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Vol. 52 • Issue 10

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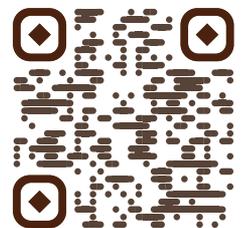
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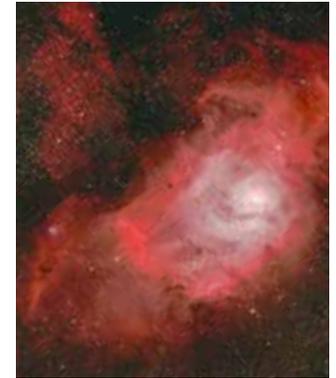
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ON THE COVER

The Lagoon Nebula in Sagittarius is one of the brightest emission nebulae in our sky, a star factory producing a new generation of suns. JOHN CHUMACK

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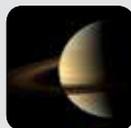
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QUANTUM GRAVITY

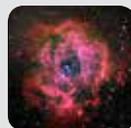
Everything you need to know about the universe this month: summits on Mars, odd radio circles, a waterlogged asteroid, Moon samples, and more.

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Headlong into the cosmos



The Dumbbell Nebula in Vulpecula, one of the sky's great examples of a planetary nebula, presages the future of our own Sun and solar system.

MARK GERMANI



One of the most exciting experiences for an amateur astronomer is when we get a new telescope or pair of binoculars and get a “new view” of the universe. I recall vividly when I received an 8-inch Celestron as a holiday gift; it opened my eyes to all manner of things that I had only vague notions of before seeing them myself.

What would the Andromeda Galaxy look like in my new window to the vastness of space? How would the Orion Nebula stack up compared with images I saw in magazines that were imprinted indelibly in my mind? Fortunately, this kind of rediscovery of the citizens of the cosmos happens whenever we

get a new instrument to aim skyward, an improved place from which to view, or a new sense of previously unknown targets to go after.

I soon discovered that the great bulk of what we see in telescopes lies within the domain of the so-called deep sky, far beyond our little solar system. The gigantic Milky Way Galaxy hosts many thousands of these objects — double stars, variable stars, star clusters, and nebulae. A small telescope from a dark location reveals these targets on any given clear, moonless night. And beyond our own galaxy lies the universe of other galaxies first unlocked by Edwin Hubble a century ago. Several thousand galaxies are splendid targets in suitable backyard telescopes.

In my story this month, I introduce you to some of the finest denizens of the deep sky. Of course, because photographic processes capture and add light as they go, and because the human eye's sensitivity and color reception are limited, we don't see these objects like the colorful, intricately detailed photos now shown us pretty routinely these days.

But I say there is unique value in seeing the actual light in your own eyes — the live photons that have been traveling for tens or hundreds of thousands or millions of years before striking your retinas.

Won't you join me and discover the deep sky?

Yours truly,

David J. Eicher
Editor



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FIRECROWN





Welcome to Firecrown Media

BY CRAIG FULLER

My company, Firecrown Media, has acquired Kalmbach's esteemed hobby magazines and media properties, including renowned titles such as *Astronomy*, *Model Railroader*, *Classic Trains*, *Trains*, *Garden Railways*, and *Classic Toy Trains*.

As the new custodians of these cherished and respected brands, we are committed to upholding their legacy and nurturing their growth.

Firecrown Media, a rapidly expanding media company, is dedicated to acquiring and stewarding magazine and digital media brands in the transportation sector. Our portfolio includes *FLYING*, *Boating*, *Yachting*, and *FreightWaves*, among 50 other loved brands.

Firecrown is young; it has only been around for three years, but it is funded by a billion-dollar family office with a significant focus on media. After acquiring these signature brands, we have invested over \$40 million in them.

As Firecrown's founder, I drive much of the passion and energy behind our media strategy.

I started in media in 2017 when I launched *FreightWaves*, a digital media company often called the "Bloomberg of freight." In just seven years, it has become the most prominent voice covering the freight industry, with deep news and analysis of the trucking, rail, air, and ocean container markets. *FreightWaves* is also one of the fastest-growing B2B media companies in the world.

While I am a digital native, I love print magazines.

My love for magazines began when I was a boy; *FLYING* was a magazine I grew up reading. So, when I had the opportunity to acquire it in 2021, I did. My purchase of *FLYING* began as a passion project; I have been a private pilot since I was 17.

My initial plan was to shutter the magazine and focus on the digital edition. However, I remembered how I felt each month when I received my copy of *FLYING* in the mail. Fully understanding and appreciating the power and love of magazines, we soon realized that magazines offered an experience for readers that digital couldn't match. Unlike digital apps or online websites, consuming print content provides the reader with an undistracted



journey. When reading online, one is constantly distracted by emails, Slack messages, social media feeds, etc.

None of that exists in print.

Magazines offer the reader an experience and a journey unparalleled in any digital format. In recent years, we've seen younger generations (the "Zoomers") start to prefer print magazines over digital. For them, magazines are innovative and tangible, providing a premium experience compared to digital offerings.

After our success with *FLYING* (revenues up 5x since we acquired it in 2021), we expanded our portfolio through 20 acquisitions and

rebranded as Firecrown Media.

Firecrown's playbook for the Kalmbach titles will follow our experience with other publications and digital assets we've acquired.

We will invest significantly in the publications, creating coffee table-worthy magazines with gorgeous photography and stories that engage audiences. Magazines should be timeless and something that readers want to keep.

In addition to creating beautiful magazines, we will also make significant investments in the digital websites in our portfolio. This will include significant upgrades to *Astronomy.com*.

We also have big plans for video products and plan to introduce new podcasts to serve and engage the community.

All of these investments will take time, but in a few months, you will start to see improvements in the online products, and over the next year, you will see a relaunch of the magazines.

As the parents of five children (ages 3-17), my wife and I spend much time and effort introducing our young children to hobbies that do not involve screens and devices. We want to find experiences that exist in the physical world for them. *Astronomy* offers an experience that does exactly that.

I would love to hear your thoughts and ideas on improving the *Astronomy* experience.

📍 You can find me on X: @freightalley.

Color correction

Astronomy is a great magazine, so thank you for your hard work. I read the March 2024 Ask Astro question about green stars. The answer seemed to say that there are no green stars. But an entry from Ian Ridpath's *The Illustrated Encyclopedia of Astronomy and Space* (Thomas Y. Crowell Co., 1976) seems to say that green stars are out there, just very rare: "Beta Librae, a spectroscopic binary, is one of the few bright stars that appear green in color." Just curious which answer is correct. — **Gene L. Timpe**, Fort Collins, CO

Senior Editor Alison Klesman responds: Beta (β) Librae, also known as Zubeneshamali, does indeed seem to be a perplexing case of a visually green star. In his Burnham's *Celestial Handbook: An Observer's Guide to the Universe Beyond the Solar System*



(Dover Publications, Inc., 1978), Robert Burnham Jr. writes of this particular star: "Another mystery concerns the fact that this white star has so often been described as 'greenish' or 'pale emerald.' Olcott refers to it as 'the only naked-eye star that is green in color,' while T.W. Webb refers to its 'beautiful pale green hue.' Star colors are strangely elusive, of course, and there are many such discrepancies in the guidebooks, but modern observers generally agree that the only stars which definitely appear green are the close companions to red stars, such as Antares itself."

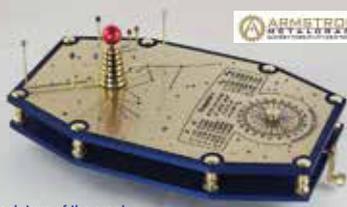
What's going on here? The answer is that we're not sure, but there are several possibilities. Physically, there are no green stars, for the reasons explained in the March issue. However, some stars may look green to our eyes for many reasons.

Everyone's eyes see colors slightly differently, so some people may see certain stars as greenish. (Many people also see Beta Librae as white.) Poorly color-corrected instruments could also contribute to the issue. Finally, as Burnham mentions, proximity to a star of a contrasting color — e.g., a red companion — can cause a star to appear to take on an unnatural hue, though this is an optical illusion.

➔ We welcome your comments via email to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.

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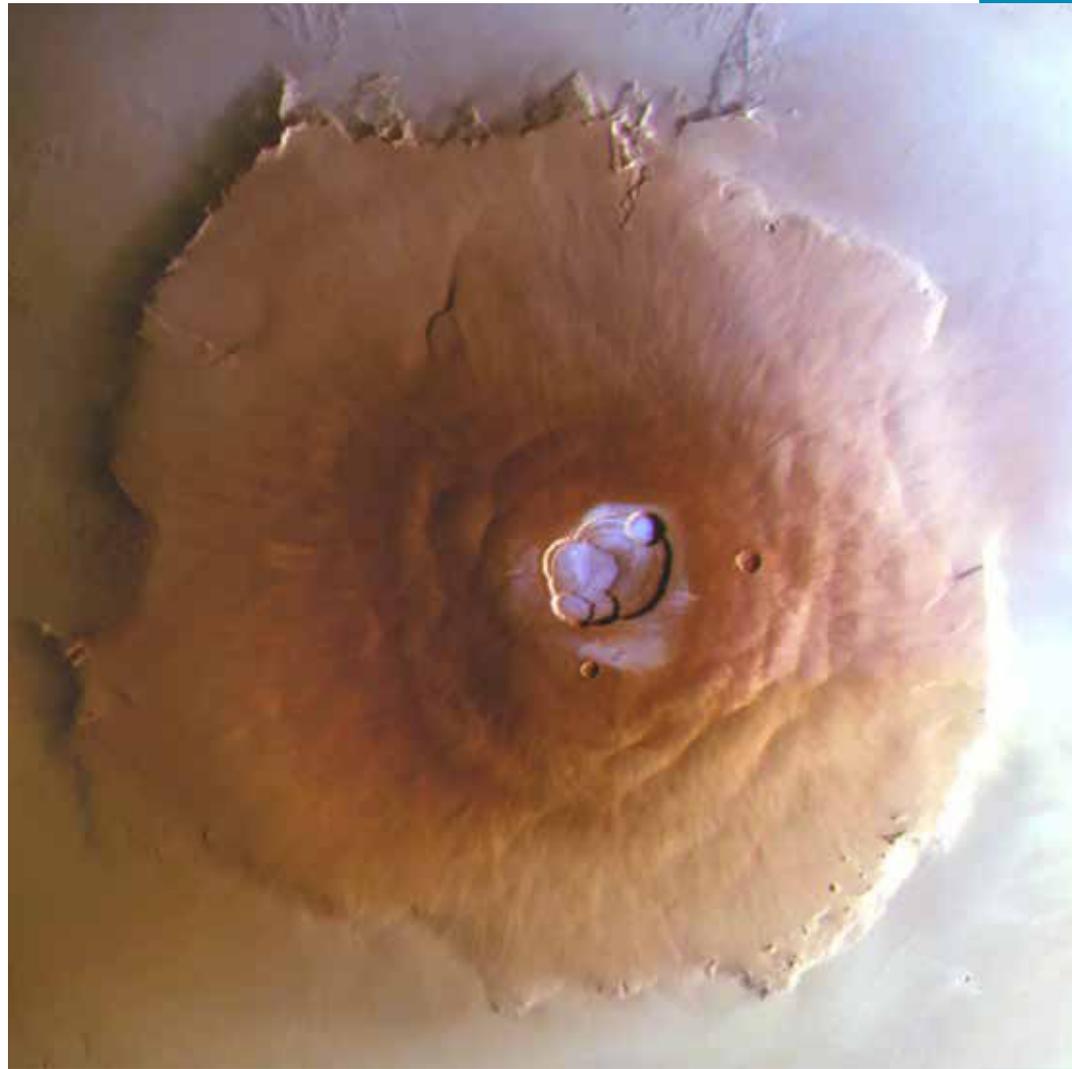
CHILLY SUMMITS ON MARS

Satellites spot ephemeral morning frost atop the tallest martian volcanoes.

The peak of Mars' Olympus Mons, along with other nearby volcanoes, sports frosty patches in the winter. This morning image of the tallest volcano in our solar system was taken by the European Space Agency's Trace Gas Orbiter and Mars Express orbiter. It shows the ice deposits, falsely colored blue, in the volcano's caldera (bowl-shaped features).

Scientists found that the icy patches collectively contain some 150,000 tons of water and are as thin as a strand of human hair. The team also found that wind travels at lower speeds within the caldera than the surrounding areas, allowing the frost to form for a few hours around sunrise during the cooler seasons before evaporating into the thin martian air.

— SHARMILA KUTHUNUR



ESA/DLR/FU BERLIN, BOTTOM FROM LEFT: LEGO, ALEX P. KOK/WIKIMEDIA COMMONS CC BY-SA 4.0, ROBERTO MOLAR CANDANOSA/JOHNS HOPKINS UNIVERSITY



HOT BYTES



BRICK BUILDING
Working with LEGO, ESA researchers have 3D printed LEGO-like bricks with meteorite dust. Future Moon explorers could print similar interlocking bricks from lunar soil to build structures.



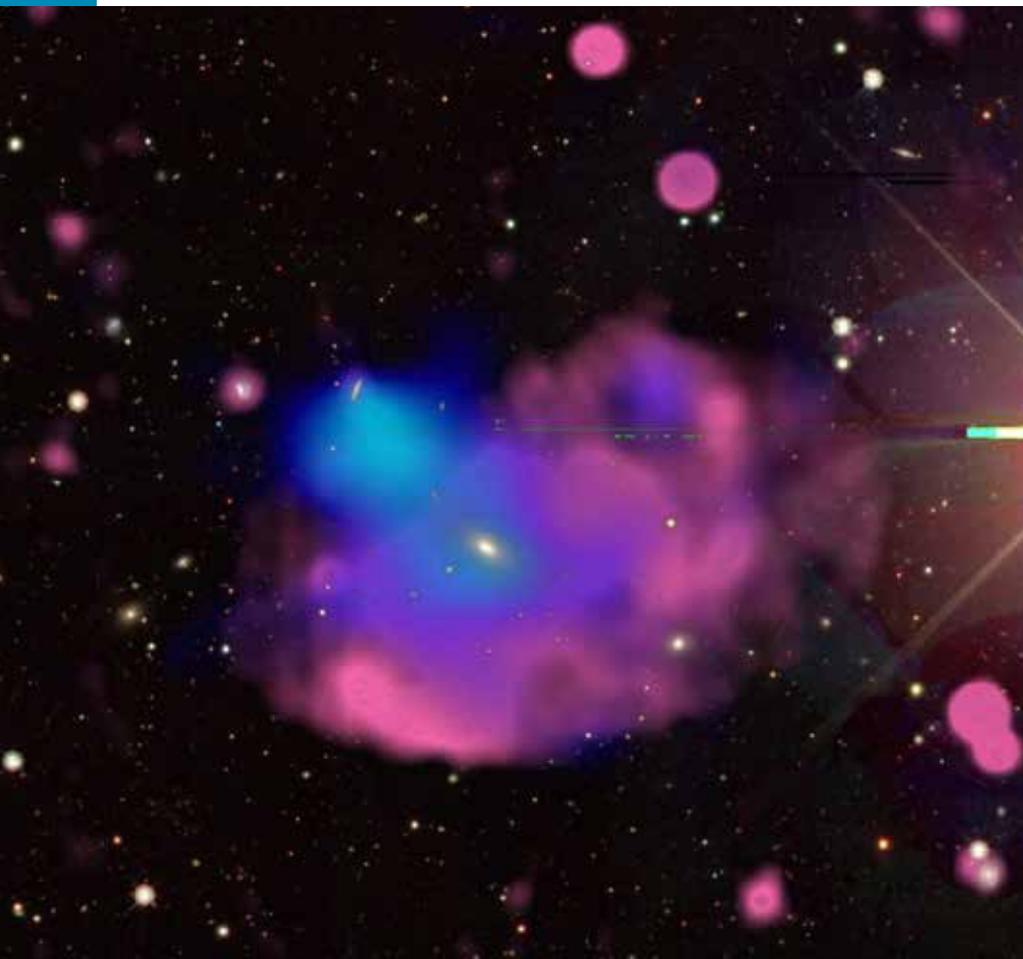
AMONG THE STARS
Dutch celestial cartographer Wil Tirion died July 5 at the age of 81. He created two landmark sky atlases — *Sky Atlas 2000.0* and *Uranometria 2000.0* (co-authored with Barry Rappaport and George Lovi) — and contributed to many more.



ICARUS COULD NEVER
Keck Observatory data show that the Neptune-sized exoplanet TIC 365102760 b retains a puffy atmosphere despite a close orbit around its red giant host star, which should have stripped it away. The planet has been dubbed Phoenix.

GALACTIC MEGAMERGERS COULD EXPLAIN ENORMOUS RADIO CIRCLES

The mysterious Cloverleaf “odd radio circle” could be a merger of a dozen galaxies.



» The Cloverleaf, a member of a new category of cosmic objects called odd radio circles (ORCs), has been observed in a new light to reveal clues to how ORCs are created. Astronomers used the Extended Roentgen Survey with an Imaging Telescope Array (eROSITA), an orbiting German/Russian X-ray telescope, to observe the Cloverleaf, which resides about 600 million light-years from Earth and spans more than 326,000 light-years. (For comparison, the

COLORS TELL ALL. The Cloverleaf odd radio circle is shown here in multiple wavelengths: visible light from the DESI Legacy Survey in white and yellow, XMM-Newton X-rays in blue, and ASKAP radio data in red. XIAOYUAN ZHANG/MATTHIAS KLUGE (MPE)/BAERBEL KORBALSKI (CSIRO)

Milky Way is about 100,000 light-years across.)

Examining the Cloverleaf’s X-ray emission gave astronomers the chance to probe high-energy processes, such as supersonic shock waves and black holes. “It was the missing key to unlock the secret of the Cloverleaf’s formation,”

said lead author Esra Bulbul, an astrophysicist at the Max Planck Institute in Germany, in a press release.

WHAT’S THIS?

In 2020, astronomers using the Australian Square Kilometer Array Pathfinder (ASKAP) discovered gigantic ghostly circles of radio emission in the sky that surpassed our Milky Way’s size tenfold. No known cosmic phenomenon can explain what they are or how they formed. Since then, astronomers have found eight of these ORCs scattered randomly in space. Each is large enough to envelop an entire galaxy, sometimes several.

The supremely inflated profiles of the behemoth circles don’t agree with circular features otherwise common in radio images, such as the shell of material shed by a dying star or a face-on view of a dusty protoplanetary disk. Because the handful of bizarre objects could be seen by more than one telescope at different times and wavelengths, astronomers ruled out the possibility that they were artifacts present in the raw data.

“The power needed to produce such an expansive radio emission is very strong,” Bulbul said. “Some simulations can reproduce their shapes but not their intensity. No simulations explain how to create ORCs.”

A NEW VIEW

Once Bulbul realized that ORCs have only been studied through radio data, she and postdoctoral researcher Xiaoyuan Zhang started diving into X-ray data from eROSITA. In short images with less than seven minutes of exposure time, the duo noticed some emission that indicated it could



LUCKY CHARM. The first ORC discovered, named ORC 1, appears in green as imaged in radio waves by South Africa's MeerKAT telescope and superimposed over an optical and infrared map from the Dark Energy Survey. J. ENGLISH (U. MANITOBA)/EMU/MEERKAT/DES

be coming from the Cloverleaf. This prompted the team to secure additional telescope time with ESA's XMM-Newton X-ray telescope.

Based on the XMM-Newton observations, a study led by Zhang and published April 30 in *Astronomy and Astrophysics Letters* proposes a possible origin for

the Cloverleaf. The team hypothesizes that it may have been created by two groups of galaxies in the midst of a messy merger. Just how many are in each group remains unclear, but the Cloverleaf seems to encompass at least a dozen galaxies in varying states of disfigurement. The XMM-Newton data also showed that as much as 700 billion solar masses' worth of hot gas wafts among the dozen galaxies, explains Zhang, reaching temperatures around 15 million degrees Fahrenheit (8 million degrees Celsius).

It's possible that the conditions generated by the merger have created shock waves that accelerated ancient cosmic ray particles within the galaxies, left over from when their central supermassive black holes were actively feeding. This acceleration could have created the observed radio emission.

Still, this finding raises other questions. For example, galaxy mergers frequently occur without any associated ORCs recorded, so it's important to pin down what creates the specific conditions that produce ORCs versus those that don't. —S.K.

GETTING WARMER

TIC 393818343 b, an exoplanet 300 light-years away, has been confirmed by citizen scientists as a "warm Jupiter," using data from NASA's TESS mission. The world may be migrating to a close-in orbit, transitioning to a hot Jupiter.

RETIREMENT PLANNING

NASA announced June 26 it has awarded SpaceX an \$843 million contract to design a vehicle to take the International Space Station out of orbit when its mission ends in 2030.

GREENHOUSE SPOTTING

To find exoplanetary life, astronomers have suggested looking for artificial greenhouse gases like perfluorocarbons, which could indicate intentional terraforming. Focusing on gases that can't be produced naturally would reduce false positives.

FAMILIAR HOSTS

Fast radio bursts (FRBs) are energy-packed flashes of radio waves. By studying how their polarization is altered by passing through their host galaxies, astronomers found that non-repeating FRBs likely come from galaxies like the Milky Way.

HUBBLE HOBbled

To save wear and tear, in June the Hubble Space Telescope switched to a mode that uses just one of its two remaining good gyroscopes while slewing. This slows the collection of data but won't affect their quality; Hubble has used one gyro while taking science data since 2021.

UNSCHEDULED FLIGHT

During a June 30 static fire test, a private Chinese Tianlong-3 rocket broke free from its test platform, launching on a brief flight. The rocket fell and exploded in the hills of Gongyi, 0.9 mile (1.5 km) southwest of the test platform. —DANIELA MATA

Growing globular gems

THE COSMIC GEMS ARC is a galaxy that can only be seen through gravitational lensing, as an extremely dense foreground object bends and focuses the incoming light of a more distant one. By training the James Webb Space Telescope on the Cosmic Gems arc (the lower of the two lensed galaxies in this image), astronomers detected five massive star clusters that might someday become globular clusters, dense balls of ancient stars. Each is only about a parsec (3.26 light-years) across, making them the smallest features ever resolved in a galaxy at this distance. We see the Cosmic Gems arc as it was 460 million years after the universe formed, during the epoch of reionization — when light from the first stars cleared away the dense fog of neutral hydrogen that prevailed in the early universe, ending the cosmic dark ages. Recent studies suggest that most of this light came from galaxies like the Cosmic Gems arc. Though such galaxies are faint in ultraviolet light overall, outflows from quickly forming star clusters could have swept away their dust, allowing their light to escape and transform the universe. —JOHN WENZ



ESA/WEBB, NASA & CSA, L. BRADLEY (STSC), A. ADAMO (STOCKHOLM UNIVERSITY), AND THE COSMIC SPRING COLLABORATION

Chang'e 6 nabs first samples from Moon's farside

» China's robotic Chang'e 6 mission returned to Earth on June 25 with an eagerly awaited stash of rocks from the Moon's farside — a historic first, and the latest achievement for the growing space power.

Chang'e 6 launched May 3 from the Wenchang Space Launch Site on the island of Hainan, atop a Long March 5 booster. It entered a highly elliptical lunar orbit May 8 and spent the rest of the month lowering its orbit and looking for a suitable landing site. (It also released a Pakistani cubesat

that imaged the Moon and captured data of its magnetic field.) Mission planners eventually chose a site in the Apollo basin, an impact crater with an eroded inner ring.

The lander touched down in Apollo at 23:23 UT on June 1, carrying with it three international instruments from the European Space Agency, France, and Italy. Over the next two days, the lander carried out its sampling work with a drill and robotic arm. Throughout the process, controllers were able to establish periodic windows of communication

with the farside using the lunar-orbiting Queqiao-2 relay satellite.

The lander then transferred the samples to the ascent stage stacked above it, which lifted off from the lunar surface at 23:38 UT on June 3. A few days later, the ascender docked with the orbiter and return vehicle, which had remained in lunar orbit. About two weeks later, the return vehicle began the journey back to Earth. After jettisoning the service module, the craft touched down in the Siziwang Banner province of China's Inner

Mongolia Autonomous Region at 06:07 UT on June 25, carrying what officials would later announce as 4.27 pounds (1,935.3 grams) of samples, just shy of the mission's target of 4.41 pounds (2 kilograms).

Scientists hope the new samples will help explain why the rugged, crater-pocked lunar farside is so different from the lava plains that mark the nearside, and shed light on the origin of both the Moon and Earth.

The China National Space Administration says it plans to offer portions of the Chang'e 6 samples to international labs, as it did in August 2023 for samples from Chang'e 5. Whether U.S. labs will be able to

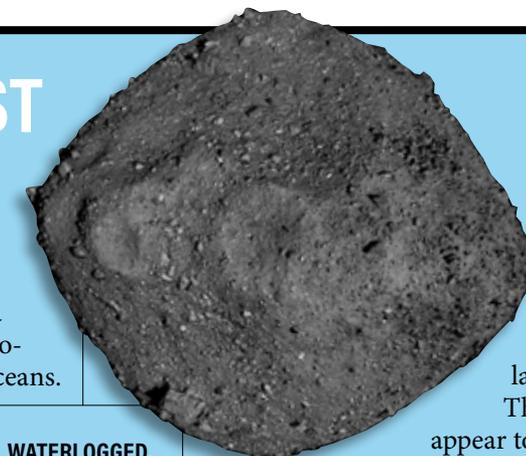
BENNU'S WATERY PAST

WHEN WE THINK OF WATERY LANDSCAPES in the solar system, the first body to come to mind likely isn't an asteroid. But an early analysis of samples returned from the asteroid 101955 Benu hints that this 0.3-mile-wide (500 meters) pile of rubble is a piece of a larger body that may have once sported an active hydrothermal system and maybe even subsurface lakes or oceans.

In a study published June 26 in *Meteoritics & Planetary Science*, researchers examined 0.5 ounce (14.9 grams) out of the total 4.3 ounces (121.6 g) of Benu's material returned to Earth in September 2023 by NASA's OSIRIS-REx mission. They found that most of the minerals are phyllosilicates. These are produced when silicate materials interact with water, especially alkaline fluids.

"Think soda water with lots of carbon dioxide," says lead author Dante Lauretta of the University of Arizona, who is also the OSIRIS-REx principal investigator.

The sample also yielded a surprise: magnesium-sodium phosphates. Lauretta says this type of phosphate is intriguing because it only forms when water has become saturated with carbonates. This suggests that pools of water persisted



WATERLOGGED.

Samples from asteroid 101955 Benu bear hallmarks of a history of flowing water. NASA/GODDARD/UNIVERSITY OF ARIZONA

on Benu's parent body for an extended time, perhaps akin to the salty brines found in evaporating lakes on Earth's surface.

The rock samples also appear to have been shaped by contact with water. Some particles

have so-called hummocky shapes resembling cauliflower, similar to rocks in southern Italy that formed in areas with shallow seas. Other particles have angular or sharp edges, suggesting that water fractured them in a higher-pressure environment.

One possibility to explain these findings is that heat from radioactive decay within Benu's parent body melted ices shortly after it formed 4.5 billion years ago. The resulting water could have altered the rocks for millions of years. "Depending on the ice-to-rock ratio, there could have been an ocean or lake capped by ice," says Lauretta. —THEO NICITOPoulos



MOON SELFIE. Chang'e 6 used largely the same technology as the successful Chang'e 5 mission, which scooped up 3.8 pounds (1.7 kg) of material from Oceanus Procellarum in December 2020. One exception was the addition of a mini-rover named Jinchang, which snapped this portrait of the lander. CNSA/HANDOUT VIA XINHUA

obtain any is yet to be seen. Since 2011, federal law has prohibited NASA from bilateral collaborations with China unless NASA certifies to Congress that there is no technology transfer or security risk. In late 2023,

NASA sought such approval for researchers to request Chang'e 5 samples; as of this writing, NASA is considering doing the same for Chang'e 6.

Chang'e 7, scheduled for 2026, will not focus on sample return but instead

land a larger scientific payload at Shackleton Crater in preparation for a future Chinese-led permanent base. Shackleton lies near the lunar south pole — the same region targeted by NASA's Artemis program. — MARK ZASTROW

320

The approximate number of basketball-sized meteorites that land on Mars each year, based on seismic data from NASA's InSight lander. This is five times higher than estimates published a decade ago based on satellite observations, suggesting that many impacts go undetected.

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Morehouse's Black Ring

A dark ring nebula hiding in plain sight.



The North America Nebula (NGC 7000) and Pelican Nebula (IC 5067/5070) harbor Morehouse's mysterious dark ring and B353. ADAM BLOCK/STEWART OBSERVATORY/UNIVERSITY OF ARIZONA; INSET: GARY IMM



BY STEPHEN JAMES O'MEARA
Stephen is a globe-trotting observer who is always looking for the next great celestial event.

→ In the pioneering days of long-exposure astrophotography in the late 19th century, the use of dry plates over wet collodion plates simplified the photographic process. The increased light sensitivity of the emulsion coatings on dry plates allowed for shorter exposure times and produced sharper images of the night sky. In 1881, the

French inventors brothers Auguste and Louis Lumière made improvements to these plates, rendering them easier and more convenient to use.

The results led to a new wave of scientific inquiries, and brought to light many features that weren't obvious to the eye. One such feature in Cygnus likely appears in many images taken by modern astrophotographers with basic equipment, though few may have noticed it.

In 1910, American astronomer Daniel Walter Morehouse used a Sigma Lumière dry plate to make a long exposure of the North America Nebula (NGC 7000) — the central figure of a region “most remarkable,” he wrote, for its variety of bright and dark nebulae. When Morehouse was developing the plate, “a number of curious spots appeared.” This was no surprise, as such features were characteristic to this brand of plate. However, a prominent dark ring appearing “a little to the north of the ‘St. Lawrence River’ region” — treating the North America Nebula as a map of its namesake — attracted his attention. Morehouse described it as “a ring formed by the absence of stars.” A second photograph at that time verified the structure's existence, although, he said, it was not as conspicuous.

Not until 1926, however — when Morehouse was president of Drake University in Des Moines, Iowa — did he return to observing the object. That summer, he

saw the dark ring standing out “with tantalizing clearness” in a 9¼-hour exposure taken over the course of two nights by Theodore G. Mehlin and Richard S. Zug with Drake Observatory's 8.25-inch refractor, newly equipped with a Brashear photographic doublet. “A careful examination of the negative,” Morehouse said, “convinced me that the structure is a ring of black nebula ... [that] forcibly reminds one of the Ring Nebula in Lyra except that it is much larger.”

The following year, he published his findings in the February issue of *Popular Astronomy*, in which he postulated that this feature is caused by a ring of black absorbing material that appeared to be in abundance throughout this portion of the Milky Way.

In June 1927, Morehouse and Zug took an additional 6½-hour exposure at Drake Observatory. They used the image to count the stars in the ring and its immediate vicinity. Their results, published in the 1928 *Proceedings of the Iowa Academy of Science*, confirmed the existence of a dark, absorbing nebula that appeared to lie some 1,500 light-years distant. However, they did not toss out the possibility that the ring could be composed of two nebulae at different distances.

After Edward Fath, director of Goodsell Observatory at Carelton College in Northfield, Minnesota, studied the ring on numerous photographs, he wrote to Morehouse in a private correspondence saying, “It is certainly a very peculiar structure in that it is so nearly circular,” and, like Morehouse, wondered if it was a dark Ring Nebula.

You'll find Morehouse's dark ring at R.A. 20h56m, Dec. 45°31', measuring 30' by 12' across. For several years prior to imaging this dark ring, Morehouse had referred to the structure as “The Bird's Nest.”

A prominent dark ring attracted his attention.

In 1927, Edward Emerson Barnard cataloged the dense eastern segment as dark nebula 353 (B353). In the ring's hollow region, toward its southern end, lies NGC 6996. It is currently uncertain whether this star group is an actual open cluster. However, recent data from the European Space Agency's Gaia mission — as well as the ground-based

2MASS survey and other independent studies — have found associated members.

While this fascinating and puzzling dark ring is easily captured in images, I'm wondering what it takes to see the complete ring visually, not just the dense eastern portion that comprises B353. I would hazard a guess that low-power views will be best, as it will condense the fainter segments of the ring, making it more apparent. As always, be sure to send reports on what you see or don't see to sjomeara31@gmail.com. ☞



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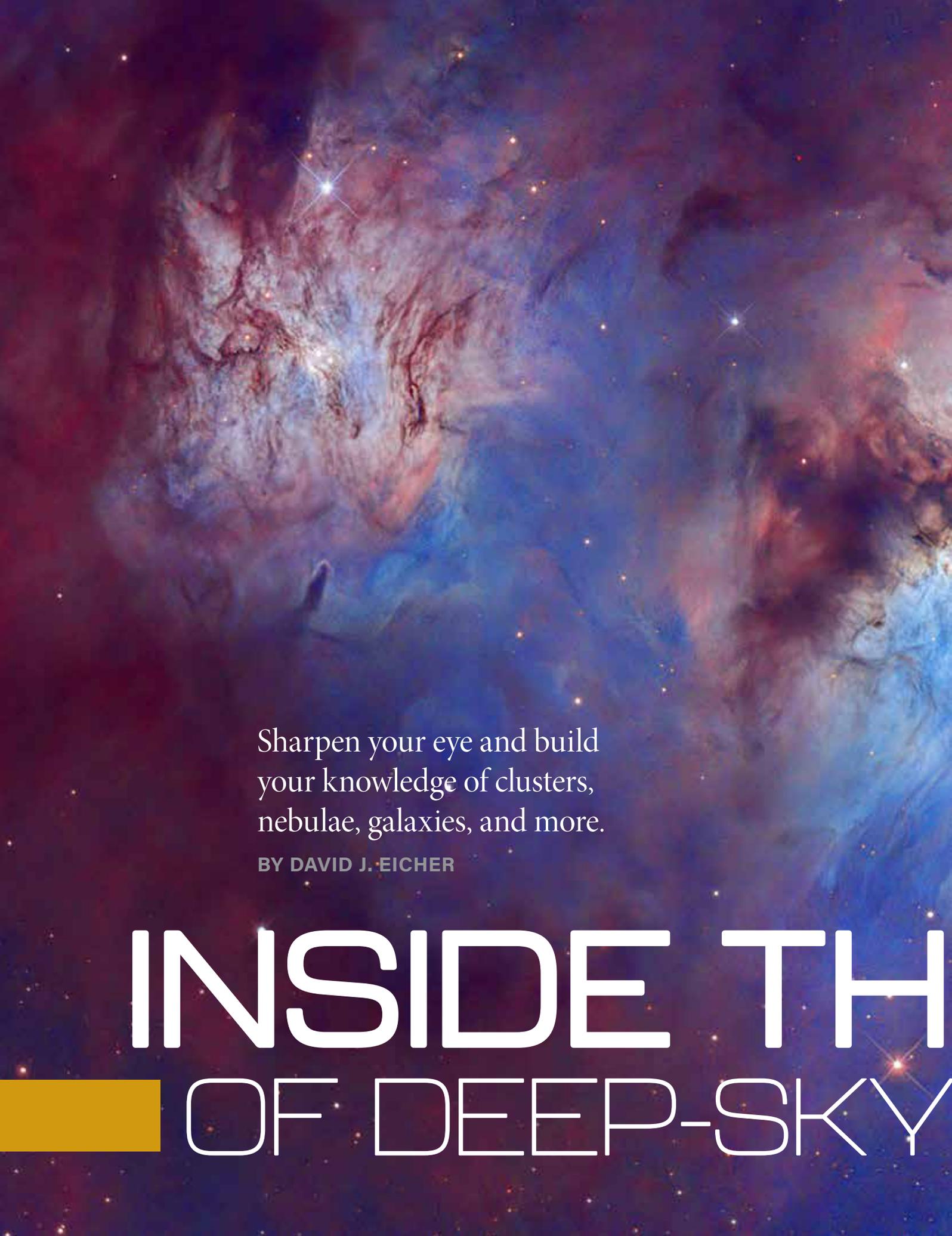
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BY DAVID J. EICHER

INSIDE THE OF DEEP-SKY



The blue reflection nebula M78 lies about 1,600 light-years away in Orion. It is a cloud of interstellar gas and dust that owes its luminosity to embedded, bright, blue, early B-type stars — making it the brightest diffuse reflection nebula in the Orion B molecular cloud complex. TONY HALLAS

E WORLD

OBJECTS

Do you remember the first time you truly discovered the universe? When I was a teenager, many moons ago, I bought my first telescope, a Celestron 8. I remember excitedly unboxing it the day it arrived. Fortunately, I had a clear sky that evening and stayed up all night observing. In the early morning, I swung the scope over to the vicinity of the constellation Cygnus. Boom. There it was, plain as day: the Veil Nebula, its faintly glowing gray-green arcs of nebulosity running through a rich, speckled, multicolored star field, appearing like luminous fragments of twisted rope. I was absolutely stunned.

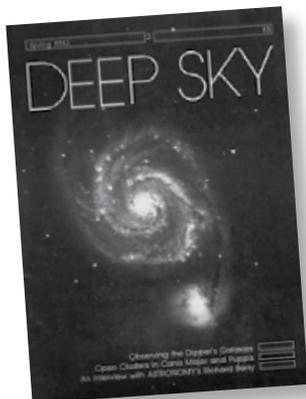


Antares

ABOVE: The variable star Antares shines brightly at 1st magnitude and is located in the Rho (ρ) Ophiuchi cloud complex, a giant molecular cloud composed partly of bright ionized hydrogen and largely of dark dust.

MASSIMO TAMAJO

RIGHT: My monthly magazine eventually became a quarterly, *Deep Sky*, when I joined the *Astronomy* magazine staff in 1982. KALMBACH MEDIA



What really surprised me is that I had read that the Veil Nebula was not supposed to be visible in a such a small telescope. That night it struck me that much of the information about sky objects was wrong, or naïve, or based on observations under poor conditions. As a result, I created a small publication called *Deep Sky Monthly*, pushing ahead in step with a growing generational

awareness of the universe. The publication coincided with the so-called Dobsonian Revolution, in which larger telescopes were rapidly becoming available to backyard astronomers.

At the same time, an information revolution was opening up new possibilities for telescopic targets. Rather than the limited few hundred objects most people thought were observable, the 1980s and 1990s saw an explosion of observers going after thousands of objects that were previously pretty much unknown. And now, a generation later, the world of deep-sky objects has never been better. Telescopes and imaging systems have improved dramatically over the last few years, and the knowledge of deep-sky objects has correspondingly sharpened.

What follows is a guide to the basic types of objects you can go after as an observer or imager targeting the distant cosmos. (*Deep-sky* simply means “beyond the solar system.” Objects within the solar system, such as the Moon and planets, will have to step aside for this article.) So buckle up and get ready for an overview of the many creatures that inhabit the Milky Way Galaxy, and distant shores of the cosmic ocean far beyond our own galaxy’s disk.

Double stars

Some of the most cherished memories I have of astronomical observing stem from my earliest teenage days. Those nights before I was familiar with the sky — when I simply went after everything, not knowing whether I could see an object or what it would look like — represented pure exploration and adventure. Everything was a surprise. In my first year of observing, before the Celestron 8, I simply had a pair of 7x50 binoculars. Scanning the sky here and there revealed countless interesting and unusual star fields. The luminous band of the Milky Way washed in and out of the field of view. And everywhere I looked, sparkling stars formed patterns. Many of them appeared to be double or multiple stars, the simplest category of deep-sky objects.

The magnificent nuclear furnace that powers our solar system and enables life on Earth — the Sun — is an exception as a solitary star. More than half of the stars in the Milky Way Galaxy and almost certainly in the universe at large are double or multiple star systems.

The term *double star* simply means two stars that appear close to each other as we see them. While some doubles are optical double stars — chance alignments that are not physically close or gravitationally bound — the majority are binaries and are physically associated systems, where the stars are orbiting each other. Additionally, some star systems are multiples and contain three stars or more orbiting each other in sometimes chaotic but generally stable ways. In the Milky Way, some 60 percent of the stars have one or more companions.

Great examples of double stars are scattered all over the sky. The middle star in the handle of the Big Dipper, Mizar, forms a nice double with Alcor. Another excellent example is the “base” star in the Northern Cross asterism of Cygnus: Albireo, a beautiful

Telescopes and imaging systems have improved dramatically over the last few years, and the knowledge of deep-sky objects has correspondingly sharpened.

golden yellow star paired with a dimmer blue star. Many other bright and well-known stars are doubles: Acrux, Capella, Polaris, Procyon, Sirius, and more.

Variable stars

Over time, carefully viewing

double and multiple star systems and plotting their positions can show their movements as the stars slowly orbit each other. Change is a relative rarity in the deep sky, as most objects are so distant and cosmic timescales so long. But the class of deep-sky objects called variable stars offers the opportunity to see changes in stellar behavior over shorter timescales.

The term *variable* hints at their nature: stars that vary in apparent brightness over time. The earliest known written record of a variable star is in a 3,200-year-old ancient Egyptian calendar documenting the regular changes in brightness of Algol in Perseus; other early known variables include Betelgeuse and Antares. Variable stars change their light output for a variety of reasons. Some are intrinsic variables, with brightness

NGC 104, or 47 Tucanae, is the second brightest globular star cluster in the night sky at magnitude 4.1. Located in the constellation Tucana, this globular contains hundreds of thousands of members — 27 of them fast rotating pulsars. FERNANDO OLIVEIRA DE MENEZES

NGC 104, or 47 Tucanae

swings caused by changes in a star's internal properties. These include pulsating variables, eruptive variables, and cataclysmic variables that undergo enormous changes like novae and supernovae.

A second major classification of variable stars is extrinsic variables, star systems that vary in brightness due to external properties. These include eclipsing

binaries, star systems with members that occasionally eclipse their partner suns, and rotating variables, stars whose light output is affected by rotational characteristics. Some stars, for example, have enormous starspots that when aimed toward us, diminish the star's brightness.

Within these broad categories, many subtypes exist. Some have been incredibly important in the

history of astrophysics. Cepheid variable stars, for example, are named for the well-known prototype Delta (δ) Cephei. They vary in highly precise ways, such that their absolute brightnesses can be determined very well. So when Edwin Hubble discovered a Cepheid variable in 1923, in what was then called the Andromeda Nebula, the incredibly dim magnitude of the star could be used to calculate its great distance.

This revealed that Andromeda was a galaxy separate from the Milky Way, not a nebula within it — a breakthrough that unlocked the nature of galaxies in a first step toward understanding the vast cosmic distance scale.

Open star clusters

One major aspect of the universe is that it operates like a giant, well-crafted recycling program. Hydrogen, helium, and other light elements are converted into heavier elements in the bellies of stars. When the stars die, they spit these elements back out into the interstellar medium to form nebulae, which eventually collapse through gravity and become stars once again. These clouds tend to produce groups of stars, which we call open star clusters. (Our Sun was born as part of such a group.)

Open clusters abound in our sky, so you're undoubtedly familiar with a few. Those close to us in the galaxy include the Hyades, the V-shaped cluster that makes up the brightest part of the constellation Taurus. It lies 153 light-years away. Another smaller bright cluster, the Pleiades (M45), lies 444 light-years away. Altogether, the Milky Way contains some 1,100 open clusters, each containing dozens to several hundred stars.

The Ursa Major Moving Group is not an open cluster, but it's the closest physically associated group of stars at only 80 light-years away. The group's nucleus contains 14 stars that

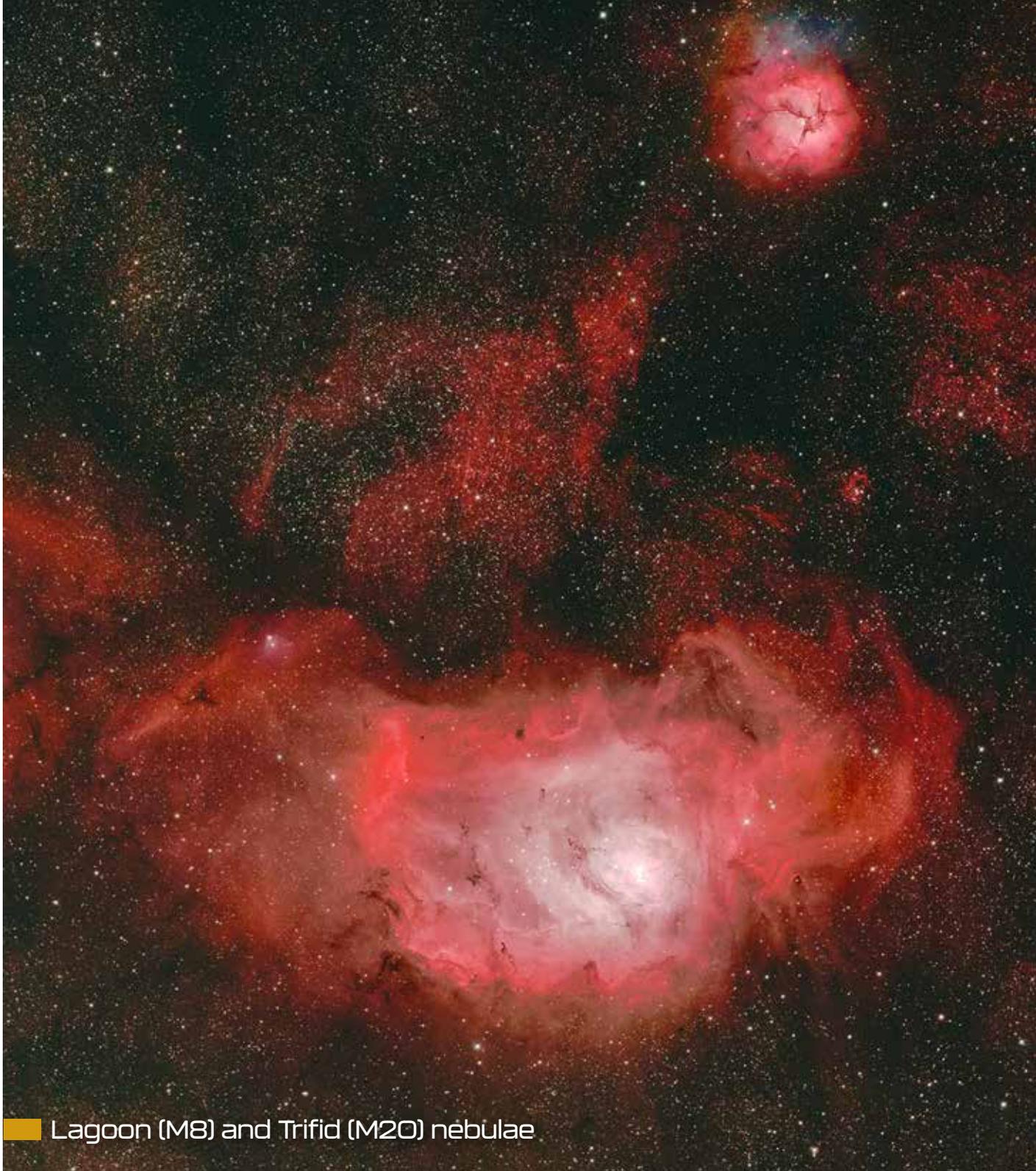
RIGHT: M27 is the Dumbbell Nebula, which lies more than 1,200 light-years away and glows at an apparent magnitude of 7.5. The clumps of gas and dust seen in this planetary nebula are caused when the stellar winds are not powerful enough to disperse them. As the nebula expands, the clumps are reshaped.

MARK GERMANI

BELOW: Mizar and Alcor are two stars that form a binary system visible to the naked eye. Mizar is the second star from the end of the handle of the Big Dipper and Alcor is the dimmer companion. In ancient times, this system was used as a vision exam.

MASSIMO DI FUSCO





Lagoon (M8) and Trifid (M20) nebulae

formed together several hundreds of million years ago. These stars include most of the stars in the familiar Big Dipper asterism.

So, if stars are born in open clusters and are surrounded by their dozens or hundreds of siblings, why is it that our Sun is a solitary star? Stars may be born in large groups, but the gravity

between them is not strong enough to keep them together forever. As open clusters orbit the Milky Way's center, tidal forces tear the stars from each other and scatter them into individuals or smaller associations. Thus, our Sun's siblings have long since departed for other areas of the galaxy.

Globular star clusters

While open star clusters exist in the Milky Way's disk and contain relatively young stars, another type of cluster plays the opposite role. Globular star clusters, named after their globelike shapes, lie scattered far out in the galaxy's halo, away from the younger disk. They contain hundreds

The stunning Lagoon (M8) and Trifid (M20) nebulae — located at the bottom and top of this image, respectively — display a diverse range of objects and systems, such as open clusters and emission, reflection, and dark nebulae. JOHN CHUMACK



The Pipe Nebula

The Pipe Nebula is composed of several smaller Barnard dark nebulae: B59, B65, B66, B67, B72, B77, and B78. The Pipe Nebula is a part of the Ophiuchus dark cloud complex, around 650 light-years from Earth.

FERNANDO OLIVEIRA DE MENEZES

of thousands — sometimes as many as a million — stars, predominantly old and yellowish. Astronomers believe that globulars formed in the early days of galaxy formation from material that did not fall into the rotating disks of their parent systems.

Although globular clusters lie at far larger distances than open clusters, many examples are bright and large enough to see nicely in amateur telescopes. They include M13 in Hercules and M22 in Sagittarius, as well as Omega Centauri and the great 47 Tucanae in the southern sky. Altogether, we know of about 160 globulars in the Milky Way, and it appears that nearly all galaxies have populations of globular clusters.

Some of the largest galaxies known are the giant elliptical galaxies that have grown as galaxies merge. These behemoths can contain as many as 15,000 globular clusters. One outstanding example is M87 — the most massive galaxy in the Virgo Cluster.

The largest globular clusters have an even more interesting tale to tell. Astronomers have concluded that these may be the remnant cores of disrupted dwarf galaxies whose material was partially dispersed, sending the core into a new life as a rich grouping of tightly packed stars. Omega Centauri is one such cluster; it contains 10 million suns and stretches over a diameter of at least 150 light-years, making it the most formidable globular cluster belonging to the Milky Way.

Emission nebulae

Our Milky Way and other galaxies do not contain stars alone. They are vast storehouses of gas. Under the right conditions, we see this gas as either glowing — excited by stars and fluorescing like an incandescent bulb — or simply reflecting light from bright stars toward us. These reflection and emission nebulae, along with other types of nebulae, make up some of the most interesting and

varied objects in our local part of the universe to observe with a telescope.

The primary type of nebula in our sky is emission nebulae. These glowing clouds of mostly hydrogen gas are the stellar nurseries of our Milky Way Galaxy. We can see magnificent examples with small telescopes from a dark-sky site.

Some emission nebulae are so bright and so large that they can be seen with the naked eye. In the Northern Hemisphere, the most celebrated example is the Orion Nebula, visible as a fuzzy “star” in the center of Orion’s Sword. This glowing gas cloud lies about 1,500 light-years away, spans nearly 25 light-years, and is slowly churning out a cluster of infant stars. In the Southern Hemisphere is the spectacular Carina Nebula, the brightest and largest nebula in Earth’s sky. This beast glows with the brightness of a 1st-magnitude star and covers some 300 light-years of space — impressively bright from a distance of 7,500 light-years.

A raft of bright and interesting emission nebulae exists in the general direction of the galactic center. Here you will find stunning examples such as the Lagoon and Trifid nebulae, the Omega Nebula, the Eagle Nebula, and many more.



M60

Planetary nebulae

Also glowing by fluorescence but at the other end of the stellar life cycle are planetary nebulae. William Herschel is believed to have originated the term in the 1780s based on these objects' resemblance to planetary disks in the telescope. They have no connection to planets, however: Instead, they are the result of stars with about the same mass as the Sun approaching the ends of their lives.

As stars go about their existence, they convert hydrogen and other light elements into heavier elements by nuclear fusion. At some point, these stars transform as the supply of hydrogen is exhausted. Just by looking at the 3,500 known planetary nebulae in our galaxy, we can foresee the future of our solar system. In about 6 billion years, the Sun will start to exhaust the hydrogen fuel at its core, swell into a red giant, and begin to fuse helium. This will lead to instability and eventually force the Sun to puff off a shroud of gas that will constitute a planetary nebula. The first puffs will be relatively slow, followed by higher-velocity outbursts. The interaction between the gas and intense ionizing radiation from the star will cause the shroud to glow for something like 20,000 years.

Life on Earth will have been

As stars go about their existence, they convert hydrogen into heavier elements by nuclear fusion.

long gone before our Sun's planetary nebula stage arrives. But we can look through our telescope eyepieces to observe many examples of bright planetaries in our sky — some circular and others more elongated, like a squashed bug. A popular example is the Ring Nebula in Lyra, with its famous central dark hole and faint central star, dimly glowing away. Another is the Dumbbell Nebula in Vulpecula, appearing, as its nickname suggests, with a tapered center and rounded ends. Many others are scattered along the Milky Way, giving us a glimpse of our cosmic neighborhood's distant future.

Supernova remnants

Stars evolve and expire in an array of different ways. The least massive stars churn away with fusion for vastly long intervals; they may be the final, dimly glowing remnants in the cosmos'

distant future. Sun-like stars end as planetary nebulae and white dwarf remnants, as we've seen. More massive stars, however, with about eight times the mass of the Sun or more, have shorter lifespans and more violent ends.

The end result of a massive star's life is a cataclysmic explosion producing a supernova, which can briefly unleash so much energy that it outshines its entire host galaxy as it collapses to either a neutron star or a black hole. The byproduct of a supernova explosion is a supernova remnant — a glowing cloud of gas — and these nebulae can be observed for periods of hundreds of thousands of years before they dissipate into the interstellar medium.

You may well know of some celebrated examples of supernova remnants in our sky. The very first object in Charles Messier's famous list of deep-sky objects, M1, is the Crab Nebula — a supernova remnant. The bright exploding star was observed in various early cultural records in 1054, and we now see the slowly expanding remnant as a nebula. Other great examples also lie around the sky, including the Veil Nebula, the Vela Supernova Remnant, IC 443, and the small remnant cloud produced by the closest recent supernova, SN 1987A, in the Large Magellanic Cloud.

Left to right are examples of the three main types of galaxies in Edwin Hubble's tuning-fork classification: M60 in Virgo is an elliptical galaxy, though some say it could be lenticular; M95 in Leo is a barred spiral galaxy; and M104, also known as the Sombrero Galaxy, in Virgo is a spiral galaxy — without a bar. LEFT TO RIGHT: HARSHWARDHAN PATHAK; BERNARD MILLER; ADAM BLOCK/MOUNT LEMMON SKY CENTER/UNIVERSITY OF ARIZONA



M95



Sombrero Galaxy (M104)



Gemini / Jellyfish Nebula (IC 443)

Located 5,000 light-years away in the constellation Gemini is a supernova remnant called the Jellyfish Nebula (IC 443). The two exceptionally bright stars in this wide-field telescopic view are Tejat (top) and Propus (bottom).

MARTIN BRACKEN

Reflection nebulae

While emission nebulae, planetary nebulae, and supernova remnants all glow via excited atoms, not all nebulae are luminous. Reflection nebulae are clouds of interstellar dust that are visible from Earth because the geometry works in such a way that they reflect starlight toward us. They're

illuminated either by stars embedded within them or bright stars lying nearby.

The dust that comprises these nebulae contains minute particles of carbon, nickel, iron, and other elements. The presence of metallic elements (like iron and nickel) results in some reflection nebulae being aligned with the galactic

magnetic field. (This can happen with planetary nebulae as well.) Because they are not glowing, most reflection nebulae are faint. Good examples exist, however, such as M78 in Orion, the Witch Head Nebula in Eridanus, and the Merope Nebula surrounding the brightest stars in the Pleiades.

Many nebulae consist of combinations of emission and reflection nebulae. The most famous example with both types side by side is the Trifid Nebula, with its pinkish emission and bluish reflection “halves.”

Dark nebulae

A final broad category of galactic clouds is dark nebulae. These dense interstellar molecular clouds block starlight from beyond and therefore are seen as “negative spaces” in the fabric of the galaxy. The astronomer Edward E. Barnard recorded several hundred such objects in his famous catalog called “Barnard’s Catalogue of 349 Dark Objects in the Sky,” published in 1927. The particles that make up dark nebulae are coated in carbon and quite small, perhaps about the size of those in smoke. A great density of these particles needs to be present to block the light of stars lying behind them.

Observing dark nebulae can be a challenge, because to see them well requires a really dark sky. Under good conditions, though, huge dark nebulae can be seen running along and through the luminous band of the Milky Way from a dark sky site. Other notable smaller dark nebulae include the celebrated Horsehead Nebula in Orion, the Coalsack in the southern constellation Crux, the Pipe Nebula in Ophiuchus, Barnard’s E (B142 and B143) in Aquila, and many more.

Galaxies

In late 1923, Edwin Hubble made his breakthrough discovery of the nature of the Andromeda Galaxy. In the decades since, astronomers



Pleiades (M45)

The Pleiades (M45) is an open star cluster in Taurus surrounded by a reflection nebula. The cluster is composed of more than a thousand stars but is mostly known for a handful of dominating stars, earning M45 the nickname Seven Sisters. ANTONIO FERRETTI/ATTILIO BRUZZONE

have not only discovered that the Milky Way and Andromeda are two big galaxies in our Local Group, but that the universe contains at least on the order of 100 billion galaxies, and that they display a few basic types of morphology.

Three sizable galaxies exist in our own Local Group: the two just mentioned and M33. But just like stars, the most numerous galaxies are dwarfs. At least 80 such members reside in the Local Group, and possibly more — nearly all of them dwarfs. Setting dwarfs aside, however, normal galaxies constitute several types. The first is the spiral galaxy, which consists of a flattened bright disk of stars, gas, and dust, with a dark matter halo and a cloud of globular clusters surrounding it. Countless galaxies familiar to readers and observers are spirals, including Andromeda, M33, the Whirlpool Galaxy, M81, M101, and many more.

For decades astronomers believed the Milky Way was a “normal” spiral galaxy. However,

in the last 20 years, astronomers have mapped the existence of a prominent bar in our galaxy, placing it into the second major type, barred spirals. A barred spiral galaxy has a bright disk, but its distinguishing feature is a prominent, elongated bar of material passing through the nucleus, anchoring spiral arms at each end. Barred spirals are common. Aside from our galaxy, examples include M95, M109, and the Large Magellanic Cloud — one of the Milky Way’s satellite dwarf galaxies.

The third major type of galaxy is the elliptical. Rather than a flat disk of stars, ellipticals are spherical balls of stars with very little gas and dust. Because of their shape, they can contain a vastly larger amount of matter than a flattened disk with the same diameter. For years astronomers struggled with ideas of how elliptical galaxies form. Today, the consensus is that they are created from the mergers of disk galaxies. We now know that the Milky Way and Andromeda are moving

toward each other and will eventually merge, turning into a single, massive elliptical something like the well-known galaxy Centaurus A in the Southern Hemisphere. Countless examples of ellipticals litter the sky, and include M49, M60, and M87.

The realm of the deep sky has completely transformed over the past generation. Thirty years ago, the great majority of enthusiasts were targeting the same couple hundred objects, starting with the Orion Nebula and Andromeda Galaxy. Now, the information explosion has redirected people to vastly more distant places. Armed with smart scopes, better info, and curiosity, we can go after strange nebulae, vistas of star formation, strange galaxy clusters, and binary star systems that house hidden black holes. The sky is truly now the limit. ☾

David J. Eicher is editor of *Astronomy*, author of 26 books on science and history, and a member of the boards of the *Starmus Festival* and of *Lowell Observatory*.

Tour the Sculptor's Workshop

This faint southern constellation contains a smattering of galaxies — and one standout globular cluster — to explore. **BY MICHAEL E. BAKICH**

THE CONSTELLATION SCULPTOR is not an easy star pattern to find, but it's worth the effort because it contains some gorgeous deep-sky objects.

Its name comes from French astronomer Nicolas Louis de Lacaille, who surveyed the southern sky from 1750 to 1753 at the Cape of Good Hope. He called the pattern "The Sculptor's Workshop," but this was later shortened.

Sculptor lies south of the border between Cetus and Aquarius and north of Phoenix. The best time to see this constellation is in the early fall in the Northern Hemisphere, when it reaches its highest point at midnight.

Although Sculptor isn't huge or bright, the best observers always set aside a few hours each year during its brief window of visibility. It doesn't contain any Messier objects, but it does boast a handful of nice galaxies and a sweet globular cluster. So, consider packing your telescope and heading south if necessary to place the Workshop and all of the under-observed



NGC 300 is nicknamed the Southern Pinwheel Galaxy, a reference to the Pinwheel Galaxy (M33) in Triangulum. The Southern Pinwheel lies just 6.5 million light-years away. **DAN CROWSON**

and overlooked deep-sky objects it holds high in your sky.

Our first object is **Bond's Galaxy**, also known as NGC 7793, one of five galaxies with a proper name in this faint constellation. (Sculptor lies at the top of the constellation heap in terms of having common names for objects.)

This face-on flocculent — meaning that it has a fluffy or patchy appearance — spiral glows at magnitude 9.0, which lands it on the top 40 chart for brightest galaxies. Indeed, even observers with small telescopes at a dark site won't have trouble seeing NGC 7793 for two reasons: First, it measures 9.3' by 6.3', and second, it has a high surface brightness.

To locate it, aim your scope 5° south-southeast of Delta (δ) Sculptoris, which glows at magnitude 4.6. For those of you using 8-inch or larger instruments, view NGC 7793 through eyepieces that give ever-higher powers until the seeing (steadiness of the sky) breaks down. See if you can trace the closely packed spiral arms by following the gentle curves made by star-forming regions that appear brighter than the gas and dust around them.

Scottish astronomer James Dunlop discovered this galaxy in 1826 from Paramatta, Australia. He found it while using a 9-inch reflector to survey southern sky objects. But the galaxy's namesake is American astronomer

George Phillips Bond, who independently discovered it in 1850 from Cambridge, Massachusetts. At that time, Dunlop's much earlier discovery was unknown.

Second on our list is the **Southern Cigar Galaxy**, which also goes by the designations Caldwell 72 and NGC 55. Amateur astronomers gave NGC 55 its common name because it resembles the Cigar Galaxy (M82) in Ursa Major — a lot. At magnitude 7.9, this barred spiral is visible through high-quality binoculars from a dark site. Its large apparent size (32' by 6') is due to its distance, a scant 6.5 million light-years away.

To locate this galaxy, point your telescope roughly 4° northwest of 2nd-magnitude Ankaa (Alpha [α] Phoenicis). Then get comfortable, because there's a lot to see here.

If you start with low magnification, the first thing you'll notice is that the galaxy isn't centered on its core; most of the galaxy lies west of it. The overall appearance, then, is that of a celestial cigar. If you then view it at high power, you'll separate the main part of NGC 55, which contains the most stars, from the other, less starry side.

All along its length, the Southern Cigar Galaxy displays many star-forming regions. One of them even has its own designation, IC 1537. You might be able to spot some of these stellar nurseries if you use an Oxygen-III filter in combination with an 11-inch or larger telescope. (You'll need that much light-gathering power because the filter won't let through much light.)

Our third target is the barred spiral galaxy **NGC 134**. You'll find it 0.5° east-southeast of 5th-magnitude Eta (η) Sculptoris. It glows at magnitude 10.4 and measures 8.5' by 1.9'.

Put an eyepiece that gives a magnification of about 100x into an 8-inch telescope and look for an elliptical glow surrounding a starlike nucleus. You won't see the spiral arms because of their orientation. Through 16-inch and larger telescopes, you'll just start to see indications of them. They'd be easy to spot if NGC 134 were face on, but they appear tightly wrapped and are thus difficult to separate.



At a distance of 12 million light-years and around 105,000 light-years across, NGC 253's angular length is close to the diameter of the Full Moon. VIKAS CHANDER



Next, point your telescope at another, slightly smaller, barred spiral galaxy, **NGC 150**. To locate it, look 5.5° west-northwest of Alpha Sculptoris. It glows at magnitude 11.3 and measures $3.4'$ by $1.6'$.

Medium-size telescopes won't show a lot of detail in this galaxy because it's only half the size of the Milky Way and 70 million light-years away — but you will notice its bright, concentrated core. If you can use an 11-inch telescope, crank the power up as much as the seeing will allow. Then look for a faint ring of light surrounding the brighter core. NGC 150's spiral arms only show up through 16-inch and larger scopes.

OK, enough of the faint stuff. It's time to observe one of the top 10 galaxies in the sky, the **Silver Coin Galaxy**. Also known as Caldwell 65 and NGC 253, this object glows brightly



CLOCKWISE FROM TOP:

NGC 55's oblong shape gives it an uncanny resemblance to the Cigar Galaxy (M82).

FERNANDO OLIVEIRA DE MENEZES

NGC 150 is infrequently imaged, but doing so reveals its fainter extended outer arms. GARY IMM

In a telescope, flocculent, face-on NGC 7793 looms large and bright from a distance of roughly 12 million light-years away. DAN CROWSON

(for a galaxy) at magnitude 7.6, which puts it in easy range of pretty much all binoculars. It's also huge (again, for a galaxy), measuring $30'$ by $6.9'$. To find it, look not quite 5° north-northwest of Alpha Sculptoris.

When I was younger (OK, a lot younger), I could see NGC 253 with my naked eyes. You can try it, but it's an observation that takes a lot of patience. Your latitude matters, too. From 40° north, the galaxy climbs to a maximum altitude of 25° . Even from my current

observing location in Tucson, it's only a bit more than one-third of the way from the horizon to the zenith.

German-born British astronomer Caroline Herschel discovered the Silver Coin Galaxy in 1783 through a 4.2-inch reflecting telescope. It still looks good even through such a small instrument. (Well, better, because telescope optics have come a long way in the past two-and-a-half centuries.) But use an 8-inch or larger telescope, and details really begin to pop.

The first thing you'll notice is that the galaxy has a slightly spotty look. Observers call this trait mottling. Next, you'll notice that, unlike the majority of spiral galaxies, the central region doesn't stand out. Larger scopes and high powers may let you pick out the two main spiral arms. They are not easy to see.

Now we come to the one non-galaxy on our list, globular cluster **NGC 288**. It glows at magnitude 8.1 and has a diameter of $13.8'$.

To find this object, point your scope 3° north-northwest of Alpha Sculptoris. If your site is dark, try viewing NGC 288 and the Silver Coin Galaxy together through binoculars. NGC 288 lies a bit less than 2° southeast of the galaxy.

NGC 288 is unusual because its central region isn't densely packed, as in most globulars. Because of that, you'll be able to resolve a couple dozen stars through an 8-inch telescope with a medium-power eyepiece. Higher magnifications in bigger scopes will let you count more than 100 of them.

The next target on our list is a great one: the **Southern Pinwheel Galaxy**, cataloged as Caldwell 70 and NGC 300. This beauty glows at magnitude 8.1 and measures an impressive $20'$ by $13'$. To find it, look in southeastern Sculptor about 1.7° northwest of magnitude 5.6 Xi (ξ) Sculptoris. It was discovered by Dunlop in 1826 through a 9-inch reflector.

NGC 300 is the ninth-nearest non-dwarf galaxy, lying only 6 million light-years away. Amateur astronomers bestowed on it its common name because it looks a lot like the Pinwheel Galaxy (M33) in Triangulum.

When you observe the Southern Pinwheel, first locate its tiny core. From

CLOCKWISE FROM TOP:

NGC 288 is relatively loosely packed, without the concentrated core that is characteristic of a globular cluster. DAN CROWSON

The Sculptor Dwarf Galaxy may not be visually impressive, but it is remarkable for its history — it is much older than its host galaxy, the Milky Way, and lacks heavy elements. This makes it a valuable record of what some of the earliest galaxies in the universe were like. DAN CROWSON

The frequently overlooked spiral NGC 613 lies around 86 million light-years away, but the thinness of its spiral arms help them stand out in an 11-inch telescope. WARREN KELLER/MIKE SELBY

NGC 134 is a barred spiral galaxy, but its tilted orientation makes it tricky to see its arms. It lies about 50 million light-years away. WARREN KELLER/STEVE MAZLIN

there, move outward and take note of how wide and bright its central region is. Finally, try to identify the galaxy's two main spiral arms, which are quite thick.

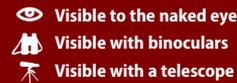
Next is the **Sculptor Dwarf**, a dwarf spheroidal galaxy (the first ever discovered), and the most difficult object on this list. To locate it, aim your telescope a bit more than 2° south-southwest of 5th-magnitude Sigma (σ) Sculptoris. Although it glows at magnitude 8.8, don't be surprised if at first you don't see it. This galaxy covers an area 1.1° by 0.8° , so it doesn't just jump out of the background. Observers who have spotted it used low-power eyepieces in large scopes. Once you're in the area, pan your field of view north and south or east and west until you detect a faint increase in the background glow. That's it.

Our final target is spiral galaxy **NGC 613**, a true under-observed gem. It glows at magnitude 10.1 and measures $5.5'$ by $4.1'$. You'll find it 0.6° northwest of 6th-magnitude Tau (τ) Sculptoris. A 6-inch telescope will show just a fuzzy oval. Step up to an 11-inch instrument, however, and lots of details will pop into view. Use as high a power as the seeing allows and look for thin spiral arms radiating outward from the bright core. ☾

Michael E. Bakich is an associate editor of *Astronomy* and enjoys slowly moving his telescope through a single constellation.



SKY THIS MONTH



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

BY MARTIN RATCLIFFE AND ALISTER LING



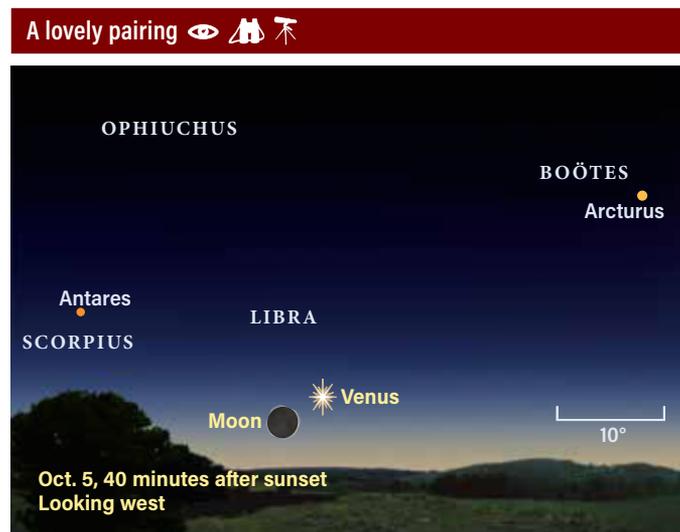
Mars (the bright object at center) is once again making its way through Gemini (whose two bright stars are at left) and increasing in size and brightness as it approaches opposition in January. ALAN DYER

» October finds Mercury and Venus in the evening sky. Mercury is shy and takes some effort to see, but brilliant Venus is not hard to find. Saturn, Neptune, Uranus, and Jupiter rise in that order before midnight. Mars becomes a fine bright object in the predawn sky, standing high in the east. And C/2023 A3 (Tsuchinshan-ATLAS) may be on show as the comet passes closest to Earth and springs into the evening sky.

Mercury comes out of superior conjunction early in the month and by the 31st reaches an elongation of 18° east of the Sun. It stays very low above the western horizon due to the shallow angle of the ecliptic. By the 24th it remains difficult to spot, even at magnitude -0.4, since it sets 35 minutes after the Sun. Mercury's visibility doesn't improve much by the end of the month, as it dims by 0.1 magnitude and remains a mere 2° high 30 minutes after sunset.

Dominating the evening is Venus, shining at magnitude -3.9 and more than 30° east of the Sun. You can use it as a guide to try and spot Mercury later in October by following a sightline down from Venus toward the direction of sunset.

On Oct. 5, look for the thin crescent Moon less than 5° from Venus. Venus sets 80 minutes after the Sun in early October, offering a lovely view in deepening twilight. Through a telescope Venus is 12" wide and 84 percent lit.



A delicate crescent Moon joins blazing Venus in the evening sky early this month. A few days earlier, the Moon could share the sky with Comet Tsuchinshan-ATLAS — if the latter is visible. ALL ILLUSTRATIONS: ASTRONOMY; ROEN KELLY

Mid-October will bring the highly anticipated Comet Tsuchinshan-ATLAS to the evening sky. It is 20° to 25° northwest of Venus on the 13th and 14th. Look for it in binoculars; by the time you read this, perhaps it could even be visible without aid. Time will tell, as comets rarely follow brightness estimates. Venus continues from Libra into Scorpius and then Ophiuchus. By the 25th, Venus stands 3° due north of Antares, a 1st-magnitude star dimly visible in evening twilight.

By the end of October, Venus has moved a bit closer to Earth, spanning 14" and 77 percent lit.

Already high in the southeastern sky as twilight falls, Saturn is ready for focused attention. By 8 P.M. local daylight time on the 1st, it stands 20° high among the stars of Aquarius. By the 31st, it's some 40° high at the same time and remains visible well into the morning hours. It stands 2° from Lambda (λ) Aquarii, a 4th-magnitude star. Saturn spends most of the month at magnitude 0.7, outshining everything in this region including 1st-magnitude Fomalhaut, 20° south of the planet. It fades by 0.1 magnitude by the 31st, when it is 842 million miles from Earth.

Saturn's shadow falls on the rings with increasing prominence throughout the month as the planet moves away from opposition. The tilt of the rings reaches 5° during October and will increase for one more month before beginning to narrow in the lead-up to the ring plane crossing next March.

The apparent size of Saturn's disk through a telescope diminishes from 19" to 18", while its squashed polar diameter drops to 16". The rings' major axis of

RISING MOON | Lava, lava, lava, dome

OBSERVING HIGHLIGHT

COMET C/2023 A3 (TSUCHINSHAN-ATLAS) makes its closest approach to Earth Oct. 12.



43" on the 1st shrinks to just over 41" by the 31st.

Titan, Saturn's largest moon, is 8th magnitude — an easy target for any telescope. It stands near the planet Oct. 3, 11, 19, and 27, located just a few arcseconds off the northern or southern limb. It stands east or west of the planet Oct. 9, 17, and 25.

Look for 10th-magnitude Tethys, Dione, and Rhea orbiting from night to night, sometimes skimming the edge of the rings or undergoing transits and occultations. Telescopes larger than 10 inches using high-speed video capture under good seeing conditions have a chance.

Iapetus reaches its brighter western elongation Oct. 13, shining near 10th magnitude and 9' due west of Saturn. It spends the rest of the month moving toward superior conjunction and is less than two days shy of this on the 31st, when it stands 1' southwest of Saturn — a great time to spot this unusual moon. Its darker face has progressively turned our way, so it has dimmed by about a full magnitude.

Neptune rises before sunset and is well placed in the southeastern sky by full dark, gaining altitude through midnight.

During October, Neptune wanders west and forms a nice triangle with 24 and 20 Piscium, which lie just over 5° southeast of — *Continued on page 34*

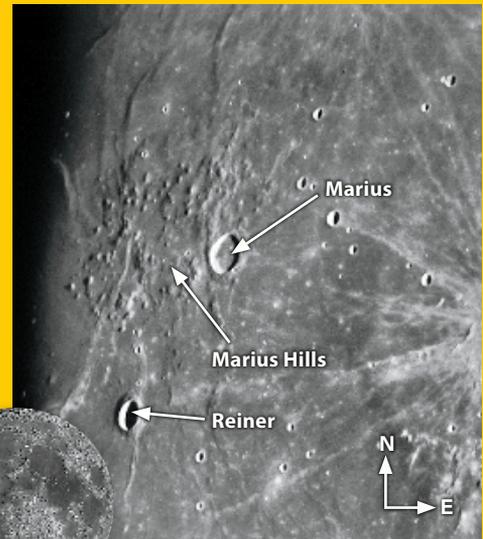
AMONG THE BEST volcanic features on the face of the Moon (not counting the huge "seas") is the field of domes known as the Marius Hills. Located in the vast Oceanus Procellarum basin near the craters Marius and Reiner in the lunar west, the coarse, sandpaper-like terrain sees first light about three days before Full phase.

The Moon is quite bright on the evening of the 14th — use a filter to reduce the glare, or even sunglasses will help. At first your eye will be drawn to Tycho's spectacular ray system and then to brilliant Aristarchus, dominating Luna's northern section at this phase. Have a look, but then shift your concentration to an area just north of the equator and boost the magnification.

How did the Moon develop this outbreak of hives? Astronomers reason that the evidence points at more than one episode. A few hundred steep-sided cone volcanoes erupted onto the scene when a huge zone of magma upwelled. Less violent eruptions then built the dome structures surrounding them. Finally, volumes of lava oozed out of cracks and vents to fill much of the vast basin surrounding the Marius Hills. To the first lunar observers, this huge expanse of darker, smoother terrain evoked a sense of the sea.

Under turbulent skies you might only see the two larger peaks. The Marius Hills will be harder

Marius Hills 🔭



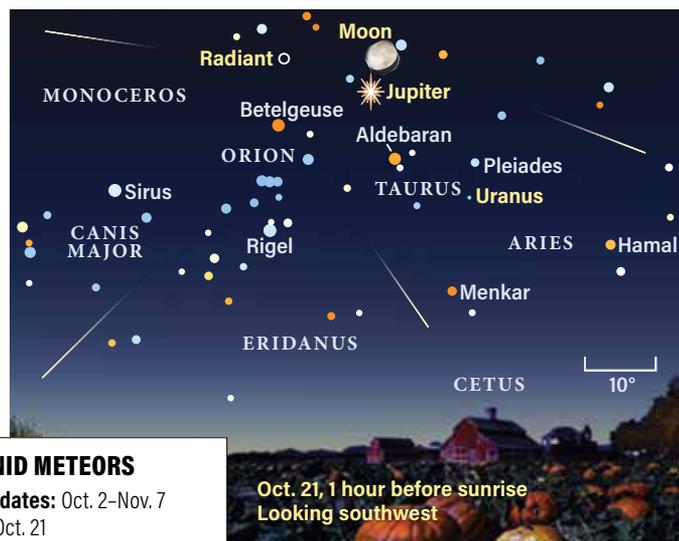
The Marius Hills lie near the craters Marius and Reiner. Kepler lies to the east, just out of view in this image. CONSOLIDATED LUNAR

ATLAS/UA/LPL. INSET: NASA/GSFC/ASU

to notice on the 15th, and by the 16th the higher elevation of the Sun will have wiped out the shadows necessary to observe textured terrain. Before moving on, take some time to admire the bright splash of rays from the relatively younger Kepler.

METEOR WATCH | Fighting moonlight

Orionid meteor shower 👁



ORIONID METEORS

Active dates: Oct. 2–Nov. 7

Peak: Oct. 21

Moon at peak: Waning gibbous

Maximum rate at peak:

20 meteors/hour

Oct. 21, 1 hour before sunrise
Looking southwest

The bright gibbous Moon will diminish this year's Orionids, but brighter meteors may still be visible.

THE REMNANTS OF HALLEY'S COMET generate the annual meteor shower called the Orionids. It's active from Oct. 2 through Nov. 7, with the peak occurring on Oct. 21. A bright gibbous Moon located on the Taurus/Auriga border will strongly affect the appearance of Orionid meteors.

The shower has a zenithal hourly rate of up to 20 meteors per hour on the morning of maximum, corresponding to an observable rate of some 15 to 18 per hour between 2 A.M. and dawn. The radiant lies in northeastern Orion and rises by 10:30 P.M. local daylight time.

STAR DOME

HOW TO USE THIS MAP

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

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

10 P.M. October 1
9 P.M. October 15
8 P.M. October 31

Planets are shown at midmonth

MAP SYMBOLS

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

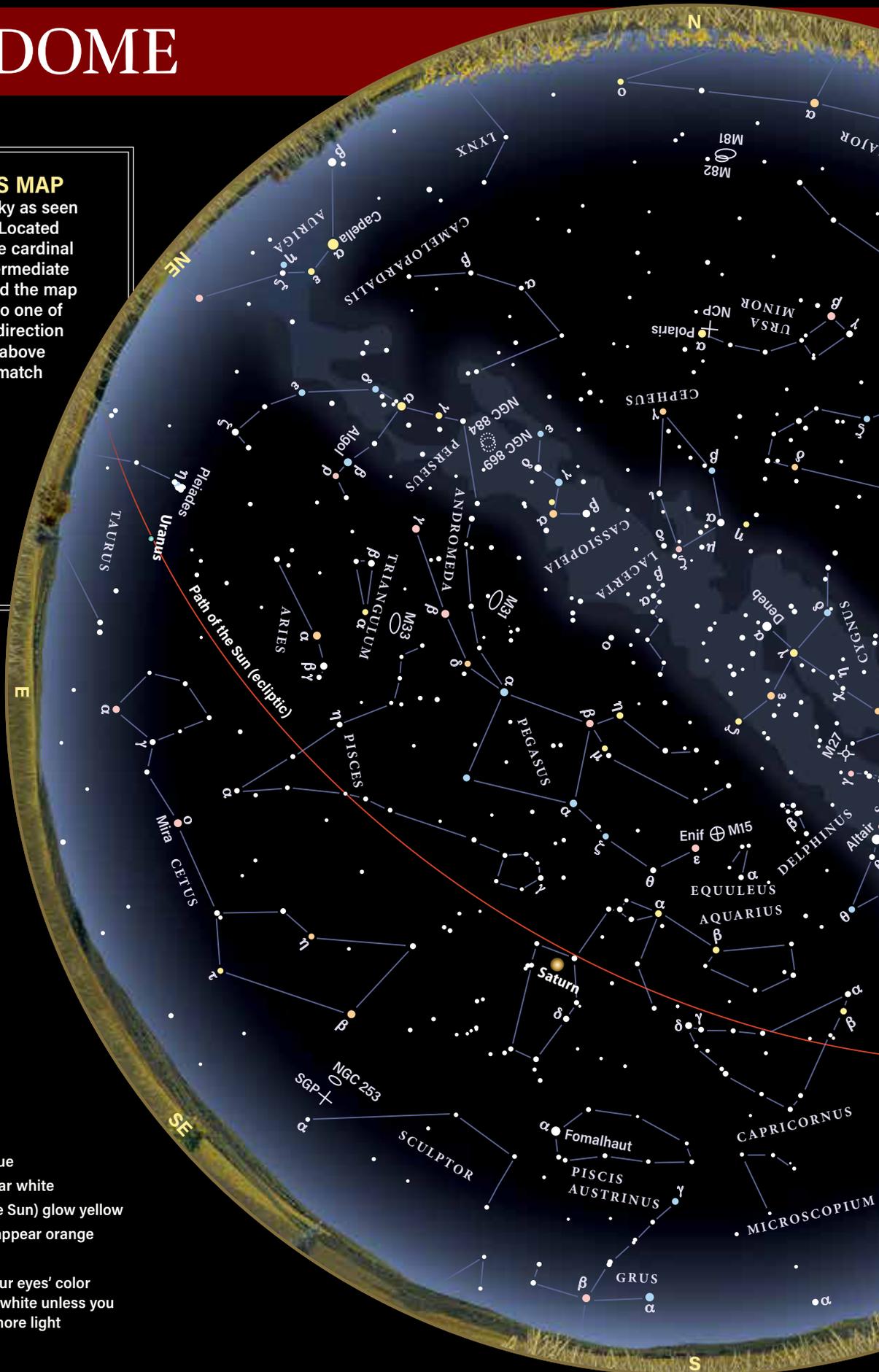
STAR MAGNITUDES

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

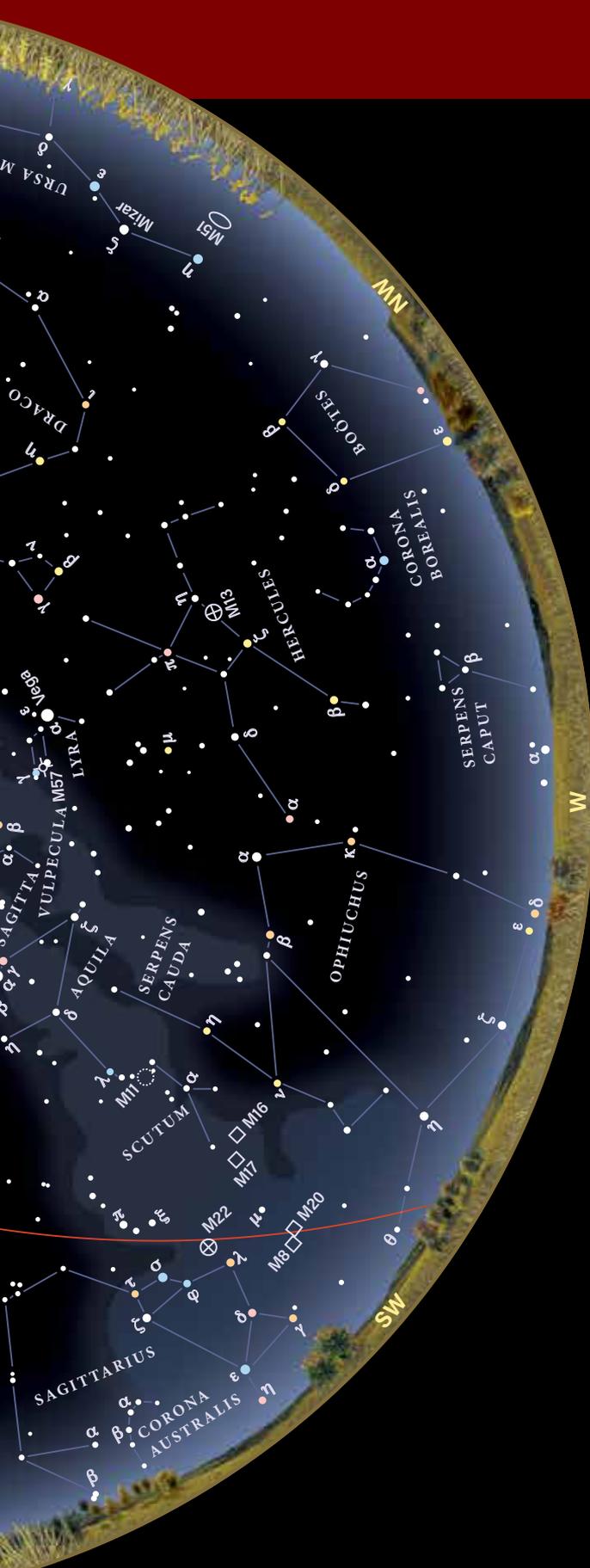
STAR COLORS

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.



OCTOBER 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		

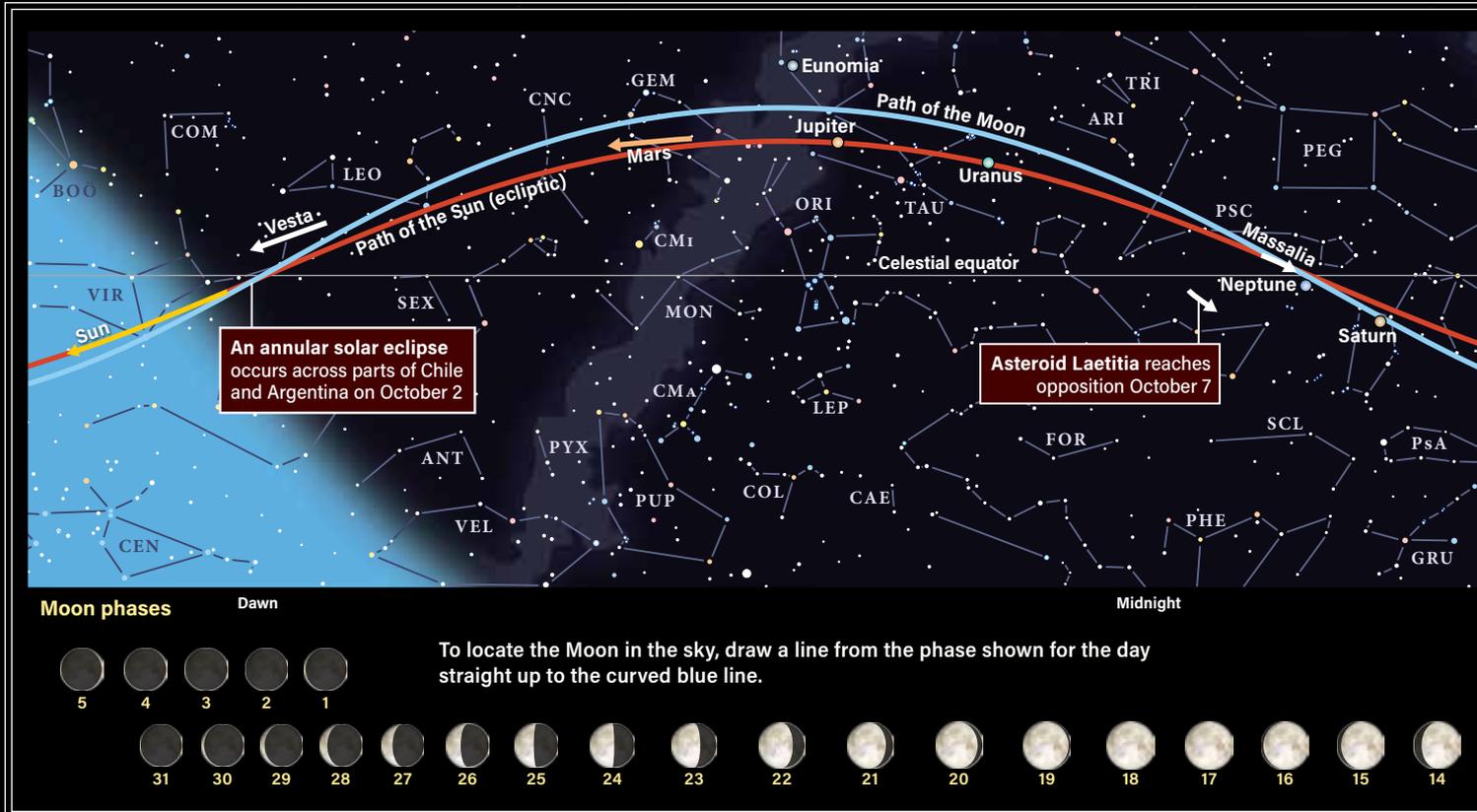
ILLUSTRATIONS BY ASTRONOMY ROBIN KELLY

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

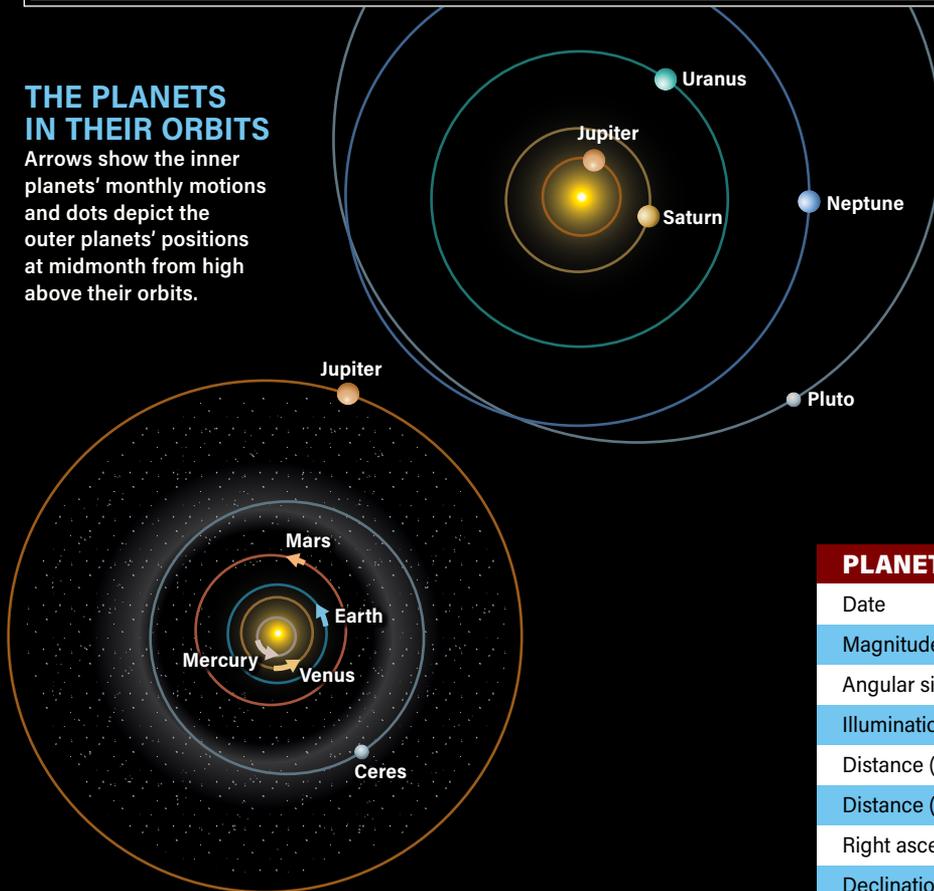
- 2 New Moon occurs at 2:49 P.M. EDT; annular solar eclipse
The Moon is at apogee (252,597 miles from Earth), 3:39 P.M. EDT
- 5 The Moon passes 3° south of Venus, 4 P.M. EDT
- 7 Asteroid Laetitia is at opposition, 2 P.M. EDT
The Moon passes 0.2° south of Antares, 3 P.M. EDT
- 9 Jupiter is stationary, 3 A.M. EDT
- 10 First Quarter Moon occurs at 2:55 P.M. EDT
- 11 Pluto is stationary, 10 P.M. EDT
- 14 The Moon passes 0.1° north of Saturn, 2 P.M. EDT
- 15 The Moon passes 0.6° north of Neptune, 2 P.M. EDT
- 16 Asteroid Juno is in conjunction with the Sun, 11 A.M. EDT
The Moon is at perigee (221,938 miles from Earth), 8:51 P.M. EDT
- 17 Full Moon occurs at 7:26 A.M. EDT
- 19 The Moon passes 4° north of Uranus, noon EDT
- 21 Orionid meteor shower peaks
Mars passes 6° south of Pollux, 2 A.M. EDT
The Moon passes 6° north of Jupiter, 4 A.M. EDT
- 23 The Moon passes 4° north of Mars, 4 P.M. EDT
- 24 Last Quarter Moon occurs at 4:03 A.M. EDT
- 25 Venus passes 3° north of Antares, 3 P.M. EDT
- 29 The Moon is at apogee (252,377 miles from Earth), 6:50 P.M. EDT

PATHS OF THE PLANETS



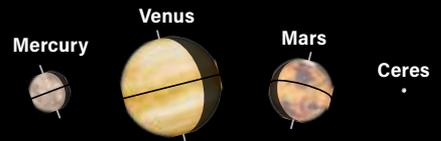
THE PLANETS IN THEIR ORBITS

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

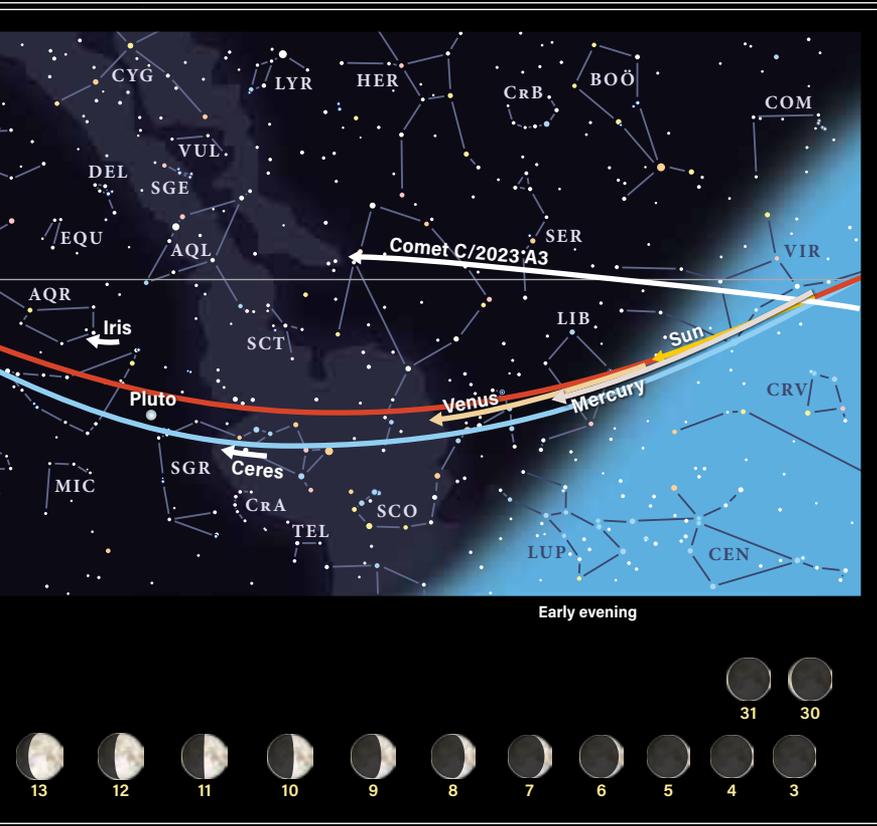
These illustrations show the size, phase, and orientation of each planet and the two brightest dwarf planets at 0h UT for the dates in the data table at bottom. South is at the top to match the view through a telescope.



PLANETS	MERCURY	VENUS
Date	Oct. 31	Oct. 15
Magnitude	-0.3	-3.9
Angular size	5.2"	13.0"
Illumination	87%	82%
Distance (AU) from Earth	1.284	1.281
Distance (AU) from Sun	0.459	0.728
Right ascension (2000.0)	15h31.6m	15h34.8m
Declination (2000.0)	-21°02'	-20°16'

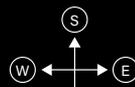
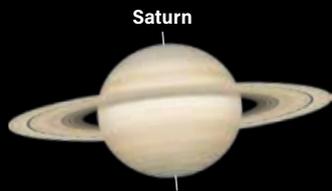
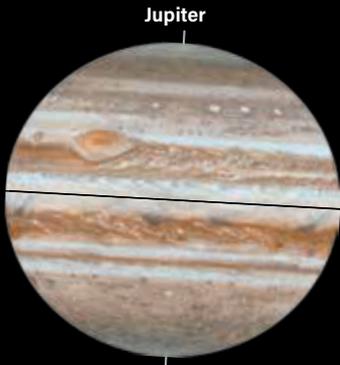
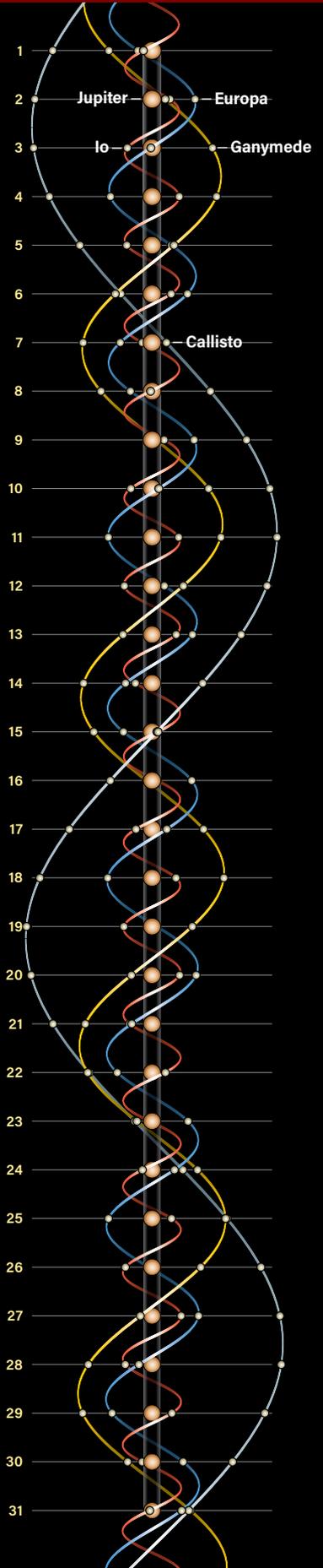
This map unfolds the entire night sky from sunset (at right) until sunrise (at left). Arrows and colored dots show motions and locations of solar system objects during the month.

OCTOBER 2024



JUPITER'S MOONS

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



MARS	CERES	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Oct. 15	Oct. 15	Oct. 15	Oct. 15	Oct. 15	Oct. 15	Oct. 15
0.3	9.1	-2.6	0.7	5.7	7.7	15.3
8.2"	0.5"	44.1"	18.8"	3.8"	2.4"	0.1"
88%	97%	99%	100%	100%	100%	100%
1.143	2.924	4.473	8.855	18.735	28.985	34.974
1.521	2.952	5.058	9.654	19.566	29.896	35.118
7h33.3m	19h02.2m	5h20.8m	23h01.4m	3h35.7m	23h53.0m	20h08.7m
22°36'	-30°03'	22°25'	-8°37'	19°02'	-2°12'	-23°29'

WHEN TO VIEW THE PLANETS

EVENING SKY

Mercury (southwest)
Venus (southwest)

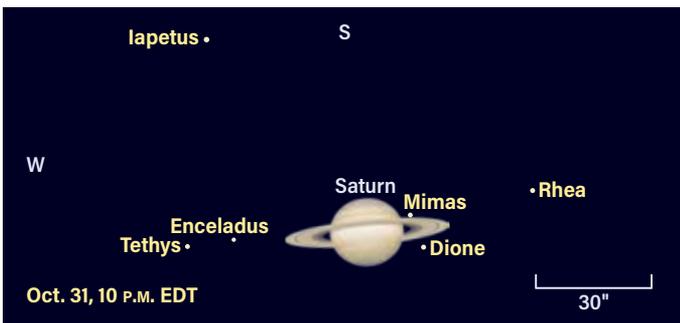
MIDNIGHT

Mars (east)
Jupiter (east)
Saturn (south)
Uranus (east)
Neptune (south)

MORNING SKY

Mars (southeast)
Jupiter (southwest)
Uranus (west)
Neptune (west)

Infrequent visitor



By Oct. 31, Iapetus is 11th magnitude, approaching superior conjunction close to Saturn. Enceladus is 12th magnitude and Mimas is 13th magnitude; these moons may be difficult to spot. Hyperion (14th magnitude) is not shown.

Lambda Psc. Follow Neptune's motion relative to these stars through binoculars. Around mid-month, you'll find the 8th-magnitude planet 1° due north of 24 Psc. A telescopic view reveals a 2"-wide disk with a distinctive bluish hue.

A waxing gibbous Moon stands about 10° southeast of Neptune on Oct. 14 and half

that far northwest of the planet on the 15th.

Uranus rises by 9 P.M. local daylight time on the 1st, and two hours earlier by the 31st. It stands about 6° southwest of the Pleiades (M45) all month. The easiest way to spot it is with binoculars. Scan south of M45 to find a pair of 6th-magnitude stars, 13 and 14 Tauri, aligned

east-west. Uranus stands 1.3° southwest of 13 Tau on Oct. 1, a gap that increases to 2.3° by the 31st. Uranus is the same brightness as 13 Tau: magnitude 5.7.

With Uranus high in the sky in the pre-dawn hours, it's a great time to view the planet through a telescope. The disk spans 4", revealing little to the earthbound observer but a nice challenge for video capture with telescopes 14 inches and larger.

Jupiter rises just after 10 P.M. local daylight time on Oct. 1 and two hours earlier on the 31st. Early morning sees Jupiter at more than 60° in altitude, a boon that offers stunning views for Northern Hemisphere observers. It's located in Taurus and brightens to magnitude -2.7 this month. A waning gibbous Moon joins Jupiter Oct. 20 and 21; the Moon passes within 0.5° of Elnath, the northern horn of the Bull.

Even small telescopes can view detail in Jupiter's turbulent atmosphere. On some nights the Great Red Spot appears, its motion evident within 10 to 15 minutes. The jovian disk starts October at 42" and grows to 46" by the 31st.

Galilean moons Io, Europa, Ganymede, and Callisto transit

COMET SEARCH | Comet of the year

GET OUT AND ENJOY Comet C/2023 A3 (Tsuchinshan-ATLAS), whether with binoculars, a small telescope, or unaided eyes. It doesn't matter if you're in the town or country. Look often — it might peak and fizzle or split and surge within a day or two. Regardless, this comet will absolutely delight amateurs like us. It might even be the best of the decade, but not worth a last-minute plane ticket to the desert.

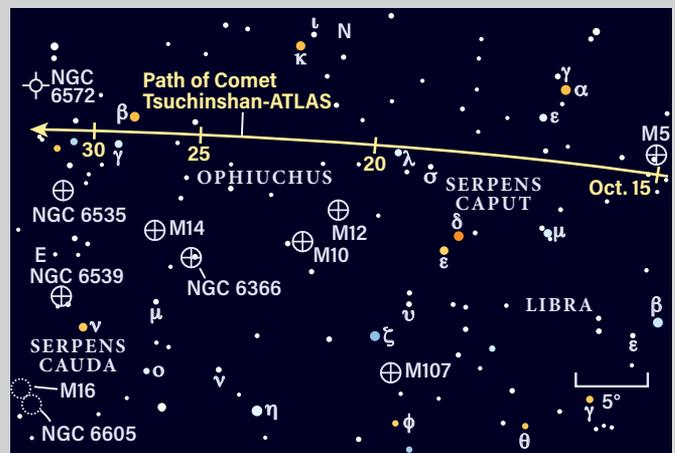
When September closes, the comet is at perihelion, closest to the Sun. The head is visible only as dawn breaks, with its tails streaming toward Sirius. What structures will be visible? Will we get a magnetic disconnection in the solar wind? By Oct. 7, follow it online through the field of view of NASA's SOHO LASCO C3 for a few days.

Then get set ... and go! On the 9th, scan the sky with binoculars shortly after sunset — if Tsuchinshan-ATLAS gets as bright as Venus (unlikely), you'll see it! An hour later, the blue ion tail stretches up to Arcturus like an auroral spike. On the 10th, the comet's head glows brightly in the deep twilight with the ion tail straight up. The dust tail should be super bright because of the forward-scattering effect when it lies between us and the Sun.

By the 13th we should see a sunward-pointing anti-tail forming. It's a trick of perspective as Earth passes through the comet's orbital plane on the 14th, the dust fan edge-on toward us. On this night, casual observers will discover another "comet" with their binoculars: the large globular star cluster M5. Imagers can nab fainter comet 13P/Olbers in the same field, quite an uncommon sight!

Never mind the glow from the Moon; use a telescope to study

Comet C/2023 A3 (Tsuchinshan-ATLAS)



Oct. 13 to 21 will be the best time to see what kind of performance the comet exhibits as it crosses from eastern Virgo into Serpens and Ophiuchus.

Tsuchinshan-ATLAS' inner coma. There's a decent chance to see a shadow channel projected onto the fan of dust. From the 20th onward, the Moon rises after the sky is fully dark, maximizing the contrast between the tails and the sky. Alas, the comet is fading, yet still visible to the unaided eye from a dark site.

LOCATING ASTEROIDS |

A joyous time

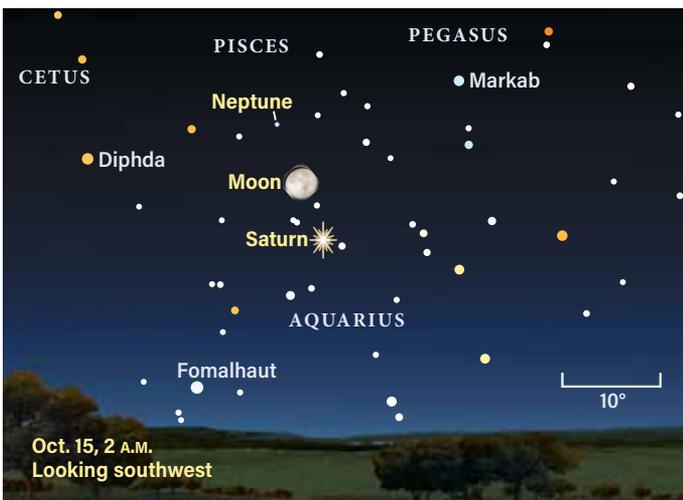
I LOVE THE FALL SEASON. Many long, sometimes mild, transparent nights are a gift after those short, summer nights of haze and smoky skies.

Main-belt asteroid 39 Laetitia, perhaps some 100 miles wide, glows at magnitude 9.5 due to reflected sunlight. It won't present a simple "spot and run" observation, but as long as you make a basic sketch one night by dropping four or five dots into a log-book circle, the next time you return one of the points will have shifted. On the 11th and 12th, it sits inside a quadrangle of stars at low power, and moves just outside it by the 13th.

Some additional sunlight delight might pass through this month as you peer into the eyepiece. For Northern Hemisphere observers, dots will drift into and then pass out of view if your scope has a drive. These are geostationary satellites — they just happen to have solar panels reflecting the Sun to you at the perfect angle this month, perhaps reaching 3rd magnitude. Without a drive, the satellites appear stationary while the stars drift across.

Laetitia was named in honor of a minor Roman goddess whose realm was gaiety. So, have some fun out there!

Group shot   



In mid-October, the Moon stands between Saturn and Neptune. Note that Neptune will need binoculars or a telescope to spot.

in front of the disk or become hidden behind it from time to time. Here are some — but not all — of the month's events.

The evening of Oct. 2 finds Europa's shadow crossing the disk of Jupiter, starting around 11:48 P.M. EDT and ending at 2:18 A.M. EDT (Oct. 3 in all U.S. time zones except Pacific).

Ganymede takes many minutes to disappear behind Jupiter's limb the night of Oct. 8/9 at 1:29 A.M. EDT. It reappears exactly two hours later. The large moon transits the southern polar region of the planet Oct. 26/27 from 10:35 P.M. to 12:40 A.M. EDT (ending after midnight on the East Coast only). The transit is underway as Jupiter rises in the Mountain time zone and the latter portion is barely visible from the West Coast.

By contrast, Europa suddenly reappears Oct. 11/12 at 1:30 A.M. EDT, popping into view at the eastern limb near the Northern Equatorial Belt.

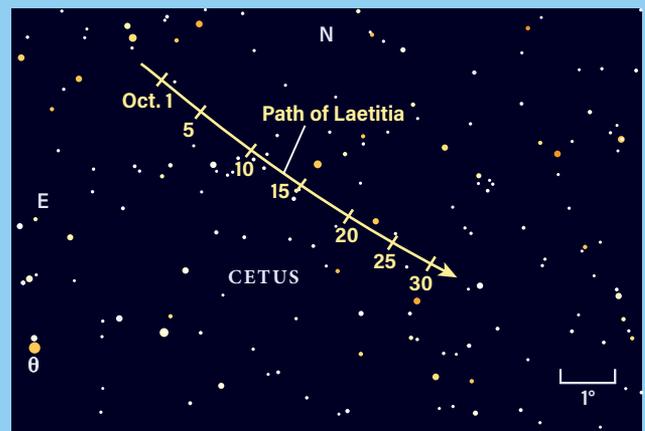
Oct. 14/15 hosts Io and its shadow transiting the disk, with

both visible for an hour starting around 4:23 A.M. EDT. Callisto is due south of Jupiter on the 15th at 6:30 A.M. EDT, missing the planet entirely. Io and its shadow repeat their journey Oct. 23/24, with both visible on the disk from about 12:37 A.M. and 1:48 A.M. EDT. And once again, you'll find Callisto due south of Jupiter early on the evening of the 31st.

Mars rises shortly before local midnight on Oct. 1 and by 11 P.M. local daylight time on the 31st. The Red Planet tracks eastward across Gemini and moves into Cancer by the 29th. It starts the month at magnitude 0.5 and brightens to magnitude 0.1 by the 31st, standing on that date 7.5° southeast of Pollux. In the hour before dawn, Mars is an impressive 70° in altitude.

Mars' disk reaches 9" wide and 89 percent lit by the end of October. The Red Planet now reveals some of its surface secrets, hidden from Earth for more than a year. Now is the time to brush up on your video-capture and processing

Swimming with satellites  



Laetitia is moving through a region where passing geostationary satellites may reflect the sunlight into your eyepiece.

techniques before opposition in January 2025.

Mars stands high in the eastern sky at 4 A.M. local daylight time; the following features are visible at that time throughout the month (determined for the mid-U.S.): Oct. 3, Sinus Meridiani; Oct. 10, Syrtis Major and the Hellas Basin; Oct. 18, Mare Sirenum; Oct. 26, Olympus Mons; Oct. 31, Tharsis Ridge and Valles Marineris.

About an hour before sunrise, Oct. 1 hosts a fine crescent Moon and possibly Comet Tsuchinshan-ATLAS if it is bright enough. The comet sits 12° to the right of the Moon but

is quickly affected by twilight, if it is visible. It crosses into the evening sky in the second week of October and quickly increases its elongation from the Sun.

The comet comes closest to Earth Oct. 12, at a distance of 43.7 million miles. After this, it could reach 1st or 2nd magnitude and be a lovely object in binoculars. ☾

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.



GET DAILY UPDATES ON YOUR NIGHT SKY AT www.Astronomy.com/skythisweek.

Our 14th annual **STAR PRODUCTS**

**BY PHIL
HARRINGTON**

Once again, we've scoured the astromarketplace to find the finest, most practical, and most innovative products for *Astronomy* magazine's Star Products, 2024 edition.

This collection of 35 items, in no particular order, offers a diverse selection. From tools tailored for visual observing to those crafted for astrophotography, there's something here for everyone, whether you're a novice or an expert.

Phil Harrington is a contributing editor of Astronomy and a dedicated equipment collector.

➔ Apertura Dobsonian Performance Upgrade Kits

These kits may be designed for Apertura telescopes, but they are suitable for similar-style Dobsonians across various brands. The kits are available for apertures ranging from 6 to 12 inches, in 2-inch increments. Each one features two pieces of flat black flocking material, strategically sized to fit perfectly around the primary mirror and opposite the secondary mirror to reduce stray light and enhance image contrast. The kit includes three collimation knobs to replace factory-installed screws (allowing manual adjustment of the secondary mirror alignment), and a Phillips head screwdriver. Apertura also includes three upgraded primary mirror collimation springs to maintain optimal mirror positioning.

\$69.95–\$89.95

www.highpointscientific.com



2 ➔ Apertura Easy Leveler

The Apertura Easy Leveler is a versatile tool designed for effortless and precise leveling in a variety of applications. While designed originally for the Seestar S50 smartscope, it also can be used for cameras and small telescopes atop any photographic tripod that uses 3/8"-16 screws. The Easy Leveler employs a three-bubble level indicator and built-in adjustment knobs for accurate alignment, ensuring that your gear is perfectly straight every time. This clever device features a compact and lightweight design, making it easy to transport and install; its intuitive operation allows users to level equipment in less than 10 minutes.

\$46.95

www.highpointscientific.com



3 Apertura Roll Easy Kit for Dobsonian Telescopes

Dobsonian telescope owners know their instruments can be difficult to move around due to their size and weight, but the Apertura Roll Easy Kit for Dobsonian Telescopes makes it simple. The kit includes three locking casters you attach to the base's ground board with the included mounting plates. This lessens the work required to maneuver the instrument over various terrains. The durable construction ensures stability and protection during movement. With a straightforward installation and a secure fit, the Roll Easy Kit simplifies the process of transporting your telescope to and from observing sites.

\$219.95

www.highpointscientific.com



4 Energizer UE30068 Power Bank

The internal batteries in smart telescopes and portable tracking mounts only last so long. But the Energizer UE30068 Power Bank, a compact powerhouse boasting an impressive 30,000 mAh capacity, is engineered to keep your equipment charged while on the move. Featuring dual USB-A ports and a USB-C Power Delivery port, it ensures broad compatibility and swift recharging. Its sleek design and compact build are highlighted by an LCD indicator for monitoring the power bank's battery level, allowing real-time monitoring of the remaining battery capacity.

\$59.99

www.energizerpowerpacks.com



5 Askar 120 APO Triplet Air-Spaced Refractor

Askar's refractor is a precision-crafted telescope designed for discerning astronomers and astrophotographers. With its 4.7-inch aperture and apochromatic triplet objective lens, Askar's 120 APO delivers stunningly sharp and color-corrected images. The air-spaced design reduces chromatic aberration to produce sharp, contrasty views of stars, planets, and deep-sky wonders. Its robust construction and high-quality optics make it a reliable instrument for both visual observation and astrophotography. The included accessories, such as the dual-speed focuser and sturdy mounting rings, enhance usability and stability. Overall, the Askar 120 APO offers exceptional performance and value for enthusiasts seeking top-tier optics.

\$1,499

www.sharpstar-optics.com



6 Astronomik 1.25" UHC filter

Astronomik's filter is a great addition for amateur astronomers seeking clear, high-contrast views of deep-sky objects. With a 1 1/4" diameter, it threads into most standard eyepieces. Its Ultra High Contrast (UHC) design improves contrast by selectively blocking light pollution and other unwanted wavelengths while highlighting nebulae. Constructed with high-quality glass and multilayer coatings, it ensures minimal light scattering and maximum transmission, preserving image brightness and detail. Easy to install and compatible with various astrophotography setups, this filter reveals elusive celestial wonders with remarkable clarity and definition.

€83.19

www.astronomik.com



7 Celestron Origin Intelligent Home Observatory

Celestron has simplified astrophotography further with features like the patented Rowe-Ackermann Schmidt Astrograph (RASA) optics and AI-driven image processing with Origin. Its fast 6-inch f/2.2 system and Sony IMX178 sensor deliver sharp, detailed images. The built-in StarSense technology automates setup and alignment in a matter of minutes. With the Origin app, users can easily navigate the night sky and capture images of celestial objects. It also supports livestreaming through the app, casting to your smart TV, remote operation, or scheduled imaging sessions. A built-in filter drawer provides optional filters that enhance views and mitigate light pollution. The system includes a NexStar Evolution mount and is portable and easy to assemble, making it ideal for both beginners and advanced amateurs.

\$3,999

www.celestron.com





8 My Science Shop Sun Globe

This globe of the Sun offers a captivating glimpse into the heart of our solar system. Using images from NASA's Solar Dynamics Observatory, this globe unveils the Sun's active corona, revealing various phenomena like sunspots, prominences, and flares. Each composite image represents different ultraviolet wavelengths, depicted in shades of red, green, and blue. Crafted from durable plastic with a single seam, the globe includes a clear acrylic base that can also serve as a magnifying glass for close-up examination. Offering a unique perspective on solar activity, this globe is a must-have for space enthusiasts seeking to explore the dynamics of our home star.

\$34.95

www.myscienceshop.com

9 Celestron StarSense Autoguider

Celestron's SSAG changes the game for visual observers and astrophotographers alike. Its patented technology swiftly aligns your telescope in about three minutes, eliminating the need for manual alignment. This accessory enhances pointing accuracy and simplifies autoguiding for sharp long-exposure images. With its onboard computer and sensitive CMOS sensor, it delivers exceptional guiding accuracy. The autoguider is compatible with newer Celestron mounts, offering flexibility in control options via PC or hand control. Advanced features like dithering and comet guiding to enhance imaging capabilities are expected to be available with future firmware updates.

\$799.95

www.celestron.com

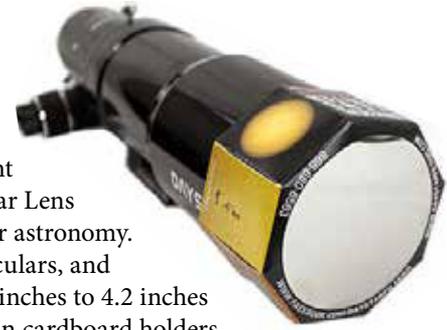


10 Daystar's Universal Solar Lens Filters (ULFs)

Observing and photographing the dynamic surface of the Sun is captivating, but safety is paramount in order to shield eyes and equipment from harmful radiation. Daystar's Universal Solar Lens Filters (ULFs) offer an affordable entry into solar astronomy. They are available in six sizes for cameras, binoculars, and small telescopes, and will fit apertures up to 1.9 inches to 4.2 inches (50 mm to 109 mm). The filters come mounted in cardboard holders that fold up like cups to slide over the front of instruments. All meet ISO 12312-2 transmission standards. The ULFs produce orange-tinted views of the photosphere, allowing observers to follow the ever-changing sunspots.

\$12.95–\$39.95

www.daystarfilters.com



11 Pegasus Astro SmartEye

It may look like a typical 2-inch eyepiece at first, but the Pegasus Astro SmartEye is anything but typical. Inside, a Sony IMX533 color CMOS sensor collects light from whatever a telescope is aimed toward. Live stacking technology then generates a high-resolution 90° apparent-field-of-view display at the top of the eyepiece for viewing as you would a normal eyepiece. The SmartEye effectively turns a small telescope into a larger instrument by delivering vibrant images of targets that otherwise would be too faint to see with conventional eyepieces. It also can be used as an imager to record images and save to share with others later.

\$1,500

www.pegasusastro.com



12 DWARF 3 Smart Telescope by DwarfLab

DwarfLab's latest creation, DWARF 3, is a compact dual-lens device with a unique folded optical design. It includes apochromatic lenses and a SONY IMX678 Starvis 2 sensor for sharp imaging. Available in a Classic and Deluxe edition, both feature an effortless setup via a smartphone app, with autofocus capability and customizable settings. The telescope offers options for JPEG, PNG, and raw FITS or TIFF file formats, exposure settings, and filter choices. It stacks images automatically and has a range of about 33 feet (10 meters) for remote operation. Despite its small aperture, it delivers impressive results for deep-sky imaging.

\$469.00

www.dwarflab.com





13 Explore Scientific FirstLight 152mm Maksutov-Cassegrain Telescope

The 152mm Maksutov-Cassegrain Telescope is a high-quality instrument boasting a generous 6-inch aperture and a sophisticated Maksutov-Cassegrain optical design. This telescope delivers exceptional views of celestial objects with sharp, contrast-rich images. The EXOS2-GT equatorial mount supplies smooth and precise tracking for capturing stunning astronomical photographs or conducting detailed observations. The instrument's lightweight yet sturdy construction makes it ideal for both backyard stargazing and on-the-go observing sessions. It is as great for exploring distant galaxies as it is for viewing planetary surfaces.

\$749.99

www.explorescientific.com

14 Explore Scientific Galileoscope Refractor STEM Kit with Solar Filter

The Galileoscope Refractor STEM Kit containing a solar filter merges learning with excitement, offering a dynamic approach to solar observation. This educational kit combines the Galileoscope — a 50mm-diameter, 500mm-focal-length refractor — with a specially designed solar filter. With the filter securely attached, users can safely observe the Sun's changing sunspots with remarkable clarity. The kit's compact design and straightforward assembly make it accessible to novices, fostering a deeper understanding of our home star. Whether for classroom use or personal exploration, the Galileoscope with Solar Filter delivers an engaging and enlightening experience that ignites curiosity about the wonders of the cosmos. A tripod is available separately.

\$83.95

www.explorescientific.com



15 iOptron HAE69 Dual AZ/EQ SWG Mount

iOptron's mount is a robust and versatile equatorial mount designed to meet the needs of both astrophotographers and observers. With its high payload capacity and precise tracking capabilities, it provides a stable platform for capturing stunning images of celestial objects. Equipped with an advanced stepper-motor drive system and built-in GPS, the HAE69 ensures accurate alignment and automatic location of celestial targets. Its intuitive hand controller and integrated Wi-Fi module enable convenient remote operation and firmware updates. Whether imaging deep-sky wonders or planetary details, the iOptron HAE69 mount offers exceptional performance and reliability, making it a top choice for serious astrophotography enthusiasts.

\$3,998

www.ioptron.com

16 Jackery 500Wh Portable Power Station

The Jackery 500Wh Portable Power Station is a reliable power source for all-night viewing sessions. With a 500-watt-hour lithium-ion battery, it provides ample energy to power all of your devices, such as a telescope mount, phone, laptop, camera, or any other piece of technology. Its compact and lightweight design makes it effortless to transport, while multiple charging options (including one AC outlet, two DC ports, one carport, and three USB-A ports) offer flexibility for different devices. The integrated LCD screen provides real-time battery status updates, ensuring peace of mind during extended outings.

\$499

www.jackery.com



17 ↻ MallinCam SkyRaider DS10c

MallinCam has created a revolutionary deep-sky video camera. Thanks to innovative technology, it captures stunning live views of celestial objects in vibrant color and detail. The DS10c features a sensitive Sony IMX294 class 1 CMOS Industrial sensor and advanced image processing, delivering high-resolution images of galaxies, nebulae, and star clusters in real time. Its compact and lightweight design makes it easy to integrate with telescopes of all sizes, while the included software provides intuitive control and customization options. Whether for public outreach or personal exploration, the MallinCam SkyRaider DS10c offers a wonderful visual experience under the night sky.

\$949.99

www.mallincam.net



18 ↻ Celestron SkyMaster Pro ED 20x80 Porro Binoculars

Celestron's new and powerful binoculars offer superior optics for amateur astronomers. Featuring BaK-4 Porro prisms, ED glass, and XLT coatings, they provide clear, vivid images with minimal chromatic aberration. Their waterproof and nitrogen-filled design ensures performance in all weather conditions. Retractable eyecups, a diopter adjustment range of ± 3 , and tripod adaptability offer comfort and versatility for users. The binoculars accept standard 1¼" eyepiece filters, which can help lessen light pollution while enhancing nebulae. Celestron's high-quality ED glass and XLT coatings improve light transmission, delivering brighter, sharper images, especially in low-light conditions. Their field of view encompasses 3.4° , while eye relief is a reasonable 15.4mm.

\$429.95

www.celestron.com

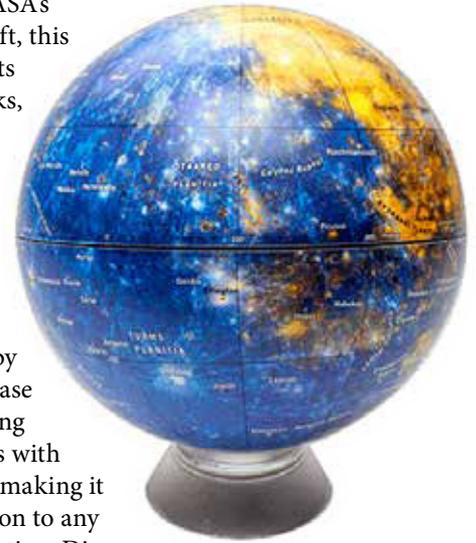


19 ↻ My Science Shop Mercury Globe

Experience Mercury like never before with the My Science Shop Mercury Globe. This vibrant 6-inch globe showcases the planet's surface features in enhanced color. Crafted using imagery from NASA's MESSENGER spacecraft, this detailed globe highlights 211 planetary landmarks, including Antoniadi Dorsa and Raphael Crater. Perfect for astronomy enthusiasts, it's made of durable plastic with a single seam between hemispheres, accompanied by a clear acrylic display base doubling as a magnifying glass. Each globe comes with an informational flyer, making it an indispensable addition to any space enthusiast's collection. Dive into the mysteries of Mercury with this stunning depiction, offering both educational value and aesthetic appeal.

\$34.95

www.myscienceshop.com



20 ↻ Masuyama Series 53° Ortho Plössl Eyepieces

If you are looking for a do-it-all line of oculars, then Masuyama Series 53° Ortho Plössl Eyepieces are a great choice. Available in focal lengths ranging from 5mm to 30mm, these eyepieces use five fully multicoated elements arranged in three groups to create a 53° apparent field of view. By minimizing internal reflections and maximizing light transmission, each member in the series promises crisp views of the Moon, planets, and deep-sky objects. Whether you're a casual stargazer or a seasoned amateur, the Masuyama Series 53° Ortho Plössl eyepieces deliver exceptional performance and represent excellent value for the investment.

\$179–\$189

www.astrohutech.store



21 OCOOPA UT2S Mini 5200mAh Hand Warmers

OCOOPA's hand warmers boast a unique dual-piece design for extended use during cold nights. Just put one half in each side pocket for up to six hours of warmth. With three adjustable heat levels, users can tailor their comfort to suit different weather conditions. Rechargeable in just 90 minutes, the internal battery also serves as a power bank for external devices, enhancing their versatility. Whether for winter observing or just everyday convenience, these hand warmers deliver reliable warmth and practicality, making them an indispensable companion in colder climates.

\$31.99
www.ocoopa.com

22 Pegasus Astro Indigo Filter Wheel

Another inventive tool is the Pegasus Astro Indigo Filter Wheel, a compact and versatile accessory designed for astrophotographers. This ingenious accessory facilitates effortless switching between seven different filters during imaging sessions. With its robust build, the wheel accommodates up to seven 2" mounted or 50mm unmounted filters, offering diverse options for capturing breathtaking images. Its motorized mechanism guarantees accurate and

dependable filter changes, while advanced functionalities ensure smooth integration with leading astrophotography software. Whether capturing deep-sky phenomena or intricate planetary features, the Indigo Filter Wheel provides convenience and versatility, catering to astrophotographers at every skill level.

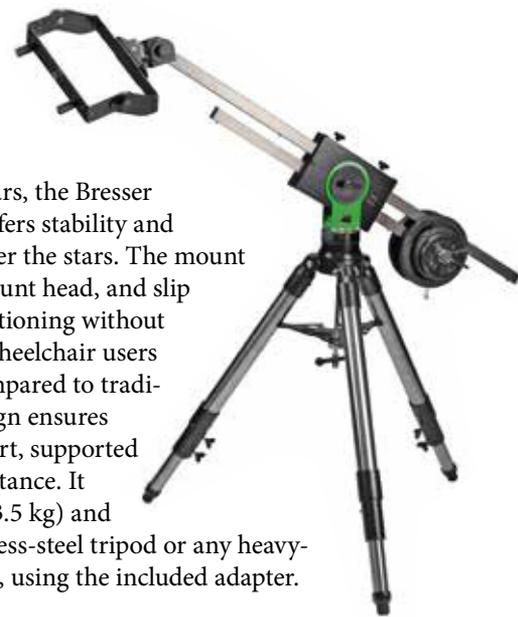
\$459.00
www.pegasusastro.com



23 Bresser Slider Binocular Mount with Tripod

For owners of large and heavy binoculars, the Bresser Slider Binocular Mount with Tripod offers stability and reduces fatigue during long nights under the stars. The mount includes adjustable rails, a cardanic mount head, and slip couplings, which allow for flexible positioning without touching the binoculars themselves. Wheelchair users may find it particularly convenient compared to traditional tripods because its patented design ensures smooth adjustments with minimal effort, supported by precise bearings and adjustable resistance. It supports binoculars up to 7.7 pounds (3.5 kg) and can be paired with Bresser's own stainless-steel tripod or any heavy-duty tripod with a 3/8-inch central shaft, using the included adapter.

€999
www.bresser.de



24 My Science Shop Cosmic Cliffs Button-Down Shirt

The Cosmic Cliffs Button-Down Shirt is a celestial-inspired fashion statement for astronomy enthusiasts. Featuring a captivating print of the James Webb Space Telescope's famous "Cosmic Cliffs" portrait, it brings the wonders of the universe to your wardrobe. Whether you're an astronomy aficionado or simply appreciate cosmic beauty, this soft and breathable button-down is a stylish way — with a touch of sophistication — to express your passion for the cosmos at casual outings or scientific gatherings.

\$34.99
www.myscienceshop.com

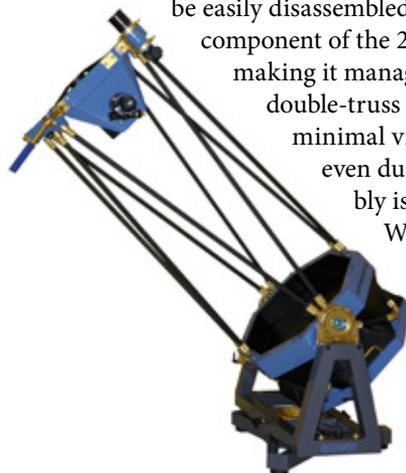


25 Reginato Supermaser 20" f/3.4 Dobsonian

This 20-inch Dobsonian is a portable altazimuth telescope crafted entirely of metal. It features a quick-release truss system, allowing it to be easily disassembled into three parts. Despite its size, the heaviest component of the 20-inch model weighs only 46 pounds (21 kg), making it manageable for one person. Its steel frame and double-truss design guarantee exceptional stability and minimal vibration during use. Optics remain collimated even during transportation and assembly. And assembly is straightforward, without the need for tools.

With high-quality optics, the Supermaser offers excellent performance for both deep-sky and planetary observations.

€13,000
www.reginatotelescopes.com



26 Sky-Watcher CQ350 Pro

This recent addition to Sky-Watcher USA's family of German equatorial mounts optimizes weight distribution over the mount's center of gravity for precise slewing and guiding. Weighing 53 pounds (24 kg), it supports up to 77 pounds (35 kg) of instrument load. Its dual-format saddle fits both Losmandy-D and Vixen-style mounting bars. Integrated cable management prevents entanglement, with USB 3.0 and power ports provided. Controlled via Sky-Watcher's SynScan GoTo hand paddle, it offers a database of over 42,000 objects. Each mount comes with two 22-pound (10 kg) counterweights. The CQ350 Pro

can be paired with a heavy-duty steel field tripod and an illuminated polar-alignment scope, both sold separately.

\$3,500

www.skywatcherusa.com

27 Vixen XY Red Dot Finder II

Vixen offers an easy way to aim telescopes accurately. With its XY axis adjustment, the finder provides accurate alignment, letting users swiftly locate celestial quarries. Its red-dot reticle aids in pinpointing targets against the night sky without ruining night vision. The compact design attaches easily to most telescopes. The finder's sturdy construction promises durability, while its lightweight nature adds convenience during transport and use. Overall, the Vixen XY Red Dot Finder II is a reliable accessory for stargazers who prefer to find targets by eye, the old-fashioned way.

\$84.99

global.vixen.co.jp/en



28 Small Steps and Giant Leaps Playing Cards

These ingenious playing cards by graphic designer James Round celebrate humanity's journey into space with stunning artwork and informative details. Each card features iconic missions, astronauts, and spacecraft, capturing the spirit of exploration. The deck serves as both a captivating collectible and an educational tool, offering insights into space history with every hand dealt. The high quality of the cards promises durability for countless games and displays. These playing cards are a must-have for space enthusiasts, combining entertainment with a tribute to humankind's greatest achievements.

£20

www.jamesrounddesign.com



29 QHY5III715C

The QHY5III715C color camera is an advanced 8.4-megapixel planetary imaging and autoguiding camera by QHYCCD. Featuring a Sony IMX715 CMOS sensor, it boasts a high spatial resolution of less than 1 arcsecond per pixel, ideal for planetary imaging. Operating at up to 42 frames per second (fps) in 8-bit mode or 23 fps in 16-bit mode, its 512MB DDR3 image buffer ensures no frame drops. Designed for 1¼"



focusers with minimal back focus requirements, it doubles as an autoguider with standard ST-4 compatibility. Accessories include USB 3.2 Type-C and guiding cables, filter adapters, and a focus locking ring.

\$199

www.qhyccd.com

30 The Dobson Factory Ultralight 16" Dobsonian Telescope

This Dobsonian telescope combines portability with quality mirrors from Lightholder Optics, making it a stargazer's dream. Weighing just under 50 pounds (22.7 kg), it's remarkably easy to transport compared to traditional telescopes of similar aperture. The 16-inch primary mirror gathers an impressive amount of light, revealing intricate details of celestial objects with clarity. Its Dobsonian mount provides smooth, effortless movement, allowing for precise navigation of the night sky. The sturdy construction and quality materials inspire confidence in its durability. If you're a seasoned deep-sky observer, this telescope offers breathtaking views and exceptional performance — a true gem for any stargazing adventure.

\$2,695

www.sites.google.com/site/thedobsonfactory3



31 ↻ TAKAHASHI TPL Plössl Eyepieces

TAKAHASHI's Plössl Eyepieces are precision-crafted optics that will improve your observing experience. Featuring a four-element design with high-quality glass, they deliver exceptional clarity, contrast, and edge-to-edge sharpness. With focal lengths ranging from 6mm to 50mm, they cater to a variety of magnification needs for both deep-sky and planetary observation. The ergonomic design makes for comfortable viewing sessions, even during long all-nighters. While they come at a premium price, their performance justifies the investment for serious astronomers. Overall, these eyepieces are a testament to Takahashi's long history of commitment to optical excellence.

\$185–\$540

www.takahashiamerica.com



34 ↻ Stargazer "Just One More Telescope" Sweatshirt

Stargazer provides a cozy garment that captures the passion of amateur astronomers. Crafted from soft, high-quality fabric, it offers comfort during chilly stargazing nights or casual outings. Its humorous yet relatable slogan, "Just One More Telescope," will resonate with telescope enthusiasts.

\$39.95

www.stargazerstuff.com



32 ↻ Starfield EDT115 f/7 Triplet APO

Starfield Optics has made this triplet APO ideal for wide-field imaging thanks to its triple-element multicoated objective lens with extra-low dispersion (ED) glass optics and robust GÉAR series accessories. It includes a 2.5" rack-and-pinion dual-speed focuser for precise focusing and a retractable dew shield. Thanks to the standard camera angle rotator, it's easy to frame objects without flex or focus position changes. Weighing 15 pounds (6.8 kg), the EDT115 is compatible with Vixen-style dovetail plates. It also includes heavy-duty rings and a handle designed to mount accessories. A soft case with die-cut foam and an optical test report are also provided.

\$2,212

www.starfieldoptics.com



33 ↻ UniStellar Odyssey

The Odyssey revolutionizes smart telescopes by blending advanced tech and a user-friendly design. Its compact form incorporates a 3.35-inch f/3.9 Newtonian reflector with a 4.1-megapixel imaging sensor. The combination lets users take wonderful images of the cosmos with ease. Equipped with automated tracking and object identification, the Odyssey effortlessly guides viewers to celestial objects from the Moon to far-off galaxies. The telescope's app interface provides an immersive experience, offering educational content and community engagement. While its price may be steep for beginners, the Odyssey's performance validates the investment for enthusiasts who seek convenience and breathtaking results.

\$2,499

www.unistellar.com



35 ↻ ZWO Seestar S50 Smart Telescope

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BLACK HOLE BUGALOO

JWST discovers a pair of black holes merging in the early universe.

BY RICHARD TALCOTT

WHEN THE JAMES WEBB SPACE TELESCOPE (JWST) first opened its eye to the universe in 2022, astronomers looked forward to gaining a fresh perspective on galaxy evolution. The powerful observatory has not disappointed. Perhaps the biggest surprise so far has been the telescope's discovery of a large population of active galaxies in the first billion years of cosmic history.

Active galaxies represent nature's way of turning darkness into light. At the heart of each of these energetic systems lies a black hole with a mass millions or billions of times that of the Sun. The beast's strong gravity pulls in nearby gas, creating an accretion disk that can reach a temperature of millions of degrees. This hot gas produces the intense radiation we see coming from these galaxies.

RECORD-SETTING DUO

Now astronomers have detected an ongoing merger between two extraordinarily distant active galaxies and their central black holes. The pair is so remote that the universe's expansion has shifted its light far to the red. The radiation JWST records has a wavelength 8.15 times longer than when it left the galaxies. This means all the visible light they emit ends up in the infrared part of the spectrum where the space telescope operates.

The system, known as ZS7, existed when the universe was just 740 million years old. This makes the galaxy pair both the most distant and the youngest known merging black holes.

Hannah Übler of the University of Cambridge in England led the team that made the discovery. The researchers analyzed the system's spectrum and found one source exhibits a broad line of neutral hydrogen, identifying it as a so-called Seyfert 1 galaxy. This radiation comes from a region close to its black hole where high-density gas moves fast. The team estimates this black hole contains about 50 million solar masses, making it more than 10 times larger than the Milky Way's central black hole.

The second source displays narrow lines of doubly ionized oxygen, which classifies it as a Seyfert 2 galaxy. These narrow lines originate from hotter gas located farther from its black hole. JWST's exquisite resolution places this black hole just 2,000 light-years from its neighbor. Dense gas obscures the black hole, though the team suspects it weighs about the same as the other.

Both galaxies are rather small by Milky Way standards. They likely hold several billion solar masses of material, roughly equivalent to the mass of our galaxy's largest satellite, the Large

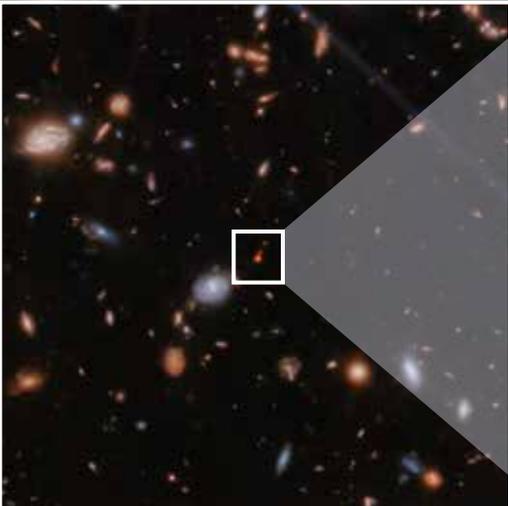
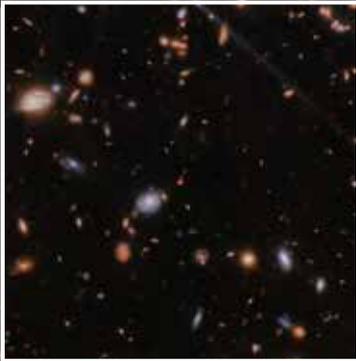
Magellanic Cloud. JWST also found three fainter galaxies belonging to the ZS7 system, though they show no signs of activity.

DYNAMIC UNIVERSE

"Our findings suggest that merging is an important route through which black holes can rapidly grow, even at cosmic dawn," said Übler in a press release. The results will help scientists better understand the role these behemoths play in how galaxies evolved in the chaotic early universe.

The finding also will open up an exciting new dimension in multi-messenger astronomy. Merging black holes generate gravitational waves, and systems like ZS7 should be visible to future detectors such as the Laser Interferometer Space Antenna (LISA), currently scheduled for a 2035 launch. "Webb's results are telling us that lighter systems detectable by LISA should be far more frequent than previously assumed," says LISA Lead Project Scientist Nora Luetzgendorf of the European Space Agency. "This is just the tip of the iceberg." ❖

Contributing Editor Richard Talcott wrote about JWST's observations of globular star cluster NGC 6440 in the September issue.



ABOVE: This exquisitely rich field in the constellation Sextans harbors hundreds of distant galaxies and a smattering of Milky Way foreground stars. Two active galaxies at the center of the image are in the process of merging. ALL IMAGES: ESA/WEBB, NASA, CSA, J. DUNLOP, D. MAGEE, P.G. PÉREZ-GONZÁLEZ, H. ÜBLER, R. MAIOLINO, ET AL.

FAR LEFT AND LEFT: Zeroing in on the ZS7 system reveals two merging galaxies — a bright Seyfert 2 at center and a dimmer Seyfert 1 to its immediate upper right. They and their central black holes lie 2,000 light-years apart.

WE TEST

STARIZONA'S NEXUS COMA CORRECTOR

This accessory boosts fast Newtonian astrographs with superb flattening to the edges of your field. **STORY AND IMAGES BY CHRIS SCHUR**

AFFORDABLE FAST NEWTONIAN ASTROGRAPHS are game changers for astrophotographers. Most of these instruments have a focal ratio in the vicinity of $f/4$, allowing them to capture light from deep-sky objects more than six times faster than the $f/10$ Schmidt-Cassegrain telescopes that dominate the market.

But with that faster speed comes a huge problem: a curved focal plane and severe coma, making images taken with such instruments sharp in the center and blurry around the edges. To combat this, manufacturers offer various Newtonian coma correctors, designed to alleviate (to varying degrees) this optical defect and allow users to fill the full frame of their CCD or CMOS cameras with sharp stars. However, the effectiveness of this correction varies among designs, with some performing much better than others.

Here, I evaluate a new type of coma

corrector: the Starizona Nexus 0.75x Newtonian Focal Reducer/Coma Corrector. As implied by the name, rather than slowing the telescope — as typical coma correctors do — the Nexus addresses coma while also reducing the focal ratio for an even faster scope.

Correcting coma

Without correction, fast parabolic mirrors produce images that are sharp only in the center and degrade rapidly as you move off-axis. This isn't due to a bad or defective mirror, but is inherent in the



This shot of the Pleiades (M45) — which comprises two hours of integration time taken with a 10-inch scope, Atik 16200 CCD, and Starizona's Nexus 0.75x Newtonian Focal Reducer/Coma Corrector — displays sharp details out to the edges.



Newtonian optical design. The faster the mirror, the more quickly the image degrades. For an $f/4$ or $f/5$ mirror, this equates to sharp stars only in the central half of the field for a full-frame sensor, or about three-quarters of the frame for a common APS-C-sized chip.

Inserting a complex lens system (a coma corrector) just before the

focal point — typically 2.2 inches (55 millimeters) in front of the sensor — can flatten out and turn those bird-shaped stars in the corners into sharp, round points again.

Over the past decade, two designs have dominated the market for this purpose. The first was Tele Vue Optics' Paracorr, followed more recently by the

Baader Planetarium Multi-Purpose Coma Corrector (MPCC). In my experience with several $f/3.6$ to $f/4$ Newtonian astrographs, each of these works reasonably well; however, there are drawbacks to each design. While these correctors create mostly sharp fields, both still show a tiny amount of residual coma in the corners of frames. Additionally, both the



ABOVE: The Nexus coma corrector (to the left of the box) comes with a metal cap for its 48mm threaded camera end and a plastic cap for the lens end. All parts are packaged in a custom, foam-lined box.

FAR LEFT: The author installs an Atik 16200 CCD (at the right of image) with the Nexus coma corrector (middle) attached into the focuser of his scope (at left) for imaging.

Paracorr and the first version of the Baader MPCC magnify the image in the process of flattening it, increasing the focal length and f-number, thereby slowing the scope.

The newer Baader MPCC Mark II and Mark III have 1x magnification, so as to not change the field of view or focal ratio of your telescope. This is a big advantage, as a faster speed is better for dim, diffuse deep-sky nebulae and galaxies. And although the Paracorr's small 1.2x magnification is insignificant compared to other limiting factors, such as skyglow or the variable quality of the night sky, the idea of putting in the optical path anything that slows down the telescope's speed can be a bit unnerving.

But now, we have a third choice for coma correction, one that was unavailable only a few years ago: the Nexus from Starizona.

Not only does this corrector produce pinpoint stars all the way to the corners with an f/4 telescope, its 0.75x reduction actually increases your field by 25 percent and makes your scope nearly two times faster, turning it into an f/3!

The speed increase and larger field alone were enough to convince me that this is a superior product. And after you've

seen the incredible stars this corrector produces, you, too, will be convinced.

I spent the better part of a year evaluating this product with a variety of instruments under many different sky conditions, from suburban Bortle 6 to world-class Bortle 1 dark skies. The product performed beyond all expectations and is now a permanent resident in my astroimaging toolbox.

The Nexus not only corrects coma, it also increases field of view and telescope speed. This intricately detailed single frame of the Rosette Nebula, taken with the Nexus and Atik 16200 CCD on the author's 10-inch scope, has an exposure time of only 5 minutes. The resulting field of view is more than 2°.



Field testing

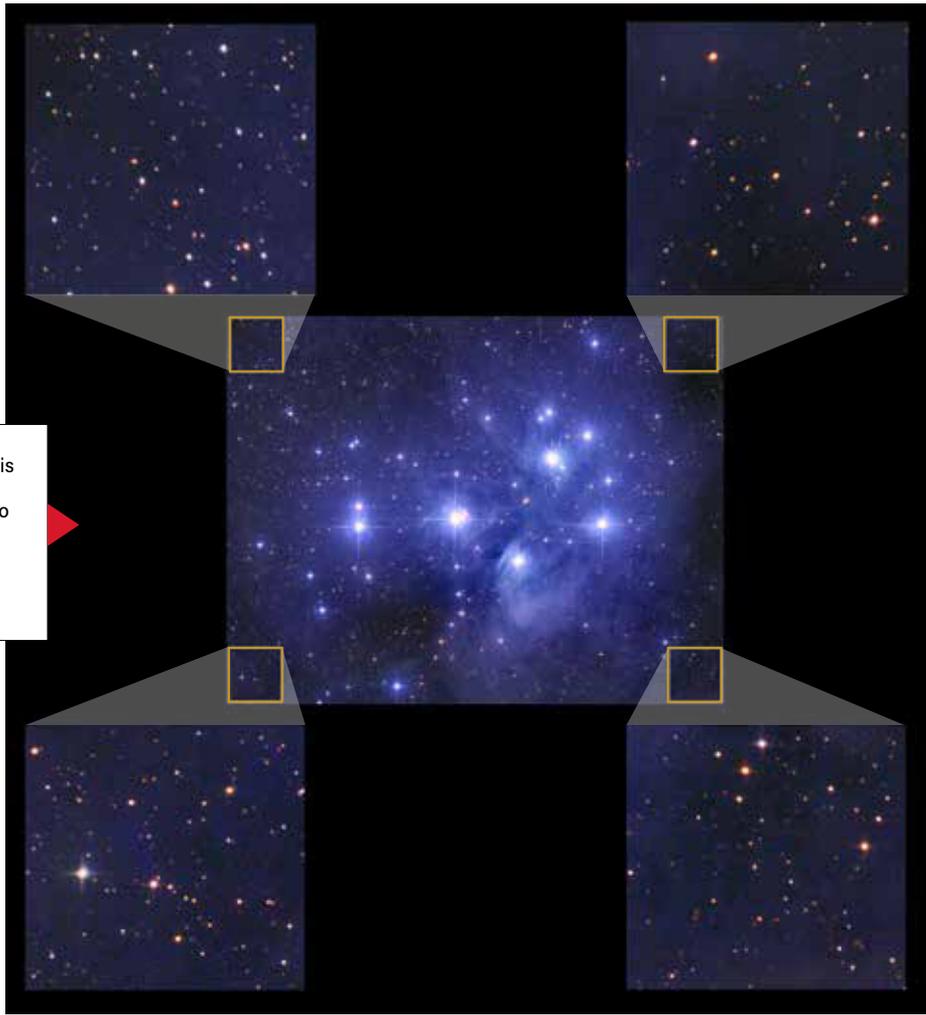
The quality of the machining and fit and finish of the Nexus are impressive. Even the black box the Nexus comes in is lined with form-fitted foam and gives the impression of a high-quality product. Starizona provides a metal screw-on cap for the 48mm threaded camera end of the Nexus and a black ABS plastic cover for the lens end.

The barrel of the Nexus is quite long compared to competing products. This becomes apparent when inserting the camera and corrector assembly into the drawtube of the telescope. What I found surprising is that even with the corrector installed, the focal point on the drawtube is essentially the same. This is an impressive feat of optical engineering.

I tested the Nexus coma corrector with two different Newtonian astrographs: a GSO 8-inch $f/3.9$ and a 10-inch $f/3.9$. Both are permanently mounted in roll-off roof observatories under moderately dark to pitch-black sky conditions. I also tested the Nexus with two different cameras: a ZWO ASI071MC Pro APS-C color CMOS (26mm diagonal) and an Atik 16200 monochrome camera with a larger APS-H sensor (35mm diagonal). I used standard off-the-shelf spacers from ZWO to get the required 55mm backspacing with the ASI071MC Pro, while the Atik 16200 and integrated filter wheel required a custom spacer from www.preciseparts.com. The resulting focal ratio of the Nexus with these two instruments became a blistering $f/2.9$.

With both cameras, the first test images that came up on the computer screen were somewhat of a shock. Stars in the corners were every bit as sharp as in the center of the frame. I had never seen such perfection in my images. Further surprising me, the Atik monochrome camera was able to capture sharp stars right to the corners, even with the large-format chip. This means Starizona's claim of 28mm coverage for correction is definitely on the conservative end.

My final test was to see whether all colors in the filter wheel in the monochrome camera would come to the same



All four corners of this image of M45 show sharp stars, thanks to the incorporation of the Nexus coma corrector into the imaging assembly.

focus. While using both the Paracorr and MPCC, it had become habit to refocus whenever switching RGB filters, mainly because the blue filter focus was so different from the red and green. This is not the case with the Nexus! All three filters were so close to focus that I didn't touch the focus knob at all once the shot was focused for white light.

The speed increase was immediately noticeable on the first images as well. Even a five-minute subframe showed incredible detail and faint nebulosity never visible with competing correctors in such a short exposure. The larger field of view was very similar to what I get with my Stellarvue SV80 refractor with its coma corrector, yet with much sharper stars, higher overall resolution, and absolutely no chromatic aberrations. There was some noticeable light falloff in the extreme corners; however, using a flat from an LED panel took care of that without any problems. Taking the normal one- to two-hour sets resulted in

some of the most breathtaking deep-sky images I had ever produced. My mind was made up: This would be my primary imaging setup for the immediate future!

Superb performance

The Nexus 0.75x Newtonian Focal Reducer/Coma Corrector is a well-built and superbly corrected lens. Testing with $f/3.6$ to $f/4$ Newtonian astrographs indicates superior performance and speed compared with similar products that have been on the market longer.

If you're currently using a fast Newtonian for your astroimaging, consider adding this product to your optical arsenal. Although it is a bit costly compared to some competing products, it will make achieving world-class results with your imaging setup routine. ☛

Chris Schur is a retired mechatronics engineer living in Payson, Arizona, who uses his engineering knowledge to continually improve the quality of his astroimages.

Your first astroimaging rig

These recommendations will give you a capable setup with plenty of room to grow.



The author captured the Rosette Nebula under Bortle 2 skies with a ZWO ASI2600MC Pro camera on an Astro-Tech 72ED refractor atop an iOptron CEM40 mount. This image comprises 104 three-minute exposures. MOLLY WAKELING



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



Getting started in astrophotography can be daunting. With so many different telescopes, cameras, and mounts and all their variations, where do you start?

The first piece of equipment you should choose is a mount, the mechanical base that the telescope attaches to. For astrophotography, the mount must be motorized, and ideally computer-controllable. This might sound crazy, but the quality of the mount is more important

than the quality of the telescope! Even the best quadruplet refractor won't produce good images if the stars are streaked from poor tracking.

While it is possible to do astrophotography on an altitude-azimuth (alt-az) mount, they are limited; an equatorial mount will serve you much better. Equatorial mounts are aligned with the celestial pole so that only the right ascension axis is tracking the sky, while the declination axis is only used for small corrections. To get the best use out of a mount, it should be able to communicate with a computer, usually via USB, so that software can command it where to slew and send fine correction commands using a process called autoguiding.

Expect to spend at least \$2,000 on a mount with reasonable payload capacity — I recommend at least 25 pounds (11.3 kilograms) for use with small refractors. Don't forget about the weight of the other gear you may eventually use, such as the camera, focuser, filter wheel, and guide scope, as well as the dovetail and rings or clamps you use to attach the telescope.

These days, the listed payload capacity of many mounts is its true astrophotography capacity; for some manufacturers and for older mounts, a rule of thumb of using 50 percent of the capacity for astrophotography

applies. Nearly all manufacturers' listed capacities account for counterweights, so don't worry about adding those into your weight calculation.

In my opinion, the iOptron CEM40 is an excellent place to start if you want to get serious about astrophotography. It is small and lightweight with a payload capacity of 40 pounds (18 kg), and has excellent long-exposure tracking when used with an autoguider.

Now, we come to the telescope itself. I highly recommend starting with a small refractor, with an aperture in the 60mm to 90mm range. Short focal lengths (400–700mm) and relatively fast focal ratios ($f/5$ or $f/6$) make them very forgiving of tracking errors. This means you can start imaging without the complication of autoguiding, while still gathering enough light to make a nice image. Refractors range vastly in quality and price; you can do reasonably well with some doublets but will get less chromatic aberration (blue halos around stars) with a triplet or apochromatic telescope. I've been impressed with the Astro-Tech AT72ED that I picked up last year from a friend (the newer AT72EDII retails for \$519), and a lot of people I know love their William Optics refractors; their apochromatic Zenithstar line ranges from around \$600 to \$1,000.

Finally, the camera. For the beginning astrophotographer, a one-shot-color (OSC) camera is the way to go. You can also start simply with a DSLR, preferably a midgrade computer-controllable type, but you will get better results and have more functionality with a cooled astrophotography camera. While monochrome cameras deliver images with higher resolution and signal-

to-noise ratios, the added complication and cost of four filters (luminance, red, green, and blue) and a filter wheel, as well as the additional image processing required, make them a difficult place to start.

A cooled OSC camera will deliver excellent images and can be used with both multi-narrowband and light pollution filters, which are especially helpful when imaging from the city. I love my ZWO ASI2600MC Pro (\$1,499) and have also gotten nice images from my ZWO ASI294MC Pro (\$999). Be

sure to use a luminance or UV/IR-cut filter with an OSC camera on a refractor to avoid UV/IR halos.

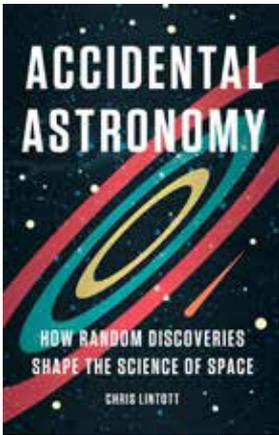
In the end, start with anything you already have and know how to use. I took my first astroimages with an 8-inch $f/10$ Schmidt-Cassegrain on an alt-az mount with a DSLR, which is about the hardest possible place to start! But a high-quality equatorial tracking mount, a small refractor, and a OSC camera are an excellent way to get into astrophotography. ☺

The quality of the mount is more important than the quality of the telescope!



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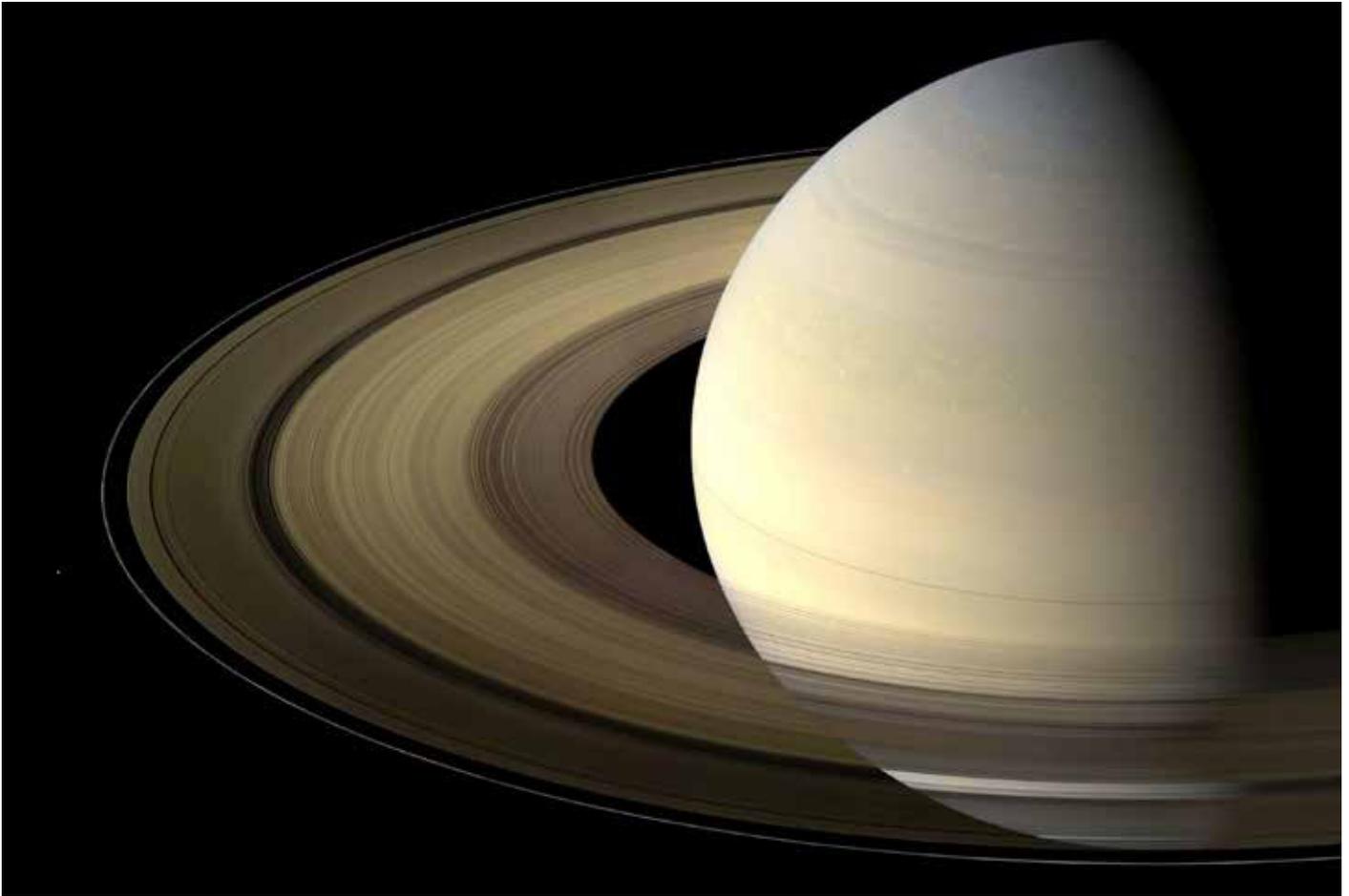
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NASA's Cassini spacecraft took this detailed image of Saturn and its rings in August 2009. Cassini helped scientists determine that the rings are relatively young — and also short-lived — particularly with measurements taken during its Grand Finale, threading the gap between planet and rings. NASA/JPL-CALTECH/SPACE SCIENCE INSTITUTE

Saturn's disappearing rings

Q | DO ASTRONOMERS HAVE ANY ESTIMATES OF WHEN SATURN'S RINGS WILL DISAPPEAR?

*Doug Kaupa
Council Bluffs, Iowa*

A | All four of the solar system's giant planets have ring systems. The rings of Jupiter, Uranus, and Neptune are dark, sparse belts or ringlets. Only Saturn's massive main rings are dense and bright, made of almost pure water-ice particles ranging in size from dust and pebbles to boulders. You can visualize Saturn's rings as an enormous swarm of snowballs and snowman-sized pieces orbiting the planet.

Most planetary scientists once thought Saturn's rings were as old as Saturn itself: 4.5 billion years. But the Cassini spacecraft, which orbited Saturn from 2004 to 2017, accumulated evidence that the rings are relatively recent. If early dinosaurs were smart enough to build telescopes, they might not have seen rings around Saturn at all. Cassini's findings also suggest the rings are short-lived, with a lifetime of hundreds of millions of years.

Astronomers arrived at these estimates based on several measurements.

Cassini ended its mission in 2017 with its Grand Finale, 22 plunging orbits in which the craft swooped between Saturn and its innermost ring, the D ring. This allowed Cassini to determine the rings' mass by comparing the gravitational pull on the spacecraft during its close-in orbits to the pull it experienced when orbiting farther out, exterior to the rings. The mass of the ring system is comparable to but less than that of Saturn's innermost icy moon Mimas.

At the same time, Cassini observed material flowing from the rings into Saturn at many tons per second.

Combining this mass loss with the rings' current mass suggests a remaining ring lifetime (or mass-loss age) of only a few hundred million years.

Cassini also determined the rings' so-called pollution age. During its 13 years orbiting Saturn, Cassini's onboard dust detector measured the impact rate of interplanetary micrometeoroids. These dust particles are pulled in by Saturn's gravity and strike the ring particles. Interplanetary dust is mostly dark, non-icy stuff. Over time then, the rings should grow polluted. How fast they darken depends on the dust influx rate and the ring mass. Based on Cassini's measurements, researchers determined that this influx would darken the rings to the current observed level in at most a few hundred million years. This independently determined pollution age agrees with the mass-loss age.

The mass deposited in the rings by these meteoroids also reduces the orbital angular momentum of the ring particles and causes them to drift inward. Such dust impacts can additionally exert a negative torque. Furthermore, micrometeoroids hit at tens of miles per second. This is like setting off a firecracker in a snowball. Debris gets thrown around the rings, and some can even rain down directly onto Saturn. The combination of all these dynamical effects produces inflow at rates comparable to the inflow rate Cassini observed.

So, the conclusion is that Saturn's rings are not more than a few hundred million years old and will not exist as bright, dense rings for more than another few hundred million years. What will they become? They may persist for billions of years, looking more like the sparse, dark ring systems of the other giant planets.

Richard H. Durisen and Paul R. Estrada
*Professor Emeritus of Astronomy, Indiana University,
 Bloomington, Indiana, and Research Scientist,
 NASA Ames Research Center, Mountain View, California*

Q | HOW MUCH COLOR SHOULD I BE ABLE TO SEE IN SKY OBJECTS THROUGH A 10-INCH TELESCOPE?

Dennis Holt
Concordia, Kansas

A | Unfortunately, when you look at distant galaxies and nebulae, you won't see much color through your telescope. That's because you're viewing objects that are too faint to trigger your eyes' color receptors. This is the same reason why on Earth we see lots of color in the daytime but not much at night.

However, two classes of celestial objects — double

CASSINI'S FINDINGS SUGGEST SATURN'S RINGS ARE SHORT-LIVED, WITH A LIFETIME OF HUNDREDS OF MILLIONS OF YEARS.

stars and planetary nebulae — break this rule. The reason is their sizes. Stars are point sources, and planetaries typically measure less than 1' across. (As a comparison, the Full Moon spans 31'.) So although these objects are not all that bright, their light is concentrated in a small area. In astronomical terms, their surface brightnesses are high. The table below provides 10 colorful objects to observe.

Michael E. Bakich
Associate Editor

SEND US YOUR QUESTIONS

Send your astronomy questions via email to **askastro@astronomy.com**. Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.



The Blue Snowball (NGC 7662, at center) often shows its eponymous color through a telescope eyepiece. STEPHEN RAHN

COLOR TEST

Here are 10 objects — five double stars and five planetary nebulae — in which you should see color. They are organized by group and then right ascension.

Object	Designation	Colors
Albireo	Beta (β) Cygni	Blue and gold
Achird	Eta (η) Cassiopeiae	Yellow and red
Al Risha	Alpha (α) Piscium	Yellow and blue
Almach	Gamma (γ) Andromedae	Yellow and blue
Kaffaljidhma	Gamma Ceti	White and blue
The Little Gem	NGC 6818	Green
The Blue Flash	NGC 6905	Blue
The Saturn Nebula	NGC 7009	Blue-green
The Blue Snowball	NGC 7662	Blue
Cleopatra's Eye	NGC 1535	Blue

1. SALT LAKE PRETTY

The Milky Way is reflected in the flooded salt flats of Badwater Basin in California's Death Valley in this 21-panel panorama taken with an astro-modified Nikon Z 6II full-frame mirrorless camera and zoom lens at 20mm. Sky panels consist of 180-second frames taken at f/3.2 and ISO 800; the foreground and reflection panels were 120-second exposures at f/2.8 and ISO 1600. • *Abhijit Patil*

2. MAKING WAVES

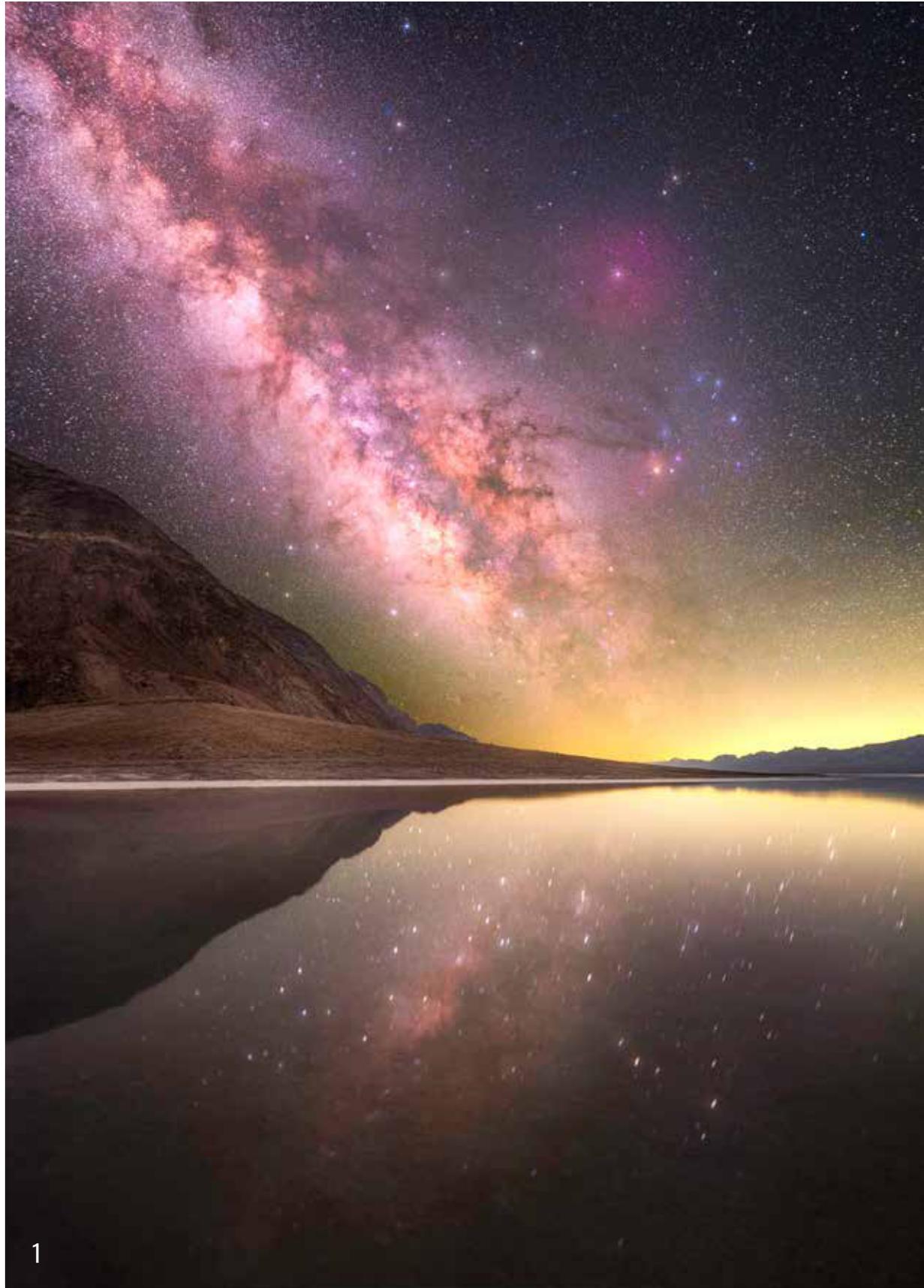
Billowing swells of gas and dust frame this vista of a pair of emission nebulae in Cygnus — Sharpless 2-115 at upper right and the small planetary nebula Sh 2-116 at lower right. The shot was taken with 17 hours of exposure in SHO and RGB filters with a 6-inch f/4 scope. • *David Gluchowski*

3. CLOAK OF THE OWL

Surrounding the familiar visage of the Owl Nebula (M97) in Ursa Major is a much fainter, rarely seen outer shell of emission from ionized oxygen. This imager captured it with an 8-inch scope at f/4.8, taking 32 hours of data with an H α /OIII dual-band filter, plus an additional 14.9 hours with a light-pollution filter. • *Massimo Di Fusco*

4. BURGER DISJOINT

NGC 3628 — sometimes called the Hamburger Galaxy — is best known as part of the Leo Triplet of galaxies. This portrait, taken over 14.1 hours with a 10-inch f/4.0 scope in H α LRGB filters, shows its warped dust lane and extended tidal tail caused by an interaction with another galaxy. • *Sergey Trudolyubov*

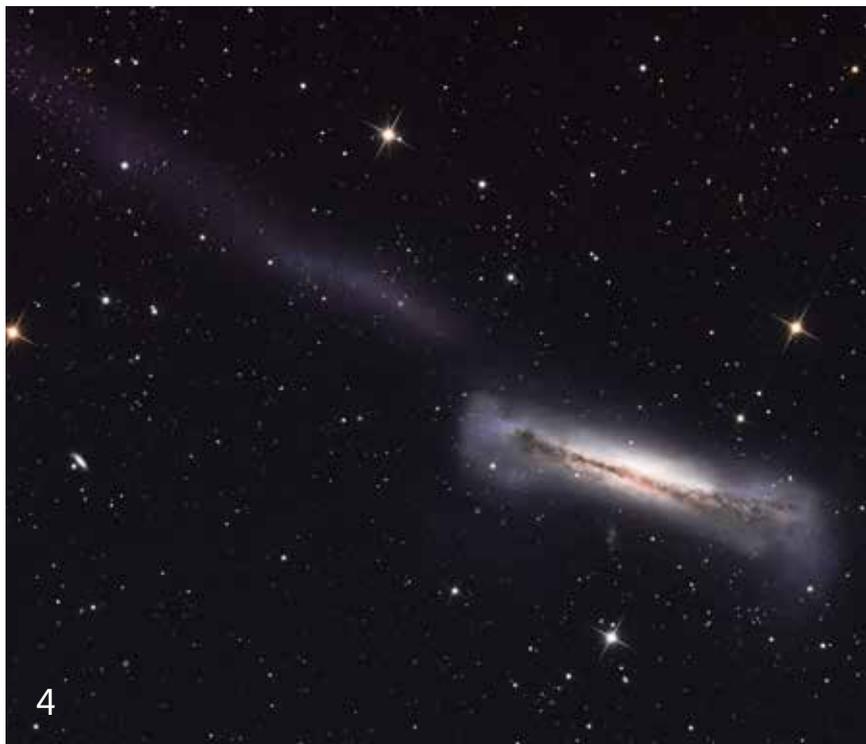




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5. A KNOTTY TAIL

Comet 13P/Olbers reached perihelion June 30, flaunting a faint but intricate ion tail corkscrewing off of its nucleus. This image comprises 30 minutes of exposure taken with an 8-inch f/2 RASA scope. • *Chris Schur*

6. GATHERING STORMS

The fireworks of solar cycle 25 continue, as seen in this H α shot from July 2 featuring a filament at lower left and prominences leaping off the limb of the active Sun. The shot was taken with a 6-inch refractor fitted with an energy rejection filter and a Lunt etalon stacked with a Daystar H α "eyepiece." • *Mark Johnston*

7. STARING DOWN THE IRIS

The Iris Nebula (LBN 487) is a reflection nebula 1,300 light-years away in Cepheus, lit by the open star cluster NGC 7023, which lies within it. This rendition comprises 6.7 hours of exposure with a 2-inch scope. • *Michael Telesco*



6



7



8



9

8. BOLD IN BLUE

The reflection nebula IC 4605 is lit by the star 22 Scorpii and is one of the most prominent features in the colorful Rho Ophiuchi cloud complex. The orange wash at the bottom of the frame is reflected light from the supergiant Antares, out of frame. This image was taken with nearly 15 hours of exposure on a 6-inch refractor. - **Fernando Oliveira de Menezes**

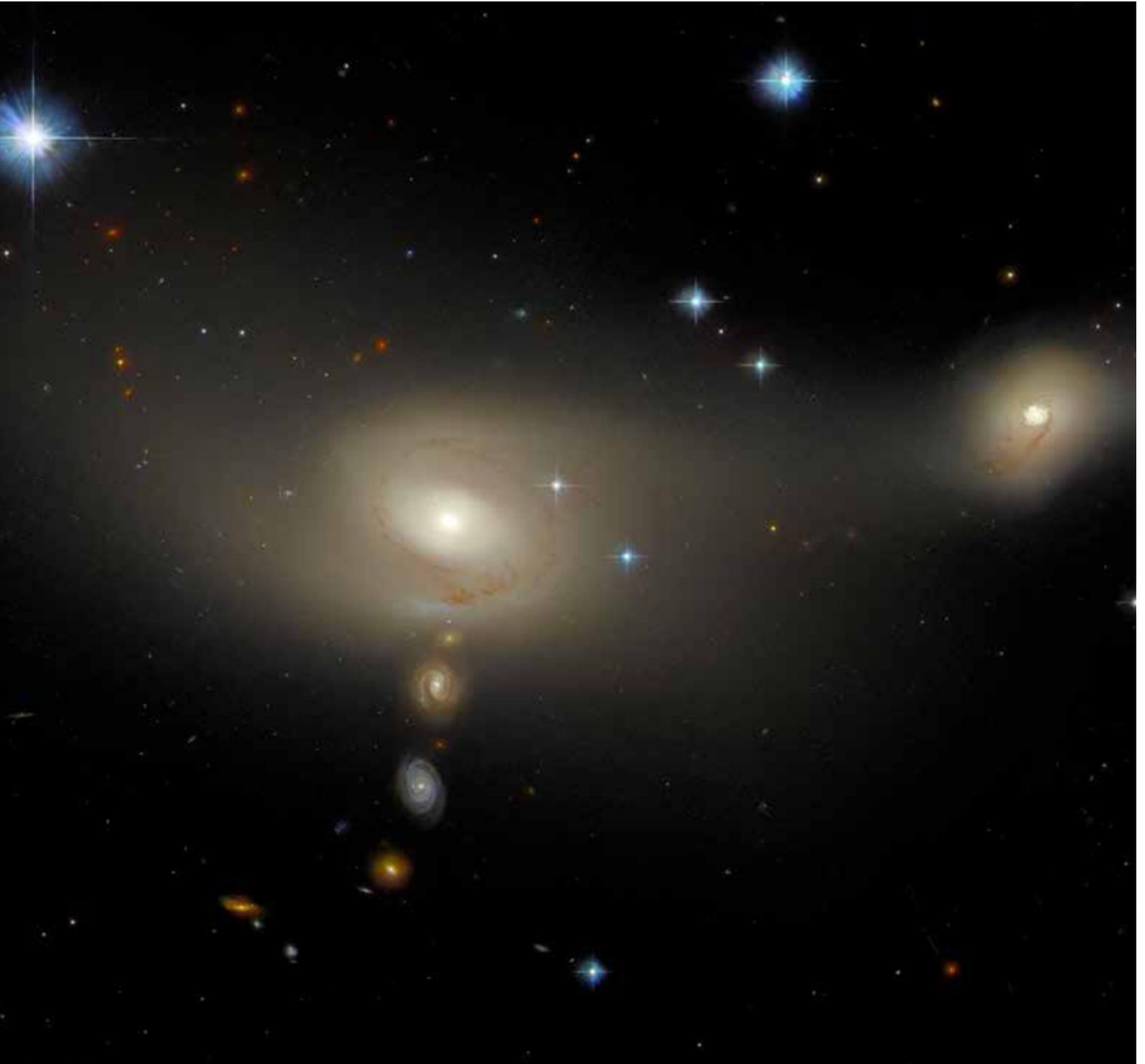
9. SKY ISLAND UNIVERSE

The Andromeda Galaxy (M31) hovers over the mountains of Kyrgyzstan near Tash Rabat in this shot taken with a Nikon Z 6II and a 135mm lens at f/2. The sky frames consist of sixty 20-second exposures at ISO 1000; the foreground was captured with three 2-minute exposures at ISO 1600. - **Basudeb Chakrabarti**



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Please include the date and location of the image and complete photo data: telescope, camera, filters, and exposures.



SPIRALING OUT OF CONTROL

Although Arp-Madore 2105-332 lies in the southern constellation Microscopium the Microscope, you need a powerful telescope to see it clearly. One of 6,000 odd-looking objects in the *Arp-Madore Catalog of Southern Peculiar Galaxies*, entry 2105-332 features two spiral galaxies interacting with each other. Each has two loosely wound arms that are laced with dark dust lanes and show signs of active star formation. The brighter galaxy, ESO 402-10 (left), glows at 14th magnitude while its companion, ESO 402-9, appears two magnitudes dimmer. The pair lies some 200 million light-years from Earth. A chain of three fainter, more distant galaxies string out below ESO 402-10. This portrait combines images from the 2.5-meter Hubble Space Telescope and the 4-meter Victor M. Blanco Telescope in Chile. ESA/HUBBLE & NASA, J. DALCANTON, DARK ENERGY SURVEY/DOE/FNAL/NOIRLAB/NSF/AURA

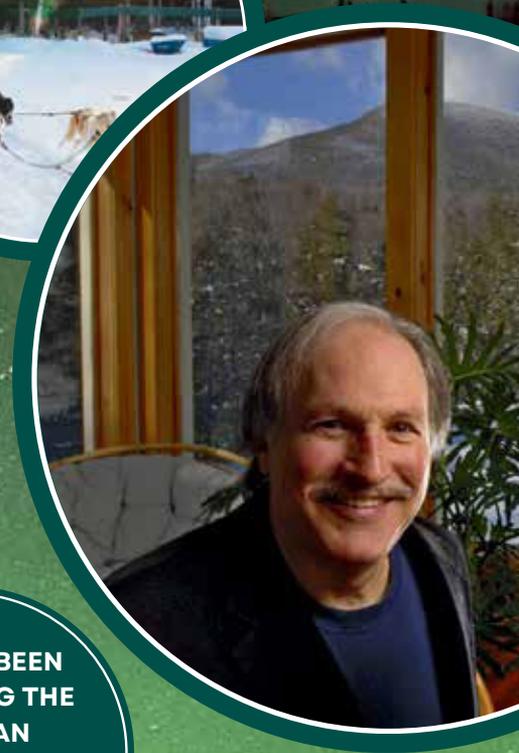
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