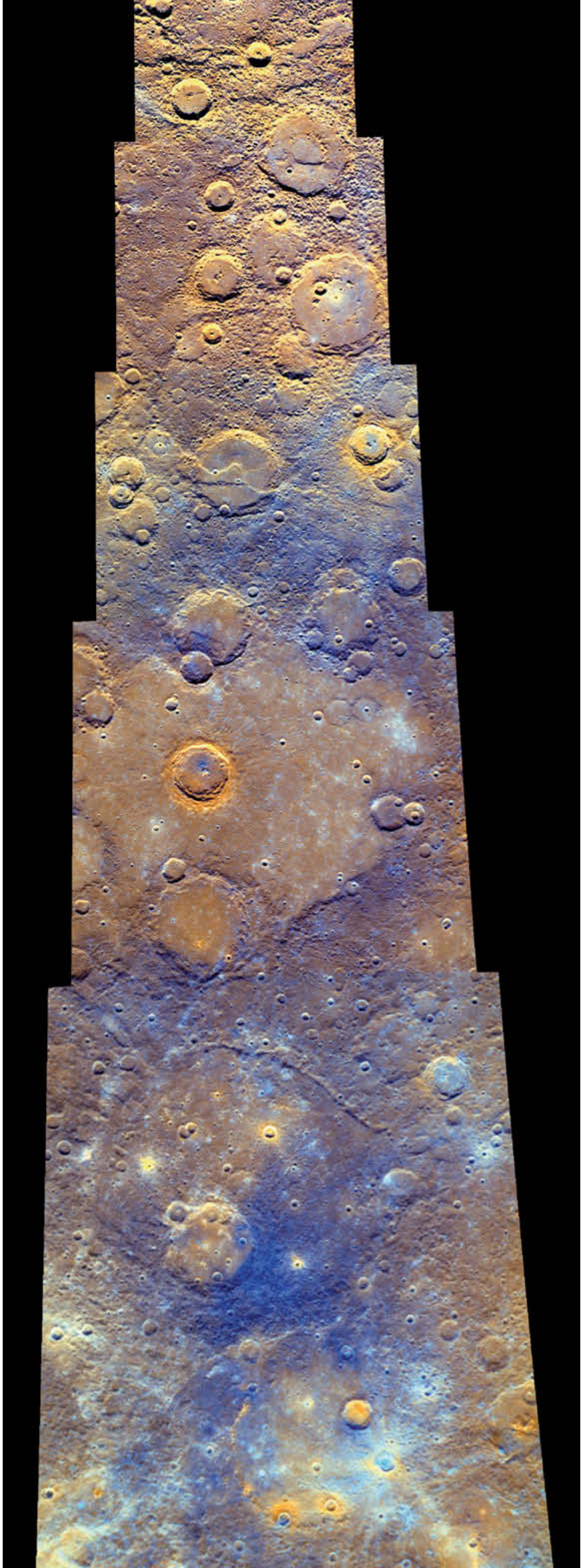
But there's a problem: a dynamo-generated field should be stronger than what Messenger has observed around Mercury. Perhaps, as Daniel Heyner (Technical University, Braunschweig, Germany) and others suggest, the magnetospheric bubble that surrounds the Iron Planet combines with the solar wind in a way that creates negative feedback and weakens the overall field strength. Alternatively, Steven Hauck II (Case Western Reserve University) and others argue that the lower mantle must consist of an unexpectedly dense material — perhaps iron sulfide — that could be damping the dynamo's field before it ever reaches the surface.

"There's an incredible richness of magnetospheric data," Solomon says. The spacecraft has found sodium, magnesium, calcium, oxygen, helium, and even water molecules streaming away from the planet. Yet the streams aren't uniform — sodium and calcium seem to



On average, the surface of Mercury (*left*) is about 15% darker than the Moon's nearside (*right*, from Clementine orbiter). Yet Mercury's surface rocks contain less iron, the element that contributes most to lunar rocks' dark appearance.

This enhanced-color mosaic shows a strip of Mercury's surface as seen by Messenger during its second flyby. The colors come from the 11 filters of the spacecraft's Wide Angle Camera. The distance between the centers of the two orange-tinted craters in the middle is just over 100 miles.



concentrate over the polar cusps, whereas magnesium and helium are distributed more evenly. And space physicists would like to know why bursts of energetic electrons, ranging from 10,000 to 200,000 electron volts (200,000 eV is the energy of photons used in some medical X-rays), are showing up like clockwork whenever the spacecraft passes over mid-northern latitudes. "We have a lot of mysteries to solve with these data," he admits.

Homework Assignments

Fortunately, Messenger's observations won't be ending in mid-March, at the conclusion of its primary mission. Last November, NASA managers wisely decided to extend operations through December 2012, which gives the science team more time to sort out some of the confusion and to make headway on some must-have answers.

For example, mission scientists are only beginning to disentangle the planet's gravitational field and, from that, its interior structure. Geologists would like to know where all those volatiles are coming from, how long the episodes of volcanism continued throughout the planet's history, and just how much the crust distorted and contracted as the planet cooled.

And then there's the mysterious compound that's puddled at Mercury's poles. It's been 20 years since radar astronomers discovered highly reflective spots at the very top and bottom of the planet. Not many things can reflect pulses of radio energy so efficiently, and one of them is water ice. Mercury might be blisteringly hot at high noon, but because of its virtually nonexistent axial tilt, the floors of craters near the poles are never exposed to sunlight. It might seem utterly implausible, so close to the Sun, but water ice could remain stable in those shadowed hideaways for a very long time.

Messenger carries a neutron spectrometer that can sense the presence of hydrogen in the ground below it, sunlit or not. Every time the spacecraft swoops in close over the north pole — as it has more than 700 times since entering orbit — the spectrometer counts neutrons slowed by collisions with hydrogen atoms, presumably those in water molecules. But the radar-bright deposits could be something else, such as iron sulfide. The team has been chasing this mystery with a variety of methods, Solomon says, and researchers hope to have a yes-or-no answer to the water-ice question very soon. ✦

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*Senior contributing editor **J. Kelly Beatty** dreams of skiing down the ice-covered inner slopes of Mercury's permanently shadowed polar craters.*

Rare Astronomical Confluence

Did the Moon

Donald W. Olson, Russell L. Doescher & Roger W. Sinnott

On April 10, 1912, the *Titanic* sailed from Southampton, England, on its maiden voyage. After picking up passengers at Cherbourg, France, and Queenstown (now Cobh), Ireland, the liner headed west across the North Atlantic to New York. But it would never get there. At 11:40 p.m. on April 14th, the *Titanic* struck an iceberg, and by 2:20 a.m. on April 15th the great ship had slipped beneath the waves. Although some 700 people were rescued from lifeboats, about 1,500 passengers and crew perished in the icy waters.

The year 2012 marks the centennial not only of the *Titanic*'s sinking, but also that of the little-known extreme lunar perigee of January 4, 1912. We investigated whether these two events could have been related through the Moon's effect on ocean tides.

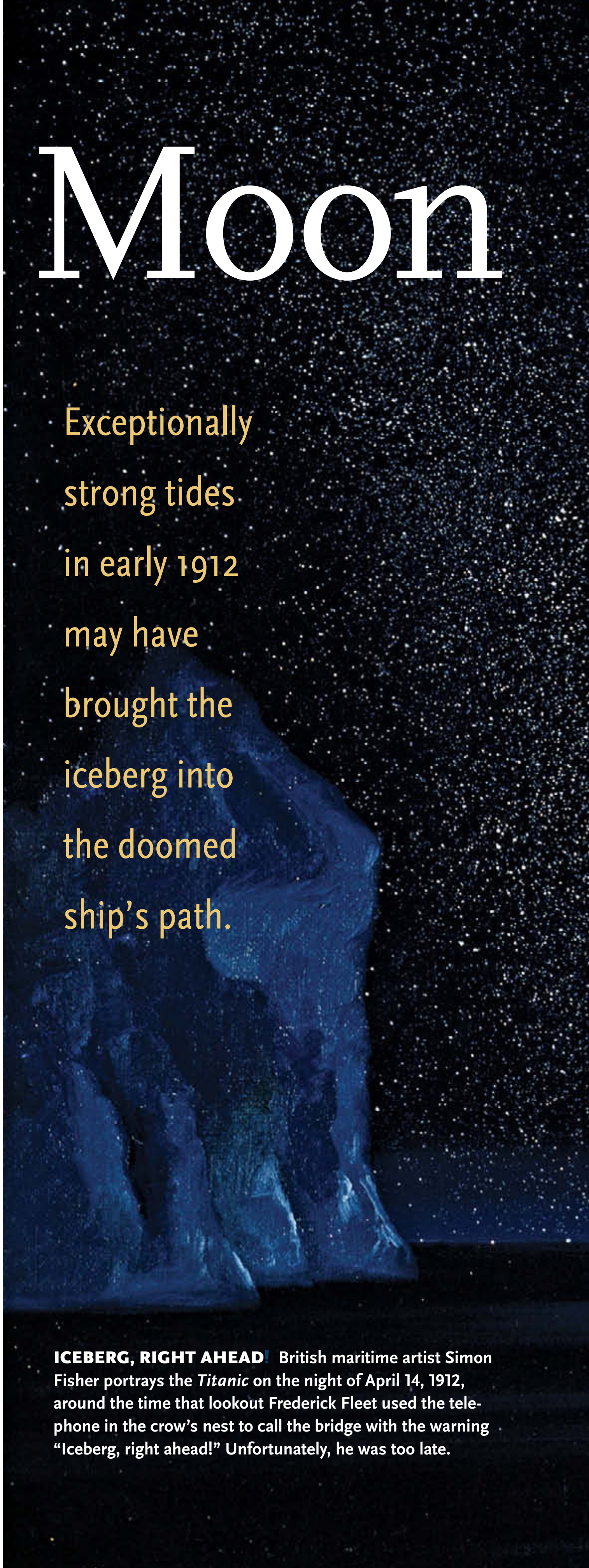
A Moonless Night

David Rubincam and David Rowlands emphasized one lunar connection to the *Titanic* sinking in the October 1993 *S&T* (page 79). They noted, "At night lookouts normally watched for waves breaking around the exposed portion of an iceberg; the white surf made a berg easier to spot. But on this night there was virtually no swell or wind; little surf would be generated around any icebergs that might be in the vicinity. And there was no Moon. Moonlight . . . might have made what foam there was, or even the berg itself, easier to see."

When Second Officer Charles H. Lightoller testified before the British inquiry, he was asked to explain the circumstances of that night. He answered, "In the first place, there was no moon."

Passenger Lawrence Beesley, gazing around from a lifeboat after the *Titanic* disappeared, noticed something else about the sky. In his 1912 book *The Loss of the SS. Titanic,* he wrote:

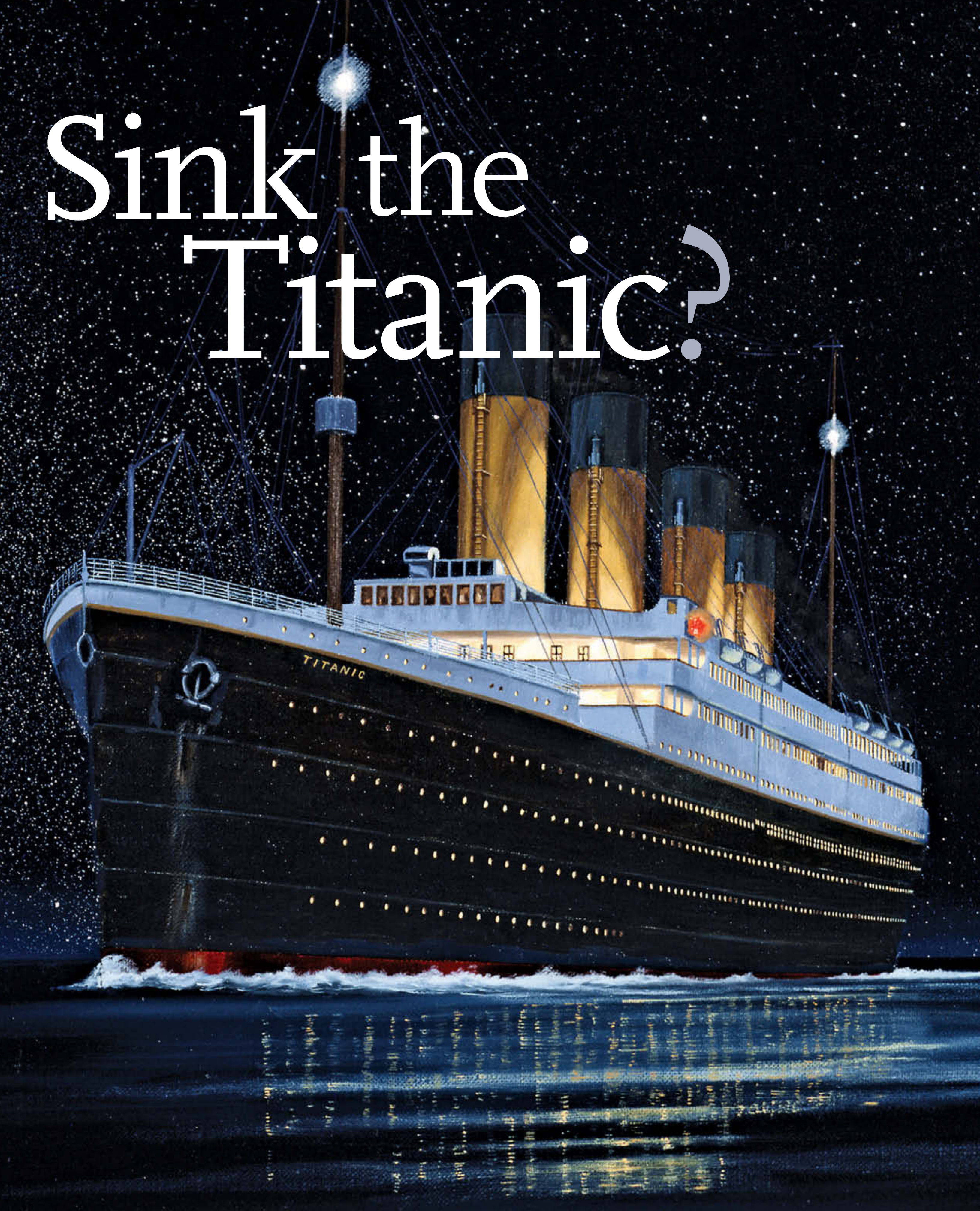
> First of all, the climatic conditions were extraordinary. The night was one of the most beautiful I have ever seen: the sky without a single cloud to mar the perfect brilliance of the stars, clustered so thickly together that in places there seemed almost more dazzling points of light set in the black sky than background of sky itself ... where a star came low down in the sky near the clear-cut edge of the waterline, it still lost none of its brilliance.

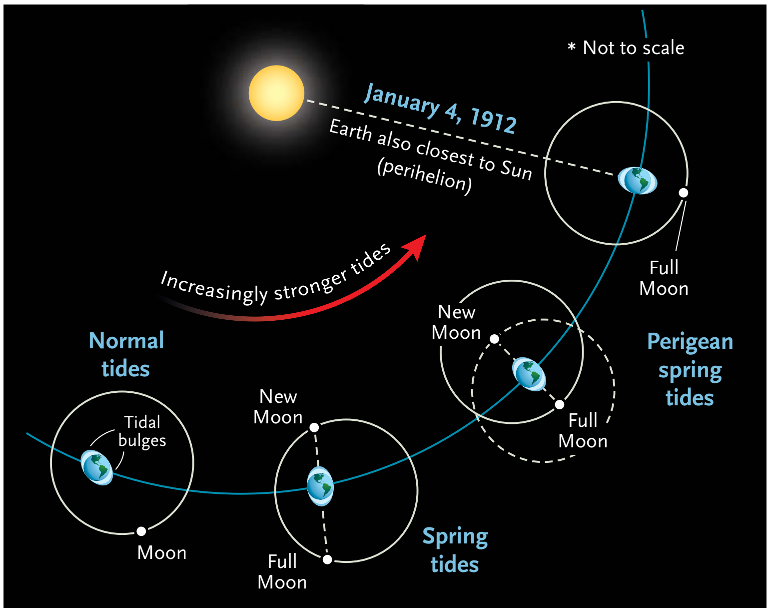


Exceptionally strong tides in early 1912 may have brought the iceberg into the doomed ship's path.

ICEBERG, RIGHT AHEAD! British maritime artist Simon Fisher portrays the *Titanic* on the night of April 14, 1912, around the time that lookout Frederick Fleet used the telephone in the crow's nest to call the bridge with the warning "Iceberg, right ahead!" Unfortunately, he was too late.

Sink the Titanic?





S&T: LEAH TISCIONE

RUSSELL DOESCHER

TIDAL CONVERGENCE The convergence of three astronomical effects on January 4, 1912, enhanced the strength of the tidal force on Earth's oceans. The Moon was on the opposite side of Earth from the Sun, making it a full Moon (creating a spring tide). The Moon was at its closest point to Earth (perigee) in its eccentric orbit, enhancing its gravitational tug on Earth. And Earth was near its closest point to the Sun (perihelion) in its annual orbit, boosting the Sun's gravitational influence. The increased tidal force on January 4, 1912, along with close perigees on December 6, 1911, and February 2, 1912, may have refloated the iceberg that eventually drifted south into the *Titanic*'s path.

At last, shortly before sunrise on April 15th, Beesley realized that rescue was at hand when he saw the approach of a passenger vessel. The eastern sky brightened as his lifeboat was rowed toward the *Carpathia*:

> And then, as if to make everything complete for our happiness, came the dawn. First a beautiful, quiet shimmer away in the east, then a soft golden glow that crept up stealthily from behind the sky-line ... And next the stars died, slowly, – save one which remained long after the others just above the horizon; and near by, with the crescent turned to the north, and the lower horn just touching the horizon, the thinnest, palest of moons.

This last remaining "star" was actually Venus, as Rubincam and Rowlands noted.

Lunar Perigee in 1912

If the Moon had been out that fateful night, the *Titanic*'s lookouts probably would have spotted the iceberg in time to avoid the collision. But the Moon's absence on the night of the sinking is only part of the story. An unusually large number of icebergs reached North Atlantic shipping lanes in the spring of 1912, perhaps resulting from a rare confluence of astronomical events that produced ocean tides with unusual range. Did these tides play a role in bringing the iceberg into the *Titanic*'s path?

The rare celestial combination first involved the convergence of a *spring tide* and a *perigean tide*. Spring tides occur at both new Moon and full Moon, when the Sun, Earth, and Moon line up, and the tide-raising forces of the Sun and Moon combine for a greater net effect. Perigean tides occur when the Moon is nearest Earth (at its perigee) in its eccentric orbit, so the lunar tide-raising force is greatest. If a lunar perigee falls near either new Moon or full Moon, then *perigean spring tides* with unusually large range will occur. Perigean spring tides are not particularly rare. Whenever a perigee coincides with a new Moon, 6½ and 7½ lunar months later the perigees will fall near full Moons, and after a similar interval the perigees will again fall near new Moons, and so on.

But an even rarer configuration occurs when perigean spring tides occur near the time of year (early January) when Earth is at perihelion, its closest approach to the Sun, when the solar tide-raising force is also greatest. Such an astronomical coincidence occurred in early 1912:

Earth at perihelion 10h 44m UT	January 3, 1912
Full Moon 13h 29m UT	January 4, 1912
Lunar perigee 13h 35m UT	January 4, 1912

The calculated times of the full Moon and lunar perigee in January 1912 were separated by *only six minutes*. This timing of a Sun-Earth-Moon lineup, coupled with the strong solar influence, produced an exceptionally close lunar perigee distance of 356,375 km (221,441 miles) on January 4, 1912; a typical perigee distance is about 363,000 km. On that date, the total tide-raising force, combining both lunar and solar effects, was 74% stronger than that of the Moon at its mean distance from Earth.

As far as we know, Fergus J. Wood, a tide expert at the National Ocean Survey (later NOAA), was the first author to call attention to this date, which he noted as having the most extreme lunar perigee during the years 1600 to 1999 (*The Strategic Role of Perigean Spring Tides*, 1978, page 219). Independently, Roger Sinnott alerted Belgian astronomer Jean Meeus to this rare event (*S&T:* August 1981, page 110), and Meeus later refined the calculations and extended the range of years in his 2002 book *More Mathematical Astronomy Morsels* (Willmann-Bell). To find a closer lunar perigee distance than the one in 1912, it's necessary to go back to the year 796 (356,366 km) or forward to the year 2257 (356,371 km). The extreme lunar perigee on January 4, 1912, therefore marked the Moon's closest approach to the center of the Earth during a period of more than 1,400 years.

Enhanced Iceberg Calving?

Glaciers in western Greenland are the source of the vast majority of icebergs carried by ocean currents into North Atlantic shipping lanes. When glacial ice reaches the Greenland coast, the ends of the glaciers break off (a process known as *calving*) and are set adrift as icebergs. Especially prolific is the coastline's northern half, extending from Humboldt Glacier on Kane Basin down to Jakobshavn Glacier on Diskø Bay.

To explain the unusually abundant ice that reached shipping lanes in the spring of 1912, the *New York Times* interviewed U.S. Hydrographic Office scientists for an article appearing on May 5, 1912. These experts argued that Arctic weather conditions during the preceding year played an important role

> **in the creation of an enormously large crop of icebergs from the West Greenland glaciers.... Ice now observed in the North Atlantic Ocean prevails because of an unusually hot Summer in the arctic last year, followed by an unusually mild Winter.... This warm Summer caused a greater melting of the glaciers, perhaps a more rapid movement of them, and the formation of a larger number of icebergs, together with the liberation of congested bergs and field ice, held there perhaps for many previous seasons, and that in consequence the drift southward was larger than in normal years.**

Fergus Wood was apparently the first author to suggest that the extreme lunar perigee in January 1912 may have played a role in the origin of the *Titanic* iceberg. In the 1995 *Journal of Coastal Research*, he argued that tongues of ice extending from the Jakobshavn Glacier into the fjord would flex up and down in response to the increased tidal range. Wood stated that "the calving frequency of icebergs increases noticeably during spring tides" and specifically emphasized the ocean tides caused by the "precise astronomical circumstances existing on January 4, 1912 . . . because of their extreme concentration of gravitationally augmenting forces." He concluded that the "probable date of the *Titanic* iceberg's calving into the open sea was around January 4, 1912."

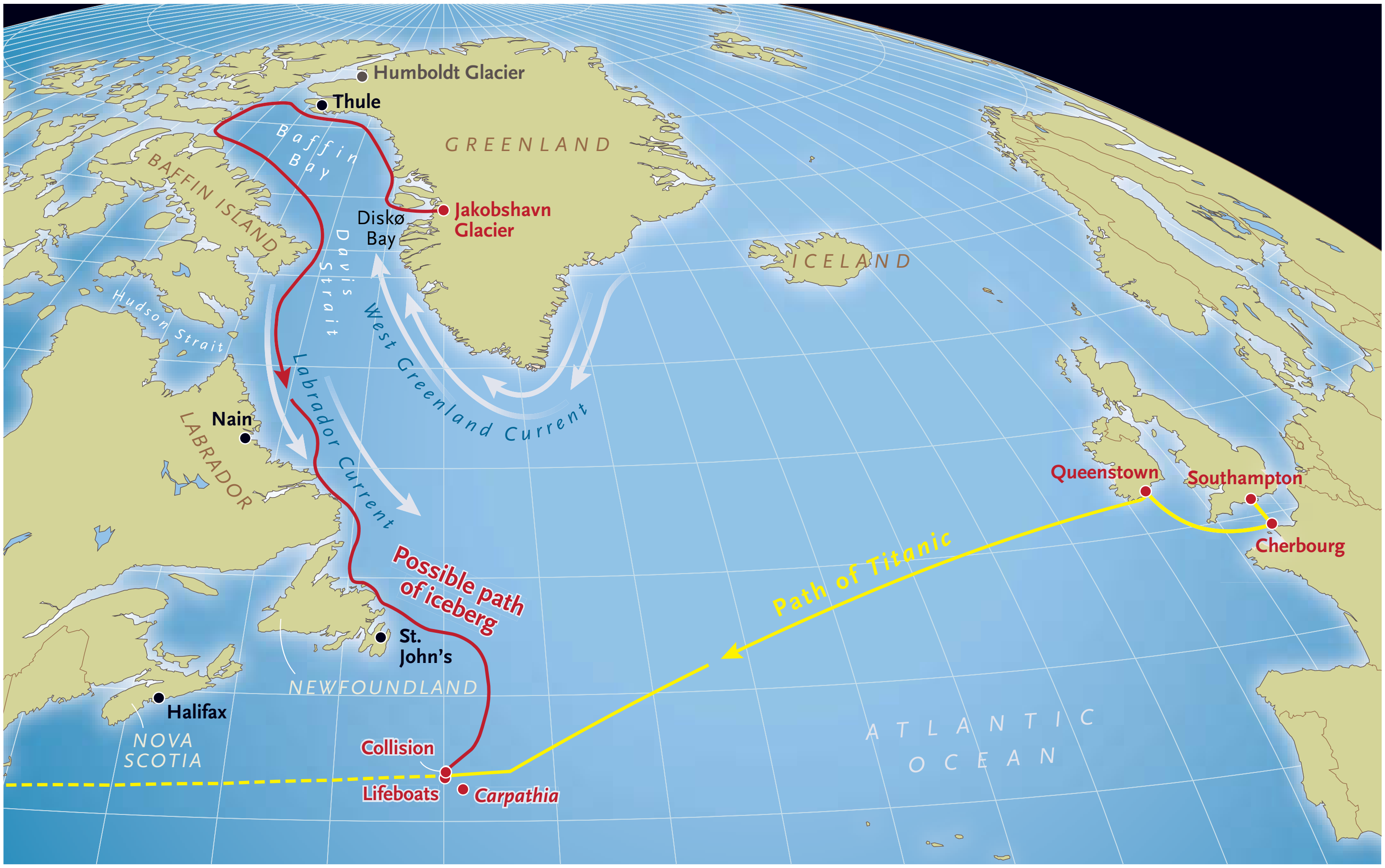
But Wood himself recognized a problem with this idea — an iceberg calved near Diskø Bay in early January would have to travel unusually fast in order to meet the *Titanic* in the shipping lanes on April 14th. Wood realized that "icebergs are subject to numerous impairing, retarding, deflecting, and even stranding or grounding influences" that might increase travel times. He was forced to assume that the icebergs calved in Greenland in January 1912 made their way "rapidly and expediently toward their eventual destinations" and that the *Titanic* iceberg in particular followed one of the "most rapid-transportation cases" possible.

The 1938 edition of the Bowditch *American Practical Navigator* manual gave a general rule for the time required: "If bergs on their calving at once drifted to the southward and met with no obstructions their journey of about 1,200 to 1,500 [nautical] miles would occupy from 4 to 5 months. . . ." The distance from Diskø Bay to the *Titanic* collision site is closer to 1,640 nautical miles, suggesting a typical iceberg moving directly south without any delays would need about 5½ months.

There's another difficulty with accepting Wood's idea that the iceberg moved rapidly south after being calved.

BONNIE WARD

VISIONARY OCEANOGRAPHER **Fergus J. Wood, shown here at Coronado, California, made the connection between the extreme lunar perigee in January 1912 and the sinking of the *Titanic* a little more than three months later.**



S&T: GREGG DINDERMAN

NEWFOUNDLAND AND LABRADOR TOURISM

COLLISION COURSE This map shows the known route of the *Titanic* and a possible path for the iceberg. We will never know the iceberg's actual trajectory, but modern knowledge of currents and drift patterns make this a highly plausible scenario. Had it not been for the enhanced tidal effects a few months earlier, the iceberg might have run aground on the Labrador or Newfoundland coast, and remained permanently stuck until it melted.

ICY VISITOR As icebergs travel south toward Atlantic shipping lanes, they often drift into shallow water and run aground. This iceberg got stuck just off Dunfield, Newfoundland, but it later refloated on a spring tide and headed south. Did the same thing happen to the *Titanic* iceberg?

The prevailing West Greenland Current usually carries icebergs first to the *north* and then counterclockwise around Baffin Bay before the icebergs even begin their southward journey many months later. As explained in the 1962 Bowditch manual, "The most prolific source of icebergs is the west coast of Greenland. . . . The west Greenland current carries them northward and then westward until they encounter the south-flowing Labrador current. West Greenland icebergs generally spend their first winter in Baffin Bay. During the next summer they are carried southward by the Labrador current. In many cases, their second winter is spent in Davis Strait."

Voyage of the Iceberg

If the *Titanic* iceberg calved from its parent glacier in Greenland in 1910 or 1911, then it might appear that

STEPHEN BRUNEAU

ICEBERG CALVING **This aerial photo shows icebergs that have broken off Jakobshavn Glacier on the east end of Diskø Bay, on Greenland's west coast. Glaciers originating from the west coast of Greenland are the source of the vast majority of icebergs that are carried by ocean currents into North Atlantic shipping lanes, and Jakobshavn Glacier is an especially prolific site.**

the ocean tides in January 1912 have no relevance to the *Titanic*'s sinking. But we can suggest a modification of Wood's idea — a scenario in which the extreme lunar perigee on January 4, 1912, still played an important role in the history of the *Titanic* iceberg, even if it didn't cause it to break off from Greenland in the first place.

As icebergs travel southward along the coasts of Labrador and Newfoundland, they can drift into shallow water and run aground. The Canadian Hydrographic Service glossary defines two terms that describe stationary ice: "grounded ice" is floating ice that is temporarily aground in shoal water, while "stranded ice" is ice that, after floating, has been deposited on the shore by retreating high water. Some grounded icebergs remain in place and decay without moving farther, but in other cases they refloat and resume moving south. The icebergs "find their way into the Labrador Current and begin their journey to the southward" in a stop-and-go manner, the 1938 Bowditch manual explains:

> **Many ground in the Arctic Basin and break up there; others reach the shores of Labrador, where from one end to the other they continually ground and float... So many delays attend their journey and so irregular and erratic is it that many bergs seen in any one season may have been made several seasons before.**

Exactly this kind of journey is described in Richard Brown's 1983 book *Voyage of the Iceberg*, which offers a unique look at the *Titanic* disaster — from the iceberg's point of view. Although the text is fictional, the author intended his account to be scientifically plausible. In Brown's book, the iceberg calved from Jakobshavn Glacier in September 1910, moves out of Diskø Bay, and is then carried northward up the coast by the West Greenland Current. Brown's berg spends the winter of 1910–11 in the north end of Baffin Bay, drifts westward in the summer, and begins to drift southward in August 1911. The iceberg runs aground and refloats several times, and drifts into the path of *Titanic* on April 14, 1912.

We will never know the origin and path of the actual *Titanic* iceberg, of course, but Brown's narrative, with the iceberg grounding and refloating several times, is a plausible scenario. Tidal streams might help to erode the bases of grounded icebergs, and the high waters during perigean spring tides could play a role in refloating grounded and even apparently "stranded" icebergs, especially those stranded at the time of a normal high water.

On December 6, 1911, a full Moon occurred 22 hours before a lunar perigee. On January 4, 1912, a full Moon and a lunar perigee were separated by only six minutes. On February 2, 1912, a full Moon occurred 22 hours after a lunar perigee. As a modification of Wood's original idea linking astronomy and the *Titanic*, we suggest that perigean spring tides during each of those three months — especially the period near the extreme lunar perigee on January 4th — could have helped to refloat icebergs.

The *Titanic* iceberg may well have spent time among those grounded or stranded near Hudson Strait or along the coasts of Labrador and Newfoundland. These locations are far enough south that refloated icebergs resuming their southward drift would have sufficient time to reach the shipping lanes by mid-April, the time when the lookout Frederick Fleet peered into a starlit night and called out the words: "Iceberg, right ahead!" ✦

Don Olson *and* ***Russell Doescher*** *teach in the Department of Physics at Texas State University.* ***Roger Sinnott*** *is an* S&T *senior contributing editor.* *The authors are grateful for research assistance from Fergus Wood (1917–2000), Stephen Bruneau at the Memorial University of Newfoundland, and Margaret Vaverek at Texas State University's Alkek Library.*

To view more images related to this article, visit skypub.com/titanic.

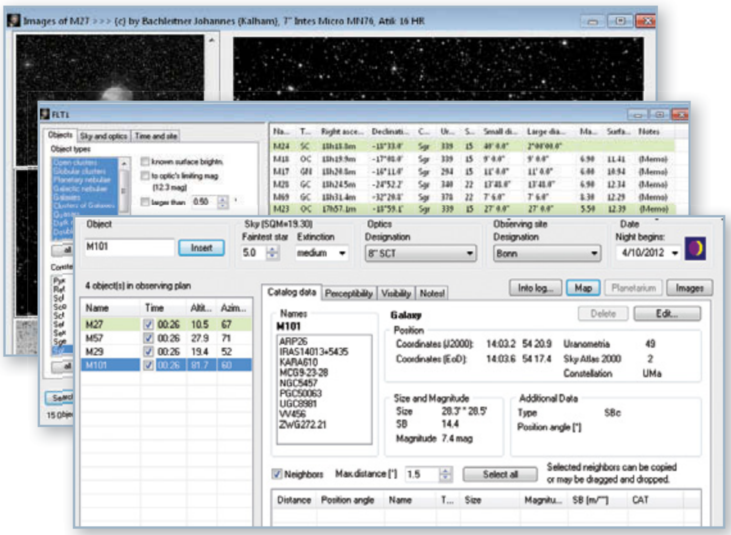
MARILYNN OLSON

COAUTHORS **Left to right: Russell Doescher, Don Olson, and Roger Sinnott enjoy a sunny day on the beach at Dover, England.**

New Product Showcase

▼ **OBSERVING PLANNER** *Eye & Telescope* 3.0 ($75) is a new observing planner for serious observers developed by Thomas Pfleger. The program runs on *Windows 98SE* or higher and allows users to generate observing lists based on their equipment and specific observing conditions. Navigate the sky with easy-to-operate maps showing objects you can really see with your binoculars or telescope, or control the pointing of any *ASCOM*-compliant Go To telescope mount. With *Eye & Telescope*, you can filter objects by type, time, location, and sky brightness to let you plan a night's observing without wasting precious time searching for objects beyond your capabilities. The software also allows you to easily document your observations, and provides observing notes from deep-sky observers, including *S&T* contributing editor Steve Gottlieb. Requires a DVD-ROM drive, 256 megabytes of RAM, a 1-gigahertz processor, and a 256-color graphics card. ISBN 978-0-521-15115-3

Eye & Telescope 3.0
Distributed through Cambridge University Press, www.cambridge.org

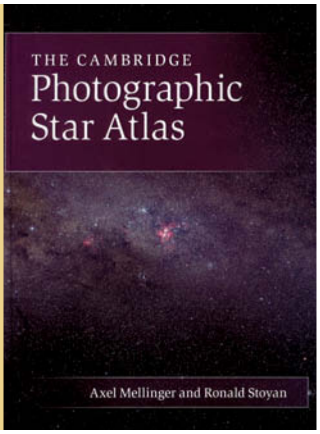


▲ **COMPACT ASTRO CAMERA** Atik Cameras unveils its newest compact CCD imager, the Atik 428EX ($2,250). This new camera features the sensitive 2.8-megapixel Sony ICX674 CCD detector with square 4.54-micron pixels. The Atik 428EX is a roughly 2-by-5-inch compact body that can cool down to 30°C (54°F) below ambient temperature. The camera connects to your PC via a mini-USB 2.0 cable and is controlled using the included *Artemis Capture* software; drivers are included for *MaxIm DL*, *CCDSoft*, or any *ASCOM*-compliant control program. Also included are a 3-meter (9.8-foot) USB cable and 1.8-meter cigarette-lighter power cable. The company's website has additional details.

Artemis CCD Ltd.,
Beacon House, Nuffield Rd.,
Cambridge, CB4 1TF, UK www.atik-cameras.com

► **PHOTO ATLAS** *The Cambridge Photographic Star Atlas* by Axel Mellinger and Ronald Stoyan ($48) is an aptly named atlas covering the entire sky, based on Mellinger's all-sky mosaic. A short preface describes the challenges he faced when undertaking the two-year project using modern digital astrophotography techniques. The final mosaic was divided into eight-two 10-by-13½-inch charts, with each sky segment presented twice on a double-page spread: in natural color on the right-hand page and as a black-and-white negative chart on the left. Constellation names and bright stars are plotted, as are the brightest double stars, variables, open clusters, globular clusters, nearby galaxies, and bright and dark nebulae. Cambridge University Press, 176 pages, ISBN 978-1-107-01346-9.

Available from Cambridge University Press, www.cambridge.org



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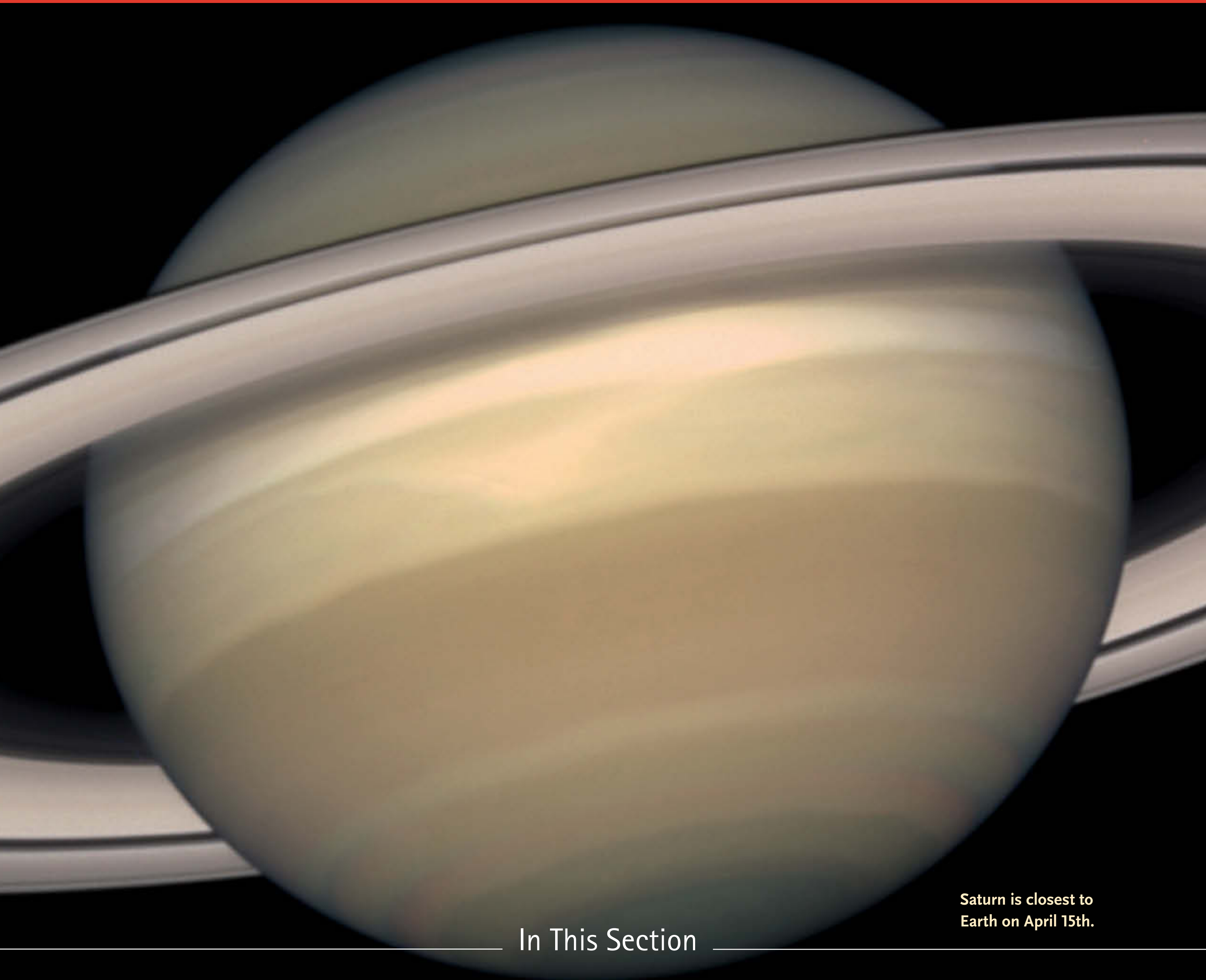


Saturn is closest to Earth on April 15th.

In This Section

PHOTOGRAPH FROM THE HUBBLE SPACE TELESCOPE

Sky at a Glance

2–3 Evening: In the west, Venus passes through the southern outskirts of the Pleiades. This sight is best viewed in binoculars or a wide-field telescope. In the east, the waxing gibbous Moon forms a shallow arc with Mars and Regulus on the 2nd and a narrow triangle with them on the 3rd. See page 48.

6 Evening: Spica is close to the Moon's left, and brighter Saturn is farther left of Spica.

15 All night: Saturn is at opposition, rising around sunset and setting around sunrise.

17 Evening: Algol is at minimum brightness for about 2 hours centered on 10:44 p.m. EDT (9:44 p.m. CDT). This is the last chance until August to see a minimum of Algol in the evening sky from North America.

21–22 Late Night: The modest Lyrid meteor shower peaks tonight at new Moon. It's best viewed from midnight to the first light of dawn on the 22nd; see page 53.

22 Dusk: Jupiter shines just below an extremely thin crescent Moon very low in the west-northwest in twilight, a splendid photo op.

23 Early Evening: The Pleiades are to the right of a very thin crescent Moon.

24 All Evening: Venus is upper right of the thin crescent Moon; see page 49.

30 Evening: Look above the Moon for bright Mars (on the left) and dimmer Regulus.

Planet Visibility

	◀ SUNSET	MIDNIGHT	SUNRISE ▶
Mercury		Visible in binoculars at mid-month.	E
Venus	W	NW	
Mars	SE	S	W
Jupiter	W		
Saturn	E	S	W

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

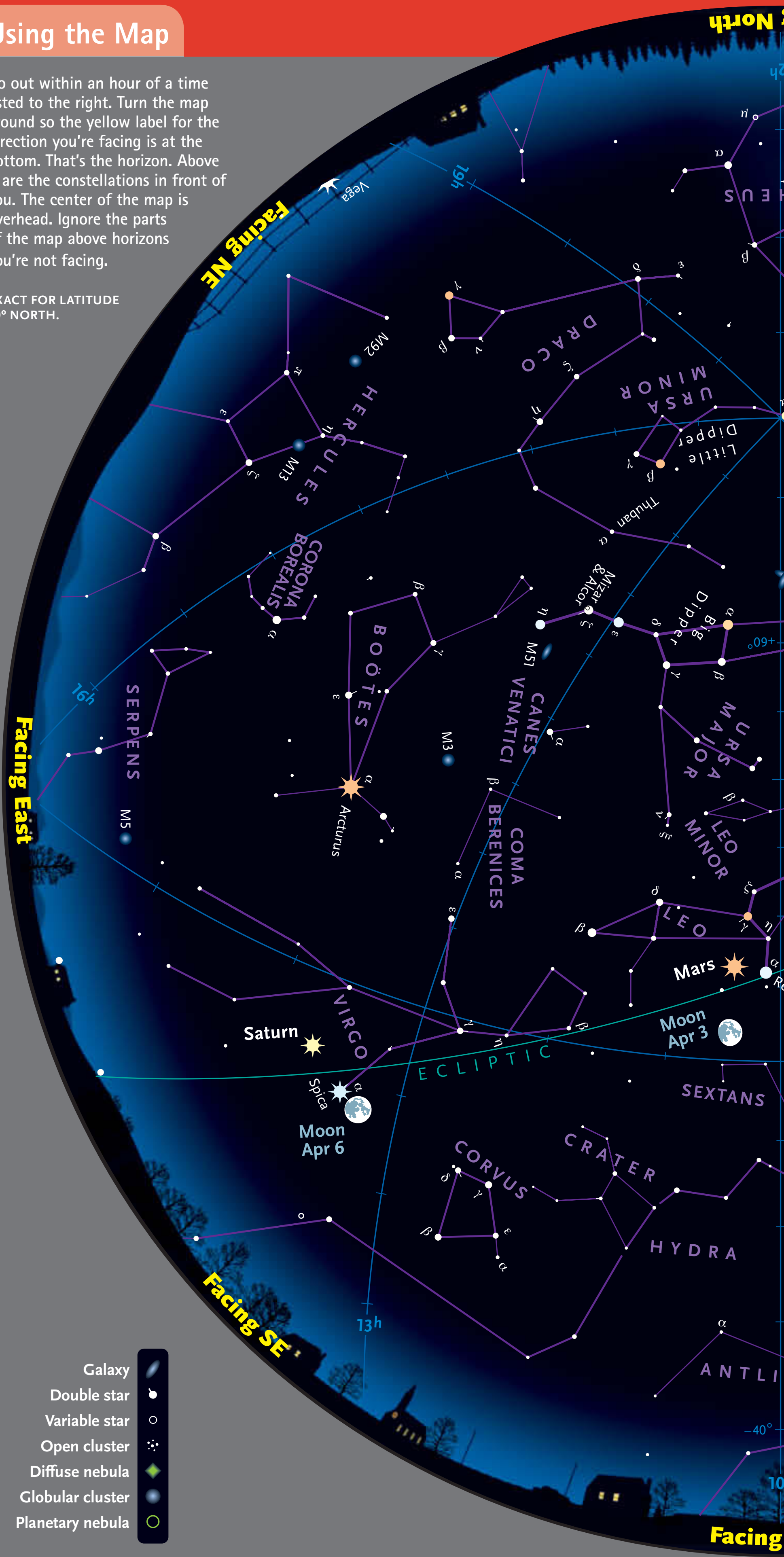
Moon Phases

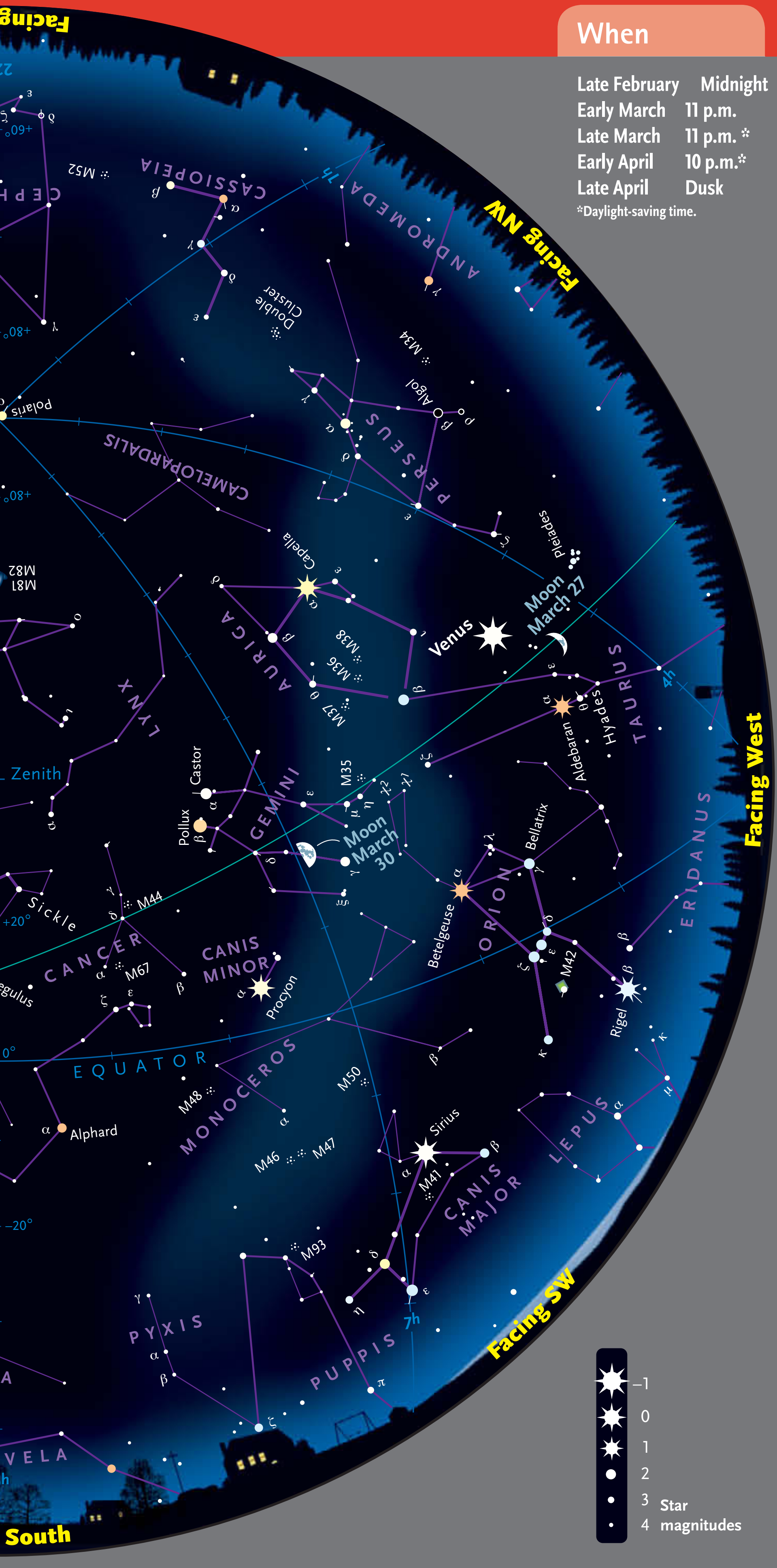
SUN	MON	TUE	WED	THU	FRI	SAT
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

Using the Map

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

EXACT FOR LATITUDE 40° NORTH.





When

Late February	Midnight
Early March	11 p.m.
Late March	11 p.m.*
Early April	10 p.m.*
Late April	Dusk

*Daylight-saving time.

Binocular Highlight

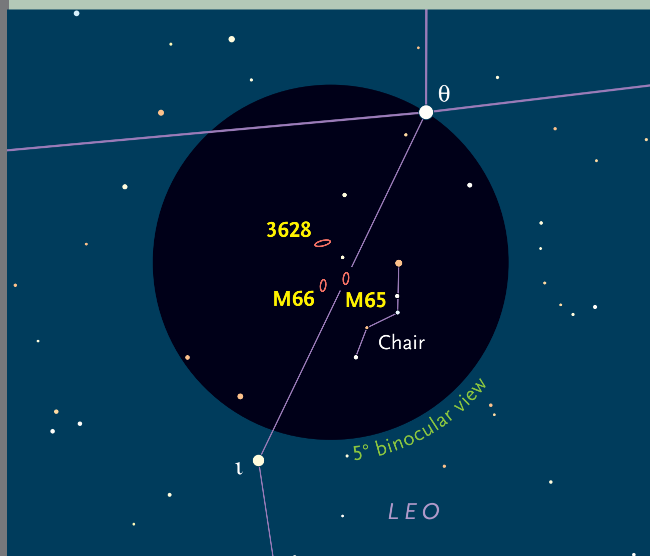
Leo's Galaxy Trio

The spring sky is littered with galaxies. That's the good news. The bad news for binocular observers is that virtually all of them are tough to see and require reasonably dark skies. But even a difficult target often can be glimpsed if you know exactly where to look — so a prominent signpost is a big plus.

The Messier duo of **M65** and **M66** in Leo is situated in the same binocular field as 3.3-magnitude Theta (θ) Leonis, which helps. But the two galaxies are also positioned just east of a stick-figure chair asterism. If you can find this grouping of 6th- and 7th-magnitude stars, you'll have a pretty good chance of sighting the galaxies.

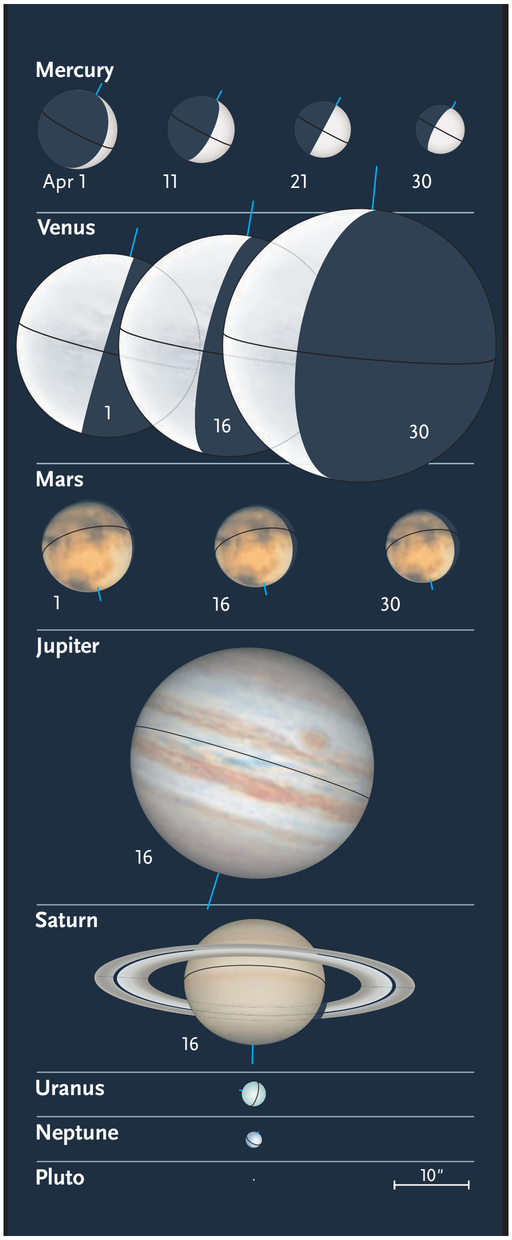
I can see both galaxies in my 10×50s, but 9.0-magnitude M66 is definitely the easier of the two. It's even possible to discern its elongated shape and orientation (roughly north/south) with these binos. At magnitude 9.3, M65 is a little more difficult and needs averted vision to pull it in from the background sky. In mounted 15×70s, both galaxies are readily seen under dark skies, and the north-south orientation of M65 becomes discernible.

The two Messier galaxies are part of a grouping well known to telescopic observers as the famed Trio in Leo. The third galaxy in that trio is **NGC 3628**. I was able to glimpse it intermittently in both my 15×45 image-stabilized binos and my 15×70s, though it wasn't easy. Glowing at magnitude 9.8, NGC 3628 is not only fainter, it's also larger than either Messier galaxy, so its dim light is spread out farther. Little wonder that completing the Trio is so challenging for binocular observers. ✦ — *Gary Seronik*



Watch a SPECIAL VIDEO

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

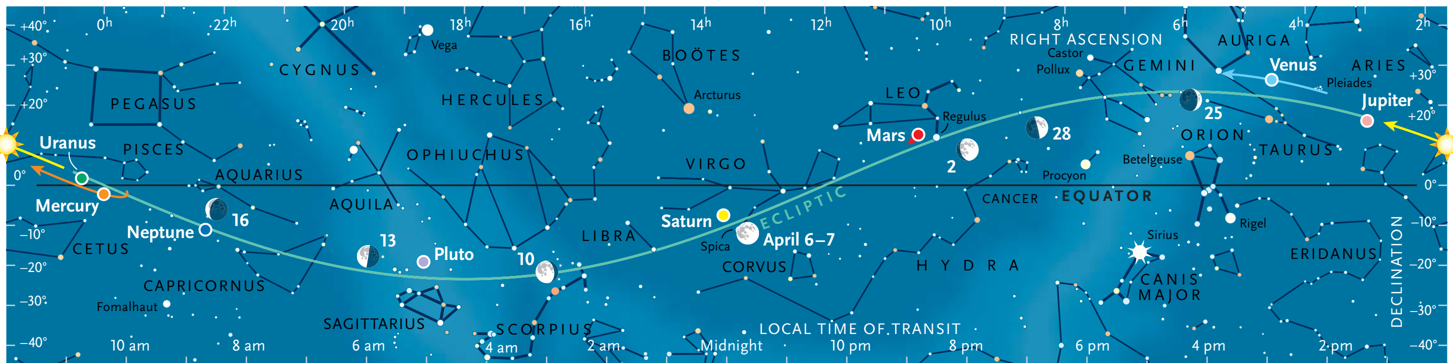


Sun and Planets, April 2012

	April	Right Ascension	Declination	Elongation	Magnitude	Diameter	Illumination	Distance
Sun	1	0^h 42.3^m	+4° 33′	—	–26.8	32′ 01″	—	0.999
	30	2^h 29.9^m	+14° 47′	—	–26.8	31′ 45″	—	1.007
Mercury	1	23^h 37.2^m	–1° 24′	17° Mo	+2.1	10.7″	13%	0.631
	11	23^h 45.6^m	–2° 59′	26° Mo	+0.7	9.0″	33%	0.745
	21	0^h 18.3^m	–0° 50′	27° Mo	+0.2	7.6″	50%	0.890
	30	1^h 00.6^m	+3° 24′	25° Mo	–0.1	6.5″	63%	1.027
Venus	1	3^h 36.9^m	+22° 56′	46° Ev	–4.5	24.8″	48%	0.673
	11	4^h 14.8^m	+25° 24′	45° Ev	–4.6	28.0″	42%	0.595
	21	4^h 48.6^m	+27° 01′	43° Ev	–4.7	32.2″	35%	0.519
	30	5^h 13.0^m	+27° 43′	40° Ev	–4.7	36.9″	28%	0.453
Mars	1	10^h 30.8^m	+12° 54′	143° Ev	–0.7	12.6″	97%	0.745
	16	10^h 25.7^m	+12° 42′	127° Ev	–0.4	11.2″	94%	0.834
	30	10^h 30.3^m	+11° 40′	115° Ev	–0.1	10.0″	92%	0.935
Jupiter	1	2^h 43.9^m	+14° 57′	32° Ev	–2.1	33.9″	100%	5.813
	30	3^h 10.3^m	+16° 54′	10° Ev	–2.0	32.9″	100%	5.985
Saturn	1	13^h 44.7^m	–7° 52′	164° Mo	+0.3	19.0″	100%	8.753
	30	13^h 36.4^m	–7° 05′	165° Ev	+0.3	19.0″	100%	8.750
Uranus	16	0^h 21.6^m	+1° 35′	21° Mo	+5.9	3.4″	100%	21.007
Neptune	16	22^h 18.0^m	–11° 10′	54° Mo	+7.9	2.2″	100%	30.579
Pluto	16	18^h 39.7^m	–19° 13′	107° Mo	+14.1	0.1″	100%	31.908

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

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



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

Fred Schaaf *has authored 13 books on astronomy.*

Fred Schaaf

Cluster Light, Cluster Bright

April evenings are ideal for viewing nearby star clusters.

The name of the month April may come from its once being the "aperture" (opening) of the year. Or perhaps it was the month of Aphrodite (Venus).

The latter idea is particularly appealing every eight years when April begins with one of my favorite recurring celestial events: the close meeting of Venus, the loveliest naked-eye planet, with the Pleiades or Seven Sisters, the loveliest naked-eye star cluster (see page 48).

In fact, April evenings are a time when all the great naked-eye star clusters are on display.

The Ursa Major Group. The five central stars of the Big Dipper are the core of a "moving group" of at least 16 stars that are drifting through space in the same direction. These stars were all born together, but they're gradually drifting apart because their mutual gravitational attraction isn't very strong. It's the group of physically related stars closest to Earth — centered about 80 light-years away. Its members are spread across at least 30 light-years in space and 23° of sky.

The Coma Cluster. At about 280 light-years, the Coma Star Cluster is the third-closest, after the Ursa Major Group and the Hyades. It's centered about halfway between Beta Leonis (Denebola) and Alpha Canum Venaticorum (Cor Caroli). It represented the tuft of Leo the Lion's tail until the third century BC, when its name was changed to mark the amber tresses of Queen Berenice, wife of Ptolemy III of Egypt. The surprising full story of the queen and her locks is brilliantly told in Guy Ottewell's historical novel *Berenice's Hair*, available from **www.universalworkshop.com**.

The Coma cluster is an irregular scattering — beautifully disheveled hair — of a few dozen stars spread across about 5° of sky. Binoculars are needed to see the cluster in light-polluted skies, but at least five of the stars are brighter than magnitude 5.5.

M44, the Beehive Cluster. Cancer's M44 spans more than a degree of sky. Ten of its stars shine between 6.3 and 6.9. About seventy more are brighter than 10th magnitude. M44 is just north of the ecliptic and thus makes a fine big target for the Moon and planets. M44 is about 580 light-years from Earth.

The Alpha Persei Association. Alpha Persei (Mirfak) shines at magnitude 1.8. It's surrounded by a loose grouping of somewhat fainter stars spanning more than 3°. Many of these are visible to the unaided eye, but binoculars and ultra-wide-field telescopes give the best view. These stars are roughly 550 light-years away and are all quite young, born about 50 million years ago.

DAVID CORTNER

Venus last passed through the Pleiades on April 3, 2004.

The Hyades and Pleiades. The Hyades include at least 16 stars brighter than magnitude 5.5 and span about 6°. They're much more tightly bound than the Ursa Major Group, so they're often considered the closest true star cluster, some 150 light-years distant.

The Pleiades, roughly 400 light-years distant, are even more tightly bound. Nowhere are so many naked-eye stars packed into such a small area of sky — eight stars brighter than magnitude 5.5 within a 1° circle.

The Pleiades Cluster is young, roughly 100 million years old, as attested by the preponderance of bright, hot, bluish stars.

The Pleiades play hostess to Venus in early April. But next month, after passing close to Beta Tauri, the planet begins a retrograde loop that is partially hidden by solar glare. When Venus finally starts to emerge from bright twilight at dawn in late June, it has — surprise! — moved into the Hyades. ✦

Farewell Jupiter, Welcome Saturn

The ringed wonder enters the early evening sky in April.

At dusk on April 1st Venus blazes high in the western sky, with Jupiter about halfway to the horizon below it. Mars is high in the southeast, and Saturn is about to rise.

The configuration changes as the month progresses. By the end of April Venus is a little lower at dusk and Jupiter is much lower, barely visible in bright twilight. Mars is near its highest in the south, and Saturn is well up in the southeast.

DUSK AND EVENING

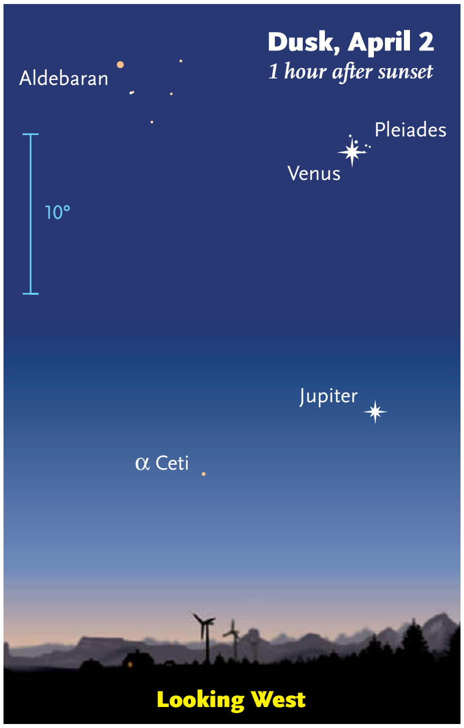
Venus rules the western evening sky. It remains high in the west long after nightfall, setting 4 hours after sunset in the opening days of April and still more than 3½ hours after sunset as the month ends. What's more, Venus skims the Pleiades, shines at its brightest, and presents a lengthening and narrowing crescent in telescopes.

Every eighth April, just after Venus reaches the peak of the highest evening apparition in its 8-year cycle, the brilliant planet makes its closest pass by the lovely Pleiades. Throughout the 21st century, each of these close passes will carry Venus farther north and deeper into the cluster. Not for two more 8-year cycles — in 2028 — will Venus go between any of the bright named Pleiades stars. But this year Venus is just ½° southeast of Alcyone, and ¼° south of the Atlas-Pleione pair, on the American evening of April 3rd. Venus is about 1° from the cluster's center the night before and after. Venus's great radiance overwhelms the naked-eye view of the Pleiades, but binoculars and wide-field telescopes will show both planet and cluster beautifully.

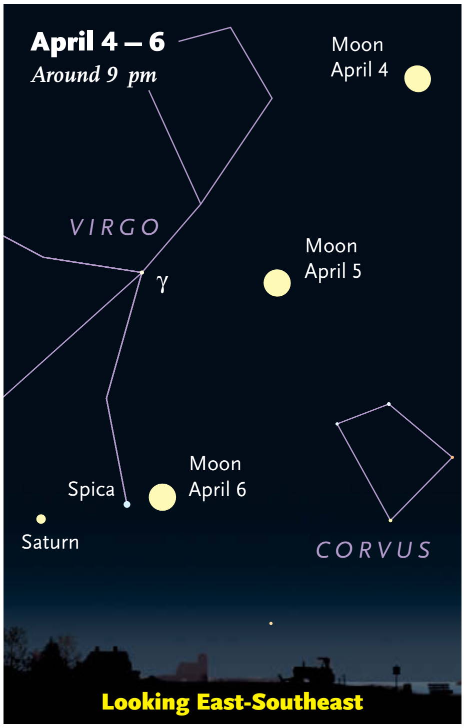
Venus glides onward through Taurus for the rest of April, passing a huge 10° north of Aldebaran at mid-month and coming close to Beta Tauri (Elnath) at month's end.

Venus starts April at magnitude –4.5 and ends the month at –4.7, the brightest it will become this year. Telescopes show its apparent diameter increasing from 25″ to 37″ while its phase thins from 48% to 28% lit. If you hope to see any subtle detail in Venus's clouds, observe before the sky gets too dark and Venus dazzles with glare. This is an ideal month to view Venus in broad daylight through your telescope — or even with your naked eyes.

Jupiter is almost directly below Venus in twilight, and it's much less bright at magnitude –2.0. Jupiter moves farther down below Venus every week on its way to leaving the evening stage entirely; it sets 2½ hours after the Sun on April 1st but only ¾ hour after the Sun on April 30th. In a telescope Jupiter shrinks to just 33″ wide.

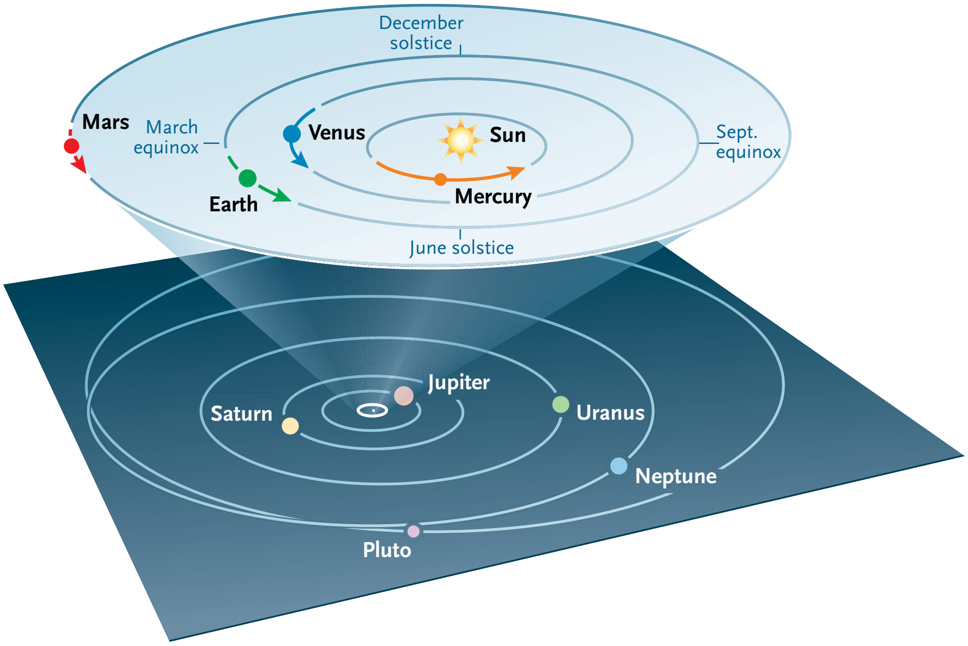


These scenes are drawn for near the middle of North America (latitude 40° north, longitude 90° west); European observers should move each Moon symbol a quarter of the way toward the one for the previous date. In the Far East, move the Moon halfway. The blue 10° scale bar is about the width of your fist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



ORBITS OF THE PLANETS

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



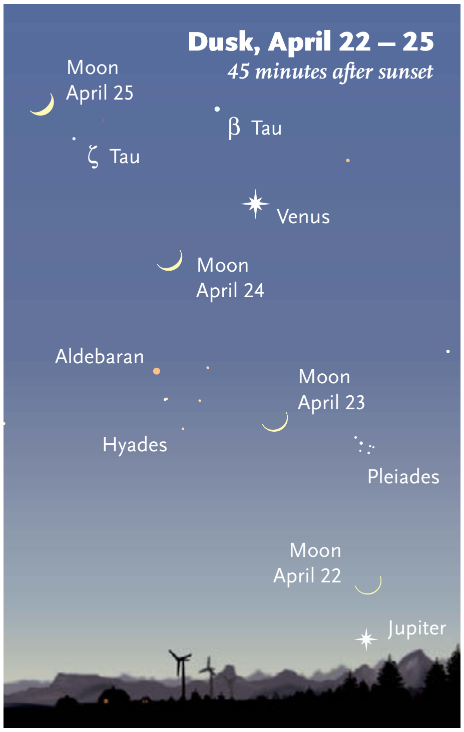
DUSK TO DAWN

Mars, in Leo, comes into view halfway up the east-southeast sky at dusk in early April, and high in the south in late April. Mars fades like an orange-yellow ember from magnitude –0.7 to –0.1 during the month. Compare its brightness and hue to zero-magnitude, ginger-ale-colored Arcturus very far to its lower left. Mars's disk shrinks from 12.6″ to 10.0″ wide — still large enough to glimpse details through a telescope when the seeing is good.

Mars slows and halts its retrograde (westward) motion on April 15th, just 4° from much dimmer Regulus, before starting to move eastward away from Regulus again.

Saturn reaches opposition on April 15th, the same day that Mars halts its retrograde motion. The two planets lie similar distances east of 1st-magnitude stars. Saturn is a little more than 5° east of Spica. Saturn shines at magnitude +0.3, roughly twice as bright as Spica.

Saturn's globe now measures 19″ across at the equator, and its rings span 43″. The rings will narrow slightly for the next few months; in April their tilt decreases from 14° to 13°.



DAWN

Mercury reaches greatest elongation on April 18th, but it's having its poorest morning apparition of 2012. Mercury rises less than an hour before the Sun all month for viewers at mid-northern latitudes. It takes a shallow path up from the east horizon, so observers in the U.S. will probably need binoculars to see it at all.

Pluto, in Sagittarius, is fairly high as morning twilight begins this month. **Neptune**, in Aquarius, and **Uranus**, in Pisces, can probably be spotted in telescopes just before dawn in late April, but they're still very low.

MOON PASSAGES

The **Moon** glows near Mars and Regulus on April 2nd and 3rd and forms a dramatic short line with Saturn and Spica on April 6th. A very slender lunar crescent shines not far above Jupiter very low in the west at dusk on April 22nd. The crescent is between Aldebaran and the Pleiades on the 23rd and nearly between Venus and Aldebaran on the 24th. A gibbous Moon returns to visit Mars and Regulus on April 30th. ✦

To see what the sky looks like at any given time and date, go to SkyandTelescope.com/skychart.

Making the Most of Mars

Now's your last good chance until 2014 to examine our next-out neighbor.

Mars is unique for its Earthlike aspects that you can see in a telescope: polar caps, changing white clouds, and surface markings that reveal a rotation period of just over 24 hours. This year Mars comes to opposition on March 3rd and is nearest Earth on March 5th, after most subscribers receive this issue. Mars remains in convenient evening view as it shrinks for months to come.

But as Mars oppositions go, this is the most distant in the planet's 15.8-year cycle of oppositions near and far. Mars will appear only 13.9 arcseconds wide even at its closest, a far cry from the 24″ or 25″ of its oppositions around the peak of the cycle (which last came in 2003 and will arrive next in 2018).

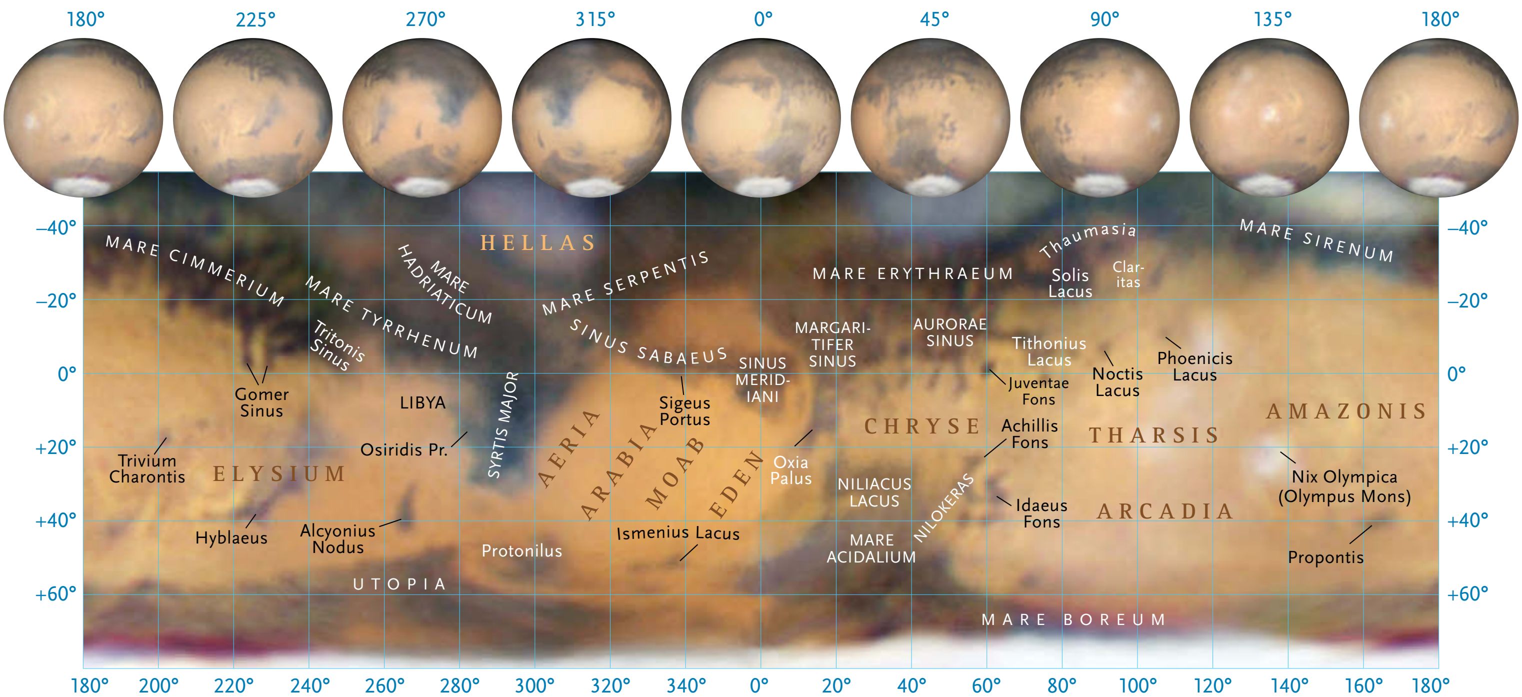
But astronomy is all about making the most of distant, difficult views. With a good, well-collimated 4-inch or larger telescope on a night of excellent steady seeing, you'll first spot the North Polar Cap, especially in the weeks around opposition. In the following weeks and months the cap shrinks in the Martian northern summer, and you may detect the narrow dark collar that becomes exposed right around the dwindling cap.

The dark surface markings ("albedo markings") will probably be harder to discern, depending on which side of Mars is facing us when you look. Remember to give your telescope plenty of time to cool to the temperature of the nighttime air. Devote lots of time to watching in order to catch fleeting glimpses of detail! Every bit of what you see will be a hard-won prize.

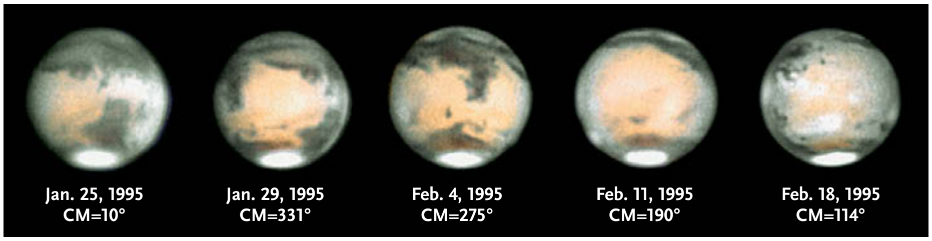
The real amateur planetary excitement these days, however, is in imaging. With an 8-inch scope, a cheap webcam or (better) an astronomical video camera, a laptop, and frame-stacking software, you can match or beat the best Mars imaging done at major observatories a generation ago. And you can certainly beat what you see by eyeball in the same telescope. See Damian Peach's article on imaging Mars in the December 2009 issue, page 70.

Using the Map

It's one thing to detect a tiny, vague smudge or two on Mars's little disk. The smudges become much more exciting if you can identify and name them and mark their comings and goings on subsequent nights. The Mars map below allows you to identify features by referring to the globes just above it.



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



Whenever Mars comes to opposition in February or March, its North Polar Cap is tipped toward Earth and is shrinking in the Martian northern spring. Mars was last oriented this way a decade and a half ago, when long-time planetary observer Don Parker took these images.

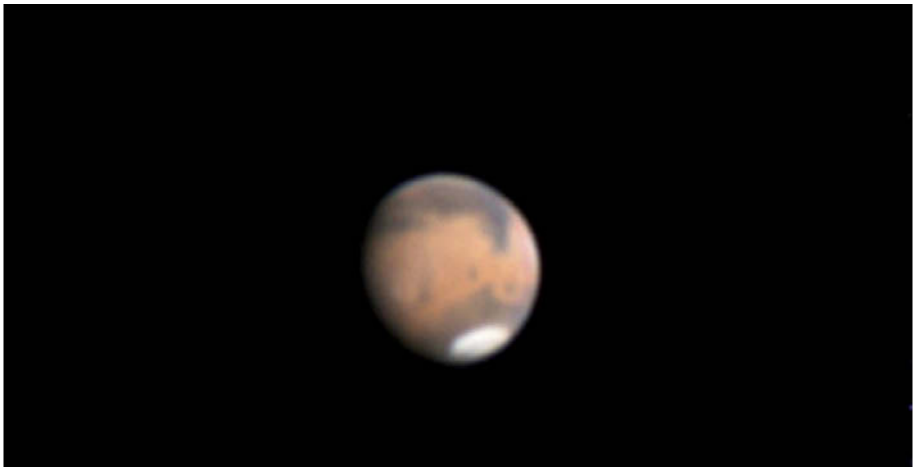
To find which side of Mars is facing Earth at the time you observe, find the west longitude that's on Mars's central meridian (CM) at the time using any number of astronomy programs or web resources, such as our Mars Profiler (**skypub.com/marsprofiler**). Find this longitude along the bottom of the map. Features near this part of the map will be facing you on the planet's disk.

COLOR FILTERS

Color filters definitely help a bit with visual planetary observing. A red or orange filter increases the contrast of Mars's surface markings slightly, and it may also help steady the atmospheric seeing. As you move away from the red end of the spectrum toward the blue, color filters show less of the Martian surface and emphasize more of the atmosphere: hazes and clouds.

For More Information

At each apparition, the Mars Section of the Association of Lunar and Planetary Observers (**alpo-astronomy.org**) receives numerous observations and webcam images. Also see the International MarsWatch site at **elvis.rowan.edu/marswatch**, and the International Society of the Mars Observers at **mars.dti.ne.jp/~cmo/ISMO.html**. These have more information on observing and imaging the planet, what's happening as the apparition proceeds, recent images from observers worldwide, and instructions for uploading your own.



When Mars was still just 9.0″ wide on January 1st, Jim Phillips in South Carolina captured this image with a 10-inch f/9 TMB apochromatic refractor and a SKYnyx color video camera. The central-meridian longitude was 246°. Syrtis Major is at upper right. Note the white cloud haze on the right (morning) limb and, near the evening terminator lower left of center, the patch of cloud in Elysium next to dark Hyblaeus.

A Mars Observer's Calendar

Mars tips its northern hemisphere far into our view from now through September, exposing the North Polar Cap as the cap shrinks through the Martian northern hemisphere's late spring and summer. Can you detect the cap's edge becoming ragged? As the dwindling cap loses water vapor to the atmosphere, clouds are likely to increase around the globe. Thin clouds are especially visible near the Martian limb, where we see them nearly edge on. Major dust storms are unlikely because Mars is far from the Sun; it was at aphelion on February 14th.

Here's a forecast of changes to watch for, condensed from Jeffrey Beish's calendar (**alpo-astronomy.org/jbeish/2012_MARS.htm**) on the Mars page of the Association of Lunar and Planetary Observers.

March 3, diameter 13.9″. Mars is at opposition. It's late spring in Mars's northern hemisphere; the North Polar Cap (NPC) has probably begun its rapid retreat. Are limb arcs of clouds increasing? Is the edge of the South Polar Cloud Hood visible on the southern limb?

March 5, diameter 13.9″. Mars is closest to Earth, 62.6 million miles (100.8 million km).

March 30, diameter 12.7″. Northern-hemisphere summer begins (winter in the south). Look for orographic (mountain-generated) clouds in Tharsis, site of the great shield volcanoes, and local clouds around Syrtis Major, especially Libya. Look for pieces of the shrinking NPC becoming detached.

April 7, diameter 12.0″. Orographic clouds over the Tharsis volcanos, maybe creating the W-Cloud formation? The Rima Tenuis rift may appear in the NPC north of Arabia and Nix Olympica.

April 30, diameter 10.0″. NPC retreating; look for its newly exposed sharp dark collar. Do you see any signs of the growing South Polar Hood, tilted mostly out of view, or discrete clouds at spots around the planet?

May 30, diameter 8.0″. Is Mare Acidalium broad and dark now? Can you see bright spots in Arcadia-Tharsis-Amazonis? Local clouds should be increasing.

July 20, diameter 6.0″. NPC greatly reduced. Both polar caps now possibly visible, and look for haze canopy in the south. Clouds elsewhere prominent. Syrtis Major becomes broad.

An April Asteroid Array

Among the first few asteroids to be discovered were 5 Astraea, 6 Hebe, and 8 Flora, all found in the heady asteroid-discovery years from 1845 to 1847. This March and April they move across constellations of the eastern evening sky, glimmering in small-telescope range at 9th and 10th magnitude. All three are moderately large: 80 to 125 miles (130 to 200 km) across. "Asteroid" means "starlike," and that's exactly how they appear from Earth. Except they move.

Use the charts here to pick them out of the sparse springtime star fields. Boxes on the small key chart show the areas of the zoomed-in blowups. Those cover the period from March 12th, after the Moon is gone from the early-evening sky, through April. During this time Astraea fades gradually from magnitude 9.1 to 10.4 and Hebe from 9.6 to 10.7. Flora holds steady around magnitude 9.8 through March, and then fades to 10.7 by April's end.

Stars are plotted to magnitude 10.5. The asteroids' positions are marked with ticks every four days at 0:00 Universal Time on the dates indicated. In the time zones of the Americas, this falls on the afternoon or evening of the previous date (at 8 p.m. Eastern Daylight Time).

Using the Charts

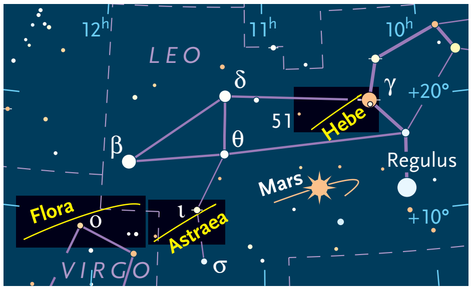
Whenever using star charts with a telescope, first remember that you need to know how wide your finderscope's field of view appears on them. Otherwise you'll be lost. Typical finders have a field about 6° wide. Compare this to the declination scale on the charts' left or right edges.

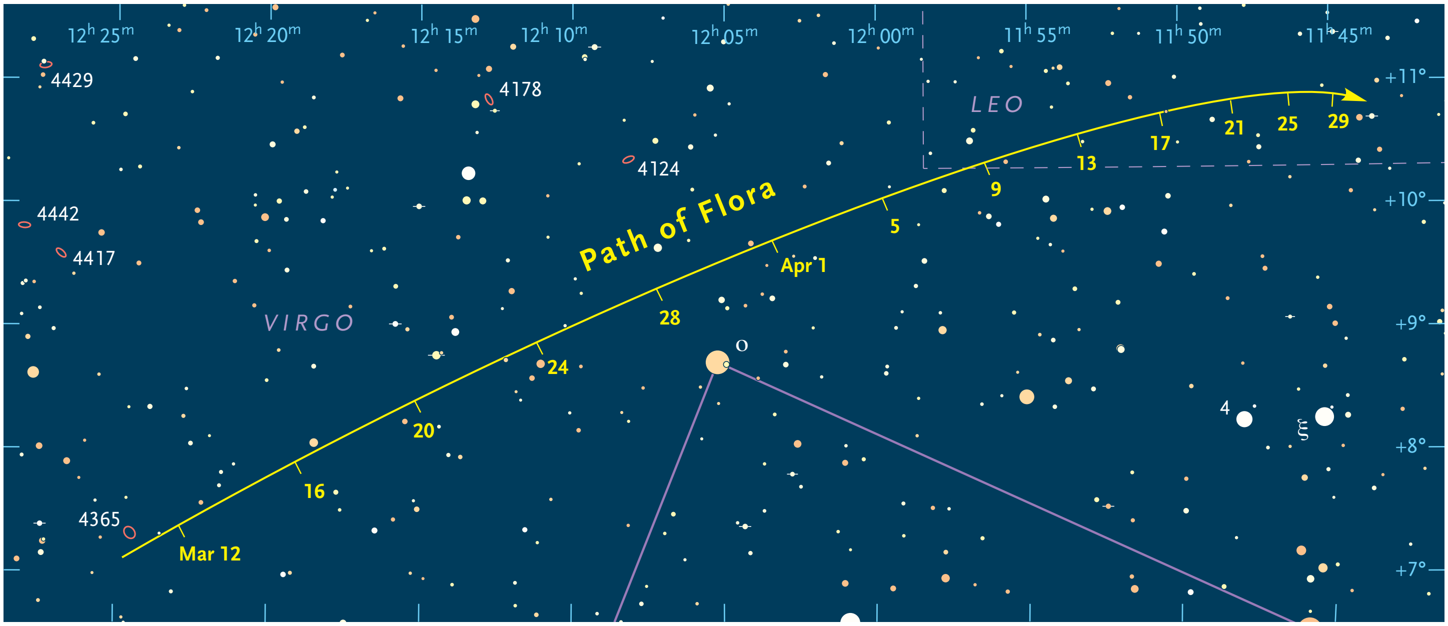
On star charts, north is usually up. To find which way is north in your telescope's or finderscope's view, nudge the scope slightly toward Polaris. New stars will enter the view from the view's *north edge.* Turn the chart around to match.

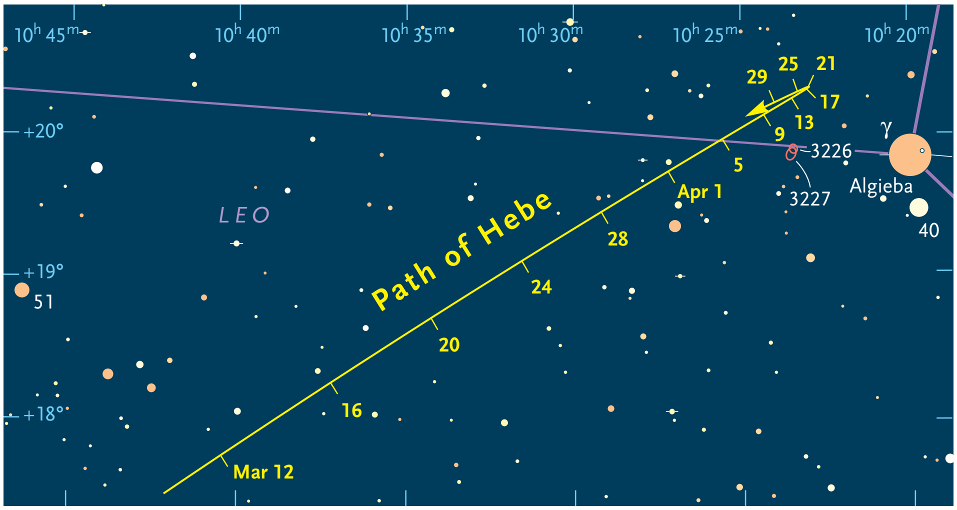
East is left on sky charts. In the view, east is 90° counterclockwise from north if you're looking at a correct-reading view — such as you see in a straight-through finderscope or a Newtonian reflector.

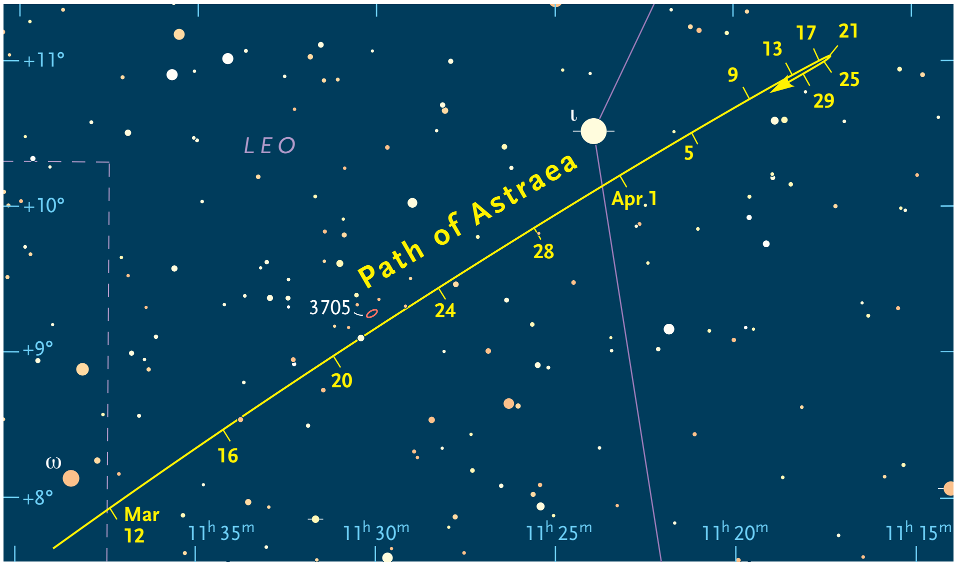
If you have a mirror-image view, as usually comes from using a right-angle star diagonal at the eyepiece, east is 90° *clockwise* from north, and you'll have to flip the chart left-for-right. You can do this in your head (tricky), or scan the chart on a scanner, flip it left-for-right in software, and print out the mirror-image version for use at your scope. Making a printout also allows you to print it as large as you like.

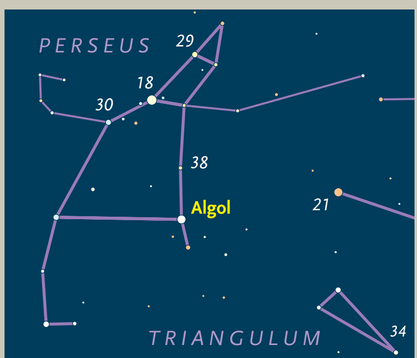
Another key tip: The way to star-hop across a chart to your target location, and across the corresponding scene in your finderscope, is by looking for little triangles and quadrilaterals of the most eye-catching stars — not just lone stars — to compare with your view. Individual stars look alike, but every triangle is unique. ✦











Algol, the prototype eclipsing variable star, fades every 2.87 days from its usual 2.1 magnitude to 3.4 and back. It stays near minimum light for two hours, and it takes several additional hours to fade and to rebrighten. Shown above are magnitudes of comparison stars (with the decimal points omitted). Predictions at right courtesy Marvin Baldwin.

Minima of Algol

Mar.	UT	Apr.	UT
3	5:36	3	18:38
6	2:25	6	15:28
8	23:15	9	12:17
11	20:04	12	9:06
14	16:53	15	5:55
17	13:43	18	2:44
20	10:32	20	23:34
23	7:21	23	20:23
26	4:11	26	17:12
29	1:00	29	14:01
31	21:49		

Lyrid Meteors

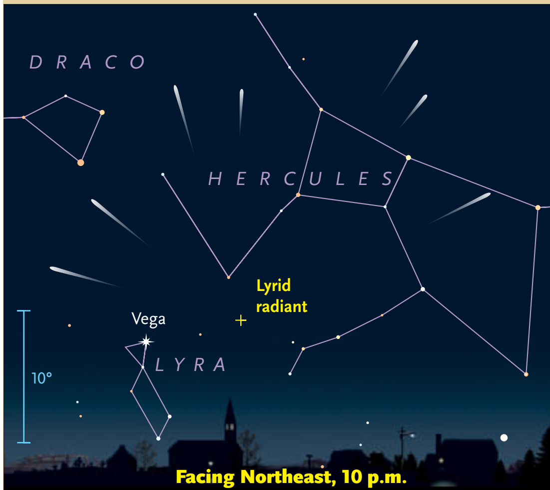
No moonlight will interfere with this April's Lyrid meteor shower. The Lyrids are due to peak on the morning of April 22nd, perhaps around 5^h or 6^h UT according to the International Meteor Organization — excellent timing for observers in North America. But what the shower will actually do remains unknown.

It probably won't do much. The Lyrid shower usually produces only about a dozen meteors visible per hour under dark skies even when the radiant point (near Vega) is highest before dawn. But in 1982 the zenithal hourly rate briefly reached 90. Other short outbursts in other years may have gone unnoticed.

There's a slim chance of something extraordinary. In 1803 a newspaper in Richmond, Virginia, wrote of the Lyrid shower:

> Shooting stars. This electrical [sic] phenomenon was observed on Wednesday morning last at Richmond and its vicinity, in a manner that alarmed many, and astonished every person that beheld it. From one until three in the morning, those starry meteors seemed to fall from every point in the heavens, in such numbers as to resemble a shower of sky rockets.

And in 687 B.C., a Chinese chronicler recorded that Lyrid meteors "dropped down like rain."



The Lyrids' radiant point will be up as early as 10 p.m., but meteors are more likely to appear when the radiant is much higher before dawn.

Over the Edge

Lunar librations allow you to observe the farside of the Moon.

There are enough fascinating landforms on the nearside of the Moon to keep even the most active observer enthralled for a lifetime. But the Moon offers a little bit more to see just past the edges. The nearside is the lunar hemisphere defined by the –90° and +90° longitude meridians. These mark the extreme edge of visibility when the Moon is at zero *libration*. That's the term describing the tilting of the Moon that permits us to peek beyond the 90° limits. There are three main kinds of librations. Lunar cartographer Antonin Rükl compared two of these effects to shaking your head left and right in a "no" gesture and nodding up and down to signal "yes." The librations allow us to see up to about 10° beyond the nearside's east and west limbs, and past the poles by about 6°.

Librations in longitude are due to the Moon having a slightly eccentric orbit. As Johannes Kepler discovered, an object's speed varies along an elliptical orbit. When the Moon is close to Earth, it travels faster than when it's more distant. But the Moon's rotation on its axis is constant. These two factors mean that sometimes the Moon is ahead or behind its average position, so parts of its east or west limbs are more, or less, visible. If the lunar orbit were circular, there would be no longitudinal librations — the Moon also wouldn't appear noticeably bigger because of being closer.

The Moon's "yes" noddings are due to its equatorial plane being tipped about 6.5° compared to its orbital plane around Earth. This means that each pole alternately tilts toward and away from Earth.

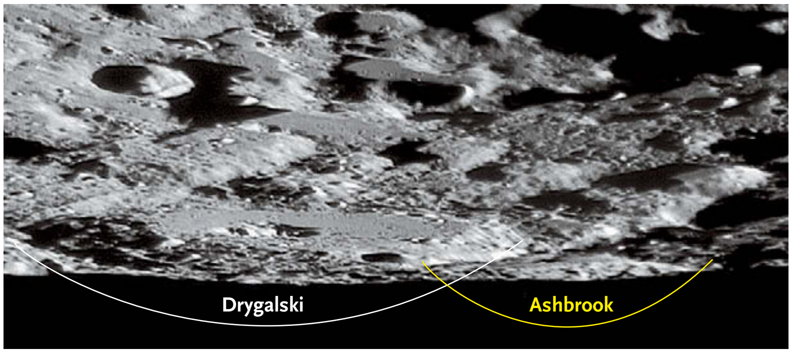
The third type of libration depends on our observing position on Earth. At moonrise, we observe from one edge of Earth as seen from the Moon, and at moonset we look from the opposite Earth limb. Our observations of the rising and setting of the Moon are vantage points separated by roughly 7,900 miles (Earth's diameter), allowing us to see a little farther beyond the Moon's east and west limbs. This is the smallest libration, but one noticeable at full Moon if you observe all night.

All of these motions interact in a complicated pattern so that each time we see the Moon there is a slightly different view of the limb regions. The lighting angle also changes constantly, so often a particularly favorable libration frustratingly occurs when that limb is in shadow. All of these constant changes make every observing session delightfully different, and seeing a farside feature even more of a treat. You can plan libration observations well in advance using the libration chart in this magazine to see which part of the limb will be best exposed.

So what are some of the grand sights lying beyond the nominally limiting 90° longitudes? A great place to start is the Orientale Basin, the giant bull's-eye whose center is at 93° east, just beyond **Montes Rook** (the Rook Mountains). During particularly excellent western librations you can see across the dark lavas of **Mare Orientale** to the other side of the circular Rook Mountains at about 112° east. This is well beyond the maximum 10° of libration because the farside Rooks rise high above the average surface elevation.

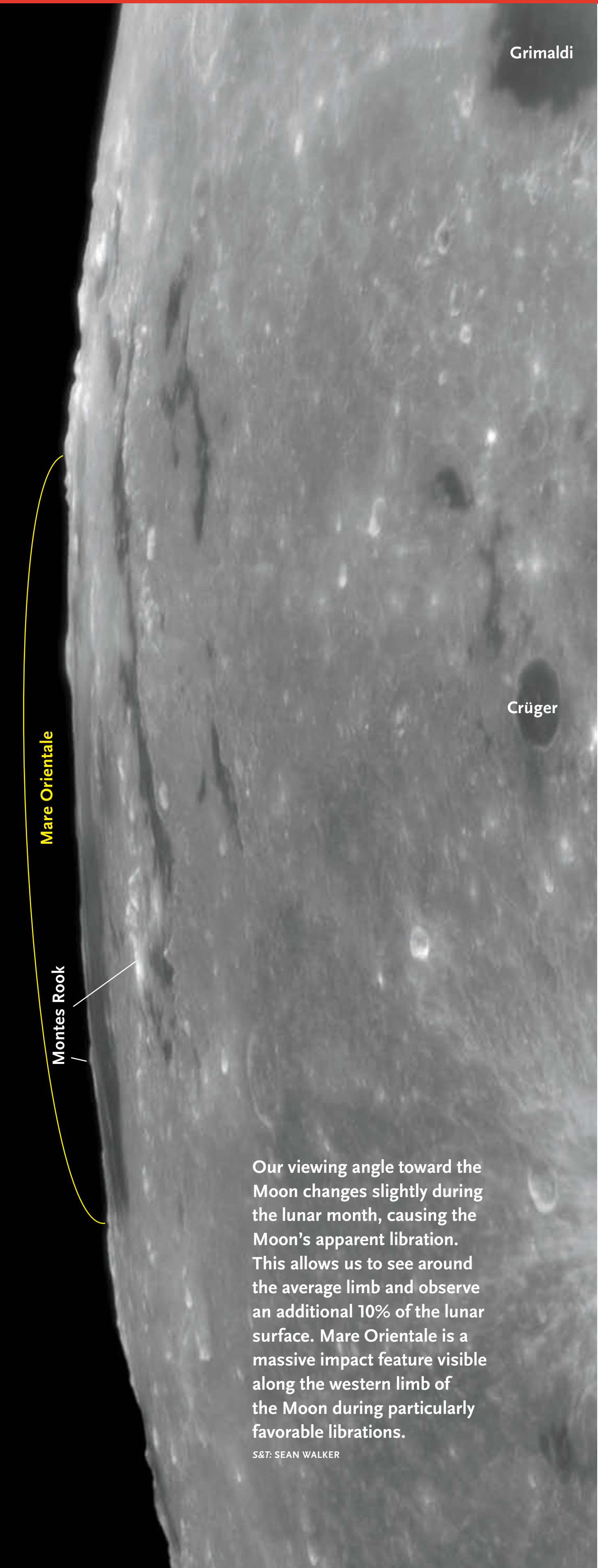
A similar circumstance occurs on the almost diametrically opposite limb of the Moon at **Mare Humboldtianum**. Here again a relatively small patch of dark mare lavas sits on the nearside edge, but with a good eastern libration you can see the farside rim of the 123-mile-wide (198-km) crater **Bel'kovich**. Even rarer is to spy the central peak of the farside crater Compton that can be seen in profile 15° beyond the nominal limb.

The poles also provide extreme opportunities. The most dramatic are near the South Pole, due to the great number of deep craters and mountains interspersed with shadows. Along the southwest limb the 90° line passes near the centers of the large craters **Hausen** and **Drygalski**. With luck you may glimpse 97-mile-wide (156-km) **Ashbrook**, a crater just beyond Drygalski named for the late *Sky & Telescope* editor in chief Joe Ashbrook. If you can see Joe's crater, or the far rims of Hausen and Drygalski, you are definitely an experienced farside explorer. ✦



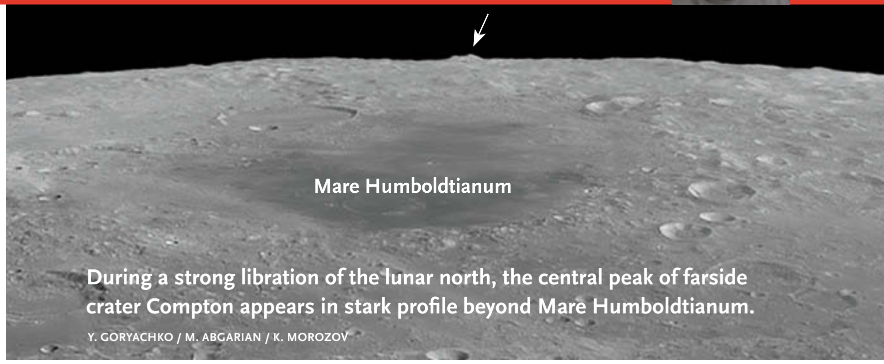
HARALD PALESKE

The large crater Drygalski is often visible along the lunar limb just east of the Moon's south pole, but just beyond the crater and to its right is the rarely seen crater Ashbrook, visible only during very strong southern librations.



Our viewing angle toward the Moon changes slightly during the lunar month, causing the Moon's apparent libration. This allows us to see around the average limb and observe an additional 10% of the lunar surface. Mare Orientale is a massive impact feature visible along the western limb of the Moon during particularly favorable librations.

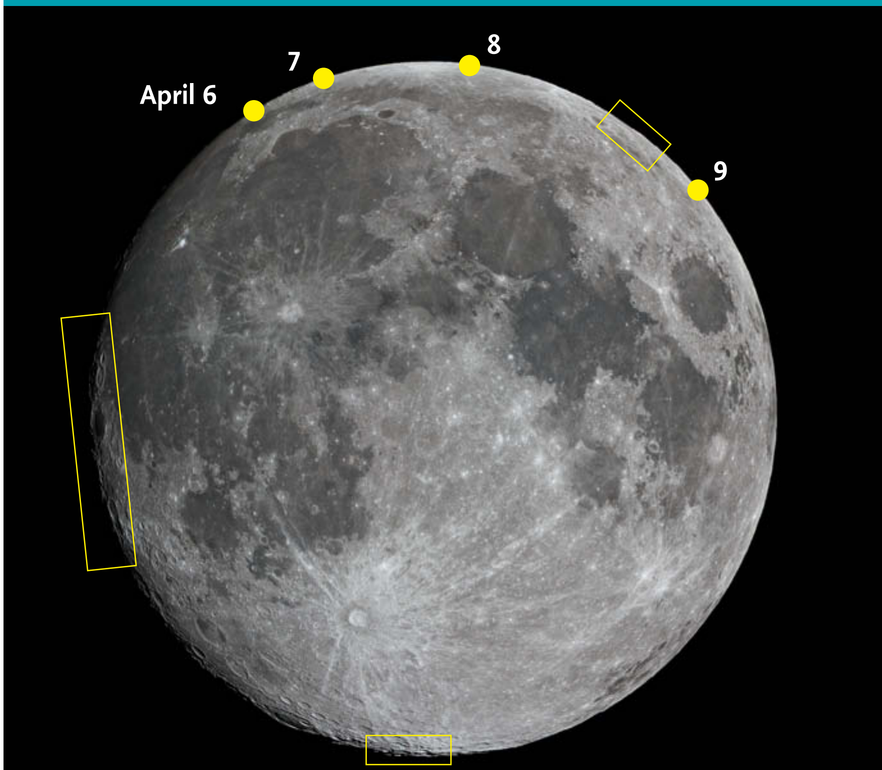
S&T: SEAN WALKER



During a strong libration of the lunar north, the central peak of farside crater Compton appears in stark profile beyond Mare Humboldtianum.

Y. GORYACHKO / M. ABGARIAN / K. MOROZOV

The Moon • April 2012



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

S&T: DENNIS DI CICCO

Phases

FULL MOON	LAST QTR MOON	NEW MOON	FIRST QTR MOON
April 6 19:19 UT	April 13 10:50 UT	April 21 7:18 UT	April 29 9:57 UT

Distances

Perigee	April 7, 17h UT
225,912 miles	diam. 32′ 52″
Apogee	April 22, 14h UT
250,195 miles	diam. 29′ 41″

Librations

Babbage (crater)	April 6
Pascal (crater)	April 7
Challis (crater)	April 8
Endymion (crater)	April 9

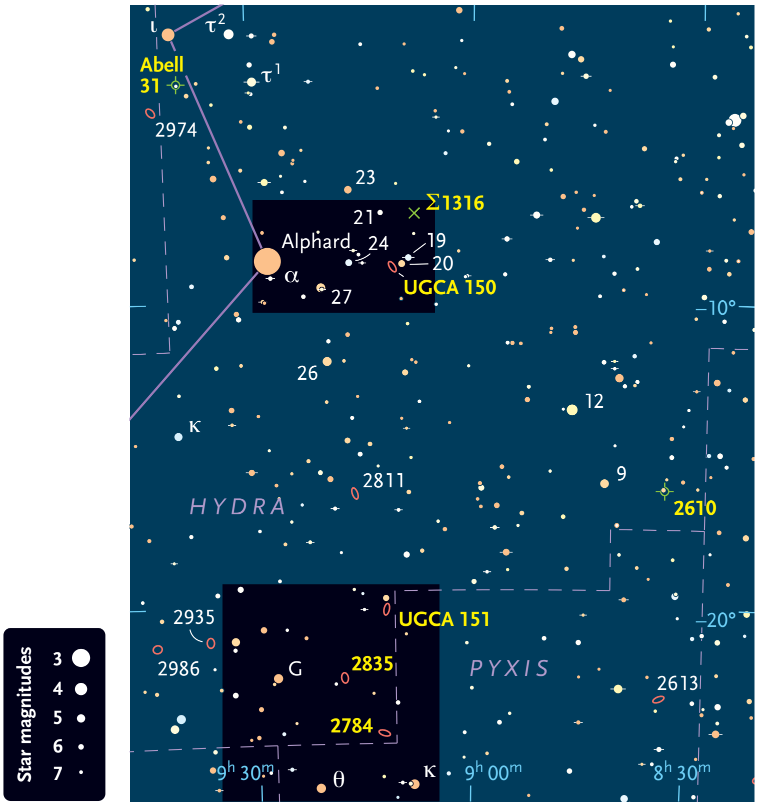
Hydra's Coils

Western Hydra hosts some remarkable galaxies and nebulae.

The Hydra next her giant length extends —
Around the Centaur's head her tail she bends.
Above her coiled back the Lion stands —
Close o'er her glittering head dark Cancer hangs.
On the mid coil a Goblet rests — below,
As pecking at her skin, the crafty Crow.
— Aratus, *Phaenomena*

This passage relates the phenomenal length of Hydra, the Water Snake, as she coils beneath Cancer, Leo, and Virgo; carries Crater and Corvus on her back; and taps Centaurus on the head with her tail. We know Hydra is a female serpent because of her feminine name. The celestial vault also bears a male water snake, Hydrus, in the sky's deepest south.

Let's explore the region of Hydra near her brightest star, saffron Alpha (α) Hydrae, also known as Alphard. Look for 6th-magnitude 21 Hydrae 4° west-northwest of Alphard, and then sweep 1° west to the lovely triple star



Struve 1316 (Σ1316). The 8.8-magnitude primary star looks yellowish through my 105-mm refractor at 47×. It sits at the center of a tight little arc formed with companions 7.5″ west and 7.3″ southeast, magnitude 9.9 and 10.7, respectively. The fainter attendant is just visible, but it stands out much better at 87×. I tried to determine the colors of the companions with my 10-inch reflector. The brighter one may be deep yellow and the fainter one orange, but it's difficult to be sure. What colors do you see?

Struve 1316 and 21 Hydrae share a finderscope field with 19 and 20 Hydrae to the south, each about magnitude 5½. A short hop 19′ east-southeast from yellow 20 Hydrae takes us to the flat galaxy **UGCA 150**. Flat galaxies are disk-shaped systems, with little or no central bulge, that we view edge-on from our vantage point on Earth. I find their slender profiles charming, even though most aren't particularly bright. Indeed, UGCA 150 is barely visible through my 105-mm scope at 87×. This ashen, 2½′-long streak of light tilts north-northeast and leans against a faint star ¾′ northeast of its center. A much brighter star rides the opposite flank, west of center, and hampers our view. UGCA 150 lengthens to 4′ through the 10-inch scope at 170×. The faint star looks peculiar, and boosting the magnification to 220× shows that it's actually a star pair.

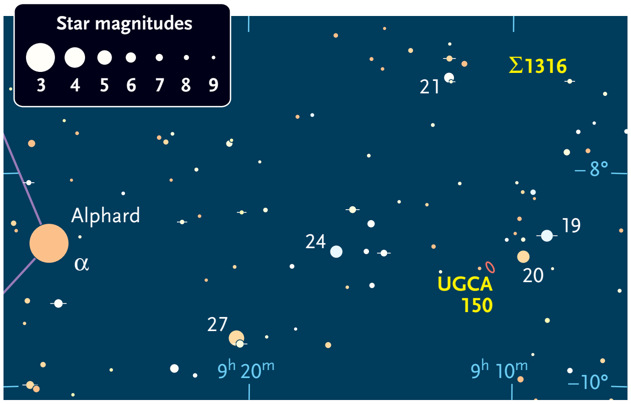
UGCA denotes galaxies listed in the *Catalogue of Selected Non-UGC Galaxies*, sometimes called the *Uppsala General Catalogue Addendum*.

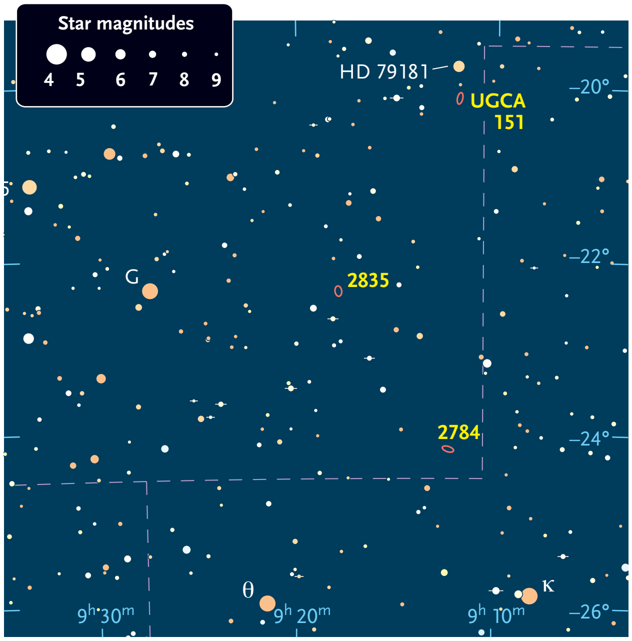
Now we'll zig southwest to the planetary nebula **NGC 2610**, which lies 2° west of golden 9 Hydrae. In the 105-mm refractor at 87×, this nebula appears small and round. It decorates the northern arm of a pretty seven-star V, 10′ tall with curved sides. The brightest and northernmost star has a golden hue and sits 3.4′ northeast of the planetary. A very faint star pins the planetary's northeastern rim, and a line of three faint stars cuts crossways between the nebula and its golden neighbor. Upping the magnification to 122x makes the superposed star much easier to see.

With a narrowband or O III filter, the 10-inch scope at 220× shows traces of annularity in NGC 2610. The view is very nice in my 15-inch reflector at 135× through an O III filter. The nebula is somewhat darker in the center and about ¾′ across. Although I could not, some observers with telescopes this size are able to spot the planetary nebula's dim central star. Can you?

Sue French *observes the deep sky from her semirural backyard in upstate New York. She always welcomes questions and comments at scfrench@nycap.rr.com.*

Sue French






POSS-II / CALTECH / PALOMAR OBSERVATORY

The planetary nebula NGC 2610 is the large, overexposed circular blob with no diffraction spikes. The field of view is 23′ wide and 30′ long.

Zagging east-southeast to the yellow 5.7-magnitude star HD 79181 takes us to the neighborhood of **UGCA 151**, probably the flattest galaxy I've ever seen. Look for it 22′ south of the star. UGCA 151 isn't a small-scope target, but I find it quite lovely through my 10-inch under dark skies. At 208× it's exceedingly slender and leans a bit west of north. There's a very faint star in the southern tip and another superposed north of center, each about 15th magnitude. The galaxy's ghostly slash cuts across 3′ to 3½′ of sky. Brightness variations along its length together with its subtle core and superposed stars conspire to make UGCA 151 look like a beaded silken string.

UGCA 151 is classified as an Scd galaxy. Such galaxies have diminutive cores and loosely wound, chaotic spiral arms dominated by individual star-forming regions. Both UGCA 151 and UGCA 150 are roughly 100 million light-years distant.

The much brighter galaxy **NGC 2835** rests 2.6° south-southeast, where it marks the tip of a 19′ isosceles triangle that it makes with two stars, magnitude 7 and 8. My 105-mm refractor at 28× shows a little fuzzy spot with 10th-magnitude stars lying a few arcminutes west and southeast. At 47× it becomes obvious that this is only the core of the galaxy, which now occupies the heart of a slightly dimmer north-south oval. A faint star east of the core closely guards the oval's flank. At 87× the galaxy grows large enough to wear the faint star as an ornament for its edge. From the little eyepiece sketch in my notes, the galaxy seems to cover approximately 4½′ × 3′. In the 10-inch reflector at 213×, NGC 2835 is about 5′ long and includes a very faint star in its southern tip.

Photographically, NGC 2835 is a stunning galaxy dominated by two pairs of spiral arms. You may be able to trace out their most prominent arcs with a 16-inch or larger telescope.

Ronald J. Buta and his coauthors write in *The de Vaucouleurs Atlas of Galaxies*, "NGC 2835 is an excellent example of type Scd in our view." Thus, UGCA 151 would look similar if we viewed it face on, except that NGC 2835 is only one-third as far away.

The lenticular galaxy **NGC 2784** lies 2.2° southwest of NGC 2835 and 1.9° north-northeast of Kappa (κ) Pyxidis. Through my 105-mm refractor at 28×, it's ensconced in a 10′ right triangle formed by three 10th-magnitude stars. NGC 2784 leans east-northeast and shows a bright oval core enveloped by a faint halo. A magnification of 87× adds a stellar nucleus and a very faint star on the northern side of the eastern tip. The galaxy spans about 5′ × 1¾′.

Lenticular galaxies, such as NGC 2784, are highly flattened disks without spiral arms. They take their name from the fact that they look like double-convex lenses when viewed edge-on.

Let's zoom back northward, past Alphard to yellow-orange Iota (ι) Hydrae. From there we'll drop 1.7° south to our final target, the planetary nebula **Abell 33** (PK 238+34 1). Here you'll find a 19′-tall, upside-down Y of four 7th- to 9th-magnitude stars, the brightest marking the fork of the Y. When I swept up the Y with my 130-mm refractor at 23×, I was surprised that I could see the nebula immediately without checking its exact position. Most Abell planetaries are more difficult to spot. The Y's brightest star nuzzles the south-southwestern edge of the nebula. A narrowband filter offers some improvement in contrast, while an O III filter gives a better boost. At 63× Abell 33 is about 4½′ across, and a faint star adorns its north-northwestern rim.

California stargazer Eric Graff sketched the extremely subtle planetary nebula Abell 33 as it appeared through his 6-inch scope and an O III filter at 45×. The field of view is 70′ wide.

With the help of an O III filter, Abell 33 appears round and subtly annular through the 10-inch scope at 118× and the 15-inch at 133×. The latter also reveals a companion to the faint star on the north-northwestern rim.

Under dark skies, folks have nabbed Abell 33 in telescopes as small as 3 inches in aperture, but I've never heard of the central star being seen in anything less than an 18-inch scope. Let me know how you see Abell 33. ✦

Selected Sights in Western Hydra

Object	Type	Mag(v)	Size/Sep	RA	Dec.
Struve 1316	Triple star	8.8, 9.9, 10.7	7.5″, 7.3″	9h 07.9m	–7° 08′
UGCA 150	Flat galaxy	11.3	6.5′ × 0.7′	9h 10.8m	–8° 53′
NGC 2610	Planetary nebula	12.7	42″	8h 33.4m	–16° 09′
UGCA 151	Flat galaxy	13.4	4.8′ × 0.3′	9h 11.9m	–20° 07′
NGC 2835	Spiral galaxy	10.5	6.6′ × 4.4′	9h 17.9m	–22° 21′
NGC 2784	Lenticular galaxy	10.2	5.2′ × 2.2′	9h 12.3m	–24° 10′
Abell 33	Planetary nebula	12.6	4.5′	9h 39.2m	–2° 49′

Angular sizes and separations are from recent catalogs. Visually, an object's size is often smaller than the cataloged value and varies according to the aperture and magnification of the viewing instrument. Right ascension and declination are for equinox 2000.0.

ROBERT GENDLER

NGC 2835 is morphologically similar to the flat galaxy UGCA 151. But they look very different because we see NGC 2835 face-on and UGCA 151 edge-on.

DID YOU KNOW?

The richest section of the Sky & Telescope website is skypub.com/objects. It contains more than 100 articles on subjects ranging from asteroids and auroras to the Sun and variable stars. They include guides to specific objects, general observing techniques, and historical background.

Great Spring

This season is notable for its many fine binaries.

James Mullaney

This is the final installment of my four-part roundup of attractive doubles. The previous ones appeared in the February, July, and October 2011 issues. Unlike other deep-sky wonders, multiple stars are easily found and observed on all but the worst of nights, and literally thousands of these gems lie within reach of the smallest telescope. Here are a few favorite targets visible in the spring sky.

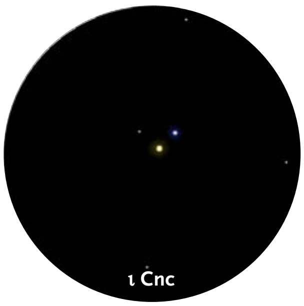
Iota Cancri (ι Cnc) offers a beautifully contrasted combination of pale orange and clear blue suns readily split even in a 2-inch scope at just 25×. This pair reminds many observers of famed Albireo — so several years ago I dubbed it the "Spring Albireo." The well-known double-star enthusiast Sissy Haas considers this "the most striking color-contraster in the sky" and sees the tints as Sun yellow and royal blue.

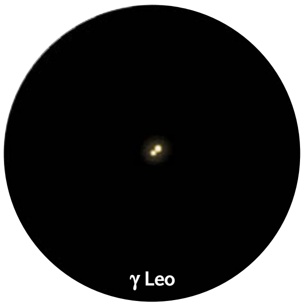
Struve 1266 (Σ1266). This dim roomy pair of stars lies in the same wide eyepiece field with Iota Cancri. But it's often overlooked because it's so much fainter than its neighbor. Can you spot it without consulting our chart?

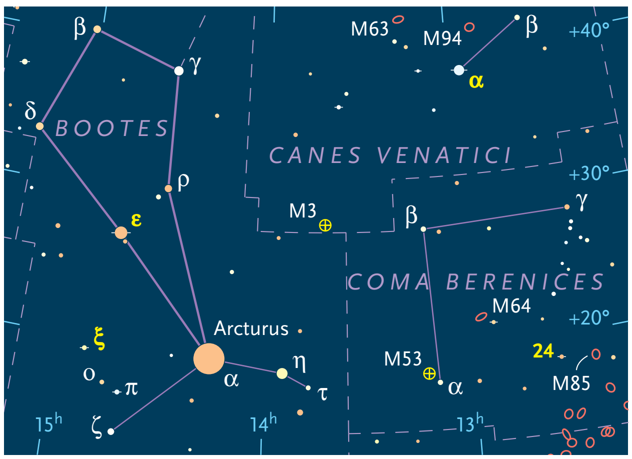
Algieba (γ Leonis) is a superb pair of radiant golden yellow suns that ranks as one of the finest doubles in the sky. Some observers see traces of orange and green here, which I've found to depend upon sky conditions. The 19th-century astronomy popularizer William Henry Smyth called the components bright orange and greenish yellow, while his contemporary Thomas William Webb found them gold and greenish red. Like many bright pairs, this duo is best seen while the sky is not completely dark, reducing glare and making color perception more certain. A 3-inch scope at 100× neatly separates this double, while 150× or more reveals two striking diffraction disks hugging each other.

24 Comae Berenices is justly regarded as a clone of Albireo, though noticeably fainter than that showpiece. The primary is generally described as orange or rich yellow, while the companion has been called aqua, emerald, blue, lilac, and greenish-white. In a 5-inch scope at 50×, I see this pair as orange and emerald. Located amid the many faint lights of a galaxy-rich region, this lovely pair is certainly well worth searching out.

Porrima (γ Virginis) is one of the most famous and dynamic binary systems in the heavens, with an orbital period of 169 years. Once a bright easy pair for small scopes, its two suns began noticeably closing up in the mid-1990s and became a challenge to resolve in backyard telescopes by 2000. Now slowly opening from their closest

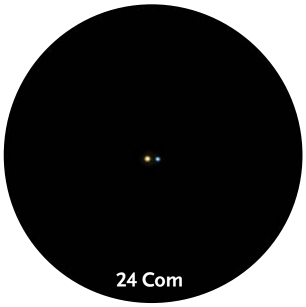


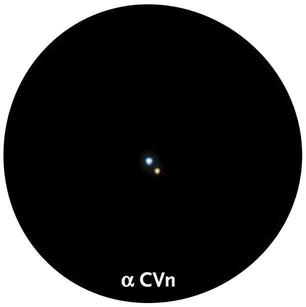


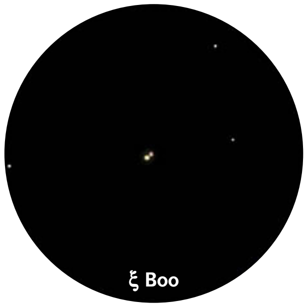


The main chart and the close-up of Cancer show stars to magnitude 5.5 and 8.5, respectively. Look on the center star chart on page 44 for stars not shown in these charts. All sketches here were prepared by Arizona stargazer Jeremy Perez based on his views through a 6-inch reflector at 240×.

Double Stars







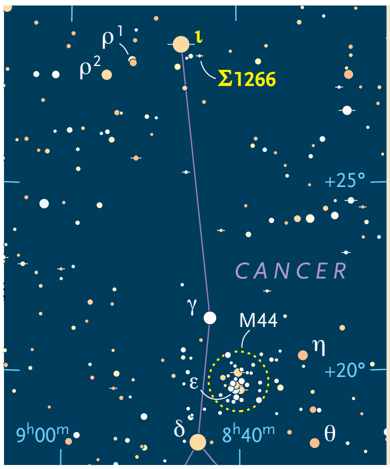
approach in 2005 (when their images appeared to merge!), they are currently separated by 1.8″ and can be split in 4-inch scopes given good seeing.

Cor Caroli (α Canum Venaticorum) is a striking unequal pair in even the smallest telescope. There's a subtle color contrast between the stars but it's not easy to pin down. While most see the primary as bluish white, the companion has been reported to look pale lilac, pale orange, pale copper, pale red, pale olive blue, sea-green, and even tawny in hue. Defocusing the image slightly may help color perception by spreading the light of the stars over a larger area of the retina.

Izar (ε Boötis) is a superb gold and blue-green tight pair that moved the great double-star astronomer Wilhelm Struve to call it Pulcherrima, meaning "the most beautiful one." Among the colors seen here by various observers are light yellow, amber yellow, gold, pale orange, and orange for the primary; and green, blue, deep blue, blue-green, marine-blue, and sea-green for the companion. Using magnifications of 150× or higher on 3- to 4-inch telescopes (to reveal the stars' diffraction disks) may help color perception. Good seeing is needed for a clean split in small scopes. On such nights, I can detect the companion at 75× in my 5-inch SCT, and it's definitely resolved at 100×.

Xi Boötis (ξ Boo) is a double that leaves little uncertainty about its hues — they're yellow and reddish purple in all apertures I've used, ranging from 2 to 14 inches. Words like "breathtaking," "unforgettable," and "enchanting" are just some of the superlatives this combo has evoked. At least one observer has mentioned that the companion sometimes glows with an eerie reddish-violet light — something that I've also seen on occasion. Lying just 22 light-years from us, it's an exquisite sight in a 6- or 8-inch aperture at magnifications of 50× or higher. ✦

James Mullaney, coauthor with Wil Tirion of The Cambridge Double Star Atlas, *has been observing these stellar gems for more than 50 years.*



Double Stars of Spring

Name	Alias	Mag.	Sep.	PA	RA	Dec.	Dist.	Period
ι Cnc	—	4.1, 6.0	31″	310°	8h 46.7m	+28° 46′	300 l-y	—
Σ1266	—	8.8, 10.0	24″	68°	8h 44.5m	+28° 27′	—	—
γ Leo	Algieba	2.4, 3.6	4.6″	126°	10h 20.0m	+19° 50′	130 l-y	510 years
24 Com	—	5.1, 6.3	20″	271°	12h 35.1m	+18° 23′	400 l-y	—
γ Vir	Porrima	3.5, 3.5	1.8″	13°	12h 41.7m	–1° 27′	38 l-y	169 years
α CVn	Cor Caroli	2.8, 5.5	19″	229°	12h 56.0m	+38° 19′	120 l-y	—
ε Boo	Izar	2.6, 4.8	2.9″	343°	14h 45.0m	+27° 04′	200 l-y	—
ξ Boo	—	4.8, 7.0	5.9″	306°	14h 51.4m	+19° 06′	22 l-y	150 years

Sean Walker

The Imaging Source DMK 21AU618.AS

Is this the best planetary camera yet from Imaging Source?

S&T: SEAN WALKER

The Imaging Source DMK 21AU618.AS

U.S. price: $490, including PC control software, USB cable, and 1¼-inch nosepiece
The Imaging Source
6926 Shannon Willow Rd., Suite 400, Charlotte, NC 28226
Phone: 704-370-0110, www.astronomycameras.com

WHAT WE LIKE:

Compact, lightweight design

Easy to use

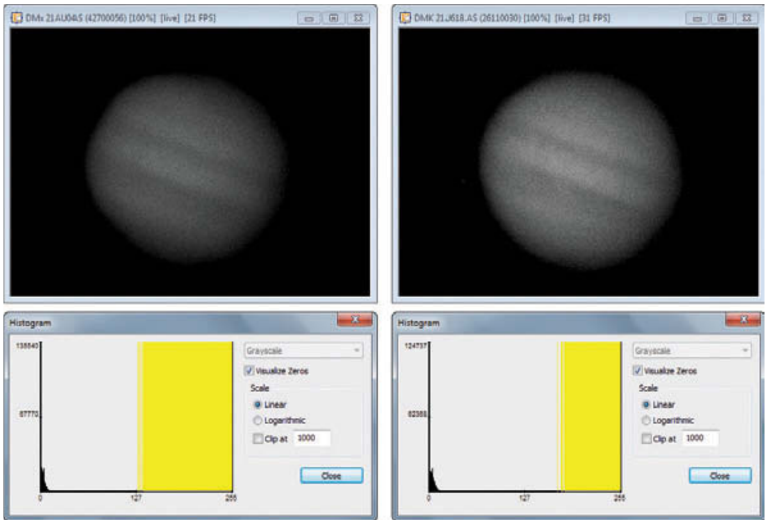
WHAT WE DON'T LIKE:

Short USB cable

JUST WHEN I THINK that planetary imaging has reached its zenith in both camera abilities and quality of achievable results, something new comes along. For several years we've had lightning-fast cameras that record video at 60 frames per second (FPS) and automatic stacking programs that "freeze" moments of steady seeing captured by these videos to reveal planetary details with resolutions approaching ¼ arcsecond. As good as this is, planetary imagers always long for more, and now the Imaging Source has delivered with its new DMK 21AU618.AS video camera.

Much like its predecessor, (the DMK 21AF04.AS reviewed in our October 2007 issue, page 36), the new camera is a compact 2-inch-square design. It connects to a Windows-based PC computer using an included USB cable, and it fits in any 1¼-inch telescope focuser using the C-to-1¼-inch nosepiece that's also included. One minor quibble: the USB cable is only 5 feet (1.5 meters) long, which is too short to be useful with most Newtonian telescopes that have their focusers high off the ground when imaging planets near the meridian. I replaced the cable with a 10-foot Belkin Gold USB cable I picked up at a local computer store.

The big change with this camera is its new Sony ICX618ALA CCD detector, which boasts higher sensitivity across the visible spectrum, and especially at red wavelengths, compared with the ICX098BL chip in the



S&T: SEAN WALKER

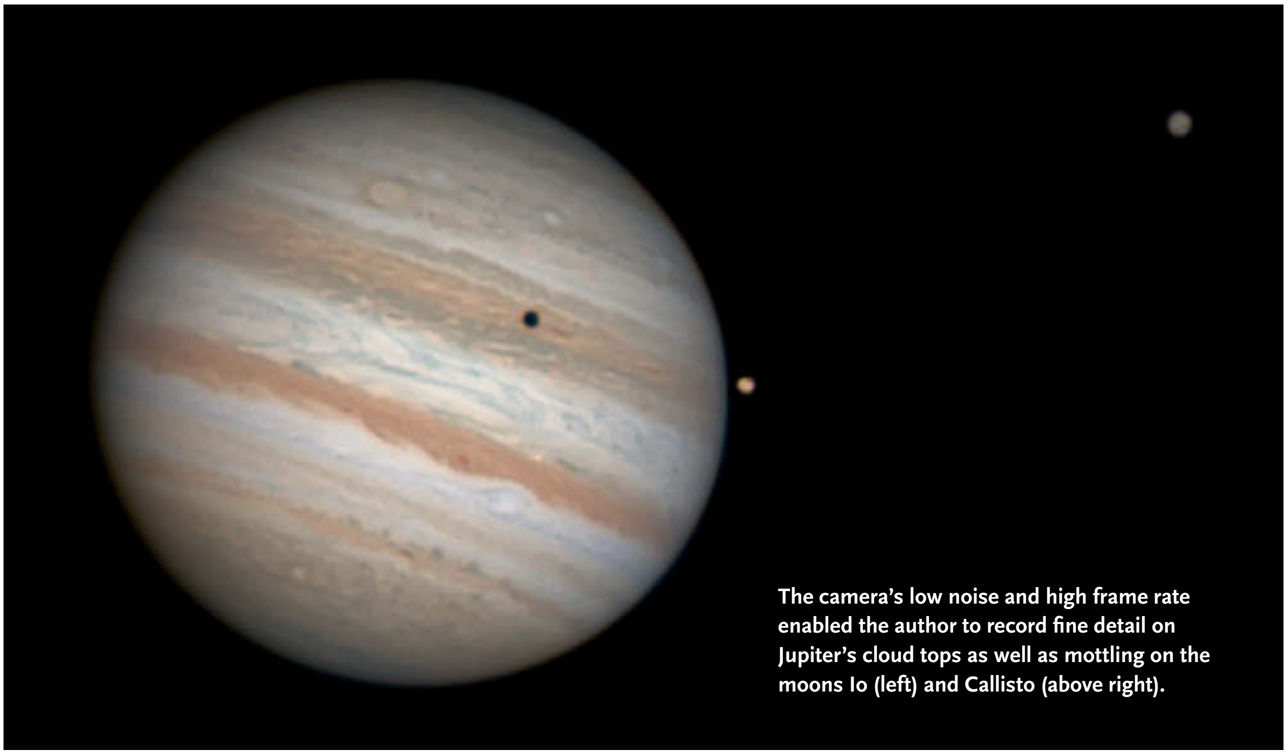
Though physically identical to its predecessor, the Imaging Source's new DMK 21AU618.AS video camera is significantly more sensitive, especially at the red end of the spectrum. These back-to-back recordings of Jupiter made through a red filter and the author's 12½-inch reflector show that the old camera (*far left*) produces a fainter image and less data as indicated by the greater portion of the histogram showing zeros (yellow area).

original camera. The new camera records brighter images than the original when shooting at the same image scale, reducing the need for high gain settings that create noisy image stacks.

At the telescope, the new camera performs almost exactly like the old one. It's capable of recording uncompressed AVI video streams at rates as high as 60 FPS. But to take advantage of this huge data stream, your computer should have a 7,200-RPM hard drive in order to avoid dropping frames during recording.

I found the 21AU618.AS to be noticeably more sensitive than its predecessor, enabling me to use lower gain settings when capturing videos of Jupiter and Mars. This difference was particularly dramatic in red and near-infrared wavelengths. The sensitivity increase was less apparent at green wavelengths, and it was hardly noticeable when I was shooting through blue filters.

There's a difference in the new camera's handling of planet video streams recorded at 60 FPS. Users of the older camera often noticed a limb artifact on planetary videos that appeared as a dark curve inside the left edge of the planet's image — it looked a bit like a sharpening artifact on a stacked image, though it appeared in every frame in the raw video. This limb artifact was less appar-



The camera's low noise and high frame rate enabled the author to record fine detail on Jupiter's cloud tops as well as mottling on the moons Io (left) and Callisto (above right).

S&T: SEAN WALKER

ent when shooting lunar and solar video clips at 60 FPS. With the new camera, I found no sign of the artifact on videos I made of Jupiter and Mars at 60 FPS. At the time of this review, Saturn was too low to shoot in the morning twilight.

The new model comes with the camera-control and video-recording program *IC Capture.AS* version 2.2.315.1235. The software performs its assigned task of recording AVI video streams to my computer without problems. One feature that I'd like to see added to future updates of the program is the ability to store various camera settings and file-name prefixes. With the current version of *IC Capture.AS*, every time I switched to a different color filter I had to manually adjust the camera's gain settings to achieve proper exposure and re-title the video file with a prefix that reflects which filter I was using. The software automatically numbers each video sequentially as they are recorded, but I had to be mindful of which filter was used for each video clip and re-title them accordingly at the end of my observing session.

Like all Imaging Source cameras, the DMK 21AU618.AS records 8-bit data, which means that more total frames may be required to produce the smoothest stacked result when compared with cameras that generate 12-bit data. But the end result is essentially the same; exquisite, highly detailed images of our solar system neighbors. Though I only tested a monochrome version of the camera, a one-shot color version is also available. In addition to USB, there are camera models with Firewire and high-speed GigE computer interfaces available from the manufacturer and its dealer network.

The camera's only shortcoming is its relatively small chip size. Often when imaging the Moon, I lamented the camera's limited field of view.

The DMK 21AU618.AS is currently among the most sensitive planetary cameras on the market. Its compact design

Quick Look *Dennis di Cicco*

Explore Scientific's Hyperwide Eyepiece

9-mm 120° Eyepiece

U.S. price: $999.95
Explore Scientific
621 Madison St.
Springdale, AR 72762
Phone: 877-385-1669
www.explorescientific.com

Explore Scientific's new 9-mm 120° "hyperwide-field" eyepiece comes with extraordinary bragging rights. Foremost is the 120° apparent field of view — the largest ever offered by an astronomical eyepiece. Next is the 2.80 pound (1.27 kg) weight, which makes it the heaviest mass-marketed eyepiece in existence. Last, and most dubious, is the $999.95 street price (list price — and I hope you're sitting down — is a whopping $1,499.95). If there's a more expensive eyepiece available today, I haven't heard about it.

For several weeks last January I got to play with this King Kong ocular. If you've looked through any of today's 100° eyepieces, you know that they have huge apparent fields. But even by that standard, the field in Explore's 120° eyepiece is shockingly larger. Its edge is so far off in my peripheral field of vision that I only have a sensation of its presence rather then the feeling that I'm seeing the edge directly. This had a dramatic affect on my deep-sky observing experience, but, for now, just hold that thought.

I tested the eyepiece on a variety of scopes, including three 4- and 5-inch-caliber refractors ranging from f/5 to f/11, a 12½-inch f/5 Dobsonian, and a 16-inch f/10 Schmidt-Cassegrain. The eyepiece's optical performance was similar on all of them. I had to add a counterweight to the Dob to prevent it from nosediving under the weight of the eyepiece. The weight was also an issue for

S&T: DENNIS DI CICCO

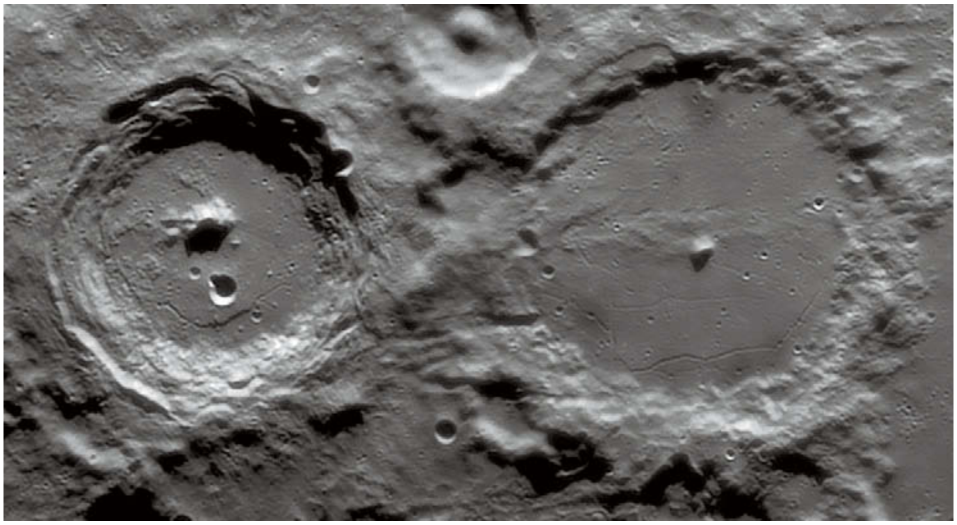
WHAT WE LIKE:
Deep-sky "Wow" factor

WHAT WE DON'T LIKE:
Not multi-purpose eyepiece

Explore Scientific's premium wide-field eyepieces dwarf a conventional 1¼-inch ocular, but this picture only hints at how much larger the new 9-mm 120° model (left) is compared with its 14-mm 100° cousin. Although this pre-production sample of the 9-mm eyepiece is marked "nitrogen-purged," inert argon gas is being used for the production models.

and intuitive control software make it a pleasure to use. It's the one I'm reaching for to image the current apparition of Mars and the one I'll be using for the upcoming transit of Venus in June.

S&T imaging editor ***Sean Walker*** *is an avid lunar and planetary photographer living in New Hampshire.*



S&T: SEAN WALKER

High-resolution close-ups of the Moon often require stitching multiple frames together to cover larger craters. This four-frame mosaic of Arzachel (left) and Alphonsus was made with the DMK camera during the first-quarter Moon last December.

the focuser on one of the refractors, which would slip when the scope was aimed high in the sky.

Although the eyepiece was engraved with serial number 1, Explore's Scott Roberts told me the unit is a pre-production sample that is identical to the production eyepieces, which should be available by the time you're reading this review. Like Explore's 100° eyepieces, the 120° model has all air-to-glass surfaces multi-coated, and it's waterproof, but it's purged with argon rather than nitrogen. The eye relief is only 13 millimeters, so this eyepiece is best for people who don't wear glasses when they observe.

Given the competition among telescope manufacturers, it's reasonable to assume that breaking the 100° barrier for an astronomical eyepiece has presented significant obstacles, especially since Explore Scientific is only the second company to do it (the first being Tele Vue, which introduced its 110° 3.7-mm Ethos-SX two years ago). Whatever compromises Explore's optical designers considered in achieving the 120° field, it seems that the image quality of stars wasn't one of them. The eyepiece offers very good star images across its field.

Under critical examination, the 120° Explore eyepiece reveals a modest amount of pincushion distortion. This causes the Moon and planets to appear slightly distorted at the edge of the field, and when you're sweeping the sky, stars appear to move more slowly at the edge of the field than they do at the center.

The eyepiece's most significant aberration, however, is lateral color, which some observers have dubbed a "ring of fire" in other wide-field eyepieces. Looking into the eyepiece with a telescope pointed toward a daytime sky shows an orange rim near the edge of the field. I too have experienced this with other wide-field eyepieces, but I can't recall one showing the effect more than the 120° Explore. It isn't a fatal flaw, especially for deep-sky observing, but you'll certainly be aware of the lateral color if you use the eyepiece during the daytime.

So what does all this mean for observers? Well, at the expense of being blunt, the 120° Explore wouldn't be my first choice for looking at birds during the day. And there are also far less expensive 9-mm eyepieces that are great for the Moon and planets.

The 120° Explore's real forte is deep-sky observing, and perhaps the best way to explain why is to relate an anecdote from my first night using the eyepiece under a moonless sky with the 16-inch Schmidt-Cassegrain. Fitted with the 120° Explore eyepiece, this scope yields a magnification of 450× and a true field almost 19 arcminutes across. My first target was the brilliant star Rigel. There were no ghost images or flare, making it extremely easy to resolve Rigel's 7th-magnitude companion 9 arcseconds south-southwest of the primary. The lateral color wasn't visible against the sky's dark background.

Then I slewed to the Orion Nebula, M42. Looking into the eyepiece I literally uttered out loud "Oh Wow!" All six stars in the Trapezium were immediately visible, thanks to the high magnification. But even more impressive was the vast and detailed expanse of bright nebulosity surrounding them in the same field of view. Because the edge of the field just drifted away in my peripheral vision, there were moments when I felt I was among the stars and not looking at them through a telescope. It was a stunning view.

I also examined M42 with Explore's 100° 14-mm eyepiece, which has a slightly wider true field (I measured the field stops in the 9- and 14-mm eyepieces as 22 and 24½ mm, respectively). But the 14-mm dropped the magnification by 35%, greatly reducing the "Wow factor" that I experienced with the 9-mm eyepiece. The same was true for my views of the planetary nebula at the edge of the open cluster M46 and the Eskimo Nebula.

Viewing deep-sky objects with high magnification is not a new concept, but doing it with a big chunk of surrounding sky in the same field adds more to the experience than I was expecting. The feeling of being "in" the field of view, rather than just looking at it, was truly singular. I'm looking forward to hearing how others react to their views through the 120° Explore eyepiece. ✦

Every winter since 1963, senior editor ***Dennis di Cicco*** *has taken time to enjoy the Orion Nebula.*

A Beauty of a Binoscope

Superb design and craftsmanship yield big results.

Two of my great astronomical joys are binocular observing and making gear. I also admire builders who can turn out equipment with so much skill and polish that it makes my stuff look like it's the product of caveman technology. So it's probably easy for readers to imagine why I find the binocular telescope by fellow Victoria, British Columbia, telescope maker James Stilburn so appealing. It's both exquisitely functional *and* beautiful.

My focus with this column is to have it be a source for practical how-to information, *and* a narrative where readers can find inspiration in the achievements of others. Jim's binocular scope falls largely into the latter category. I've only met a handful of ATMs who possess the talent and skill necessary to make something as mechanically excellent as Jim's scope, but everyone can surely appreciate the effort involved. And we can dream.

Jim's binoscope consists of twin optical-tube assemblies (OTAs) featuring air-spaced, three-element, 4-inch (100-mm), f/6 objectives. The lenses were originally housed in big, porro-prism binos made for the Chinese military. To utilize the lenses in a non-prism design, Jim had to do some tweaking. "I took apart one lens and determined its prescription," he recounts. "Entering the data into Zemax optical-design software showed that by changing the

ALL PHOTOGRAPHS BY THE AUTHOR

Jim Stilburn's exquisite 4-inch binoscope is the product of careful planning and skilled execution. It's fit and finish rivals that of the finest commercially made equipment. The 38-pound (17.2 kg) optical-tube assembly rides on a beautifully crafted mount that adds 25 pounds to the total instrument.

***Left:* Each binocular half features a Crayford focuser and a housing that holds two diagonal mirrors feeding light to the eyepiece and providing a right-reading view. *Right:* The adjustments that align the two optical tubes are crucial to the performance of a binocular telescope. The large black knob controls the intra-ocular spacing, while the gold-plated brass knob governs the vertical alignment.**

spacing of the elements slightly, I could improve the image fidelity significantly."

Each lens feeds a pairs of diagonal mirrors that provide a right-reading view at the eyepiece. The tubes are ABS plastic pipe painted white, while the other main components are made from machined and anodized aluminum, and gold-plated brass. Jim even fabricated the splendid Crayford-style focusers in his garage.

In addition to optimized optics, the quality of a binocular's image hinges on the mechanical alignment of the OTAs. It's here that Jim's talent with a lathe and milling machine shine brightly. His binoscope design incorporates a series of linkages that allow for interocular adjustments with the turn of a large click-stop knob, and for exact alignment by precisely changing the tilt and toe angles between the OTAs.

The binoculars rest on an altazimuth mount that is made with the same care and precision. The altitude axis has a pair of machined Delrin plastic disks riding Dobsonian-style on pads of moleskin fabric and Teflon tape, while the azimuth motion is achieved with ball-bearings and a variable-friction control. Both axes move smoothly with finger-touch force. A laser pointer mounted on the strut between the OTAs facilitates accurate pointing.

The tweaked optics and precise collimation result in sharp, detailed images. "At a magnification of 100× the system will easily split both doubles in Epsilon Lyrae, and show a pleasing amount of detail on Jupiter and Saturn," Jim reports. Of course, wide-field views hold the greatest attraction for binocular users, and here too the binoscope delivers. "As you might expect, I get beautiful views of the Pleiades and other open clusters, but the binos also work well for terrestrial viewing," adds Jim. "One evening I used 50× to view an owl perched 50 feet away, and the bird filled the whole field of view!"

Though it's unlikely that many readers will attempt a binoscope exactly like this one, Jim's experiences yield a few general pointers for prospective builders. First, binoculars this big are going to be heavy — in Jim's case, 38 pounds (17 kg) plus another 25 pounds for the mount. Shaving significant weight off of these totals is more difficult than many would think. "If you need something that's easily transportable," Jim advises, "build the scope so that it breaks down into several smaller pieces." Second, be prepared to spend a good deal of effort refining your design and allow plenty of time for the actual construction. "Building a binoscope like this one takes about four times as much effort as a regular scope," Jim warns, "but for a gearhead like me, designing and making all the bits and pieces is where the real fun is!" Readers wanting additional advice can reach Jim via e-mail at: jimsylvi@telus.net. ✦

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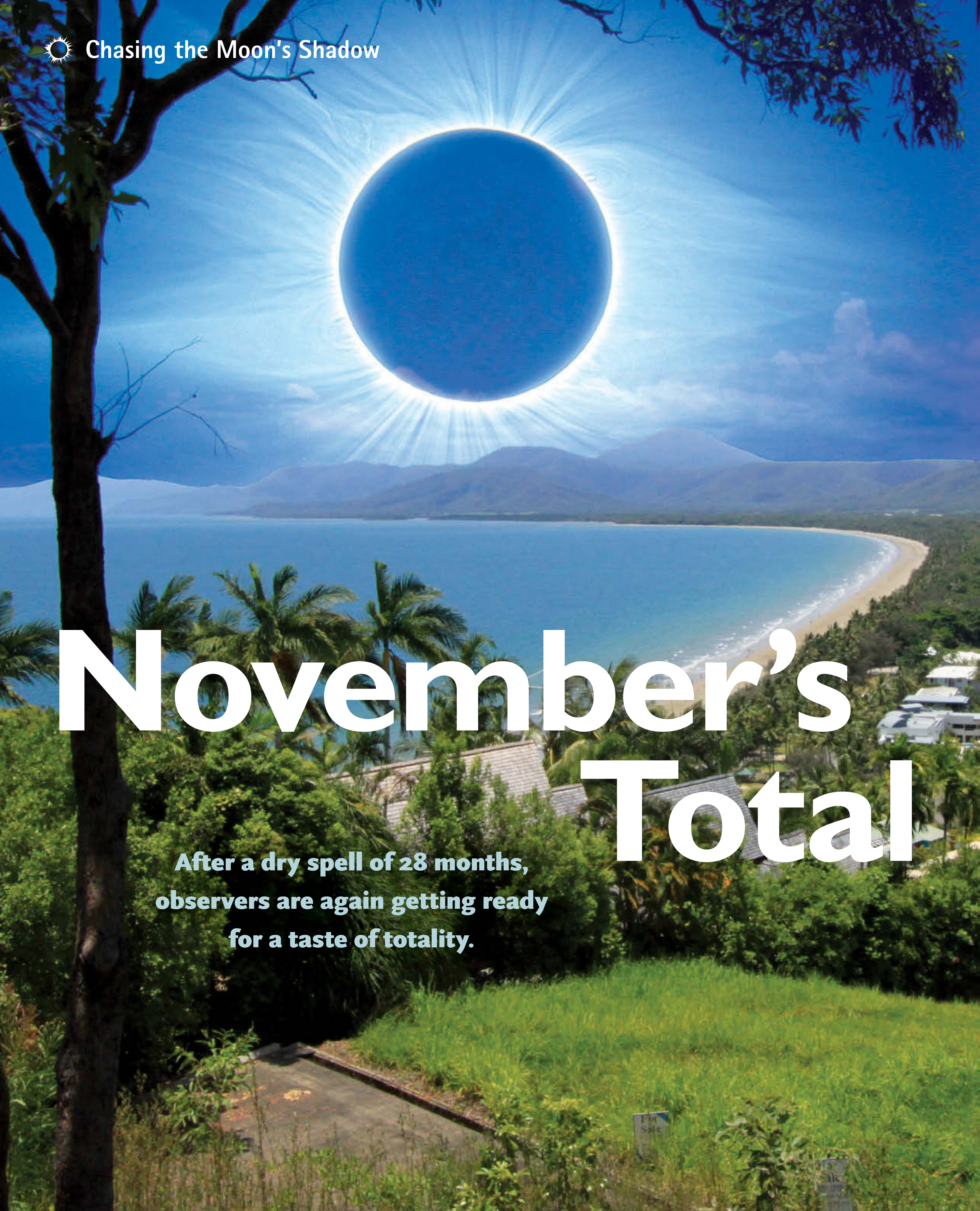
*Contributing editor **Gary Seronik** is a long-time ATM and binocular observer who is having second thoughts about his caveman ways after seeing Jim's scope in person.*



November's Total

After a dry spell of 28 months, observers are again getting ready for a taste of totality.

Solar Eclipse

FRED ESPENAK & JAY ANDERSON

Challenging weather conditions and limited land within the path of totality make the Pacific coast of Queensland the preferred location for eclipse chasers heading to Australia for this coming November's total solar eclipse.

S&T PHOTO ILLUSTRATION; BEACH: JAY ANDERSON; SOLAR ECLIPSE: *S&T* PHOTO

TOTAL ECLIPSES OF THE SUN are rare events that offer a unique opportunity for ground-based observers to enjoy a spectacular view of the solar corona. The upcoming eclipse in November has a maximum duration exceeding 4 minutes, but, unfortunately, most of the eclipse path is over the Pacific Ocean.

The central eclipse begins at 20:36 Universal Time on November 13th, which is the morning of the 14th in Australia, when the Moon's umbral shadow first touches down about 190 kilometers (120 miles) east of Darwin in Australia's Northern Territory, along the northeastern border of Kakadu National Park. Sweeping east-southeast, the shadow quickly crosses Arnhem Land and the Gulf of Carpentaria. Barely 80 seconds from the beginning of its landfall, the umbra reaches the west coast of Cape York Peninsula in Queensland near the mouth of the Mitchell River delta. At mid-totality here, the Sun's altitude is already 9° and the central duration of totality is 1 minute 57 seconds.

The Moon's shadow crosses the entire Cape York Peninsula in just over 100 seconds and reaches the Pacific coast of Queensland at 20:39 UT. The Sun is now 14° high and the central duration is 2 minutes 5 seconds. The coastal cities of Port Douglas and Cairns are deep within the umbral path, lying 10 km north and 23 km south of the central line, respectively. Each city will enjoy over 2 minutes of totality. Well known as popular tourist destinations for trips to Australia's Great Barrier Reef, these cities will also be the chief destination of most 2012 eclipse expeditions, since the shadow track through Queensland's interior encounters little more than an occasional cattle ranch.

After leaving Australia, the remaining 93% of the umbra's path stretches across the South Pacific with no other landfall. Greatest eclipse occurs at 22:12 UT with the Sun 68° above the horizon during 4 minutes 2 seconds of totality. But the nearest land is the North Island of New Zealand some 1,800 km west of the path, making it an unlikely spot for observers. Continuing on its solitary sojourn, the shadow gradually curves to the northeast, where the total eclipse ends at 23:47 UT as the umbra lifts off Earth's surface more than 500 km west of Chile's coast.

Weather Prospects

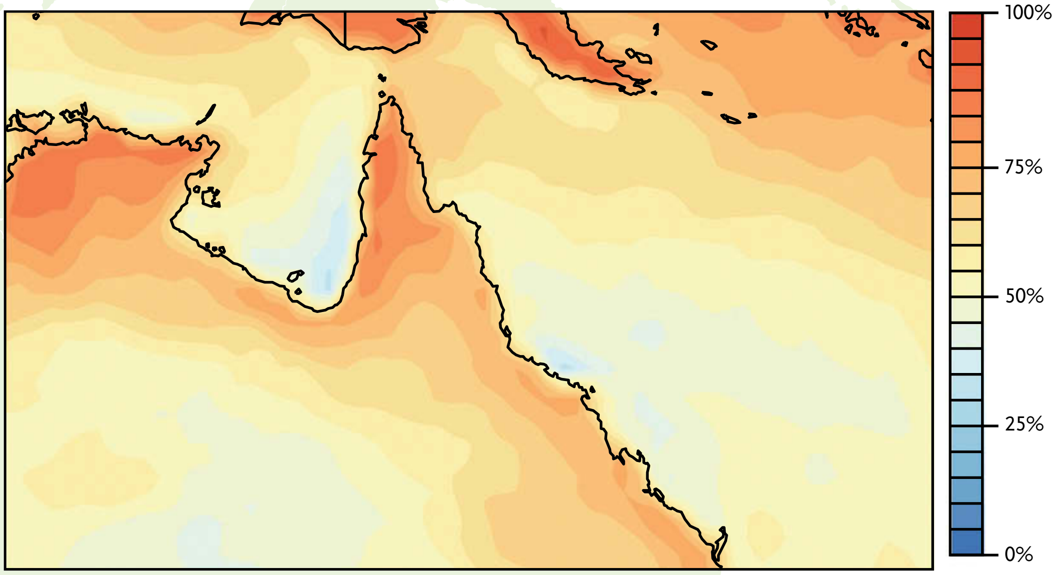
Cloud cover over Australia is dictated by a location's proximity to the sea, the terrain, the winds of the day, and the state of the oncoming rainy season, locally known as the "wet." Add to these the very early hour of the eclipse, when nighttime influences are fading and sunlight is beginning to warm the land, and it will come as no surprise that the cloud cover is capricious and difficult to outsmart in most regions. Fortunately, Urania, the muse of both meteorology and astronomy, has spared a small part of the continent for the better fortune of eclipse chasers.

At the start of the eclipse track, in the Northern Territory, a quarter century of satellite observations show an average cloudiness of 75% or more for November. Compounding the weather woes are a road network that suffers from considerable delays or even becomes impassable during the wet season, a very sparse population, and the need for special permission to travel into much of the area crossed by the eclipse track. We cannot recommend eclipse viewing here because of the frequency of heavy clouds, but if travel to exotic destinations is your *raison d'être,* then the Northern Territory could provide a great adventure.

In Queensland, the lunar shadow encounters gradually improving weather conditions, with lower cloud coverage and fewer rainy days. From a climatological point of view, it's apparent that offshore waters and the immediate beachfront have a lower average cloudiness than any of the inland areas. As such, on average the best eclipse sites will be right along the Pacific coast.

Clouds increase significantly just inland from the coast, reflecting the tendency for the mountains of the Great Dividing Range to form clouds in the prevailing southeast winds. But the data in the accompanying map apply to the afternoon hours, which are cloudier than those at sunrise. In the early morning, before the Sun has a chance to warm the slopes, this terrain-induced cloudiness will be lower than shown on the map, though still not as good as the coastal strip.

Even on a very sunny morning, there are always



S&T: GREGG DINDERMAN; SOURCE THE AUTHORS

Color-coded regions showing the percentage of cloud cover determined from a quarter century of satellite data reveal considerable cloudiness over the land areas crossed by the track of totality. The data, however, are for afternoon conditions, and somewhat more favorable skies may exist during early morning hours when the eclipse takes place.

patches of cloud on the slopes or lines of cloud offshore. Completely clear skies are rare, which is typical for tropical environments. These cloud patches can be scattered and widely dispersed, or they can cover up to half the sky with a mixture of broken and open cloudiness. They are constantly changing, forming ephemeral holes in the cloud cover that vary at 15-minute intervals. But observers contemplating moving from one spot to another nearby may make the situation worse rather than better. Furthermore, chasing these openings may be nearly impossible, especially at Port Douglas, as large crowds are expected to gather for a Solar Eclipse Marathon scheduled to begin at the moment totality ends.

If heavy clouds are piling up along the coast during the early hours on eclipse day, a better location can probably be found on the western side of the Dividing Range. But the terrain there takes some distance to smooth out, so the topography's cloud-making effects continue for 100 or 150 km beyond the highest coastal peaks. Nevertheless, the ups and downs of air flow across the terrain will open holes in all but the wettest weather, and so when all else is lost, a trip into and across the Dividing Range will offer the best chances for a view of the Sun. But beware — the roads are cut through areas of tall trees and the terrain is rugged, so you will only get a clear view of the low-altitude Sun from selected locations. Scouting ahead of time is essential.

Perhaps the most promising option in the Outback is to move well behind the high peaks of the Great Dividing Range, to a location near or west of Mount Carbine along the Mulligan Highway. The highway lies in a shallow valley stretching from Mount Molloy to Mount Carbine, with high peaks to the east and lower ones to the west, which afford some protection from moist ocean winds. At Mount Carbine, the Mulligan Highway turns westward and adopts an orientation aligned toward the rising Sun. Along this route, the Sun should be clear of the mountains at eclipse time.

If you're interested in a remote observing site, note that Outback travel is not a task for beginners. The roads are not designed for wet weather and there is a risk that travelers could be held up for days if the rainy season begins early. Experienced guides and a cautious eye on the forecast are highly recommended.

Eclipse Day Strategy

Because of the proximity of an international airport, abundant accommodations, and an infrastructure geared to handle tourism, the area around Cairns and Port Douglas is serving as the focus for many eclipse tours. Although Highway 44 links the two cities with 40 miles of good-condition, two-lane roadway, heavy traffic congestion on eclipse morning may make last-minute moves difficult.

From the area around Cairns, tall hotels and palm trees, coupled with the low altitude of the Sun at totality, demand a viewing location along the waterfront. Unfortunately, Cape Grafton lying to the east will block a view of the Sun at sunrise as well as the first 20 minutes of the partial phases.

North of Cairns there are clear views to the eastern horizon from many good public beaches along Highway 44, but parking is often limited. For those choosing a beach location during the early morning hours on eclipse day, be aware that the new Moon will bring unusual

Visit skypub.com/eclipses for articles on viewing and imaging eclipses.

extremes in the tides. An abnormally low tide expected around 3 a.m. will offer large expanses of beachfront that will vanish as a high tide of up to 3 meters (10 feet) peaks around 9 a.m. This could prove disastrous to anyone setting up early near the water's edge.

Recommended locations with shorefront above the high-water mark include Kewarra Beach, Trinity Beach, and Palm Cove. If possible, scout out an observing location a day or two before the eclipse around the time of high tide. Alternatively, there are many agricultural fields within a few miles of the coast that offer good views with low horizons. Although trees will block the start of the partial phases, the Sun should be clear of any foreground objects by the time of totality.

Once again, advanced planning and site reconnaissance several days before the eclipse are critical to finding a good viewing location. Because the eclipse occurs so early in the day, there will be little time to change locations. Furthermore, the anticipated high traffic volume and rapidly changing cloud patterns may make staying put and hoping for the best the preferred strategy on eclipse day.

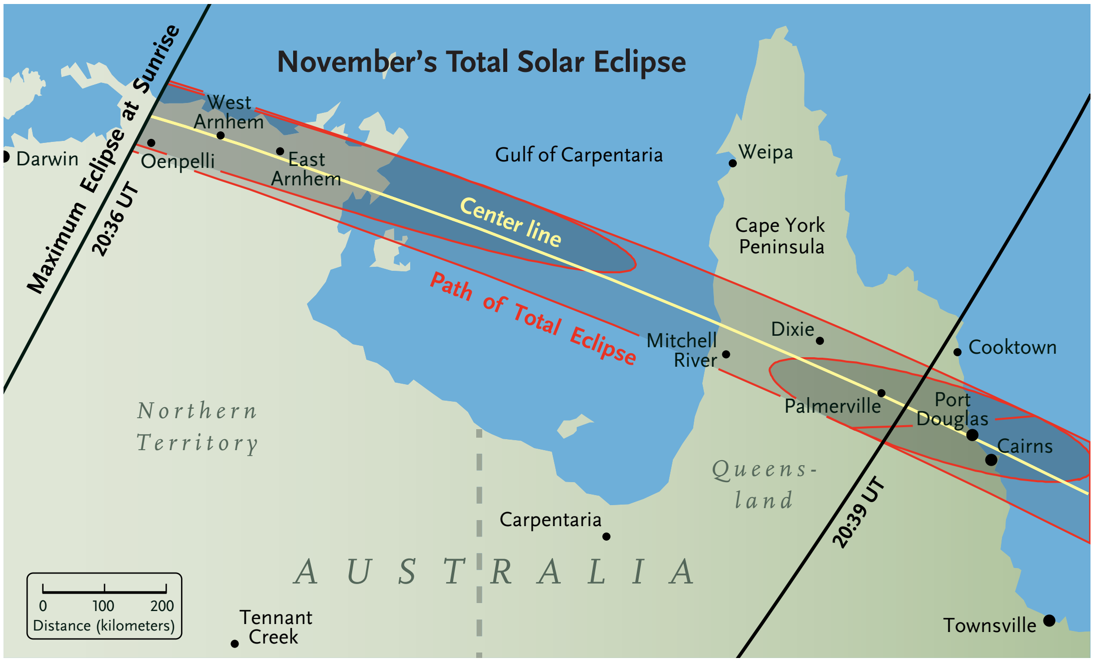
In spite of the challenges presented by the 2012 event, it is still the most promising total solar eclipse until the great American eclipse on August 21, 2017. ✦

Retired astronomer ***Fred Espenak*** *masters two eclipse websites (****http://eclipse.gsfc.nasa.gov*** *and* ***www.mreclipse.com****) and is a coauthor of* Totality: Eclipses of the Sun *with Mark Littmann and Ken Willcox. Meteorologist* ***Jay Anderson*** *(University of Manitoba, Canada) has written eclipse weather forecasts since 1979 and has journeyed worldwide to confirm his predictions in person.*

Some of the best sites for eclipse viewing will be at beaches between Cairns and Port Douglas, but observers need to be aware that astronomically low tides at around 3 a.m. will reveal far more beachfront than will be available as the tide rolls in at eclipse time.

JAY ANDERSON (2)

The Mulligan Highway west of Port Douglas offers potential for eclipse chasers, but trees will limit suitable observing sites.



S&T: GREGG DINDERMAN; SOURCE THE AUTHORS

Although it crosses half the globe, the Moon's umbra (shown as ovals at the indicated times) makes landfall only in relatively remote regions of northeastern Australia. As such, the focus of most eclipse chasers will be the cities of Cairns and Port Douglas, where there is abundant tourist infrastructure.

Rethinking SOLAR ECLIPSE Photography

Dennis di Cicco

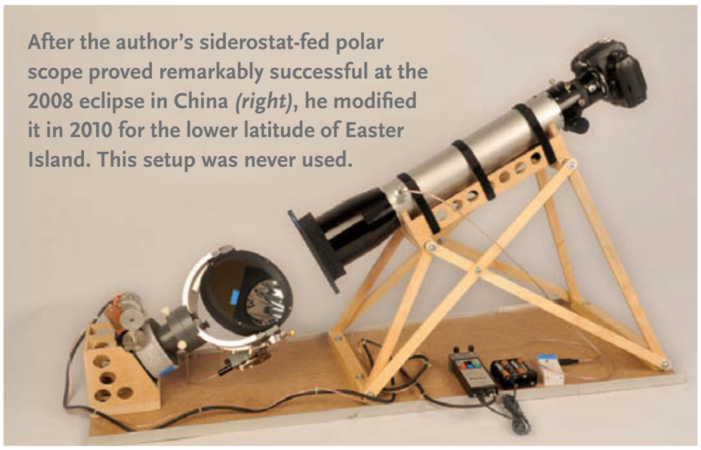
DIGITAL PHOTOGRAPHY IS CHANGING THE GROUND RULES FOR ECLIPSE CHASERS.

a large print of the 2010 Easter Island eclipse (*facing page*) graces my office wall. After 40 years and 20 eclipse-chasing adventures (including 16 into the paths of totality), I finally have a picture to hang on the wall, or so I tell visitors. Nevertheless, it's not the picture's wall-worthy credentials, but rather the crude method in which it was made (due to a last-minute change in plans), that inspired the title of this article.

For the record, I've witnessed total solar eclipses from land, sea, and air. My photography preparations have also run the gamut, ranging from several years spent designing, building, and shipping a half ton of research equipment into the Sahara Desert in 1973 to frantically tossing gear into a suitcase a decade later as I headed to Indonesia on less than 24 hours notice (no kidding!). Recently, however, my globe-trotting pursuits of the Moon's shadow have been like those of most other eclipse chasers — travelling with an organized tour and subject to the normal restrictions for airline baggage.

As such, I spent several weeks before the August 2008 eclipse in China building the portable setup pictured below. The outgrowth of numerous discussions with other eclipse photographers, especially my colleague Roger Sinnott, and past experiences, it's a variant of a polar telescope fed by a siderostat. Since the scope's optical axis lies on an imaginary extension of the siderostat's polar axis, the mount has to be made for the latitude of the observing site.

Because the telescope (a Tele Vue TV-85 objective fitted to my own lightweight tube assembly) remains fixed, I was able to make an exceptionally rigid, yet lightweight mounting from little more than a few wooden sticks — I dubbed it the Tinker-Toy mount. I fashioned the siderostat around a polar drive scavenged from a broken German equatorial mount made by Carson



After the author's siderostat-fed polar scope proved remarkably successful at the 2008 eclipse in China *(right)*, he modified it in 2010 for the lower latitude of Easter Island. This setup was never used.

The original mount had a taller stance due to the observing site's higher latitude. Sand-filled plastic bags placed on the base gave added stability.

ALL PHOTOGRAPHS ARE BY THE AUTHOR

As explained in the text, *S&T* imaging editor Sean Walker processed this view of the 2010 total eclipse using the author's bracketed exposures made with a non-tracking telescope.

Telescopes. Best of all, the whole setup disassembles to fit in a carry-on suitcase that meets airline size and weight requirements (and provides a bit of entertainment for airport-security personnel).

In addition to being compact and lightweight, this setup keeps the camera at a comfortable position to look through and operate. One downside of a fixed polar telescope, however, is that the sky appears to slowly rotate at the focal plane, but this is of little concern during the brief exposures used for an eclipse.

Almost to my surprise, the equipment worked exceedingly well in China. Nevertheless, the whole Tinker-Toy structure was in a hotel trash can a few hours after the eclipse since it was only good for the latitude of my site in China. Before the Easter Island eclipse rolled around in July 2010, I made a new version of the Tinker-Toy mount. In addition to the new angle of the polar axis, its wooden pieces have a little more "polished" look about them.

Unfortunately, I never got to use it. Weather and logistics delayed my arrival at the observing site, and I wasn't sure there would be enough time to prepare a flat patch of ground for the setup. Moreover, a powerful wind was constantly blowing off the ocean, and I feared it would shake the relatively lightweight mount. So, at the last minute, I had to devise a "Plan B."

My best option was to simply prop the telescope's front end on a convenient stone wall and mount the camera on a tripod, which served as the back support. Calling the arrangement crude is an understatement, but it was extremely stable in the blowing wind. That was the good news. The bad news was that my exposures were made with a non-tracking telescope; something that produced only mediocre results when I photographed the rushed 1983 Indonesian eclipse with a similar setup using film.

But the picture above speaks for itself. Digital photography is clearly a game changer for solar-eclipse photography. You can obtain truly excellent results with a non-tracking telescope; at least when working at focal lengths up to the 595 millimeters I was using (and perhaps even longer). Vibration has probably ruined more eclipse pictures than clouds, and the culprit is almost always traced to the lightweight tracking mounts that many people tote

When limited time and a powerful on-shore wind scrapped the author's plans to use the gear pictured on page 72, he simply propped his telescope on a rock wall and hit the shutter button.

along on eclipse trips. There is no end to the ways a fixed telescope can be solidly mounted. Old habits die hard, and I may have to fight the urge, but I suspect that I'll forgo tracking at upcoming eclipses. If I can duplicate the results I got on Easter Island in the future, I'll be a very happy eclipse chaser indeed, not to mention one who can travel with a much lighter load.

Camera Notes

One of the biggest advantages that the digital revolution brings to eclipse photography is image processing, as my *S&T* colleague Sean Walker explains in the accompanying sidebar that tells how he processed my Easter Island exposures. But digital cameras themselves have played a major role in letting people shoot better pictures, and it has to do with more than just the increased sensitivity of digital detectors.

Most of today's DSLR cameras offer features that are tailor-made for eclipse work. Foremost among them is automatic exposure bracketing. The key to making a dramatic image of totality is combining a set of images made with varying exposures that record different levels of coronal brightness to advantage. In the days of film, this meant fumbling with a camera's shutter-speed dial in the twilight illumination and fleeting moments of totality. You'll need to check your camera's manual to learn if and how your camera handles bracketing, but I know that it's available with many brands of DSLRs.

For example, my Nikon D700 used on Easter Island and the D300 I used in China allow auto bracketing of up to nine frames with as much as a full exposure stop between each frame. As such, I can set the shutter speed to 1⁄30 second and shoot a sequence that runs from 1⁄500 to ½ second without ever having to touch the camera. Furthermore, by switching the camera from single-exposure to continuous-shooting mode, I can simply hold down my remote-release button and the camera will run the nine bracketed frames as a continuous burst that stops when it's done — something that takes only three seconds to accomplish for the sequence above.

I highly recommend that eclipse photographers page through their camera manuals looking for other features they might find useful. That's how I stumbled upon one that's buried deep in the shooting menu of my Nikons (and probably available in other models too). Called "exposure delay mode," it inserts a pause of about one second between the time the mirror flips up and the shutter opens. This lets any mirror-induced vibration in the telescope die down before the exposure is made. The delay adds to the total time it takes to make an auto-bracketed sequence, but it's well worth it when shooting at long focal lengths that exaggerate the effects of vibration.

Many of today's cameras are packed with features that typical photographers might use rarely, if at all, so it's easy to forget that they exist. It's a good reason you should check for unusual features buried in the menus of your own camera. I can't think of many situations where a nine-frame bracketing sequence or the exposure delay mode would come in handy for conventional photography, but they're so useful for eclipse shooting that it makes me wonder if an amateur astronomer was part of Nikon's design team. Maybe you'll find similar features tucked away in the digital recesses of your camera.

S&T *senior editor* ***Dennis di Cicco*** *is already looking forward to the total eclipse that sweeps across the United States in August 2017.*

EARLY LEARNING

The plane flight to your eclipse destination is not the time to be learning how to use a digital camera. Read the manual and explore the camera's menus beforehand to learn what features will be useful for eclipse photography *and* then practice using them.

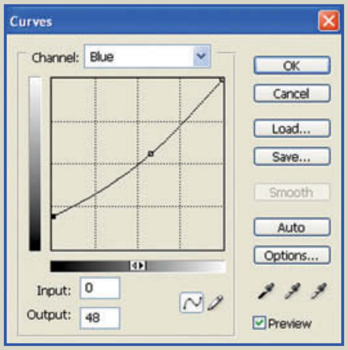
Improving Your Eclipse Photos by Sean Walker

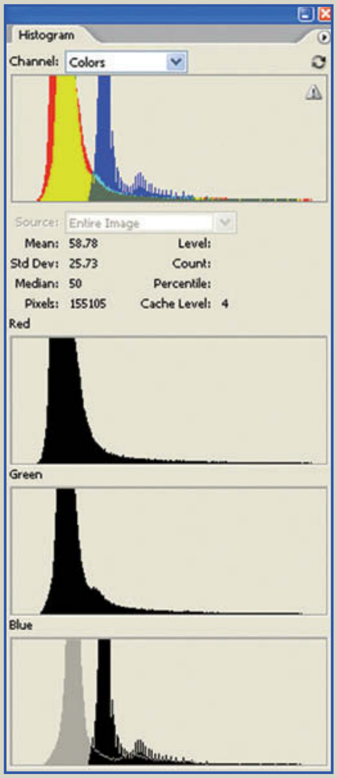
High-dynamic-range (HDR) image processing using programs such as *Photomatix Pro 4.1* (*left*) has become standard practice for depicting the large brightness range of the solar corona.

While capturing bracketed exposures of a total solar eclipse has gotten easier thanks to features available on many new DSLR cameras, processing the results hasn't changed much since the article I wrote in the June 2009 issue, page 64. Whether your intention is to faithfully depict the visual appearance of the eclipse or to reveal as much detail as possible within the solar corona, high-dynamic-range (HDR) processing techniques are still the way to go.

Most everything discussed in my earlier article remains relevant, though if you shoot your eclipse exposures without a tracking mount, you'll need an additional software program to register your images before combining them. For the image of the 2010 Easter Island eclipse on page 73, I worked with Dennis di Cicco's four groups of nine bracketed exposures. I used *MaxIm DL 5.08* to register the corona in each exposure using two stars that appear near the Sun and were detectable even in the brief, 1/500-second exposures — a testament to the sensitivity of the Nikon D700 and the sharp focus Dennis achieved with the Tele Vue TV-85 objective and Hotech field flattener. Without having field stars to register each frame, image shift caused by a fixed telescope during the exposure sequence reduces your ability to precisely combine the exposures into a single HDR result.

After aligning and cropping each of the 36 exposures, I used *Photomatix Pro* to combine them ①. I also made sure to save a copy of this "raw" HDR file in case I learned new processing tricks in the future. Next, I moved on to the program's Tone Mapping section. As HDR processing has matured, *Photomatix Pro* has kept pace with new updates. Now on version 4.1, *Photomatix Pro* includes new tone-mapping presets that didn't exist in 2009, and it also allows you to save your own custom settings so you can duplicate your process on many images. The parent company, HDRsoft, offers a basic version of the software called *Photomatix Essentials* for $39 that performs many of the same functions. You can check the company's website, **hdrsoft .com**, to compare both





2

programs and decide which one best suits your needs.

Using the latest version, I combined the 36 frames essentially the same way as I described in the 2009 article. But due to the greater length of totality, the Moon moved noticeably relative to the corona between the first and last images in the sequence, blurring its image in the HDR stack. I easily fixed this in *Adobe Photoshop* by using a single HDR stack of just one 9-image sequence and blending the central portion of it into my full stack. This blending layer is also useful for reducing the HDR program's propensity to excessively brighten the closest part of the corona adjacent to the lunar disk.

I opened both sets of stacked images (one made with all 36 exposures, and another with just one bracketed set) in *Photoshop*. Though *Photomatix* is very good at combining the bracketed images to reveal the corona's innermost details as well as its outer extent in the same image, it doesn't render the background color accurately. So my first task in *Photoshop* was to adjust the curves palette to brighten the background sky of the full stack ② and add a bit of blue to it, without affecting the inner corona. Next, I experimented with sharpening to bring out additional details within the corona. I prefer to sharpen using High-Pass Filter layers that were detailed in the 2009 article, followed by some noise reduction near the edges of the image.

Once I was satisfied with the sharpness, I worked on the Moon's appearance. I started by selecting the 9-image HDR stack, copying it, and pasting it over the full 36-image stack. To get the best of both images, I simply used the Elliptical Marquee Tool with feathering set to about 5 pixels, and selected the area of the photo that includes the Moon, plus a little bit of the inner corona ③. Next, I copied this selection and pasted it onto the same location of the image, and then deleted the layer that included the entire 9-image HDR stack. I was left with two layers, the entire stack on the bottom, followed by the 9-image stacked Moon layer on top.

Here I adjusted the Moon layer with the Curves palette again, this time to darken the Moon and inner corona. One thing I couldn't fix in curves is the unnaturally bluish Moon and its bright rim. This is mostly an artifact of the HDR process. An easy way to compensate for this is to open the Channels window and click on the green channel. Again using the Elliptical Marquee Tool, I selected the Moon, but this time I set the feathering to 2 pixels and tried to select as close to the lunar limb as possible. When I was pleased with the selection, I copied it. I then clicked on the RGB channel in the Channels window to select all channels, and pasted the green Moon channel into the image. This gave the Moon a neutral gray appearance, which I found less distracting. I could then brighten or darken the Moon layer independent of the inner or the outer corona layers, or use the burn tool to further darken the lunar limb if necessary. The "before" and "after" Moons are shown in the illustration below.

While the resulting photograph is different from how the eye sees the corona, images such as this allow us to see extremely subtle tonal variations, as well as fainter stars than weren't noted visually during the event. ✦

Imaging editor ***Sean Walker*** *is constantly in search of new image-processing techniques.*

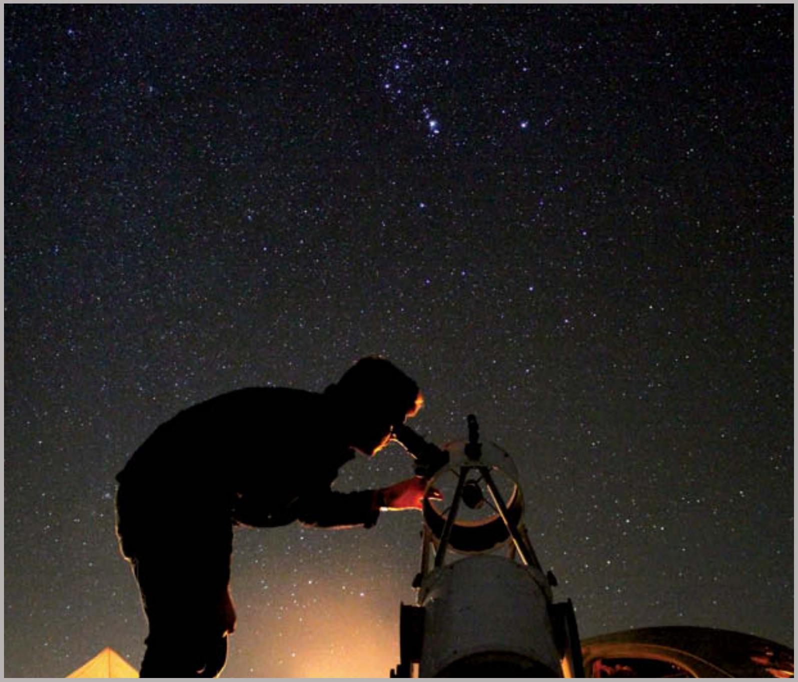
FREQUENTLY SAVE YOUR WORK
Save your images at each step during processing so that you don't have to repeat your work in the event of a computer crash.

THE SPAGHETTI NEBULA
Bob Holzer
Delicate filaments trace the outer extent of supernova remnant Simeis 147. Remains of a star estimated to have exploded 40,000 years ago, this faint nebula spans nearly 3° of the sky along the border of Auriga and Taurus.
Details: *Takahashi FSQ-106N astrograph with FLI ProLine PL16803 CCD camera. Total exposure was 50 hours through FLI color and Astrodon hydrogen-alpha filters.*

▲ **CLOUDS OF THE HYADES**

Alistair Symon

Just a degree to the west of Epsilon Taurus (top left) resides a small bright spot (upper right) known as Sharpless 2-239, a Herbig-Haro object largely buried within a thick region of the Taurus Molecular Cloud. **Details:** *Takahashi TOA-130 refractor with SBIG STL-11000M CCD camera and AO-L active optics. Total exposure was roughly 15 hours through Astrodon color filters.*



► **CARE FOR A VIEW?**

Neil Kopicki

It's easy to imagine sharing Neil Kopicki's view of M42, the Orion Nebula, through his 10-inch Dobsonian. **Details:** *Canon EOS Rebel T3 DSLR with 18-to-55-mm zoom lens at 18-mm. Total exposure was 12 seconds at ISO 6400.*

Visit SkyandTelescope.com/gallery for more images online.

▲ **RISING LUNAR ECLIPSE**
Oshin D. Zakarian
The Moon enters Earth's shadow as seen above the Zagros Mountains in Iran on the evening of December 10, 2011. The next total lunar eclipse will not occur until April 15, 2014.
Details: *Sky-Watcher 80-mm refractor with Canon EOS 40D DSLR camera. Single exposure of ½ second.*

◂ **LOVEJOY'S SURPRISE**
Lester Barnes
In December 2011, Comet C/2011 W3 (Lovejoy) survived a perihelion graze roughly 100,000 miles above the Sun's visible surface to become a spectacular dawn object with a bright tail stretching more than 20°.
Details: *Canon 20Da DSLR camera with 50-mm lens at f/3.2. Total exposure was 1 minute at ISO 800.* ✦

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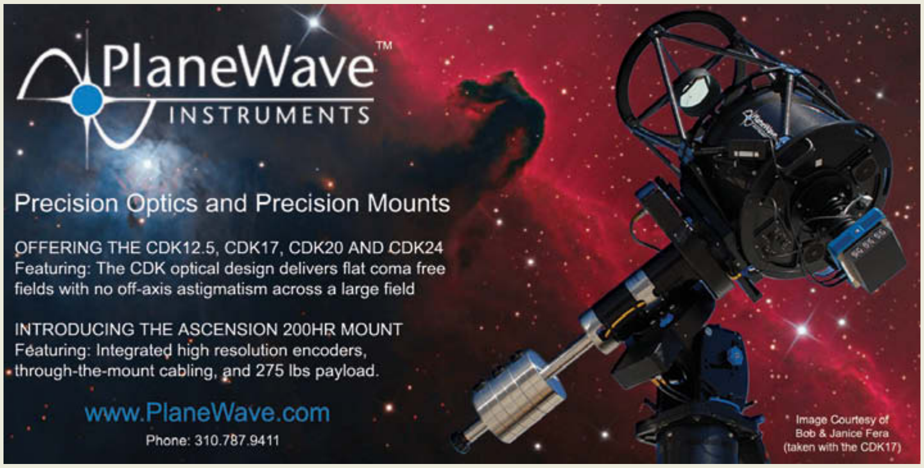

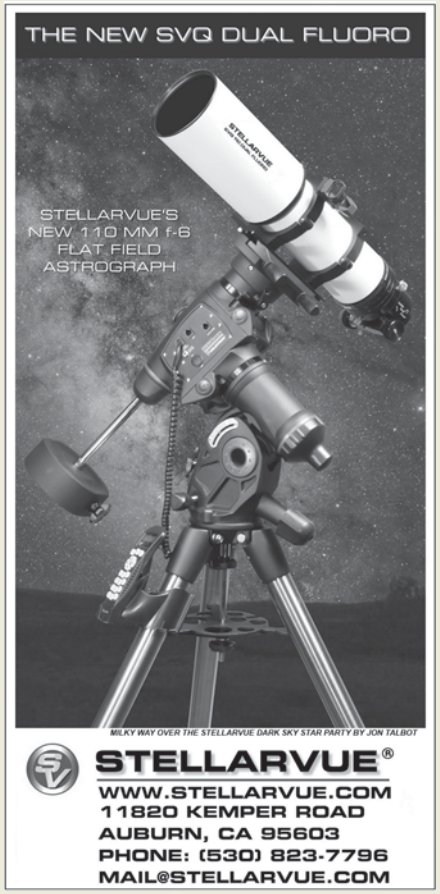

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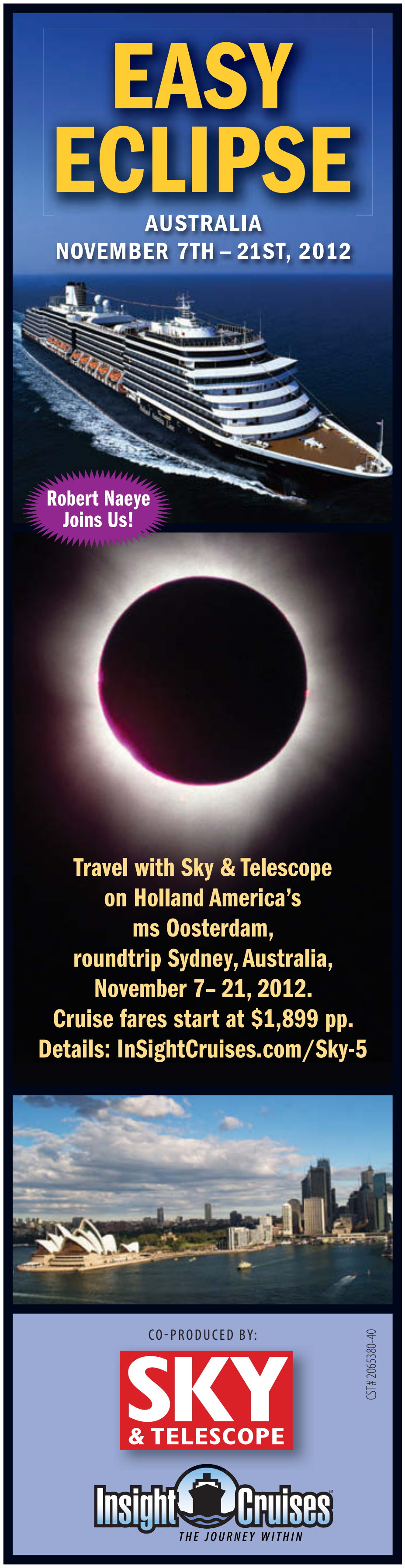

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Comet Lovejoy
Expected to disintegrate as it rounded the Sun, this intrepid comet survived long enough to put on a great show for Southern Hemisphere skywatchers.

Astronomy in National Parks
Renowned for their terrestrial beauty, U.S. National Parks are among the best places to revel in the splendor of the night sky.

Saturn Storm

With a lot of help from amateur astronomers, researchers got their best views yet of a raging storm on the Ringed Planet.

Saturn Observing Guide
S&T editors tell you what you need to know about how to observe Saturn as it comes to opposition.

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Malcolm E. Brown

Observing the Telescope Tribe

Astronomy's two major sects are "screen scanners" and "visual observers."

My eyes bulged with disbelief and delight in the clubhouse bathroom of the Norwich Astronomical Society in England. The toilet lid enthralled me with its images of constellations. "Oh yes!" I said to the four walls, punching the air with excitement. I *had* to become a club member if such was their enthusiasm! I had long been interested in astronomy, but had seldom observed for decades.

I have a Ph.D. in sociology and, like an anthropologist, the shock of first contact with a new tribe is my stock in trade. It enables me to see. What did I discover about today's strange tribe of amateur astronomers? How had astronomers changed since my youth?

One major change flooded into my brain. Astronomers had divided themselves into two sects: the screen scanners and the visual observers. An approximately equal number of each had turned up that night. The scanners and visual observers looked down upon each other. This is normal. It's a commonplace observation of social anthropologists that any particular sect will consider itself superior and disparage other sects. The sect members were friendly to each other, but light-hearted banter bubbled in the background.

The red-lit warmth of the clubhouse smelled pleasantly of coffee. The screen scanners hunched over laptops, faces bathed in pools of light. They tapped keys. They tweaked their images of galaxies — their favorite "little soft fuzzes." They seldom looked through eyepieces.

These "imagers," to use tribal jargon, accumulated light for minutes or hours. They stored and brightened light. Software manipulated digital data. Computers constructed images that visual observers could not discern. The screen scanners are rapidly evolving. In my youth, astrophotography was an esoteric endeavor requiring film, trial-and-error exposures, and agonizing waits for wet chemical development.

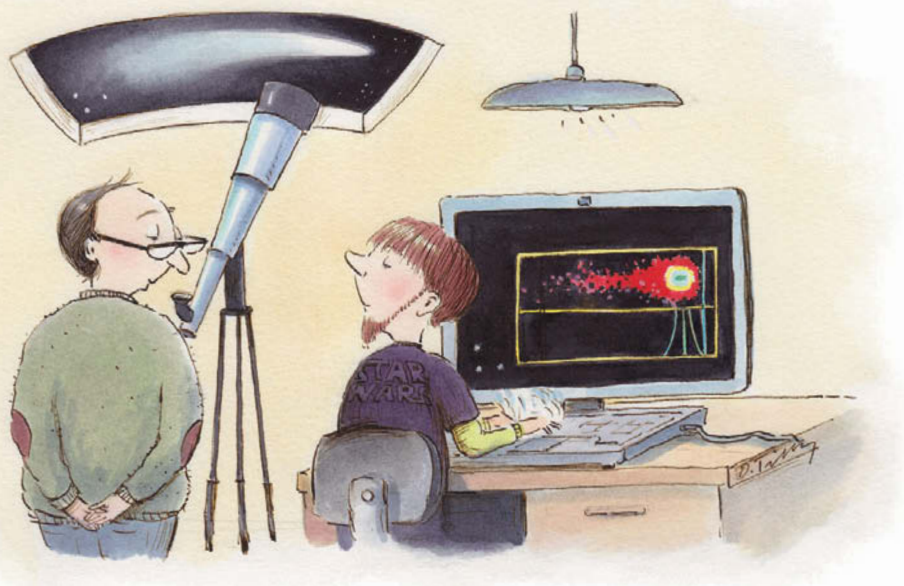
Outside I met their protagonists: the visual observers. Frost crunched underfoot. One elite faction inhabited a ghetto, perched atop ladders beside gargantuan tubes: "Dobsonian Alley." A 16-inch mirror had become a "baby Dob," "big" was 24 inches. Some visual-sect members proudly labeled themselves "common, garden, or agricultural observers." That their tiny eyepieces can expand a view that seems to encompass the entire universe delighted them. "Seeing is believing," they argued.

Their militants explained that their perception is stenciled *directly* from the "real." It was therefore superior to observing a cinematographic recording, no matter how spectacular. Visual observers also relished producing images, but by using skillful hands drawing with graphite upon paper.

Imagers viewed that with disdain. It seemed a nostalgic, quaint, perverse throwback. Their antecedents, many generations ago, used those techniques — before more objective recording devices were invented. "What a waste of expensively collected light!" said one imager. Another dismissed meticulously crafted sketches of solar prominences as "sad!"

So which sect do I belong to, screen scanner or visual observer? I am both. I savor the variety. I use my webcam poorly, but I'm endeavoring to improve, working toward deep-sky DSLR imaging. I also enjoy photographing noctilucent clouds. However, I vividly recall a night of public observing when a youngster first viewed Saturn through a telescope and exclaimed, "Awesome!" Such joy!

But whatever joy I receive from such activities, my favorite occupation is observing the astronomers. ✦



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