35 **HOT NEW PRODUCTS** for every observer p. 54

ENTER TO WIN A MERCURY GLOBE See p. 63

NOVEMBER 2018

Astronomy®

The world's best-selling astronomy magazine

VOYAGE TO A WORLD OF EXTREMES

A fresh look at Mercury p. 20

FALL'S BEST

deep-sky objects p. 44

www.Astronomy.com

BONUS ONLINE CONTENT CODE p. 4

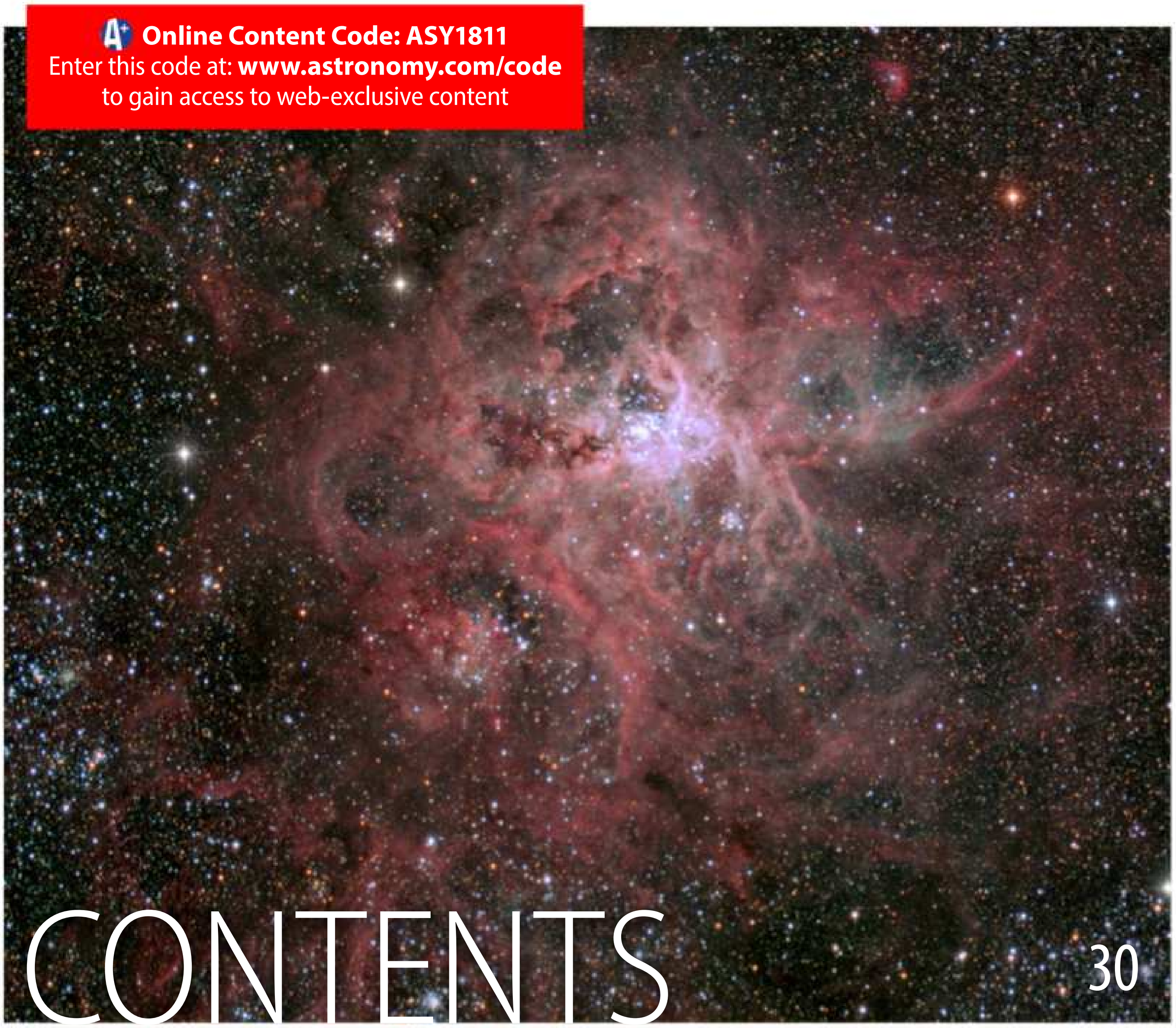
Vol. 46 · Issue 11

AND MORE

Bob Berman on dark matter p. 12

Jeff Hester on why TV science is crazy p. 64

Complete sky event coverage p. 36

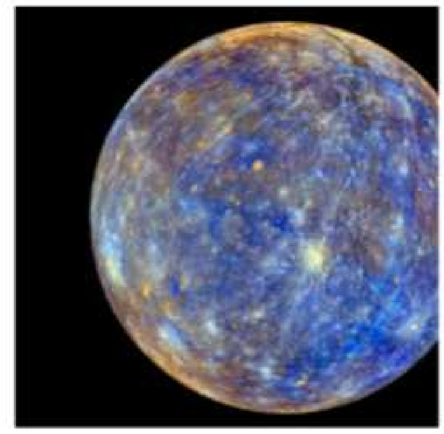


Online Content Code: ASY1811
Enter this code at: **www.astronomy.com/code**
to gain access to web-exclusive content

CONTENTS

30

NOVEMBER 2018
VOL. 46, NO. 11



NASA/JHUAPL/CIW

ON THE COVER

Mercury, the closest planet to the Sun, remains a world of mysteries. The BepiColombo spacecraft aims to unravel some of these.

FEATURES

COLUMNS

QUANTUM GRAVITY

IN EVERY ISSUE

ONLINE FAVORITES >>

Go to **www.Astronomy.com** for info on the biggest news and observing events, stunning photos, informative videos, and more.

My Science Shop
Perfect gifts for your favorite science geeks.

News
The latest updates from the science and the hobby.

Picture of the Day
Gorgeous photos from our readers.

Trips and Tours
Travel the world with the staff of *Astronomy*.

Astronomy (ISSN 0091-6358, USPS 531-350) is published monthly by Kalmbach Media Co., 21027 Crossroads Circle, P. O. Box 1612, Waukesha, WI 53187–1612. Periodicals postage paid at Waukesha, WI, and additional offices. POSTMASTER: Send address changes to *Astronomy*, P.O. Box 62320, Tampa, Fla. 33662-2320. Canada Publication Mail Agreement #40010760.

FROM THE **EDITOR**

BY DAVID J. EICHER

Take a trip with us

As part of the 2019 solar eclipse tour to Chile and Peru, *Astronomy*'s travelers will visit the famous and ethereal site Machu Picchu, an icon of Inca civilization. VITMARK/DREAMSTIME

Talk to any astronomer about the job, and they'll invariably tell you that travel is an exciting part of it. Observatories get built on mountaintops in exotic locations for a reason — the great seeing and transparency — so visiting astronomical sites takes you to some pretty cool places in the world.

We take pride in partnering with TravelQuest International, an experienced touring company based in Arizona that handles our trip logistics. On our tours, editors travel with you to provide guidance and astronomical expertise. Why not join us on one of our upcoming journeys?

We currently offer several exciting options. In February 2019, you can join me on our 16th annual Costa Rica Southern Sky Party. My old friend, the great astronomer Bart Bok, used to say, "All the good stuff's in the southern sky." That exaggeration isn't far off. The Magellanic Clouds, Southern Cross, rich star fields of Crux and Carina, and the Sagittarius Milky Way high overhead make mesmerizing sights. It's an important trip to observe dozens of deep-sky objects we can't see at all from the Northern Hemisphere.

The trip takes place at a base camp near the Gulf of Nicoya, on Costa Rica's Pacific coast. There, we can explore the magical forest during the day, as well as ride horses, watch huge numbers of bird species and other wildlife, and enjoy soothing waters. At night, as the stars come out in a dark sky and the telescopes roll out, you'll experience some of the most memorable observing of your life.

For more, visit www.astronomy.com/magazine/trips-tours

For more information, visit www.astronomy.com/magazine/trips-tours/2019-costa-rica

Or you could travel in May 2019 on the Arizona Skies tour with Senior Editor Michael E. Bakich. He will take you to a flurry of Arizona's greatest astronomical sites, including Kitt Peak National Observatory, the mirror-making lab at the University of Arizona, Sedona's red rock formations, the Grand Canyon, Lowell Observatory, and Meteor Crater.

Check out the details at www.astronomy.com/magazine/trips-tours/2019arizona

And of course, there's a major trip next year for eclipse chasers. The total solar eclipse on July 2, 2019, will be visible from Chile, and we're running a trip that will explore that beautiful country as well as sites in Peru.

Associate Editor Jake Parks will be your guide here. The gems on this trip include the legendary Machu Picchu, as well as Lima, Cuzco, and observatories at La Serena.

See the full itinerary here: www.astronomy.com/magazine/trips-tours/2019-chile-northbound

Join us to explore our beautiful planet and the amazing skies, and an eclipse! See you on the road!

Yours truly,

David J. Eicher
Editor

Follow the Dave's Universe blog:
www.Astronomy.com/davesuniverse
Follow Dave Eicher on Twitter: **@deicherstar**

Astronomy

Editor David J. Eicher
Art Director LuAnn Williams Belter

EDITORIAL
Senior Editors Michael E. Bakich, Richard Talcott
Production Editor Elisa R. Neckar
Associate Editors Alison Klesman, Jake Parks
Copy Editor Dave Lee
Editorial Assistant Amber Jorgenson

ART
Graphic Designer Kelly Katlaps
Illustrator Roen Kelly
Production Specialist Jodi Jeranek

CONTRIBUTING EDITORS
Bob Berman, Adam Block, Glenn F. Chaple, Jr., Martin George, Tony Hallas, Phil Harrington, Korey Haynes, Jeff Hester, Liz Kruesi, Ray Jayawardhana, Alister Ling, Steve Nadis, Stephen James O'Meara, Tom Polakis, Martin Ratcliffe, Mike D. Reynolds, Sheldon Reynolds, Erika Rix, Raymond Shubinski

SCIENCE GROUP
Executive Editor Becky Lang
Design Director Dan Bishop

EDITORIAL ADVISORY BOARD
Buzz Aldrin, Marcia Bartusiak, Timothy Ferris, Alex Filippenko, Adam Frank, John S. Gallagher III, Daniel W. E. Green, William K. Hartmann, Paul Hodge, Edward Kolb, Stephen P. Maran, Brian May, S. Alan Stern, James Trefil

Kalmbach Media
Chief Executive Officer Dan Hickey
Senior Vice President, Finance Christine Metcalf
Vice President, Content Stephen C. George
Vice President, Consumer Marketing Nicole McGuire
Vice President, Operations Brian J. Schmidt
Vice President, Human Resources Sarah A. Horner

Senior Director, Advertising Sales and Events David T. Sherman
Advertising Sales Director Scott Redmond
Circulation Director Liz Runyon
Art and Production Manager Michael Soliday
New Business Manager Cathy Daniels
Retention Manager Kathy Steele
Single Copy Specialist Kim Redmond

ADVERTISING DEPARTMENT
Phone (888) 558-1544
Advertising Sales Manager Steve Meni
Advertising Sales Representative
Dina Johnston, djohnston@kalmbach.com
Ad Services Representative
Christa Burbank, ads@astronomy.com

RETAIL TRADE ORDERS AND INQUIRIES
Selling *Astronomy* magazine or products in your store:
Phone (800) 558-1544
Outside U.S. and Canada (262) 796-8776, ext. 818
Fax (262) 798-6592
Email tss@kalmbach.com
Website www.Retailers.Kalmbach.com

CUSTOMER SALES AND SERVICE
Phone (877) 246-4835
Outside U.S. and Canada (813) 910-3616
Customer Service Astronomy@customersvc.com
Digital Astronomy.Digital@customersvc.com
Back Issues Astronomy.SingleCopy@customersvc.com

CONTACT US
Ad Sales adsales@astronomy.com
Ask Astro askastro@astronomy.com
Books books@astronomy.com
Letters letters@astronomy.com
Products products@astronomy.com
Reader Gallery readergallery@astronomy.com
Editorial Phone (262) 796-8776

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

GREGG RUPPEL

Faint Mizar B

A thank you to Phil Harrington for writing his enjoyable and informative Binocular Universe columns in *Astronomy*. Unfortunately, there's an error in the caption of the photo of Alcor and Mizar on p. 68 of the June 2018 issue. That caption says, "Alcor is the fainter star between and just below the brighter twin suns of Mizar A and B." In fact, Mizar and Alcor are the brighter two of the three stars visible in the image, as those two represent an optical double.
— **Scott Satko,** Lewisville, NC

Astronomy responds

Yes, the editors apologize for the mislabeled caption.

Tributes to Lucy and her discoverer

I quite enjoyed reading Joel Davis' "Exploring Jupiter's Trojan Asteroids" article in the June 2018 issue. I serve on the board of the Institute of Human Origins (IHO) at Arizona State University, founded by noted paleoanthropologist Dr. Donald Johanson. It is an honor to have a Discovery-class robotic mission named after Lucy, our ancient human ancestor discovered by Dr. Johanson. And now, Lucy will fly by a main belt asteroid named Donaldjohanson, a tribute to the IHO's founder. I love all things science, but having paleoanthropology and astronomy complement each other in this way is sure to expand the number of people following Hal Levison's mission.
— **Carol A.P. Saucier,** Cockeysville, MD

Various viewpoints

I believe that Jeff Hester has mischaracterized C.S. Lewis in the June issue. Having read many of his books, I'm convinced that even though he was a scholar of medieval lit, he did not pin his own viewpoint to it. Rather, he consistently presented a Neoplatonic view meshed with Christianity, and would not have had a problem with any current, up-to-date cosmology. But he did consider the material universe to be a secondary reality to the supremely real spiritual universe. He could easily accept scientific truth while dressing up a Christian worldview in Neoplatonism. — **Russ Hickman,**
Port Charlotte, FL

Correction

In the July issue, we misidentified this galaxy in Reader Gallery on p. 72. The correct designation is IC 4617, not NGC 6207. IC 4617 lies some 500 million light-years away.

RODNEY POMMIER

QUANTUM GRAVITY

EVERYTHING YOU NEED TO KNOW ABOUT THE UNIVERSE THIS MONTH . . .

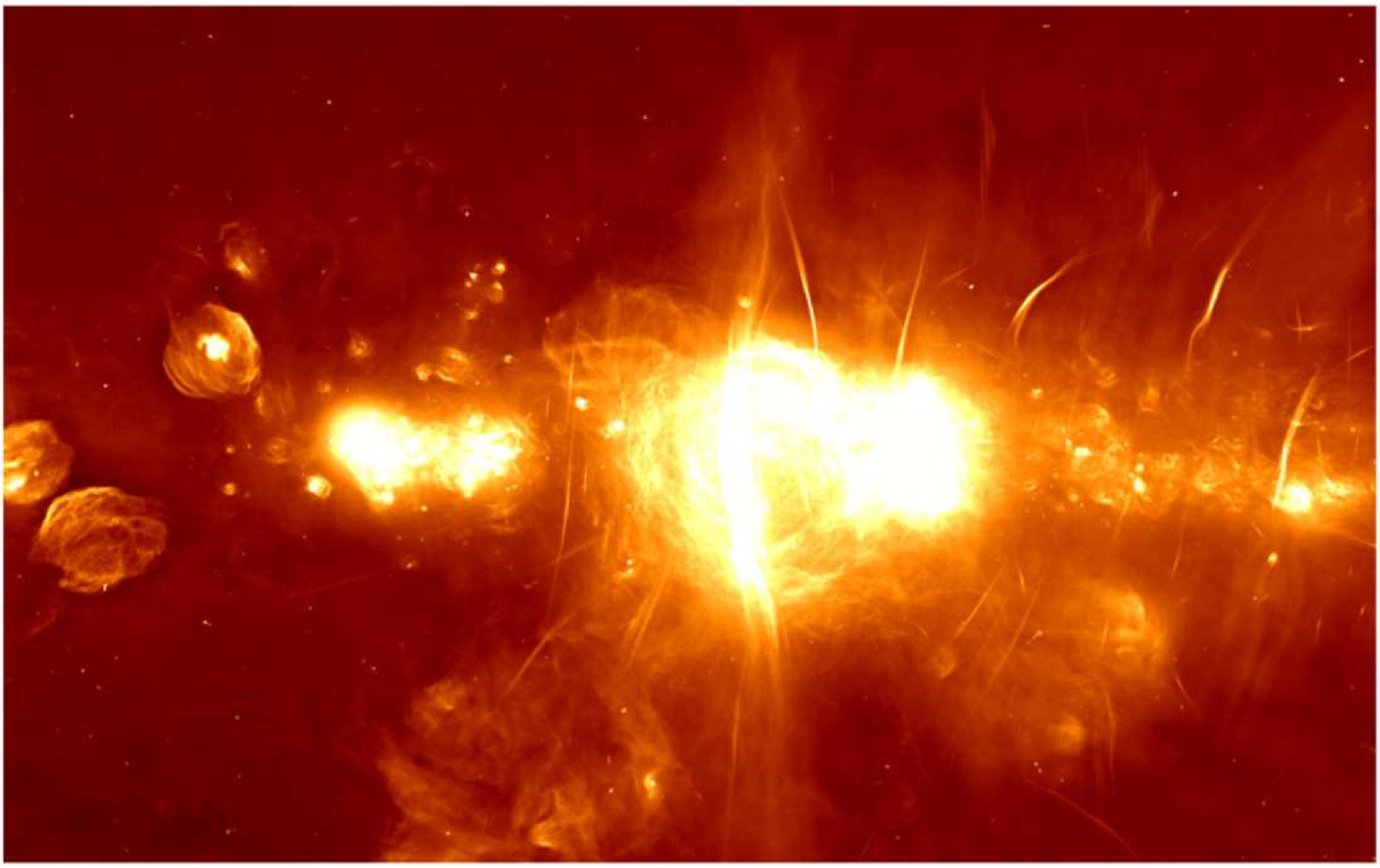
HOT BYTES >>

TRENDING TO THE TOP

BREAKFAST TIME
Scientists have determined that a collision between our galaxy and a sausage-shaped dwarf galaxy 8 to 10 billion years ago shaped the modern Milky Way.

GRAVEYARD ORBIT
When NASA's Dawn spacecraft runs out of fuel by October, it will remain non-operational, in orbit around the dwarf planet Ceres.

SPACE SHARD
Searchers have found a fragment of asteroid 2018 LA, which exploded above Botswana June 2 just hours after its discovery.



THE SOUTH AFRICAN RADIO ASTRONOMY OBSERVATORY (SARAO); TOP FROM LEFT: V. BELOKUROV (CAMBRIDGE, U.K.), BASED ON IMAGE BY ESO/JUAN CARLOS MUÑOZ; NASA/JPL-CALTECH/UCLA/MPS/DLR/IDA; PETER JENNISKENS

SNAPSHOT

Supermassive start

MeerKAT begins with a bang.

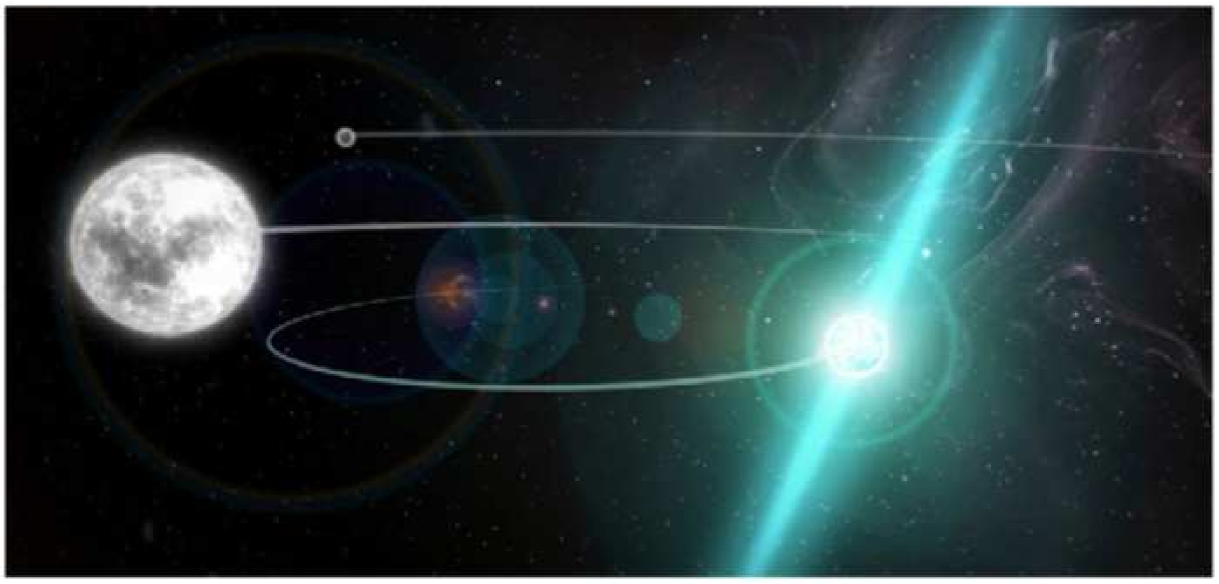
South Africa's Department of Science and Technology's long-awaited MeerKAT radio telescope is officially operating after a decade of construction. During its inauguration July 13, MeerKAT showcased a sample of its impressive capabilities: a stunning panoramic view of the area surrounding the Milky Way's central supermassive black hole, Sagittarius A*.

MeerKAT used its 64 antennas to capture this incredibly detailed radio image, which covers an area of about 1,000 by 500 light-years. Built in the Karoo region of the Northern Cape and operated by scientists at the South African Radio Astronomy Observatory, the telescope can penetrate the thick clouds of gas and dust that encompass the black hole, picking up radio emission that is invisible to visible-light telescopes.

MeerKAT researchers now plan to use the telescope's unprecedented image quality to dissect the black hole's mysterious properties. The telescope is a precursor to the Square Kilometre Array (SKA), an international collaboration to build the world's largest radio telescope. MeerKAT will be part of the SKA's first phase. — **Amber Jorgenson**

 EDGE OF SPACE. The Kármán line — the boundary between Earth's atmosphere and outer space — is about 20 percent (12.5 miles [20 km]) closer to Earth's surface than previously thought, new research says.

ALL OBJECTS, EVEN STARS, FALL THE SAME WAY



TEST BED. The triple-star system PSR J0337+1715, shown in this artist's impression, is a unique place to test gravity based on predictions made by Einstein's theory of relativity. PSR J0337+1715 contains a neutron star (right) orbiting a white dwarf (left); the pair orbits a second, more distant white dwarf (upper left). NRAO/AUI/NSF, S. DAGNELLO

The equivalence principle states that all objects should fall the same way, regardless of mass. The principle has been tested time and again — and passed with flying colors — on Earth. It's even been tested on the Moon, when Apollo 15 astronaut David Scott dropped a hammer and a feather from the same height. The two objects reached the lunar surface at the same time.

Einstein's theory of general relativity takes this concept a step further. It assumes the strong equivalence principle, which states that the laws of gravity should act the same, regardless of where in space-time they are tested. And now, for the first time, an international team of astronomers has confirmed this principle using a unique star system: PSR J0337+1715, which contains a rapidly spinning neutron star known as a pulsar, and two remnants of Sun-like stars, called white dwarfs. Their results were published July 4 in *Nature*.

Located 4,200 light-years away in the constellation Taurus, PSR J0337+1715's neutron star closely orbits one of the white dwarfs. The two circle each other every 1.6 days. The pair also orbits a second white dwarf over a much longer period of 327 days. This system is the perfect test bed for the strong equivalence principle because the neutron star, which compacts more mass than the Sun into an object about 12 miles (20 kilometers) across, has enough gravity to warp space-time within its own interior. Despite this, the strong equivalence principle says the neutron star should still "fall" (i.e., orbit) around the distant white dwarf at the same rate as its nearer companion. However, several alternative theories state that the strong self-gravity of the neutron star should change its gravitational properties slightly when compared with other objects (such as the white dwarf). If this were the case, the neutron star would wobble slightly over time as it orbits the more distant white dwarf with its less massive companion.

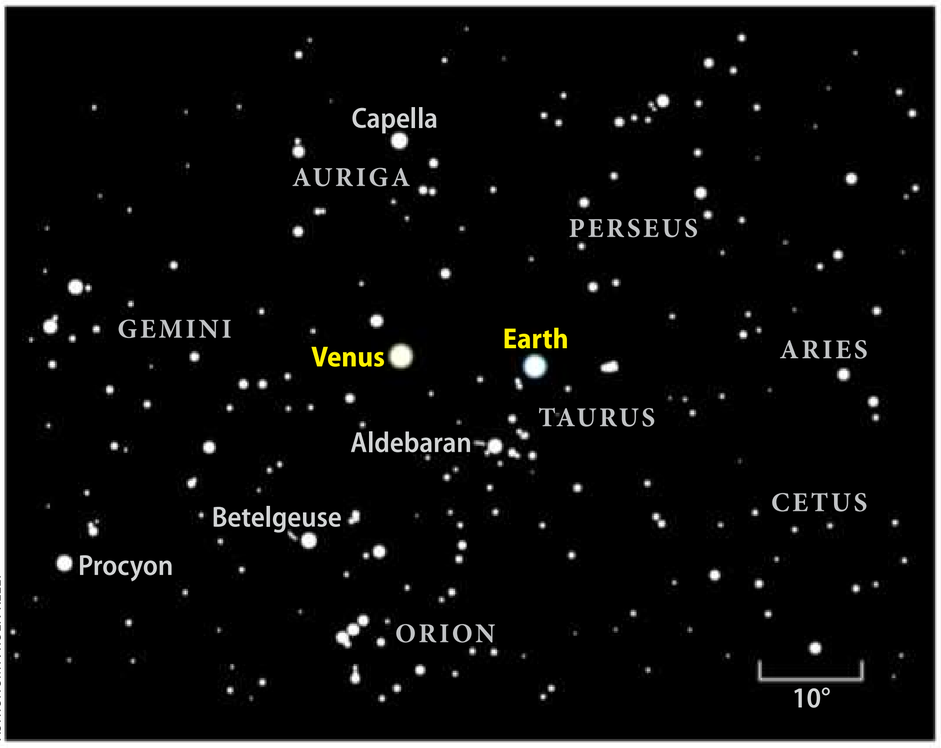
The researchers have observed the system regularly since its discovery in 2011, using the Robert C. Byrd Green Bank Telescope in West Virginia, the Westerbork Synthesis Radio Telescope in the Netherlands, and the Arecibo Observatory in Puerto Rico. These powerful radio telescopes picked up the radio pulses from the pulsar as it spins 366 times each second.

"We can account for every single pulse of the neutron star since we began our observations," said Anne Archibald of the University of Amsterdam and the Netherlands Institute for Radio Astronomy, and first author of the paper, in a press release. "We can tell its location to within a few hundred meters. That is a really precise track of where the neutron star has been and where it is going."

Based on that precise track, the team concluded that any change in acceleration between the neutron star and the nearer white dwarf is too small to detect. "If there is a difference, it is no more than three parts in a million," said Nina Gusinskaia of the University of Amsterdam, a co-author on the paper.

The results are another win for general relativity, which has passed several recent, increasingly rigorous tests. This finding also rules out several alternatives to general relativity, including some versions of string theory, and confirms what scientists currently believe about gravity and the way it acts, both on Earth and throughout the universe. **— Alison Klesman**

MERCURY'S GRAND VIEW



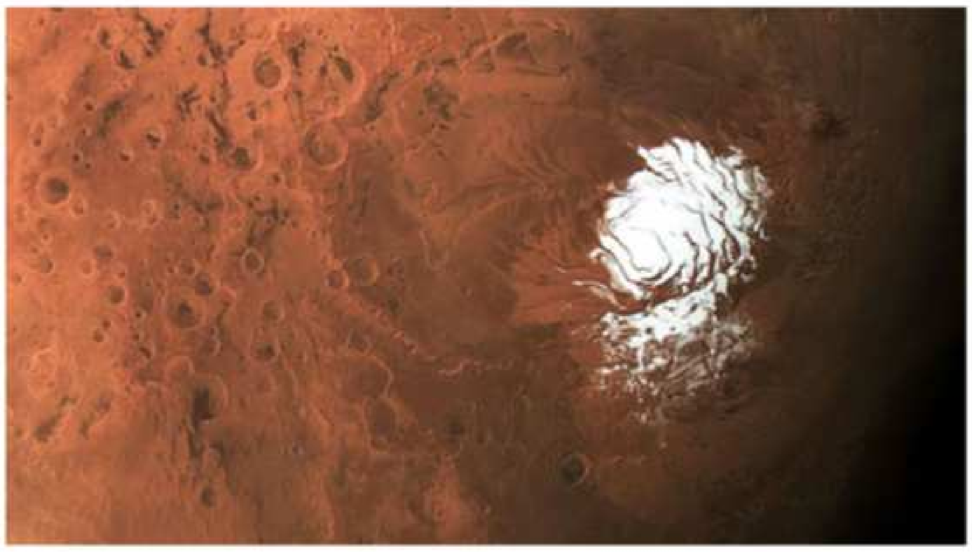
ASTRONOMY: ROEN KELLY

TWIN PLANETS. Earthbound skywatchers get to see Mercury low in the southwest after sunset November 6, when it reaches greatest elongation. But have you ever wondered what the night sky would look like from Mercury? Although the stars would all look the same, the planets would appear strikingly different. From the inner world on November 6, Venus and Earth would look almost like twins, dazzling gems set against the backdrop of Taurus the Bull. **— Richard Talcott**

From Mercury, Venus would gleam at magnitude –5.3, nearly four times brighter than magnitude –3.9 Earth. FAST FACT

BIG LITTLE MAGNET. For the first time, astronomers have measured the magnetic field around supernova remnant SN 1987A, finding it about 50,000 times weaker than a refrigerator magnet.

Lake of liquid water found on Mars



DEEP RED SEA. The European Space Agency's Mars Express orbiter captured this image of the planet's south polar cap and Hellas basin. Scientists recently discovered a 12-mile-long subsurface lake in this region. ESA/DLR/FU BERLIN

Astronomers have announced the discovery of a large underground lake of liquid water lurking just below Mars' surface. The new-found lake stretches some 12 miles (19 kilometers) from end to end. It was discovered using a radar instrument called Mars Advanced Radar for Subsurface and Ionosphere Sounding (MARSIS) on board the European Space Agency's Mars Express spacecraft, which reached Mars nearly 15 years ago. The results were published August 3 in the journal *Science*.

"This is just one small study area," said lead author Roberto Orosei, who is also principal investigator of the MARSIS experiment, in a press release. "It is an exciting prospect to think there could be more of these underground pockets of water elsewhere, yet to be discovered."

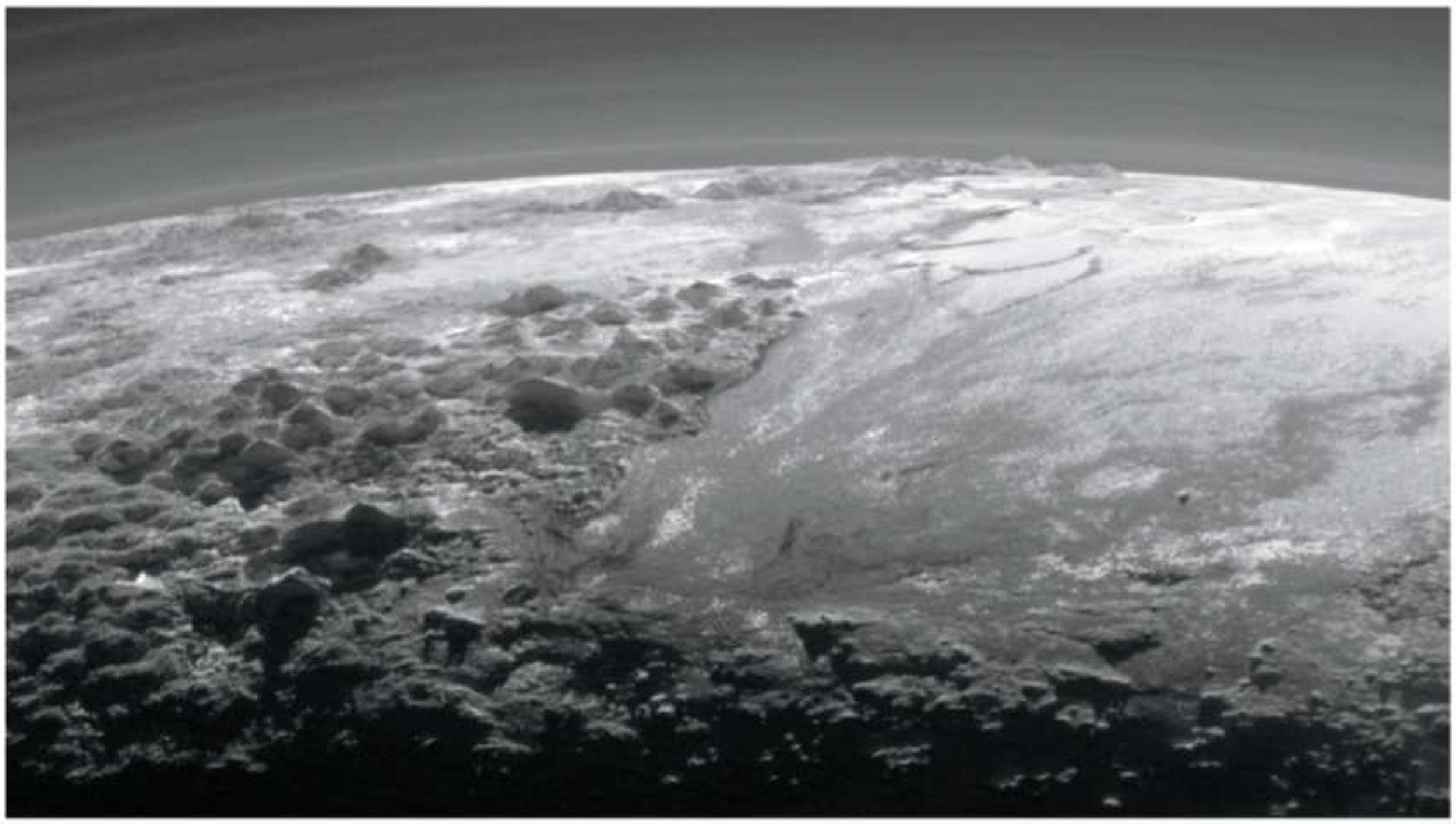
Scientists found the lake by sending radar pulses from the orbiter to penetrate the surface and reflect back, revealing secrets from just below the surface. They found it while surveying the Planum Australe region near Mars' southern ice cap, which is made of water ice covered by frozen carbon dioxide.

Though researchers have found hints of martian subsurface features before, data resolution in the past was too low to confirm their existence. But the team found a new way to operate the instrument that avoids processing data on the aging spacecraft and instead sends observations to Earth, resulting in crisper images on smaller scales.

The discovery is especially intriguing because similar underground lakes are also found near Earth's poles, particularly in Greenland and Antarctica. In recent years, scientists drilled deep beneath the Antarctic ice into one of these, the subglacial Lake Whillans, which has been cut off from the surface for millions of years. They found bacteria living there in complete isolation.

However, while the find is tantalizing for astrobiologists eager to find alien life, it's also a bit of a tease. It will be decades before astronauts can visit Mars, and likely much longer before we can drill a mile beneath the dusty surface. So we may not see any martian fishing expeditions in our lifetime. **— Eric Betz**

First global maps of Pluto and Charon published



NASA/JHUAPL/SWRI

MAJESTIC MOUNTAINS. Prior to New Horizons' 2015 flyby, planetary scientists could only speculate about the terrain on Pluto and its largest moon, Charon. The spacecraft revealed mountains, valleys, and much more. This image, taken 15 minutes after New Horizons' closest approach to Pluto, shows a near-sunset view of a stretch of icy mountains on the dwarf planet. Norgay Montes appears in the foreground, with Hillary Montes in the distance. Haze in Pluto's tenuous atmosphere is also visible. Recently, the first global maps of Pluto and Charon based on that data have been published and archived in the Planetary Data System (pds.nasa.gov), available to researchers and the public. The maps took two years to produce as images from the spacecraft's Long Range Reconnaissance Imager and Multispectral Visible Imaging Camera were received, analyzed, and combined into mosaics containing topographic information. **— A.K.**

QUICK TAKES

LUNAR LIFE?
New research indicates the Moon could have sustained simple life-forms during two periods in its history: 4 billion and 3.5 billion years ago.

MOONS GALORE
Astronomers have discovered a dozen new moons around Jupiter, bringing the planet's roster of satellites to 79.

COSMIC CANNIBAL
For the first time, astronomers may have witnessed a young star devouring its own planets.

HOW BIG?
Physicists have refined the limits on the size of neutron stars, finding the hyperdense objects typically have a radius between 7.5 and 8.5 miles (12 and 13.5 kilometers).

SPACE GERMS
Some bacterial spores are able to survive on decontaminated spacecraft, thanks to both peroxide and radiation resistance.

RAY GUNS
Eta Carinae's two massive stars (90 and 30 solar masses) generate intense stellar winds capable of producing high-energy cosmic rays.

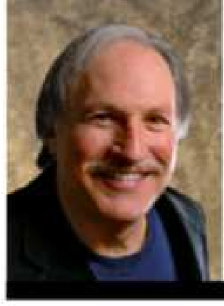
COSMIC BILLIARDS
A gigantic object roughly twice the size of Earth likely hit Uranus nearly 4 billion years ago, giving the gas giant its dramatic sideways tilt.

LET IT POUR
A recent study found that the valley networks carved into Mars likely formed from the flow of rainwater.

MULTI-MESSENGER
China confirmed plans to launch a satellite that will hunt for gamma rays from gravitational wave events.

TRICKLE TRACKER
A new instrument installed on the International Space Station will measure the temperature of plants to monitor their water use and study the impact of droughts.

CHAOTIC START
New research suggests that more chaotic protoplanetary disks push giant planets outward, while calmer disks drag them inward. **— Jake Parks**



STRANGE**UNIVERSE**

BY BOB BERMAN

Dark matter alters autumn

Unseen forces are at play in the November sky.

For countless millennia, the sky has provoked questions — and inspired the hard work that yields answers. What are those moving planets? Why do the stars shine? Resolving such ancient riddles has let today's backyard observers gaze into familiar constellations where much is known.

But scientific comfort has always been ephemeral. The conception of dark matter in the 1930s and dark energy in the 1990s meant the universe is dominated by powerful-but-elusive entities. These raise a basic and valid question: Do these major, mysterious headline-makers show themselves in the visible heavens?

Dark energy does not. The universe may be blowing itself apart at an accelerating tempo, but this enigmatic anti-gravity force simply doesn't manifest itself locally within any particular cluster of galaxies, including ours. So the multimillion light-year range of the naked eye, even under ideal unpolluted rural skies, yields no trace of dark energy, whatever it might ultimately prove to be.

Dark matter is a different story. First recognized by Fritz Zwicky 75 years ago, it is an invisible substance that exerts enough gravitational force to glue together our Local Group of galaxies despite each member's high speed. Without its pull, Andromeda wouldn't continue to zoom in our direction on a collision course at 70 miles (113 kilometers) per second. Seen as a naked-eye smudge, its brightest companion galaxies easily show up through backyard telescopes. Our own galaxy is likewise escorted like an aircraft carrier, by small galaxies trapped within our gravitational epoxy.

Three years ago, a research team published a new analysis of the Milky Way's inner rotation. That's the section that fills your southern sky this month. The study, published in the journal *Nature Physics*, concluded that the Sun and Earth couldn't be zooming along at 143 miles (230 km) a second, keeping pace with all the galactic contents around us, if lots of dark matter didn't pervade our galaxy. If the galaxy's spin were dictated solely by the baryonic matter that comprises stars, planets, and black holes, it would rotate much differently from the way it does. The unseen matter isn't concentrated, but diffusely scattered as an immense halo. So the familiar spiral we imagine ourselves to be in is like a ship in a bottle.

Dark matter's proof sprawls around us on November nights.

The Milky Way is best seen at nightfall, especially during November's more moonless first half. Without dark matter critically influencing the way we spin, stars closer to the center — in the direction of Sagittarius — would orbit faster than we do. Conversely, stars farther away, like those in Orion now rising by 10 P.M., would get left behind. Instead, the Milky Way rotates as if it were a solid structure, a vinyl record, so that the same stars tend to keep us company.

This makes the constellations far more durable. And on a larger but still visible scale, there's our Local Group of about four dozen galaxies, blithely defying the universe's expansion. While the universe blows itself apart, we and neighbors like M33 are so glued together that we'll hang out together for the entire duration. Dark matter's proof sprawls around us on November nights.

But one aspect of dark matter *will* change our view of the autumn sky. While Andromeda is aligned a mere 13° from the plane of tilt of our galaxy, it lies at a galactic longitude offset 90° from our core. This is changing. As the Milky Way spins, our brisk rotation at 143 miles per second (230 km/s) will whirl us around to the other side of our galaxy in about 100 million years. Then the thick central bulge will block Andromeda behind opaque clouds of carbon dust for about 15 million years. Our sister galaxy will be gone.

MIKULSKI ARCHIVE FOR SPACE TELESCOPES (MAST), STScI, AND NASA

Observe Arcturus while you can! Thanks to dark matter, the solar system's motion through the galaxy means this bright star will be visible only for another 50,000 years.

Another change: While the strange uniformity to our galaxy's rotation means that most familiar stars like Vega and the Dipper gang will keep hanging out near us like adjacent horses on a carousel, Arcturus will be gone. It circles our galaxy's center not by orbiting along the dusty crowded disk, but instead traveling perpendicular to it. For the past 500 centuries, it's been diving down toward us from the north, from the empty "halo" region. These days it's about as close to us as possible, a mere 36 light-years away. It will keep going until it reaches the limits of naked-eye visibility in a mere 50,000 years. When it returns to its present location, we will be somewhere else. We will never meet again.

So before we get too carried away with either dark matter's promise of permanence or the suggestion of celestial evanescence, we should keep things in perspective. This strange entity is indeed making many celestial favorites stick around. It's preserving the constellations. But it can't promise us the stars.

Join me and Pulse of the Planet*'s Jim Metzner in my new podcast,* Astounding Universe, *at* **http://astoundinguniverse.com.**

BROWSE THE "STRANGE UNIVERSE" ARCHIVE AT **www.Astronomy.com/Berman.**

RENDEZVOUS WITH RYUGU. On June 27, the Japanese Hayabusa2 spacecraft arrived at asteroid Ryugu, where it will eventually collect a sample and return it to Earth.

Astronomers catch ghost particle from distant galaxy

Neutrinos rarely interact with normal matter. They are notoriously hard to detect, much less associate with their source. On July 12, the IceCube Collaboration announced that the first confirmed extragalactic neutrino had been traced to its origin, in the central supermassive black hole of a galaxy 3.7 billion light-years away in the constellation Orion. The finding was published the same day in the journal *Science*.

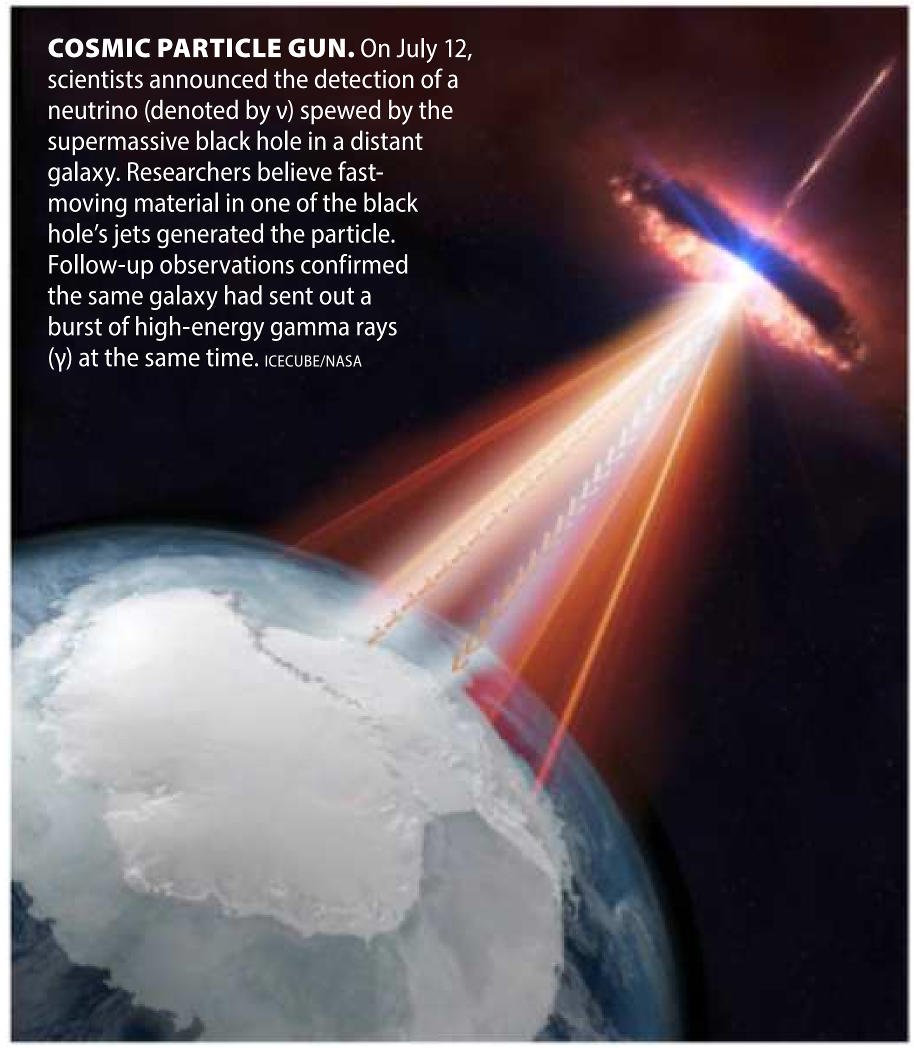
IceCube-170922A, as the neutrino is called, struck the Antarctic ice September 22, 2017, generating a particle called a muon in a flash of blue light. That event was picked up by several of IceCube's 5,160 detectors embedded beneath the ice. IceCube-170922A was about 300 million times more energetic than neutrinos our Sun produces. Its trajectory allowed scientists to trace it back to TXS 0506+056 — a blazar, or accreting supermassive black hole, in a distant galaxy. As it pulls matter in, the black hole shoots out powerful jets; blazars are a class of galaxies that are tilted in such a way that the jet points directly at Earth.

Less than a minute after the detection, IceCube sent out a worldwide alert. Several facilities followed it up, among them the Major Atmospheric Gamma Imaging Cherenkov Telescope in the Canary Islands and NASA's Neil Gehrels Swift Observatory, Fermi Gamma-ray Space Telescope, and Nuclear Spectroscopic Telescope Array. These observations confirmed that the neutrino strike coincided with a burst of gamma rays from the same galaxy, clinching the case for the blazar as the particle's origin.

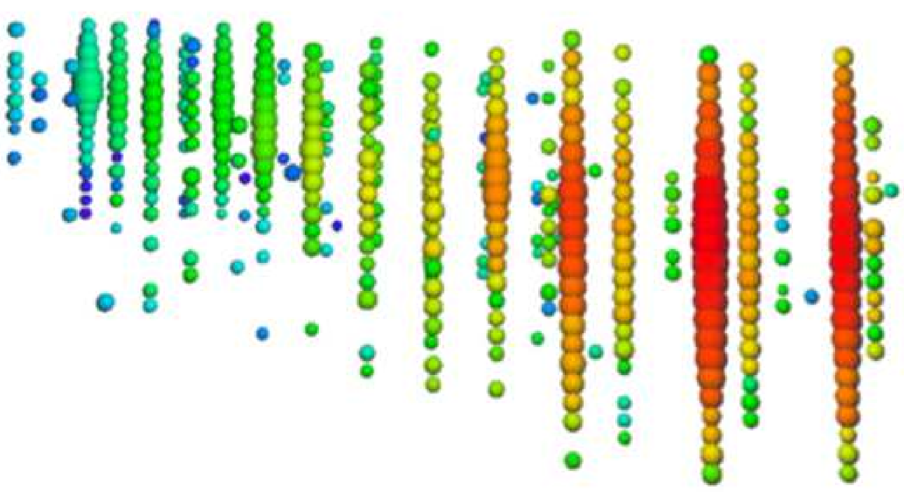
Tracing IceCube-170922A to its source is a twofold achievement. Not only is it the first time a neutrino has been tracked to a specific extragalactic source, it also confirms blazars as high-energy neutrino generators. Combing through nearly 10 years of prior data, researchers led by scientists from the Technical University of Munich and the European Southern Observatory found that TXS 0506+056 emitted high levels of gamma rays between September 2014 and March 2015. This period overlaps with other neutrino detections made by IceCube, coming from the same direction.

Archived data also show an increase in radio emissions from the blazar in the 18 months prior to IceCube-170922A's detection. This could indicate an increase in jet activity, which astronomers believe accelerates particles to high energies to create the cosmic rays that result in high-energy neutrino emission.

"This identification launches the new field of high-energy neutrino astronomy, which we expect will yield exciting breakthroughs in our understanding of the universe and fundamental physics, including how and where these ultra-high-energy particles are produced," said Doug Cowen of Penn State University, a founding member of IceCube Collaboration as well as a co-author of the paper, in a press release. "For 20 years, one of our dreams as a collaboration was to identify the sources of high-energy cosmic neutrinos, and it looks like we've finally done it!" **— A.K.**

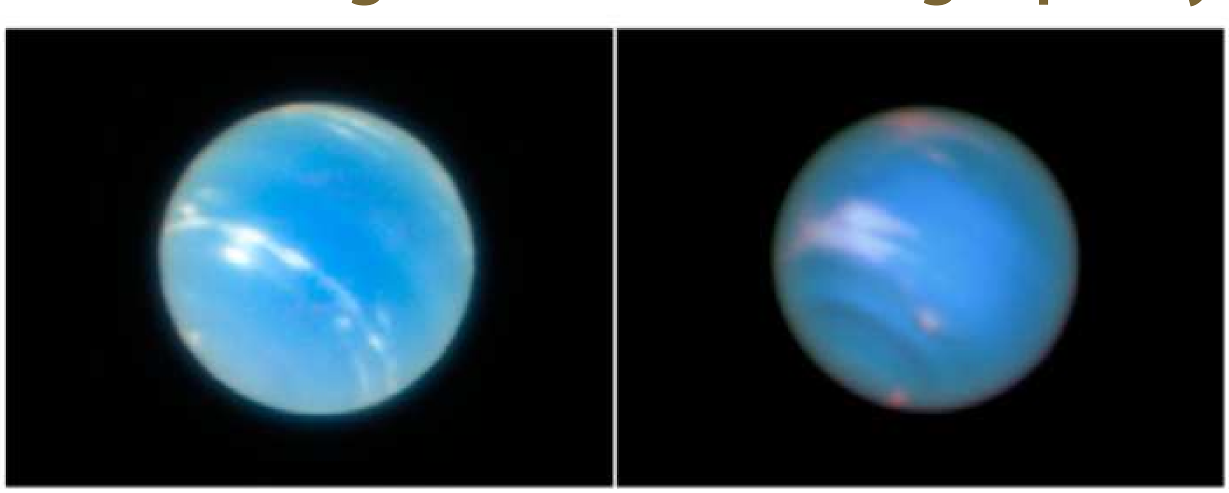


COSMIC PARTICLE GUN. On July 12, scientists announced the detection of a neutrino (denoted by ν) spewed by the supermassive black hole in a distant galaxy. Researchers believe fast-moving material in one of the black hole's jets generated the particle. Follow-up observations confirmed the same galaxy had sent out a burst of high-energy gamma rays (γ) at the same time. ICECUBE/NASA



FOLLOW THE RAINBOW. When neutrino IceCube-170922A sparked the creation of a muon, several of IceCube's subsurface detectors recorded the event. This figure shows the track of the resulting muon as seen by the detectors, each of which is denoted by a sphere. The color gradient, from red to green and blue, shows the time of the signal's arrival. ICECUBE COLLABORATION

VLT challenges Hubble for image quality



ESO/P. WEILBACHER (AIP)/NASA, ESA, AND M.H. WONG AND J. TOLLEFSON (UC BERKELEY)

SUPER SHARP. The Multi Unit Spectroscopic Explorer (MUSE) instrument on the European Southern Observatory's Very Large Telescope in northern Chile has just unveiled the first images with its new adaptive optics unit, the Ground Atmospheric Layer Adaptive Corrector for Spectroscopic Imaging. Adaptive optics systems compensate for the fuzziness that occurs when imaging through Earth's turbulent atmosphere in real time, allowing ground-based telescopes to create crisper images. These images of Neptune show the results achievable with MUSE's adaptive optics system (left), compared with the image quality from the Hubble Space Telescope (right) from above our atmosphere. Using sophisticated adaptive optics techniques, it is now possible to achieve from the ground images on par with — and at times better than — Hubble at visible wavelengths over small fields of view. **— A.K.**


THE NINE PLANETS RING
HANDCRAFTED WITH AN ORBITING
GIBEON METEORITE BAND
IN 18K GOLD SET WITH 9 GEMSTONES
NINEPLANETSRING.COM
831.336.1020


ScopeBuggy
• For use with most tripods, DOBs and piers
• 10" Pneumatic tires for soft ride
$345.00*
Plus S&H
Approx. $60 Shipping USA
*Subject to change
SCOPEBUGGY
P.O. BOX 834
Elephant Butte, NM
87935
Patent Pending
Still #1
915-443-9010
www.scopebuggy.com


OPTICAL STRUCTURES
Astrodon
LUMICON
By Farpoint
JMI
Optical Structures Incorporated (OSI) Astronomy Products Are Available at:
FarpointAstro.com
FARPOINT


The best $299 eyepiece you'll ever buy.
No computer required. Battery-powered 7" color monitor included.
M16 Eagle Nebula
8" Celestron Evolution
Metropolitan Skies
REVOLUTION IMAGER
RevolutionImager.com
High Point Scientific
Agena AstroProducts
Oceanside Photo & Telescope
Woodland Hills Telescope
Skies Unlimited
Orange County Telescope


SPECIAL INTEREST
TOURS
Northern Lights Tour
Marvel at the wonders of Alaska's earth and sky with Bob Berman!
March 6th-11th 2019
Anchorage Ext.
March 3rd-5th
Enjoy talks by experts, dogsledding, natural hot springs, and much more!
info@specialinteresttours.com | 727-330-7738
www.specialinteresttours.com


WH
Woodland Hills
Camera & Telescopes
Top Brands
Knowledgeable Staff
Free Shipping*
Worldwide Delivery
We are your one stop shop for telescopes, cameras, observatories, printing and more!
Visit
TelescopeS.NET/astrothanks
for a reader appreciation gift!
Call us! Open M - Sat.
818.347.2270
Extended holiday hours start November 23rd.
*see restrictions

 WORKING MODEL. A final data release from the Planck mission confirms the current standard cosmological model provides an excellent description of the universe's matter and energy content.

'Oumuamua is likely a comet, not an asteroid

Ever since astronomers first spotted 1I/2017 U1 'Oumuamua zipping through the solar system in October 2017, the peculiar object has been the target of intense scrutiny. And recently, researchers showed the object is slowly and steadily accelerating away from the Sun, suggesting that 'Oumuamua is likely a comet, rather than an asteroid as previously thought.

"Our high-precision measurements of 'Oumuamua's position revealed that there was something affecting its motion other than the gravitational forces of the Sun and planets," team lead Marco Micheli of the European Space Agency said in a press release.

The team's findings were published June 27 in *Nature*. The researchers explored a number of possible scenarios in an attempt to explain 'Oumuamua's surprising speed. After considering all possibilities — such as pressure from the photons in sunlight, frictionlike forces, and magnetic interactions with the solar wind — the team concluded the most likely explanation is that 'Oumuamua is venting gas and dust from its surface in a process called outgassing, which almost exclusively occurs in icy comets, not rocky asteroids.

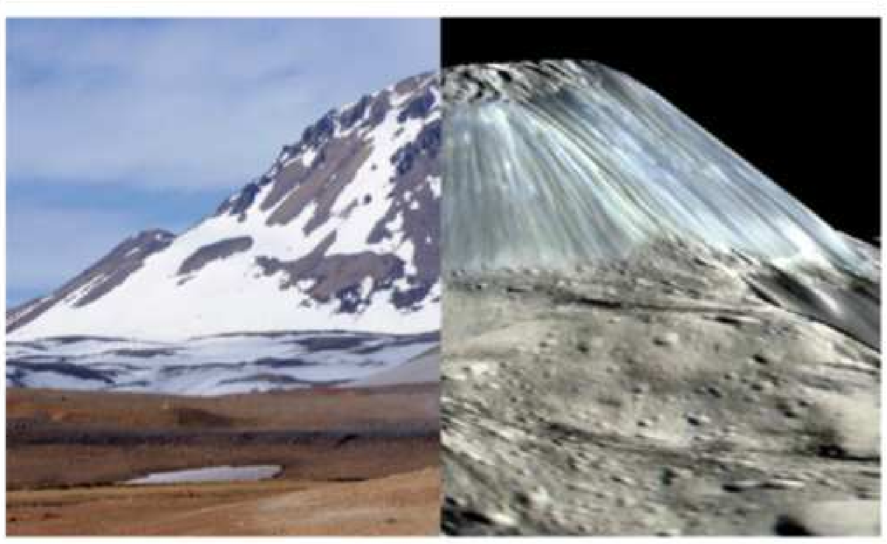
As the Sun sublimates ices trapped just below 'Oumuamua's surface, turning the solids directly into gas, the process generates a tiny amount of thrust. Though this thrust is small, it is enough to account for 'Oumuamua's observed boost in speed, the researchers say.

ESA/HUBBLE, NASA, ESO, M. KOMMESSER

SPEED BOOST. New research suggests the first known interstellar interloper, 'Oumuamua (shown in this artist's concept), is accelerating away from the Sun faster than expected, thanks to its venting of gas.

Although the suspected outgassing tells us a bit about the composition of 'Oumuamua, it unfortunately makes determining the origin of this puzzling object that much more challenging. "The true nature of this enigmatic interstellar nomad may remain a mystery," said co-author Olivier Hainaut of the European Southern Observatory. "'Oumuamua's recently detected gain in speed makes it more difficult to be able to trace the path it took from its extrasolar home star." **— J.P.**

2 The number of times Apollo 12 was struck by lightning during launch November 14, 1969.

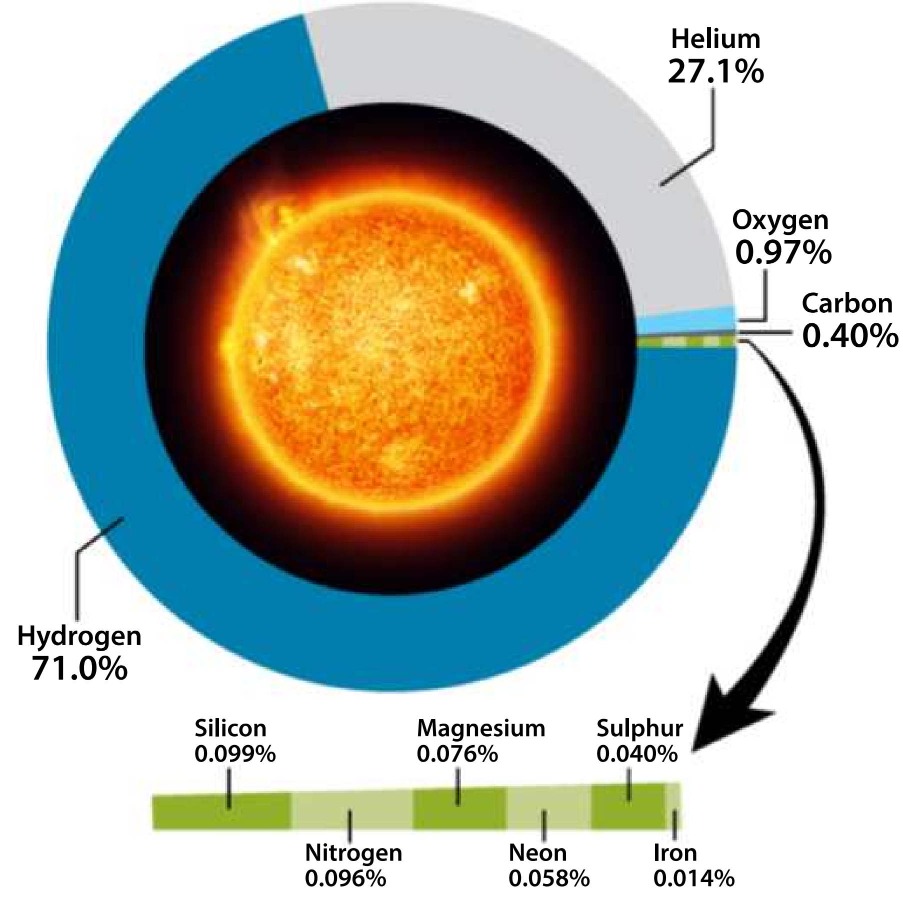


HANSUELI KRAPF/CREATIVE COMMONS/NASA/JPL-CALTECH/UCLA/MPS/DLR/IDA

Earth and Ceres: Striking similarities

TERRESTRIAL ANALOGS. Situated in the asteroid belt between Mars and Jupiter, Ceres is a small, dark dwarf planet with bitterly cold temperatures and no atmosphere. But NASA's Dawn spacecraft, which has been orbiting the world since 2015, has revealed that despite its differences from Earth, Ceres also shows remarkably similar features. The left side of this image shows the dome of Hlíðarfjall, an Icelandic mountain, with a digital projection of Ceres' Ahuna Mons, a cryovolcano that spews cold water and mud instead of lava, on the right. The structures are roughly the same height and width, and both are made up of fine-grained, loose material. Other similarities between Earth and Ceres include landslide remnants, bright surface minerals left over from saltwater evaporation, and pingos — large domes that form when subsurface ice pushes upward beneath looser soil. The worlds are far from twins, but forming from similar materials has resulted in some uncanny resemblances. **— A.J.**

WHAT'S THE SUN MADE OF?



ASTRONOMY: ROEN KELLY

ELEMENTARY. Like every other normal star, our Sun is mainly hydrogen and helium. But which elements are next most abundant? Here are the top 10 that make up our daytime star, arranged by the percentage each has of the Sun's total mass. **— Michael E. Bakich**

FAST FACT

Solar physicists have cataloged 67 elements in the Sun so far.

MORE THAN $2,000 IN PRIZES!

2018 ASTRO SWEEPSTAKES

GRAND PRIZE: Advanced VX 6" Refractor Telescope

For planetary imaging and brighter deep-sky objects, many astroimagers say there's no better choice than a refractor. Refractors offer no obstruction of the aperture, giving you the highest possible contrast. This refractor setup features an f/8 objective lens, which can be paired with one of Celestron's Nightscape CCD cameras to image brighter deep-sky objects or NexImage 5 Solar System Imager to create dazzling images of the planets.

Retail value: $1,439.00

1ST PRIZE

Astro Fi 102 mm Maksutov-Cassegrain Telescope

This fully featured telescope can be controlled with your smartphone or tablet using the free Celestron SkyPortal app. Celestron's SkyPortal app replaces the traditional telescope hand control for a 100% wireless experience. Just hold your smart device up to the night sky. When you find an object you'd like to view, tap the screen. Your Astro Fi telescope automatically slews to the object, while the screen displays information about it. It's never been more fun to explore the universe!

Retail value: $429.95

2ND PRIZE

Cometron 114AZ Telescope

Even beginning stargazers can catch stunning views of the next comet with Celestron's Cometron 114AZ. Designed specifically for viewing comets, Cometron 114AZ offers a 114 mm parabolic mirror to capture the sharpest views of even dim comets on their journey toward the Sun. Two high-quality Kellner eyepieces are included to enhance your views. The simple Newtonian reflector optical design, altazimuth mount, and included red-dot finderscope make it easy to navigate the night sky. A steel tripod provides stability.

Retail value: $179.95

3RD PRIZE

Skymaster Pro 15x70 Binoculars

SkyMaster Pro binoculars are the ideal choice for amateur astronomers or anyone that observes at great distances. The 70 mm objective lenses have tremendous light gathering capabilities, delivering superior low light performance, even in the dimmest conditions. Every air-to-glass surface is multi-coated with Celestron's proprietary XLT coating technology. These coatings coupled with BaK-4 prisms increase light transmission through the optical path and deliver crisp, high contrast images with outstanding resolution.

Retail value: $199.95

4TH PRIZE

1-Year *Astronomy* Subscription

(5 awarded)

Receive 12 exciting issues of knowledgeable science reporting, insights from top experts, monthly sky charts, spectacular celestial photography, informative equipment reviews, and more. Plus, enjoy all the subscriber-only benefits at Astronomy.com.

Retail value: $42.95 each

Sponsored by:

Astronomy magazine

CELESTRON

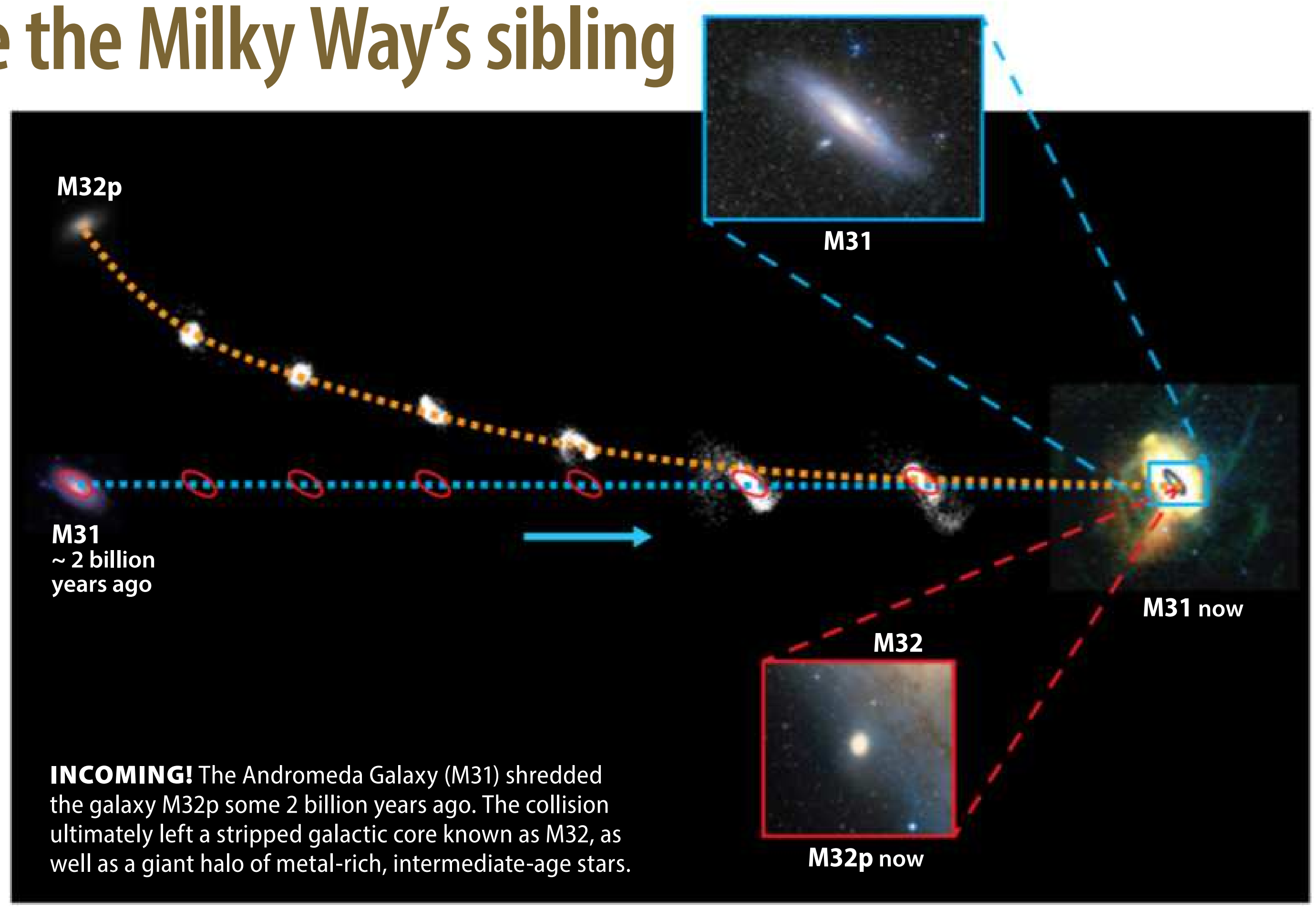
ENTER TODAY! Enter Online at Astronomy.com/Sweeps

Hurry! Entries must be transmitted by October 31, 2018 See page 69 for Official Sweepstakes rules.

P33577

ASTRO**NEWS** **E PLURIBUS UNUM.** An array of 10 modest telescopes will make up the Magdalena Ridge Observatory Interferometer, which will achieve the resolution of a single 347-meter telescope.

Andromeda ate the Milky Way's sibling



INCOMING! The Andromeda Galaxy (M31) shredded the galaxy M32p some 2 billion years ago. The collision ultimately left a stripped galactic core known as M32, as well as a giant halo of metal-rich, intermediate-age stars.

R. D'SOUZA; M31: COURTESY OF WEI-HAO WANG; STELLAR HALO OF M32: AAS/IOP

The Andromeda Galaxy (M31) is the largest member of the Milky Way's gang of galactic neighbors, known as the Local Group. With around a trillion Suns' worth of mass, Andromeda's gravitational influence is a force to be reckoned with. And, according to new research, no galaxy knows this better than M32, an oddball satellite galaxy now orbiting Andromeda.

In a study published July 23 in *Nature Astronomy*, researchers used cosmological simulations of galaxy formation to show that about 2 billion years ago, the Andromeda Galaxy cannibalized what was once one of the largest galaxies in the Local Group, turning it into the strange compact elliptical galaxy now known as M32. The massive collision stripped M32's progenitor galaxy (dubbed M32p) of most of its mass — taking it from a hefty 25 billion solar masses to just a few billion solar masses.

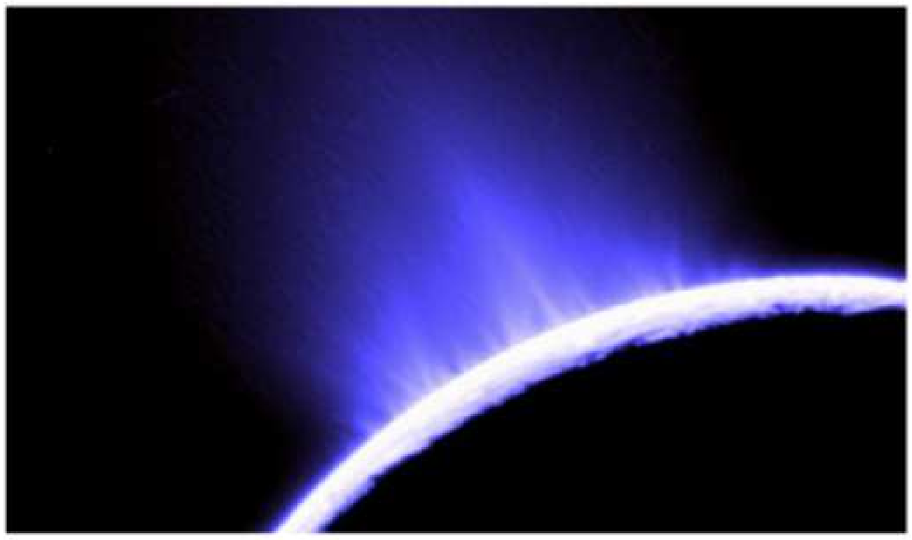
"It was shocking to realize that the Milky Way had a large sibling, and we never knew about it," said co-author Eric Bell, an astronomer from the University of Michigan, in a press release.

According to the researchers, this massive merger with M32p helps explain why Andromeda has a massive population of intermediate-age stars in its stellar halo, which have compositions similar to those in M32. Andromeda's particular population of halo stars would not be the case if the galaxy underwent sporadic bursts of star formation during multiple small mergers. Furthermore, a single large collision would explain why Andromeda possesses a thickened disk and experienced a significant burst in star formation about 2 billion years ago, when about 20 percent of its stars were born.

By applying the same technique used in this study to other galaxies, the researchers hope to better understand how various mergers can drive the growth of galaxies throughout the universe. And considering that Andromeda is currently on a collision course with the Milky Way, which will lead to a merger between the two galaxies in about 4 billion years, the more we know about such mergers, the better. **—J.P.**

4,300 **The dayside temperature (in degrees Celsius) of KELT-9b, the hottest known exoplanet.**

Massive organic molecules found in Enceladus' plumes



NASA/JPL/SPACE SCIENCE INSTITUTE

SPRINKLER SYSTEM. Enceladus' south pole spews water ice and other molecules from fissures known as tiger stripes. NASA's Cassini spacecraft spotted complex organic molecules as it sampled the plume, shown here in false color. Such molecules bolster the case for Enceladus as a hospitable home for life in the solar system.

The Cassini spacecraft may be gone, but its data continue to reveal new details of the Saturn system. One is the discovery of complex, carbon-rich organic molecules in the plumes that spew from the southern hemisphere of Saturn's icy moon Enceladus.

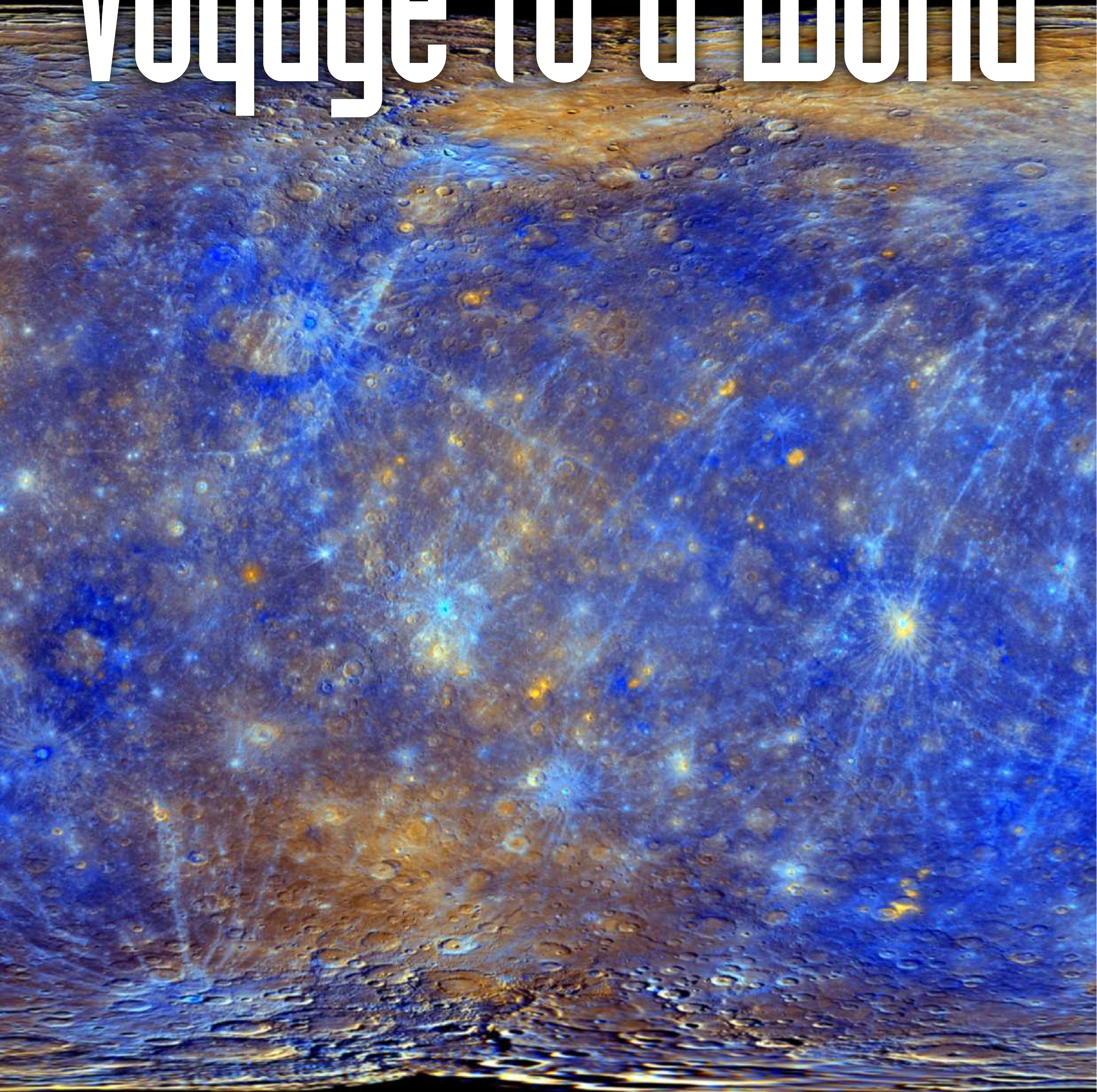
"It is the first-ever detection of complex organics coming from an extraterrestrial water-world," Frank Postberg of the University of Heidelberg, Germany, the first author of the discovery paper published June 27 in *Nature*, said in a press release.

Before its mission ended in September 2017, Cassini used its Cosmic Dust Analyzer (CDA) and Ion and Neutral Mass Spectrometer (INMS) instruments to sample the plume emanating from the 300-mile-wide (500 kilometers) world. CDA tasted the plume to determine its composition, while INMS measured the impacts of molecules against its sensor to derive their mass. About 3 percent of the molecules sampled approached the limits of the sensor's detection range at 200 atomic mass units — more than 10 times heavier than methane.

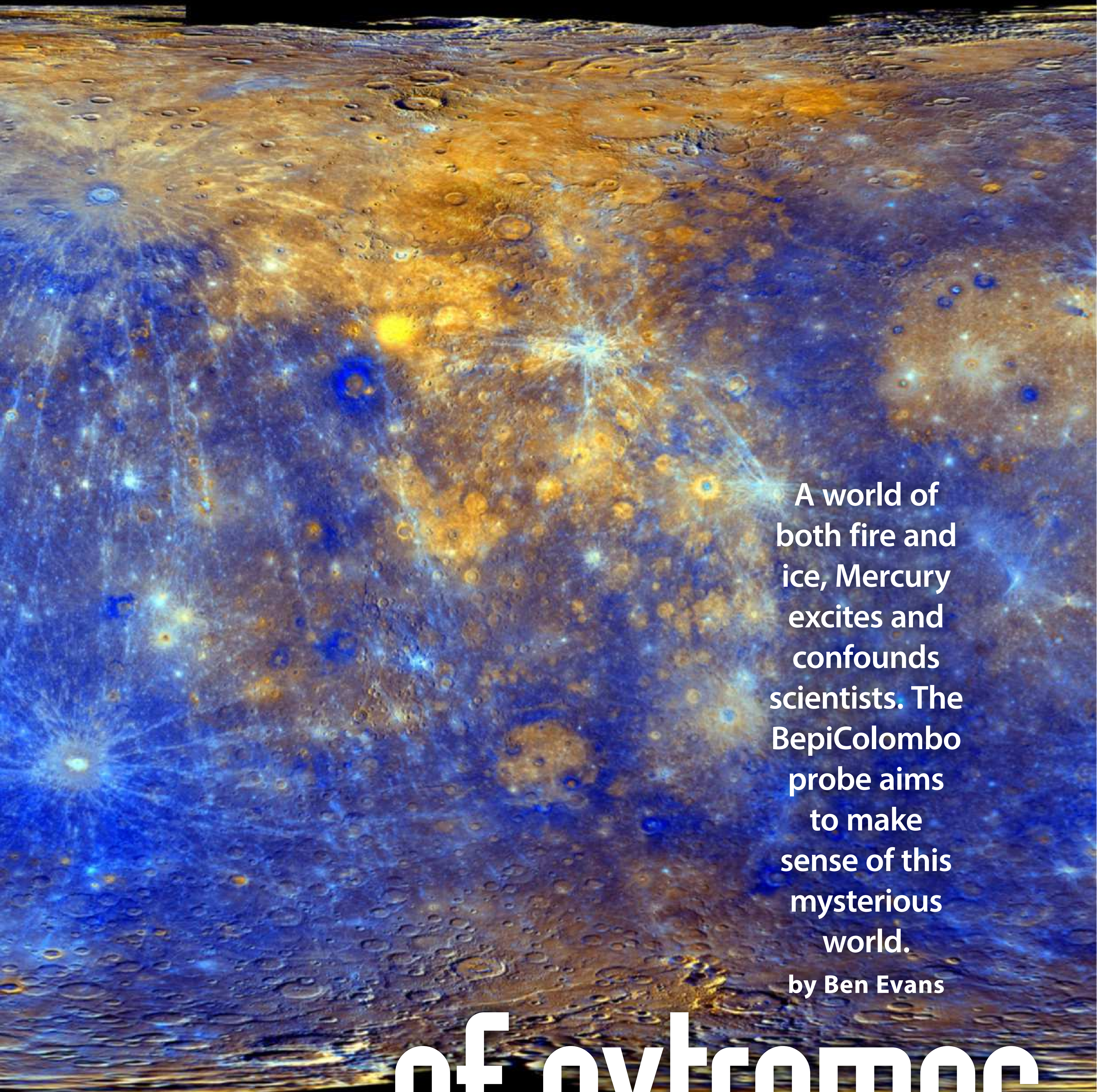
The presence of such large, complex organic molecules is something researchers would expect to see if life was present. Furthermore, Cassini detected molecular hydrogen in the plume during a 2015 flyby. "Hydrogen provides a source of chemical energy supporting microbes that live in the Earth's oceans near hydrothermal vents," said Hunter Waite of Southwest Research Institute (SwRI), a co-author of the paper.

Though these findings are far from evidence of actual life, "with complex organic molecules emanating from its liquid water ocean, this moon is the only body besides Earth known to simultaneously satisfy all of the basic requirements for life as we know it," said SwRI's Christopher Glein.
—Nathaniel Scharping, A.K.

Voyage to a world



Color explodes from Mercury's surface in this enhanced-color mosaic taken through several filters. The yellow and orange hues signify relatively young plains likely formed when fluid lavas erupted from volcanoes. Medium- and dark-blue regions are older terrain, while the light-blue and white streaks represent fresh material excavated from relatively recent impacts. ALL IMAGES, UNLESS OTHERWISE NOTED: NASA/JHUAPL/CIW



A world of both fire and ice, Mercury excites and confounds scientists. The BepiColombo probe aims to make sense of this mysterious world.

by Ben Evans

# of extremes

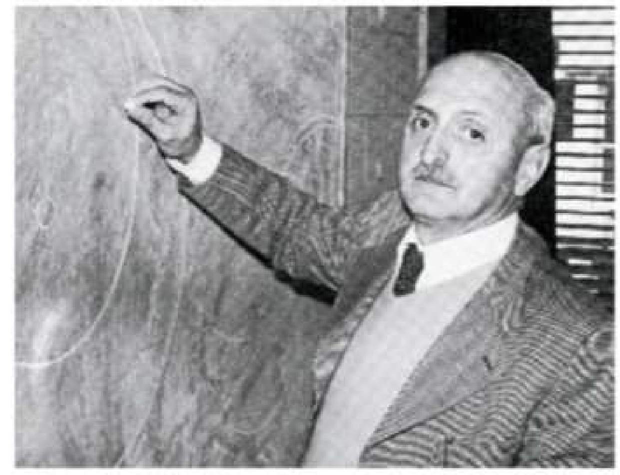
Mercury is a land of contrasts. The solar system's smallest planet boasts the largest core relative to its size. Temperatures at noon can soar as high as 800 degrees Fahrenheit (425 degrees Celsius) — hot enough to melt lead — but dip as low as –290 F (–180 C) before dawn. Mercury resides nearest the Sun, and it has the most eccentric orbit. At its closest, the planet lies only 29 million miles (46 million kilometers) from the Sun — less than one-third Earth's distance — but swings out as far as 43 million miles (70 million km). Its rapid movement across our sky earned it a reputation among ancient skywatchers as the fleet-footed messenger of the gods: Hermes to the Greeks and Mercury to the Romans.

Even though Mercury lies tantalizingly close to Earth, it is frustratingly hard to get to. Only two spacecraft have ever visited this barren world. But that is set to change October 19, when the international BepiColombo spacecraft begins a decade-long odyssey to unlock the secrets of a planet that seems to defy common sense.

The mission's namesake — Italian scientist, mathematician, and engineer Giuseppe "Bepi" Colombo (1920–1984) — was instrumental in devising a means to deliver a spacecraft from Earth, via Venus, to Mercury. Scientists already knew that a planet's gravitational field could bend the trajectory of a passing spacecraft and enable it to rendezvous with another celestial body. In the early 1970s, Colombo showed that if a spacecraft encountered Mercury, it would end up with a period almost twice that of the planet's orbital period. He suggested that a precisely targeted flyby would present a possibility for an economical second encounter.

NASA confirmed the idea and used it to send the Mariner 10 spacecraft past the innermost planet three times. The probe encountered Mercury in March 1974, September 1974, and March 1975. Its photographs gave humanity its first close-up views of the world, and the last ones we would see for a generation.

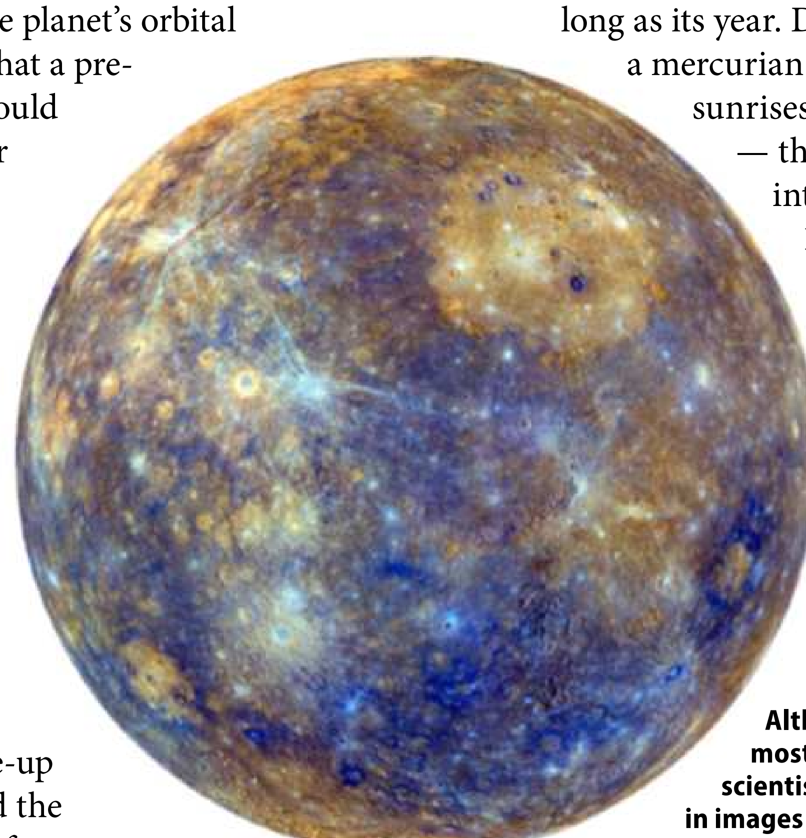
Sadly, Mariner 10 provided only a partial view because of a quirk in Mercury's orbital parameters.



Italian scientist Giuseppe "Bepi" Colombo helped develop a technique for sending a space probe to Mercury and having it execute multiple flybys. The European Space Agency honored his contributions by naming the BepiColombo spacecraft after him. ESA

Before the Space Age, telescopic observations indicated that Mercury was tidally locked to the Sun, rotating once for each 88-day orbit and thus perpetually showing the same hemisphere to its parent star. But in the 1960s, radar measurements pegged its actual rotation at 58.6 days, two-thirds of its orbital period. In essence, the planet spins about its axis three times for every two solar orbits.

As Colombo first described, this means a day on Mercury lasts twice as long as its year. Day and night each last a mercurian year apiece, with new sunrises arriving every 176 days — the same as the six-month interval between Mariner 10 flybys. So, the Sun illuminated the same hemisphere of Mercury during all three encounters, and the spacecraft was able to map only about 45 percent of the planet's surface.



Although Mercury appears mostly gray to the human eye, scientists often enhance the colors in images to heighten differences in chemical, physical, and mineralogical properties among surface rocks. The circular tan feature at upper right is the giant Caloris Basin. The center of this hemispheric view lies at 0° latitude and 140° longitude.

Upper left: Explosive eruptions driven by superheated volcanic gases left behind these bright yellow deposits in Mercury's southern hemisphere. This cluster of volcanic vents ranks among the largest on Mercury.

Lower left: When planetary scientists first saw this oddly bumpy and grooved landscape, they informally dubbed it "weird terrain." The region formed when seismic waves from the mammoth impact that created the Caloris Basin converged on the planet's opposite side.

Right: Bright blue depressions litter the floor and mountain peaks in the Raditladi impact basin. These shallow "hollows" typically have smooth floors unmarked by impact craters, suggesting that they are among Mercury's youngest features. Scientists created this five-image mosaic by merging high-resolution black-and-white photos with a lower-resolution image in enhanced color.

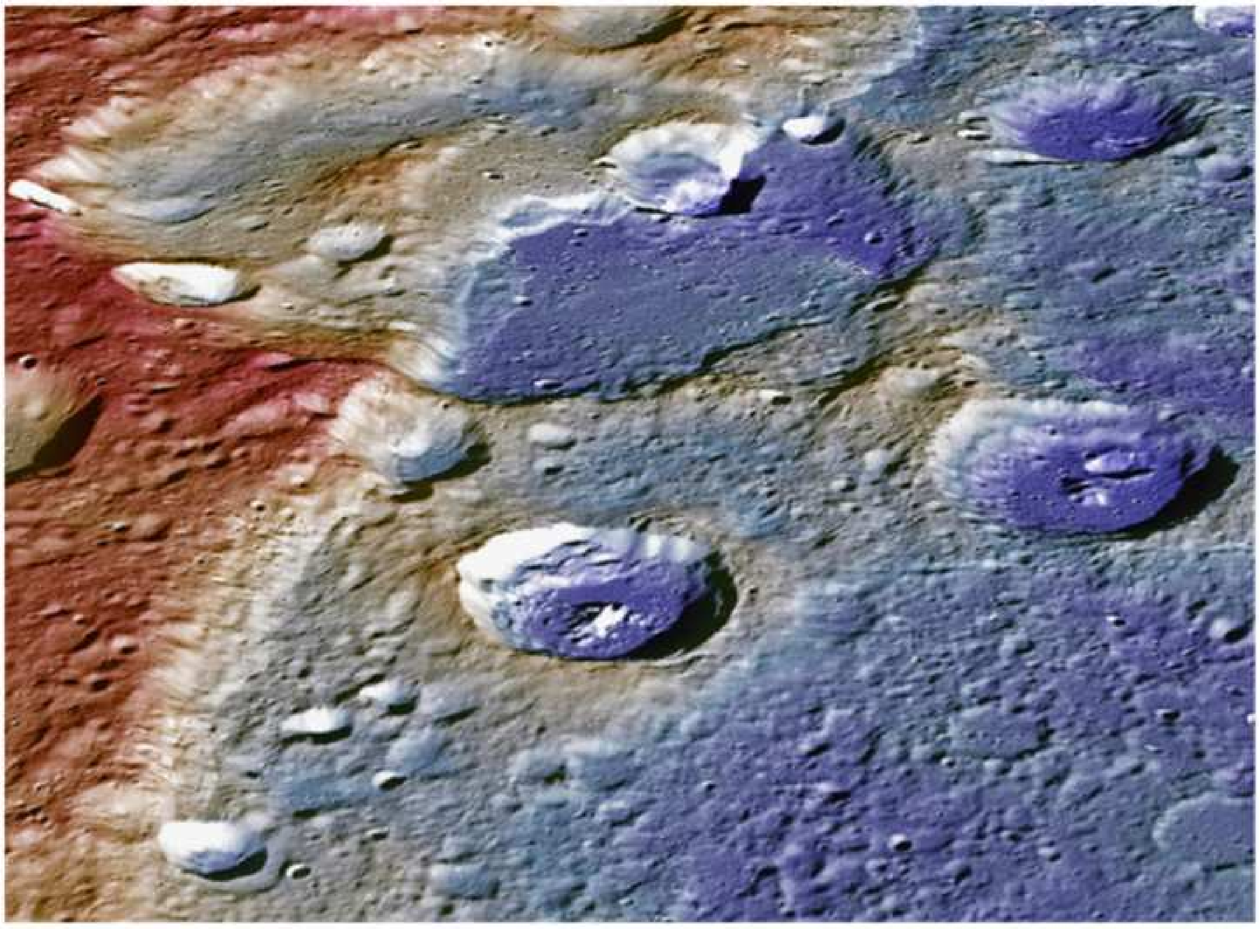
A STRANGE, OLD WORLD

Mariner 10 revealed an ancient terrain of rugged highlands and smooth lowlands, strikingly reminiscent of our Moon. Yet the similarities aren't even skin deep. Mercury's craters differ markedly from lunar ones, because their impact ejecta blankets a smaller area, partly due to the planet's much stronger gravity. The highland regions are less saturated with craters; instead they are mixed with rolling "intercrater plains" that constitute one of the oldest-known surfaces on the terrestrial planets.

The plains were laid down some 4.2 billion years ago during the Late Heavy Bombardment, when remnants from the solar system's birth rained down on the infant planets. Mercury was only a few hundred million years old, and the plains obliterated older craters, buried several large basins, and carved many of the pits and bowls seen today. The plains boast groups of secondary craters that occur in chains and clusters, covering the highlands.

In contrast, the sparsely cratered lowlands formed near the end of the Late Heavy Bombardment, about 3.8 billion years ago. Mariner 10 data suggested that the lowlands formed either from volcanic activity or from the molten material splashed onto the surface after large impacts. Although the spacecraft found no obvious smoking gun for volcanism — such as lava flows, volcanic domes, or volcanic cones — it did uncover strong circumstantial evidence.

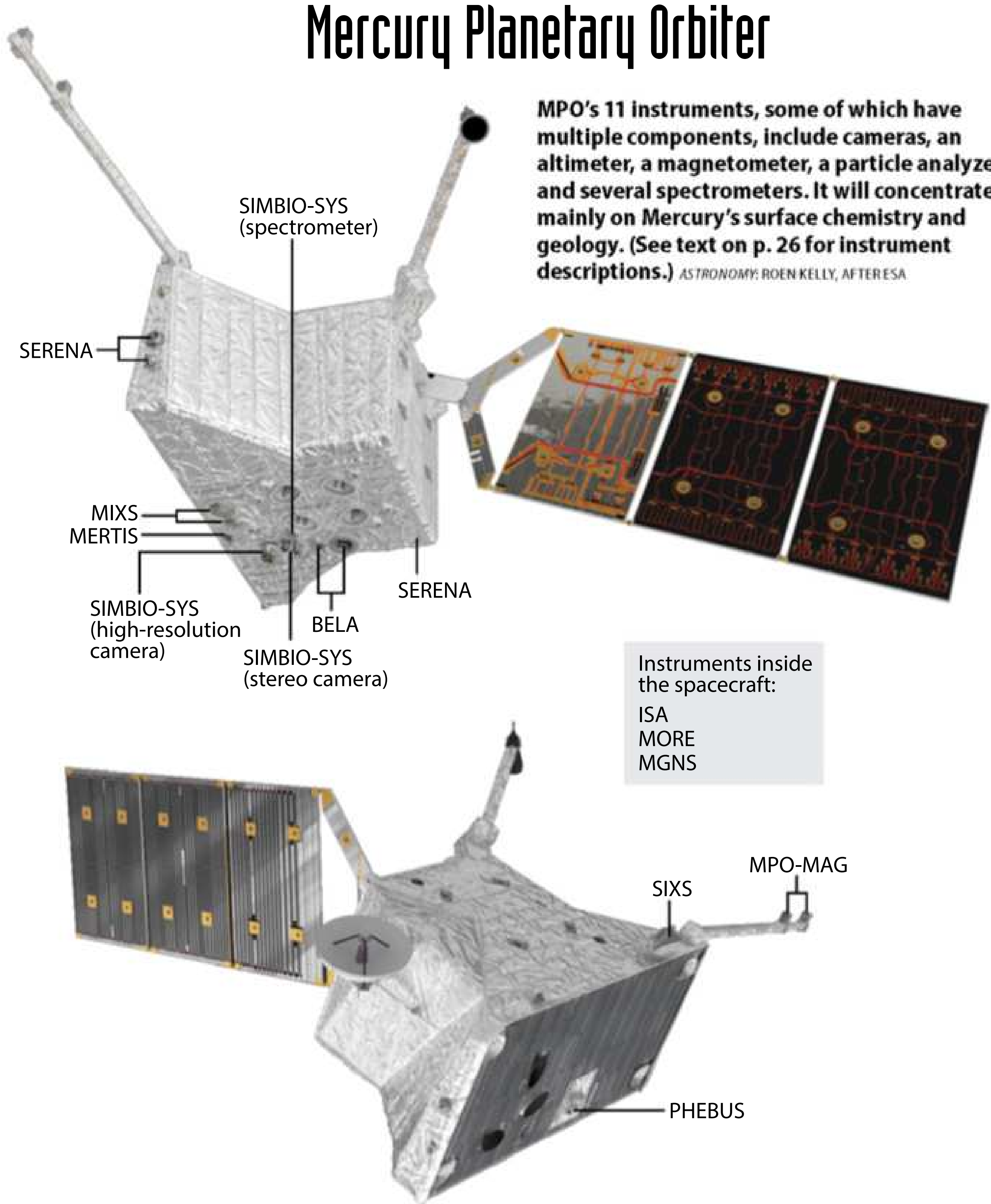
Mariner 10's successor, NASA's MESSENGER spacecraft, provided the proof. During its initial flyby in January 2008, the probe revealed a fractured region of ridges and furrows within the huge Caloris Basin. MESSENGER would go on to fly past Mercury twice more, in October 2008 and September 2009, and then orbit the inner world for four years



As Mercury's interior cooled, the planet's radius shrank by up to 4 miles (7 km). The contraction buckled the surface and left behind steep cliffs, including Carnegie Rupes, seen here cutting through Duccio Crater. The colors in this perspective view highlight elevation changes, with red indicating the highest terrain and blue the lowest.

The raven-colored rim of Poe Crater stands out from the smooth volcanic plains inside Caloris Basin. Note the hundreds of tiny blue-white hollows that dot the rim of this 48-mile-wide (77 km) crater.

Mercury Planetary Orbiter



MPO's 11 instruments, some of which have multiple components, include cameras, an altimeter, a magnetometer, a particle analyzer, and several spectrometers. It will concentrate mainly on Mercury's surface chemistry and geology. (See text on p. 26 for instrument descriptions.) *ASTRONOMY*: ROEN KELLY, AFTER ESA

starting in March 2011. While in orbit, the spacecraft discovered at least nine overlapping volcanic vents, each up to 5 miles (8 km) across and a billion years old, near Caloris' southwestern rim. Elsewhere on Mercury, MESSENGER uncovered residue from more than 50 ancient pyroclastic flows — violent outbursts of hot rock and gas — tracing back to low-profile shield volcanoes, mainly within impact craters.

Caloris itself is an impressive relic from Mercury's tumultuous early days. The Sun illuminated only half the basin during Mariner 10's visits, so it was left to MESSENGER to fully reveal its structure. Caloris spans 960 miles (1,550 km), placing it among the largest impact features in the solar system, and it is ringed by a forbidding chain of mountains that rises 1.2 miles (2 km) above the surroundings. Beyond its walls, ejecta radiate in meandering ridges and grooves for more than 600 miles (1,000 km). The impact that created Caloris was so globally cataclysmic that strong seismic waves pulsed through Mercury's interior and fragmented the landscape on the planet's opposite side, leaving a region of jumbled rocks, hills, and furrows that some scientists have dubbed "weird terrain."

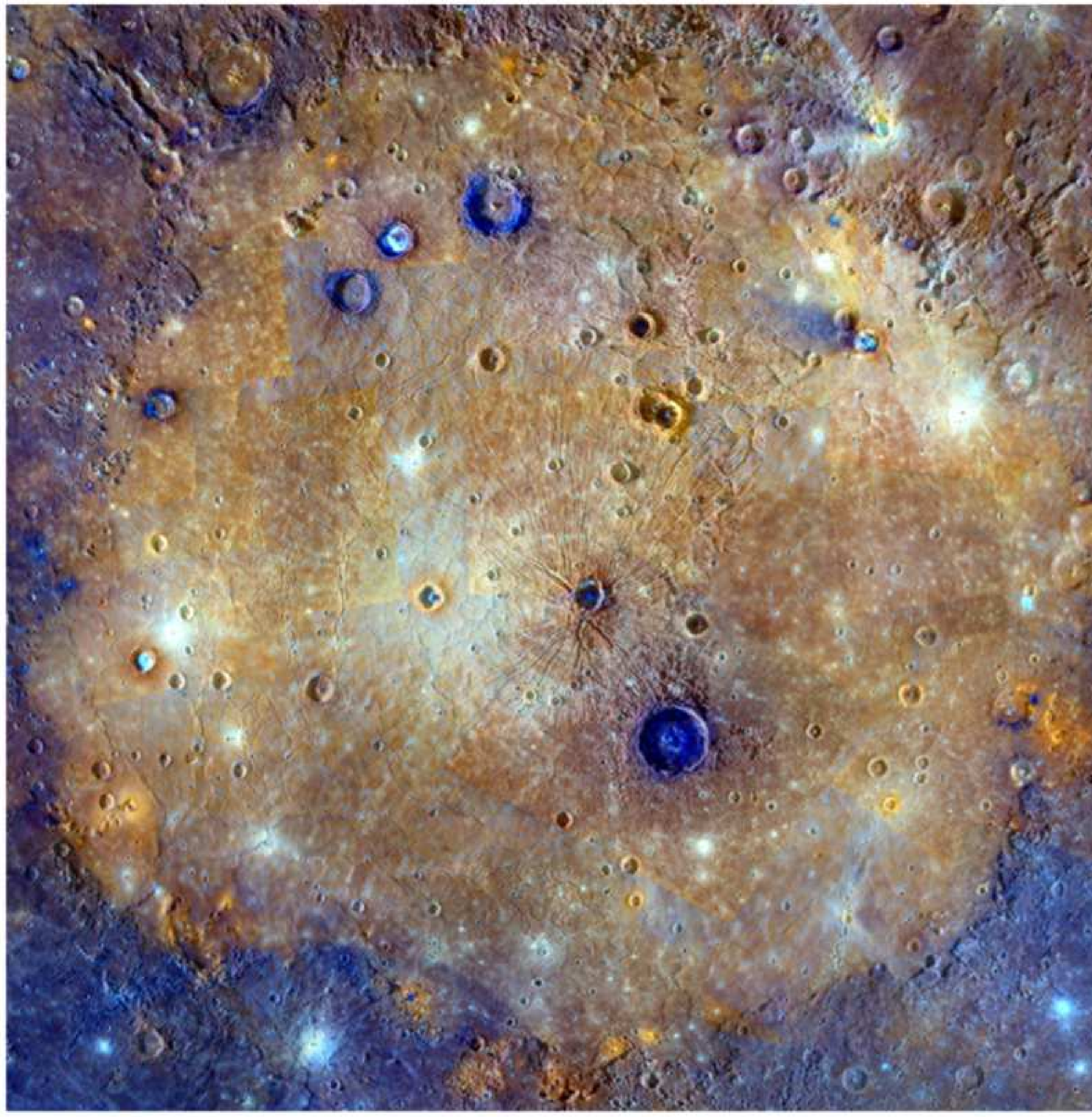
Despite Caloris' huge dimensions, Mercury itself is quite small — just 3,032 miles (4,879 km) in diameter. The planet's small size and high temperature led mid-20th-century astronomers to suspect it could not retain an atmosphere. But Mercury is full of surprises. Mariner 10 discovered a thin layer of loosely bound atoms, known as an exosphere, albeit with a surface pressure trillions of times less than that at sea level on Earth. It contains hydrogen and helium atoms captured from the solar wind — the stream of charged particles emanating from the Sun — together with oxygen atoms liberated from the surface by micrometeoroid impacts. Spectroscopic observations also revealed sodium, potassium, calcium, magnesium, and silicon. Caloris and the weird terrain appear to be key sources of sodium and potassium, indicating that impacts can release gases from below the surface.

DIGGING DEEPER

Farther down, the planet's interior remains a puzzle. Before Mariner 10, scientists assumed Mercury had a solid interior that produced no intrinsic magnetic field. They did realize, however, that the planet has an inordinately high density. Overall, Mercury's density averages 5.4 times that of water, close to those of the much larger Earth (5.5 times water) and Venus (5.2 times water). But the gravity of these bigger worlds crushes their interiors to far higher densities than they would have otherwise.

The only reasonable way to explain Mercury's high density is with the presence of heavy elements — some 70 percent iron and nickel overall — with most of them concentrated in the planet's giant core. This makes Mercury by far the most iron-rich planet in the solar system. Scientists think the winding cliffs that reach up to a mile high and run for hundreds of miles formed when the surface buckled as the interior cooled and contracted. Despite this shrinkage, MESSENGER revealed that Mercury's core stretches to within 250 miles (400 km) of its surface.

Scientists also were surprised when Mariner 10 discovered a magnetic field together with a small magnetosphere that weakly deflects the solar wind around the planet. A solid, slowly rotating planet shouldn't be able to generate the strong internal dynamo needed to create an intrinsic field, even one that's just 1 percent as strong as Earth's. MESSENGER showed the field is offset along the rotational axis by 20 percent of Mercury's radius and suggested that the planet possesses a partially molten outer core that surrounds a solid inner core.



Caloris Basin spans about 960 miles (1,550 kilometers) and ranks among the oldest and largest impact features in the solar system. Lava eventually flooded the floor to a depth of about 1.6 to 2.2 miles (2.5 to 3.5 km). The lava appears orange in this enhanced-color mosaic; more recent impact craters exposed darker material (blue) from below.

Astronomers still aren't sure what keeps the core in an electrically conductive, semi-liquid state. Perhaps it is the slow decay of the radioactive elements Mercury was born with. The Sun's gravity, which raises tides as the planet follows its eccentric orbit, could flex the interior and play a contributing role.

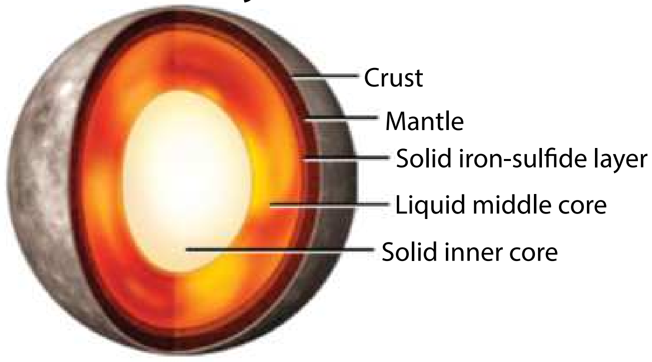
Despite this internal heat and the blazing Sun above, Mercury also appears to be a land of ice. In the 1990s, ground-based radar observations revealed a number of bright spots within 6.5° of the planet's north and south poles. Many scientists interpreted these findings as evidence for ice deposits on the floors of permanently shadowed craters, where temperatures can drop as low as –370 F (–225 C). In November 2012, MESSENGER identified up to 1 trillion tons of water ice near the poles — enough to encase Washington, D.C., in a frozen block 2.5 miles (4 km) deep.

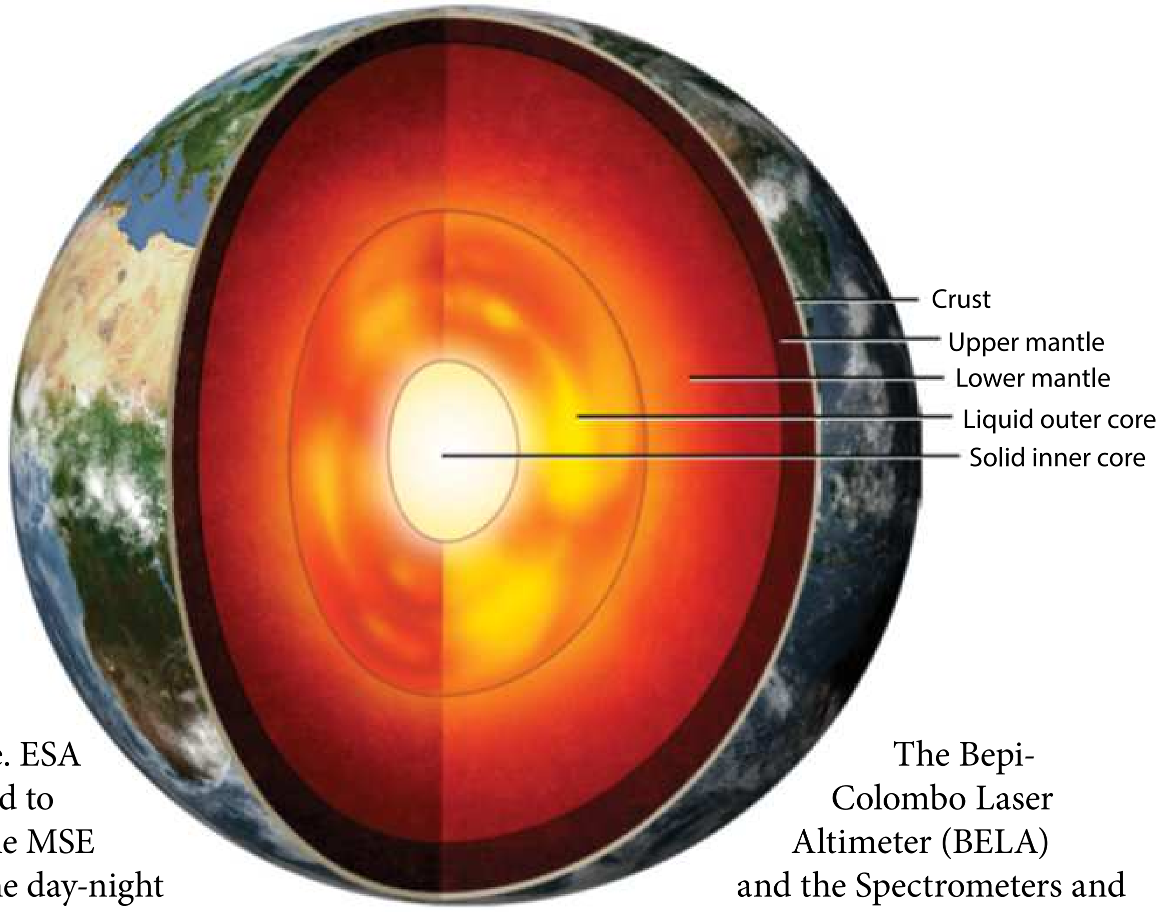
BEPICOLOMBO COMES ON THE SCENE

Despite Mariner 10's and MESSENGER's incredible discoveries, scientists still have many questions about this enigmatic world. That's where BepiColombo comes in. The European Space Agency (ESA) initially envisioned three spacecraft for this ambitious venture: The Mercury Planetary Orbiter (MPO) and Mercury Magnetospheric Orbiter (MMO) would work in tandem to unlock Mercury's mysteries from above, and the Mercury Surface Element (MSE) would explore the

Beneath two planets' skin

Mercury's interior differs significantly from Earth's. The inner world's gigantic core starts just 250 miles (400 kilometers) below the surface and is surrounded by a relatively thin mantle and crust. Most of Earth's volume resides in its mantle. The liquid parts of both planets' cores help generate their magnetic fields. *ASTRONOMY*: ROEN KELLY





MESSENGER took this mosaic in October 2008, moments after it flew past Mercury for the second time. The probe captured the first image (at left) nine minutes after closest approach; subsequent images came with the probe farther away (and thus show more area) and the Sun higher in the planet's sky. This equatorial swath spans about 1,200 miles (1,950 km).

surface. ESA planned to land the MSE near the day-night terminator and have it survive for about a week in the harsh environment. The lander would carry heat-flow sensors, a spectrometer, a magnetometer, a seismometer, a soil-penetrating device, and a tiny rover.

Unfortunately, budget considerations forced ESA to abandon the lander in November 2003. "The decision to cancel the lander was a loss for the mission," says BepiColombo project scientist Johannes Benkhoff. "What we miss is a so-called 'ground truth.' We can do many things remotely with our instruments, which are already on the other spacecraft, but the measurements of a lander would have been used to calibrate them, and that can unfortunately not be recovered."

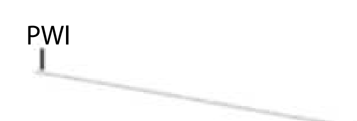
The rest of the mission continued, however. ESA led the development of the 2,535-pound (1,150 kilograms) MPO spacecraft. The probe's 11 instruments were fabricated by 35 scientific and industrial teams in Switzerland, Germany, Italy, the United Kingdom, Russia, Finland, Sweden, Austria, France, and the United States.

The Bepi-Colombo Laser Altimeter (BELA) and the Spectrometers and Imagers for MPO BepiColombo Integrated Observatory System (SIMBIO-SYS) will create digital terrain models to quantitatively map Mercury's geology, elemental composition, and surface age. Together with the Mercury Radiometer and Thermal Infrared Spectrometer (MERTIS), Mercury Gamma-Ray and Neutron Spectrometer (MGNS), and Mercury Imaging X-Ray Spectrometer (MIXS), they will identify key rock-forming minerals, measure global surface temperatures, and address competing theories of the planet's origin and evolution. These tools also will search for additional ice deposits and other volatile substances at high latitudes as well as provide insights into the role of volcanism.

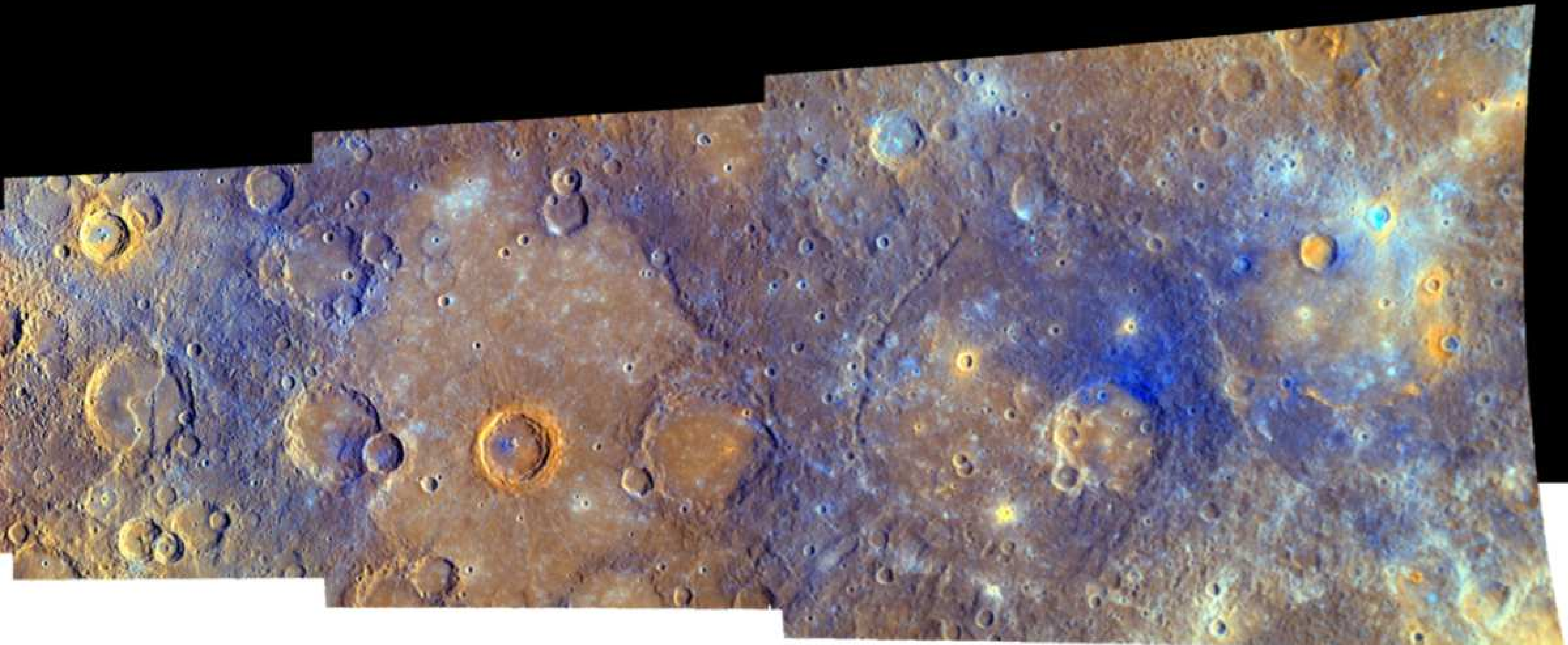
To analyze the composition, structure, and formation of Mercury's exosphere, MPO provides BepiColombo's Probing of Hermean Exosphere by Ultraviolet Spectroscopy (PHEBUS) and Search for Exosphere Refilling and Emitted Neutral Abundances (SERENA) instruments. Meanwhile, the Solar Intensity X-Ray and Particles Spectrometer (SIXS) will study the role of the solar wind in weathering the planet's surface.

MPO carries two instruments to help understand why Mercury has so much iron and what this reveals about its evolutionary history. The Italian Spring Accelerometer (ISA) and Mercury Orbiter Radioscience Experiment (MORE) will investigate the planet's global gravitational field to understand the size and nature of the core as well as the structure of the mantle and crust. MPO also houses one-half of the Mercury Magnetometer (MERMAG) that will study the magnetic field for clues to the dynamo lurking inside.

MPO carries a 24.6-foot-long (7.5 meters) solar array with integrated optical reflectors designed to keep the spacecraft at a temperature below 390 F (200 C). When in orbit around Mercury, the array must continuously rotate to balance MPO's power requirements with the need to keep the probe under its redline temperature. Meanwhile, a radiator angled toward the planet will reflect the intense infrared radiation coming from Mercury's searing surface.



"The solar arrays will be exposed to high-frequency, high-intensity ultraviolet radiation, combined with high temperatures, which was discovered to induce an unexpectedly fast degradation in solar-cell performance," explains BepiColombo project manager Ulrich Reininghaus. "This was resolved by a complex method of continuous solar array steering control, in order to maintain the temperature always below an allowed maximum, and by a specific redesign of the solar cells."



JAPAN LENDS A HAND

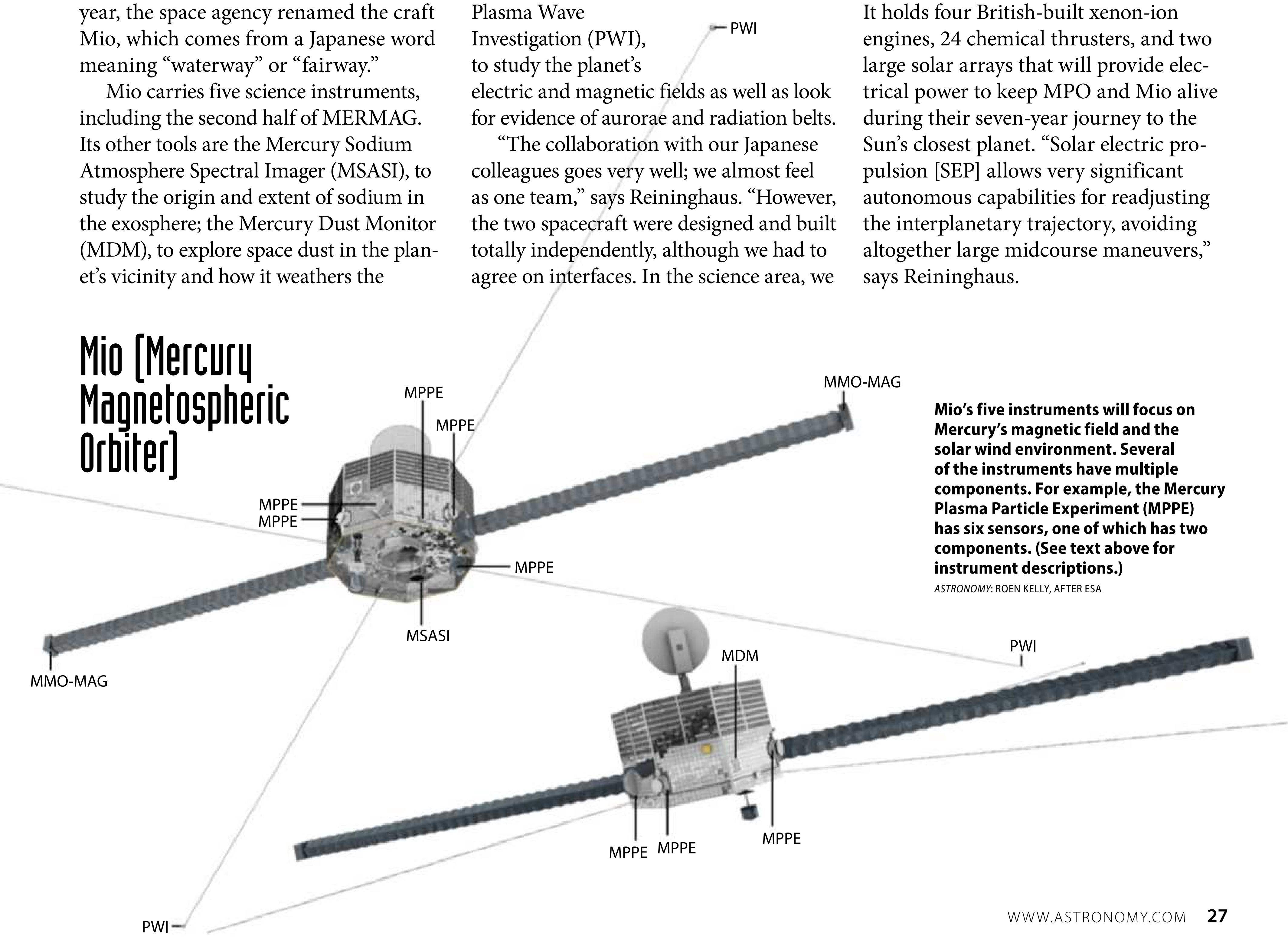
The mission drew more international collaboration when the Japan Aerospace Exploration Agency (JAXA) joined the project. JAXA developed the 630-pound (285 kg) MMO spacecraft. Earlier this year, the space agency renamed the craft Mio, which comes from a Japanese word meaning "waterway" or "fairway."

Mio carries five science instruments, including the second half of MERMAG. Its other tools are the Mercury Sodium Atmosphere Spectral Imager (MSASI), to study the origin and extent of sodium in the exosphere; the Mercury Dust Monitor (MDM), to explore space dust in the planet's vicinity and how it weathers the mercurian surface; the Mercury Plasma Particle Experiment (MPPE), to scrutinize the planet's magnetic field and its interaction with particles in the solar wind and particles coming from Mercury; and the Plasma Wave Investigation (PWI), to study the planet's electric and magnetic fields as well as look for evidence of aurorae and radiation belts.

"The collaboration with our Japanese colleagues goes very well; we almost feel as one team," says Reininghaus. "However, the two spacecraft were designed and built totally independently, although we had to agree on interfaces. In the science area, we hold regular joint meetings. Some of our science goals can only be reached if we work closely together."

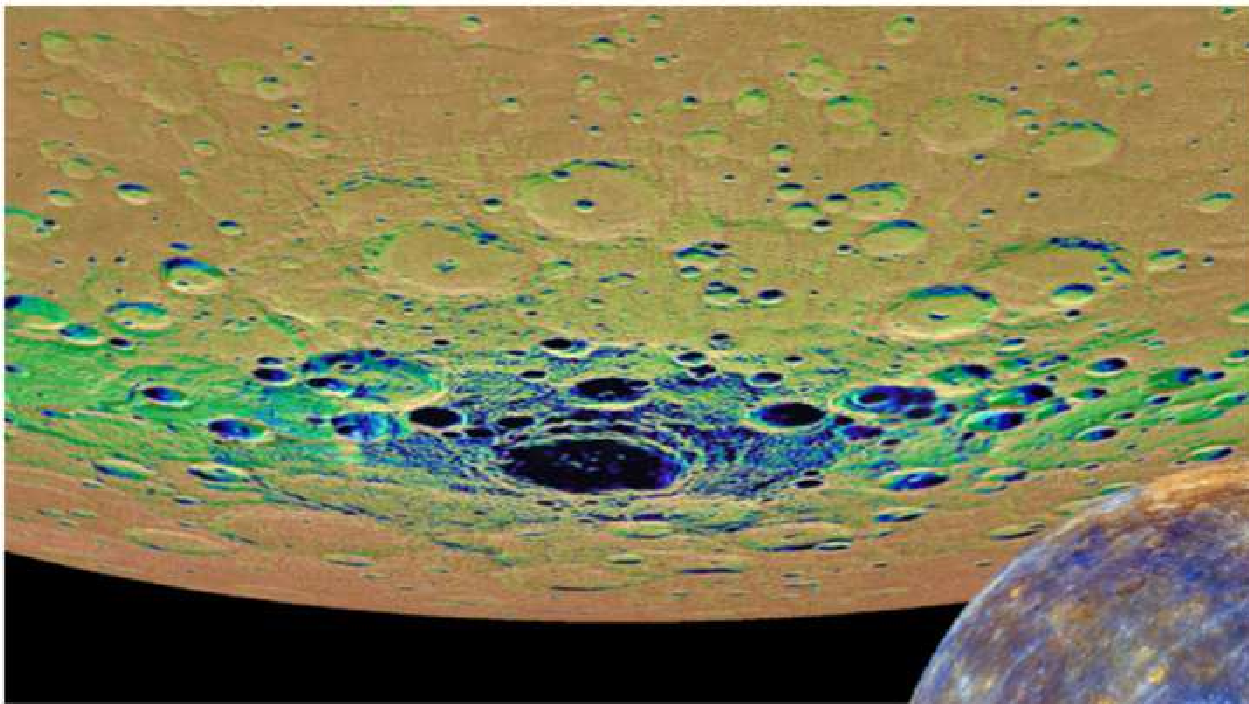
The final element of the spacecraft is the Mercury Transport Module (MTM). It holds four British-built xenon-ion engines, 24 chemical thrusters, and two large solar arrays that will provide electrical power to keep MPO and Mio alive during their seven-year journey to the Sun's closest planet. "Solar electric propulsion [SEP] allows very significant autonomous capabilities for readjusting the interplanetary trajectory, avoiding altogether large midcourse maneuvers," says Reininghaus.

Mio [Mercury Magnetospheric Orbiter]

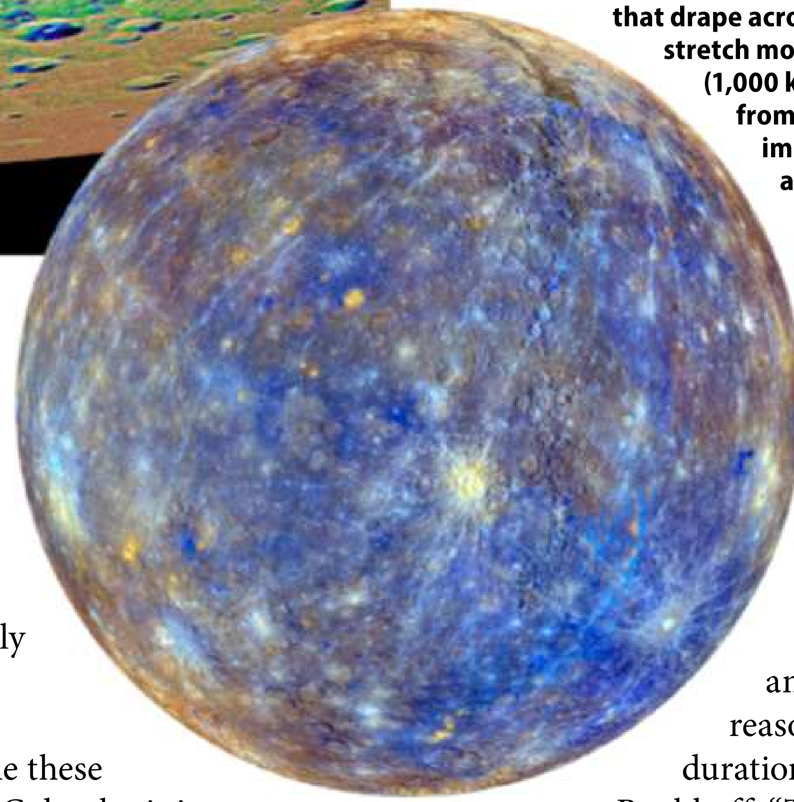


Mio's five instruments will focus on Mercury's magnetic field and the solar wind environment. Several of the instruments have multiple components. For example, the Mercury Plasma Particle Experiment (MPPE) has six sensors, one of which has two components. (See text above for instrument descriptions.)

ASTRONOMY: ROEN KELLY, AFTER ESA



Left: Despite its proximity to the Sun, Mercury boasts some of the coldest spots in the solar system. The colors in this view of Mercury's south pole show the fraction of time that specific regions lie in sunlight. The black areas are those in permanent shadow, the largest of which is the crater Chao Meng-Fu. MESSENGER found solid evidence that abundant water ice exists in this crater.



Below: This enhanced-color view shows the half of Mercury centered at 0° latitude and 320° longitude. The bright bluish rays that drape across this hemisphere stretch more than 600 miles (1,000 km) and emanate from the relatively fresh impact crater Hokusai at upper right.

Although the solar electric thrusters provide low thrust, they operate over a long time, delivering what rocket scientists call high impulse. In fact, the thrusters will accumulate the greatest total impulse ever achieved by a space mission. This posed considerable challenges during preflight testing. "[We resolved this through] multiple test campaigns in different chambers and with different test articles, combined with a sophisticated modeling approach that allowed us to accurately predict end-of-life performance of the thrusters," explains Benkhoff.

GETTING THERE

Like Mariner 10 and MESSENGER before it, BepiColombo will take a circuitous route to reach Mercury. The spacecraft will launch from Kourou, French Guiana, atop a giant Ariane 5 rocket, perhaps as early as October 19 (the first chance during a six-week launch window). It will depart Earth 7,770 mph (12,510 km/h) faster than the escape velocity from our planet. Although impressive by many standards, this speed is problematic for a spacecraft heading directly into the Sun's powerful gravitational field. In fact, the energy needed to get to Mercury is larger than it would be to reach Pluto and leave the solar system. Moreover, Mercury's orbital velocity of 105,900 mph (170,500 km/h) is 60 percent greater than Earth's, demanding a substantial velocity change and correspondingly high fuel consumption.

To overcome these obstacles, BepiColombo initially will enter an orbit similar to Earth's, using its high-impulse, low-thrust xenon-ion engines to slowly decelerate against solar gravity and adjust its orbital plane. "Solar electric propulsion was the only option to reach Mercury," says Benkhoff. "In principle, one can fly a mission to Mercury with chemical propulsion, but it all depends on the thrust-to-mass ratio. SEP is about eight times more efficient than chemical fuel. Thus, for BepiColombo, we would have needed at least 2 tons more mass to accommodate this."

The spacecraft will complete 1.5 circuits of the Sun, returning to Earth in April 2020 to pick up a gravitational boost. This will propel it to Venus for rendezvous in October 2020 and August 2021, which will reduce BepiColombo's perihelion to about the same distance as Mercury. Critically, this ingenious use of gravitational fields requires little propulsive intervention from the spacecraft.

"These flybys depend on the [arrangement] of the planets, and that is the reason for the long duration," says Benkhoff. "The flybys provide almost half of the needed energy to go to Mercury. The SEP engine will be used for about 50 percent of the time."

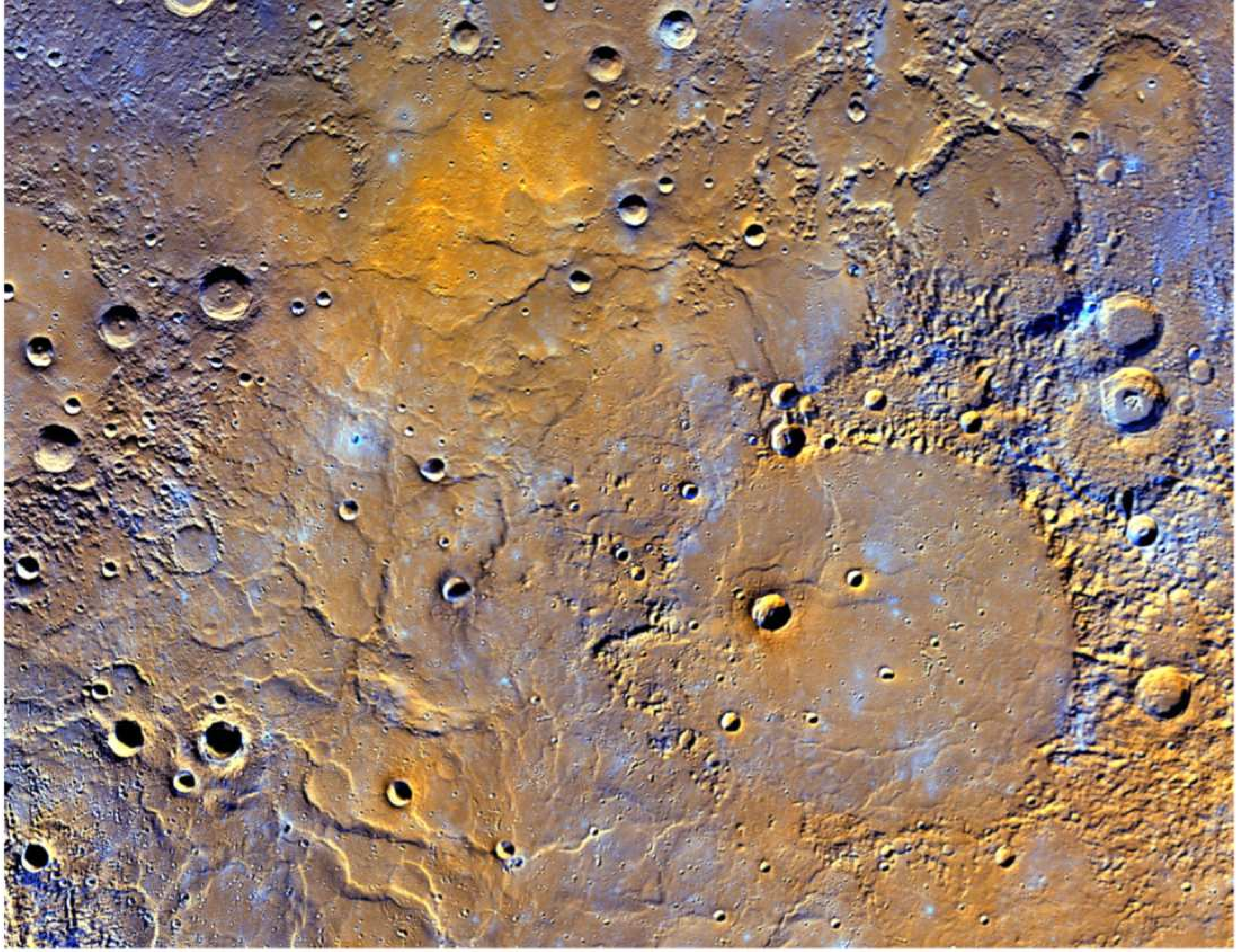
Six flybys of Mercury between October 2021 and January 2025 will slow BepiColombo's inbound trajectory until its orbit nearly matches that of the planet. Finally, in December 2025, Mercury will weakly capture the spacecraft into a polar orbit that comes within 420 miles (675 km) of the planet's surface and swings out to 110,600 miles (178,000 km). This so-called weak-stability-boundary technique adds flexibility compared with traditional approaches, where a single engine firing typically brings a spacecraft into orbit. BepiColombo's chemical thrusters will stabilize the orbit gradually and, after traveling 5.5 billion miles (8.9 billion km), the mission will at last be underway.

After the MTM separates from the probes, Japan's Mio will be spring-ejected

On the road to Mercury

- *Launch: October 19, 2018*
- *Earth flyby: April 6, 2020*
- *First Venus flyby: October 12, 2020*
- *Second Venus flyby: August 11, 2021*
- *First Mercury flyby: October 2, 2021*
- *Second Mercury flyby: June 23, 2022*

Mission planners expect to launch BepiColombo as early as October 19, 2018. As long as the mission commences by November 29, subsequent timeline dates will remain the same.



Molten lava once covered Mercury's vast northern volcanic plains. Lava nearly filled the 181-mile-wide (291 km) Mendelssohn impact basin, which lies at the lower right of this enhanced-color image. As the lava cooled, it formed large ridges that appear particularly prominent at bottom left. Meanwhile, the bright orange region near the scene's top shows the location of a volcanic vent that unleashed one of the planet's largest pyroclastic flows.

from its protective sunshield and part company with Europe's MPO. Three months later, the pair will commence autonomous operations, the former controlled from the Usuda Deep Space Centre in Nagano, Japan, and the latter from the Cebreros ground station near Madrid, Spain. "However, from the standpoint of science operations, coordination planning will be maintained among the principal investigators of the two spacecraft, and a certain amount of joint observations will certainly take place," explains Reininghaus.

All told, the two spacecraft will bring about 275 pounds (125 kg) of scientific instruments to bear upon one of the least-known worlds in the solar system. MPO will occupy a looping, 2.3-hour orbit at a distance that ranges from 300 miles (480 km) to 930 miles (1,500 km); Mio will follow a highly elliptical path that will carry it as close to Mercury's surface as 365 miles (590 km) and as far away as 7,230 miles (11,640 km) during a 9.3-hour orbit.

Scientists expect the baseline mission to last until May 2027, but there's a good chance ESA will grant a one-year extension. As a bonus, BepiColombo will make precise measurements of Mercury's orbital parameters. Because the planet lies so close to the Sun, this should allow astronomers to chart our star's gravitational field in detail and provide a rigorous test of Albert Einstein's general theory of relativity.

Although the spacecraft's roundabout route to Mercury is hardly in keeping with the fleet-footed nature of the planet's mythological namesake, the mission and the god do share some similarities. Both will deliver an abundance of learning, and both will accomplish their goals through ingenuity, an element of trickery, and a pinch or two of old-fashioned good fortune.

British spaceflight writer **Ben Evans** *authored the multivolume* History of Human Space Exploration, *published by Springer-Praxis.*

Third Mercury flyby: June 20, 2023

Fourth Mercury flyby: September 5, 2024

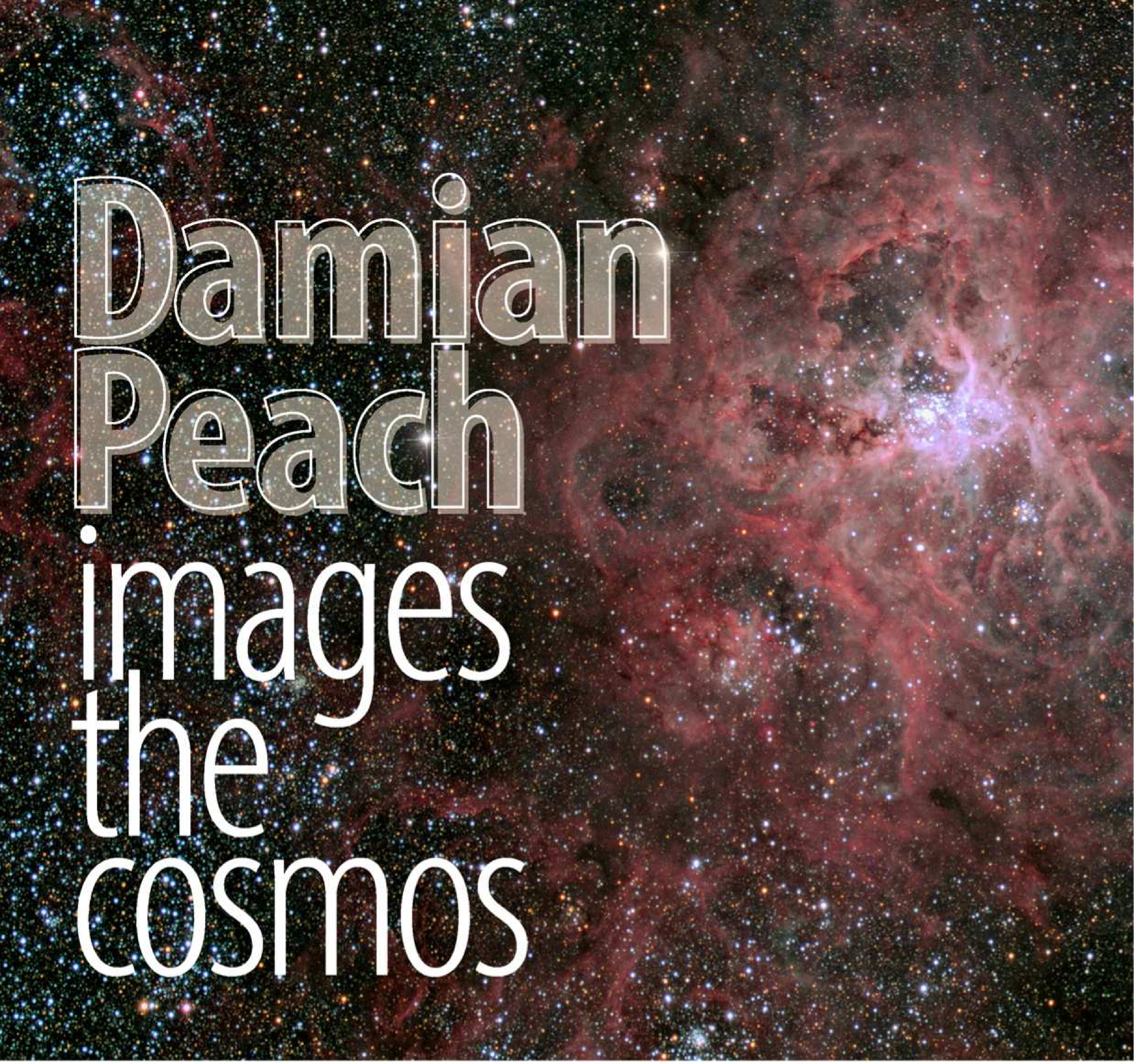
Fifth Mercury flyby: December 2, 2024

Sixth Mercury flyby: January 5, 2025

Arrival at Mercury: December 5, 2025

End of nominal mission: May 1, 2027

End of extended mission? May 1, 2028



Damian Peach images the cosmos

Although best known for planetary photography, the author is equally adept at capturing comets, stars, and galaxies.

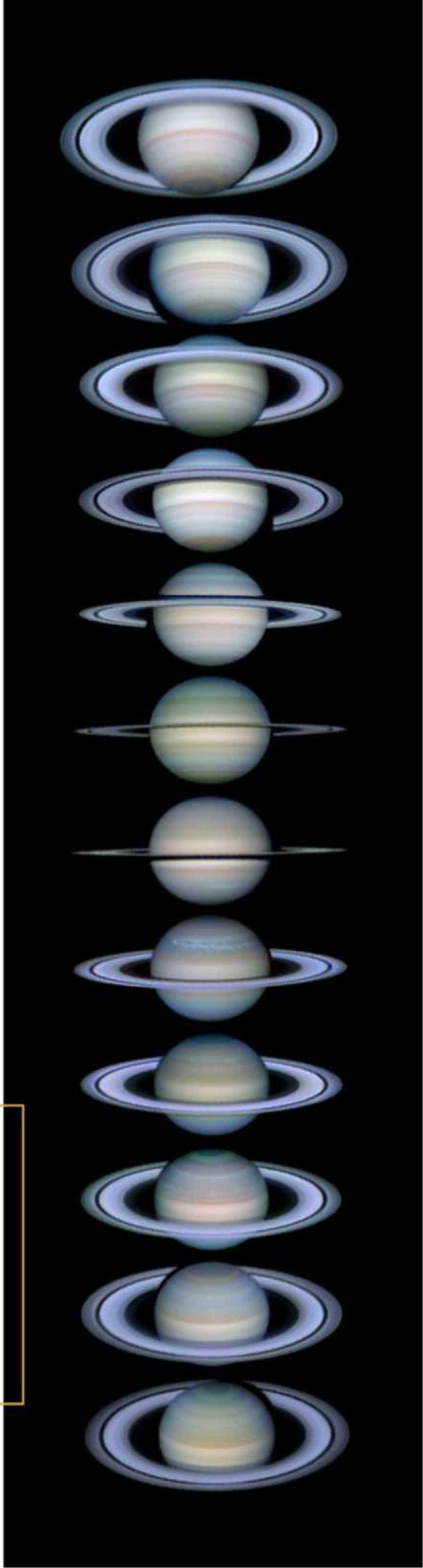
text and images by Damian Peach

My interest in astronomy really took flight at age 9 or 10. While looking through books in my primary school library, I became fascinated by the amazing pictures of far-off worlds and galaxies that filled the pages.

Neither of my parents was interested in astronomy. One of my uncles, however, owned a telescope, and another was a successful photographer.

The first books I ever read on astronomy were the introductory *Man and Space* by Neil Ardley, *Astronomy* by Iain Nicolson, and *Travellers in Space and Time* by Sir Patrick Moore, all of which I still own. Another book from around this time that I also loved was *The Universe From Your Backyard* by current *Astronomy* Editor David J. Eicher. It included many drawings of nebulae and galaxies as they appeared through amateur telescopes.

Soon after finishing that book, I got my first astronomical instrument: 8x30 binoculars, with which I learned my way around the sky. I recall vividly my first views of the Andromeda Galaxy (M31)

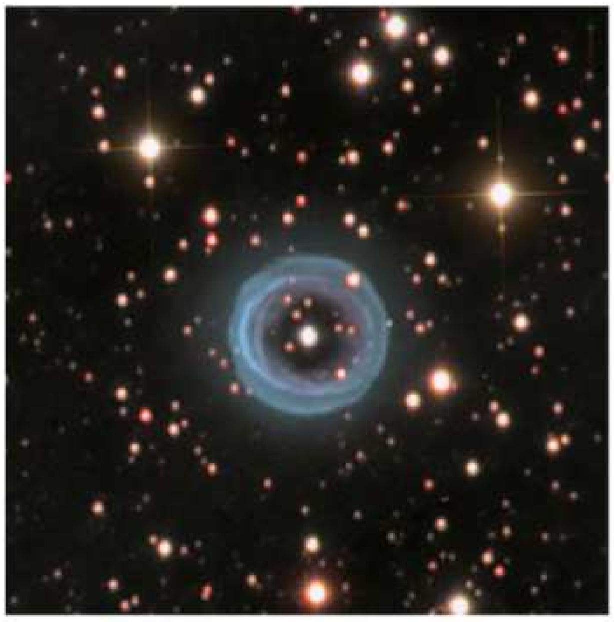


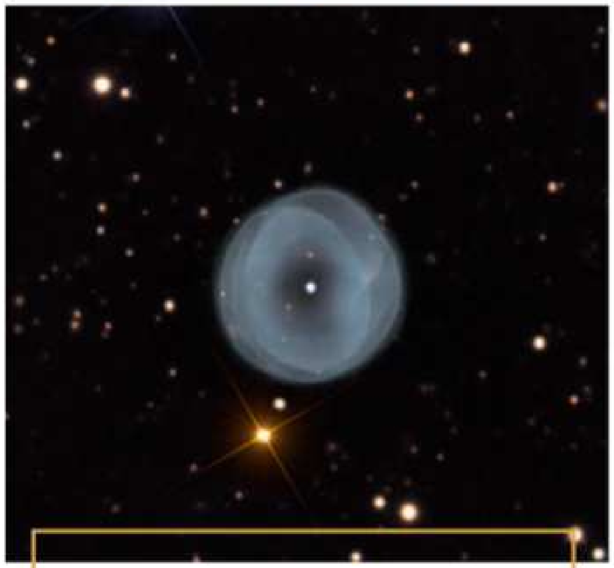
and Jupiter through them. I also had a small 10x30 Russian spotting scope, which I used to track the nightly motions of the jovian moons. Even in these early days, the planets were my favorite objects to observe.

When I was 13, after pestering my mother constantly, I finally got my first telescope: a 2-inch red tube Tasco refractor. I still remember my first view of a 50-percent-illuminated Venus through it. I was amazed! By this time, I was also an avid watcher of the BBC's *The Sky at Night*, hosted by the legendary Sir Patrick Moore.

Above: The Tarantula Nebula (NGC 2070) lies some 160,000 light-years away in the Large Magellanic Cloud. For this image, the author collected six hours of exposures through a 27-inch corrected Dall-Kirkham telescope.

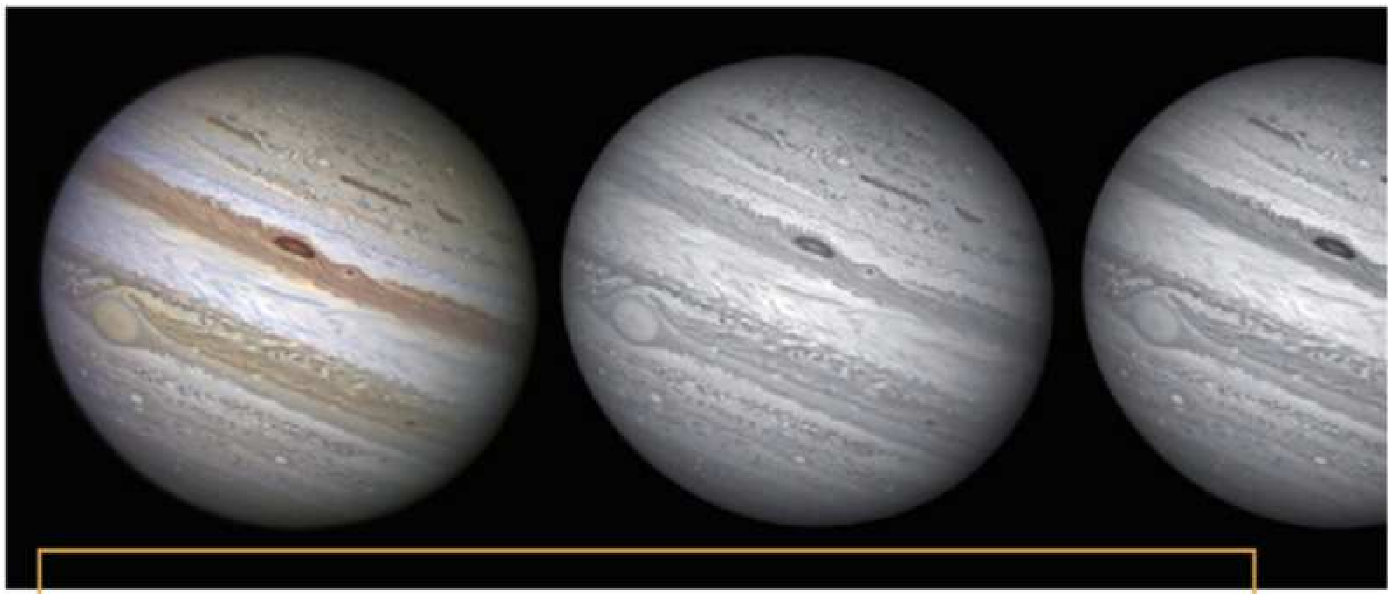
Right: When you image for as many years as the author has, you can compile comparisons like this one, showing Saturn's orientation from 2004 (top) through 2015. It's also a seasonal review. During this span, Saturn passed from summer in its southern hemisphere to summer in its northern half.





Planetary nebulae are well within the author's reach. Shapley 1 (top) lies in Norma, about 1,000 light-years from Earth. IC 5148 is three times as far away in the constellation Grus. Each is an LRGB image with exposures of 60, 5, 5, and 5 minutes, respectively, taken through a 27-inch corrected Dall-Kirkham telescope.

Comet 17P/Holmes suddenly brightened by more than 14 magnitudes in 2007. The author captured it in December of that year through a 3.15-inch refractor. He used a DSLR and stacked twenty 1-minute exposures.



To create the color image (left) of Jupiter on September 30, 2011, the author combined exposures through red, green, and blue filters (second, third, and fourth images, respectively). He had to work quickly so that Jupiter's rapid rotation wouldn't blur the result. It took him a scant 2 minutes and 7 seconds to get the data. At the time, the planet stood 45° high and sported a diameter of 48.29".

His boundless enthusiasm further nurtured my growing fascination with the night sky.

I later got a second 2-inch white tube Tasco refractor, which was of better quality than the first one. I still have that telescope today. It gave sharp images and allowed views of all manner of objects: double stars, the belts of Jupiter, the rings of Saturn, and the phases of Venus.

My foster father, in particular, really encouraged me in astronomy during the early 1990s, helping me with telescopes and driving me to meetings of the Boston Astronomical Society of Lincolnshire. Sadly, he passed away in 1999, so he never got to see what I would accomplish. I'm sure he would not have been surprised that my lifelong obsession has brought some rewards.

It wasn't until 1992 or so that my attention seriously turned toward the planets. Around this time, I joined the Boston Astronomical Society, led by well-known British amateur astronomer Paul Money. His captivating talks and infectious enthusiasm really rubbed off on me. He even visited my home and gave a talk in my living room for my family — something I still remember well!

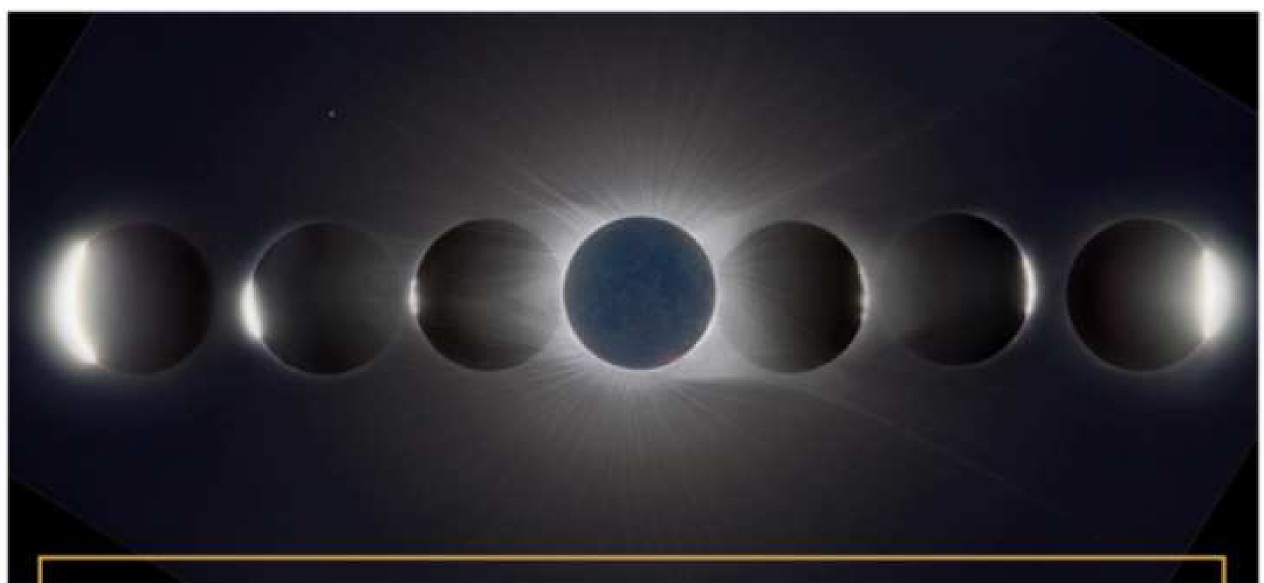
After joining the society, I was able to use the group's 4.5-inch and 10-inch reflecting telescopes. Finally, I could see the kind of details that I had read so much about. I spent many nights during my teenage years observing the planets, with a special fascination for Jupiter.

In the mid-1990s, I acquired my own "proper" telescopes, a 6-inch f/6 Newtonian reflector and a 3.5-inch f/11 refractor. The Newtonian was a poor instrument, so I didn't use it much, but the refractor gave wonderful views. I recall well the stunning views of Mars and comets Hyakutake and Hale-Bopp.

In 1997, thanks to my mother, I acquired an 8-inch Meade Schmidt-Cassegrain telescope (SCT). I had relocated to the town of Kings Lynn, on the Norfolk coast of England. During the summer of 1997, I experienced what I can only describe as the most amazing sight through a telescope ever.

On July 23, I saw a spectacular view of Jupiter. My logbook, which I still have today, is filled with exclamation marks, along with my comments at the eyepiece.

The author has captured many lunar vistas. This one, taken in 2016, shows Plato Crater and the lunar Alps. The straight gash dividing the mountain range is Vallis Alpes (the Alpine Valley). The author's choice of cameras for high-resolution lunar and planetary imaging is either a SKYnyx 2.0M or an LU075M, both by the Lumenera Corp.



During the August 21, 2017, total solar eclipse, the author traveled to Hodges, South Carolina, where he experienced 2 minutes 30 seconds of totality. This montage from second to third contact includes both diamond rings and Baily's beads.

So much detail was visible; I could not hope to sketch it all. From that point on, I was totally hooked on observing the giant planet. Around this time, I joined the British Astronomical Association and the Association of Lunar and Planetary Observers (ALPO).

During that year, I also discovered the amazing images by Florida planetary photographer Donald Parker. His images of Jupiter revealed the details I was seeing, and much more.

With further superb views of the planet during 1997, I began to seriously consider buying a CCD camera and trying to take my own images. I upgraded my telescope to a 12-inch Meade SCT. I also purchased an SBIG ST-7 CCD camera. The learning curve was steep in those early days, but I soon had everything working well.

My very first session targeting Jupiter at the beginning of the planet's 1998 apparition was disappointing, even after many practice sessions on deep-sky objects with my new camera. I soon learned that capturing finely detailed images was far harder than it looked. However, during the second session a few nights later, the seeing conditions (of which I knew next to nothing) must have been good because there before me were detailed images showing everything that I could see through the eyepiece and more. From then on, my results rapidly improved.

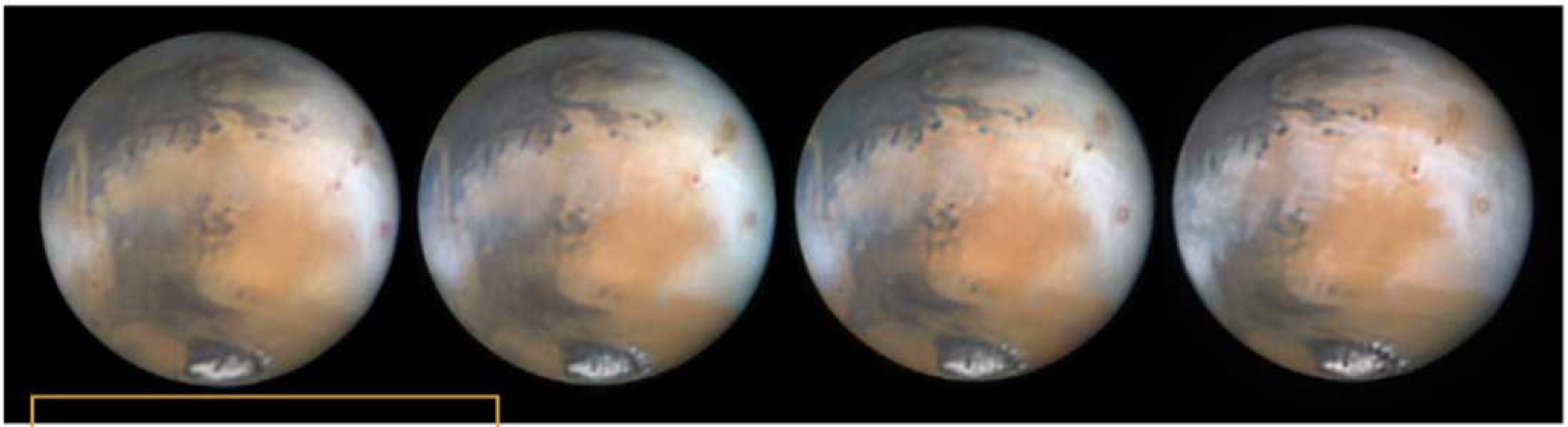
In the years that followed, my images continued to improve. I moved briefly to Tenerife in the Canary Islands in 2002–2003, where I spent more than 100 nights imaging the planets. At this time, I started using the new Philips Toucam webcam, which revolutionized planetary imaging. Also in 2003, to coincide with the great Mars opposition that year, I traveled to La Palma in the Canary Islands to image Mars live on British national television. The whole event was a great success.

Later that year, I finally got to meet Moore — author, TV host, and my astronomical hero since childhood. I traveled to his home in Selsey for an afternoon visit, and I ended up spending three days there! From then on, we became good friends and remained so until his death in 2012. It was always a great pleasure to

NGC 1232 in the constellation Eridanus is one of the sky's finest face-on spiral galaxies. At magnitude 9.9, it's visible through even moderate scopes from a dark site. Note the small companion galaxy, NGC 1232A, to the left of the main object.

The author captured globular cluster 47 Tucanae (NGC 104) through a 20-inch corrected Dall-Kirkham reflector. He took 45 minutes of exposures through R, G, and B filters. Note how the star density increases toward the core. Visually, this gives the cluster a 3D appearance.

The Southern Beehive (NGC 2516) is a gorgeous open star cluster in the constellation Carina. It's bright, too, shining at magnitude 3.8. The author captured this LRGB image of it through a 20-inch corrected Dall-Kirkham reflector.



On April 14, 2014, the author captured this four-part rotational sequence of Mars under excellent seeing conditions. At the time, the Red Planet's apparent diameter was 15.16". Tharsis and the giant volcanoes are shrouded in bright clouds to the right, while the North Polar Cap at bottom shows the dark Chasma Borealis rift.

spend time with him, often talking late into the night.

A surreal moment happened when, in 2003, Moore asked me to appear on his *The Sky at Night* program. I appeared on the show many times during the next several years, and it was always a great pleasure and privilege to be part of this historic program.

The year 2008 was special, as I finally got to meet Parker, the Florida planetary photographer who had inspired me to become a planetary observer. I spent a

The author created this detailed look at the amazing tail structure of Comet ISON (C/2012 S1) with a 4.3-inch refractor at f/5.6. It's an LRGB image with exposures of 10, 2, 2, and 2 minutes, respectively, taken November 15, 2013.

The author created this image of Hind's Crimson Star (R Leporis) to show the intense red hue of this carbon star. He points out that he applied no extra color saturation — this is a true RGB image of one of the reddest stars in the sky.

Damian Peach has used a variety of telescopes and cameras during the years he's created celestial images. Many have appeared in *Astronomy.*

week with him at his home, and it remains one of the highlights of my career. It was great fun imaging and observing together, and we had many laughs — mainly due to Don's wicked sense of humor.

During my astronomical journey, I've had some acclaim. In 2004, I received ALPO's Walter H. Haas award for my contributions to planetary observing.

Two years later, in 2006, I was awarded the British Astronomical Association Merlin Medal, again for contributions to planetary observing and photography. In 2007, I was featured in the Explorers of the Universe exhibition at the Royal Albert Hall, one of only a few amateur astronomers to be chosen.

In 2011, I was crowned winner of the Royal Greenwich Observatory "Astro-photographer of the Year" competition, in which I was a prize-winning finalist from 2012 through 2015. I also won first place in the National Science Foundation's Comet ISON (C/2012 S1) photo competition for my image, which was used by the media throughout the world during ISON's close approach to the Sun.

In 2014, I was elected a fellow of the Royal Astronomical Society and made honorary president of the Adur Astronomical Society. NASA and ESA also have used my images to illustrate what ground-based telescopes can achieve in photographing the planets, and the support they can provide to space-based missions.

In 2017, I was part of a small team of observers who used the famous Pic du Midi Observatory 1.06-meter telescope to obtain some of the most detailed ground-based images of Jupiter and Saturn. You can read about that trip in the June 2018 issue of *Astronomy.* That same year, the International Astronomical Union designated asteroid 27632 Damianpeach for my contributions to amateur astronomy. Finally, in 2018, I was elected to the board of the Aster Academy scientific committee and also awarded the Astronomical League's Leslie C. Peltier award for my contributions to astronomy.

My life could have turned out much differently. But astronomy has provided many wonderful friends, lots of travel, and a bit of recognition for my images. I wouldn't trade it for the universe!

Damian Peach *is the finest planetary imager on Earth. He's contributed to* Astronomy *for more than 15 years.*

MARTIN RATCLIFFE and ALISTER LING describe the solar system's changing landscape as it appears in Earth's sky.

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

November 2018: Mars remains a beacon

Saturn (top) and Mars (right) appeared near the bright globular star cluster M22 in late March. Although Mars has long since moved on, Saturn remains in the same binocular field as M22. DAMIAN PEACH

Several bright planets linger in November's evening sky. You'll want to catch Jupiter early in the month before it disappears in the Sun's glow. Mercury holds on a bit longer, but it succumbs to the solar glare after midmonth. Saturn fares much better, delivering nice views well after darkness falls, though even it pales in comparison to dazzling Mars. The ruddy world dominates the sky until midnight. Then, after an hours-long lull without any bright planets, brilliant Venus emerges into the predawn sky.

To see **Mercury** and **Jupiter**, you'll have to be ready to observe at dusk. Both hug the southwestern horizon in early November, so find a site that offers an unobstructed view in this direction. On the 1st, Jupiter hangs 4° high 30 minutes after sunset and Mercury stands 5° to its left. At magnitude –1.7, Jupiter appears four times brighter than its magnitude –0.2 companion. Plan to use binoculars to observe the planetary pair.

Jupiter vanishes in twilight during November's second week as it makes its way toward solar conjunction on the 26th. Mercury maintains its altitude through midmonth, however, before our star's light overwhelms it during November's third week. The innermost planet passes between the Sun and Earth on the 27th.

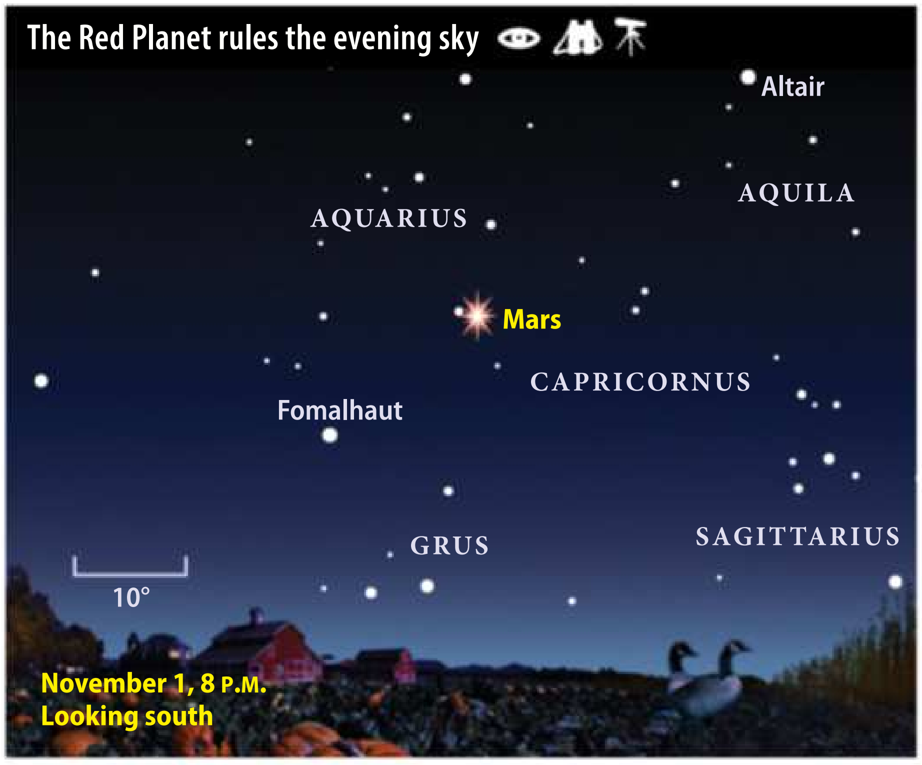
You can afford to let the sky darken some before hunting for **Saturn**. The ringed world stands 20° above the southwestern horizon an hour after sunset in early November. Under a dark sky just 30 minutes later, the background stars of Sagittarius and the central regions of the Milky Way nicely frame the planet. Saturn shines at magnitude 0.5, more than a full magnitude brighter than any of the Archer's stars.

Be sure to scan this area through binoculars. Several bright star clusters lurk in the region as well as the gorgeous Lagoon and Trifid nebulae (M8 and M20, respectively). These two gas clouds lie just 4° west of Saturn in early November.

The planet's eastward motion against this backdrop carries it 3° farther from the Lagoon and Trifid by the end of November, when star clusters replace nebulae in the binocular vista. On the 30th, Saturn lies 3.6° south of the 5th-magnitude open cluster M25 and 1.5° northwest of the similarly bright globular cluster M22.

You'll also want to observe the ringed planet through a telescope. The best views come in early evening during November's first couple of weeks, when it still lies reasonably high. As Saturn sinks lower, its image starts to dance like a bowl of jello. On the 1st, Saturn's globe measures 16" across the equator, and the ring system spans 36".

Pay particular attention to the rings. They currently tip 26.4° to our line of sight, just 0.6° less than at their maximum last year. They tilt this wide open only twice during the planet's 29.5-year orbit, and will appear slightly thinner next year. So take this opportunity to view the dark Cassini Division that separates the outer A ring from the brighter B ring. Under excellent observing conditions, you also might spot the



Although Mars reached opposition four months ago, it still dominates the southern sky after darkness falls. ALL ILLUSTRATIONS: *ASTRONOMY*: ROEN KELLY

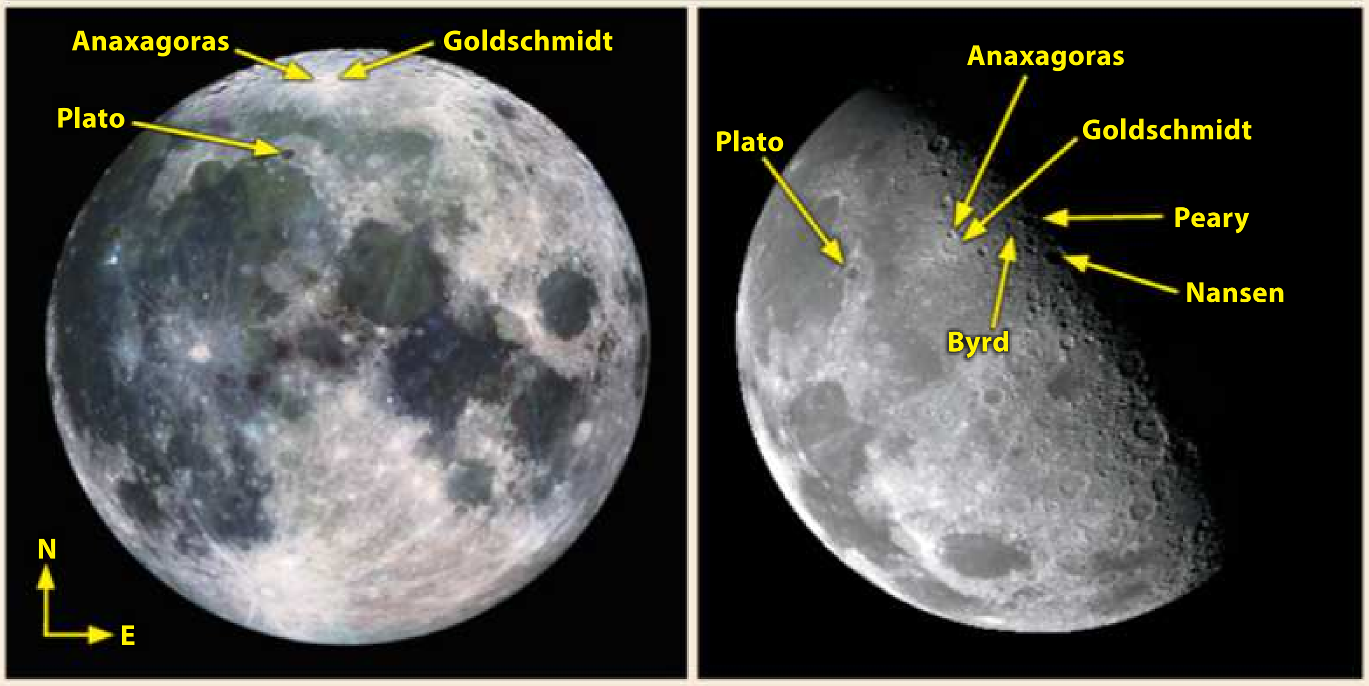
RISING**MOON**

Explore the Moon's north pole

A visual trip to the polar regions of the Moon proves far easier than an actual excursion to Earth's poles. After all, there's no need to bundle up in your heaviest winter parka (even though November evenings can get quite chilly). When you examine the lunar landscape, you'll recognize many craters in the far north and south take their names from early explorers of Earth's polar regions.

To see the Moon's poles well, timing is key. The Sun best illuminates these areas near Full Moon, but our satellite also has to be positioned so that one of its poles tips in our direction. The geometry works out perfectly in November to give us a nice view of the lunar north pole.

Byrd, Peary, and Nansen



The viewing geometry on the November 22/23 Full Moon is perfect for glimpsing craters near the lunar north pole. The Jupiter-bound Galileo spacecraft took both these images in December 1992. LEFT: NASA/JPL/USGS; RIGHT: NASA/JPL

On the evening of the 22nd, the Full Moon's orientation will be similar to the Galileo spacecraft image at left. First, pick out the landmark craters Plato, Anaxagoras, and Goldschmidt. Then, let the Galileo image at right guide you to Byrd, then Peary, and finally Nansen. If the weather cooperates the next few nights, return to this region and watch the shadows of the crater rims shift from one side of their southern flanks to the other.

ghostly C ring closest to the planet. It looks like a faint shadow cast onto the planet's atmosphere, but in reality it is blocking light reflected from the bright cloud tops.

A telescope also reveals Saturn's brightest satellites. You can see 8th-magnitude Titan, the planet's largest and brightest moon, through any scope. A 4-inch instrument also pulls in a trio of 10th-magnitude moons: Tethys, Dione, and Rhea. All three orbit closer to Saturn than their big brother.

Scan one constellation east of Sagittarius, and you'll be among the relatively inconspicuous stars of Capricornus. But in early November, the Sea Goat hosts stunning **Mars**, the star of our evening show. The Red Planet shines at magnitude –0.6 and, from mid-northern latitudes, it stands 34° high in the south

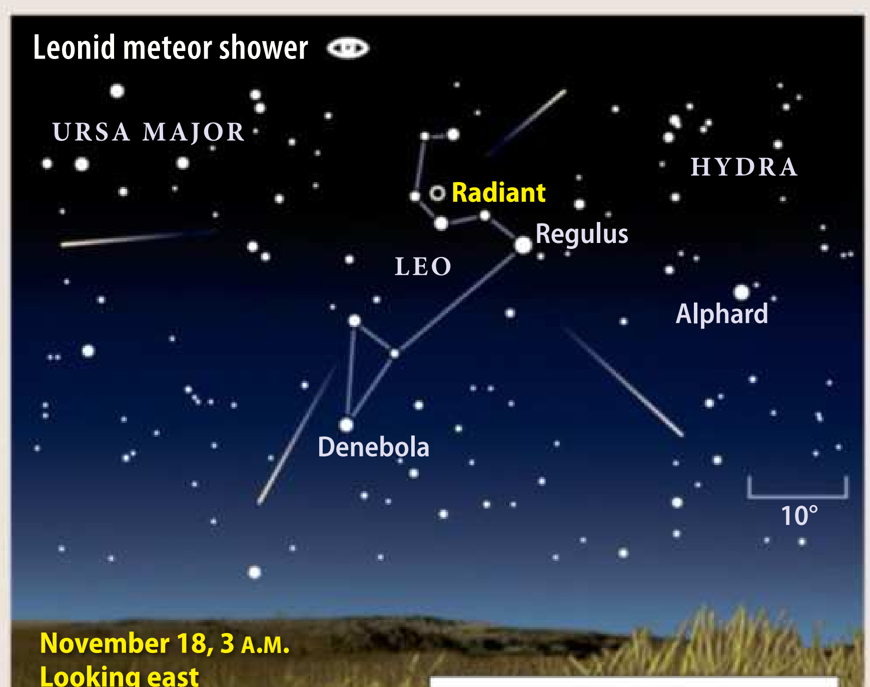
— Continued on page 42

METEORWATCH

Dark skies to see the Lion roar

The Leonid meteor shower peaks the night of November 17/18. The waxing gibbous Moon sets before 2 A.M. local time and morning twilight starts after 5 A.M., leaving more than three hours of undisturbed viewing. The meteors radiate from the constellation Leo the Lion, which climbs more than 60° high in the southeast before dawn.

The Leonid shower derives from debris ejected over many millennia by Comet 55P/Tempel-Tuttle. This periodic visitor last returned to the inner solar system in 1998, and astronomers don't anticipate any unusual meteor activity this year. Still, observers under dark skies could see an average of between 15 and 20 meteors per hour.



Viewers have more than three hours of dark skies to enjoy this prolific shower once the Moon sets around 2 A.M. local time.

Leonid meteors

Active dates: Nov. 6–30
Peak: November 17/18
Moon at peak: Waxing gibbous
Maximum rate at peak: 20 meteors/hour

OBSERVING HIGHLIGHT Asteroid Juno reaches opposition and peak visibility November 17, when it shines brighter than it has in 35 years.

STAR DOME

How to use this map: This map portrays the sky as seen near 35° north latitude. Located inside the border are the cardinal directions and their intermediate points. To find stars, hold the map overhead and orient it so one of the labels matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

The all-sky map shows how the sky looks at:

10 P.M. November 1
8 P.M. November 15
7 P.M. November 30

Planets are shown at midmonth

STAR MAGNITUDES

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

STAR COLORS

A star's color depends on its surface temperature.

- The hottest stars shine blue
- Slightly cooler stars appear white
- Intermediate stars (like the Sun) glow yellow
- Lower-temperature stars appear orange
- The coolest stars glow red
- Fainter stars can't excite our eyes' color receptors, so they appear white unless you use optical aid to gather more light

MAP SYMBOLS

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

NOVEMBER 2018

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

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

ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

Calendar of events

5 The Moon passes 10° north of Venus, 9 P.M. EST

6 Mercury is at greatest eastern elongation (23°), 10 A.M. EST

7 New Moon occurs at 11:02 A.M. EST

9 Mercury passes 1.8° north of Antares, 1 A.M. EST

The Moon passes 7° north of Mercury, 7 A.M. EST

11 The Moon passes 1.5° north of Saturn, 11 A.M. EST

12 The Moon passes 0.9° north of Pluto, 1 P.M. EST

13 Venus is stationary, 10 P.M. EST

14 The Moon is at apogee (251,245 miles from Earth), 10:56 A.M. EST

15 First Quarter Moon occurs at 9:54 A.M. EST

SPECIAL OBSERVING DATE

15 The First Quarter Moon passes 1.0° south of Mars in this evening's sky.

16 Mercury is stationary, midnight EST

17 The Moon passes 3° south of Neptune, 1 A.M. EST

Asteroid Juno is at opposition, 5 P.M. EST

Leonid meteor shower peaks

20 The Moon passes 5° south of Uranus, 3 P.M. EST

23 Full Moon occurs at 12:39 A.M. EST

25 Neptune is stationary, 3 A.M. EST

26 Jupiter is in conjunction with the Sun, 2 A.M. EST

The Moon is at perigee (227,807 miles from Earth), 7:12 A.M. EST

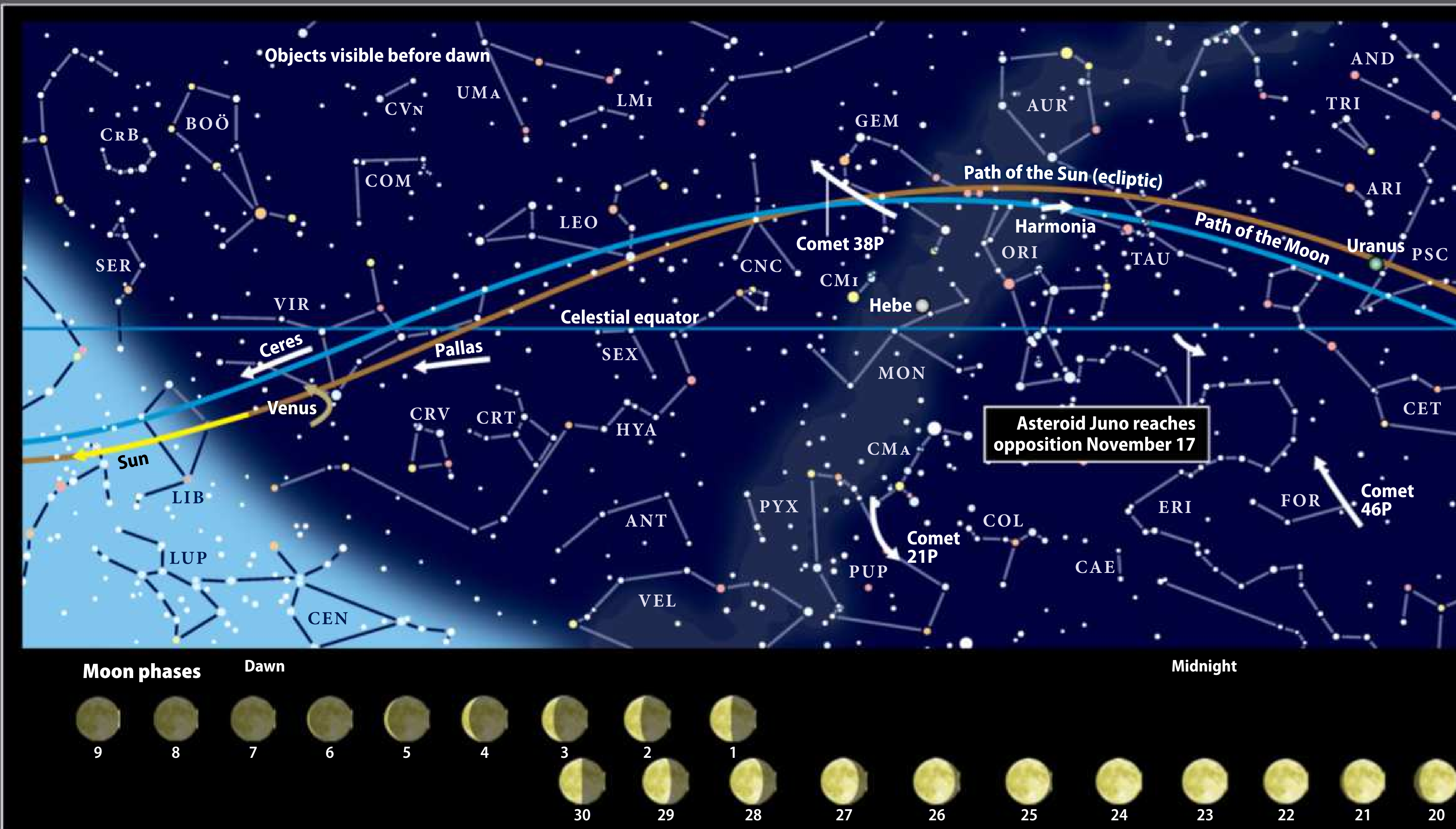
27 Mercury is in inferior conjunction, 4 A.M. EST

29 Last Quarter Moon occurs at 7:19 P.M. EST

BEGINNERS: WATCH A VIDEO ABOUT HOW TO READ A STAR CHART AT **www.Astronomy.com/starchart.**

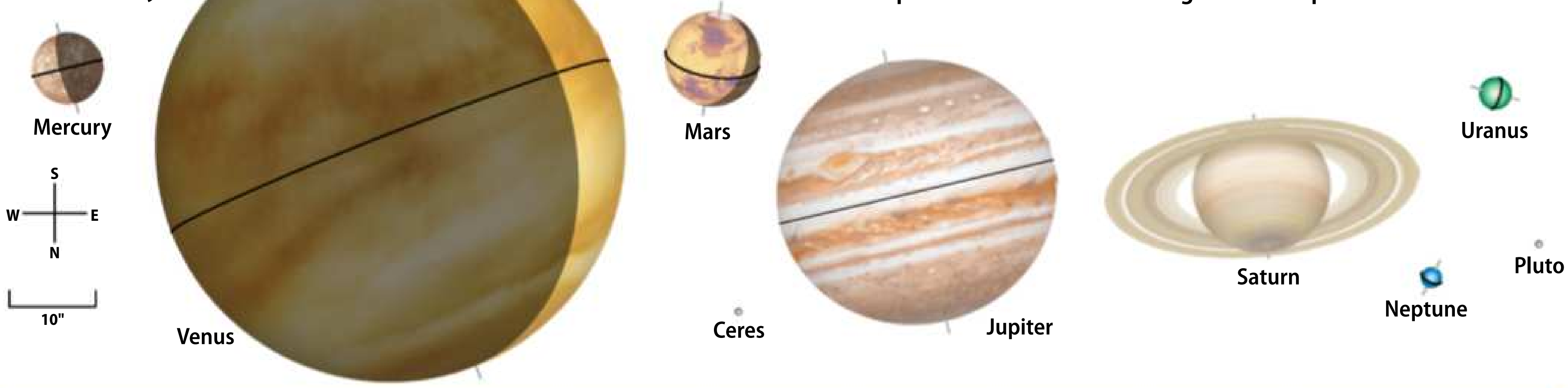
PATH OF THE PLANETS

The planets in November 2018



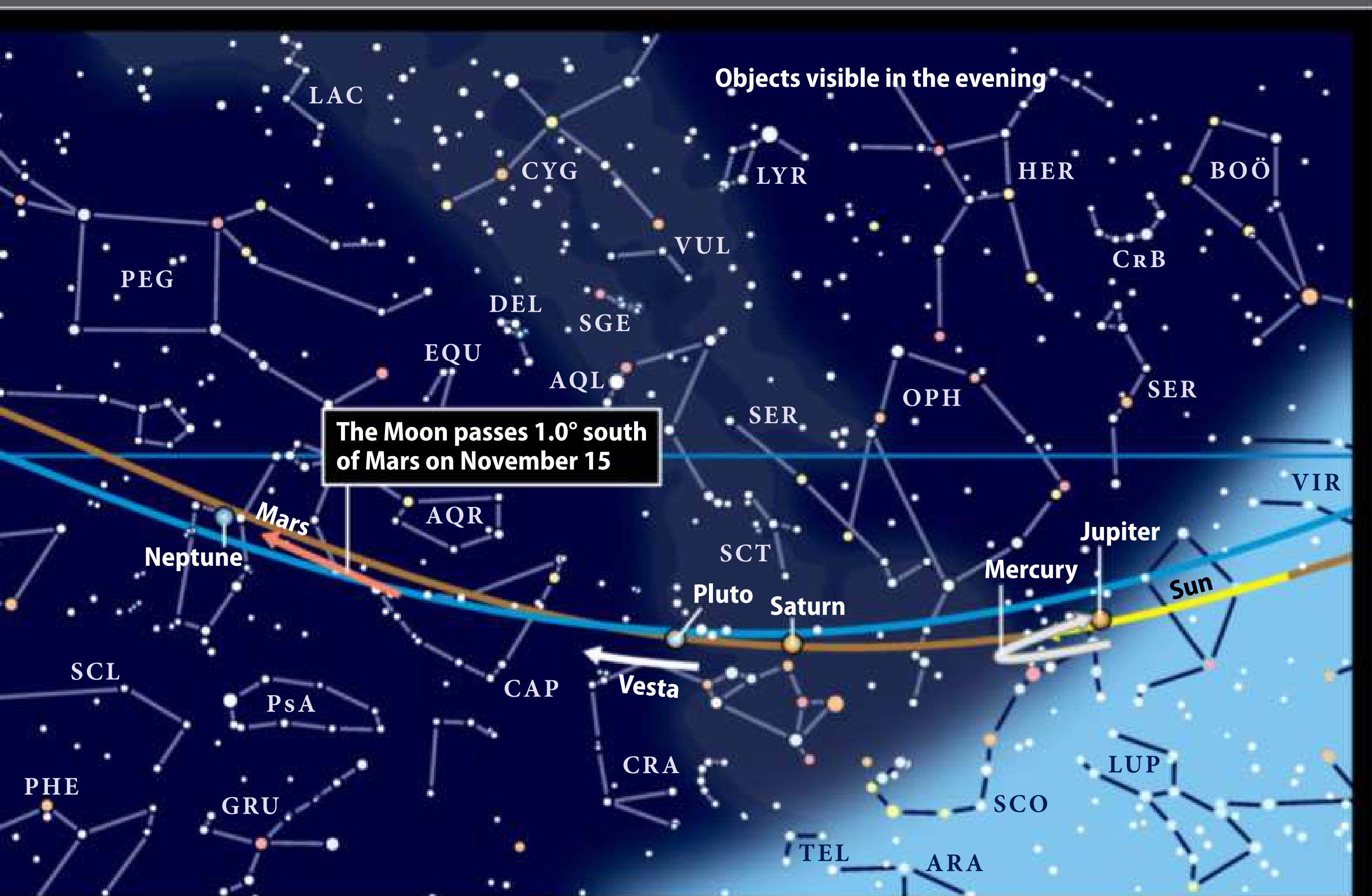
The planets in the sky

These illustrations show the size, phase, and orientation of each planet and the two brightest dwarf planets at 0h UT for the dates in the data table at bottom. South is at the top to match the view through a telescope.



Planets	MERCURY	VENUS	MARS	CERES	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Date	Nov. 15	Nov. 15	Nov. 15	Nov. 15	Nov. 1	Nov. 15	Nov. 15	Nov. 15	Nov. 15
Magnitude	0.1	–4.7	–0.3	8.8	–1.7	0.6	5.7	7.9	14.3
Angular size	8.0"	52.4"	10.5"	0.4"	31.3"	15.5"	3.7"	2.3"	0.1"
Illumination	39%	11%	86%	99%	100%	100%	100%	100%	100%
Distance (AU) from Earth	0.844	0.318	0.888	3.511	6.290	10.755	18.952	29.568	34.214
Distance (AU) from Sun	0.360	0.721	1.406	2.622	5.367	10.062	19.867	29.939	33.681
Right ascension (2000.0)	16h44.7m	13h30.3m	22h07.6m	14h05.2m	15h44.1m	18h25.7m	1h50.2m	23h00.6m	19h22.3m
Declination (2000.0)	–24°41'	–11°15'	–13°22'	–5°37'	–19°04'	–22°45'	10°45'	–7°25'	–22°07'

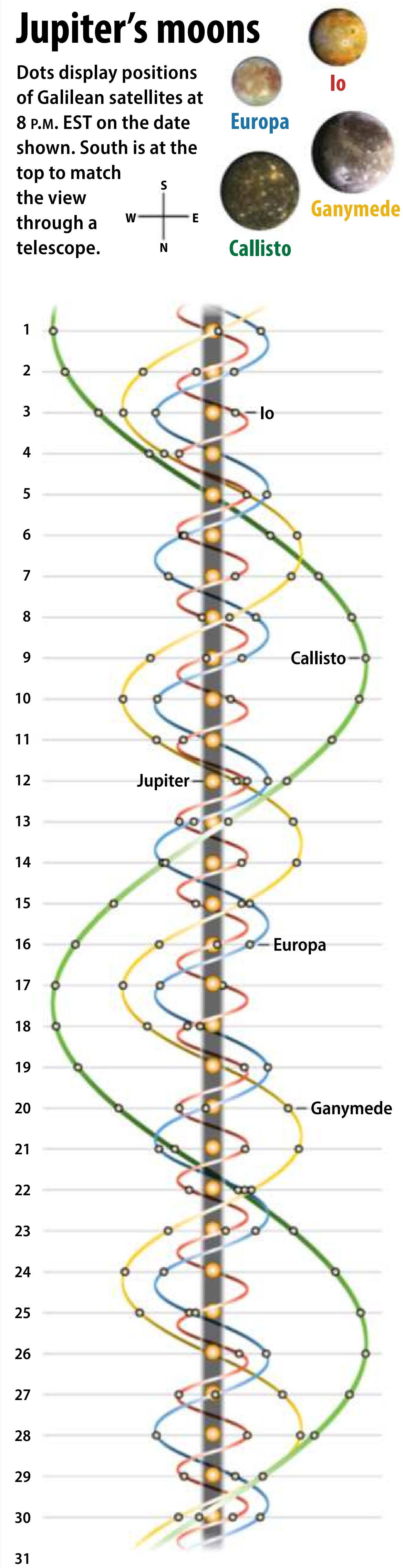
This map unfolds the entire night sky from sunset (at right) until sunrise (at left).
Arrows and colored dots show motions and locations of solar system objects during the month.

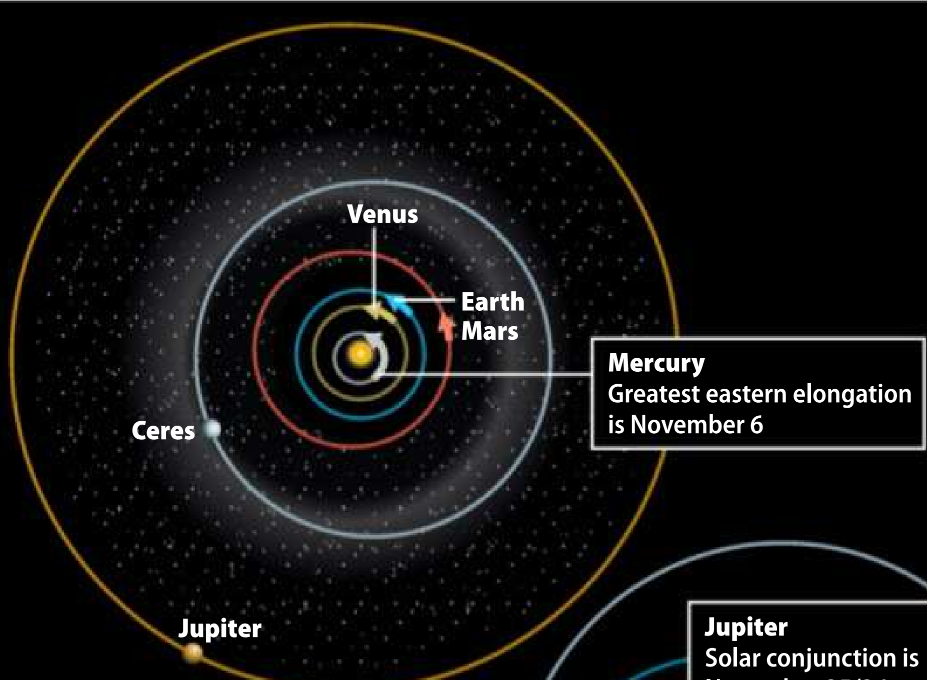


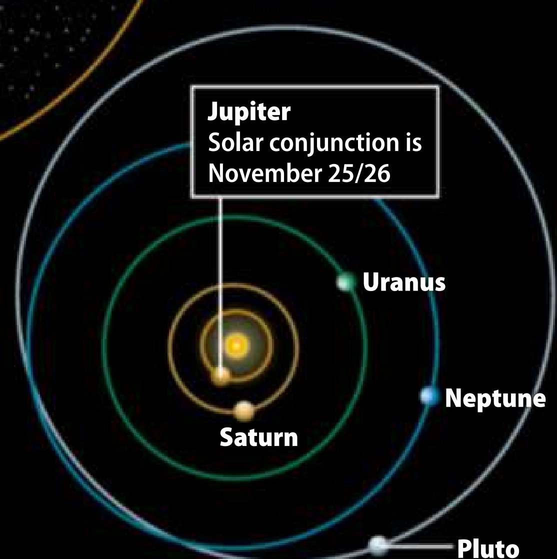
To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line. **Note:** Moons vary in size due to the distance from Earth and are shown at 0h Universal Time.

Jupiter's moons

Dots display positions of Galilean satellites at 8 P.M. EST on the date shown. South is at the top to match the view through a telescope.







The planets in their orbits

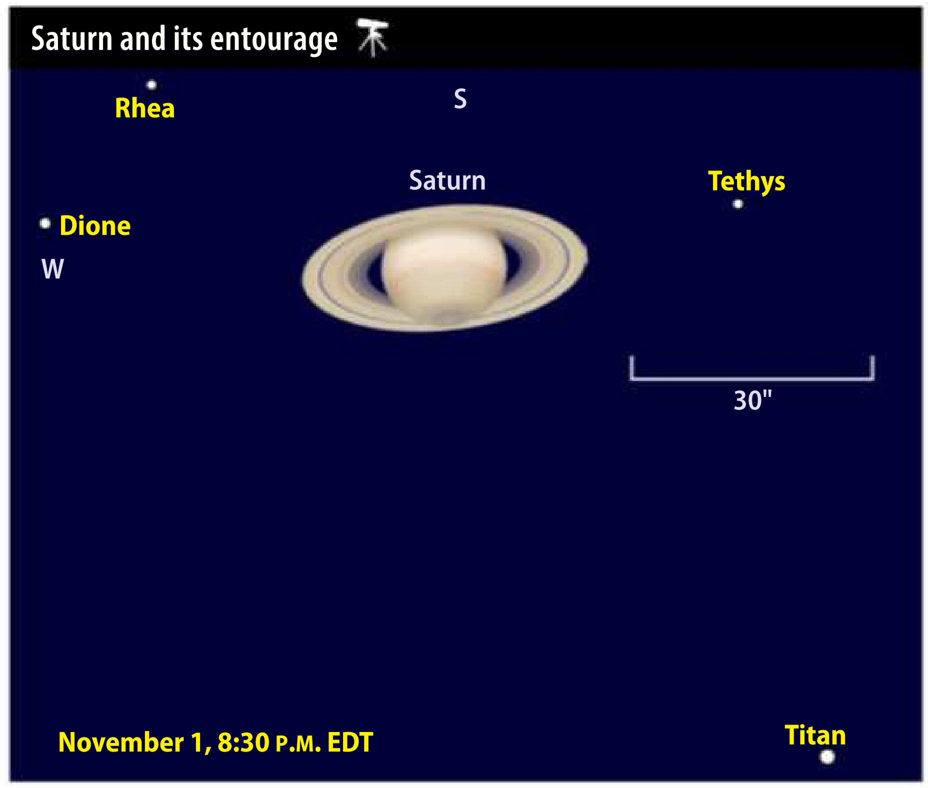
Arrows show the inner planets' monthly motions and dots depict the outer planets' positions at mid-month from high above their orbits.

ILLUSTRATIONS BY ASTRONOMY: ROEN KELLY

— *Continued from page 37*

WHEN TO VIEW THE PLANETS

EVENING SKY	MIDNIGHT	MORNING SKY
Mercury (southwest)	Uranus (southwest)	Venus (southeast)
Mars (south)	Neptune (west)	
Jupiter (southwest)		
Saturn (southwest)		
Uranus (east)		
Neptune (southeast)		



Target the ringed planet through a 4-inch telescope the evening of November 1, and you'll easily spot its four brightest moons.

as the last vestiges of twilight fade away. The orange-colored world doesn't dip below the horizon until 1 A.M. local daylight time.

Mars' eastward motion relative to the starry background carries it 0.6° north of magnitude 2.8 Delta (δ) Capricorni on November 5. The planet crosses into neighboring Aquarius on the 11th and, two evenings later, it passes within a Moon's width of magnitude 4.3 Iota (ι) Aquarii.

If you have trouble visualizing how big the Moon looks against the sky, be sure to look the evening of November 15. The First Quarter Moon then passes 1.0° (two Moon-widths) south of Mars. The planet seems to gain its own bright moon on the 24th, when it passes 8' southeast of magnitude 4.8 Sigma (σ) Aqr.

By the time November wraps up, Mars glows at magnitude –0.1 and lies 2.5° southwest of magnitude 3.8 Lambda (λ) Aqr. The planet's rapid easterly motion this month helps it keep pace with the Sun. It still lies due south as evening twilight ends on the 30th, but now at an altitude of 41°.

This higher elevation improves viewing conditions for Northern Hemisphere observers, and partially compensates for the planet's shrinking size. Mars' disk spans 11.8" the evening of the 1st and 9.3" on the 30th. This is still large enough to show some details through amateur scopes, though it's a far cry from the 24.3" at its peak in late July.

Fortunately, two of the planet's most conspicuous features lie near the center of the martian disk on November's first few evenings. Look for the dark, wedge-shaped Syrtis Major just north of Mars' equator. If you see it clearly, you also should notice the bright oval Hallas basin to its south.

While the parade of bright planets attracts attention to the southwest and south these November evenings, the east and southeast quietly introduce the distant ice giant worlds, Neptune and Uranus. **Neptune** is up first, residing among the background stars of Aquarius some 40° above the southeastern horizon as darkness falls. It stands just 2° from Lambda Aqr, the 4th-magnitude star Mars

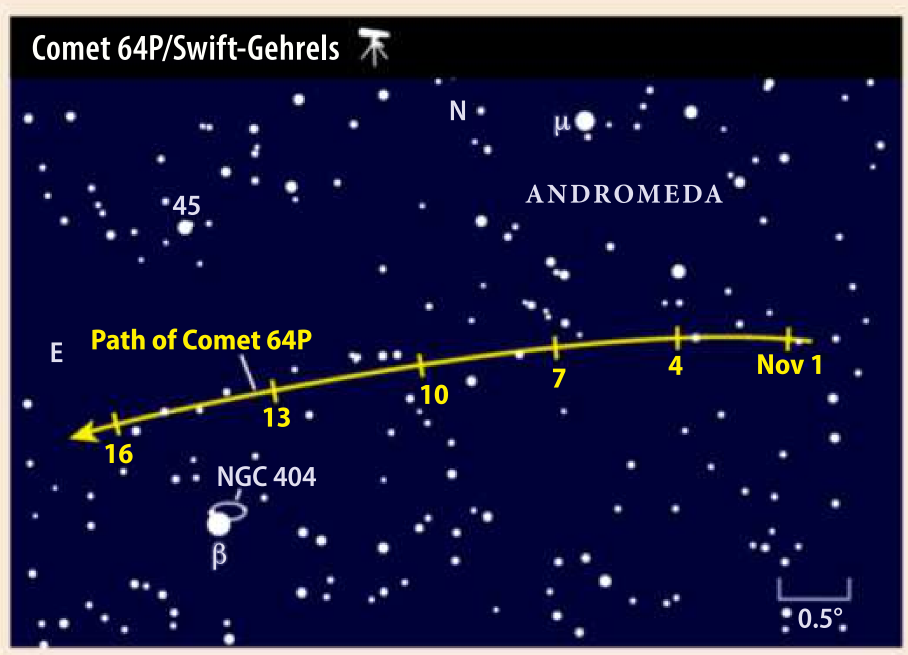
COMET SEARCH

The Princess' ghostly apparition

After whetting our appetites for brighter objects later this year, Comet 21P/Giacobini-Zinner has started to fade away. The best of the lot in November should be 64P/Swift-Gehrels, which passes nearly overhead during the evening hours. It should hold us until the year's brightest comet, 46P/Wirtanen, comes to the fore in December.

Plan to look for Swift-Gehrels during the first half of November when the Moon won't affect viewing. The comet moves eastward during this period slightly north of the 2nd-magnitude star Mirach (Beta [β] Andromedae). Astronomers think 64P could peak near 10th magnitude, coincidentally near the same total brightness as the nearby elliptical galaxy NGC 404. Observers have dubbed this distant fuzzy the "Ghost of Mirach" because it lies a mere 7' northwest of Beta and has tricked unwary skywatchers into thinking it was an internal reflection of the star.

Swift-Gehrels should be easier to see than NGC 404, but it depends on how large and diffuse the comet is — the more its light spreads out, the lower its surface brightness and the harder it is to see. Use a 4-inch or larger telescope and medium power (at least 100x) to darken the background sky and make the comet appear larger. Then try averted vision (glancing to the side of the field) to take advantage of your eye's sensitive peripheral vision.



This periodic visitor slides north of 2nd-magnitude Beta (β) Andromedae and its galactic neighbor, NGC 404, in mid-November.

The inner planet passed between the Sun and Earth in late October, but it quickly emerges as the brightest point of light in the morning sky.

approaches at the end of the month.

Because Neptune glows at magnitude 7.9, you'll need binoculars or a telescope to spot it. On the 1st, you can find it 2.1° east of Lambda and 0.3° south-southwest of 6th-magnitude 81 Aqr. The planet creeps westward until the 25th, when it reaches its stationary point 0.1° closer to Lambda. It then heads off on an easterly track for the rest of the year, though its position barely budges by November's close.

Every star looks like a point of light through a telescope, but a planet lies close enough to Earth that it shows a distinct disk. It's a small one in Neptune's case, just 2.3" across, so you'll need moderate magnification to see it. A scope's added light-gathering power also reveals Neptune's subtle blue-gray color. The best views will come during midevening when the planet lies high in the south.

Uranus trails about three hours behind Neptune. It lies in the southwestern corner of Aries the Ram, about 10° due south of 3rd-magnitude Beta (β) Arietis. Uranus shines at magnitude 5.7, so it's barely visible to the naked eye from under a dark sky and an easy target through binoculars.

Your best bet for finding it is to start at 4th-magnitude Omicron (ο) Piscium in neighboring Pisces. Uranus stands 2.4° northeast of this star November 1 and 1.6° north-northeast of it on the 30th. Don't confuse the planet with the magnitude 5.9 star SAO 92659. Uranus passes 14' due south of this star on the 9th. The easiest way to tell the two apart is to point a telescope at them. Only Uranus shows a disk, which spans 3.7" and sports a distinctive blue-green color.

At just about the same time Uranus dips below the western horizon, **Venus** appears in the east. Although the inner planet passed between the Sun and Earth during October's final week, it quickly establishes itself as the brilliant "morning star" in the predawn twilight. On November 1, Venus rises about a half-hour before the Sun. That grows to an hour on the 4th, two hours on the 13th, and three hours on the 25th.

A brightness surge accompanies this quick leap into the morning sky. The inner world shines impressively at magnitude –4.2 in early November but appears twice as bright (magnitude –4.9) by month's end. The changes to Venus' telescopic appearance are no less dramatic. On the 1st, the planet spans 61" and the Sun illuminates just 2 percent of its Earth-facing hemisphere. Its diameter dwindles to 41" by the 30th while its phase waxes to 25 percent lit.

You'll want to set your alarm early November 6 to see Venus hanging 9° to the right of a slender crescent Moon. It's also worth watching from the 11th to the 19th, when the planet approaches within 2° of 1st-magnitude Spica.

Martin Ratcliffe *provides planetarium development for Sky-Skan, Inc., from his home in Wichita, Kansas. Meteorologist* **Alister Ling** *works for Environment Canada in Edmonton, Alberta.*

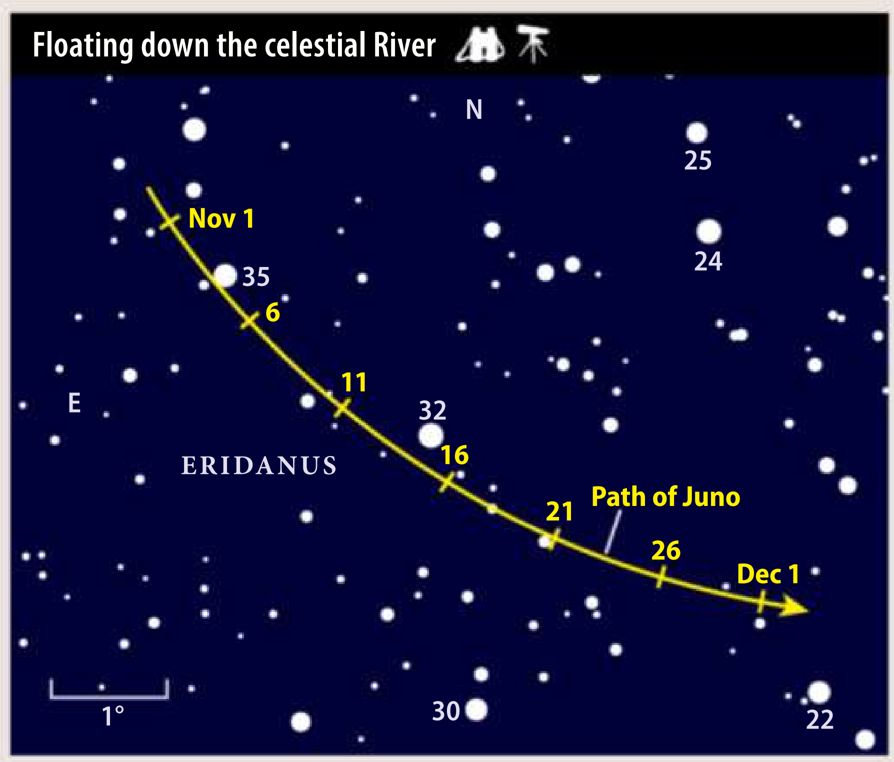
LOCATING**ASTEROIDS**

Juno makes a historic return

Asteroid 3 Juno reaches opposition November 17. But this is no ordinary opposition — Juno peaks at magnitude 7.4, the brightest it has been since October 1983.

Juno rises during twilight and by midevening appears in the southeastern sky to the lower right of Aldebaran. The asteroid resides in northern Eridanus the River, a region lacking in prominent stars. In fact, only a handful of the stars in the finder chart are brighter than Juno. You should be able to pick out the asteroid based solely on its location plotted below. If in doubt, sketch the four or five brightest objects in your telescope's field of view. Come back a night or two later and find the "star" that has shifted position. That is Juno.

Use 5th-magnitude 35 Eridani as a guide during November's first week. On the 4th, Juno lies 0.1° southeast of this star and the same distance northwest of a fainter star. The three objects form a straight line that changes noticeably in less than an hour as Juno heads southwest. In mid-November, the asteroid passes the magnitude 4.7 star 32 Eri. Juno remains within 0.5° of this star from November 13–16.



When asteroid 3 Juno reaches opposition against the backdrop of Eridanus in mid-November, it glows brighter than it has in 35 years.

November's 50 finest deep-sky objects

Set aside some time under a moonless sky to view this wide variety of celestial treats. **by Michael E. Bakich**

NGC 925

AMATEUR ASTRONOMERS LOVE LISTS, probably because we're goal oriented. So, for this roundup, I chose 50 deep-sky objects best seen throughout November. Of course, you'll also be able to spot them several months before and after this month. Because most of our readers live north of the equator, I didn't select any targets in the far-southern sky. And I list them in order of right ascension, so if you start observing selections at the top of the list, subsequent objects will rise higher as the night goes on.

Before you start, let me offer three tips. First, dress warmly, because observing involves just sitting (or standing) and looking. Second, head to as dark a site as you can find because my list contains galaxies, and you won't see those from a city. Third, although I've chosen some objects for small scopes (and even a few for naked eyes or binoculars), haul out the biggest telescope you can. You won't be sorry. Good luck!

NGC 891
Andromeda

NGC 891's only problem is that it's Andromeda's second-best galaxy. Not bad, except the constellation's top dog is one of the sky's supreme wonders — the Andromeda Galaxy (M31). Despite that, NGC 891 — also known as the Silver Sliver Galaxy — ranks as one of the sky's best edge-on spirals. It inclines only 1.4° to our line of sight, glows at magnitude 9.9, and measures 13.0' by 2.8'.

A 10-inch telescope reveals a symmetrical object with a noticeable but narrow central bulge. A dark dust lane bisects the galaxy and runs nearly its entire length. Dozens of foreground stars populate the field, adding a third dimension to the view. At magnifications above 200x, note the sections of NGC 891's nucleus on each side of the lane. The western section is slightly brighter.

NGC 908
Cetus

To find this spiral galaxy, look 5.4° east of Upsilon (υ) Ceti. Through an 8-inch telescope, magnitude 10.4 NGC 908 appears as an oval haze 5.9' by 2.3' stretched roughly east to west. The core is quite a bit brighter, and ghostly hints of spiral structure appear at high magnifications.

Through a 16-inch scope, an arm that radiates to the north of the core and turns abruptly to the west is quite prominent. A fainter arm extends due east and ends near a 15th-magnitude star. The core also appears irregular.

NGC 925
Triangulum

This attractive, nearly face-on barred spiral galaxy glows at magnitude 10.1 and measures 12.0' by 7.4'. To find it, point your telescope 2° east of Gamma (γ) Trianguli. Through a small scope, NGC 925's figure appears indistinct, but an 8-inch or larger instrument reveals the spiral arms that fold back abruptly from a long bar. At high magnification, say, above 250x, you'll spot the stellar nucleus.

Polaris
Ursa Minor

The first double star on this list is the North Star. William Herschel discovered that Polaris was binary in 1780. Although the yellow magnitude 2.0 primary outshines the blue magnitude 9.0 secondary by more than 600 times, the separation is a worthy 18.3", so a 3-inch telescope at 100x easily will show you Polaris B.

NGC 956
Andromeda

This magnitude 8.9 open cluster lies 5.7° east-northeast of Almach (Gamma Andromedae). This odd group has a 9th-magnitude star at both its north and south end, a couple more 10th-magnitude stars, and about a dozen magnitude 12 and fainter stars. It spans 6'.

NGC 957
Perseus

This open cluster, which glows at magnitude 7.6 and spans 10', lies about 1.5° east-northeast of the famous Double Cluster. Through an 8-inch scope at 100x, you'll count two dozen

NGC 925: ADAM BLOCK/MOUNT LEMMON SKYCENTER/UNIVERSITY OF ARIZONA, **NGC 891:** R. JAY GABANY, **POLARIS:** JEREMY PEREZ, **NGC 956:** MARTIN C. GERMANO, **NGC 908:** GEORGE AND LAURA MISHLER/ADAM BLOCK/NOAO/AURA/NSF

NGC 1023

stars. A magnitude 8.0 star sits slightly southeast of the cluster's center. At the cluster's southwest edge sits a magnitude 8.5 star.

IC 1805 Cassiopeia

Because this object, also known as the Heart Nebula, has a diameter of 1°, you can approach observing it either with low or high magnification. Each requires at least an 8-inch telescope and a dark sky. Look 4.9° east-southeast of Epsilon (ε) Cassiopeiae.

For an overall view, insert a nebula filter and identify the Heart's brightest regions: the central cluster, the knot of nebulosity to the east, and the crescent of gas to the southwest.

NGC 1027, a magnitude 6.7 open cluster, shines 1.2° east of the nebula and spans 15'. Another bright nebulous knot, NGC 896, lies 1° southwest of the Heart. Many observers see this 20'-wide object before they spot IC 1805.

NGC 986 Fornax

To find this magnitude 10.8 spiral galaxy, first locate Iota (ι) Eridani, then move 1.6° west-northwest. Small telescopes will show an oval shape (4' by 3.2') elongated northeast to southwest. Through 11-inch and larger scopes, you'll spot the two broad but incredibly short spiral arms, one on the north end and the other angling south.

The Fornax Dwarf Fornax

Although the Fornax Dwarf Galaxy's stated magnitude is 8.1, its size (12' by 10.2') makes its surface brightness low. That said, I've spotted this object through a 4-inch refractor using a wide-angle eyepiece. Through an 8-inch scope, choose an eyepiece that yields a 1° field of view, and slowly sweep the area. You're looking for a faint haze just brighter than the background sky.

Once you've located the Fornax Dwarf, crank up the magnification and aim for its northern edge. There sits globular cluster NGC 1049. This object shines at magnitude 12.6 and measures roughly 1.2' across.

NGC 1023 Perseus

The magnitude 9.3 spiral galaxy (known as the Perseus Lenticular) measures more than twice as long as it is wide (8.6' by 4.2'), stretching in a rough east-west direction. Through small telescopes, the core appears almost starlike. Use a 14-inch or larger scope, however, and you'll see that the central region spans half of this galaxy's overall length.

NGC 1027 Cassiopeia

You'll find this nice open cluster not quite 6° east-southeast of Epsilon Cassiopeiae. It glows at magnitude 6.7 and spans 15'. Through an 8-inch telescope at 100x, you'll see the brightest 15 or so members in front of a haze of fainter stars. A 12-inch scope resolves about 20 more stars. A magnitude 7.0 star glows at the heart of NGC 1027.

NGC 1052 Cetus

At the eastern edge of Cetus, 3.8° west of Azha (Eta [η] Eridani) lies a nice trio of galaxies highlighted by magnitude 10.5 NGC 1052. Through an 8-inch telescope, it appears oval (2.5' by 2.0') with an extended central region surrounded by a slight haze.

Only 15' to the southwest lies the magnitude 11.0 spiral NGC 1042. It's more than 50 percent bigger than NGC 1052, but you'll need at least a 16-inch scope to bring out any trace of the arms.

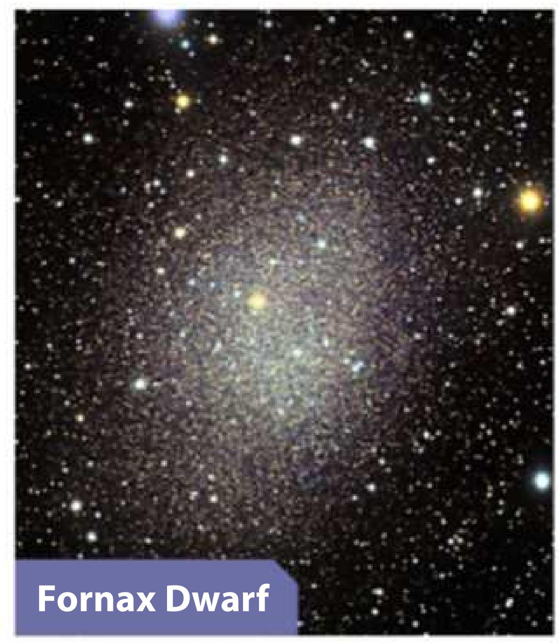
Even fainter is magnitude 12.2 NGC 1035, 23' northeast of NGC 1042. This galaxy is three times as long as it is wide, but doesn't show details through most scopes. Use a magnification around 100x to catch all three galaxies at once.

NGC 1055 Cetus

Look 39' east of Delta (δ) Ceti, and you'll find this magnitude 10.6 spiral galaxy. Through a 6-inch telescope, it appears twice as long as wide (7.3' by 3.3') and aligned nearly east-west. Just to the north of the galaxy you'll find a magnitude 11.2 star.

M34 Perseus

From a dark site, you'll find the Spiral Cluster with your naked eyes roughly 5° west-northwest of Algol (Beta [β] Persei). At magnitude 5.2, it contains 10 stars brighter than



Fornax Dwarf

9th magnitude spread out over an area 35' across.

A 4-inch scope reveals three dozen member stars between 8th and 12th magnitude. At 100x, look for chains of faint stars crisscrossing the field of view.

M77 Cetus

Cetus A (the first strong radio source discovered in this constellation) lies 0.9° east-southeast of Delta Ceti. The galaxy's central area, one-third its width, will command your attention. Although you can spot M77, which glows at magnitude 8.9 and measures 8.2' by 7.3', through any telescope, an 11-inch or larger instrument and a magnification above 300x will let it put on a show.

Ignore the bright core and search the disk surrounding it for signs of mottled structure.

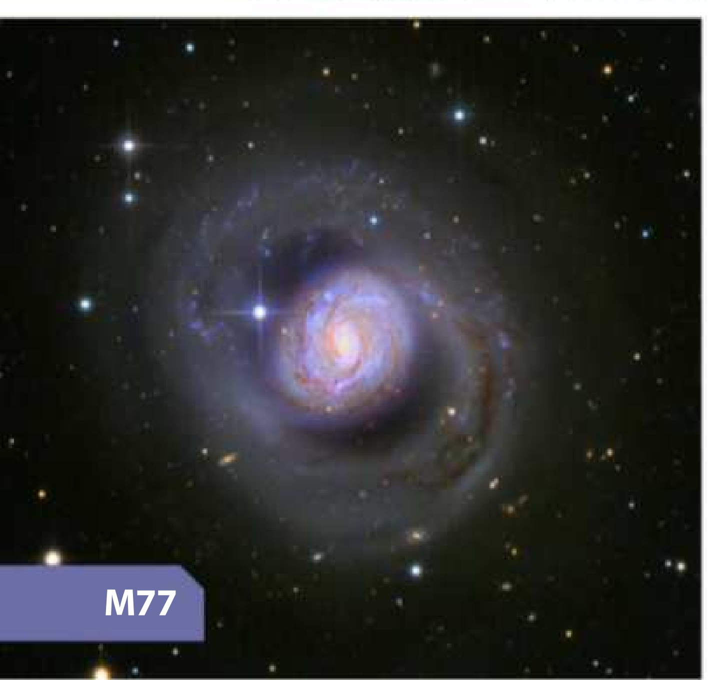
NGC 1023: KEN CRAWFORD, **FORNAX DWARF:** JASON JENNINGS, **M34:** ANTHONY AYIOMAMITIS, **NGC 1052:** ADAM BLOCK/MOUNT LEMMON SKYCENTER/UNIVERSITY OF ARIZONA, **NGC 1027:** ANTHONY AYIOMAMITIS, **IC 1805:** BOB FERA, **M77:** ADAM BLOCK/MOUNT LEMMON SKYCENTER/UNIVERSITY OF ARIZONA, **NGC 957:** ANTHONY AYIOMAMITIS, **NGC 1055:** KEN CRAWFORD

M34

NGC 1052

NGC 1027

IC 1805



M77

NGC 957

NGC 1055

NGC 1097

Look for the tightly wound spiral arms — the brightest one lies southeast of the core.

Kaffaljidhma
Cetus

This colorful double, also known as Gamma Ceti, is a bit puzzling. The magnitude 3.5 primary appears white or "just a bit" yellow. There's not much dispute about that. Lying 2.8" away, however, the magnitude 7.3 companion should not appear the shade of blue most observers report. It's a spectral class F star, which is hotter, and therefore should be just a bit whiter, than our Sun. What color do you see?

Musca Borealis
Aries

Indulge me on this object. I'm something of a constellation historian, so I thought it would be fun if something on this list no longer existed in its original form. This naked-eye object is the extinct constellation Musca Borealis the Northern Fly. Dutch mapmaker Petrus Plancius introduced it around 1614 under the name Apes (the Latin word for "bee"), but it was later changed. Plancius formed it from four stars — 33, 35, 39, and 41 Arietis.

To find them, look about 9° east-northeast of Hamal (Alpha [α] Arietis). The brightest of these stars, 41 Arietis, shines at only magnitude 3.6, and the faintest, 39 Ari, glows at magnitude 5.3. If you have any trouble seeing the group, use binoculars. The Northern Fly spans only 2.5°.

NGC 1084
Eridanus

This magnitude 10.7 spiral galaxy lies 2.9° west-northwest of Azha. Through a 4-inch telescope, NGC 1084 has a nearly rectangular shape and is twice as long as it is wide (2.8' by 1.4'). A 12-inch scope won't reveal much more, but it does show the core is broad — as much as three-quarters the galaxy's length. The edges of this galaxy are irregular with no hint of spiral structure.

NGC 1097
Fornax

Our next object is a magnitude 9.2 barred spiral that sits 2° north of Beta Fornacis. Through an 8-inch telescope, you'll see NGC 1097's core as a bright disk surrounded by an oval haze. Within that oval is the galaxy's faint bar. You won't see much of the thin spiral arms no matter what scope you observe through. This system measures 10.5' by 6.3'.

IC 1848
Cassiopeia

The Baby (or Soul) Nebula sits 2.5° east-southeast of the Heart Nebula (IC 1805). Although equally as wide (1°) as the Heart, the Baby doesn't cover as

IC 1848

NGC 1245

NGC 1300

NGC 1275

much area, so it appears more concentrated.

A nebula-filtered view shows two large regions that form the head and body. The head appears denser, while the body surrounds a small star cluster within. To see the stars better, remove the nebula filter. Through a 12-inch or larger scope, you'll notice brightness differences along the body's edge. Look for two crescent-shaped nebulae, a smaller one to the northeast and a larger one to the west.

Struve 331
Perseus

This stellar pair lies near the Pleiades (M45), but the easiest way to find it is to start at Tau (τ) Persei, and head 1.5° northwest. The 12.1" separation allows splits through even small telescopes. The magnitude 5.3 primary shines lemon yellow, and the magnitude 6.7 secondary is pale blue.

Algol
Perseus

The variable star Algol (Beta Persei) normally shines at a bright magnitude 2.1. Every 2 days, 20 hours, and 49 minutes (2.867 days), however, it dims to magnitude 3.4. So, at maximum, Algol is 3.3 times as bright as at its minimum. This dip in brightness occurs when a faint, unseen star orbiting Algol passes in front of it and blocks some of its light. Each eclipse lasts approximately 10 hours.

Algol's brightness changes are easy to observe. Most of the time it appears nearly as bright as magnitude 1.8 Mirfak (Alpha Persei), but keep an eye on it and you may catch it when it's fainter than magnitude 3.0 Delta Persei.

NGC 1232
Eridanus

Although a 4-inch telescope will reveal magnitude 10.0 NGC 1232, I recommend instruments with at least 12 inches of aperture. Seeing — the steadiness of the air above your observing site — is the key to discerning the individual spiral arms. Can you see three? Four? More? It all depends on your seeing.

NGC 1232 isn't quite round. It measures 6.8' by 5.6'. Through a large scope, this galaxy's nucleus has a slight east-west elongation, which puts it in the barred spiral category.

NGC 1245
Perseus

To find NGC 1245, which glows at magnitude 8.4, draw a line between Iota and Kappa (κ) Persei. This nice cluster lies less than 1° east of the line's center point. Through an 8-inch telescope, you'll see more than 50 stars evenly distributed across its 10'-wide face. A magnitude 8.0 star gleams at the cluster's southern edge.

NGC 1275
Perseus

At magnitude 11.9, spiral galaxy NGC 1275 is the brightest member of the Perseus galaxy cluster (Abell 426). To find it, look 2° east of Algol. This galaxy appears small and nearly circular (3.2' by 2.3'). Don't confuse it with NGC 1272, a similar but slightly fainter galaxy just 5' to the west.

Through a 10-inch telescope, you'll spot a dozen galaxies in a field of view 1° across. Most lie south and west of NGC 1275.

Pazmino's Cluster
Camelopardalis

This small-telescope target is also known as Stock 23. To find it, scan 5.3° northeast of Eta Persei. The cluster shines at a respectable magnitude 6.5. Through your finder scope, Stock 23 is an unresolved clump of stars. View it through a 3-inch telescope at a magnification of 50x, however, and you'll spot two

Kaffaljidhma

Pazmino's Cluster

Struve 331

NGC 1232

NGC 1097: R. JAY GABANY, IC 1848: BOB FERA, NGC 1245: ANTHONY AYIOMAMITIS, NGC 1300: R. JAY GABANY, NGC 1275: R. JAY GABANY, KAFFALJIDHMA: JEREMY PEREZ, PAZMINO'S CLUSTER: BERNHARD HUBL, STRUVE 331: JEREMY PEREZ, NGC 1232: GEORGE GREANEY


NGC 1333


NGC 1316


NGC 1491


Melotte 20

dozen stars spread across an area 15' wide.

Four cluster stars shine brighter than 8th magnitude, including double star ADS 2426 at the center. Its separation is only 7". If you can't split it at 50x, just double the power, and you'll have no problem.

NGC 1291 Eridanus

You'll find this magnitude 8.5 spiral galaxy 3.7° east of Theta (θ) Eridani. NGC 1291 appears slightly oblong (11' by 9.5'), but, apart from a faint outer halo, you'll see no details here through even a medium-sized telescope. With larger apertures, you may see two faint, broad arcs of light.

NGC 1300 Eridanus

NGC 1300 has a simple shape — that of a squashed letter S — making this magnitude 10.4 wonder a classic barred spiral with two arms. Both originate from the ends of the bar and move out at right angles to it.

To find NGC 1300, look 2.3° due north of Tau^4 Eridani. Crank up the magnification past 200x, and you'll first spot the bright oval nucleus, roughly twice as long as it is wide. The next features that will become evident are the beginnings of the spiral arms. They're quite clumpy near the nucleus. Finally, through a large scope try to trace the thin spiral arms as they tightly curve past the nucleus on the northern and southern sides.

NGC 1316 Fornax

The powerful radio source Fornax A is a bright (magnitude 8.9) spiral galaxy you can find 1.4° south-southwest of Chi^1 (χ^1) Fornacis. This galaxy's spiral arms wrap so tightly around its core that it appears elliptical through most telescopes. NGC 1316 is about half again as long as it is wide (11' by 7.6'), and it orients northeast to southwest.

Slightly more than 6' north of Fornax A lies NGC 1317, a similar spiral that also has tight spiral arms. This galaxy glows at magnitude 11.9.

Melotte 20 Perseus

The Alpha Persei Association, as the name implies, surrounds the star Mirfak (Alpha Persei). At magnitude 1.2, this large, scattered group of stars is obvious to the naked eye. For the best view, however, try binoculars or a rich-field telescope. Keep the magnification under 20x. You'll see 50 bright stars with the most prominent being Mirfak and Psi (ψ) Persei. All told, more than 100 young stars brighter than magnitude 12 spread across the association's 3° width.

NGC 1332 Eridanus

The magnitude 10.5 elliptical galaxy NGC 1332 lies 1.6° east-northeast of Tau^4 Eridani. This highly elongated object (5' by 1.8') appears like a stubby cigar three times as long as it is wide. Through small telescopes the surface brightness remains remarkably constant across NGC 1332's surface. Larger scopes reveal the outer 10 percent is fainter than the rest, and it fades rapidly with increasing distance from the core.

NGC 1333 Perseus

You'll find this mix of emission and reflection nebulosity 3.3° west-southwest of Omicron (o) Persei. Through an 8-inch telescope, you'll see a 6' by 3' haze that's brightest at the northeastern end, where a magnitude 10.5 star that illuminates the nebula resides. You'll also spot several voids.

Because this object contains emission and reflection nebulae, a nebula filter will dim the reflection component, increasing the contrast of the emission nebulosity. Remove the filter, and your mind will fool you into thinking the reflection nebulosity has gotten brighter.

NGC 1342 Perseus

This magnitude 8.9 open cluster lies 5.7° west-southwest of Epsilon Persei. Through an 8-inch telescope at 150x, you'll spot 50 stars evenly distributed across its 11.0' by 7.6' face. A 12-inch scope shows lines and arcs of the brighter members and brings 50 more stars into view.

NGC 1360 Fornax

If you expect planetary nebulae to appear round, you're not alone. Magnitude 9.4


NGC 1342


NGC 1360


NGC 1365


NGC 1444


NGC 1499


M45

NGC 1360, however, appears twice as long as it is wide, extended in a roughly north-south orientation. To find it, look 5.6° northeast of Alpha Fornacis.

Through a 12-inch telescope at a magnification above 200x, both sections have a darker lane crossing them. The brighter northern half's lane enters from the east and is thin. By contrast, the dark region in the southern half of NGC 1360 is wide, extending all the way from the southern tip to the 11th-magnitude central star.

NGC 1365 Fornax

The best example of a barred spiral — NGC 1365 — languishes in Fornax, more than one-third the way from the celestial equator to the South Celestial Pole. It's a relatively bright magnitude 9.3, and you can star-hop to it if you first find a triangle of three faint stars, Chi[1], Chi[2], and Chi[3] Fornacis. From Chi[2], which is the brightest, move 1.3° east-southeast.

Through even a 4-inch telescope at a dark site, you'll see NGC 1365's bar and brighter central region. The galaxy spans 8.9' by 6.5'. Notice how the bar near the core appears dimmer than it does farther out. An 8-inch scope shows the spiral arms. The brighter one extends northward from the bar's west end. The other arm, only slightly fainter, appears somewhat blotchy, revealing huge star-forming regions within it.

NGC 1399 Fornax

This bright (magnitude 9.6) galaxy appears ever-so-slightly oblong (8.1' by 7.6') under high magnifications. To find NGC 1399, draw a line from Chi[1] to Chi[2] Fornacis, and extend that line five times the distance between those two stars. The large central region takes up three-quarters of this galaxy's diameter. Only a quickly fading fuzz lies outside.

NGC 1404 Fornax

This galaxy lies a scant 10' south-southeast of NGC 1399. Although both galaxies are similar ellipticals, NGC 1404 is smaller (4.8' by 3.9') and slightly fainter (magnitude 10.0). A magnitude 8.1 star lies just 3' south-southeast of NGC 1404.

NGC 1444 Perseus

This nice magnitude 6.6 open cluster combines the magnitude 6.7 star SAO 24248 and about 10 others. It has a diameter of 4'. To find it, look 3.5° northwest of Lambda (λ) Persei.

M45 Taurus

One of the finest naked-eye objects also ranks as the sky's brightest star cluster (magnitude 1.2). It's the Pleiades (M45). Often called the Seven Sisters, most people see only six stars. Observers with good vision can spot more than that, with reports of up to 13 naked-eye stars within the cluster. Although M45 is a great target to just look at, it's terrific

NGC 1333: THOMAS V. DAVIS, **NGC 1316:** DANIEL VERSCHATSE, **NGC 1491:** ADAM BLOCK/MOUNT LEMMON SKYCENTER/UNIVERSITY OF ARIZONA, **MELOTTE 20:** RICK BENO, **NGC 1342:** ANTHONY AYIOMAMITIS, **NGC 1360:** ADAM BLOCK/MOUNT LEMMON SKYCENTER/UNIVERSITY OF ARIZONA, **NGC 1365:** DON GOLDMAN, **NGC 1444:** MARTIN C. GERMANO, **NGC 1499:** ADAM BLOCK/NOAO/AURA/NSF, **M45:** MARK HANSON/JEFF HAPEMAN through binoculars. Choose a unit that magnifies between 10 and 15 times.

32 Eridani
Eridanus

This double star sits in a lonely part of northern Eridanus near the Taurus border. It's worth seeking out, however, because the two stars, separated by 6.8", have a nice color contrast. The yellow primary shines at magnitude 4.8, and its blue companion glows at magnitude 6.1.

NGC 1491
Perseus

This emission nebula lies 1.1° north-northwest of Lambda Persei. A 10-inch telescope equipped with a nebula filter clearly shows its bright fan shape. Start with a magnification of about 75x, then gradually increase the power.

NGC 1491 appears brightest on the western edge and fades gradually toward the more diffuse eastern side. A 16-inch scope reveals striations that extend away from the southern tip. Don't expect to see an object that even approaches the cataloged size of 25'. Through the eyepiece it scarcely spans 4'.

NGC 1499
Perseus

From a dark site, sharp-eyed observers can spot the California Nebula with their naked eyes — almost. Look through either a Hydrogen-beta or deep-sky nebula filter. (An Oxygen-III filter will reduce what you can see.) When you switch to a telescope, select your eyepiece that provides the lowest magnification. NGC 1499 spans 160' by 40', so if even that view isn't wide enough, slowly move the telescope back and forth.

NGC 1501
Camelopardalis

Move 6.9° west of magnitude 4.0 Beta Camelopardalis to find the Blue Oyster Nebula. An 11-inch telescope shows a circular disk 52" across. Through larger scopes at magnifications above 350x, however, you'll note that the magnitude 11.5 planetary is ever-so-slightly oval in an east-west orientation.

The magnitude 14 central star is easier to see than its brightness suggests. It peeks through a slightly darker center that suggests the presence of a thick ring structure. The planetary's face also appears patchy, with several small dark areas visible.

Kemble's Cascade
Camelopardalis

This object is a chance alignment of stars first described by the late Franciscan amateur astronomer Father Lucian Kemble, who found it through binoculars. A magnification of 15x works best for framing the starry chain. The Cascade is 15 stars that stretch 2.5°. Most of the stars range from 7th to 9th magnitude. The exception is the 5th-magnitude sparkler SAO 12969 that sits in the center.

At the southeast end of Kemble's Cascade, in the same field of view, sits the tight open cluster NGC 1502 (7' across). You'll need a telescope to see its individual stars, but you won't miss its overall magnitude 5.7 glow.

NGC 1514
Taurus

The Crystal Ball Nebula is a round, magnitude 10.9 hazy planetary that spans 114". It sits 3.4° east-southeast of Atik (Zeta [ζ] Persei). The magnitude 9.4 central star can be a bit distracting. An OIII filter will dim it. If you still have trouble spotting the nebula, try increasing the magnification to 150x or beyond. This object is brighter along its rim. Bright knots intermingle with the gas on the northwestern and southeastern sides.

NGC 1532
Eridanus

This object is a double galaxy. It combines the magnificent edge-on spiral NGC 1532 (magnitude 9.9) with elliptical NGC 1531 (magnitude 11.7), which sits less than 2' to the northwest. But NGC 1532 is the real treat here. It appears nearly four times as long as it is wide (11.2' by 3.2'). Find this pair 1.5° northwest of Upsilon^4 Eridani.

Through a 16-inch or larger telescope, you'll see the spiral arms extend in a north-northeast to south-southwest orientation. With magnifications of 200x or more, the brilliant core appears surrounded by an oblong haze.

NGC 1528
Perseus

This magnitude 6.4 open cluster lies 1.6° east-northeast of Lambda Persei. Sharp-eyed observers may just detect NGC 1528 as a hazy star from a dark observing site. Through a 4-inch telescope, use 150x to spot 50 member stars spread across 18'. Many group into whirls and other patterns. An 8-inch scope will show nearly 100 stars.

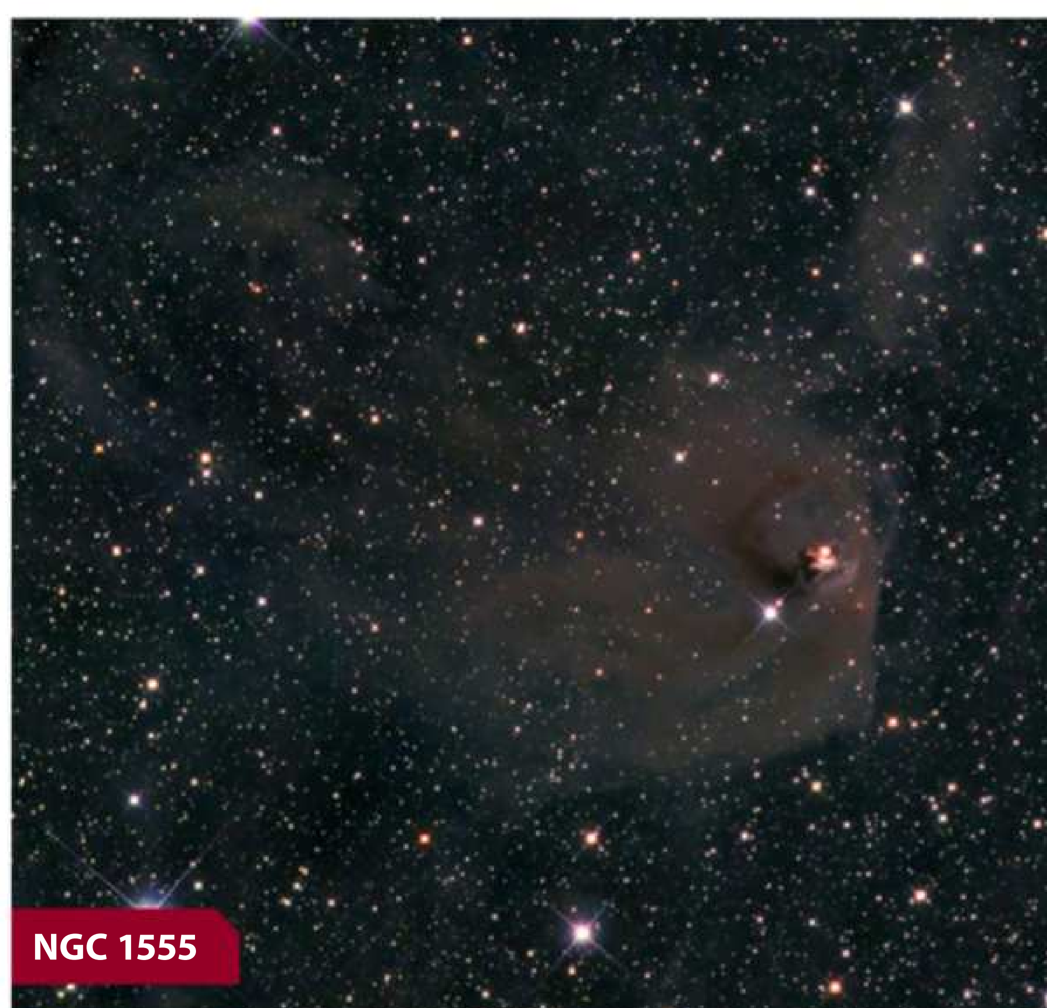
NGC 1535
Eridanus

You'll find Cleopatra's Eye, a magnitude 9.6 planetary nebula, 4° east-northeast of Zaurak (Gamma Eridani). Through a 6-inch telescope, NGC 1535 has a sharply defined disk (18" across) surrounded by a faint envelope. Double that aperture to 12 inches, and you'll begin to pick up this object's color. Now, crank the magnification past 300x, and you'll observe a dark hollow around the central star. At this aperture and power, you'll note that the contrast between the sharp inner disk and the fainter outer shell is at its maximum.

NGC 1545
Perseus

This magnitude 6.2 open cluster lies 2.3° east of Lambda Persei. Look for it as a faint, fuzzy star with your naked eyes. Through a 4-inch telescope, you'll see about 20 stars


NGC 1514


NGC 1555

spanning 12'. The three brightest (magnitudes 7.1, 8.1, and 9.3) form an isosceles triangle near NGC 1545's center.

Spend some time with this cluster at magnifications above 200x. You'll see many colored stars and also several nice double stars.

Chi Tauri
Taurus

You'll find this double star equidistant from the Pleiades (M45) and Epsilon Tauri. Although most observers see some combination of a yellow magnitude 5.5 primary and a blue magnitude 7.6 secondary, others have seen the brighter star as blue-white and its companion as deep blue.

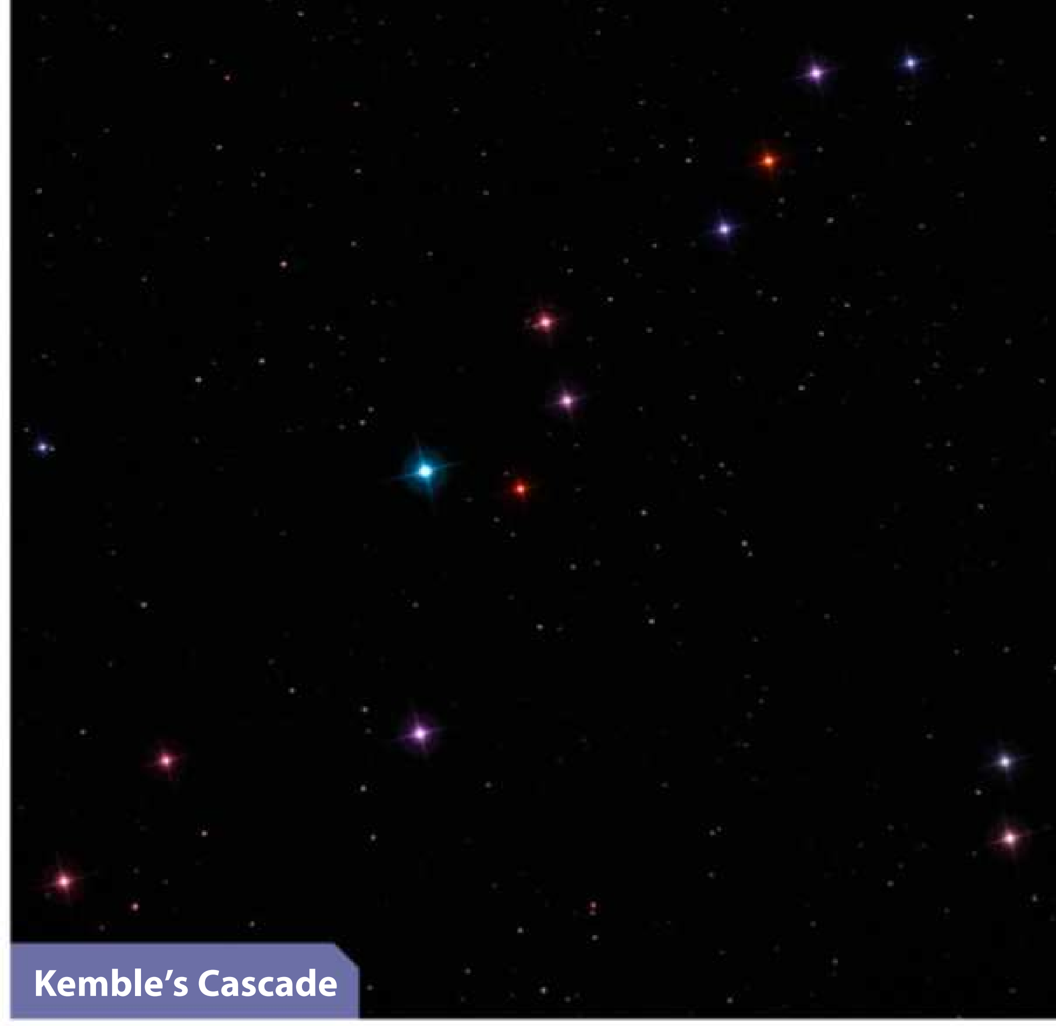
Decide for yourself by cranking up the magnification as much as the sky will allow and moving first the primary, then the secondary, out of the field of view. Seeing the stars alone will give you a better gauge of their true colors. The separation is 19.4".

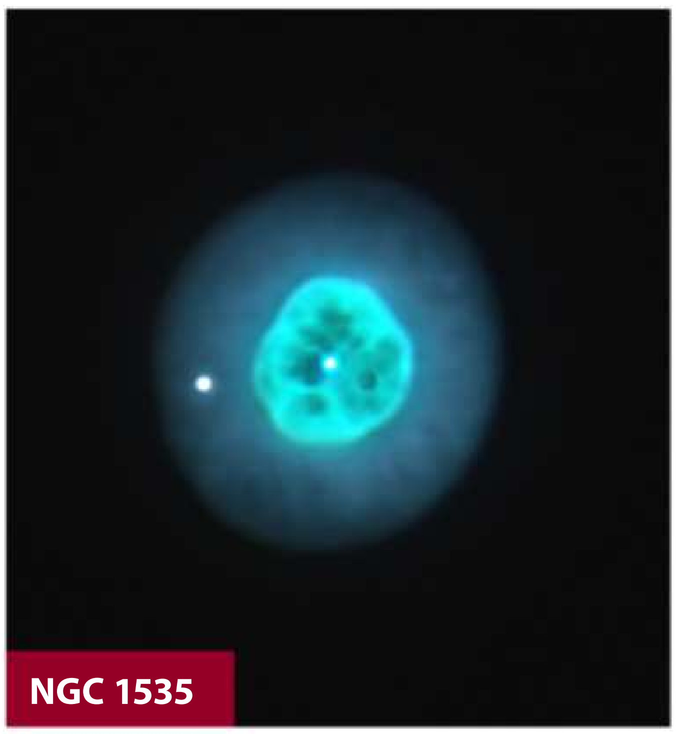
NGC 1554/1555
Taurus

This emission nebula combines two objects in one. Observers refer to NGC 1554 as Struve's Lost Nebula, and NGC 1555 is Hind's Variable Nebula. Note the name for NGC 1554, and don't look for it. It's not there.

To start your search for NGC 1555, head 1.7° west-northwest of Epsilon Tauri. Near that position, you'll see a magnitude 8.4 star. From there, move 5' northeast, and you'll encounter the variable star T Tauri, which usually shines at magnitude 9.6. Hind's Variable Nebula appears as a faint wisp of nebulosity near T Tauri. It's tiny (1'), so use a big scope.

Michael E. Bakich *is a senior editor of* Astronomy *who has been making lists of deep-sky objects for decades.*


Kemble's Cascade


NGC 1535


NGC 1528


NGC 1545


NGC 1501


NGC 1532

NGC 1514: RUBEN KIER, **NGC 1555:** THOMAS V. DAVIS, **KEMBLE'S CASCADE:** JOHN CHUMACK, **NGC 1535:** ADAM BLOCK/MOUNT LEMMON SKYCENTER/UNIVERSITY OF ARIZONA, **NGC 1528:** MARTIN C. GERMANO, **NGC 1545:** MARTIN C. GERMANO, **NGC 1501:** RUBEN KIER, **NGC 1532:** KEN CRAWFORD

Astronomy magazine 2018 Star Products

Our eighth annual STAR PRODUCTS

by Phil Harrington

Once again, it's time for *Astronomy's* annual Star Products. We've combed manufacturers' catalogs and surfed the web to come up with a selection of 35 products (roughly alphabetical) that are sure to fuel your astronomical passion.

Phil Harrington *is an* Astronomy *contributing editor and author of* Cosmic Challenge: The Ultimate Observing List for Amateurs *(Cambridge University Press, 2010).*

1 10MICRON GM1000 HPS German equatorial mount

The importance of a high-quality mount rises exponentially as telescope aperture and weight grow. To address this, 10Micron from Caronno Pertusella, Italy, offers a series of German equatorial mounts for serious scopes. The smallest, the GM1000 HPS, can handle a 55-pound (25 kilograms) scope. Inside, a pair of servo motors drives a worm gear smoothly, with zero backlash. Users can control the mount either with the included hand controller, or by connecting it via Ethernet to a PC with the RS-232 serial port. The RS-232 port can also control a dome, making this mount ideal for robotic observatories.

$9,541 • www.10micron.eu/en

2 ALTAIR ASTRO Lightwave Hyperwide 20mm Eyepiece

This 20mm eyepiece from Altair Astro is shaped like a hand grenade and delivers images with a bang. With its 100° apparent field of view, the Lightwave doesn't just show you the universe, it pulls you into it. The nine-element optical system uses special low-dispersion glass, blackened lens edges, and fully multicoated internal surfaces for excellent image sharpness and contrast, along with 14.5 millimeters of eye relief. The Lightwave Hyperwide's 2" barrel also features a rubberized grip and folding eyecup. At nearly 2 pounds (875 grams), it's no lightweight, but if you have a heavy-duty focuser, you'll find the performance impressive.

$400 • www.altairastro.com

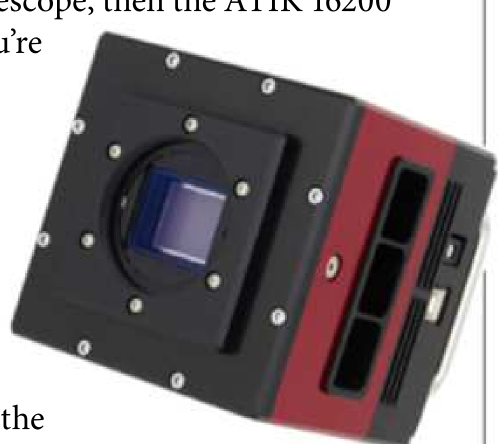
3 APM TELESCOPES
LMS 16×70 ED APO Magnesium Series Binocular

This binocular offers exceptional image quality and contrast with no chromatic aberration, whether you're viewing distant galaxies, the Moon, or terrestrial scenery. That's thanks to the optical heart and soul within it: fully multicoated twin objectives with FK-61 extra-low-dispersion glass and BAK-4 Porro prisms. Eyeglass wearers also will rejoice at a comfortable 20 mm of eye relief, letting them take in the full 4.1° field of view with glasses on. Topping everything off, the manufacturer purged the magnesium barrels of air and filled them with nitrogen to prevent internal fogging.

$684 • www.apm-telescopes.de, www.farpointastro.com in the U.S.

4 ATIK
16200 CCD camera

If you're in the market for a top-end CCD camera to couple to your telescope, then the ATIK 16200 may be just what you're looking for. Its 16.2-megapixel KAF-16200 class II sensor can be used with a wide range of telescopes. It is just as adept at photographing wide-angle views of the night sky as it is at capturing intricate detail in small, faint targets, thanks in part to the sensor's 6-micrometer pixel size. The housing is sealed and argon-purged to keep the innards dry, while a dual-stage cooling system lowers the sensor to 81 degrees Fahrenheit (45 degrees Celsius) below ambient temperature to minimize electronic noise.



$3,570 • www.atik-cameras.com

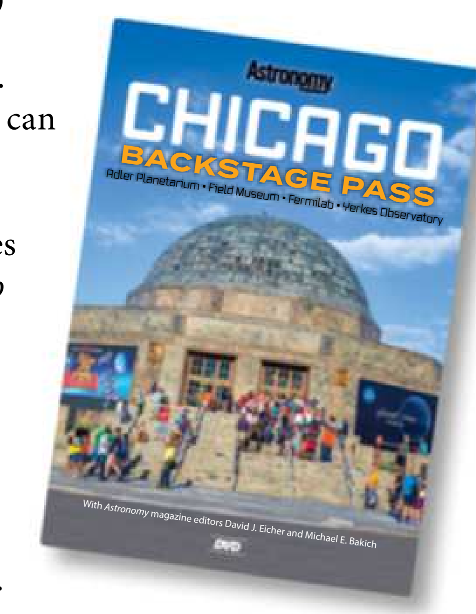
5 ASTRO-TECH
AT60ED

Here's a mighty mite of a telescope that's perfect for travel, whether halfway around the world or out to the yard for a quick midweek look-around. Although it measures only 9.5 inches (24 centimeters) long with the dew shield retracted and weighs just 3.25 pounds (1.5 kg), the AT60ED is a lot of scope. Its 2.4-inch f/6 FPL-53 air-spaced doublet delivers excellent resolution and sharpness with no spurious color. The dual-speed 2" rack-and-pinion focuser moves smoothly with no backlash, making it perfect for on-the-go photography as well as visual observing. The AT60ED includes a mounting ring to attach to any standard photographic tripod.

$369 • www.astronomics.com

6 ASTRONOMY MAGAZINE
Backstage Pass: Chicago

Thanks to *Astronomy* magazine's Editor David J. Eicher and Senior Editor Michael E. Bakich, you can get your own private tour on DVD of four great institutions in and around Chicago: Adler Planetarium, the Field Museum, Fermilab, and Yerkes Observatory. *Astronomy Backstage Pass: Chicago* is a three-hour informal account of the editors' visit to these wonderful facilities. You'll see and hear people at each location talk about current programs, exhibits, and research, and you'll "walk through" some fascinating public — and not-so-public — areas. And stay tuned: This DVD is just the first in the Backstage Pass series.



$29.95 • www.myscienceshop.com

7 ASTRONOMY MAGAZINE
Venus globe

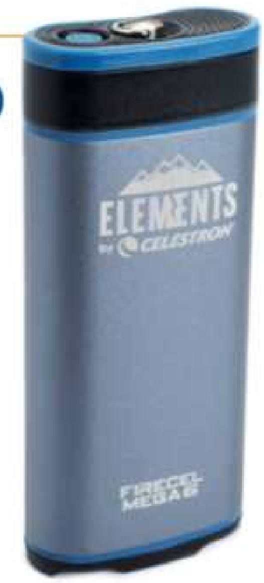
Venus is often called Earth's sister planet. The Magellan orbiter, which imaged 84 percent of the planet's surface, proved that our "sister" is more like a distant relative. Based on those images, *Astronomy*'s Venus globe pulls back the curtain of the second planet's opaque atmosphere to unveil a colorful (albeit false-color) complex surface. More than 200 features — such as Beta Regio, Atanua Mons, Epistle Regio, Var Mons, and Maxwell Montes — are labeled, as are all 10 Venera landing sites. Measuring 12 inches (30.5 cm) in diameter, the injection-molded globe comes with a clear acrylic display base.

$99.95 • www.myscienceshop.com

8 BAADER 17.5mm Morpheus 76° Eyepiece

From Germany's Baader Planetarium comes this new entry in the wide-field eyepiece market. The Morpheus offers a 76° apparent field for a panoramic view that is sharp and distortion-free right to the edge. Thanks to the 20 mm of eye relief, that full field can be enjoyed by everyone, including observers who wear glasses. Want to photograph the view? The folding rubber eyecup comes with an integral M43 threaded metal ring for attaching a camera.

$239 • www.baader-planetarium.com



9 CELESTRON Elements FireCel Mega 6

This is a must-have multitool for every backyard stargazer. Using a rechargeable 6000 mAh lithium-ion battery, the FireCel Mega 6 combines a hand warmer, a USB power bank, and a four-mode red and/or white LED flashlight. Cold fingers? The hand warmer can reach a toasty temperature of 114 F (45.6 C) for up to eight hours. The FireCel can power cameras, phones, and other USB-connectable devices, as well as light your way to and from your telescope. The unit measures 2 inches by 1 inch by 4.63 inches (51 by 24 by 118 mm) in size and weighs just 6.2 ounces (177 g).

$59.99 • www.celestron.com

10 KASAI TRADING WideFinder 28

The WideFinder marries one side of Kasai's WideBino 28 to a red-dot reflex finder to boost what you see when aiming your scope. The erect (right-side-up) image means you can still aim with both eyes open. Like other reflex finders, the WideFinder's view includes two concentric circles, ½° and 2° in diameter. Their brightness is adjustable, and you can set them to pulse or shine continuously. Kasai includes two bases, two dust covers, and a dew/light shield.

$220 • www.kasai-trading.jp

11 BERLEBACH Charon observer's chair

Spending time at the eyepiece is something we all enjoy. But bending over while doing so is decidedly unpleasant. Many opt for the comfort of an observing chair to ease the burden on their backs. Such chairs come in several designs, but Berlebach's folding Charon chair is one of the best. It's made from birch plywood, and the seat has 12 height settings from 4 to 36.6 inches (10 to 93 cm). This makes it ideal for viewing through Newtonian reflectors, which require a broad range of seating positions. The chair weighs less than 13 pounds (5.9 kg), yet can support 264 pounds (120 kg) of astronomer.

$189 • www.berlebach.de, www.mrstarguy.com in the U.S.

12 CELESTRON NexStar Evolution 8 HD with StarSense

Celestron set a high standard when it created its latest flagship Schmidt-Cassegrain telescope. The NexStar Evolution 8 uses Edge HD optics to deliver sharp images free of coma and field curvature. The one-armed computer-driven mount serves as a steady platform that is accurately controlled by precision worm gears on both axes. Wireless control ends the hassle of dangling cables, which can be such a nuisance at night. Finally, the StarSense employs a small digital camera that takes a series of wide-field sky images to align the telescope. The result is an exceptionally versatile instrument, both visually and photographically.

$2,099 • www.celestron.com

13 CORONADO
SolarMax III 70mm Solar Telescope

Coronado's SolarMax III Hydrogen-alpha refractor delivers unparalleled images of our star's turbulent nature. Available in several models, the Solar Max III's design places its H-alpha etalon filter in front of the objective. This improves contrast and sharpness. Two variations of each model are available, either with a single filter and a 0.7-angstrom bandpass or a double-stacked filter offering a 0.5-angstrom bandpass. Each comes with a 2" dual-speed rack-and-pinion focuser, a 90° diagonal with a built-in blocking filter, an 18mm CEMAX eyepiece, a Sol Ranger Solar Finder, a Vixen-style dovetail mounting rail, and a black and gold aluminum carrying case.

$2,299 and up • www.meade.com

15 GREAT AMERICAN ECLIPSE
Eclipse maps for 2024

The next total solar eclipse visible in the United States will be on Monday, April 8, 2024. For those of us who are already planning where we will be, Michael Zeiler has created an indispensable series of detailed maps showing the exact eclipse path from the Rio Grande River to northernmost Maine, as well as over portions of southeastern Canada. Like his similar work for the 2017 eclipse, the 2024 maps are available in different formats. It's never too early to start planning for the next Great American Eclipse.

$10 and $29.99 • www.greatamericaneclipse.com

14 IOPTRON
SkyTracker Pro

Never one to rest on its past successes, iOptron's latest nightscape camera drive, the SkyTracker Pro camera-tracking platform, improves on previous versions that have been popular for years. The SkyTracker Pro attaches to any tripod with either ¼" or ⅜" threads. Once you align it to the celestial pole using the included polar finder scope — easily done thanks to the geared altitude-azimuth base — the tracker will move your camera in time with the sky to create dramatic nightscapes. iOptron states that the rechargeable internal battery can run the SkyTracker Pro continuously for up to 24 hours on a single charge.

$399 • www.ioptron.com

16 DAYSTAR
SR-127 Dedicated Solar Telescope

Looking for even more aperture for studying the Sun? DayStar's SR-127 should satisfy the need. It features the company's Quark H-alpha filtering technology combined with a 5-inch achromatic objective made by iStar Optical. Four models varying in bandpass width from 0.7 angstrom to an incredible 0.1 angstrom are available. Each includes a digital readout for precise tuning control accurate to 0.01 angstrom. And if that isn't enough, the SR-127 includes a carbon-fiber tube, a 2" rack-and-pinion focuser, mounting rings with a Vixen-compatible dovetail, and a hardwood case.

$5,745 to $9,890 • www.daystarfilters.com

17 DAYSTAR
80mm Solar Scout

DayStar offers its 80mm achromatic Solar Scout dedicated solar scope for the price other companies charge for smaller apertures. Two models are available, both based around DayStar's Quark H-alpha filter. One is designed to highlight prominences, while the other is meant to capture chromospheric details such as filaments. Power to control the internal etalon tuning is delivered using the included 110-volt AC adapter or an optional 24-mAh battery. DayStar gave the Solar Scout a carbon-fiber tube, an internal helical focuser, a Solar Bullet finder, and a Vixen-style mounting plate.

$2,695 • www.daystarfilters.com

18 IOPTRON
AZ Mount Pro

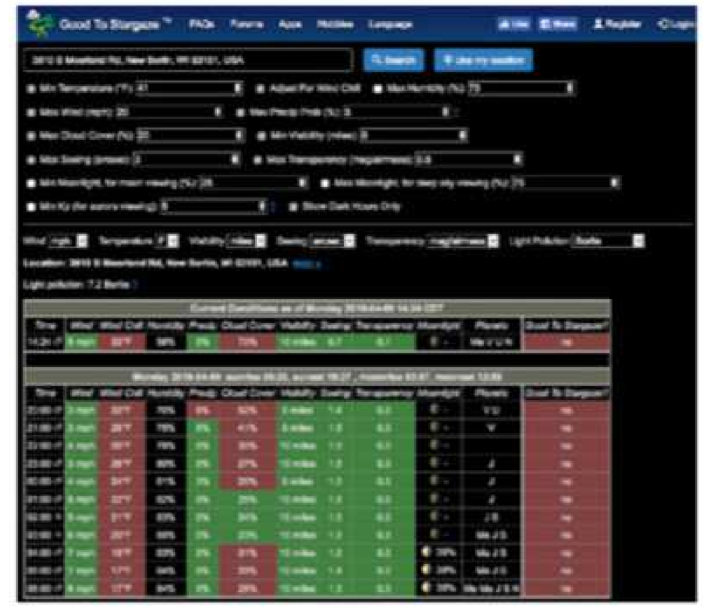
Here's a mount that's an outstanding choice for visual observers looking for a travel-ready, state-of-the-art way to view the universe. Designed for telescopes weighing up to 33 pounds (15 kg), the AZ Mount Pro is a compact all-in-one unit that features full computer control, a rechargeable lithium-ion battery, and iOptron's "level-and-go" technology for simplified setup. Tracking and go-to aiming accuracy are both spot-on. With its AZ Mount Pro, iOptron proves once again that it remains a leading manufacturer of sophisticated portable mounts.

$1,299 • www.ioptron.com

20 KASAI TRADING
WideBino 28

Kicking back and viewing the night sky is both fun and relaxing. But have you ever wished that your eyes had a little more light-gathering power? Check out Kasai's 2.3x40 WideBino 28 binoculars. Non-prismatic in design, the WideBino combines two-element multicoated objective lenses with two-element eyepieces to produce a stated 28° true field of view. This gives you a one- to two-magnitude gain over traditional naked-eye viewing. Do note, however, that the field you see depends on how you use the binoculars. To see the widest field, you'll need to press your eyes close to the eyepieces. Also, the field of view of a Galilean optical system like this depends on pupil size — the 28° field is viewable only when the pupils are fully dilated to around 7 mm. Kasai also sells a custom viewing goggle to hold the WideBino in place for hands-free viewing.

$170 • www.kasai-trading.jp

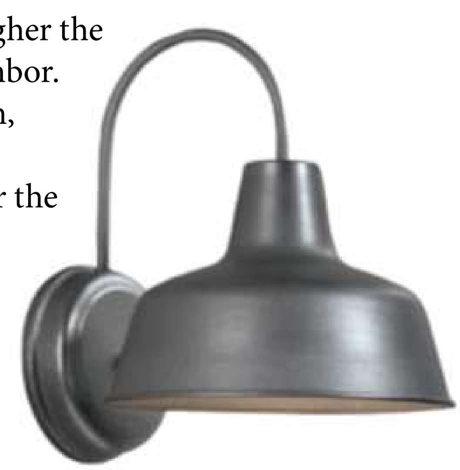


19 MATTHEW LLOYD
Good To Stargaze app

Will the stars be out tonight? Or should you plan to catch up on your Netflix viewing instead? Basing that decision on the local weather forecast can be frustrating because meteorologically clear and astronomically clear can be quite different. Good To Stargaze, created by Matthew Lloyd, gathers the local weather forecast, transparency, seeing, and light pollution all in one handy app. It's free from your app store for both iOS and Android phones.

Free • www.goodtostargaze.com

21 LOWE'S
"Good Neighbor" dark-sky-friendly lighting



It's been said that the higher the wall, the better the neighbor. For astronomers, though, the saying could be the darker the sky, the better the neighbor. Lowe's Home Center offers a variety of shielded outdoor fixtures designed to aim lighting earthward, not skyward. One such product is the lantern-style Ellicott wall light by Portfolio. Measuring 10.75 inches (27.3 cm) tall by 10.5 inches (26.7 cm) in diameter, the silver Ellicott lights doorways and other entrances without any annoying glare or light-spill. All light stays approximately 30° below the horizon. And if your local Lowe's doesn't carry them on the shelf, or if there is no Lowe's in your area, you can always order them online.

$39.98 • www.lowes.com

22 OMEGON Panorama II 10mm eyepiece

Omegon may not be a familiar name to most readers, but this small company from Landsberg, Germany, sells a line of four eyepieces with huge fields of view. Each focal length in their Panorama II collection offers a spacious 100° apparent field. We've singled out the 10mm eyepiece because it combines that wide view with 19.7 mm of eye relief, all in a housing that fits into 1¼" focusers. The 10mm is built around an eight-element design set in a waterproof barrel. The combination of moderate magnification and field size hits the sweet spot especially for fainter deep-sky objects.

$199 • www.omegon.eu

23 MASUYAMA 60mm eyepiece

If you own a long-focal-length telescope, you're usually restricted to small fields of view. While that's perfect for planets and binary stars, it's also nice to be able to stretch now and then and view larger targets. Masuyama's 60mm super-low-power eyepiece is your redemption. Housed inside its 2" barrel are five lens elements set into three groups, creating a "hybrid Plössl" design. Weighing in at 21 ounces (600 g), the Masuyama 60 measures 5.8 inches (148 mm) long and 2.6 inches (65 mm) in diameter. If you remove the rubber grips from the barrels, a pair of these eyepieces will slim down enough to fit into many 2" binoviewers.

$595 • www.hutech.com

24 ORION 6" f/4 Newtonian Astrograph Reflector

If you're looking to break into wide-field astrophotography on a budget, then you'll find this 6-inch reflector from Orion of special interest. The primary mirror is made of Schott B270 glass to quickly reach thermal equilibrium when brought out into the cool night air, while the secondary mirror is oversized to deliver excellent field illumination for photography. Both are coated with enhanced aluminizing to heighten contrast. The dual-speed Crayford focuser will hold heavy cameras without slipping, while a steel reinforcing plate underneath the focuser effectively eliminates flexure. The entire package — even with the included tube rings, extension tube for visual use, Vixen-style dovetail mounting plate, and 8x50 finder scope — weighs only 12.7 pounds (5.8 kg). Given the fast focal ratio, an optional coma corrector is recommended to eliminate inherent coma.

$399.99 • www.telescope.com

25 MEADE 70mm apochromatic refractor

The competitive niche market of astrophotography-specific telescopes, or astrographs, just got a little hotter with Meade Instruments' 2.76-inch apochromatic refractor. Its fast f/5 focal ratio means that it will record lots of detail quickly in wide-field shots that feature targets like the Andromeda Galaxy (M31), the North America Nebula (NGC 7000), and the Pleiades (M45). Its four-element objective, incorporating FPL-53 extra-low-dispersion glass, delivers images that are sharp to the edge — no field flattener required — and free of false color. Meade designed this scope with DSLRs in mind. Not only is the 10:1 dual-speed Crayford focuser well made, it allows a camera body to be threaded directly onto the focus tube using the included adapter.

$1,199 • www.meade.com

26 THE MARTIAN GARDEN Mars Regolith Simulant kit

One look at any color photo of the red, iron-rich surface of Mars and it's pretty obvious that you're not in Kansas anymore. Although we have yet to return a sample of martian soil to Earth, our armada of robotic landers and rovers has precisely investigated the chemical composition of the Red Planet's soil. Based on those analyses, scientists have found that crushed basalt from an ancient volcano in the Mojave Desert is a good replica. Can martian soil support plant life? You can find out for yourself with a Mars Regolith Simulant kit. Each includes simulated martian soil, a plastic greenhouse, and a seed mix of cabbage, kale, spinach, and broccoli.

$14.99 • www.themartiangarden.com

27 QHYCCD QHY183M camera

The QHY183M, a 20-megapixel back-illuminated camera, is the latest addition to QHYCCD's lineup of high-end digital imagers. While its near twin, the QHY183C, is a one-shot color camera, the monochromatic QHY183M expands your creative freedom to allow RGB, luminance, or narrowband exposures using a filter wheel (sold separately). Thanks to Sony's IMX183 CMOS sensor, pixel size is only 2.4 micrometers, promising high-resolution results using modest-sized telescopes with fast focal ratios. Its two-stage thermoelectric cooler drops the sensor's temperature 72 to 81 F (40 to 45 C) below ambient to reduce noise. Finally, USB 3.0 connectivity makes download times quick, up to 15 full-resolution frames per second.

$1,099 • www.qhyccd.com

28 STELLARVUE Optimus 9mm eyepiece

Like all four members in Stellarvue's family of highly acclaimed ultra wide-angle eyepieces, the 9mm Optimus features everything that you would expect from a $600 eyepiece: sharp, high-contrast views of everything it's aimed toward across a vast 100° apparent field of view that engulfs the observer. Further, 15 mm of eye relief and a foldable rubber eyecup makes viewing comfortable. It doesn't get any better, until you realize that this "$600 eyepiece" costs only $349. Owner Vic Maris has done what others couldn't do, creating a world-class eyepiece that is 40 percent less expensive than its nearest competition. The 9mm is an excellent choice for general viewing. Its moderately high magnification enhances contrast to bring out faint targets, while the wide field prevents cosmic claustrophobia.

$349 • www.stellarvue.com

29 SKYSAFARI 6 Pro app

Since it was introduced in 2009, SkySafari by Simulation Curriculum has become the most popular astronomy app for iOS devices. Earlier this year, version 6 came out with many new features that have raised the bar even higher. The basis for the app is the UCAC5 star catalog, which includes 25 million stars as faint as 15th magnitude. The Pro version ups that number to more than 100 million stars, as well as adds 3 million galaxies down to 18th magnitude and a full inventory of solar system objects. The app also offers wireless telescope control with voice activation. And if you feel like slewing your telescope toward random targets, aim your phone or device skyward, and SkySafari's "tilt to slew" option will move the telescope in that direction.

$39.99 • www.skysafariastronomy.com

30 ORION Tritech CFX tripod

This accessory offers sturdy support for cameras, spotting scopes, and binoculars, but weighs just over 6 pounds (2.8 kg) — about 30 percent less than comparable metal tripods. That's because the Tritech's three extendable legs are made of carbon fiber, which is lightweight yet strong and great at dampening vibrations. The tripod is topped with an aluminum fluid-pan-head with three axes of motion. A pair of twist-lock handle grips allows smooth control in all directions. The Tritech comes with a quick-release mounting plate featuring a captive ¼"-20 threaded post, with additional plates sold separately. When the legs and center post are fully extended, the tripod can raise its payload to 65 inches (165 cm). Collapsed, it measures 29 inches (73.6 cm) long, fitting neatly into its soft carrying case.

$299.99 • www.telescope.com

31 STELLARVUE SV152T refractor

Stellarvue's new flagship, the 6-inch f/7.9 SV152T apochromatic triplet refractor, excels as both a visual and photographic instrument. Optically, it uses a three-element objective with a conventional front element, an FPL-53 center element, and a lanthanum rear element. That winning combination produces images that are extremely sharp and high in contrast. The scope comes with a Feather Touch dual-speed focuser, a right-angle finder, a Losmandy-compatible mounting plate, and rotating mounting rings. The aluminum tube, weighing 27 pounds (12.2 kg) and measuring 44½ inches (1.1 meters) long with the dew shield retracted, sits safe and sound in the standard, wheeled storage case. Optional accessories include a 2" star diagonal, a field flattener, and a focal reducer.

$8,995 • www.stellarvue.com

32 UNIVERSE2GO Personal planetarium

This smartphone-based viewer combines virtual reality with real reality. By installing the free app on your iOS or Android smartphone, and then mounting it to the lightweight handheld viewer, Universe2Go brings the sky to you. Look up, and an overlay of the app's screen is superimposed on the actual sky, identifying planets, stars, constellations, and a wealth of deep-sky objects. You'll find a full list of compatible smartphones on the Universe2go website.

$49.90 • www.universe2go.com

33 TAKAHASHI FSQ-130ED Astrograph

What makes a great telescope? To me, it must be a superb optical performer, have solid mechanical construction, and be outfitted with no-compromise components. Finding all three of those qualities in a single instrument is difficult, until you look at Takahashi's 5.1-inch f/5 FSQ-130ED Astrograph apochromatic refractor. The outstanding five-element optical system consists of a three-element objective plus a two-element rear corrector. These effectively squelch spherical and chromatic aberrations. Takahashi's dual-speed rack-and-pinion focuser is beautifully made, designed to support even heavy cameras with ease. A mount, tripod, tube rings, and finder are each sold separately.

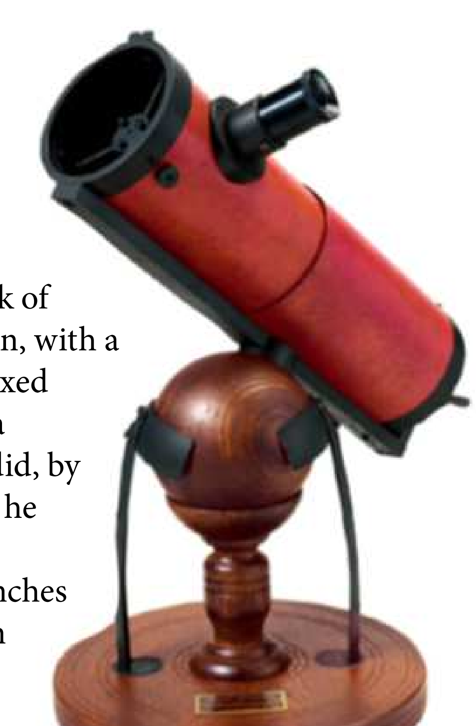
$13,460 • www.takahashiamerica.com

34 VIXEN Atera Vibration Cancelling Binocular

Using a proprietary prism system mounted in a two-axis gimbal base, Vixen's Atera Vibration Cancelling Binocular effectively steadies out jitters even at a magnification of 12. A battery-powered sensor (two AAA batteries required) detects motion and then compensates for it by adjusting the prism assembly in the direction needed to maintain a stable field of view. With fully multicoated optics and phase-coated roof prisms, the Atera promises excellent images across its 4.2° field. At less than 6 inches (15 cm) long and weighing less than a pound (0.5 kg), the Atera is small and light enough for one-handed support.

$649 • www.vixenoptics.com

35 VIXEN Replica of Isaac Newton's original reflector



The company calls it a replica, but it's not just a reproduction. It's a working 2.8-inch f/4 telescope. Outwardly, it faithfully re-creates the look of the original instrument built by Sir Isaac Newton, with a two-part sliding aluminum tube wrapped in waxed parchment paper and an ash globe mount atop a metal base. The scope focuses just as Newton's did, by turning a key behind the primary mirror — but he could only dream of what's inside this replica. Newton's reflector had an aperture of only 1.3 inches with a speculum primary made of an alloy of tin and copper. Vixen's optical system brings this into the 21st century, with a multicoated glass mirror teamed with a pair of 1¼" eyepieces.

$299 • www.vixenoptics.com

OBSERVING**BASICS**

BY GLENN CHAPLE

Juno's planetary past

Though once considered a full-sized planet, the third asteroid ever discovered faced demotion long ago.

A few months ago, we were privy to a close opposition of Mars — an event that occurs all too infrequently. This month, we set our sights on another favorable but uncommon opposition of a planet: Juno.

"Wait a second," you protest. "Juno isn't a planet!" Actually, it was — two centuries ago.

Here's the story. By the end of the 18th century, the distances from the Sun to the known planets seemed to obey a mathematical sequence as proposed by Johann Titius and Johann Bode. But there was a glitch: No planet existed between Mars and Jupiter, where Bode's law predicted one should be. Then, on the very first day of 1801, Italian astronomer Giuseppe Piazzi discovered a body, later named Ceres, in the prescribed location. The solar system was complete, according to Bode's law.

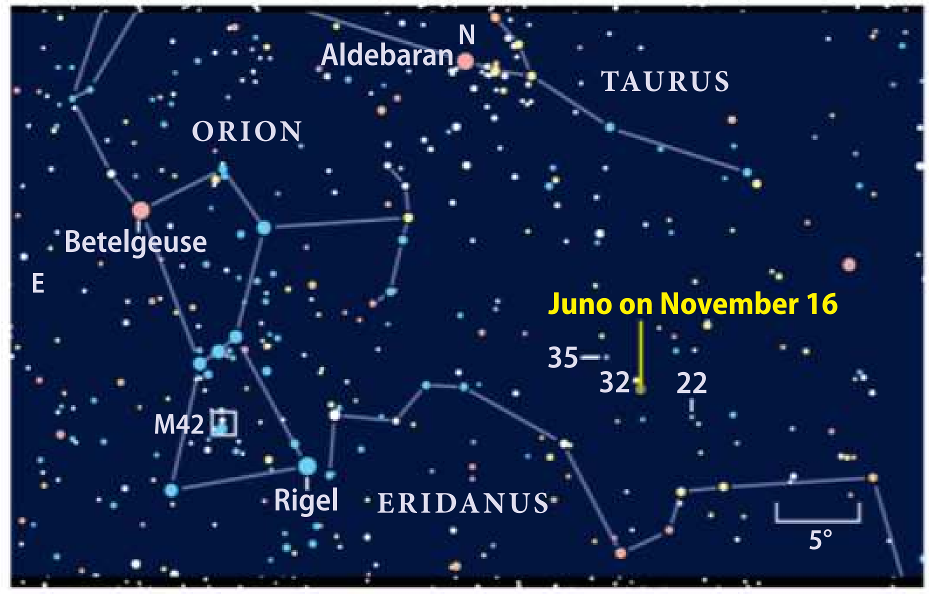
However, things began to unravel when, during the next six years, three more bodies — Pallas, Juno, and Vesta — were discovered orbiting in the same zone as Ceres. Worse yet, none of these bodies, dubbed "asteroids" by William Herschel, came close to approximating the size of the known planets. A rash of asteroid discoveries in the mid-1800s sealed the deal.

Ceres, Pallas, Juno, Vesta, and the others were reclassified as minor planets. And in 1846, a newly discovered planet — Neptune, which orbits the Sun more than 800 million miles closer than suggested by Titius-Bode — closed the book on that so-called law.

This state of affairs set a precedent for Pluto's recent fall from planetary grace. Like Ceres, Pluto was originally thought to be the only body of its kind in that part of the solar system. It, too, was much smaller than the traditionally known planets. When more "Plutoids" came to light — including Eris, which is slightly smaller than Pluto — these two, along with Ceres, were reclassified as dwarf planets.

Because Juno appears as a mere telescopic speck, we'll need to mentally enhance the view with some background knowledge. Juno was discovered in 1804 by German astronomer Karl Harding and named after the highest-ranking Roman goddess. As one of the larger asteroids (10th or 11th in rank), it has a diameter of 150 miles (240 kilometers), roughly the width of New Hampshire and Vermont combined. Juno orbits the Sun once every 4.7 years, with oppositions about every 15.5 months. Like Mars, its eccentric orbit means that not all Juno oppositions are created equal. During

"Wait a second," you protest. "Juno isn't a planet!" Actually, it was — two centuries ago.



Throughout the month of November, observers can spot dwarf planet Juno as it treks within a degree of a trio of bright stars. Juno is shown here during its opposition on November 16, when it will sit next to the binary star 32 Eridani. *ASTRONOMY*: ROEN KELLY

a typical opposition, Juno might shine at magnitude 9 or 10. Every 13 years, however, an opposition coincides with Juno's closest approach to the Sun. Such is the case with this month's opposition, which occurs on the 16th. Juno will be 96.3 million miles away and an easy magnitude 7.4 binocular target. We'll have to wait until October 2031 to see Juno this bright again.

Now that you know Juno is much more than a diminutive speck of light through binoculars or a telescope, you'll want to view it for yourself. First, you'll need the finder chart on the right side of page 43. If you're a "star hopper," focus on those times when Juno passes within a degree of a bright field star. During November, these opportunities occur when Juno encounters 35 Eridani (magnitude 5.3) early in the month, 32 Eridani (magnitude 4.5) at midmonth, and 22 Eridani (magnitude 5.5) at month's end. Because none of these stars is bright, you want to set up in an area with reasonably dark skies.

And now I must digress: 32 Eridani is a showpiece double star whose G8 and A2 spectral class components appear distinctly yellow and blue. The magnitudes are 4.8 and 5.9 with a separation of 6.9". It was a easy choice to make my Double Star Marathon list, and it is a definite bonus for anyone who looks for Juno during its close encounter with this pretty pair.

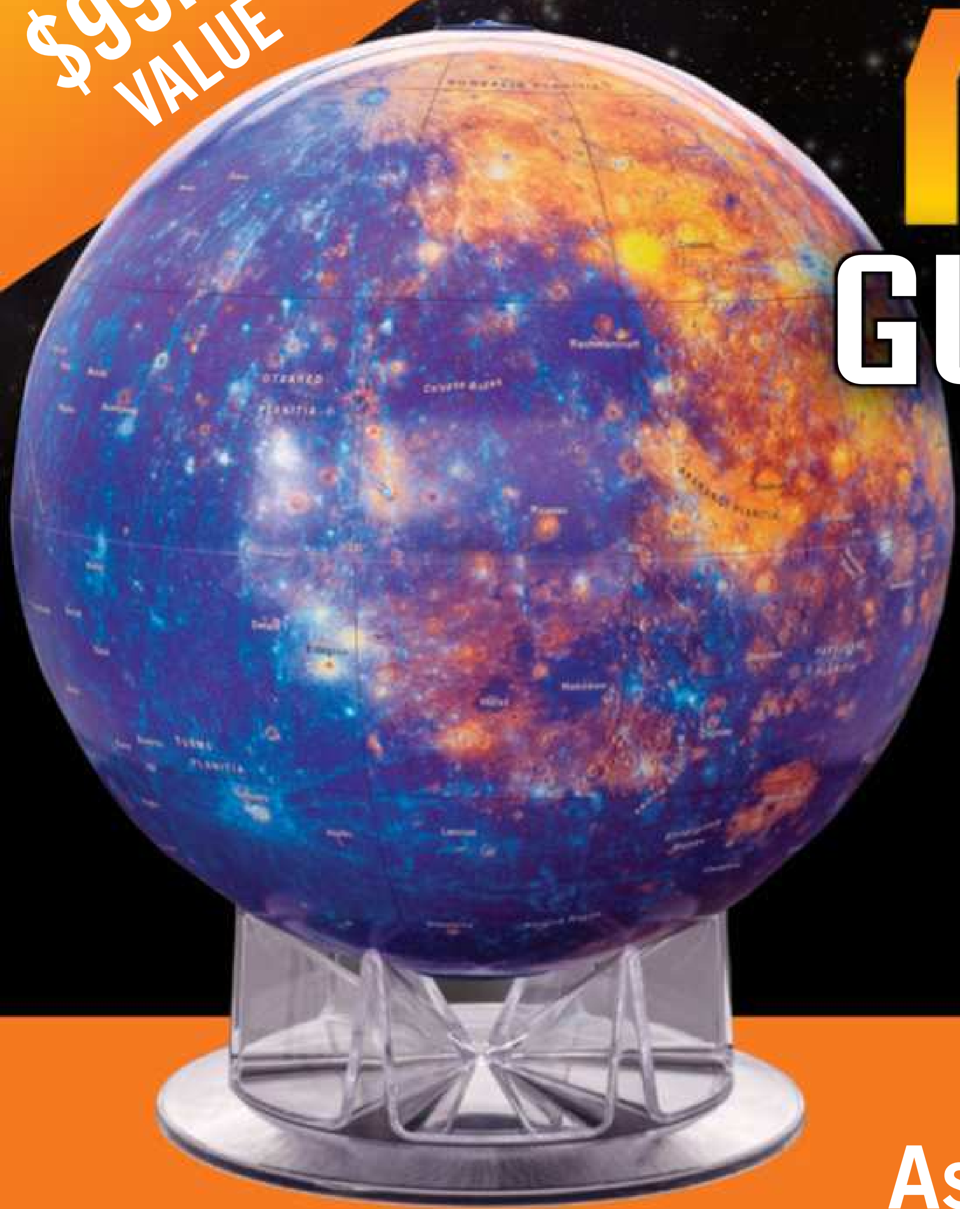
Now back to Juno. Since it looks like a star, how do you know you're seeing the real deal? Your first clue is if your suspect is close to where the finder chart indicates. If you're like me and want to be 100 percent sure, take advantage of the fact that asteroids move — stars don't. Make a sketch of the field that includes your possible Juno and nearby field stars. Mounting your binoculars on a tripod will help a lot. Through a telescope, use low magnification to encompass as large a chunk of sky as possible, particularly the area where Juno is predicted to be one or two evenings later. On the next clear night, reobserve the area. If the suspect you sketched is no longer in the original spot but has moved to the location predicted for that night, break out the champagne — you've captured Juno!

Questions, comments, or suggestions? Email me at gchaple@hotmail.com. Next month: The treasures of the triangle. Clear skies!

Glenn Chaple has been an avid observer since a friend showed him Saturn through a small backyard scope in 1963.

$99.95 VALUE

MERCURY GLOBE GIVEAWAY!



ENDS NOVEMBER 15, 2018!

Enter to win a richly detailed, 12" desktop globe of the planet Mercury! This *Astronomy* exclusive uses images from the Mercury Dual Imaging System aboard the spacecraft MESSENGER and identifies an astounding 236 planetary features with labels.

ENTER ONLINE AT: Astronomy.com/GlobeGiveaway

Mercury Globe Giveaway – Official Rules

NO PURCHASE NECESSARY TO ENTER OR CLAIM PRIZE. A PURCHASE WILL NOT INCREASE YOUR CHANCE OF WINNING. VOID WHERE PROHIBITED.

1. Eligibility. The Mercury Globe Giveaway (the "Sweepstakes") is open to residents of the United States and Canada (except Quebec) only, who are age 18 years or older and have reached the age of majority in their state/province of residency at the time of entry. Employees (and their dependents and immediate household members) of Kalmbach Media ("Sponsor"), are not eligible to participate. Void in Quebec and where prohibited by law. Sweepstakes is subject to all applicable federal, state, and local laws.

2. Sweepstakes Period. The Sweepstakes begins on September 20, 2018 at 12:00 a.m. CT, and all entries must be transmitted online no later than November 15, 2018 at 11:59 p.m. CT.

3. How to Enter. To enter, complete the Sweepstakes Official Entry Form online at Astronomy.com/GlobeGiveaway with your email address and then click on the SUBMIT MY ENTRY button. You may submit only one entry through the Sweepstakes Online Entry Form during the Sweepstakes Period. Entries from any person submitting more than the stated number will be disqualified.

4. Prizes/Approximate Retail Value ("ARV") in U.S. Dollars. One (1) Grand Prize consisting of a Mercury globe. ARV of Grand Prize: $99.95.

5. Drawing/Odds/Notification. A random drawing for the Grand Prize will be held on or around November 20, 2018. Odds of winning depend on the number of entries received. The average total circulation for *Astronomy* magazine is 95,959. Winners will be notified by email on or before November 21, 2018.

6. Prize Restrictions. No cash equivalent or prize substitution permitted. All prizes subject to the guarantees/warranties of the manufacturer. Any applicable federal, state, and/or local taxes are the responsibility of the winner.

7. Validation and Acceptance. Winner(s) in the Sweepstakes will be selected in a random drawing. If a potential winner cannot be contacted within a reasonable time period, if the potential winner in ineligible, if any notification is undeliverable, or if the potential winner otherwise fails to fully comply with these Official Rules, he/she will forfeit that Prize, and if time permits, an alternate winner will be randomly drawn from among all remaining Sweepstakes entries.

8. Limitations of Liability. Sponsor is not responsible for and shall not be liable for: (i) telephone, electronic, hardware or software program, network, Internet, or computer malfunctions, failures, or difficulties of any kind; (ii) failed, incomplete, garbled, or delayed computer transmissions; (iii) any condition caused by events beyond the control of Sponsor that may cause the Sweepstakes to be disrupted or corrupted; (iv) any injuries, losses, or damages of any kind arising in connection with or as a result of the prize, or acceptance, possession, or use/misuse of the prize, or from participation in the Sweepstakes; (v) any printing or typographical errors in any materials associated with the Sweepstakes; (vi) any change in participant's telephone number, mailing address, or email address. Sponsor reserves the right, in its sole discretion, to suspend or cancel the Sweepstakes at any time if a computer virus, bug tampering, unauthorized intervention, or other technical problem of any sort corrupts the administration, security, or proper play of the Sweepstakes. Sponsor also reserves the right to disqualify, in its sole discretion, any person tampering with the entry process, the operation of the website, or who is otherwise in violation of the rules. By participating in the Sweepstakes, each participant agrees to release and hold Sponsor, their employees, officers, and directors, their advertising and promotional agencies, and sponsoring companies harmless from any and all losses, damages, rights, claims, and actions of any kind in connection with the Sweepstakes or resulting from acceptance, possession, or use/misuse of any prize, including without limitation, personal injury, death, and property damage, and claims based on publicity rights, defamation, or invasion of privacy.

9. Additional terms. By entering the Sweepstakes, participants agree to be bound by these official rules and all decisions of Sponsor. Except where prohibited, each entrant agrees that: (1) any and all disputes, claims, and causes of action arising out of or connected with this Sweepstakes shall be resolved individually, without resort to any form of class action, and exclusively by state or federal courts situated in Wisconsin, (2) any and all claims, judgments and awards shall be limited to actual out-of-pocket costs incurred, but in no event attorneys' fees, (3) no punitive, incidental, special, consequential or other damages, including, without limitation, lost profits, may be awarded (collectively, "special damages"), and (4) entrant hereby waives all rights to claim special damages and all rights to such damages multiplied or increased. Wisconsin law, without reference to choice of law rules, governs the Sweepstakes and all aspects related thereto.

10. Sponsor. Sponsored by Kalmbach Media, P.O. Box 1612, Waukesha, WI 53187-1612.

P33956

FOR**YOUR**CONSIDERATION

BY JEFF HESTER

'Miracle' work

A run-in with a show aimed at the incredibly credulous.

MIK3812345/DREAMSTIME

I've done a lot of television interviews over the years, but maybe the most improbable was for an old TV show called *Sightings*. To be honest, I had never heard of the show and almost backed out when I discovered its standard fare involved flying saucers, ESP, and things that go bump in the night. But the producer seemed reasonable and insisted that he just wanted to talk to a real scientist for a change.

Ultimately I took the gamble, and they actually did a pretty nice job. I doubt the segment inspired anyone to recommit their life to truth, justice, and the American way, but at least there was one fewer story about how Bigfoot saved Grandma's ghost from being eaten by the Loch Ness monster. I'll chalk that up as a win.

The shoot itself was fun because the crew was a hoot! I'd never considered that there are perfectly reasonable, intelligent people who make their living flying all over the country interviewing vocal members of the tinfoil hat crowd. But that's exactly how this crew spent its working hours.

They had some hilarious stories. One I remember involved a self-professed "world's leading expert on alien abductions." During their visit, this guy told the crew, in all earnestness, that he was sure they all had been abducted by aliens at some point. "You see," he explained, "everybody has! We just don't remember because they wipe our brains afterwards."

Feigning shock and suppressing a guffaw, one of the crew asked the obvious question. "If our memories are erased, how can we tell when we've been abducted?"

"Simple! Just put your underwear on backwards when you go to bed. Then if you get up in the morning and your underwear is the right way around, you'll know space aliens took you!"

Speaking personally, if I roll out of bed wearing disheveled clothes it probably has more to do with tequila than little green men, but that's just me.

Eventually we stopped laughing and got back to my interview. But that's not what I want to talk about. The real story is what came next.

After my interview, the cameraman asked if he could show me some footage from a documentary he was working on. This was back when sharing a video meant sending a VHS tape to a TV station and crossing your fingers. The producer of this nascent documentary had gotten hold of a handful of such videos that purported to show "miraculous events."

I don't recall the videos in detail. What I do recall is noting that they were so badly faked that Ed Wood's special effects were photorealistic by comparison. Before long, I was sitting in front of another camera. This time I was going through the "miraculous" videos one by one, pointing out that it didn't take an expert in astronomy or optics to tell that these things were frauds.

I forgot about the whole business until some months later when I got an email that the documentary was scheduled to air. The program started out with a disclaimer: "We present both sides of controversial topics. We leave it to the viewer what to believe." What followed was mostly "experts" asserting, "No one could ever fake that," followed by me saying something like, "There are things we don't understand."

It's not that people who pander to the public's taste for anti-science have necessarily been taken in.

After I managed to pick my jaw up off the floor, I called the producer of the "documentary" to say, "Dude!?!" OK. I used more colorful language than that. I got the sense it wasn't the first time he'd gotten a French lesson from "the talent."

"You do remember me debunking that nonsense, right?" He said yes, and even complimented me on how effectively I'd torn them to shreds.

"So you know that the program you just aired is a stinking pile of bovine manure?" He seemed insulted. Of course he knew it was bogus! Did I think that he was a complete idiot?

It was then that he unapologetically disabused me of my naiveté.

"Documentaries on stuff like this aren't meant to educate people. They're meant to sell soap. My job is to tell the intended audience exactly what it wants to hear. If people want to see miracles and space aliens, I show them miracles and space aliens. That way they tune in, watch to the end, leave happy, and buy the sponsors' products."

There it was, bald-faced and direct from the horse's mouth. It's not that people who pander to the public's taste for anti-science have necessarily been taken in. Mostly they're just plain, old-fashioned carnival hucksters, picking the pockets of gullible people they play for rubes.

There wasn't much to do at that point but thank him for his time and hang up. At least now I was in on the joke.

Jeff Hester is a keynote speaker, coach, and astrophysicist. Follow his thoughts at **jeff-hester.com.**

BROWSE THE "FOR YOUR CONSIDERATION" ARCHIVE AT **www.Astronomy.com/Hester.**

SECRET**SKY**

BY STEPHEN JAMES O'MEARA

Lessons from the bush

We can learn a lot from Earth-focused nature observers.

I have great respect for Botswana's safari veterans — especially the guides. Their visual awareness and keen knowledge of the bush wilderness is unrivaled. How often I have sat in amazement of their ability to pick out birds and animals in a rugged landscape — while driving a vehicle — usually long before I, or anyone else, notices them. I'm not talking about the broadside of an elephant, but about the white tip of a wild dog's tail or the flick of a bushbuck's ear barely visible above a wide expanse of tall grass. The guides are shining examples of how training leads to outstanding visual acuity that reaches far beyond the norm.

So this month, I thought I'd look at some basics of how these expert wilderness observers train, and apply them to visual telescopic observing, particularly of the planets. I'll use Mars as my example because it's still magnificent in the evening sky and has a relatively permanent large-scale landscape.

Lesson 1: Learn the landscape

Unlike a city with its moving traffic and construction, the bush landscape (barring catastrophe) changes little day to day. Because the natural environment is relatively static, when guides make repeat observations of it, they recall from their memories large-scale structures. This cache of images forms the foundation upon which discoveries are made.

Seasoned Mars observers approach their target the same way. They first familiarize themselves with the biggest bright features, such as the polar caps, and the extensive dark features, like Syrtis Major and Sinus Sabaeus. They thus build firm knowledge of the large-scale martian landscape, and that forms the foundation on which they can search for finer features or rogue phenomena, such as clouds and dust storms.

Lesson 2: Make a quick scan

Both skilled terrestrial and telescopic observers begin their observations with a quick scan of the environment using their peripheral vision. As Marc Antrop and Veerle Van Eetvelde explain in their book *Landscape Perspectives: The Holistic Nature of Landscape* (Springer, 2017), a quick glance provides a wide-angle view in which the eye traces contours and fixes on objects that are conspicuous in the scene, noting the shape, size, and color of objects as the brain creates a mental image.

Once the general appearance of large-scale objects is stored in memory, any notable change in shape, size, or color can set off a mental alarm. For instance, an owl standing on a tree branch will distort the known contour of the branch (even when seen at a great distance), thereby making it conspicuous to the trained observer but "invisible" to a novice. Similarly, as seen through a telescope, a new dark marking on Mars — protruding, say, from Syrtis Major — will distort that feature's familiar wedge-shaped pattern and grab the attention of a skilled observer, but perhaps not that of a novice.

Five animals are visible in this image — try locating them before reading further. Most identifiable at a glance are the three impala. The warthog, near center, can be easily mistaken for a log. The most difficult animal to see is the giraffe. Its spotted neck rises above the tall hedge of grass just right of center. Look at the 2 o'clock position beyond the impala at far right. Training your eyes to see earthly objects will help you become a better observer. STEPHEN JAMES O'MEARA

Lesson 3: Perform a detailed inspection

When an alarm sounds in the mind, the eye/brain system shifts gear, changing from peripheral vision (sensitive to general shapes and movement) to direct vision (sensitive to fine detail and color). So if a safari veteran notices a foreign bulge on a tree with peripheral vision, the eye's central vision can resolve it into an owl. This all occurs within a matter of seconds.

That the eye's peripheral vision is sensitive to movement is another factor in picking out birds and animals in the bush. A wild dog whose body is hidden in the tall grass can give its location away to a perceptive observer with a swish of its tail. Once locked on to that tail, the observer's central vision can perceive its white tip, thus identifying it as a distinctive marking of a wild dog.

In backyard astronomy, we generally use motion detection when searching for satellites. If a faint naked-eye satellite had no motion, we'd have no chance of detecting it at a glance. Motion also comes into play when we observe the planets. The primary cause is the vagaries of Earth's turbulent atmosphere, which can shift details about and create false markings. But one trick of the amateur astronomer trade is to not track the planet with a clock drive.

As the planet drifts through the field of view, skilled observers use peripheral vision to wait out the times of bad seeing and catch glimpses of details under moments of steady seeing — before locking on to them with direct vision. The exchange between peripheral and direct vision can occur in a fraction of a second. By continually repeating this exercise, an observer can walk away from the telescope with a mental map of a planet's appearance that may exceed expectations.

So give it a try. Both Mars and Saturn are well placed this month for learning their landscape, scanning their faces, and inspecting any fine details. As always, send your thoughts and comments to sjomeara31@gmail.com.

Stephen James O'Meara is a globe-trotting observer who is always looking for the next great celestial event.

BROWSE THE "SECRET SKY" ARCHIVE AT **www.Astronomy.com/OMeara.**

INDEX *of* ADVERTISERS

The Advertiser Index is provided as a service to *Astronomy* magazine readers. The magazine is not responsible for omissions or for typographical errors in names or page numbers.

NEW PRODUCTS

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

6-inch reflector

Omegon
Landsberg, Germany

Omegon's Pro RC 154/1370 OTA is a 6-inch f/9 Ritchey-Chrétien reflector with a focal length of 1,370mm. The company uses hyperbolic primary and secondary mirrors made of BK7 glass with 92 to 94 percent reflectivity. The tube weighs 12.1 pounds (5.5 kilograms).

$465
+49-(0)8191-94049-0
www.omegon.eu

Solar telescope

Daystar
Warrensburg, Missouri

Daystar's 60MM Solar Scout is a 2.4-inch Hydrogen-alpha telescope with a 930mm focal length in a carbon fiber tube. The included helical focuser can't slip and doesn't turn the eyepiece. You can choose either the Prominence or Chromosphere model. A knob tunes the center wavelength plus or minus 0.5 angstrom.

$1,295
866.680.6563
www.daystarfilters.com

3.5-inch telescope

Orion Telescopes & Binoculars
Watsonville, California

Orion's BX90 EQ 90mm Equatorial Refractor Telescope has an f/6.7 focal ratio. The 3.5-inch primary lens is an air-spaced doublet. The scope comes with an equatorial mount, tripod, counterweight, star diagonal, and 25mm (24x) and 10mm (60x) eyepieces. It weighs 15.5 pounds (7 kg) when assembled.

$229.99
800.447.1001
www.telescope.com

12-inch astrograph

iOptron
Woburn, Massachusetts

The Photron Ritchey-Chrétien astrograph from iOptron features quartz primary and secondary mirrors. The primary is fixed in position and is corrected to better than $1/12$ wave. It has a dual-speed Crayford focuser, a 2"-to-1¼" adapter, and 2" and 1" focus extension rings.

$4,295
866.399.4587
www.ioptron.com

SEE REPORTS ON 350+ PRODUCTS AT **www.Astronomy.com/equipment.**

2018 ASTRO SWEEPSTAKES – OFFICIAL RULES

NO PURCHASE NECESSARY TO ENTER OR CLAIM PRIZE.
A PURCHASE WILL NOT INCREASE YOUR CHANCE OF WINNING.
VOID WHERE PROHIBITED.

1. **Eligibility.** The 2018 Astro Sweepstakes (the "Sweepstakes") is open to residents of the United States and Canada (except Quebec and Rhode Island) only, who are age 18 years or older and have reached the age of majority in their state/province of residency at the time of entry. Employees (and their dependents and immediate household members) of Kalmbach Media, ("Sponsor"), and of Celestron L.L.C., their advertising and promotional agencies, and sponsoring companies are not eligible to participate. Void in Quebec and Rhode Island, and where prohibited by law. Sweepstakes is subject to all applicable federal, state, and local laws.
2. **Sweepstakes Period.** The Sweepstakes begins on August 1, 2018 at 12:00:00 a.m. Central Time, and all entries must be transmitted online no later than October 31, 2018 at 11:59:59 p.m. Central Time.
3. **How to Enter.** To enter, complete the Sweepstakes Official Entry Form online at Astronomy.com/sweeps with your name, address, city, state or province, and ZIP or postal code, and then click on the SUBMIT MY ENTRY button. You may submit only one entry through the Sweepstakes Online Entry Form during the Sweepstakes Period. However, when you submit your entry online, you will receive a link that you can share on Facebook, Twitter, or by email; you will automatically receive one additional entry for each person who enters the Sweepstakes using that link. The online entry form must be filled out completely to be eligible. This Sweepstakes is in no way sponsored, endorsed, administered by, or associated with, Facebook or Twitter. Entries from any person submitting more than the stated number will be disqualified.
4. **Prizes/Approximate Retail Value ("ARV") in U.S. Dollars. One (1) Grand Prize** consisting of Celestron Advanced VX 6" Refractor Telescope. ARV of Grand Prize: $1,439.00. **One (1) First Prize** consisting of Celestron Astro Fi 102 mm Maksutov-Cassegrain Telescope. ARV of First Prize: $429.95. **One (1) Second Prize** consisting of Celestron SkyMaster Pro 15x70 Binocular. ARV of Second Prize: $199.95. **One (1) Third Prize** consisting of Celestron Cometron 114AZ Telescope. ARV of Third Prize: $179.95. **Five (5) Fourth Prizes** consisting of a one-year subscription to *Astronomy* magazine. ARV of Fifth Prize: $42.95. TOTAL ARV of all prizes is $2,463.60.
5. **Drawing/Odds/Notification.** A random drawing for the Grand Prize, First Prize, Second Prize, Third Prize, and Fourth Prize will be held on or around November 3, 2018. Odds of winning depend on the number of entries received. Limit one prize per person. The average total circulation for *Astronomy* magazine is 95,959. Winners will be notified by email on or before November 3, 2018.
6. **Prize Restrictions.** No cash equivalent or prize substitution permitted. All prizes subject to the guarantees/warranties of the manufacturer. Any applicable federal, state, and/or local taxes are the responsibility of the winner. For prizes of $600 or more in value, winner's Taxpayer I.D. will be required to issue a Form 1099-MISC showing prize ARV as income.
7. **Validation and Acceptance.** Winner(s) in the 2018 Astro Sweepstakes will be selected in a random drawing. The potential winner(s) may be required to sign and return an Affidavit of Eligibility, publicity release, and Release of Liability within fourteen (14) days of notification. If a potential winner cannot be contacted within a reasonable time period, if the potential winner is ineligible, if any notification is undeliverable, or if the potential winner otherwise fails to fully comply with these Official Rules, he/she will forfeit that Prize, and if time permits, an alternate winner will be randomly drawn from among all remaining Sweepstakes entries. Canadian prize winners subject to skill test requirement.
8. **Winners List.** For a list of winners, see the *Astronomy* website (Astronomy.com) after November 5, 2018, or send a stamped, self-addressed envelope to: 2018 Astro Sweepstakes Winners List, P.O. Box 1612, Waukesha, WI 53187-1612. (Residents of FL, VT, and WA may send a self-addressed envelope without the stamp.) Requests for Winners List must be received by November 5, 2018.
9. **Limitations of Liability.** Sponsor and Celestron, are not responsible for and shall not be liable for: (i) telephone, electronic, hardware or software program, network, internet, or computer malfunctions, failures, or difficulties of any kind; (ii) failed, incomplete, garbled, or delayed computer transmissions; (iii) any condition caused by events beyond the control of Sponsor that may cause the Sweepstakes to be disrupted or corrupted; (iv) any injuries, losses, or damages of any kind arising in connection with or as a result of the prize, or acceptance, possession, or use/misuse of the prize, or from participation in the Sweepstakes; (v) any printing or typographical errors in any materials associated with the Sweepstakes; (vi) any change in participant's telephone number, mailing address, or email address. Sponsor reserves the right, in its sole discretion, to suspend or cancel the Sweepstakes at any time if a computer virus, bug tampering, unauthorized intervention, or other technical problem of any sort corrupts the administration, security, or proper play of the Sweepstakes. Sponsor also reserves the right to disqualify, in its sole discretion, any person tampering with the entry process, the operation of the website, or who is otherwise in violation of the rules. By participating in the Sweepstakes, each participant agrees to release and hold Sponsor, Celestron, their employees, officers, and directors, their advertising and promotional agencies, and sponsoring companies harmless from any and all losses, damages, rights, claims, and actions of any kind in connection with the Sweepstakes or resulting from acceptance, possession, or use/misuse of any prize, including without limitation, personal injury, death, and property damage, and claims based on publicity rights, defamation, or invasion of privacy.
10. **Additional terms.** By entering the Sweepstakes, participants agree to be bound by these official rules and all decisions of Sponsor. Except where prohibited, each entrant agrees that: (1) any and all disputes, claims, and causes of action arising out of or connected with this Sweepstakes shall be resolved individually, without resort to any form of class action, and exclusively by state or federal courts situated in Wisconsin, (2) any and all claims, judgments and awards shall be limited to actual out-of-pocket costs incurred, but in no event attorneys' fees, (3) no punitive, incidental, special, consequential or other damages, including, without limitation, lost profits, may be awarded (collectively, "special damages"), and (4) entrant hereby waives all rights to claim special damages and all rights to such damages multiplied or increased. Wisconsin law, without reference to choice of law rules, governs the Sweepstakes and all aspects related thereto.
11. **Sponsor.** Sponsored by Kalmbach Media, P.O. Box 1612, Waukesha, WI 53187-1612.

1. ENCHANTED BELT
Orion's Belt, a line of three bright blue stars, serves as a visual guide to find the Horsehead and Flame nebulae. At the bottom left in this image, you can see the reflection nebula M78, along with a bit of Barnard's Loop. Dark clouds — part of the Orion Molecular Cloud Complex — surround the entire scene. • ***Manolis Petrakis***

2. LONE STARGAZER
A solitary observer targets the 6.8-percent-illuminated waxing crescent Moon on March 19, 2018, at 7:39 P.M. EDT. Also visible are bright Venus, to the left of the telescope, and fainter Mercury, visible through the tripod's legs. • ***Chris Cook***

— Continued on page 72

— *Continued from page 70*

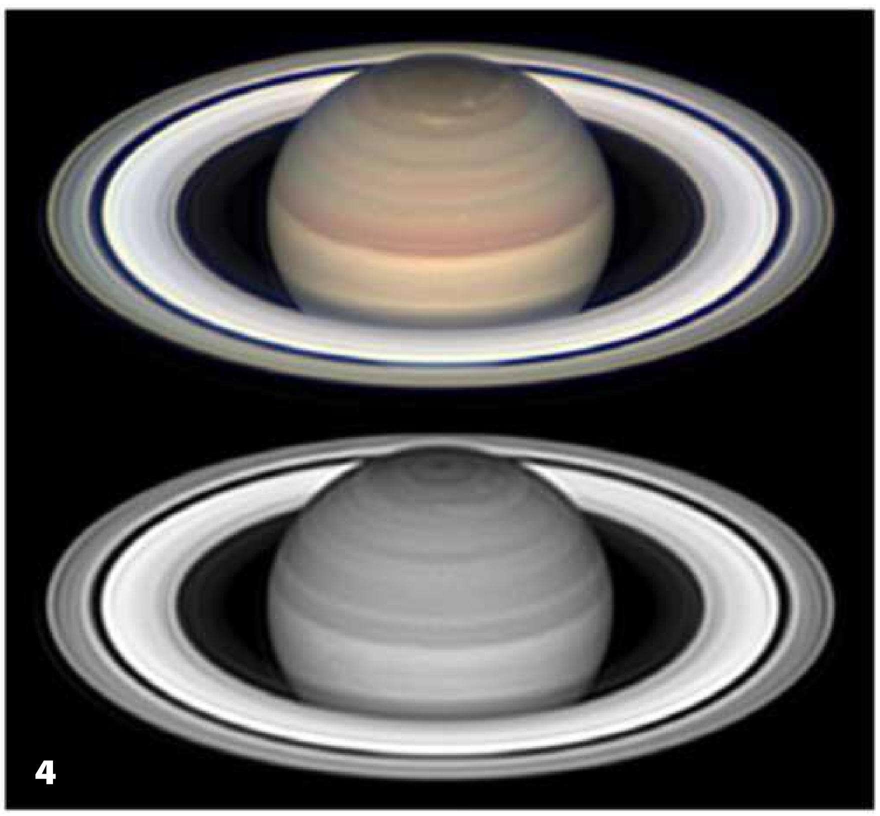
3. CROWN JEWELS
King 5 is a little-known open cluster in the constellation Perseus the Hero. It contains some 40 stars, the brightest of which glows faintly at 13th magnitude. • ***Dan Crowson***

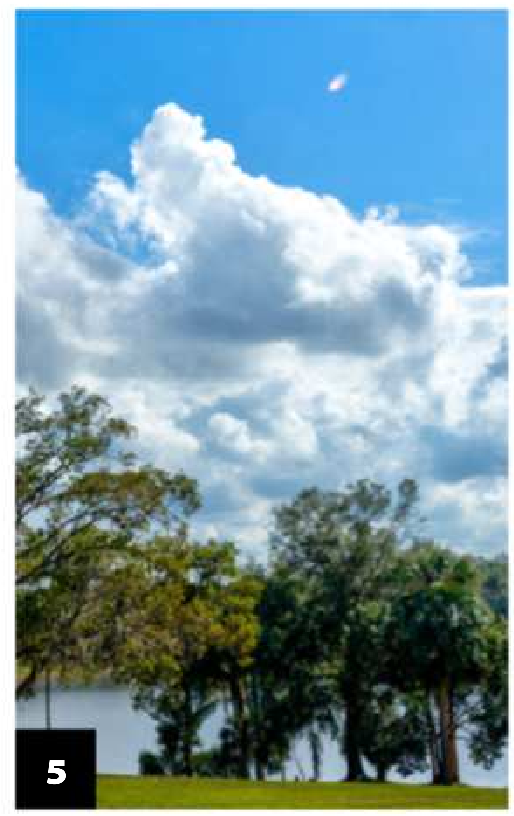
4. RINGED GLORY
This image, taken one day before Saturn's 2018 opposition, shows the Seeliger effect, a brightening of the planet's rings. The brightening occurs for two reasons: The ring particles are scattering sunlight coming from directly behind the observer, and all the particles' shadows are hidden by the fronts of particles illuminated by the Sun. Because of the Seeliger effect, Saturn's cloud tops seem pale by comparison. Note the polar hexagon and the multiple storms visible in the polar region. • ***Christopher Go***

5. DAYTIME FIREBALL
A blazing, bright meteor streaks across this dramatic scene from Zellwood, Florida. The photographer didn't realize what he captured until he viewed the image on his computer. He took it just past noon December 5, 2017. • ***Victor Lee***

6. NICE VIEW
The staff facility at Cerro Tololo Inter-American Observatory in Chile sits peacefully under the spectacular southern Milky Way. Alpha (α) and Beta (β) Centauri point to Crux near the top, just to the right of center, while the two Magellanic Clouds lie near the horizon. The photographer was there as part of the Astronomy in Chile Educator Ambassadors Program when she captured this nine-panel panorama. • ***Samara Nagle***


3


4


5


6

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

BREAK THROUGH

The HAWK takes flight

Dust clouds typically shroud optical views of the youngest star clusters. Although searing radiation from massive newborn suns in the cluster's core excites surrounding gas to incandescence, it has yet to blow away much dust. Short-wavelength infrared radiation pierces this dust, however, revealing young stars and protostars. This recent image showcases the cluster RCW 38, which lies 5,500 light-years from Earth in the constellation Vela the Sails. Scientists captured it through one of the 8-meter telescopes at Paranal Observatory in Chile during test observations of the HAWK-I infrared imager and its adaptive optics system. ESO/K. MUZIC


OWN THE NIGHT
STELLARVUE
SVR102T-3SV
SV102T-3SV
Shown with optional
50-mm Finderscopes,
Finder Rings, and
M002C Mounts
Image copyright Jon Talbot

MARTIN GEORGE describes the solar system's changing landscape as it appears in Earth's southern sky.

January 2019: Totality comes to the Crab

Six months ago, Southern Hemisphere observers feasted on a smorgasbord of bright planets spread high across the evening sky. But as the New Year dawns, we're left with only crumbs. The lone survivor of winter's glory is **Mars**, and it's just a shadow of its former self.

The Red Planet shines at magnitude 0.5 in early January and dims to magnitude 0.9 late in the month. Still, it stands out nicely against the backdrop of Pisces the Fish, which holds few prominent stars. Look for the ruddy world in the west-northwest as darkness falls. Unfortunately, Mars appears only 7" across when viewed through a telescope and likely won't show any surface details.

Planet viewing grows more appealing at the other end of the night. The brightest of the predawn worlds is **Venus**, which reaches greatest elongation January 6. It then lies 47° west of the Sun and rises three hours before sunup. Gleaming at magnitude –4.6, it is by far the brightest object in the eastern sky.

The inner planet begins the year in the constellation Libra, but it moves quickly eastward. It crosses through Scorpius during January's second week and enters Ophiuchus around midmonth. Be sure to look for it January 2, when a waning crescent Moon passes nearby.

Keep an eye on Venus through a telescope during January. On the 1st, it shows a fat crescent phase on a disk that spans 26". The planet appears 25" across and half-lit at greatest elongation. And, by the end of the month, the Sun illuminates 62 percent of its 19"-diameter disk.

The second-brightest point of light in the predawn sky belongs to **Jupiter**. The giant world shines at magnitude –1.8 against the background stars of Ophiuchus. Like Venus, it treks eastward relative to the starry backdrop. As an outer planet, however, Jupiter moves far more slowly. The gas giant appears to Venus' lower right in early January, but the gap closes day by day. On January 22, the two pass 2° from each other.

As Jupiter gains altitude during January, it becomes a much better target for telescope owners. The planet shows a noticeably flattened disk — it measures 32.5" across its equator and 30.4" through the poles at midmonth — with a wealth of colorful features in its cloud tops. Also keep an eye out for Io, Europa, Ganymede, and Callisto. The giant planet's four bright moons show up through any telescope.

You can catch a final morning view of **Mercury** during January's first week. The innermost world then hangs at least 5° high in the east-southeast 30 minutes before sunrise. Glowing at magnitude –0.4, it stands out in twilight under good conditions. (Binoculars can help you spot it initially.) But Mercury soon disappears in the Sun's glare, and it passes behind our star January 30.

Although **Saturn** also passes behind the Sun from our perspective this month (on the 2nd), it returns to view by month's end. On January's final morning, the ringed world rises two hours before our star and lies about 10° high in the east-southeast an hour later. Shining at magnitude 0.6 against the backdrop of Sagittarius, Saturn should be easy to spot with your naked eye. Unfortunately, the planet's low altitude means it won't look exceptional through a telescope. Much better views await in the months to come.

A **total lunar eclipse** graces the skies above South America and parts of Africa on January 21. The Moon lies among the background stars of Cancer the Crab, about a binocular field away from the lovely Beehive star cluster (M44). From South America, this region stands fairly high in the north around mid-eclipse. The partial phases begin at 3h34m UT and end at 6h51m UT, while totality runs from 4h41m UT to 5h43m UT.

The starry sky

If you stay up until twilight fades away these January evenings, you'll get a nice view of the Milky Way stretching from the northern to the southern horizon. The disk of our galaxy climbs high in the east, arching from just east of Orion to Crux the Cross.

Scattered along this band are many objects of interest. Take a few moments to view open cluster M41, which lies a few degrees south of brilliant Sirius. Then scan the region to the upper left of Crux, which contains several more stunning clusters. About halfway between these two areas lies the beautiful wide multiple star Gamma (γ) Velorum. Observing just this handful of deep-sky objects can make for a pleasant hour or so on a warm summer's evening.

Have a good look at the Gamma Velorum system. You may be surprised to learn that a huge but nearly invisible object surrounds this spot. The Gum Nebula spans about 40°, but its light spreads so thinly that it's difficult to see anything but the brightest areas.

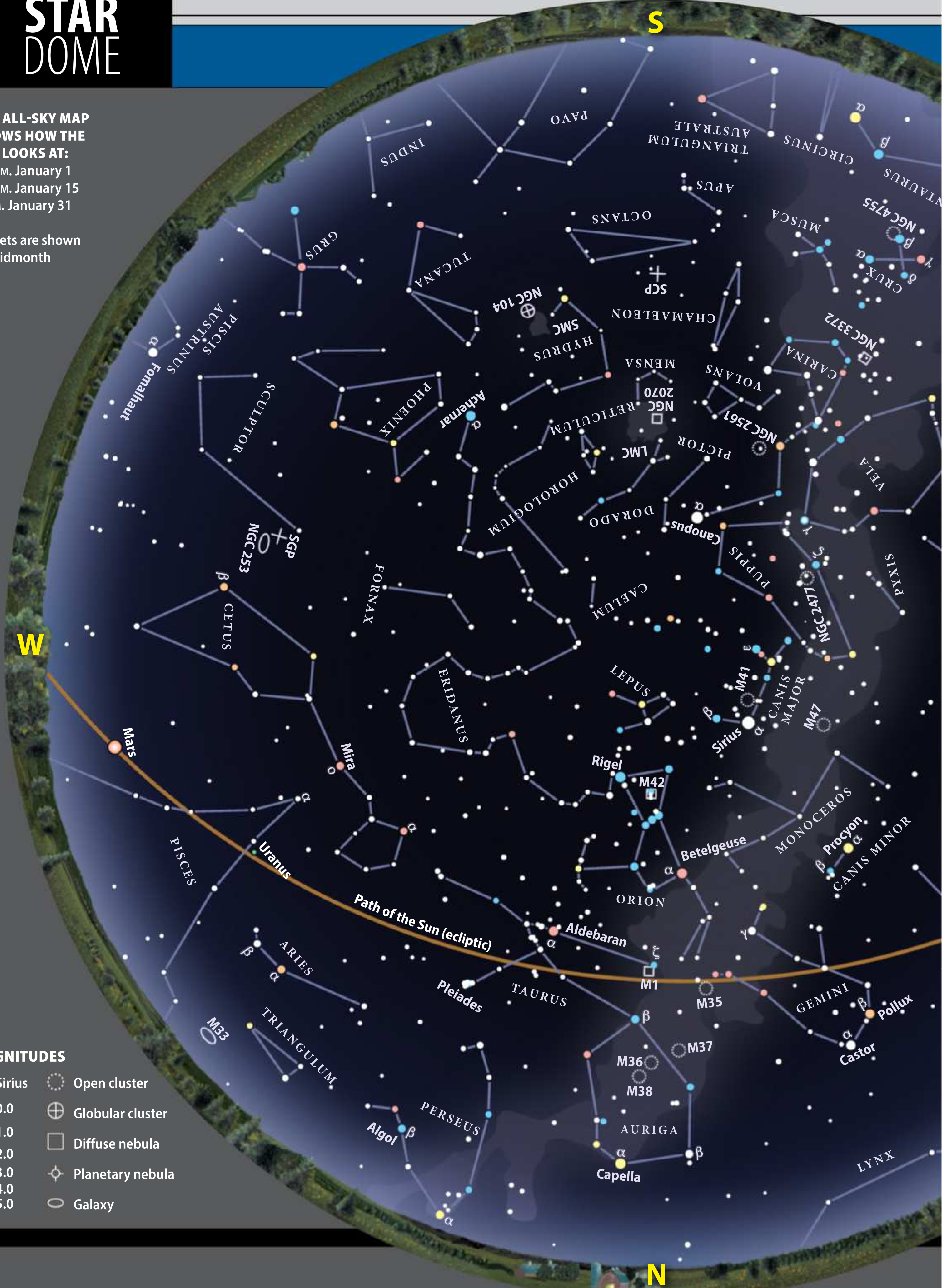
Australian astronomer Colin Stanley Gum (1924–1960) first described the nebula in a 1952 paper. He included it as the 12th entry in his 1955 catalog of ionized hydrogen regions in the southern sky. The Gum Nebula's irregular shape is centered near right ascension 8h20m and declination –40°, just a few degrees from Gamma Vel. Astroimagers can capture the nebula quite easily, though it shows up best in Hydrogen-alpha images, which increase the contrast between the nebula and its surroundings.

Astronomers suspect the Gum Nebula is the remains of a titanic supernova explosion that occurred a million or more years ago, though some researchers suggest more than one supernova may have been responsible. As you gaze in this direction on a beautifully clear January night, contemplate the vast-yet-unseen contours of the Gum Nebula. It extends from Gamma Vel south to the vicinity of the False Cross, east to the constellation Antlia, and west into central Puppis.

STAR DOME

THE ALL-SKY MAP SHOWS HOW THE SKY LOOKS AT:
11 P.M. January 1
10 P.M. January 15
9 P.M. January 31

Planets are shown at midmonth



MAGNITUDES

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

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

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

STAR COLORS: Stars' true colors depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white without optical aid.

Illustrations by *Astronomy*: Roen Kelly

JANUARY 2019

Calendar of events

1 The Moon passes 1.3° north of Venus, 22h UT

2 Saturn is in conjunction with the Sun, 6h UT

3 Earth is at perihelion (147.1 million kilometers from the Sun), 5h UT

The Moon passes 3° north of Jupiter, 8h UT

6 New Moon occurs at 1h28m UT

Venus is at greatest western elongation (47°), 5h UT

7 Uranus is stationary, 2h UT

9 The Moon is at apogee (406,117 kilometers from Earth), 4h29m UT

10 The Moon passes 3° south of Neptune, 22h UT

11 Pluto is in conjunction with the Sun, 12h UT

12 The Moon passes 5° south of Mars, 20h UT

14 First Quarter Moon occurs at 6h46m UT

The Moon passes 5° south of Uranus, 12h UT

15 Venus passes 8° north of Antares, 21h UT

21 Full Moon occurs at 5h16m UT; total lunar eclipse

The Moon is at perigee (357,342 kilometers from Earth), 20h00m UT

22 Venus passes 2° north of Jupiter, 6h UT

27 Last Quarter Moon occurs at 21h10m UT

30 Mercury is in superior conjunction, 3h UT

31 The Moon passes 3° north of Jupiter, 0h UT

The Moon passes 0.09° north of Venus, 18h UT

Astronomy magazine

BEGINNERS: WATCH A VIDEO ABOUT HOW TO READ A STAR CHART AT **www.Astronomy.com/starchart.**