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JULY/AUGUST 2019 $5

ASTEROID SURPRISES
PAGE 20

Golden Moon

While America commemorates the 50th anniversary of the first lunar landing, scientists are still learning from Apollo's bounty

THE UNIVERSITY OF TEXAS AT AUSTIN McDONALD OBSERVATORY

StarDate™

JULY/AUGUST • Vol. 47, No. 4

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Features

Departments

NASA

On The Cover

Astronaut Edwin 'Buzz' Aldrin poses for Neil Armstrong, who is reflected in Aldrin's visor, during the Apollo 11 Moon walk. July 20 marks the golden anniversary of the first lunar landing.

This Page

Hubble Space Telescope caught this view of the disintigrating asteroid 6478 Gault. The 4- to 7-kilometer-wide asteroid is trailed by two comet-like tails, each respresenting a separate event that spewed material into space. Gault's destruction is thought to result from heating by the Sun. This caused the asteroid to release gasses, and, in turn, spin faster — until it began to fly apart. This is known as the YORP process, after the initials of its four discoverers.

Coming Up

In our September/October issue, astronomer Barbara Ryden discusses the latest research into how magnetic fields influence star formation. And Nick D'Alto returns to celebrate the 200th anniversary of the birth of Léon Foucault, the French physicist whose pendulum proved to the 19th century masses that Earth rotates on an axis.

MERLIN

Dear Merlin,

Is Barnard's Star coming toward our solar system? If so, could we be in danger, and when?

Michael A. Peeples
Hazel Park, Michigan

Fret not. Although it is moving closer to the solar system, Barnard's Star represents absolutely no threat to Earth.

The star is named for Edward Emerson Barnard, an American astronomer who, in 1916, discovered that it is moving across the sky faster than any other known star — the equivalent of the width of the full Moon in about 175 years.

Later observations revealed that Barnard's Star is 5.96 light-years from Earth. Only the three stars of Alpha Centauri are closer. And Barnard's Star is moving closer to the solar system by more than 300,000 miles (500,000 km) every hour. It's not moving directly toward the solar system, though, so it will make its closest pass, at a distance of 3.75 light-years, around the year 11,800. By then, Proxima Centauri, the closest member of the Alpha Centauri system, will have moved even closer, so Barnard's Star won't become the Sun's nearest neighbor.

Even though it will be much closer in that far future, Barnard's Star still won't be visible to the unaided eye. It belongs to the faintest class of stars, known as red dwarfs. At visible wavelengths, it shines only about 0.04 percent as brightly as the Sun, so it will remain hidden in the darkness of space.

Incidentally, the odds of any star hitting the Sun are astronomically small. The average separation between stars in our part of the galaxy is tens of millions of times greater than the sizes of the stars themselves. That means that stars give each other a wide berth as they travel through the galaxy.

Dear Merlin,

Do any of the thousands of known exoplanets have rings?

Stephen Harty

There are a couple of pretty good suspects.

The first possible ring system, discovered in 2007, appears to encircle J1407b, a giant planet (or possibly a brown dwarf) orbiting a young Sun-like star. Over a period of a couple of months, astronomers saw the star's light flicker. The most likely explanation for the change is that a ring system around an orbiting planet was passing in front of the star, blocking some of its light. The rings would be more than 100 times wider than Saturn's rings. (Some recent research, though, suggests that the purported ring system doesn't exist.)

A second suspect is in a system known as PDS 110, in which astronomers saw similar changes in the star's light. The changes could be caused by a ring system almost 200 times wider than Saturn's.

These systems were seen only because of the great span of their possible ring systems. But the presence of rings around all four of the solar system's giant planets suggests that rings should be fairly common in other star systems, too.

Dear Merlin,

Do antimatter black holes exist? If so, what are their properties? How would astronomers determine whether a black hole is made of matter or antimatter?

Leonard C. Boucek
Monmouth Junction, New Jersey

It's entirely possible for a black hole to be made of antimatter. If any exist, though, it's unlikely that astronomers will ever know it.

Astronomers can measure only three characteristics of a black hole: its mass, its spin, and its electric charge.

The mass is how much material the black hole contains. A stellar-mass black hole forms when the core of a heavy star collapses, trapping the equivalent of several times the Sun's mass. The original star could be made of either matter or antimatter, which have opposite electric charges and a few other differences, but otherwise behave in the same way and follow the same laws of physics. So the mass is no help in determining the composition of the star from which the black hole formed.

The black hole's spin rate is determined by the spin of the original star and the motions of material falling into the black hole, so that doesn't reveal anything about a possible antimatter origin, either. And neither does electric charge, which can be either positive or negative. (If any black hole has an electric charge it's tiny; no charge has ever been measured.)

So there is absolutely no way to tell if a black hole formed from matter or antimatter.

And if a black hole that formed from matter collided with one formed from antimatter, they would simply merge to form a bigger black hole.

Merlin is unable to send personal replies. Answers to many astronomy questions are available through our web site:

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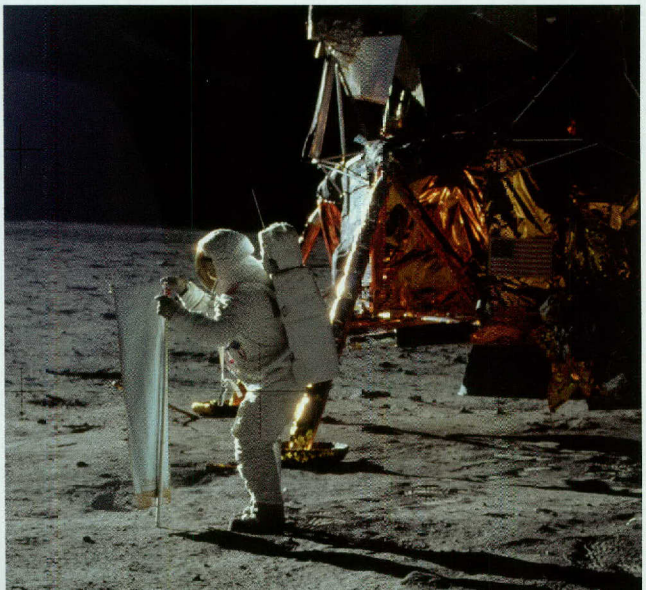
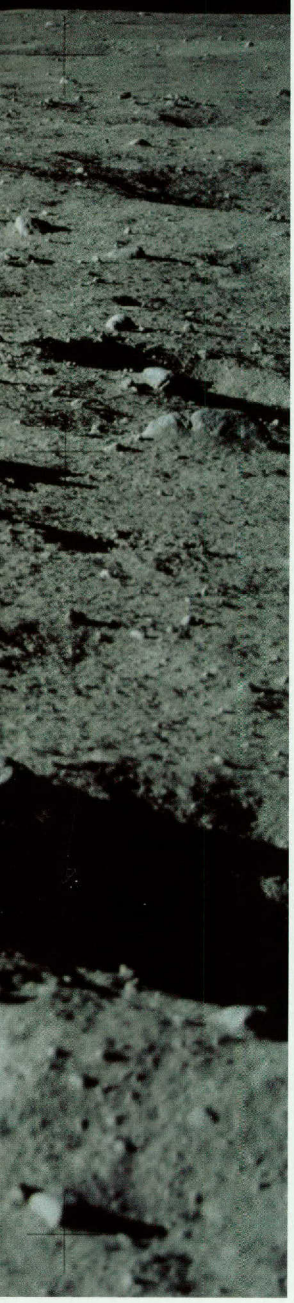
THE GIFT THAT KEEPS ON GIVING

NASA (6)

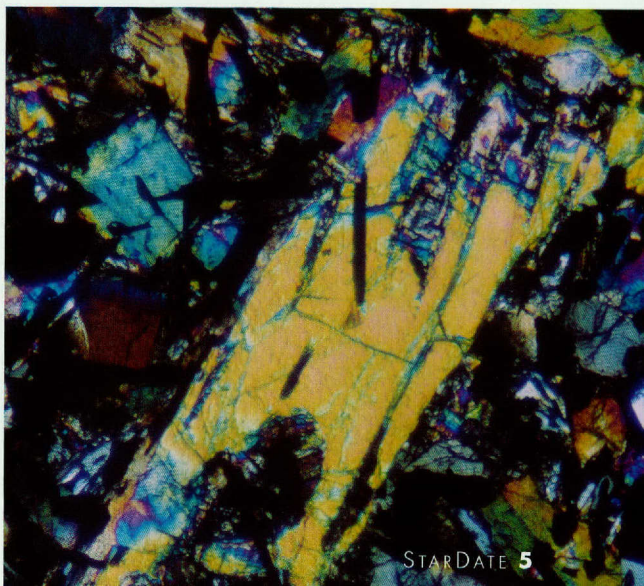




USING TECHNIQUES AND IDEAS THAT DIDN'T EXIST AT THE TIME OF THE APOLLO MISSIONS TO PROBE LUNAR SAMPLES, SCIENTISTS ARE MAKING NEW DISCOVERIES ABOUT THE MOON — AND THE REST OF THE SOLAR SYSTEM

BY DAMOND BENNINGFIELD

APOLLO 11 ON THE MOON *Left: The desolate landscape of the Apollo 11 landing site. Bottom, from left: The lunar module, Eagle, flies free on its way to a landing; Buzz Aldrin deploys a device to collect particles of the solar wind; a full Moon viewed on the way home; a box of Moon rocks collected by Aldrin and Neil Armstrong; a microscopic view of one of the Apollo 11 samples.*



WHEN SCIENTISTS FIRST PROBED THE LUNAR ROCKS AND DIRT BROUGHT HOME BY APOLLO ASTRONAUTS, THEY FOUND NO HINT OF WATER — THE BITS OF THE MOON WERE DRIER THAN THE MOST ARID DESERT ON EARTH. OVER THE PAST DECADE OR SO, THOUGH, USING TECHNOLOGY THAT IS MUCH IMPROVED OVER THAT AVAILABLE IN THE APOLLO DAYS, THEY HAVE TAKEN A NEW LOOK AT THE SAMPLES. THEIR EFFORTS HAVE REVEALED WATER (OR ITS CHEMICAL COUSIN, HYDROXYL) FROM SEVERAL LUNAR LOCATIONS. THE WATER WAS CONTAINED IN VOLCANIC GLASS BEADS THAT ERUPTED FROM FAR BELOW THE LUNAR SURFACE; IN A 4.5 BILLION-YEAR-OLD ROCK THAT FORMED PART OF THE MOON'S EARLY CRUST; AND IN PIECES OF THE DEEP CRUST, NEAR THE BOUNDARY WITH THE NEXT LAYER DOWN, THE MANTLE.

The discoveries support observations by lunar orbiters that water permeates the powdery lunar dirt, known as regolith, and that it may be found in abundance at the Moon's poles. Perhaps more important, though, they suggest the Moon was born with or quickly acquired substantial amounts of water and similar compounds, challenging ideas about the formation and early evolution of Earth's satellite world.

"We're making paradigm-shifting discoveries almost 50 years after the collection of some of these samples," says Clive Neal, a professor of engineering at the University of Notre Dame who has been working with Moon rocks for more than three decades. "They've changed our whole view of the Moon, going from dry to, well, no, it's actually quite moist. ... So [the samples] are the gift that keeps on giving."

These and other recent discoveries were possible because NASA and its original Apollo scientists decided to preserve most of the samples. While researchers were eager to plunge into the boxes of goodies brought back by Neil Armstrong and Edwin "Buzz" Aldrin, who landed on the Moon on July 20, 1969, as well as those collected by the five later lunar-landing missions, they understood that it was important to hold some in reserve for the future. Improved technology would allow new generations to analyze the samples in greater detail, while new ideas, based in large part on earlier discoveries, would present new questions for scientists to ponder.

"The samples continue to be a treasure," says David Kring, a senior research scientist at the Lunar and Planetary Institute in Houston, adjacent to NASA's Johnson Space Center (JSC). "Our analytical techniques get better, our ideas evolve, so we have the opportunity to look at the samples again and learn new things."

Astronauts gathered more than 2,200 samples of the Moon — a total of 842 pounds (382 kg) of rocks, pebbles, regolith, and other materials. "The scope of the material returned and how insightful the astronauts were in selecting the samples is just phenomenal," says Charles Shearer, a research professor at the University of New Mexico who also has studied the samples since the 1980s.

Most of the collection resides in the Lunar Sample Laboratory Facility, in JSC's Building 31N, a two-story, 14,000-square-foot complex that opened in 1979. (As a backup against Gulf hurricanes or other catastrophes, about 15 percent of the collection is stored at JSC's White Sands Test Facility in New Mexico). The complex includes a vault for storing the samples and laboratories where technicians process them for distribution to researchers.

Samples are stored in stainless-steel lock boxes filled with purified nitrogen inside clean-room environments. Workers don protective gear and doff jewelry and other adornments before they enter, and are blasted with air to sweep away lint, pollen, dead skin cells, and other contaminants. Air pressure in the work areas (and the nitrogen pressure in the cabinets) is slightly above that of the outside atmosphere, maintaining a flow away from the samples.

The samples are processed in boxes "that are kind of like germ-warfare glove boxes," says G. Jeffrey Taylor, a retired research professor at the University of Hawaii who first studied lunar samples in 1970. The boxes also are filled with nitrogen, and technicians touch the samples only with special tools made primarily

of Teflon or stainless steel, which don't contaminate their treasures.

The facility processes roughly 700 samples — most of them weighing no more than a gram or two — for about 60 research projects per year, says Ryan Zeigler, curator of the lunar collection and head of the Astromaterials Acquisition and Curation Office, which also stores and processes meteorites, cosmic dust, and other extraterrestrial materials. The lunar samples are packed in small air-tight containers for shipment to laboratories around the world. Researchers must submit plans for safeguarding the samples and return any unused bits to JSC for storage and possible reuse.

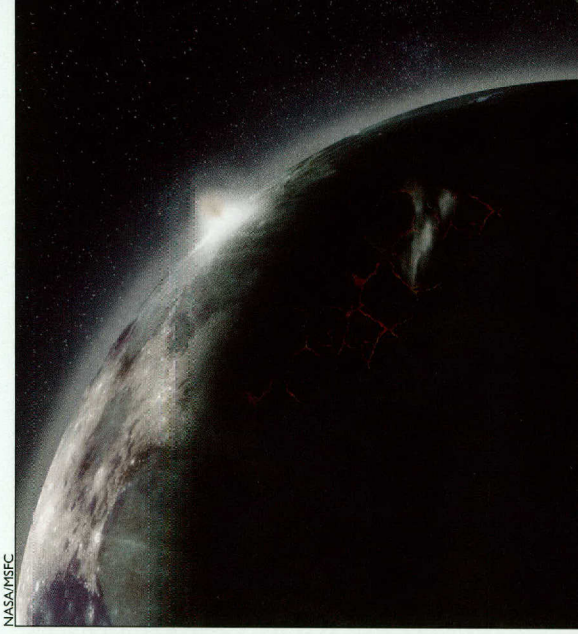
About five percent of the lunar samples (by mass) have been destroyed during approved testing, five percent have been studied and returned to JSC for storage and future analyses, and five percent have been doled out for public displays. The remaining samples have never left the Houston lab. (Bits of almost every rock and regolith sample have been analyzed, although the bulk of each remains intact and unstudied.)

"There's still a lot of good science to be done on the Apollo samples," says Zeigler (who adds that responsibility for the collection is "equal parts exciting and terrifying"). "This is the culmination of development of new, more sensitive instruments. We can look at smaller scales, and we're able to do more with less — we can do some studies with a fraction of a gram. And with new scientists and new ideas, we can open up whole new avenues of research."

Some of those new avenues may open later this year, when NASA releases the few samples that have remained untouched. These samples have been sealed in their original vacuum containers, stored in helium, or frozen to maintain their supplies of elements that are easily lost to Earth's atmosphere. Nine research teams will dig into those samples, which were collected by the final three missions, Apollo 15, 16, and 17, in 1971 and '72. "This is like having a new sample-return mission," says Taylor.

Six of the teams will study a core sample from Apollo 17, known as 73001. Astronaut Gene Cernan drove a hollow stainless-steel tube deep into the lunar surface during his second moonwalk, on December 12, 1972, filling it with layers of pebbles and regolith that represent millions of years of lunar history. Cernan sealed the sample, which is the deeper half of a two-part tube, inside a vacuum container, which was sealed inside a larger vacuum chamber after it was returned to Earth. Neither container has been opened since.

The core might shed new light on lunar volatiles — materials that vaporize at low temperatures, such as water, carbon dioxide, hydrogen, and many others. "Because these samples are uniquely preserved, they might still contain lightly-bound volatiles in minerals, which likely were destroyed in other samples in the collection," says Shearer, who leads one of the teams that will study 73001. "So we may get a whole new view of lunar volatiles from these samples."



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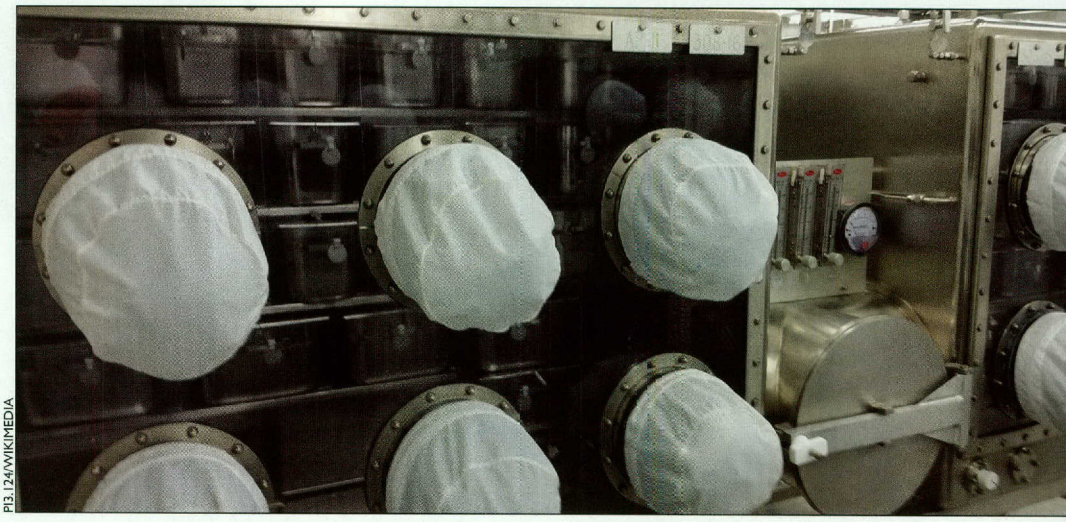


PI3.124/WIKIMEDIA

Apollo 11 samples are stored in this nitrogen-filled cabinet. Top: An artist's concept shows an atmosphere developing around the Moon as gas erupts from volcanic vents.

Volatiles are important because their story helps reveal the big-picture story of the birth of the Moon and the evolution of the solar system.

Early studies found far lower levels of most of these materials in the lunar rocks and dirt than on Earth. These studies, along with others that measured the composition of higher-temperature substances in the lunar samples, helped lead to the top theory of the Moon's formation. Known as the giant impact hypothesis, it suggests that a Mars-sized planet rammed into the embryonic Earth 4.5 billion years ago, blasting material into space. The debris formed a disk around Earth. Its gas and molten rock quickly coalesced to form the Moon (or, based on studies a few years ago, two or more moons, with only the present-day satellite surviving.)

The original version of the hypothesis conjectured that the debris from the impact was so hot that any volatiles it contained boiled away, leaving the Moon with little of them. Studies over the last decade or so, though, have revealed that the Moon contains larger amounts not only of water than suggested by the earlier analyses, but of zinc, sulfur, chlorine, and other volatiles as well, suggesting that the giant impact hypothesis might need some tweaking.

The first detection of water in the lunar samples, in 2008, used a technique called secondary ion mass spectrometry to sort particles in millimeter-size volcanic glass beads by their size and electric charge. The beads included some found in perhaps the most

famous Apollo sample, a patch of orange regolith discovered by Cernan and Apollo 17 crewmate Jack Schmidt.

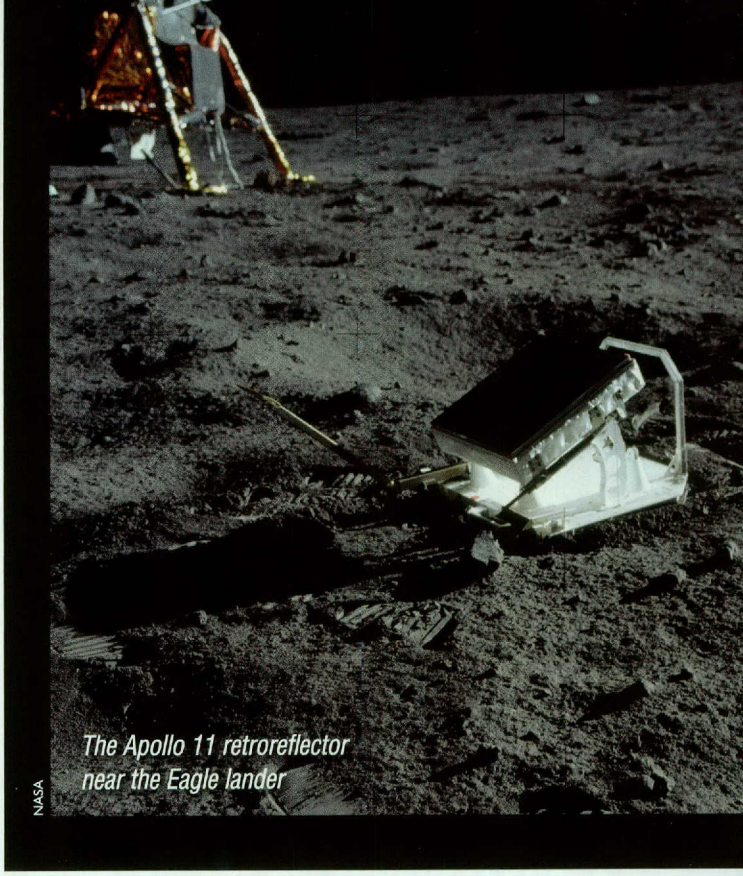
The spectrometry technique had been used since soon after the Apollo days, but early equipment provided only crude measurements, so they revealed no water. More modern technology allowed scientists to detect water and other volatiles at much lower concentrations. The water found in the glass beads, for example, was measured at just 46 parts per million. From that, the study concluded that water accounted for 260 to 745 parts per million of the Moon's early mantle. The higher level is comparable to the concentration found in the mantle of present-day Earth.

Using a similar technique, a 2018 study compared different forms of several volatiles in the lunar samples to those on Earth. The researchers found similar ratios of several volatiles in the two worlds, suggesting a common origin — either Earth and Moon were born with the same supply of them or they acquired them later from the same source.

A study released earlier this year by Kevin Righter, a planetary research scientist at the JSC astromaterials facility, suggested that option A was the best fit: the Moon formed from material from Earth itself.

Righter created multiple models of the Moon's composition. He then compared the abundances of 14 volatile elements in his models to the amounts measured in about 35 published studies of the Apollo samples. The results didn't match early concepts of the giant impact hypothesis.

"For a couple of decades, lunar scientists have favored the idea that the Moon was made of material from the impactor" — the body that hit Earth, Righter says. "As we started exploring different aspects of the giant impact, though, we realized that there are ways you can make a Moon from material of the [young] Earth, or a mixture of both." In fact, Righter's work showed that the model in which the Moon was made from material from Earth itself best fit the measurements of the Moon's chemistry.


NASA

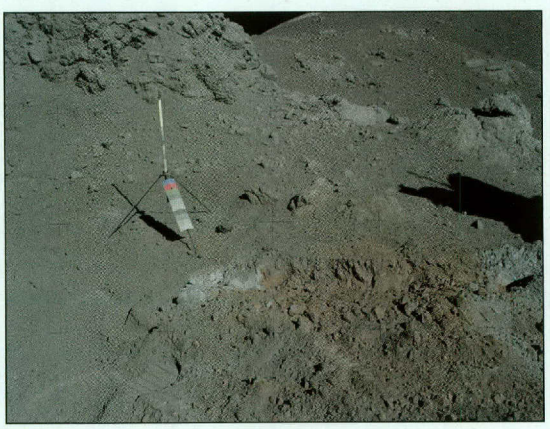
The Apollo 11 retroreflector near the Eagle lander

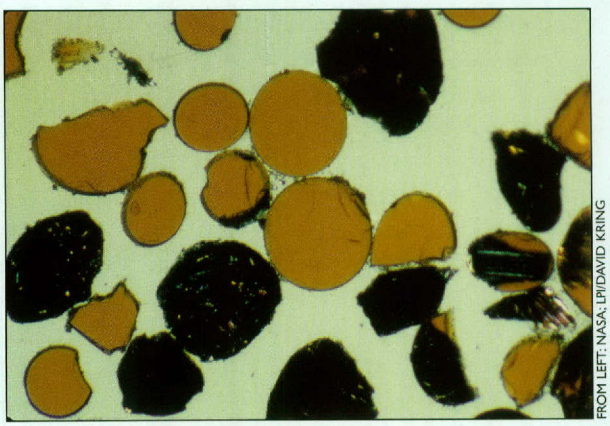
Based on the results of this and other studies, Righter says, planetary scientists have proposed several possible modifications to the impact hypothesis.

One possibility is that, instead of a smaller impactor hitting Earth at a glancing angle, Earth and the impactor were about the same size and collided head-on. Another is that both bodies were spinning rapidly when they hit; the spin and the angle of attack favor the Moon forming from terrestrial materials. Another says that Earth was largely molten at the time of the impact, making it easier to splash material from its outer layers into space. And yet another emerging idea is that the Moon resulted not from a single giant impact, but from 20 or so smaller ones. "There's a new debate about this, and it's getting pretty lively," Righter says.

While the Moon may have inherited many of its volatile compounds from Earth, perhaps including some of its water, most of the Moon's early water supply probably was deposited after the giant impact, while the young Moon was still molten. A 2016 study, in fact, concluded that most of the lunar water came from asteroids, which are mountain-sized rocky leftovers from the formation of the planets, during the first 200 million years of the Moon's history.

"Once our colleagues began detecting water in the Apollo collection, we began searching for the water's source," says Kring, one of the study's leaders. In particular, his team compared the different forms of hydrogen and nitrogen found in many lunar samples to those found in asteroids and comets, both of which can contain large amounts of water ice. "When you combine the hydrogen and nitrogen analyses, you can separate the origin of the water from asteroids and




FROM LEFT: NASA; LPI/DAVID KRING

From left: The orange glass beads (discolored patch, bottom center)at the Apollo 17 landing site, which were found to contain water molecules; microscopic view of the beads

LOOKING INTO THE LIGHT

Apollo 11 was about half way to the Moon when Mission Control asked astronauts Neil Armstrong, Edwin Aldrin, and Michael Collins to look back toward Earth. "We got a laser, it's a blue-green laser that we're going to flash on and off," said capcom Charles Duke. "It's coming out of McDonald Observatory... . Would you please take a look through the telescope and see if you can see it?"

The astronauts didn't see it, but a special device Armstrong and Aldrin left on the Moon two days later did. The observatory's laser first found the lunar laser-ranging retroreflector a few weeks after the astronauts departed the Moon. The observatory continued to ping the reflector, along with four others left by other missions, for more than four decades.

Each retroreflector bounces pulses of laser light back to their sources on Earth. Scientists time the round-trip travel time of each pulse, allowing them to measure the Earth-Moon distance to within a millimeter. A half-century of these observations has provided precise measurements of the shape of the Moon's orbit, wobbles in the Moon's rotation, and other parameters. Those, in turn, have helped scientists determine how fast the Moon is moving away from Earth (1.5 inches per year), probe the Moon's interior structure, and test Albert Einstein's theory of gravity to some of the highest levels of precision yet obtained.

McDonald's role in the laser ranging program "was Harlan Smith's baby," says Peter Shelus, a University of Texas at Austin research scientist who worked on the project beginning in the early 1970s. "Supposedly, Maui was going to be the observatory to observe the Apollo 11 reflector. But Harlan [McDonald Observatory's director] always had his ear to the ground, and he surmised that Maui wouldn't make the deadline. NASA was already paying to build the new 107-inch telescope, so Harlan said, 'Hey, we can get it ready by the time Apollo lands on the Moon.' Harlan had a lot of clout and an excellent reputation, so they said 'okay.'"

Working with researchers from the University of Maryland, the observatory made the deadline. It used the 107-inch telescope (now named for Smith) for the project until the 1980s, when it was switched to a smaller telescope dedicated exclusively to laser observations.

McDonald ended its lunar-ranging program a few years ago, although other observatories continue the project — the only Apollo surface experiment that continues to provide data. **DB**

comets. And it turns out the composition of the lunar water is similar to the water in asteroids." Since Earth was bombarded by the same types of objects as the Moon, that suggests that most of the water on our own planet came from asteroids as well.

The finding also may help scientists better understand the formation and evolution of the solar system's other planets, Kring says. "If we're getting our water from asteroids, that implies a different feeding mechanism to the Earth-Moon system than would delivery [of water] by comets. And the delivery mechanisms are linked to the formation and orbital evolution of the planets. So this is telling us something about how and when Jupiter and Saturn and Uranus and Neptune accreted [came together from smaller pieces] and how their orbits evolved," he says. "In the end, the data from lunar samples are going to tell us a lot about the evolution of the outer solar system."

Water from the asteroids and comets was embedded in the Moon's mantle, beneath a "lid" of minerals that rapidly cooled and crystallized, preventing the water from escaping — for a while. Another study, by Kring and colleague Debra Needham of NASA's Marshall Space Flight Center, found that massive outpourings of volcanic rock beginning about four billion years ago (perhaps as the result of a new barrage of asteroids, which punched holes in the crust) brought huge amounts of water and other volatiles to the surface. By about 3.5 billion years ago, in fact, so much water vapor and other gases had erupted that they formed an atmosphere about one percent as dense as that of present-day Earth. The atmosphere could have persisted for up to 70 million years.

Circulation models show that some of the water and other volatiles could have been carried to the Moon's poles, where they were deposited in craters that remain in permanent shadow. The water would have frozen there, perhaps creating the large deposits of ice detected by orbiting spacecraft. "The amount of gases vented by these volcanoes is far more than we think exists as ice at the poles," Kring says. "So it's possible that most, if not all, of these ices came from the atmosphere. We won't know until we actually go there and check it out."

Returning to the Moon to check out possible ice deposits and other features is a high priority for many lunar scientists. The Apollo samples were collected from just six locations on the Moon, and provided insights into a limited set of lunar formations. Among other missing pieces, no samples have been gathered from the Moon's largest impact structure, known as the South Pole-Aitken Basin, or from the lunar farside, which has far fewer dark volcanic plains than the nearside.

"We absolutely need to collect samples from other areas to answer key questions about the origin and evolution of the Moon," says Needham, who was lead author on the study about the lunar atmosphere. "The Apollo samples, though invaluable in their own right, were collected as 'float' rocks loose in the lunar regolith, without important geologic context for where they originated. As our understanding of the Moon has evolved — mostly as a result of analyses of these loose rocks — our need for samples from more selective areas has grown."

NASA has announced plans to return astronauts to the Moon as early as 2024, and is developing its own robotic missions as well as instruments for commercial landers. That could put new samples in the JSC vault — and in the hands of researchers — within half a decade.

New samples could tamp down interest in the Apollo collection, says Zeigler, the curator — but not for long. "People would go and study the new rocks. That would raise more questions, so they would come back to the Apollo samples to check and cross check," he says. "So I think they're going to be a valuable collection forever, essentially. I'm not worried about going out of business any time soon."

Damond Benningfield is executive editor of StarDate *and writer/producer of the StarDate radio program.*

SKY CALENDAR

by Alan MacRobert

As we head deeper into summer, solar system giants Jupiter and Saturn put on impressive appearances in the nighttime sky. Saturn is at opposition now, after it was Jupiter's turn in June. In August, the summer constellations Scorpius — which looks like a giant letter "J" — and Sagittarius — which looks like a teapot — hang over the southern horizon at dusk.

JULY 1 - 15

Maybe you remember last summer's dramatic row of four bright planets arching across the southern evening sky. This summer the row is down to two: Jupiter and Saturn.

Jupiter is the first "star" you're likely to see coming out as twilight fades; it's the brightest point in the evening sky this season. Watch for it to appear moderately high in the south-southeast after sundown.

Don't see it? Keep looking. Whenever you try to find a star or planet in a still-bright sky, you'll probably see nothing but blue — and then all of a sudden it will pop out and you'll wonder how you missed it. Why? Because your center of vision has to land precisely on the correct point, and that usually takes a lot of looking around before you hit it. Your very center of vision is the only part of your retina with high resolution. In the low-resolution areas a little away from there, the speck appears larger, so its little bit of light widens and merges into the blue-sky background.

Normally we're quite unaware, as we look around, that every moment we're seeing only a very small sharp area in a wider scene of fuzz and blur. That's because our brains have evolved to process our visual input (and the input from our other senses) to form a coherent, consistent model of the 3-D world we need to get around in. This normally happens below the level of consciousness. But how fragmentary and incomplete our sensorium proves to be, when studies reveal what's below all the filtering and model-making. What poor, messy raw data our limited senses collect!

Remember this while watching for Jupiter. Studying astronomy leads in all sorts of unexpected directions. (And so, for that matter, does studying anything else.)

Once you've got Jupiter, use it as the starting point to watch for another speck to emerge nearby: Antares, summer's orange-red supergiant star. Antares is to Jupiter's right and a little below, by less than the width of your fist at arm's length (8 degrees to be exact).

Again, be patient. Antares is magnitude +1.0 compared to Jupiter's -2.5, which means it's only 1/25 as bright.

Once you find Antares, you shouldn't have too much trouble with Saturn. Look for it low in the southeast about three fists to the lower left of Jupiter. Saturn outshines Antares, though there will be some haze and atmospheric dimming at Saturn's lower altitude.

After dark, Saturn is higher, Jupiter is at its highest due south, and Antares has become one of the many stars of Scorpius scattered around it and to its upper right — an orange topaz among specks of diamond.

Look for a bright star high to Saturn's upper left. This is Altair. It's the lower-right corner of the Summer Triangle. The triangle's other two corners are brighter Vega, nearing the zenith from the east, and Deneb, to the lower left of Vega.

Meanwhile, Arcturus shines Vega-bright high in the west, tinted like a ginger-ale drop shining in the Sun.

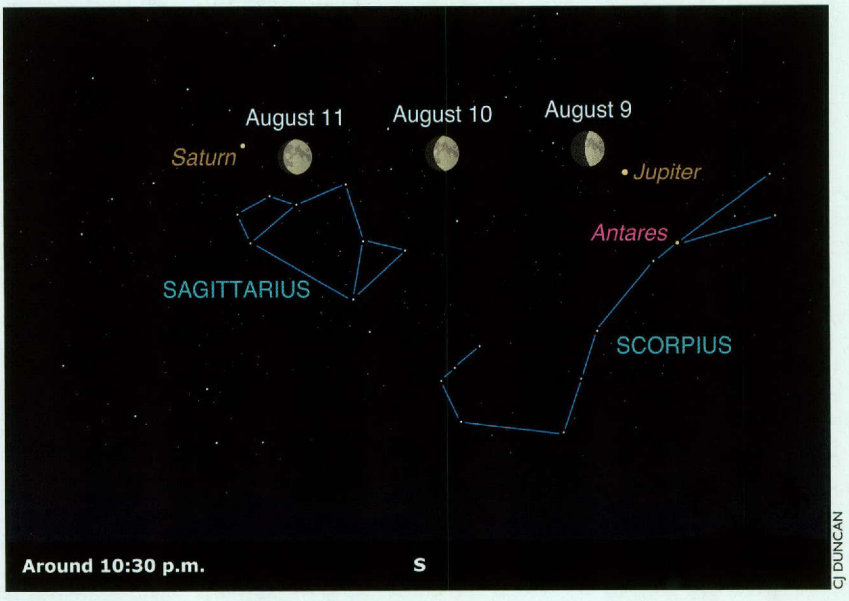
And with summer well under way, the Big Dipper, high in the northwest (upper right of Arcturus), has turned around to hang down by its handle. As night grows later, and as summer advances, watch for the Dipper to dip lower and start to scoop its bowl to the right.

JULY 16 - 31

Two weeks on, you'll find that Jupiter and Saturn are noticeably westward (to the right) of where they appeared at the same time of night two weeks earlier. Remember the formula for the turning of the sky: Looking *two weeks* later is the same as looking *one hour* later.

The host constellations of Jupiter and Saturn offer interesting comparisons. Look to the right and lower right of Jupiter for Antares and other stars forming the neck and head of Scorpius. The rest of the scorpion curves down from Antares and then left, ending with an uptick for the tail. The tail contains a pair of modestly bright stars called the Cat's Eyes. They're separated by 0.6 degree, hardly a pinky-tip at arm's length. The otherwise invisible cat is literally cockeyed; he's tilting his head, and his right eye is dimmer than his left.

Look to the lower right of Saturn for the teapot of Sagittarius, less showy than Scorpius but obviously a teapot. It's about fist-size at arm's length,



with its handle on the left and its triangular spout on the right. The teapot is starting to tilt and pour. As the night and the summer proceed, it will tilt farther to pour itself out.

Very high in the east, the big Summer Triangle is topped by Vega almost overhead now. Deneb is about 2½ fists to Vega's lower left when you face east, and Altair is 3½ fists to Vega's lower right. Vega, Deneb, and Altair are the leading stars of Lyra, the harp; Cygnus, the swan; and Aquila, the eagle, respectively. In ancient times Lyra was a vulture before it was a musical instrument, so all three constellations represented starry birds circling high in the summer night.

AUGUST 1 - 15

For stargazers like me who have gloomy memories of returning to school after summer vacation, the celestial portents of fall look foreboding as early as the beginning of August. The Great Square of Pegasus, fall's signature asterism, is already up in view in the east. It's balancing on one corner, a bit larger than your fist at arm's length. From the Great Square's left corner, the main star-line of Andromeda extends to the lower left. In the northeast, chilly Cassiopeia has risen almost as high as the summery Big Dipper has sunk in the northwest. Below Cassiopeia, Perseus is poking up into view.

No longer do you have to crane your neck for Arcturus in the west. And if you wait up till about 11 p.m. (depending on where you live), Fomalhaut, the so-called "autumn star," rises to twinkle portentously above the southeast horizon.

Jupiter and Saturn, meanwhile, remain on station with respect to the scorpion and teapot. They're the most distant bright planets from the Sun and Earth, so they appear to shift only slowly against their starry backdrops. Being far from the Sun, they move slowly along their orbits. Being far from Earth, our planet's own movement around the Sun gives Jupiter and Saturn relatively small "reflex motions" as our viewing platform moves. So there they stay, more or less.

A year from now, though, they'll both be in Sagittarius, closer together.

AUGUST 16 - 31

August is Sagittarius month the way July is Scorpius month. Both abutting constellations are rich in deep-sky targets for binoculars and telescopes: star clusters large and small, open and globular, and one of the finest star-forming nebulae in the sky. That's because here we look toward the center of our Milky Way galaxy with its concentrated riches.

The sky-spanning band of the Milky Way itself is, of course, the greatest deep-sky object of all, and its brightest section runs up from between Scorpius and Sagittarius. If the August vacation season lands you under a dark rural sky, plan to make Milky Way study a prime part of your getaway! With binoculars and a simple, basic sky map showing stars to 5th or 6th magnitude, you can find the eerie Lagoon Nebula above the tip of the teapot's spout, the little globular-cluster fuzzblob of M22 between the Lagoon and Saturn, and the spangly open clusters M6 and especially M7 between the spout-tip and the tail of Scorpius.

A deeper star atlas with stars to magnitude 7.5 or fainter will enable you to hunt for many less-prominent sights, for which you need to know more precisely the exact spot to examine.

Even in the light-polluted suburbs you may have at least a dim, low-resolution view of the Milky Way. Its brightest patch is the Large Sagittarius Star Cloud, above the teapot's spout. More patches run upward from there, culminating in the Cygnus Star Cloud along the shaft of the Northern Cross on high. From there down to the northeast the Milky Way is narrower and dimmer — because now you're looking not toward the galaxy's rich center, but away toward its outer rim.

Alan MacRobert is a senior editor of Sky & Telescope.

A Perseid meteor streaks over Orion on August 13, 2013.

KIM MYOUNGSUNG

Meteor Watch

The Shower

Perseids

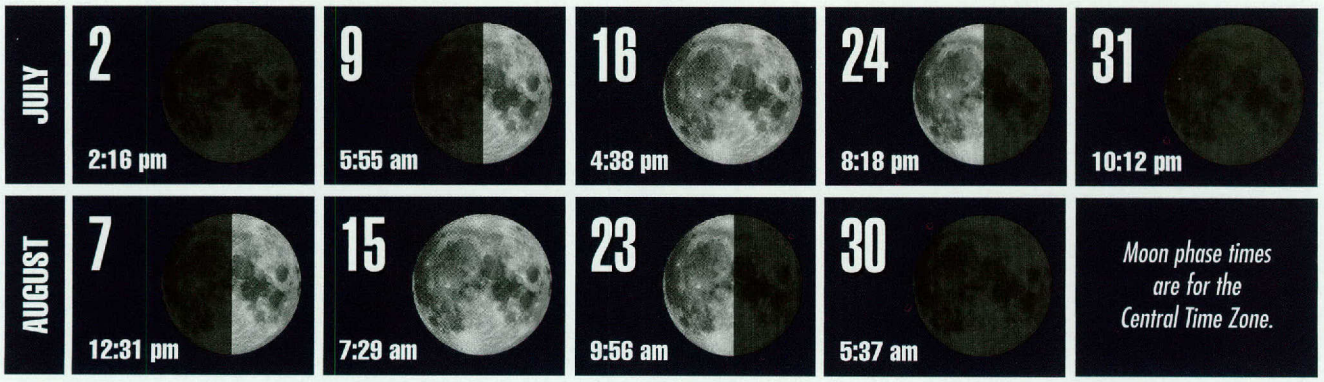
Named for the constellation Perseus, the hero, which climbs into view in the early morning hours.

Peak

Night of August 12

Notes

The Moon will be almost full, so its glow will overpower most of the meteors.

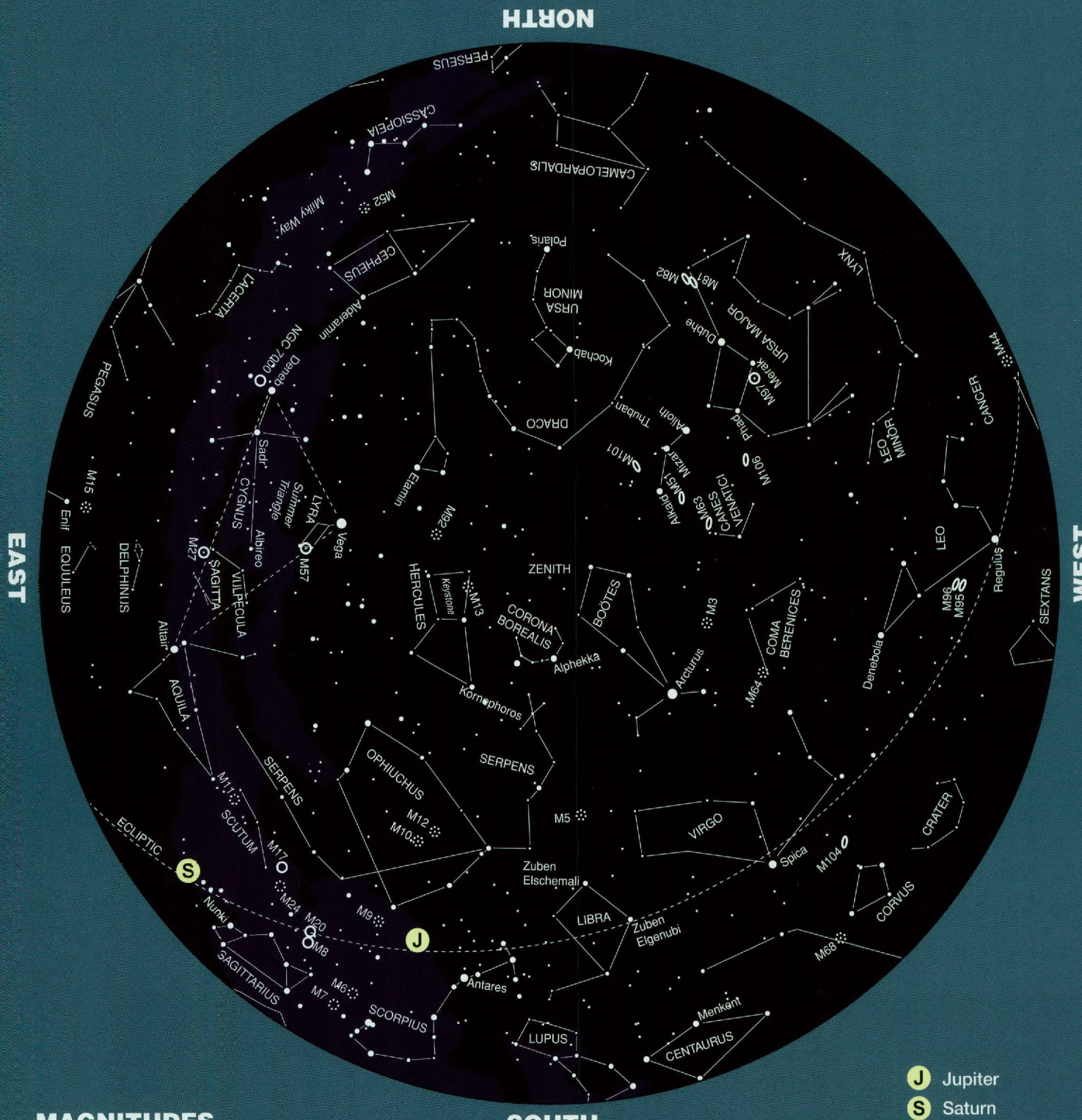


JULY

How to use these charts:

1. Determine the direction you are facing.
2. Turn the chart until that direction is at the bottom.

June 20	**11 p.m.**
July 5	**10 p.m.**
July 20	**9 p.m.**



MAGNITUDES

- 0 and brighter
- 1
- 2
- 3
- 4 and fainter

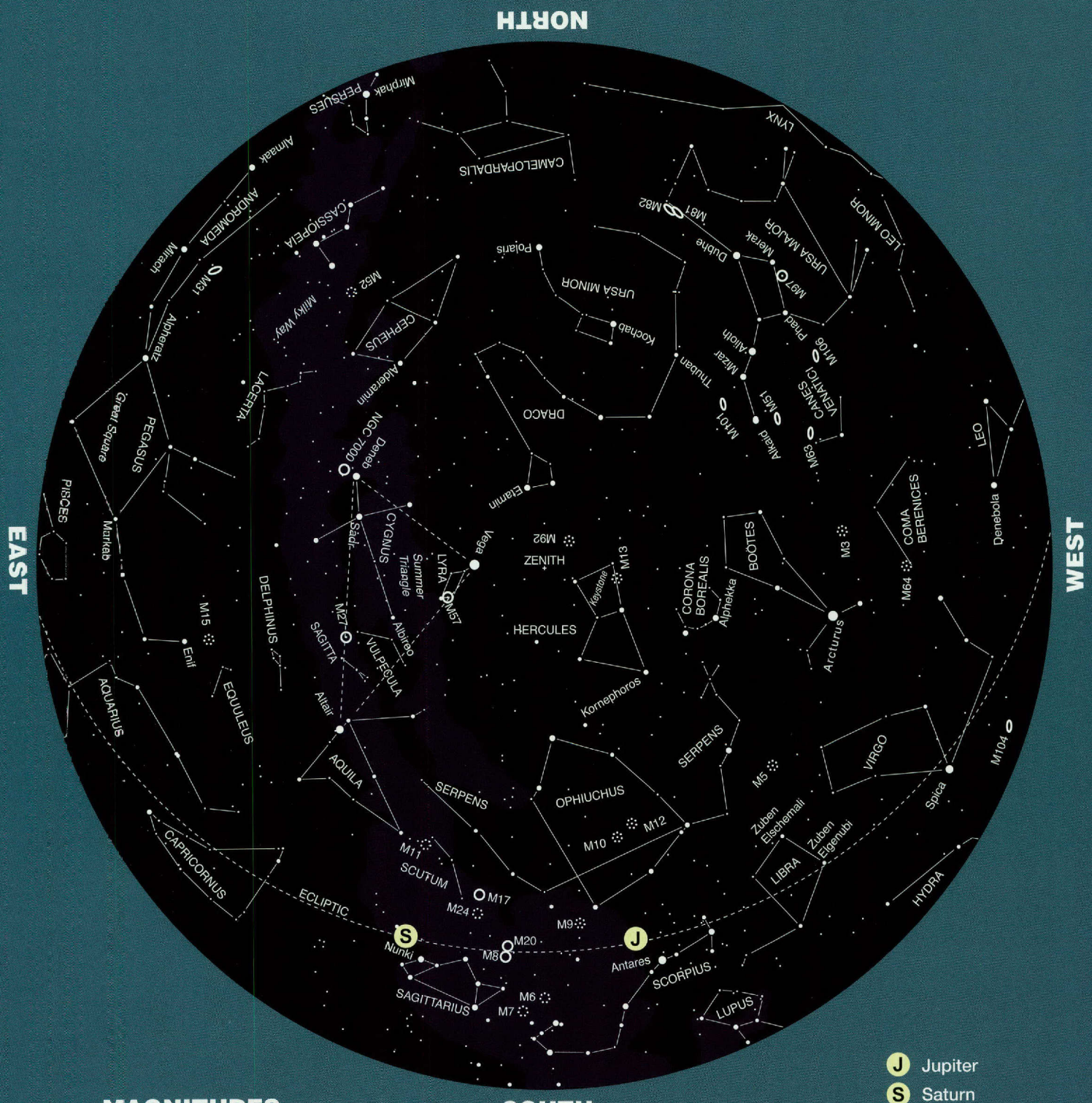
- J Jupiter
- S Saturn
- open cluster
- globular cluster
- nebula
- planetary nebula
- galaxy

AUGUST

How to use these charts:

1. Determine the direction you are facing.
2. Turn the chart until that direction is at the bottom.

July 20	**11 p.m.**
August 5	**10 p.m.**
August 20	**9 p.m.**



MAGNITUDES

- 0 and brighter
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- J Jupiter
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- planetary nebula
- galaxy

Send Your Name to Mars

You might not be able to get to Mars yet, but you can send your name. NASA is taking names to be etched onto a silicon chip that will be mounted on its Mars 2020 rover, which could launch as early as July 2020 and touch down in February 2021.

NASA/JPL-CALTECH

Using an electron beam, engineers at the Jet Propulsion Laboratory will etch up to a million names on a microchip about the size of a dime, which will be mounted on the rover under a glass cover.

The rover, which weighs about 2,300 pounds (1,000 kg), will search for signs of past microbial life, study Mars' climate and geology, and collect samples for future return to Earth. It is part of a series of projects helping to pave the way for future human exploration of the planet.

Participants sign up online, and will receive email updates on their "frequent flier miles" from NASA once the rover is en route to Mars.

go.nasa.gov/Mars2020Pass

Take a Journey Through an Exploded Star

A new online tool allows you to explore the remnant of a supernova in three dimensions. Called "Journey Through an Exploded Star," it uses real data from the Chandra X-Ray Observatory, Spitzer Space Telescope, and two large ground-based telescopes. The tool was created by the Smithsonian Center for Learning and Digital Access.

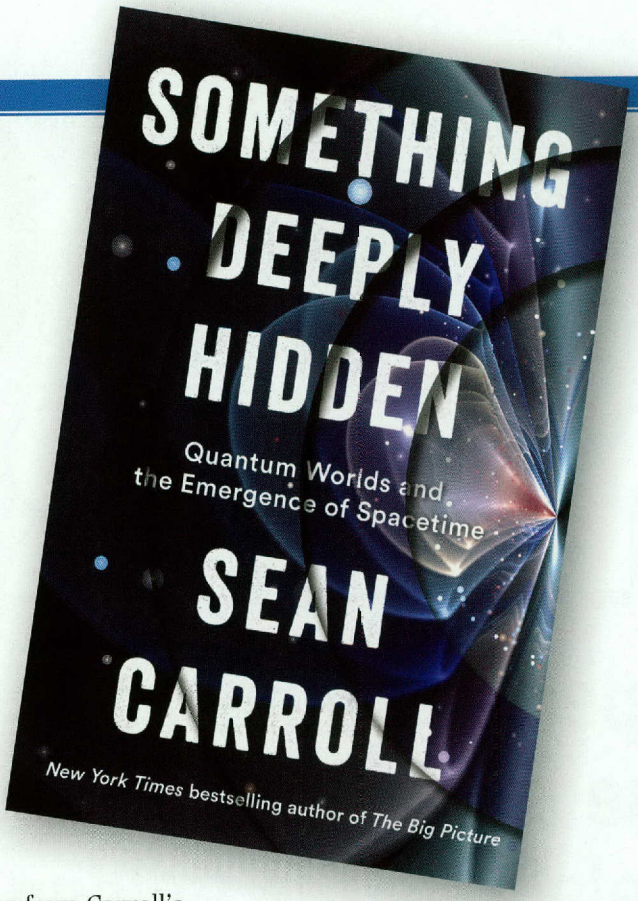
The website includes multiple ways to explore. These include an interactive simulation, where users can navigate the supernova and manipulate data to make their own visualizations; a video tour narrated by Kimberly Arcand (visualization leader for Chandra); and high-school level instructional materials on supernova science.

s.si.edu/supernova

Supernova visualization from 'Journey Through an Exploded Star'

SMITHSONIAN CENTER FOR LEARNING AND DIGITAL ACCESS

Taking a Quantum Dive with Sean Carroll

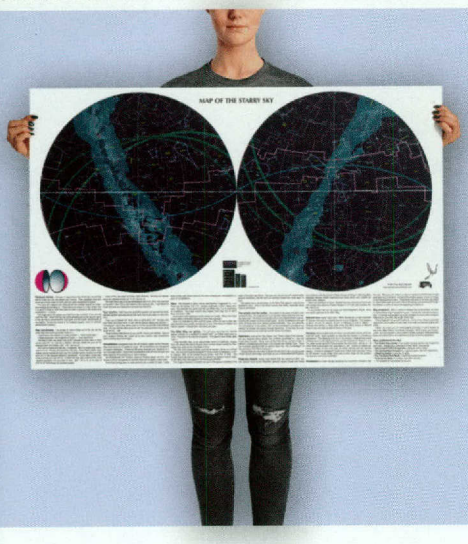


Something Deeply Hidden is Caltech physicist and prolific author Sean Carroll's pop science thesis on a new quantum world order. In an age when our understanding of physics on the smallest scale — the atomic universe — always seems to be in flux, Carroll's main idea is that to find a "theory of everything," we must put aside our aversions and embrace the possibility of a "many worlds theory."

Methodically and through palatable language, Carroll lays out his support of the "many worlds theory," which posits that every time you make a decision, any time any event occurs, a new reality splits off from the one you currently inhabit. In that reality, you never began reading this, or never scratched your head, or never took a deep breath — an infinite number of realities are created every second, all the time.

Though Carroll's work is widely extolled as good for a lay audience, in this book he does not start from ground zero. In order to glean an understanding from Carroll's smart analogies and smooth prose, a basic knowledge of quantum physics is helpful. Carroll does not begin with step-by-step explanations or even with the history of quantum thought, but rather systematically builds his case for this particular theory. But as you progress through the book, you will get a generalized sense of the theories and discoveries that led us to our present-day reality: a post-Newtonian, post-Einsteinian world based in Carroll's not-so-mysterious quantum physics.

Something Deeply Hidden
Quantum Worlds and the Emergence of Spacetime
By Sean Carroll
Available in September
Hardcover; $29



Universe at a Glance

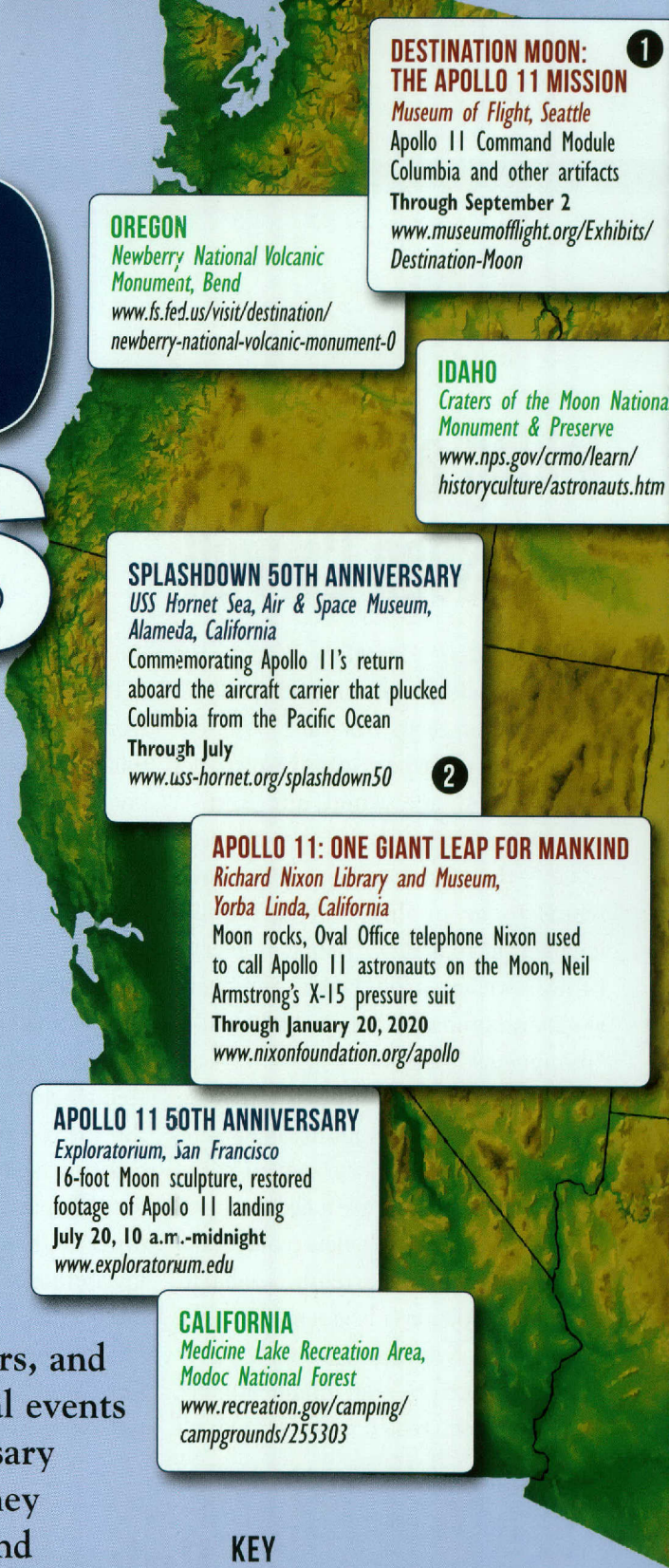
A new poster from Guy Ottewell's Universal Workshop shows a detailed view of the entire sky, in two hemispheres. Called the "Map of the Starry Sky," the poster measures 24x36 inches and is printed on thick, glossy paper. It shows 1,300 stars (labeled and color-coded by type), as well as more than 100 star clusters, nebulae, and galaxies.

Additional details include constellation outlines and official boundaries, important sky markers like the ecliptic, the galactic poles, the center of the Milky Way galaxy, and more. Our galaxy's outline is detailed in six brightness levels. The poster retails for $31.95.

www.universalworkshop.com/map-of-the-starry-sky

T+50 YEARS

Special events across the country will celebrate the Golden Anniversary of the Apollo 11 landing in the Sea Of Tranquility



DESTINATION MOON: THE APOLLO 11 MISSION 1
Museum of Flight, Seattle
Apollo 11 Command Module Columbia and other artifacts
Through September 2
www.museumofflight.org/Exhibits/Destination-Moon

OREGON
Newberry National Volcanic Monument, Bend
www.fs.fed.us/visit/destination/newberry-national-volcanic-monument-0

IDAHO
Craters of the Moon National Monument & Preserve
www.nps.gov/crmo/learn/historyculture/astronauts.htm

SPLASHDOWN 50TH ANNIVERSARY
USS Hornet Sea, Air & Space Museum, Alameda, California
Commemorating Apollo 11's return aboard the aircraft carrier that plucked Columbia from the Pacific Ocean
Through July
www.uss-hornet.org/splashdown50 2

APOLLO 11: ONE GIANT LEAP FOR MANKIND
Richard Nixon Library and Museum, Yorba Linda, California
Moon rocks, Oval Office telephone Nixon used to call Apollo 11 astronauts on the Moon, Neil Armstrong's X-15 pressure suit
Through January 20, 2020
www.nixonfoundation.org/apollo

APOLLO 11 50TH ANNIVERSARY
Exploratorium, San Francisco
16-foot Moon sculpture, restored footage of Apollo 11 landing
July 20, 10 a.m.-midnight
www.exploratorium.edu

CALIFORNIA
Medicine Lake Recreation Area, Modoc National Forest
www.recreation.gov/camping/campgrounds/255303

Museums, art galleries, NASA centers, and many other venues will host special events to commemorate the 50th anniversary of the Apollo 11 lunar landing. They will feature images and artifacts from Apollo and other missions, talks by astronauts and space experts, Moon rocks, movies, music and games, and many other goodies. Here's a brief guide to some of them, including a few that will span entire towns. Most of these are free or low cost, and most are family friendly. We've also listed some places where the astronauts trained for their moonwalks, allowing you to follow in the footsteps of Earth's first moonwalkers.

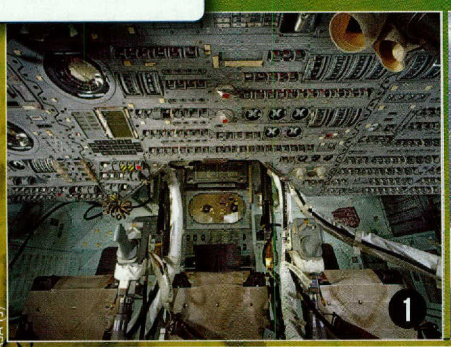
KEY

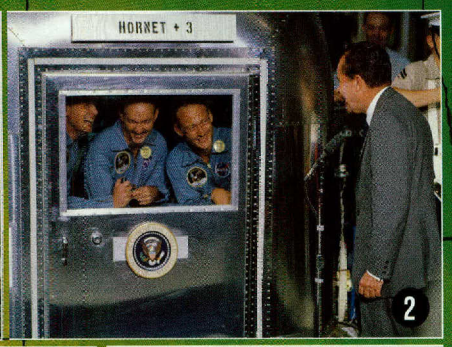
EVENTS
Special events to commemorate the anniversary

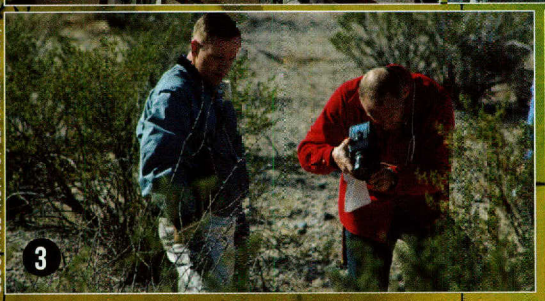
ARTIFACTS/EXHIBITS
Apollo hardware or special exhibits that will last beyond the anniversary

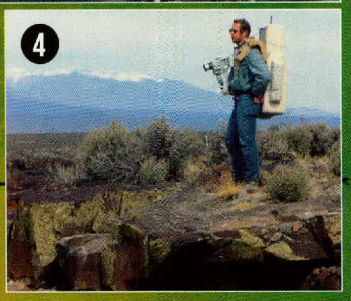
IN THEIR FOOTSTEPS
Places where the astronauts trained for their lunar expeditions

ALASKA
Katmai National Park & Preserve
www.nps.gov/katm/index.htm









CLOCKWISE FROM TOP LEFT: NASA/NASM; NASA (3)

1. Interior of Columbia; 2. President Richard Nixon greets Neil Armstrong, Michael Collins, and Buzz Aldrin, who were in a biological containment facility, aboard the USS Hornet; 3. Armstrong (left) and Aldrin examine rocks near Sierra Blanca, Texas; 4. Astronaut Dave Scott ponders the geology of Rio Grande Gorge.

APOLLO PALOOZA
Wings Over the Rockies Museum, Denver
Activities, seminars, exhibits, and more
July 13-20
wingsmuseum.org/events/apollo

ARIZONA
Meteor Crater, Flagstaff
meteorcrater.com
Grand Canyon National Park
www.nps.gov/grca/index.htm

NEW MEXICO
Valles Caldera National Preserve, Jemez Springs
www.nps.gov/vall/planyourvisit/index.htm
Rio Grande Gorge, Taos

FLAGSTAFF LUNAR LEGACY
Various venues, Flagstaff, Arizona
Includes programs at facilities that played key roles in the Apollo program
July
www.flagstaffarizona.org/go/lunarlegacy

ANNIVERSARY CELEBRATION
Arizona Science Center, Phoenix
July 20
www.azscience.org

SUMMER SCIENCE SATURDAY
Lunar and Planetary Laboratory, University of Arizona, Tucson
Celebration of the 50th anniversary
July 20, 10 a.m.-4 p.m.
www.lpl.arizona.edu

McDONALD OBSERVATORY HISTORY
McDonald Observatory, Fort Davis, Texas
New exhibit on the history of the observatory, including its role with the Apollo lunar laser ranging experiment
Through summer 2020
mcdonaldobservatory.org

TEXAS
Big Bend National Park
www.nps.gov/bibe/index.htm
Sierra Blanca

SOME OTHER APOLLO STUFF

TELEVISION

PBS will air several Apollo-themed programs during July:

American Experience, Chasing the Moon, **July 8-10, 8-10 p.m. CDT.**

8 Days: the Journey of Apollo, joint documentary with the BBC featuring new mission audio, **July 17, 8 p.m.**

Nova, Back to the Moon, **July 10, 7 p.m.;** *The Planets,* **July 24, 8 p.m.**

www.pbs.org/about/blogs/news/pbs-announces-summer-of-space-lineup

FILM

Apollo 11: First Steps Edition, directed by Todd Douglas Miller. A chronicle of the mission featuring newly released 70-millimeter footage, told with audio recordings of the astronauts and flight controllers. Showing at science centers and museums around the country.

apollo11firststeps.com

BOOKS

Shoot for the Moon: The Space Race and the Extraordinary Voyage of Apollo 11, by James Donovan. Tales from the early days of the American space program.

American Moonshot: John F. Kennedy and the Great Space Race, by Douglas Brinkley. A look at the politics behind the space program and the decision to send astronauts to the Moon.

The Book of the Moon: A Guide to Our Closest Neighbor, by Maggie Aderin-Pocock. Lunar science and exploration, combined with the literature and folklore of the Moon.

Moon Rush: The New Space Race, by Leonard David. A look at plans for future lunar exploration by the United States and other countries.

Chasing the Moon: The People, the Politics, and the Promise That Launched America into the Space Age, by Robert Stone and Alan Andres. A companion to the PBS program "American Experience."

MINNESOTA
Ely
www.twincities.com/2016/10/03/ely-mn-pillow-rock-moving-2-7-billion-year-old-rock

THE YEAR OF APOLLO: THE MOON AND BEYOND
Bell Museum, St. Paul, Minnesota
Lunar sample, 5K fundraiser, activities, NASA artifacts
Through July 20
www.bellmuseum.umn.edu/year-of-apollo

APOLLO AT 50 MOON FEST!
Cradle of Aviation Museum, Garden City, New York
Astronauts, VR experiences, model rockets, solar viewing
July 20, 9:30 a.m.-5 p.m.
www.cradleofaviation.org/plan_your_visit/apollo

ANNIVERSARY CELEBRATION
Strategic Air Command & Aerospace Museum, Ashland, Nebraska
July 20, 9 a.m.-2 p.m.
Activities, new space exploration exhibit, talk by former astronaut Clayton Anderson
sacmuseum.org

COUNTDOWN TO APOLLO 50
Science Center of Iowa, Des Moines
July 20, 9 a.m.-2 p.m.
www.sciowa.org/apollo50/

ANNIVERSARY CELEBRATION
Great Lakes Science Center, Cleveland
Hands-on activities, Moon rock, other programming
July 19-20
greatscience.com/explore/events-programs/apollo-50-next-giant-leap

FIRST ON THE MOON
Wapakoneta, Ohio
Balloon rally, parade, summer Moon festival, concert, exhibits at Armstrong Air & Space Museum
July 12-21
www.firstonthemoon.org/anniversary-celebration

LANDING ON THE LAWN
Hutchinson Community College, Hutchinson, Kansas
Lab demonstration, Apollo 11 landing footage, Moon and planet observing; adjacent to Kansas Cosmosphere, which houses the Apollo 13 Command Module, Odyssey
July 20, 6-11:30 p.m.
cosmo.org

MOON LANDING PARTY
Saint Louis Science Center, St. Louis
Aviation and space experts, exhibits, other events
July 20, 9:30 a.m.-5:30 p.m.
www.slsc.org

APOLLO 11 50TH ANNIVERSARY
Purdue University, West Lafayette, Indiana
Various events across campus
July 20
www.purdue.edu/apsac/events

FAMILY DAY ANNIVERSARY CELEBRATION
National Museum of the US Air Force, Dayton, Ohio
Apollo 11 VR, model rocket building, space trivia
July 20, 9 a.m.-3 p.m.
www.nationalmuseum.af.mil/Education/Family-Day/

PARTY LIKE IT'S 1969! 2
Various Venues, Huntsville, Alabama
Model rocket launches, music, other events, plus a Saturn V at the U.S. Space and Rocket Center, where the Moon rocket was created
Through July
www.huntsville.org/apollo-50th-anniversary
www.rocketcenter.com/apollo50

MOON ROCKS, SATURN V, MISSION CONTROL 1
Space Center Houston, Houston
The world's largest public collection of Moon rocks, a Saturn V Moon rocket, the restored Apollo control center, a full-scale Lunar Module, Apollo 17 Command Module
Ongoing
spacecenter.org/apollo-50

APOLLO 11 ANNIVERSARY EVENTS
Kennedy Space Center Visitor Center, Merritt Island, Florida
Various events, including tours of Apollo launch facilities
July 16-24
www.kennedyspacecenter.com

TO THE MOON!

McAuliffe-Shepard Discovery Center, Concord, New Hampshire

Special exhibition on lunar science and exploration

Opens July 20

www.starhop.com/current-and-upcoming-exhibitions

APOLLO'S MUSE: THE MOON IN THE AGE OF PHOTOGRAPHY

The Met Fifth Avenue, New York

Visual representations of the Moon from the dawn of photography to the present, plus a selection of space-flown cameras

July 3-September 22

www.metmuseum.org/exhibitions/listings/2019/apollos-muse-moon-photography

SPACE DAY

John F. Kennedy Presidential Library and Museum, Boston

Events and artifacts commemorating Kennedy's challenge to send a man to the Moon

July 20, 9 a.m.-5 p.m.

www.jfklibrary.org

BY THE LIGHT OF THE SILVERY MOON: A CENTURY OF LUNAR PHOTOGRAPHS TO APOLLO 11

National Gallery of Art, Washington, DC

50 works, from 19th century to the Space Age

July 14-January 5, 2020

www.nga.gov/press/exh/5079.html

NEIL ARMSTRONG'S SPACESUIT

National Air & Space Museum, Washington, DC

The suit worn by Armstrong on the Moon, plus five-day celebration on the National Mall, Late-Night Moon Landing celebration, more

Beginning July 16

airandspace.si.edu/apollo50

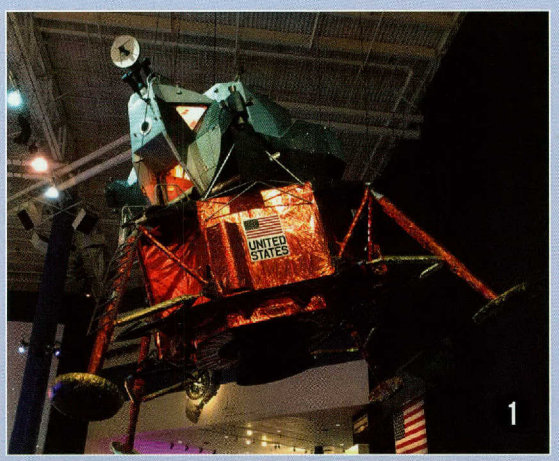
ONE GIANT LEAP FESTIVAL

North Carolina Museum of History, Raleigh

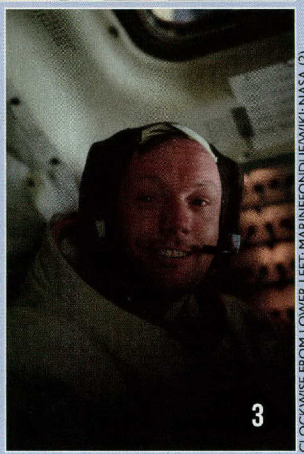
VR lab, demonstrations, activities

July 20, 11 a.m.-4 p.m.

www.ncmuseumofhistory.org/one-giant-leap-festival



1. A Lunar Module test vehicle; 2. A Saturn V Moon rocket; 3. Neil Armstrong aboard Eagle, the Apollo 11 Lunar Module, after his historic moonwalk



CLOCKWISE FROM LOWER LEFT: MARINEFONDUE/WIKI; NASA (2)

SCULPTURE

Museum of the Moon

A 23-foot light-and-audio glass sculpture of the Moon, compiled from NASA imagery, by Luke Jerram. Several copies are touring the United States and other countries.

my-moon.org/tour-dates

COINS

The United States Mint has issued a set of Apollo 11 commemorative coins. The curved coins are available in four denominations.

catalog.usmint.gov/interests/apollo-11-50th-anniversary

U.S. MINT

OTHER MISSIONS

Apollo sent nine manned missions to the Moon and two to Earth orbit, generating a lot of hardware. Relics of these historic missions can be found across the country. Some are located at venues in our events listings, but here are a few more.

Command Module, Apollo 8

Museum of Science and Industry, Chicago

First lunar orbital mission

www.msichicago.org

Command Module Gumdrop, Apollo 9

San Diego Air & Space Museum

Earth-orbital test of Lunar Module

sandiegoairandspace.org

Command Module Yankee Clipper, Apollo 12

Virginia Air & Space Center

Second lunar-landing mission

www.vasc.org/exhibit/spacecraft

by Damond Benningfield and Rebecca Johnson

An Asteroid Gives Up its Secrets

First results from OSIRIS-REx necessitate mission changes

Planetary scientists are getting some surprising results from asteroid Bennu, courtesy of the OSIRIS-REx spacecraft currently orbiting this skyscraper-sized body. After its 2016 launch, the craft went into orbit around Bennu on New Year's Eve 2018. Now, mission scientists are announcing a number of findings from their first months of a multi-year stay.

Born in the main asteroid belt between Mars and Jupiter, Bennu migrated inward at some point in the past to become a Near-Earth Asteroid (NEA) whose orbit swings it closest to Earth every six years. Given this history, Bennu's surface characteristics have surprised scientists.

"We expected small, kilometer-sized NEAs to have young, frequently refreshed surfaces," said team member Kevin Walsh of the Southwest Research Institute (SwRI). "However, numerous large impact craters as well as very large, fractured boulders scattered across Bennu's surface look ancient." These features indicate that the asteroid's surface is 100 million to 1 billion years old.

The unexpectedly rugged surface is forcing mission planners to rework some of their plans. OSIRIS-REx is scheduled to land on Bennu in summer 2020 to collect samples for return to Earth in 2023. The sample collection process was designed for a site with a smooth surface, 25 meters (82 feet) wide, with few obstacles. But the team hasn't been able to find such a site, and now is busy revamping its plans and looking for smaller sites.

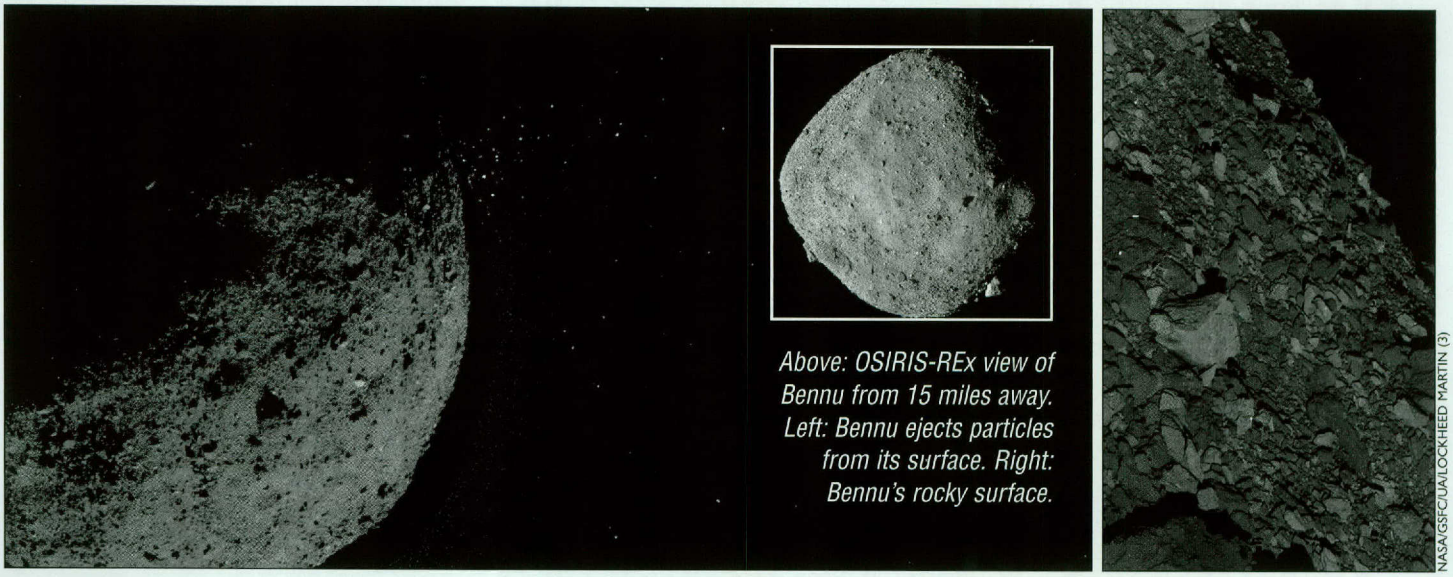
The discovery of particle plumes was another surprise. OSIRIS-REx found that some particles were ejected from the asteroid while others orbited it like tiny satellites before eventually falling to the surface. The team is still studying possible causes for the plumes.

"The discovery of plumes is one of the biggest surprises of my scientific career," said mission principal investigator Dante Lauretta of the University of Arizona. "And the rugged terrain went against all of our predictions. Bennu is already surprising us, and our exciting journey here is just getting started."

In one of the most important, though not necessarily surprising discoveries, a team from SwRI discovered evidence of water-bearing minerals on Bennu's surface with OSIRIS-REx's spectrometer. According to team leader Victoria Hamilton, "Scientists are interested in the composition of Bennu because similar objects may have seeded the Earth with water and organic materials."

She explained that, "During planetary formation, scientists believe that water was one of the many chemical components that accreted to form Earth; however, most scientists think additional water was delivered in part by comets and pieces of asteroids, including water-bearing carbonaceous meteorites. Many of these meteorites also contain prebiotic organic chemicals and amino acids, which are precursors to the origin of life. The details of water delivery to Earth as well as the larger issue of the different inventories of water ice in the early solar system affect how we view solar system formation."

Other initial findings from Bennu indicate that it is largely porous, with up to 60 percent of its volume being void space. The asteroid is basically a gravitationally bound pile of rubble, made up of pieces left over from the collision of larger asteroids in the main belt. OSIRIS-REx scientists think that though Bennu is too small to have hosted liquid water, the water-bearing minerals they discovered indicate that one of the parent bodies involved in the ancient collision that formed Bennu did hold liquid water. They anticipate that studies of returned samples from Bennu will help them understand more about the history of water in the main asteroid belt. **RJ**



Above: OSIRIS-REx view of Bennu from 15 miles away. Left: Bennu ejects particles from its surface. Right: Bennu's rocky surface.

NASA/GSFC/UA/LOCKHEED MARTIN (3)

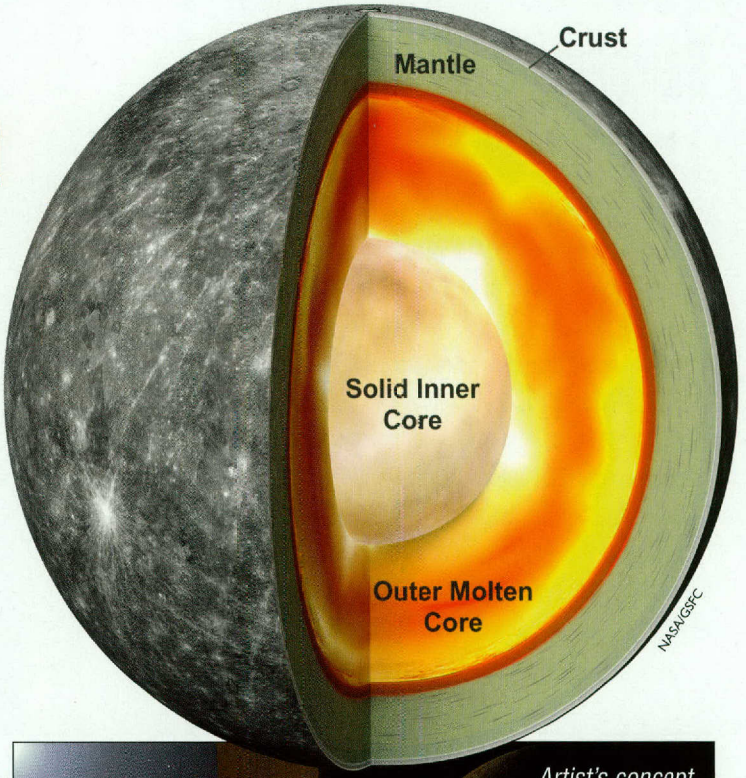
A Giant Iron Core for a Tiny Planet

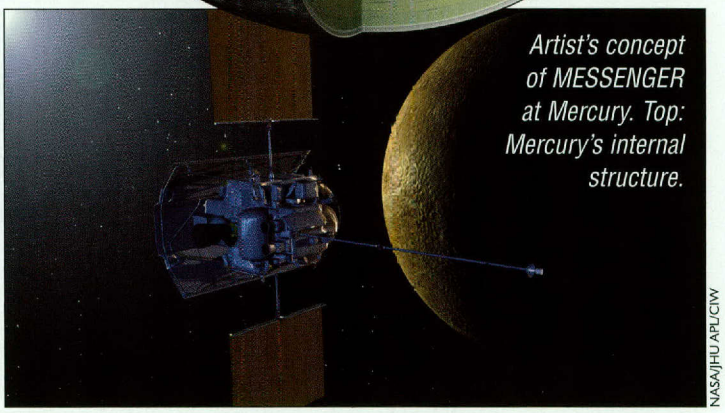
New results from the MESSENGER spacecraft that orbited Mercury from 2011 to 2015 have shown that, like Earth, the planet has a solid metal inner core. Unlike Earth, the tiny planet's core takes up 85 percent of its interior, leading some scientists to describe our solar system's innermost planet as "a cannonball." (Earth's core takes up only about 30 percent of its interior.)

The MESSENGER team inferred Mercury's make-up by measuring how much the planet gravitationally tugged on the spacecraft as it passed over different areas. The most accurate measurements were made when MESSENGER's orbit dropped to less than 105 kilometers (65 miles) above the surface, just before a planned impact on Mercury ended the mission on April 30, 2015.

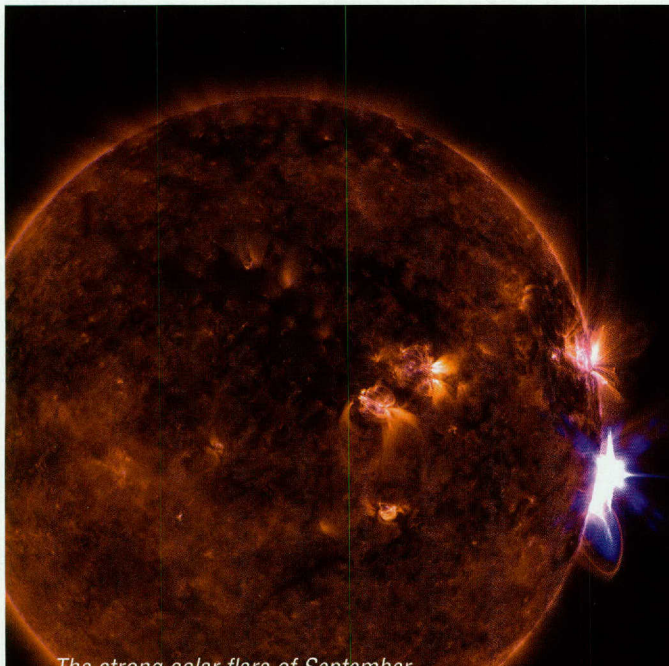
Earlier Earth-based radar studies of Mercury had determined that its outer core is made up of liquid metal, another similarity with Earth. This research, combined with the new MESSENGER results, show that when it comes to its core, Mercury can be looked at as a miniature Earth. Studies of the tiny planet could help predict our planet's geological future.

"Mercury's inner core is still active, due to the molten core that powers the planet's weak magnetic field," said team leader Antonio Genova of Rome's Sapienza University. "Mercury's interior has cooled more rapidly than our planet's. Mercury may help us predict how Earth's magnetic field will change as the core cools." **RJ**




NASA/JHU APL/CIW

Artist's concept of MESSENGER at Mercury. Top: Mercury's internal structure.


NASA/SDO/GODDARD

The strong solar flare of September 10, 2017, seen at far right in this false-color, composite image from the orbiting Solar Dynamics Observatory.

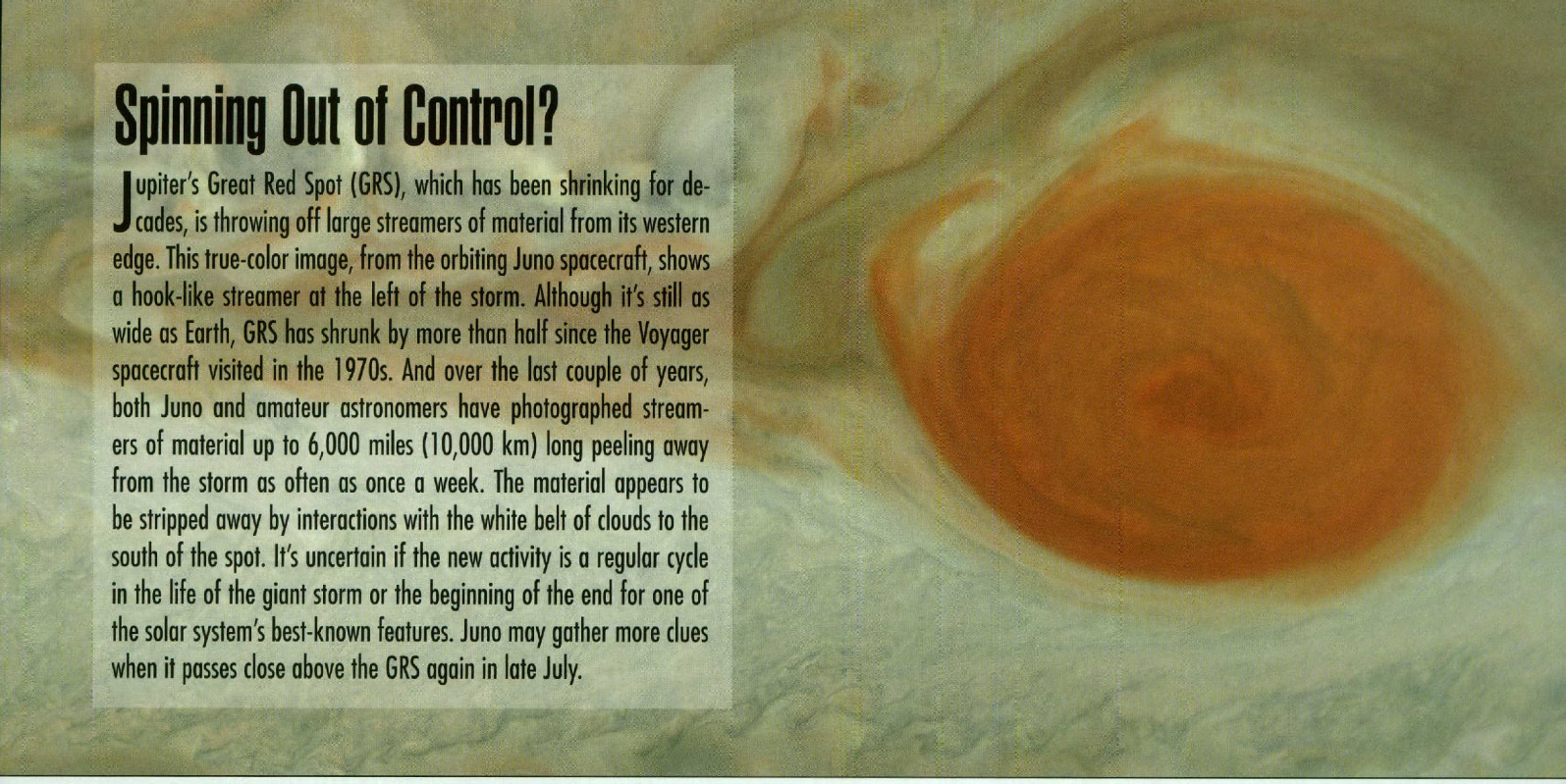
Serendipitous Find Illuminates the Sun

Astronomer David Kuridze of Wales' Aberystwyth University was observing the Sun on September 10, 2017, when a particularly strong solar flare erupted. On the downside, it disrupted communications satellites in Earth orbit, also affecting GPS systems. On the upside, Kuridze happened to have a telescope focused directly on the point of the Sun's surface where the flare originated.

"This is the first time we have been able to measure accurately the magnetic field of the coronal loops, the building blocks of the Sun's magnetic corona, with such a level of accuracy," he said. That's because usually, the signals coming from the Sun's atmosphere are extremely weak by the time they reach Earth. Even this strong flare involved magnetic fields similar in strength to a refrigerator magnet.

Kuridze's serendipitous measurement shows that the Sun's magnetic field is 10 times stronger than previously believed. Better understanding of the Sun's atmosphere improves scientists' understanding of space weather and its effects on Earth.

Kuridze made his observations with the 1-meter Swedish Telescope at Roque de los Muchachos Observatory in the Canary Islands. He reported his results in a recent issue of *The Astrophysical Journal.* **RJ**



Spinning Out of Control?

Jupiter's Great Red Spot (GRS), which has been shrinking for decades, is throwing off large streamers of material from its western edge. This true-color image, from the orbiting Juno spacecraft, shows a hook-like streamer at the left of the storm. Although it's still as wide as Earth, GRS has shrunk by more than half since the Voyager spacecraft visited in the 1970s. And over the last couple of years, both Juno and amateur astronomers have photographed streamers of material up to 6,000 miles (10,000 km) long peeling away from the storm as often as once a week. The material appears to be stripped away by interactions with the white belt of clouds to the south of the spot. It's uncertain if the new activity is a regular cycle in the life of the giant storm or the beginning of the end for one of the solar system's best-known features. Juno may gather more clues when it passes close above the GRS again in late July.

Astronomers Ponder a Mismatch

Two techniques give two numbers for the expansion rate of the universe

The universe has been expanding since the Big Bang. Knowing how fast it's expanding can reveal the universe's age, its fate, and much more. But astronomers can't agree on what the expansion rate is because different techniques for measuring it give different results. And the discrepancy became harder to ignore with the publication of a new set of Hubble Space Telescope observations in April.

Astronomers express the expansion rate with a number known as the Hubble constant. It's named for Edwin Hubble (for whom the telescope is also named), who discovered the expansion of the universe and made the first estimate of the rate of expansion.

Astronomers use several techniques to measure the Hubble constant, but the best numbers come from two of them. One technique uses space telescopes to measure the distances to certain types of stars in other galaxies. Those distances are compared to how fast the galaxies are moving away from us as a result of the expanding universe.

The other technique uses observations from another space telescope, Planck, which measured tiny differences in the temperature of the universe soon after the Big Bang.

Both techniques have produced precise numbers. In fact, the new study, which measured the distances to stars in the Large Magellanic Cloud, a companion galaxy to the Milky Way, nailed it down with an uncertainty of just 1.9 percent.

But the numbers obtained with the two techniques don't match. They are off by less than 10 percent, but there's so little wiggle room in either number that there's no way to reconcile them even when astronomers account for dark energy, which appears to be causing the universe to expand faster as it ages.

It's possible that the expansion rate was different when the universe was young, which could skew the measurements of the universe's expansion rate today. It's also possible, though, that scientists will need to develop new physics to explain how the universe is expanding **DB**

Living on Mars (Sort of)

Although there's no evidence of life on Mars, several types of microscopic organisms from Earth managed to survive more than a year of Mars-like conditions or worse aboard the International Space Station.

Bacteria, fungi, lichens, and other organisms obtained from Mars-like environments on Earth were exposed to space as part of BIOMEX (Biology and Mars Experiment), which was installed on the outside of the station's Russian module. Some of the organisms were embedded in materials that simulate the dirt on Mars, others in Moon simulants, and others in various minerals common on Earth. They were exposed to vacuum and varying levels of ultraviolet radiation from October 2014 to February 2016. They returned to Earth four months later, where they were examined by researchers.

At a conference in March, scientists reported that primitive single-cell organisms known as cyanobacteria fared best, showing metabolic activity and the ability to grow after they returned to Earth. Some of the fungi and algae survived but suffered significant damage, as did yeast and bacteria in a kombucha biofilm (the same ingredients found in the popular beverage).

The results don't tell us whether life exists on Mars, only that it's possible for some tough microbes to survive in the Red Planet's cold, dry, radiation-drenched environment.

HONOR APOLLO'S LEGACY AT McDONALD OBSERVATORY

The Apollo 11 astronauts left something on the Moon for McDonald Observatory to target: special mirrors that our largest telescope could target with laser beams, to measure the light's round-trip time as it bounced back to Earth. The resulting science measured the Earth-Moon distance with exquisite precision, showed how fast the Moon's orbit is increasing, and provided tests of General Relativity.

This research continued at McDonald for 40 years. This summer, a new exhibit on our 80 years of history highlights the 50th anniversary of the connection between McDonald Observatory and the Apollo program.

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Millions of young stars blaze forth on one side of NGC 4485, a galaxy that's 25 million light-years from Earth. The outburst of new stars probably is the result of a near collision with another galaxy (not in the frame). The gravity of the passing galaxy squeezed clouds of gas and dust in NGC 4485, causing them to collapse and give birth to new stars. Some of the stellar nurseries form the wispy red structures at right, which are intertwined with clouds of hot blue stars. The left side of the galaxy is unaffected by the encounter, so it shows some of the galaxy's original spiral shape.