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ON THE COVER

The effects of artificial light at night are a global issue, spanning multiple countries and continents.

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# The losing fight against light pollution



City lights like those shown here in Calgary, Alberta, pose an enormous hazard to viewing astronomical objects because countless photons scatter skyward.

ALAN DYER



When I was a young lad, I was fortunate enough to live in a relatively small town in southwestern Ohio. Oxford hosted Miami University, but its native population was then only about 18,000. The Eicher family lived in a residential neighborhood adjacent to farmland outside the town, and I could walk outside of our house and look up into a dark sky.

Years ago, the night sky in many places was much darker than it is today. Astronomy enthusiasts are facing increasing challenges to find dark skies in which to observe. Look at a nighttime map of the U.S. and you can see how grim the current situation is. Small areas of darkness exist practically everywhere outside cities, but to find very large areas of darkness, you essentially need to be west of the Mississippi River.

The same situation exists in many parts of the world. Science journalist Chris Cokinos describes the current state of the battle against light pollution in his story on page 14: Light pollution not only destroys our capability to view the night sky at its best, but it also adversely affects animal behavior and harms patterns of human health.

Some 150 years ago, light pollution basically didn't exist. It's a byproduct of the surge of industrial growth and the desire to light up everything around cities, driven by the mistaken belief that by spreading photons everywhere, the cities are somehow safer. Studies dispel that notion.

Moreover, vast amounts of light visible in satellite images of Earth reveal the stupidity and waste of the current lighting schemes. Sending light skyward accomplishes nothing. Shielding lights and aiming photons downward would best serve human activities. But much of the current waste is driven by utility companies that don't give a damn about science and are happy with fat profits. Ah, yet another area in which we have a long way to go to achieve a perfect society.

Yours truly,

David J. Eicher  
Editor



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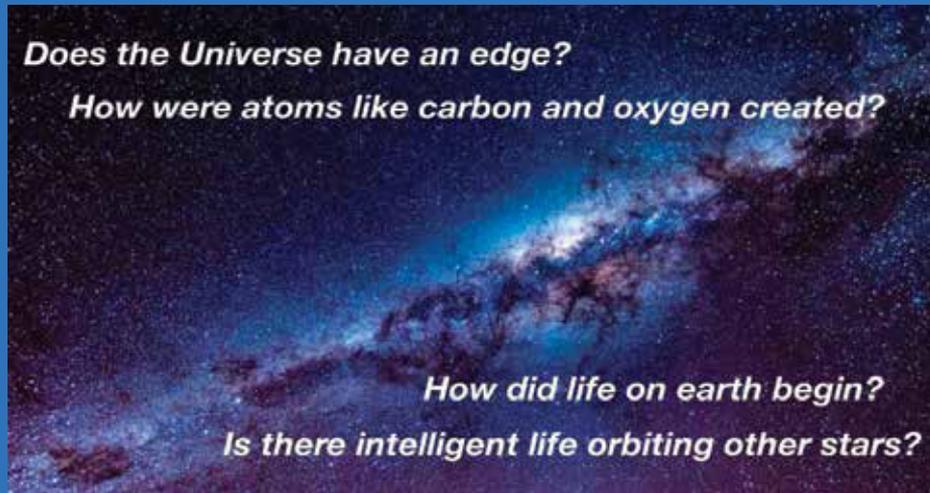
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An eclipse can still look great even from behind clouds.

CHRIS COOK

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

## Behind the clouds

I very much appreciated *Astronomy's* recent "eclipse edition" (April 2024), particularly the weather- and cloud-related info. Years ago, some friends and I drove to the Florida panhandle to observe the March 7, 1970, eclipse. We were disappointed to find the sky totally socked in with

a thick stratus cloud layer — all we could discern was a gradual dimming of daylight leading up to the event. Disappointed, that is, until the umbra appeared in the southwest as a remarkably sharp shadow on the underside of the clouds and rolled over us at incomprehensible speed. It was almost frightening in its scope and grandeur. I've observed several solar eclipses since then, but that one still stands out in my mind as perhaps the most awe-inspiring. —**Rush Elkins**, Huntsville, AL

## Calculating view time

I enjoyed the article and pictures by Stephen James O'Meara in "Ultimate guide to the eclipse" (April 2024).

As a substitute math teacher for 14 years, I had calculated the amount of time to view the 2017 eclipse anywhere in the path of totality based on the perpendicular distance from the center line. I have on occasion used it in class to challenge students to derive the equation. I was thinking for future eclipses, if your readers were going to drive several hours or even days, they would like to know how long they had to view the total eclipse anywhere within the path.

Obviously, the closer to the center line, the longer the viewing time, but it is not a linear relationship. Just a few miles closer to the center line can make a considerable difference and justify the half-hour more drive. To determine how much time (in minutes) to view this unforgettable experience, use the following equation:  $\text{Time} = 4.5 \cos(\sin^{-1}(Y/62))$ , where  $Y$  is the distance in miles from the center line. —**William Ellis**, Athens, AL

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**SNAPSHOT**

## STARS OF THE SHOW

This multistar system has a variety of attractions.

The FS Tau system caught the attention of the Hubble Space Telescope in an image released March 25 featuring a dazzling pair of young stars: FS Tau A, a T Tauri binary system (two young variable stars orbiting each other), and FS Tau B, a forming protostar. FS Tau A shines brilliantly near the middle of the image. FS Tau B presents a different show on the far right: Despite being obscured by a vertical line of dust — a planet-forming disk seen edge-on — the protostar stands out with a blue, asymmetric, double-sided jet. This unbalanced appearance is likely due to the ejecta being expelled at different rates. — DANIELA MATA



### HOT BYTES



#### RECOGNIZING PLUTO

Although the International Astronomical Union stripped Pluto of its rank as a planet nearly 18 years ago, the state of Arizona, where it was discovered, disagrees: On March 29, Gov. Katie Hobbs signed a bill designating Pluto the state's official planet.



#### FAREWELL TO A PIONEER

Former NASA astronaut Tom Stafford died March 18. He flew two Gemini missions — including piloting the first rendezvous in space — and voyaged to the Moon as commander of Apollo 10, flight-testing the Lunar Module in a dress rehearsal for Apollo 11's landing.



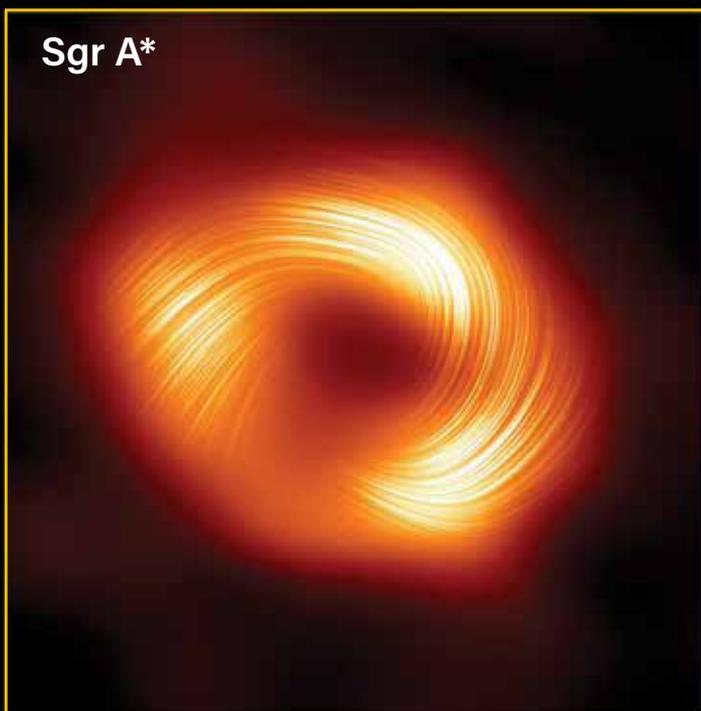
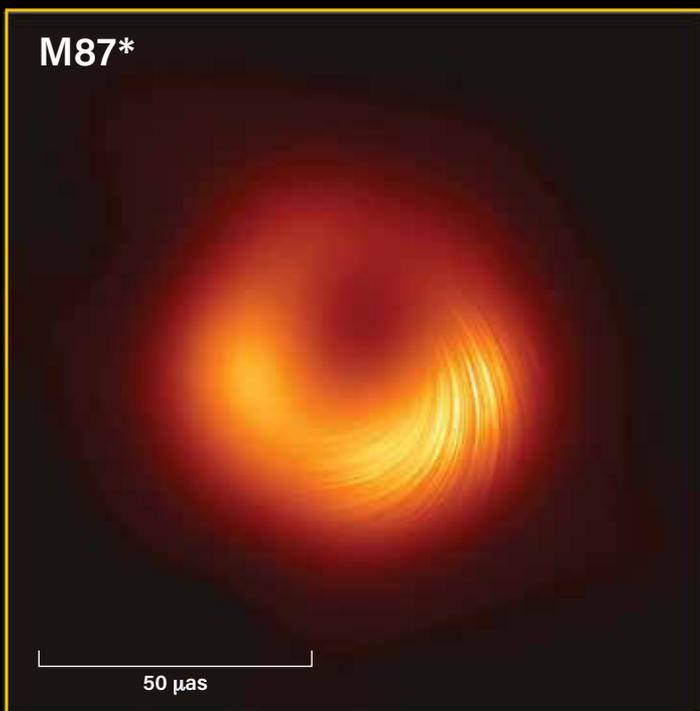
#### LOCKED IN PLACE

Data from the defunct Spitzer Space Telescope has yielded the most concrete evidence yet of an exoplanet that is tidally locked to its star. The super-Earth LHS 3844 b is relatively cool, indicating that its period of tidal braking is over, leaving the planet with permanent day and night sides.

NASA, ESA, AND K. STAPELWELDT (NASA JPL); IMAGE PROCESSING: GLADYS KOBER (NASA/CATHOLIC UNIVERSITY OF AMERICA). BOTTOM FROM RIGHT: NASA/JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS LABORATORY/SOUTHWEST RESEARCH INSTITUTE; NASA; NASA/JPL-CALTECH/R. HURT (IPAC)

# THE MILKY WAY'S CENTRAL BLACK HOLE COULD HAVE A HIDDEN JET

Imagery of our galaxy's supermassive black hole in polarized light reveals unexpected structure.



**DOPPELGÄNGER.** The orientation of polarization of light outside the event horizon of M87's and the Milky Way's central black holes is indicated by the lines overlaid. When seen in polarized light, M87\* and Sgr A\* look remarkably similar, suggesting they also have similar magnetic field structures. EHT COLLABORATION

» At 4 million times the mass of the Sun, the black hole at the center of the Milky Way Galaxy is rather humdrum, as far as supermassive black holes go. But a new analysis of data from the Event Horizon Telescope (EHT) reveals that it's more like its larger cousins than scientists thought.

The new study looks at the polarization of the light bent around our galaxy's central black hole, known as Sagittarius A\* (or Sgr A\*). The visualization produced by the team reveals a spiraling pattern of polarization, indicating that the black hole has a surprisingly strong and organized

magnetic field. It may even be able to harness its magnetic field to fire out a jet of material, albeit a smaller version of the jets produced by the most powerful and voracious black holes.

Astronomers have yet to detect any jet, but if they do, "it might imply that almost every galaxy may have a hidden jet lurking at its center, but that we actually usually miss them because they're simply too weak," says Angelo Ricarte, a fellow at the Center for Astrophysics (CfA) | Harvard & Smithsonian in Cambridge, Massachusetts, and one of the leaders of the polarization analysis.

The work was published March 27 in two papers in *The Astrophysical Journal Letters*.

## EYE OF THE STORM

The image is the latest in a groundbreaking series from the EHT, which began observations in 2017 as a network of eight radio telescopes around the globe. The team targeted two supermassive black holes: the one at the center of the galaxy M87, 55 million light-years distant, and the one at the heart of our own Milky Way.

Although the black hole M87\* is much farther away than Sgr A\*, it's

much larger than Sgr A\* and appears roughly the same size on the sky. Its heft also gives it a calmer overall appearance, in the same way that a hurricane appears more stable than a tornado, making its data easier to process.

In 2019, the international EHT team released their portrait of M87\* — the first-ever image of a black hole’s shadow and the light that gets bent around it. In 2021, the team reported how that light was polarized — meaning how the electromagnetic waves that make up the light are oriented. This is imprinted on light by the black hole’s intense magnetic field, indicating how strong and organized it is.

The analysis of M87\* showed a strong spiral signature, indicative of a strong magnetic field. This made sense, as M87\* also sports a big, bright jet beaming out from the galactic core at near light-speed, powered by the black hole’s rotation and magnetic field.

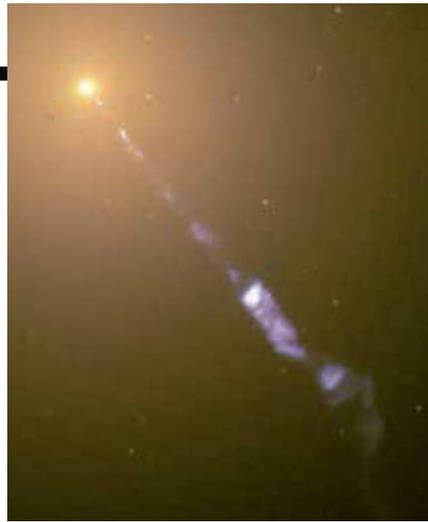
But the more turbulent appearance of Sgr A\* proved harder to tame. In 2022, the EHT released their initial image of Sgr A\*, which represents an average of the total light acquired by the telescopes. “That was already a huge challenge because all the techniques we had developed for M87 were broken by Sgr A\*,” says CfA fellow and project co-leader Sara Issaoun.

When the team began work on extracting a polarization image from the Sgr A\* data, “we didn’t expect to see anything,” says Issaoun, as polarization “is even more challenging than working with total light.” On top of that, the team also expected the relatively small size of Sgr A\* to result in a weak, chaotic magnetic field.

But to their surprise, they quickly saw signs of structure, much like M87\*. After spending some time training their imaging software, these details “came out again super easily,” says Issaoun, “this beautiful kind of ordered spiral.”

Intriguingly, that strong pattern is best matched in the team’s models by black hole configurations and magnetic fields that ought to produce a jet. “We really need to be able to see the jet before we believe it,” cautions Ricarte. “But it’s very suggestive.”

Issaoun says the EHT team thinks



**JET-SETTING.** The jet emanating from the center of galaxy M87 (imaged here by the Hubble Space Telescope) has been observed in all wavelengths. The first visual detection of the jet by an amateur astronomer was made by Barbara Wilson in a 20-inch reflector at the 1991 Texas Star Party.

NASA AND THE HUBBLE HERITAGE TEAM (STSCI/AURA)

they can directly detect the jet in the next two years. “I think that’s going to be the next adventure for us,” she says.

### THE VARIABILITY CRISIS

Other astronomers are also struck by the similarities between the two black holes. “It is surprising that Sgr A\* and M87\* would have similar magnetic fields, as they are two very different supermassive black holes,” says Yvette Cendes, a CfA radio astronomer who was not involved in the work. She adds, “The claim of a hidden jet will definitely keep theorists busy for years.”

Part of the puzzle is understanding why Sgr A\* turned out to be less chaotic than predicted, in both total and polarized light — what theorists are calling “the variability crisis.”

The conundrum affects more than just our understanding of supermassive black holes. Theorists think that jets from these black holes play a key role in their host galaxy’s overall life story, determining how long a galaxy can form stars. That’s because jets pump energy back out into a galaxy, which can blow away its reservoir of star-forming gas or heat it to the point where it can no longer collapse and make new stars.

Currently, says Ricarte, “the majority of cosmological simulations will only turn on a jet in more massive galaxies ... because that is where we’re confident that we see the jets. If they also exist in Sgr A\*, that requires some kind of model modification.” — MARK ZASTROW

### EUCLID DE-ICED

ESA’s Euclid mission carried out a procedure to clear a buildup of water ice on the space telescope’s mirrors, which was dimming its vision. Controllers had to take care to avoid excessive heat that could throw off its optical alignment.

### A CHANCE OF SPACE TRASH

A 1.6-pound (0.7 kg) piece of a metallic post from a pallet of batteries discarded by the International Space Station in 2021 survived reentry and smashed through the roof of a Florida man’s house March 8, 2024.

### PLANETARY DIGESTION

At least one in every dozen stars appears to have swallowed one of its own planets, a survey of 91 stellar pairs finds. Looking at pairs with similar origins allowed researchers to identify the change in a star’s chemical signature when it ingested a planet.

### RADIO SANCTUARY

Astronomers gathered in Turin, Italy, March 21–22 to call for protecting the Moon’s farside from radio interference. Shielded from Earth, the lunar farside is a pristine environment for radio astronomy, but future human exploration could disrupt it.

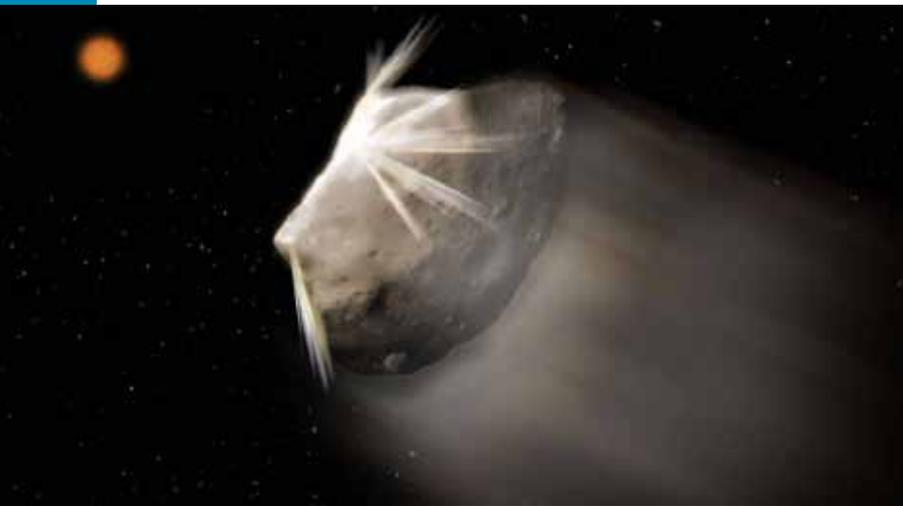
### HEAVYWEIGHT BINARY

The pair of supermassive black holes at the center of elliptical galaxy B2 0402+379 weigh in at a combined 28 billion solar masses, making them the most massive black hole binary yet measured.

### SINGLE-CELLED OPTIMISM

Lab experiments show that the Europa Clipper orbiter, set to launch to its namesake jovian moon later this year, can detect a single bacterial cell in a single grain of ice. The results raise hopes that the craft might find signs of life in water ejected from the moon’s subsurface ocean.

— M.Z.



**CHIMERIC CREATURES.** While the centaurs of Greek mythology were half-human and half-horse, solar system centaurs look like asteroids but can sometimes sprout cometary tails. PAMELA L. GAY/PSI

## How centaurs sprout their tails

» Centaurs are small rocky solar system objects that straddle the line between asteroids and comets. Of the more than 300 centaurs known today, 39 have shown cometlike outbursts, sprouting a nebulous coma and sometimes a tail (including 2060 Chiron in the late 1980s and early '90s).

Scientists now know that these objects trickled inward from the frigid Kuiper Belt, the source of many of the solar system's comets. What causes only some centaurs to display cometlike behavior is still unknown.

But a team of researchers led by Eva Lilly, a senior scientist at the Planetary Science Institute in Tucson, Arizona, has shown that all centaurs observed with comae and tails have something in common: Each experienced recent changes to their orbits that Lilly and her colleagues call jumps.

The researchers discovered this while simulating the orbits of all known centaurs over the past 5,000 years. In the model, jumps

happened when the objects had a close encounter with Saturn or Jupiter, which pulled them into more circular orbits closer to the Sun. The work was published in January 2024 in *The Astrophysical Journal Letters*.

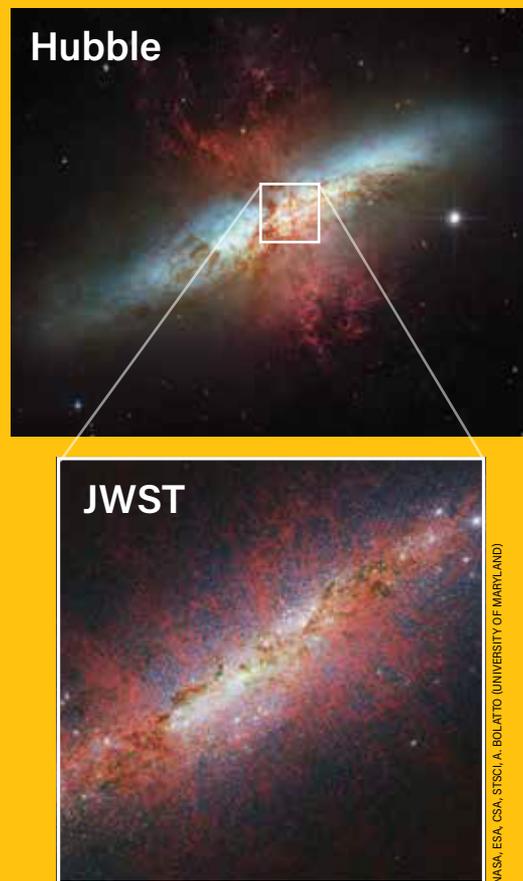
The simulations are more precise than previous work, with shorter time intervals between each step. This allowed the team to identify many orbital jumps that otherwise would not have been noticeable. "I wasn't expecting how very fast they would happen," Lilly tells *Astronomy*.

The team's thermal modeling shows that the extra warmth from being closer to the Sun can penetrate centaurs and cause buried water ice to turn to vapor or crystallize, releasing gases that could form a cometlike atmosphere.

Lilly's team also identified three centaurs (2014 SW223, 31824 Elatus, and 32532 Thereus) as targets for future surveys to check for cometary activity. These objects will reach their closest approaches to the Sun in about 15 years and the team's simulations showed that all had recent jumps. —THEO NICITOPOULOS

## LIGHTING UP THE CIGAR

**ASTRONOMERS HAVE KNOWN** for decades that M82 (the Cigar Galaxy) has an extraordinarily high star-formation rate. About 12 million light-years away, it is forming new stars 10 times faster than the Milky Way. Now NASA's James Webb Space Telescope (JWST) and its infrared sensitivity can pierce through obscuring gas and dust, yielding an accurate count of M82's star clusters. It has also delivered a detailed picture of the wind streaming from its core, driven by the rapid star formation. The top image was taken by the Hubble Space Telescope; the inset is from JWST. Stars or star clusters are white specks, the red tendrils are gaseous streamers formed by galactic winds, and green denotes concentrated areas of iron, mostly from supernova remnants. —D.M.



NASA, ESA, CSA, STSCI, A. BOLIATO (UNIVERSITY OF MARYLAND)



# Interstellar debris claim debated

**WAS IT ALIENS — OR WAS IT A TRUCK?** That's the latest twist in the ongoing saga of the metallic spherules recovered last June from the floor of the Pacific Ocean. Harvard University astrophysicist Avi Loeb has controversially claimed these tiny spheres are of interstellar origin, and possibly even pieces of alien technology.

The spherules were found within a search zone informed in part by an analysis co-authored by Loeb of seismic readings from Manus Island in Papua New Guinea. The readings coincided with reports from U.S. government sensors of a suspected interstellar meteor, IM1, entering and breaking up in Earth's atmosphere Jan. 8, 2014.

But a new study presented March 12 at the Lunar and Planetary Science Conference in Houston suggests that the seismic activity in question likely has a more down-to-Earth explanation: It was

from a truck driving along a nearby road.

"The signal changed directions over time, exactly matching a road that runs past the seismometer," said team leader Benjamin Fernando, a seismologist at Johns Hopkins University, in a press release. He added that his team found "lots of signals like this," and that "they have all the characteristics we'd expect from a truck and none of the characteristics we'd expect from a meteor."

Using seismic data from different stations, Fernando and his colleagues triangulated a rough position for IM1's fireball, centered about 105 miles (170 kilometers) away from Loeb's search zone. "Not only did they use the wrong signal, they were looking in the wrong place," Fernando said.

The work adds to a chorus of dissent from scientists regarding Loeb's claims. Objections include the large

uncertainties of pinpointing such a speedy object and that natural or human processes are more likely explanations for the compositions of the recovered spherules, a handful of which are unusually rich in beryllium, lanthanum, and uranium.

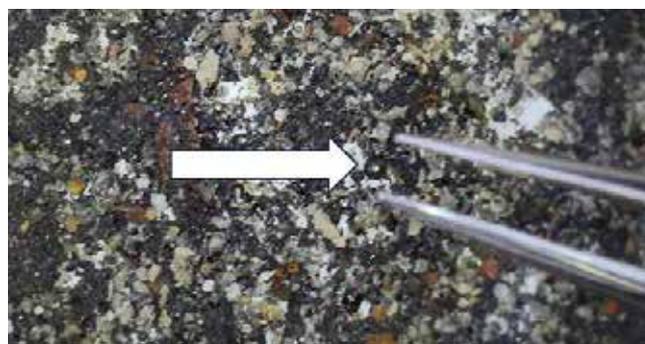
Loeb disputed the conclusions of the seismic analysis, writing on his blog that the search zone was mainly determined by U.S. military satellite observations; the seismic readings were used only to refine the location

## IM1, WHAT'S YOUR 20?

Scientists suspect that a truck driving on the road next to the Manus Island seismic station was the source of the pseudo-meteor signature. ROBERTO MOLAR CANDANOSA AND BENJAMIN FERNANDO/JOHNS HOPKINS UNIVERSITY, WITH IMAGERY FROM CNES/AIRBUS VIA GOOGLE

within it. However, the U.S. military has not publicly released the full dataset. Loeb also noted that the 90-percent-confidence ellipse for the location of IM1 derived by Fernando's team covers a large area, and that the search zone falls within it.

— ELIZABETH GAMILLO, M.Z.



**HOTLY DEBATED.** This spherule recovered from the Pacific seafloor is 0.016 inch (0.4 mm) across. AVI LOEB/MEDIUM

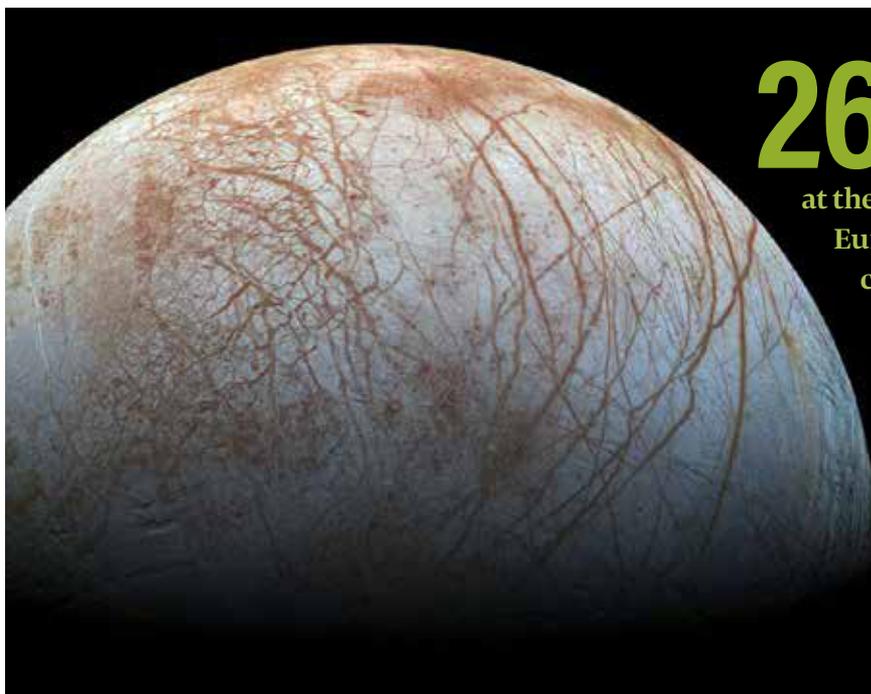


ESO/VPHAS+ TEAM. ACKNOWLEDGEMENT: CASU

## A MAGNETIC MYSTERY SOLVED

**LOCATED 3,800 LIGHT-YEARS AWAY,** the binary system HD 148937 makes an odd couple. Its stars lie within a stunning nebula (NGC 6164/5) — a rare find, as their powerful winds should have blown away any residual gas and dust from their formation. New observations from the Very Large Telescope Interferometer, published April 11 in *Science*, reveal these stellar companions have an age gap, with one star some 1.5 million years

younger than the other. The younger star is also highly magnetic, but its older counterpart is not. The nebula is even more recent: It formed 7,500 years ago but contains high amounts of carbon, nitrogen, and oxygen — elements normally found in the depths of stars. This evidence points to a violent history, suggesting the binary was once a trinary but the third star was destroyed in a merger, creating the young, magnetic star seen today. —D.M.

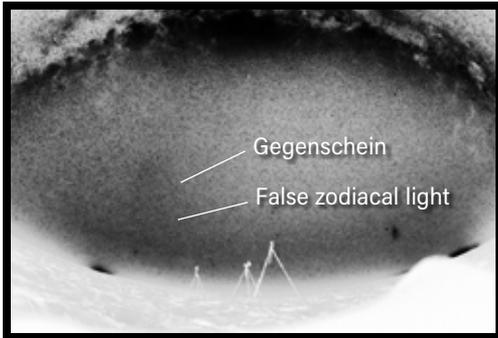


NASA/JPL-CALTECH

**26** The number of pounds (12 kg) of oxygen produced at the surface of Jupiter's icy moon Europa every second due to charged particles impacting and breaking apart water molecules, according to measurements published March 4 in *Nature Astronomy*. This is at the low end of estimates, but if the oxygen finds its way into the ocean below, it could serve as a source of energy for life.

# The Gegenschein puzzle

Scholars have long disputed who discovered the “counterglow.”



The gegenschein rests at the tip of the dimmer pyramidal-shaped false zodiacal light. STEPHEN JAMES O'MEARA



In April 1961, *Galaxy* magazine contained an article entitled “The Puzzle Called Gegenschein,” by German-American science writer Willy Ley. Referring to the mystery of who was the first to identify the faint glow of the gegenschein, Ley wrote: “Historians of astronomy are in fair agree-

ment that the first discoverer of the *Gegenschein* was the Danish astronomer Theodor Brorsen [in 1854] ... but Brorsen himself stated that he was not the first to see it.”

Brorsen credited French astronomer Esprit Pézenas as having seen it in 1730. But in 2021, Donald Olson, an astronomer at Texas State University, determined that what Pézenas took for the gegenschein (which he described as red) was instead an aspect of a great auroral display that occurred Feb. 15, 1730.

In the January 2024 issue of *Journal of the British Astronomical Association*, Marinus A. van der Sluijs argues that U.S. Navy chaplain George Jones (1800–1870) appears to have observed the gegenschein a couple of months prior to Brorsen. On the morning of Jan. 30, 1854, Jones observed what he called a diffuse “Zodiacal Light” slightly east of Regulus (in the region of the antisolar point) at 2:00 A.M., which he followed for another three hours. About two weeks later, he said it appeared like a “dim branch of the Milky Way, that has strayed off from the general course.”

Unfortunately, in all this discussion, the man who decades earlier gave the gegenschein its name has been overlooked, though I argue this is a mistake. I'll explain.

## What is the gegenschein?

*Gegenschein* is a German word meaning “counterglow,” and refers to a faint oval glow. About 10° across at its largest, it would fit comfortably inside the bowl of the Big Dipper. It appears at a position directly opposite, or counter to, the Sun on the ecliptic — the pathway of the Sun, marked by the zodiacal constellations.

The gegenschein is a part of the same complex of dimly shining features that includes the zodiacal light and the much fainter zodiacal band. The minuscule

particles orbiting the Sun form a dust disk on the ecliptic plane, and light reflecting off it creates all these phenomena. While the dust cloud's origin is still being debated, observations from NASA's Juno spacecraft reveal that dust storms on Mars may be the source of the dust disk, which lies between the orbits of Earth and Mars.

Of these phenomena, the zodiacal light is the most intense. It is a diffuse cone of light (often described as a pyramid) seen in the western sky in the evening. It first appears around the end of astronomical twilight and sets about two hours later; the cone's tip then reappears as it begins to rise about two hours before sunrise, and appears highest just before dawn.

In his book *Cosmos* (Vol. 1), German scientific explorer and naturalist Alexander von Humboldt recorded that on the night of March 16, 1803, when the zodiacal light was “most strongly luminous,” he observed a pyramidal counterglow — *gegenschein*, in his native language — in the east. Although the name survived, scholars have generally discredited Humboldt's observations, believing that what he described as an eastern zodiacal pyramid was actually an atmospheric phenomenon called the false zodiacal light.

But would Humboldt really have been fooled? The false zodiacal light is visually much dimmer than the appearance of the rising gegenschein. And, as E.R. Hope of Canada's Defence Research Board explained in the Nov. 25, 1961, issue of *Nature*, the false zodiacal light is an atmospheric effect that “opens out” from the gegenschein toward the horizon, creating this pyramid.

**I would not have noticed the false pyramid had it not been for the gegenschein.**

My observations of the false zodiacal light made on Aug. 8, 2023, from the extremely flat Makgadikgadi Pans in Botswana, confirmed these attributes. On that night, I first spotted the gegenschein rising in the east at the end of astronomical twilight. Only after determining the location of the gegenschein against the

stars did I notice the much dimmer skirt of the false zodiacal light trailing down from the horizon. So yes, there was a pyramid of light in the east — just as Humboldt reported. The gegenschein formed its tip and was also the most prominent part. In other words, I would not have noticed the false pyramid had it not been for the presence of the gegenschein.

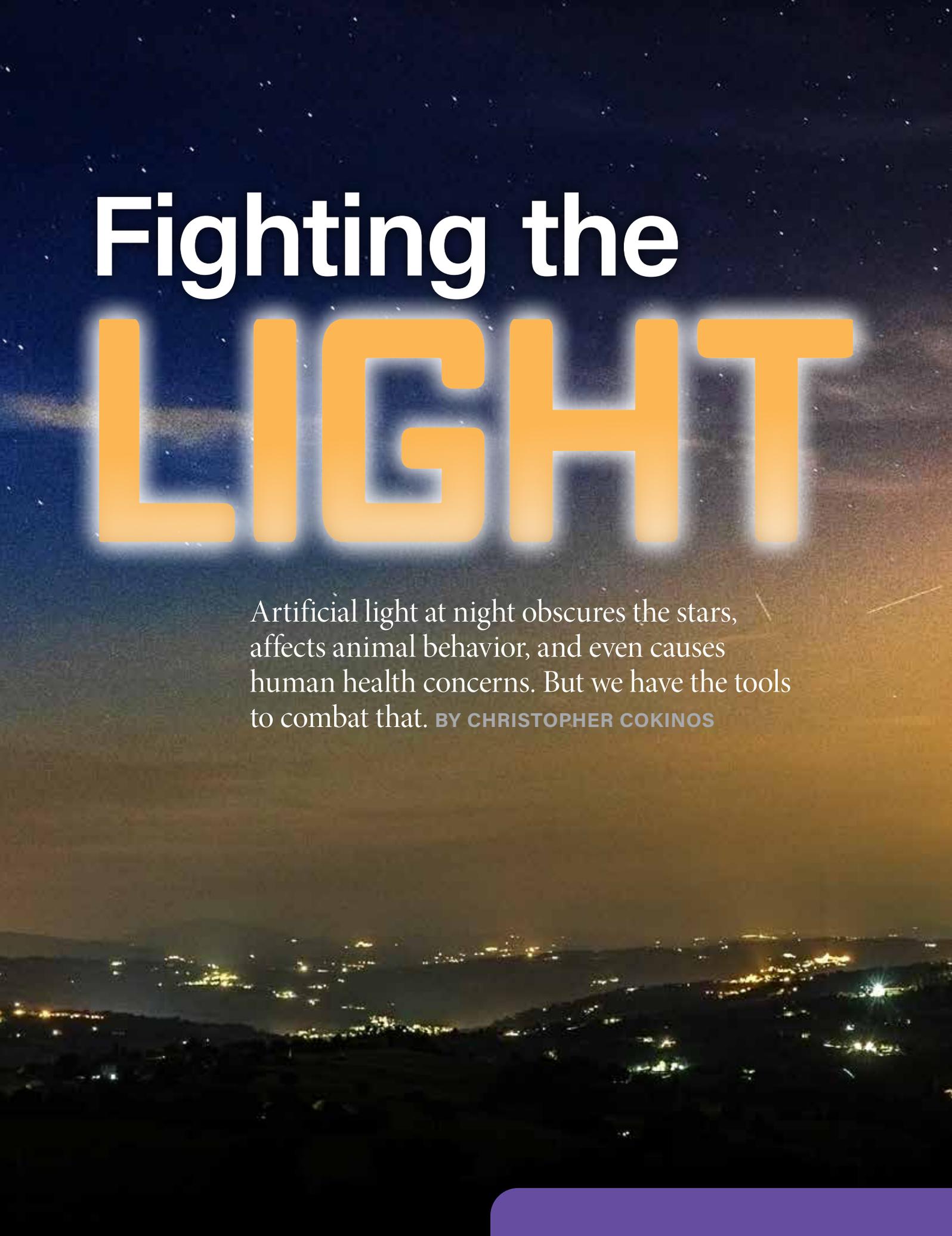
So, who discovered the gegenschein? I'll go out on a limb and say that not only did Alexander von Humboldt discover and name the phenomenon in March 1803, but he was also the first to discover the false zodiacal light as well. And Brorsen was the first to give a detailed description. As always, thoughts and observations are welcome at [sjomeara31@gmail.com](mailto:sjomeara31@gmail.com). ☺



BROWSE THE “SECRET SKY” ARCHIVE AT  
[www.Astronomy.com/OMeara](http://www.Astronomy.com/OMeara)



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

The background of the entire page is a night sky filled with stars. At the bottom, there is a panoramic view of a city at night, with numerous lights from buildings and streets illuminating the landscape. The sky transitions from a dark blue at the top to a lighter, hazy orange near the horizon.

# Fighting the

# LIGHT

Artificial light at night obscures the stars, affects animal behavior, and even causes human health concerns. But we have the tools to combat that. **BY CHRISTOPHER COKINOS**

## ON A CRISP NIGHT LAST FALL IN THE ARIZONA DESERT,

I stood amid sand and scrub at the intersection of Valencia and Kolb on the outskirts of Tucson and beheld a gleaming gas station.

To say that this coruscating beacon of convenience was well lit would be like calling a dinosaur incinerated by the Chicxulub meteor impact well done. LED lights shed painfully bright white light across the sidewalks and pavement, attracting swarms of desert crickets. Several faulty lights nearby added a dystopian purple haze.

Across the street stood a second gas station — just as large, but with lighting that seemed softer, warmer, and not as glaring.

With me was a small group of dark-sky activists, including John Barentine, a Tucson-based astronomer and consultant on dark-sky issues. From our vantage point, it was obvious which gas station was the larger emitter of light pollution. But, Barentine explained, both buildings met Tucson's lighting code. I nodded, feeling depressed about the state of artificial light at night, or ALAN.

The threat of ALAN has long been known to astronomers and shows no sign of abating. Not only is it growing, it's acquiring new forms. Today, you can be far out in wild country and still witness urban light domes and passing satellite constellations looking like moving sculptures in space. And the widespread adoption of cheap and efficient LEDs has allowed blue-white light to spread across the sky like a science-fiction fog.

Perhaps even more unsettling is the growing realization of light pollution's impacts on ecosystems and even society. Losing dark nights doesn't just mean losing stars: New research is showing that ALAN can be deadly to animals and harmful to humans.

As a result, light pollution is no longer just a rallying cry for astronomers — it is increasingly recognized as an



**ABOVE: SKYGLOW FROM THE CITY OF CALGARY,** Alberta, some 12 miles (20 km) away drowns out the sky to the northeast of Rothney Astrophysical Observatory in Priddis, Alberta. ALAN DYER

**BACKGROUND: THE BRIGHT SKYGLOW** from city lights can easily wash away the night sky, hiding the stars from view. But they are still there, shining — and we can reveal them with collaborations and initiatives underway around the world.

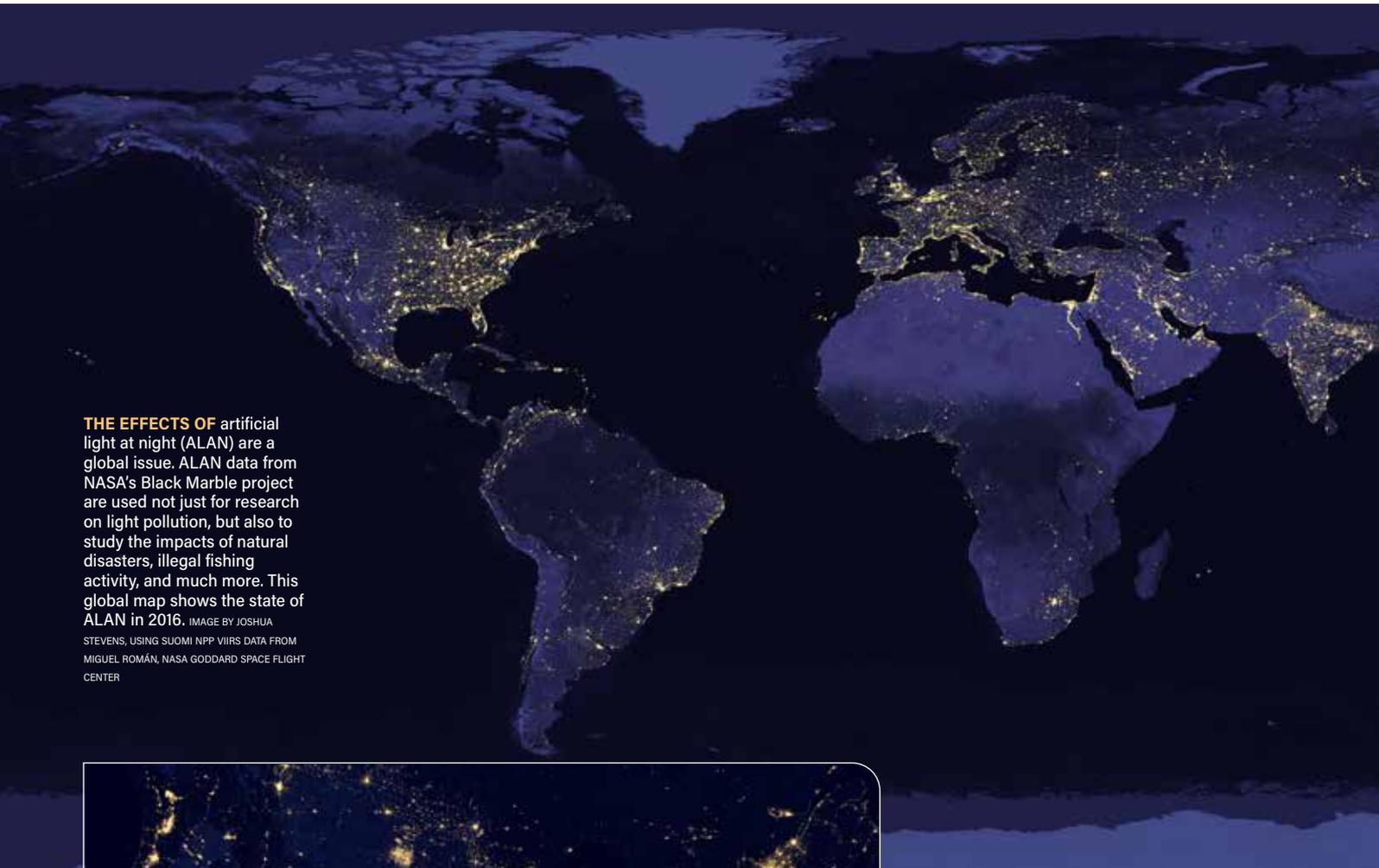
CATIAMADIO/DREAMSTIME.COM

environmental crisis. This means that astronomers have new allies in the global fight against the light. Arizona — with its historic observatories and tough lighting codes — is just one of many communities on the frontlines.

### A snapshot of ALAN

In response to the growing sense of crisis, in June 2023 the journal *Science* devoted a special issue to light pollution, defining it as “illumination at times and locations that are unnecessary, excessive, intrusive, or harmful.” Sometimes there is too much lighting in one location. Often, fixtures shed light in directions other than down, where it is intended for public safety. *Science* cites many sources beyond streetlights, including buildings, vehicles, advertising, and sports facilities.





**THE EFFECTS OF** artificial light at night (ALAN) are a global issue. ALAN data from NASA's Black Marble project are used not just for research on light pollution, but also to study the impacts of natural disasters, illegal fishing activity, and much more. This global map shows the state of ALAN in 2016. IMAGE BY JOSHUA

STEVENS, USING SUOMI NPP VIIRS DATA FROM MIGUEL ROMÁN, NASA GODDARD SPACE FLIGHT CENTER



**THE PREVALENCE OF** bright city lights in the U.S. already makes it difficult for anyone living east of the Mississippi River to see the night sky. Even in the west, more lights and poor lighting practices have begun to take a toll. IMAGE BY ROBERT SIMMON, USING SUOMI NPP VIIRS DATA PROVIDED COURTESY OF CHRIS ELVIDGE (NOAA NATIONAL GEOPHYSICAL DATA CENTER)

Lighting follows development, explained Amy Oliver, public affairs officer for the Center for Astrophysics | Harvard & Smithsonian, as she drove us along a dark rural stretch of Pima County. And we saw evidence backing her words: A school we passed had an

intensely bright digital sign promoting everything from enrollment days to sporting matches — a glaring presence that temporarily blinded me. Beyond it, the empty sports field's lights were on.

Barentine and co-authors Miroslav Kocifaj and Stefan Wallner explain in the

*Science* special issue that a decade ago, ALAN was increasing globally at an average rate of about 2 percent a year, based on satellite observations of upward-directed light. But, Barentine says, those observations undercount the real change by only considering light that makes it through the atmosphere. A more recent *Science* study, he says, which doesn't suffer from the same bias, estimates the sky's brightness is increasing at about 10 percent each year.

In a 2023 talk, Smith College astronomer James Lowenthal, who heads the light pollution subcommittee of the American Astronomical Society, put the consequences for a naked-eye observer in visual terms: "We're already losing about one star per day. In a decade, most parts of the United States could have lost thousands of stars from their sky."

### The bad guys ... sort of

If there are bad guys in this story, they are



“We’re already losing about one star per day. In a decade, most parts of the United States could have lost thousands of stars from their sky.”



**THE MMT OBSERVATORY** sits atop Mount Hopkins in the Santa Rita Mountains, where the lights of both Tucson and Nogales are visible. PYRONORDICMAN/WIKIMEDIA COMMONS

ignorance and LEDs — or, more precisely, the latter’s misapplication. While the first is a longstanding foe, the second is a newcomer that has made swift advances. LEDs are everywhere, having proliferated due to their low cost, high efficiency, purported safety benefits, and a global wave of bans on old-fashioned incandescent bulbs. LEDs are supposed to be good for energy budgets and Earth’s climate, but when left unchecked, they produce harsh light that can overwhelm the night sky, polluting more than the lighting it replaced.

Most LED parking lot and streetlight fixtures shine at a correlated color temperature (CCT, which describes the hue of lighting perceived by the human eye) of 3,000 kelvins, bluer than light at 2,700 K — the lowest CCT that manufacturers produce, which is still bluer than the amber glow of older sodium-vapor lamps. For comparison, a CCT of 5,000 K is closer to daylight.

Bluer light, with a higher CCT, is

## RESPONSIBLE LIGHTING

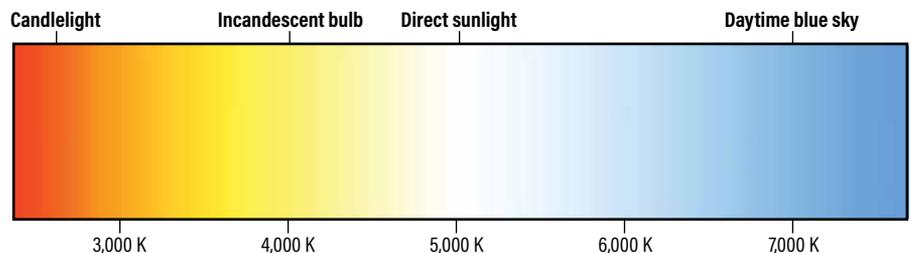
**DarkSky’s Responsible Outdoor Lighting at Night (ROLAN)** manifesto is a straightforward policy document that city councils, companies, and schools can adopt. Developed by a collaboration of dark-sky activists, policymakers, and lighting experts, its points include:

- Everyone should have the right to access darkness and quality lighting, and light needs to be used and distributed fairly without discrimination.
- Designs should start with darkness and add light only if needed to create a space where people are encouraged to dwell; this lighting should also protect a view of the stars.
- Planners should add light only to create safe spaces for people to be in and move through. These benefits should be maximized while simultaneously limiting each project’s environmental and financial costs.

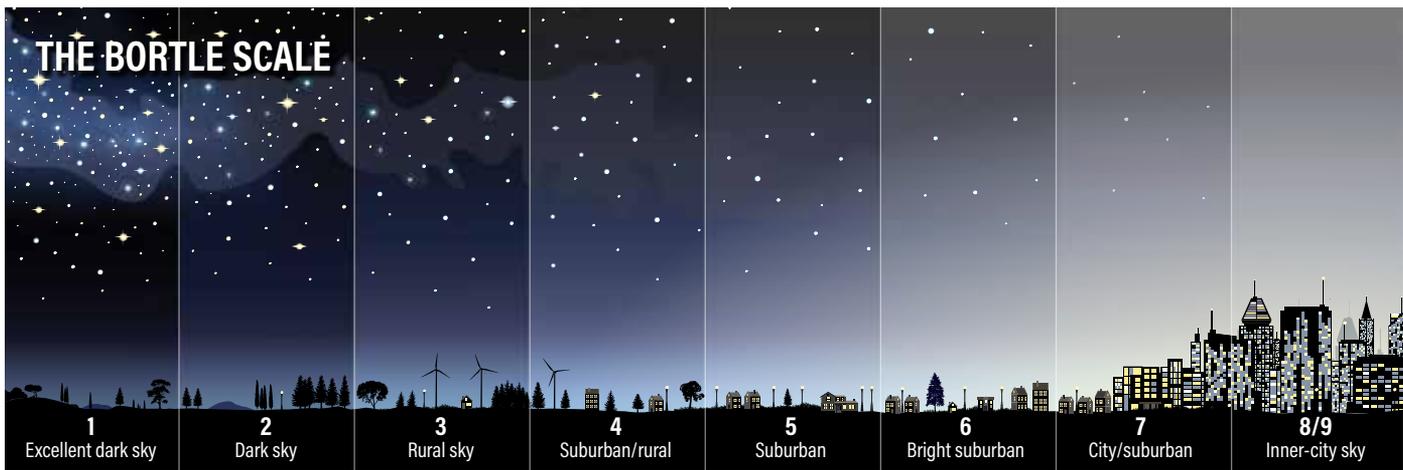
Further, ROLAN cites the “Five Principles of Good Outdoor Lighting:” that it has a justifiable purpose, it isn’t brighter than necessary for that purpose, it points only where it needs to, it uses warm colors, and it’s off when it’s not needed. The key elements to a good lighting code are similar: putting light only where it’s needed; using shielded streetlights; and employing warmer, lower-temperature light in the yellow part of the spectrum instead of blue-white light.

Budding light-pollution activists can find the manifesto at [www.darksky.org/news/responsible-outdoor-lighting-at-night-rolan-manifesto-for-lighting/](http://www.darksky.org/news/responsible-outdoor-lighting-at-night-rolan-manifesto-for-lighting/) or search online for the lighting codes for both Tucson and Flagstaff. — C.C.

### COLOR TEMPERATURE SCALE



**THE CORRELATED COLOR** temperature (CCT) of light, measured in kelvins, determines the warmth and color we see. Older sodium-vapor lamps had a CCT of 2,700 K, while most outdoor LED lighting has a CCT of 3,000 K or higher. Sunlight has a CCT of 5,000 K, with daytime blue skies even higher. Early LED lighting tended to have a CCT of 4,000 K. More recently, outdoor lights with a CCT of 3,000 K are being employed; although this CCT is considered warmer than daylight, according to an American Medical Association report, our eyes still perceive light with this CCT as white. ASTRONOMY: ROEN KELLY



more harmful to astronomy: It has a shorter wavelength, which the molecules in Earth's atmosphere more easily scatter, washing out more of the sky. For astronomers, this reduces the contrast between their target and the background sky, resulting in "not detecting the object at all or needing either a much bigger telescope or longer exposure time to detect it," explains Barentine.

Scattering from blue-rich LEDs is a



problem even in the Atacama Desert of Chile, home to many of the world's great observatories. At the seemingly pristine site of the Las Campanas Observatory — home to the twin Magellan Telescopes and the forthcoming Giant Magellan Telescope — half of the background sky-glow comes from road lighting 25 miles (40 kilometers) away, according to a 2022 study in *Monthly Notices of the Royal Astronomical Society*. Its authors find that some two-thirds of all large observatories experience skies 10 percent brighter than natural levels, which is the limit for a light-polluted observatory site as defined by the International Astronomical Union and International Commission on Illumination.

But Tucson has shown that light pollution can be reduced with large-scale public intervention. In 2016 and 2017,

**DESPITE ITS SIZE**, Flagstaff has maintained fairly dark skies with carefully crafted lighting codes and cooperation from the public, the local government, and city businesses. LEFT: CHON KIT LEONG/DREAMSTIME.COM. BELOW: COCONINO NATIONAL FOREST/BRADY SMITH



**THE BORTLE SCALE** is a common way to measure the darkness of the night sky. It ranges from 1 to 9. At one end, a value of 1 refers to a perfectly dark sky free of light pollution, while a score of 9 is reserved for the most heavily light-polluted, inner-city skies.

ASTRONOMY: ROEN KELLY

90 percent of street fixtures — nearly 20,000 lights — were replaced with downcast lights, most of which are shielded, meaning the lighting element is inset into the fixture. The lights are set at 90 percent maximum brightness, but dimmed further — down to 60 percent — between either midnight or 3 A.M. (depending on location) and the hour before dawn.

There were no complaints from the public. "Nor has there been an increase in crime or traffic accidents that we can detect in the available data," Barentine says, as we zip down Aviation Highway. Most residents — including myself — didn't notice the change at all.

## Bye, ALAN

Tucson's lighting code is already considered strong. In northern Arizona, Flagstaff's night-sky protection is trailblazing.

Flagstaff is the world's first designated International Dark Sky Community and home to several astronomical facilities, including Lowell Observatory. It's often said that Flagstaff and astronomy grew up together: The first pro-astronomy lighting ordinance was passed there in 1958, when famed astronomer E.C. Slipher got the city to ban advertising searchlights.

Now, dark-sky activist and retired astronomer Chris Luginbuhl leads the charge. When we met over lunch at the aptly named Dark Sky Brewing, Luginbuhl noted that Flagstaff is both



#### MULTIPLE SATELLITES STREAK

through this composite of the Coma Berenices cluster, shot through a wide-field telescope over the course of about an hour. The trails mostly run north-south, so the photographer posits they are due to polar-orbiting satellites, rather than the largely west-east tracks of Starlink. ALAN DYER

unusual and an example, in that the city and county government have well-written lighting codes — including enforcement — integrated across departments with buy-in from businesses and the community. According to Tiffany Athol, a senior city planner, Flagstaff allows streetlights only at corners and intersections. Like Tucson, crime has not increased.

I can attest that Flagstaff’s skies are considerably darker than any other city of its size I’ve visited. Surrounding communities in Coconino County have dark skies that any astronomer would envy. And just recently, more restrictions on lighting were added around the U.S. Naval Observatory.

“What’s left to do now?” Luginbuhl says. “Everything.” Flagstaff will continue to grow. Research shows that growth will lead to a 20-percent increase in light pollution over the Naval Observatory, says Luginbuhl. But, he notes, retrofitting old fixtures with updated lighting would cut that increase to 10 percent. He’s now conducting a study to produce an atlas showing the brightness of the night sky around the world, as seen from the



SEVERAL PARALLEL SATELLITE tracks show the telltale sign of recently launched Starlink satellites passing through the skies above Carson National Forest, New Mexico. M. LEWINSKY (CC BY 2.0)

ground, if every community followed Flagstaff’s example.

Of course, not every city has Flagstaff’s astronomical heritage and largely sympathetic public. Taking on ALAN around the globe will require nurturing and growing city-dwellers’ willingness to become code-literate — and, perhaps more fundamentally, their

sense of personal investment in the night sky. And even in Flagstaff, Luginbuhl often hears residents say they support lighting restrictions because they’re happy to help the astronomers. “But I ask, ‘Doesn’t it matter to you?’” he says.

### Profound effects

After all, light pollution isn’t just bad

for the sky. A growing body of research shows that it's bad for us, too.

Architect and professional lighting designer K.M. Zielinska-Dabkowska and collaborators write in the *Science* special issue that “nocturnal light exposure can strain the visual system, disrupt circadian physiology, suppress melatonin secretion, and impair sleep.” Although more research is needed, blue light at night also appears correlated with a rise in cancer risk and may even change our gut microbiome. The American Medical Association already recommends street lighting CCTs be lower than 3,000 K. However, Barentine notes, “it’s very difficult to link outdoor lighting to human health problems” because indoor light likely has larger effects.

Poorly directed and overly bright light can also temporarily blind, reducing safety, especially for drivers suddenly shifting from very bright to very dark



**THE FAMILIAR SIGHT** of insects swarming around lights at night may occur because they mistake the lights for moonlight. NADET SRIPHAKHOT/DREAMSTIME.COM

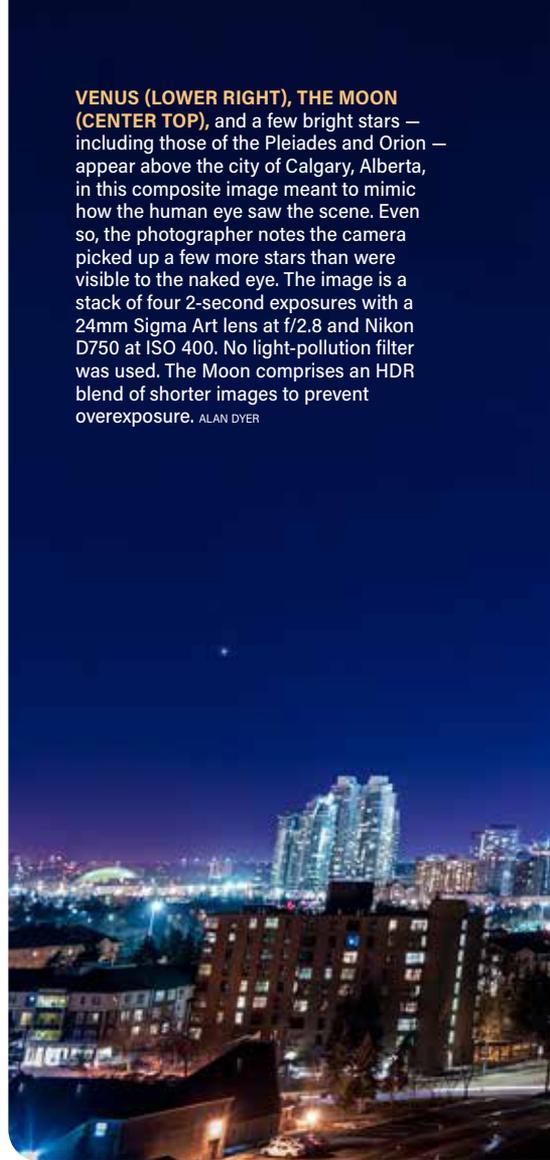
environments. At the same time, nighttime lighting brings powerful liberatory benefits, of which dark-sky advocates need to be mindful. The study notes that in rural areas of developing countries, “children often gather in publicly lit areas with streetlights to study and do homework” to avoid unhealthy light sources, like wood fires, at home. Yet such access does not mean we have to pollute the night sky. That’s one of the challenges.

And light pollution affects more than humans. Insects swarm around artificial lights at night because they may confuse them for moonlight, the special issue of *Science* and a January 2024 paper in *Nature* find. According to the *Science* paper, “blue light attracts more insects than the yellow and red parts of the spectrum.” (Bats are also more bothered by blue light than red and may abandon roosts due to human light sources.) Swarming exhausts insects and might be one reason their populations are plummeting. Their decline also affects birds and other creatures who feed on them.

Bright glass buildings are also dangerous to birds. On just one night in October 2023, nearly 1,000 migrating songbirds collided with Chicago’s lit-up McCormick Place Lakeside Center. And newly hatched sea turtles confuse lit beaches for the reflective ocean, drawing them in the wrong direction, often to their deaths.

The U.S. Forest Service has found that deer and mountain lions change their behavior near urban areas. Deer are attracted to light for protection but also forage more quickly, perhaps leading to

**VENUS (LOWER RIGHT), THE MOON (CENTER TOP),** and a few bright stars — including those of the Pleiades and Orion — appear above the city of Calgary, Alberta, in this composite image meant to mimic how the human eye saw the scene. Even so, the photographer notes the camera picked up a few more stars than were visible to the naked eye. The image is a stack of four 2-second exposures with a 24mm Sigma Art lens at f/2.8 and Nikon D750 at ISO 400. No light-pollution filter was used. The Moon comprises an HDR blend of shorter images to prevent overexposure. ALAN DYER



less nourishment by spending less time looking for food. And attracting large mammals of any kind into urban settings presents dangers to them and to humans.

In addition, rodents and amphibians live shorter, less fertile lives because of ALAN. Even plants change their behavior in response to ALAN, whether holding on to leaves longer in the fall or sending more biomass into leaves instead of roots.

While these accruing negative effects are overwhelming, it does mean new

**THE DESIGN OF** outdoor lighting plays a huge role in the amount — or lack — of light pollution produced. Non-cutoff lights have no shielding and spray photons in all directions, while those with progressively more shielding (semi-cutoff, cutoff) reduce the amount of wasted light not pointed at the ground. Lights with a full cutoff design are best — these eliminate any light at or above an angle of 90° from the pole and focus their full intensity downward for the greatest efficiency and protection of the night sky. ASTRONOMY: ROEN KELLY, AFTER INTERNATIONAL DARK-SKY ASSOCIATION





allies in the fight against the spread of excessive blue-white LED light. The Tucson Audubon Society and Sky Island Alliance have helped organize town halls and community meetings tackling light pollution and its impact on biomes around Whipple Observatory, Oliver notes. Whipple stands atop Arizona's Mount Hopkins in the Santa Rita Mountains, which is home to a fragile and unique "sky island" ecosystem. This year, Whipple — along with DarkSky International's Southern Arizona chapter, several entomologists, experts from the National Forest Service, and the Xerces Society for Invertebrate Conservation — will launch a light-pollution-monitoring project that includes studying its effects on the local glow worm population.

That more people are seeing light pollution as an environmental cause is a critical development. "We need as many

strong voices as possible to share the full story of the impact of light pollution," Oliver says.

### Constellations of our own making

All that's just here on Earth.

In low Earth orbit, more and more satellites are lighting up the night, especially megaconstellations like SpaceX's Starlink.

Satellites leave bright trails through long-exposure images that overwhelm the faint targets that astronomers are trying to observe. "It's like trying to see someone holding a candle flame in the dark while that person is also shining a flashlight in your face," says Barentine.

The problem has quickly come to a head as the pace of commercial launches soars. "In the last three years, humankind has launched more satellites into space than we did from the beginning of

the Space Age up to 2019," says University of Illinois astrophysicist and Assistant Professor of Aerospace Engineering Siegfried Eggl. Filings with the Federal Communications Commission (FCC), which regulates communications satellites, indicate that up to 100,000 satellites could be launched in the foreseeable future, he notes. Without strategies to combat that, "such a large number of satellites will affect essentially all branches of astronomy, even space-based observatories such as the Hubble Space Telescope unless they are stationed far from Earth."

A 2023 study in *Nature* found that 40,000 Starlink satellites will "essentially pollute every [ground-based] image with at least one streak," he says.

But Eggl says that "with enough motivation, technical solutions can be found to almost any problem."

Those solutions require cooperation

## BUILDING A DARK-SKY COALITION

In the fight against light pollution, “constituents make a difference,” says John Barentine. “What we’re missing is political will. We can reverse light pollution tomorrow. Nobody suffers when we decrease light pollution.”

The Flagstaff Dark Skies Coalition is a group focused on “celebrating, promoting, and protecting night skies,” says Chris Luginbuhl, the organization’s president. The first two verbs are key — they help build coalitions. And over time, conversation — not confrontation — can do wonders.

Change requires citizens who are, in the words of James Lowenthal, “patient, persistent, and polite.” By speaking up, meeting with officials, and engaging the public in star parties, he says, this daunting issue can become both “winnable and fun.”

Lowenthal advocates taking guidelines on responsible lighting to community centers, schools, and other institutions. Tiffany Athol adds, “You’ve got to make friends with the planners. Where are the push and pull points in your community?”

“Relations come first,” Lowenthal says. “The rest will follow.”

Those relations could be your neighbors. My friend and dark-sky activist Julie Swarstad Johnson once dreaded nights living next to a rental house’s poorly oriented and overly bright security lights. When she and her husband offered to buy dark-sky-friendly fixtures, the landlord agreed.

Even corporations can make concessions. Amy Oliver suggests talking to businesses about “fostering an ethos.” The McDonald’s in Sedona, Arizona, doesn’t light its iconic golden arches. Rather, they glow in the dark. — C.C.



**THESE STAIRS IN FRONT** of a hospital in Potsdam, Germany, are an excellent example of good lighting. Warm-colored lights installed beneath the handrails direct light exactly where it is needed — and not where it isn’t. CHRISTOPHER KYBA (CC BY 4.0)

between astronomers and satellite operators, and they are making progress. The U.S. National Science Foundation now has an agreement with SpaceX to reduce the effects of Starlink by, among other steps, lessening the satellites’ brightness and telling astronomers when and where they’ll pass overhead. But these agreements do not have the force of law.

Other companies have plans for large constellations, like AST SpaceMobile. A 2023 article in *Nature* found that the company’s prototype BlueWalker 3 satellite is one of the top 10 brightest night-sky

objects. Here, too, astronomers are trying to work with the company to mitigate its impact on observatories.

While astronomers seek collaboration, activists are going to court. In late 2022, the advocacy group DarkSky International filed an appeal of the FCC’s decision to approve SpaceX’s plans for 7,500 Starlink satellites, arguing that it should have considered their astronomical and environmental impacts under the National Environmental Policy Act. In a press release, the organization wrote: “It is unprecedented for [DarkSky] to resort



**THESE PHOTOS SHOW** a before (top) and after (bottom) comparison following an upgrade to better lighting at a Circle K gas station near Oracle State Park in Arizona. The change included installing lighting within — rather than below — the canopy, as well as choosing a warmer CCT of light with less emission in the blue portion of the spectrum. MIKE WEASNER (CC BY 4.0)

to the court system to resolve disputes. But in this case, we felt compelled to act.” A ruling is expected in mid-2024.

### Global effort

The night after our tour of Tucson, Oliver showed me the view from outside the dome of the 6.5-meter MMT Observatory on Mount Hopkins. Weather kept the stars obscured, but I could see clearly against the clouds and fog the light dome

over Nogales, Mexico, 25 miles (41 km) to the south, as well as the twinkling lights of Tucson 35 miles (56 km) to the north, strung out like a glowing abacus.

Had I been alone, I would have assumed the worst. But Oliver tells me the Nogales light dome actually is shrinking.

Fernando Ávila, who heads the Dark Skies Law Office at the Astronomy Institute of the Universidad Nacional Autónoma de México, is working with Oliver on a Smithsonian Institution project called DarkSky Net to address light pollution in Arizona and Mexico.

“In 2021, the [Mexican] federal environmental law was modified to include the terms of *light pollution* and *intruding light*,” Ávila says. “It defined the excess of artificial light at night as a pollutant.” Now Ávila is working with officials to zone areas such as astronomical observatories, natural parks, and reserves, setting maximum light levels for each. “We are trying to set these places as maximum protected areas,” he says. Ávila, too, has allies, including groups protecting sea turtles and fireflies.

Although the changes to national law have yet to trickle to the municipal level, Ávila says, most new public lighting systems have a full cutoff design that projects light downward. Although they are bright LEDs with a CCT of or over 4,000 K, the transition has been shown to shrink the light dome in the city of Ensenada. “I wouldn’t be surprised that this is what’s going in Nogales and any other city that is doing the same,” says Ávila.

And there is another factor: “a big



PHOTOMALL/DREAMSTIME.COM

**Lights with a lower color temperature (left) appear warmer and more golden. Those with a higher color temperature (right) look bluer.**

push to promote astrotourism as viable economic activity for small communities,” says Ávila. Boosting tourism to dark-sky sites around the world could be a powerful impact multiplier, exposing people to the beauty of the night sky and Indigenous astronomical traditions while also benefiting those communities economically.

At the Namibia University of Science and Technology in Windhoek, researcher and senior lecturer Sisco Auala is also focused on this combination. “I think

astrotourism can play a big role as an advocate to preserve night skies,” she says.

She adds: “I believe that Namibia has a unique opportunity to capitalize on our dark skies that could contribute to sustainable development and mitigate poverty in rural Namibia.” Ultimately, she hopes to secure the involvement of Indigenous communities and incorporate their astronomical lore into the narrative that astrotourists experience.

It’s an uphill battle, however, to “convince tourism stakeholders, including government officials, of the real potential of this niche tourism product for Namibia’s sustainable tourism development,” she says, noting that historically, the country’s tourism has been focused on wildlife. But Auala is hopeful.

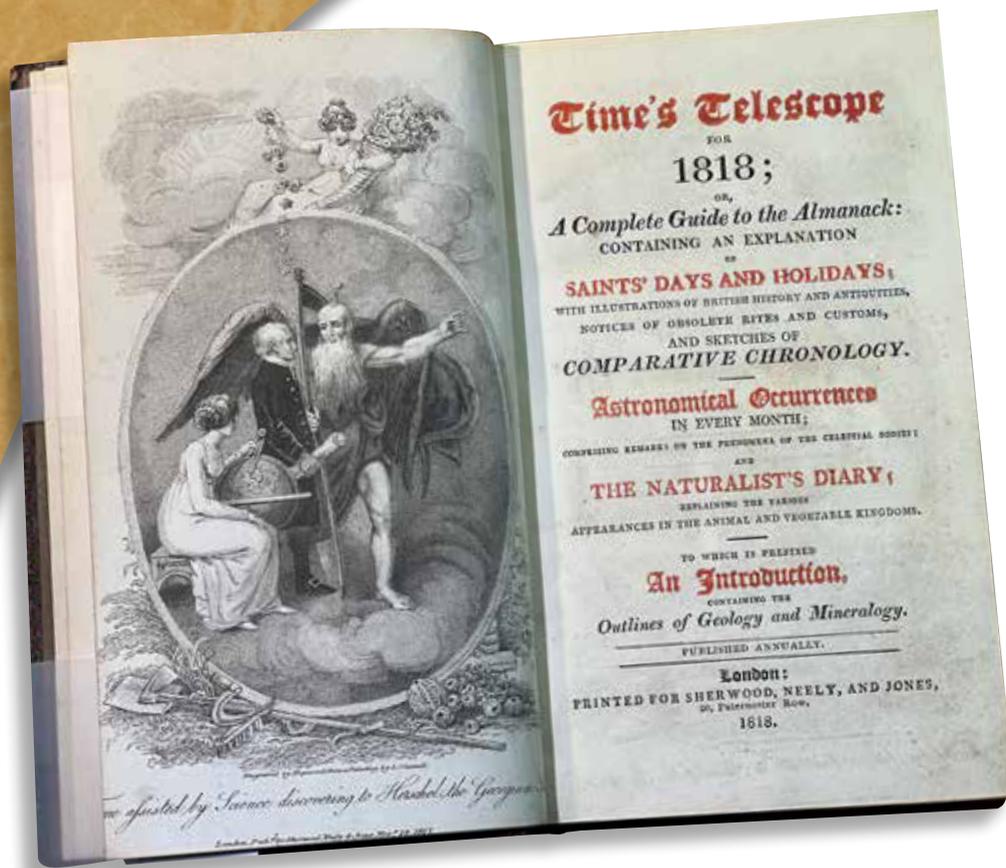
### **At the precipice of change**

Famed conservationist Aldo Leopold wrote: “One of the penalties of an ecological education is that one lives alone in a world of wounds.” Yet wounds can be healed. At just the moment when light pollution is bleeding across the night sky, our awareness of it and our potential for partners is also increasing.

Light-pollution activism spans the globe. We know what the problem is. We have allies in the cause. And we have the tools.

The stars we’re trying to protect are our inspiration. And they’re still shining. ♀

**Christopher Cokinos** is the author of *Still as Bright: An Illuminating History of the Moon from Antiquity to Tomorrow (Pegasus Books, 2024)*.



thousands of years.” Today, astronomical almanacs provide positions of the Sun, the Moon, and the planets. They guide automated telescopes, set planetariums, and help in navigation.

### Early almanacs

For centuries, these almanacs were produced by astronomers through painstaking calculations. The process was difficult — and the resulting publications were often filled with errors from faulty instruments and poor observational skills.

The basic format of modern almanacs took shape in Europe in the Middle Ages. Almanacs of saints’ days, church celebrations, and dates of Easter were produced by monasteries. The books provided practical information for everyday living, and included positions the Moon and planets.

But the first true astronomical almanac was produced in the 15th century by Johannes Müller von Königsberg. Better known as Regiomontanus, the mathematician and astrologer produced his greatest work in 1474: the *Calendarium and Ephemerides*. Spanning over 700 pages, the massive almanac contained lunar and solar eclipse predictions, star and planet positions, and even usable paper astronomical instruments.

Regiomontanus’s almanac was intended for astrologers, but its astronomical data came in handy to sailors. On his fourth voyage to the Americas, Christopher Columbus had to beach his ships in Jamaica. The Indigenous peoples supplied food, but after six months, became fed up with the crew’s demands. Faced with starvation, Columbus consulted his copy of the *Calendarium*, which predicted a total lunar eclipse the night of Feb. 29, 1504. Columbus threatened to inflame the Moon if the locals didn’t cooperate. That night, the Moon rose and turned blood red, proving the “power” of Columbus and his God, and saving the Europeans.

# THE RISE OF astronomical almanacs

Since the Middle Ages, these annual publications have provided valuable information to observers of the sky. **BY RAYMOND SHUBINSKI**

ABOVE: *Time's Telescope* was an almanac published in London from 1814 to 1834. RAYMOND SHUBINSKI

**EACH SEPTEMBER**, almanacs start to appear across America. Most notable is *The Old Farmer's Almanac*, which has been in print since 1792. Its cover states that it is “Useful, with a Pleasant Degree of Humor,” and the little book is filled with astronomical information, weather predictions, and more.

The U.S. government is also in the almanac business, and has been

for more than 150 years. Its publications include *The Nautical Almanac*, *The Air Almanac*, and *The Astronomical Almanac*.

The website of the Astronomical Applications Department of the U.S. Naval Observatory notes: “Scientific research, timekeeping, calendars, and navigation have all depended upon the practical skills of positional astronomy for

## Growth in Britain and America

In 1766, Britain commissioned the first *Nautical Almanac and Astronomical Ephemeris*. Since the beginning of the 18th century, the nation had been in a race to develop an accurate way to determine longitude at sea. In 1714, Parliament offered a prize of 20,000 pounds to anyone who could find a “simple and practical method for the precise determination of a ship’s longitude at sea.”

Astronomer Royal Nevil Maskelyne favored the lunar distance method. This involved measuring the angular separation between the Moon and a bright star and comparing the observation with an almanac based on Greenwich time. The key was an almanac that gave accurate positions of the Moon and bright stars.

While astronomers were producing ever more accurate almanacs for navigation, there was also a need for information to help farmers, merchants, and others. As a result, publishers throughout Europe began to produce a growing number of almanacs. They ranged from books with a few pages to leatherbound volumes. By the early 19th century, these almanacs became indispensable.

Across the pond, the first colonial almanac, *An Almanac for New England for the Year 1639*, was written by William Pierce and printed at Harvard College. But *Poor Richard’s Almanack*, written and printed by Benjamin Franklin, is without a doubt the most famous American almanac. He may have gotten the idea while living in London, where he undoubtedly saw *Rider’s British Merlin*, a volume published in England since 1656.

Another important almanac came from Benjamin Banneker, who was born a free African American in 1731. A brilliant self-taught man most famous for surveying what would become the District of Columbia, he was also deeply interested in astronomy, and successfully predicted a solar

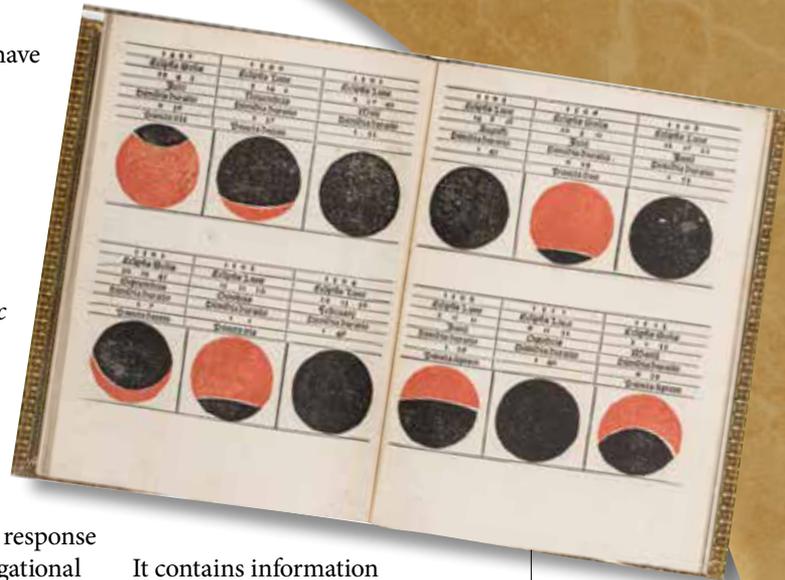
eclipse in 1789. This may have inspired him to print the *Pennsylvania, Delaware, Maryland, and Virginia Almanack and Ephemeris* from 1792 to 1797.

## The gold standard

*The Old Farmer’s Almanac* and others of its type provide lots of astronomical information, but astronomers require more. The publication of England’s *The Nautical Almanac* began in 1767 in response to the need for better navigational accuracy. The *American Ephemeris and Nautical Almanac* appeared in 1855 and continued through 1980. In 1981, the U.S. and England joined forces to publish a single book, *The Astronomical Almanac*.

Most observatories and planetariums have a copy of *The Astronomical Almanac* on hand, or have an online subscription to its content. The amount of information it contains is staggering — more than what most people need on every aspect of astronomy.

Other astronomical almanacs are more useful to amateurs. One of the best is the *Observer’s Handbook* published by The Royal Astronomical Society of Canada.



It contains information similar to *The Astronomical Almanac*, but with additional details that are helpful with planning observations.

## An ephemeral guide

Almanacs are filled with astronomical data for observers, and they can serve the farmer or gardener in their yearly toil. By their nature, almanacs are ephemeral, tracing celestial movements and the passage of time.

The scholar George Lyman Kittredge wrote, “Nothing is more strictly contemporary than an almanac. ... It is issued for the time being and becomes obsolete, by a natural and inevitable process, when its successor appears.” Almanacs provide insights into the past, information for the present, and a glimpse of the future. ➤

The left-hand page of Regiomontanus’ *Calendarium and Ephemerides* shows the total lunar eclipse of 1504, which Christopher Columbus used to trick the Native peoples of Jamaica into providing food for his crew.

HINDMAN AUCTIONS

**Raymond Shubinski** is a contributing editor of *Astronomy and an almanac collector.*



## “NOT GUILTY”

*The Old Farmer’s Almanac* is credited with saving a man from the gallows. Just after midnight on Aug. 29, 1857, a witness claimed to see Duff Armstrong bludgeon a man to death in Beardstown, Illinois. Abraham Lincoln, who was a friend of the Armstrong family, agreed to defend Duff. During the trial, the witness, Charles Allen, said he was standing about 150 feet (46 meters) away when the murder occurred. Lincoln produced an almanac and said it was too dark for Allen to have seen much of anything at that distance: Page 21 of the 1857 *Old Farmer’s Almanac* shows that the Moon was at First Quarter and riding “low” to the horizon. Armstrong was found not guilty, thanks to an almanac that cost a few pennies.

RAYMOND SHUBINSKI

# TINY GALAXIES PACK A HUGE WALLOP

JWST shows that dwarf galaxies played an outsized role in ending the cosmic Dark Ages. **BY RICHARD TALCOTT**

**FEW EVENTS IN THE UNIVERSE'S HISTORY** had a more profound effect than the ending of the cosmic Dark Ages. It saw the universe transform from nightlike gloom into a vibrant cornucopia of stars and galaxies. Now, astronomers using the James Webb Space Telescope (JWST) have shown that the earliest dwarf galaxies produced the radiation that triggered this revolution, revealing how the smallest things sometimes can have the biggest impacts.

## THE FIRST BILLION YEARS

Let's start at the beginning: the Big Bang. Some 13.7 billion years ago, the universe emerged out of nothing. Within minutes, it formed a hot, dense, ionized soup of hydrogen nuclei (protons), helium nuclei, electrons, and electromagnetic radiation (photons). But the photons were essentially trapped in the expanding cosmos — they could travel only short distances before matter absorbed and then reemitted them.

That all changed 380,000 years later, once the blistering maelstrom had cooled to around 3,000 kelvins (nearly 5,000 degrees Fahrenheit). At this point, protons and electrons could capture one another and form neutral hydrogen. The

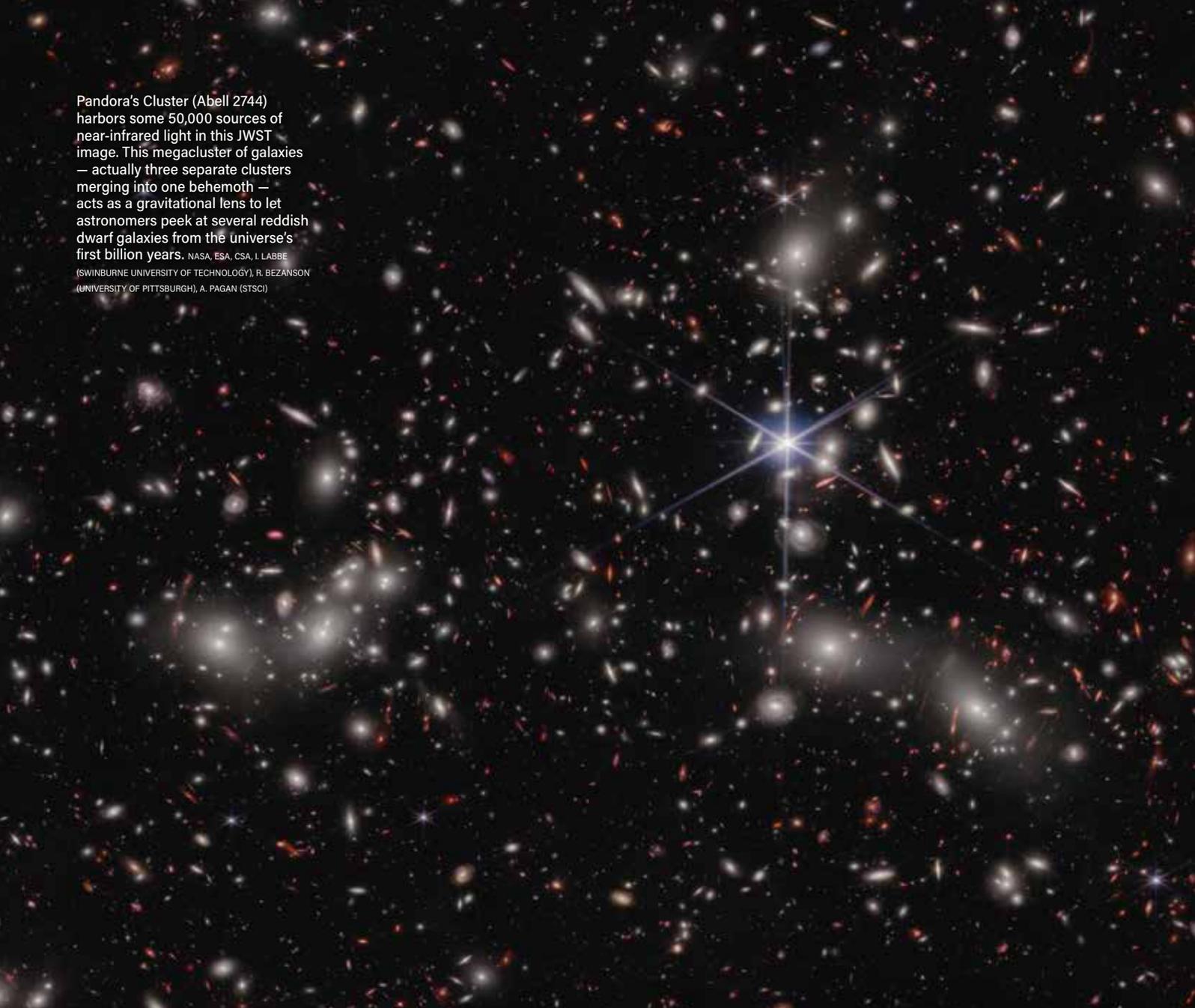
photons were then free to travel unimpeded. This light still permeates the universe as the cosmic background radiation, which now glows at a frigid 2.7 K.

This major transformation also ushered in the Dark Ages. Although light could travel unhindered, the background radiation glowed at infrared wavelengths and no light-producing objects yet existed. The darkness was total.

It would take a few hundred million years before the first stars appeared. These were beasts with masses up to 300 times that of the Sun and prodigious producers of high-energy ultraviolet radiation. They and the nascent galaxies to which they belonged slowly started to reionize the universe and clear the hydrogen fog, bringing about the end of the Dark Ages. This so-called epoch of reionization peaked around 600 million



In this 2011 image, Hubble captured about half of Pandora's Cluster, but was not able to see as deeply into the early universe. NASA, ESA, AND D. COE (STSCI)/J. MERTEN (HEIDELBERG/BOLOGNA)



Pandora's Cluster (Abell 2744) harbors some 50,000 sources of near-infrared light in this JWST image. This megacluster of galaxies — actually three separate clusters merging into one behemoth — acts as a gravitational lens to let astronomers peek at several reddish dwarf galaxies from the universe's first billion years. NASA, ESA, CSA, I. LABBE

(SWINBURNE UNIVERSITY OF TECHNOLOGY), R. BEZANSON (UNIVERSITY OF PITTSBURGH), A. PAGAN (STSCI)

to 800 million years after the Big Bang and ended about 1 billion years after the universe began.

### **TINY BUT POWERFUL**

Until JWST opened its eyes, however, scientists still wondered what sources drove the bulk of this reionization. Could it be the many luminous quasars that inhabited the early universe, the first bright galaxies, or a large population of dwarf galaxies?

An international team of astronomers led by Hakim Atek of the Institut d'Astrophysique de Paris in France set about the task of finding out. As part of the UNCOVER program (an acronym

for Ultradeep NIRSpec and NIRCam Observations before the Epoch of Reionization), the team targeted the massive Pandora's Cluster (Abell 2744) in Sculptor. Although it lies "just" 4 billion light-years from Earth, its tremendous mass acts as a gravitational lens to magnify and distort objects much farther away.

Using deep JWST images, the researchers selected eight extraordinarily faint galaxies dating from the epoch of reionization occupying a tiny field. They then took spectra of these dwarf galaxies and discovered that they produce four times more ionizing radiation than astronomers thought.

"These cosmic powerhouses collectively emit more than enough energy to get the job done," said Atek in a press release. "[The abundance of these low-mass galaxies] during this period is so substantial that their collective influence can transform the entire state of the universe."

So far, these conclusions apply only to this one field of view in Sculptor. To confirm the results, astronomers plan to observe other gravitationally lensed fields with JWST. ☉

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*Contributing Editor **Richard Talcott** wrote about JWST's observations of 19 nearby spiral galaxies in the June issue.*

# SKY THIS MONTH

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

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

BY MARTIN RATCLIFFE AND ALISTER LING



For a brief time this month, Taurus will appear to have two eyes as Mars (upper left) moves northwest of Aldebaran (below center), as in this 2023 photo. Comet C/2022 E3 (ZTF) is also visible here, to Aldebaran's lower left. ALAN DYER

## JULY 2024

# A bull with two eyes

» The planets are spreading out this month. Mercury and Venus lie in the evening sky; after midnight the next set of planets rises one after the other, led by Saturn. It's followed into the early-morning sky by Neptune, Mars, Uranus, and Jupiter. Saturn in particular is stunning, with the rings at their narrowest for the year.

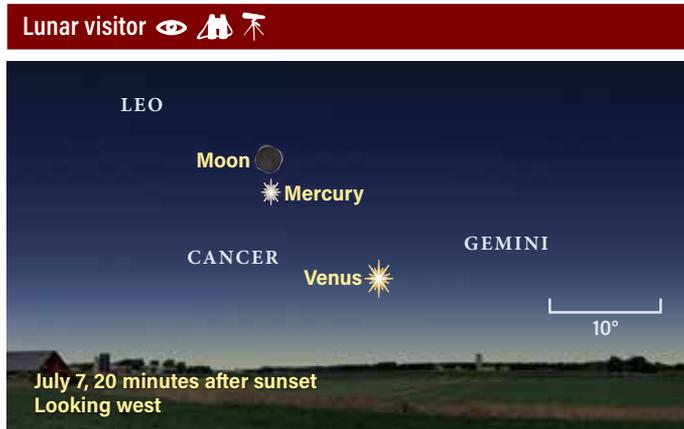
First to set after the Sun on July 1 is **Venus**. It's a challenging object to find, disappearing within 30 minutes of sunset. If you have a very clear western horizon, look for the magnitude  $-3.9$  planet in bright twilight, standing only  $2^\circ$  high 15 minutes after sunset.

Try again on July 6, when the crescent Moon appears  $7^\circ$  high about 20 minutes after sunset. Venus lies  $5^\circ$  below it and once again sets quickly.

By the end of July, Venus is nearly  $16^\circ$  east of the Sun but still hugs the horizon from northern temperate latitudes. It stands  $3^\circ$  high 30 minutes after sunset, and those scanning the horizon with binoculars might spot 1st-magnitude Regulus, Leo's brightest star,  $5^\circ$  east of the

planet. Mercury is also present, at the same altitude as Venus and  $4.7^\circ$  south of Regulus, shining at magnitude 0.9.

Rewinding a bit, **Mercury** shines in the evening sky at magnitude  $-0.6$  on July 1. A healthy  $18.5^\circ$  from the Sun, it remains  $7^\circ$  high 30 minutes



A delicate crescent Moon stands above Mercury the evening of July 7, one day after it passes over Venus. ALL ILLUSTRATIONS: ASTRONOMY: ROEN KELLY

after sunset. As the sky darkens, Mercury will be an easy object to catch. Watch for Castor and Pollux, Gemini's pair of 1st-magnitude stars, which stand at the same altitude above the horizon northwest of Mercury.

Mercury slides away from the pair of stars quickly and by July 7, the waxing Moon stands  $3^\circ$  above Mercury — a beautiful sight in twilight. Look for earthshine illuminating the dark hemisphere of the Moon.

Mercury fades as it increases its distance from the Sun and reaches its greatest eastern elongation of  $27^\circ$  on July 22. It has now dimmed to magnitude 0.5 and stands within  $3^\circ$  of Regulus. The planet has become more challenging to find. Mercury stands  $5^\circ$  high 40 minutes after sunset, a good time to spot it.

Due to the low angle of the ecliptic to the horizon in the Northern Hemisphere, this isn't as favorable as elongations that occur in March. Southern Hemisphere observers will have a better view.

**Saturn** rises at midnight on July 1, located in northeastern Aquarius just  $2.1^\circ$  from Phi ( $\phi$ ) Aquarii. It's easy to spot at magnitude 0.9. The ringed world barely moves at first, then slowly progresses along its retrograde path and ends the month within  $1.5^\circ$  of Phi.

On July 24, a waxing gibbous Moon stands about  $7^\circ$  west of Saturn. Later in the day for regions in Africa, Asia, and Indonesia, the Moon occults Saturn. The planet brightens to magnitude 0.7 by the end of July

## RISING MOON | Rack up the balls

### OBSERVING HIGHLIGHT

**THE MOON** occults **SATURN** on July 24 from some locations in Africa, Asia, and Indonesia.



in preparation for September's opposition.

The rings appear very fine and nearly edge-on through a telescope, tilted by only 2° to our line of sight. Its disk spans 18" and the wide axis of the rings stretches roughly 41" across. Through the end of the year, the rings will widen before closing again and appearing edge-on in March 2025.

Now that the ring plane is almost edge-on, Saturn's satellites cross in front of or behind the planet. Titan, the brightest moon at magnitude 8.5, orbits every 16 days. The moon is occulted by Saturn July 8 around 2:40 A.M. EDT (not visible in the Pacific time zone). It takes several minutes to disappear, so begin watching 10 to 20 minutes earlier. A second occultation occurs July 24 around 1:30 A.M. EDT (not visible in Mountain or Pacific time zones).

On July 16, Titan begins a transit across Saturn just before 2:30 A.M. EDT (again, not visible on the West Coast). The transit lasts nearly four hours, with egress occurring around 4:20 A.M. MDT (in daylight for the East Coast and nearly sunrise in the Midwest).

The transit starting July 31/Aug. 1 at 1:15 A.M. EDT is the first easily seen from the Mountain time zone, although Saturn is at an elevation of only 13°.

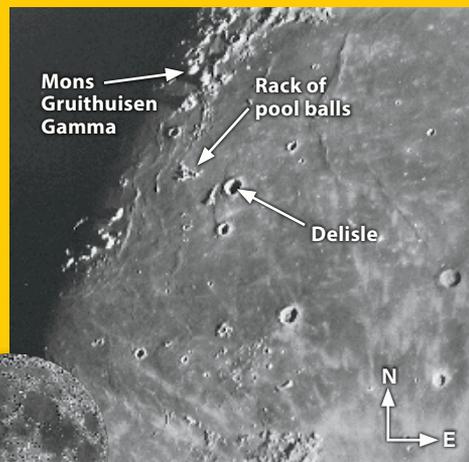
Dione begins a transit an

A LAZY, HAZY summer night is the perfect time to relax your scientific gaze and let your mind wander, your eyes meandering slowly along the day-night lunar zone we call the terminator. You may have seen the more famous Lunar X or V, examples of a clair-obscur effect — when the play of light and shadow bring to mind a letter, number, animal, face, or other object. But will you see a rack of pool balls July 16th, just west of the crater Delisle?

In reality, this is a clump of peaks left over from the giant impact that carved out Mare Imbrium, towering above the plains of lava that welled up afterward. Yet our earthbound brains crave familiarity in a foreign land. A couple of hours later, another region west of Mons Gruithuisen Gamma suggests an upturned sink or bathtub to some observers.

If this pareidolia tickles your fancy, do a search for "Moon clair-obscur lunarism" to find dozens of blogs and videos with dates and times that focus on these features. Mike Rowles has compiled a list of 99 such lunarisms — some you can see two nights

### Delisle and Mons Gruithuisen Gamma



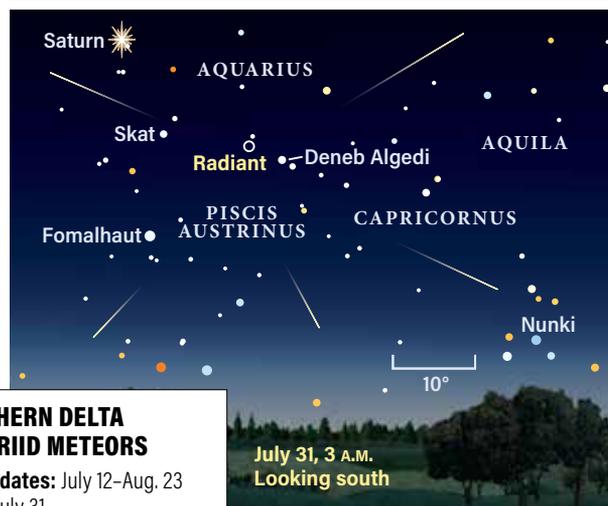
The interplay of shadows with lunar terrain can create all sorts of images for the brain to pick up on. CONSOLIDATED LUNAR

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

in a row, others fleetingly for an hour or two. Relive that childhood enjoyment of seeing shapes in clouds.

## METEOR WATCH | A broad peak

### Southern Delta Aquariid meteor shower



#### SOUTHERN DELTA AQUARIID METEORS

**Active dates:** July 12–Aug. 23

**Peak:** July 31

**Moon at peak:** Waning crescent

**Maximum rate at peak:** 25 meteors/hour

The Southern Delta Aquariids are best seen south of the equator, but plenty of shower meteors still grace the Northern Hemisphere sky.

**JULY BEGINS QUIETLY** on the meteor shower front, with rates increasing toward the end of the month as the early Perseids begin and the Southern Delta Aquariid shower reaches its peak. The latter is active from July 12 through Aug. 23 and peaks on July 31, although activity is fairly broad across a few days on either side of this date.

The radiant is near the star Skat in Aquarius, which reaches 30° elevation around 3 A.M. local daylight time, resulting in observed rates of about half the predicted zenithal hourly rate of 25 meteors per hour. The waning crescent Moon will have some effect on the visibility of fainter meteors.

The Southern Delta Aquariids are the result of Comet 96P/Machholz. This is 1 of 8 showers related to the comet, which has a 5.3-year orbital period.

hour later, led by its shadow, which appears behind Titan on the cloud tops — an extraordinary alignment. Dione is a

small moon that shines at 10th magnitude, so it's difficult to see against the bright background of Saturn. It's easier to capture

using high-speed video and image-refining techniques.

Several moons also skim the  
— Continued on page 34

# STAR DOME

## HOW TO USE THIS MAP

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

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

midnight July 1  
11 P.M. July 15  
10 P.M. July 31

Planets are shown at midmonth

## MAP SYMBOLS

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

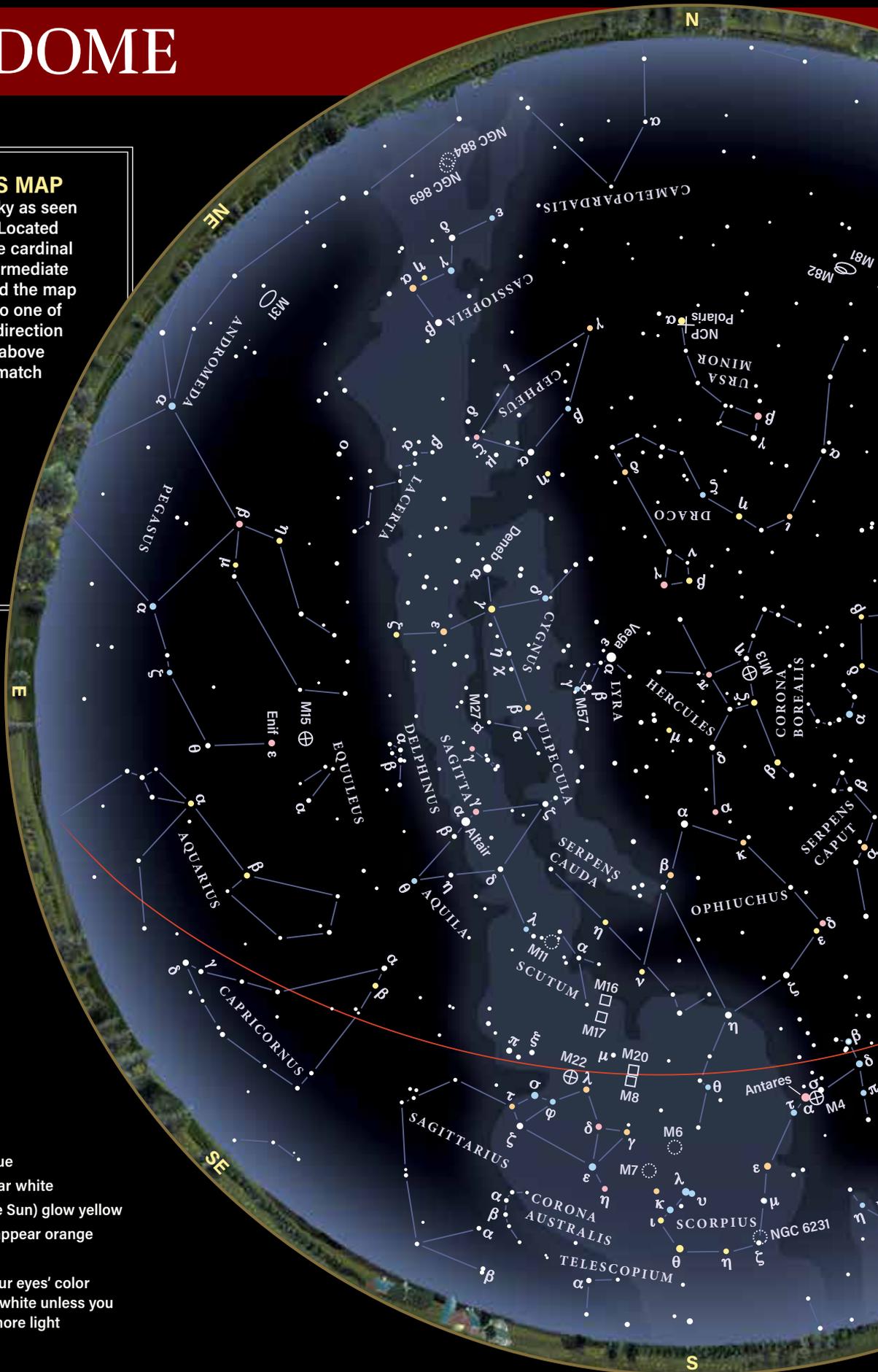
## STAR MAGNITUDES

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

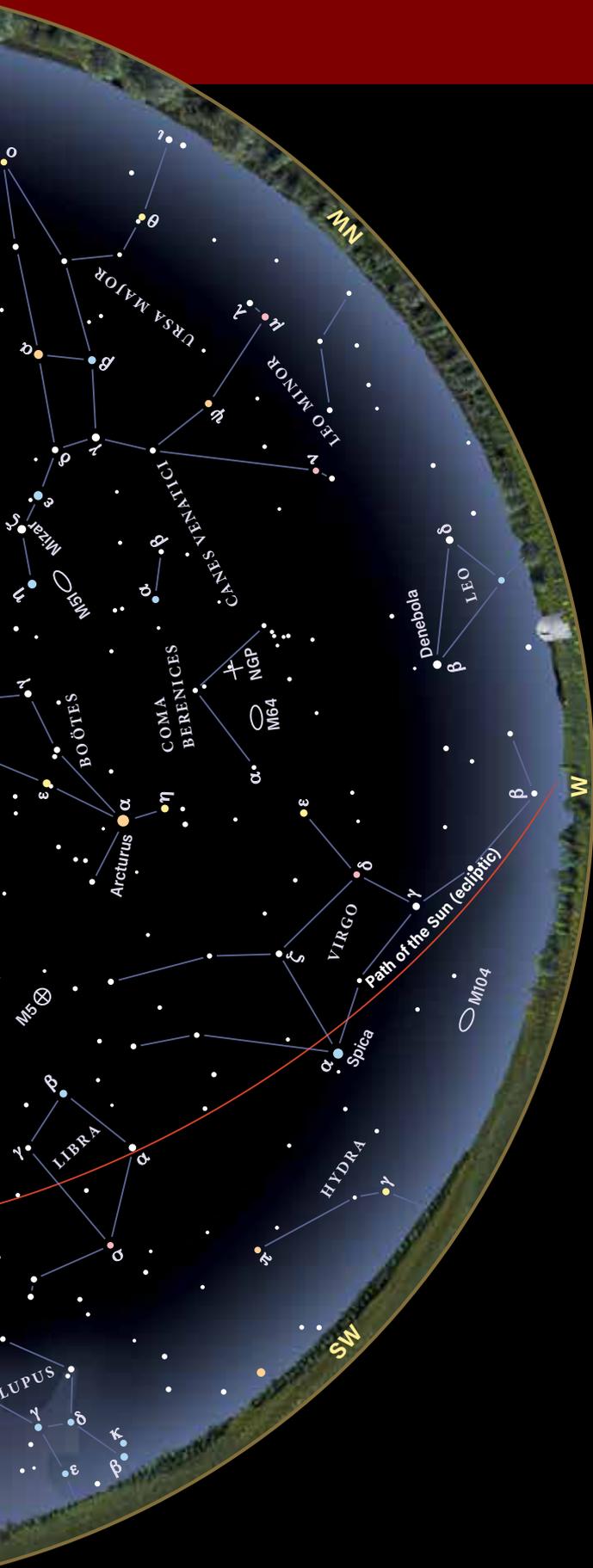
## STAR COLORS

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](http://www.Astronomy.com/starchart).



# JULY 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   |        |      |      |

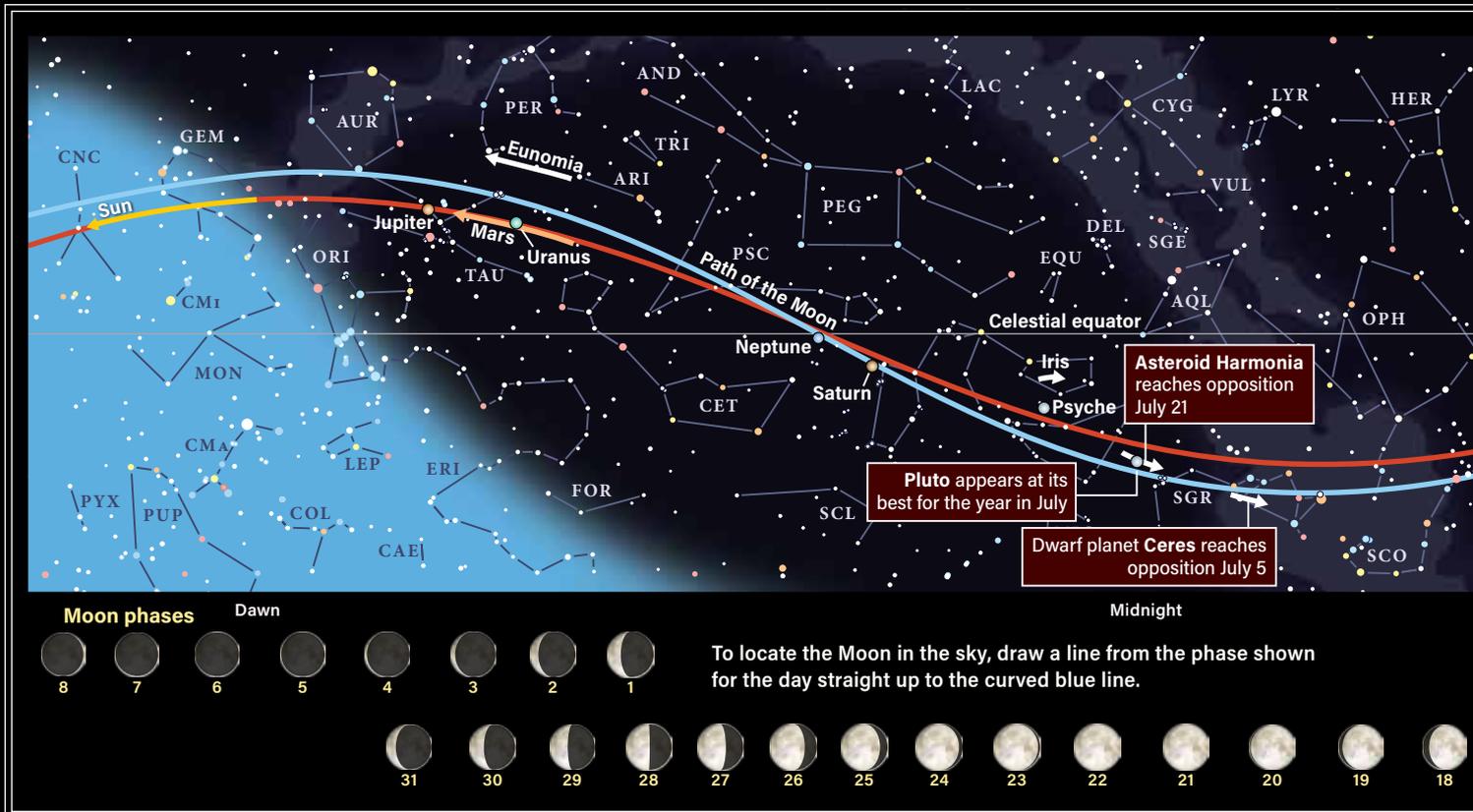
ILLUSTRATIONS BY ASTRONOMY ROBIN KELLY

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

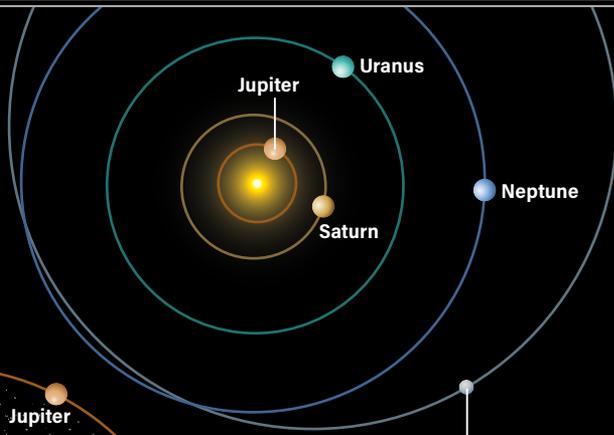
- The Moon passes 4° north of Mars, 2 P.M. EDT
- The Moon passes 4° north of Uranus, 6 A.M. EDT  
Neptune is stationary, 11 P.M. EDT
- The Moon passes 5° north of Jupiter, 4 A.M. EDT
- Earth is at aphelion (94.5 million miles from the Sun), 1 A.M. EDT  
 New Moon occurs at 6:57 P.M. EDT  
Dwarf planet Ceres is at opposition, 8 P.M. EDT
- The Moon passes 3° north of Mercury, 3 P.M. EDT
- The Moon is at apogee (251,259 miles from Earth), 4:11 A.M. EDT
- Jupiter passes 5° north of Aldebaran, 3 A.M. EDT  
 First Quarter Moon occurs at 6:49 P.M. EDT  
The Moon passes 0.9° north of Spica, 11 P.M. EDT
- Mars passes 0.6° south of Uranus, 5 A.M. EDT
- The Moon passes 0.2° north of Antares, 4 P.M. EDT
- Asteroid Pallas is stationary, 5 P.M. EDT
- Asteroid Harmonia is at opposition, 4 A.M. EDT  
 Full Moon occurs at 6:17 A.M. EDT
- Mercury is at greatest eastern elongation (27°), 3 A.M. EDT
- Pluto is at opposition, 2 A.M. EDT
- The Moon is at perigee (226,749 miles from Earth), 1:41 A.M. EDT  
The Moon passes 0.4° north of Saturn, 5 P.M. EDT
- The Moon passes 0.6° north of Neptune, 11 A.M. EDT
- Mercury passes 3° south of Regulus, 8 A.M. EDT  
 Last Quarter Moon occurs at 10:52 P.M. EDT
- The Moon passes 4° north of Uranus, 2 P.M. EDT
- The Moon passes 5° north of Mars, 7 A.M. EDT  
The Moon passes 5° north of Jupiter, 8 P.M. EDT  
Southern Delta Aquariid meteor shower peaks

# PATHS OF THE PLANETS



## THE PLANETS IN THEIR ORBITS

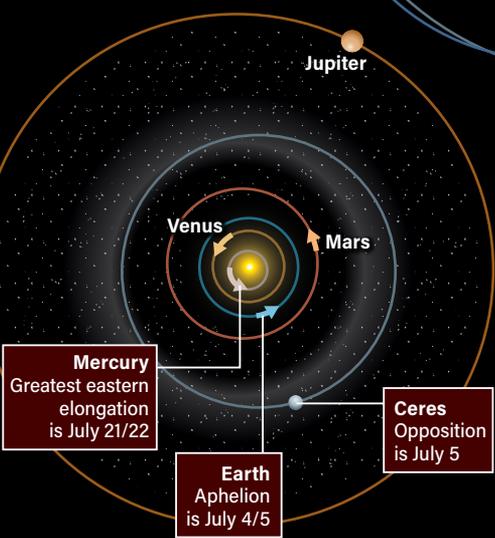
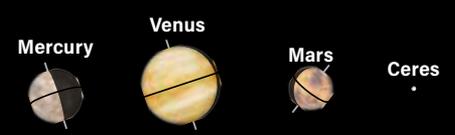
Arrows show the inner planets' monthly motions and dots depict the outer planets' positions at midmonth from high above their orbits.



**Pluto**  
Opposition  
is July 22/23

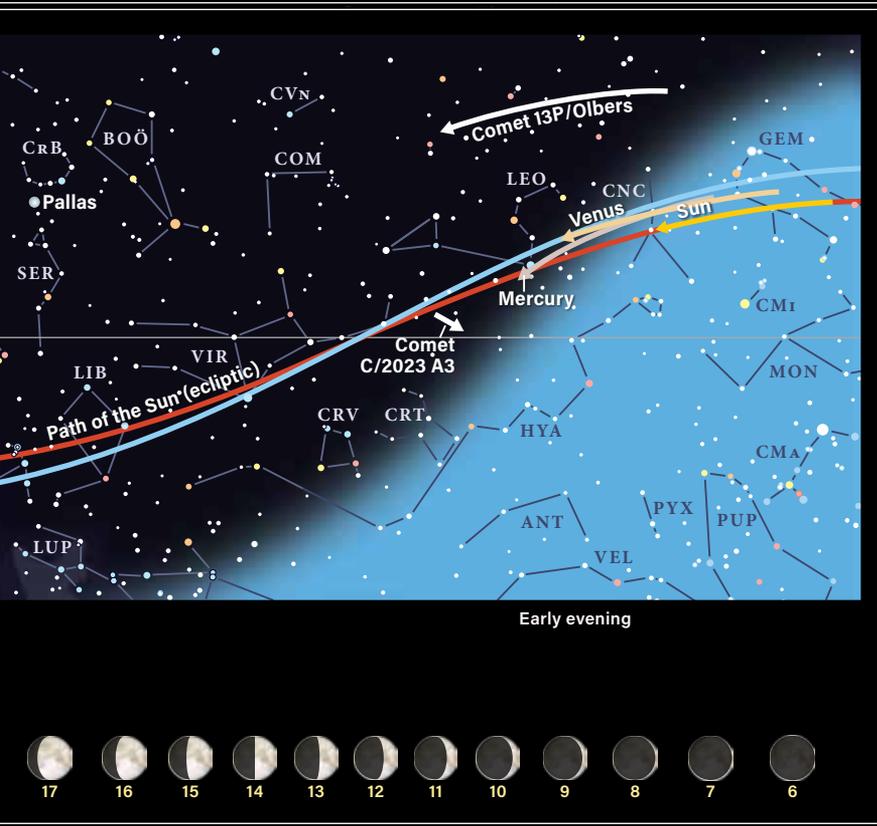
## THE PLANETS IN THE SKY

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.



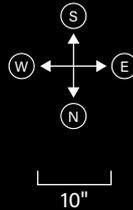
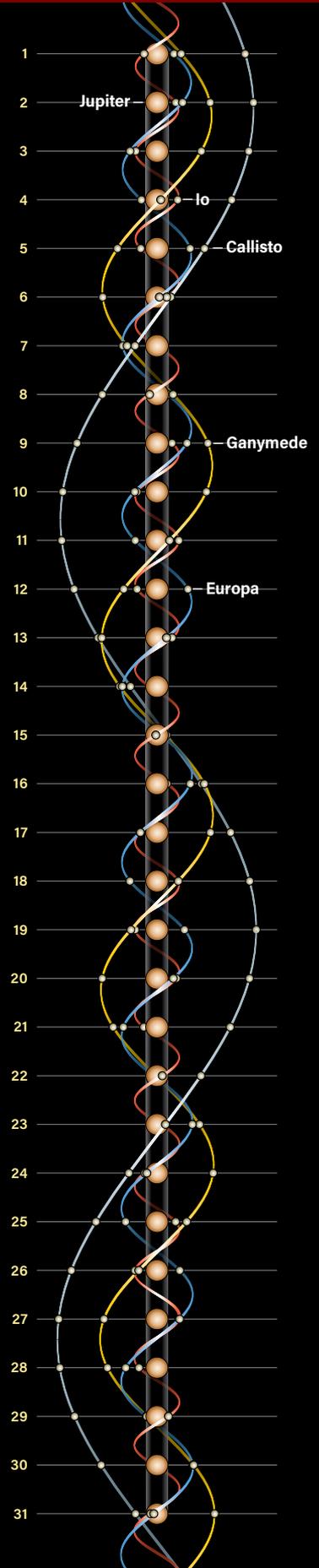
| PLANETS                  | MERCURY | VENUS   |
|--------------------------|---------|---------|
| Date                     | July 15 | July 31 |
| Magnitude                | 0.2     | -3.9    |
| Angular size             | 6.9"    | 10.2"   |
| Illumination             | 56%     | 96%     |
| Distance (AU) from Earth | 0.969   | 1.644   |
| Distance (AU) from Sun   | 0.445   | 0.719   |
| Right ascension (2000.0) | 9h23.9m | 9h44.9m |
| Declination (2000.0)     | 15°40'  | 15°07'  |

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



## JUPITER'S MOONS

Dots display positions of Galilean satellites at 5 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    |
|---------|----------|---------|----------|---------|---------|----------|
| July 15 | July 15  | July 15 | July 15  | July 15 | July 15 | July 15  |
| 0.9     | 7.5      | -2.1    | 0.8      | 5.8     | 7.7     | 15.0     |
| 5.6"    | 0.7"     | 34.3"   | 18.3"    | 3.5"    | 2.3"    | 0.1"     |
| 90%     | 100%     | 100%    | 100%     | 100%    | 100%    | 100%     |
| 1.678   | 1.905    | 5.742   | 9.079    | 20.121  | 29.485  | 34.050   |
| 1.413   | 2.905    | 5.031   | 9.681    | 19.582  | 29.899  | 35.055   |
| 3h33.8m | 18h55.7m | 4h37.4m | 23h22.4m | 3h34.8m | 0h00.4m | 20h14.7m |
| 18°22'  | -29°54'  | 21°23'  | -6°16'   | 18°59'  | -1°22'  | -23°08'  |

## Shadows and light



Io and its shadow are crossing the face of Jupiter as Ganymede reemerges from an occultation early on the 22nd. Callisto lies east of the planet at this time, while Europa is undergoing an occultation of its own.

edge of the rings as seen from Earth, although these are also difficult to observe. Again, high-resolution imaging can catch these events.

Iapetus orbits at a much greater distance from Saturn every 79 days. It moves 1' north of Saturn on July 6, reaching inferior conjunction as it heads toward western elongation on the 27th. Between early July and this date, Iapetus brightens from about 11th magnitude to magnitude 10.2.

**Neptune** is in southwestern Pisces, some 5° southeast of Lambda (λ) Piscium in the Circlet. It rises around midnight and reaches a good height in the eastern sky by 2 A.M. local daylight time. As you scan with binoculars, look for a parallelogram of 4th- to 5th-magnitude stars. The northernmost bright one is 29 Psc; much dimmer Neptune lies nearly 2° to its north. Neptune shines at magnitude 7.7.

On July 25, the waning gibbous Moon stands about 4.5° southwest of Neptune two hours after rising. By dawn they're less than 3° apart. Neptune reaches its stationary point early in July and the planet barely moves all month.

The next planet up is **Mars**, rising just after 2 A.M. local daylight time on July 1 with a waning crescent Moon. The Red Planet shines at magnitude 1

in southeastern Aries, 15° from the Pleiades (M45). Mars moves into Taurus by July 12.

Mars is closing in on **Uranus**, also in western Taurus, and they're just over 2° apart on the 12th. Look again on July 15, when Mars and Uranus stand only 0.6° apart. Binoculars will reveal the dim, greenish-blue-hued disk of Uranus due north of Mars. Uranus shines at magnitude 5.8. The pair now stand

6° southwest of the Pleiades. Check each consecutive night as Mars pulls away from Uranus, moving about 0.7° east per day.

On July 20, Mars stands 4.8° due south of M45. By the 22nd, it's brightened to magnitude 0.9. Mars continues eastward and at the end of July stands 5.5° northwest of Aldebaran, matching the star in magnitude. For a time, Taurus the Bull appears to have two eyes. A waning crescent Moon joins Mars a day earlier, on July 30. Along with M45 and Jupiter, also in Taurus, the view is spectacular.

Through a telescope, Mars is a challenging 6" across and stands 30° high in the east as twilight begins on July 31.

Uranus remains near the western edge of Taurus all month. Its disk spans only 3" through a telescope, challenging to see unless conditions are excellent. Once Mars has left

# WHEN TO VIEW THE PLANETS

## EVENING SKY

Mercury (west)  
Venus (west)

## MIDNIGHT

Saturn (east)  
Neptune (east)

## MORNING SKY

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

the scene, you can spot Uranus in binoculars 2° west of a pair of 6th-magnitude stars, 13 and 14 Tauri, which are less than 0.4° apart and about 4.5° due south of the Pleiades.

**Jupiter's** visibility improves each day as it climbs higher in the pre-dawn sky. The gas giant rises around 3:30 A.M. local daylight time on July 1, north

## COMET SEARCH | On your mark, get set, go!

**THE BEST TWO COMETS** of the night are sinking below 15° altitude by sunset, so be on target as darkness arrives. Head straight south of Leo's tail to get to C/2023 A3 (Tsuchinshan-ATLAS). On track to blow our socks off in October, it currently glows at a modest 8th magnitude and should sport a faint eastward tail if skies are dark and transparent enough. Approaching Mars' orbit, the carbon atoms released with its dust are just turning on for imagers to catch a classic green coma. By the end of July, the comet is swallowed by twilight — see you in three months!

Quickly swing northwest to the feet of Ursa Major, where 13P/Olbers is traveling through Lynx and Leo Minor. It reached perihelion June 29 and will give us three more months of telescopic viewing. Binocular observers, challenge yourself to find the 8th-magnitude glow. Push the magnification past 100x and note that Olbers should be lopsided compared to spiral galaxy NGC 2841, some 9° to the north on July 8. Whose core is sharpest and brightest?

Need an overnight comet? Bring along a good chart to help you navigate the forest of 7th-magnitude stars between Cepheus and Draco to get to the challenging 10th-magnitude C/2021 S3 (PanSTARRS).

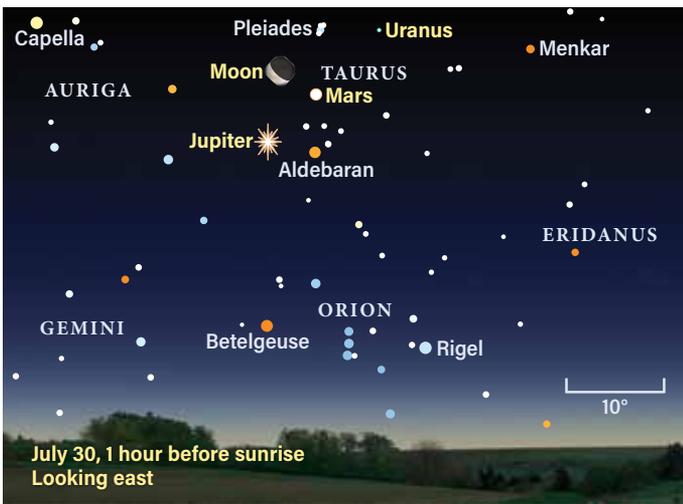
### Comet C/2023 A3 (Tsuchinshan-ATLAS)



Comet Tsuchinshan-ATLAS covers a small portion of Leo in July. Visit our website for more details on the other comets mentioned this month.

## LOCATING ASTEROIDS | Sweetening the (tea)pot

### Together in Taurus



Jupiter, Mars, and the Moon all congregate in Taurus on July 30, with the Red Planet providing the Bull with a second “eye.”

of the Hyades star cluster in Taurus. A waning crescent Moon joins it July 3. By the 13th, Jupiter stands 5° due north of Aldebaran. The crescent Moon again joins Jupiter July 30 and 31. The planet starts the month at magnitude -2 and brightens by 0.1 magnitude by July 31, now rising before 2 A.M.

Through a telescope, Jupiter spans 35" and is joined by the four Galilean moons, Io, Europa, Ganymede, and Callisto. Catching a transit or occultation is a great way to start a summer morning.

Early on July 4, Ganymede transits Jupiter's south polar region. The event is underway as Jupiter rises in the western U.S. Ganymede slowly exits the disk around 5:50 A.M. MDT in twilight, while it's still dark in the Pacific time zone.

Io and Europa put on a pair of events the morning of July 6. Europa's transit begins at 4:42 A.M. EDT, visible from the eastern U.S. The moon's shadow is already nearly done with a transit, approaching the western

limb. As Jupiter rises farther west, Io's shadow starts to transit at 5:15 A.M. CDT, as twilight encroaches on the Midwest. Observers in the western U.S. will see Io begin its transit at 5:02 A.M. MDT, with Europa exiting the disk minutes later, around 5:12 A.M. MDT.

Ganymede's huge shadow crosses Jupiter's south polar region July 11 between 4:52 A.M. and 6:40 A.M. MDT. (The exit occurs in daylight for the Mountain time zone but twilight in the Pacific time zone.) Europa's shadow crosses the disk July 13, starting around 5:15 A.M. EDT, as Europa closes on Jupiter's eastern limb and begins its own transit around 5:30 A.M. MDT.

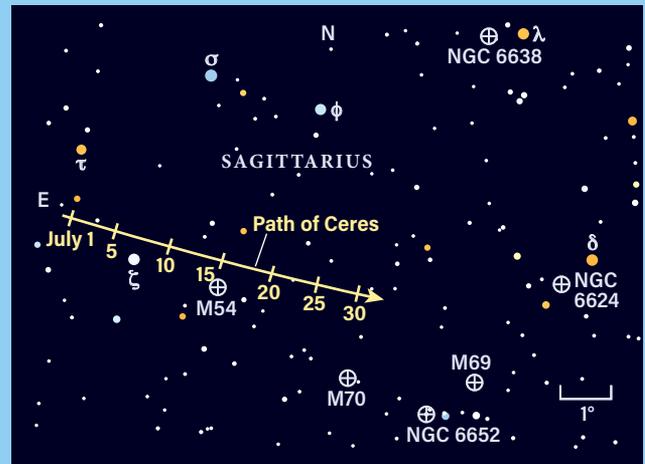
One of the most interesting events of the month is the transit of Io with its shadow as Ganymede reappears from eclipse on July 22. The first pair of events is better observed across the eastern half of the U.S. Io's shadow begins a transit at 4:31 A.M. EDT (when Jupiter is only 10° high in the Midwest).

**WITHIN REACH** of binoculars from the suburbs, dwarf planet 1 Ceres gives us a nice and easy asteroid search this summer. Stargazers familiar with the heart of the galaxy know the collection of stars called the Teapot of Sagittarius. Magnitude 2.6 Zeta (ζ) Sagittarii anchors the base of the Teapot's handle and will be our signpost to find Ceres.

The large dwarf planet (roughly 600 miles across) reflects the most sunlight at opposition on the 5th, raising it to magnitude 7.3 and leaving it largely uncontested in the eyepiece by the legions of fainter stars toward the galaxy's hub. You can track its nightly shift against the background by penciling three or four stars onto a logbook sheet and returning an evening or two later to confirm the point that moved.

On the 20th, Ceres is sliding away from a trapezoid of stars (fainter than the limiting magnitude below); if you stay up late you might notice its tiny shift. For a laugh, can you see it on the 19th, a mere two lunar diameters south of the nearly Full Moon?

### Easy view



The large, bright, main-belt world Ceres should be a simple find among the stars of Sagittarius' Teapot.

Ganymede is occulted by Jupiter's northwestern limb seven minutes later. Meanwhile, Io is approaching the eastern limb and begins to transit at 5:31 A.M. EDT. Ganymede passes behind Jupiter and reappears around 4:36 A.M. MDT, in bright twilight for the Midwest.

Another set of events occurs July 29. Ganymede enters Jupiter's extended shadow west of the planet just before 4:40 A.M. EDT, followed by Europa just over an hour later, shortly before sunrise in the Eastern time zone. Then, Io's shadow begins a transit at the eastern limb at 5:25 A.M. CDT.

Within minutes, Ganymede exits the shadow still northwest of Jupiter at 5:28 A.M. CDT, a process that takes a few minutes. Watch it brighten as Io's shadow moves onto the cloud tops. Io itself begins to transit around 5:30 A.M. MDT, now in bright twilight across the Mountain time zone but well seen in Pacific states. ☾

**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.



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# Robert Reeves' POSTCARDS FROM THE MOON

Luna's rugged surface is full of fascinating features to explore. Here are some you've heard of — and some you probably haven't.

STORY AND PHOTOS BY  
ROBERT REEVES

**F**or over 400 years, legions of lunar cartographers have been surveying the surface of the Moon — first by telescope and then by spacecraft — charting and naming its features.

The resulting lunar map is constantly evolving. Over time, new names are added while existing names are dropped or changed after research shows a feature to be of a different geological type. The International Astronomical Union (IAU) establishes guidelines for lunar names; their approval is required to make a name official. These efforts keep scientific order in how we identify features and navigate the face of the Moon.

But our relationship with the Moon is not all science and regulated order. It is human nature to create endearments

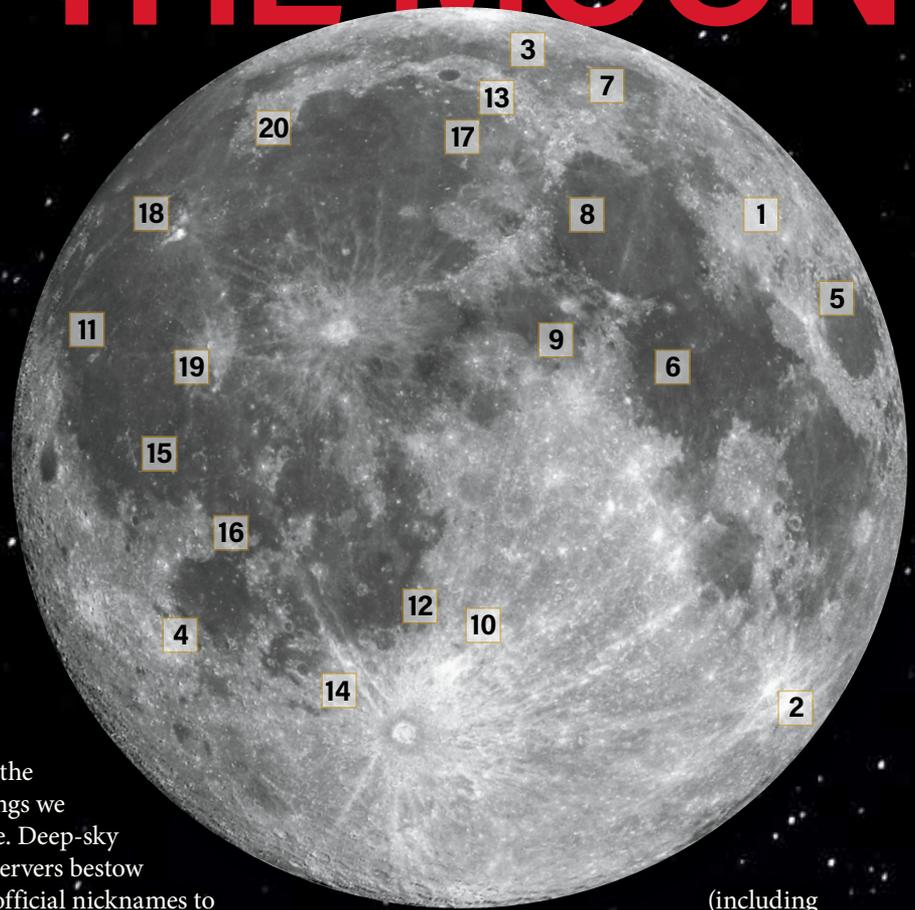
for the things we love. Deep-sky observers bestow unofficial nicknames to many, like the Lagoon (M8), Rosette (NGC 2237-9/44), and California (NGC 1499) nebulae. Luna is no exception; it too has its share of fanciful unofficial names for its features.

Human whimsy often trumps science in these names, such as the Cobra Head at the volcanic source that once fed flowing lava into Schröter's Valley. During the Apollo expeditions, many astronauts made their mark on the Moon by giving features unofficial names, such as Jim Lovell's famous Mount Marilyn, which he named after his wife during Apollo 8. While some of these popular lunar names are eventually rubber-stamped by the IAU

(including Mount Marilyn in 2017), others do not appear on a map, but persist by general acceptance.

The selection of unofficial names presented here include some modestly proposed by the author. Whether they stick in lunar lexicon depends on the whims of Moon lovers everywhere.

Lunar nicknames bring life and familiarity to a stark and unforgiving landscape that is nonetheless appealing because of its alien strangeness. For the avid astronomer, the names here should become as familiar as the terms of endearment that we apply to the gems of the Milky Way and beyond. ☾



## 1 ■ The Steppingstones

**Named by:** Robert Reeves  
**Official name:** Cleomedes, Burckhardt, Geminus, and Messala craters

**Size:** 81 miles (131 km), 34 miles (54 km), 51 miles (82 km), 76 miles (122 km)

**Coordinates:** centered at 33.5° N, 57.8° E

**Feature named after:** Appearance of sequential steppingstones

The linear string of four large craters extending north from Mare Crisium (at far lower right in this image) is reminiscent of steppingstones leading off to an adventuresome place. Each step is a leap through time, as none of these craters are the same age. The southernmost is flat-floored Cleomedes, an 81-mile-wide (131 kilometers) Nectarian-epoch crater that dates back 3.85 billion to 3.95 billion years ago. The smaller and slightly younger Imbrian-epoch crater Burckhardt follows. Farther north the sharper form of Geminus is even younger, dating to the Eratosthenian epoch. The final steppingstone, massive, ruined, pre-Nectarian-epoch Messala, is the oldest.

## 2 ■ The Headlights

**Named by:** Unknown  
**Official name:** Furnerius A, Stevinus A  
**Size:** 7 miles (11 km), 5 miles (8 km)  
**Coordinates:** 33.0° S, 54.7° E  
**Feature named after:** Appearance of oncoming car headlights

Satellite craters usually do not draw the casual observer's attention, but the brilliant, similar-sized Furnerius A and Stevinus A are an exception. Both young Copernican-epoch craters display disproportionately bright ray systems. The brilliant craters bracket the 45-mile-wide (72 km) Stevinus on the Moon's southeast quadrant, creating the illusion of approaching car headlights.

## 3 ■ The Lunar Good-Luck Charm

**Named by:** Robert Reeves  
**Official name:** Meton, Meton C, D, E  
**Size:** 124 miles (200 km)  
**Coordinates:** 72.6° N, 20.0° E  
**Feature named after:** Appearance of a four-leaf clover

The merged forms of craters Meton C, D, and E overlaying Meton Crater on the northern polar landscape create a four-leaf clover shape representing a lunar good-luck charm. The interiors and rims of all four pre-Nectarian-epoch craters were buried by the

wave of ejecta thrown from the Imbrium Basin impact 3.85 billion years ago, forming a common floor lying 5,000 feet (1,500 meters) below the surrounding territory.

## 4 ■ The Liebig Wall

**Named by:** Unknown  
**Official name:** Rupes Liebig  
**Size:** 90 miles (145 km)  
**Coordinates:** 45.9° W, 25.1° S  
**Feature named after:** Scarp with the same name

Lengthy Rupes Liebig arcs along the western shore of Mare Humorum and descends 2,300 feet (700 m) to the mare floor. The 6-mile-wide (9 km), 5,600-foot-deep (1,700 m) crater Liebig F lies atop the scarp and inspires the unofficial designation of the Liebig Wall.

## 5 ■ Hill's Waterfall

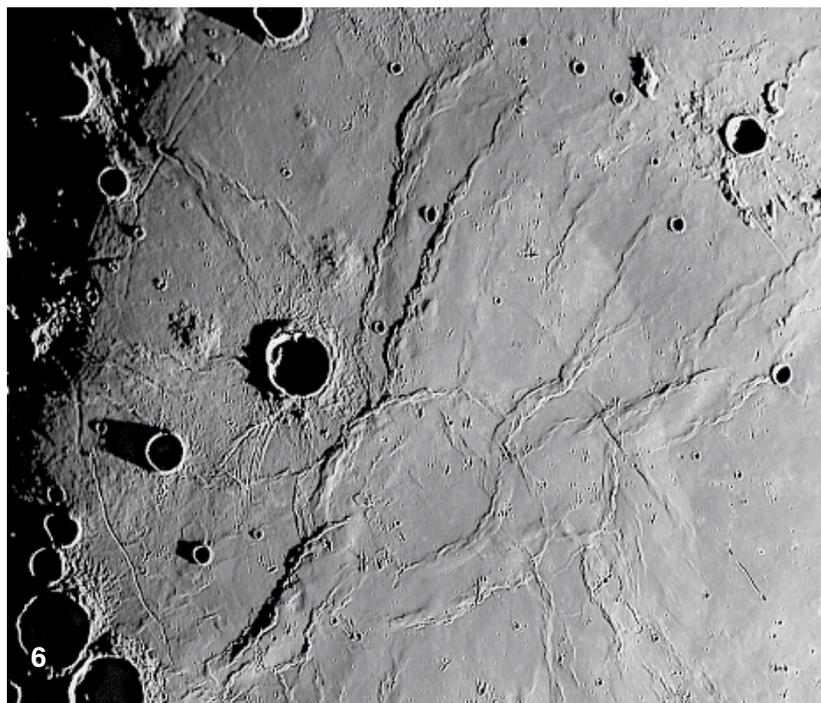
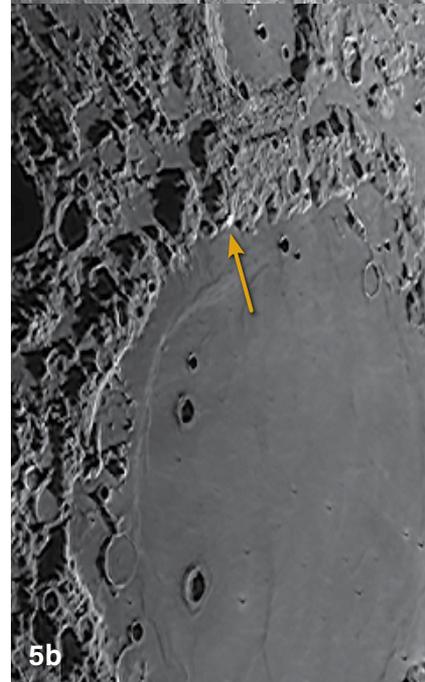
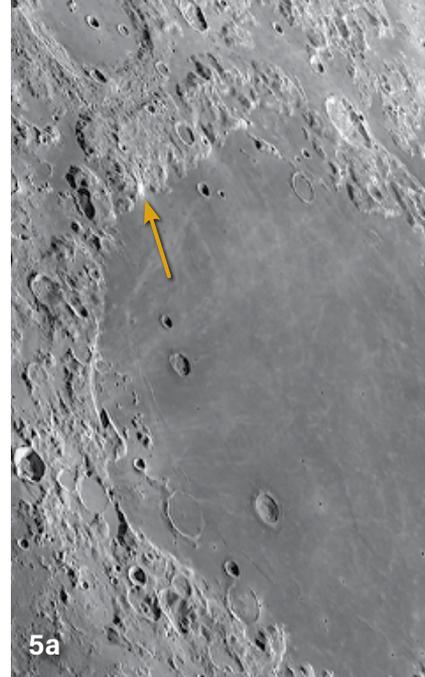
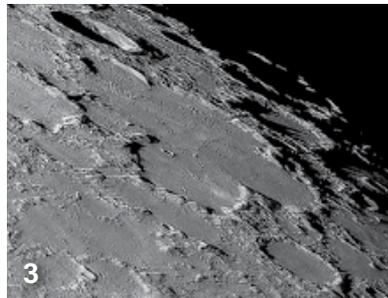
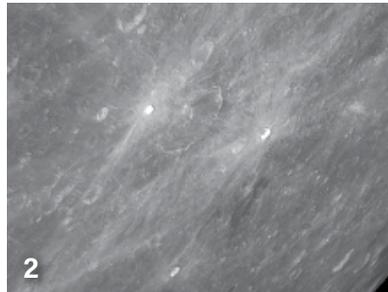
**Named by:** Robert Reeves  
**Official name:** None  
**Size:** 6 miles (10 km)  
**Coordinates:** 22.0° N, 55.5° E  
**Feature named after:** Resembles a waterfall cascading down a mountainside

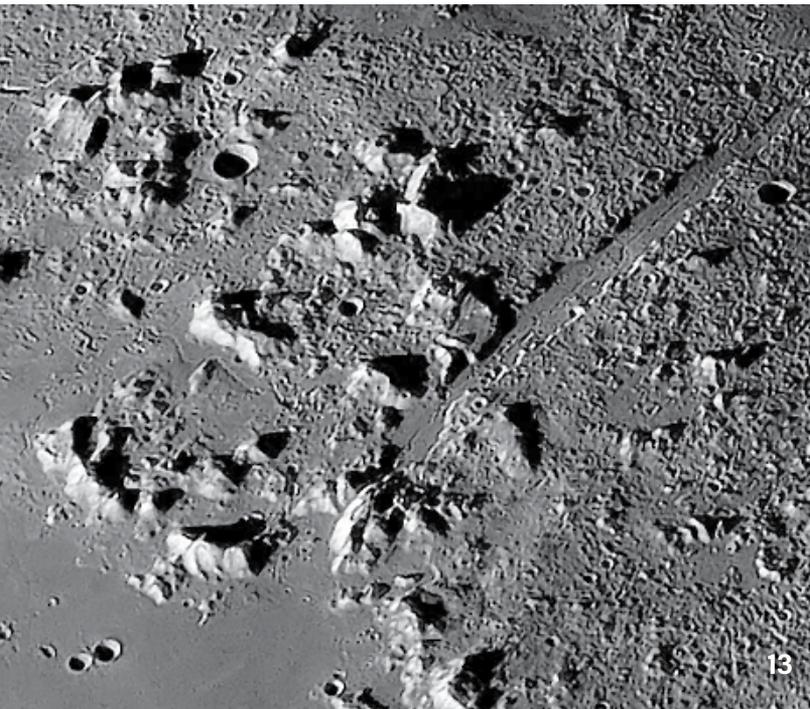
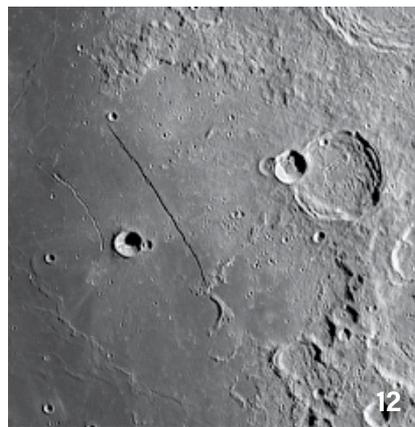
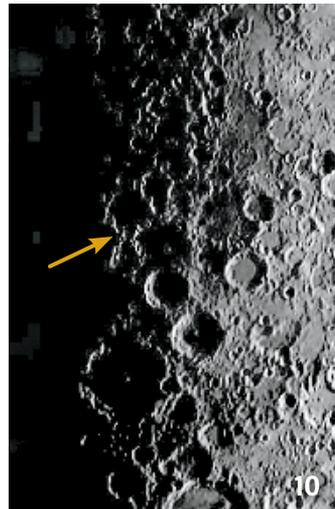
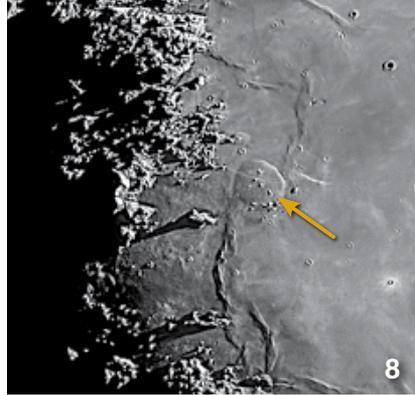
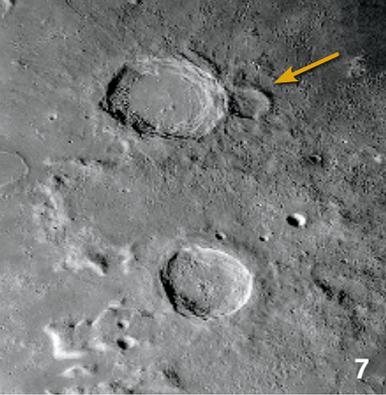
A bright splash of light-colored material ejected from a 0.8-mile-wide (1.3 km) craterlet on a mountainside on the northern rim of Mare Crisium looks almost as if it were a waterfall cascading down to the plain below. This bright, white spot can be found by following the northward arc of the craters Picard, Pierce, and Swift on the western side of Crisium. The spot has been reported to be a transient lunar event, as its reflectivity is variable and dependent on the Sun illumination angle, as seen in a comparison of these two images. The physical feature, however, is permanent. While the spot has no official name, Rik Hill, now retired from the University of Arizona, published an analysis of it — thus, it is referred to as Hill's Waterfall.

## 6 ■ The Spider

**Named by:** Robert Reeves  
**Official name:** Lamont  
**Size:** 52 miles (83 km)  
**Coordinates:** 5.1° N, 23.3° E  
**Feature named after:** Spiderlike appearance

First charted as a ghost crater on western Mare Tranquillitatis, Lamont is now regarded as a small ghost basin due to the 84-mile-wide (135 km) outer ring surrounding it. Lamont contains a spiderlike structure consisting of a system of lengthy radial wrinkle ridges that rise between 330 and 1,000 feet (100 and 300 m) above their surroundings. These form the legs of the spider.





## 7 ■ The Lunar S

**Named by:** Robert Reeves  
**Size:** 44 miles (70 km)  
**Coordinates:** 50.2° N, 20.1° E  
**Feature named after:**  
 Appearance of the letter S under sunset illumination

The apparition of the letter S appears for several hours at sundown on the eastern flank of Aristoteles Crater. The S is a combination of the northern rim of 19-mile-wide (30 km) Mitchell Crater, protruding from under Aristoteles' eastern rim, and the swirl of topography north of Mitchell.

## 8 ■ Valentine Dome

**Named by:** Unknown  
**Official name:** Linné A 1  
**Size:** 22 miles (35 km)  
**Coordinates:** 30.4° N, 10.1° E  
**Feature named after:**  
 Appearance of a Valentine's heart

The volcanic dome Linné A 1, just right of center in this image, rises 1,000 feet (300 m) above western Mare Serenitatis and is topped by half a dozen smaller volcanic domes, some capped with a small caldera. The rounded pancake-shaped dome resembles a classic Valentine's heart.

## 9 ■ Heart of the Moon

**Named by:** Robert Reeves  
**Official name:** None  
**Size:** 93 miles (150 km)  
**Coordinates:** 10.5° N, 6.8° E  
**Feature named after:** Heart-shaped appearance

Some 370 miles (600 km) south of Valentine Dome lies another heart-shaped feature: the dark volcanic-ash-dusted mountains north of Rima Hyginus on Mare Vaporum, which reach 3,300 feet (1,000 m) in elevation. The mountains have no official name, but the overall appearance of the rugged region prompts the unofficial designation of the Heart of the Moon.

## 10 ■ The Lunar X

**Named by:** Unknown  
**Official name:** None  
**Size:** 68 miles (110 km)  
**Coordinates:** 25.4° S, 1.0° E  
**Feature named after:**  
 Appearance of the letter X

As the First Quarter sunrise terminator crosses the merged rims of the adjacent craters Purbach, La Caille, and Blanchinus, they protrude in an X-shaped pattern that catches the first rays of sunrise and remains visible for about four hours.

## 11 ■ The Marius Hills and Tadpole

**Named by:** Unknown  
**Official name:** Hills: none; Tadpole: Reiner Gamma  
**Size:** Hills: 171 miles (275 km); Tadpole: 124 miles (200 km)  
**Coordinates:** Hills: 12.6° N, 53.9° W; Tadpole: 7.6° N, 58.6° W  
**Feature named after:** Hills: nearby crater Marius; Tadpole: resemblance to a frog tadpole

The Marius Hills are the unofficial name for the 262 individual mounds on a 27,000-square-mile (70,000 square km) region of Oceanus Procellarum west of the crater Marius. Although casually called hills, the features are volcanic domes and cinder cones. Reiner Gamma, located west of the Marius Hills and affectionately known as the Tadpole, gets its nickname from its resemblance to this stage in a frog's life cycle. This feature possesses no vertical relief, does not cast a shadow, and is officially classified as an albedo feature.

## 12 ■ Straight Wall and Ancient Thebit

**Named by:** Straight Wall: Birt and Lee (1865); Ancient Thebit: Chuck Wood  
**Official name:** Straight Wall: Rupes Recta; Ancient Thebit: none  
**Size:** Straight Wall: 72 miles (116 km); Ancient Thebit: 105 miles (170 km)  
**Coordinates:** 21.7° S, 7.7° W  
**Feature named after:** Straight Wall: Linear appearance; Ancient Thebit: Proximity to Thebit Crater

Rupes Recta is a lengthy linear feature known by the beloved name of Straight Wall (a rough translation of its Latin name). It is also known as Huygens' Sword in honor of 17th-century astronomer Christiaan Huygens, who studied the feature. The curved exposed crater rim at the southern end of Rupes Recta is also known as the Stag's Horn. Straight Wall lies in an unnamed ghost crater marked by a horseshoe-shaped bay east of the Wall and the circular wrinkle ridges west of it. This crater was unofficially designated Ancient Thebit by Chuck Wood after the nearby, younger Thebit Crater.

## 13 ■ The Guardians

**Named by:** Chuck Wood  
**Official name:** None  
**Size:** 13 miles (21 km)  
**Coordinates:** 47.8° N, 0.3° W  
**Feature named after:** Two mountains "guarding" a narrow gorge

The mouth at the western end of the Alpine Valley (Vallis Alpes) slashing through the lunar Alps (Montes Alpes) funnels from 13 miles (21 km) across down to a gorge just 660 feet (200 m) wide at the valley's entrance. The narrow

channel is bounded by a northern massif that rises 6,500 feet (2,000 m), while the southern massif rises 8,200 feet (2,500 m) above the plains of Mare Imbrium. Chuck Wood unofficially named the twin mountains the Guardians.

## 14 ■ The Railroad Tracks

**Named by:** Unknown  
**Official name:** Tycho rays  
**Size:** 447 miles (720 km)  
**Coordinates:** 32.8° S, 19.5° W  
**Feature named after:** Parallel placement, akin to railroad tracks

Tycho Crater's two prominent northwestern ray streamers do not diverge from a point within Tycho, and each ray is tangential to the crater's rim. This unusual parallel nature prompted the unofficial designation of the Railroad Tracks.

## 15 ■ Ghosts of Procellarum

**Named by:** Robert Reeves  
**Official name:** Flamsteed P, Wichmann R  
**Size:** 62 miles (100 km), 40 miles (64 km)  
**Coordinates:** 4.5° S, 40.7° W  
**Feature named after:** Ghost crater locations

The Moon's large basins were once dotted with craters, before volcanic flooding flooded many of them and created the maria. Some remain visible as ghost craters with their crowns protruding above the mare basalt. Those on southern Oceanus Procellarum are collectively known as the Ghosts of Procellarum.

## 16 ■ The Fireman's Hat

**Named by:** Unknown  
**Official name:** None  
**Size:** 44 miles (70 km)  
**Coordinates:** 16.8° S, 31.5° W  
**Feature named after:** The appearance of a fireman's helmet

The Fireman's Hat, sometimes called the Helmet, is the popular name for the half-Moon-shaped light-colored volcanic mound at upper left in the image. In this north-up view, the Fireman's Hat is upside down. The 43-by-31-mile (70 by 50 km) feature has no official name, but is also unofficially called the Agatharchides Dome, in reference to its proximity to Agatharchides Crater.

## 17 ■ Thor's Hammer

**Named by:** Robert Reeves  
**Official name:** Piton Gamma  
**Size:** 11 miles (18 km)  
**Coordinates:** 38.2° N, 1.8° W  
**Feature named after:** Similarity to Thor's warhammer

The T-shaped ridges of Piton Gamma on northern Mare

Imbrium mimic the shape of the magical hammer Mjolnir wielded by the mythical Norse god Thor. The 6-mile-wide (9 km) hammer head rises 1,300 feet (400 m) above the surrounding plains, while the 11-mile-long (18 km) handle rises 1,600 feet (500 m).

## 18 ■ The Cobra Head

**Named by:** Unknown  
**Official name:** None  
**Size:** 5 miles (8 km)  
**Coordinates:** 24.5° N, 49.2° W  
**Feature named after:** Appearance of a snake head

The unnamed volcanic pit at the source of the lava flows that channeled through Schröter's Valley on the Aristarchus Plateau is no wider than the rille forming the valley. While small compared to prominent craters, it is one of the largest volcanic pits on the Moon. The snakelike appearance of Schröter's Valley inspires the name the Cobra Head.

## 19 ■ The Ninja Star

**Named by:** Unknown  
**Official name:** Kepler rays  
**Size:** 311 miles (500 km)  
**Coordinates:** 8.1° N, 38.1° W  
**Feature named after:** Ray pattern resembling a ninja star

Kepler Crater's spectacular ray system is noted for its unusually thick western spokes and nearly solid fan of eastern rays. Mountain ridges west of Kepler act like a dam, breaking the westward flow of the rays into individual spokes. This circular splash of rays inspires the nickname the Ninja Star.

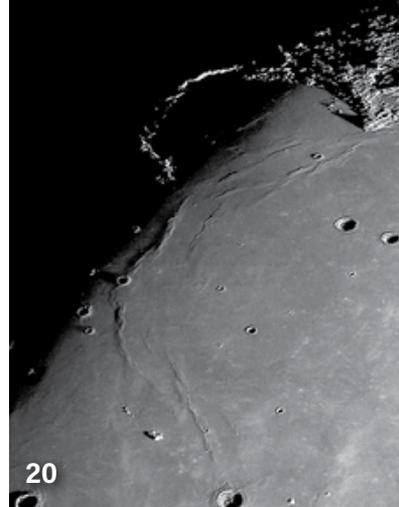
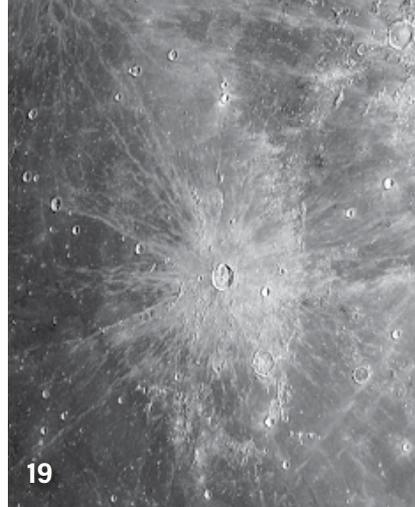
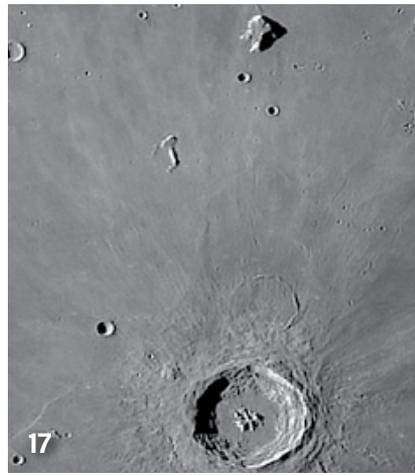
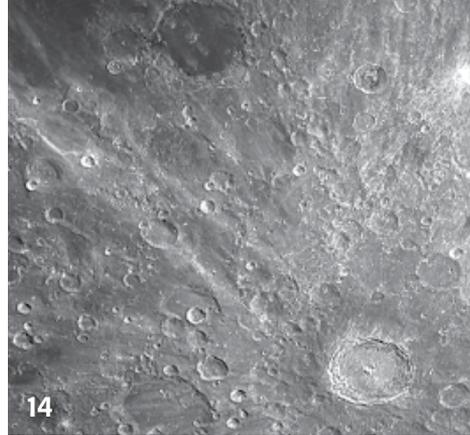
## 20 ■ The Golden Handle

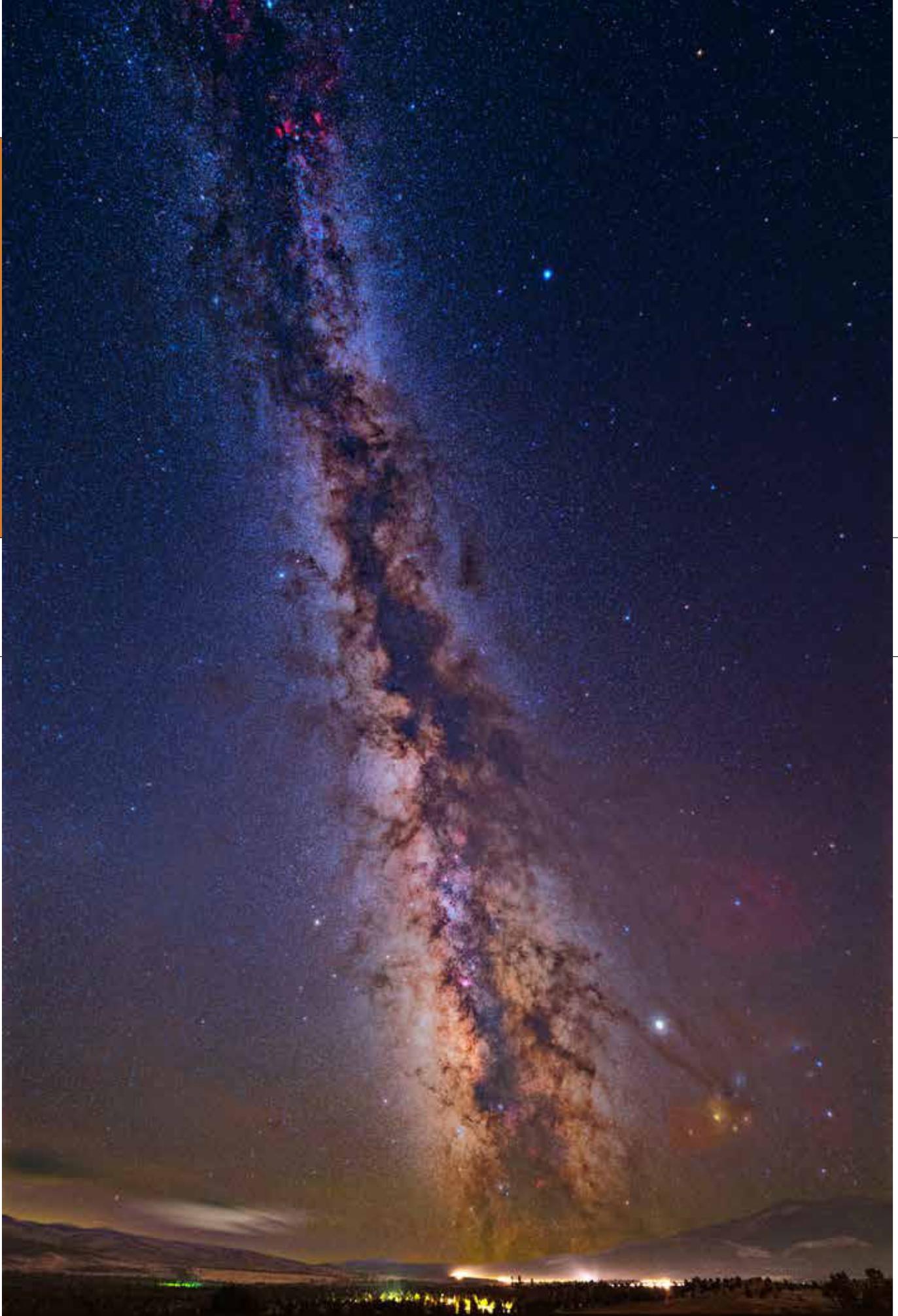
**Named by:** Unknown  
**Official name:** Jura Mountains  
**Size:** 155 miles (250 km)  
**Coordinates:** 47.5° N, 36.7° W  
**Feature named after:** Appearance of a curved handle at regional sunrise

Sunrise breaking across the crest of the Jura Mountains (Montes Jura) cradling Sinus Iridum on the northwestern edge of Mare Imbrium illuminates the mountain range before the floor of Sinus Iridum becomes visible. The bright mountain rim floating above the darkness creates the illusion of a curved handle against the black background of space.

### Robert Reeves

*is an accomplished astrophotographer and author, with a passion for lunar photography and science.*





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# THE JOYS OF WIDE-FIELD IMAGING

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Capture your own deep-sky vistas with these simple tips.

STORY AND PHOTOS BY FRANK DIBBELL

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I love taking wide-field images of the night sky. Revealing the hidden depths of a large swath of the heavens in a long-exposure photograph shows me that space isn't actually empty — it's filled with unfathomably large amounts of gas and dust. And with today's cameras and specialized filters, amateurs can produce stunning views of the heavens that exceed what professional observatories could produce just a few short decades ago.

This is especially true in wide-field imaging, which has several advantages over more specialized astroimaging setups. These include cost, portability, and near-immunity to bad seeing — aspects that appeal to beginners and experienced astroimagers alike.

The universe is filled with wondrous sights, and wide-field imaging technology can display it all in living color.

## Best beginner systems

One reason wide-field imaging is so compelling is that you don't need a lot of expensive equipment to make great images. A DSLR

camera on an equatorial tracking platform with a wide-angle lens is perfect for a shot of the Milky Way — whether it's solely overhead or framed against a panoramic background, such as a mountain range or desert plain.

You can also capture wide-field telescopic views. There are a number of telescope manufacturers who make refractors with short focal lengths, typically 50mm to 80mm in aperture with focal ratios ranging from  $f/4.5$  to  $f/6$ . These make efficient lenses for shooting wide-field subjects when paired with a DSLR, mirrorless, or CMOS imaging camera with at least an

APS-C-sized sensor. Mount this gear on a small equatorial mount paired with an off-axis guider or external guide scope, and you'll have yourself a wonderful wide-field imaging system. My favorite wide-field system uses a 71mm refractor with an APS-C-sized



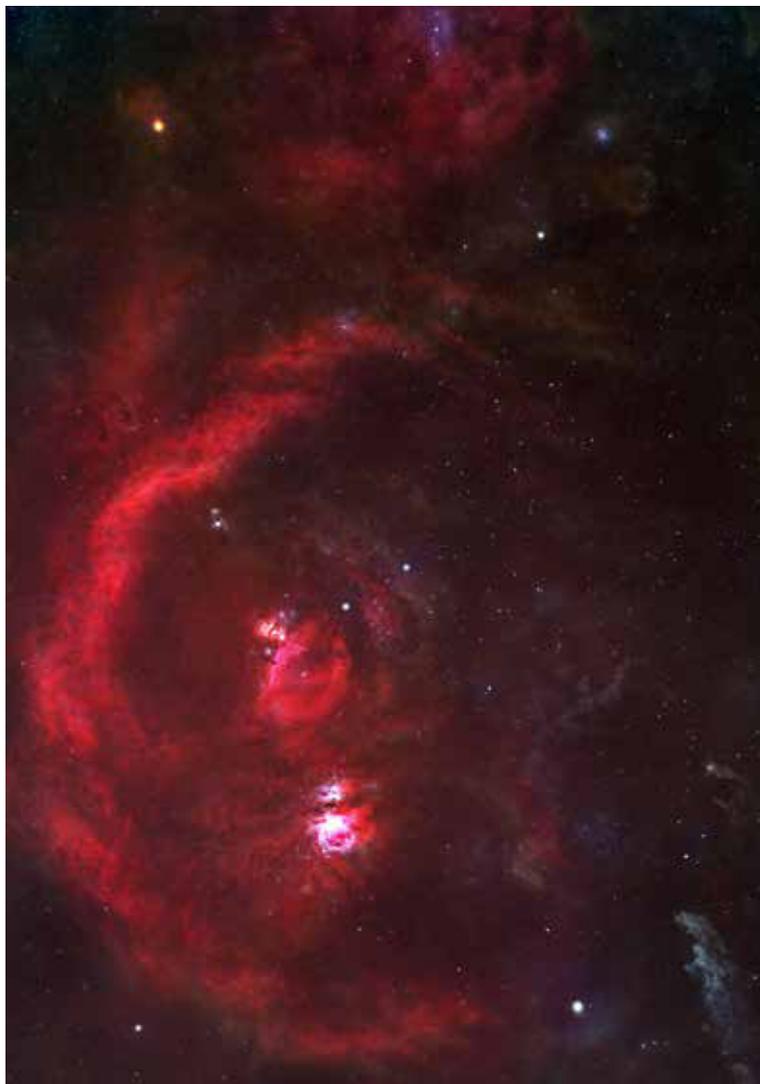
 The summer Milky Way was photographed from a hilltop over the Modoc Plateau in California using ten 3-minute exposures and a Sigma Art 14mm lens. All photos were taken with a Nikon D750 DSLR, pre-processed in Adobe Bridge, and post-processed in Adobe Photoshop.

 To take the photos in this story, a Nikon D750 DSLR body was astromodified to better capture wavelengths of light emitted by deep-sky objects. NIKON



📷 Comet C/2020 F3 (NEOWISE) gleams in the sky and waters of Modoc County, California, in this shot taken with a Samyang 24mm lens. Eight 30-second exposures were taken for the comet and one 30-second exposure was taken for the foreground.

📷 To capture this image of Barnard's Loop (Sharpless 2-276) and the Orion Nebula (M42), the author captured eight 4-minute exposures in RGB plus eight 6-minute exposures in H $\alpha$ .



CMOS camera on a small equatorial mount.

Whether you have a small refractor with a dedicated camera or an equatorial platform and DSLR, both combinations are highly portable, relatively easy to set up, and can produce stunning images in a single evening under the stars. This is an important aspect to consider if you are like me and must travel to a dark-sky site. When you can only spend a single evening in a location, shooting a wide-field subject becomes a perfect goal.

### Pick your battles with the sky

In all forms of astronomy, our atmosphere dictates what we can and cannot do every night. In addition to the obvious issues like clouds, the atmosphere can also present limits to transparency (dust, smoke, and water vapor) and seeing (turbulence). As far as clouds and transparency go, sadly there is nothing to be done.

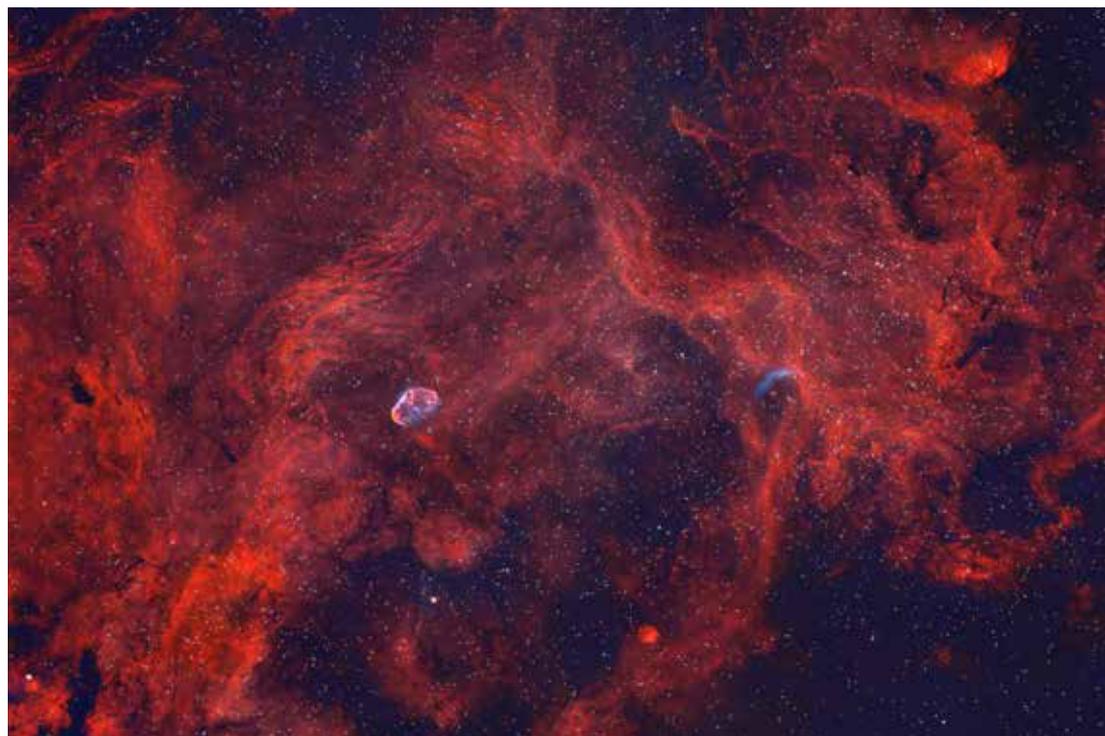


But seeing, on the other hand, we can do something about. This is where wide-field images come perfectly into play.

On nights when the seeing is below average, the short focal lengths of wide-field imaging systems do very well. These systems may have image scales of 4 to 6 arcseconds per pixel, whereas a more traditional imaging platform may have image scales of 0.5 to 2 arcseconds per pixels.

A night of below-average seeing, where the atmosphere limits resolution to 4 or 5 arcseconds, will sideline the traditional imaging system. But a wide-field system with an image scale larger than the seeing resolution will not be affected. This immunity from below-average seeing is perhaps the biggest benefit of all.

One of my favorite wide-field imaging systems consists of my astromodified Nikon D750 mounted on an equatorial tracking platform. This is perfect for shooting wide vistas of the Milky



## A WORD ON WIDE FIELDS

**IT'S DIFFICULT TO PIN DOWN** a precise definition of a wide field on the night sky. But for me, a wide-field image is one that encompasses a minimum area of approximately 4 square degrees, or about eight Full Moons side-by-side. An image of this scale will perfectly frame the North America Nebula (NGC 7000) and its companion the Pelican Nebula (IC 5070) in a field rich with glowing clouds of hydrogen.

When your field becomes extremely wide, you find yourself in the realm of nightscapes — images of the night sky that may also include terrestrial vistas, like Orion and the winter Milky Way setting over Mount Whitney in California's Sierra Nevada shown on page 45. Other astrophotographers consider these to be wide-field images as well. — *F.D.*

Way and celestial visitors like bright comets. It is highly portable and fits into a backpack. I have used this system a number of times when circumstances dictated a hike to the best spot for a photo. One example was when I captured the summer Milky Way from a hilltop over the Modoc Plateau in northeastern California (page 40). For this wide-field shot, I used my Nikon D750 with a Sigma Art 14mm lens on an AstroTrac equatorial tracking platform.

Another photo location

requiring a bit of a hike was the image I took of Comet C/2020 F3 (NEOWISE; see image at top left). This was shot with a Nikon D750 and the Rokinon 24mm lens carried on a Vixen Polaris equatorial tracking platform. Being highly

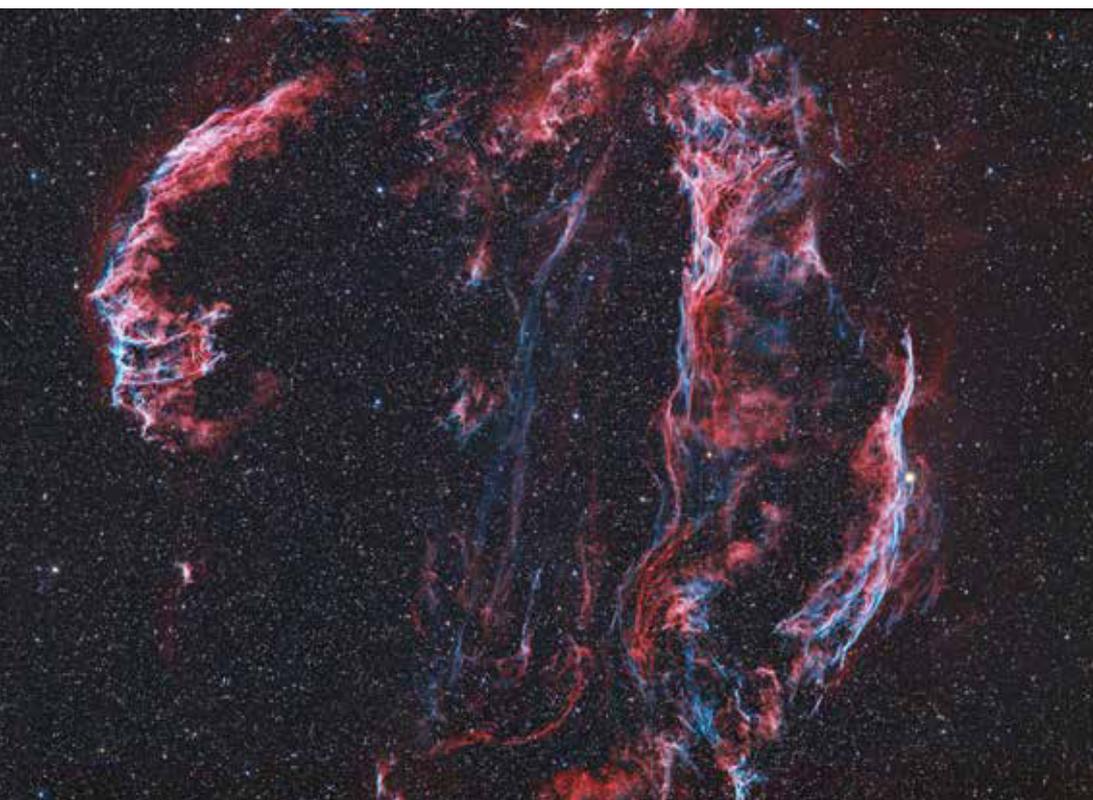


 A 200mm ASKAR lens paired with an iOptron L-Ultimate filter (which passes H $\alpha$  and OIII wavelengths) can capture deep-sky gems in the Sadr region in Cygnus, like the Crescent Nebula, shown here with 24 exposures of 10 minutes each.

 The compact Vixen Polaris Star Tracker is designed with precise tracking at different speeds and for time-lapse photography. The author attached it to his Nikon D750 DSLR. VIXEN

 The fiery depths of the North America (NGC 7000) and Pelican (IC 5070) nebulae (located 1,600 and 4,000 light-years away, respectively) were imaged using one of the author's favorite wide-field systems. This photograph consists of twenty-four 10-minute exposures in H $\alpha$  and OIII.

 Combining the Nikon D750 DSLR with Stellarview's SVQ100 Astrograph, the wispy streams of the Veil Complex were photographed stunningly with twelve 5-minute exposures.



portable is one great advantage of a wide-field system!

### The sky is your oyster

Constellations are also excellent wide-field targets. Orion is a marvelous candidate because there are several objects within

its boundaries to surprise you. This area is rich with ionized hydrogen, so I added a 12nm clip-in Hydrogen-alpha (H $\alpha$ ) filter to my Nikon specifically to capture all of Barnard's Loop (Sharpless 2-276), as well as the famous Orion Nebula (M42) and

Horsehead Nebula (Barnard 33). With a Sigma Art 85mm lens on an equatorial platform, I took five-minute H $\alpha$  exposures and three-minute RGB exposures (bottom-left photo on page 42).

Another favorite wide-field system of mine consists of an Askar 200mm f/4 Astro lens paired with my Nikon D750 DSLR and an Optolong L-Ultimate filter, which passes H $\alpha$  and Oxygen-III (OIII) wavelengths. For this setup, I use a small equatorial mount for guiding and imaging.

During the summertime, around June, the constellation Cygnus is perfectly positioned to take wide-field shots of its various sections. One highlight is the Sadr Region in Cygnus (top-right on page 43), a field roughly 6° by 9°. The region features rich nebulosity as well as objects such as the Crescent Nebula (NGC 6888), the blue-colored shock wave from the Wolf-Rayet star known as WR 134, and the Tulip Nebula (Sharpless 2-101).

Another popular area of Cygnus for a wide-field imager is the North America Nebula



complex. This field is saturated with ionized hydrogen — so much so that the North America Nebula (NGC 7000) and its companion, the Pelican Nebula (IC 5070), can appear lost in an undulating red sea (top left).

My largest wide-field system pairs a 71mm f/4.5 refractor with my APS-C-sized CMOS camera — it provides extreme detail and the option of taking wide-field panoramas. Adding a filter wheel to the monochrome CMOS camera allows more flexibility when processing the image. I personally like to shoot with the H $\alpha$  and OIII filters to create a bicolor image of nebulosity, then shoot with RGB filters to capture the colors of the background stars in the field. I photographed the Veil Nebula complex (bottom left) with this system, combining my

bicolor H $\alpha$ /OIII exposures and the proper star colors from the exposures with my RGB filter set. Note that there are many techniques for these activities, it's all about experimenting and finding the one that works best.

### A broader view

From time to time, nature will intervene and do its best to mess up a wide-field session. One moment you're setting up your system for the perfect shot; the next, you see multiple clouds magically appear.

This very scenario occurred on a trip I took to photograph the winter Milky Way setting over California's Mount Whitney. I set up my equipment at sunset and waited patiently for dark, but then clouds started forming. It was clear that soon there would be no Milky

Way to see, much less photograph. But when you're shooting a wide field, you have the flexibility to improvise. As you can see in the photo above, I may not have captured my Milky Way shot but I still captured a beautiful photo of the constellation Orion setting over the peak, with the clouds as an integral part of the picture.

Wide-field imaging is a great way for a beginner to start out in astroimaging, but that's not the only reason to do it: No matter your skill level, learning how to photograph in wide-field gives you a wonderful supplement to more traditional narrow-field views. By portraying celestial objects in their larger surroundings, we can gain a different perspective of the sky overhead, and see our wondrous universe as a grand vista. ☾

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

☾ Wide-field images can still prevail when the weather presents challenges, as this image of Orion the Hunter rising over California's Mount Whitney proves. This image was shot with a Samyang 24mm lens.

☾ Astronomik's clip-on H $\alpha$  filter allows emission from hydrogen gas in nebulae to pass through while blocking most of the remaining visual spectrum as well as infrared light.

ASTRONOMIK



# Celestron's SkyMaster binoculars

## REVIEWED

Porro prisms and extra-low dispersion glass create razor-sharp views of the sky.

BY MICHAEL E. BAKICH

→ *Astronomy* Contributing Editor Phil Harrington loves binoculars. Indeed, his catchphrase is, “Two eyes are better than one.” He’s not wrong. Observing is naturally more relaxed when you can keep both eyes open. But low-power units with small apertures and questionable optics offer little to amateur astronomers. Luckily, there are also robust binoculars with top-notch glass.

Recently, Celestron of Torrance, California, introduced an upgrade to the Pro models in its line of SkyMaster Porro binoculars by equipping them with extra-low dispersion (ED) glass and larger prisms. The company produces three models with ED glass: the 7x50, 15x70, and 20x80 (where the first number is the magnification and the second is the length of the objective lens in millimeters). When I was given the choice as to which to review, needless to say, I picked the largest one.



↑ Celestron has upgraded the Pro models in its line of SkyMaster Porro binoculars with ED glass lenses and larger prisms. This review covers the 20x80mm model.

### The exterior: Less is more

Celestron packages the SkyMaster Pro ED 20x80mm Porro binoculars in a single box. Inside were the binoculars, a flexible nylon case, two pairs of lens caps (the larger one already attached to the binoculars), a neck strap, and a built-in tripod adapter attached to what the company calls a balance compensation rail. A large locking knob on the adapter lets you slide the binoculars forward or backward to get the perfect balance on your tripod. (The two smaller models in the Pro ED lineup do not include a tripod adapter, but any standard adapter for binoculars will do.)

Although the Pro ED binoculars come with a neck strap, I'm not sure any

observer in worse shape than the average NFL player could hand-hold them for very long. Weighing in at 7.7 pounds (3.5 kilograms), with a length of 14 inches (35.6 cm) when the eyecups are fully extended, the 20x80mm unit is solidly built, to say the least. The body is armored with a sleek flat-black rubber, with the exception of a few hints of orange (Celestron's signature color) and some small lettering in silver.

Because both eyes don't focus the same for most humans, Celestron added a key feature where the right eyepiece has a diopter adjustment with a range of  $\pm 3$  that compensates for that difference. In addition to getting a precise observing session, the focusing and eyecup movement are both smooth as silk.

Another feature that sets the Pro ED binoculars apart: The eyepieces accept 1¼-inch filters. However, the filters don't screw into the bottom of the eyepieces, as with those for telescopes. Instead, the outside of each eyepiece is threaded to accept them. I'm fairly heavy-handed, so I always worry when I'm installing or removing a small, delicate eyepiece filter. These binoculars, however, I just set front-lenses-down on a flat surface and screwed the filters into the eyepieces.

### It's the inside that counts

The inside of the binoculars is a testament to proper engineering. The company uses Porro prisms (a pair of right-angled prisms that allows the optical path to be folded) because they can be widely spaced, creating a better 3D view. The prisms are made from high-density BaK-4 glass, generally considered to have better optical properties than the other choice for prisms BK-7 glass.

The 80mm objective lenses are each essentially a 3.15-inch telescope. All the glass surfaces (objectives, eyepieces, and prisms) are fully multicoated with Celestron's proprietary XLT coating technology. This boosts light transmission and reduces reflectivity throughout the system. Finally, the interior is filled with nitrogen, an inert gas that will not promote any type of degradation. It also prevents fogging if you move the binoculars from a warm to a cold environment.

## PRODUCT INFORMATION

### SkyMaster Pro ED 20x80mm Porro binoculars

**Prisms:** BaK-4 Porro prisms

**Eye relief:** 15.4 mm

**Interpupillary distance:** 2.2 to 2.8 inches (56 to 72 mm)

**Field of view:** 3.4°

**Weight:** 7.7 pounds (3.5 kg)

**Length:** 14 inches (356 mm)

**Price:** \$429.95

**Contact:** Celestron

2835 Columbia Street

Torrance, CA 90503

310-329-9560

### Putting them to the test

Before using the binoculars at night, I spent a few hours in the day scanning the mountain ranges to my north and east. The SkyMaster Pro ED binoculars provided views of ridges and clefts that were impressive from a virtual distance 20 times closer than I really was. And there's no finer treat than viewing the majesty of a Harris's hawk or a great horned owl at that magnification.

Of course, our focus is on the sky. The first astronomical object I looked at was the Orion Nebula (M42). Just as I had expected, the nebula was colorless, but the overlapping parts of the nebulosity were quite apparent. I then moved on to the Trapezium Cluster, visible as four distinct stars during moments of good seeing — Orion was sinking into the western horizon at the time.

Next up was a sweet pair of globular clusters, M3 in Canes Venatici and M5 in Serpens. Each appeared as a soft ball of light against a black velvet background, notwithstanding the few foreground stars. When both clusters reached a higher altitude, I could make out a few faint points of light at their extremities. At a limited magnification of 20x, the vast bulk of their stars remained unresolved.

Later in the evening, the constellation Lyra had climbed to an altitude where I wondered if I could spot the Ring Nebula (M57). And, indeed, there it was, a distinct disk of pale light. Finally, I took my time admiring the satisfying view of one of my favorite deep-sky objects, the Wild Duck Cluster (M11) lying in the Scutum Star Cloud. With its 3.4° field of view, the Pro ED binoculars framed this area well, expanding the nearly ¼°-wide cluster as well as a large number of foreground stars.

→ The SkyMaster Pro ED 20x80mm Porro binoculars comes with a tripod adapter and a neck strap to provide support while observing.

### The bottom line

With a retail price of \$429.95, and considering all that the unit offers, Celestron's SkyMaster Pro ED 20x80mm Porro binoculars are a real deal. If you (or, more specifically, your tripod) can handle binoculars that weigh nearly 8 pounds (3.6 kg), get ready for some amazing daytime and nighttime views for many years to come. ☞

**Michael E. Bakich** is a contributing editor of *Astronomy* who loves the easy setup that binoculars offer.



# Under dark skies

Light pollution is harder than ever to escape — but doing so has never been more fulfilling.



The same telescope captured these images of M81 and M82. The left image is 50 hours of exposure from Dayton, Ohio — a Bortle 7 — using a monochrome camera and H $\alpha$ LRGB filters; the image on the right is only five hours from a Bortle 3.5 site using a one-shot color camera and a light pollution filter.

MOLLY WAKELING



Have you ever seen the Milky Way? Only 20 percent of people in the U.S. live in a location where they can. Away from light pollution, the wide, ghostly band almost looks like clouds, and the stars overhead look so big and real that you feel you might fall into the sky. Through the eyepiece of a telescope, galaxies and nebulae normally obscured by the haze of city lights stand out in stark contrast.

The story is a little different for the astrophotographer — light pollution matters less these days with the ability to stack hundreds of subframes and use light pollution or narrowband filters to block out city lights. It's difficult to lug your equipment out to a dark-sky site, so many are often content to stay home and image from the backyard — myself included. You may even live hours away from rural skies and ask: Is it worth the trip?

For city-based imagers, narrowband filters are especially effective at cutting down on the worst of light pollution; they block most light except for tiny slices of the visible spectrum that correspond to wavelengths emitted by deep-sky objects. There are also traditional light-pollution filters, which reduce light at wavelengths produced by mercury- and sodium-vapor lamps. Although many cities have switched to broad-spectrum LED lights, light-pollution filters still make a difference. And in post-processing, background extraction and gradient removal tools can do wonders for reducing background haze and allowing dim features to shine through.

With these tools, going to a dark-sky site may feel superfluous. However, a brighter background isn't the

only problem with light pollution — all those extra photons introduce additional “shot noise,” which is a quantum mechanical effect related to the discrete nature of the electrons and the photons that created them in the camera sensor. To beat down the light pollution and added noise, one must take many more hours of subframes to increase the signal-to-noise ratio. For astrophotographers who live in places with less-than-ideal weather, every hour of clear sky is precious. Typically, I will spend 20 to 40 hours on a target from my backyard, but from a dark-sky site, I can usually get a better image in three to six hours — sometimes less.

We quantify how dark the sky is in units of stellar magnitudes per square arcsecond (mag/arcsec<sup>2</sup>). For example, in the downtown area of a large city, the sky might have a brightness of 17.5 mag/arcsec<sup>2</sup>, which is essentially the same as filling the whole sky with dim stars; one can practically read by the reflected city light. This is the bright extreme of the Bortle dark-sky scale, at Bortle 9. Most constellations are not visible, with only the brightest stars and planets shining through.

On the other hand, when I was at the Okie-Tex Star Party in 2022, it got as dark as 21.7 mag/arcsec<sup>2</sup>, on the border of Bortle 1 and 2. In such a sky, the Milky Way is vivid and shows structure, several galaxies and star clusters are visible naked-eye, and bright stars and planets can cast shadows. The strangest thing about being at a dark-sky site is that the clouds are black, since there is no light from the ground for them to reflect!

Sometimes we must put up with the light pollution we have and try to observe and image what we can. But I highly recommend getting out to a dark-sky site as often as possible; a weekend camping trip to your local astronomy club's dark-sky site can be fun and rewarding.

In the longer term, there are ways to reduce light cast to the sky; primarily pointing lights at the ground and cutting off sideways- and upward-looking light fixtures. DarkSky International (IDA, <https://darksky.org>) has ideas for responsible lighting solutions and resources for advocating for

your local city or municipal government to implement responsible lighting ordinances. (See page 14.)

It can sometimes feel impossible to escape light pollution, but it is well worth it to get out under a dark sky, even if it's only a few Bortle steps lower. You will be amazed at how much more you can see with your camera and your eye. Make some time to bask in the light of the Milky Way and fall into the thousands of stars that lie overhead. ☾

**Away from light pollution, the stars look so big and real that you feel you might fall into the sky.**



BROWSE THE “OBSERVING BASICS” ARCHIVE AT [www.Astronomy.com/author/molly-wakeling](http://www.Astronomy.com/author/molly-wakeling)



**BY MOLLY WAKELING**

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

## NEW PRODUCTS



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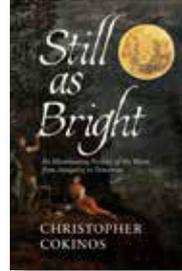
The EXOS2-GT PMC-Eight mount with WiFi and Bluetooth can handle up to 28 pounds (12.7 kilograms) for astrophotography and up to 40 pounds (18.1 kg) for visual scopes. The mount can be controlled wirelessly with a phone or tablet — an upgrade over the previous version of this product. Belt-driven stepper motors help the mount handle loads under strain without damage.

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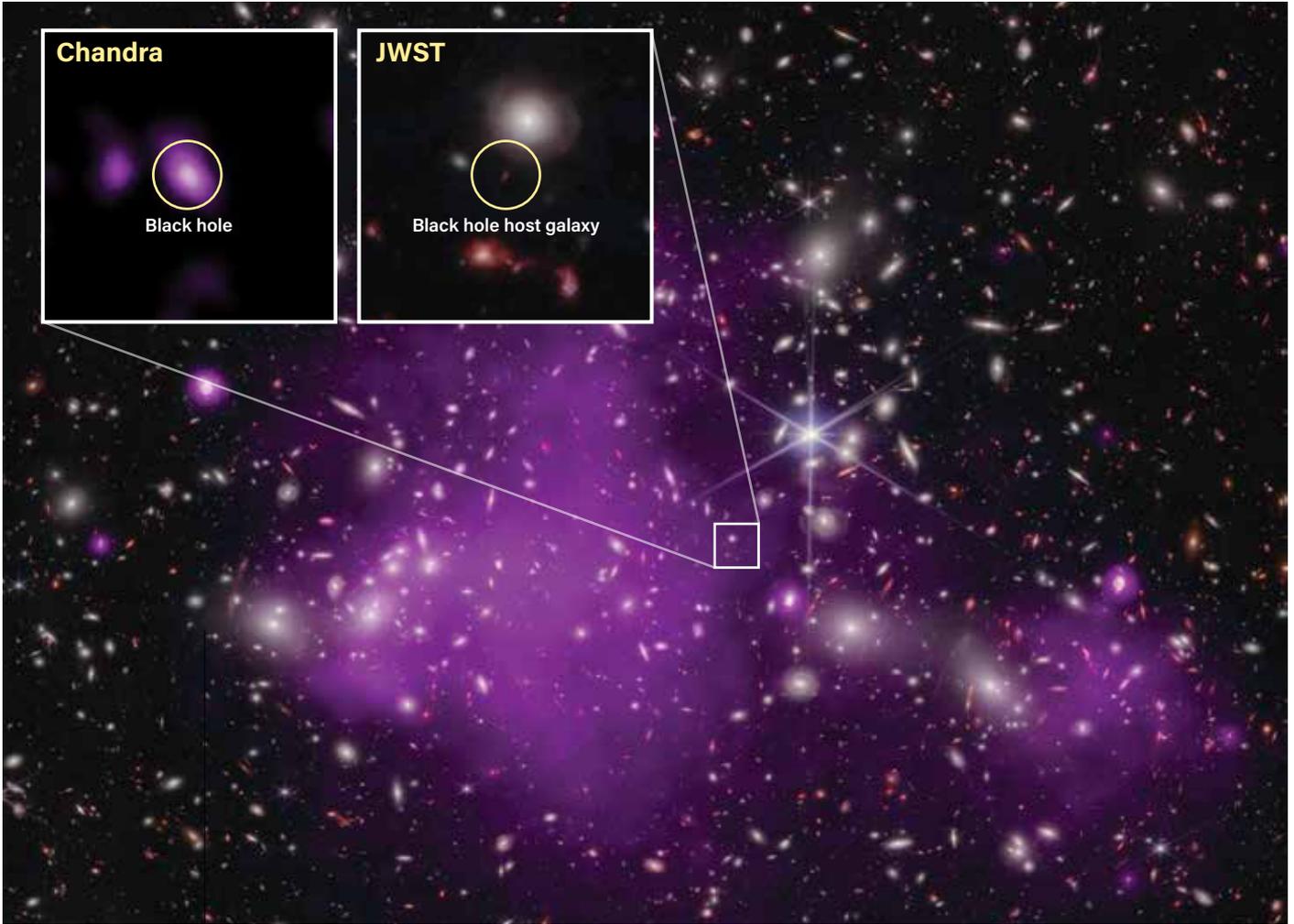
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This composite image shows the galaxy cluster Abell 2744 as seen by JWST and the Chandra X-ray Observatory. Overlaid on the infrared image of the galaxies is a purple “haze” created by hot, X-ray-emitting gas in the cluster. But in the background lies the distant galaxy UHZ1 (right inset), whose central supermassive black hole is also emitting X-rays (left inset).

X-RAY: NASA/CXC/SAO/ÁKOS BOGDÁN; INFRARED: NASA/ESA/CSA/STSCI; IMAGE PROCESSING: NASA/CXC/SAO/L. FRATTARE & K. ARCANO

# The oldest black hole

**Q** | IT WAS RECENTLY IN THE NEWS THAT ASTRONOMERS SPOTTED THE OLDEST, MOST DISTANT BLACK HOLE SINCE THE BIG BANG. HOW DO THEY KNOW IT IS THE OLDEST AND MOST DISTANT?

*Heather Mazatlán, Sinaloa, Mexico*

**A** | A research team led by Akos Bogdan of the Center for Astrophysics | Harvard & Smithsonian discovered a supermassive black hole (SMBH) in UHZ1, a galaxy whose light has taken 13.2 billion light-years to reach us. This means astronomers are observing it as it was 13.2 billion years ago, when the universe was only 3 percent its current age, making it the oldest black hole yet detected.

The concept of distance is tricky to define when dealing with vast stretches of both space and time. Thus, it’s simplest to say that UHZ1’s light-travel distance is 13.2 billion light-years, though that does not account for the universe’s expansion during the time the light has been traveling toward us. And a galaxy’s estimated distance and age will vary depending on which cosmological model you use. But under any model, because UHZ1 has a longer light-travel time than any other known black hole, it is also the most distant.

The physical characteristic of a galaxy that astronomers measure — from which they calculate its distance and age — is redshift: the elongation of light waves that results from a celestial body’s movement away from us. This is similar to the Doppler effect we experience with sound. When a police siren moves away from us, the frequency at which sound waves reach us is reduced,

which we perceive as a lower pitch. The same principle applies to light.

The fact that all distant galaxies are receding from us is due to the expansion of the universe. The farther away a galaxy is, the more space there exists between us to expand, meaning more distant objects appear to be moving away from us faster than closer objects. This principle, known as the Hubble flow, enables scientists to estimate the distances of galaxies: The higher a galaxy's redshift, the faster it is receding and the farther it is from us. Astronomers denote redshift as a value called  $z$ . The  $z$  value of UHZ1 is 10.1, corresponding to its light-travel time of 13.2 billion years in standard cosmological models.

An additional stroke of luck enabled Bogdan's research team to detect this SMBH: The galaxy cluster Abell 2744 happens to lie between us and UHZ1, at a distance of nearly 4 billion light-years, along the same line of sight. The gravity of Abell 2744's substantial mass is bending light from UHZ1 around it, focusing it like a magnifying glass. As a result of this gravitational lensing, UHZ1 appears four times brighter than it normally would. This allowed the James Webb Space Telescope and the Chandra X-Ray Observatory to collect data that led the team to identify a source of X-rays as UHZ1's central black hole.

**Edward Herrick-Gleason**

*Planetarium Director, Southworth Planetarium,  
University of Southern Maine, Portland, Maine*

**Q** | WE ALL ACCEPT THAT THE COLDEST TEMPERATURE ANY OBJECT CAN REACH IS ABSOLUTE ZERO. IS THERE A THEORETICAL MAXIMUM TEMPERATURE ANYTHING CAN ATTAIN?

**Stephen Kitterman**  
*Thomasville, North Carolina*

**A** | Temperature is a measure of the average energy of a collection of particles. (This is in contrast to kinetic energy, which is a measure of the energy carried by a single particle.) So, to answer a question about temperature, we have to find some collection of particles to measure.

One such collection is found in the core of our Sun, where temperatures of about 15 million kelvins (27 million degrees Fahrenheit or 15 million degrees Celsius) are reached. Very massive stars can have core temperatures upwards of 500 million kelvins (900 million F or 500 million C). Just before a massive star explodes as a supernova, some theoretical models predict its core can reach temperatures above 100 billion

**TEMPERATURE IS A MEASURE OF THE AVERAGE ENERGY OF A COLLECTION OF PARTICLES.**

kelvins in the process of imploding, as it approaches the extremely high density of a neutron star.

Before the universe was one second old, matter was a dense plasma of nucleons and elementary particles at densities higher than that of lead. We can predict the temperature of this plasma,  $T$ , in kelvins using the formula  $T = 10^{10}/\sqrt{t}$ , where  $t$  is the time in seconds since the Big Bang. By 10 microseconds, the average temperature of the universe's contents is 3 trillion kelvins, equivalent to the energies that the Large Hadron Collider explores in quark-gluon plasmas (about 300 million electron volts). But depending on how far back (i.e., closer in time to the Big Bang) you want to push, you can get still-higher temperatures.

The theoretical limit may be what is called the Planck temperature of  $10^{32}$  kelvins, derived by using the fundamental constant for gravity ( $G$ ), the speed of light ( $c$ ), Planck's constant ( $h$ ), and the Boltzmann constant ( $k$ ). This is believed to be the limit where space and time break down due to quantum gravity effects and you can't put more energy into a system of particles without creating quantum black holes for your effort.

**Sten Odenwald**

*Senior Outreach Coordinator, NASA HEAT Program,  
Kensington, Maryland*

Workers walk past a section of magnets in the Large Hadron Collider at CERN, where researchers are probing plasmas like those that filled the early universe.

SAMUEL JOSEPH HERTZOG/CERN

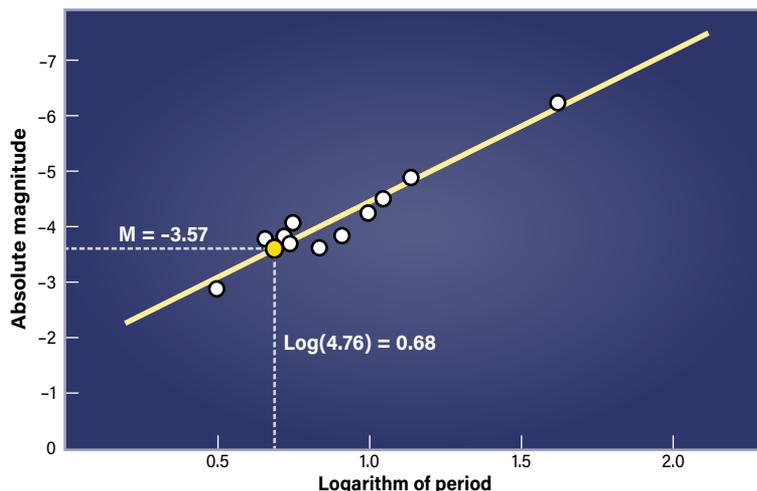


RIGHT: RS Puppis is a Cepheid variable star whose brightness varies by a factor of five roughly every 40 days. NASA, ESA, AND THE HUBBLE HERITAGE TEAM (STSCI/AURA)-HUBBLE/EUROPE COLLABORATION; ACKNOWLEDGMENT: H. BOND (STSCI AND PENN STATE UNIVERSITY)

BELOW: The linear relationship between the logarithm of the periods of Cepheid variables and their apparent magnitudes is called the Leavitt law, or period-luminosity relationship. This graph shows the period-luminosity relationship, calibrated by measuring the distances to Cepheid variables in the Milky Way. These distances were used to calculate the stars' true luminosities, or absolute magnitudes, shown on the y-axis. Astronomers then use the calibrated law to determine any Cepheid's distance from only its period and average apparent magnitude. In this case, an example Cepheid with a period of 4.76 days yields an absolute magnitude of  $-3.57$ . ASTRONOMY: ROEN KELLY, AFTER AUSTRALIA TELESCOPE NATIONAL FACILITY



## THE PERIOD-LUMINOSITY RELATIONSHIP



## Q | HOW DO CEPHEID VARIABLES INDICATE DISTANCE?

*Roger Brady  
Tamal, California*

**A** | Cepheid variables are a type of star that undergo regular pulsations. The length of a Cepheid's pulsations is always related to its intrinsic, or absolute, brightness in a simple way: The longer its pulsations last, the larger and brighter the star. This means that if you can measure the period of a Cepheid variable, or the time it takes to undergo one full cycle of brightness changes (say, from bright to dim to bright again), you can use a relationship called the Leavitt law to calculate the star's intrinsic brightness. The law is named for Henrietta Swan Leavitt, who first recognized this property of Cepheids while cataloging stars at Harvard University in the early 1900s.



What makes Cepheids so valuable as distance indicators is that getting a star's intrinsic brightness is otherwise very hard. Intrinsic brightness is an innate property of a star. It's much easier to measure a star's *apparent* brightness, which is simply how bright a star appears to us here on Earth.

If we know a star's intrinsic brightness as well as its apparent brightness, we can use those values to easily calculate its distance. In the absence of other factors, all light sources appear dimmer with distance. A 30-watt bulb, for example, always shines with a brightness of 30 watts, but it will appear much fainter if you are standing far away.

Specifically, an object's brightness grows dimmer by  $1/d^2$ , where  $d$  is the distance from the object. So, because we can easily glean a Cepheid's absolute luminosity from its period, we have exactly the information we need to confidently calculate their distance.

**Alison Klesman**  
Senior Editor

## Q | HOW DO LIGHT POLLUTION FILTERS WORK? DO THEY ACTUALLY HELP?

**Kyle Norris**  
Peoria, Arizona

**A** | Light pollution reduction (LPR) filters work because many outdoor lighting sources do not shine evenly across the visible spectrum. Instead, they emit radiation at only a few distinct wavelengths. For instance, a high-pressure sodium streetlight radiates

principally in yellow wavelengths. LPR filters suppress those and similar wavelengths while allowing others through.

LPR filters don't reduce all forms of light pollution, despite their name. They do little to reduce the impact of car headlights, lights directed onto buildings, and other fixtures that (unfortunately for astronomers) emit all visible wavelengths.

Another common fallacy is that these filters make sky objects look brighter. Filters only subtract light, dimming everything. In the process, however, the background sky and field stars darken more than the target. This boosts the contrast, making celestial objects easier to spot.

Some amateurs believe these filters dim the view so much that they can't use them with small telescopes. That's also not true. Any telescope can benefit from these filters.

Under urban and suburban skies, LPR filters perform best on bright nebulae. While a filtered view seldom shows more detail than an unfiltered one, or reveals an otherwise invisible target, LPR filters improve the visual aesthetics by darkening the background sky. And even from a dark site where there's no light pollution, nebulae tend to look a bit better.

If you live under a dome of light pollution, consider adding an LPR filter to your equipment arsenal. Once you start using filters, you'll be amazed at what you've been missing. It's the same pleasant experience as putting on your "shades" on a sunny day.

**Michael E. Bakich**  
Contributing Editor

This stunning image of the Orion Nebula (M42) was captured under heavily light-polluted skies, thanks to the aid of a light-pollution filter.

STEPHEN RAHN

To learn more about the effects of light pollution on the night sky, read "Fighting the light" on page 14.

## SEND US YOUR QUESTIONS

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

# Cosmic portraits



## 1. CROWNING GLORY

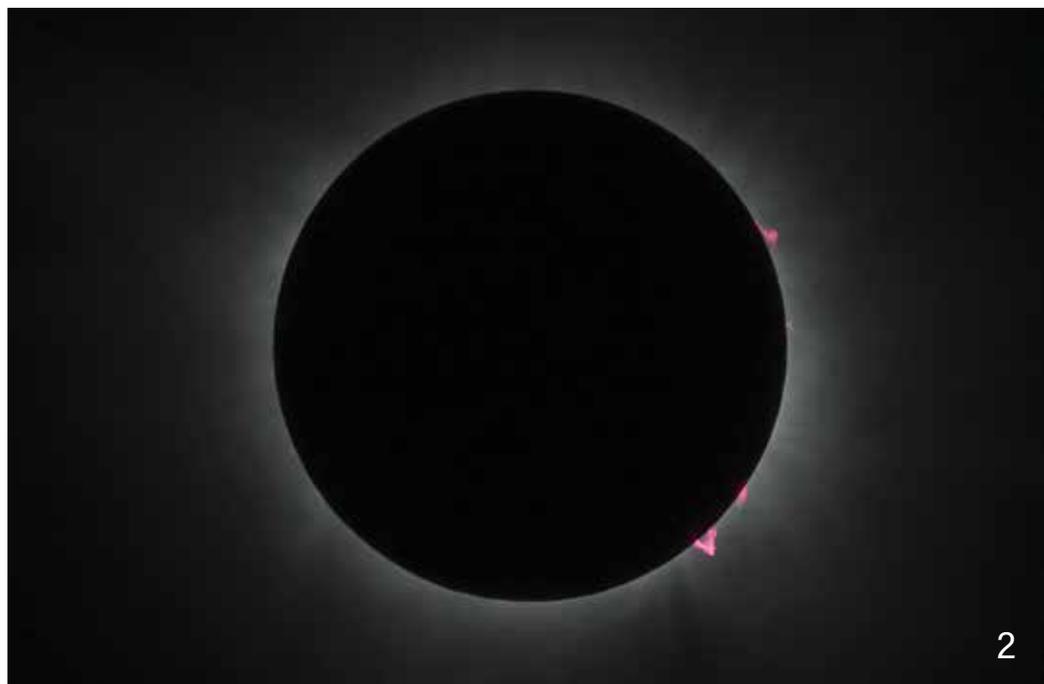
The total solar eclipse of April 8 dazzled viewers across North America with a view of the active Sun's brilliant corona. This HDR composite taken from Torreón, Mexico, reveals the Sun's outer atmosphere in all its complexity, with countless loops and streamers. The imager used a Canon EOS R5 full-frame mirrorless camera and 600mm lens to take a bracketed set of exposures ranging from one second to 1/800 second.

- **Brent Bowen**

## 2. PROMINENT FEATURES

This eclipse featured several naked-eye prominences, especially in the later stages of totality, as seen in this image captured from Batesville, Arkansas. The photographer used a Nikon Z9 full-frame mirrorless camera and a 600mm zoom lens at f/8 to take an exposure of 1/500 second and ISO 100.

- **Jeffrey A. MacQuarrie**





**3. DAYTIME TWILIGHT**

As totality falls over the desert southwest of Torreón, clouds in the area and the effect of twilight from all directions cause the desert landscape to bloom with color.

• *Augustin Garza*

**4. WANDERING WARTHOG**

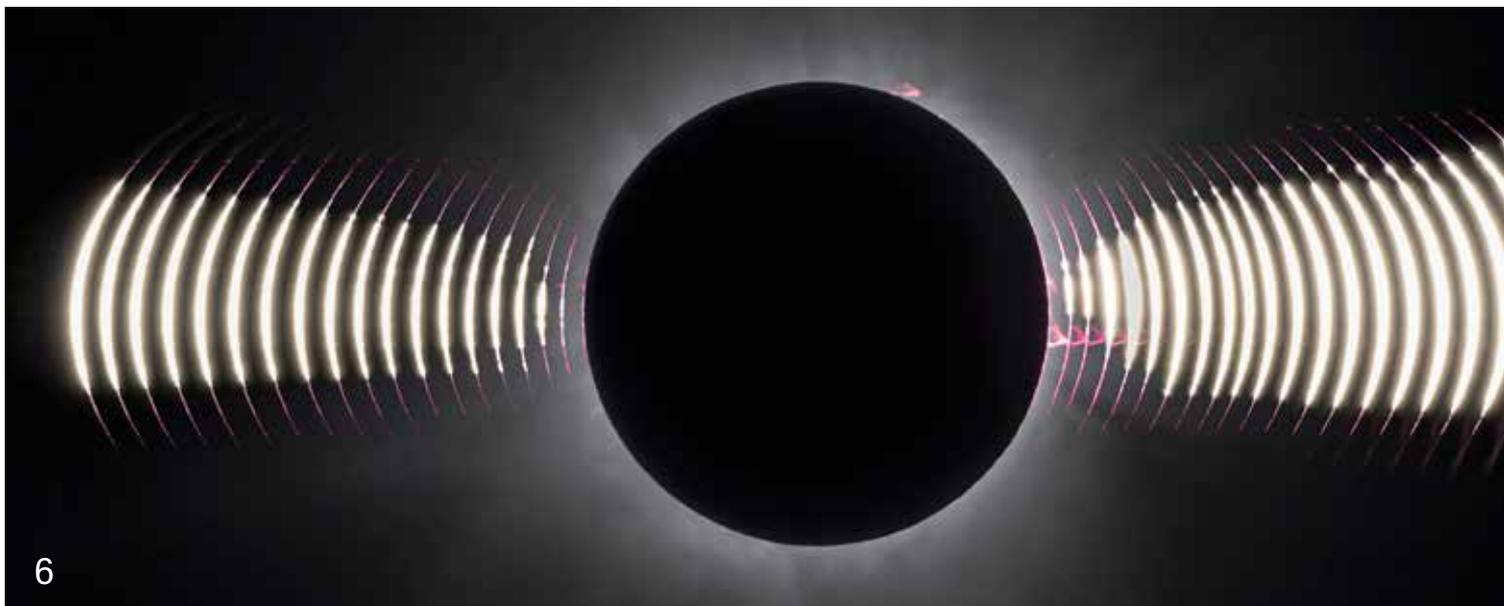
An A-10 Thunderbolt II attack aircraft makes its own eclipse of the Sun, as seen over Cape Girardeau, Missouri, during totality. This image is a screencap from video taken on a ZWO Seestar S50 smartscope.

• *Bonnie Tiedt*

**5. A TALE OF TWO CORONAE**

The Sun's outer atmosphere isn't the only corona in this image. An atmospheric corona — a ring around the Sun caused by sunlight diffracting through thin clouds — also appears in this diamond-ring shot taken from Mazatlán, Mexico.

• *Chirag Upreti*

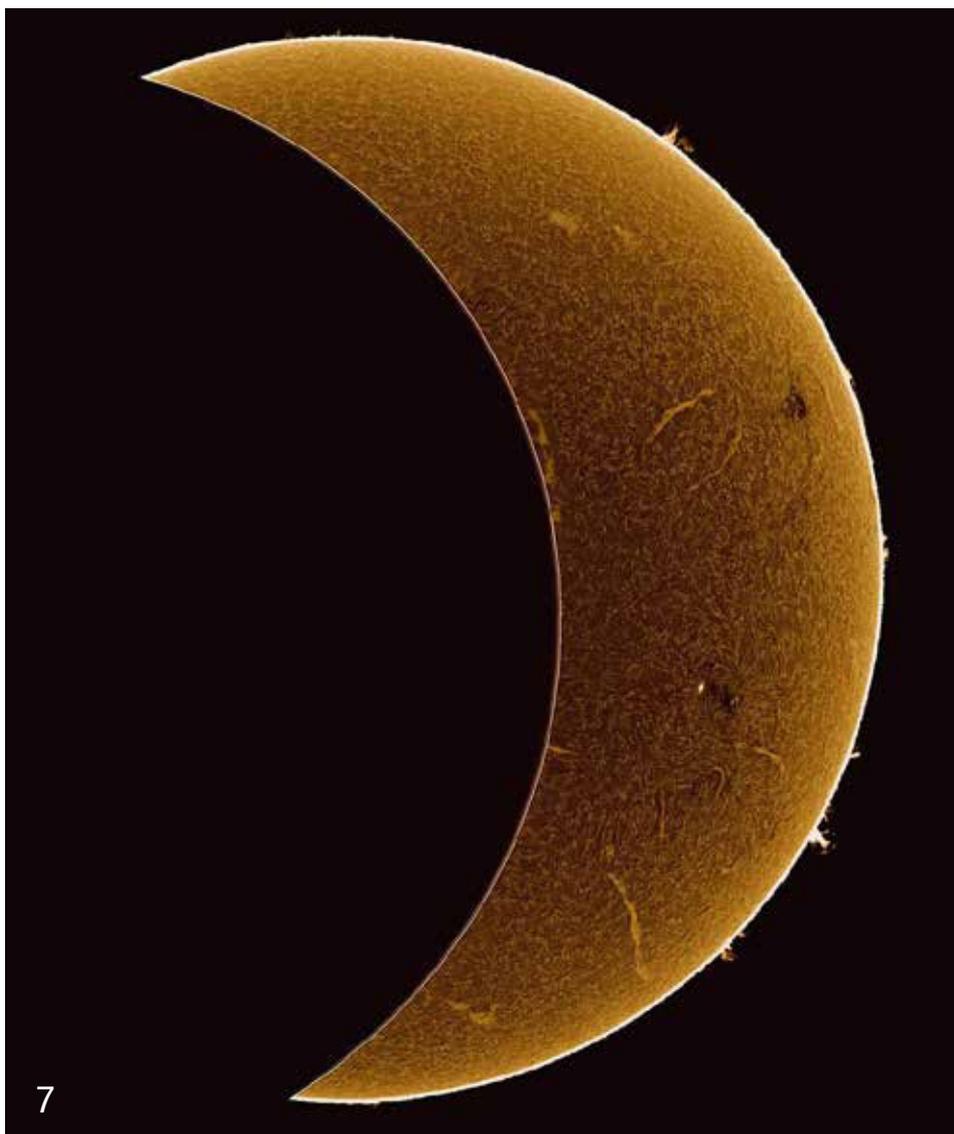


**6. BEADS AND BUTTON**

The appearance of Baily's beads — formed by sunlight streaming through low points on the Moon's limb — at both second and third contact is captured in this sequence taken from Sherman, Maine. The photographer used a Canon EOS R5 and 800mm lens at f/22 with a 2x teleconverter to take 1/1000-second exposures at ISO 200. • *Rathijit Banerjee*

**7. HERE COMES THE MOON**

The active Sun and its many filaments are eclipsed by the encroaching Moon in this partial-phase shot. The imager used a Lunt LS50 50mm H $\alpha$  solar telescope and a ZWO ASI178MM CMOS camera. • *Rich Ruffini*





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### 8. DIAMOND IN THE SKY

A diamond ring appears at second contact as the Moon slides across the Sun over Houlton, Maine. The photographer used a Canon EOS R5 and 500mm lens to take a 1/8-second exposure at f/9 and ISO 200. - *Falu Bakrania*

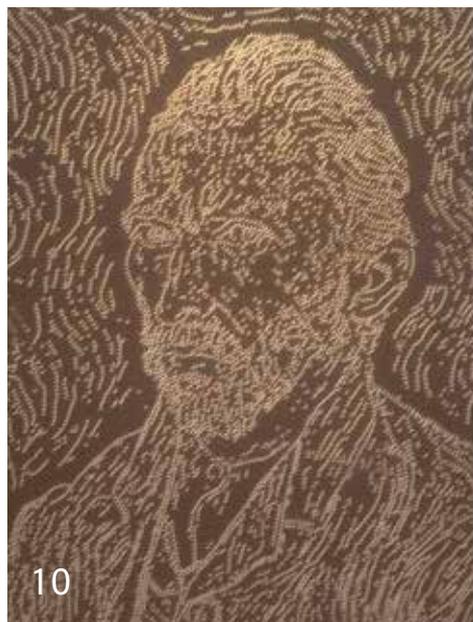
### 9. TOTAL IMMERSION

The progression of the eclipse is captured in this composite from Burlington, Vermont. The eclipse frames were taken with a Canon full-frame DSLR and wide-angle zoom lens at 16mm and f/8, with exposures of 1/6400 second at ISO 400; the landscape shot was taken with an iPhone 13 Pro Max.

- *Gowrishankar Lakshminarayanan*



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### 10. STARRY DAY

The visage of Vincent van Gogh is rendered in crescent Suns in this pinhole-projected spin on pointillist art captured during the eclipse's partial phases in Paducah, Kentucky.

- *Clay Norton*

### 11. FILL LIGHT

A 1/8-second exposure reveals the shadowed side of the Moon lit dimly by earthshine in this composite taken from Lac Mégantic, Quebec. - *Philippe Moussette*



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



## A BEAST OF A DIFFERENT COLOR

Amateur astronomers are accustomed to seeing star-forming regions portrayed in dazzling colors. Ionized hydrogen that glows red tends to dominate these stellar nurseries, while dust that scatters light from hot blue stars adds pleasing contrast. Yet this is only what human eyes see. To the infrared detectors of the 4.1-meter Visible and Infrared Survey Telescope for Astronomy on Chile's Cerro Paranal, the star-forming regions in the southern constellation Chamaeleon take on ethereal shades of reddish-brown. Scientists chose to use these hues to emphasize subtle differences in this dusty area, which lies around 500 light-years from Earth. Pay particular attention to the image's lower-right quadrant, where jets spew from Herbig-Haro object 909A, a protostar on the first legs of its journey to becoming a Sun-like star. ESO/MEINGAST ET AL.

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