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THE MOON ISSUE

CELEBRATING OUR
CELESTIAL COMPANION



A MOON WORTHY OF WAXING POETIC

Appreciating our natural satellite and the humans who explore it

by Bill Nye

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WELCOME TO THE lunar issue. Earth's Moon — the Moon, as we call it — has a special place in our sky and in our hearts. Its size and position in space produce remarkable effects here on Earth. First, as ancient biblical authors wrote, it's as though we have two sources of light to find our way: the Sun by day and the Moon by about half of our nights. Then, the Moon's gravity provides about half the tractive force that raises ocean tides, which in turn create entire ecosystems. When conditions are right, the Moon blocks or subtends (what a word!) about half a degree of arc, almost exactly the same width and breadth of sky as our closest star: our Sun. In the next few months, the Moon will produce two dramatic solar eclipses in North America. Because they'll be accessible by all sorts of roads and highways, I encourage everyone in this part of the world to make travel plans to be in the shadows. There's nothing quite like it. We'll have plenty of information about these events in this issue and in upcoming issues.

Along with the physical influence of the Moon's gravity and reflected light, its cultural influence is amazing. Ancient Greek observers noticed that when Earth's shadow falls on the Moon, it's always curved. The only object conceivable that casts a curve in any orientation is a sphere. Therefore, they realized that Earth is round. By inference, so is the Moon. Even without a telescope, you can see the Moon's round shape and topography. With a telescope or binoculars, one easily discovers the craters — thousands of them — pockmarking its surface.

The Moon has also made us a spacefaring species. It's as though nature provided our species with an ideal jumping-forth place to explore the Cosmos. It is always up

there beckoning. As humankind took flight, the Moon became the obvious destination beyond the sky. With an enormous investment, humans walked on its surface. And indeed, new crews will be back there in just a few years. Just think about what they'll discover. Speaking of discovering things, the Moon is inspiring, and so we chose it as one of the first topics shared in our new kids' program, Planetary Academy.

And speaking of news of new crews, as you read this issue, you'll see that the Moon has also become the perfect place for international cooperation in space. You'll hear from one of the world's leading experts in space policy about why that has come to be. You'll also see astonishing photos that members like you have taken of our Moon, all of which were shared in your online member community. This virtual meeting place for members has been up and running since March; I continue to be amazed by the quality of discussion, the wonderful events, and the passion that our members have for space science and exploration. Every three lunar orbits or so (every quarter), I present this column. I often go on about how none of what we do here at the Society to engage members, inspire kids and families, and influence the space policies of governments around the world would be possible without you. It's absolutely true. So, thank you. And now, to the Moon! 🌕

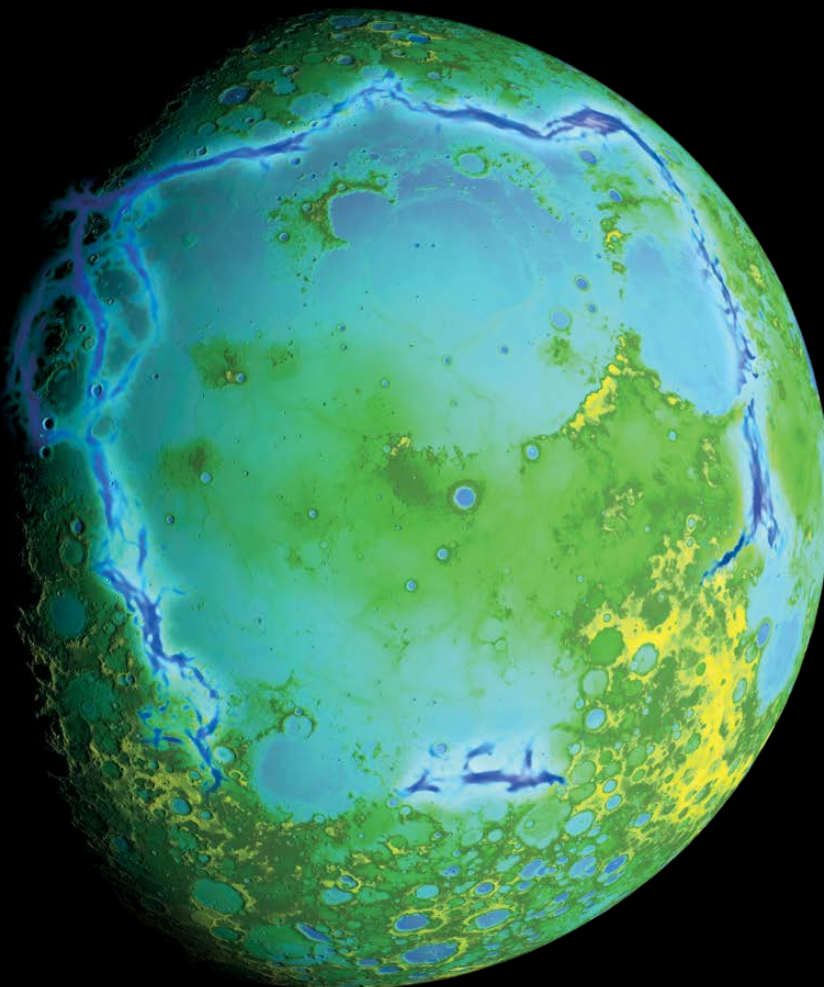
Bill Nye



BILL NYE is chief executive officer of The Planetary Society.

Topography of Earth's Moon generated from data collected by the Lunar Orbiter Laser Altimeter aboard NASA's Lunar Reconnaissance Orbiter, with the gravity anomalies bordering the Procellarum region superimposed in blue. The border structures are shown using gravity gradients calculated with data from NASA's Gravity Recovery and Interior Laboratory (GRAIL) mission. These gravity anomalies are interpreted as ancient lava-flooded rift zones buried beneath the volcanic plains (or maria) on the near side of the Moon.

NASA/COLORADO SCHOOL OF MINES/MIT/GSFC/SCIENTIFIC VISUALIZATION STUDIO



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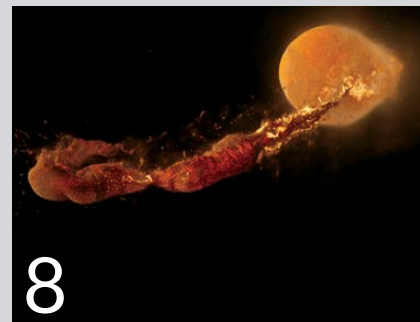


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ON THE COVER: This gorgeous image captured by astrophotographer Andrew McCarthy in early 2020 shows the Moon shrouded by clouds while simultaneously occulting Mars, reminding us of our Earthly connection to our only satellite and its role in the future human exploration of our Solar System. Image: Andrew McCarthy * The Planetary Report (ISSN 0736-3680) is published quarterly at the editorial offices of The Planetary Society, 60 South Los Robles Avenue, Pasadena, CA 91101-2016, 626-793-5100. It is available to members of The Planetary Society. Annual dues are \$50 (U.S. dollars) for members in the United States as well as in Canada and other countries. Printed in the USA. Third-class postage at Pasadena, California and at an additional mailing office. Canada Post Agreement Number 87424. * Viewpoints expressed in articles and editorials are those of the authors and do not necessarily represent positions of The Planetary Society, its officers, or its advisers. © 2023 by The Planetary Society. All Rights Reserved. The Planetary Society and The Planetary Report: Registered Trademarks ® The Planetary Society. Planetfest™ The Planetary Society.

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MOONSTRUCK

Human culture's long relationship with the Moon

by Kate Howells

ABOVE This is a 17th century engraving titled "The Influence of the Moon on Women's Minds."

SCIENCE PHOTO LIBRARY

THE PLANETS OF our Solar System are named after deities. In Roman mythology, Mars was the god of war, for example, and Pluto was the god of the underworld. Moons are mostly named after figures related to the host planet's mythological namesakes, like Europa, who was the consort of the god Jupiter. But Earth's Moon has a different story. Unlike most other celestial bodies that are named after unrelated deities, the Moon itself has been considered a god figure by many cultures for millennia.

The ancient Romans called this deity Luna, and the Greeks called her Selene (often associated with another goddess, Artemis, namesake of NASA's lunar exploration program today). In Hindu mythology, the Moon is personified as the god Chandra and in China, as the goddess Chang'e. The Incas called her Mama Quilla, and the Aztecs called her Mētztli. In ancient Yemen, people worshiped the moon god Ta'lab. The list goes on and on.

In many of these cultures' mythologies, the Moon has a role in the creation of the world or of human life. In many cases, the Moon is the partner of the Sun and sometimes its enemy. Across the board, the Moon shows up in myths as a powerful, influential, and often mysterious figure.

The Moon holds such a special place in human culture because it has always been with us. It is a striking feature of the sky whether appearing during the day or at night. It shows up in different but dependable ways, marking the passage of time with its movements and changing face. The Moon affects the land, water, plants, and animals. And every so often, it turns blood red or obscures the Sun. With such a dynamic and powerful nature, it's no wonder people looked to the Moon and thought it had to be more than just a rock in the sky.

Today, we know so much about the science of the Moon that to some, it may



LEFT This image shows the Hindu Moon god Chandra, depicted by Ravi Varma.

RAVI VARMA PRESS

have lost its mystery. But its meaningfulness to human culture can still be seen in the language we use.

The English word “month,” for example, comes from the Old English “mōnath,” related to “mōna,” meaning moon — no great surprise considering the length of a month is about the length of a lunar cycle. The words “lunatic” and “lunacy” come from the Latin root “luna,” meaning “moon.” You see the same thing in other Latin-based languages, like Italian, French, and Portuguese. But that’s not all; the Dutch, Russian, and German words for “lunatic” all stem from the words for “moon” in those languages as well. These etymologies reflect the long-held belief that human behavior was affected by the cycles of the Moon — the root of the werewolf myth.

The Moon also holds a special place in the language of romance. You might find yourself mooning over a crush or promising your new sweetheart the Moon, planning a romantic walk in the moonlight, or going on your honeymoon. It’s hard to avoid Earth’s natural satellite when you’re in love.

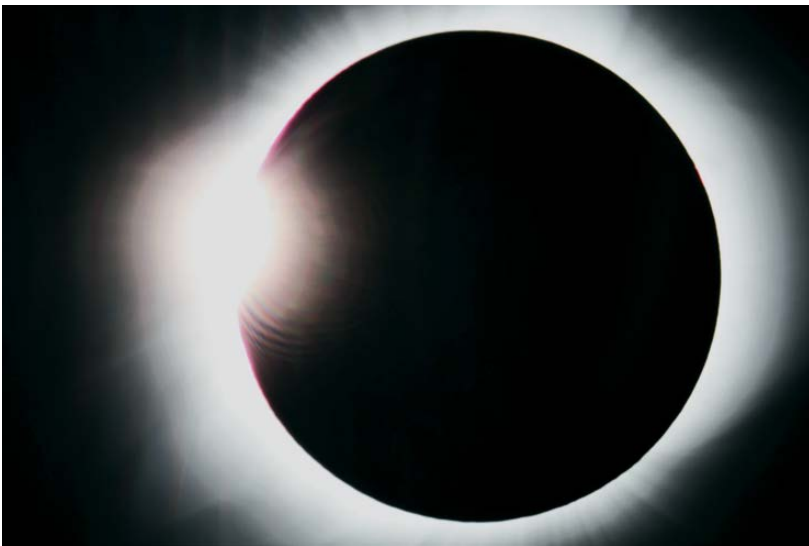
Although how we think about the Moon has changed over millennia, what remains constant is its place in Earth’s cultures. As we explore and maybe even build settlements on our celestial neighbor, there’s no doubt that the Moon will take on new meaning in the words and stories of future cultures. 🌙



KATE HOWELLS is the public education specialist for *The Planetary Society*.

MEMBER MOON SHOTS

IN OUR ONLINE member community, we invited Planetary Society members to share photos taken of the Moon, and you came through! These are some of our favorite Moon shots taken by members. You can find more at community.planetary.org in the “Look Up!” space.



Planetary Society member Jim Peterson captured a moment of magic with this photo of the Moon completely eclipsing the Sun in August 2017, taken from Silverton, Oregon.



Planetary Society member Sean Pyl's photo of a third-quarter daytime Moon was taken from Rainier, Oregon.

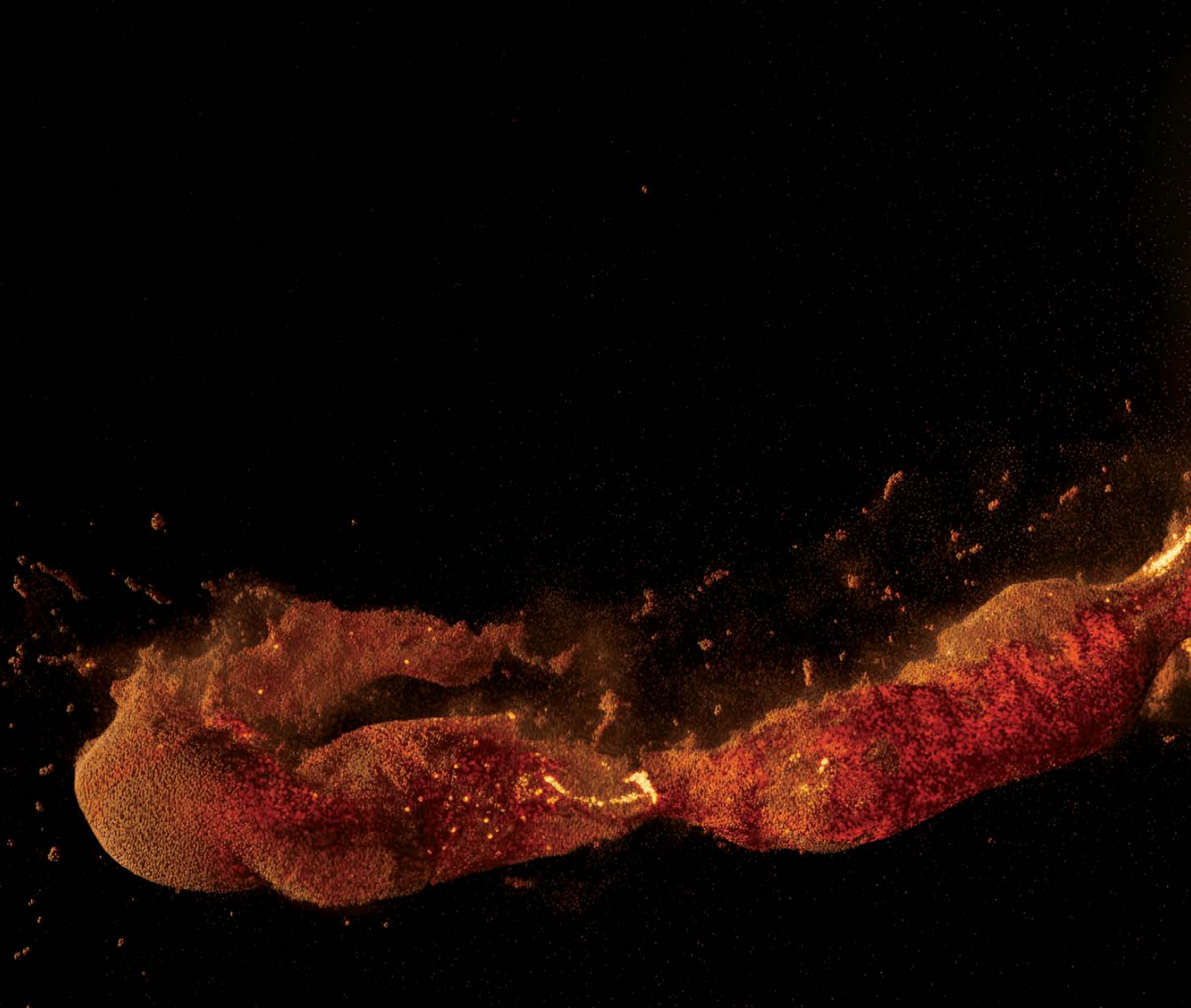


Planetary Society member Sabine Vollenhofer-Schrumpf captured the red hue of a total lunar eclipse from Vienna, Austria.

Planetary Society member Justin Foley took this photo of the full Moon rising behind the radio towers on Mount Wilson. It was taken from the Griffith Observatory in Los Angeles, California.



Planetary Society member Alex Briatico got a close-up of the Moon with this shot taken from Borgomanero, Italy.



A Lunar Saga

The Moon's storied past
and how it may shape the future of exploration

by Kate Howells



This still from a NASA Ames simulation shows what the scene might have looked like shortly after a Mars-size world named Theia struck early Earth. Molten debris, seen here streaming out from the collision, is believed to have formed the Moon.

NASA AMES RESEARCH CENTER

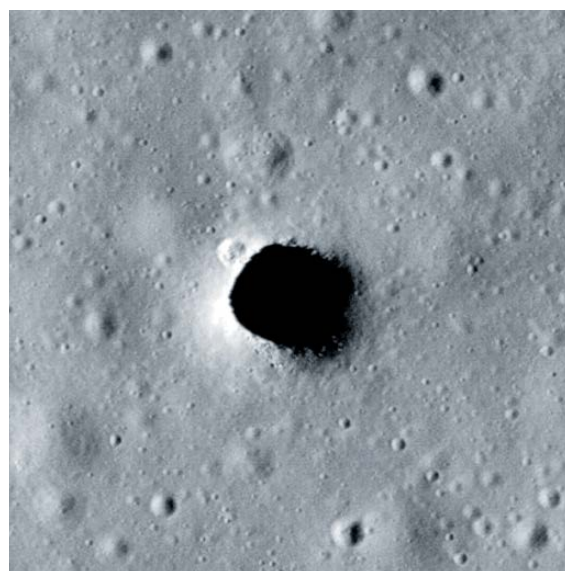
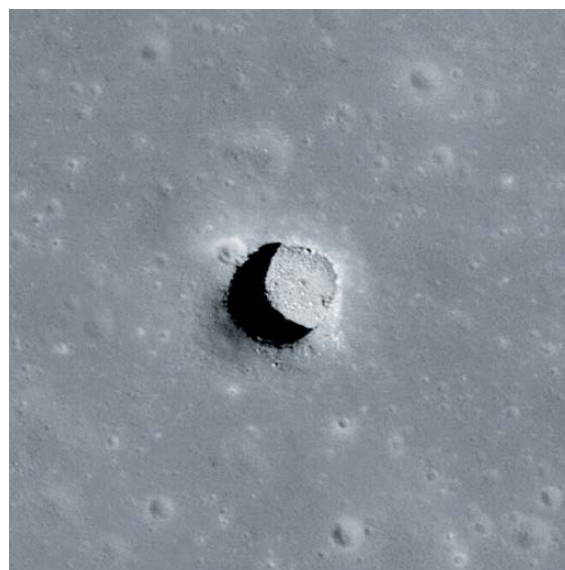
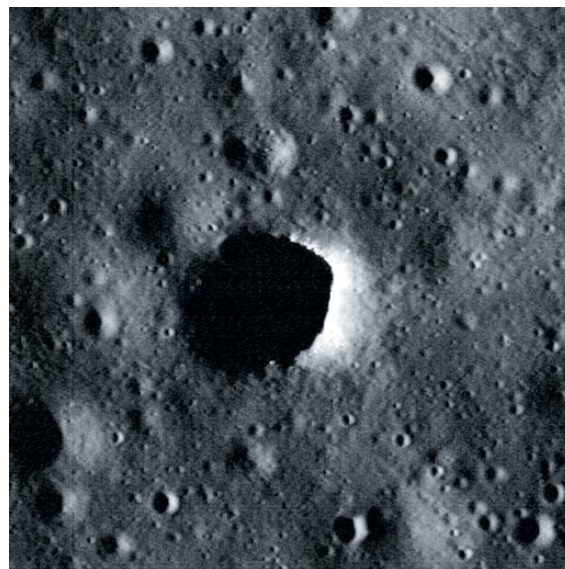
WHEN THE MOON entered the planetary scene some 4.5 billion years ago, it did so in dramatic fashion. This set the stage for an era of the Moon's history in which it was very different from its serene present-day form. But evidence of this colorful past can still be found on our celestial companion, and new research continues to uncover wild stories from its youth.

The Moon was forged when Earth collided with a Mars-size object named Theia. The two colliding planets threw huge chunks of super-heated rock into space, which came together gravitationally to form the Moon. New research suggests that this may have happened within a matter of hours — not months or years as previously thought.

This violent, rapid event brought the Moon into existence, but it took a long time before it became the Moon we know today.

As we know from far-flung moons like Enceladus and Io, when a celestial body is squeezed by gravitational forces, it produces thermal energy that can melt ice and even rock beneath the surface. The thermal energy produced by a little squeezing is nothing compared to that produced by a massive collision and a rapid accretion of material. Naturally, the formation of the Moon generated an enormous amount of heat. For tens or even hundreds of millions of years after its formation, the Moon was a ball of magma.

The way the Moon cooled down from this magma state may explain why the lunar nearside and farside look so different today. The theory is that as the Moon's outer crust cooled enough to harden, it did so more quickly on the lunar farside. This happened because the Moon established its tidal locking — rotating at just the right speed to always have the same side facing Earth — fairly quickly. Because Earth was pretty red-hot from its impact with Theia for quite some time as well, it warmed the side of the Moon that faced it. This likely made the nearside crust harden more slowly, allowing subsurface magma to break through while it remained thin.



RIGHT *These three images of the Marius Hills pit on the Moon were imaged by NASA's Lunar Reconnaissance Orbiter. Re-analysis of ground-penetrating radar data from Kaguya suggests that the extensive lava tubes under Marius Hills might be large enough to house cities.*

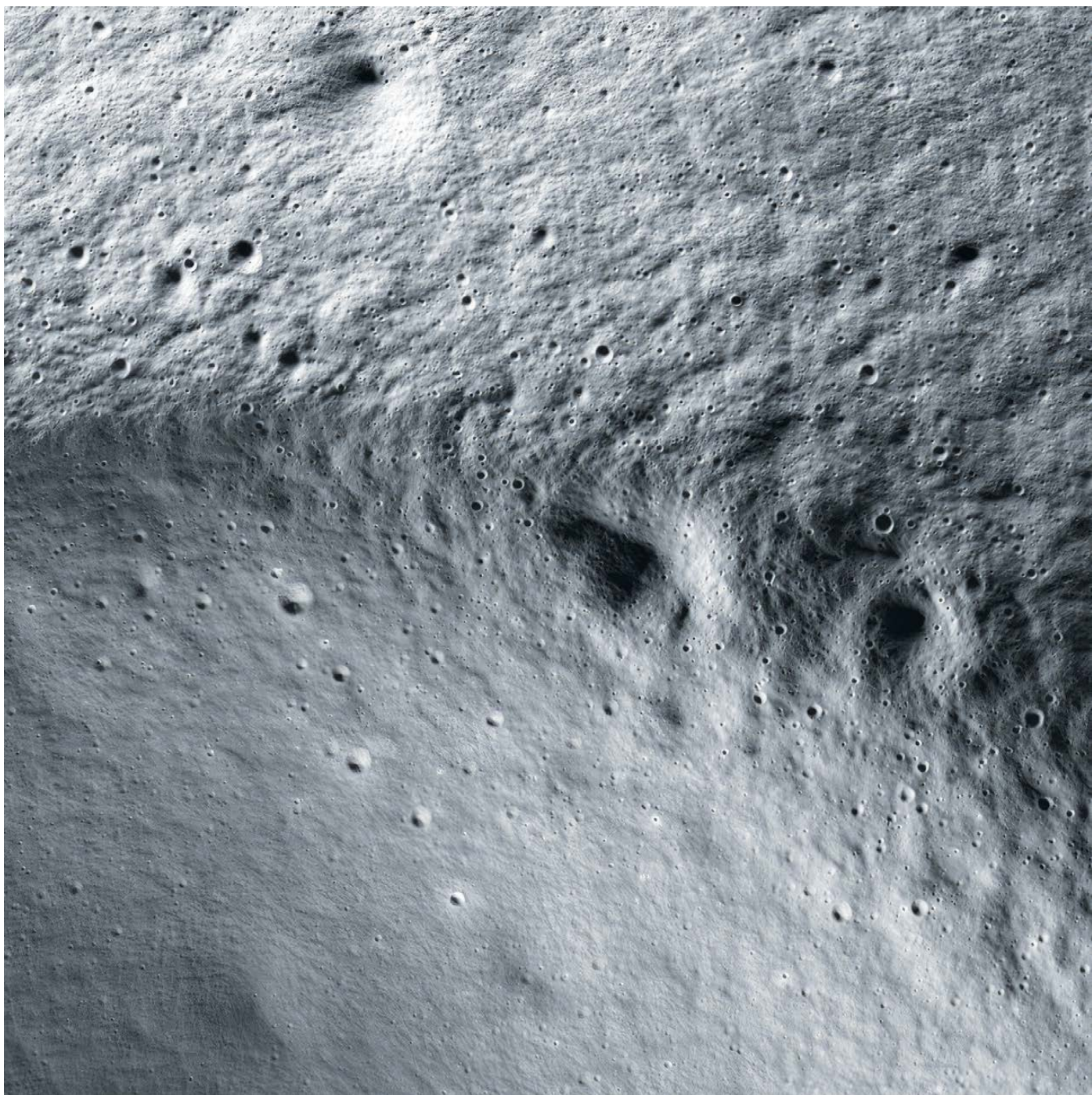
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The implication of this is that the Moon had active volcanoes on its surface, especially on its nearside, for many billions of years. That volcanic activity is thought to have generated atmospheric gases, leading to a lunar atmosphere that may have been twice as thick as Mars' current atmosphere. The idea of the Moon as a smoggy world with red-hot lava pouring from volcanoes seems totally bizarre compared to what we see now, but it represents a long part of the Moon's history. The Moon's volcanic activity only completely ceased about 50 million years ago.

Although we aren't treated to such exciting sights when we look up at the Moon today, we do see the aftermath of its volcanic era. The familiar face of the Moon has dark areas all over it, which scientists call plains, seas, or maria. These are made of basaltic rock, which erupted from volcanoes and settled into low-lying areas like impact craters.

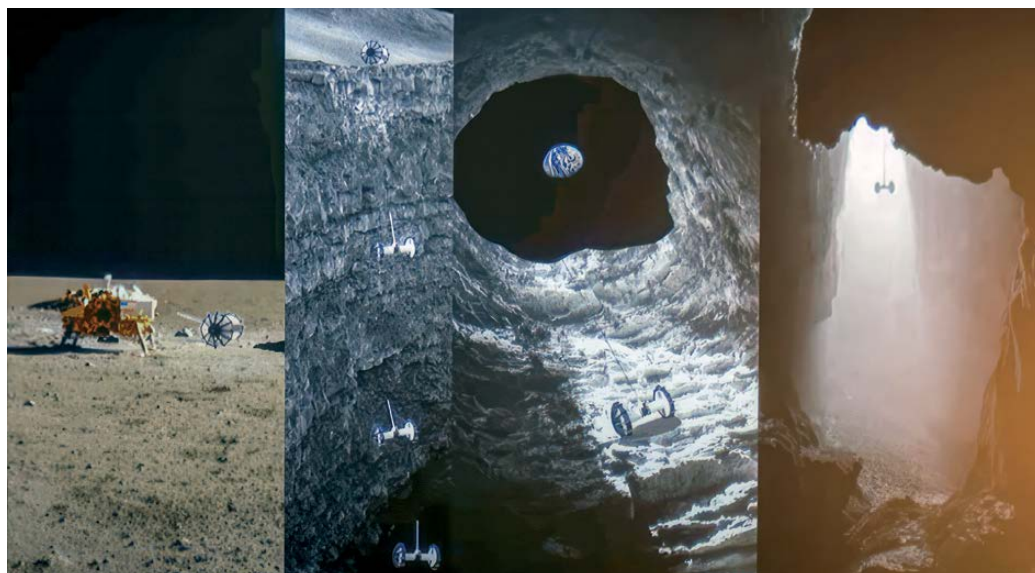
In 2009, the Japanese lunar orbiter Kaguya observed another remnant of the Moon's past volcanism. The spacecraft imaged a large pit that is too deep for its width to be an impact crater. Instead, it appears to have been formed by lava.

Back in its volcanic days, the Moon's low gravity allowed much larger volumes of lava, especially low-viscosity ballistic lava, to



ShadowCam, a hypersensitive camera provided by NASA to fly on Korea's Danuri lunar orbiter, took this high-resolution image of the rim of Marvin crater, a permanently shadowed region of the lunar south pole. Although areas like this never receive any direct sunlight, ShadowCam is sensitive enough to capture detailed images using only the tiny amount of sunlight reflected off Earth or off nearby mountains and crater walls.

NASA/KARI/ASU



ABOVE RIGHT An artist's depiction of a rover descending into a lunar skylight, developed as part of the Moon Diver mission proposal from Principal Investigator Laura Kerber at NASA's Jet Propulsion Laboratory.

KERBER ET AL.

flow from volcanic eruptions across much greater distances than we see with lava flows on Earth. Sometimes, a flow would carve out a channel in the rock below, and the top layer of lava would cool down. The remaining magma would continue to flow beneath in a tube-shaped passage until all the magma eventually drained out, leaving the tube behind.

These subsurface tubes reveal themselves to orbiting spacecraft when a portion of the tube collapses due to a nearby impact or some other disturbance, leaving a hole called a skylight that can be seen from above by spacecraft like Kaguya.

Since this first skylight discovery, various lunar orbiters have found more than 200 others on the maria (the flat, dark plains) of the lunar nearside. They range in diameter from about 5 meters (16 feet) to more than 900 meters (2,950 feet) and are believed to lead to particularly enormous lava tubes. The biggest lava tubes we've found on Earth, in Kazumura Cave on the Big Island of Hawai'i, are about the size of a typical tunnel through which you'd drive a car. On the Moon, some are 300 to 700 times that size. There are lava tubes tall enough to fit the world's tallest building inside them, and others are large enough to contain a whole city.

Indeed, these lava tubes might be the ideal places to establish human settlements on the Moon. The rock surrounding these tubes could protect against harmful solar radiation, micrometeoroid impacts, and the huge temperature swings that the surface experiences due to its lack of

atmosphere. Various mission concepts from NASA and the European Space Agency have explored ways of sending rovers down into these lunar skylights, helping determine whether they and the lava tubes to which they lead would be suitable for developing human settlements.

The other big requirement for establishing long-term settlements on the Moon is water, both for keeping astronauts hydrated and for producing fuel. And luckily, more and more evidence of water is being found on the Moon, contained in rocks throughout its surface and interior and in ice deposits within permanently shadowed craters at its poles.

New discoveries of water on the Moon are being made all the time from data collected by missions, including India's Chandrayaan-1 orbiter, NASA's Lunar Reconnaissance Orbiter and Lunar Crater Observation and Sensing Satellite, China's Chang'e-5 sample return mission, and even new studies of the Moon rocks brought home by Apollo astronauts.

The question of where this water came from remains unanswered. It's possible that comets bombarded the Moon along with Earth in the earlier days of the Solar System, bringing in ice from the frozen reaches of the Kuiper Belt. It's also possible, though, that water might have been present on Earth and/or Theia prior to their collision and accreted along with the rest of the Moon when it formed. Only by continuing to study our surprisingly storied satellite can we find out whether its beginnings were as watery as they were fiery. 🌕



LEFT National Space Council Executive Secretary Scott Pace speaks at the first meeting of the National Space Council Users' Advisory Group, June 19, 2018, at NASA headquarters in Washington.

NASA/JOEL KOWSKY

TO THE MOON TOGETHER

Why exploring the Moon is something the world can — and must — do together

edited by Kate Howells

SPACE EXPLORATION HAS taken many forms since the first satellite launched in the 1950s. Space has been the domain of fierce geopolitical competition; peaceful scientific cooperation; and more recently, commercial ambition. The U.S.-led Artemis program, which aims to return astronauts to the Moon's surface and develop a sustainable infrastructure in lunar orbit, involves a slightly different approach: inviting countries and companies from around the world to take part in a grand collaborative effort that none could accomplish alone.

Dr. Scott Pace, director of the Space Policy Institute at the George Washington University's Elliott School of International Affairs, has been a

longtime advocate for the Moon as the ideal destination for sustainable, internationally cooperative human space exploration. As executive secretary of the United States' National Space Council from 2017 to 2021, Dr. Pace helped establish the Artemis program and the Artemis Accords, a set of principles for peaceful and cooperative exploration that 25 countries and one territory have signed to date.

The Planetary Society's chief of space policy, Casey Dreier, interviewed Dr. Pace to talk about why human exploration needs to be an international endeavor and why the Moon is the ideal place to do that.

The interview transcript has been edited for length and clarity. You

can listen to the full conversation at planetary.org/radio.

CASEY DREIER: Thank you for joining me, Dr. Pace. To start with, what do you think the Artemis program has provided to the U.S. in terms of its national interests that was lacking when the Moon wasn't the central focus of human space exploration?

SCOTT PACE: I think the central change is that Space Policy Directive One, which led to the Artemis program, includes commercial and international partnerships. The world today is a much more globalized one, a much more democratized one in terms of space. We have companies doing

amazing things in space. We have countries doing amazing things in space. And I think prior efforts did not really take into account how different the global environment is today versus what it was a few decades ago or certainly at the beginning of the Space Age.

One of the reasons that I was so very critical of the Obama administration's Journey to Mars program was not Mars per se. Mars is great, and I think it's important to have that as a stretch goal. But the problem was that the Journey to Mars concept didn't really provide on-ramps for other countries.

The Journey to Mars was a program designed to meet internal domestic policy needs. In contrast, the Apollo-Soyuz program was geopolitical. The International Space Station was geopolitical. And I think Artemis has done better as a geopolitical program. And because of that, I think it's more sustainable and will survive longer. This is not something that just NASA is responsible for, but it's part of our diplomatic engagement with the world.

In 2010, I had a head of a foreign space agency ask me if the United States government really supported international cooperation. And I said, carefully, "Well, I believe they do." And the guy looks at me and very plainly says, "Well, we don't think so. We don't think you're sincere." And I go, "Really? Why would you say that?" And they said, "Well, because you picked a goal — Mars — that we can't do. I can't go to my finance ministry and ask for money to go to Mars with the Americans because it would just be too much. So we think you really only want to go to Mars with countries like Russia who are capable of this, and you're not really sincere about

involving smaller countries like my own." And I said, "I have something really bad to tell you. We didn't think about you at all." And we want to change that.

CD: So, what does the Moon offer that Mars can't? Is it purely just technology, or is there some symbolic aspect of the Moon that feels more achievable to other nations?

SP: I like to say that the Moon has many different price points, much more so than Mars does. Meaning you can have a very high-end activity, such as Japan building a pressurized rover for the surface or the Europeans providing a service module for Orion — major contributions that are essential to the overall project. But then you can have smaller countries looking at taking rides on commercial lunar rovers, putting small payloads on the Moon, or putting payloads in orbit around the Moon. Countries of many different levels of capability can find ways to meaningfully participate.

There is international participation on the Mars rovers and landers today; Perseverance, Curiosity, and Opportunity all have international participation. But that tends to be fairly specialized scientific participation. And not to diminish that at all but it's not as politically visible as some other activities, like human spaceflight, which also tend to be more expensive overall.

So, it's not just the psychology of the Moon being closer; the technical reality of exploring the Moon has an affordability level to it that allows for greater adjustments for countries to match their national interests to what's available. It provides more on-ramps and ways for meaningful engagement.

CD: I would add that even frequency is an advantage; you can launch to the Moon on a monthly basis versus the 26-month cadence of launching to Mars. And by having high frequency, you can build up production lines.

SP: Absolutely. If you do everything in a bespoke, handcrafted way, it's a different economy than if you're making a production line.

CD: On top of all that, the Artemis Accords basically grant free entry for participation in some capacity. It doesn't cost anything to sign on to the Artemis Accords. You can functionally raise your hand as a nation and just say "we share these values" and start there.

SP: Signing the Artemis Accord doesn't mean you're in the Artemis program because that still takes decisions as to what you want to contribute. But the Artemis Accords are helpful for starting the conversation about what our common values are going to be. And they're fairly conservative. They represent only existing international law. They don't really represent any large breakthrough. That's why countries find it fairly easy to sign up because it represents where they are now.

But I think that in the course of engagement in and on and around the Moon, there will be further elaborations of these norms of behavior and further creation of mechanisms for coordination with each other, not just among Artemis Accord countries but I would hope all countries. We'll need coordination with each other as we develop new understandings about what safe and responsible space operations look like.

Artemis

Apollo

CD: I'm struck by the old JFK speech of "Why go to the Moon?" The answer was, well, why climb the highest mountain? Because it's there. Artemis reframes the answer: that we go to the Moon because it's there — nothing else is that close. It's a destination because of its accessibility.

SP: I think that doing space exploration and development and utilization requires a training program. The Moon is the training. How far we go and what we can do is not determined at all.

The question is: Is there a human future in space? The answer is yes or no, and either is profound. It depends on two subquestions: Is it possible to live off the land, or do you always have to be supplied from Earth? And is it possible to do something that pays your way, or are you always dependent upon taxpayers on Earth?

If you can live off the land and pay your own way, then you get the human expansion envisioned by science fiction. If the answer to both questions is no, then space is some form of Mount Everest that you visit — a place of high adventure symbolism, but nobody really lives there. If you can live off the land and use local resources but you're always still dependent upon the taxpayer to fund it all, then space is some version of Antarctica. If you can do something out there that pays but you always have to come back to Earth for whatever reason — biophysical, physiological, psychological, or other reasons like that — then space is something like a North Sea oil platform.

Those are four very, very radically different kinds of visions. And we actually don't know which one will pan out. Some people think they know, but I would argue that's mostly a faith-based assumption.

But I think the way to have a sustainable space program is to not only align it with enduring national interest but make sure it's sustainable by those interests. So, being able to do things in a one-off wartime level of effort worked in the case of Apollo, but it was somewhat of a bubble at a particular time and place. The reason for going to the Moon today is not only practical but it's also a way of training and equipping ourselves to create a more capable space-faring civilization that then becomes more capable of going to Mars in a way that would be more sustainable.

We're still exploring which of these human futures is possible. But no matter what, it's incredibly important to have international and commercial partners because we cannot answer the question of a human future without all of human society in it. 🧑🏻‍🚀

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ASTEROID HUNTERS THRIVE WITH SUPPORT FROM PLANETARY SOCIETY MEMBERS



MEET THE NEWEST ROUND OF GRANT-WINNING ASTEROID HUNTERS

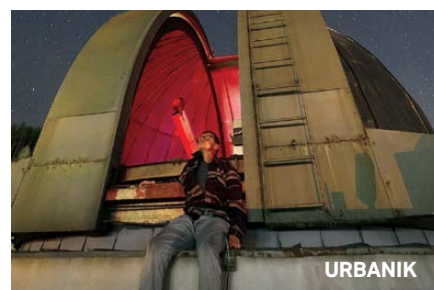
Thanks to the support of our members, we're thrilled to announce the newest winners of our Shoemaker Near-Earth Object (NEO) Grant program, named after pioneering planetary geologist Gene Shoemaker. Shoemaker Grants support very advanced amateur astronomers around the world in their efforts to find, track, and characterize near-Earth asteroids.

Fabrizio Bernardi and observatory director **Maura Tombelli** of Gr.A.M. (Gruppo Astrofili Montelupo — a large group of amateur astronomers) at the Beppe Forti Observatory in **Italy** are awarded \$9,672 for a filter wheel, UBVRI filters, a light pollution filter, a star guider, and an adaptive optics component to add to the CMOS camera that was purchased



with a 2021 Shoemaker NEO Grant. This combination will increase the capabilities of the observatory to track fainter NEOs discovered by the professional surveys and to facilitate better characterization.

Michel Ory of **Switzerland** as part of the Swiss-French amateur Morocco Oukaimeden Sky Survey (MOSS) is awarded \$5,055 to purchase a new CMOS camera for their observatory in the High Atlas Mountains of Morocco. The camera will improve their sensitivity and efficiency to do follow-up tracking observations of dimmer NEOs. Ory and Claudine Rinner operate the 50-centimeter (20-inch) MOSS telescope at an elevation of 2,750 meters (9,022 feet). Since opening in 2011, they have submitted more than 1 million astrometric measurements. They were also awarded a 2017 Shoemaker NEO Grant.



Miguel Sanchez Gonzalez of **Spain** along with **Sergio Alonso, Antonio R. Reche, Javier Flores, and Alexis Castillo** as part of amateur astronomy group Sociedad Astronomica Granadina is awarded \$6,200 for a telescope mount, camera, and dew heater. They observe stellar occultations by NEOs (when the NEO passes in front of a star), often with mobile telescopes moved to locations where a given event can be observed. These observations provide precise astrometry and can also help infer asteroid sizes and shapes. The upgrades will allow observation of longer occultation events and will improve sensitivity.

Marian Urbanik in **Slovakia** is awarded \$6,100 for a new camera and field rotator for use in follow-up astrometry as well as photometry at Kysuce Observatory. With a wider



field of view and greater sensitivity, the new setup will enable increased precision in photometry and in NEO follow-up tracking as well as enabling tracking of faster (closer) NEOs.

Gonzalo Fornas of Spain along with **Álvaro Fornas, Enrique Arce, Rafael Barberá, and Fernando Huet**, all of the 300-member amateur astronomers' organization Asociación Valenciana de Astronomía (AVA), are awarded \$8,067 for a camera, an off-axis guider, a filter wheel, and a guiding camera. This will replace the camera on their 43-centimeter (17-inch) telescope. The new setup will improve follow-up tracking of fainter and faster asteroids.

Alain Maury of the MAP survey in **Chile**, working with **Georges Attard** and **Florian Signoret** in **France** and **Daniel Parrot** in the **United States**, are awarded \$8,000 for two CMOS

cameras for two new telescope setups they are creating. This will increase sky coverage and therefore the number of discoveries. They have the fourth-highest discovery rate in the world, trailing only the three large NASA-funded surveys. In less than three years, they have discovered more than 140 NEOs. Their Atacama Desert location provides a very dark sky with excellent Southern Hemisphere coverage. They were also awarded a 2021 Shoemaker NEO Grant.

Andrea Soffiantini in **Italy** at the Serafino Zani Astronomical Observatory as part of UAB (Unione Astrofili Bresciani) along with **Vladimiro Marinello** (UAB), **Gianpaolo Pizzetti** (UAB), and **Marco Micheli** (ESA NEO Coordination Center) are awarded \$13,120 for a more sensitive camera with a wider field of view, a filter wheel, and filters.

These will aid their ability to respond promptly and accurately to alerts on NEOs moving quickly across the sky (so relatively nearby NEOs) and imminent impactors to help promptly define their orbital paths.

Grzegorz Duszanowicz of **Sweden** is awarded \$12,220 for a camera, corrector lens, computer, and software to upgrade and devote a second telescope to NEO discovery and follow-up observations from the Moonbase South Observatory in **Namibia**. Starting their NEO project with one telescope, Duszanowicz's team discovered 17 NEOs in only eight months. They hope the additions will more than double their discoveries and enable observations of dimmer objects. Their Namibian location has extremely dark skies and lots of clear nights and helps fill a geographical gap in NEO observations. 🌌

THE 5 DAYS OF ASTEROID WEEK

#AsteroidDay took place on June 30, but a single day was not enough for us! We spent a week celebrating the mysteries and missions related to understanding these tiny worlds, through social media, the web, our podcast, and video.

Asteroid Day, a UN-sanctioned global awareness campaign, takes place every year on June 30 — the anniversary of the Tunguska event in 1908, the most harmful known asteroid-related event in Earth's recent history. Asteroid Day's mission is to inspire, engage, and educate the public about asteroid opportunities and risks. The Planetary Society is a proud partner. Go to asteroidday.org to learn more.

BRINGING PLANETARY DEFENSE EXPERTISE TO THE PALM OF YOUR HAND

In our member community app, we held a members-only webinar with Planetary Society Chief Scientist Bruce Betts to discuss the latest updates around protecting Earth from dangerous asteroids and comets. The webinar took place during our campaign to raise support for our Shoemaker Grant program, and we're pleased to announce that thanks to you, we raised more than \$103,000. Watch the full recording at community.planetary.org.



MEET OUR 2023 ZED FACTOR FELLOW

The Planetary Society once again partnered with the Zed Factor Fellowship, which aims to empower and engage aspiring aerospace professionals from underrepresented backgrounds through hands-on, practical experiences working for and contributing to the leading companies of the aerospace community. This summer, University of Pittsburgh Natural Sciences graduate Ariel Barreiro joined us to develop her skills in pursuit of her goal to work in space science communication. Read an interview with Ariel at planetary.org/zedfactor2023.

THE PLANETARY SOCIETY IS FIGHTING FOR VICTORY FOR VERITAS

VERITAS, NASA's first mission to Venus in decades, is in danger of not making it to the launch pad thanks to budget cuts from NASA. The mission would map Venus' surface to determine the planet's geologic history and understand why it developed so differently than Earth. Thanks to a global campaign led by The Planetary Society and our members, interest in the endangered mission to Venus has been reinvigorated. More than a thousand individual supporters penned letters to their representatives, while others



BOOKWORMS OF THE UNIVERSE UNITE!

The Planetary Society's new book club, accessible via our digital member community, has had some stellar guests in our inaugural lineup.

APRIL Andy Weir, "Project Hail Mary"

MAY Phil Plait, "Under Alien Skies"

JUNE Ann Druyan, "Contact"

JULY Matthew Shindell, "For the Love of Mars"

AUGUST Mary Roach, "Packing for Mars"

SEPTEMBER Louis Friedman, "Alone But Not Lonely"

Each month's read is accompanied by a live Q+A with the author. Join the book club and access previous sessions at community.planetary.org.

shared content through various media channels, raising awareness and rallying support for the mission. Leaders from the VERITAS mission joined us for an educational presentation during our digital Day of Action; for an interview on our weekly podcast, Planetary Radio; and on Capitol Hill to meet with policymakers alongside our advocacy team. The campaign has inspired a slew of global media coverage about the mission. We'll continue to keep you posted on our progress to achieve victory for VERITAS.



GO SEE THE ANNULAR SOLAR ECLIPSE!

On Saturday, Oct. 14, 2023, a spectacular annular solar eclipse will cross North, Central, and South America. It will be visible in parts of the United States, Mexico, and many countries in South and Central America.

An annular eclipse occurs when the Moon appears slightly smaller than the Sun and cannot cover the Sun completely. This leaves an annulus, or circle, of Sun still visible on the outside of the Moon. This is sometimes called the “ring of fire.”

ANNULAR SOLAR ECLIPSE VIEWING TIP

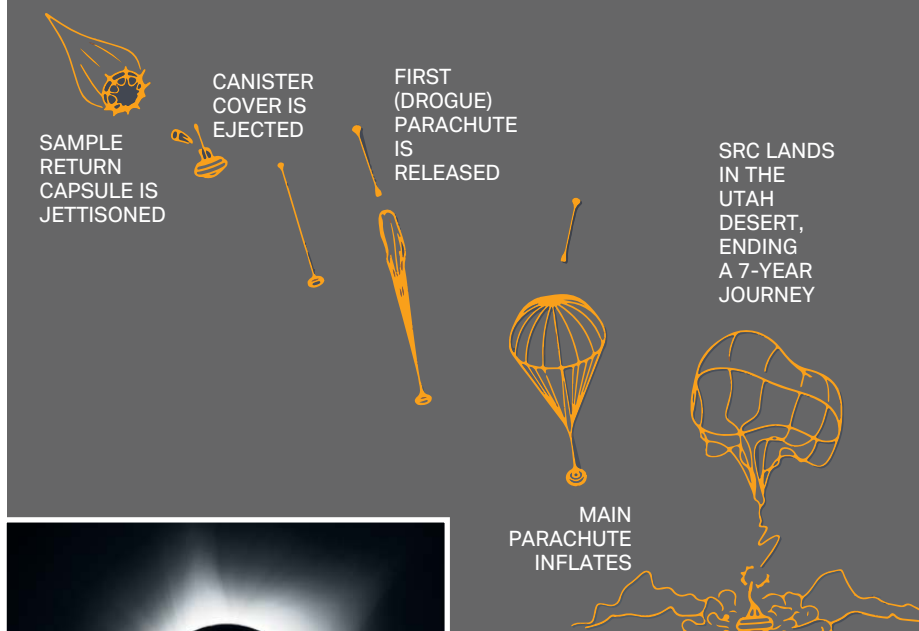
Never look directly at the Sun during an annular eclipse. The Sun is never completely blocked by the Moon during an annular solar eclipse. Therefore, during an annular eclipse, it is never safe to look directly at the Sun without specialized eye protection designed for solar viewing.

HOW TO WATCH

The annular solar eclipse begins in Oregon at 9:13 a.m. PDT and ends in Brazil at 5:13 p.m. CST.

LOCATION	PARTIAL ECLIPSE BEGINS	ANNULARITY BEGINS	MAXIMUM	ANNULARITY ENDS	PARTIAL ECLIPSE ENDS
Eugene, Oregon	8:06 a.m. PDT	9:16 a.m. PDT	9:18 a.m. PDT	9:20 a.m. PDT	10:39 a.m. PDT
Richfield, Utah	9:09 a.m. MDT	10:26 a.m. MDT	10:28 a.m. MDT	10:31 a.m. MDT	11:56 a.m. MDT
Albuquerque, New Mexico	9:13 a.m. MDT	10:34 a.m. MDT	10:35 a.m. MDT	10:39 a.m. MDT	12:09 p.m. MDT
San Antonio, Texas	10:23 a.m. CDT	11:52 a.m. CDT	11:54 a.m. CDT	11:56 a.m. CDT	1:33 p.m. CDT
Belize City, Belize	9:52:56 a.m. CST	11:31:49 a.m. CST	11:34:24 a.m. CST	11:36:59 a.m. CST	1:19:52 p.m. CST
Campeche, Mexico	9:45:26 a.m. CST	11:22:25 a.m. CST	11:24:42 a.m. CST	11:27:00 a.m. CST	1:09:27 p.m. CST
Natal, Brazil	3:29:29 p.m. CST	4:43:55 p.m. CST	4:45:43 p.m. CST	4:47:32 p.m. CST	5:13:34 p.m. CST

OSIRIS-REx SAMPLE RETURN



SAVE THE DATE: ECLIPSE-O-RAMA 2024

The last total solar eclipse in North America for 20 years takes place on April 8, 2024. Mark your calendar for a celestial celebration designed especially for Planetary Society members. Eclipse-O-Rama 2024 will take place in Fredericksburg, Texas, from April 7-8, with live music, educational talks, and engaging activities for all ages. Our CEO, Bill Nye the Science Guy, will be there to share his passion for all things space. Bring your camping gear to stay with us under the stars or book a room in one of our hotel blocks for two unforgettable days of science, discovery, and fun. For updates, visit planetary.org/eclipseorama2024.

NASA'S FIRST ASTEROID SAMPLE WILL ARRIVE SOON

On Sept. 24, 2023, Earth will receive the ultimate space souvenir: a sample from the near-Earth asteroid Bennu, delivered by NASA's OSIRIS-REx (Origins, Spectral Interpretation, Resource Identification, Security-Regolith Explorer). We're planning to watch the return and celebrate with Planetary Society members near the drop-off location in Salt Lake City, Utah. Even if you can't join us, it will be worth tuning into the NASA livestream to watch the nail-biting delivery — the spacecraft must approach Earth at a precise speed and direction to safely deliver its sample return capsule into Earth's atmosphere. Learn more at planetary.org/osirisrex.



Get your limited release Bill Nye + The Planetary Society eclipse glasses!



ISO compliant and CE-certified



IT'S ALMOST INTERNATIONAL OBSERVE THE MOON NIGHT!

On Oct. 21, Moon enthusiasts and curious individuals will unite to learn about lunar science and exploration, take part in celestial observations, and honor personal and cultural connections to the Moon. You can participate in International Observe the Moon Night from anywhere. Join virtual or in-person events, observe from home, and engage with fellow enthusiasts through social media platforms using #ObserveTheMoon. Learn more at moon.nasa.gov/observe-the-moon-night.

CALENDAR OF EVENTS

SEPTEMBER

18

The Planetary Society's Day of Action (Washington, D.C.)

23

Fall/spring equinox

24

OSIRIS-REx returns sample of Benu to Earth

OCTOBER

2-6

International Astronautical Congress (Baku, Azerbaijan)

4-10

World Space Week

5

NASA's Psyche mission launch window opens

14

Annular solar eclipse (North America)

21

International Observe the Moon Night

21-22

Orionids meteor shower

28

Partial lunar eclipse (Europe, Asia, Africa, and western Australia)

NOVEMBER

17-18

Leonids meteor shower

30

Manhattanhenge

DECEMBER

13

Geminid meteor shower



ENHANCE YOUR YOUNG EXPLORER'S RETURN TO SCHOOL

If you know a kid who's fascinated by the Cosmos, now's the perfect time to sign them up for Planetary Academy, a Planetary Society membership designed exclusively for kids ages 5 to 9. Members receive an educational adventure pack every three months that is developed by our space science experts and filled with stunning images, fascinating facts, hands-on activities, experiments, games, and unexpected delights. Your young explorer will be transported to a new world every three months, giving them a full tour of our Solar System. Sign them up today for \$99 a year with an option to renew annually. Go to planetary.org/planetary-academy.



ROBYN VON SWANK

PLANETARY ACADEMY IS ENDORSED BY LEADING EDUCATIONAL MINDS

"Through my roles on 'Star Trek' and 'Reading Rainbow,' I have seen generations of curious minds inspired by the strange new worlds explored in books and [on] television. I know how important it is to encourage that curiosity in a young explorer's life. That's why I am excited to share with you a new program from my friends at The Planetary Society. It's called Planetary Academy, and anyone can join. A lifelong passion for space, science, and discovery starts when we're young. Give the gift of the Cosmos to the explorer in your life."

LeVar Burton
Planetary Society Supporter

YOU ARE PART OF LIGHTSAIL'S LEGACY

Thanks to you, the success of the LightSail® solar sailing missions is one of our greatest shared accomplishments. And we want to continue that legacy by sharing the remarkable impact of LightSail with scientists, engineers, and space enthusiasts around the world. That's where you come in! Your support can help The Planetary Society publish a commemorative book and continue to educate the world about the possibilities of solar sailing.

Your gift of any amount will help us continue to share the story and success of LightSail.

Visit planetary.org/legacy today.



WHAT'S UP?



The Lunar Reconnaissance Orbiter Camera imaged this bright 1.8-kilometer (1.1-mile) crater on Nov. 3, 2018. The Sun shone from the west (left). This image covers an area about 5 miles (8.1 kilometers) across.

NASA/GSFC/ARIZONA STATE UNIVERSITY

ANNULAR ECLIPSE AND A MOST EXCELLENT METEOR SHOWER

IN THE SKY

Super-bright Venus is in the predawn east, dropping lower to the horizon as the weeks pass. Very bright Jupiter and yellowish Saturn are in the eastern evening sky. They move westward as the weeks pass. There is an annular solar eclipse on Oct. 14. Those on the path of annularity (find more information on page 19) will see an annulus (ring) of the Sun surrounding the Moon, and much of the rest of North and South America will see a partial solar eclipse. Use proper eye protection! On Oct. 28, there is a partial lunar eclipse visible from Europe, Africa, Asia, and Australia, but only a small portion of the Moon enters the dark umbral part of Earth's shadow. The Geminids meteor shower peaks Dec. 13/14 with increased activity several days before and after. The Geminids is usually the best shower of the year with 100+ meteors per hour from a dark site, and this year, there will be little interference from a crescent Moon. For more night sky tips, you can always check out [planetary.org/night-sky](https://www.planetary.org/night-sky).

RANDOM SPACE FACT

Having essentially no atmosphere to protect it, the Moon's surface darkens with age over long periods of time due to space weathering, including interactions with the solar wind. This darkening is the main reason material thrown out by younger craters appears brighter than the surroundings.

TRIVIA CONTEST

Our March equinox contest winner is Chris Mills of Arlington, Virginia, USA. Congratulations! The question was: **Other than on Earth, where in the Solar System is there a feature named Thor?** The answer: **On Jupiter's moon Io. Thor is a volcano.**

Try to win a copy of the new book "Solar System Reference for Teens" by Bruce Betts and a Planetary Radio T-shirt by answering this question:
In our Solar System, how many moons are larger than Earth's Moon?

Email your answer to planetaryreport@planetary.org or mail your answer to The Planetary Report, 60 S. Los Robles Ave., Pasadena, CA 91101. Make sure you include the answer and your name, mailing address, and email address (if you have one). By entering this contest, you are authorizing The Planetary Report to publish your name and hometown. Submissions must be received by December 1, 2023. One entry per person. The winner will be chosen in a random drawing from among all the correct entries received.

SOCIETY TRAVEL



Please contact Terri or Taunya at Betchart Expeditions for brochures and updated information on COVID and travel. Call 1-800-252-4910 or go to [betchartexpeditions.com](https://www.betchartexpeditions.com).

We invite you to join other members of The Planetary Society to discover the world on Betchart Adventures!

GRAND STAIRCASE UTAH ANNULAR SOLAR ECLIPSE OCT. 9-17, 2023

See the annular solar eclipse over the stunning red rock country of southern Utah, led by geologist Dr. Andre Potochnik. See the north rim of the Grand Canyon, Monument Valley, and more!

ALASKA AURORA BOREALIS MARCH 7-13, 2024

Discover magnificent Denali and the northern lights in the pristine splendor of Alaska in winter. With leadership by astronomer Dr. Joe Llama.

MEXICO COPPER CANYON & DURANGO TOTAL SOLAR ECLIPSE APRIL 1-9, 2024

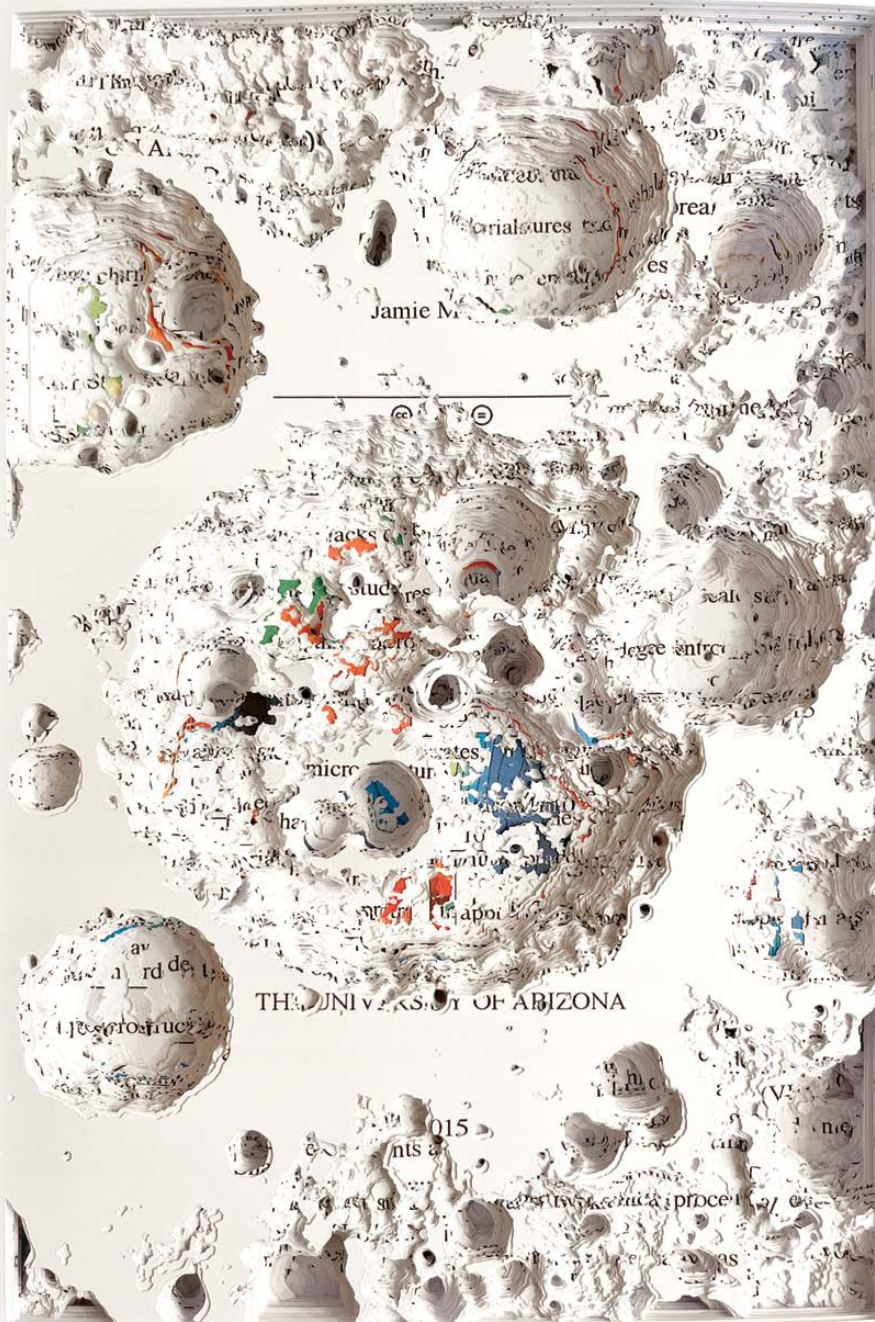
Discover Copper Canyon and Mazatlan and then see the total eclipse in historic Durango. *Book now. Almost sold out.*

ARGENTINA ANNULAR SOLAR ECLIPSE SEPT. 26-OCT. 7, 2024

See the annular eclipse near historic Puerto San Julian on the Atlantic Coast of Argentina, where the historic sailing voyages of Magellan, Sir Francis Drake, and Charles Darwin stopped en route to the Pacific Ocean. Also visit Buenos Aires and see stunning Iguazu Falls.

EASTER ISLAND ANNULAR SOLAR ECLIPSE SEPT. 27-OCT. 5, 2024

Explore the extraordinary cultural and archaeological wonders of legendary Easter Island and see the annular solar eclipse! *Book now. Almost sold out.*



The Book of Moon

Jamie Molaro

It's a tradition among many grad students to burn a copy of their Ph.D. thesis after successfully defending it. When planetary scientist and artist Jamie Molaro finished her Ph.D. at the University of Arizona, she opted for a different form of catharsis. "My thesis focused on how rocks weather and break down on the Moon, so from the pages, I carved a cratered lunar landscape," said Molaro. She used data from the Lunar Orbiter Laser Altimeter aboard NASA's Lunar Reconnaissance Orbiter to carve accurate, detailed lunar topography into her thesis, page by page. "It juxtaposes the science behind the breakdown process with the beauty of the landscape it helps to produce. You can also see the text and figures on the pages peek through the topography. So, the pages of the thesis also reveal the scientific process, juxtaposing the creation of knowledge with the creation of art."

Do you want to see your artwork here? We love to feature our members throughout this magazine. Send your original, space-related artwork to connect@planetary.org.