WEBB SCOPE CAPTURES DRAMATIC STAR BIRTH p. 36

JUNE 2024

Astronomy®

The world's best-selling astronomy magazine

CHASING VISITORS from other SOLAR SYSTEMS p. 12

EDMOND HALLEY AND HIS COMET p. 22

HOW TO CAPTURE NIGHTSCAPE PHOTOS p. 38

www.Astronomy.com

READER QUESTIONS ON BLACK HOLES p. 50

CELESTRON STARSENSE AUTOGUIDER REVIEWED p. 44

COMPLETE NIGHT SKY VIEWING INFORMATION p. 28

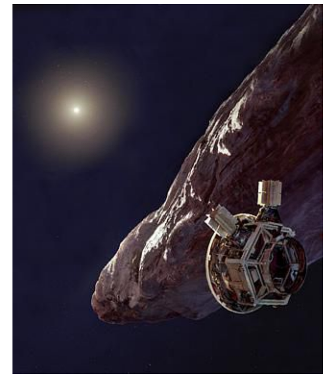
BONUS ONLINE CONTENT CODE p. 3

Vol. 52 • Issue 6

Online Content Code: ASY2406
Enter this code at **www.astronomy.com/code** to gain access to web-exclusive content.

CONTENTS

JUNE 2024
VOL. 52, NO. 6



ON THE COVER
Future spacecraft missions may encounter unusual visitors to our solar system like 'Oumuamua, an asteroid that whizzed past the Sun in 2017. MACIEJ REBISZ

FEATURES

COLUMNS

IN EVERY ISSUE

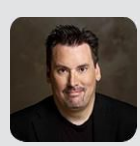
ONLINE FAVORITES

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.

Picture of the Day
Gorgeous photos from our readers.

News
The latest updates from the science and the hobby.

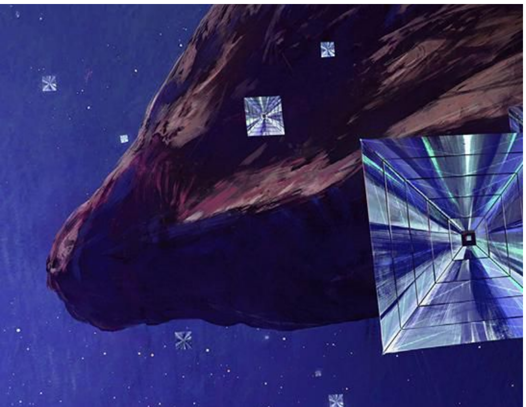


Dave's Universe
The inside scoop from the editor.

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*, PO Box 850, Lincolnshire, IL 60069. Canada Publication Mail Agreement #40010760.

FROM THE EDITOR

Visitors are here



Future interstellar visitors like the asteroid 'Oumuamua might be swarmed by spacecraft like the proposed set of laser-powered interlopers shown in this artist's illustration. MACIEJ REBISZ

In 2017, when astronomers discovered the asteroid 1I/2017 U1, it soon dawned on them that they had a weird object on their hands. The calculated orbit showed this elongated rock to be simply passing through the solar system, and therefore its origin not of this world, as they like to say in the movies. Subsequently named 'Oumuamua (from the Hawaiian word for "scout"), the object raised memories of an old *Star Trek* episode, "For the World is Hollow and I Have Touched the Sky," in which a long, tubular asteroid proved to be an alien ship in disguise.

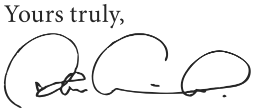
There's nothing surprising about interstellar objects passing through our neighborhood. Or there shouldn't be, at least. There's no magical barrier at the boundary of our solar system. Although we see a sky full of stars and in our telescopes detect hundreds of clusters and nebulae, most of the space in a galaxy's disk is practically empty, save for the thin interstellar medium.

This month, science journalist David Chandler, an institute writer at MIT and long a veteran science reporter at *The Boston Globe*, delivers a fascinating look at the potential for spacecraft missions to interstellar interlopers. Catching up to 'Oumuamua now would be virtually impossible. This thin, tumbling, cigar-shaped rock, stretching about 1,300 feet (400 meters) long, is hurtling along at about 16 miles per second (26 km/s) and is already as far away as the average distance to Pluto.

But there's no doubt that other visitors from other stars will come by again. This has unquestionably happened countless times in the 4.6-billion-year history of our star and its planets — and now, astrophysics is in an advanced state. Every day we learn about primitive conditions long ago in the solar system by studying meteorites and other objects. Analyzing the chemistry of material from the origin days of other stars? That would be amazing, and who knows what could be found from such priceless relics.

That's another comforting thought to keep in mind as you read David's story and then gaze up into a dark sky full of wonder.

Yours truly,



David J. Eicher
Editor

Follow Dave on
Facebook:
facebook.com/davidjohneicher
X (formerly Twitter):
@deicherstar
Instagram:
eicher.david

FOLLOW *ASTRONOMY*

facebook.com/AstronomyMagazine
twitter.com/AstronomyMag
youtube.com/user/AstronomyMagazine
instagram.com/astronomy.magazine

Astronomy

Editor David J. Eicher
Assistant Design Director Kelly Katlaps

EDITORIAL
Senior Production Editor Elisa R. Neckar
Senior Editors Alison Klesman, Mark Zastrow
Associate Editor Daniela Mata
Editorial Assistant Samantha Hill

ART
Illustrator Roen Kelly
Production Specialist Jodi Jeranek

CONTRIBUTING EDITORS
Michael E. Bakich, Bob Berman, Adam Block, Martin George, Tony Hallas, Phil Harrington, Alister Ling, Stephen James O'Meara, Martin Ratcliffe, Raymond Shubinski, Richard Talcott, Molly Wakeling

EDITORIAL ADVISORY BOARD
Buzz Aldrin, Marcia Bartusiak, Jim Bell, 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
Chief Financial Officer Christine Metcalf
Chief Marketing Officer Nicole McGuire
Vice President, Content Stephen C. George
Vice President, Operations Brian J. Schmidt
Vice President, Human Resources Sarah A. Horner
Circulation Director Liz Runyon
Director of Digital Strategy Angela Cotey
Director of Design & Production Michael Soliday
Retention Manager Kathy Steele
Single Copy Specialist Kim Redmond

ADVERTISING DEPARTMENT
Sr. Advertising Sales Manager Michael Wieloch
Phone (262) 798-6625
Email mwieloch@kalmbach.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 (847) 313-3921
Customer Service AstronomyMagazine@Omeda.com

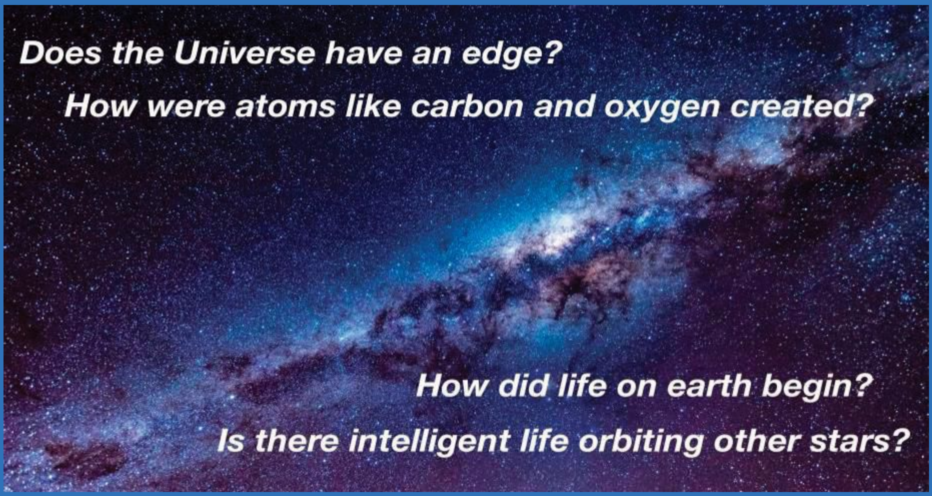
CONTACT US
Ad Sales adsales@astronomy.com
Ask Astro askastro@astronomy.com
Books books@astronomy.com
Letters letters@astronomy.com
Products products@astronomy.com
Reader Gallery readergallery@astronomy.com
Editorial Phone (262) 796-8776

For reprints, licensing, and permissions:
PARS International at www.parsintl.com

Adventures in Astronomy: Approaching Infinity

Tuesdays, 7:30 PM-9:00 PM, Eastern Time, over Zoom

June 11, 2024 thru August 13, 2024



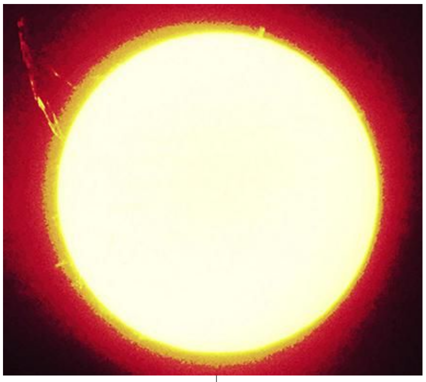
Dr. George Roush will explore

1. Geo-centrism & the Copernican Revolution
2. Our sun & its planets
3. The birth, evolution & death of stars
4. Telescopes
5. Our Milky Way Galaxy
6. Other galaxies & their evolution
7. Dark matter: What is it?
8. Dark energy & the expanding universe
9. Relativity & black holes
10. The Big Bang: The beginning of spacetime
11. Is intelligent life orbiting other stars?

Email: astronomy.teacher0@gmail.com; Telephone: (203) 536-0006

To learn more and to register visit astronomyteacher.net.

Adventures in Astronomy is a non-profit 501(c)(3) organization.



A solar prominence (upper left) is seen on July 27, 2012, during a period of high solar activity. NORMAN IZETT

Solar prominence

I congratulate Randall Hyman for that fantastic article in the March edition on the ways our world will end. It was absolutely gripping, factual, and so well presented. The very large coronal mass ejections (CMEs) mentioned reminded me of this image (at left) of the largest outburst from the Sun I have ever seen. I missed it till some days later while reviewing my images, then tried to process it more. I have never witnessed another CME like this. **—Norman Izett,** Whakatāne, New Zealand

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.*

Fantastic, unique, and beautiful

I write today to thank you for the fantastically informative and visually stunning January 2024 issue with the "101 Weirdest Cosmic Objects." If we're using Merriam-Webster's definition of *weird* as fantastic, then I absolutely agree with you. Other appropriate descriptive adjectives are *unique* and *beautiful*. I commend authors Bakich, Goldstein, Harrington, and O'Meara for such concise and informative write-ups about objects raging from Wolf-Rayet stars to Seyfert galaxies. The January issue helped me understand them better. **—Michael Van Vooren,** Ellisville, MO

Goodbye, Berman

I can't believe Bob Berman's Strange Universe will no longer be a part of *Astronomy*. In busy months it would often be the only article I would make sure to read! A last paragraph bombshell, for sure. I, at least, will sorely miss it. Thank you for so many years of wonderful strangeness. **—Donna Ferch,** St. Peters, MO

Written communication regarding your *Astronomy* magazine subscription will arrive from Lincolnshire, IL, instead of Big Sandy, TX, beginning in spring 2024. Renewals and invoices received with a Lincolnshire, IL, return address are legitimate notices about your subscription. We thank you for your continued interest in *Astronomy*!

SNAPSHOT

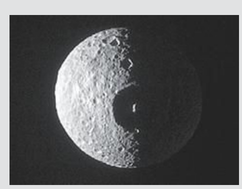
WIND IN THE SAILS

This blast definitely rocked the boat.

Almost 11,000 years ago, a massive star in the constellation Vela the Sails exploded into a vast array of delicate, gaseous filaments and veils, captured here in a dazzling portrait taken by the Dark Energy Camera (DECam) on the Victor M. Blanco 4-meter Telescope in Chile. The Vela supernova remnant is one of the closest to us, just 800 light-years from Earth, and spans nearly 100 light-years. This gives us a close-up view that includes the shock wave triggered by the explosion, which is still plowing through the surrounding area. In this image, that shock wave runs from upper left down to the bottom of the image just right of center; the light that we see is emitted by gas heated as the wave barrels through.
—ELIZABETH GAMILLO

HOT BYTES

WATER ...
Radio observations from the Atacama Large Millimeter/submillimeter Array in Chile have spotted several oceans' worth of water vapor in the disk around the star HL Tauri where planets are likely being born, 450 light-years away.



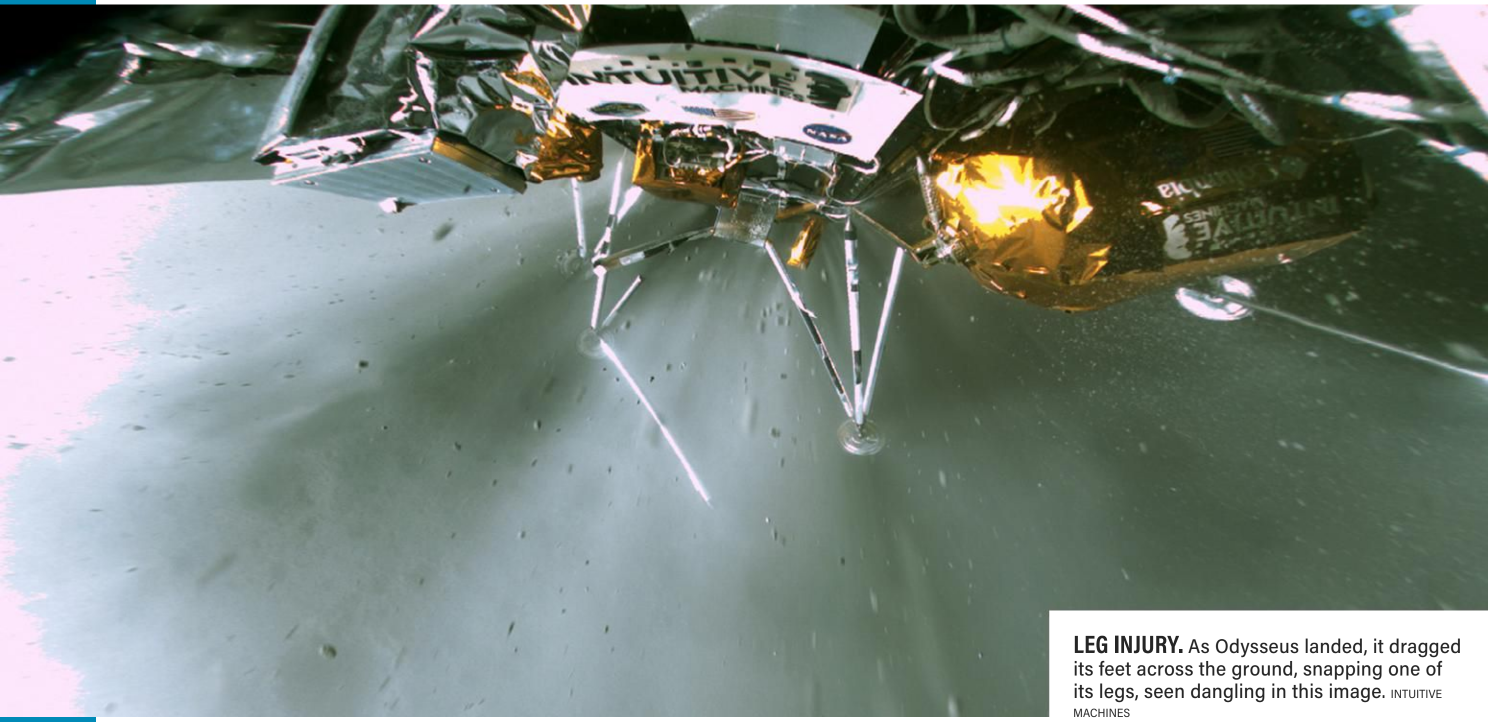
WATER ...
Saturn's moon Mimas has a subsurface ocean 12 to 19 miles (20 to 30 km) beneath its icy surface that formed just tens of millions of years ago, according to a Feb. 7 study in *Nature*. The ocean was detected based on how its sloshing alters the moon's orbit.

... EVERYWHERE.
Data from NASA's retired jumbo-jet-borne infrared telescope SOFIA has yielded the first direct detection of water on asteroids. The presence of water ice on 7 Iris and 20 Massalia supports the idea that asteroids could have delivered water to early Earth.

CTIO/NOIRLAB/DOE/NSF/AURA; IMAGE PROCESSING: T.A. RECTOR (UNIVERSITY OF ALASKA ANCHORAGE/NSF'S NOIRLAB), M. ZAMANI & D. DE MARTIN (NSF'S NOIRLAB). BOTTOM FROM LEFT: ALMA (ESO/NAOJ/NRAO)/S. FACCHINI ET AL.; NASA/JPL/SPACE SCIENCE INSTITUTE; COURTESY OF NASA/CARLA THOMAS/SWRI

ODYSSEUS MAKES EPIC LUNAR JOURNEY, BREAKS LEG, PHONES HOME

The historic lander is the first commercial mission to make a soft landing on the Moon.



LEG INJURY. As Odysseus landed, it dragged its feet across the ground, snapping one of its legs, seen dangling in this image. INTUITIVE MACHINES

» On Feb. 22, the lunar lander Odysseus touched down softly — if somewhat awkwardly — on the Moon, becoming the first American-made craft to land there since 1972. It also became the first non-governmental craft to ever do so, after previous private attempts had failed.

It wasn't a flawless landing. As Odysseus — about 14 feet (4.3 meters) tall and weighing roughly 1,488 pounds (675 kilograms) — neared the lunar surface, instead of hovering stably before touching down, it was still drifting slowly. When its feet touched down, they skidded across the Moon's surface, snapping one of the craft's six landing gear legs. As the engine shut off, Odysseus gently toppled partially over, coming to rest at about a 30° angle from upright.

Despite the tumble, the lander was able to generate power from its solar panels, allowing all its payloads to collect and return data. However, the awkward landing altered the mission because the craft's solar panels could not aim directly at the Sun. The lander was scheduled to collect data for as long as 10 days but instead was put into hibernation after six days as lunar night approached.

Odysseus was not designed to survive the cold night, but Intuitive Machines hoped that as the Sun rose overhead three weeks later, enough light would reach its solar panels to wake it up. Flight controllers started listening for a signal on March 20, but after three days of radio silence, the team called time on Odysseus and declared its mission had ended.

SOUTHERN LANDING

Odysseus carried six payloads for commercial companies and another six under contract for NASA. Several of NASA's payloads were intended to test navigation and landing technology that will be used for the agency's Artemis program, which will return astronauts to the Moon. "All of the data that can be used for Artemis will be used for Artemis," said NASA's Sue Lederer during a press conference Feb. 28.

Odysseus landed about 185 miles (300 kilometers) from the Moon's south pole,

CANTED GET-UP. Odysseus came to rest at an angle, leaning against a crater slope. INTUITIVE MACHINES

near a crater named Malapert A. The area is part of the rugged polar highlands, the same region Artemis landings will target.

Due to a wiring error, Odysseus was forced to fly its touchdown without its built-in laser rangefinders, a key navigation instrument. Engineers delayed the landing to put together a last-minute hack, rerouting data from the laser-ranging tools on one of the science payloads. However, Intuitive Machines revealed that the patch didn't work; in the scramble, engineers missed a flag in the code to tell the navigation algorithm the data were valid.

As a result, the lander came to rest about 0.9 mile (1.5 km) outside of its intended landing zone, at a higher elevation than expected, and on a 12° slope within a small crater. These factors contributed to its slightly clumsy touchdown.

Still, for Intuitive Machines, the fact that the craft managed to land softly using only data from its cameras and internal motion sensors is a feat in itself. "It's the first time anybody's flown this algorithm, and it exceeded expectations because we live to tell about it," said Tim Crain, the company's chief technology officer.

TECHNOLOGY DEMONSTRATIONS

The NASA payloads included a variety of tests and demonstrations, including landing technologies (involved in the failed laser rangefinder patch), tracking the lander's fuel in zero gravity, and other navigation and communication tools.

One instrument was designed to observe how the landing engine exhaust interacts with the lunar surface and its sharp, abrasive dust. Unfortunately a hardware failure prevented it from collecting data during the descent and landing, but controllers were able to later fix this and make observations from the landing site.

In another spaceflight first, Odysseus' engine runs on a mixture of liquid methane and liquid oxygen. These propellants must be stored at very low temperatures, as even in space, heat from the Sun or spacecraft exhaust can cause them to boil off. Such cryogenic fuels are expected to play a key long-term role in the Artemis program.

The lunar lander also brought a payload to study radio emissions from objects like the Sun, Jupiter, and Earth. This is an early first step toward a long-held dream of astronomers: placing a radio telescope on the Moon's farside, shielded from interference from Earth.

The landing is the second mission of NASA's Commercial Lunar Payload Services (CLPS) initiative, which contracts commercial companies to deliver tools and technology to the Moon. The first CLPS mission, the Peregrine lander built by the U.S. company Astrobiotic, failed to reach the Moon and burned up in Earth's atmosphere in January. — E.G., MARK ZASTROW

Neptune's true hues

Ever since NASA's Voyager 2 flew past Neptune in 1989, the ice giant has often been depicted in a deep, dark ultramarine (top). But the authors of a Jan. 5 paper in *Monthly Notices of the Royal Astronomical Society*, who reprocessed the Voyager 2 data, point out that Neptune is not actually *that* blue (bottom). The misconception arose due to the way NASA technicians originally processed the image, scaling the intensity and contrast to retain details in bright storms in the planet's atmosphere. In fact, Neptune's natural color is much closer to the pale blue of Uranus. — M.Z.

PATRICK IRWIN/NASA/JPL-CALTECH

QUICK TAKES

THE TENSION IS REAL

JWST has confirmed the Hubble Space Telescope's measurement of the rate of expansion of the modern universe by observing Cepheid variable stars, whose pulsations are linked to their intrinsic brightness and can be used to gauge cosmic distances. The result differs from models and data of the early universe, deepening the so-called Hubble tension.

TELESCOPE TROUBLE

In February, the National Science Foundation's board recommended capping U.S. funding of next-gen extremely large telescopes at $1.6 billion. This could mean one of two planned observatories — the Giant Magellan Telescope in Chile and the Thirty Meter Telescope on the island of Hawai'i — may lose out on funds needed for construction.

NEW MOONS

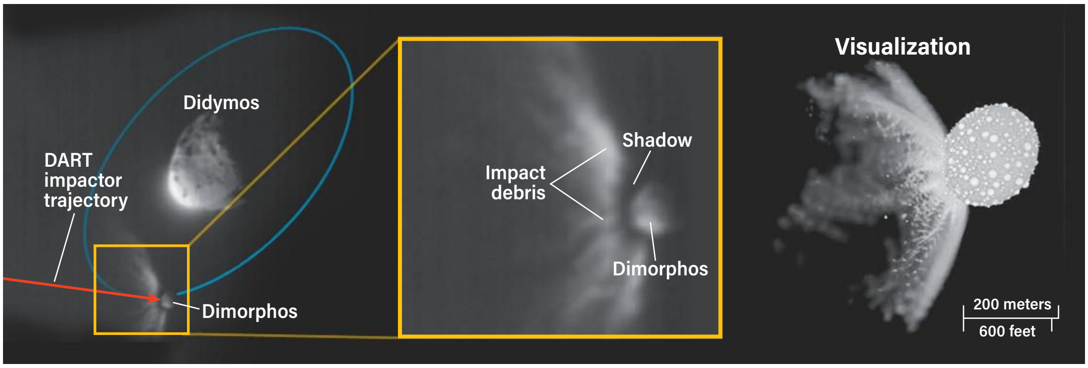
Ground-based telescopes have discovered three new moons in our solar system — one around Uranus and two around Neptune. All are between 5 and 14 miles (8 to 23 km) in diameter.

EPOCH ROW

By a 12–4 vote, a committee of geologists rejected a proposal to declare 1952 the start of a new, human-dominated geological epoch, the Anthropocene. Some proposal critics argued that its sole defining geological feature — the appearance of nuclear testing fallout — does not fully capture how humans have altered Earth.

OBERPFAFFENHOFEN, HOW DO YOU READ?

Future European astronauts exploring the Moon will communicate with a new ESA crewed lunar mission control center to be established in the German city of Oberpfaffenhofen, near Munich, according to a letter of intent signed March 13. — M.Z.



BOULDER SPLASH. The DART mission's goal was to smash into Dimorphos and alter its orbit around its parent asteroid Didymos (left). The impact (middle) was captured by an Italian-built cubesat that rode along with DART. These images of the impact and its ejecta were compared against simulations (right) to deduce the consequences for Dimorphos. *ASTRONOMY:* ROEN KELLY AFTER ASI LICIACUBE/S.D. RADUCAN

How DART reshaped Dimorphos

WHEN NASA PURPOSELY CRASHED a spacecraft into a diminutive asteroid in 2022, the collision not only flung large boulders into space and changed the space rock's orbit, but also transformed its shape.

The DART mission (short for Double Asteroid Redirection Test) smashed a 1,300-pound (600 kilograms) spacecraft into Dimorphos, the tiny moon of the larger asteroid Didymos, to test a technique to deflect future asteroids that may be aimed at Earth.

Within an hour of the crash, a sizable amount of Dimorphos' material had been flung into space, its low gravity and rubble-pile nature offering little resistance to escaping boulders. But a much bigger portion was merely shifted from the impact site and regrouped elsewhere on the asteroid. It rounded out the previously oblate space rock and left behind little to no trace of the crater that would normally be prominent from such an event, researchers reported Feb. 26 in *Nature Astronomy*.

DART likely crashed into a weak region of the asteroid where gravity is vanishingly low, "so basically the crater grew so much that it doesn't look like a crater anymore," says Sabina Raducan, a postdoctoral researcher at the University of Bern in Switzerland and the study's lead author. Part of the 33-minute chop in Dimorphos' orbit around Didymos after DART's impact would be due to this change in the asteroid's shape, says Raducan.

In the study, Raducan and her colleagues simulated DART's impact using data from telescopes that had watched the crash in real time, including the Hubble Space Telescope and the Italian LICIACube spacecraft accompanying DART. In the best-matching simulation, Dimorphos has barely any friction between its boulders. This meant just 1 percent of its mass was blasted into space and a whopping 8 to 9 percent rearranged itself elsewhere on the space rock.

And scientists should soon get a close-up view of the aftermath. The European Space Agency's Hera mission is scheduled to launch this October and arrive at the Didymos-Dimorphos system at the end of 2026.

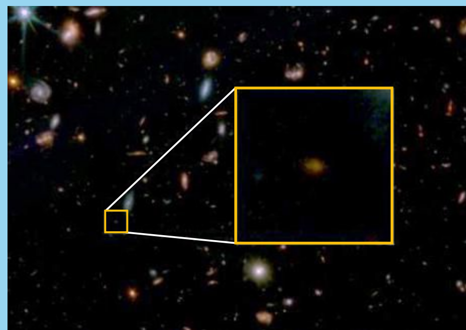
"We may be looking at what for all intents and purposes is a brand-new asteroid," says Tom Statler, DART program scientist at NASA, who was not involved with the new study. —SHARMILA KUTHUNUR

A MATTER OF PERSPECTIVE

Galactic mergers are messy. When two galaxies collide, their stars, dust, and gas mix and warp, flung about by gravity — as seen in NGC 4753, 60 million light-years distant in Virgo. Its twisted structure was sculpted when NGC 4753 merged at a slight angle with a smaller, gas-rich dwarf galaxy, triggering star formation and spreading their dust out into a disk. The dust lanes that curl out from the nucleus were formed by the wobblelike motion called precession, similar to a spinning top. For NGC 4753, the rate of precession for material closer to the center was faster than on the outer edges of the disk, smearing it out into a series of crests, shown in fine detail in the image at upper right from the 8-meter Gemini South Telescope in Chile. But this complex structure is only visible because of our edge-on view. The series of images at lower right depict a model of NGC 4753 tilted toward us in increments of 10° — revealing that if viewed face-on, it would appear to us like a normal spiral galaxy. —E.G.

TOP: INTERNATIONAL GEMINI OBSERVATORY/NOIRLAB/NSF/AURA; IMAGE PROCESSING: J. MILLER (INTERNATIONAL GEMINI OBSERVATORY/NSF'S NOIRLAB), M. RODRIGUEZ (INTERNATIONAL GEMINI OBSERVATORY/NSF'S NOIRLAB), M. ZAMANI (NSF'S NOIRLAB). BOTTOM: NOIRLAB/NSF/AURA/STEIMAN-CAMERON ET AL./P. MARENFELD

THE GALACTIC DEAD REMAIN



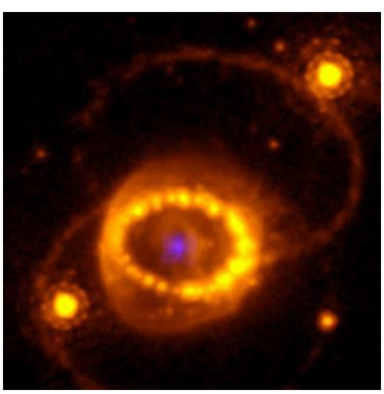
GALACTIC GRAVESTONE. The dead galaxy JADES-GS-z7-01-QU is shown within the Great Observatories Origins Deep Survey (GOODS) field in this image. JADES COLLABORATION

NASA'S JAMES WEBB SPACE TELESCOPE (JWST) has spotted a dead galaxy — a galaxy that has stopped forming stars — in the early universe. Designated JADES-GS-z7-01-QU, this galaxy most likely had a quick burst of star formation that lasted between 30 million to 90 million years. But it seems to have stopped developing stars just 10 million to 20 million years earlier than the snapshot in time in which we observe it.

Understanding what causes galaxies to shut down star production is one of the biggest outstanding questions about galaxy evolution. Astronomers know that by the time the universe was 3 billion years old, about half of its massive galaxies had stopped forming stars. But this galaxy died much earlier in the universe's history. JWST sees it as it existed just 700 million years after the Big Bang, making it the oldest galactic corpse found.

A galaxy can stop forming stars when its central supermassive black hole either blows away or heats up the interstellar reservoir of gas and dust from which stars are born. A galaxy can also form stars too quickly, exhausting its supply of gas before it can be replenished by pulling in surrounding gas. The team is unsure if this halt was caused by one of these scenarios, but plans to clarify these questions by finding similar galactic corpses — and perhaps even some that have reanimated and sprung back to life, once again producing new stars. —E.G.

JWST peers inside SN 1987A



BLUE MARKS THE SPOT. The emission from the center of SN 1987A detected by JWST is shown in blue. The bright stars to the left and right of the inner ring are unrelated to the supernova. HST WFPC-3/JWST NIRSPEC/J.LARSSON

ON FEB. 23, 1987, astronomers had an incredible front-row seat to a once-in-a-lifetime cosmic event: Just 168,000 light-years away, a star in the Large Magellanic Cloud collapsed in on itself and caused a spectacular supernova, designated SN 1987A.

According to theory, a star of its size — 15 to 20 solar masses — should become a neutron star. But confirming this in the case of SN 1987A remained an elusive goal for over 35 years. Radio observations were able to find hints of it, but it wasn't until the powerful infrared capabilities of the James Webb Space Telescope (JWST) that astronomers were able to resolve the core and verify that there is indeed a neutron star inside its surrounding dust cloud.

Observations published Feb. 22 in *Science* reveal emission from hot argon gas originating from the center of the supernova remnant, being heated and ionized by the neutron star itself. The neutron star is about the size of a city and contains 1 or 2 solar masses.

Future observations will help build a timeline of what happens in a star system for the first few decades after it explodes, and will help astronomers know what to look for the next time a nearby supernova explodes. —JOHN WENZ

Can we catch an INTERSTELLAR

Scientists are racing to design spacecraft to reach the enigmatic 'Oumuamua — or be ready for the next one.

BY DAVID L. CHANDLER

Now far from the Sun in the outer solar system, the strange interstellar object known as 'Oumuamua is depicted here as it's approached by a questing spacecraft. Project Lyra is hoping to launch such a craft to explore our first known visitor from another solar system and provide the detailed study scientists desperately seek. MACIEJ REBISZ

INTERLOPER?

1I/2017 U1 (‘Oumuamua) was discovered in October 2017; shortly after, it was determined to be the first object ever seen inside the solar system that had come from beyond it. But by the time its origins had been discerned, the interstellar interloper had already rounded the Sun and was speeding away at some 85,700 mph (138,000 km/h). Just an estimated 1,300 feet (400 meters) across, it faded from view of even the most powerful telescopes within weeks.

The only way to gather more data and uncover its true nature would be to send a spacecraft to study it up close. But uncertainties in ‘Oumuamua’s exact trajectory, the difficulty of detecting its ever-dimming light, and its rapid retreat make the idea of designing, building, and launching a mission in time to catch up to it seem utterly impossible.

Or is it?

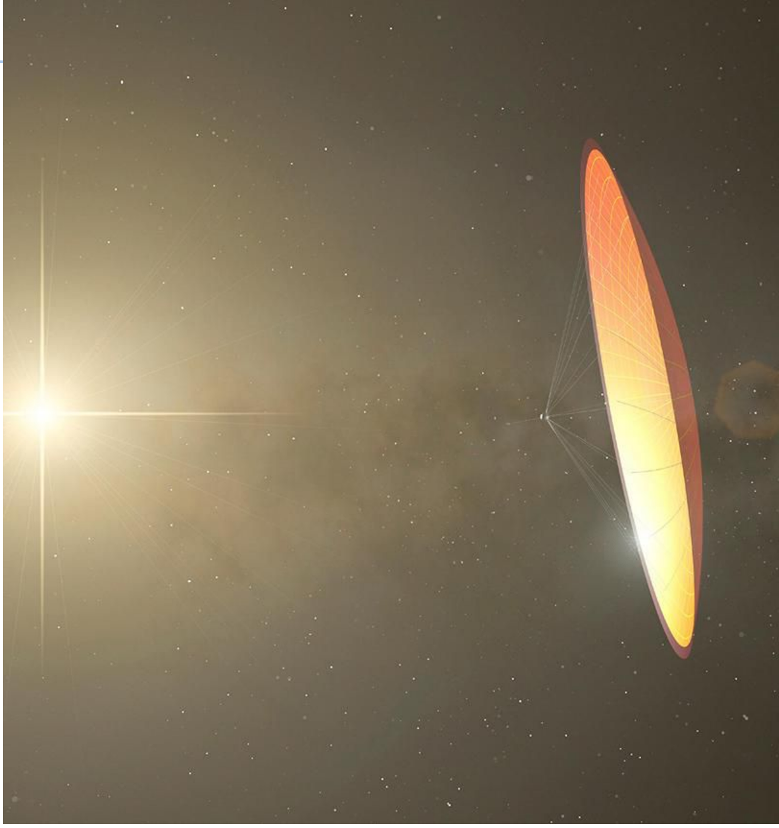
Several groups of researchers have been working to find ways of reaching this increasingly distant object. They have come up with a variety of proposals that could lead to a close-up encounter with ‘Oumuamua within decades. And if that doesn’t work out, others are working on a mission to rendezvous with the next interstellar object that comes wandering by.

Strange visitor

Why bother with such a mission? Because ‘Oumuamua — named after a Hawaiian word for “visitor” and designated 1I as the first interstellar object found — is unique and tantalizing for many reasons.

As astronomers observed it, its brightness cyclically rose and fell. Analysis of this pattern indicated the object was not only tumbling, but it had a shape unlike anything seen before in space. Either a long, thin cylindrical object or a large, flat, disklike shape could account for these variations in brightness, but no known asteroids have a shape that extreme.

More significantly, as

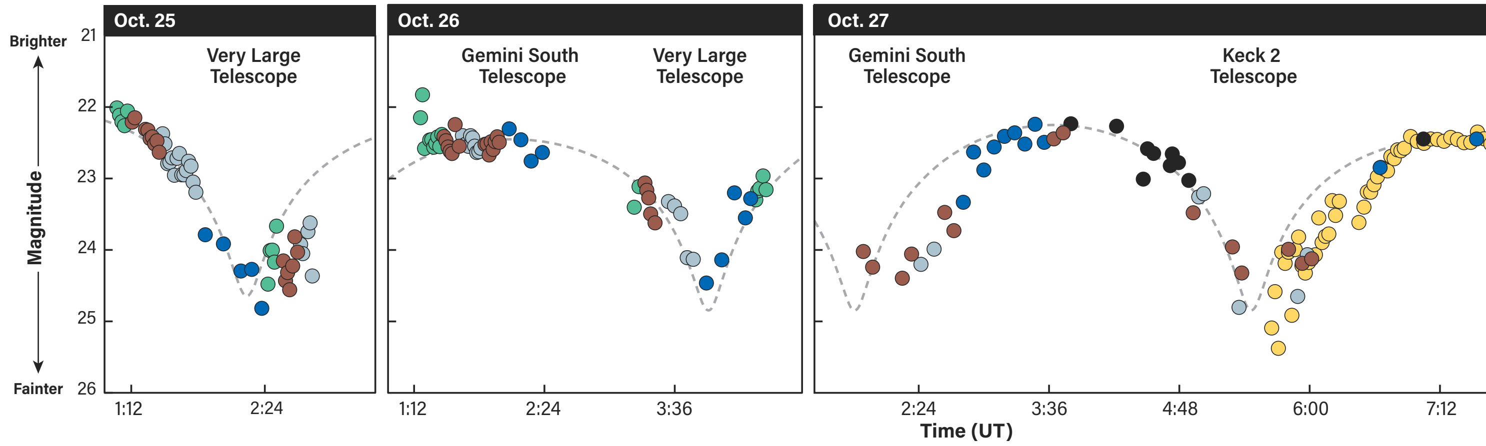


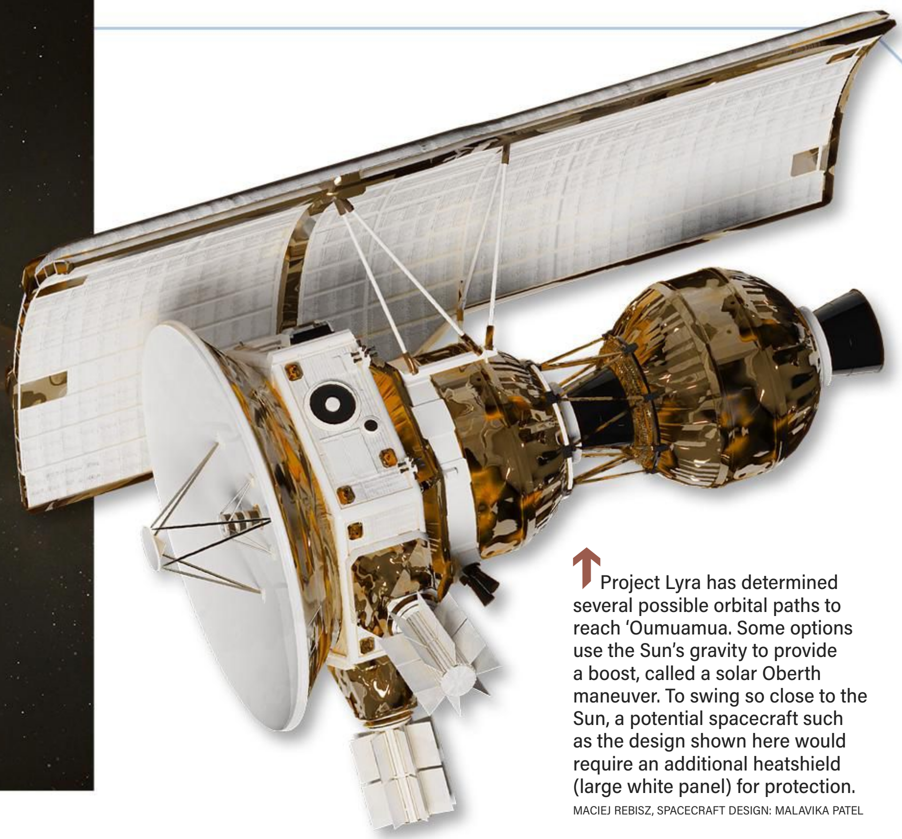
One possible explanation for ‘Oumuamua’s shape is that it is not a natural object, as depicted at right, but an artificially created solar sail or alien probe, such as the device imagined at center. MARK GARLICK/SCIENCE PHOTO LIBRARY/ALAMY STOCK PHOTO

‘Oumuamua left the Sun behind, it sped up in a way that could not be explained by gravity alone. Sometimes comets speed up on their outbound journeys as a result of outgassing, as the Sun’s heat boils off volatile materials like water ice and frozen carbon dioxide. But that process leaves a clearly visible trail of gas and dust — the comet’s tail. ‘Oumuamua emitted no such visible trail, so its movement could not be explained by such emissions either.

Some astronomers have proposed that ‘Oumuamua is a chunk of frozen hydrogen or a hydrogen-helium mix, like an iceberg, whose evaporation might account for the object’s acceleration without leaving a detectable trail. Alternatively, it could be a

‘OUMUAMUA’S LIGHT CURVE





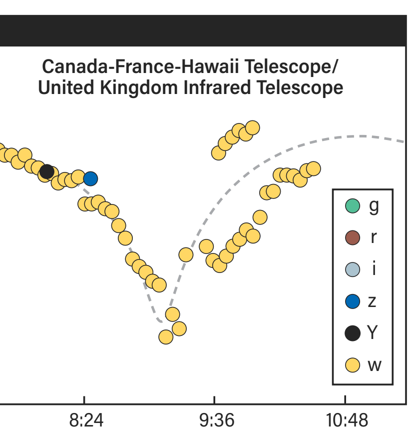
Project Lyra has determined several possible orbital paths to reach ʻOumuamua. Some options use the Sun's gravity to provide a boost, called a solar Oberth maneuver. To swing so close to the Sun, a potential spacecraft such as the design shown here would require an additional heatshield (large white panel) for protection.
MACIEJ REBISZ, SPACECRAFT DESIGN: MALAVIKA PATEL

kind of loose agglomeration of particles or filaments, so lightweight that the pressure of the solar wind alone could rapidly push it outward without the need for outgassing to propel it.

Or perhaps there's another explanation: Astrophysicist Avi Loeb, former chair of the astronomy department at Harvard University, finds ʻOumuamua's behavior so strange that he has argued in a series of peer-reviewed papers and a popular science book that the object is most likely a relic of alien technology.

Loeb says that natural explanations for ʻOumuamua all invoke "rocks of a type we've never seen before" and lack a plausible explanation for how they might have formed. He argues that an artificial origin can better explain its anomalous features. In addition to its strange shape, if the object is made of thin, flat, lightweight material, it could be acting as a solar sail, propelled outward by the force of sunlight. No such object could arise naturally, he says. It would have to be some structure built by a sophisticated alien civilization — if not a dedicated solar-propelled craft, then perhaps a piece of an alien Dyson sphere, a device to collect the energy from a star.

Many astronomers are skeptical of Loeb's case, and contend that ʻOumuamua is an ordinary asteroid, albeit one on an unusual trajectory. Karen Meech, an astrobiologist at the University of Hawaiʻi who led the characterization of the object after



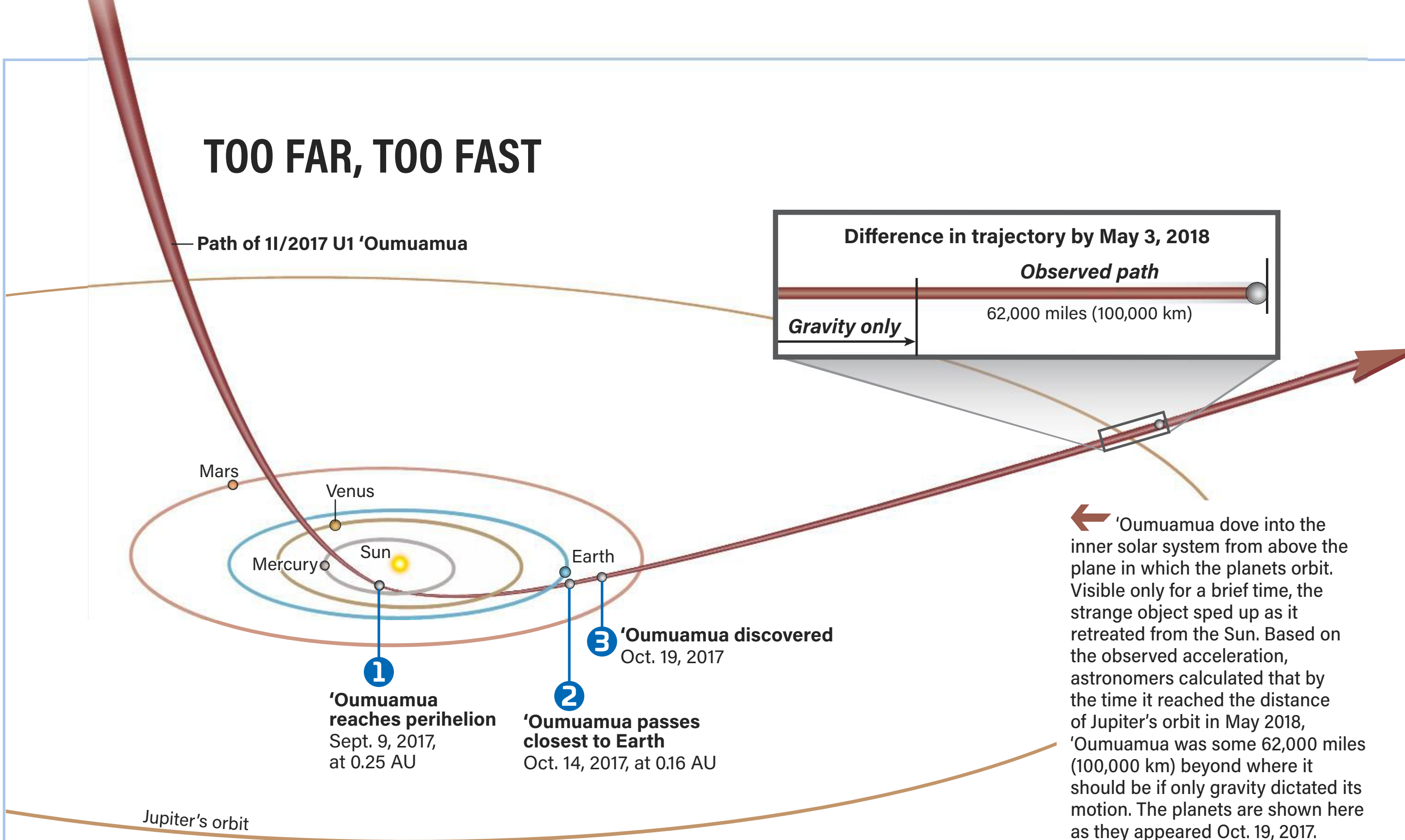
A light curve records brightness over time. It can reveal details about the size, shape, and rotation of an object. This light curve shows ʻOumuamua's brightness over three days in October 2017; each color depicts measurements taken in a different filter. The large changes in brightness indicate that ʻOumuamua is long but skinny, like a cylinder. The dotted line represents the light curve of a model object that is 10 times longer than it is wide.
ASTRONOMY: ROEN KELLY, AFTER OLIVIER HAINAUT (ESO)/K. MEECH ET AL.

WHAT INTERSTELLAR OBJECTS CAN TEACH US

In our own solar system, asteroids and comets comprise some of the earliest building blocks of the planets. Particularly in the case of asteroids, their composition represents the pristine, unprocessed materials that formed first in the solar nebula surrounding our young Sun. Studying their chemistry therefore lets us rewind the clock to take a peek at the conditions in our forming solar system, building a better picture of what it looked like in the beginning and how it has changed over time.

Interstellar objects represent similar pieces of the past, only not from our solar system, but others. Their size and chemical makeup carry firsthand accounts of the conditions around other suns — a treasure-trove of information for scientists studying how stars and planets form and evolve.

The fact that interstellar objects are traveling between the stars at all also contains valuable information. The number of objects we find, as well as their speed and path — if we can trace it back — can tell us about the dynamics of the systems from which they were ejected, such as whether they originated in multiple-star systems or might have had a giant planet like Jupiter, whose gravity could have knocked the object from its home system, sending it out into space. —*Alison Klesman*



'Oumuamua dove into the inner solar system from above the plane in which the planets orbit. Visible only for a brief time, the strange object sped up as it retreated from the Sun. Based on the observed acceleration, astronomers calculated that by the time it reached the distance of Jupiter's orbit in May 2018, 'Oumuamua was some 62,000 miles (100,000 km) beyond where it should be if only gravity dictated its motion. The planets are shown here as they appeared Oct. 19, 2017. *ASTRONOMY*: ROEN KELLY

its discovery, says "its characteristics were consistent with a planetesimal with cometary activity." Pointing out that we only have about a week's worth of data from its passage, she stresses, "expecting to have a complete understanding of anything with so little data is unrealistic."

She adds that "the lack of detection of gas was not a mystery. By the time we could get on the object it was faint for doing high-quality spectroscopy, where one can detect gas." And follow-up observations using the Spitzer space telescope were "not completely inconsistent" with limits predicted for the amount of outgassing needed to explain its motion, she says.

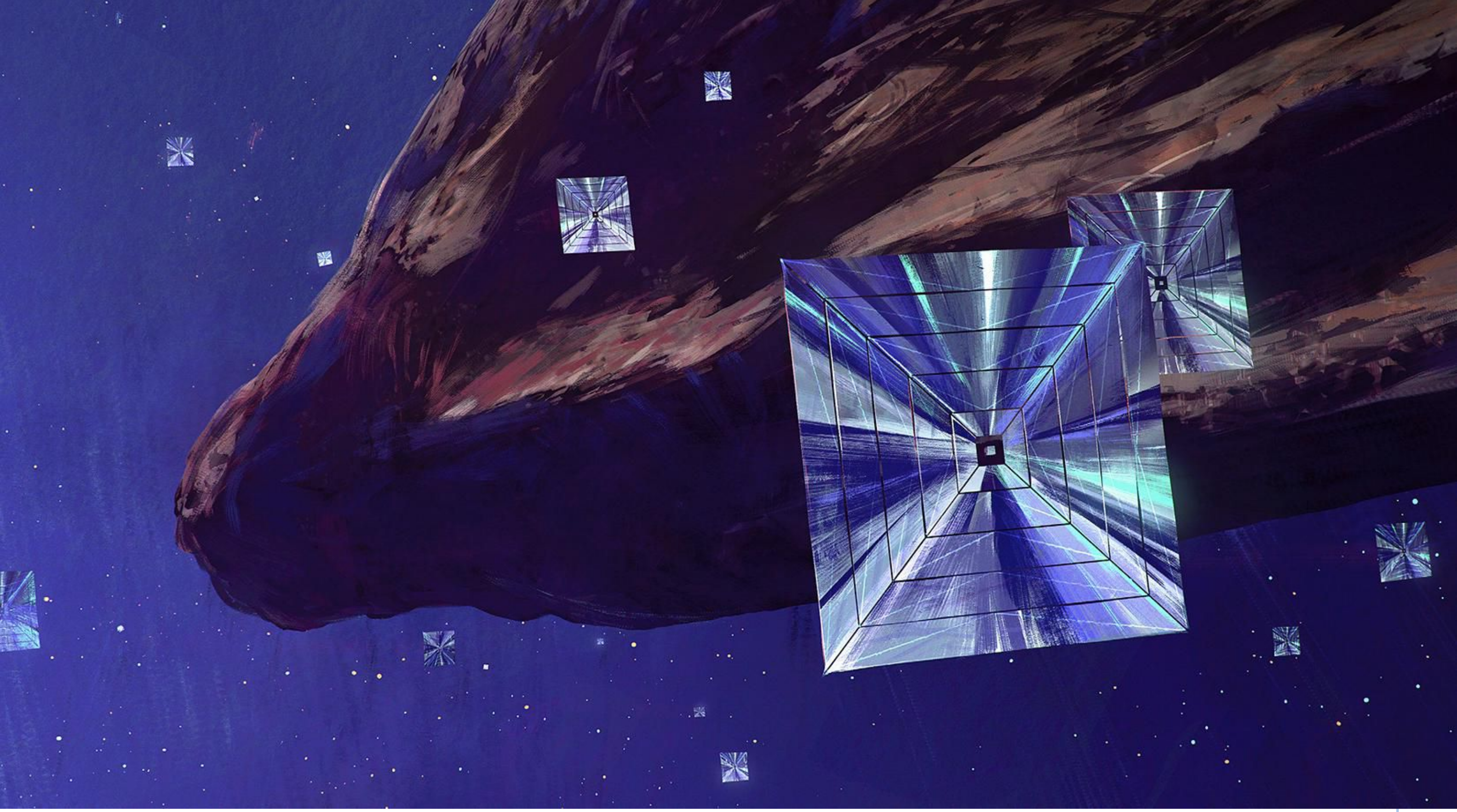
Nevertheless, Meech agrees that close-up observations of 'Oumuamua or any similar object would be useful. "If we had been able to have a close-up image of it, that would have been fabulous!" she says. "I think an in situ mission would be spectacular. Then we could get a good chemical characterization of any gases coming off — perhaps even isotopic ratios" to better understand its formation and origin.

And if Loeb is right, "if you can tell the composition, you can say that the composition is such that nature never produces such things," he says. "Or you can tell the structure, the shape of it. … If it looks like a spacecraft, it's definitely different from a rock. So, what you need is detailed enough information — especially if it has signatures of technology."

Catching up

Loeb himself is convinced that a mission to catch up with 'Oumuamua is impossible, both because of the enormous speed required and the difficulty of finding

The Vera C. Rubin Observatory nears completion in Chile in this December 2023 photo. Once operational, the observatory's 8.4-meter telescope will image the entire southern sky every few nights, picking up numerous transient objects — including, astronomers believe, more interstellar interlopers like 'Oumuamua and Borisov. RUBINOBS/NSF/AURA/H. STOCKEBRAND



Rather than sending a single spacecraft to seek out ʻOumuamua, researchers could plan two missions: an initial scout mission followed by a dedicated spacecraft once the space rock's position has been found. The scout mission would comprise a swarm of tiny, laser-propelled craft, such as those seen approaching ʻOumuamua in this artist's depiction. MACIEJ REBISZ

the small object in the vastness of space. But others have published a number of plausible mission designs to reach ʻOumuamua within a reasonable timeframe of a few decades.

The key to catching up to ʻOumuamua is building up enough speed to overtake the object, which is zooming away at some 16 miles per second (26 km/s). Existing chemical rockets are not capable of reaching such speeds on their own. But they could by using slingshot flyby maneuvers — dipping close to the Sun, Jupiter, or other planets — to gain speed and adjust trajectory. This is a variation of the technique used to get interplanetary probes like the Voyagers to the outer planets. Called a gravity assist or Oberth maneuver, it involves passing close to a large mass, such as a planet or the Sun, and adding a rocket boost just as the spacecraft reaches its closest point, providing significant acceleration.

Adam Hibberd, an independent software engineer based in the U.K. who has worked on the trajectory optimization software for the European Space Agency's (ESA) Ariane 4 rocket, was already developing software of his own for designing interplanetary trajectories when he learned of ʻOumuamua's discovery. He was testing the software by recreating historical missions, he says, "when this strange object appeared in our heavens that was the first interstellar object to be discovered. … I decided to solve missions to this object with my software, which seemed like an obvious thing to do." He soon found some workable trajectories.

Shortly after, he joined a group called Project Lyra, which had formed within months of ʻOumuamua's discovery. The team has devised

HOW RUBIN WILL CHANGE OUR VIEW

The nearly completed Vera C. Rubin Observatory houses the 8.4-meter Simonyi Survey Telescope, equipped with a 3,200-megapixel CCD camera — the largest ever built. Once operational, it will continuously survey the entire Southern Hemisphere sky every three to four days for 10 years. This immense effort is called the Legacy Survey of Space and Time (LSST).

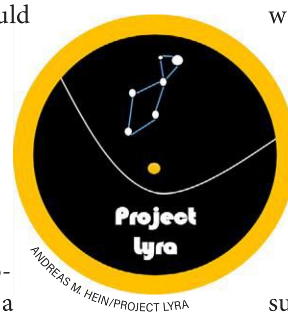
In 2017, ʻOumuamua was spotted by the 1.8-meter PanSTARRS1 telescope on Maui. The object was discovered less than a week after making its closest approach to Earth and more than a month after its closest pass of the Sun (called perihelion). In a 2019 interview, astrobiologist Karen Meech told *Astronomy* that the Vera C. Rubin Observatory, had it been operating at the time, should have spotted ʻOumuamua some three months before PanSTARRS1, before the object had passed perihelion.

The immense database LSST will create — logging some 20 terabytes of data per night for a total of 2 million images over the course of a decade — will be ideal for spotting changes in the sky, including the motions of asteroids and comets. This includes some 6 million moving objects in our solar system, some of which will be only visitors, passing through from other star systems. In a 2023 paper available on the *arXiv* preprint server and accepted for publication in the *Planetary Science Journal*, researchers estimated LSST could find as many as 70 ʻOumuamua-like interstellar objects each year, with sizes averaging 160 to 1,970 feet (50 to 600 m), though the number heavily depends on how common such travelers are through space, how fast they are moving, and how frequently they visit our solar system. *—A.K.*

and published a variety of flight plans that could make the rendezvous possible. One such scenario, using a launch date in 2030, would be able to reach ‘Oumuamua within about 22 years, he says.

Initial ideas involved close passes to the Sun, which would require extensive shielding to protect the craft from the heat, imposing a severe penalty on payload mass. So Hibberd and others began working on similar maneuvers that avoided the Sun and used Jupiter's mass instead.

The tricky part is "you have to generate enough speed to get to Jupiter from Earth," Hibberd says. He and the Project Lyra team found two possible ways to do this with a series of slingshots past the inner planets. Both options, he says, would get a spacecraft to Jupiter with plenty of fuel left to carry out the gravity-assist maneuver there, which would fling the craft onward toward ‘Oumuamua. The trip would take about 31 years — about nine years longer than trajectories that involve a risky close approach to the Sun.

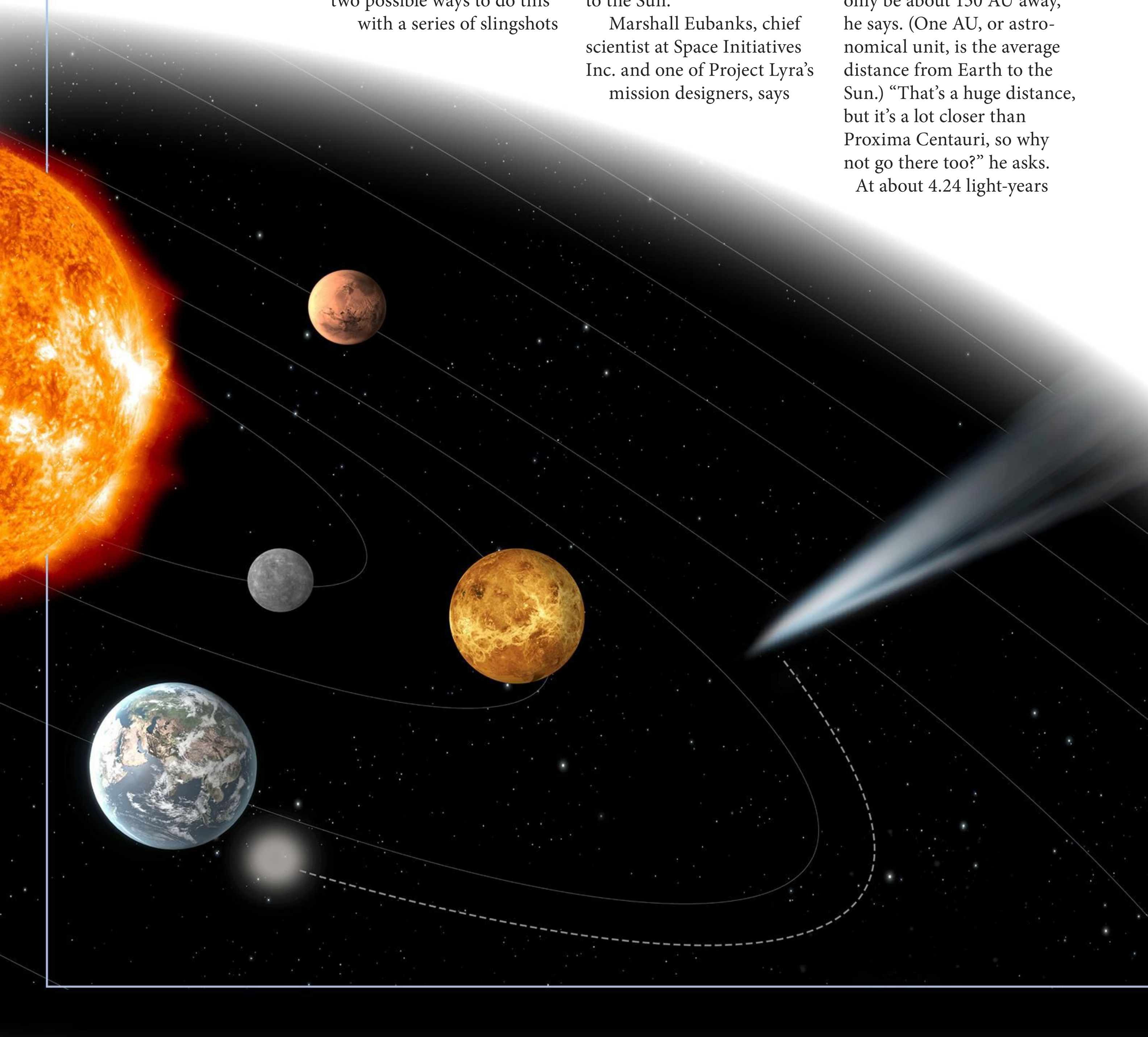


ANDREAS M. HEIN/PROJECT LYRA

Marshall Eubanks, chief scientist at Space Initiatives Inc. and one of Project Lyra's mission designers, says that he feels it is inevitable that a mission will be sent to ‘Oumuamua, one way or another. Already, he points out, people are coming up with proposals to send missions to the planets of nearby stars, yet even a century from now ‘Oumuamua will still be vastly closer than such destinations.

"In a hundred years, it'll only be about 150 AU away," he says. (One AU, or astronomical unit, is the average distance from Earth to the Sun.) "That's a huge distance, but it's a lot closer than Proxima Centauri, so why not go there too?" he asks.

At about 4.24 light-years



Comet Interceptor will stay "parked" at the L2 Lagrange point of the Earth-Sun system (depicted as the bright spot just beyond Earth in this mission concept art) until a suitable target — the comet at center — is found. Then, the spacecraft will leave L2 to rendezvous for scientific study. Note that this graphic is not to scale. ESA

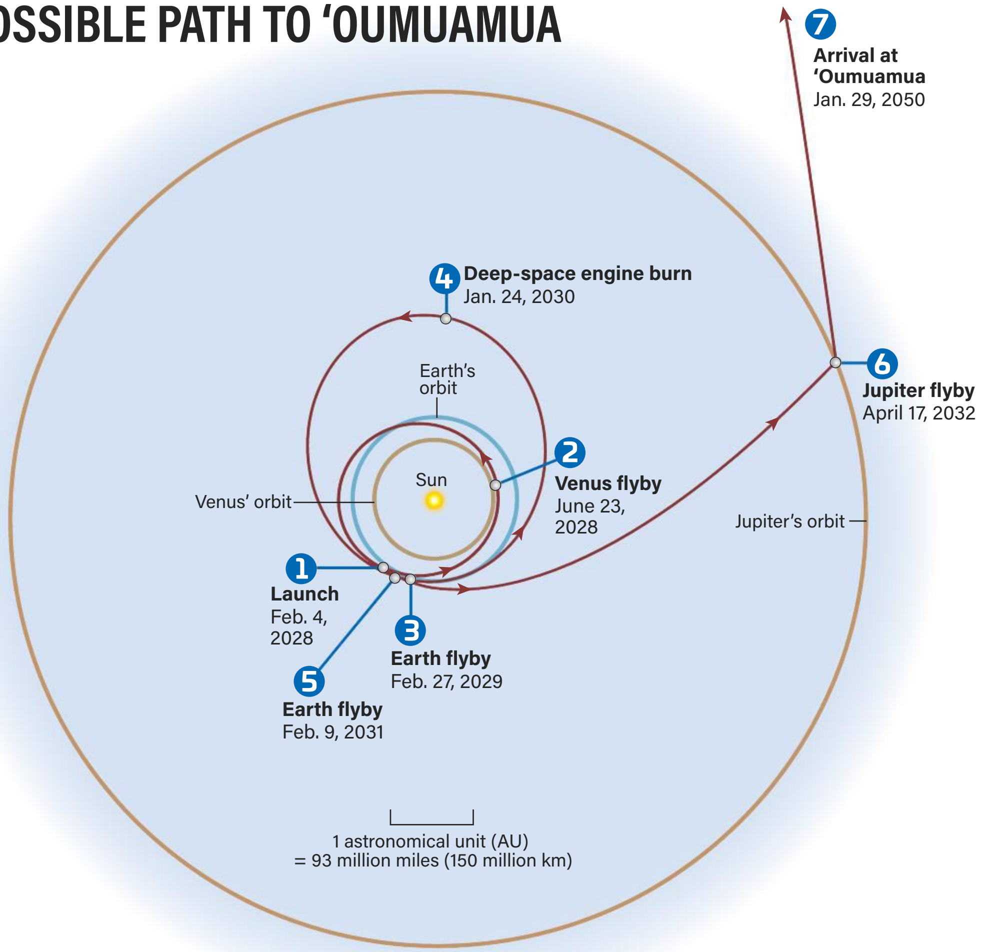
— more than 268,000 AU — Proxima Centauri is the closest star to the Sun.

It's "certainly not physically impossible" to catch up to 'Oumuamua, Eubanks says. "It's certainly not beyond our technical expertise." Such a slingshot-based mission could be carried out with existing rockets such as the Falcon Heavy from SpaceX, he says.

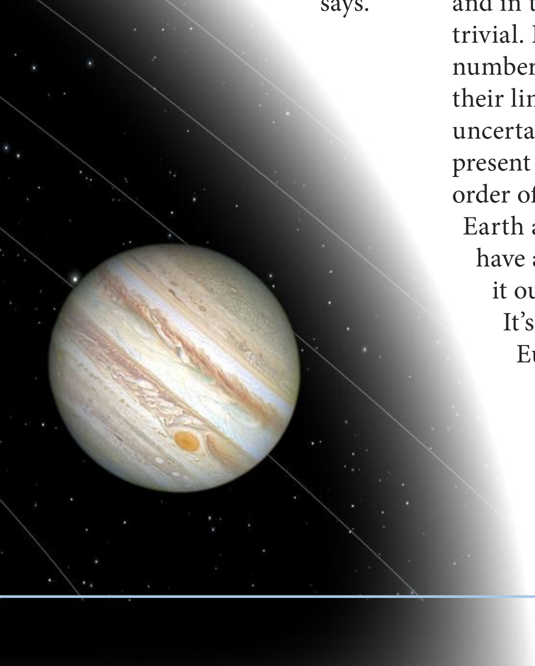
Some researchers argue that we should just wait for the next such object, Eubanks says, since new telescopes like that of the Vera C. Rubin Observatory — scheduled to begin operations next year — will potentially discover many such objects. But with only two interstellar objects found so far, we really don't know how scarce such objects may be. We also don't know whether any others we find will be highly unusual like 'Oumuamua. The only other interstellar object we've found is Comet 2I/Borisov — and that was a fairly humdrum, typical-looking comet.

"If you really think ['Oumuamua] is an object that's a real outlier, you should want to go and investigate it," Eubanks says.

POSSIBLE PATH TO 'OUMUAMUA



↑ One possible trajectory could deliver a spacecraft to 'Oumuamua in just over two decades, though the researchers suggest a longer flight time is more realistic. Following a February 2028 launch, the craft would perform a flyby of Venus in June, return to Earth for a flyby in 2029, make a deep-space burn of its engines in 2030, fly by Earth a second time in 2031, then use Jupiter for a final gravity boost in 2032. The mission could catch 'Oumuamua by 2050 (or later with a more relaxed timeline). *ASTRONOMY*: ROEN KELLY, AFTER HIBBERD ET AL., *ACTA ASTRONAUTICA*, 2022



"You'll never solve it otherwise."

Locking on target

Getting a rocket moving fast enough is only half the problem. You also have to know where you're going — and in this case, that's not trivial. Because of the small number of observations and their limited precision, the uncertainty in 'Oumuamua's present position is on the order of the distance between Earth and the Moon. "You'll have a hard time finding it out there in the dark. It's not a big object," Eubanks says.

One option is to send a scout mission to pinpoint the location before launching a larger spacecraft to get close for measurements and observations. This precursor could take two forms, Eubanks says. It could be one spacecraft with a large telescope, perhaps half the size of Hubble, to scan the sky for the object. Or we could send a swarm of hundreds or thousands of tiny spacecraft to fan out and blanket the survey area. The Breakthrough Starshot project is currently working on developing this technology (and has substantial financial backing), with the aim of sending such probe swarms to the planets of nearby stars.

The tiny spacecraft would be thin disks, perhaps the size of frisbees, propelled by laser beams aimed at them from somewhere on Earth, the Moon, or in space. But even once this technology is developed, reaching anything in the solar system is still going to be much easier than trying to reach even the nearest star, Eubanks says. "And 1I is still in the solar system, even though it's not *of* the solar system," he stresses. Such laser-propelled craft could theoretically make it to 'Oumuamua in just a couple of years.

Even these scout probes would provide significant

In December 2022, ESA and European space system provider OHB signed the contract allowing design and construction of Comet Interceptor to begin. ESA, CC BY-SA 3.0 IGO

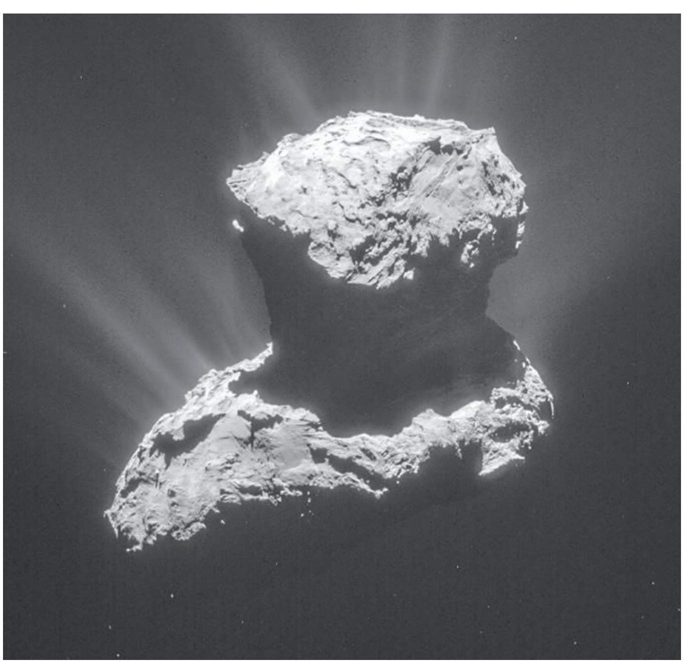
return, he says: If one finds 'Oumuamua and reports back its position, even with no further data, that would reveal whether the object had continued to experience non-gravitational acceleration after it was last seen and if so, how much.

Any follow-up mission would have to be much larger, at least equivalent to NASA's New Horizons spacecraft that studied Pluto up close and is still exploring the Kuiper Belt. Such missions cost on the order of $1 billion. It's quite possible that no government, or even individual billionaire, would be willing to put up the money for such a mission, which could end up either failing to find its target or getting there and finding a relatively ordinary rock.

The next time

Regardless of whether 'Oumuamua ever gets visited by a spacecraft, there's always next time. And there is one mission already fully approved and funded that may be ready when the next interstellar object comes along.

ESA's Comet Interceptor is scheduled to launch in 2029 with one large spacecraft and two smaller probes attached. The craft will travel to the L2 Lagrange point of the Earth-Sun system, about 932,100 miles (1.5 million km) beyond Earth, and wait there for either a newly found interstellar object or a never-before-seen pristine comet from the outer solar system. It will then fly by the target and take images, spectra, and other measurements. About 200 people are currently working on the mission. "It's the first implementation of a so-called rapid-response mission," says Comet Interceptor Project Scientist Michael Kueppers.



The most recent mission to visit a comet was ESA's Rosetta, which gathered close-up images of Comet 67P/Churyumov-Gerasimenko. Comet Interceptor won't stay in orbit around its target like Rosetta, but instead fly past it to create 3D images and take other measurements in conjunction with its two smaller probes. ESA/ROSETTA/NAVCAM – CC BY-SA IGO 3.0

"We have a range of instruments," says the project's interdisciplinary scientist, Geraint Jones. Comet Interceptor carries three different cameras, he says — one on the main craft and one each on the two smaller probes — to provide three-dimensional views as they zip past. The mission will also take infrared images and carry a mass spectrometer to measure the composition of gases that may be emanating from a comet.

The main craft is designed to pass within about 620 miles (1,000 km) of the comet. At that distance, its main camera will have a resolution of about 26 feet (8 m) per pixel, Kueppers says — enough to get plenty of detail on an object like 'Oumuamua. The smaller probes would get even closer, with one approaching

This artist's concept shows the three spacecraft of the Comet Interceptor mission — the larger, main craft in the foreground at left and the smaller probes in the distance at right — approaching their as-yet-unknown target for study. GERAINT JONES, UCL MULLARD SPACE SCIENCE LABORATORY

FAST FACTS

COMET INTERCEPTOR

AGENCIES: European Space Agency (ESA), Japan Aerospace Exploration Agency (JAXA)
MISSION CLASS: Fast (F) class
NUMBER OF SPACECRAFT: 3 (1 primary and 2 probes)
TOTAL MASS: 1,500 pounds (700 kg), including 77 pounds (35 kg) for each probe
TOTAL DIMENSIONS (STOWED): 6.6 feet by 6.6 feet by 8.2 feet (2 m by 2 m by 2.5 m)
TOTAL NUMBER OF INSTRUMENTS: 11
PLANNED LAUNCH: 2029
LAUNCH VEHICLE: Ariane 62, shared with ESA's ARIEL mission
MISSION DURATION: 6 years

to 530 miles (850 km) and the other to 250 miles (400 km).

The craft will have about a five-year window to find and decide on its target. And if it does succeed in finding a suitable interstellar object within that time, "that's very tantalizing," Jones says. "The two confirmed interstellar objects we've seen so far were very different from each other. Comet Borisov was remarkably similar to solar system objects — if it wasn't on such an unusual trajectory, it probably wouldn't stand out as a particularly unusual comet. And then at the other extreme you have 'Oumuamua, where there was a very low activity level [no tail], and we know very little about that body other than hints of a very unusual shape and color. And yes, it would be fantastic to be able to see one of these objects from another star system and compare and contrast it with what we know about comets in our solar system."

Would Comet Interceptor be able to detect whether an object had an artificial rather than a natural origin? "I don't know what an interstellar spacecraft would look like," Kueppers says. But a highly unusual shape might make it clear. For example, "I guess it would be quite obvious," he says, if the target is a long, thin, cylindrical object, as some have invoked to explain 'Oumuamua's variations in brightness.

Whatever Comet Interceptor's future target might be, getting up close and personal with an object from the depths of interstellar space is bound to teach us new things about stars, planets, and the processes that form them. And if one day we end up with a close look at something that was built by intelligent beings from another world, it would rank as one of the most epochal discoveries in history, and a major turning point in humanity's view of itself in the cosmos.

David L. Chandler *is a long-time science writer whose work has also been published in* Nature *and* The Atlantic.

Painted in 1690 by Thomas Murray, this portrait features young Edmond Halley holding a paper with a diagram of an elliptical orbit.

EDMOND HALLEY

THE MAN BEHIND THE COMET

The legendary English astronomer's pursuits included cataloging the southern stars, investigating tides, and captaining multiple expeditions. **BY DAN FALK**

IF you're an amateur astronomer of a certain age, you'll remember where you were in the winter of 1985–86, when Halley's Comet passed Earth. I was in Halifax, Nova Scotia, which was relatively free of light pollution at that time, so I grabbed my dad's binoculars and headed to the park across the street from our house. Shivering from the cold, I did manage to spy the comet, faint and fuzzy as it was. If you're too young to have such a memory, you may well be looking ahead to 2061, when the comet will make its next appearance in our skies.

The comet became so well known that it can sometimes overshadow Edmond Halley's other work — of which there was a great deal. In his early adulthood, Halley sailed the Atlantic to chart the southern stars. He later mapped Earth's magnetic field and studied the tides and monsoons; he even tried to solve the problem of measuring longitude at sea. And that's just a few of his pursuits.

On a visit to England in the last year, I walked in Halley's footsteps in an effort to learn more about his life and legacy.

Halley's memory is very much alive at the Royal Society of London. One of the world's oldest scientific societies, it was founded in 1660 when it was granted a royal charter by King Charles II. Halley was elected a fellow of the society in 1678, and would later take on the role of secretary. Today, the Society's headquarters occupy part of a stately townhouse in the heart of London.

Keith Moore, the head librarian, explained to me that the Society possesses two of the five known portraits of Halley — one, painted when the astronomer was in his 70s, hangs on a second-floor wall; an earlier portrait had been placed in storage, but Moore offered to retrieve it. Grasping it only with gloved hands, he leaned it gently against a cabinet. The painting, by the Scottish painter Thomas Murray, dates to the 1690s. It shows the youthful Halley with long hair — his own hair, rather than a wig (which would

be the fashion just a few decades later). Halley was at the height of his powers, says Moore: "It's when he's doing his best work." In Halley's hand is a sheet of paper that appears to show cometary orbits. "Halley's Comet is what he's known for these days," says Moore. "But in many ways, it's the least of what he did."

YOUNG ACADEMIC

Halley was born in 1656 in Haggerston, a village about a mile and a half (2.4 kilometers) northeast of the old city of London (and today fully absorbed in the capital's urban sprawl). The son of a wealthy soapmaker, Halley showed a keen interest in mathematics and astronomy from an early age. In 1673, he enrolled at Queen's College in Oxford; he would later return in 1704 as Savilian Professor of Geometry, a highly regarded chair position at the school.

While still an undergraduate, Halley published papers on the solar system and sunspots. As a precocious and sometimes overconfident young man, he wrote to John Flamsteed, England's first astronomer royal, to alert him to mistakes he had found in published tables on the positions of Jupiter and Saturn, and in the star positions published by the Danish astronomer Tycho Brahe. This sparked a working relationship between the two men for years to come.

Although his academic life is well documented, we unfortunately know little about Halley's day-to-day life in either London or Oxford. We at least know he married Mary Tooke in 1682, with whom he later had three children. Beyond that, though: "The fascinating thing about Halley is just how little we know about his personal life," says Rob Iliffe, a historian of science at Oxford. "We know a lot about his career as an astronomer, but not much else."

OBSERVE AND DOCUMENT

The early years of Halley's career were not just filled with books and charts, but also with adventure. In 1676, not long after his 20th birthday, he sailed to St. Helena, a remote South Atlantic Island 1,200 miles (2,000 km) from the southwestern coast of Africa, determined to accurately chart the southern stars.

Unfortunately, the island's rainy weather made that difficult. He tried to observe both a solar eclipse and a lunar eclipse in the spring of 1677, but on both occasions was plagued by clouds and overtaken by wind. In a letter to the mathematician and surveyor Jonas Moore, Halley wrote that "such hath been my ill fortune" that clouds "sometimes for some weeks together hath hid the Stars from us." He had better luck with a transit of Mercury, which he observed Oct. 28, 1677.

Halley persevered, and after about two years, succeeded in charting positions of 341 stars in the southern sky. He returned to England the following spring. His catalog of the southern stars was titled *Catalogus stellarum Australium* (*Catalog of Southern Hemisphere Stars*). Along with the star charts, the book included an account of the transit of Mercury, a discussion of lunar parallax, and a planisphere of the southern sky.

These remnants are all that's left of Halley's St. Helena observatory, which he used to view the transit of the planet Mercury and chart hundreds of southern stars. DAVID STANLEY/FLICKR

HALLEY PERSEVERED, AND AFTER ABOUT TWO YEARS, SUCCEEDED IN CHARTING POSITIONS OF 341 STARS IN THE SOUTHERN SKY.

LEFT TO RIGHT:

Halley was enrolled as an undergraduate at The Queen's College in Oxford. DAN FALK

Halley drew this printed Southern Hemisphere star chart from 1678. © NATIONAL MARITIME MUSEUM, GREENWICH, UK

The Royal Observatory Greenwich sits on a hill overlooking Greenwich Park. The red brick building is Flamsteed House, which dates from 1676. DAN FALK

It was around this time that Halley pondered the motion of the Moon and the planets. He knew of Kepler's theory of elliptical orbits but wondered why orbits assumed that particular shape. In 1684, he visited Cambridge to consult with Isaac Newton, who at that time was still "an obscure professor," as Iliffe puts it. (Newton had been thinking deeply about theology and alchemy, not so much about physics.) To Halley's surprise, he found that Newton had already claimed to have solved the problem some years earlier. Unable to find his original calculations, he promised to redo them. Newton made good on his promise with a small book titled *De motu corporum in gyrum* (*On the Motion of Bodies in an Orbit*); over the next few years Newton would expand this work, publishing the resulting tome in 1687 as *Philosophiæ Naturalis Principia Mathematica* (*The Mathematical Principles of Natural Philosophy*), widely seen as one of the most influential scientific works ever written. After initially nudging Newton toward publishing this book, Halley continued to support him by editing and financing the project.

"We know that Halley had worked quite closely in helping Newton, not just in terms of the book's printing," says Iliffe. "He was commenting in technical detail on some of the things that Newton was saying. So, he had a hand in more than one way in the emergence of the *Principia*."

By the time of that first meeting with Newton, Halley had also spent some time thinking about comets. In the fall of 1682, he carried out a series of observations of the comet that would eventually bear his name. He found that the object bore a striking resemblance to those comets viewed in 1531 and 1607. He concluded that the comet must be moving in an orbit with a period of roughly 75 years, predicting that it would return in 1758. It did, right on schedule, though Halley was not alive to see it. But the return of Halley's Comet served as an enormous vote of confidence for Newton's ideas. It was "the key piece of evidence to convince people of the general truth of Newton's theory," Iliffe says. Comets were now tamed, their appearance no longer a great mystery.

MAPMAKER

Halley would take to the Atlantic several more times, including two voyages in the final years of the 1690s, with the aim of mapping Earth's magnetic field. Because the magnetic pole is several hundred miles from the geographic pole, a compass needle can diverge from true north by several degrees, depending on one's location. That made detailed knowledge of Earth's magnetic field vital for navigation, and therefore a priority for the Royal Navy.

But it was not always smooth sailing. As Halley approached the Cape Verde Islands in the winter of 1699, his ship, the HMS *Paramore*, was fired on by an English warship that suspected Halley's vessel was a pirate ship flying false colors. (The likely problem was that the *Paramore* was a pink — a small, flat-bottomed ship with a narrow stern that was somewhat of a rarity in the British navy, and therefore not immediately recognizable.) But they were able to get away unscathed.

Later in that same voyage, Halley faced near-mutiny on board his own vessel from his first mate, Lieutenant Edward Harrison, who was deeply resentful of his command. Though Halley was a commissioned officer, his subordinates, egged on by Harrison, questioned his competence. Facing growing unrest from his crew, he cut the voyage short and returned to England more than a year ahead of schedule. It was only later that Halley learned the reason for Harrison's wrath: Halley had written a dismissive review of Harrison's anonymously published pamphlet, *Idea Longitudinis*, which attempted to solve the problem of

NEAR RIGHT: This portrait shows Halley in 1720 after he became the second astronomer royal, succeeding John Flamsteed. © NATIONAL PORTRAIT GALLERY, LONDON

FAR RIGHT: Halley's 8-foot mural quadrant is on display at the Royal Observatory Greenwich. The attached telescope pivots in the plane of the meridian, allowing the user to measure the altitude of a star as it reaches the highest point in its arc across the sky. DAN FALK

determining longitude at sea. In spite of these misadventures, Halley was, as far as we know, as skilled a captain as any other in the navy's service.

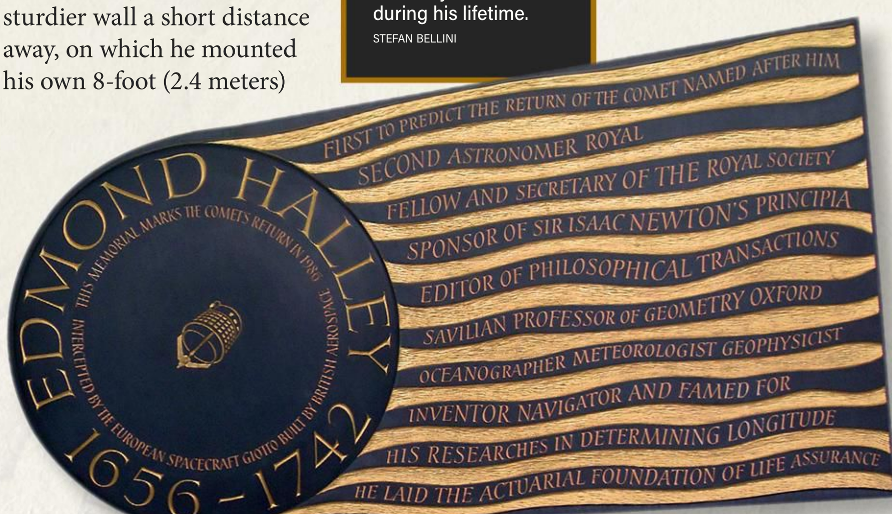
Further adventures awaited Halley a few months later, when the *Paramore* sailed the Atlantic's southern reaches. At one point, his crew spied three unusually flat, treeless "islands" that were "covered with snow, milk white with perpendicular cliffs all round them." These were, of course, icebergs, and as fog descended, the ship came dangerously close to becoming trapped in ice. Luckily, the *Paramore* was able to escape northward, eventually reaching the island of Tristan da Cunha, the most remote inhabited archipelago in the world, where Halley was able to "recover the warm [Sun] who we had not seen in a fortnight."

HOME ONCE MORE

After years of globetrotting, Halley returned to England where he was named astronomer royal in 1720, following the death of Flamsteed. On arriving at the observatory in Greenwich, however, he was met with a surprise. "He found that it had been stripped of its instruments by his predecessor's wife, Margaret Flamsteed," explains Louise Devoy, senior curator of the Royal Observatory Greenwich (as the institution is now called). Mrs. Flamsteed "pretty much cleared out the observatory, arguing that Flamsteed had paid for the instruments himself, so they were his property." Halley eventually persuaded the government to pay him an extra 500 pounds sterling (roughly £130,000 in today's currency, or $103,000) to acquire new equipment.

Halley also noticed that the stone wall on which Flamsteed had mounted his mural arc — and which effectively marked the prime meridian, the "zero" of longitude — was beginning to tilt as the ground beneath it subsided. Halley erected a new, sturdier wall a short distance away, on which he mounted his own 8-foot (2.4 meters) mural quadrant. Attached to it was a telescope that pivoted in the plane of the meridian, allowing the user to measure the altitude of a star as it reached the highest point in its arc across the sky. It could be used in conjunction with an accurate pendulum clock to determine the right ascension and declination of a heavenly body by noting the sidereal time at which the object crossed the meridian. The keen-eyed visitor will notice that there are in fact three "prime meridians" marked on the floor: Halley's; then one established by his successor, James Bradley, a dozen or so feet farther

A plaque to Halley in the South Cloister of Westminster Abbey resembles a comet in reference to just one of his many discoveries during his lifetime. STEFAN BELLINI



FAR LEFT: The tomb of Edmond Halley lies in the graveyard of St. Margaret's Church in Blackheath, London, about a mile south of the observatory in Greenwich. In all, five members of Halley's family are buried in the grave, along with John Pond, who served as astronomer royal from 1811 to 1835. DAN FALK

NEAR LEFT: As a professor, Halley lived in a three-story house at 7 New College Lane. Today, the gatepost in front of the house bears a handsome if somewhat minimalist plaque, displaying Halley's name, his birth and death dates, and a stylized depiction of a comet. DAN FALK

HALLEY HELD THE POSITION OF ASTRONOMER ROYAL UNTIL HIS DEATH AT THE AGE OF 85.

east; and finally, still farther east, the one set by George Airy, who would serve as astronomer royal through the middle part of the 19th century. It was Airy's line that was chosen in 1884 as the prime meridian of the world — and whose extension, marked by a brass line that stretches across the observatory's plaza, is now a prime spot for tourist selfies. However, modern GPS systems actually use yet another imaginary line about 330 feet (100 m) farther east; this is the International Reference Meridian, or IRM.

Halley held the position of astronomer royal until his death at the age of 85. He was laid to rest about a mile (1.6 km) south of the observatory, in the cemetery of St. Margaret's Church in Blackheath — the resting place of his wife, who predeceased him six years earlier in 1736. When the church was rebuilt in the 1840s, the original gravestone was moved to Greenwich, where it can be seen today, mounted on a wall at the observatory. Meanwhile, a new monument was erected at St. Margaret's, though unfortunately its inscription is now badly eroded. The Latin text reads, in part: "Beneath this gravestone, Edmond Halley, unquestionably the most eminent of the astronomers of his age, rests peacefully with his dearest wife. ... [A]s he was a man so greatly cherished by his fellow-citizens during his lifetime, so let a grateful posterity venerate his memory." In all, five members of Halley's family are buried in the grave, along with John Pond, who served as Astronomer Royal from 1811 to 1835. Halley is also honored with a memorial plaque in Westminster Abbey, not far from the tombs of other notable British minds such as Newton, Charles Darwin, and Stephen Hawking.

A POLYMATH'S LEGACY

It is difficult to describe all of Halley's contributions to science during his lifetime. Halley's investigation of the tides, which he pursued for decades, was among his most noteworthy accomplishments; together with his geomagnetic surveys, they position Halley as one of the first modern geophysicists. This eventually led him to try to scientifically date Stonehenge, based on estimates of changes in Earth's magnetic field over time. He dated it to 456 B.C.E. — an inaccurate estimation by a couple of thousand years, but one which opened the door for more research in the area.

He also designed and built a diving bell, whose occupants breathed fresh air sent down from the surface in weighted barrels. In one demonstration, Halley and five companions descended to 60 feet (18 m) beneath the Thames River, remaining there for an hour and a half. The list of his endeavors goes on.

"It does seem a shame that people only know him because of the comet, when there are so many other contributions to his name," says Devoy, and Moore adds, "He's one of my favorite scientists, because he's so prolific. He did so many things. He's not one of those scientists who plows a single furrow."

Halley was also more adventurous than the average scientists he was around, like Newton, who spent virtually his entire adult life in Cambridge and London. "Newton doesn't move; he gets other people to send results to him, so he can crunch that data," says Moore. "Whereas Halley is not afraid to get out into the world."

His comet, meanwhile, continues its silent sojourn. Last December, it reached the most distant point in its orbit, known as aphelion; at that moment, it lay over 35 times farther from the Sun than the Earth is on average, or 3.28 billion miles (5.27 billion km) out, beyond the orbit of Neptune. But rest assured, it will be back. Halley proved it.

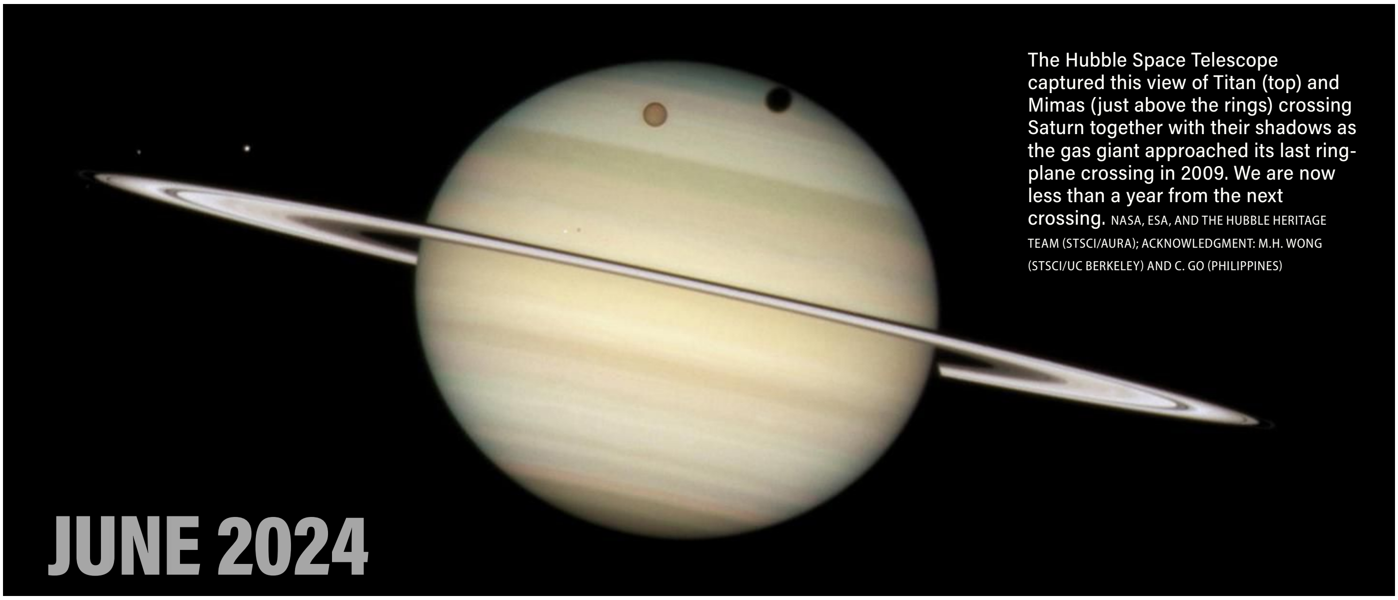
Dan Falk *is a science journalist based in Toronto, and the author of* The Science of Shakespeare *(Thomas Dunne Books, 2014).*

SKY THIS MONTH

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

THE SOLAR SYSTEM'S CHANGING LANDSCAPE AS IT APPEARS IN EARTH'S SKY.

BY MARTIN RATCLIFFE AND ALISTER LING



The Hubble Space Telescope captured this view of Titan (top) and Mimas (just above the rings) crossing Saturn together with their shadows as the gas giant approached its last ring-plane crossing in 2009. We are now less than a year from the next crossing. NASA, ESA, AND THE HUBBLE HERITAGE TEAM (STSCI/AURA); ACKNOWLEDGMENT: M.H. WONG (STSCI/UC BERKELEY) AND C. GO (PHILIPPINES)

Many worlds line up

June's pre-dawn sky finds six planets strung along the ecliptic, spanning 72° on the 1st. In order of increasing elongation from the Sun, they are Jupiter, Mercury, Uranus, Mars, Neptune, and Saturn. A 24-day-old waning crescent Moon joins the line of objects, 16° east of Saturn. It's a great time to become acquainted with many planets all in one go, and during nice weather to boot.

Some of the planets switch places early in the month, while the Moon wanders across the line over the span of four days. Most are visible to the unaided eye, though Mercury is challenging as its elongation quickly diminishes in bright twilight after the 1st. Uranus and Neptune both require binoculars to spot.

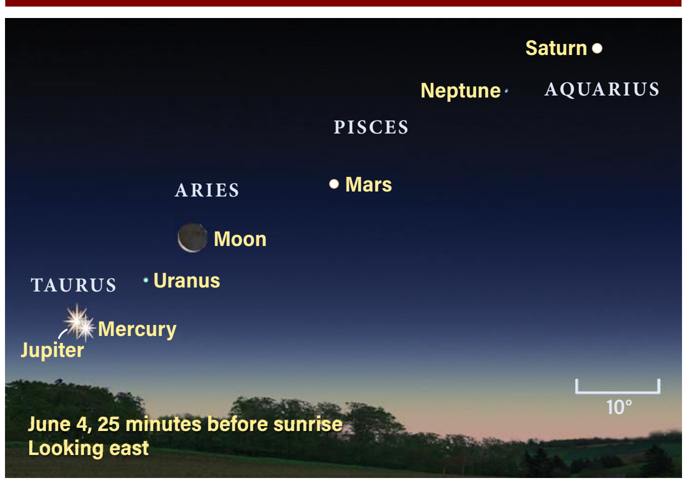
Let's take a look at the spread of planets, starting with the first to rise.

Saturn lies in eastern Aquarius and shines at magnitude 1 on June 1. It rises just before 2 A.M. local daylight time and stands 1.5° east of Phi (ϕ) Aquarii. It extends this distance to 2.1° by June 30, when the ringed planet reaches its stationary point. Saturn and a gibbous Moon lie less than 3.5° apart on the morning of June 27.

You can see practically the full disk for the first time in 14 years. It spans 17" and the wide axis of the rings stretches almost 40". We are a year away from the ring-plane crossing, which occurs in March 2025. Now that the ring plane is almost edge-on, the satellites of Saturn appear to criss-cross in front or behind the planet. Titan, the brightest of Saturn's moons at magnitude 8.6, orbits the planet every 16 days. It transits Saturn's southern hemisphere on June 14, beginning shortly after 4 A.M. CDT. With dawn approaching on the East Coast and Saturn 30° high in the Midwest (and lower farther west), its visibility will be affected by local seeing conditions.

Titan's transit lasts four hours, with the latter parts visible from the western U.S. The fainter satellite Rhea begins a transit at 4:20 A.M. MDT, its shadow appearing behind Titan as both moons transit — quite an extraordinary alignment. Rhea is a small satellite and shines at only magnitude 10, so it's very difficult to see against the bright background

Close encounter



June opens with Jupiter and Mercury mingling in the morning sky. The smaller planet quickly disappears from view within days. Uranus and Neptune cannot be seen with the naked eye. ALL ILLUSTRATIONS: *ASTRONOMY*: ROEN KELLY

OBSERVING HIGHLIGHT

JUPITER and **MERCURY** stand just 7' apart in bright twilight on June 4.

of Saturn. High-speed video and image-refining techniques should capture it.

Eight days later, on June 22, Titan passes behind Saturn in an occultation. It approaches the northwestern limb of the planet and disappears just before 4 A.M. EDT, taking a few minutes to become fully occulted. Given local seeing conditions and its altitude, see how long you can keep track of Titan before it's gone. Meanwhile, magnitude 10.5 Tethys skims along the northwestern edge of the rings.

A nice challenging observation occurs the morning of June 25, when Dione (magnitude 10.6) is visible off the western limb of Saturn. The moon crosses into the planet's shadow around 3 A.M. EDT and disappears behind Saturn's disk at 3:43 A.M. EDT. Meanwhile, Tethys is transiting in front of Saturn and may be visible in the very narrow dark shadow just south of the rings on the planet.

You'll often see the moons skimming the edge of the rings, a perspective effect that is intriguing to watch. Tethys, Dione, and Mimas congregate very close to the rings on the morning of June 21. Their relative motion can be spotted within 15 minutes.

Iapetus orbits at a much greater distance from Saturn than the other moons and takes

— Continued on page 34

RISING MOON | Celebrate!

ENJOY THE "EARTHINESS" of a nearly Full Moon on the summer solstice. This date — the longest day and the shortest night of the year — is strongly tied to the progression of the seasons and cherished by cultures worldwide. Consider seeking out your local Indigenous community — their sky is different than the official IAU constellations. You might even feel more of a connection to their stories than to the classical Greek mythology.

Adding to the festivities, the Strawberry Full Moon shines on the 21st. Although more than 24 hours after the solstice, the pairing will still make the news. It's reasonably common if you break the arbitrary hard lines of the Western calendar: Full Moons fall on the 18th in 2027, the 23rd in 2032, the 20th in 2035, and the 22nd in 2043. More will follow.

Because the Sun and Moon are opposite each other in the sky, it's fairly well known that the Full Moon rises at sunset and sets at sunrise. There is little surprise to be had at this at lower latitudes, but farther north it's notable how late the moonrise is. For some places, thanks to the daylight saving protocol, the Full Moon doesn't rise until after midnight! The extra lag is due to the current alignment of the lunar orbit's 5° tilt to the rest of the planets' (the ecliptic plane). Low this summer, Luna is clipping Antares, but will sail well above it nine years from now.

Strawberry Moon

The Full Moon rises above McGregor Lake in Alberta, Canada, in June 2021. ALAN DYER

METEOR WATCH | Glowing display

Rippling clouds

Displays of noctilucent clouds can develop unique patterns, thanks to high-altitude winds. STUART ATKINSON

JUNE IS A QUIET MONTH for meteors, with no major showers occurring. The so-called sporadic background rate from random meteors or remnants of long-gone showers reveals up to seven meteors per hour, and always keep a look out for the occasional fireball.

Noctilucent clouds are glorious features of the summer sky from northern latitudes. They are preferentially seen from latitudes of 55° north to 70° north and are located more than 10 times the height of ordinary cirrus clouds. They have an iridescent pearly glow and remain in sunlight long after the Sun has gone down. Ice crystals forming on high-flying dust particles generate the spectacle, and time-lapse photography reveals beautiful flows produced by extremely high wind patterns. They don't appear every night, but always cast a glance to the northern sky to see if they're present.

STAR DOME

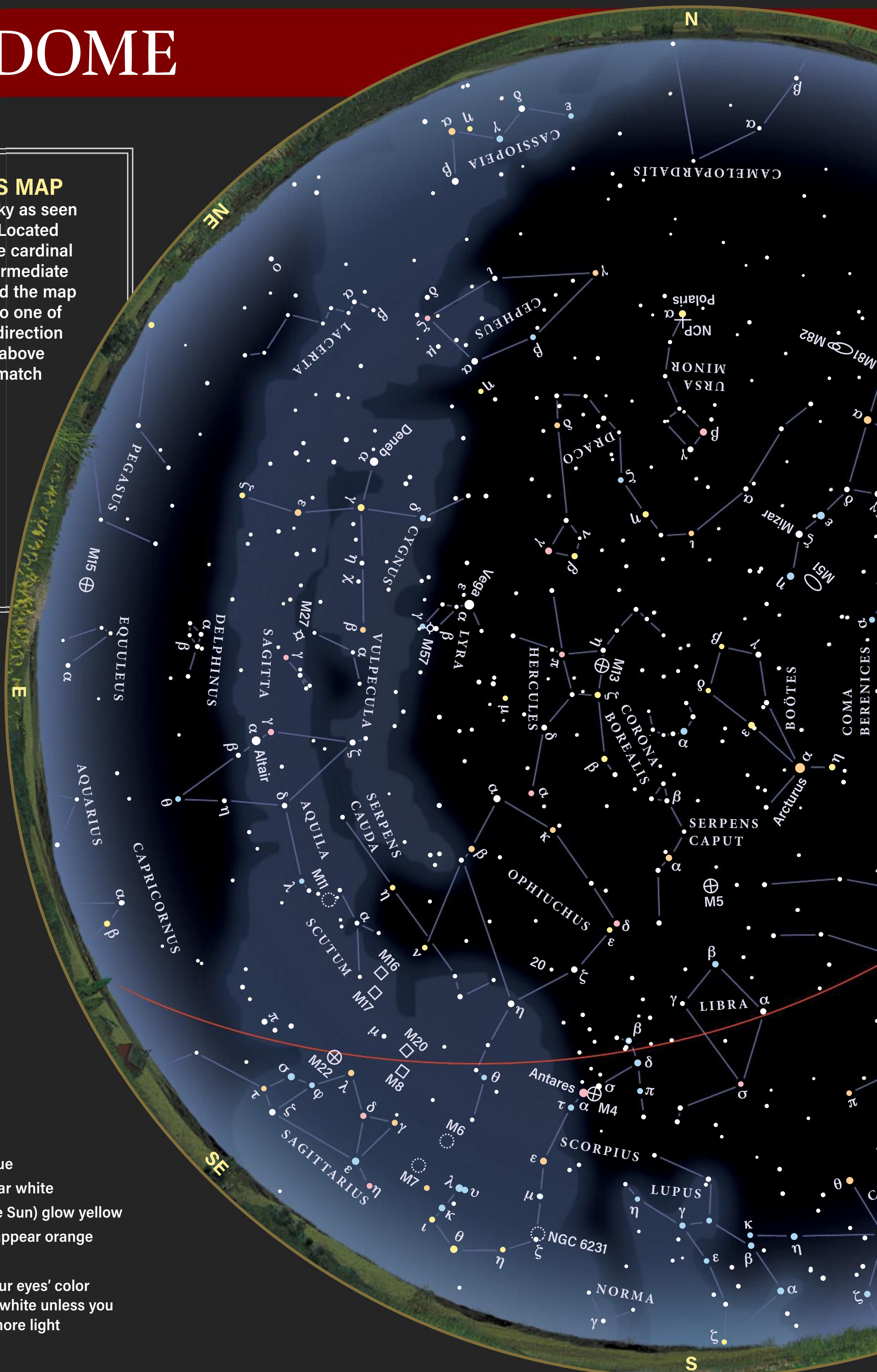
HOW TO USE THIS MAP

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:

midnight June 1
11 P.M. June 15
10 P.M. June 30

Planets are shown at midmonth



MAP SYMBOLS

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

STAR MAGNITUDES

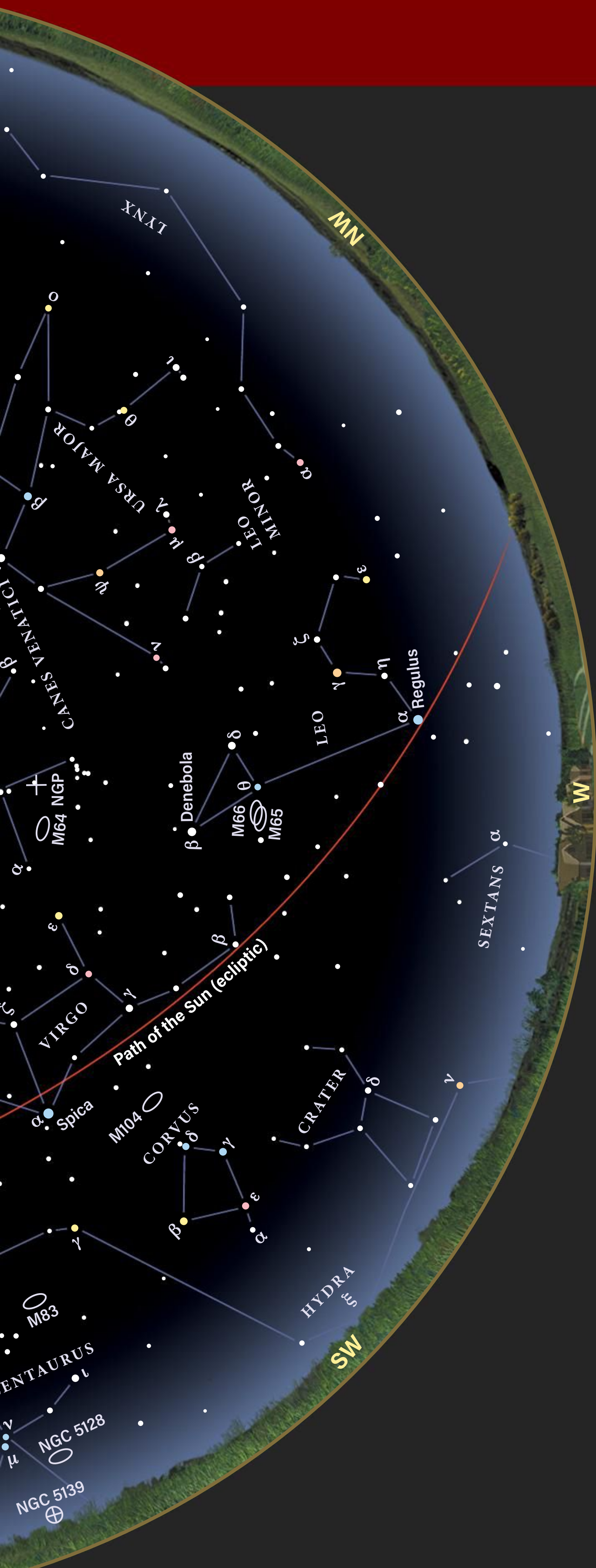
- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

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

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



JUNE 2024

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

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

CALENDAR OF EVENTS

2 The Moon is at perigee (228,728 miles from Earth), 3:16 A.M. EDT

The Moon passes 2° north of Mars, 8 P.M. EDT

4 Mercury passes 0.1° south of Jupiter, 6 A.M. EDT

Venus is in superior conjunction, noon EDT

The Moon passes 4° north of Uranus, 9 P.M. EDT

5 The Moon passes 5° north of Jupiter, 10 A.M. EDT

6 New Moon occurs at 8:38 A.M. EDT

13 The Moon passes 0.5° south of asteroid Juno, 5 A.M. EDT

14 First Quarter Moon occurs at 1:18 A.M. EDT

The Moon is at apogee (251,082 miles from Earth), 9:35 A.M. EDT

Mercury is in superior conjunction, 1 P.M. EDT

16 The Moon passes 1.2° north of Spica, 2 P.M. EDT

20 The Moon passes 0.3° north of Antares, 7 A.M. EDT

Summer solstice occurs at 4:51 P.M. EDT

21 Full Moon occurs at 9:08 P.M. EDT

23 The Moon passes 1.0° north of dwarf planet Ceres, 1 A.M. EDT

27 The Moon is at perigee (229,464 miles from Earth), 7:30 A.M. EDT

The Moon passes 0.08° north of Saturn, 11 A.M. EDT

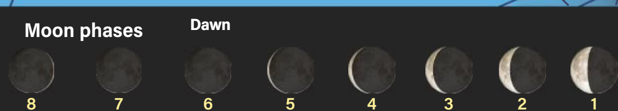
28 The Moon passes 0.3° north of Neptune, 5 A.M. EDT

Last Quarter Moon occurs at 5:53 P.M. EDT

29 Mercury passes 5° south of Pollux, 6 A.M. EDT

30 Saturn is stationary, 5 P.M. EDT

PATHS OF THE PLANETS

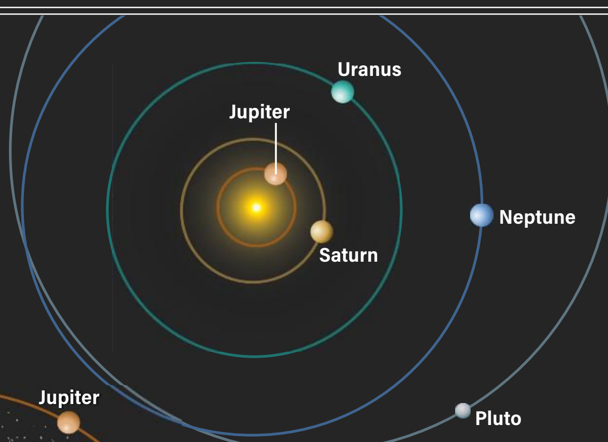


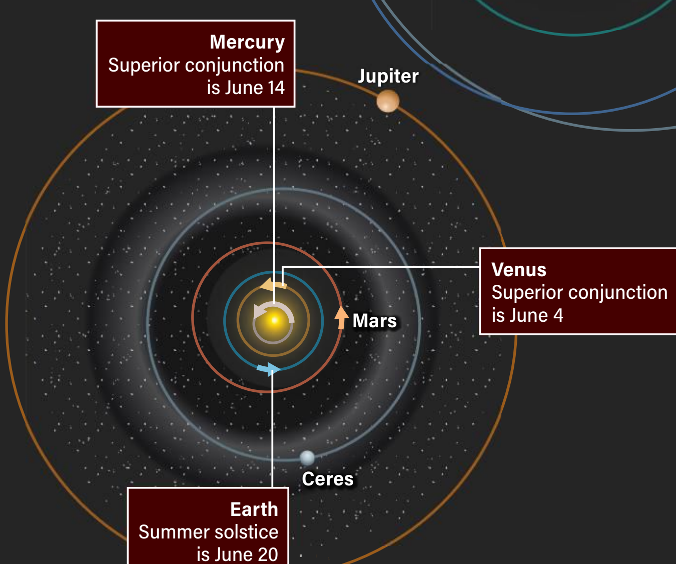
Midnight

To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.

THE PLANETS IN THEIR ORBITS

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





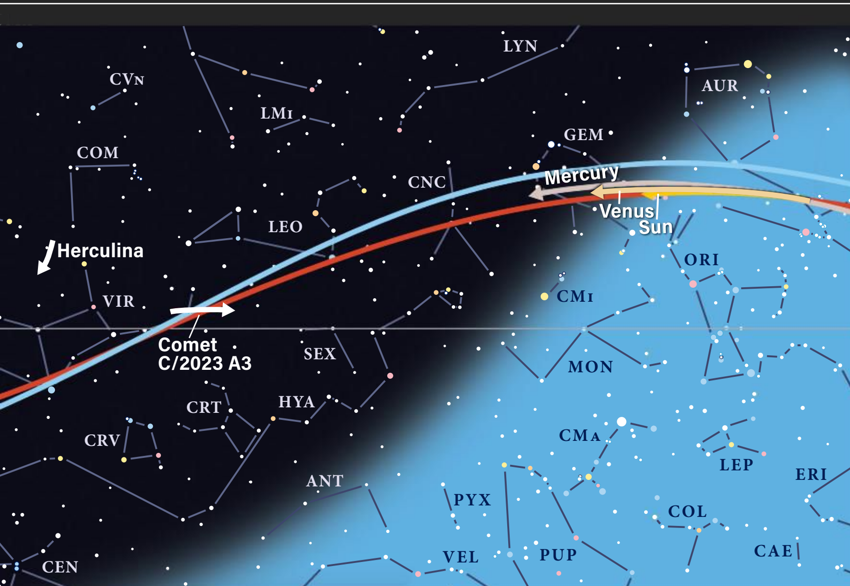
THE PLANETS IN THE SKY

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.

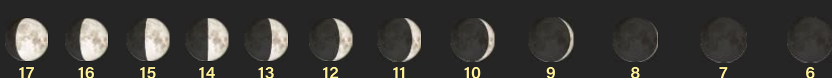
PLANETS	MERCURY	VENUS
Date	June 30	June 15
Magnitude	–0.7	–3.9
Angular size	5.6"	9.6"
Illumination	80%	100%
Distance (AU) from Earth	1.197	1.732
Distance (AU) from Sun	0.371	0.720
Right ascension (2000.0)	7h50.0m	5h46.4m
Declination (2000.0)	22°57'	23°45'

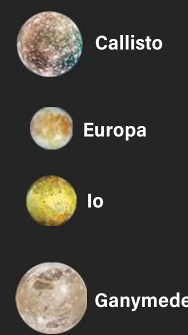
This map unfolds the entire night sky from sunset (at right) until sunrise (at left). Arrows and colored dots show motions and locations of solar system objects during the month.

JUNE 2024



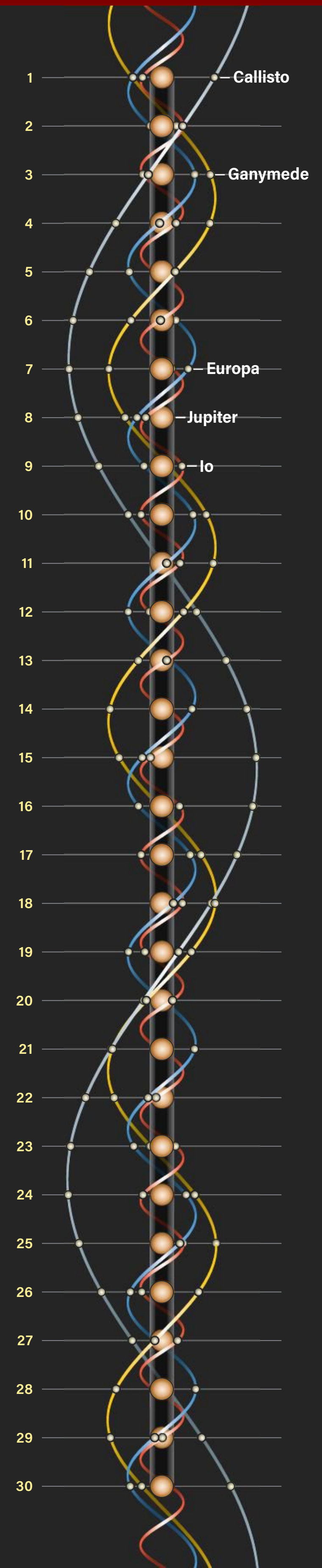
Early evening

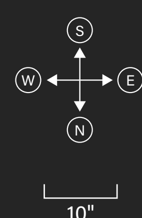


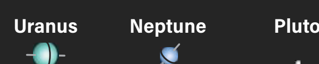


JUPITER'S MOONS

Dots display positions of Galilean satellites at 6 A.M. EDT on the date shown. South is at the top to match the view through a telescope.



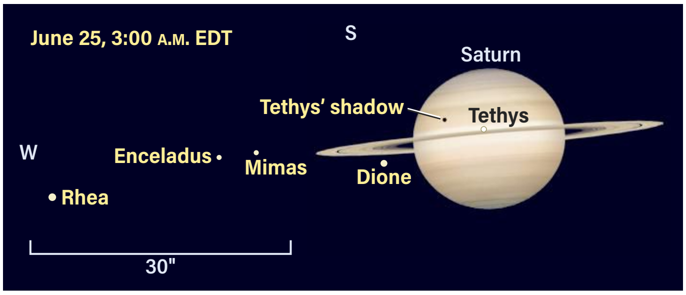




MARS	CERES	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
June 15	June 15	June 15	June 15	June 15	June 15	June 15
1.0	7.7	–2.0	1.0	5.8	7.8	15.1
5.2"	0.7"	33.0"	17.4"	3.4"	2.3"	0.1"
91%	99%	100%	100%	100%	100%	100%
1.804	1.933	5.967	9.546	20.465	29.979	34.223
1.392	2.886	5.023	9.690	19.587	29.900	35.035
2h08.4m	19h23.0m	4h09.9m	23h22.2m	3h29.2m	0h00.2m	20h17.3m
11°49'	–27°32'	20°19'	–6°09'	18°40'	–1°21'	–22°56'

 — *Continued from page 29*

Setting up



Early on June 25, Dione is closing in on Saturn; it will disappear shortly in an occultation. Meanwhile, Tethys and its shadow are transiting, with the moon appearing to just skim the southern edge of the rings.

just over 79 days to perform a complete loop. Iapetus also varies in brightness as it orbits, a result of the difference between its bright and dark hemispheres. It shines near 10th magnitude at western elongation and closer to 12th magnitude at its eastern limit. This month, Iapetus reaches its fainter eastern elongation in mid-June (the 17th), standing 8.5' from the planet.

Neptune is located about 10.5° east of Saturn and 9° southwest of the Circlet of Pisces. The 5th-magnitude star 27 Piscium is a useful guide to the 8th-magnitude planet. Scan the region with a pair of 7x50 binoculars; find Saturn and look two fields of view to its east. Look for a parallelogram of four stars in the 4th- to 5th-magnitude range. 27 Psc is the northernmost bright one; you'll find the much dimmer Neptune about 2° north-northeast of it. Neptune remains near its stationary point this month — it is moving constantly but the combined motion with Earth's orbit makes it appear to stand almost still.

If you need a brighter guide to finding Neptune, look no further than the waning gibbous Moon on June 28. Neptune rises at 12:30 A.M. local daylight time, with the Moon just to its southwest for observers in the eastern half of the U.S. At 3:30 A.M. EDT, Neptune stands 0.7° due north of the Moon. As the morning progresses, the Moon moves northeastward, so an hour later, it's west of the planet. The distance slowly increases and by dawn in the Midwest, they're just over 1° apart.

Mars is up next, rising shortly before 3:30 A.M. local daylight time on June 1. The Red Planet glows at magnitude 1.1. In the pre-dawn sky of June 2, it stands 6.5° east of the waning crescent Moon in eastern Pisces. By June 6, Mars is within 0.5° of Omicron (ο) Psc, a 4th-magnitude star that glows more than 100 times brighter than our Sun and lies nearly 300 light-years away. The star is an aging sun that appears orange in telescopes. So does Mars, although the planet's color is due to the hue of its surface dust. How do their colors compare?

Mars soon moves into Aries (on the 10th) and skips across two-thirds of this constellation by June 30. By this time, the Red Planet rises before 2:30 A.M. local daylight time Through a telescope Mars spans 5", and if you can see enough detail, note the 91-percent-lit disk. Mars is just over six months from opposition and will grow in prominence for the rest of the year.

Uranus rises next and on June 1 it's up by 4:45 A.M. local daylight time. The twilight strongly interferes. However, note that Uranus and **Mercury** are 2.5° apart, and Mercury shines at magnitude –0.9. If you can spot Mercury, try using binoculars and scan

WHEN TO VIEW THE PLANETS

EVENING SKY
Mercury (west)

MORNING SKY
Mercury (east)
Mars (east)
Jupiter (east)
Saturn (southeast)
Uranus (east)
Neptune (southeast)

COMET SEARCH | All night short

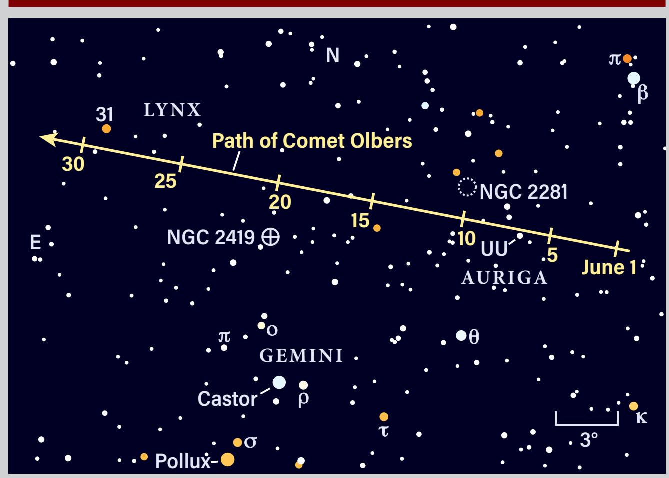
WELL BEFORE astronomical twilight ends, have your scope on Comet 13P/Olbers, low in the northwest. At 8th magnitude, it's the brightest of a trio of comets tonight — but sadly, it's quickest to set. Take in the modest star cluster NGC 2281 along the way. The two make a wide-field pairing 2° apart from the 8th to the 10th. Never seen a lynx? The sky version is just as camouflaged, so at the end of the month, use the feet of Ursa Major to close in on Olbers.

If it's too faint for the eye, the bluish ion tail may be the prize for imagers. The classic broad fan shape of the comet goes edge-on as Earth passes through its orbital plane June 17 to 18. We should be treated to an anti-tail, a trick of perspective where one of the tails appears to point back to the Sun.

Quickly slew to the south side of the Virgo galaxy cluster, already west of the meridian, to check out Comet C/2023 A3 (Tsuchinshan–ATLAS), glowing about 9th magnitude and masquerading as a galaxy.

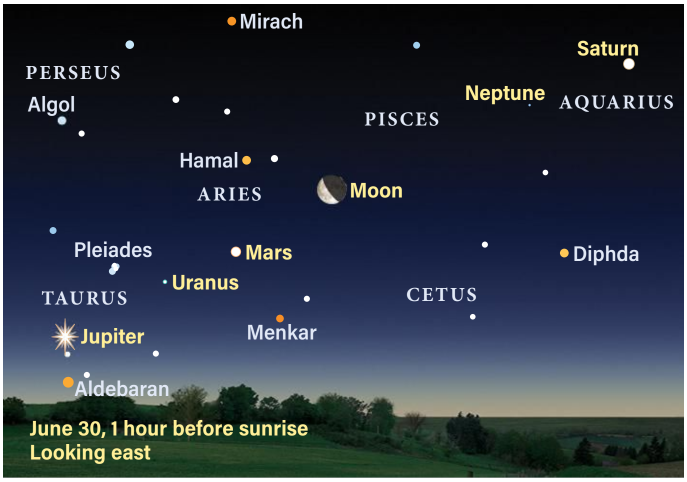
A treat for visual and observers and imagers alike, the Fireworks Galaxy (NGC 6946) and its neighboring star cluster NGC 6939 host 10th-magnitude Comet C/2021 S3 (PanSTARRS) from the 13th to 15th. This gathering may test your resolve in waiting for the Moon to set around 2 A.M.

Comet 13P/Olbers



Comet Olbers spends most of the month in Lynx. Use bright Castor and Pollux in Gemini to get you to the right region.

Giants align



At the end of the month, the Moon has returned to the morning sky. Jupiter is rising earlier and stands above the bright red giant Aldebaran. Again, note that Uranus and Neptune require optical aid to spot.

westward to spot magnitude 5.9 Uranus. This will be challenging at low elevations due to its faintness, but if you're located above 4,000 feet or so (and the higher the better), atmospheric haze is less and you'll have a good chance of spotting the seventh planet in twilight using optical aid.

Jupiter passed superior conjunction last month and reappears in the morning sky in June. Its visibility continues to improve throughout the month, rising earlier each day. On the 1st, the gas giant rises 20 minutes after Uranus and is easy to spot at magnitude –2. Jupiter and Mercury stand 5° apart, and you might even spot the Pleiades 5° north of Jupiter if you grab binoculars for viewing. The sky gets bright quickly and Uranus (and M45) will become increasingly difficult.

If you can't spot Uranus on June 1, wait until the end of the month, when the ice giant rises shortly before 3 A.M. local daylight time in a dark sky. With Mars now 10° to its west and the lovely Pleiades star cluster 6° to its northeast on the 30th, Uranus is an easier target for binoculars or a telescope.

An hour later on that date, Jupiter and Mars are low in the eastern sky, with Uranus midway between them. It's a perfect summer morning, with a waning crescent Moon standing higher in the east. Watch the sky over the following hour to see the Hyades in Taurus rising as twilight begins to roll in.

June 4 is a noteworthy but challenging date for observation, when Mercury and Jupiter are only 7' apart in bright twilight. Mercury shines at magnitude –1.1 and Jupiter at magnitude –2 so it's a bright pair, but they stand only 12° west of the Sun. Such a close conjunction is rare, so it's worth trying for. As previously mentioned, higher elevations help by reducing atmospheric haze. The farther south you are, the better the chance of seeing them as well.

Mercury sinks quickly out of view and appears in the evening sky by the end of the month, standing 6° high 30 minutes after sunset at magnitude –0.7.

Meanwhile, Jupiter continues to improve — by June 30, it rises at 3:30 A.M. local daylight time and stands 5° from Aldebaran, the brightest star in Taurus. Through a telescope its disk spans 34" and the gas giant is attended by its collection of Galilean moons: Io, Europa, Ganymede, and Callisto.

Venus reaches superior conjunction with the Sun June 4 and remains invisible this month.

The Northern Hemisphere experiences its summer solstice on June 20, when the Sun reaches its northernmost declination in the sky. This occurs at 4:51 P.M. EDT.

Martin Ratcliffe *is a planetarium professional with Evans & Sutherland and enjoys observing from Salt Lake City.* **Alister Ling**, *who lives in Edmonton, Alberta, is a longtime watcher of the skies.*

LOCATING ASTEROIDS

Look way up

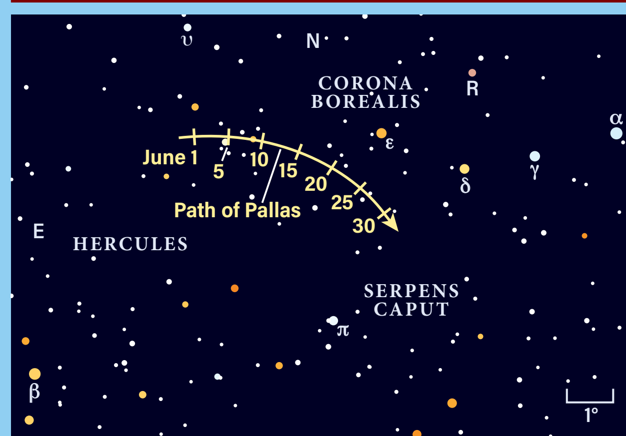
2 PALLAS IS A FAVORITE of mine — half of the time. Its orbit is tilted so much to the ecliptic (34°) that it's often too low for me, but then the asteroid vaults out of the deep south, reaching high declinations. A nice side effect is that the Moon never interferes. As a further bonus this month, it lies just east of Corona Borealis, a straightforward star-hop from magnitude 4.1 Epsilon (ε) Coronae Borealis.

Sporting a diameter of 320 miles, Pallas checks in as the third-largest rock of the main belt. Its reflectivity, or albedo, is a pretty typical 16 percent, putting this month's brightness at magnitude 9.3, just past opposition in mid-May. In four years, it'll hit magnitude 6.6 with a close approach, relatively speaking.

Let the sky do the work for you: On the 1st, center your scope on Epsilon CrB, then come back 19 minutes later to see Pallas in the center of the field. By the 14th, it's just nine minutes before the rock arrives at center stage. The best times to frame Pallas with four or five marker stars are the first week of the month and the 17th through the 21st. Each night you come back, Pallas has moved on.

To see the main-belt object shift during a single three-hour session, go for the 8th, as it closes in on a magnitude 6.6 star. The two start at a separation similar to the Double Double (Epsilon Lyrae, 3.5'), and end with a gap like beautiful Albireo (0.5').

Close to the crown



Pallas arcs just southeast of Corona Borealis this month.

STAR FORMATION IN A NEW LIGHT

JWST takes a penetrating look at stellar birth in 19 spiral galaxies.

BY RICHARD TALCOTT

ALTHOUGH ASTRONOMERS STUDY a broad range of topics, none plays a more prominent role than stars and their life cycles. The story begins deep inside molecular clouds, where gravity converts gas and dust into luminous beacons and their planetary systems. In middle age, stars can nurture any life that might develop on surrounding worlds. And once they exhaust their nuclear fuel, stars release heavy elements and energy back into their host galaxy, seeding and occasionally initiating future star formation.

It's not surprising that scientists made star formation and its role in shaping spiral galaxies a focus for the James Webb Space Telescope (JWST). The 6.5-meter instrument sees infrared radiation, which penetrates the dust that typically hides star birth from the prying eyes of optical telescopes. And no previous observatory had the infrared sensitivity and resolution to reveal details of this process much beyond our Local Group of galaxies.

JWST MAKES AN IMPACT

Astronomers released their initial findings on star formation in 19 nearby spiral galaxies in January. The spectacular photos combine observations made at eight wavelengths, ranging from 2 to 21 micrometers. Image processors mapped shorter (near-infrared) wavelengths to blue and longer (mid-infrared) wavelengths to red, to mimic human eyesight.

The near-infrared images show the sparkling blue hues of millions of stars. While some of them spread throughout the spiral arms, others congregate in dense clusters. In contrast, the mid-infrared photos reveal warm dust glowing around and between the stars.

The JWST images display stunning details thanks to resolutions of a few dozen light-years or better. The observatory sees such fine structures to distances of some 65 million light-years, which encompasses the Virgo Cluster.

Unexpectedly, the new images also reveal several large, spherical shells cut into the gas and dust. The researchers suggest one or more exploding stars created these holes.

The 19 galaxies include normal spirals, barred spirals, and ones with active galactic nuclei. They cover a wide range of masses and star-formation rates. The scientists chose only objects that appear either face-on or incline modestly to our line of sight, so that the spiral arms show up clearly.

PART OF A BIGGER PICTURE

Although the findings are important in their own right, they take on added significance when combined with observations at other wavelengths. The science team belongs to the PHANGS collaboration (an acronym for Physics at High Angular resolution in Nearby GalaxieS).

This program includes high-resolution optical images from the Hubble Space Telescope, optical spectra gathered with one of the 8-meter mirrors of the Very Large Telescope (VLT), and observations of carbon monoxide emission from the Atacama Large Millimeter/submillimeter Array (ALMA). Because the VLT and ALMA both reside in Chile, the 19 galaxies all lie in the southern sky or at low northern declinations.

This initial JWST release is just the tip of the iceberg. The team already has started observing 55 additional nearby spirals. When all is said and done, the PHANGS team will have produced the first complete set of high-resolution data that covers all key stages in the life cycles of stars at the universe's current age.

TOP LEFT: The Phantom Galaxy (M74) in Pisces explodes with detail when observed with JWST's infrared eye. Warm dust glows orange in this view, while old stars near the galactic center appear blue. Also notice the large spherical shell to the upper right of the galaxy's core. Astronomers suspect one or more supernovae excavated this hole and the many others JWST uncovered. M74 is a nearly face-on spiral located 32 million light-years from Earth. ALL IMAGES: NASA, ESA, CSA, STSCI, J. LEE (STSCI), T. WILLIAMS (OXFORD), PHANGS TEAM

TOP RIGHT: In sharp contrast, warm dust appears brownish in Hubble's visible-light view of M74. Notice how these dark lanes obscure a lot of the fine details JWST sees in star-forming regions.

LEFT: The barred spiral galaxy NGC 1672 in Dorado shows lots of fine structures to JWST's infrared sensors (top). The orange glow comes from dust that has absorbed starlight and then re-emitted it at longer wavelengths. Hubble's view of NGC 1672 in visible light (bottom) gives a clearer picture of the spiral's barred structure. NGC 1672 lies 60 million light-years from Earth.

Contributing Editor **Richard Talcott** *wrote about JWST's observations of Herbig-Haro object 797 in the May issue.*

Outside of Ann Arbor, MI

Chasing nightscapes

STORY AND PHOTOS
BY ADRIAN BRADLEY

Nothing captures our place in the cosmos like a wide-field shot of the Milky Way suspended above softly lit terrain.

Kenton, OK

ABOVE: The Orion Arm hangs in the sky over the Okie-Tex Star Party in this two-minute exposure taken at ISO 3200. All images were shot with an astromodified Canon EOS 6D and 16–35mm f/2.8 zoom lens unless otherwise noted.

LEFT: The "steam" of the Milky Way rises from the teapot asterism in Sagittarius. This is a composite of two 2-minute shots — one tracked exposure for the sky and another for the ground — taken at ISO 800.

SEVERAL YEARS AGO, I decided to drive somewhere dark enough to see the Milky Way with the naked eye. Something had rekindled my curiosity of the heavens, and I wanted to see them for myself. So I picked a reasonably dark and clear night and drove out to an area outside of Ann Arbor, Michigan.

When I began to see more stars in the sky, I figured I had reached a location that was dark enough. I stopped by the side of the road near a cornfield, got out, and looked toward the south.

I found the constellation Sagittarius, its brightest stars forming the asterism of a teapot — and I could see "steam" pouring out of it. There it was, the Milky Way! I felt a sense of accomplishment having seen it with the naked eye.

Ever since, I've been a student of our galaxy, striving to capture the Milky Way in photographs the same way I saw it that night outside Ann Arbor, arcing across the sky above the land. These wide-field shots that incorporate the landscape and the sky above — sometimes called nightscapes — are one of the most accessible ways to get into astrophotography.

I began sharing them with others who had a passion for the sky, joining a group of avid amateurs in Ann Arbor called the University Lowbrow Astronomers. Back then, the Lowbrows were primarily a group of long-time visual astronomers, but I and a few others started presenting more astroimages to the group. I was hooked!

Shooting nightscapes allows you to get to know our galaxy. Sagittarius is home to the bright galactic center, but there are many other regions of the Milky Way that are just as interesting to target.

Why I shoot wide-field

Classic astrophotography, as I like to call it, focuses on one or more objects in space as seen from our vantage point. They are beautiful, but they are isolated images. I prefer wide-angle vistas for two reasons: First, by seeing the entire picture of that region in space, I can appreciate just how large and vast these regions are.

And second, I can add a part of our own planet to the photograph to indicate that we are a part of this universe, and that our vantage point from Earth is unique. If there is life similar to us on other worlds, their images will not contain our landscapes nor our human-made structures.

For instance, take the picture above. It speaks to why I like doing wide-field images. Orion is rising at the bottom of the frame. Most

RIGHT: The Milky Way rises over the Point aux Barques Lighthouse on Lake Huron. The two-minute sky and ground frames of this composite were taken at f/2.8 and ISO 1600.

BELOW: A chance meteor appears in this nightscape taken from the dark-sky preserve at Lake Hudson in Michigan. This shot is a single 20-second exposure taken at ISO 6400 with a Tamron 17–35mm lens at 17mm and f/2.8.

Clayton, MI

Kenton, OK

In very dark skies, the Milky Way can appear to shine in nautical twilight as clearly as it does during astronomical darkness in more light-polluted skies. This shot is a single 30-second exposure taken at ISO 3200.

astroimages from this region are close-ups of one or more objects. But in this wide-angle nightscape, we can see dust lanes and bright clusters, and get an overall view of what this galactic arm looks like from our point of view. For instance, the Rosette Nebula (NGC 2237–9/46) is a pinkish blob just above the horizon. Close-up photographs make this large emission nebula look impressive, but you get a sense of scale when you capture its light among all of the larger structures near it along our line of sight.

Also consider the California Nebula (NGC 1499) and the Pleiades (M45) at the upper center of the photograph. In a wide view, it's clear that these objects lie next to a lot of dust and gas. But an astrophotographer shooting those objects in close-up might easily mistake the galactic dust and gas for noise or an unwanted artifact, and remove it. If they were to look at this wide-field image and realize just how close those objects are to the Orion Arm, they would understand that they weren't getting noise or artifacts at all, but close-ups of the Milky Way. In fact, astrophotographers have now realized that there is galactic dust and gas everywhere we shoot in the night sky, and are "discovering" structures that were always there but never imaged as the main target.

Planning nightscape shoots

I often read social media posts or receive direct messages from fellow photographers who tried nightscape photography for the first time. They were going to be at a dark site and figured they would capture the Milky Way. But things don't always go to plan. Sometimes they are clouded out. Other times, they've chosen a time when the Moon is Full or nearly Full in the sky.

Photographing the Milky Way comes with challenges

Port Hope, MI

that may be new to those with a daytime-photography background. The Milky Way moves with the night sky and, at certain times and places, can be nearly impossible to image without specific equipment. And you can't shoot it through clouds, either — although, if you know what you're doing, you can use clouds to frame the Milky Way in your composition.

What I've learned from my years capturing the night sky is to plan, plan some more, and then have a backup plan. The following is a good checklist for planning a Milky Way imaging session in a dark sky.

First, know the lay of the land where you will be photographing and get comfortable with being there in the dark. I'm a solo imager, but bringing a friend is not a bad option. If you don't know the area, visit it during the daytime first.

Use software to plan how you want your shot to look. The smartphone and tablet app PhotoPills is popular with photographers, and planetarium apps like SkySafari work well, too. Keep in mind that the sky will rotate through the night, from sunset to sunrise. This determines the time that you should be at your location to take a shot. In the image at left, I was shooting around 4 A.M. because I wanted to capture the rising of the Milky Way core behind the lighthouse museum, gift shop, and caretakers' quarters, which were all a part of my foreground target. If I had shown up too early or too late, I would have missed this composition.

One more resource you will need is a weather app to tell you how cloudy it's going to be at the site you want to photograph. A general weather app like the Weather Channel's is a good start, but there are others specifically designed for astronomers, like Clearskychart and Astrospheric. Another one I use is SpotWX, which has proven to be very good at predicting various types of cloud cover; it even shows when there will be clearings. I've often taken advantage of that information to gather a single shot amid otherwise cloudy skies.

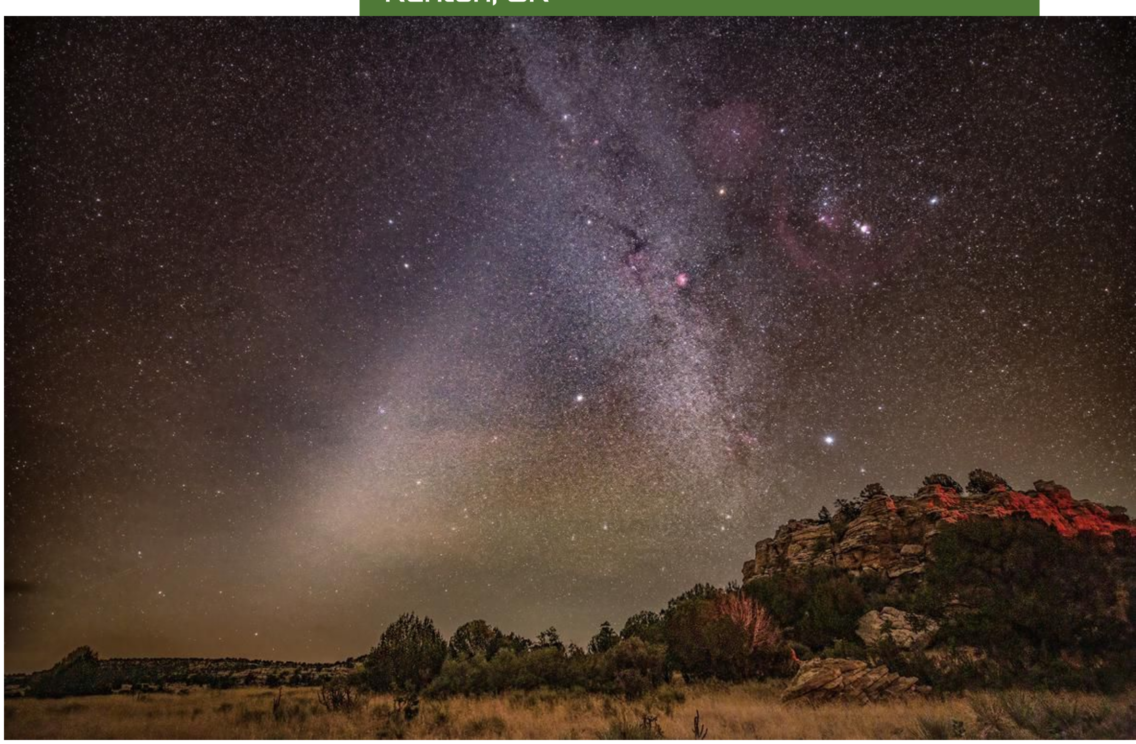
Beyond that, you'll also need to be prepared for unexpected fortunes — good or bad. You may encounter circumstances that will either ruin your shoot or make it very unique.

One example of the unexpected is the image on page 40 at top left, which I acquired early on in my nightscape photographic journey. I noticed that night that there were meteors appearing here and there across the sky, and I'd hoped to get at least one streaking through a Milky Way shot. Well, I saw one go by — right below one of my shots, out of frame. It upset me a lot! I turned the camera back to the galactic bulge, started an exposure, and walked off frustrated.

Then someone I was imaging with asked, "Hey, did you see that meteor?" I asked him where he saw it, heard my camera click as the shutter snapped closed, and when he pointed in the direction my camera was facing, I went to check the picture. I saw a raw version of the image you see printed here. I was thrilled!

Another example is at the bottom of page 40. The first time I went to the Okie-Tex Star Party, held every year at the western tip of Oklahoma's panhandle, I was blown away by the sight of the galactic center glowing brightly in nautical twilight — well before night had fully fallen. I was also blown away by the fact that when Orion rose, the zodiacal light rose with it (below), intersecting the Milky Way and creating an X

Kenton, OK



The zodiacal light crosses the Orion Spur in this image taken at the Okie-Tex Star Party. This scene is a composite of two-minute sky and ground exposures taken at ISO 1600.

Clayton, MI

Cameras can be modified to increase their sensitivity to certain bands or wavelengths of light, like Hα. This composite of two-minute sky and ground exposures was taken with such a camera at ISO 400, and reveals clouds of hydrogen gas set aglow by the radiation of young, forming stars.

in the sky. All of this goes to show that while there's no substitute for preparation, it also pays to be flexible.

Packing light

I try to keep my equipment light for night-sky imaging. I own both a Canon EOS 6D DSLR and a Sony A7R4 mirrorless camera; both are full-frame cameras. The Canon camera is modified to be more sensitive to Hydrogen-alpha (Hα) light. Deep-sky targets emit light across the electromagnetic spectrum, and nebulae, in particular, emit in Hα. Our naked eyes can't isolate that wavelength, but a modified or filtered camera can. In the image above, note the red nebulae visible along the plane of the galactic center.

In addition to a full-frame camera body, I use:

- A wide-angle lens that can shoot at f/2.8 or faster.
- A sturdy tripod. (Mine is made of carbon fiber.)
- A tracking mount like the Sky-Watcher Star Adventurer or the Move Shoot Move rotator. This allows you to take longer exposures of the night sky for composite shots, revealing more detail in the Milky Way. I find that a two-minute exposure gets pretty good results.
- A way to trigger the camera remotely so that you don't disturb and shake the camera by pressing the shutter button. You can use a wired connector or, in a pinch, use the delay setting for your shutter so that the tripod and camera are sitting still before it begins the exposure. But the best way is to use a remote shutter with an intervalometer. That way, you can take a number of shorter exposures and stack them later with software like Starry Landscape Stacker.
- Software packages to process the images. I use Adobe products (Lightroom and Photoshop), as well as Topaz DeNoise AI. The thing to remember about nightscapes is not to get overzealous with processing, and make sure you don't process away your landscape.

Other favorite targets

Sometimes, you can lose patience waiting on skies to clear and an opportune time to image any part of the Milky Way that you can get. But the night sky can be beautiful in other ways, and I like to challenge myself to capture what I see, especially with the Moon involved.

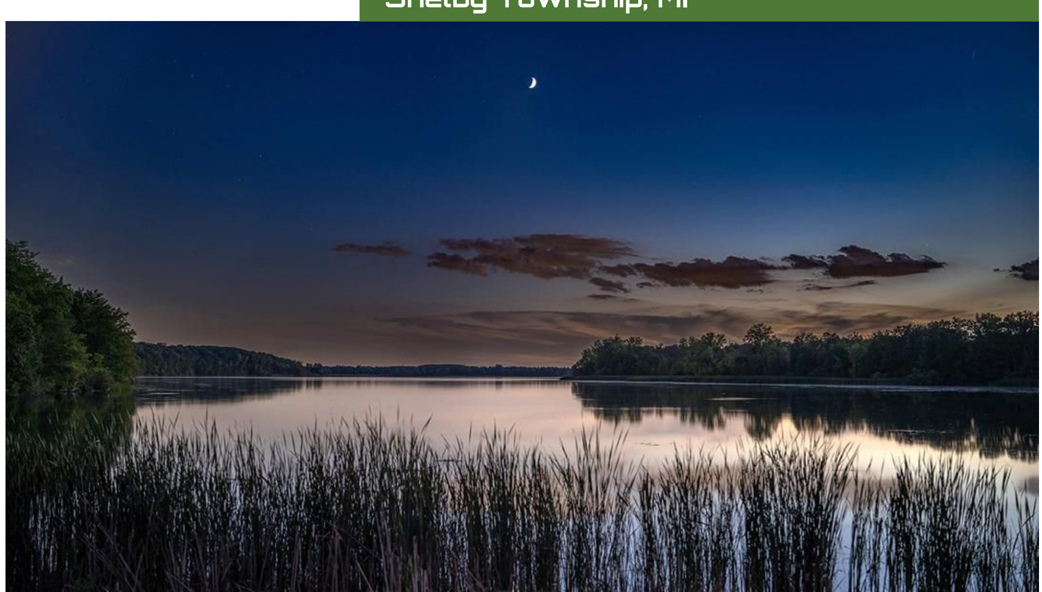
Moonscapes are more difficult because the Moon is so bright, while everything else is relatively dimly lit. But it can be done (see below).

Light pillars are rare and you have to be at the right place at the right time, when there are ice crystals in the air. But when you capture it, it makes for a magical night (top right).

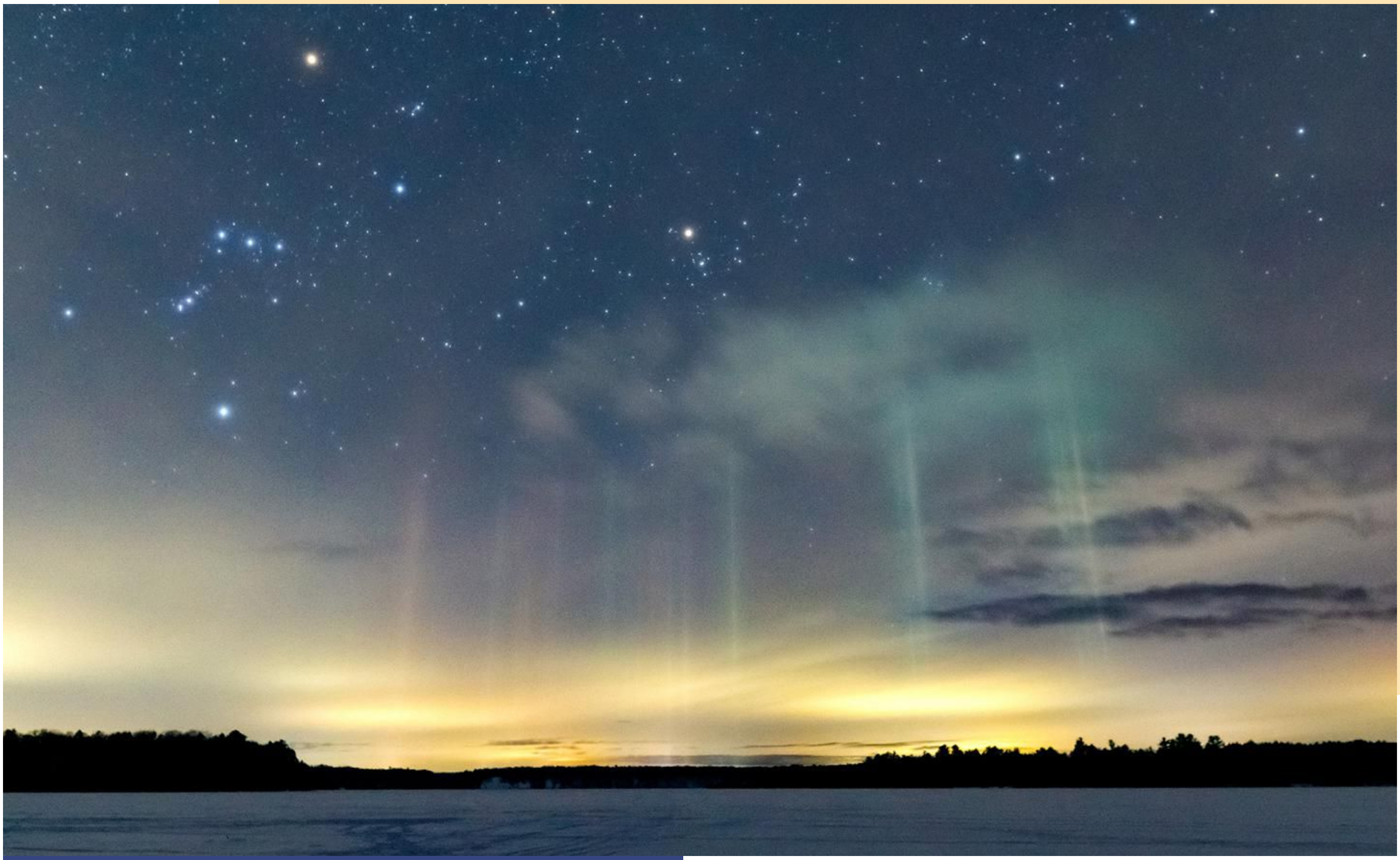
It's easy to mistake light pillars for aurorae, but once you capture real aurorae, you instantly see the difference (middle right).

Finally, there is an often-overlooked way to shoot the

Shelby Township, MI



A crescent Moon lies above Stony Creek Metropark in Michigan. This shot is a single five-second exposure taken with a Sony A7R4 at ISO 100 and a 35–150mm zoom lens at 35mm and f/2.



Glennie, MI

ABOVE: Light pillars appear in the winter sky above a nearby town in this winter scene in northern Michigan. The phenomenon is due to ice crystals in the atmosphere that reflect light. This 20-second exposure was taken with a Sony a6000 mirrorless camera and 16mm prime lens at f/2.5 and ISO 6400.

MIDDLE: The glow of the aurora borealis dazzles over Lake Huron in this shot taken from Pointe aux Barques Lighthouse park. This shot is a single 30-second exposure taken with a Tamron 17–35mm zoom lens at 17mm and f/2.8 and ISO 6400.

BELOW: The glow of dawn creeps above the horizon in this image taken from Port Sanilac Roadside Park, overlooking Lake Huron, during nautical twilight. The shot is a 30-second exposure at ISO 6400.

Port Hope, MI

Port Sanilac, MI

Milky Way itself, and that's at the start of nautical twilight, an hour or so before sunrise. Once it begins, you have about five minutes to image a fading Milky Way before it gets washed out by the oncoming Sun (bottom right).

I believe timing an image of the Milky Way at sunrise or even moonrise is harder than a sunset or moonset. That's mainly because with sunrises, you are losing your target by the second and must make sure everything goes right with your capture or you will miss it. Of course, the darker the site, the more time you have to acquire the shot.

My astroimaging journey has cost me a lot of sleep, not to mention time spent traveling long distances and taking photos that didn't come out before I got to a point where most of them do. But there's no better way under a dark sky to get to know the Milky Way, the galaxy that we call home.

Adrian Bradley *is a wide-field and landscape astrophotographer based in Ann Arbor, Michigan.*

Explore the sky with Celestron's autoguider

Celestron's state-of-the-art StarSense Autoguider (SSAG) can be mounted on many brands of telescopes. A compatibility list is available on Celestron's website. CELESTRON

The new StarSense Autoguider is a capable companion for astrophotographers. BY FRANK DIBBELL

PERHAPS YOU HAVE always wanted to try astroimaging, but were intimidated by the technical aspects, the equipment requirements, the level of expertise needed — you know, the works. The hardware requirements alone can be daunting for the novice. Luckily, Celestron has now made leaping into this endeavor a lot easier for a beginner with their StarSense Autoguider (SSAG).

Celestron has integrated their highly successful StarSense technology into a small telescope and digital camera. It's a compact and powerful piece of equipment that performs two essential functions for successful imaging: precise alignment and accurate tracking using a guide star (referred to as autoguiding).

With this equipment plugged into your Celestron mount or computerized telescope, you can easily polar align or star align your mount and precisely slew to any object in the supplied database. (You can check compatibility at www.celestron.com/products/starsense-autoguider.) You can then command the telescope to center on any desired star in your field of view, thus making your telescope ready for imaging.

Alignment: Smooth sailing

The SSAG comes ready for installation. All you need are the two provided Phillips screws to attach the bracket base to your scope. The bracket — which is pre-installed on the SSAG — can simply slide into the base. Plug one end of the auxiliary cable into the back of the SSAG unit and the other into the AUX port of your mount, and you are ready to go.

Once I installed the SSAG, it was time to delve into the manual to understand how to operate the SSAG's functions and how they work. I admit, I was left a tad confused; perhaps in the future, Celestron could include a one-page quick-start guide for an easier setup.

Fortunately, it turns out that either the hand control or Celestron's PlaneWave Instruments (CPWI) Telescope Control Software (available as a free download for Windows PCs) will walk you through the process of configuring the SSAG settings. And if you have prior experience with a Celestron mount, you will find the setup very easy. I still do recommend a good read through the manual, just to gain the basic understanding of the functions.

Before starting up your system, you should check the firmware version you are running and follow the manual's instructions for any future updates. The SSAG can be used in one of three ways: 1) with the Celestron hand control; 2) with the CPWI software; or 3) if you have a SkyPortal Wi-Fi module, you can also use the SkyPortal app for operation.

When using the hand control, you will need some basic information before starting the initial alignment procedure: your location in latitude and longitude, and the current time. The hand control will store it so you don't need to enter it again, unless you change locations.

Next, simply follow the controller's suggestions. The polar-align process is next, and is optional. This step slightly improves the overall pointing accuracy by a few arcminutes. The SSAG does not require accurate polar alignment to function, thanks to the StarSense technology (a plate-solving software). But if you do choose to polar align, the mount will automatically select several stars near the pole and perform the method of plate solving required to determine exactly where the scope's line of sight is pointing to in the sky. If a star is blocked or otherwise not visible, the routine will automatically choose another. I really appreciate this ability, which holds for star alignment as well.

Once the pole position has been determined, the hand control displays the mount's offset in altitude and azimuth and allows you to adjust each in turn by displaying an easy-to-follow linear baseline with a zero point in the center and +/- values to the right and left. If you are correcting for azimuth, simply turn the azimuth knobs and watch the real-time offset values change. When the azimuth adjustment is complete, the hand control will prompt you to do the same with altitude. It's highly convenient — there's no need to crane your neck trying to peer through a polar scope!

Once polar alignment is complete, the hand control will prompt you to do a sky align — I recommend choosing the auto-align process and letting the telescope do the work for you. When that's complete, the hand control will ask if you want to do a center calibration so SSAG can accurately place objects in your field of view.

With alignment done, you can begin one of the most exciting parts of astroimaging: choosing your target. Simply type and select the object's name, and the mount will slew to center on it. Then, go to the SSAG menu on the controller screen and turn the "Autoguide" setting on; you can now image. I should note that autoguide stays on until you either turn it off manually using the controller, or you slew to a different object, which will turn it off automatically.

Imaging with the SSAG

Imaging with the hand control only and no computer (not needed for operation) is perhaps best suited to using a DSLR or mirrorless camera. However, If you are using a computer to control a CCD or CMOS astroimaging camera, you will want to use the CPWI software instead of the hand control. Aligning the mount through CPWI is easier than using the controller. If it's the first setup, you'll still need your latitude, longitude, and time. CPWI will prompt you through the steps for alignment and center calibration.

The CPWI program is more advantageous in that it provides you with several things the controller cannot, such as a fullscreen star map showing the current pointing position of the telescope. To change targets, simply use the cursor on the map and click on that object. In addition, CPWI also provides a graph showing the guiding corrections the SSAG is sending to the mount — a nice feature to monitor while imaging.

CPWI is also Astronomy Common Object Model (ASCOM) compliant. This means the program can bridge the mount to other ASCOM-compliant programs. I had my Celestron Advanced Vector Extensions (AVX) mount simultaneously connected to both CPWI and another CMOS program for camera control.

The reasoning behind controlling a mount from two different apps is that some imaging functions, such as dithering (automatically shifting the frame a pixel or two between exposures so that when you stack the photos, the stars will align but the background noise will not), are only performed by camera control software. Alas, when the mount slews a pixel or two for dithering, CPWI shuts off the SSAG autoguider function, so dithering is not yet supported. (At the time of this writing, dithering functionality for CPWI is in beta testing.)

The star cluster NGC 281, captured in Hα using the SSAG, is located 6,500 light-years from Earth and is known as the Pacman Nebula, due to its mouthy appearance. FRANK DIBBELL

PRODUCT INFORMATION

StarSense Autoguider
Type: Double-Gauss mini-guide scope
Focal Ratio: f/4.3
Focal length: 120 mm
Sensor size: 6.46 mm
Dimensions: 8.5 inches by 4 inches
Weight: 2.92 pounds (1.3 kg)
Price: $799.95
Contact: USTechSupport@celestron.com 1-800-421-9649

Testing it out

I tested the SSAG on a small platform that a novice imager might own: a Celestron AVX mount and a Celestron C6 Schmidt-Cassegrain telescope. Setting the system up in my backyard, which contains enough trees to give the polar and star alignment procedures a good test, I used the hand control to polar align. Several stars it chose were blocked by my house, but it continued selecting alternates until it had enough.

Then I did the automatic sky alignment. Again, several stars were blocked, but the system selected alternate stars and successfully completed its task. The controller then suggested a center calibration (which aligns SSAG's field of view with that of your scope), which I did. After only 10 minutes, I was ready to image.

I chose the Pacman Nebula (NGC 281), as it was high in the sky and not obstructed. The mount veered and centered on the object. I went to the SSAG menu, turned autoguiding on, and ran a series of 10-minute exposures with a Hydrogen-alpha (Hα) filter on my CMOS camera. The C6 has a focal length of 1,500mm; that's probably a good deal longer than a novice imager should take on, but was a good test for the SSAG.

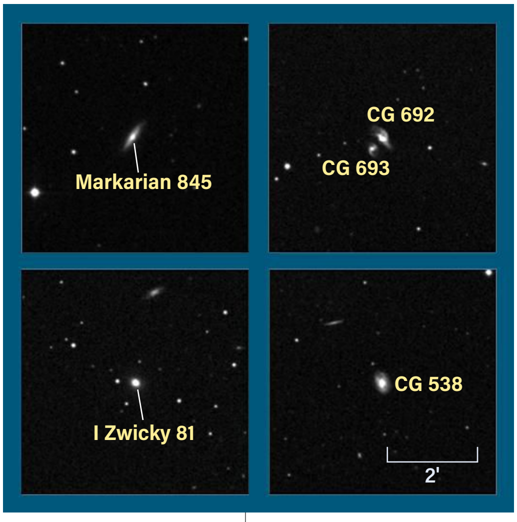
I was very pleased with its performance over a two-hour session where I captured 12 exposures. The slight differential flexure over each 10-minute exposure did result in a several-pixel shift between images, thus providing me with the dithering I needed without unduly affecting the star geometry.

I am confident that the Celestron StarSense Autoguider is a superb, state-of-the-art tool for bringing ease to an otherwise complex task and encouraging astrophotography newcomers. Even if you're a more seasoned imager, I still recommend the SSAG for its simplicity when it comes to field setups. Autoguiding is now as effortless as the push of a button or the tap of a screen.

Frank Dibbell *is an avid imager and docent at the local community observatory in Placerville, California.*

Into the Void

Find the few galaxies afloat in a cosmic ocean of nothingness.



Four "bright" members of the Boötes Void hover around 15th magnitude. Each field measures 5' on one side. DIGITAL SKY SURVEY

Usually I don't write much about deep, "holy grail" objects, but for the Boötes Void, I'll make an exception. Specifically, I'm wondering what's the smallest telescope needed to see the galaxies in the Boötes Void. If that sounds like an oxymoron — seeing something in a void — it's not.

Originally known as the Great Nothing, the Boötes (pronounced "boo-OH-teez") Void is an immense volume of galaxy-lacking space. Robert Kirshner, currently the executive director of the planned Thirty Meter Telescope, and his colleagues discovered this massive nothingness in 1981 while mapping galaxies to help determine the large-scale structure of the universe. Galaxies are visible building blocks for this large-scale structure, which we now know is a vast cosmic web. They gather in groups, clusters, and superclusters, and under the influence of dark matter arrange themselves in twisting, threadlike structures called filaments. Between the filaments lie gaps that contain few galaxies, as if they were on the surface of cosmic bubbles.

The Boötes Void is one of the largest gaps, or voids, known — classified as a supervoid and spanning some 300 million light-years. In this amount of space, astronomers would normally expect to see a few thousand galaxies. But to date, the Boötes Void has revealed only a couple of handfuls.

As seen on the two-dimensional dome of the sky, the void is a circle roughly 25° across and centered at R.A. 14h50m, Dec. 46°0', very close to the 6th-magnitude star 38 Boötis. On many star maps, you'll see some two dozen or more galaxies within this circle that shine at magnitude 13 or brighter, including the grand face-on Pinwheel Galaxy (M101) and its companions in Ursa Major, along with the magnificent Splinter Galaxy (NGC 5907) in Draco. But these objects are all relatively nearby, within a couple of hundred million light-years from Earth, whereas the Boötes Void lies much farther away, some 700 million light-years distant.

Despite its distance, the Void itself contains several galaxies within range of amateur-sized telescopes. Below you can find descriptions of four Boötes Void galaxies that are among the brightest and most condensed. Their descriptions and magnitudes (ranging from 15 to 16), are from the 1977 study "Photometry of Galaxies in the Boötes Void" in *The Astronomical Journal*.

Between the filaments lie gaps that contain few galaxies.

The objects I've selected have bright cores. So, for those using telescopes on the lower end of the large-scope scale, you may have to look for an almost stellar-like object. On the other hand, these galaxies should be a cinch for astroimagers or those with larger scopes.

1. The brightest member of the Void is Markarian 845 (R.A. 15h07.7m, Dec. 51°27.2'). Shining at magnitude 14.8, this nearly edge-on system (oriented northwest to southeast) is about 1' in length and has a very bright nucleus. Some imagers may detect a knotlike feature south of the nucleus off the elongated disk, though it is not known whether this feature belongs to the galaxy. The northwestern segment of the disk also displays some irregularities that may be indicative of spiral structure.

2. CG 692 (R.A. 15h21.1m, Dec. 50°40.3') is the brighter member of an interacting galaxy pair. This magnitude 15.2 spiral appears elongated at about 0.7' in length and is oriented northeast to southwest. CG 692 comprises a bright, complex nuclear region and a deformed spiral arm to the north of the brilliant bulge, which is suspected to have resulted from the interaction with its Seyfert 1 companion (CG 693) to the immediate southeast. This companion is a nearly face-on spiral with S-shaped arms emanating from opposite sides of the nucleus.

3. CG 538 (R.A. 14h46.4m, Dec. 43°49.9') is a compact magnitude 15.3 system with a bright elliptical nucleus in a tight elliptical disk with faint traces of asymmetrical spiral structure: two stubby arms to the north and a faint wisp arcing to the southeast. Visual observers will likely be searching for an almost starlike system only about 0.5' across.

4. I Zwicky 81 (R.A. 14h08.2m, Dec. 48°51.7') is a largely featureless magnitude 15.3 disk galaxy. Only the bright lenticular nuclear region is generally resolved well in images. However, Palomar Sky Survey images reveal mere traces of a faint disk. So, this target is a definite point source for visual observers.

Remember that galaxy magnitudes may not be totally reliable on the faint end, so some may appear brighter visually than listed. I suspect that Markarian 845 may even be seen with a decent 10-inch scope under very dark skies. As always, be sure to send notes on what you see or don't see to sjomeara31@gmail.com.

BY STEPHEN JAMES O'MEARA
Stephen 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**

Image like Hubble

Narrowband filters are the key to Hubble's famous color palette.

I captured the Eagle Nebula (M16) at the 2019 Texas Star Party using a borrowed SBIG STF-8300M and Baader 8nm Hα/OIII/SII filters on my Takahashi FSQ106N. Recognize those pillars at the center? MOLLY WAKELING

Since the early 1990s, the Hubble Space Telescope has captured breathtaking images of tens of thousands of celestial objects, inspiring a generation of professional scientists and amateur astronomers. Some of its most captivating images are of nebulae like the famous Pillars of Creation at the heart of the Eagle Nebula (M16), rendered in vibrant greens, blues, and golds. While observing these same objects through a telescope's eyepiece does not deliver as fantastic a view, astrophotographers can capture Hubble-like shots using a special set of filters and some careful post-processing.

Wideband vs. narrowband imaging

Wideband filters, such as LRGB filters for monochrome cameras, pass broad swaths of the optical spectrum, covering red, green, and blue as our eyes see them. Narrowband filters, on the other hand, zoom in on a narrow slice of the spectrum a few nanometers wide, centered around specific emissions from energized gases found in space.

Narrowband filters zoom in on a narrow slice of the spectrum.

The three most common narrowband filters are Hydrogen-alpha (Hα), Oxygen-III (OIII), and Sulfur-II (SII). The numbers and Greek letters used with the element names are associated with specific energy transitions of the electrons in the atom, which correspond with specific wavelengths of light. Hα emission is at 656.28 nm, or deep red; OIII is actually a doublet (two related, nearby spectral lines) at 495.9 and 500.7 nm, which is a blue-green; and SII is at 672.4 nm, also a deep red.

Because both Hα and SII are shades of red, the Hubble image creators decided to assign false colors to these emissions to visualize them in an appealing way: SII, being the longest wavelength, is assigned to red; Hα, having the next-shortest wavelength, is assigned to green; and OIII, having the shortest wavelength, is assigned to blue. This color assignment is known as the Hubble palette.

Astrophotographers can also create Hubble-like images by using these narrowband filters. An added bonus is that narrowband filters cut nearly all light pollution due to their narrow bandpass, making them a great asset when imaging under city lights.

Balancing color

Since hydrogen is by far the most common element in the universe, simply assigning these colors without any further adjustment would result in a very green and unappealing image. Instead, one must tweak the relative strengths (or weights) of each color and their tones to create a beautiful final photo. Beauty is in the eye of the beholder, and every astrophotographer will process their images differently, but there are some common themes to keep an eye on while working on the color balance.

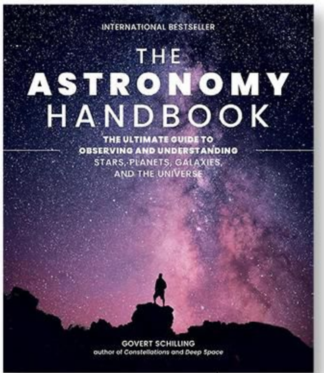
First of all, don't completely remove all of the green! Green is an essential component of other colors, such as teal and yellow. Eliminating all green makes for a boring, two-tone blue and orange image, a trap into which many astrophotographers fall. If you look closely at Hubble images such as the Pillars of Creation or the Crab Nebula (M1), you will see plenty of green mixed in, which gives the astroartist a richer palette of colors to work with.

Second, color balancing is an iterative process. Rather than just adjusting red, green, and blue in turn, use color masks to focus on specific swaths of the color wheel, adjusting the shadows, midtones, highlights, and vibrance/saturation. Then, come back to those colors and tweak them as you adjust other colors. In PixInsight, I use the updated ColorMask tool to isolate a specific segment of color, and then adjust the red, green, and blue components of that color, as well as the vibrance (c component) and saturation, using CurvesTransformation. I know an image is complete when I achieve a specific shade of teal-cyan for the blues and gold that fades to red, and the image seems to pop out of the screen. It takes time to perfect, but the stunning results are well worth the effort!

If you are an astrophotographer looking to up your game, investing in a monochrome camera and a good set of narrowband filters is well worth it. There are many emission nebulae and supernova remnants in the sky that work great with the Hubble palette, and with some careful processing, they can become the centerpieces of beautiful and captivating images.

BY MOLLY WAKELING
Molly is an avid astrophotographer active in STEM outreach. She has a Ph.D. in nuclear engineering.

BROWSE THE "OBSERVING BASICS" ARCHIVE AT **www.Astronomy.com/author/molly-wakeling**



Guide to the universe

Hachette Book Group
New York City, NY

The Astronomy Handbook, by author and amateur observer Govert Schilling, lays out everything readers need to observe and understand the night sky. This 256-page book includes details on planets, comets, eclipses, galaxies, and more. It also provides tips for amateur observers and straightforward explanations of some more challenging science topics.

$19.99 ebook;
$30.00 hardcover
customer.service@hbgusa.com
www.hachettebookgroup.com

Light contrast

Optolong
Kunming, China

The 2-inch L-Quad Enhance Filter helps get rid of light pollution in your astroimages. Great for capturing nebulae and other deep-sky targets, this filter transmits more than 90 percent of the Hα, Hβ, OIII, and SII spectral lines. The lens is multicoated for antireflectance and scratch-resistance.

$199.00
market@optolong.com
https://optolong.com

Fast capture

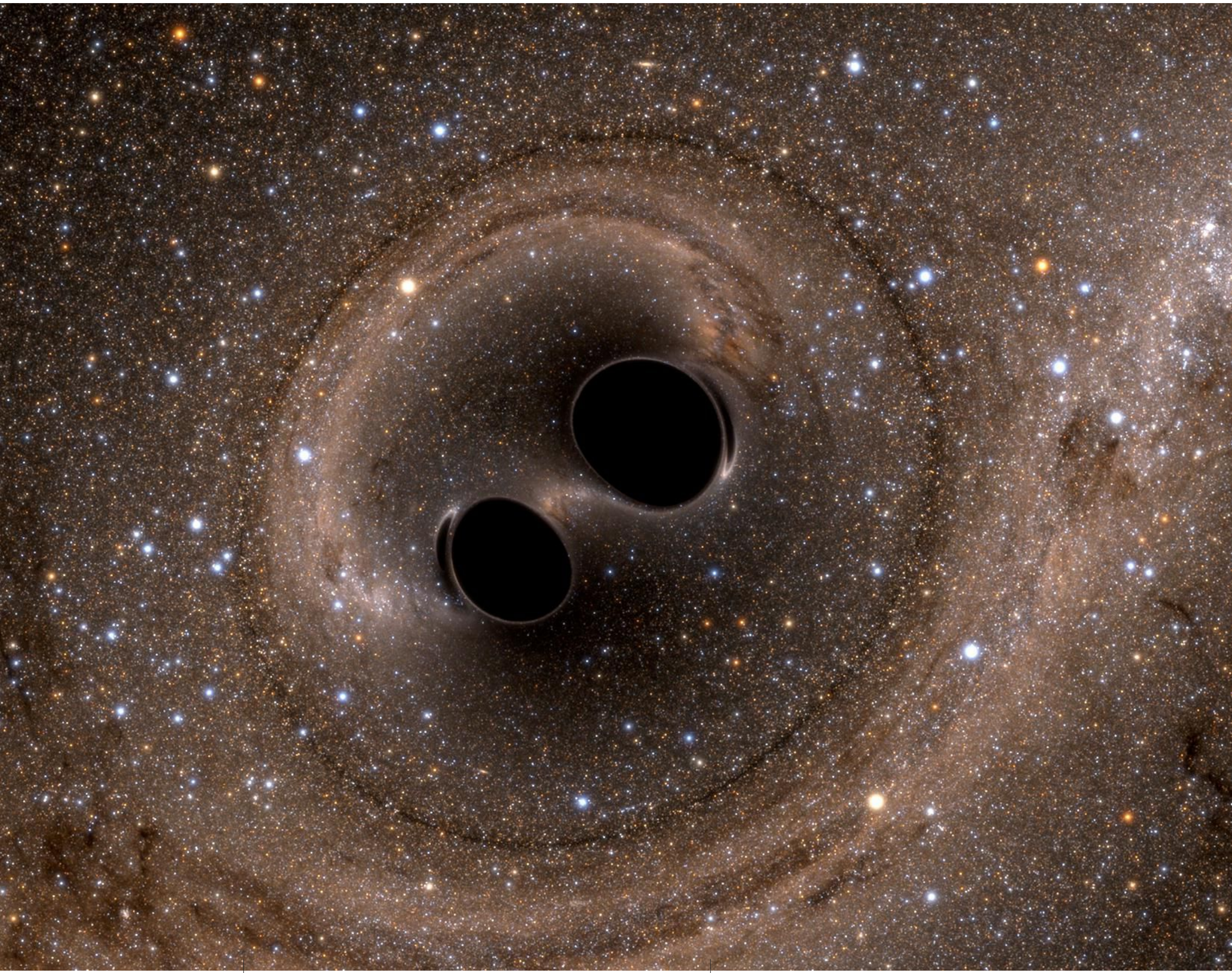
Celestron
Torrance, CA

Origin is Celestron's entry into the smartscope market. Its large, 6-inch aperture, patented RASA technology, and f/2.2 design quickly obtains images free of optical defects. Controlled via app, the scope autonomously aligns and focuses itself and can share images of your target to your phone or to a smart TV. It also comes with a built-in dew-prevention system.

$3,999.00
ustechsupport@celestron.com
www.celestron.com

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

INDEX *of* ADVERTISERS



This still from a simulation shows two merging black holes, each with tens of solar masses and one slightly larger than the other. When black holes merge, the result is larger than the originals in mass, area, and volume. THE SIMULATING EXTREME SPACETIMES (SXS) PROJECT (HTTP://WWW.BLACK-HOLES.ORG)

Merging black holes

Q | WHEN BLACK HOLES MERGE, DOES THE ACTUAL DIAMETER OF THE NEW BLACK HOLE INCREASE, OR JUST ITS MASS?

Richard Robinson
Clay, New York

A | The short answer is yes: When two black holes merge, the resulting black hole has both more mass and a larger diameter. How much bigger? Let's find out!

When astronomers talk about the size of a black hole, they're talking about the size of its event horizon — the point of no return, beyond which even the speed of light is not sufficient to escape the black hole's gravity. This is not a physical structure that you could touch, but a mathematical, spherical boundary. At its center lies the heart of a black hole: the singularity, which has mass but no volume.

For a simple, non-spinning black hole, the radius of

HAWKING'S AREA THEOREM

When Stephen Hawking answered a similar question about black holes colliding in our December 1998 issue, he noted: "An interesting feature that I realized while I was getting into bed one night in 1970 is that the area of the event horizon, or boundary, of the final black hole has to be greater than the sum of the areas of the event horizons of the original black holes. This limits the amount of energy that can be radiated in gravitational waves and also suggested that the area of the event horizon is like the thermodynamic quantity entropy, a connection that was established when I later showed that black holes radiate like hot bodies."

Called Hawking's area theorem, this concept states that a black hole's entropy — which is proportional to the area of its event horizon — cannot decrease. So, even if black holes can lose some small amount of mass during the merger, the final event horizon cannot have less area than the sum of the initial event horizons combined.

This theorem was developed some 45 years before the 2015 first detection of gravitational waves. A July 2021 paper in *Physical Review Letters* finally confirmed Hawking's theorem observationally. In it, researchers reanalyzed the first gravitational-wave merger ever seen, called GW150914, and determined with 95 percent confidence that the area of the resulting black hole's event horizon had not decreased compared to the event horizons of the progenitor black holes. —*A.K.*

the event horizon is also called the Schwarzschild radius, named for German physicist Karl Schwarzschild, who first worked out how big it would be. The Schwarzschild radius of a black hole, called r_S, is given by the equation $r_S = 2GM/c^2$, where G is the gravitational constant (6.67×10^{-11} m^3 kg^{-1} s^{-2}), M is the mass of the black hole (in kilograms), and c is the speed of light in meters per second (3×10^8 m/s).

As a simple example, if we merge two black holes with the same mass and assume no mass is lost in the smash-up, we end up with a final black hole with twice the mass and also twice the radius of either of the two black holes that went into it.

It's worth noting that in the real world, black holes *can* spin, and there are a whole host of other effects that ultimately impact the size and even way we would define a black hole's "diameter." Furthermore, some small fraction of the black holes' mass is lost when they merge, radiated away as energy via gravitational waves. So, in practice, you always end up with a final black hole whose mass is generally not *quite* the sum of the two progenitor black holes combined.

Alison Klesman
Senior Editor

Q | I HAVE A 70-MILLIMETER REFRACTING TELESCOPE. WOULD A SCOPE WITH A LARGER DIAMETER MAKE OBJECTS LOOK BIGGER OR CLOSER?

Mike Haverko
Kelowna, British Columbia

A | All other factors being the same, increasing diameter (aperture) means your image will be brighter and more detailed, but not necessarily larger. So, if you use the same eyepiece to observe Jupiter with a 2-inch, 6-inch, or 12-inch telescope — and if all three scopes have the same focal length — Jupiter will be the same size.

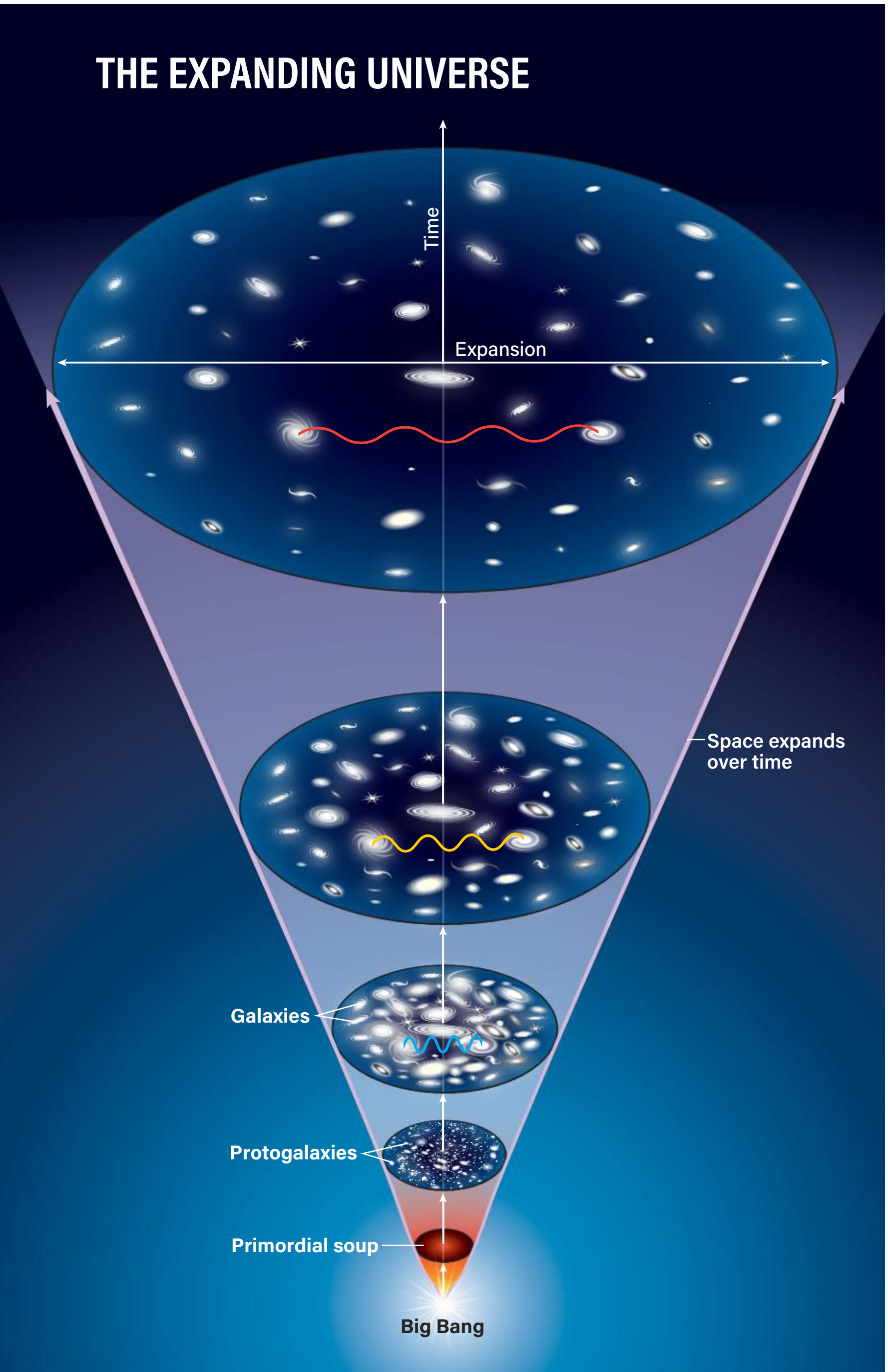
That said, larger scopes of the same design usually have longer focal lengths, so they would make a celestial object appear larger.

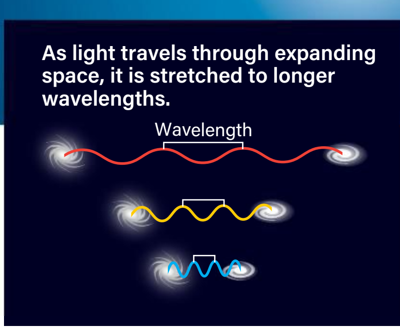
Figuring out how much an eyepiece magnifies is easy. Just divide the scope's focal length by the eyepiece's focal length. You'll find that number on the eyepiece followed by "mm." So, if you put a 10mm eyepiece into an 8-inch scope that has a focal length of 1,000mm, the magnification is 100x (the result of 1,000 divided by 10). A 4-inch scope with the same focal length and eyepiece would produce the same result (100x), but the object would not be as bright because the smaller aperture collects less light.

To make celestial objects look larger through your telescope, use eyepieces that provide higher magnification. A 10mm eyepiece provides twice the magnification of a 20mm eyepiece in the same telescope. Likewise, a 5mm eyepiece would double the magnification of a 10mm.

Michael E. Bakich
Contributing Editor

You can make images look larger through your telescope by choosing a different eyepiece. Each eyepiece has its focal length written on it — for example, 4mm or 6mm. For a given telescope, eyepieces with smaller focal lengths provide more magnification. CELESTRON





As the universe expands with time, it is the space between stars and galaxies that grows, carrying the objects with it and stretching light rays to redder wavelengths. Because the expansion of space is not limited by the speed of light, the universe is larger than 13.8 billion light-years across.

ASTRONOMY: ROEN KELLY, AFTER NASA/ESA/L. HUSTAK (STSCI)

Q | HOW CAN THE VISIBLE UNIVERSE BE 46 BILLION LIGHT-YEARS IN RADIUS WHEN THE UNIVERSE IS ONLY 13.8 BILLION YEARS OLD? AND HOW CAN WE DETECT LIGHT 46 BILLION LIGHT-YEARS AWAY WHEN THE UNIVERSE HAS BEEN IN EXISTENCE FOR A FRACTION OF THAT TIME?

Joe Murchison
Placerville, California

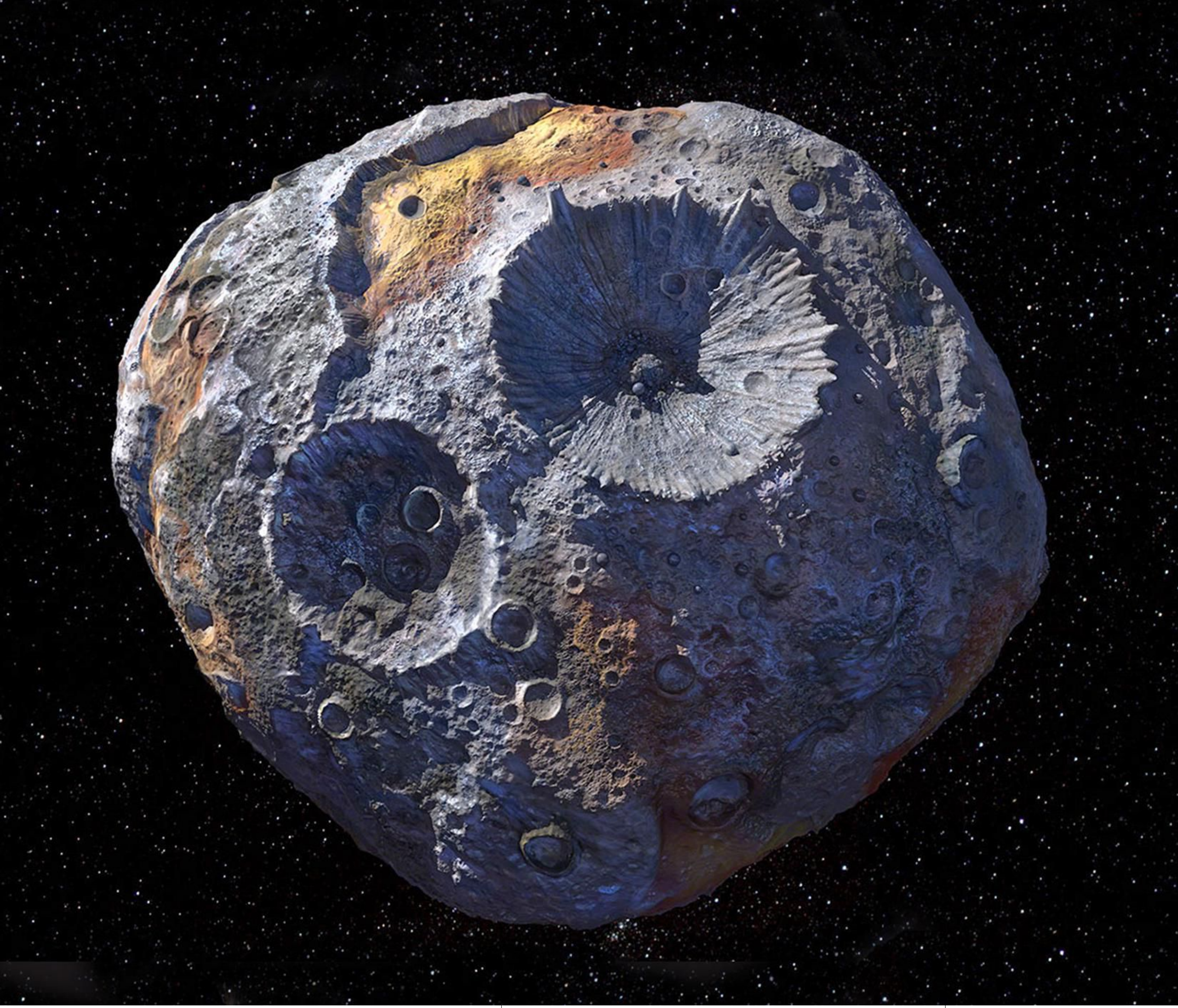
A | Astronomers widely accept that the universe formed in the Big Bang approximately 13.8 billion years ago. It has been expanding ever since. This expansion explains how a 13.8-billion-year-old universe can be so much larger than 13.8 billion light-years across.

First of all, we should explain that the light-speed limit that relativity imposes on objects within the universe doesn't apply to the universe itself. In fact, we can't refer to an absolute expansion speed of the universe because we can't measure it in reference to anything external. We can only gauge the "speeds" of distant galaxies that are receding from us relative to our own position. Apart from those that are gravitationally bound (such as, say, the Milky Way and Andromeda galaxies), all galaxies appear to be moving away from each other as the space-time in which they're embedded expands. The more distant the galaxy, the faster its recession velocity, as noted by the Hubble Law. As a consequence of this expansion, a galaxy's location changes considerably during the period of time that its light requires to travel to us.

Let's couch this in human terms: You are tossing a ball to a friend from a set distance, say 50 feet (15 meters). Provided both of you remain stationary (and you aim properly), the ball's 50-foot path will always equal the distance that separates you and your friend. But now let's assume that instead of remaining in place, you back away 10 feet (3 m) each time you toss the ball. In that case, by the time the ball reaches your friend, its travel distance will be less than the distance that now separates the two of you.

In the same way, the light we're seeing from an object 13 billion light-years away required 13 billion years to move from it to us, but during that period, the amount of space separating us from that object has increased substantially. Calculations show that this expansion would cause the current radius of the universe to be about 46 billion light-years.

Edward Herrick-Gleason
Planetarium Director, Southworth Planetarium, University of Southern Maine, Portland, Maine



The metallic asteroid Psyche, shown in this artist's concept, may be the exposed iron-nickel core — or a fragment of one — from a larger object early in the solar system. But it is likely not associated with the object that created Earth's Moon. PETER RUBIN/NASA/JPL-CALTECH/ASU

Q | COULD PSYCHE BE THE CORE OF THE PLANETESIMAL BODY THAT STRUCK EARTH AND RESULTED IN THE FORMATION OF THE MOON?

Colton Brooks
Virginia Beach, Virginia

A | Psyche appears to be an iron core, or part of one, produced during the history of collisions experienced by a fairly large asteroid with other large asteroids. The collision or collisions were likely between unusually large bodies, since Psyche itself is a relatively large asteroid (it was only the 16th discovered, and by virtue of its size can reflect a lot of light), with dimensions of about 173 by 144 by 102 miles (278 by 232 by 164 kilometers).

There seems to be little reason to associate it with the probable large collision that formed Earth's Moon, however, because Psyche has a nearly circular orbit in the asteroid belt, so it is unlikely to have come close to Earth. The object responsible for the Moon-forming collision is thought to have been one of the larger bodies that formed in the inner solar system region of Earth and Venus, and impacted Earth fairly late during the growth of our planet.

William K. Hartmann
Senior Scientist Emeritus, Planetary Science Institute, Tucson, Arizona

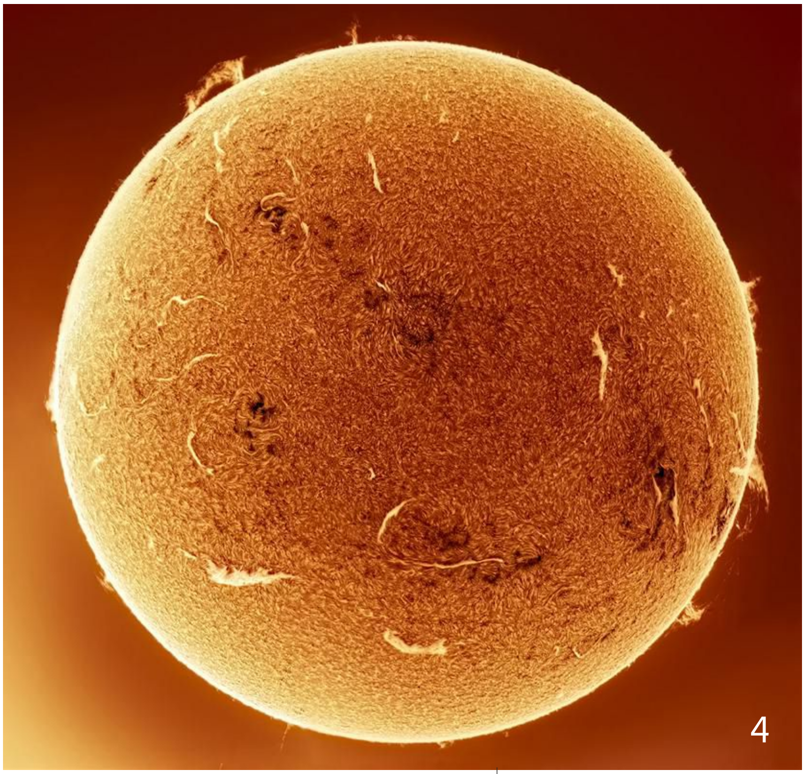
SEND US YOUR QUESTIONS

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

Cosmic portraits

1. A CHANCE OF FLOCCULENCE
NGC 4274 is a barred spiral galaxy roughly 45 million light-years away in Coma Berenices, with flocculent dust lanes and outer spiral arms that overlap to form a ring. This LRGB image represents 13.6 hours of exposure with a 12-inch f/8 scope.
• *Dan Crowson*

2. ONE-WINGED ANGEL
An aurora arcs over a fjord on the Norwegian island of Senja, roughly 3° north of the Arctic Circle, lighting up the villages of Bergsbotn and Indregård. This 1.6-second shot was taken with a mirrorless camera and a 14mm lens at f/1.8 and ISO 2500.
• *Marty Weintraub*



3. THE COMET AND THE GALAXY
Comet 12P/Pons-Brooks appears beneath the imposing figure of the Andromeda Galaxy (M31) as imaged from Egypt's Black Desert. A meteor streak is visible at upper left. The photographer used an astro-modified mirrorless camera at ISO 600 and a 135mm lens at f/3.5 to capture 20 minutes of sky data in 30- and 60-second exposures. • ***Osama Fathi***

4. THE ACTIVE SUN
Prominences and filaments snake across this six-panel mosaic of the Sun in inverted Hα, taken March 13 with a 4-inch Lunt telescope. Each panel is 200 stacked frames (out of 2,000). • ***Mark Johnston***

5. A FACE FOR RADIO
At just 12 million light-years away, edge-on Centaurus A (NGC 5128) is the closest galaxy with an actively feeding supermassive black hole. This powers jets that fire into the surrounding material and produce lobes visible only in radio waves; however, a diffuse glow is visible in optical light. The imager used a 5-inch refractor to take 11.6 hours of LRGB data for this portrait. • ***Charles Pevsner***

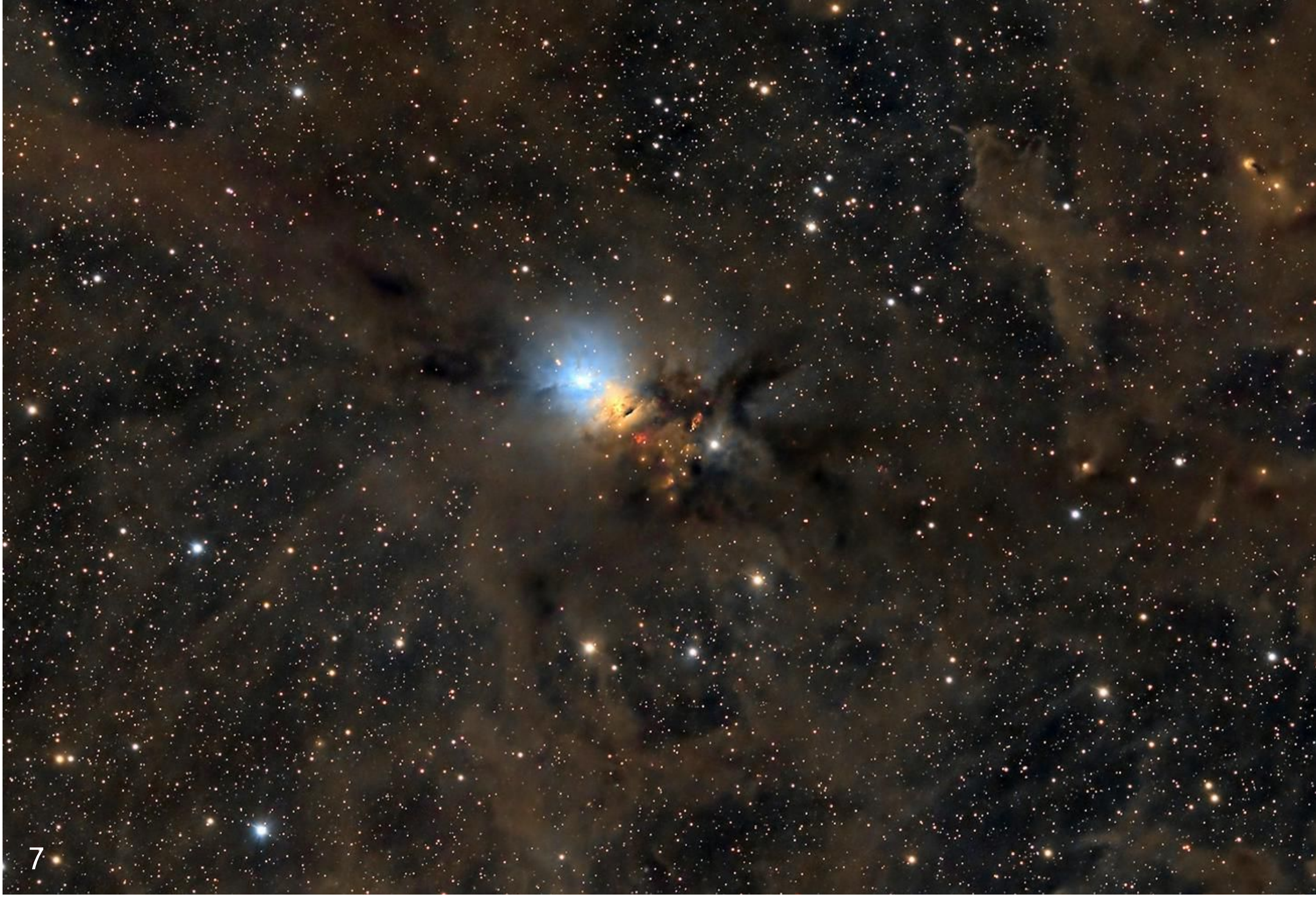
6. EXPLORING THE SAILS
The bluffs and ridges of this little-imaged nebular complex lie on the edge of a giant "super shell" of expanding molecular gas known as the IRAS Vela Shell, which lies in the Gum Nebula. This HαLRGB image was taken with 17⅓ hours of exposure with a 6-inch scope. The final result is a composite of 12 different interpretations of the data from the members of Team ShaRA. ***• Team ShaRA: Massimo Di Fusco/Aygen Erkaslan/Marco Firenzuoli/Egidio Vergani/Andrea Iorio/Rolando Ligustri/Fernando Linsalata/Donato Lioce/Alessandro Ravagnin/Riccardo Maffioli/Giampaolo Michieletto/Cristiano Trabuio***

7. A LONELY EMBRYO
NGC 1333 — also known as the Embryo Nebula — is a reflection nebula nearly 1,000 light-years distant, adrift in the vast Perseus Molecular Cloud. The cool blue light is from young, hot stars reflecting off dust; red patches of glowing hydrogen indicate where dense dust is being compacted and heated, birthing new stars. The image represents 85 minutes of exposure on a 11-inch Celestron RASA scope and a one-shot color camera. ***• Jimmy Walker/Warren Keller***

8. SAGUARO SKY
The night sky spins above the landscape of Kofa National Wildlife Refuge in Arizona in this eight-hour star trail shot. The imager used a DSLR to take 30-second exposures at f/4 and ISO 5000. ***• Chris Cook***

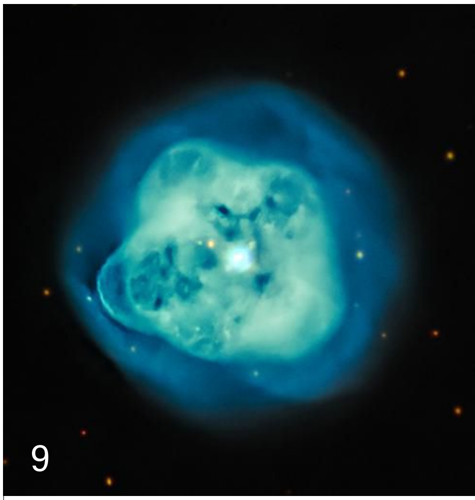
9. YOUR FUTURE IS CLOUDY...
The planetary nebula NGC 1514 (also known as the Crystal Ball) lies in Taurus at a distance of 1,500 light-years. Its central star is a binary system originally thought to have a period of 10 days; more recent spectroscopic work has shown it's actually around nine years, making it one of the longest-period binaries known to host a planetary nebula. This image was taken with an 8-inch f/10 scope and 23 hours of exposure with a dual-band Hα/OIII filter, plus 30 minutes of luminance data. ***• Andrea Arbizzi***


6



7

8



9

SEND YOUR IMAGES TO:
readergallery@ astronomy.com.
Please include the date and location of the image and complete photo data: telescope, camera, filters, and exposures.

READY TO HIT THE ROAD AGAIN

The Spare Tyre (or Tire) Nebula (IC 5148) glows softly along the neck of the constellation Grus the Crane. This planetary nebula formed when a Sun-like star puffed off its outer layers near the end of its life. The stellar debris now appears as asymmetric clumps surrounded by a faint bluish halo. At the nebula's center lies a conspicuous white dwarf — the dying star's hot core — whose ultraviolet light excites this gas to incandescence. IC 5148 is expanding at a blistering 112,000 mph (180,000 km/h), one of the fastest rates among all planetary nebulae. Australian amateur Walter Gale — the namesake of Gale Crater, current home of the Mars Curiosity rover — discovered this object in 1894. The Spare Tyre's common name comes from its shape, while its uncommon spelling derives from British English. INTERNATIONAL GEMINI OBSERVATORY/NOIRLAB/NSF/AURA

August 2024

A pair of planet conjunctions

August begins with dramatic evening views of the southern Milky Way arching high across a Moon-free sky. Before the sky darkens completely, however, look low in the west for the solar system's two inner planets.

Mercury glows at 1st magnitude in the deepening twilight. On August 1, it stands 14° high 45 minutes after sunset and should be easy to spot. A telescope reveals its 9"-diameter disk and one-quarter-lit phase.

The innermost planet loses altitude with each passing day as it heads toward inferior conjunction August 19. As Mercury dips lower, brilliant **Venus** rises to meet it. You won't mistake this world for anything else — at magnitude –3.9, it far outshines every other point of light in the sky. The two planets are in conjunction with each other on the 6th, when Mercury slides 6° south (upper left) of its brighter neighbor. Intriguingly, both worlds then span 10" when viewed with a telescope, but Mercury appears only 18 percent lit while Venus is nearly full (95 percent lit).

The Moon's presence makes August 6 even more spectacular. From Australia, the slender crescent stands 4° to Venus' upper right and 7° to Mercury's right. As an added treat, the 1st-magnitude star Regulus lies just 2° to Venus' lower left. All four objects will appear in a single field of view through typical binoculars.

Not long after Venus sets in the west, **Saturn** rises in the east. The ringed planet shines at magnitude 0.7, far brighter than any of the background stars of eastern Aquarius. Saturn slides 0.8° north of 5th-magnitude Chi (χ) Aquarii in mid-August.

The planet looks remarkably different through a telescope than it has in previous years. The rings tilt just 3° to our line of sight at midmonth, a far cry from the wider opening we're accustomed to. They currently span 43" as they wrap around the planet's 19"-diameter disk. The narrow tilt of Saturn's rings means the world's moons stand out better than usual. A 10-centimeter instrument easily reveals 8th-magnitude Titan and its 10th-magnitude cousins: Tethys, Dione, and Rhea.

A waning gibbous Moon occults Saturn on August 21. The only Southern Hemisphere locations with good views are parts of Peru, Bolivia, and Brazil. From Arequipa, Peru, Saturn disappears behind Luna's bright limb at 0h50m UT and reappears on the dark limb at 1h34m UT. Locally, this is the evening of August 20. Remember to add a few extra minutes to these times to see the Moon gradually cover and uncover the rings.

The other two naked-eye planets pair up in the morning sky. In early August, **Mars** and **Jupiter** form a beautiful equilateral triangle with 1st-magnitude Aldebaran, Taurus the Bull's brightest star. Mars shines at magnitude 0.9, nearly indistinguishable from the background star, while magnitude –2.1 Jupiter easily beats them both.

Although Mars and Jupiter trek eastward relative to the background stars of Taurus during August, Mars moves much faster thanks to its smaller orbit around the Sun. This sets up a close conjunction between the two. On the 14th, the Red Planet passes 0.3° north of its companion in front of the starry backdrop of the Bull's long horns.

A telescope delivers startlingly different views of the two worlds. Mars appears only 6" across and shows little if any detail. However, the Sun illuminates 88 percent of its Earth-facing hemisphere, near the minimum possible. Can you detect its gibbous shape?

On the other hand, Jupiter boasts a wealth of detail. The giant planet spans 37" in mid-August, a large canvas for its turbulent atmosphere to cover. Look for two dark equatorial belts, one on either side on a brighter zone that coincides with Jupiter's equator. Finer features show up during moments of good seeing. Also keep an eye out for the planet's four bright moons as they change positions from night to night.

The starry sky

The French comet-hunter Charles Messier (1730–1817) compiled the most famous catalog of galaxies, nebulae, and star clusters. Published in the *Connoissance des Temps* for 1784, his final catalog included 103 objects. (Though note that M40 is just a double star and M102's identity, which many observers accept as being the galaxy NGC 5866, seems more likely to have been a duplicate observation of M101.)

Look at the Messier Catalog today, and you'll find it contains 109 objects (110 if you erroneously include NGC 205). This happened because astronomers added several objects later — much later, between 1921 and 1960. Messier or his friend and fellow observer, Pierre Méchain (1744–1804), discovered M104 through M109. (Indeed, Méchain and others first viewed many objects on Messier's main list.) Of the new entries, American-Canadian astronomer Helen Sawyer Hogg (1905–1993) added M105, M106, and M107 in 1947.

At a declination of –13°, globular cluster M107 is the southernmost of the six additions to Messier's catalog. It lies in Ophiuchus the Serpent-bearer just 2.7° south-southwest of the magnitude 2.6 star Zeta (ζ) Ophiuchi and climbs high in August's early evening sky.

The 8th-magnitude cluster appears as a fuzzy patch in 7x50 binoculars, though it appears far nicer through a telescope. A 15cm instrument reveals some of its stars, while larger apertures offer progressively better views. Enjoy hunting down this late-winter wonder.

STAR DOME

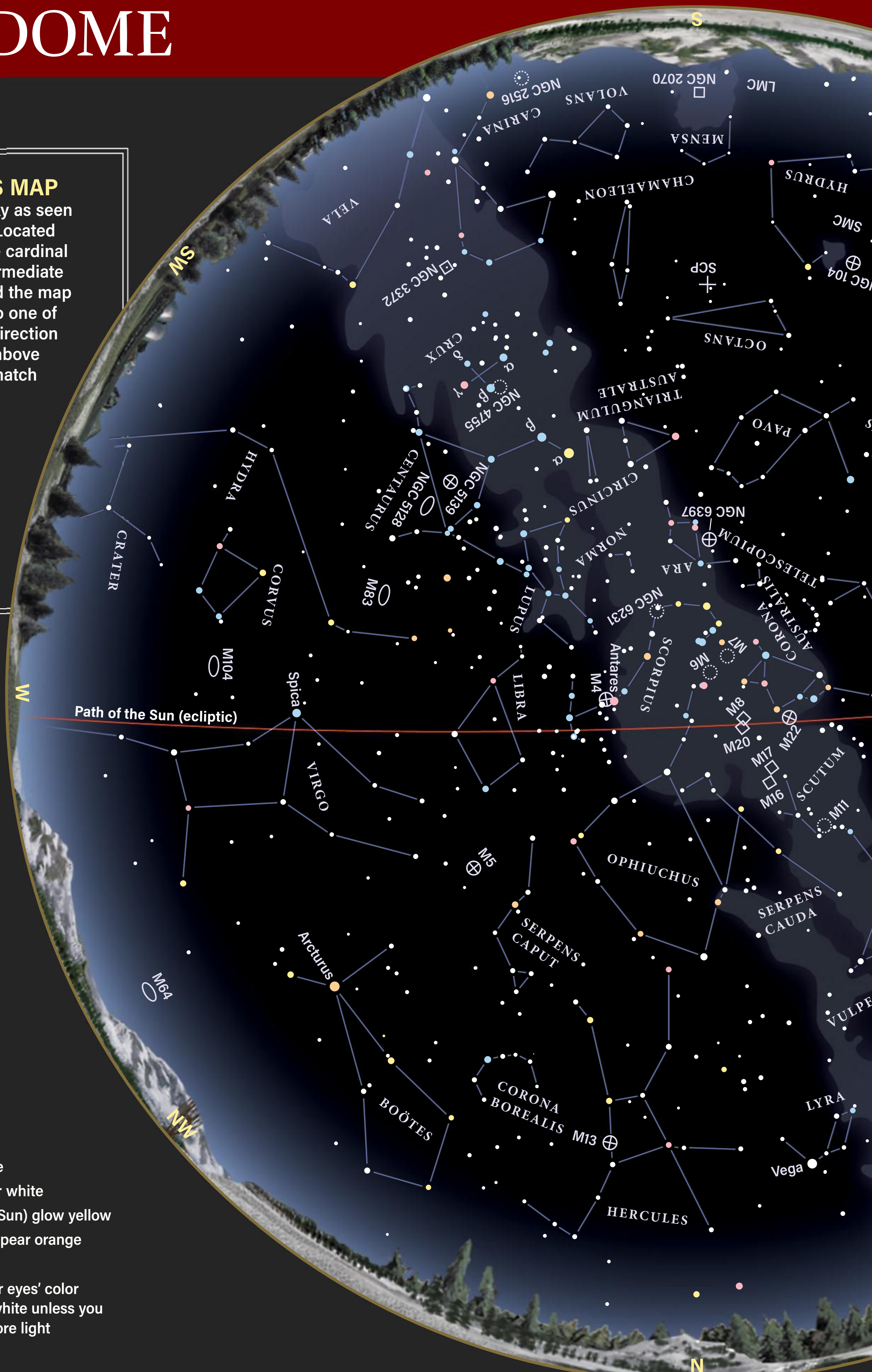
HOW TO USE THIS MAP

This map portrays the sky as seen near 30° south 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:

9 P.M. August 1
8 P.M. August 15
7 P.M. August 31

Planets are shown at midmonth



MAP SYMBOLS

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

STAR MAGNITUDES

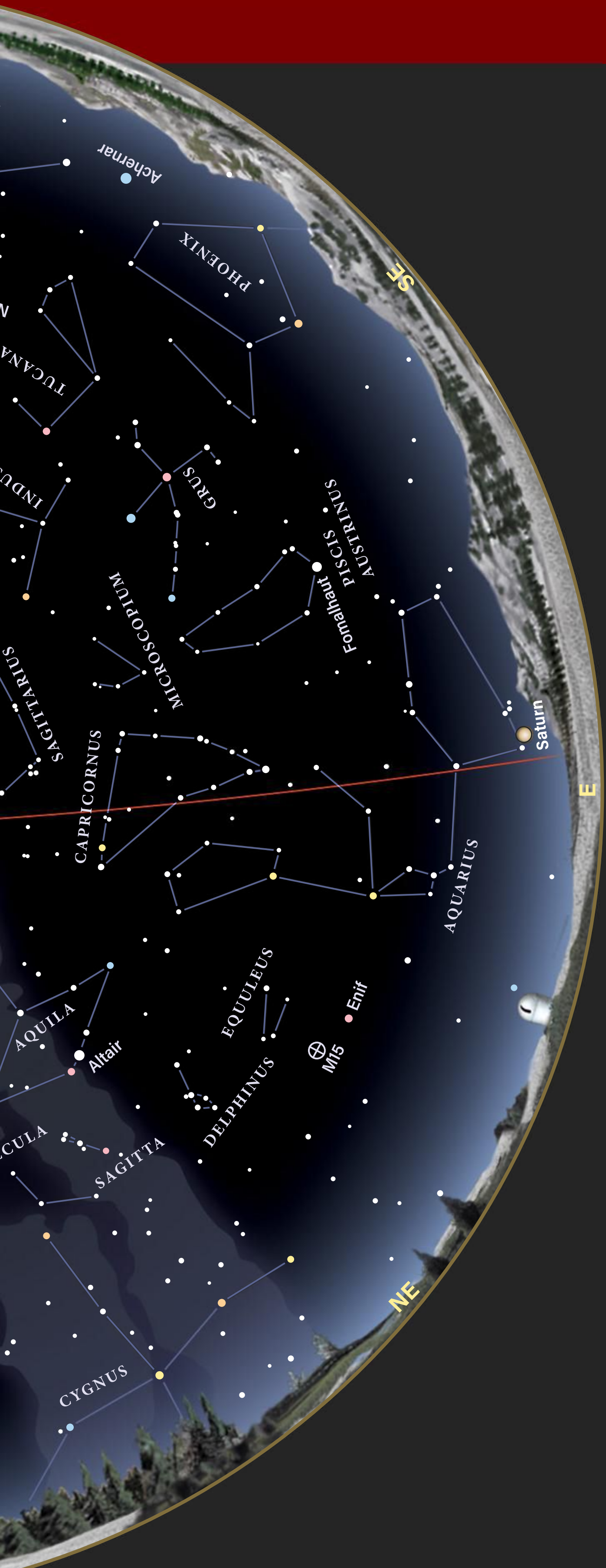
- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

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

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



AUGUST 2024

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

ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

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

CALENDAR OF EVENTS

4 Mercury is stationary, 8h UT
New Moon occurs at 11h13m UT
Venus passes 1.1° north of Regulus, 22h UT

5 Mars passes 5° north of Aldebaran, 19h UT
The Moon passes 1.7° north of Venus, 22h UT

6 The Moon passes 7° north of Mercury, 0h UT
Asteroid Psyche is at opposition, 6h UT
Mercury passes 6° south of Venus, 15h UT
Asteroid Iris is at opposition, 20h UT

9 The Moon is at apogee (405,297 kilometers from Earth), 1h31m UT

10 The Moon passes 0.7° north of Spica, 10h UT

11 Mercury passes 6° south of Regulus, 22h UT

12 First Quarter Moon occurs at 15h19m UT

14 The Moon passes 0.004° south of Antares, 5h UT
Mars passes 0.3° north of Jupiter, 17h UT

19 Mercury is in inferior conjunction, 2h UT
Full Moon occurs at 18h26m UT

20 Asteroid Vesta is in conjunction with the Sun, 9h UT

21 The Moon passes 0.5° north of Saturn, 3h UT
The Moon is at perigee (360,196 kilometers from Earth), 5h02m UT
The Moon passes 0.7° north of Neptune, 22h UT

26 The Moon passes 4° north of Uranus, 0h UT
Dwarf planet Ceres is stationary, 8h UT
Last Quarter Moon occurs at 9h26m UT

27 The Moon passes 6° north of Jupiter, 13h UT

28 The Moon passes 5° north of Mars, 0h UT
Mercury is stationary, 3h UT