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50TH ANNIVERSARY EDITION: FIRST MOON LANDING

JULY 2019

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SPECIAL ISSUE

APOLLO 11 REMEMBERED

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- See Brian May's amazing 3D images of Apollo 11 p. 34
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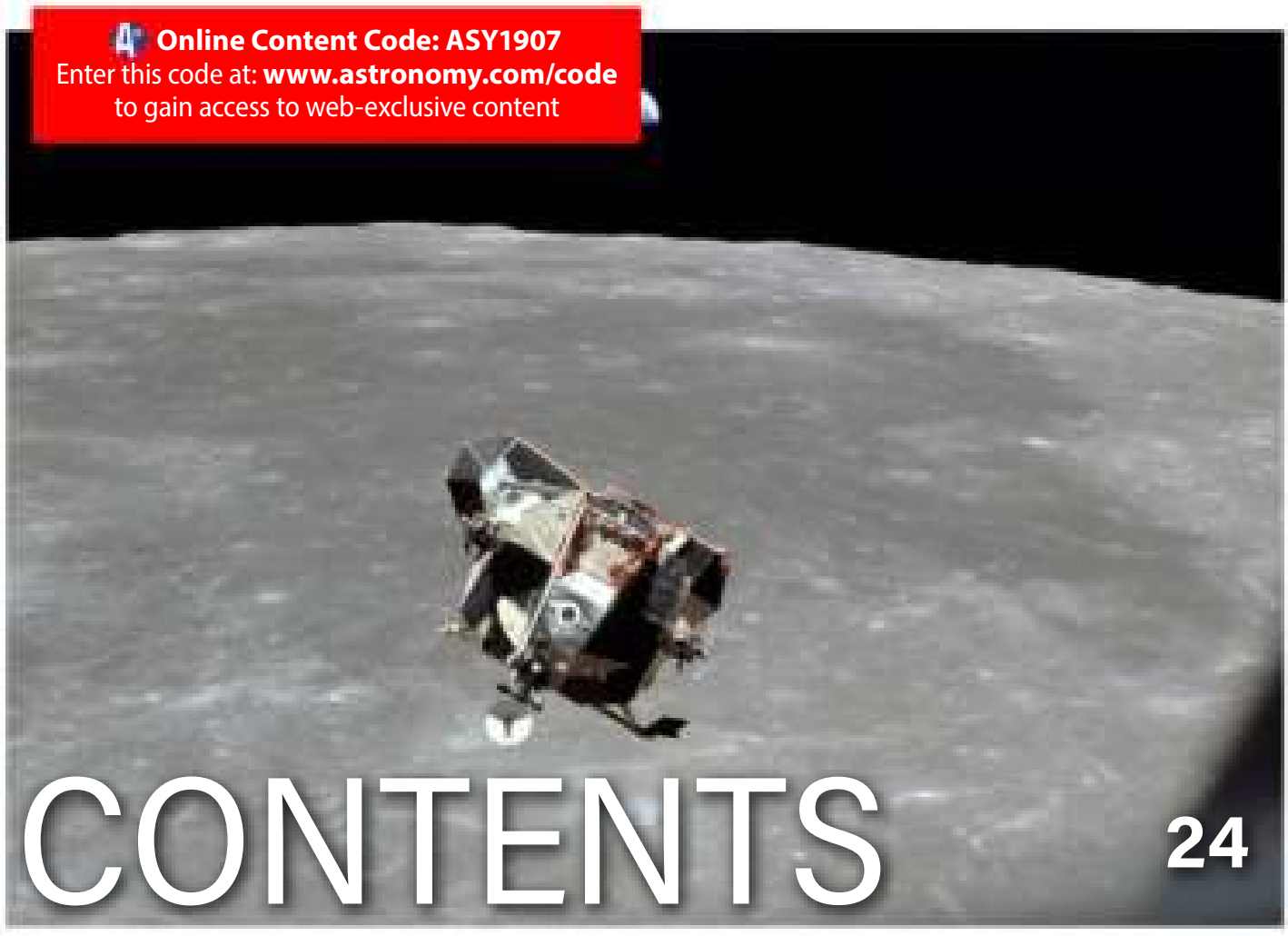
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Buzz Aldrin stands on the Moon in the most iconic image of the Space Age, shot by Neil Armstrong. NASA

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The magic of Apollo 11



Buzz Aldrin's iconic bootprint picture is one of the key images in the history of space exploration. NASA/JSC

I remember it like it was yesterday. (Well, OK, not yesterday. It was 50 years ago.) As an excited 7-year-old kid interested in space, I was abuzz to watch the first Moon landing. I remember receiving special parental permission to stay up late.

It was July 20, 1969 — an amazing time in history. Richard Nixon loomed over the White House, not yet implicated in the crimes that would bring him down. The first troop withdrawals began in Vietnam, a process that would last another six years. Preparations were commencing for the Woodstock music festival in upstate New York the following month.

And the inhabitants of planet Earth were waiting to see Neil Armstrong and Buzz Aldrin step out of the lunar module (LM) and take the first steps on another world. Overhead, Michael Collins, in the command module, circled the lunar surface and occasionally peered down toward his colleagues. The pair had landed at "Tranquillity Base," in the Sea of Tranquillity, near West Crater.

The approach and landing were nerve-wracking. As Armstrong piloted the LM downward, the craft had only seconds of fuel left. Avoiding a bumpy surface and any boulders was key to the moment.

At 10:51 P.M. EDT, Armstrong took his first steps down the ladder of the LM toward the Moon's surface. As a billion people or more watched on TV back home, he touched down on the powdery soil and then uttered the famous words: "That's one small step for [a] man, one giant leap for mankind." (Armstrong reported that he said "for a man," although the "a" was not audible in the transmission. It may have been a casualty of his slight slurring of the words or of transmission static.)

Armstrong became the first human to set foot on another world, and Aldrin followed a short time later. Their historic first moonwalk lasted 2 hours 31 minutes.

Subsequent missions would make more and longer moonwalks, collecting far greater numbers of Moon rocks for study. Ultimately, they would help to develop the most important discovery from Apollo data: that the Moon originated from a hypothesized ancient giant impact between a Mars-sized planetesimal and Earth.

Later missions brought lunar rovers, the world's most expensive cars. They covered much more territory, lasted longer, and accomplished far more science.

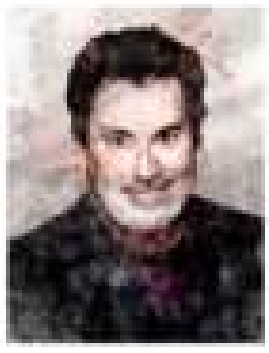
But nothing quite captured the drama of the first mission to land, Apollo 11. I hope that you will enjoy this month and the many retrospectives that look back on 50 years ago. Let's hope it doesn't take another 50 years to return to our closest cosmic neighbor.

Yours truly,



David J. Eicher
Editor





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ASTRO LETTERS



M94 is the brightest galaxy in the Canes Venatici constellation.
ADAM BLOCK/NOAO/AURA/NSF

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

Correction

On page 54 of the April issue, we mistakenly used an image of M63 as M94. (The M63 image is correct on page 55.) Here is the image we should have used.

Spotting Jupiter

I'm writing in response to Stephen James O'Meara's recent "Naked-eye Mars in daylight" column in the February 2019 issue. I live in southwest Utah, and 2012 was a banner year for us. We had an annular eclipse in May, Venus transiting the Sun in June, and the Moon occulting Venus in August. This last event was unfortunately clouded out by rain, but I did get to see Venus before the clouds moved in.

As I was watching the occultation, I spotted Jupiter in daylight through a break in the clouds. I attribute this to knowing where the giant planet was in relation to the Moon and Venus, its brightness, and pure luck. I can usually spot a bright Venus in the daylight after I locate it with binoculars, but this was the only time I have seen Jupiter during the daytime with the naked eye.
—Joe Muska, Cedar City, UT

Galactic greatness

"All About Galaxies" in the March 2019 issue is the best-ever presentation of galaxies and how they form in the universe. Congratulations are in order to all the writers for their presentations of historical contexts and the latest discoveries. Too often we forget that this work is done by men and women who are dedicated to answering questions, seeking facts, and questioning the understandings of our universe. Their challenge is to present this information in a way that is understandable to most readers, which is tough in our new age of science. Again, thank you, and congratulations on an outstanding edition. **—Donald Craig,** Indianapolis, IN

Savoring the special edition

Just a note to gush about "The Milky Way Inside and Out." I read it straight through, with increasing wonder and delight. I've never seen such a collection of readable, informative articles about the Milky Way in one place before. The whole production was top-notch and easily accessible to laymen like me. This magazine will be consulted repeatedly, with much pleasure.
—Burnis Tuck, Fresno, CA



SNAPSHOT

SPEEDING PULSAR

This neutron star could travel the Earth-Moon distance in six minutes flat.



COMPOSITE BY JAYANNE ENGLISH, UNIVERSITY OF MANITOBA, USING DATA FROM NRAO/F. SCHINZEL ET AL., DRAO/CANADIAN GALACTIC PLANE SURVEY AND NASA/IRAS. BOTTOM FROM LEFT: NAOJ; NASA/JPL-CALTECH/AGENZIA SPAZIALE ITALIANA; NASA/JPL-CALTECH/UCLA/MPS/DLR/IDA

Scientists recently discovered a bizarre neutron star brightly beaming out energy as it hurtles through space. The pulsar, named J0002+6216, is a rapidly rotating neutron star left over from a supernova explosion. Spinning 8.7 times per second, the pulsar gives off bursts of radiation like a lighthouse as seen from Earth, alerting astronomers to its whereabouts and motion. When they homed in on the object with NASA's Fermi Gamma-ray Space Telescope, they found a tail of radio emissions trailing behind it. Pointing directly at the supernova remnant that created it, the orange tail indicates the pulsar is blasting away from the explosion. Based on their calculations, astronomers think the pulsar is fleeing the remnant at 2.5 million mph (4 million km/h), putting it among the fastest 2 percent of pulsars ever measured. Luckily, it isn't heading toward Earth; instead, its quick speed will eventually launch the pulsar out of the Milky Way entirely.

— KOREY HAYNES, AMBER JORGENSON

HOT BYTES



HIDDEN GIANT

Japanese astronomers found a 30,000-solar-mass black hole hiding in an interstellar gas cloud by watching the gas swirl around the massive object.



FAMILIAR TERRAIN

Slot canyons spotted by Cassini on Saturn's moon Titan may form like those on Earth — through sporadic heavy flooding, but of methane, not water.

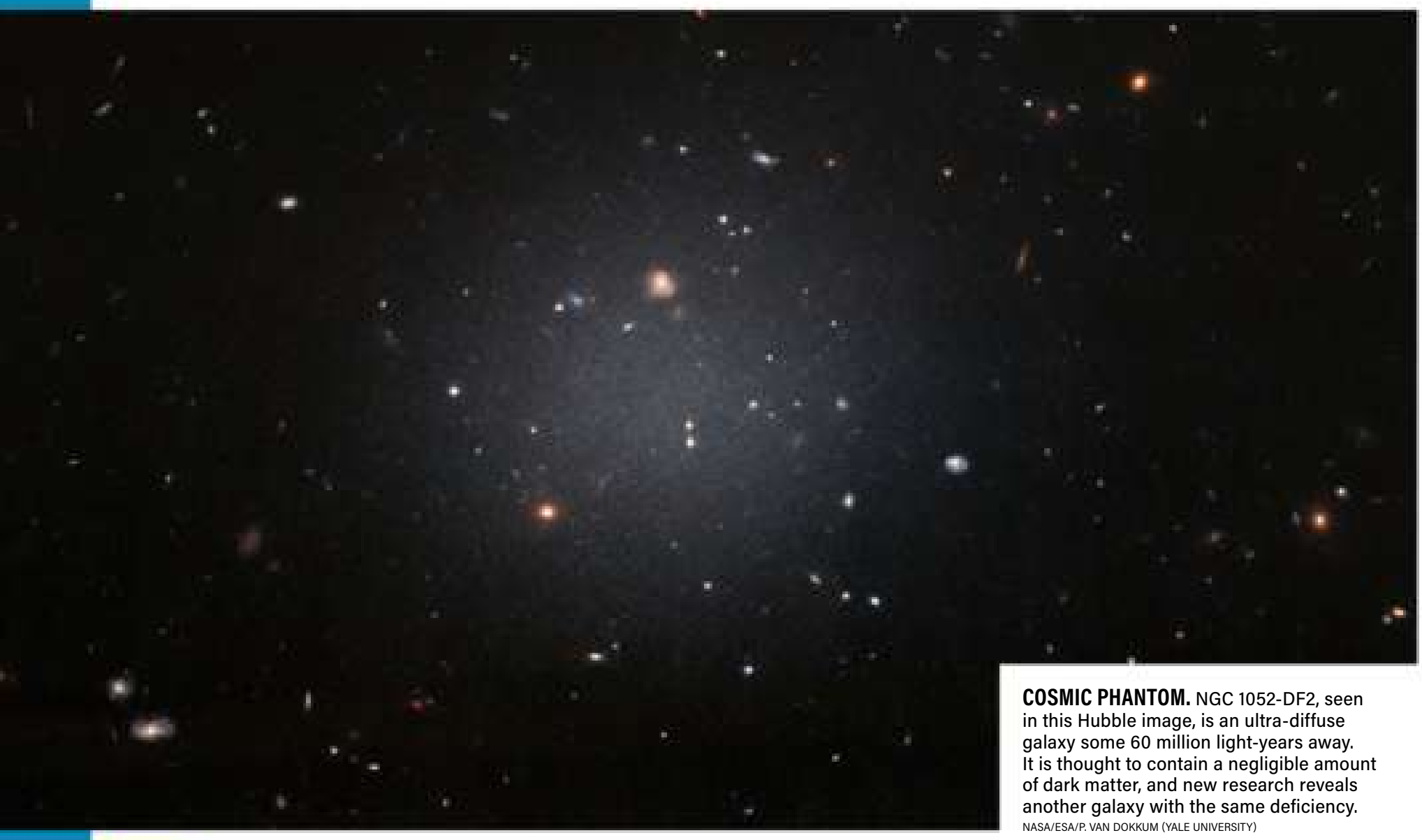


COSMIC CONNECTION

Researchers traced meteorites that fell near Sariçiçek, Turkey, to the impact that created a 22 million-year-old crater on the dwarf planet Ceres.

TWO GHOSTLY GALAXIES LACK DARK MATTER

New findings make an ironically compelling case for the existence of the mysterious material.



COSMIC PHANTOM. NGC 1052-DF2, seen in this Hubble image, is an ultra-diffuse galaxy some 60 million light-years away. It is thought to contain a negligible amount of dark matter, and new research reveals another galaxy with the same deficiency.
NASA/ESA/P. VAN DOKKUM (YALE UNIVERSITY)

Last year, astronomers were flabbergasted when they discovered a galaxy almost entirely devoid of dark matter. As the first galaxy ever found lacking the elusive substance — which is thought to account for 85 percent of the universe's mass — the find left some researchers delightfully intrigued, and others understandably skeptical.

"If there's [only] one object, you always have a little voice in the back of your mind saying, 'But what if you're wrong?'" said astronomer Pieter van Dokkum of Yale University, who led last year's groundbreaking study, in a press release. "Even though we did all the checks we could think of, we were worried that nature had thrown us for a loop and had conspired to make something look really special whereas it was really something more mundane."

Now, in new research published in *The Astrophysical Journal Letters* March 27, van Dokkum and his team have confirmed their previous work: The ghostly galaxy NGC 1052-DF2 (DF2 for short) has virtually no discernible dark matter. Furthermore, a second study published March 20 in the same journal announced the detection of yet another dim and diffuse galaxy, named NGC 1052-DF4 (or DF4), which also has an apparent dearth of dark matter.

Taken together, these papers suggest DF2 is not unique, but instead part of a larger, previously unknown population of galaxies that have somehow avoided or lost most of their dark matter. The new results may have dramatic implications for prevailing theories about the formation and evolution of galaxies, as well as the true nature of dark matter itself.

DISCOVERING AN ODDBALL

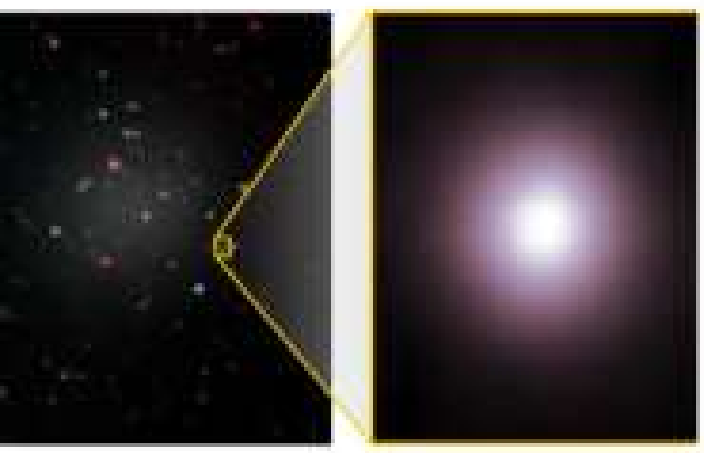
The strange galaxy DF2 is a member of a relatively new class of galaxies called ultra-diffuse galaxies (UDGs). Though

UDGs can be quite large in size, these faint specters contain far fewer stars than your average galaxy, making them difficult to spot.

Specifically, DF2 is a hazy galaxy that's part of a larger group dominated by the massive elliptical galaxy NGC 1052. Initially, the researchers were drawn to DF2 because it didn't appear the same in images captured by the Dragonfly Telephoto Array and those obtained by the Sloan Digital Sky Survey (SDSS). Dragonfly saw DF2 as a blob of dim light, while SDSS saw a group of pointlike sources. Upon closer examination with Hubble's Advanced Camera for Surveys and the 10-meter W.M. Keck Observatory, the researchers determined DF2 is a transparent UDG that rivals the Milky Way in size but contains roughly 200 times fewer stars.

Van Dokkum and his team identified 10 globular clusters (large groups of old stars) within DF2 and measured their speeds, finding the clusters are moving three times slower than expected. This suggests that DF2 contains, at most, a minuscule amount of dark matter because if it had more mass than what's visible, the clusters would orbit the galaxy much faster.

Because one of the major tenets of good science is reproducibility, van Dokkum and his team have spent the past year using the Keck Cosmic Web Imager (KCWI) to improve the precision of their previous measurements. By using KCWI to carry out high-resolution spectroscopy on DF2's diffuse starlight, the team obtained even more precise speed measurements for stars within DF2. They again calculated the galaxy's mass, and as before, the results show the amount of dark matter in DF2 is basically nil.



CLOCKING A GALAXY. To determine how quickly stars revolve around DF2, researchers first analyzed the velocities of 10 globular clusters, like the one seen in this inset. This allowed them to determine the clusters' average speed around the galaxy's center, which was used to calculate the overall mass of the galaxy. GEMINI OBSERVATORY/NSF/AURA/W.M. KECK OBSERVATORY/JEN MILLER/JOY POLLARD

DOUBLING DOWN

Meanwhile, while working to confirm DF2 is truly a galaxy deficient in dark matter, the researchers were simultaneously searching for a second galaxy made exclusively of normal matter. And they found it: DF4.

DF2 and DF4 are similar in terms of size, surface brightness, morphology, and distance. Because of this, their paper says, "We conclude that NGC 1052-DF2 is not an isolated case but that a class of such objects exists. The origin of these large, faint galaxies with an excess of luminous globular clusters and an apparent lack of dark matter is, at present, not understood."

With a sample size of only two galaxies, it's still hard to draw any sweeping conclusions. But because the effects of dark matter are evident in every other known galaxy except DF2 and DF4, the team's findings indicate dark matter is a tangible material that is separable from normal matter. If confirmed, this would mean some alternative theories to dark matter — such as Modified Newtonian Dynamics, which introduces extra gravitational forces on galactic scales — fall flat.

"We hope to next find out how common these galaxies are and whether they exist in other areas of the universe," said Shany Danieli, a graduate student at Yale University and lead author of the latest study on DF2. "We want to find more evidence that will help us understand how the properties of these galaxies work with our current theories. Our hope is that this will take us one step further in understanding one of the biggest mysteries in our universe — the nature of dark matter."

— JAKE PARKS

QUICK TAKES

FARTHER REACHES

If confirmed, a newfound dwarf planet some 140 times farther from the Sun than Earth, nicknamed FarFarOut, will become the most distant known object in the solar system.

FLUES OPEN

Two newly found exhaust vents, dubbed "galactic center chimneys," are channeling matter and energy away from the Milky Way's supermassive black hole.

TEAMING UP

NASA has its first international partner for the planned Gateway lunar outpost: Canada.

TIGHT-KNIT

Astronomers have spotted massive twin stars nestled closer together than any pair found so far. They orbit each other at some 30 AU, or about the distance between the Sun and Neptune.

FLARE-UP

NASA research has found herpes viruses reactivate, though often without symptoms, in 61 percent of the astronauts on longer missions to the International Space Station.

HOP TO IT

Sparse water molecules stuck in the Moon's soil remain tightly bound until temperatures peak around lunar noon. Then, the water can escape and briefly bounce along the surface.

SILVER LINING

A new silver- and ruthenium-based antimicrobial coating applied to the toilet door of the International Space Station dramatically reduced the number of bacteria present.

BYE-BYE

A hypervelocity star leaving the Milky Way at more than 1 million mph (1.6 million kph) may have been kicked from our galaxy by an intermediate-mass black hole. — J.P.



IN PIECES. Smacking an asteroid with a bomb or a smaller asteroid should shatter it into manageable pieces, right? Wrong. A new study says this scenario isn't likely after a minor collision. Instead, the ejected particles will fall back onto the core of the asteroid in just hours. NASA/JPL-CALTECH

Asteroids are tougher than we thought

In many science fiction stories, a bomb is deployed to shatter a life-threatening asteroid headed toward Earth. But a study published March 15 in *Icarus* shows that breaking up asteroids is actually quite difficult.

"Asteroids are stronger than we used to think and require more energy to be completely shattered," said lead author Charles El Mir, of the Johns Hopkins University's Department of Mechanical Engineering, in a press release.

El Mir's team simulated the aftermath of a collision between a 15-mile-wide (25 kilometers) asteroid and a 0.75-mile-diameter (1.21 km) basalt impactor traveling at 3 miles (5 km) per second. They used recent advancements in our understanding of how rocks fracture and improved computer code to model the impact in two different stages.

First, a material model followed short-term fragmentation inside the asteroid within just a fraction of a second. Then, the code handed over the calculations to a different type of model, called an N-body model, which ran for hours after the collision, as the asteroid's gravity influenced small pieces that might have been knocked away.

The initial strike caused millions of internal cracks to develop as the areas nearest the impact flowed like sand, forming a crater. But those cracks didn't completely shatter the asteroid. Instead, they left a body large enough to gravitationally retrieve the pieces that had flown off, ultimately leading to the asteroid reassembling itself.

These results differ significantly from studies in the early 2000s, when code was used to simulate an identical collision, but led to a shattered asteroid. The older code, the researchers say, could not take into account the smaller-scale processes during the initial collision. Because cracks propagate through an asteroid with limited speed, the authors say, they can't easily break it apart.

Although the new work indicates a Hollywood-style explosion wouldn't stop an incoming asteroid, it is a step toward determining how to act in such a situation. The work also has applications, the researchers say, for asteroid mining, because material thrown off during the collision ended up scattered back over the surface — potentially exposing internal riches for easier access. — ALISON KLESMAN

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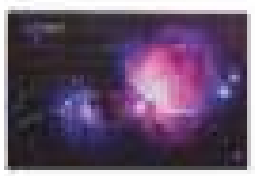
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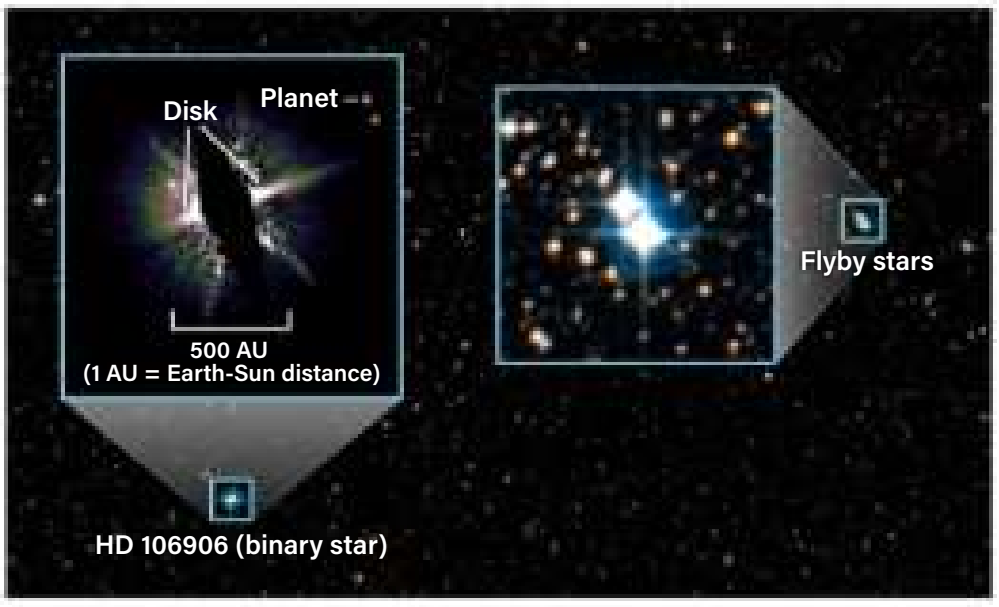
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Passing stellar duo prevents exoplanet from escaping



PAIR OF PROTECTORS. Exoplanet HD 106906 b was likely saved from being kicked out of its home system because of two passing stars. PAUL KALAS, UC BERKELEY

New observations of a distant exoplanetary system offer proof of a long-standing theory: Passing stars can change planetary orbits, for better or worse. The new evidence implies such stellar flybys might even help explain the paths of strange objects, such as the interstellar asteroid 'Oumuamua or the proposed Planet Nine.

To carry out the study, astronomers Paul Kalas and Robert De Rosa used observations from the Gaia spacecraft to analyze how an ancient flyby influenced the exoplanetary system HD 106906, located some 300 light-years from Earth. This system has a pair of stars at its center and a massive planet (HD 106906 b) 11 times the size of Jupiter orbiting around them. But the planet's orbit is suspicious: It's highly eccentric, meaning it sometimes zooms close to the stars but also swings out to more than 700 times the Earth-Sun distance.

When scientists spotted this weird world, they were skeptical that it could have formed in such an odd orbit. So how did it get there?

In research published February 28 in *The Astronomical Journal*, the team suggests the planet formed closer in with a more circular orbit. But over time, repeated kicks from its pair of host stars pumped up its eccentricity. After enough encounters, the researchers say, the planet could have been thrown out of its system entirely (which is how astronomers think objects like 'Oumuamua are flung into interstellar space).

But this exoplanet wasn't completely cast out. Instead, something stabilized its elongated orbit, nudging the planet just far enough from its parent stars to avoid ejection. Kalas and De Rosa looked at 461 stars near the system and found just one star — rather, a binary pair — that likely passed close enough to do the trick.

Kalas explained that something similar probably happened in our solar system, too. Take Planet Nine: "If it exists," says Kalas, "it's a distant planet that never approaches close to the rest of our planetary system," meaning some force had to push it farther out.

"Jupiter can send things to great distances," Kalas says. "But those objects come back to where they started and interact with Jupiter again. ... The only way to detach [Planet Nine] from repeated encounters with Jupiter is for some external force to give it an extra kick to move it farther away from the Sun." That kick would need to come from another massive object, like a passing star.

Even though astronomers haven't yet found a star that could have pushed out the hypothetical Planet Nine, we do know that Scholz's star swung through the outer fringes of our solar system some 70,000 years ago, so the notion is certainly reasonable. According to Kalas, with this new research, we now have proof that such stars do influence the systems they brush past. —K.H., J.P.



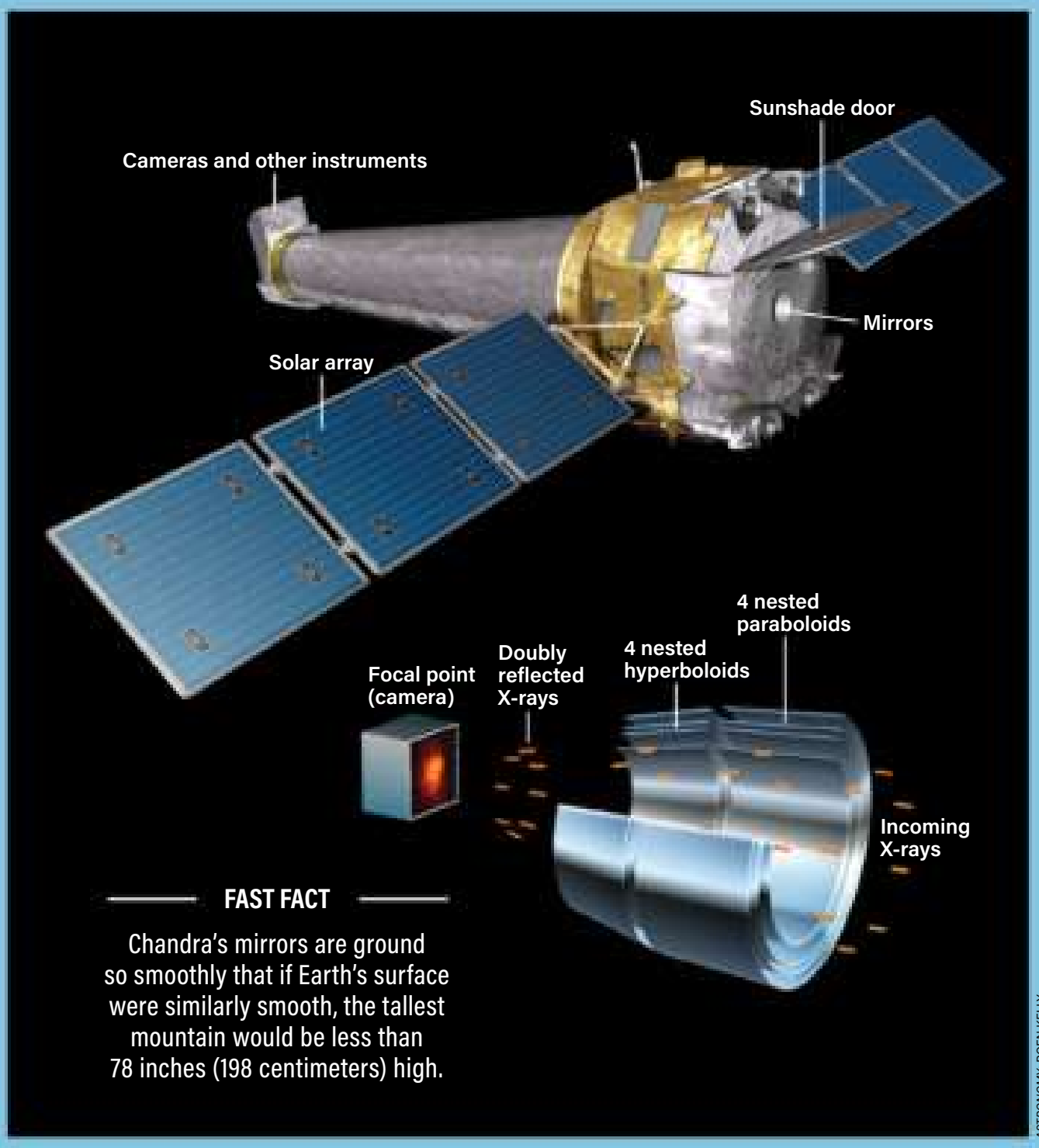
ESA/NASA/HUBBLE/A. ADAMO ET AL.

COSMIC COLLISION

This vibrant image shows a pair of intertwined galaxies known as NGC 6052, some 230 million light-years away in the constellation Hercules. In this photo captured by the Hubble Space Telescope's Wide Field Camera 3, two separate galaxies are in the middle of merging. Over the course of hundreds of millions of years, this collision will fling countless individual stars into wide, new orbits. Eventually, the stars from each galaxy will intermingle to the point where the two galaxies' initial shapes will no longer be recognizable. Even though billions of stars are being flung about, the extreme vastness of interstellar space means that the odds of any two stars actually colliding are practically non-existent — giving this fender bender a (hopefully) happy ending. —J.P., A.J.

HOW DOES CHANDRA WORK?

X-RAY VISION. The Chandra X-ray Observatory, celebrating its 20th anniversary July 23, 2019, is not like a conventional optical telescope. Optical telescopes use curved mirrors mounted perpendicular to incoming light to gather photons and bring images to a focus. But X-rays penetrate these materials, rather than bounce off to form an image. Instead, Chandra uses four pairs of mirrors mounted *parallel* to the path of incoming X-ray photons. When photons hit the barrel-like mirrors, they graze instead of striking the surfaces directly; this process guides the high-energy X-rays to focus at the telescope's detectors for observation. –A.K.



FAST FACT

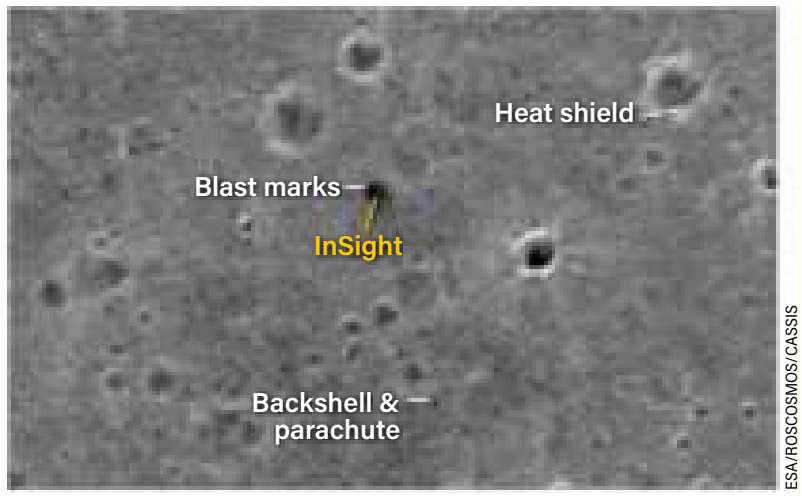
Chandra's mirrors are ground so smoothly that if Earth's surface were similarly smooth, the tallest mountain would be less than 78 inches (198 centimeters) high.

ASTRONOMY: ROEN KELLY

1.5 trillion

The total mass of the Milky Way, in solar masses, according to a study analyzing the orbits of globular star clusters. Most of the mass is dark matter.

Martian meetup



ESA/ROSCOSMOS/CASSIS

The main goal of ESA-Roscosmos' Trace Gas Orbiter (TGO) is to track sources of atmospheric gases on Mars, but it isn't too busy to say hello to a friend. Hovering above the Red Planet's Elysium Planitia region, TGO snapped this picture of NASA's InSight lander shortly after the craft touched down on Mars. As InSight descended, its powerful rockets blew dust off the martian surface, creating the dark patch in which the lander now sits. TGO also captured InSight's heat shield, which was discharged shortly before landing, and its backshell, which protected the lander during descent. TGO will continue to monitor the region surrounding InSight, looking for nearby meteorite impacts that the lander may detect with its highly sensitive seismometer. –A.J.



ESO

The Bat flies at night

In a dark, ominous corner of Orion lies a faint bat fluttering through space. A hazy nebula sitting 2,000 light-years from Earth, NGC 1788's distinct silhouette has earned it a proper nickname: the Cosmic Bat. Though NGC 1788 is invisible to the naked eye, ESO's Very Large Telescope recently captured this photo of the nebula, the most detailed image of the Cosmic Bat to date. Shrouded in thick clouds of dust and gas, the nebula itself doesn't give off any light, but is rather illuminated by the bright young stars that shine through its core. Astronomers believe that powerful stellar winds, gusting from massive nearby stars, sculpted the batlike clouds and gave the nebula flight. –A.J.

19,000

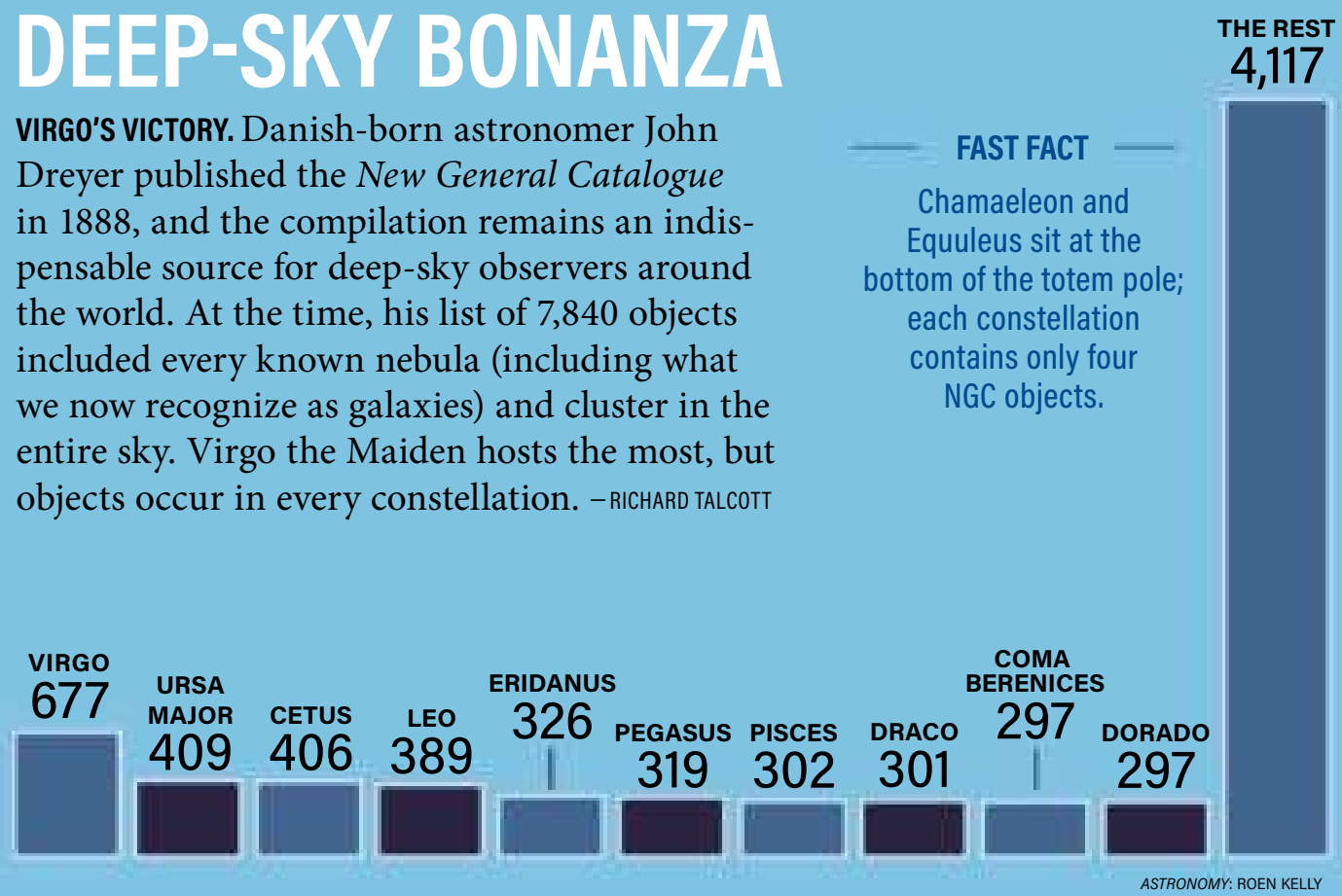
The number of hours of recorded audio during Apollo 11, now completely converted from analog tape to digital through a collaboration between NASA and the University of Texas at Dallas.

DEEP-SKY BONANZA

VIRGO'S VICTORY. Danish-born astronomer John Dreyer published the *New General Catalogue* in 1888, and the compilation remains an indispensable source for deep-sky observers around the world. At the time, his list of 7,840 objects included every known nebula (including what we now recognize as galaxies) and cluster in the entire sky. Virgo the Maiden hosts the most, but objects occur in every constellation. –RICHARD TALCOTT

FAST FACT

Chamaeleon and Equuleus sit at the bottom of the totem pole; each constellation contains only four NGC objects.



ASTRONOMY: ROEN KELLY

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CELEBRATE APOLLO 11

Suddenly, the chaotic moon discovered that its neighbor planet had become alive and aware. With poetic images, *The Shadows Moving in the Moon's Skull Eyes* uses Apollo 11 to contrast the dead moon and the living Earth.

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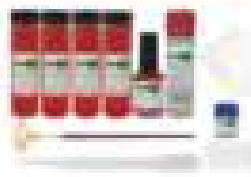


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LOCKED IN PLACE. Two primitive populations of asteroids, known as Trojans, congregate at stable points along Jupiter's orbit, and one camp has more asteroids than the other. Researchers investigating the discrepancy ran simulations that traced how the giant planets moved through the early solar system, helping them determine which migration scenario best aligns with the Trojan populations we see today.
ASTRONOMY: ROEN KELLY

Trojan asteroids reveal Jupiter's great migration

» Jupiter likely went on an inward journey through the solar system early in its life, new research published March 27 in the journal *Astronomy & Astrophysics* suggests. And it turns out it was quite the trip.

Although Jupiter now sits an average distance of 5.2 astronomical units from the Sun (an AU is the average Earth-Sun distance of 93 million miles [150 million kilometers]), the core of the gas giant likely formed some 18 AU away, according to the study. That's about twice as far as present-day Saturn. Furthermore, Jupiter apparently made its inward journey in about 700,000 years, just a blink of the eye in astronomical terms.

The idea of a wandering Jupiter is not new, but "this is the first time we have proof that Jupiter was formed a long way from the Sun and then migrated to its current orbit," said lead author Simona Pirani, a doctoral student at Lund University in Sweden, in a press release. "We found evidence of the migration in the Trojan asteroids orbiting close to Jupiter."

Jupiter's Trojan asteroids are a mysterious bunch. More than 8,000 of these dark, reddish bodies share an orbit with Jupiter, and they're divided into two main groups: the "Greek Camp," which leads the planetary goliath, and the "Trojan Camp," which trails behind. According to the study, the Greek Camp has between 40 and 100 percent more asteroids than the Trojan Camp.

"The asymmetry has always been a mystery in the solar system," said co-author Anders Johansen, a professor of astronomy at Lund University.

To investigate why Jupiter has more Trojans in its vanguard than at its rear, the researchers ran numerous computer simulations that marched the early solar system through millions of years of evolution by 50-day increments.

After running the simulations, the team found the inward migration of the giant planets always resulted in a larger swarm of Trojans in front of Jupiter than behind it. As Jupiter travels inward — propelled by gravitational interactions between the fledgling gas giant and the Sun's protoplanetary disk — it creates a wider zone of gravitational stability in front of it, leading to a surplus of Greek Camp asteroids. Other evolutionary models that rely on Jupiter forming in its current position, however, result in equal numbers of asteroids in both camps.

According to the paper, "In our scenario explored here, the Jupiter Trojans are a primordial population in which Jupiter's core formed. Therefore, they hold precious information about the building blocks of our giant planets' cores." This suggests we can learn a lot about Jupiter's humble beginning from studying the Trojans.

And fortunately, NASA plans to do just that. Slated for launch in October 2021, the Lucy mission — named after a famous 3.2 million-year-old hominin fossil — aims to spend more than a decade exploring six different Trojans in the Greek and Trojan camps. By getting up close and personal with these dim diamonds in the sky, astronomers hope to unravel the mysteries of both Jupiter and the infant solar system. –J.P.

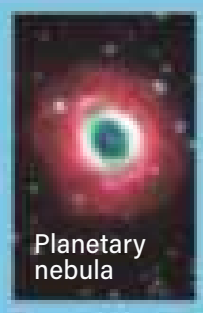
MEET THE NEBULAE

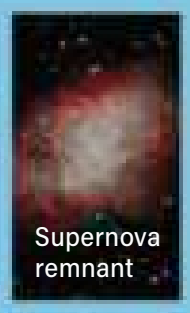
INTO THE MIST. The word *nebula* comes from the Latin word for "cloud" or "fog." And, indeed, nebulae are vast clouds of gas and dust. Astronomers usually divide nebulae into two categories: bright and dark. Observers, however, recognize these five types. – MICHAEL E. BAKICH


Reflection nebula


Emission nebula


Dark nebula


Planetary nebula


Supernova remnant

EMISSION NEBULA (LAGOON NEBULA, M8): TONY HALLAS. REFLECTION NEBULA (M78): DON GOLDMAN. DARK NEBULA (HORSEHEAD NEBULA, B33): ADAM BLOCK/MOUNT LEMMON SKYCENTER/UNIVERSITY OF ARIZONA. PLANETARY NEBULA (RING NEBULA, M57): GERALD RHEMANN. SUPERNOVA REMNANT (CRAB NEBULA, M1): BOB FERA

FAST FACT

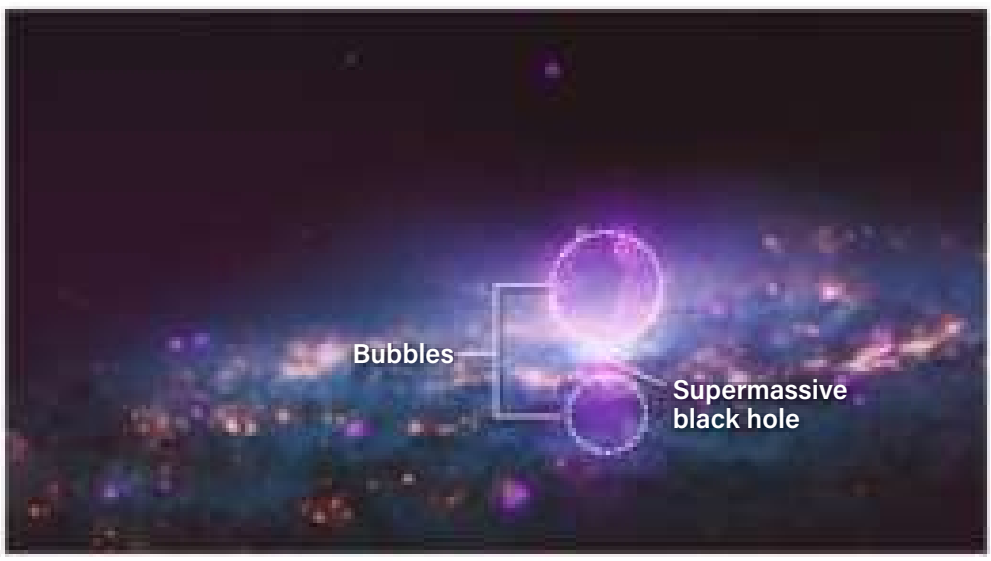
Only 12 objects (out of 109) in Charles Messier's catalog are nebulae.

$1.1 trillion

The estimated net worth of the United States' space economy by 2040, according to the wealth management company Morgan Stanley.

Black hole blows bubbles

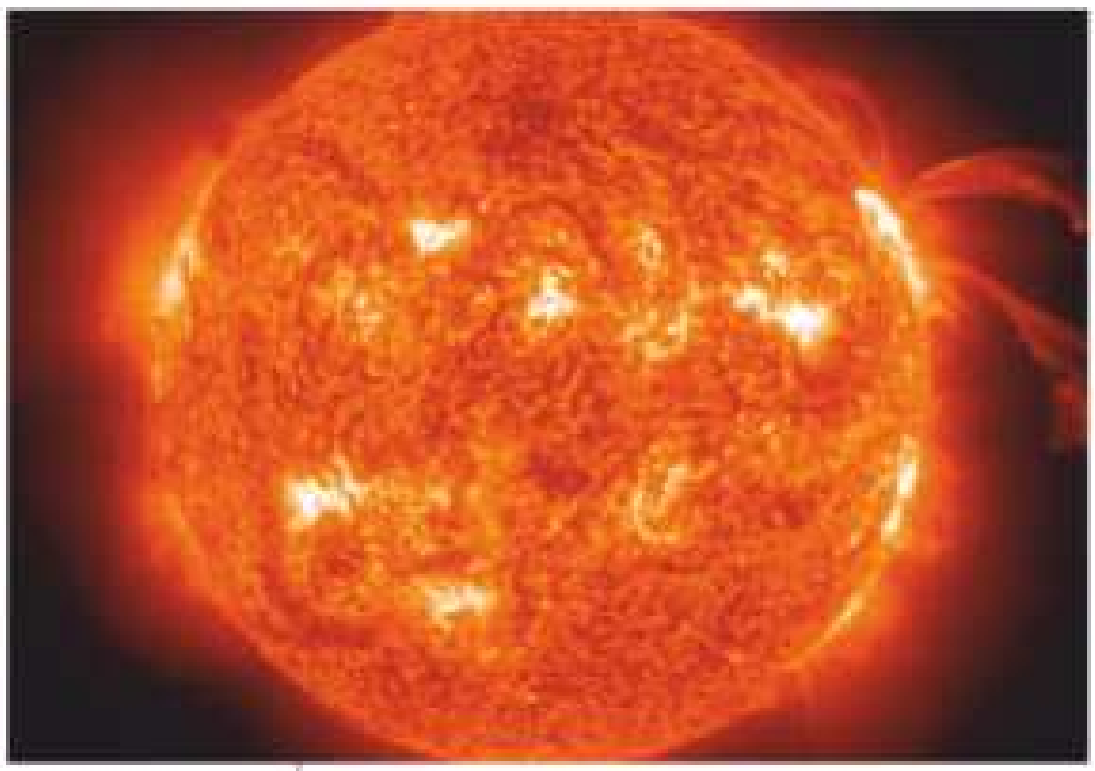
Blazing 67 million light-years from Earth is NGC 3079 — a galaxy that's bubbling up. Popping from the top and bottom of the galaxy are two gigantic "bubbles" of high-energy radiation. In this image, astronomers combined data from NASA/ESA's Hubble Space Telescope, which captured the galaxy in optical light (shown in orange and blue), and NASA's Chandra X-ray Observatory, which spotted X-rays (shown in purple and pink) spewing from the two bubbles. Stretching thousands of light-years in diameter, these balloons are believed to have formed when massive amounts of material fell toward the galaxy's supermassive black hole, causing it to spit high-energy particles, called cosmic rays, back into space. The discovery could help scientists trace the origins of cosmic rays, which regularly strike Earth from deep space. – A.J.



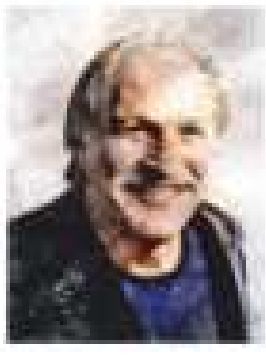
X-RAY: NASA/CXC/UNIVERSITY OF MICHIGAN/J-T LI ET AL.; OPTICAL: NASA/STScI

The Sun gets squirrelly

Amazing facts about our restless star.



In this June 2000 image of the Sun — captured by the Solar and Heliospheric Observatory at a wavelength of 304 angstroms (30.4 nanometers) — hotter areas appear lighter and cooler areas appear darker. Two prominences are erupting on the right side. SOHO (ESA & NASA)



BY BOB BERMAN
Join me and Pulse of the Planet's *Jim Metzner in my podcast, Astounding Universe, at* **www.astoundinguniverse.com**

For those in the Northern Hemisphere, the Sun is now at its highest point of the year. It screams out for attention. But it doesn't get much, since for many, the relationship is adversarial. We're warned to avoid its rays. Its ability to instigate skin tumors makes its July entry into the constellation Cancer weirdly morbid.

Some of us do spend money to view it more clearly, like with today's marvelous hydrogen-alpha instruments. Others obsessively travel to solar eclipses, which is why I'm now in Chile. But the most awesome Sun facts have not trickled into general awareness, and few seem aware that the Sun is acting very strangely nowadays.

Start with the most obvious: its disk, seen sometimes when the Sun wanders safely behind the right kind of cloud. The disk has a crisp, sharp edge. But shouldn't a ball of gas have a blurry, fuzzy circumference?

So, amazing fact No. 1 — let's call it AF1 — is that sunlight emanates solely from a thin incandescent layer just 200 miles (320 kilometers) deep. This is extremely shallow, less than 1/2,000th the Sun's radius. The photosphere is practically painted on, like shellac. No wonder the disk's edge looks so sharp.

But this layer merely releases the brilliance. The Sun's energy is created elsewhere, in its core, a teensy sphere just 1/200th the Sun's volume. If the core stood alone in the sky, it would be only a brilliant pinpoint with no discernible size, like a star, except nobody could safely look at it. Every second, this ball at the Sun's exact center emits the energy of 96 billion 1-megaton hydrogen bombs.

Arthur Eddington told us 101 years ago that the Sun's energy comes from hydrogen changing into helium, which uses up 4 million tons of the Sun per second. It's not some schoolroom abstraction. The Sun's weight actually decreases by 4 million tons per second. Call that AF2.

AF3 through AF6 blur together, so we'll stop itemizing. The Sun spins on its axis roughly once a month, just like the Moon. We've recently learned that the middle 70 percent of the Sun spins uniformly like a solid ball, but its outer 30 percent shows differential rotation, where the poles spin much more slowly than its equator. These layers meet at a newly found zone 130,000 miles (200,000 km) below the surface named the tachocline, where the awesome solar magnetic field originates.

The tachocline choreographs storm activity, manifested by sunspots — places where the local magnetic field is 5,000 times stronger than on the rest of the surface. This magnetic intensity constricts rising plasma so that it cools a bit. And yet, paradoxically, if the spots get scarce for an extended period, Earth cools down.

That's just what happened starting in 1645. During the entire reign of Louis XIV, ironically called the Sun King, there were few if any spots on the Sun for 70 years. The spots came back when the king died. Too weird. While they were gone, fishing colonies in Iceland and Greenland had to be abandoned. The Thames and the Venice Canals sometimes froze solid.

Few seem aware that the Sun is acting very strangely nowadays.

All this is important because the sunspot cycle has been very weird lately. Cycle number 24, which began in 2008, was delayed years because of a bizarrely extended sunspot absence at the end of cycle 23. Then when 24 peaked in 2013, it had only half the normal storms — behavior unseen in more than a century. Late last year, cycle 24's minimum arrived two years ahead of schedule, with another anomalously deep and extended sunspot absence. Everyone's wondering what cycle 25 will be like.

It should begin right around now and peak around 2024. Will it also be wimpy? Is the Sun entering a period of extended inactivity, as many researchers believe? If it's anemic, could it even herald the start of another lifetime-long sunspot absence that would cool Earth at the best possible time by mitigating anthropogenic climate and ocean warming?

We can only watch and wait.

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Tree through a window

Perceiving the process of perception.



An eye, carefully perceived and perceptively drawn by the author. JEFF HESTER

Sixty may be the new 40 and all that, but it's still not a bad time to take a gander at progress on the old bucket list. I've always wanted to learn to draw, so a couple of months ago, I settled on a nice drawing app for my tablet, signed up for some online drawing classes, and took the plunge.

Since then, my world has changed, and I don't mean that metaphorically. The world of my conscious experiences and perceptions — the only world that I will ever directly know — is now a different place than it was before I picked up a pencil.

Let me give you an example of what I mean: eyes. Until very recently, had you handed me a pencil and asked me to draw an eye, I would have handed you back a football with a basketball in the middle, and a handball in the middle of that. There might have been some Charlie Brown eyebrows, just for effect. Sure, I knew there was other stuff going on, but that pretty well captures the basics. Right?

How could I have been so blind? Over the last few weeks, I've probably weirded out a person or two by staring intently into their eyes for no apparent reason. Suddenly I can't help but see the fascinating, elegant, uniquely flowing forms that cradle the organs responsible for focusing and detecting light from the world around us.

I've probably weirded out a person or two by staring intently into their eyes for no apparent reason.

And pupils! The pupils veritably dance with reflections of the world. I swear those didn't used to be there! I'm certain I would remember if they had been.

OK, of course they were there. I knew that intellectually. But now they are just there. I cannot not see them. I cannot not see the world around me in those reflections. As an astrophysicist, I cannot not see the optics that form the crisp and suddenly ever-present anamorphic images in a cornea's curved surface.

I try not to gawk.

Again, nothing in the world around me has changed since I started learning to draw. But the world I consciously inhabit is now noticeably a different place.

In my February 2018 column, "Constrained hallucinations," I talked about the counterintuitive way that our brains construct our perceptions of the world. Our senses do not show us the world, no matter how much it seems that they do. Instead, our brains construct near-real-time models (simulations) of the world around us, then use those models to make predictions. Those predictions are then tested against data from the senses. After being modified to resolve discrepancies between prediction and data, the brain's simulation of the world becomes our conscious perceptions.

In short, we live inside a Matrix of our own making. Our senses do not show us the world. Instead, they provide error signals that help tether our constructed perceptions, however loosely, to objective reality.

By the way, your brain can't very well build meaning, understanding, and experience you don't have into its model of the world. Digging into the neuroscience of perception in the predictive brain is itself the kind of experience that reshapes our perceptions. Increasingly, I find myself consciously aware of the construction of my own conscious awareness. (No hallucinogenics involved, I swear!) I'm still wrapping my head around that.

When I started this column, I was thinking about the connections between art and science and the extraordinary ways that being an astrophysicist has altered my own perceptions. That still might make a good column someday.

But what I really want to do right now is ask you, the individual reader, a few questions. You read *Astronomy* magazine, so this stuff might just float your boat. I hope you'll have some fun and play along!

Which of your conceptions and experiences most profoundly shape your own unique conscious reality? What kinds of things exist in your perceptions that might not be there for most people? What sorts of stuff might be prominent in the conscious worlds of some others yet absent from your own?

You have to live with questions like that for a while to find answers, but I really hope you'll give it a shot. Imagine what you might discover by paying focused attention to how you construct your own perceptions.

Be careful, though. You can't watch yourself perceive the world without also better seeing the objective world itself. That's basically what science does, and it can really blow your hair back!



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

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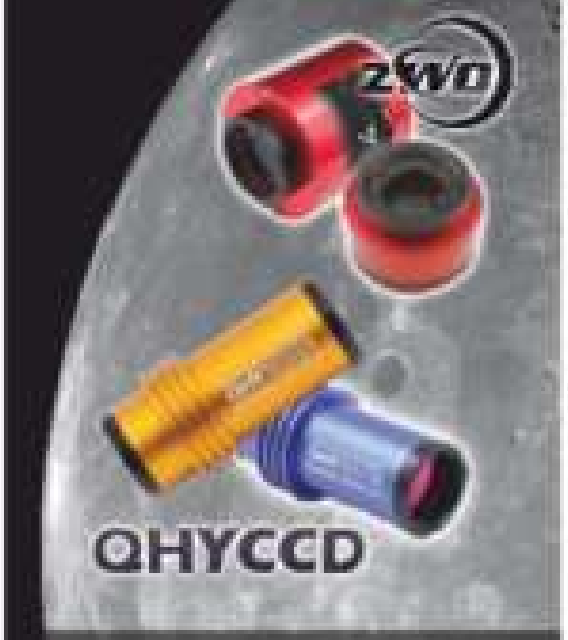


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Michael Collins

REMEMBERS APOLLO 11

The command module pilot had a unique role in the historic first Moon mission, and recalls the details of that amazing time in an exclusive interview. BY DAVID J. EICHER





HE IS OFTEN CALLED THE "THIRD MAN" OF THE MOST HISTORIC MOON MISSION EVER.

Michael Collins did not walk on the Moon; instead, he orbited the lunar surface during that first Moon landing, keeping vigil over Neil Armstrong and Buzz Aldrin as they walked the surface below. But Collins has no sense of being an outsider when it comes to Apollo 11.

His task was so critical to the mission, and he was so close to his comrades, that Collins felt no loneliness as he orbited the Moon. He looked down toward Tranquillity Base and also back toward the small Earth. Yet isolation was not in mind. During that incredible time, as the world watched and waited, Collins kept the operations in the command module sharply moving, making a successful Moon landing — and return — possible.

The product of an Army family, Collins was born in Rome, and was educated in Washington, D.C., and then at West Point, before joining the Air Force. His father was a U.S. Army major general, and his uncle was J. Lawton Collins, chief of staff of the U.S. Army.

Collins' service included periods as a fighter pilot and as a test pilot before joining NASA's third astronaut group in 1963. This set him on course to become part of the most celebrated group of astronauts ever, the Apollo 11 crew: Armstrong, Aldrin, and Collins.

Recently I had the chance to speak at length with Collins. At 88, he is still sharp and entertaining to talk with. I hope you enjoy the results of our discussion.



ABOVE: Michael Collins poses prior to the Apollo 11 mission, dressed in his spaceflight attire.
ALL IMAGES: NASA/JSC

OPPOSITE: Inside *Columbia*, Collins snaps a picture of *Eagle* as it approaches for rendezvous. Mare Smythii appears beyond the LM while a colorful, half-lit Earth appears in the background.

Astronomy: *You were selected as one of the third group of NASA astronauts in 1963. Can you talk a little bit about your early life and what led you to want to become an astronaut in the first place?*

Collins: I grew up in a military family. My brother, my father, my uncle were all in the Army. When I finished West Point, for nepotism or whatever reasons, I sort of slipped off into the Air Force and entered pilot training. I started in Columbus, Mississippi, for primary training in the T-6, the venerable old T-6. It was a wonderful experience for six months learning to fly a little bit, and then I moved on to Waco, Texas, for jet and instrument training and got my wings and so on.

I was trained in F-86 Sabre jets, which at that time were fighting the MiGs in Korea, and I had orders to go do that. But the armistice was signed and those orders were canceled, and poor me, I had to go [to] Southern California, which is quite a hardship, and after that to France where I was in a fighter squadron there for a couple of years.

Then I went out to Edwards, which was really our mecca, and entered the Air Force Test Pilot School and later a post-grad version of it which they gave a grandiose name. Instead of the Test Pilot School, it was called the Aerospace Research Pilot School, and that sort of completed my education. I joined people like Frank Borman.

Astronomy: *Your father was Maj. Gen. James Lawton Collins, an important Army veteran of both World War I and II. Did his background and your upbringing in a military family influence your desire for exploration?*

Collins: I did have a strong Army background. At that time, my father, who was a major general, as you say, and had various assignments in World [War] I and II, and my brother at that time was a colonel in the Army, and later went on to become a brigadier general, but the main force there was my father's younger brother who was the Army chief of staff at that time. He was J. Lawton Collins, nickname was Lightning Joe, and he was given that nickname because he had led an Army division from Normandy across France and into Germany at a very rapid speed during World War II.

Astronomy: *Moving on a couple of years later, in 1966 you were the pilot for Gemini X and went into space along with John Young. This was a complex rendezvous docking and extravehicular activity (EVA) mission.*



1. Collins studies mission briefings during a test period inside the command module simulator.

2. In an image taken after the undocking of the command module and LM, the command/service module appears to float over the lunar surface, with Collins inside and the eastern part of the Sea of Fertility below.

3. A view of the front of the LM, taken during Collins' visual inspection of the craft to make sure all is OK and that the landing gear is down prior to descent.

4. In an image taken by Collins, Neil Armstrong floats inside a tunnel connecting the command module and the LM.

Can you describe the flight and your recollections of it?

Collins: I really loved Gemini. It was kind of like a neat little flying motor scooter. It was called the Gemini Program, named after the Gemini Twins because it carried two people. I thought — well, Janus, I guess, was the god of doorways, and I thought Gemini should more probably have been called Project Janus because like that god, it looked backwards and it looked forwards. It was backward to the Mercury Program and it looked forward to flying to the Moon on Apollo, and its job was to link those two, to take the experiences of Mercury and to concentrate on three areas. The first one was bringing two vehicles together in space, rendezvous and docking them, and then the next was to be able to go out onto the surface of the Moon and therefore these were our first ventures outside a spacecraft to do spacewalks.

Astronomy: *In order to achieve your rendezvous with an Agena target vehicle, you orbited a then-greatest distance from Earth, some 474 miles (763 kilometers) above Earth's surface. What was that sensation like, when you were in what then was considered to be deep space?*

Collins: Well, [474 miles] was, as you say, a world record at that time, and as a former test pilot we always loved to set records, so John and I were happy to be able to do a new altitude record on Gemini X. But in terms of anything [happening] on board, it was nothing. Once you get above 100 miles or so it doesn't matter really whether you're 200, 300, 400, or 500. The view out the window changes imperceptibly as you go up, but those were just little numbers on our instrumentation rather than any sensation.

Astronomy: *You made two EVAs, taking images of stars and testing the realism of color photography in orbit. You also explored space near the craft, retrieving a micrometeorite collector and maneuvering over to the Agena target vehicle. What was it like doing those maneuvers in orbit?*

Collins: The spacewalking, EVAs as we called them, that was the part I suppose I

remember most vividly about the flight of Gemini X. We had our own Agena, which we had docked with. It was our motor. So we used that motor to get us up to the orbit of where a dead Agena was awaiting us, an Agena without any power, and then John's job was to maneuver the Gemini very close to the Gemini VIII Agena. That was a difficult task.

And then I got all prepared with my EVA gear. We dumped the cabin pressure in the Gemini, opened the hatch, and I floated out. So, the first time that I approached the Agena, I guess we were maybe 20 feet away from it, slightly below it, and so I just sort of gently pushed out and I went over and hit the Agena down at one end of it. The experiment package that I was to receive was, I guess, maybe 10, 15 feet up the side of the Agena, and as I was going toward it, there were no manufactured handholds or anything for me to grab a hold of.

So I was sort of slithering along the side of it, and when I got to the experiment package, I had enough momentum in my body that I couldn't stop there. I reached down and grabbed the package with one hand, but I just slid right on by it, and then I went sort of spinning past and above it out to the end of my umbilical, which was a big, long 50 feet. I was way above and past the Agena, and as I swung around, I could look down and, of course, see both of them, but I couldn't do much about it. So, with the umbilical fully extended, I then entered a gentle arc and I swung around and came back and I got my legs back inside the open Gemini cockpit. And then John maneuvered again and got back where he had been before, maybe 20 feet away [from the Agena].

This time when I left the cockpit I had a little handheld maneuvering gun that just squirted gas out. I stubbed my toe a little bit as I left the cockpit, and I started pitching a little bit. I used the gun to correct that, but in the process that lifted me up a little bit higher. So, as I got over to the Agena, I almost missed it. I had to stick my hand down quickly and I grabbed some wires that were not supposed to be grabbed, I suppose. With my left hand holding firmly, I kind of swung around, and this time when I went back to the instrument package I was more careful about my body momentum. The package released very easily and then I made a return trip.

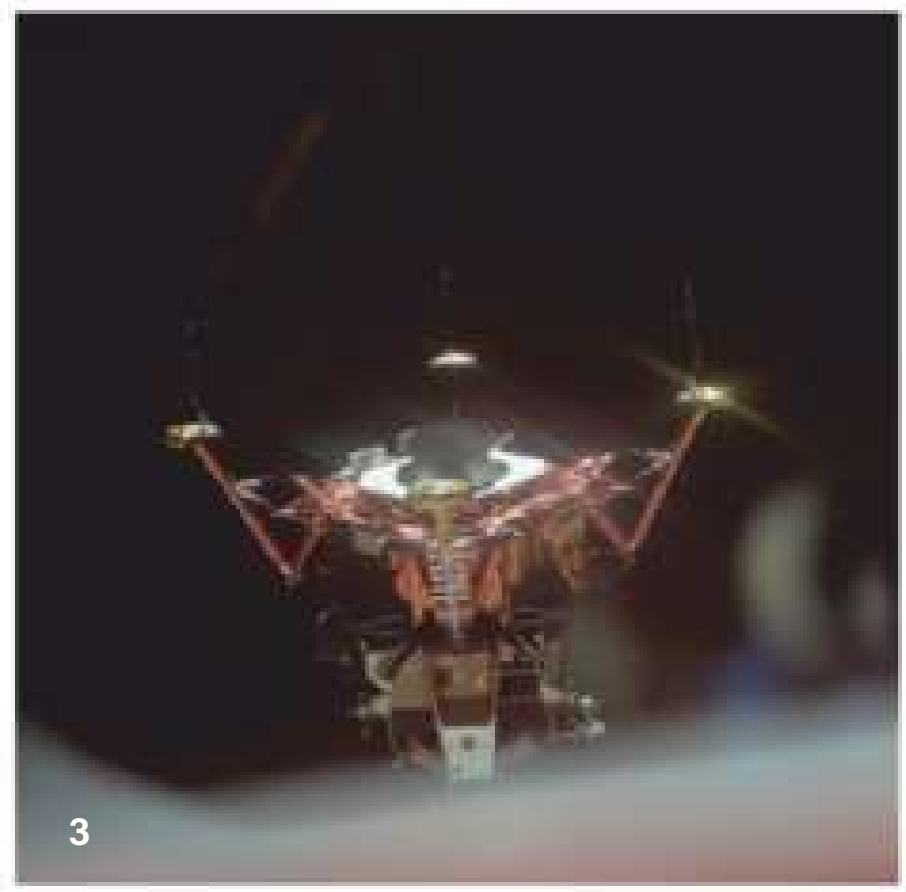
So I just had to get back inside a small space with the trailing umbilical cord, 50 feet long and very thick, because it contained oxygen. [It was] a strong, ropelike thing so it wouldn't break, and so it was like — I think I told the ground it was something like a snake at the zoo or something. I had this thing that I had to get under control. We finally stuffed it in below my feet under the instrument panel.

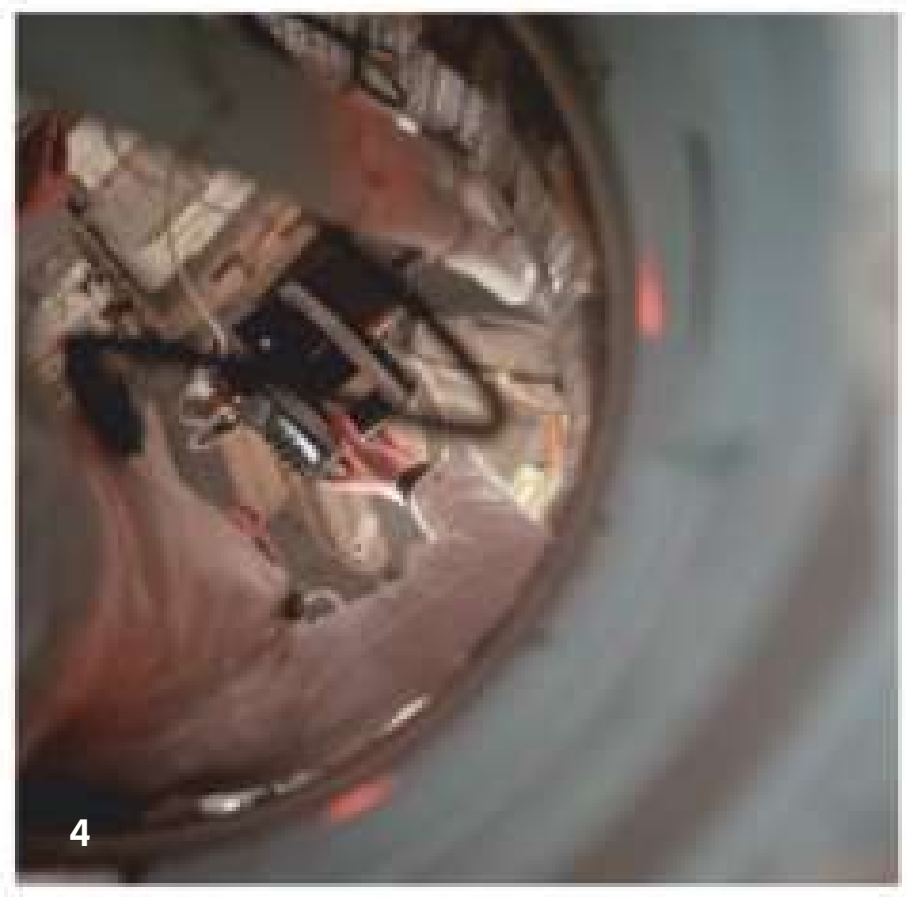
Astronomy: *In 1967, you went to the Paris Air Show, and you befriended a pair of cosmonauts. Now obviously the American and Soviet programs were pushing ahead in a thick cloud of Cold War and competition, but even by then, before the Apollo flights, were the astronaut explorers sort of becoming a bit of a fraternity aside from the political aspirations of the two nations?*

Collins: Not that early, no. They were kind of strange animals to us, and we were kind of strange to them. Vodka helped.

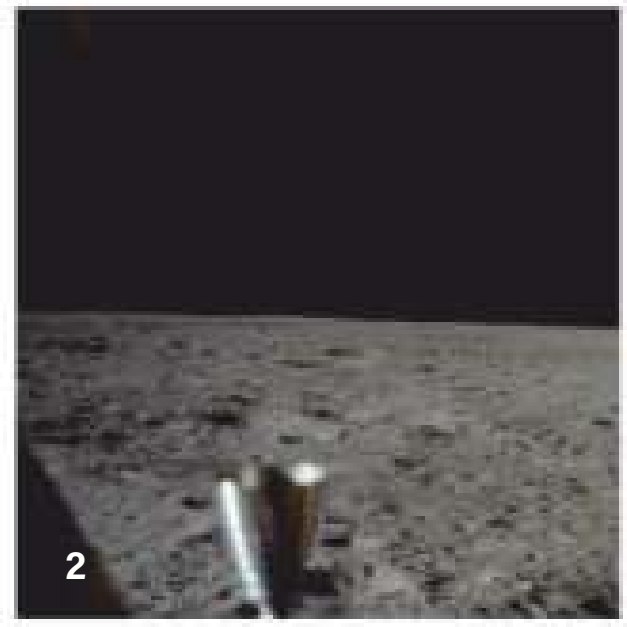
Astronomy: *[Laughs]*


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1. The view from the window of the LM, as captured by Buzz Aldrin, shows part of the Sea of Tranquillity as Armstrong and Aldrin approach their landing site.

2. This view of the lunar surface is one of the first photos shot by the Apollo 11 crew after landing. The view is toward the south, through Armstrong's window. One of the thrusters is in the foreground.

3. The lunar surface stands out in an image made soon after landing, which shows the lunar horizon and the LM's shadow.

4. The first picture during the Apollo 11 moonwalk was taken by Armstrong. It shows a jettison bag under the LM's framework, along with the south footpad, a bent probe, and strut supports.

5. Armstrong took this picture of Aldrin coming through the LM's hatch, about to climb down to the lunar surface.

Collins: We did meet [Konstantin] Feoktistov, the one that I remember, and I guess the other one was …

Astronomy: *Pavel Belyayev.*

Collins: Yeah. Anyway, the two of them. We escaped the crowd, if I remember. They were badgering us, so we escaped into a transport, which I believe was one of those Russian transports that brought them there, and for, I don't know, an hour or so we sat around and drank vodka and chatted. I liked them, and we were kindred spirits. We clearly were from opposite poles when it came to political opinions, and we didn't get into that. We talked about — I'm sorry to say it's so long ago I don't remember the details, but we talked about flying stuff, you know?

Astronomy: *Such as?*

Collins: Airplanes and spacecraft, and they seemed very friendly. We were friendly to them, and their backgrounds and their careers dovetailed with ours in many ways, so we were a compatible group. But we had no expectation going into that that we would have a meeting like that with the cosmonauts. We hadn't been briefed by the State Department or NASA or the government — "Oh, yeah, be careful of this, or do say that, or don't say the other" — it was just all spontaneous and very informal, and I think useful in a minor way in the long run.

Astronomy: *Gemini having served as a test bed for Apollo, you originally had a different assignment, of course, than Apollo 11, but the assignments were shuffled. You also had some medical issues that delayed your involvement. What was it like, sort of playing that waiting game as the missions unfolded in the early days of Apollo planning?*

Collins: Like you say, I was on the first Apollo crew with Frank Borman and Jim Lovell, and I was removed from that crew because I had two vertebrae in my upper spine with problems. One of them had come loose, and I had to have those two vertebrae fused together. So for about six months, I was not allowed to fly airplanes because my spine hadn't fully healed and also I couldn't really keep up with the training regimen that was required of the crew. So I was removed, and my job then became the guy in Mission Control who talked to them on the radio. That flight, when I was assigned to it, was to be a very high orbit, but in the Earth's orbit. I think we were supposed to go up — I don't know precisely but, oh, 600 miles or maybe more than that — I've forgotten the numbers, but very high Earth orbit.

But at that time, I [think] NASA in its mission planning got a bit more venturesome. George Low, I think, was the primary man involved, but somewhere along the line, the hierarchy at NASA decided that the one and only predecessor Apollo flight, Apollo 7, had been a 13-day or so test in Earth orbit of the command module systems and that the LM was kind of lagging at that point. So it seemed like it was a good idea and a daring idea to take the command module, and instead of just flying into a high Earth orbit as we had planned — 1,000 miles maybe? — they decided to change that and fly all the way to the Moon. And of course that was Apollo 8, which we all remember because the crew read from the Bible in orbit around the Moon.

My part of it was, of course, minuscule, but there I am on the console in Mission Control and we're about to have what I thought [was] the most momentous instance in exploratory, if not human history. Here people were exceeding escape velocity. They were leaving Earth's gravity for the first time. They were going off to another planet for the first time. All these gigantic firsts and how would one listening

know? Well, I said, "Hey, Apollo 8, you're go for TLI [trans-lunar injection]," and Frank Borman said, "Roger." That was it.

Astronomy: *[Laughs]*

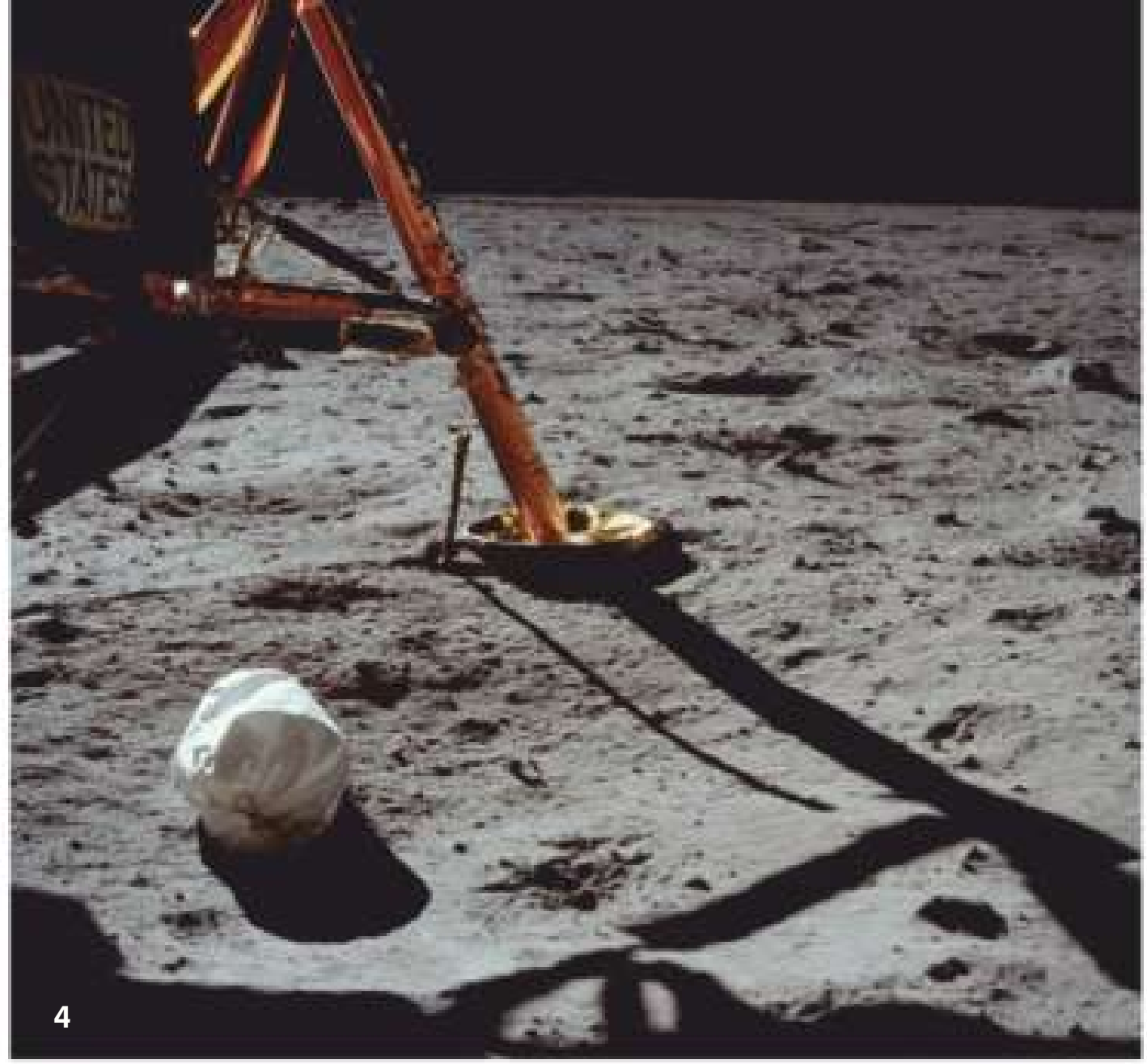
Collins: I thought, you know, drums should've played, the pope should've sent a blessing, the president should've arrived, and any other embellishments you could possibly think of.

Astronomy: *It was a moment for brevity then if nothing else.*

Collins: Yes, and you know, we had a lifetime of radio discipline. You didn't chatter on the radio.

Astronomy: *What was it like when you realized that Apollo 11 — your flight now and you're piloting the command module — would mark the first lunar landing mission?*

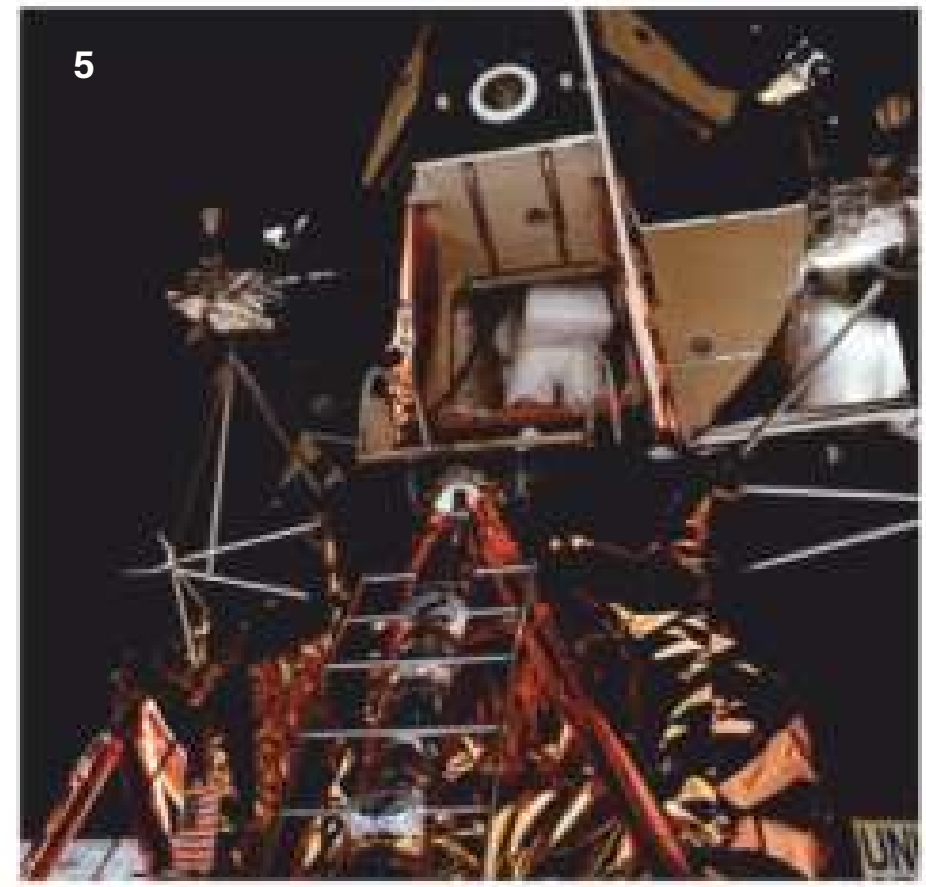
Collins: I had been a little bit disappointed, oh, maybe a year or so before that, because when I was on the first [Apollo] crew, I [was supposed to] be the lunar module pilot. [But] then, because of my dropping out, the next time I was put on a flight I was put up into the command module pilot. I was bumped out of being a lunar module pilot because we had added Bill Anders, and the rule that Deke Slayton had at that time was that if you were going to be the command module pilot and be flying by yourself solo around the Moon, then he did not want a rookie to do that; you had to have flown once before. I had flown on Gemini [and] Anders had not, so I was bumped upstairs, and I became a command module pilot. And I knew then — that would've been in '67, maybe — I knew from then on that I was not gonna walk [*laughs*] on the Moon.


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So, I guess I'd say there was just a tiny little taste of disappointment with my role on Apollo 11. However, people point that out to me all the time, and I can say with great sincerity and honesty that I was just delighted to be on that flight in any capacity. I did not have the best seat of the three — I can see that — but the seat I had thrilled me. It was a culmination of John F. Kennedy's dream, man on the Moon by the end of the decade, and to be any part of that historic flight suited me just fine.

Astronomy: *Can you describe how you felt when the three of you finally rolled out and climbed into the spacecraft and experienced the launch of Apollo 11? And what was the cruise phase to the Moon like for you?*

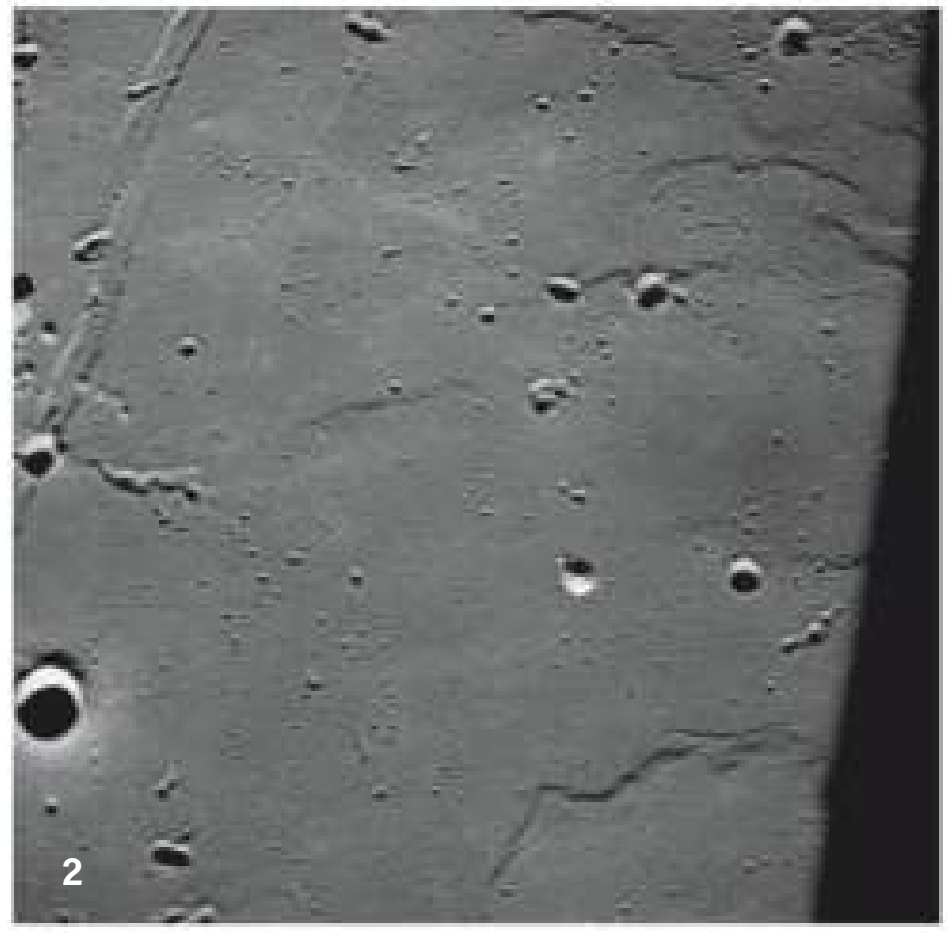
Collins: Getting into the spacecraft is sort of odd. It's not like you go out to that gigantic


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booster every day, but we'd been out there a number of times, and it was always a beehive of activity: The workmen doing this, that, and the other, big cranes going up and down. The day of launch — 16th of July, I guess it was, of '69 — it was odd because it was quiet, it



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was silent, it was — something was wrong. There was nobody around. It was just us and one other guy.

And we got on this dinky little elevator and went up roughly 360 feet and got off at what they called the white room. It wasn't white, but a little enclosure. And we got off there and then slowly one by one, other things happened.

We loaded ourselves into the command module, *Columbia*, but I had plenty of time to look around. I can remember if I closed my right eye, all I saw was the beach and the ocean and the world of Ponce de Leon, it could've been. There was no sign of humanity. It was just good Planet Earth. Vice versa, if I closed my left eye, then I saw this gigantic heap of complex machinery, the 20th century that we were, people of machines, and I can remember looking and saying, "Geez, I see that, I see that — I'm not sure if I'm in the right one." [*Laughter*] But anyway, at that stage of the game, there wasn't much I could do about that.

Astronomy: *[Laughs]*

Collins: So little by little, we got loaded up. People always ask, "What seat was yours?" There were three couches actually, side by side. The one on the left was the commander and it wasn't like Neil's seat, Buzz's seat, and my seat; it just depended on what was going on. For launch, I was over on the right-hand seat. When we got up into orbit and we wanted to retrieve the LM from its little hideaway top of the Saturn, then I went and got in the left seat. That was part of my job. And most of the time, I might be in the middle seat fooling with the computer. So, all three seats were mine in a sense.

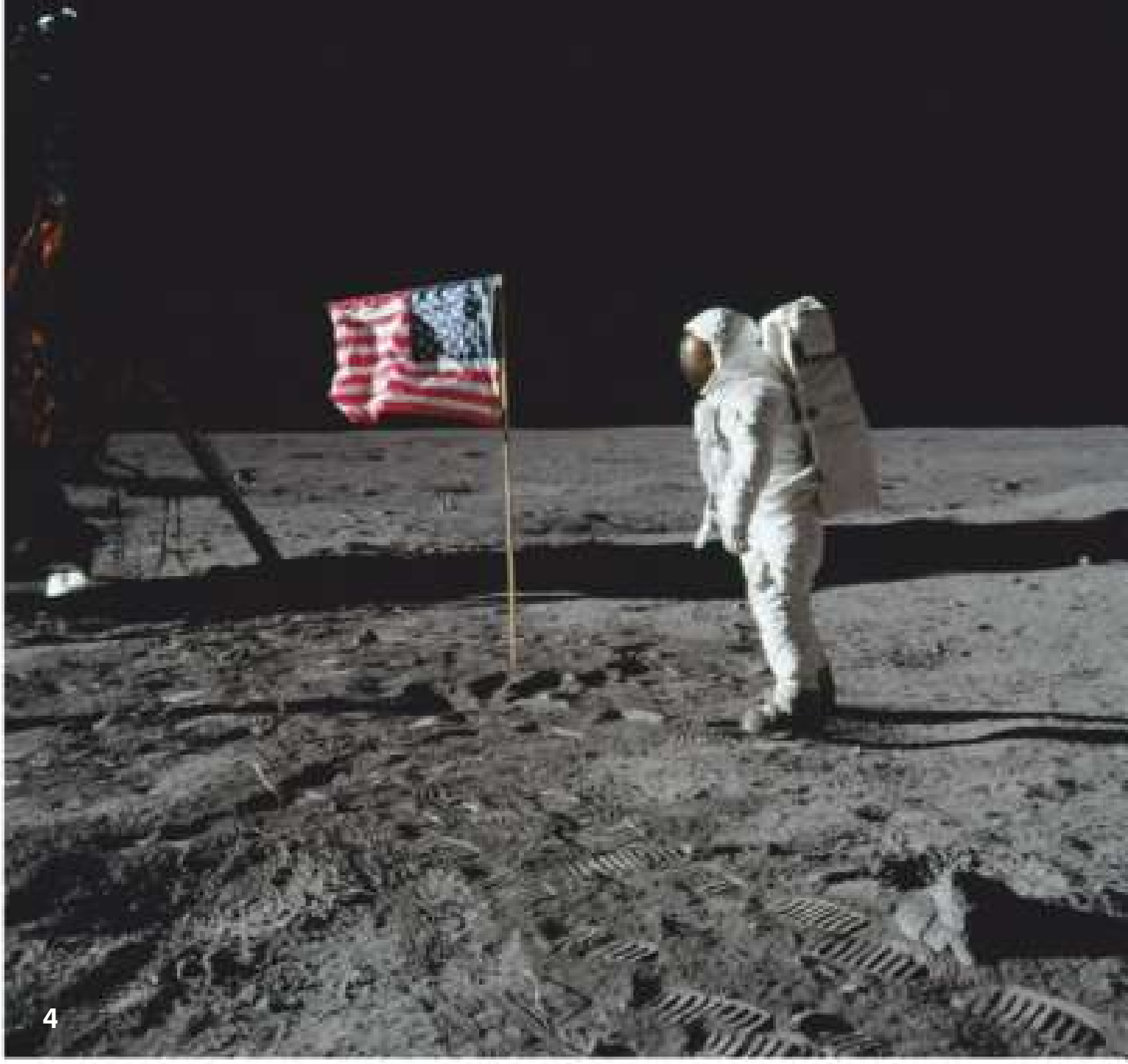
Our departure from launch pad 39A was a little different than certainly what I expected. You know, the Saturn V is such a gigantic thing — I think 7.5 million pounds of thrust from the five engines — you would expect that inside there'd just be a deafening roar, but not so. It was a lot quieter than you might imagine. We could hear each other on the radio and hear each other and the radio by itself, and the acceleration was very slight. It leaves the pad extremely slowly.

The surprising thing is it has to keep itself poised because it's only 2 feet away from the tower, and if it goes sideways a little bit too far, it bumps into the launch apparatus. Of course, that [would be] the end of it right there. So, to compensate, you have to, in our case, use those rocket engines as swivels, and so they were swiveling back and forth to keep us absolutely straight upright and not bumping into the launch tower. And the sensation that we felt, I always describe it as a nervous novice driver driving a wide car down a narrow alley; he or she will be jerking the wheel back and forth a little bit to keep you on track and not hitting the walls of the alley.

And we had the same problem; so we went with these little spasmodic jerks for the first while, and then once we cleared and that all settled down, the rocket ride is pretty smooth. I think the Gemini went up to about 7.5 gs at its peak. On Apollo it was like 4.5 gs. So, it was a relatively easy ride. When the first-stage engine quit, there's an instant

of noise and confusion — not so much noise, but visual confusion as you get separation. It's almost like an explosion. The stuff out your window, you're not sure what the hell is happening, but it's fire and man-made particles and craft out there, and that lasts just a second or two. And then you're past it, and you're into the second-stage burn.

The second stage during its testing had not been quite up to snuff as compared to the first and the third. They'd had some problems with it, and we were, I think, probably worried about that second stage — not excessively — but it turned out to be smooth as glass. It was a beautiful ride, and then the third stage took over briefly to put us into orbit around the Earth. The third stage was not quite as smooth with little hiccups here and there, but it worked fine. The next thing we knew, we were in Earth orbit.



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Astronomy: *Much has been made, of course, of Armstrong and Aldrin descending in the LM and the first moonwalk. But this was a three-man mission, and your orbiting overhead obviously was critically important. You've said that you've never really felt lonely when you were in lunar orbit. How did you feel once you got to the Moon?*

Collins: Oh yeah, lonely. I tend to forget the word *lonely*, but you bring it back to me. Well, OK, when I got back from the flight, we were subjected to a lot of press inquiries. And when they came to me, most of them centered on, "Weren't you the loneliest man in the lonely history of space, behind the lonely Moon all by your lonely self?" And what I say in my book is, "Geez, what are they talking about? I've got white mice on my mind." We are in a lockup there at Houston, hoping we hadn't brought any alien pathogens back from the Moon. And we have this colony of white mice — whom I liked, I liked to interact with them — and so these guys are talking about — was I what? Lonely?

Astronomy: *[Laughs]*

Collins: I thought their question was ridiculous. I was tempted to laugh at them, the press, but ooh, that's a mistake because they can retaliate. So I simply said that I was too busy to be lonely; however, the truth was considerably different.

I was very happy with the command module. In a way, I thought that it was like a little miniature cathedral. I had the transept, if you will, or the three couches, and then I went down this aisle into the altar area. The altar was really our guidance and navigation station, and we didn't have any clerestory windows, but we had nice lighting inside, and it was an elegant, sturdy, spacious place. It was my home. I was king, and you know, like most kings I had to be careful. Like, there goes fuel cell No. 3 acting up again.

I can't say that I really was relaxed, but I was happy to be there, [and] I felt very much a part of the mission. I felt like I was doing a useful job and I felt included, not excluded, and so I was king of my domain, and I was very happy to be there that way and lonely — no! Let's talk about white mice. Geez.

Astronomy: *Can you describe what was going through your mind, hearing about the descent of the LM, the landing, the EVAs conducted by your colleagues? That must have been a fairly exciting but also tense time to*

1. Collins smiles during a press conference prior to the mission.

2. A haunting image from the command module shows the western Sea of Tranquillity. The Apollo 11 landing site is just above and to the left of the spacecraft, near the center of the image. The sharp-rimmed crater at lower left is Moltke.

3. A good view of what it must have been like flying over the Moon: This image shows a northward view toward the rayed crater Giordano Bruno.

4. The Sun reflects in Aldrin's visor as he stands alongside the U.S. flag on the Moon's surface, in this image shot by Armstrong.



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hope that everything unfolded as it should have.

Collins: I wasn't too worried about the landing. I thought that it was — I don't want to say a straightforward procedure, but it was one that had been practiced over and over again. I thought that Neil somehow would find a place to land, and it turned out it wasn't our first choice, but he overflew several boulder fields over several crater areas. He finally found a place that suited him with about 30 seconds or so of gas left, and I thought he did a masterful job. I had expected that he would, and I'm glad that everything worked out. There was a radio delay and I couldn't really tell what was going on, and it made me anxious for a few minutes there, but then when I was told that they were safely down I was, you know, not stressed.

My worry had been the rendezvous subsequent. You know, we're in the space program, we're big believers in redundancy, and we had redundant equipment wherever it was possible. It was not possible in the case of the Lunar Module Ascent Engine. It was one engine, one engine bell — I suppose multiple lines leading into it, but at one point — one incident of combustion where the engine lights or doesn't light. If it doesn't light, they're dead men, and so I was very worried about that aspect, their getting off the Moon.

And then, once they got off the Moon, if they got into a perfect trajectory — which they didn't do — then the rendezvous and docking was something we had practiced over and over and over again. However, if there were variations on the theme — what if things didn't get out of control exactly, but they got crazy? I was in orbit, zooming by some 60 miles overhead, and if they timed it perfectly with my approach, and then they lifted off — OK. And they got into an orbit below me and then later transferred up to my orbit.

If they were late getting off, I couldn't have slowed down for them, so they would have had to catch me quicker, and the way you catch someone quicker in orbit is to go lower. So maybe they're a little bit late, so they go lower in their orbit.

If they are later yet, the orbit's gotta be lowered until they are just skimming the mountaintops of the Moon. If you're a second or two later than that, the whole system reverses itself. Instead of going low, they have to go as high as they can go and let me, if possible, dip down — or then I have to make an extra turn around the Moon and catch them instead of them catching me. This is from a procedural point of view [and] is a totally different situation, and it's just one of many.

Suppose they veer left or right? Suppose the orbit they get into is too high or too slow or too fast or too something or other? I had around my neck a book, a big book — 8-by-10-inch loose-leaf notebook kind of a book — with 18 variations of the rendezvous and docking. Some of them we had practiced over and over. Some of the others were so obscure, we never even practiced them in the simulator, but they were mathematically possible, and they could've happened. That's the kind of stuff that I was worried about then.

I'd been worried about that for, you know, months before, and so once they got into a good orbit, I breathed a big sigh of relief. Once we got docked back together, a second sigh of relief. Then our next big hurdle was just — again, we were relying on one engine, but that engine — or TEI as we called it, Trans-Earth Injection — that was our get-us-home-burner.

Astronomy: *Here's a question that Brian May wanted to ask because he's very much into stereo photography. Did any of your training include taking stereo images? Because, as he points out, while your buddies were foraging on the lunar surface, you*

took many nice images of craters and other features from orbit.

Collins: Well, no. He will laugh at me because of our idiotic simplicity, but it was nice. We had Hasselblads, and the experts said, "Well, on the timing, ½₅₀ of a second is what you want." And so the [photos] we were taking were all at infinity or almost all without the windows, of course. So right away, you've got two-thirds of your camera settings decided for you. You're shooting at ½₅₀ of a second, and you're shooting at infinity. The only thing left is your f-stop. Well, it was always at 11 — not always, but you might dip down to f/8 or go all the way up to f/16, but not usually. You could take a baboon and teach him to do ½₅₀, f/11 at infinity, and he'd be as good a photographer as me any old day.



3

Astronomy: *Now after your Apollo time, you had a distinguished career. You were a major general in the Air Force, assistant secretary of state for public affairs, director of the National Air and Space Museum, undersecretary at the Smithsonian Institution. Could you just talk a little bit about what life was like for you in all those incredibly active areas that you were in after your days as an astronaut?*

Collins: I had decided that Apollo 11 would be my last flight, and the reasons for it were complex. They had to do with the timing. We had what I called a knit-two, purl-one rotation. After 11, I'd have skipped two, been on the backup crew as a commander and then, eventually down the road, it turns out I would've been Gene Cernan's on 17 — but at that time, it had nothing to do with being the last flight. I think at that time, there was an 18 and a 19. It wasn't that; it was simply that I saw myself living in motel rooms for the next three years, being separated from my family.

I felt that we'd done what Kennedy told us to do and then it was gonna be a bit anticlimactic after that. But again, it wasn't any single thing. It was probably centered more on my family. I put all that together and mixed it up. I said, "Uh-uh, that's enough."

So then I left. I wanted a clean break from Apollo, from the space program, from NASA. Then came the Air and Space Museum, which was then just kind of developing on Independence Avenue. It was a wonderful transition, and lots of fun.



4

1. At Mission Control in Houston, participants celebrate the successful return of the spacecraft.

2. After splashdown, the three astronauts sit inside a quarantine facility at Ellington Air Force Base. In the center, Armstrong strums a ukulele while Collins (foreground) and Aldrin gaze out a window.

3. Heroes of the Moon, Armstrong, Aldrin, and Collins receive a ticker tape parade through downtown Chicago.

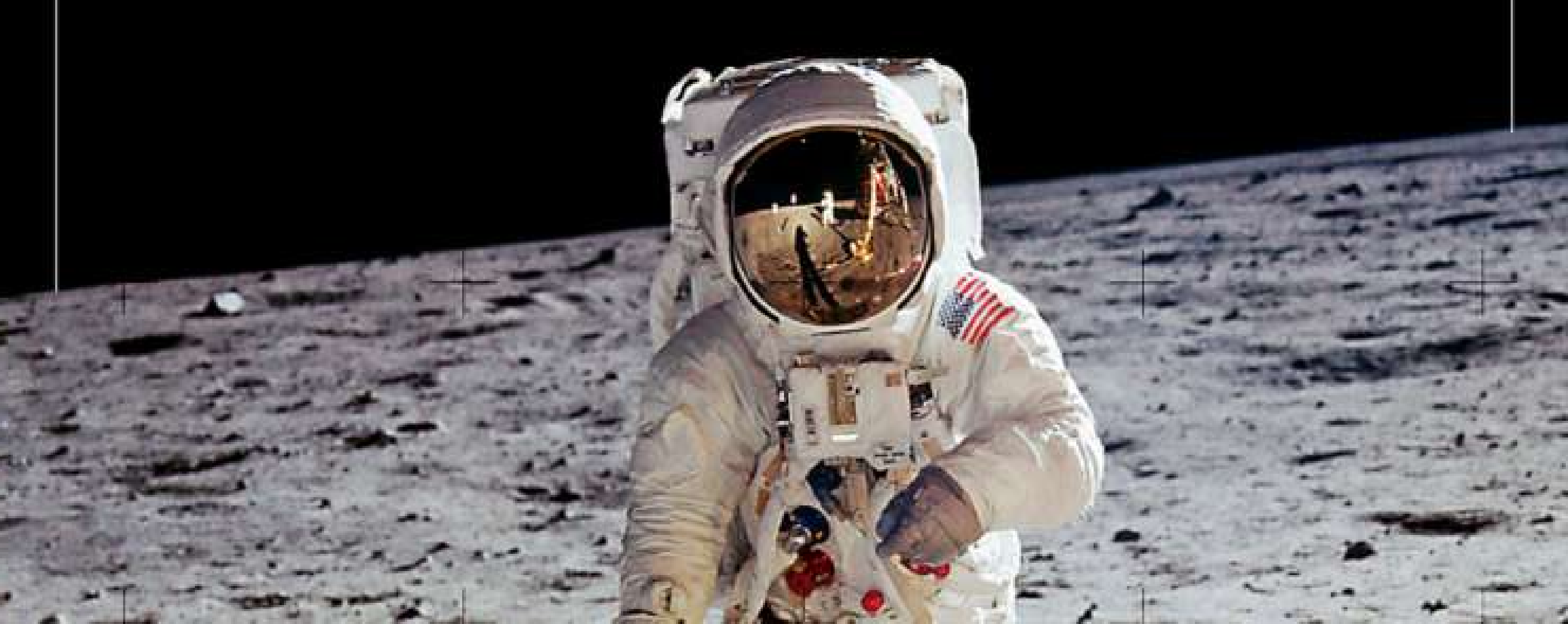
4. After the mission, Collins sits inside the hatch of the command module after its return to the Lunar Receiving Laboratory.

David J. Eicher *is editor of* Astronomy *and author, along with Brian May, of the new book* Mission Moon 3-D.

One small step

A 3D look at how Apollo 11 made history.

BY DAVID J. EICHER AND BRIAN MAY





In this iconic image, perhaps the most famous from the Apollo program, Buzz Aldrin stands on the Moon, gazing at the checklist taped to his wrist. In his helmet, you see the reflection of the photographer, Neil Armstrong, as well as the lunar module *Eagle* and Aldrin's shadow.

ALL IMAGES BY NASA/JSC UNLESS NOTED

THE FLIGHT OF APOLLO 11,



the mission chosen to attempt the first lunar landing, was scheduled to launch July 16, 1969. After the success of Apollo 10, it appeared that NASA would indeed keep the promise that John F. Kennedy made eight years earlier.

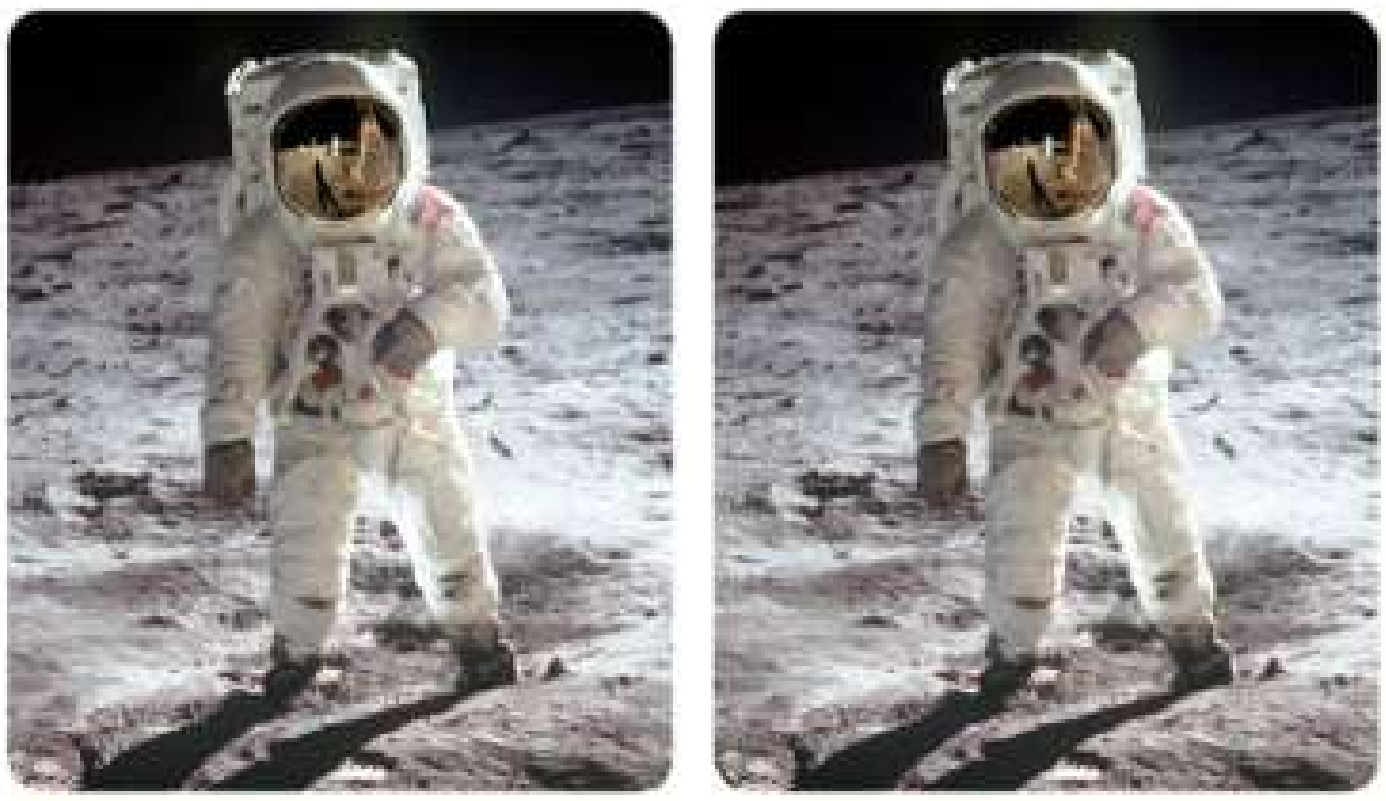
The crew consisted of an all-veteran, multipurpose group: Commander Neil Armstrong, Command Module Pilot Michael Collins, and Lunar Module (LM) Pilot Buzz Aldrin. For all three, it would be their second time in space.

Armstrong, 38, an Ohio-born naval aviator and test pilot, was among the second group of NASA astronauts. Along with David Scott, he flew aboard Gemini VIII in 1966. Collins, also 38, was born in Rome. The son of a U.S. Army major general, he became an Air Force test pilot before being selected to the third group of NASA astronauts. He, with John Young, was a veteran of Gemini X, which flew in 1966. Aldrin, 39, was an engineer and Air Force pilot who was selected in the third astronaut group; he flew with Jim Lovell on Gemini XII in 1966. The support crew for Apollo 11 included capsule communicators (capcoms) Charlie Duke, Ronald Evans, Ken Mattingly, Bruce McCandless, Harrison Schmitt, and Jack Swigert.

Mission planning went smoothly. Not everyone in NASA was amused by the informal names of the Apollo 10 command and lunar modules — *Charlie Brown* and *Snoopy*, respectively — so more serious names were given to the Apollo 11 counterparts: *Columbia* for the command module and *Eagle* for the LM. *Eagle* took its name from the emblem of the United States. *Columbia* borrowed its name in part from the European historical name for the Americas, and also in a reference to Jules Verne's 1865 novel, *From the Earth to the Moon*.

Anticipation for the launch was immense. After years of planning, the Gemini missions, and all of the Apollo mission testing, the big day was finally near.

In the summer of 1969, the decade was rocketing to a close, portraying a far different world from the summer of love in 1967 and the hippie culture of 1968.



President Richard Nixon had ordered the first troop withdrawals from Vietnam. Former President Dwight Eisenhower lay in state in the U.S. Capitol. Students overran the administration building at Harvard University to protest the Vietnam War.

The Beatles played their last public concert, on the London rooftop of Apple Records. Led Zeppelin released its first album. Plans came together for Woodstock, to be held in August in New York. Brian Jones of the Rolling Stones drowned in his swimming pool. Blind Faith played its first show in front of a massive crowd in London's Hyde Park.

And the world's eyes increasingly turned toward that bright ball of light in the night sky.

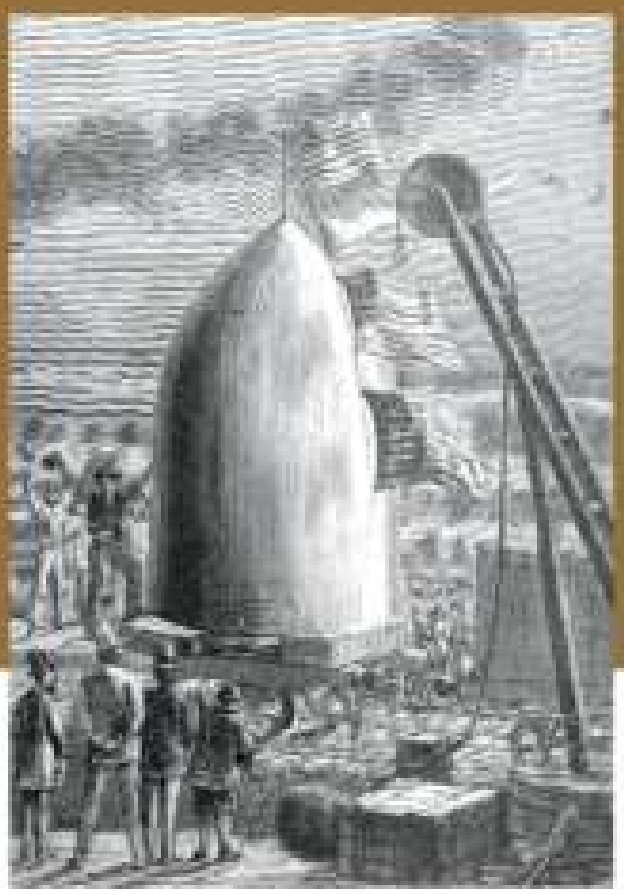


CLOCKWISE FROM ABOVE LEFT: This close-up of Armstrong's reflection in Aldrin's visor was produced by Markus Mehring.

Commander Armstrong, Command Module Pilot Michael Collins, and Lunar Module Pilot Aldrin pose at the Kennedy Space Center prior to their historic mission.

This digitally enhanced version by Eric Nelson shows a tiny blue dot at the top of Aldrin's visor: Earth.

This stereoscopic version of the celebrated image, the first ever made, was produced by David Burder.





ABOVE LEFT: The name of the command module, *Columbia*, is connected to Jules Verne's 1865 French novel, *From the Earth to the Moon*, one of the earliest science fiction titles, and a satire of Americans. In the book, set after the Civil War, a cannon called the Columbiad fires a projectile into space.

ABOVE RIGHT: Space capsule communicators (capcoms) at Mission Control in Houston keep in close contact with the Apollo 11 crew during the historic mission and landing July 20, 1969. They included, left to right, Charlie Duke, Jim Lovell, and Fred Haise.

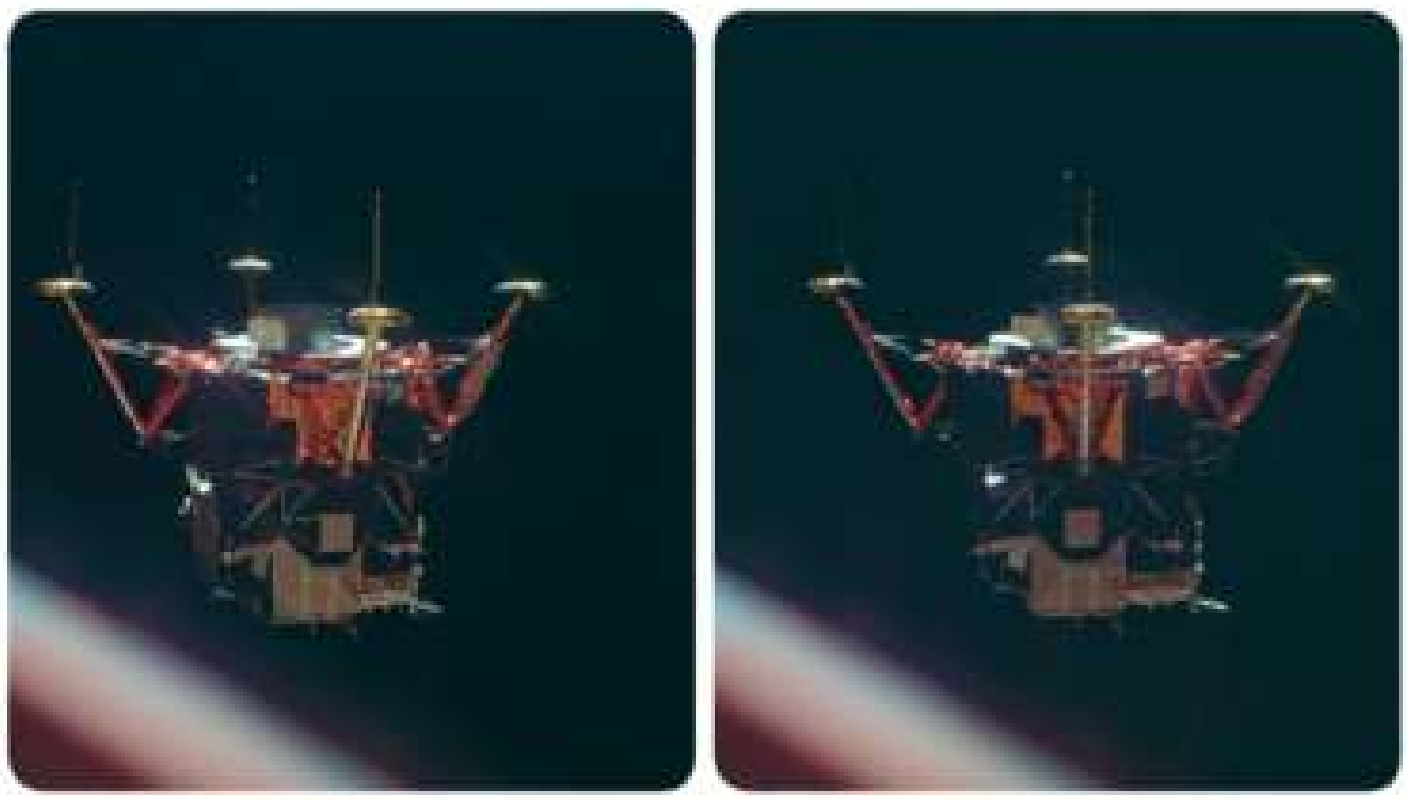
BELOW: The lunar module *Eagle* undocks from the command module July 20, 1969, to carry Armstrong and Aldrin to the lunar surface. This is one of a series of images made by Collins from the command module as *Eagle* rotated.

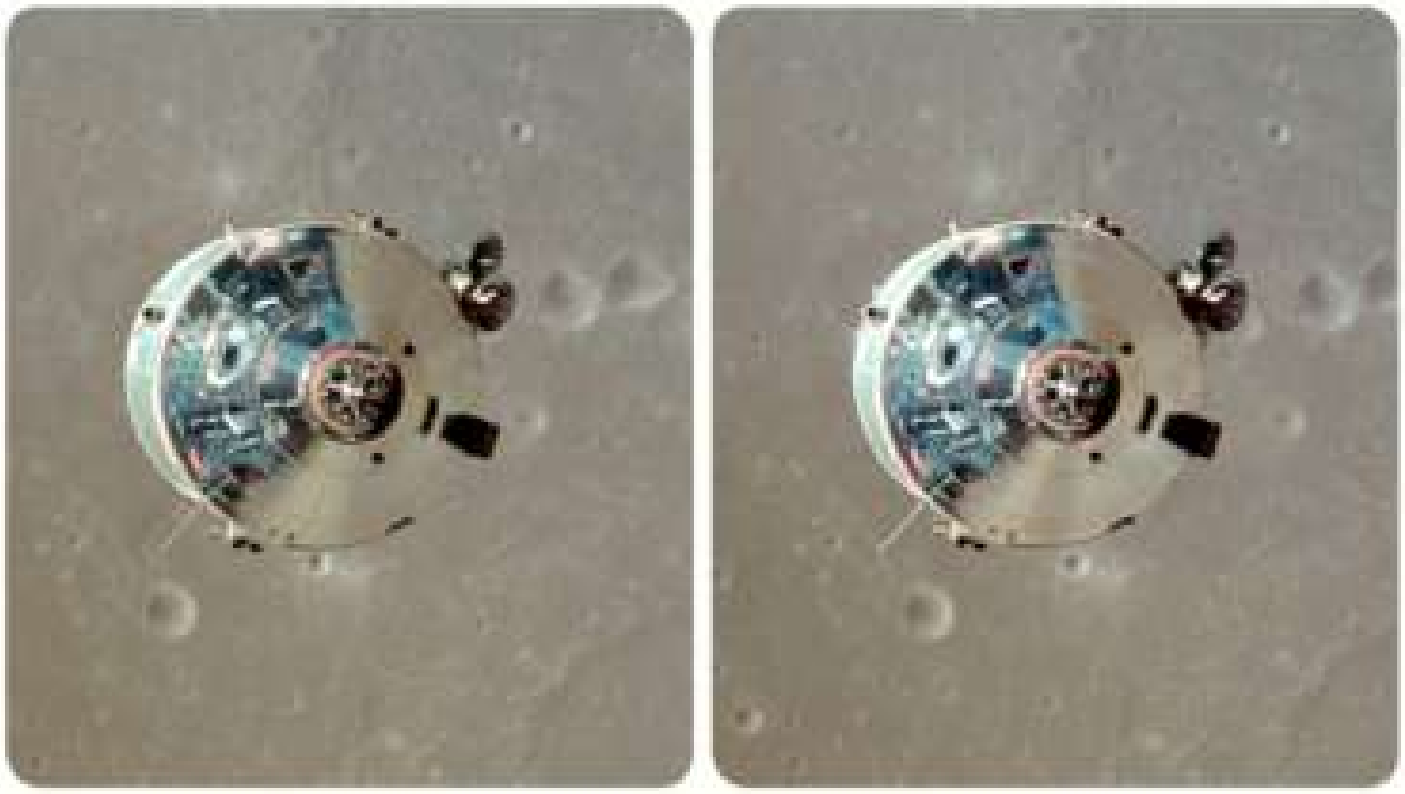
We have liftoff

Wednesday, July 16, 1969, dawned clear and bright at Kennedy Space Center in Florida. Thousands of people crowded along roads, around the public viewing areas, and even far off in other parts of the state to watch the rocket's towering flame head skyward. Jack King, NASA's chief of public information, supplied commentary for TV network coverage.

With Armstrong, Aldrin, and Collins secured in the capsule, the mighty Saturn V rocket was slated to lift off from the now-historic launchpad 39A, and the countdown began in the early morning. At 9:32 A.M. EDT, the rocket ignited, and Apollo 11 lurched upward with millions watching. The mission to land on the Moon was underway.

The launch was picture-perfect, and within 12 minutes the craft entered Earth orbit at an altitude of about 100 nautical miles (185 kilometers). After an orbit and a half, the third-stage engine fired and moved the spacecraft into a trans-lunar injection, sending it toward our celestial







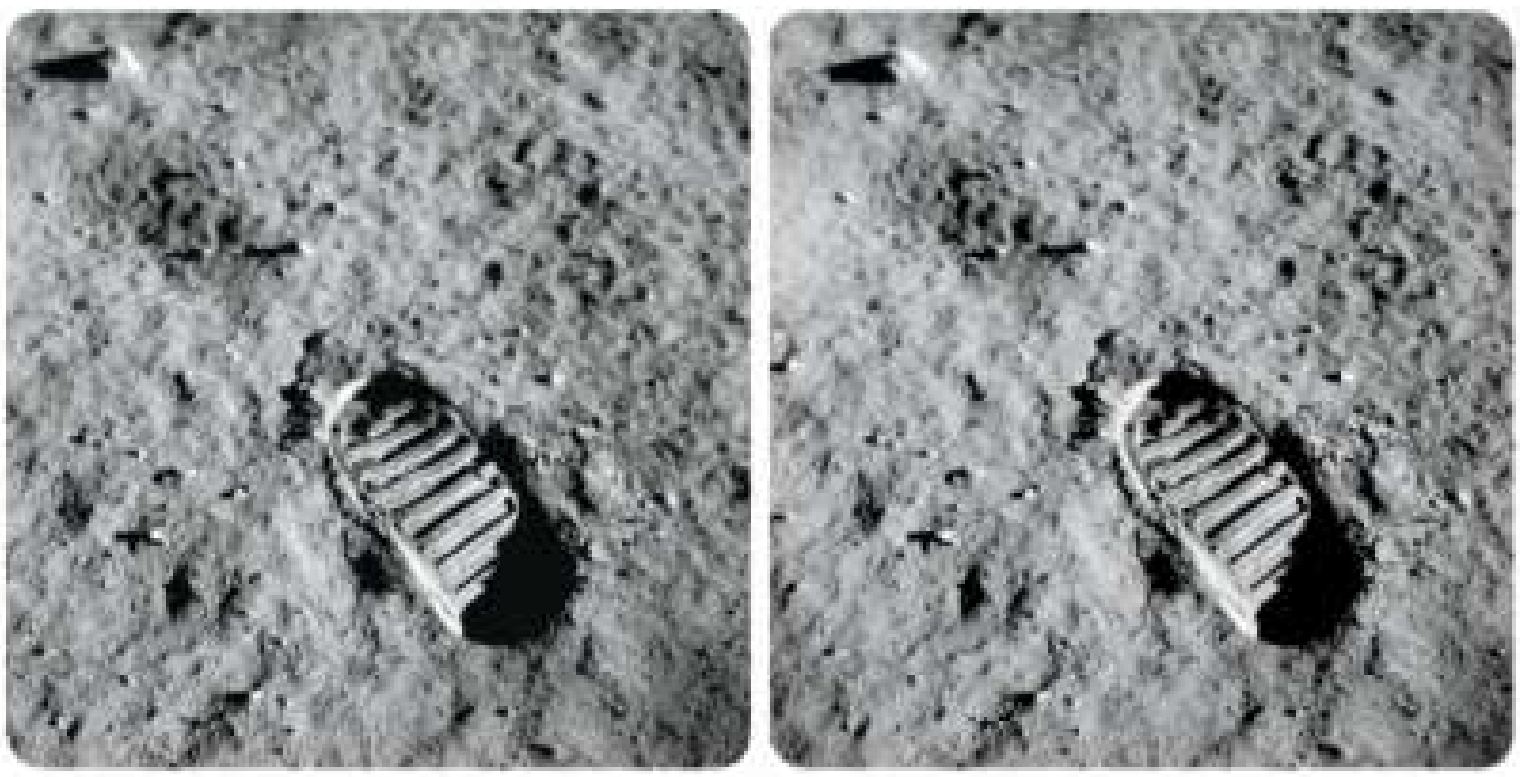
neighbor. Some 30 minutes later, the crew performed the maneuver that separated the command/service module from the spent rocket stage and allowed docking with the LM. After the rocket stage was discarded, the command module and the LM headed moonward.

The cruise to the Moon lasted three days, and by July 19, the craft passed close enough to the Moon to fire its propulsion engine, setting it on a course to orbit the Moon. Armstrong, Aldrin, and Collins orbited the Moon 30 times and observed all manner of craters and other formations, paying particular attention to the region where they planned to land, the Sea of Tranquillity. Previous unmanned spacecraft had imaged the area, and it appeared to be a safe landing site because of its flat terrain. The exact

TOP: The command module *Columbia* hovers over the lunar surface, photographed from *Eagle* on July 20, 1969. The portion of the Moon visible below lies in the north-central region of the Sea of Fertility.

ABOVE: This is Armstrong's view of the primary control panel in *Columbia*. The panel includes velocity, altitude and attitude indicators, as well as guidance and navigation controls. The spherical indicator at right is the Flight Director Attitude Indicator, also known as the "eight-ball." It shows the spacecraft's attitude, rotation rate, and attitude error for all three vehicle axes.





TOP: This stereo view of the Apollo 11 landing site explains the difficulties Armstrong faced as he piloted the LM to what was expected to be a smooth landing plain. The image, made with the Lunar Reconnaissance Orbiter spacecraft July 29, 2010, shows the *Eagle* descent stage about 162 feet (50 meters) west of Little West Crater, connected by a visible trail traced by Armstrong in his excursion.

ABOVE: Aldrin took this picture of his boot print in the powdery lunar soil for his soil mechanics experiments. The fine-grained dust at Tranquillity Base made the impression clear as it compacted under the boot's tread. The image is often mistaken for the legendary "small step" taken by Armstrong.

position was about 12 miles (19 km) southwest of the crater Sabine D, a 1.5-mile-diameter (2.4 km), dish-shaped welt on the lunar surface that later would be renamed Collins in honor of the command module pilot.

Stick the landing

On July 20, operations commenced that would lead to humanity's first steps on another world. Collins stayed aboard *Columbia* as Armstrong and Aldrin climbed aboard *Eagle* and began a descent operation. As the two craft separated, Collins carefully viewed *Eagle* for any possible signs of physical damage as the lunar lander turned in front of him.

Standing inside the cramped LM, Armstrong and Aldrin frantically checked readings and looked through

the craft's narrow window. As they recognized landmarks, they realized they were seeing them about four seconds ahead of the planned exercise — they were going "long," and the spacecraft would pass the intended landing site.

As they slowly descended and approached an altitude of about 6,000 feet, two program alarms sounded: The spacecraft computer recognized that it could not accomplish all the checks it should in real time. At Mission Control in Houston, engineers were not overly concerned, and they allowed the descent to continue. Later, NASA computer programming chief Margaret Hamilton wrote that the overload occurred due to a checklist error for the spacecraft preparation, and that the computer automatically ignored lower-priority tasks in order to focus on the descent.

As *Eagle* continued to descend, Armstrong and Aldrin focused intensely, hoping to avoid any mishap. Armstrong was consumed in piloting the craft, with Aldrin calling out altitude marks to him. On the ground, Duke served as capcom while he sat next to Lovell and Haise. All were nervous about the upcoming landing.

As the LM slowly lowered at the speed of a hotel elevator, Armstrong peered outside and saw a boulder-strewn field, north of a crater later determined to be West Crater. He took semi-automatic control of *Eagle* and realized the craft had very little fuel left. In fact, the astronauts received an erroneous "low fuel" warning because of fluid sloshing in the tank and washing away from a sensor. But fuel was still running out. Mission Control was aware of the fact, too. As *Eagle* lowered — no one knew exactly what the landing impact would feel like — it had less than half a minute of fuel remaining.

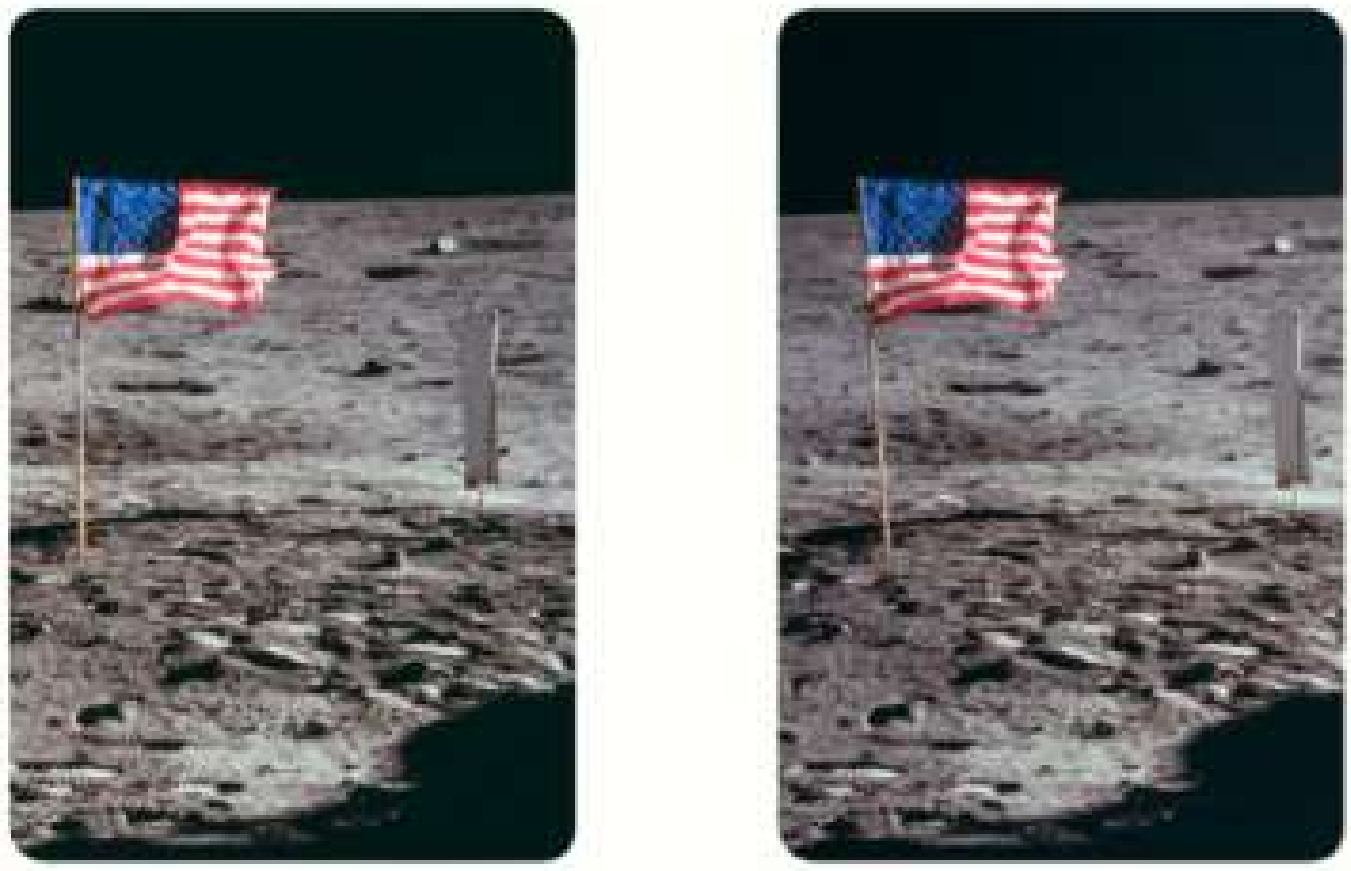
The spacecraft sank toward the Sea of Tranquillity. Moments before landing, Aldrin called out, "Contact light!" as one of the hanging probes dangled onto the powdery lunar surface. Three seconds later, the craft landed squarely, and Armstrong said, "Shutdown." After a few more words from Aldrin and Armstrong, Duke blurted: "We copy you down, *Eagle*."

Moments later, Armstrong uttered, "Houston, Tranquillity Base here, the *Eagle* has landed." Duke replied, with a bit of stumble, "Roger, Twan — Tranquillity, we copy you on the ground. You got a bunch of guys about to turn blue. We're breathing again. Thanks a lot."



ABOVE: This narrow stereo view, looking southeast of *Eagle*, was assembled from two sequential frames taken by Armstrong for a panorama. Hollows and small craters dotting the plain are discernible. The landing site in Mare Tranquillitatis was not as flat as mission planners had believed.

BELOW: Armstrong and Aldrin had a hard time planting the American flag on the Moon, as the hard lunar soil proved difficult to penetrate with the flagstaff. The rod along the flag's top edge did not extend fully, causing the wavy flag to appear to be windblown. The planting of the flag was symbolic of the first landing on another world, and was not intended to be a territorial claim by the United States.









CLOCKWISE FROM ABOVE: The three Apollo 11 astronauts await pickup by a helicopter dispatched from the USS *Hornet* on July 24, 1969. The fourth man in the life raft is a U.S. Navy underwater demolition team swimmer. All four men are wearing biological isolation garments. The Apollo crew splashed down about 812 nautical miles (1,503 km) southwest of Hawaii and only 12 nautical miles (22 km) from the *Hornet*.

President Richard Nixon was aboard the USS *Hornet* to welcome the Apollo 11 crew. Armstrong, Collins, and Aldrin are situated in the quarantine facility as the president looks on.

This spectacular stereo view of our home planet, taken July 17, 1969, shows most of Africa and portions of Europe and Asia. It combines two views made from the Apollo 11 spacecraft when the ship was 98,000 nautical miles (181,500 km) from Earth.

Released after three weeks in quarantine, the Apollo 11 astronauts enjoyed ticker tape parades in New York (pictured), Chicago, and Los Angeles.

It was July 20, 1969, at 4:18 P.M. EDT, and Duke wasn't the only one who was relieved: Millions around the world were watching, and celebrations erupted when the news of the successful landing broke. Kennedy's vision had come true. Humans had landed on another world. And now the fun part was coming — the exploration. What would the Moon really be like?

First steps

About two and a half hours later, Armstrong and Aldrin prepared to walk on the Moon, as Collins orbited overhead in *Columbia*. They were supposed to sleep for about five hours, but they were too excited. Before readying for the moonwalk, Aldrin broadcast a message home: "This is the LM pilot. I'd like to take this opportunity to ask every person listening in, whoever and wherever they may be, to pause for a moment and contemplate the events of the past few hours and to give thanks in his or her own way." Then Aldrin, an elder at his Presbyterian church, held a communion ceremony for himself.

Peering out from *Eagle*'s windows, Armstrong and Aldrin could see about a 60°-wide field of the surface, which appeared bright and gray. The pair intended to plant a U.S. flag in the soil and deploy an experiment called the Early Apollo Scientific Experiment Package (EASEP), which would collect various data. After more than two hours of preparation, at 10:39 P.M. EDT on July 20, Armstrong opened the LM's hatch and began to squeeze through it. At 10:51 P.M. EDT, Armstrong began climbing down the nine-rung ladder to the surface; a mounted slow-scan TV camera captured his descent. At 10:56 P.M. EDT, Armstrong stepped onto the lunar surface. Black-and-white TV footage of the event was broadcast to countless millions of homes around the world. As kids at the time, many of our readers surely remember the thrill of staying up late to watch this incredible moment.

Mounted on the LM was an aluminum plaque with icons showing Earth's hemispheres, the astronauts' signatures, and a statement from Nixon: "Here men from the planet Earth first set foot upon the Moon, July 1969 A.D. We came in peace for all mankind."

About six and a half hours after *Eagle*



landed, Armstrong stepped into the powdery lunar surface dust and proclaimed, "That's one small step for [a] man, one giant leap for mankind." The "a" wasn't audible in the transmission, altering Armstrong's quote in many accounts. Armstrong always maintained he said "for a man," and the "a" was probably obscured by static.

Armstrong then collected a soil sample. Some 12 minutes later, Aldrin climbed down the ladder and joined his colleague on the surface. The astronauts planted the U.S. flag, described walking around in the light lunar gravity as "easy," and spoke to Nixon via a telephone-radio hookup from the White House.

The moonwalkers kicked up substantial amounts of dust as they walked around. As they then focused on experiments, they shot photographs, deployed a seismometer, set up a retroreflector, and collected rock samples. The excursion was to last 34 minutes, but the tasks took longer than expected. So Houston gave them 15 more minutes. Armstrong strolled almost 200 feet from the LM.

After only 21 hours since landing on the Moon, it was time to go home. Aldrin entered the LM first, followed by his comrade. The two had collected more than 47 pounds (21 kilograms) of rocks. Aldrin accidentally damaged a circuit breaker inside the LM, leading to concern about the engine. But after seven hours of rest, the pair woke up, fired the ascent engine, and lifted off. They reconnected with Collins on *Columbia* and set a course back to Earth. The crew splashed down in the Pacific Ocean on July 24, returning as worldwide heroes.

The Moon had been conquered. Kennedy's dream came true. A new era in human history began. And no one was exactly sure where this amazing moment would lead the world next.

Astronomy Editor **David J. Eicher** *is an author of 23 books on science and history.* **Brian May** *is an astronomer and founding member and guitarist of the legendary rock band Queen.*

This story is adapted from Mission Moon 3-D: A New Perspective on the Space Race*, by David J. Eicher and Brian May, foreword by Charlie Duke, afterword by Jim Lovell (2018), by London Stereoscopic Co. and MIT Press, Boston.*

EXPLORE FROM HOME

Mission Moon 3-D: A New Perspective on the Space Race by David J. Eicher and Brian May (with foreword by Charlie Duke and afterword by Jim Lovell) presents the story of the historic lunar landings and the events that led up to them, told in text and three-dimensional images.

Mission Moon 3-D contains new and unique stereoscopic images of the Apollo Moon landings to show what it was like to walk on the lunar surface. The triumph of the Apollo 11 Moon landing takes center stage, with detailed stories and visually stunning images from the six lunar missions that followed. The book includes 150 stereo photos of the Apollo missions and space race — the largest group ever published — and presents photos never before seen in stereo.

The book delivers a comprehensive tale of the space race. New stories appear from the astronauts, including Jim Lovell's anecdotes about the perilous return of Apollo 13.

Mission Moon 3-D also includes a history of the special and musical movements of the 1960s and beyond that transformed the world, from Vietnam and Woodstock to Live Aid. Don't miss out on this unique treasure.



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The Apollo Lunar Module was born from the idea of Lunar Orbit Rendezvous, in which two astronauts would descend to the lunar surface in a dedicated landing craft, while a third remained in orbit. NORTHROP GRUMMAN

Building Apollo

Changing requirements, trial and error, and outside-the-box thinking were all behind the design of the crafts that carried Apollo astronauts to the Moon and back. BY AMY SHIRA TEITEL

ON MAY 25, 1961, President John F. Kennedy stood before a joint session of Congress and challenged America to land a man on the Moon by the end of the decade. "No single space project in this period will be more impressive to mankind, or more important for the long-range exploration of space; and none will be so difficult or expensive to accomplish," he said.

His words kicked off arguably the greatest engineering feat in modern history.



LM-1, an incomplete first version of the Lunar Module (note it has no landing legs), is lowered for mating to the spacecraft–LM adapter in November 1967. This LM was flown as part of the unmanned Apollo 5 mission, which tested the LM's ascent and descent engines. NASA

Making a Moon ship

The Apollo Command/Service Module (CSM) was conceived as the mothership — the spacecraft that would keep the crew alive throughout the lunar mission all the way to splashdown. The problem was no one knew exactly what that mothership would look like or need to do.

Taking experience from the one-man Mercury program into consideration — NASA had just one suborbital Mercury mission under its belt when Kennedy promised America the Moon — the space agency determined that the Command Module would be a truncated cone with a blunt, rounded bottom. The design was equal parts simplicity and necessity: It was easier to replicate an existing design than start from scratch, and the blunt end protected the crew from the heat generated during atmospheric reentry. It was coupled to the cylindrical Service Module, which carried the consumables (water, oxygen, power) the astronauts needed in space. Only the Command Module would carry the astronauts through reentry; the Service Module would be jettisoned beforehand.



To connect the LM and CSM, engineers devised a "drogue and probe" system. The probe at the top of the conical CSM was designed to latch into the drogue of the LM during docking. Once the two craft were locked together, both drogue and probe were removed; in this Apollo 11 image, the detached drogue appears in the upper right. NASA

Apollo mission planners believed that the simplest mission profile, or mission mode, was Direct Ascent, in which a craft would go straight to the Moon, land, and return. The entire spacecraft would have to land upright on the Moon; that single spacecraft would also have to carry the propellant necessary to launch from the Moon's surface and generate enough velocity to return to Earth. Not only was this option complicated, but it involved a heavy payload that would need a massive, not-yet-developed rocket called Nova to get off the ground. An alternate plan involved launching this massive spacecraft in pieces on two smaller Saturn rockets and effectively building it in Earth orbit in a mode called Earth Orbit Rendezvous.

NASA released its first call for proposals July 28, 1961. Interested aerospace companies were asked to present their bids for a three-man spacecraft that could keep astronauts alive in a shirtsleeve environment (i.e., no spacesuit required) for two weeks, with an additional two days of emergency life support in case of an off-target landing. What NASA didn't ask for at this time was the landing payload; contractors were left to assume that some additional landing stage would turn their cone-shaped mothership into the landing ship. On October 11, 1961, NASA was presented with five bids: three from groups of contractors and two from single



How do you land on the Moon?

When NASA began working out the details of how to land on the Moon, the mission involved one spacecraft, not two. But when the agency changed its approach in July 1962, committing instead to Lunar Orbit Rendezvous, a new plan emerged. Now, one astronaut would stay aboard the heavy mothership in lunar orbit, while his two crewmates would descend to the surface.

What they would descend in was unclear. No one knew how to land on another world, much less how to build something that could land on the Moon, so NASA asked interested contractors to submit bids to build the Lunar Excursion Module.

The Grumman Aircraft Engineering Corporation won the contract November 7, 1962. Work officially began January 14, 1963, just a little under seven years to the end-of-decade lunar landing deadline. Things immediately moved quickly, but while North American Aviation attempted to preserve a year's worth of work with the Block concept, the Lunar Excursion Module suffered through its own development changes.

The first — and simplest — change was the name. NASA decided the word *excursion* sounded like a school field trip, and so renamed it the Lunar Module (LM). The rest of the spacecraft's development was much more complicated, right down to the most basic question of how it would be flown.

Grumman engineers merged necessity and experience. Necessity and NASA's contract specifications dictated the LM would be a two-stage vehicle, wherein the descent stage would land on fixed gear and then serve as a launchpad for the ascent stage. Experience told Grumman that the simplest vertical landing vehicle was a helicopter, so engineers designed the LM with two seats and four bubblelike windows for ample visibility. But those windows caused a huge problem. Not only were they heavy, but they were weak points that opened the LM to potentially fatal temperature fluctuations. To solve this problem, engineers at either NASA or Grumman — recollections are divided — realized that there was no rule saying astronauts had to fly sitting down. Standing closer to smaller windows would give the same visibility and in the Moon's lower gravity field, just one-sixth what we feel on Earth, human legs would be more-than-adequate shock

NOVA: THE ROCKET THAT NEVER WAS

Before NASA decided to launch Apollo on the Saturn V rocket, the agency considered a larger rocket called Nova. The necessary launch vehicle for the heavier Direct Ascent mission profile, this mindblowingly large rocket was never built.

The Saturn V was massive. Standing 363 feet (110 meters) tall with a 33-foot (10 m) diameter, it delivered 7.5 million pounds (3.4 million kilograms) of thrust at the moment of launch. This three-stage rocket had five F-1 engines in its first stage, five J-2 engines powering its second stage, and a single J-2 engine on its third stage.

Nova was conceived as both taller and wider than the Saturn V, and almost twice as powerful. Its first stage was powered by eight F-1 engines, each of which could deliver 1.5 million pounds (680,000 kg) of thrust — bringing the rocket's total power to a whopping 12 million pounds (5.4 million kg) of thrust at launch. The second stage was powered by four liquid-hydrogen M-1 engines that could produce an additional 4.8 million pounds (2.2 million kg) of thrust. The third and final stage was akin to the Saturn V's — it had one J-2 engine, whose 200,000 pounds (90,000 kg) of thrust could send a heavy payload to the Moon.

Because Direct Ascent was NASA's preferred mission mode in the earliest days of Apollo, Nova was the frontrunner for launch vehicle in 1958. But when NASA realized it could launch the same spacecraft on two smaller — and simpler — Saturn rockets (Earth Orbit Rendezvous mode), the larger, more complicated Nova design was pushed to the back burner. It stayed there when NASA later settled on Lunar Orbit Rendezvous for Apollo; there was just no need for a rocket as big as Nova.

Nevertheless, Nova was poised to make a comeback after Apollo. As they looked ahead, program managers and engineers expected this rocket to be the workhorse that would extend humanity's reach to the other planets and deep into the solar system after landing on the Moon. Of course, this never happened. Toward the end of the 1960s, the rising cost of Apollo brought a new emphasis on reusable rockets; rather than develop a larger and more powerful launch vehicle, NASA was instead directed to develop the space shuttle system in the 1970s. — *A.S.T.*

Amy Shira Teitel *is a spaceflight historian and popular YouTube personality. She also pens the Vintage Space blog for* Discover *magazine.*

companies, one of which was North American Aviation.

North American was the underdog in this race. A month earlier, it had won the bid to build the second stage of the Saturn V rocket, and no one thought it could possibly win a second major piece of Apollo. When NASA reviewed the bids, North American scored second, behind the Martin Company. But North American had unique experience: Not only had it built exceptional planes like the P-51 Mustang and the B-25 bomber, it also had built the rocket-powered X-15 that was breaking speed and altitude records flying to the fringes of space. North American ultimately knew more about the technical and physical stresses of spaceflight than the other contractors, and so it won the contract.

Not one, but two

As North American began building the CSM in early 1962, NASA began considering a new mission mode: Lunar Orbit Rendezvous. This mode kept the CSM and its heavy load of fuel for the return flight in orbit around the Moon, while a dedicated landing vehicle descended to the Moon's surface. Though the rendezvous made the mission more complicated, it also made the payload lighter, because the lander could be smaller and thus require less fuel to escape the Moon's gravity. The whole payload would be light enough to launch on a single Saturn V rocket, which was simpler to develop and gave NASA the best chance at meeting Kennedy's end-of-decade deadline. To the surprise of many within the agency, Lunar Orbit Rendezvous quickly became the favored approach; NASA committed to it July 11.

Suddenly, North American had not only lost the glory of their module landing on the Moon, but the company was also now responsible for modifying its spacecraft to enable docking with the second ship and giving the astronauts some means to travel between the vehicles while they were connected. The required changes were significant; it was almost like building a whole new spacecraft. In an effort to retain its first year of work, North American came up with a buglike craft that would be launched in a protective shroud and would only fly in a vacuum, Grumman engineers designed the LM from the inside out without worrying about aerodynamics.

Inside the LM, the crew would fly standing up, secured in place by hook-and-loop fasteners on the floor, as well as cables that clipped into their suits at waist level. Around them were 12 instrument panels housing 158 switches, 16 variable controls, four hand controllers, two computer keyboards, and a host of displays. Housed within this hardware was the absorbers for the moment of lunar touchdown.

A buglike craft

By the fall of 1964, after only two years of development, the LM had become a spacecraft designed to do the unimaginable: land on the Moon.

On the outside, it almost didn't look up to the task. Because it would be launched in a protective shroud and would only fly in a vacuum, Grumman engineers designed the LM from the inside out without worrying about aerodynamics.



John F. Kennedy stands in front of a North American Aviation mock-up of a potential lunar lander design as the president prepares to address employees at the Manned Spacecraft Center in Houston on September 12, 1962. NORTHROP GRUMMAN



During launch, the LM sat in a folded configuration inside a compartment of the Saturn V rocket, called the spacecraft–LM adapter (SLA). In this image, dated January 1, 1969, the completed Apollo 11 CSM is ready for mating to the SLA. NASA/MARSHALL SPACE FLIGHT CENTER



The Block I Command Module that would fly in the unmanned Apollo 6 mission is lifted into place above the Service Module in the Manned Spacecraft Operations Building at Kennedy Space Center, prior to mating the two in early December 1967. NASA

with the "Block" concept. The original spacecraft, which couldn't support a mission in conjunction with the Lunar Module, was called Block I. The Block II CSM would be designed to support a lunar mission.

The first Block I mission was scheduled as Apollo 1 in early 1967. Owing in large part to the amount of flammable material in the cabin, the pure oxygen environment under high pressure, and the heavy, inward-opening, three-part hatch, when a fire broke out during a routine pre-launch test, the crew had no chance of escape. Virgil "Gus" Grissom, Roger Chaffee, and Ed White were killed on the launchpad January 27, 1967, and for a moment, it looked like the Apollo program might not recover.

The subsequent accident investigation forced NASA to eliminate all Block I manned missions. Block I CSMs flew only on unmanned missions, in some cases with elements of the Block II version added to test them in advance of manned flights. Block II underwent several design changes following the tragedy. Now boasting a safer mixed gas environment on the launchpad as well as a different layout of material inside the spacecraft and a simpler two-part hatch, it made its first flight with Apollo 7 in October 1968.

From that point on, the CSM successfully flew on 10 Apollo missions, six of which landed on the Moon, bringing every astronaut home safely and serving as their home away from home en route to the Moon and back.

Primary Guidance and Navigation Section (or PGNS, pronounced "pings"), the onboard digital autopilot system. While the computer monitored the craft's position, environment, and consumables vital to the landing, the crew could keep an eye on displays and the lunar terrain, taking over manual control if needed. The crew cabin was a snug 92 inches (234 centimeters) in diameter and 42 inches (107 cm) deep, with the LM's external structure built directly around this hardware. The result was a lumpy ascent stage over an octagonal descent stage, which provided extra storage for surface experiment packages, lunar rovers (on later missions), and a special compartment for the flag.

The astronauts didn't love the LM at first blush. As hotshot fighter pilots used to streamlined, aerodynamic planes, they thought the buglike spacecraft looked more gangly than flight-worthy. The crew of Apollo 9 even gave their LM the call sign *Spider* when it flew in March 1969.

But they came to love it. Two years ago, I had a chance to talk to David Scott, command module pilot of Apollo 9 and commander of Apollo 15. I asked him which of all the planes he'd ever flown was his favorite, and he answered, "The LM on fumes." He said it was so light and responsive it was an absolute dream to pilot.

Though each spacecraft played a specific role, the CSM and LM together became the backbone of 11 Apollo missions — even famously so, on Apollo 13. Through triumphs and one successful failure, the Apollo Command/Service and Lunar Modules kept 24 men alive on what was arguably humanity's most audacious journey.



RIGHT TOP: Two Grumman workers constructing the midsection of LM-5's ascent stage provide some idea of the cockpit's small dimensions. LM-5 was the Lunar Module used in the Apollo 11 Moon landing.
NORTHROP GRUMMAN



RIGHT BOTTOM: Workers check one leg of a completed LM; attached to the leg is the aluminum ladder that the astronauts descended to reach the lunar surface.
NORTHROP GRUMMAN

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



SATURN LOOMS LARGE when it reaches opposition this month. With the rings tipped wide open, observers should look for the dark Cassini Division and other fine details. NASA/ESA/A. SIMON (GSFC) AND THE OPAL TEAM/J. DEPASQUALE (STScI)

JULY 2019

The ringed planet at its peak

These warm summer nights bring magnificent views of Saturn. The ringed planet remains visible all night, a feat nearly matched by its equally stunning sister world, Jupiter. Alas, the solar system's smaller planets don't fare as well. Mercury and Mars hang low in evening twilight, while Venus appears just before dawn.

Let's start our celestial tour with **Mercury** and **Mars**, which we can see only in early July. The two planets glow faintly in the west-northwest shortly after sundown. Your best opportunity to find them comes July 3, when a waxing crescent Moon points the way.

The one-day-old Moon then stands 5° above the horizon 30 minutes after sunset. Once you locate it, use binoculars to spy magnitude 1.8 Mars 3° to the upper left. Mercury glows a bit brighter, at magnitude 1.4, some 4° to the Red Planet's left.

In between the brilliant flashes and explosions of your local July 4 fireworks, look to the west for a noticeably fatter crescent Moon, now some 15° high a half-hour after sunset. The two planets lie about 10° to our satellite's lower right.

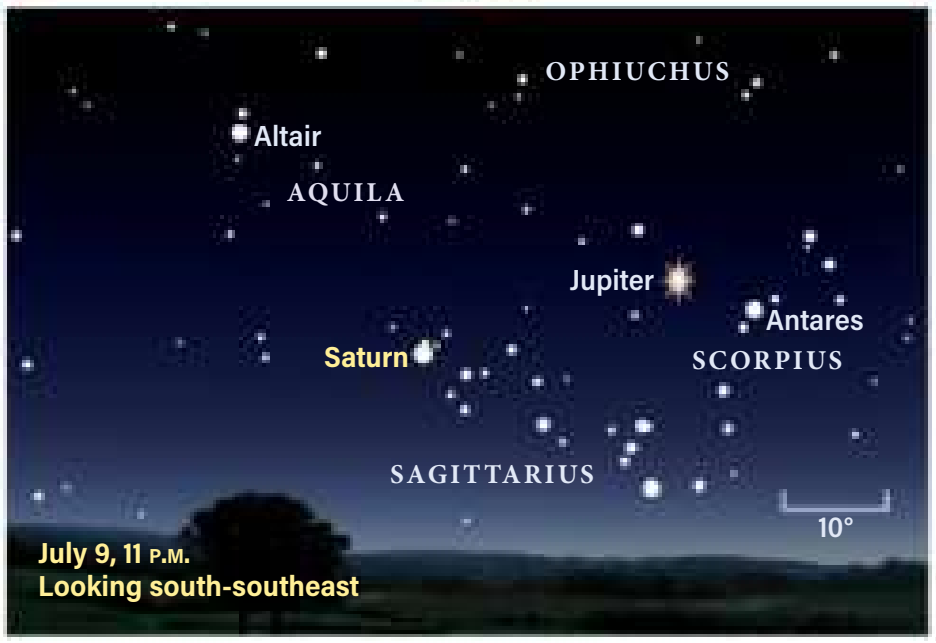
Mercury and Mars are in conjunction with each other July 7. That evening, magnitude 2.0 Mercury lies 4° south (lower left) of magnitude 1.8 Mars, though both prove difficult to see in the bright twilight even through binoculars. The two planets continue to drop lower with each passing day and will disappear within a week.

You won't have to search as hard to find **Jupiter**. The giant planet stands clear of the southeastern horizon after sunset and climbs nearly 30° high in the south well before midnight. It shines at magnitude –2.5 against the faint backdrop of southern Ophiuchus the Serpent-bearer.

Any telescope shows Jupiter's disk. In mid-July, the world spans 44.4" across its equator and 41.6" through its poles. The 6 percent discrepancy, caused by a combination of Jupiter's gaseous nature and its less than 10-hour rotation period, becomes obvious once you know to look for it.

Even more striking are the details you can see in the jovian atmosphere. Look for two dark cloud belts straddling a brighter zone that coincides with the

Saturn takes center stage



The gas giant shines at magnitude 0.1 at opposition July 9, when it remains visible all night among the stars of Sagittarius. ALL ILLUSTRATIONS: *ASTRONOMY*: ROEN KELLY

OBSERVING HIGHLIGHT

SATURN peaks July 9, when it shines at magnitude 0.1 and spans 18.4" with rings extending 41.8" when seen through a telescope.

equator. The southern belt carries the Great Red Spot, which appears obvious whenever the planet's spin brings it onto the Earth-facing hemisphere.

Jupiter's four bright moons — Io, Europa, Ganymede, and Callisto, in order of increasing distance — circle the gas giant in periods ranging from a couple of days to a couple of weeks. The three inner satellites cross in front of and pass behind the planet once each orbit. Many observers consider these events the highlight of a Jupiter viewing session.

Let's take a look at a few of July's best. Io transits Jupiter's disk during the evening hours July 4, 11, 18, and 27. On the 4th, the transit begins at 10:02 P.M. EDT while the moon's shadow follows 34 minutes later. Both appear against the planet's North Equatorial Belt. The July 11 transit starts at 11:48 P.M. EDT with the shadow trailing 42 minutes behind. The longer gap arises from a shift in the relative positions of Jupiter, the Sun, and Earth.

Io circles Jupiter quickly, and the following evening you can see the moon as it comes around the planet's far side. At 11:51 P.M. EDT on the 12th, Io emerges from Jupiter's shadow some 14" off the eastern limb and adjacent to the South Equatorial Belt.

— *Continued on page 54*

RISING MOON | A crater worthy of an eminent astronomer

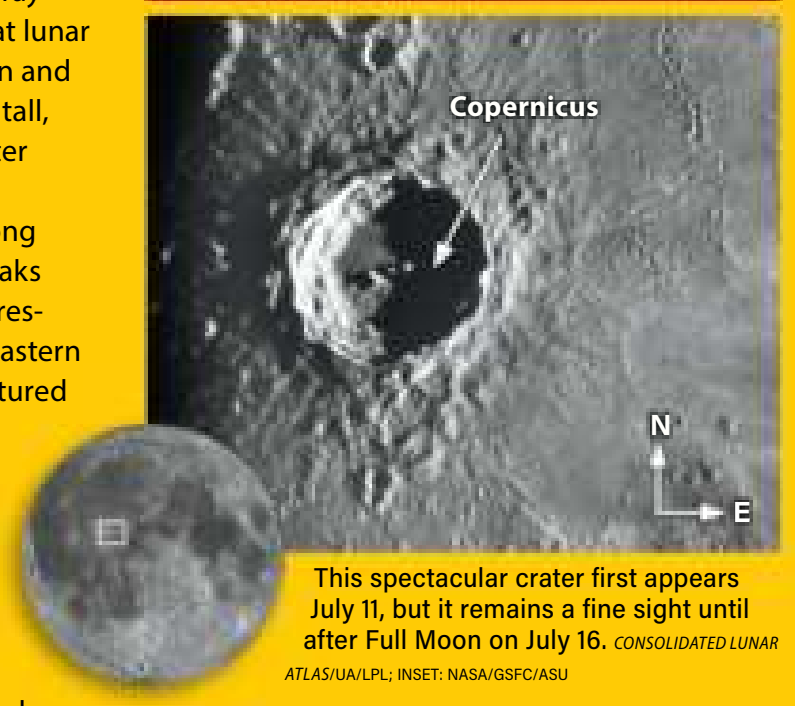
TERRACED WALLS, complex central peaks, a rough ejecta blanket, and an expansive ray system at Full Moon — it's no surprise that lunar observers visit the crater Copernicus again and again. The Sun first rises over this crater's tall, modestly sharp rim July 11, two nights after First Quarter phase.

The low Sun angle on the 11th casts long shadows, accentuating the visibility of peaks and bumps as well as holes and mild depressions. Notice the jagged black teeth the eastern rim projects onto Copernicus' floor. A textured apron surrounds the entire crater. It originated when surface material got splattered outward in all directions in the immediate aftermath of the impact that created Copernicus. Lunar geologists call it an ejecta blanket.

The terraced walls are a delight to see at high power. To imagine how they formed, dig a hole in a wet sandy beach. Within seconds, the steep walls collapse inward to form giant staircases down to the floor. Sharp-eyed observers may notice that Copernicus' terraces tilt down to the outside because the higher inner edge casts a shadow toward the rim. The eastern terraces show up best on the 11th. In case you get clouded out, the sequence almost repeats the evening of August 9, but with an even lower Sun angle than the image shown here.

For a few days on either side of the July 16 Full Moon, the nearly overhead Sun beats down on the 60-mile-wide crater. Thread in a filter to reduce the glare, pump up the power, and take in the scenery. The rough terrain and differences in elevation and texture have completely disappeared, replaced by a land of light rays and darker mare material showing through from underneath. These brightness variations help astronomers piece together the history of the lunar surface. The impacting asteroid may have landed in a dark lava field, but the blast excavated down to lighter-hued rocks and hurled them outward to create the superb ray system.

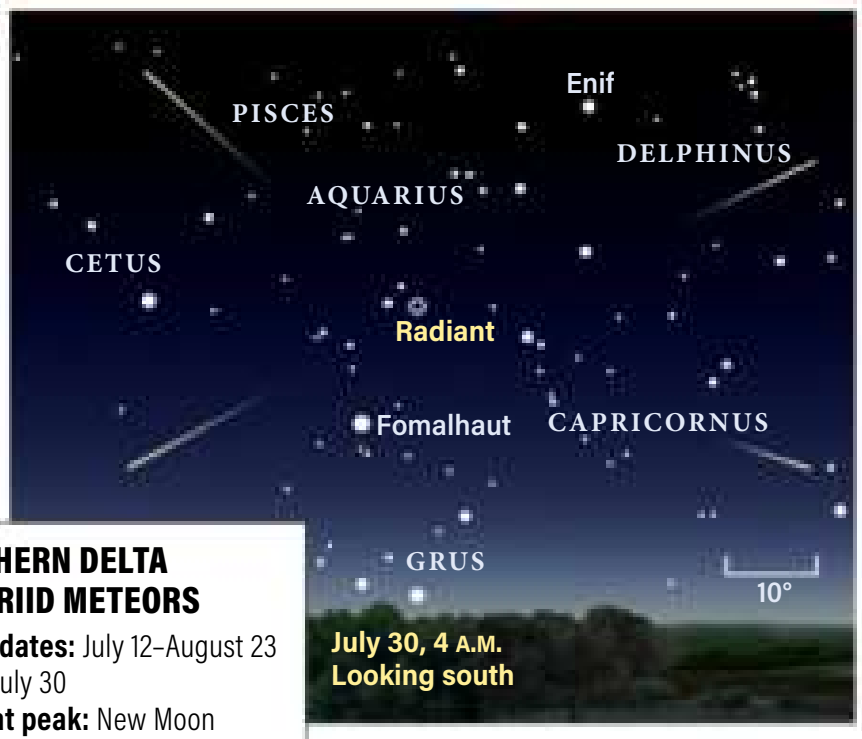
Copernicus



This spectacular crater first appears July 11, but it remains a fine sight until after Full Moon on July 16. *CONSOLIDATED LUNAR ATLAS*/UA/LPL; INSET: NASA/GSFC/ASU

METEOR WATCH | The year's longest-running show

Southern Delta Aquariid meteors



With New Moon arriving just one day after this shower peaks, viewing conditions should be ideal.

SOUTHERN DELTA AQUARIID METEORS

Active dates: July 12–August 23
Peak: July 30
Moon at peak: New Moon
Maximum rate at peak: 25 meteors/hour

THE SOUTHERN STRAND of the Delta Aquariid meteor stream encounters Earth during much of July and August, but reaches a broad peak from July 28–30. And with New Moon arriving on the 31st, viewing conditions this year should be close to perfect. Under a dark sky with the radiant — the point in Aquarius from which the meteors appear to emanate — overhead, observers could see up to 25 meteors per hour.

Unfortunately for Northern Hemisphere skygazers, the radiant never passes overhead. From mid-northern latitudes, the radiant peaks at an altitude of 35° between 3 and 4 A.M. local daylight time. This cuts the observed number of meteors roughly in half, with observers in the southern United States seeing a few more and those in Canada a few less.

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

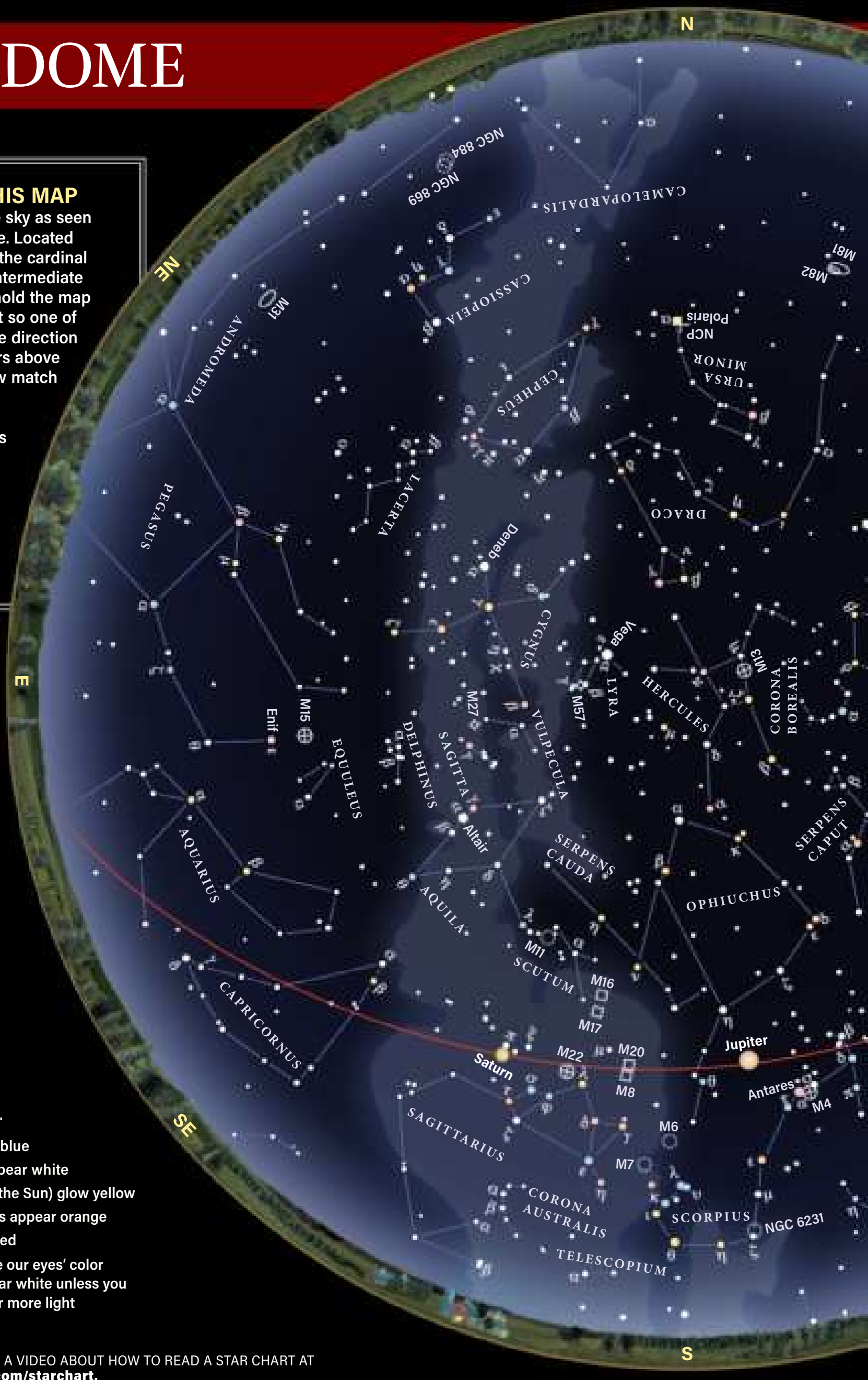
STAR MAGNITUDES

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

STAR COLORS

A star's color depends on its surface temperature.

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



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



JULY 2019

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

ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

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

CALENDAR OF EVENTS

1 Asteroid Melpomene is at opposition, 9 P.M. EDT

2 New Moon occurs at 3:16 P.M. EDT; total solar eclipse

4 The Moon passes 0.09° north of Mars, 2 A.M. EDT

The Moon passes 3° north of Mercury, 5 A.M. EDT

Earth is at aphelion (94.5 million miles from the Sun), 6 P.M. EDT

5 The Moon is at perigee (226,009 miles from Earth), 1:00 A.M. EDT

6 Mercury is stationary, midnight EDT

7 Mercury passes 4° south of Mars, 10 A.M. EDT

9 First Quarter Moon occurs at 6:55 A.M. EDT

Saturn is at opposition, 1 P.M. EDT

13 The Moon passes 2° north of Jupiter, 4 P.M. EDT

14 Pluto is at opposition, 11 A.M. EDT

16 The Moon passes 0.2° south of Saturn, 3 A.M. EDT

The Moon passes 0.04° north of Pluto, 1 P.M. EDT

Full Moon occurs at 5:38 P.M. EDT; partial lunar eclipse

19 Dwarf planet Ceres is stationary, 1 P.M. EDT

20 The Moon is at apogee (251,954 miles from Earth), 7:59 P.M. EDT

21 The Moon passes 4° south of Neptune, 4 A.M. EDT

Mercury is in inferior conjunction, 9 A.M. EDT

24 Last Quarter Moon occurs at 9:18 P.M. EDT

25 The Moon passes 5° south of Uranus, 3 A.M. EDT

30 Southern Delta Aquariid meteor shower peaks

31 Mercury is stationary, 3 P.M. EDT

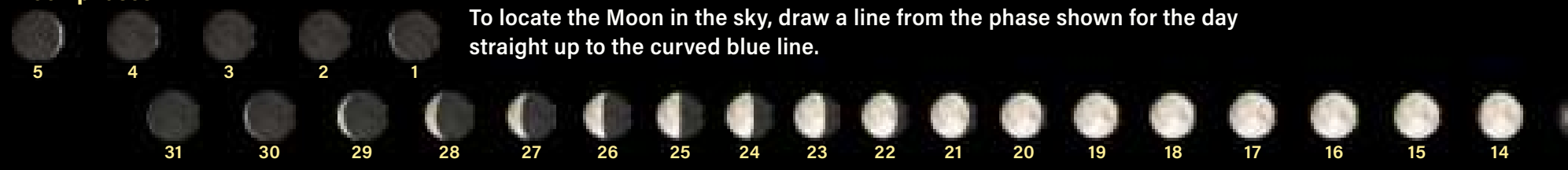
New Moon occurs at 11:12 P.M. EDT

PATHS OF THE PLANETS



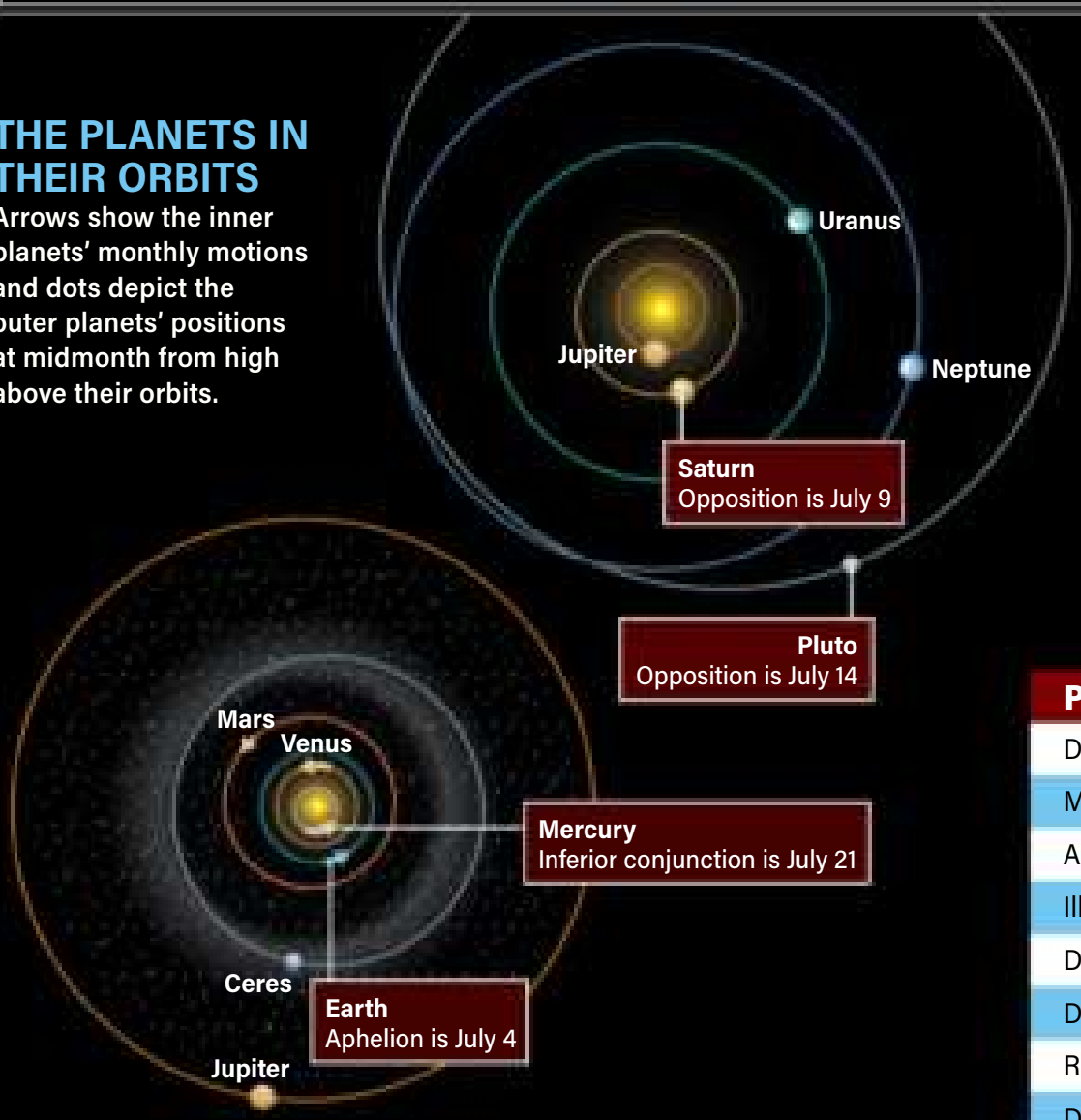
Moon phases

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



THE PLANETS IN THEIR ORBITS

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



THE PLANETS IN THE SKY

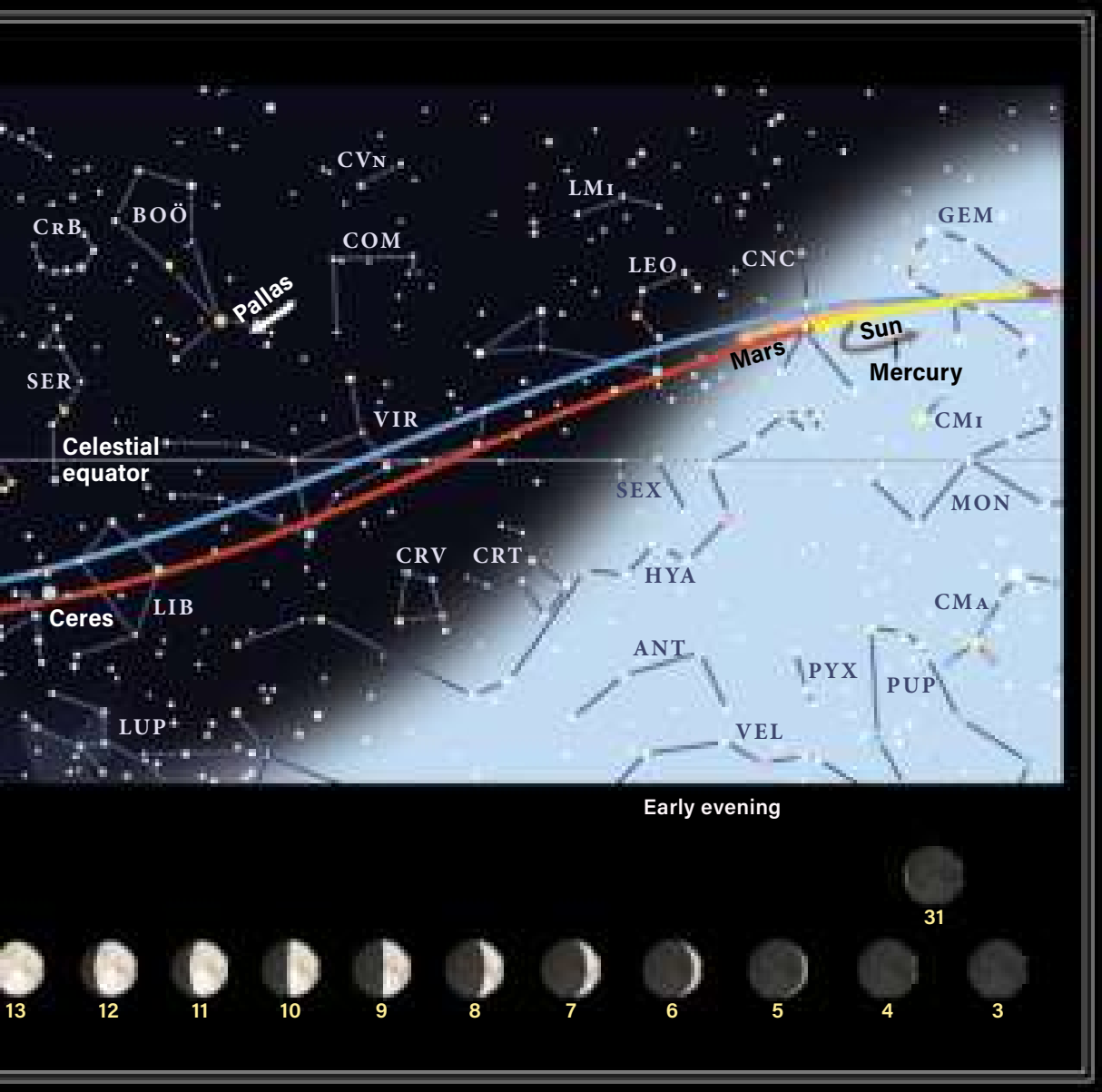
These illustrations show the size, phase, and orientation of each planet and the two brightest dwarf planets at 0h UT for the dates in the data table at bottom. South is at the top to match the view through a telescope.



PLANETS	MERCURY	VENUS
Date	July 1	July 1
Magnitude	1.0	–3.9
Angular size	9.4"	9.9"
Illumination	27%	98%
Distance (AU) from Earth	0.717	1.683
Distance (AU) from Sun	0.461	0.721
Right ascension (2000.0)	8h17.6m	5h44.8m
Declination (2000.0)	18°45'	23°12'

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.

JULY 2019

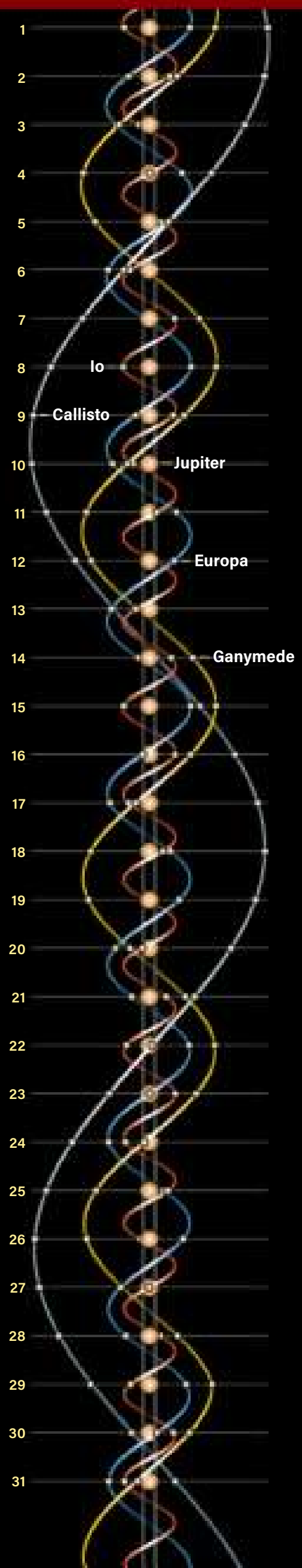


Early evening



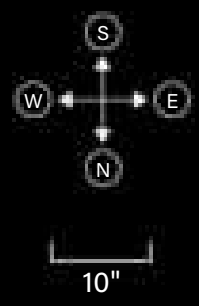
JUPITER'S MOONS

Dots display positions of Galilean satellites at 11 P.M. EDT on the date shown. South is at the top to match the view through a telescope.







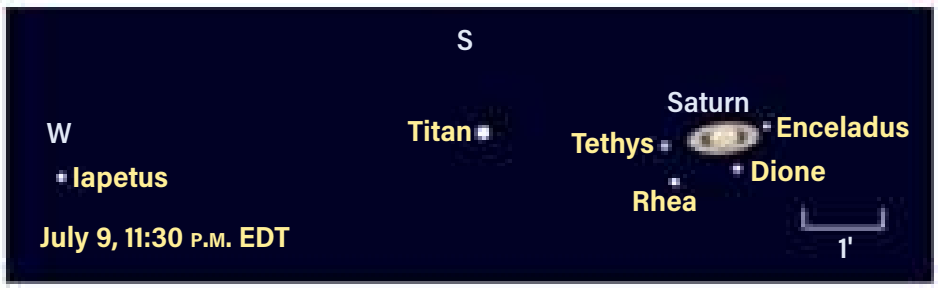




MARS	CERES	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
July 1	July 15	July 15	July 15	July 15	July 15	July 15
1.8	8.1	−2.5	0.1	5.8	7.8	14.2
3.7"	0.7"	44.4"	18.4"	3.5"	2.3"	0.1"
99%	98%	100%	100%	100%	100%	100%
2.564	2.055	4.437	9.037	20.061	29.360	32.823
1.651	2.801	5.288	10.049	19.839	29.936	33.839
8h06.1m	15h53.2m	16h56.7m	19h11.6m	2h15.5m	23h18.6m	19h33.7m
21°29'	−19°20'	−22°09'	−22°06'	13°04'	−5°34'	−22°07'

 — *Continued from page 49*

See Saturn's top six satellites



With outer Iapetus in line with Titan and inner Enceladus near greatest elongation, the ringed world's moons show up well at opposition July 9.

Europa transits Jupiter's disk starting at 9:54 P.M. EDT on July 23. The satellite traverses three-quarters of the disk before its shadow drops onto the jovian cloud tops at 11:45 P.M. The icy white moon crosses the North Temperate Zone and practically disappears against the bright cloud band, while its black shadow stands out against the same zone. Europa tracks farther north than Io because the satellites' orbits currently tip 3° to our line of sight.

Jupiter's darker and largest moon, Ganymede, crosses the gas giant's north polar region the evening of July 24. The transit begins before sundown, but viewers in the eastern half of North America can watch it wrap up at 9:58 P.M. EDT. The moon's shadow first touches the jovian disk at 11:26 P.M. EDT and takes 2 hours 27 minutes to finish its trek. Ganymede offers an encore performance on the 31st.

Lovely **Saturn** lies among the background stars of Sagittarius the Archer, just south of that constellation's Teaspoon asterism. It moves westward relative to this backdrop throughout July, passing 1.1° south of magnitude 2.9 Pi (π) Sagittarii on the 20th and ending the month 0.7° southeast of magnitude 3.8 Omicron (o) Sgr.

The ringed planet reaches opposition and peak visibility July 9, when it lies opposite the Sun in our sky and thus stays out all night. Opposition also brings the world closest to Earth, so it shines at its brightest for the year, magnitude 0.1. As an outer planet, however, Saturn changes slowly, and it remains within a few hundredths of this magnitude all month.

For viewers at mid-northern latitudes, Saturn reaches a peak altitude of nearly 30° at 1:30 A.M. local daylight time July 1 and about 30 minutes earlier each week thereafter. Skywatchers farther north will find Saturn lower in the sky, and those farther south will see it climb higher.

Observers should take every opportunity to view the ringed world through a telescope. The best times are within an hour or two of its peak altitude, when the planet's light passes through less of Earth's turbulent atmosphere. At opposition, Saturn's equator measures 18.4" across and the polar diameter is 16.9". (This 7 percent flattening is more pronounced than Jupiter's.) But the star attraction is Saturn's beautiful ring system, which spans 41.8" and tilts 24° to our line of sight. Look for details, most noticeably the dark Cassini Division that separates the outer A ring from the brighter B ring.

Saturn provides observers with more moons than Jupiter.

WHEN TO VIEW THE PLANETS

EVENING SKY
Mercury (west)
Mars (northwest)
Jupiter (south)
Saturn (southeast)

MIDNIGHT
Jupiter (southwest)
Saturn (south)
Neptune (east)

MORNING SKY
Venus (northeast)
Saturn (southwest)
Uranus (east)
Neptune (south)

378 **The average number of days between successive oppositions of Saturn.**

COMET SEARCH | Take a dip in the celestial sea

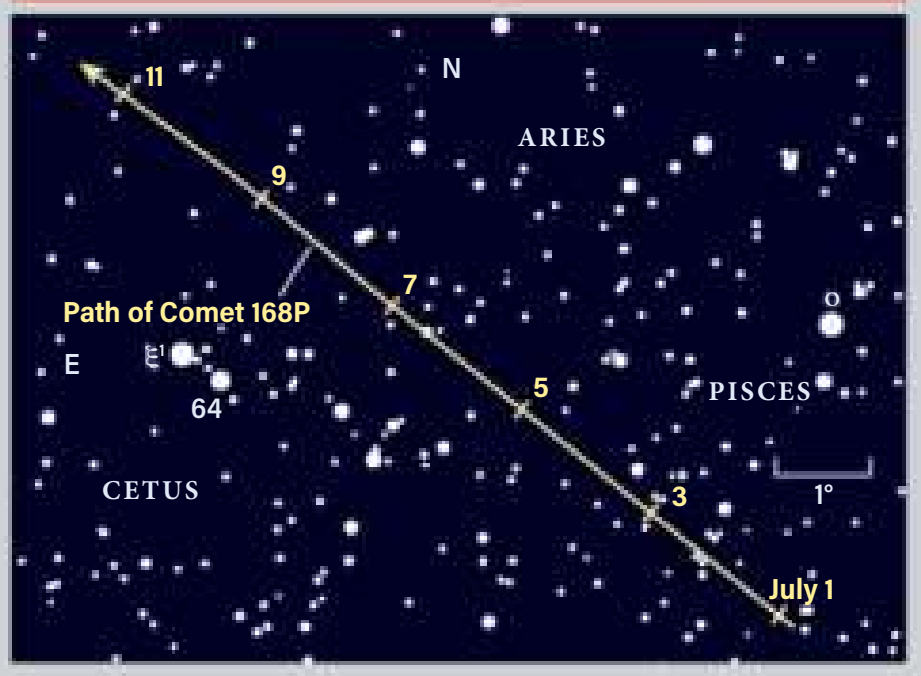
AFTER A FEW MONTHS' LULL, things are looking up for comet observers. It appears we'll see at least one comet glowing at 10th magnitude or brighter every month starting this autumn and running through the end of next year.

You can get a head start before dawn breaks these short summer nights. Comet 168P/Hergenrother swims the waters near the border between Pisces the Fish and Cetus the Whale before emerging onto the dry land of Aries the Ram during July's second week.

Hergenrother loops through the inner solar system every 6.8 years. On its last time through in 2012, the dirty snowball experienced an outburst and brightened past 10th magnitude. If we aren't lucky again, the comet may reach only 12th magnitude in July and be a difficult fuzzball. The best observing window comes during the month's first two weeks when the Moon stays out of the morning sky.

As its high number attests, 168P/Hergenrother is a relatively recent find. American astronomer Carl Hergenrother first spotted it in 1998 during a survey to discover asteroids.

Comet 168P/Hergenrother



The stars near the intersection of the constellations Pisces, Cetus, and Aries serve as steppingstones to the dim glow of this periodic visitor.

Totality comes to Chile and Argentina



Observers along a narrow track can see the Sun's corona blossom into view during the July 2 total eclipse. PATRICK MARTINEZ

Any telescope reveals 8th-magnitude Titan, which circles the planet once every 16 days. When the giant satellite lies north or south of Saturn, it appears 1.3' away. At greatest eastern or western elongation, Titan lies 3.1' from the planet.

Three 10th-magnitude moons — Tethys, Dione, and Rhea — lie closer to Saturn than Titan and appear through 4-inch and larger scopes. You'll need a bigger instrument to spot 12th-magnitude Enceladus. It orbits in 1.4 days and shows up only when it is farthest east or west of the planet. It happens to be at greatest eastern elongation on opposition night; hunt for it 16" from the A ring's edge.

Outer Iapetus glows at 10th magnitude in the days around its July 15 greatest western elongation. Your best chance to see it comes on opposition night when it lines up with Titan. The outer moon then lies 8.4' west of Saturn, some 2.7 times farther away than Titan.

The two outer planets appear best during the morning hours. **Neptune** rises around midnight local daylight time July 1 and by 10 P.M. on the 31st. It lies in Aquarius, just east of 4th-magnitude Phi (ϕ) Aquarii. The planet's westward motion against this backdrop reduces the gap between it and Phi from 1.3° to 0.9° during July. Magnitude 7.8 Neptune shows up easily through binoculars; a telescope at high magnification shows the planet's 2.3"-diameter disk and blue-gray color.

Uranus stands 20° above the eastern horizon as twilight begins July 1 and more than doubles that altitude by month's end. It resides in southern Aries, 10° south and slightly east of 2nd-magnitude Hamal (Alpha [α] Arietis), the Ram's brightest star. The magnitude 5.8 planet stands out surprisingly well through binoculars in a sparse region 2.3° south of the magnitude 5.7 star 19 Ari. When viewed through a telescope, Uranus shows a distinctive blue-green color on a disk that spans 3.5".

July 1 provides your best chance to see **Venus** before it disappears in the Sun's glare. Use the waning crescent Moon as a guide. It appears 5° high in the east-northeast 30 minutes before sunrise, and Venus lies one binocular field to the lower left. Despite gleaming at magnitude –3.9, the planet barely shows up against the brightening sky. You might be able to track Venus for a few more days, but it drops out of view by the end of July's first week.

A total solar eclipse occurs July 2 along a narrow track that crosses the South Pacific, Chile, and Argentina. The Moon's umbral shadow first touches South America on the Chilean coast near La Serena and completes its trek as the Sun sets just south of Buenos Aires.

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

LOCATING ASTEROIDS |
A dwarf planet swings through Libra

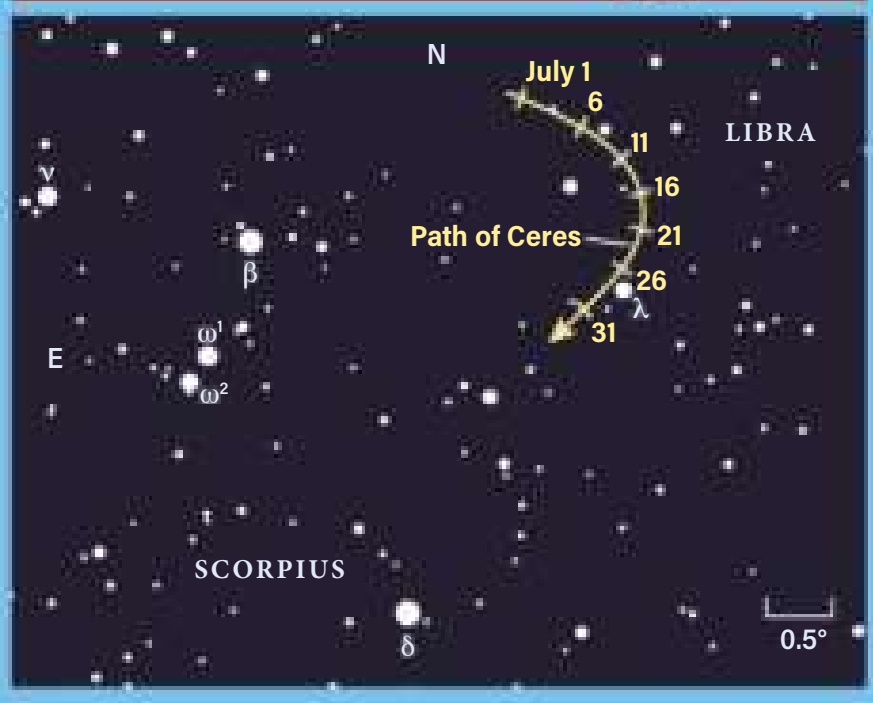
THE DWARF PLANET CERES climbs highest in the south as darkness falls, making a tempting target during the early evening hours. Glowing at 8th magnitude, it's easy to find through binoculars or a small telescope among the bright stars near the border between Scorpius the Scorpion and Libra the Scales.

Ceres lies about 15° west of Jupiter all month, but it's simpler to locate by hopping from the lovely 2nd-magnitude double star Beta (β) Scorpii. The dwarf planet lies within 3° of Beta all month. It ventures even closer to magnitude 5.0 Lambda (λ) Librae during July's final week. Only 8' separate the two at their closest the evening of the 27th.

To identify Ceres from the background stars, make a sketch at the eyepiece that includes three or four stars in addition to the dot you think is the dwarf planet. Return to the same field a night or two later and see which object shifted position. The "star" that moved is Ceres. Fortunately, the Milky Way dust lanes that thread through this region help suppress the number of faint background stars that could confuse matters.

Ceres is the undisputed king of the asteroid belt. Its substantial size, nearly 600 miles across, and nearly spherical shape helped persuade astronomers to raise its status from asteroid to dwarf planet.

Ceres barely evades the Scorpion's reach



The invisible border between Scorpius and Libra seemingly blocks the Scorpion's claws from snatching this 8th-magnitude object.

Martin Ratcliffe *provides planetarium development for Sky-Skan, Inc., from his home in Wichita, Kansas.* **Alister Ling**, *who lives in Edmonton, Alberta, has watched the skies since 1975.*

One giant leap



Neil Armstrong prepares to step off the footpad of the Apollo 11 lunar module, *Eagle*. The TV camera's grainy footage was the only way people could experience this historic moment.

ALL PHOTOS, UNLESS STATED: NASA

BEAMED ACROSS 241,000 MILES (388,000 kilometers) of space, the grainy images reminded me of a scene from the classic TV series *The Outer Limits*. But what I was seeing on my family's small-screen, black-and-white television were live pictures of Neil Armstrong preparing to step onto the lunar surface from the Apollo 11 lunar module (LM), *Eagle*.

"I'm at the foot of the ladder," he says in a remarkably calm voice. "The LM footpads are only depressed in the surface about 1 or 2 inches, although the surface appears to be very, very fine-grained as you get close to it. It's almost like a powder." A half-minute later, he declares: "OK. I'm going to step off the LM now."

After what seemed like an eternity (though it lasted only 11 seconds), Armstrong uttered the words that still resonate across half a century: "That's one small step for man, one giant leap for mankind." It marked the culmination of a mission that had begun on a sunny Florida morning four days before, the fulfillment of a goal set eight years earlier by President John F. Kennedy, and the achievement of the dreams of countless people over the centuries who had stared in awe at Earth's brilliant satellite.

After waiting anxiously for 20 minutes, Buzz Aldrin descended the *Eagle*'s ladder and joined Armstrong on the surface. For two and a half hours, the astronauts gathered soil samples, deployed scientific experiments, planted a U.S. flag, and talked with President Nixon from the Oval Office. All the while, the third member of the Apollo 11 crew, Michael Collins, orbited some 66 miles (106 km) overhead.

The following pages showcase a small sample of the more than 1,000 photographs the Apollo crew captured during this historic mission. So sit back, grab a cup of coffee (or glass of Tang), and experience humankind's grand adventure one more time.

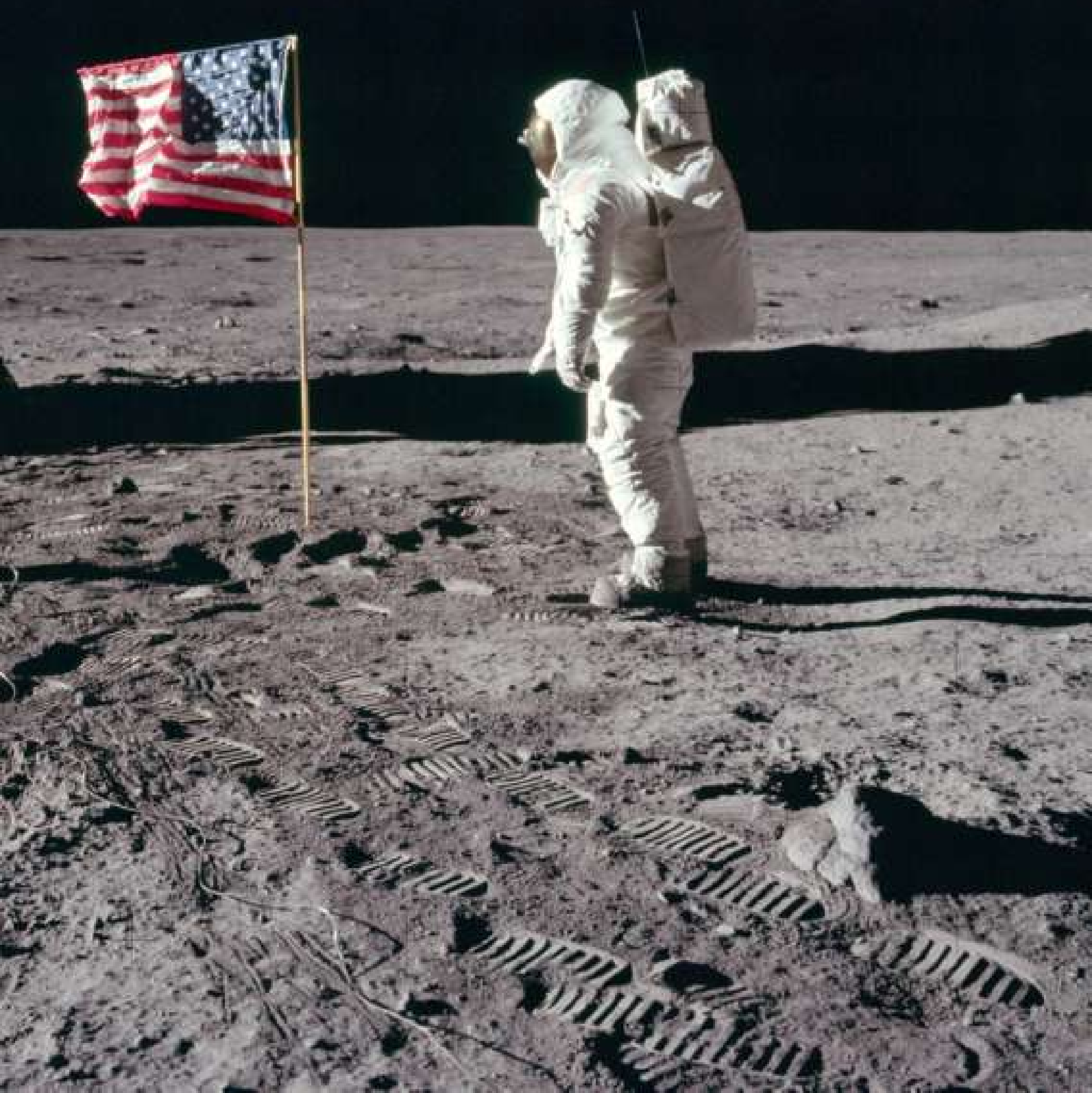
Senior Editor **Richard Talcott** *was a gangly, 14-year-old kid who dreamed of one day going to the Moon while watching the Apollo 11 mission unfold.*



Buzz Aldrin salutes the American flag as he looks directly toward the Sun. (You can see his fingertips on the far side of the helmet.) Several well-defined bootprints appear in the foreground.

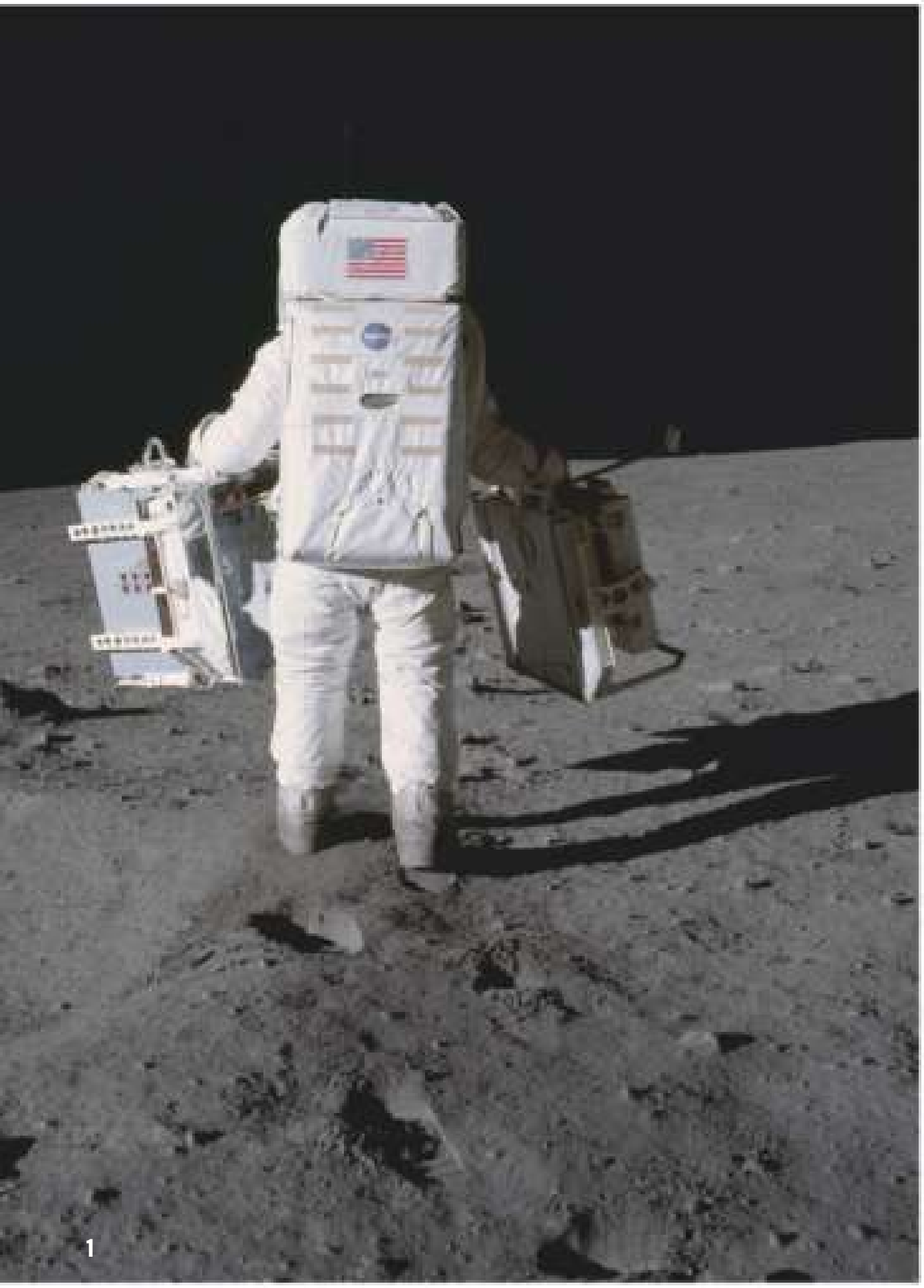
for mankind

It's hard to believe 50 years have passed since humans first set foot on the Moon. BY RICHARD TALCOTT





Seconds after the Saturn V's rockets ignited on the morning of July 16, a fisheye camera lens mounted on the launch tower captured the massive rocket passing by.



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1. Aldrin carries the Lunar Ranging Retro-Reflector in his right hand and the seismometer in his left. He skirts the edge of a small crater as he heads south from *Eagle* toward the deployment sites for the two experiments.

2. The Apollo 11 astronauts greet their wives — Pat Collins, Jan Armstrong, and Joan Aldrin (left to right) — from inside the Mobile Quarantine Facility after they arrived at Ellington Air Force base in Texas on July 27.

3. The loneliest man in the universe, Michael Collins, kept busy photographing the Moon's surface while in orbit. Here, he captured the large crater Daedalus, which lies on the Moon's farside just south of the point precisely opposite the center of the lunar disk we see from Earth.

4. Earth grows smaller and smaller as the astronauts cruise toward the Moon. The continent of Africa dominates this view of their home world.

5. Armstrong photographed the fully deployed Lunar Ranging Retro-Reflector, which still reflects laser signals sent from Earth, to help give a precise distance to our satellite.



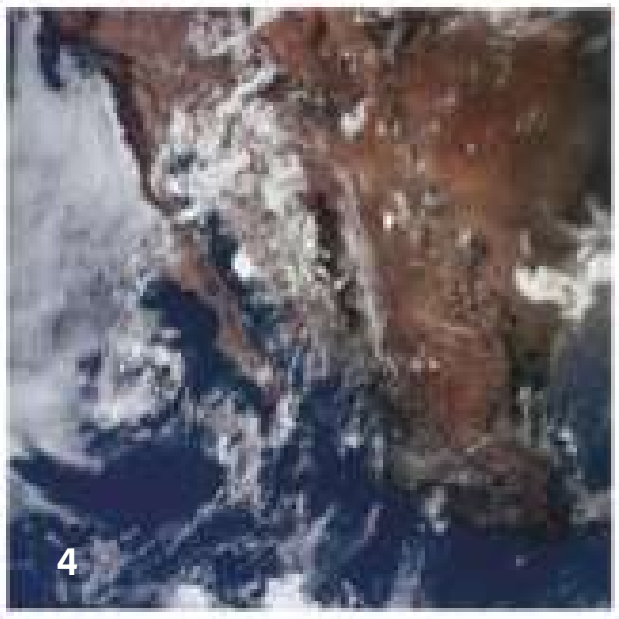
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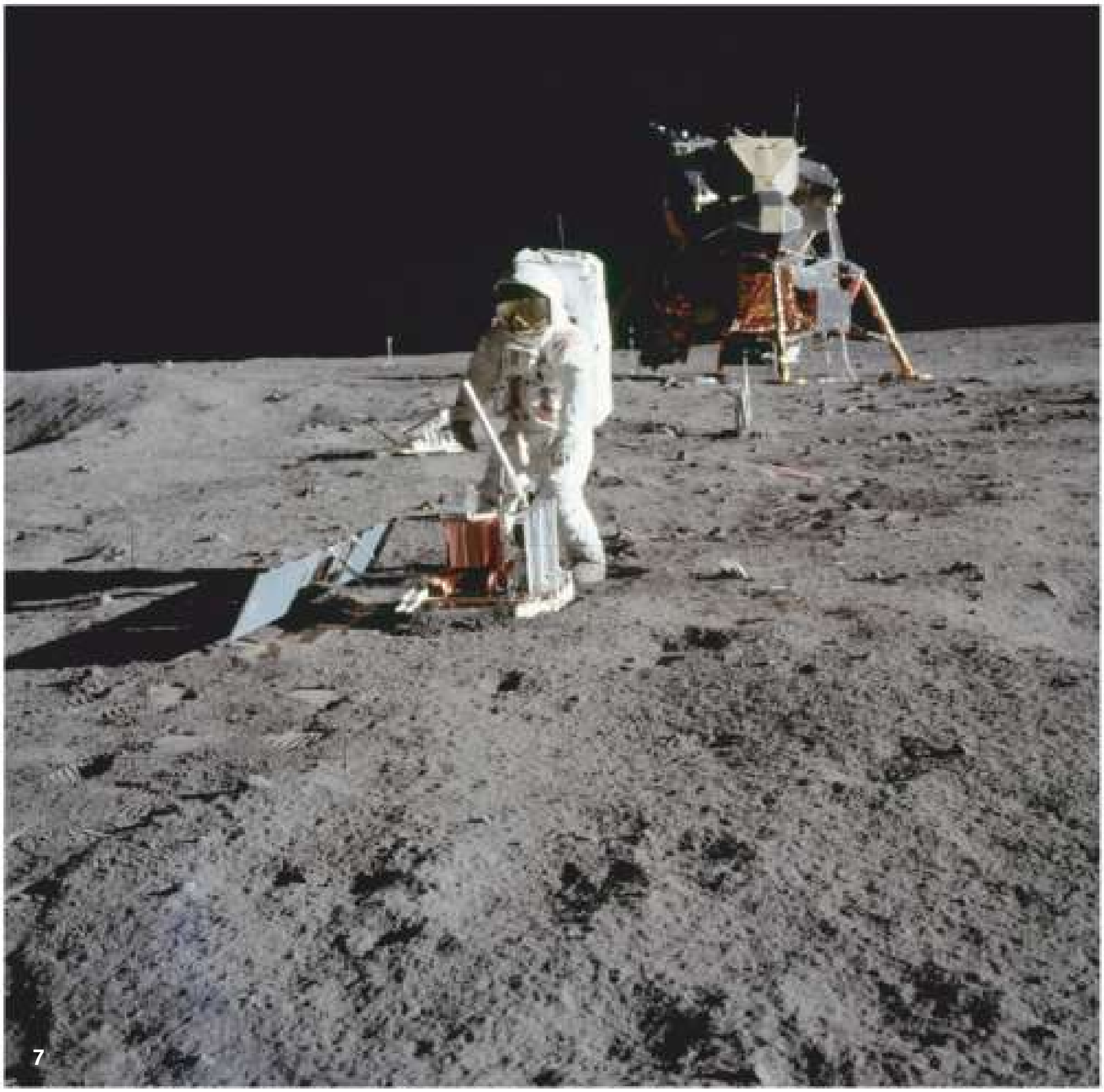
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1. A photographer on an Air Force EC-135N plane captured Apollo 11 rising into the clear blue sky above Kennedy Space Center on Florida's east coast.

2. After his historic walk on the Moon, Armstrong relaxes with his helmet off back inside *Eagle*.

3. As the astronauts headed back to Earth, they captured a few final shots of their recent home. Circular Mare Crisium (Sea of Crises), which lies near the Moon's eastern limb when viewed from Earth, appears just left of center.

4. The Apollo 11 astronauts got their final close-up views of their home planet while they initially circled Earth. Here, they were orbiting above Mexico and Baja California.

5. Aldrin sits inside the LM as he and Armstrong perform their initial inspection of the vehicle that will ferry them to the Moon's surface.

6. The astronauts left behind the LM's descent stage, which includes this plaque. It reads: "Here men from the planet Earth first set foot upon the Moon July 1969, A.D. We came in peace for all mankind." It carries the signatures of the three Apollo 11 astronauts and President Nixon.

7. Aldrin works to get the seismometer up and running. He has already deployed one of the experiment's two solar arrays and will soon finish the second one. The Apollo 11 seismometer sent three weeks' worth of data to Earth and gave scientists their first look at lunar seismology.



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1. Armstrong waves to well-wishers as he and Collins (Aldrin is hidden behind) make their way to the van that will take them to the Saturn V launch vehicle on July 16.

2. The command module, *Columbia*, poses for the astronauts on *Eagle* while the two craft continue to orbit the Moon. The lunar surface below lies in the northern part of Mare Fecunditatis (Sea of Fertility).

3. Armstrong took the eight photos in this panorama near the end of the astronauts' surface activities. Little West Crater dominates the right foreground, while the LM stands 200 feet (60 m) away.

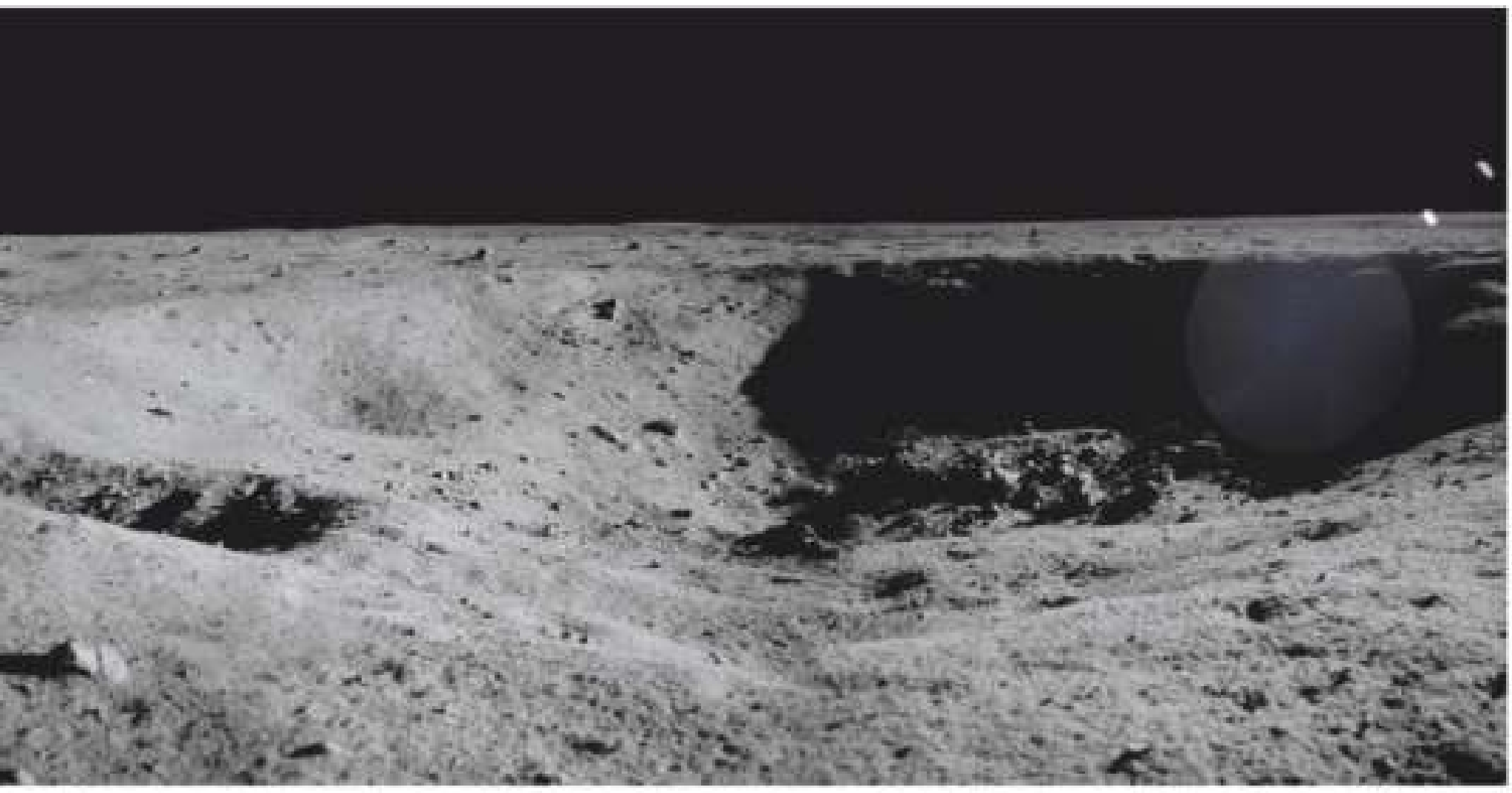
4. The 363-foot-tall (111 m) Saturn V rocket inches its way — at 1 mph (1.6 km/h) — along the 3.5-mile (5.6 km) trek from the Vehicle Assembly Building to launchpad 39A on May 20, 1969.

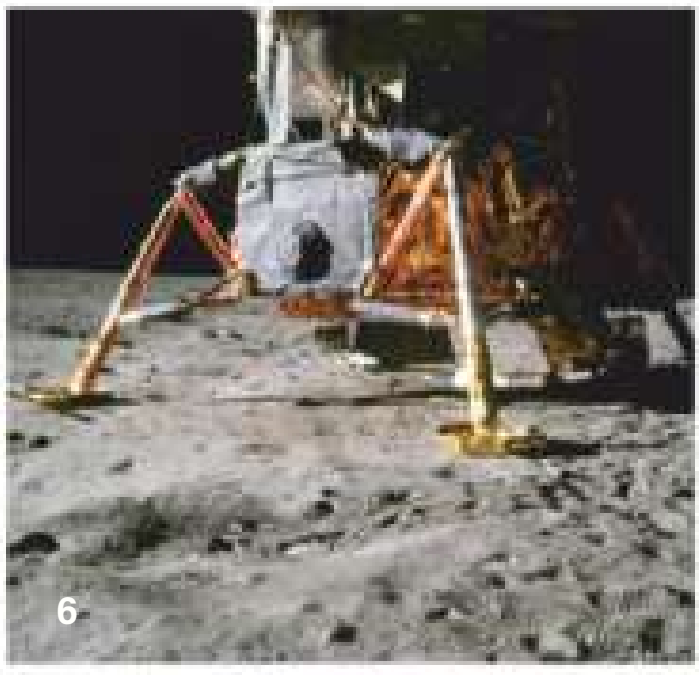
5. About 30 minutes after firing the third-stage rocket and beginning their journey toward the Moon, the astronauts set about docking the command and lunar modules. This view shows the top of the LM as the two craft approach each other.

6. The *Eagle*'s descent stage dominates this view. Aldrin took this image as he was wrapping up a multiphoto panoramic image of the landing site.

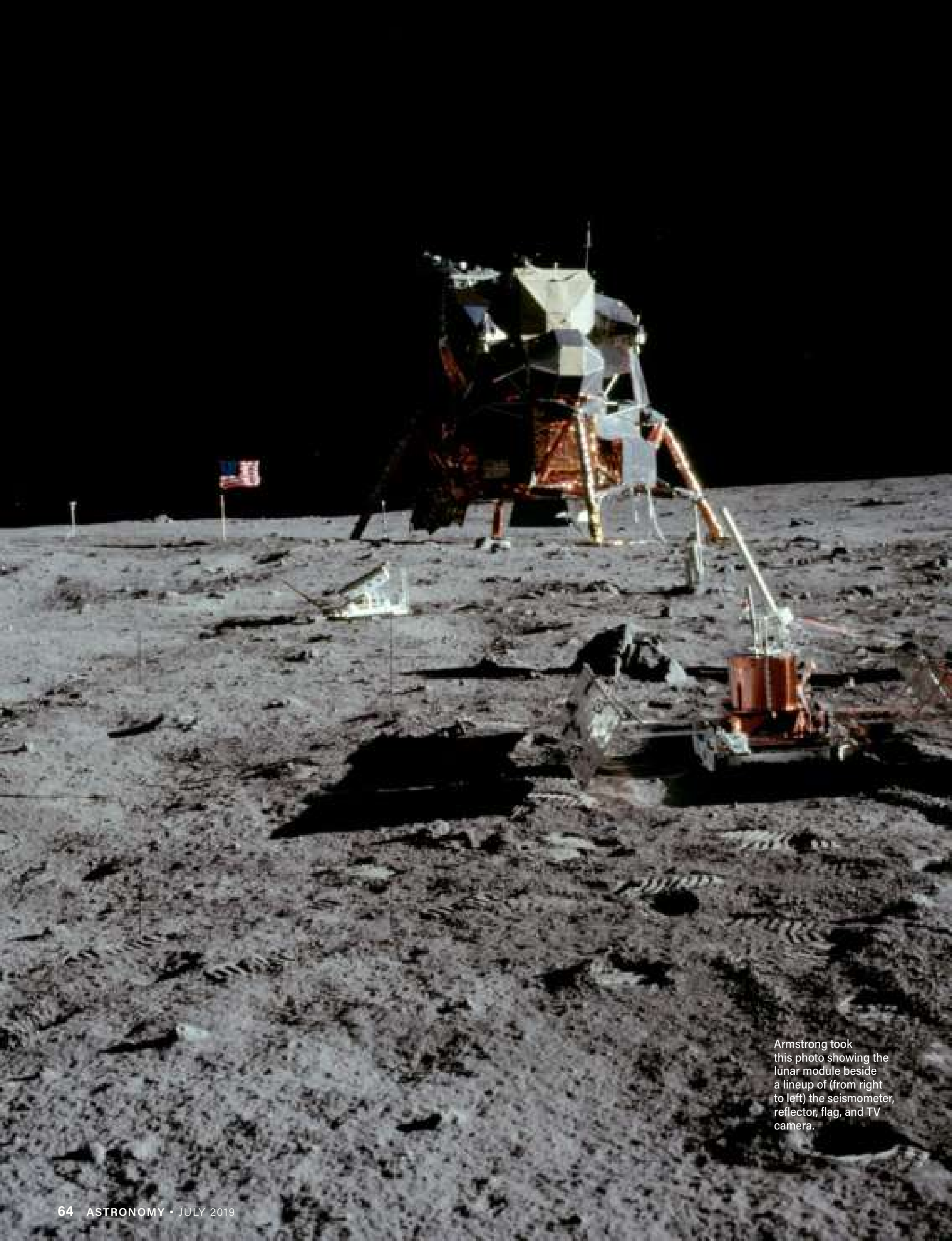
7. NASA's Lunar Reconnaissance Orbiter captured this view of the Apollo 11 landing site May 22, 2010, from an altitude of 25 miles (41 km). The lunar module appears as a bright spot at upper left, not far to the left of Little West Crater.

NASA/GSFC/ASU









Armstrong took this photo showing the lunar module beside a lineup of (from right to left) the seismometer, reflector, flag, and TV camera.

Armstrong captured the Moon's rocky surface during his first sequence of photos after stepping onto the surface. Rocks scatter across the foreground, and a split boulder appears near the frame's right edge.




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1–4. Aldrin descends the *Eagle*'s ladder on his way to becoming the second man to stand on the Moon's surface. As Aldrin stood on the footpad, Armstrong said, "Magnificent sight out here," to which Aldrin replied, "Magnificent desolation."

5. Aldrin took this photo of his boot and a partial bootprint as he tests the mechanics of the lunar soil. The rock in front of his toe measures 2 inches (5 cm) across.

6. Armstrong took most of the photos on the lunar surface, so there are few good shots showing the first man on the Moon. Here, Aldrin captures Armstrong storing some rocks on the LM with the flag and Solar Wind Collector nearby.

7. Aldrin deploys the Solar Wind Collector. He angles the foil sheet toward the Sun so it can capture the charged solar particles. After being exposed for a little more than an hour, Aldrin rolled it up to bring it back to Earth for analysis.


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1–6. Earth rises above Mare Smythii, which lies near the Moon's eastern limb when viewed from our planet. The photos in this sequence span about 90 seconds.

7. Aldrin took the 11 photos in this panorama from the rim of Double Crater, a pair of overlapping impact features that lay just beneath Armstrong's LM window.

8. A key activity during the moonwalk was collecting two core samples to allow scientists to study rocks beneath the surface. Here, Aldrin works on the first sample (the larger Solar Wind Collector stands just behind); he was able to drive this one only 8 inches (20 cm) deep.

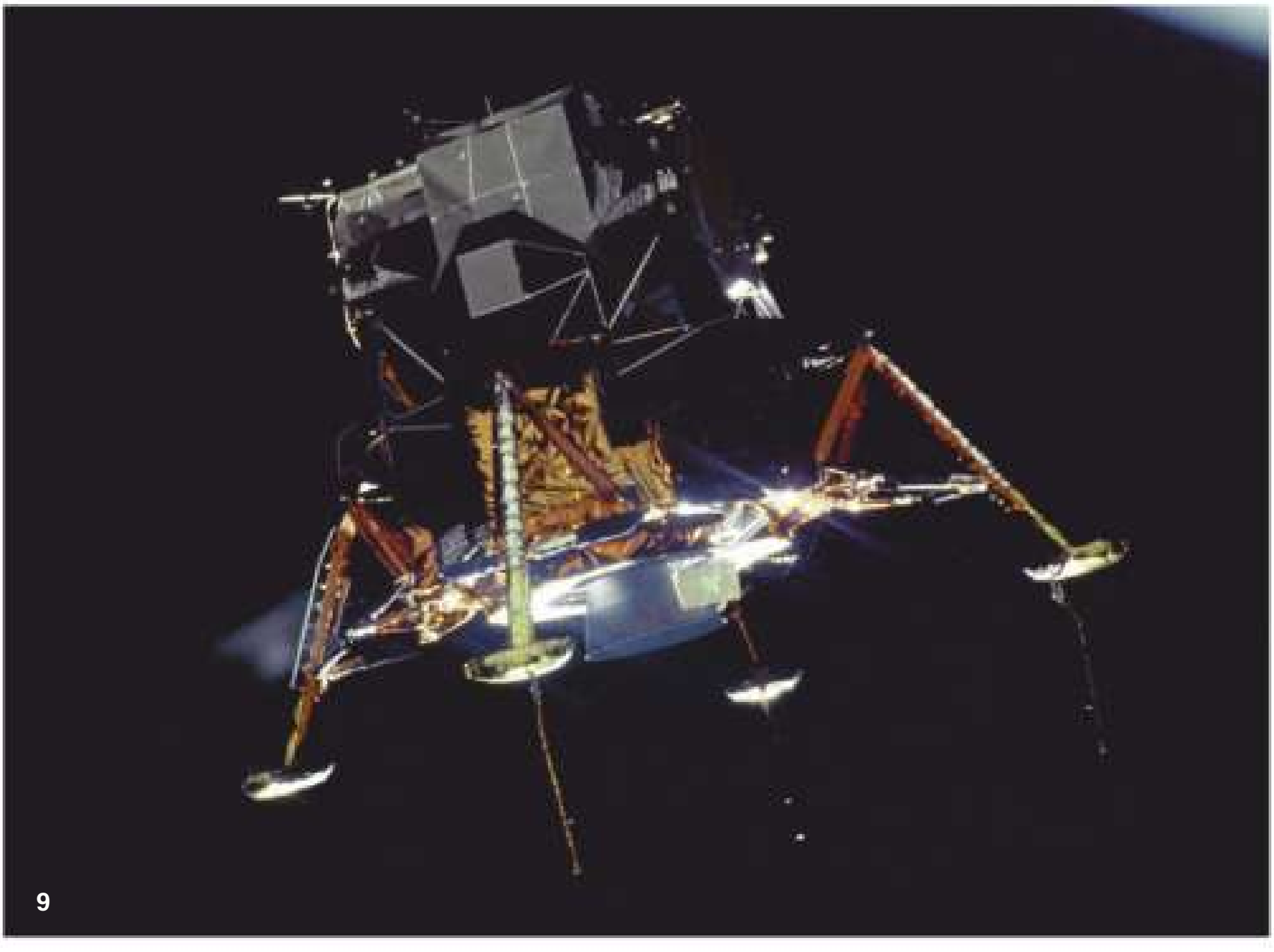
9. After separation of the command and lunar modules while in lunar orbit, Collins took this photo of *Eagle* in its landing configuration. The rodlike probes dangling from the footpads were designed to sense when the craft touches the surface and tell Armstrong and Aldrin to shut off the descent engine.


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Geologist Gene Shoemaker dreamed of going to the Moon well before the space race popularized the idea in the early 1960s. He coined the term *astrogeology* while studying the Moon from afar, in preparation for someday visiting. By the time his dream started feeling like reality, a surprise medical diagnosis disqualified him from astronaut service in 1963. Shoemaker would still go on to become one of the most influential scientists in the space program, and to create the USGS Branch of Astrogeology. Here, Shoemaker demonstrates an early space suit prototype in April 1964 at the Marshall Spaceflight Center in Huntsville, Alabama. He poses, of course, as if he were sampling rocks.

ALL PHOTOS COURTESY OF USGS

From testing space suits to determining how to traverse the Moon and collect lunar samples, American geologists were critical to the Apollo missions.

BY ANNA GROVES

The first astrogeologists

SENDING A MAN TO WALK ON THE MOON WAS AN AMAZING FEAT OF ENGINEERING. But there was another group of researchers behind the Apollo missions — and they weren't at NASA. Geologists at the U.S. Geological Survey (USGS) used lunar photographs and telescopes to make the first detailed maps of the lunar surface. They tested equipment and space suits in the rocky terrain of the Colorado Plateau, and they practiced collecting rocks and measurements while fully suited. Without geologists, the Apollo missions might have been little more than rocket ship stunts. And thanks to them, we can now be sure the Moon's not made of stinky cheese.

As the Branch of Astrogeology gained momentum in 1963, its staff moved the headquarters from Menlo Park, California, to Flagstaff, Arizona. The town had an established observatory and was near what many scientists considered Moon-like geological features, such as areas shaped by cratering and volcanism. This allowed the geologists working on Apollo — the Manned Lunar Exploration team — to use the nearby craters and rocky landscapes to test methods and equipment in the years leading up to the spaceflights. The first space suit field test took place in June 1964, using an early Gemini suit borrowed from NASA.

"The Gemini suit was a terrible thing. You couldn't stand up straight in it because it was built for sitting only," said USGS geologist Gordon Swann in a 2002 interview. "The only three guys the space suit would fit at all were Gene Shoemaker [who wore it only a short time], Jerry Harbor, and Gene Phillippi. So, they were our astronauts. However, they could only go for 15 or 20 minutes, and they were so exhausted, they couldn't even move after that."

Above, support staff prepare to send an unidentified suited test subject (thought to be Shoemaker, Phillippi, or Harbour) onto the Moon-like terrain at the Bonito Lava Flow in Sunset Crater National Monument.



By 1965, the Gemini suit had given way to a prototype Apollo suit that was much easier to maneuver in. The team continued to rehearse its plans for the upcoming Moon mission in loaner suits from NASA, allowing them to specially design and build equipment that astronauts could use on the Moon. Here, USGS scientist Joe O'Connor dons a cowboy hat and space suit during an Apollo Extension Test sometime between September 20 and October 1, 1965, at a site — a dike within the Hopi Buttes Volcanic Field in the territory of the Navajo Nation — that scientists referred to as Apollo Mesa.



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In the weeks after the first moonwalk, the studies of rock samples collected by Neil Armstrong and Buzz Aldrin resulted in what would be the first of many breakthroughs in astrogeology — ***THE GEOLOGY OF PLANETARY BODIES BEYOND EARTH.***



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1. Gordon Swann of the USGS works with a prototype of the Apollo Lunar Staff — designed to support a camera, Sun compass, and various seismographic and geological instruments — and tool carrier in 1965.

2. Geologists Tim Hait and David Schleicher explore simulated lunar terrain at the Cinder Lake Crater Field in Flagstaff in October 1967. Behind them is a mock-up of the lunar module ascent stage. The geologists wore these space suits to test how well astronauts would be able to use different maps and follow planned paths while navigating an actual crater field.

3. Astrogeologists were instrumental in planning the Apollo moonwalks and preparing the astronauts to collect samples and observations. Their endeavors included using explosives to create crater-filled replicas of the Moon's surface to use in training simulations. They tested different amounts of explosives to determine how to make craters of varying sizes. In October 1967, 96 craters were added to the Cinder Lake Crater Field 1, bringing the total to 143.

4. In July 1968, the USGS Branch of Surface Planetary Exploration added a second crater field to Cinder Lake, using 1,153 pounds (523 kilograms) of dynamite, 28,650 pounds (12,995 kg) of ammonium nitrate, and 40,000 feet (12,190 meters) of detonation cord. The geologists added extra realism (and teaching opportunities for astronauts) by salting the crater field with more rocks the following January.

5. Apollo 15 astronauts Jim Irwin (left) and Dave Scott participate in a training exercise in a mock lunar rover, November 1970 at Cinder Lake Crater Field. When it came time to build a lunar vehicle, NASA gave the job to Boeing. But a rover on Earth would collapse under a person's weight because of its Moon-gravity specs. Boeing was supposed to provide a "1 G" version, but the USGS remained roverless as astronaut training approached. So the Branch of Astrogeology's Field Test Support Unit built its own, mimicking the plans from Boeing, in just 90 days. By August 1970, the new "Grover" — geologic rover — completed its first test drive across Cinder Lake Crater Field. The Grover was used to train crews for Apollo 15, 16, and 17.

6. Harrison "Jack" Schmitt — the only geologist who would also become an astronaut — in an exercise with the Grover in June 1971. Boeing eventually built a rover suitable for Earth gravity, but it was prone to breaking and couldn't sustain field simulations. Boeing's rover cost NASA $1.25 million, while the USGS-built version cost $1,900. A report from the Branch of Astrogeology, by Gerald Schaber, recounts NASA manager Don Beattie learning how inexpensive the USGS' Grover was: "Beattie asked [mechanical engineer Putty Mills] how much did this thing cost; Putty said, 'Something like $1,900.' Beattie said, 'Oh, we couldn't say that to NASA Headquarters' — so they multiplied the cost by about ten and claimed that we built it for $20,000 — still a great bargain."

7. Dick Wiser, from the Branch of Surface Planetary Exploration's Field Test Support Group, takes an early lunar mission development vehicle, the Explorer, for a spin in July 1968 to test its newly added gyrocompass navigation system.

8. The Flagstaff team also designed and demonstrated the hand tools the astronauts would use to collect samples. Here, Hait shows how to take a soil sample from a crater wall in the Cinder Lake Crater Field in March 1968.

NASA wasn't always on board with astronauts taking the time to complete science experiments during the Apollo missions. "Fairly early in this business was when NASA told Gene [Shoemaker] that all [the astronauts] could do was plant the flag [during the first Moon landing]," USGS scientist Joe O'Connor said in a 2001 interview. "It was our job to convince NASA otherwise."

Around this same time, the USGS team figured out a way to communicate, in real time, with the astronauts on the Moon. But when they pitched their idea for a Command Data Reception and Analysis facility to NASA, their aeronautical colleagues didn't take kindly to the idea that a bunch of geologists would be "commanding" anything. In the end, the scientists were able to explain that their goal was to be available to assist the astronauts during their lunar expeditions, and NASA agreed. The Flagstaff communications room was renamed the Apollo Data Facility.

During the Apollo 11 Moon landing, Shoemaker and others from Flagstaff were in the Science Support Room at Mission Control in Houston. In the weeks after the first moonwalk, their studies of rock samples collected by Neil Armstrong and Buzz Aldrin resulted in what would be the first of many breakthroughs in astrogeology — the geology of planetary bodies beyond Earth.

Anna Groves *is an assistant editor of* Discover *magazine. She normally writes about biology and the environment, but has a thing for geologists in space suits.*

Thanks to NASA's public relations team, the Moon missions were a must-watch event for millions across the globe. Here, children tune in to live coverage of Apollo 8 on Christmas Eve 1968. BRUCE DALE/NATIONAL GEOGRAPHIC CREATIVE



A child reads the newspaper the day after Apollo 11 landed. JACK WEIR/ WIKIMEDIA COMMONS

The missions' success helped shape countless aspects of modern society, from science fiction to postage stamps.

BY ERIKA K. CARLSON

Apollo in POP

MARKETING THE MOON: How PR made the lunar landing an iconic moment.

An astronaut, a little hop, and a witty quote: Neil Armstrong's first lunar footsteps are ingrained in the minds of all humankind. But that first Moon landing might not have been such a historic cultural moment if it weren't for NASA's savvy public relations team.

Richard Jurek is a marketing executive and co-author of the book *Marketing the Moon: The Selling of the Apollo Lunar Program*. He says NASA's move to real-time, open communication made Apollo 11 "the first positive viral event that captured the world's attention."

Before NASA was established in 1958, rockets were the military's purview; that secretiveness carried over into the agency's early days. At first, NASA followed a "fire in the tail" rule, publicizing a rocket's launch only when it was already in the air, preventing it from being tampered with or prepared for. But as the agency evolved, it started announcing more details about the Apollo program. It championed its astronauts, talked openly about mission goals and challenges, and shared launch times so people could watch.

"If it had been run like it was under the military," Jurek says, "we would not have had that sense of drama, that sense of involvement, that sense of wonder."

Instead, all the PR and press hype in the years ahead of Apollo 11 brought the human spaceflight program directly into people's living rooms.

Along for the ride

As the drama of the space race neared its climax, NASA's PR officials pushed for live television broadcasts of the first humans to walk on the Moon.

Not everyone thought it was a good idea. The technology for airing live lunar missions, including cameras small enough for spaceflight, didn't exist yet. Some engineers worried that developing that equipment would distract from efforts to achieve a lunar landing.

But NASA's communications team argued that telling the story was just as important as the achievement itself. Live TV would bring the American people — and international viewers — straight to the Moon.

"I vividly recall watching the Apollo 11 landing and moonwalk at my parents' home — it was incredibly inspiring," says Alan Stern, principal investigator of the New Horizons mission to Pluto and beyond. "I think Apollo turned a huge number of my generation on to STEM careers and ultimately created the workforce that gave us things like the PC and internet revolutions."

Come landing day, which conveniently fell on a Sunday night, more than half a billion people worldwide huddled around TVs and radios to tune in to the historic moment. "We were able to come together and do something that was exciting and interesting and brought the world together," says David Meerman Scott, marketing strategist and co-author of *Marketing the Moon*. "I don't know that we've done anything like that since."



A magazine ad promoting the 1950 sci-fi movie *Destination Moon.*
ROSSANO/FLICKR

APOLLO'S INFLUENCE ON SCIENCE FICTION: It's not about the Moon; it's about us.

The exhilaration of the space race and the exploration of the Moon echoed through the arts — especially in science fiction. Historian Margaret Weitekamp curates space memorabilia and science fiction objects at the National Air and Space Museum. A lifelong sci-fi fan, she studies

CULTURE

how ever-changing attitudes toward spaceflight are represented by collectibles and works of science fiction.

"We talk a lot about popular culture reflecting society," Weitekamp says. "It's not some sort of magic mirror. It's created by people who are very much a product of their time."

For example, Jules Verne's 1865 novel *From the Earth to the Moon* depicts Americans launching themselves to the Moon with a giant cannon, as cannons were a prominent technology in the American Civil War. A century later, during the civil rights movement, *Star Trek* showed an ethnically diverse crew on the starship *Enterprise*. This vision of different races harmoniously working together added to the optimistic tone of the show, Weitekamp says, giving viewers hope for the future of spaceflight.

A long trip for a small step

Space exploration has been featured in films since long before Apollo. In 1902, *A Trip to the Moon* — inspired in part by Verne's aforementioned novel — proved that sci-fi could thrive in the new medium of movies.

Sci-fi's vision of spaceflight evolved as the decades passed, of course. "The [portrayals] that are focused on the reality of what's going on and realistic space programs tend to fall away in the 1960s, because they can't really compete with the real thing," Weitekamp says. "And so what you get are more extrapolated visions of what spaceflight could be," as in *Star Trek*.

When the Apollo missions kicked off and people realized that going to the Moon wasn't just a fantasy anymore, another prominent theme began to develop in sci-fi, says literature professor Brian Willems. Willems, of the University of Split in Croatia, studies how the Moon has appeared throughout the history of film. When it comes to the Moon landings, he says, it's the journey, not the target, which really captured our imaginations.

> *"It's not some sort of magic mirror. It's created by people who are very much a product of their time."*

For example, the film *Countdown* (1968) depicts the first Moon landing, but it primarily focuses on the challenge of getting to the surface instead of what happens next. In the movie, when Americans learn the Soviet Union will likely reach the Moon first, they abandon the Apollo program for a quicker backup plan: They send a lone astronaut on a one-way trip and plan to coordinate his return later. Like the real-life space race, the movie's entire premise is beating the Soviets to the Moon.

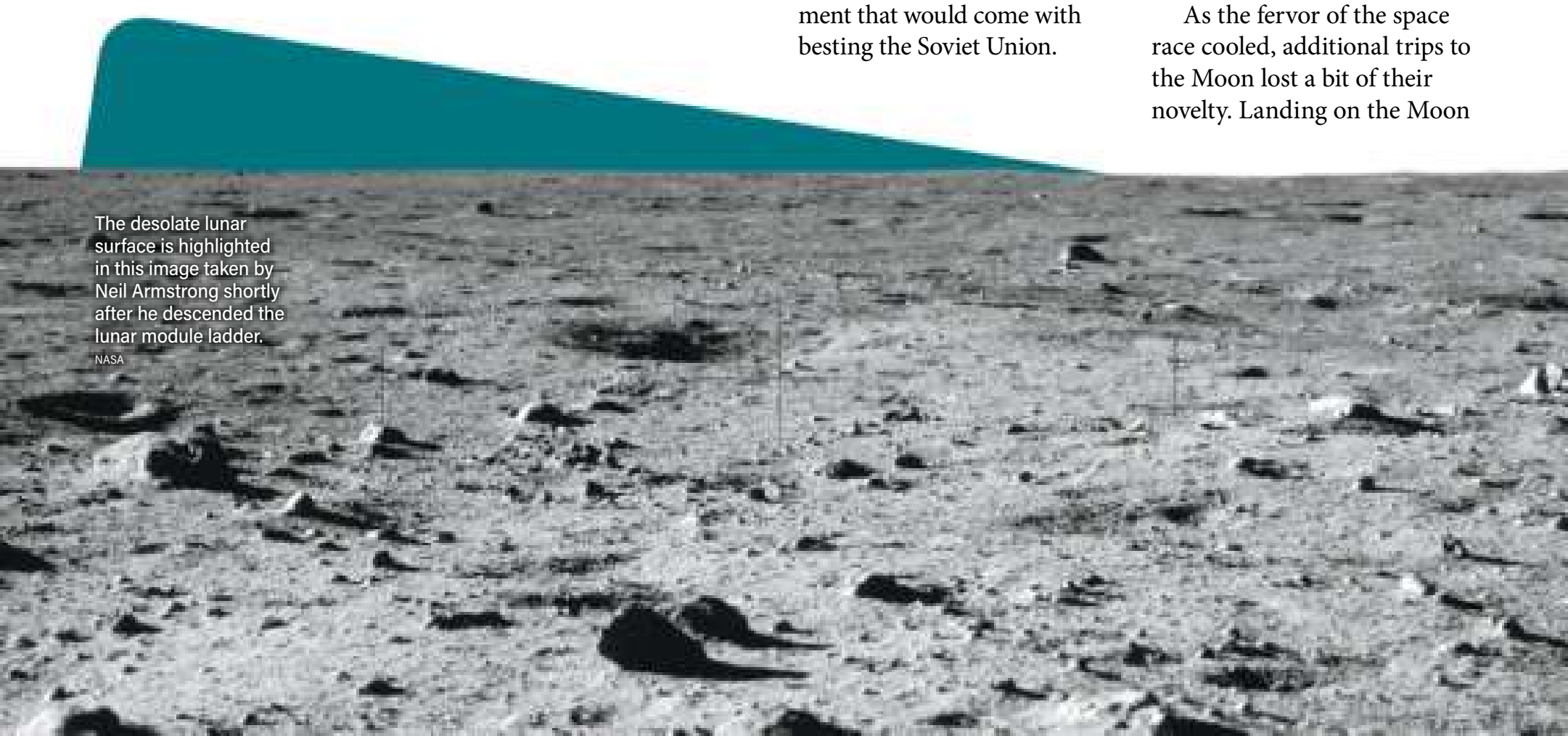
"It was all about traveling to the Moon and the ability to do it, rather than about some experience on the Moon itself," Willems says. He suggests such pre-Apollo 11 films reflect the real-life Apollo missions, in that their primary purpose was to highlight the American pride and sense of accomplishment that would come with besting the Soviet Union.

We've landed on the Moon. Now what?

The journey to the Moon was a thrilling adventure, but the Moon itself wasn't as exciting a subject, Willems explains. When Apollo 11 landed humans on the Moon in July 1969, it stunned the world, but it also revealed just how lifeless the lunar surface really is. So, to liven up an otherwise bland setting, wildly fantastical elements began appearing in sci-fi's lunar stories.

The 1970s TV show *Space: 1999* starts by blasting the Moon from Earth's orbit with explosions, sending a populated Moon base hurtling through space. In the 2011 horror movie *Apollo 18*, viewers are shown fictitious "lost footage" of the canceled mission, which reveals deadly lunar aliens camouflaged as rocks. In 2012's *Iron Sky*, it's not aliens, but Nazis, who have been hiding on the Moon since World War II. Still other movies turned the plainness of the Moon into its own character: The root of the 2009 movie *Moon* is the sense of loneliness and isolation felt by a solitary person working at a dull, secluded lunar mining site.

As the fervor of the space race cooled, additional trips to the Moon lost a bit of their novelty. Landing on the Moon



The desolate lunar surface is highlighted in this image taken by Neil Armstrong shortly after he descended the lunar module ladder.
NASA

had made it a less exotic setting, prompting sci-fi to adapt by focusing the audience's attention elsewhere.

Shifting focus from the Moon

While scouting landing sites for the Apollo missions in 1966, NASA's Lunar Orbiter 1 took the first full-view photograph of Earth from the Moon; during Apollo 8 in 1968, astronaut William Anders became the first human to capture such a shot. Once we started to see the first photos of Earth taken from the Moon, Willems says, movies with lunar scenes also began to show Earth in the background. For example, in the 1968 classic *2001: A Space Odyssey*, a scene prominently features our blue planet majestically floating above a Moon base.

"A lot of these films, they pretend to be about the Moon, but they're really about the Earth," Willems says. "It's all about how the Earth sees the Moon and not about how the Moon is a different experience or a different place than Earth in some way."

And this gets to the heart of how the Apollo missions influenced the visions of science fiction. Early on, creators of sci-fi saw the Moon as a bizarre and unexplored setting that could harbor surprising secrets. But as a trip to the lunar surface became more and more likely, sci-fi shifted its focus to the journey itself. And, once we finally reached the Moon, we were presented with humbling views of our home planet, ultimately forcing us to step back and reconsider humanity's true place in the universe.

As Weitekamp says, "Spaceflight, I think, is a rich backdrop for telling different kinds of stories."



The Jetsons, a popular animated TV series about a futuristic family living in Orbit City, featured architecture that exemplifies the Googie style. PICTURELUX/THE HOLLYWOOD ARCHIVE/ALAMY STOCK PHOTO

GOOGIE ARCHITECTURE: HOW THE SPACE AGE INFLUENCED THE RISE AND FALL OF A POPULAR ARCHITECTURAL STYLE.

HAVE YOU EVER NOTICED A DINER, or perhaps a motel, gas station, or drive-in, that looks like it would fit in the Jetsons' neighborhood? A confluence of car culture and the Atomic and Space Ages, Googie architecture (pronounced GOO-gee) is probably the reason behind that quirky, retro-futuristic look.

After World War II, U.S. suburbs were growing fast, leading to many more drivers on the roads. To capitalize on these commuters, businesses needed attention-grabbing buildings and signs that captivated those riding by.

"The architecture itself had to be really bold and vivid and noticeable," says Alan Hess, an architect and historian who has written extensively on modern architecture in the mid-21st century. "At that time, one of the things that would really attract attention was anything that looked really, really futuristic, really modern, really up to date."

The future looked bright in the 1950s and 1960s. The birth of atomic science brought promises of advanced societies powered by nuclear energy, while the beginnings of the space race made people realize that humans might soon venture to the Moon or Mars. And because a futuristic era seemed just beyond the horizon, the shift to an ultramodern architectural style was almost inevitable.

Television also reflected this optimism toward technology — it would make our daily lives easier, and allow for ever-more-ambitious achievements. In the early 1960s, *The Jetsons* portrayed a high-tech society with flying cars, housekeeping robots, and meals prepared with the push of a button. A few years later, *Star Trek* painted an idealistic future where humankind uses advanced technology to explore and understand the universe … as well as enjoy meals prepared with the push of a button.

Googie architecture exemplified this sanguine outlook. The style used unconventional shapes, eye-catching colors, and modern materials — including glass, chrome, and lots of plastic. It was bold, playful, and exuberant.

Because many businesses, such as restaurants, car washes, and bowling alleys, were being built in this style, Googie architecture was easily accessible to the average American. You didn't need to hire an architect to design a modern, futuristic house for you. You could get a taste of Googie by just hopping in your car and scoping out your local diner.

"All you needed was, you know, the price of a hamburger. And you could go into any of these restaurants, and the designs of them were intended to make you feel as if you were participating in this new age," Hess says.

continued on p. 78



The iconic welcome sign in Las Vegas, built in 1959, is a prime example of Googie architecture. KEN LANE/PXHERE



Early McDonald's restaurants also adopted the futuristic Googie style.
BRUCE MARLIN/WIKIMEDIA COMMONS

continued from p. 77

By the early 1970s, however, the Googie style waned in popularity. After Apollo 11's lunar landing in 1969, space travel was becoming less of a novelty. And with the rise of the ecology movement, Hess says, enthusiasm for futuristic technology like nuclear power was petering out. The curved roofs and shiny surfaces of Googie were no longer seen as chic, so businesses turned back to traditional styles that were perceived as more Earth-friendly.

Still, Googie remained popular for a good two decades or so — fairly long for a trendy architectural style. And although many Googie buildings were torn down after the space race, conservationists and architectural historians around the country now are working to preserve any that remain as historic landmarks. Some, like the nation's oldest existing McDonald's in Downey, California, have even qualified for the National Register of Historic Places.

Hess says visiting these sites can really give you a feel for their era. "You get that sense of optimism," Hess says. "You can still go to these places and feel that. It's very tangible when you're sitting there, having a root beer float."

DID APOLLO BOOST THE ECONOMY? Probably not how you think.

It's a believable story. With the launch of the space race, the U.S. flings itself into a flurry of activity, training more scientists and engineers and creating jobs in technology and manufacturing, ultimately boosting the nation's prosperity. But it isn't quite clear yet how much the space race actually affected the U.S. economy.

"There's really not that much evidence," says economist Alexander Whalley of the University of Calgary. He and colleague Shawn Kantor, an economic historian at Florida State University, are working on a project to measure how the space race affected jobs and economic prosperity in U.S. cities. "There's a lot of stories kind of running around, and we're trying to actually calculate or estimate how big are those effects," he says.

Economic productivity in the U.S. was booming in the 1960s, according to Whalley, but growth slowed in the 1970s. This calls into question just how much of a boon the space race really was.

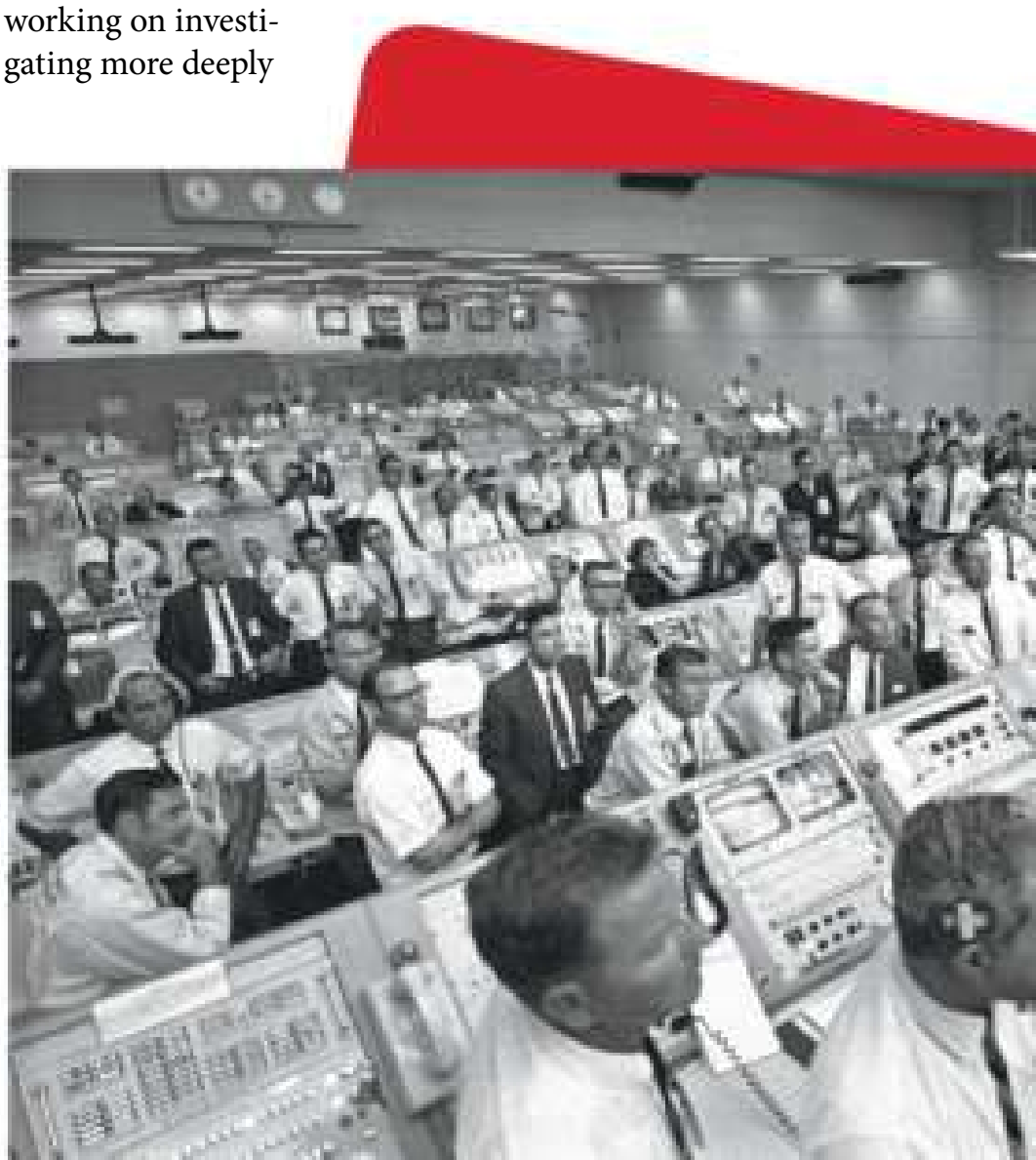
It's a question that hasn't gotten much attention from economists yet — at least not in a rigorous, quantitative way. Kantor suggests the space race wasn't quite old enough for economic historians like himself to study until recently. "It's just now becoming economic history," he says.

Whalley and Kantor caution that these results are preliminary; they're working on investigating more deeply as the project continues. But so far, their findings suggest that the space race wasn't all good news for the job market. While companies contracted by NASA grew and hired more workers, employment in other companies seemed to drop; the researchers hypothesize that improved computing technology from space race efforts might have resulted in fewer necessary workers in other industries.

Whalley and Kantor aren't trying to say whether or not the space race was worth it. But by measuring the effects it did have, they hope to help governments make informed decisions about when and how to invest in science and technology — and whether it's appropriate to use economic growth as a motivation for doing so.

Training scientists, or citizens?

When the Soviet Union launched the Sputnik satellite in 1957, then-President Dwight D. Eisenhower pushed for strengthening science education in the U.S., saying the



CELEBRATING APOLLO WITH POSTAGE STAMPS



YOU KNOW YOU DON'T NEED another refrigerator magnet or souvenir shot glass — so why are gift shops so enticing? Owning memorabilia is a way for us to feel connected to things larger than ourselves, whether it's our favorite baseball teams, vacation destinations, or concerts.

"When you look at memorabilia, you get a sense of the kinds of things that people wanted to have a souvenir of, in the kind of original French sense of the word, as a way to go back or a way to remember," says Weitekamp, the curator of space memorabilia at the National Air and Space Museum.

The Apollo missions were no exception. The Apollo program — and especially the first Moon landing — captured imaginations and spawned memorabilia across the globe.

Consider postage stamps: The U.S. alone has issued at least six stamps honoring Apollo 11, and countries worldwide have issued countless others. "Nations around the world wanted to be able to show that they celebrated this human achievement," Weitekamp says.

Of course, not all nations were equally eager to plaster their stamps with U.S. astronauts or NASA spacecraft. After all, the space race was one battlefront of the Cold War, and the Soviet Union was busy printing its own postage stamps with the faces of its cosmonauts. And some nations' stamps depicting the Apollo missions de-emphasized U.S.-specific imagery, like flags, to portray the Moon landings as a general human achievement rather than a specifically American one. "In the issuing of those stamps, there's some reflection of that broader political context," Weitekamp says.

These stamps, curated from the author's personal collection, represent just a few examples of the diverse stamps that were created to commemorate Apollo.

Clockwise from left:

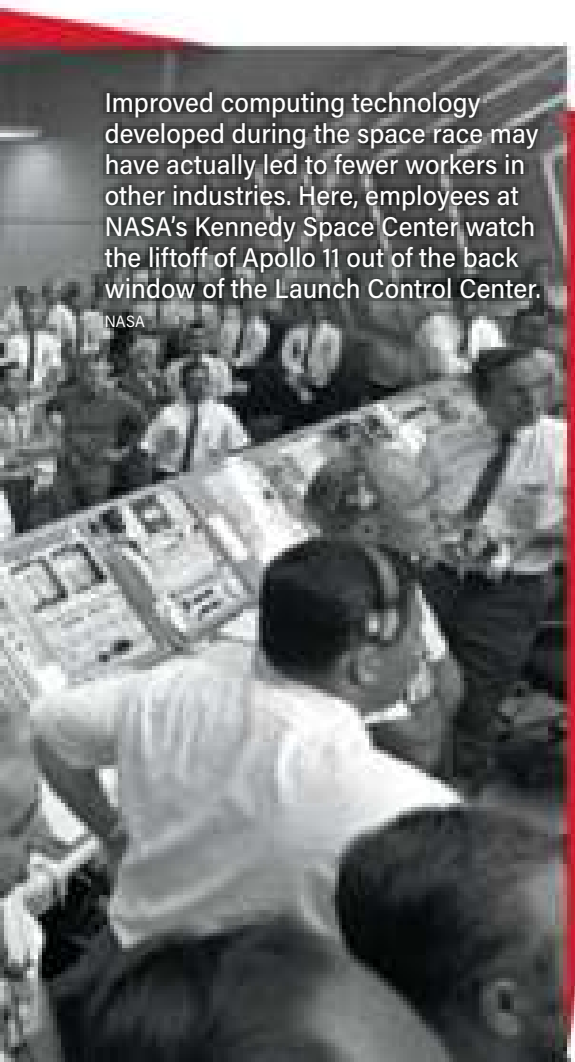
REPUBLIC OF MALI, 1973
An astronaut climbs down to the Moon's surface from the lunar module, which prominently displays a U.S. flag. The stamp also shows the Apollo 11 mission patch in the upper left corner. The message "First landing on the Moon" is in French along the right.

THE REPUBLIC OF MALDIVES, 2017
This recent stamp prominently displays former President John F. Kennedy, as well as the command/service module, the lunar module, and the Moon.

ANTIGUA, 1968
This stamp highlights the country's connection to the Apollo missions via the Dow Hill Tracking Station, which monitored Apollo spacecraft.

GRENADA, CIRCA 1970
An Apollo astronaut collects a rock sample on the Moon with the lunar module and Earth in the background. Across the top it reads, "We came in peace for all mankind."

SOVIET UNION, CIRCA 1975
This stamp commemorates the Apollo-Soyuz Test Project of 1975, when an Apollo spacecraft docked with a Soviet Soyuz spacecraft in a symbolic step toward international cooperation in space. The stamp was illustrated by the Soyuz Commander Aleksei Leonov.



Improved computing technology developed during the space race may have actually led to fewer workers in other industries. Here, employees at NASA's Kennedy Space Center watch the liftoff of Apollo 11 out of the back window of the Launch Control Center.
NASA

nation needed more scientists. But it's not quite accurate to say Sputnik's launch led the U.S. to change its science curriculum, according to John Rudolph of the University of Wisconsin–Madison, an expert on the history of science education in the U.S. "When Sputnik came along, that's what got the public's attention," Rudolph says, "but the science [education] reforms were already well underway in response to what [the United States] thought was going on in the Soviet Union."

Regardless of what triggered the reforms, science education saw dramatic changes during this time. Before the mid-1950s, high school science education in the U.S. was focused on everyday applications like nutrition and what Rudolph calls "refrigerator physics" — the science you need to understand how appliances work. But scientists were calling for the American public to learn about what they actually do, like experimentation and data analysis.

The purpose of these educational reforms after the mid-1950s was to help the general public understand the research funded by their taxes and to garner support for scientific research as a whole, not necessarily to create more scientists and engineers, says Rudolph.

"If we just start focusing on trying to get people to do science," Rudolph says, "we lose trying to understand what science is as a larger enterprise and as an institution in society."

Scientific research doesn't always have clear applications or result in economic gain right away. Societies must decide whether investing in science should always be a means to an end or whether it is a worthwhile goal in its own right.

"Should we, as a society, be having another space race … as a way to create jobs in the future?" Whalley asks. "Or is the space race more about getting people to the Moon?"

Erika K. Carlson *is a Moon-gazing science writer who dreamed of being an astronaut when she was 5.*

Target the Apollo LANDING SITES

Even a small scope can help you pinpoint these six famous locations.

BY MICHAEL E. BAKICH



Lighter areas on the Moon are called highlands. The darker ones, called maria, are regions where lava covered the surface.

JAMIE COOPER

POINTING A TELESCOPE at the Moon is an easy way to get into the immensely rewarding pursuit of amateur astronomy. Luna offers something perfect for observers of all skill levels and with all sizes of telescopes: a face that's always changing. Following the Moon through a lunar month — from its first appearance as a New Moon in the evening sky to its next such appearance — will demonstrate its dynamic nature like no book or magazine article can. The Moon is easy to find, and you can view it even under strong light pollution. And unlike the Sun, it's completely safe to look at with the naked eye.

The 50th anniversary of Apollo 11 is the perfect time to view the places where the Apollo astronauts landed. If you're a Moon watcher — and even if you're not — you need to check these six sites off your lifetime observing list. While no telescope, not even Hubble, can pick out the actual Apollo hardware that remains on the lunar surface, it's not hard to find the half-dozen spots where 12 moonwalkers made history.

When and where to look

Ironically, the worst time to view the Moon is when it's Full and at its brightest. That's when the Sun's light hits our satellite straight on, which minimizes the shadows and reveals scant detail.

There are two prime times for lunar viewing. The first one lasts from when the thin crescent becomes visible after New Moon until about two days after First Quarter (in the evening sky). The second one lasts from about two days before Last Quarter to almost New Moon (in the morning sky). Shadows are longer then, and features stand out in sharp relief. This is especially true along the Moon's shadow line — called the terminator — that divides the light and dark portions. Before Full Moon, the terminator shows where sunrise is occurring; after Full Moon, it marks the sunset line. So, when you're looking at the Moon, the terminator is where most of the action is.

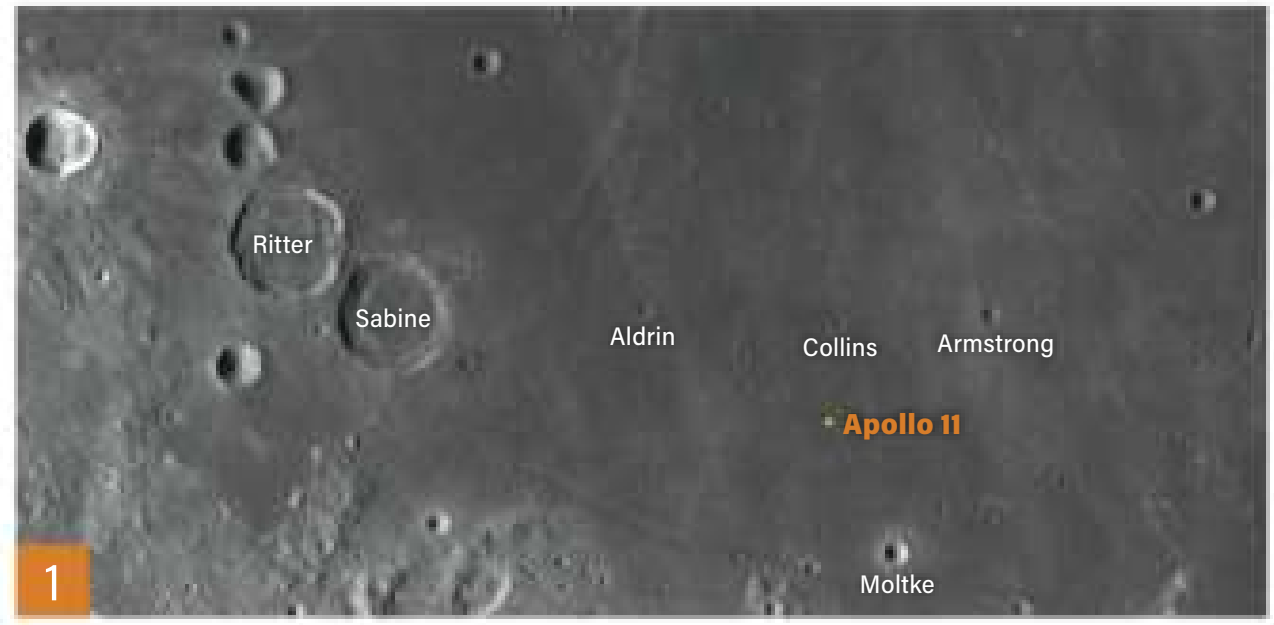
Along that shadow line, you'll see mountaintops protruding high enough to catch sunlight, while dark, low-lying terrain surrounds them. On large crater floors, you can follow "wall shadows"

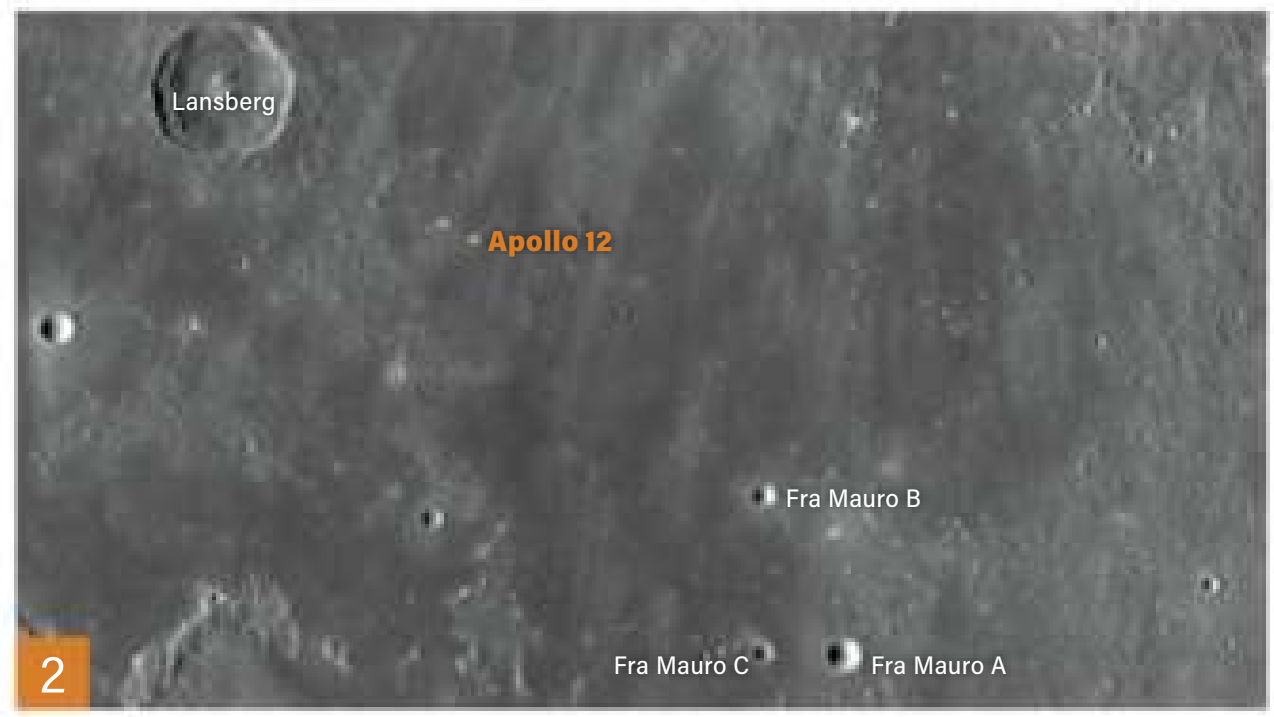


LEFT: The line that divides the Moon's light and dark regions is called the terminator. It's where lunar sunrise (between New Moon and Full Moon) or sunset (between Full Moon and New Moon) happens. The terminator is visible whenever the Moon is visible and not full. JOHN CHUMACK

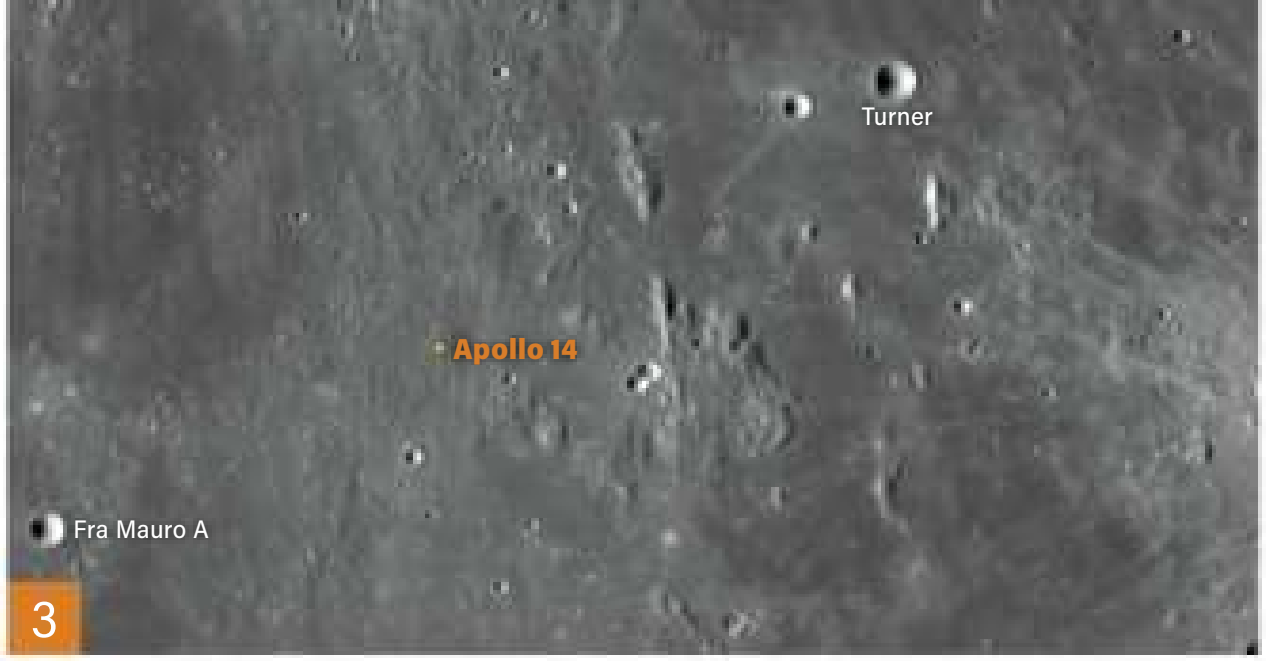
1. NASA called the Apollo 11 landing site "Tranquillity Base" because the craft touched down in Mare Tranquillitatis, the Sea of Tranquillity. Six craters form an easy-to-find pattern that leads you to the site. Once you're in the area, look for the three craters named for the mission astronauts. Because the biggest (Armstrong) is only 2.9 miles (4.6 kilometers) in diameter, you'll need a large scope to spot it. This region is visible four through 18 days past New Moon. Note that, as with all these areas, shadows will be sharper and detail will be more evident at the beginning and end of that range.

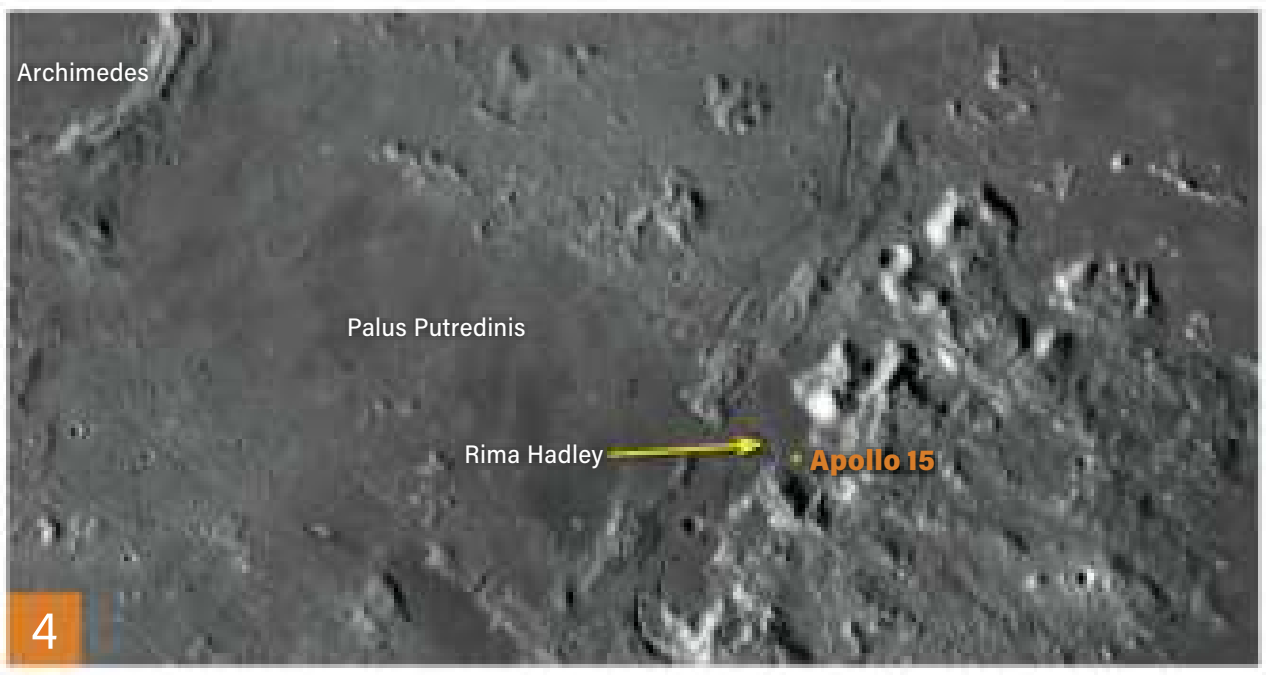
2. The Apollo 12 landing site lies within the Moon's huge Oceanus Procellarum, the Ocean of Storms. Because this feature covers 812,000 square miles (2.1 million square km), we need to refine our search a bit. First, locate Lansberg Crater, then find the triangular group of craters to its lower right. The landing site lies midway between Lansberg and the largest of the triad. This region is visible 10 through 24 days past New Moon.

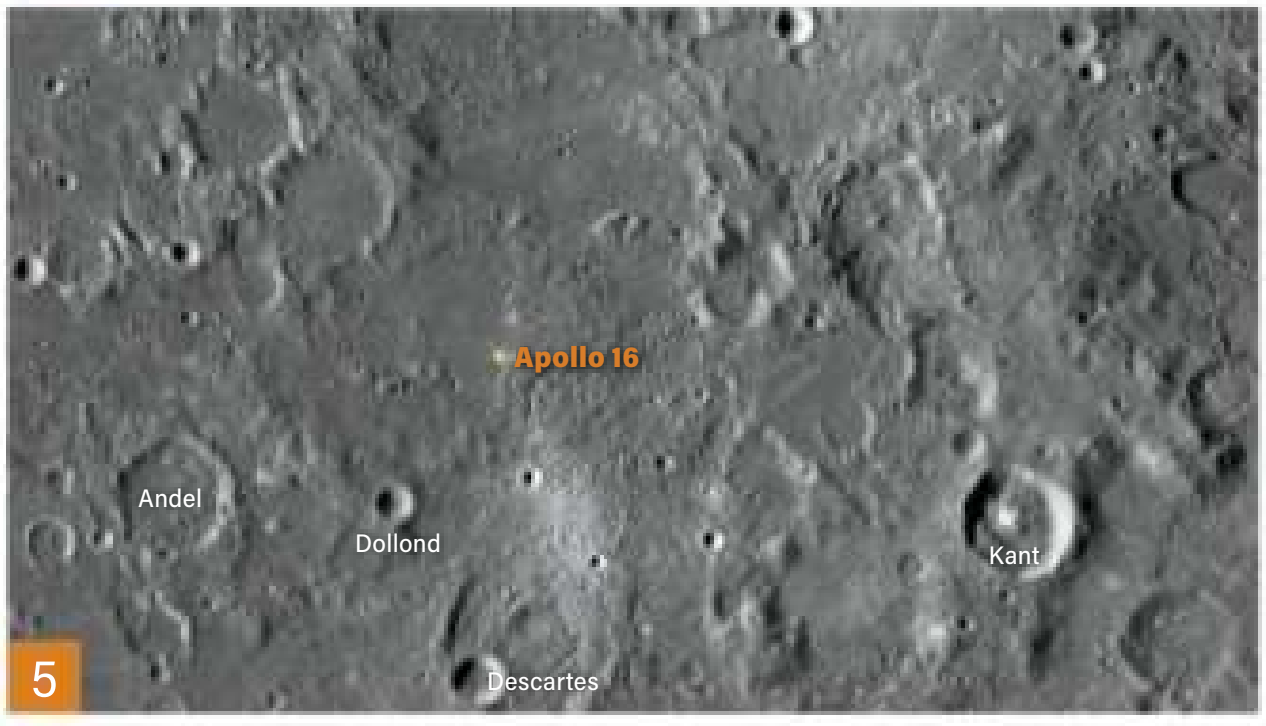




ALL IMAGES BY NASA/JSC/ARIZONA STATE UNIVERSITY UNLESS NOTED







3. You might have already spotted the Apollo 14 landing site without knowing it. Apollo 14 landed about 5° to the right of the Apollo 12 site as we view the Moon, or a scant 1/36 of our satellite's apparent diameter. Nudge your scope to the right a bit, and center the double crater at the center of this image. Those two impacts are craterlets (small craters formed from material blown out of a crater during its formation) of Fra Mauro, which lies just below the bottom of this image. This region is visible nine through 23 days past New Moon.

4. The Apollo 15 landing site is quite close to Archimedes Crater. Ease your scope's field of view a bit to the right and down some. When you see the sinuous rille, or valley, Rima Hadley — a feature that looks like a 50-mile-long (80 km) winding, dry river — you're there. This region is visible seven through 21 days past New Moon.

5. To locate the Apollo 16 landing site, aim your telescope just to the lower right of the Moon's center, then view this region, which lies north of Albufeda Crater. The distance of the landing site from Dollond Crater is the same as that crater's distance to Descartes Crater. This region is visible six through 20 days past New Moon.

cast by the sides of craters hundreds or thousands of feet high. What's more, these features change in real time, and you can see striking differences in just one night.

Two-part landscape

Scientists differentiate features on the Moon between lighter areas, called highlands, and darker features, called maria (the Latin word for seas). The dark material inside maria is solidified lava, and it dates back to periods of volcanism that ended about a billion years after the Moon formed (which happened some 4.5 billion years ago).

But the lava isn't even the oldest part of the Moon. That honor goes to the highlands, which consist of ancient lunar surface rock and materials thrown out during previous explosive impacts. The highlands are a Moon watcher's treasure-trove of mountains, valleys, bright areas, and shadows.

Then there are the craters. Of the 9,144 named features on the Moon, 8,737 (nearly 96 percent) are either craters (1,624) or satellite features (7,113). (Satellite features are small craters outside the main ones that carry the main crater name plus a letter — for example, Archimedes M.)

Many more craters dot the highlands because these areas have been around longer than the maria, which were resurfaced by their volcanic activity. Craters range in size, so a fun way to challenge yourself is by noting the size of the smallest crater you can see.

A few tips

The Moon is a bright object, and it's even brighter through a telescope. Many observers use a neutral density filter to cut down the light. Manufacturers sell small ones that screw into the barrels of eyepieces.

If you don't have access to such a filter, try these two methods of reducing the Moon's brilliance: high magnification and a device called an aperture mask. The first restricts the field of view by magnifying it so that you're looking only at a small area of the lunar surface, thereby reducing the amount of reflected sunlight. The second is a simple cardboard mask with a small hole cut out of it. If you cover the

front of your telescope with it, less light will get through, and it will be like using a smaller scope. If you're using a refractor, you can center the hole. For reflectors and catadioptric scopes, you'll need to offset the hole from the center, so it doesn't fall atop the secondary mirror. If you have a reflector, which uses four metal vanes to support the secondary, place your cardboard mask so the hole is between two of the vanes.

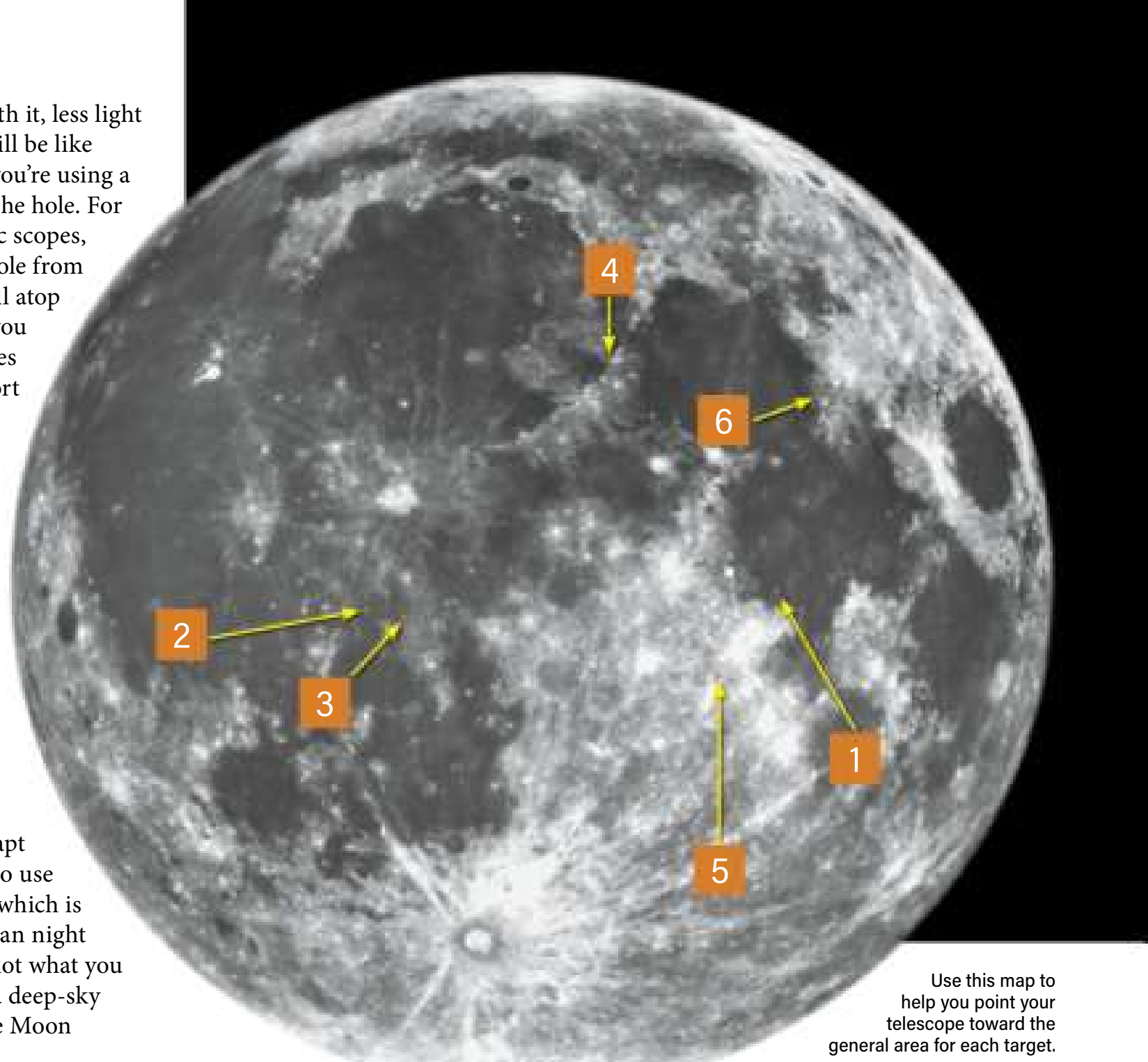
For those who want the best possible view of the Moon, turn on a white light behind or beside you as you sit at the telescope. As long as you can't see the light directly, the placement doesn't matter. Adding ambient light suppresses your eye's tendency to adapt to the dark and causes it to use normal (daytime) vision, which is of much higher quality than night vision. This definitely is not what you want if you're looking at a deep-sky object, but it works on the Moon because it's so bright.

When observing large craters, note whether you can see "rays" emanating from them. These tendrils of ejecta formed when crushed rock sprayed out after an impact. Rays appear as light, radial streaks, and they can lie a great distance from the crater. For a good example, point your scope toward the Copernicus impact crater.

Scope out the Moon

Now you're ready to head outside, set up a telescope, and search for the Apollo landing sites. The best way to start is to familiarize yourself with each of the six images of those regions you'll find in this story. Do note, though, that your scope might produce images that are upside down, flipped, or both. So, you might need to rotate the appropriate page. For scopes that flip images left to right, it might be best to photocopy each image, then shine a light on the front of the page while you look through the backlit side.

With these maps as starters, tracking down the spots where humans walked on the Moon might be easier than you think. Take your time, have fun, and good luck with "one small step" into lunar observing.



Use this map to help you point your telescope toward the general area for each target.

LICK OBSERVATORY

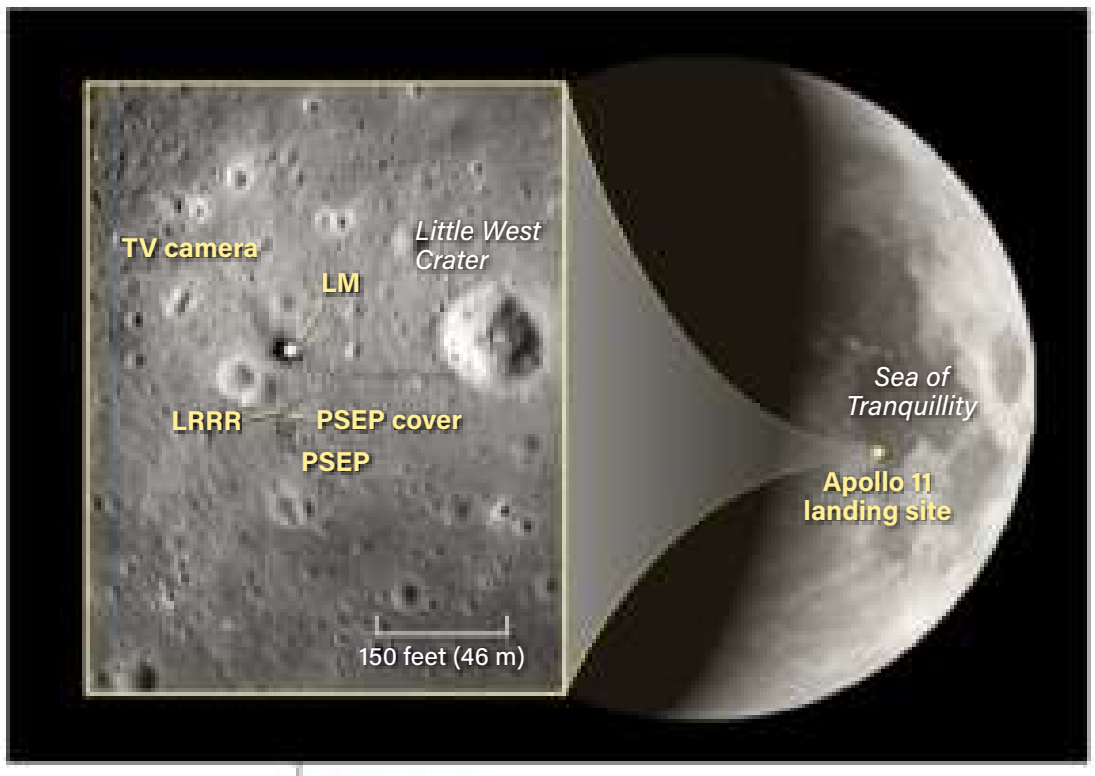


6. The Apollo 17 landing site lies in the Moon's northeastern (upper right, as we see it) quadrant. The site's name, Taurus Littrow, refers to Littrow Crater in the Taurus Mountains, just on the eastern (right) edge of Mare Serenitatis. When you find Littrow Crater, look just below it, slightly outside its southern wall. This region is visible four through 18 days past New Moon.

Michael E. Bakich *is a senior editor of* Astronomy.

A telescopic trip to the Moon

A backyard scope can take you to Tranquillity Base.



Captured by NASA's Lunar Reconnaissance Orbiter, the inset view shows the equipment left by Apollo 11, such as the lunar module, a TV camera, the Laser Ranging Retro-Reflector, the Passive Seismic Experiment Package and its cover, and a footpath to Little West Crater carved out by the astronauts during their moonwalks.

MOON: STELLARIUM.

INSET: ASA/GSFC/ASU



BY GLENN CHAPLE

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

Where were you on July 20, 1969, when Apollo 11 astronaut Neil Armstrong made his giant leap for mankind? If you're like most of the world's population, you weren't even alive. It's hard to believe that people who are old enough to appreciate the magnitude of humanity's first Moon landing are now at least in their mid to late 50s.

I'm a member of that group. Back then, I was a newly commissioned 2nd lieutenant at the U.S. Army Air Defense Artillery Branch School at Fort Bliss, Texas. It was a most appropriate assignment. While I was learning the intricacies of a 41-foot-long rocket (the Nike Hercules guided missile), Armstrong and fellow astronauts Buzz Aldrin and Michael Collins were departing Earth in a much bigger rocket: the 36-story-tall Saturn V.

I can't tell you how surreal it was to gaze at the Moon, knowing that three men were there — two of them walking on its surface. Those of us who experienced the excitement of Apollo 11 and the missions that followed find it sad and disappointing that human exploration of the Moon is once again a futuristic dream.

Eventually, we'll go back. There will even come a time when travel to the Moon will be so routine that ordinary citizens will be able to visit Tranquillity Base, site of the Apollo 11 landing. But for now, we'll have to gaze from afar with a telescope and let our imaginations take us there.

In fact, let's do just that. We'll plan our "launch" for either the evening of July 8 or July 9, when the Moon phase will mimic what it was when the Apollo 11 astronauts were there. The map on this page helps us pinpoint our goal: the Apollo 11 landing site, located on the southern part of the Sea of Tranquillity. (To explore five more Apollo program landing sites, see "Target the Apollo landing sites" on page 80.) Unlike rocket launches, there won't be any problem if clouds force us to put the mission on hold; the area will remain visible all the way to Full Moon and a few evenings beyond.

We begin with a naked-eye view of the Moon some 240,000 miles (386,000 kilometers) away. Imagine how each Apollo 11 astronaut must have felt in similar situations during the weeks and months prior to launch. The excitement and anticipation of a trip to the Moon would have been tempered by the knowledge that this would be a dangerous undertaking.

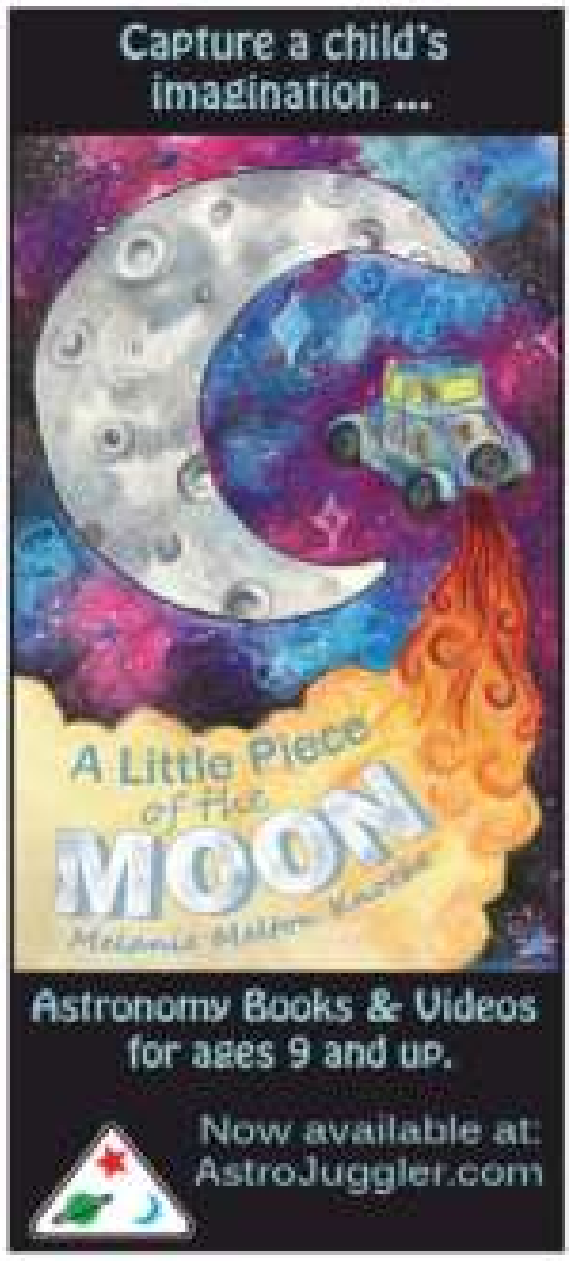
In the days after launch, the Apollo crew watched the Moon slowly grow in size. We can simulate this with the telescope by starting with low power and, eyepiece by eyepiece, increasing the magnification. Just 30x will approximate an astronaut's view of the Moon from a distance of 8,000 miles (13,000 km). A magnification of 60x will cut that distance in half. Upping the magnification to 120x (about the highest magnification a common 2.4-inch telescope will deliver) again halves the distance. We are now just 2,000 miles (3,200 km) from the lunar surface. A large-aperture scope magnifying 300x (about the upper practical magnification limit for telescopes under average seeing conditions) puts us just 800 miles (1,300 km) from touchdown.

In my mind, I'm Michael Collins, orbiting the Moon and peering through a porthole at the vista below.

Unfortunately, this is about as close to Tranquillity Base as a backyard telescope can take us. Only our imaginations will have to bring into view the lunar module, American flag, and the astronauts' footprints — still fresh after 50 years. When I look at the Moon under high magnification, I like to watch it drift across the eyepiece field. In my mind, I'm Michael Collins, orbiting the Moon and peering through a porthole at the vista below.

Questions, comments, or suggestions? Email me gchaple@hotmail.com. Next month: We dissect a scorpion. Clear skies!

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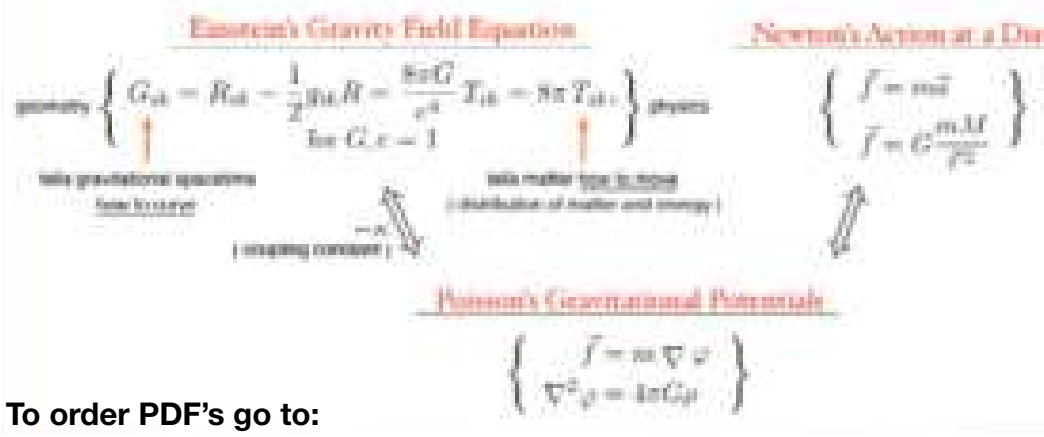






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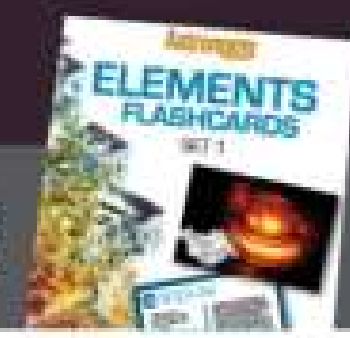
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Tough tests for the naked eye

This season's sky has double stars galore.



On a clear night, find a dark site and gaze toward Polaris (Alpha [α] Ursae Minoris). See if you can spot Lambda and 24 UMi.
STEPHEN JAMES O'MEARA

Over the last several months, I've spent evenings seeking some of my favorite naked-eye "haunts" — dim denizens that require time and effort to see . . . or not see. Here are some of the more fun ones, including a couple that continue to evade me.

A test with staying power

In 1878, English astronomer George Hunt noted that German astronomer Eduard Heis listed Lambda (λ) Ursae Minoris in *Atlas Coelestis Eclipticus*, his catalog of naked-eye stars. Hunt spent more than a year searching for this star, leading him to suspect that sighting Lambda would be an excellent test of naked-eye vision.

Hunt's failure baffled him because he consistently saw 6th-magnitude 24 UMi, which lies only 23' north of magnitude 4.3 Yildun (Delta [δ] Ursae Minoris). So, he assumed Lambda must be closer to 7th magnitude. Actually, 24 UMi shines at magnitude 5.8, while Lambda is only 0.6 magnitude fainter. Why, then, did Hunt have such difficulty?

More than the difference in magnitude, I suspect Lambda's location is the primary culprit. Lambda is a dim star in a void 1½° from Polaris — almost on a line between Polaris and Yildun. On the other hand, 24 UMi is a dim star relatively close to a brighter one, making locating and sighting it easier.

Hunt did finally spot Lambda, but only through a ¼-inch circular aperture. Also, back then, sighting Lambda had significance because it was the closest naked-eye star to the North Celestial Pole — a fact no longer true due to precession. Can you see 24 and Lambda? Did you have the same experience as Hunt?

Resolving the "mist"

Lots of amateur astronomers adore the Coathanger (Collinder 399) asterism. This remarkable 90'-wide gathering lies only 4° northwest of Alpha (α) Sagittae. Through binoculars, you'll see a line of six stars (oriented east–west) with a southward-dipping hook of four stars. Keen-eyed observers can see it without optical aid as a magnitude 3.5 mist in the Milky Way. It was first described by Persian astronomer Abd al-Rahman al-Sufi in his *Book of Fixed Stars*, which appeared in A.D. 964.

But if you dedicate half an hour to studying that patch with your unaided eyes using averted vision, see if the mist doesn't dissolve into flecks of starlight. In fact, five of the Coathanger's stars shine between magnitude 5.2 and 6.3, and seven of them are brighter than 7th magnitude. Its two brightest stars, 4 and 5 Vulpeculae, are magnitude 5.2 and 5.6, respectively. I have seen the five brightest with effort.

Now set your gaze 5° north-northeast of 4 Vulpeculae for an overlooked challenge: magnitude 4.4 Alpha Vulpeculae, which has a magnitude 5.8 companion (8 Vulpeculae) 7' to its northeast. This is a much more reasonable challenge than Zubenelgenubi listed below.

No success yet

One object that continues to baffle me is Zubenelgenubi (Alpha Librae). The magnitude 2.8 primary has a magnitude 5.2 companion 3.8' to its northwest. Now, if you consider the Double-Double (Epsilon [ε] Lyrae) to be difficult with its stars having magnitudes of 4.7 and 5.2 (a brightness difference of 60 percent) and separated by 3.5', imagine how much more difficult the task will be with a primary being nine times brighter than the secondary, as is the case with Zubenelgenubi. Nevertheless, observers have succeeded in splitting them.

Lots of amateur astronomers adore the Coathanger asterism.

In 1896, Walter Gale, a Fellow of the Royal Astronomical Society, scoffed at the idea of Alpha Capricorni (4.3, 3.6; 6.3') and Mu (μ) Scorpii (3.0, 3.5; 5.8') being tests for naked-eye vision, adding that even Epsilon Lyrae was "easy to detect." He went on to say that, while he had heard that Alpha Librae had not been split with the unaided eye, he would like to "place on record the ease with which α^1 and α^2 Librae are visible in our clear skies" — in Paddington, Sydney, Australia. Alas, I have yet to succeed, even from Botswana.

As always, send reports to sjomeara31@gmail.com. I'd love to hear from young observers, and from veteran observers who may have had eye surgery or those who wear special observing glasses, to see if these advancements help keep their vision forever young.



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

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P32725

The dark side

Dark nebulae offer great summertime binocular views.



The Galactic Dark Horse is visible on his side above the broad dust lane that runs through the central part of the Milky Way. LYNN HILBORN



BY PHIL HARRINGTON
Phil is a longtime contributor to Astronomy *and the author of many books.*

This month, let's try something a little different. Rather than looking for visible objects, we are going to look for the invisible. We are hunting for dark nebulae.

Due to their subtle nature, dark nebulae were largely overlooked by early telescopic observers. It was not until the advent of photography that the study of dark nebulae really got underway.

Most of our early knowledge about these black clouds came about through the diligence of American astronomer Edward Emerson Barnard, whose *Catalogue of 349 Dark Objects in the Sky*, published in 1927, can be thought of as the Messier catalog of dark nebulae. It contains most of the genre's showpiece objects and remains a standard reference. Another often-cited listing is Beverly T. Lynds' *Catalog of Dark Nebulae*. The Lynds catalog was published in *The Astrophysical Journal Supplement*, vol. 7, in 1962.

Barnard's catalog can be thought of as the Messier list of dark nebulae.

Let's begin big, with the largest example north of the celestial equator, the **Northern Coalsack** in Cygnus. Officially cataloged as Lynds 906, the Northern Coalsack creates a 5°-by-6° oval "hole" in the triangle framed by Deneb (Alpha [α] Cygni), Sadr (Gamma [γ] Cygni), and Gienah (Epsilon [ε] Cygni). Given good skies, the Northern Coalsack is easily visible through small pocket binoculars, and even by eye alone. Its large span will more than fill the field of most 50mm and larger binoculars, so you'll need to scan slowly to define its edges.

Scanning southward along the plane of our galaxy, let's next try our luck with **Barnard 142** and **Barnard 143**, in Aquila. Both are better known as "Barnard's E" because, under rural skies, they collectively form a very distinctive capital E against the bright background. The E is easy to locate, just 3° northwest of brilliant Altair (Alpha Aquilae) and 1° west of Tarazed (Gamma Aquilae).

Barnard 143, the northernmost of the two, resembles the prongs of a handleless fork opening toward the west. Barnard 142 lies just to the south and is shaped like an irregular, starless rectangle.

My most memorable view of Barnard's E came several summers ago while observing from the Stellafane telescope makers convention in Springfield, Vermont. Its silhouette was unmistakable against the star-filled backdrop through my 10x50s. But when I swung my 16x70s its way, curiously it lost some of its visual impact. That might have been due to their narrower field. I'd be interested to hear from readers about your own experience viewing the E.

Let's close with a large dark nebula complex in southern Ophiuchus, midway between the Small Sagittarius Star Cloud (M24) and brilliant Antares (Alpha Scorpii). This one is so large that it is assigned several individual entries in the Barnard catalog that together form the **Pipe Nebula**. From a dark-sky site, its smoking-pipe shape stands out nicely against the starry milieu. The "bowl" of the pipe, designated Barnard 78, looks roughly rectangular, while the long, thin "stem" is formed by the combination of Barnard 59, 65, 66, and 67. The Pipe is surprisingly obvious in binoculars, given good sky conditions. Note that it spans more than 7°. So, once again, a wider field of view will outmaneuver larger binoculars.

But wait, there's more. By adding in other, more subtle patches northwest of the Pipe, the area transforms into the profile of a prancing horse. Former *Astronomy* editor Richard Berry was the first person to widely publicize the shape of the **Galactic Dark Horse**.

Assembling the horse is like piecing together a cosmic jigsaw puzzle. The Pipe forms the horse's hindquarters, with the bowl of the pipe as the steed's hip and the stem its rear leg. Crescent-shaped Barnard 63 marks its bent front leg, while the remainder of the horse's torso is created by Barnard 67a, 72, 75, 261, 262, 266, 269, and 396. Barnard 276 outlines the profile of the horse's head, Barnard 259 marks its nose, and Barnard 268 completes its mane.

I hope you've enjoyed our journey into the dark side. Until next month, remember that two eyes are better than one.

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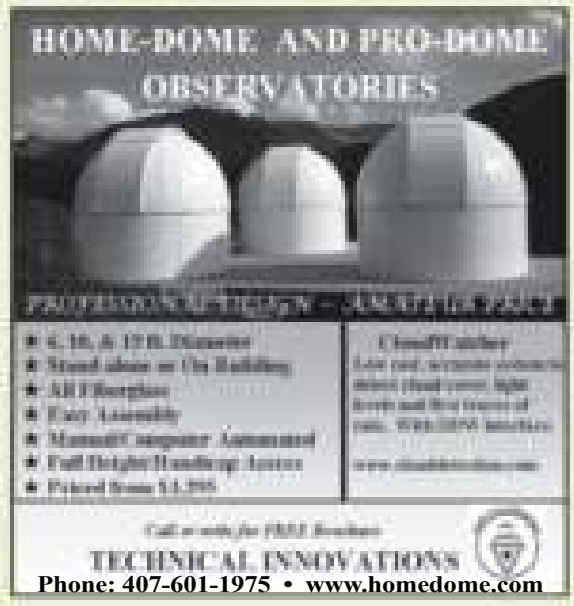


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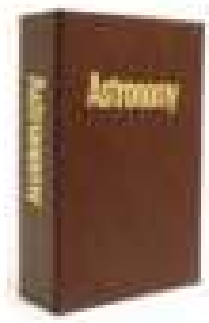
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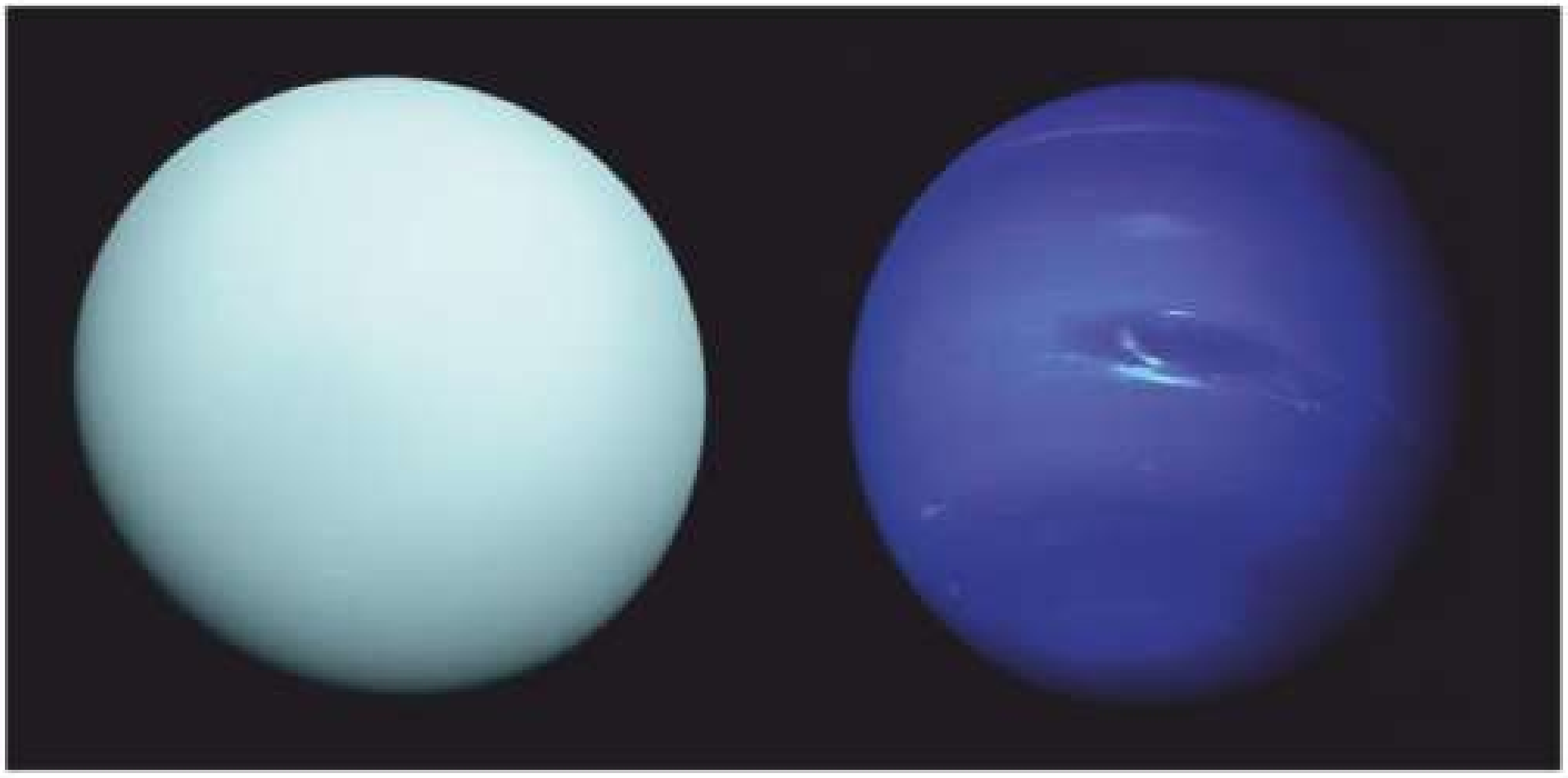
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Uranus (left) and Neptune are classified as ice giant planets because their rocky, icy cores are proportionally larger than the amount of gas they contain. The gas giants — Jupiter and Saturn — contain far more gas than rock or ice. NASA/JPL-CALTECH; NASA

Ice giants' origin story

Q WHY DO ASTRONOMERS CALL URANUS AND NEPTUNE ICE GIANTS?

Douglas Kaupa
Council Bluffs, Iowa

A Uranus and Neptune are called ice giants because they are smaller and compositionally different from Jupiter and Saturn, the gas giants. Jupiter and Saturn are composed of mostly hydrogen and helium, with large mantles of metallic hydrogen (which acts like a metal, due to the pressure and temperature within these planets) and only small cores of rock and ice. This is why they are called gas giants: They are mostly gaseous, with very little rock and ice.

Uranus and Neptune are composed of some hydrogen and helium, but they also contain heavier elements such as oxygen, carbon, nitrogen, and sulfur. Beneath their relatively thin outer shells of hydrogen and helium, these planets' mantles are largely made of compressed, slushy water and ammonia. The ice giants' rocky, icy cores are also proportionally larger than the amount of gas they contain, unlike the gas giants. This is why Uranus and Neptune are called ice giants.

The "ice giant" terminology took hold in the 1990s when researchers realized Uranus and Neptune were compositionally different from Jupiter and Saturn. Classifying them differently better reflects the variations in the formation of the outer planets, giving astronomers a clearer picture of how our solar system and others formed.

Alison Klesman
Associate Editor

Q WHAT EFFECTS WILL OCCUR ON EARTH AND IN OUR SOLAR SYSTEM WHEN THE NEARBY STAR BETELGEUSE BECOMES A SUPERNOVA?

Donald Craig
Indianapolis

A Betelgeuse is about 500 light-years away, not near enough to cause serious damage. We might see a little bit of damage to the ozone layer, or some small increase of radiation on the ground on Earth, but these would be too small to matter.

Based on the latest work with my collaborators, a massive star would need to be within about 150 light-years to cause measurable damage. We think that may have happened about 2.6 million years ago, and possibly contributed to an extinction event at the end of the Pliocene era that took out marine megafauna. (See the November 27, 2018, issue of the journal *Astrobiology*, and "Could a supernova explain an ancient mass extinction?" on page 11 of *Astronomy*'s April 2019 issue.) A supernova within about 25 light-years would probably cause a major mass extinction, which has likely happened one or more times in the past 500 million years.

The biggest current threat is probably a solar proton event, which occurs when the Sun releases high numbers of energetic protons that can disrupt communications and affect power grids. These events could be devastating for our technological civilization.

Adrian L. Melott
Emeritus Professor, Department of Physics and Astronomy, University of Kansas, Lawrence, Kansas

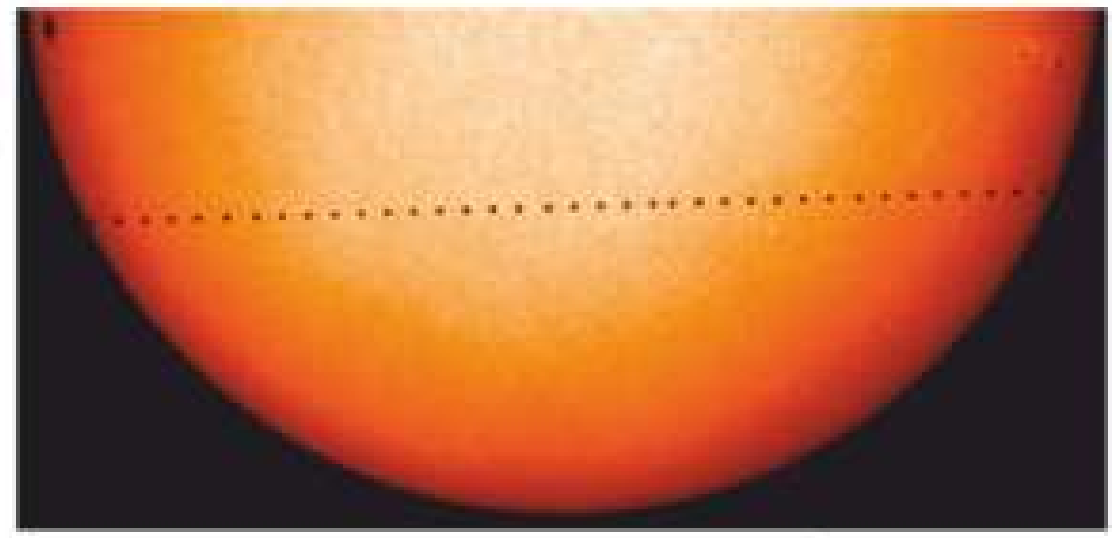
Q | IN THE NORTHERN HEMISPHERE, THE SUMMER SOLSTICE HAPPENS ON OR AROUND JUNE 21. YET THE SUMMER IS USUALLY HOTTEST THE FIRST WEEK OF AUGUST. THE OPPOSITE IS TRUE FOR THE WINTER SOLSTICE. WHY THE DELAY?

Ronald Cohen
Brooklyn, New York

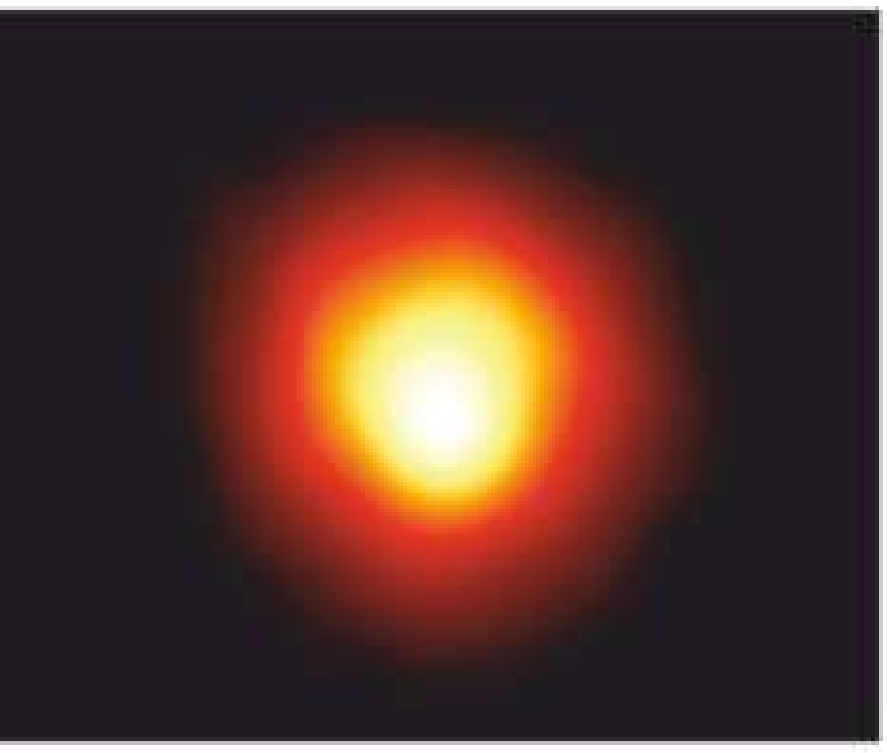
A | The reason for the delay between the longest (or shortest) day and the hottest (or coldest) temperatures of the year is similar to the reason the hottest or coldest parts of the day occur after noon and in the earliest hours of the morning, respectively. Heating and cooling aren't instantaneous — it takes time for land, water, and air to either absorb heat and warm up or release stored heat and cool down.

In the case of summer, the energy received by the hemisphere in question increases as the days grow longer in the time leading up to the solstice. Although the planet releases heat overnight, it is receiving energy faster than it can cool off, so it warms up. On the solstice, the Sun's energy input is at a maximum, then slowly begins to decrease in the following days and weeks. But the portion of the planet experiencing summer is *still* receiving high energy input from the Sun after the solstice. This energy input remains higher than the rate at which heat is released, which causes the hemisphere to continue warming, for several weeks — thus, the hottest portion of the season is delayed. The effect is the same in winter, only the processes are reversed as land, air, and water continue to release heat faster than they absorb it for several weeks after the winter solstice.

Alison Klesman
Associate Editor



From Earth's perspective, only Mercury and Venus transit the Sun. This image, taken by the Solar and Heliospheric Observatory November 8, 2006, shows Mercury crossing the face of our star. SOHO (ESA AND NASA)



Betelgeuse, shown here in a Hubble Space Telescope image, is a red supergiant about 500 light-years away in the constellation Orion the Hunter. Although astronomers predict this massive star will end its life as a supernova soon — at least in cosmic terms — the effects of such an explosion won't pose a problem for life on Earth. ANDREA DUPREE (HARVARD-SMITHSONIAN CFA), RONALD GILLILAND (STScI), NASA AND ESA

Q | CAN MARS TRANSIT THE SUN? ARE THERE ANY OTHER TRANSITS BESIDES MERCURY, VENUS, AND EARTH?

Jimmy Planck
Mexico City

A | Planetary transits of the Sun occur when a planet, from the observer's point of view, crosses the face of the Sun. From Earth, the only planetary transits we can see are Mercury and Venus because their orbits lie closer to the Sun than the orbit of Earth. So, sometimes they cross the face of our star when they lie directly between Earth and the Sun. Thus, *from Earth*, Mars cannot transit the Sun because its orbit lies outside Earth's.

However, the same isn't true for an observer who is not on Earth. As you indicate, an observer on Mars could see three planets transit the Sun: Mercury, Venus, and Earth. The last transit of Earth from Mars occurred May 11, 1984, and the next will happen November 10, 2084.

From Jupiter, you could see Mars — along with Mercury, Venus, and Earth — transit the Sun, and so on as you move outward through the solar system. Planetary transits completely rely on the observer's point of view, so future astronauts may one day see Earth, Mars, or other planets transit the Sun.

Alison Klesman
Associate Editor

SEND US YOUR QUESTIONS

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

Cosmic portraits



1

1. DUSTY REFLECTION
The zodiacal light shines brightly in the western sky from Indian Fields in Nova Scotia, Canada. In addition to the triangular patch of illumination, this 20-second exposure through a 14mm lens captures Orion, Taurus, the Pleiades (M45), and lots more. ▪ ***Barry Burgess***

2. ALL PHASES
This wide-angle composite consists of 68 frames spaced 3 minutes apart from 5:43 to 9:09 P.M. PST, January 20, 2019. The photographer started the sequence the moment the Full Moon rose. He continued it through the penumbral eclipse to the partial eclipse and finally to totality. ▪ ***Lakshminarayanan Gowrishankar***

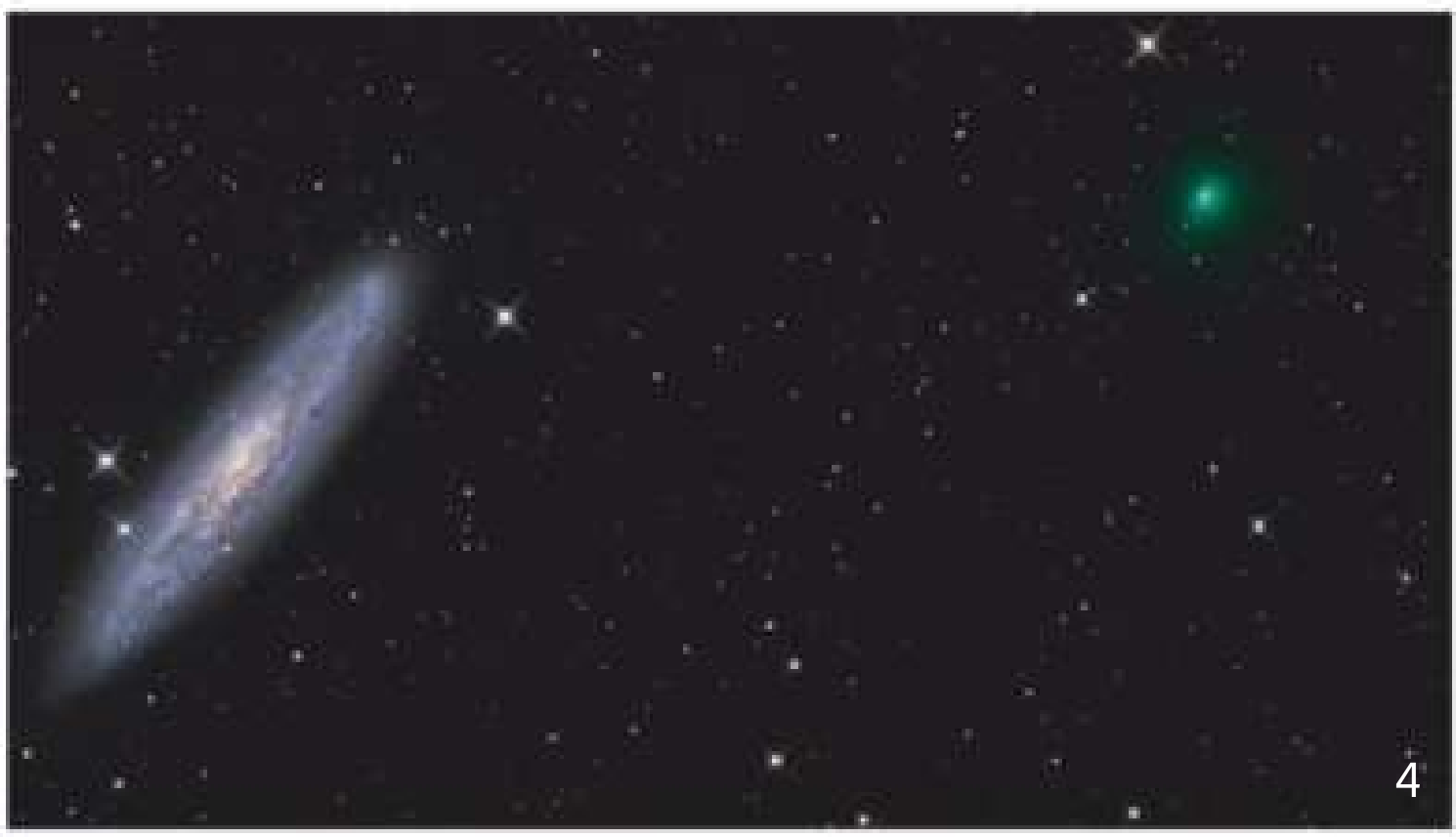


2



3

3. ASK FOR THE MOON
The Moon appears roughly three-quarters illuminated in this image captured January 16, 2019, through an 8-inch Newtonian reflector. As always with our satellite, the "action" takes place along the terminator, the line that divides the light and dark parts. ▪ ***Jamie Cooper***



4

4. COMET ENCOUNTER
Comet 66P/Du Toit drifts past the Silver Coin Galaxy (NGC 253) in the constellation Sculptor on June 22, 2018. The comet's greenish hue contrasts nicely with the galaxy's pale yellow and blue appearance. At the time, the comet was slightly brighter than 11th magnitude, much less than the galaxy, which glows at magnitude 7.1. ▪ ***Gerald Rhemann***

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



5



6

5. CLOUDS OF WATER AND STARS
The summer Milky Way stands above Pangong Lake, which lies in both India and China, at an altitude of 14,270 feet (4,350 meters) above sea level. The imager saw the Milky Way emerge behind the snowcapped Himalayan peaks between waves of monsoon clouds. But what caught his attention was how just a handful of luxury tourist tents and a few buildings could pollute this pristine night sky.
• Chirag Upreti

6. MEGA DISK
In 2018, a research team using the Dragonfly Telephoto Array in New Mexico discovered an enormous low-surface-brightness disk around spiral galaxy NGC 2841 in the constellation Ursa Major. The team reported that the disk's diameter was 450,000 light-years, more than twice the diameter of the Milky Way's disk. ***• Kent Wood***

7. WHAT A TANGLED WEB
The Spider Nebula (Sharpless 2–234), also known as IC 417, is an emission nebula in the constellation Auriga. The nebulosity surrounds open star cluster Stock 8. A smaller nebula, NGC 1931, lies nearby, spurring some to label them the Spider and the Fly.
• Mark Hanson



7



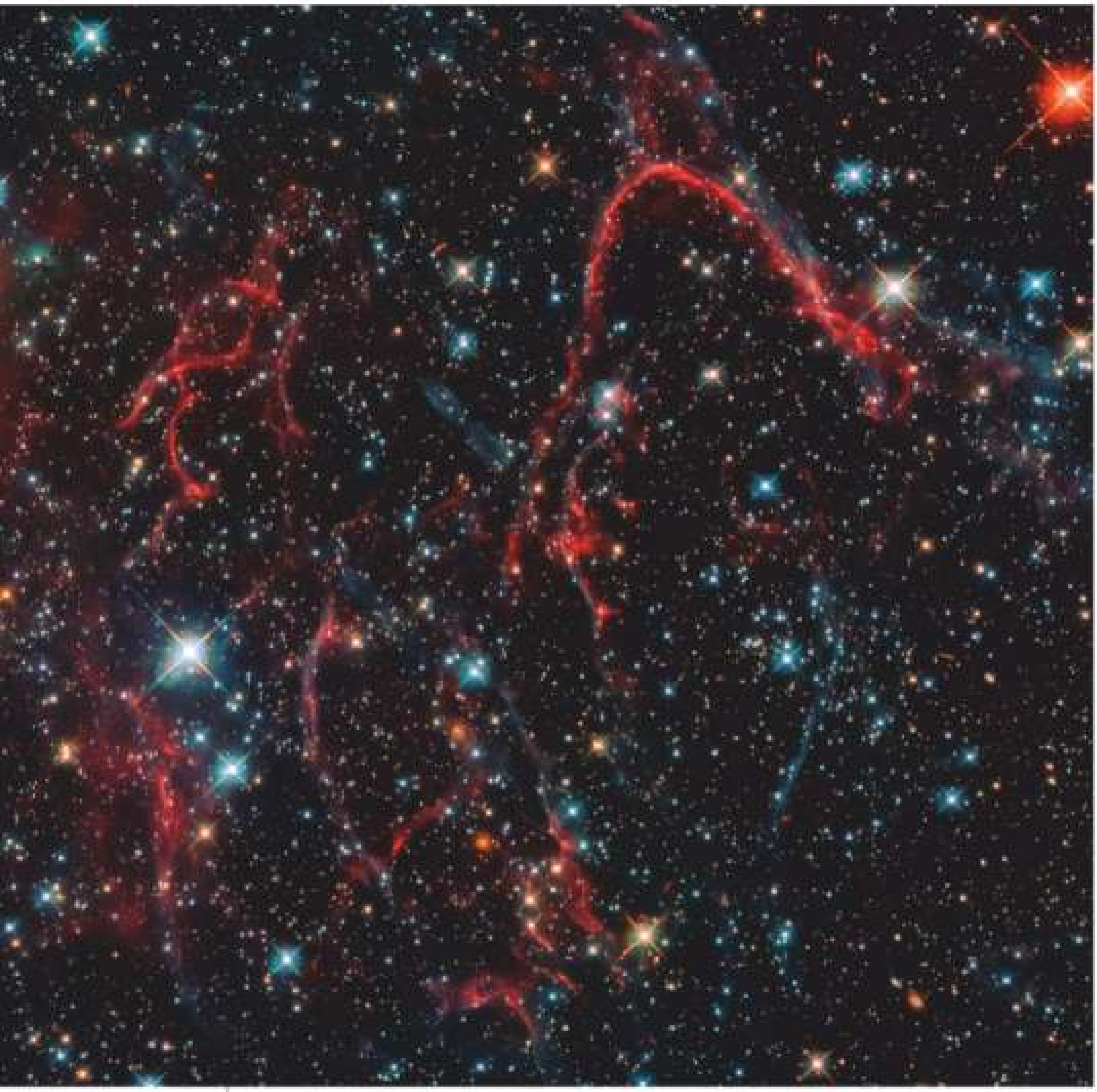
8. DARK AS NIGHT
The Cave Nebula (Sharpless 2–155) is a complex of emission (red), reflection (blue), and dark nebulosity in the constellation Cepheus the King. This image took nearly 20 hours of exposures to create. ***• Rodney Pommier***

9. A SPOT AT LAST
The Sun has been relatively quiet lately. So, spots like this one, named AR 2738, taken April 10, 2019, at 9h59m UT, are a nice change of pace.
• David Tyler

10. GALAXY GROUP
Spiral galaxy NGC 691 sits to the right of center in this image. To its lower left is S-shaped IC 167. The tiny blue-purple "cotton ball" to the left of IC 167 is NGC 694. On the left edge above center is the large elliptical NGC 680, and just below it on the very edge is IC 1730.
• Madhup Rathi

11. WHEN 39 = 1
This image of the Milky Way arcing above Bryce Canyon, Utah, is a panorama that combines 39 separate exposures. The photographer visited the region around the dark of the Moon in early April 2019.
• John Vermette





A BLAST FROM THE NOT-SO-DISTANT PAST

The delicate appearance of these gaseous tendrils belie their origin in a cataclysmic supernova explosion. The remnant, SNR 0454–67.2, lies about 160,000 light-years away in one of the Milky Way's satellite galaxies, the Large Magellanic Cloud. Astronomers think light from this explosion lit up Earth's sky roughly 30,000 years ago. An excess of iron near the remnant's center suggests this was a type Ia supernova, created when a white dwarf siphons too much material from a companion star. Researchers captured this image with the Hubble Space Telescope's Wide Field Camera 3. ESA/HUBBLE, NASA

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

September 2019: Evening extravaganza

As spring begins, the two largest members of the Sun's family continue to be showpieces in the evening sky. **Jupiter** is the first point of light to emerge after the Sun sets. Gleaming at magnitude –2.1, it easily outpaces all other planets and stars from its perch in the southern part of Ophiuchus the Serpentbearer. The giant world rides high in the northwest as darkness falls and doesn't set until after midnight local time, at least until September's final week. It spends the month a bit less than 10° northeast of the ruddy 1st-magnitude star Antares in neighboring Scorpius the Scorpion.

Jupiter lies 22° south of the celestial equator, which is why it appears so high in our sky. Its great altitude affords us stunning telescopic views because its light passes through less of Earth's image-distorting atmosphere. Even a small scope reveals several details in the gas giant's cloud tops. Look for two dark equatorial belts, one on either side of a brighter zone that coincides with the planet's equator. During moments of steady seeing, you should see a series of alternating belts and zones. You also should notice that Jupiter's disk looks squashed: Its equatorial diameter of 37.4" is 2.4" larger than its polar diameter.

One of my favorite skywatching activities as a child was to chart the positions of Jupiter's four bright satellites — Io, Europa, Ganymede, and Callisto — as they danced around the planet from night to night. The moons glow at 5th and 6th magnitude and show up clearly through any telescope.

Southern Hemisphere observers currently have the best of both worlds — if by "worlds" you mean the solar system's two gas giants. Although **Saturn** lies as far south of the celestial equator as Jupiter does, the ringed planet stands nearly 30° east of its sister world and thus trails about two hours behind. This places Saturn almost overhead as twilight fades to darkness. You can find the magnitude 0.4 planet among the background stars of northern Sagittarius the Archer.

Saturn looks impressive to the naked eye, but it truly shines when viewed through a telescope. The planet currently displays a disk that measures 17" across the equator encircled by a ring system that spans 39" and tilts 25° to our line of sight. Also keep an eye out for 8th-magnitude Titan, Saturn's largest satellite, which shows up through any telescope. A 10-centimeter instrument also reveals a trio of 10th-magnitude moons — Tethys, Dione, and Rhea — that circle the planet inside Titan's orbit.

The evening sky gains two more planets by the end of September. Although **Mercury** passes on the far side of the Sun on the 4th, it reappears in the western sky at dusk after midmonth. On September 30, the innermost planet stands nearly 10° high 45 minutes after sunset. Glowing at magnitude –0.2, it should be easy to pick out of the twilight. A slender waxing crescent Moon then stands 7° — about one binocular field — to the planet's right. Look more carefully and you should see 1st-magnitude Spica, the blue-white luminary of Virgo the Maiden, 2° to Mercury's lower left. A telescope reveals the planet's 5"-diameter disk and gibbous phase.

Wait a few minutes and you can also grab your first evening views of **Venus** in nearly a year. Use binoculars to spy the planet 6° below Mercury on the 30th. Venus appears just 5° high a half-hour after sundown. It shows up largely because it shines at magnitude –3.9, making it the brightest point of light in the sky.

Like Mercury, **Mars** also passes on the Sun's far side in early September (on the 2nd), but it remains out of sight all month. It will return to view before dawn in November.

The starry sky

September evenings provide great opportunities to explore the Milky Way. One of the few constellations totally immersed in the glow from the myriad stars in our galaxy's disk is Scutum the Shield. I wrote about this constellation, the fifth smallest, some years ago. It lies just south of the celestial equator and currently stands high in the north in the early evening. Although Scutum holds several objects worth viewing through a telescope, it is one constellation that also rewards a look with the naked eye.

Its best naked-eye feature is the Scutum Star Cloud, which ranks among the brightest patches in the entire Milky Way. That's because less dust lies in this direction to block the view of more distant stars.

Although not as bright as the Sagittarius Star Cloud, the Scutum Cloud is a fine sight in its own right. In light-polluted areas or when there's a bright Moon out, these two star clouds are typically the most obvious signs of the Milky Way.

Famed American astronomer Edward Emerson Barnard called the Scutum Star Cloud "the Gem of the Milky Way." It spans about 5° and is bounded by Beta (β) Scuti on the north and Epsilon (ε) Scuti on the south. The famous Wild Duck Cluster (M11) on the cloud's northeastern edge is a must-see object through a telescope.

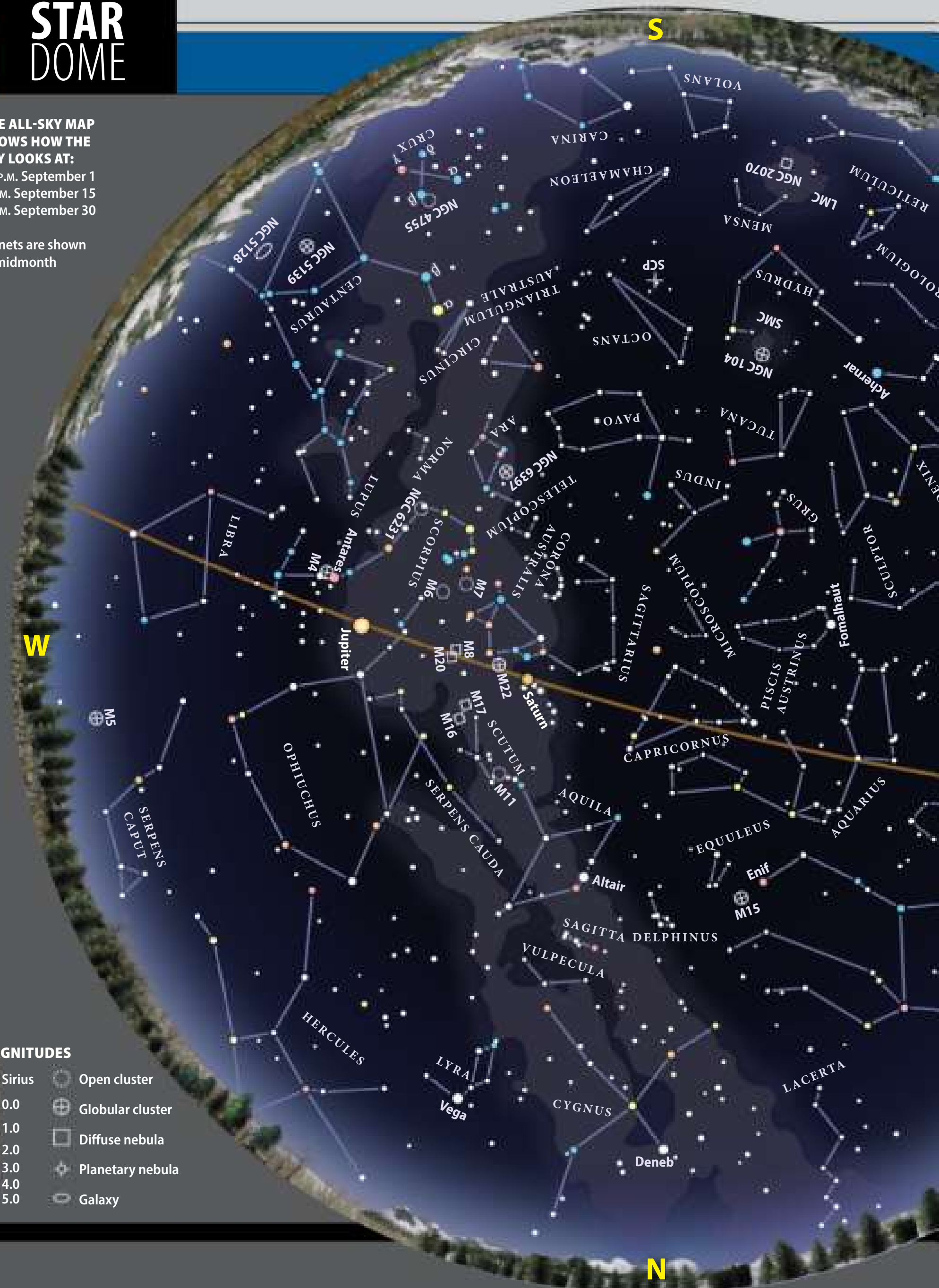
I recently had the pleasure of visiting the Vienna Museum in Austria, where I viewed the oil painting *The Relief Battle of Vienna*. This Franz Geffels (1625–1694) painting depicts the end of the siege of Vienna in 1683, in which King John III Sobieski of Poland led the relief forces. Polish astronomer Johannes Hevelius introduced the constellation Scutum in 1684 as Scutum Sobieski (Sobieski's Shield), in large part because the king had strongly supported the astronomer.

If you're ever in Gdansk, Poland, check out Ulica Jana Heweliusza (Johannes Hevelius Street). Not far away is a statue of the great man and a sundial onto which sculptor Jan Szczypka engraved a diagram of Scutum with its seven main stars in their correct positions.

STAR DOME

THE ALL-SKY MAP SHOWS HOW THE SKY LOOKS AT:
10 P.M. September 1
9 P.M. September 15
8 P.M. September 30

Planets are shown at midmonth



MAGNITUDES

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

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



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

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

Illustrations by *Astronomy*: Roen Kelly

SEPTEMBER 2019

Calendar of events

2 Mars is in conjunction with the Sun, 11h UT

4 Mercury is in superior conjunction, 2h UT

6 First Quarter Moon occurs at 3h10m UT

Asteroid Hertha is at opposition, 6h UT

The Moon passes 2° north of Jupiter, 7h UT

8 The Moon passes 0.04° south of Saturn, 14h UT

9 The Moon passes 0.08° north of Pluto, 3h UT

10 Neptune is at opposition, 7h UT

13 The Moon is at apogee (406,377 kilometers from Earth), 13h32m UT

The Moon passes 4° south of Neptune, 18h UT

14 Full Moon occurs at 4h33m UT

17 The Moon passes 4° south of Uranus, 20h UT

18 Saturn is stationary, 6h UT

22 Last Quarter Moon occurs at 2h41m UT

23 September equinox occurs at 7h50m UT

25 Asteroid Vesta is stationary, 5h UT

28 The Moon is at perigee (357,802 kilometers from Earth), 2h24m UT

Asteroid Lutetia is at opposition, 4h UT

New Moon occurs at 18h26m UT

Mercury passes 1.4° north of Spica, 23h UT

29 The Moon passes 6° north of Mercury, 22h UT

Astronomy magazine

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