

# Astronomy<sup>®</sup>

THE WORLD'S BEST-SELLING ASTRONOMY MAGAZINE /// NOVEMBER 2024

EVERYTHING WE KNOW ABOUT

# THE SUN

## PLUS:

THE  
STARMUS  
FESTIVAL  
ROCKS  
SLOVAKIA

WEBB  
UNLOCKS  
STARBIRTH  
IN SERPENS

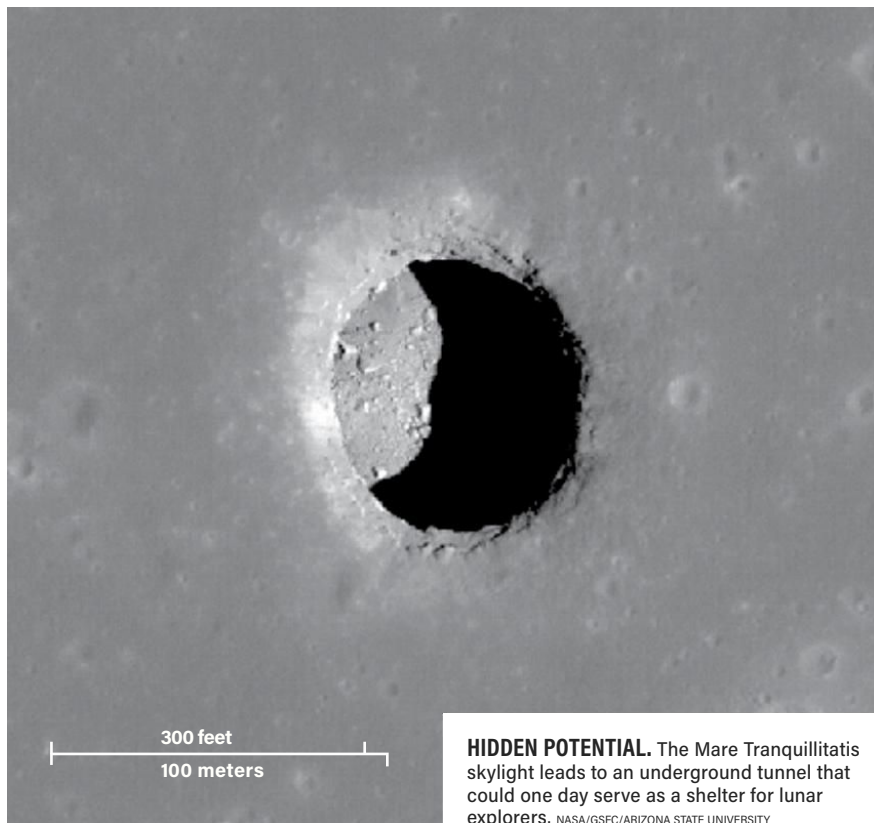
BEHIND  
THE SCENES  
AT A  
ROCKET  
LAUNCH

WHAT  
CAUSES  
RAINBOWS  
AND  
MOONBOWS?

**BONUS  
ONLINE  
CONTENT  
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# LUNAR LAVA TUBE COULD SHELTER A FUTURE MOON BASE

A volcanic eruption formed an underground tunnel on the Moon, uncovered by a recent analysis of radar data.



**HIDDEN POTENTIAL.** The Mare Tranquillitatis skylight leads to an underground tunnel that could one day serve as a shelter for lunar explorers. NASA/GSFC/ARIZONA STATE UNIVERSITY

» The Moon's surface presents an unforgivingly harsh environment. Without an atmosphere or magnetic field, it is vulnerable to deadly coronal mass ejections from the Sun, levels of hazardous radiation 150 times greater than on Earth, and a perpetual rain of impacting meteorites. Its temperature ranges from 260 degrees Fahrenheit (127 degrees Celsius) in the daytime to -280 F (-173 C) during lunar night.

For all these reasons, prospective lunar explorers are increasingly considering an alternative to living on the Moon's surface: living beneath it, in subsurface caves. Over the past

15 years, satellite images have revealed hundreds of large pits lined with ledges that appear to overhang their floors. Researchers have hoped these could be openings to more cavernous underground spaces, like lava tubes — subsurface channels through which molten lava once flowed — left over from volcanic eruptions billions of years ago. But evidence has been lacking.

A new analysis of radar observations, published July 15 in *Nature*, indicates that at least one such pit, located in Mare Tranquillitatis (Sea of Tranquillity), leads to an underground tunnel that extends for tens of meters — and possibly much longer.

## A NEW TRANQUILLITY BASE?

Scientists first recognized lunar pits 15 years ago in images from Japan's Kaguya and NASA's Lunar Reconnaissance Orbiter (LRO). Since then, more than 200 skylightlike pits ranging from 16 to 1,000 feet wide (5 to 300 meters) have been found with the additional help of India's Chandrayaan and China's Chang'e orbiters. Around a dozen pits have shown promise of leading to underground chambers.

A 2017 study of one example in the Marius Hills, a former volcanic hot spot on Oceanus Procellarum, combined Kaguya radar data with gravity data taken by NASA's Gravity Recovery and Interior Laboratory (GRAIL) mission. It revealed that areas around the Marius Hills pit with a deficit of gravity also tended to have a distinct double radar echo — a strong indication of subsurface voids, with a cave floor producing a second echo bounce.

The skylight discussed in the new work was discovered in LRO imagery in 2011. It spans 210 feet (65 m) and features a boulder-strewn floor 120 feet (36 m) below the surface.

The study analyzes the radio signal reflected from Mare Tranquillitatis using LRO's Miniature Radio Frequency instrument in 2010. The radio return signal is consistent with an initial bounce off the Moon's surface and a second bounce from the floor of a subsurface chamber.

3D modeling of the radar signal, accounting for the viewing angle of the satellite, indicates that an underground conduit extends west of the pit and the collapsed rock pile at its center. Further observations could determine whether the conduit continues in the opposite direction, to the east, the team says.



**BLOWING UP THE MARKET.** Future habitats placed in the shelter of lunar lava tubes could be based on the inflatable BEAM module currently being tested on the International Space Station. NASA

This result is “the first direct evidence of an accessible lava tube under the surface of the Moon,” Lorenzo Bruzzone, a remote-sensing expert at the University of Trento and study co-author, said in a press release. It “suggests that the [Mare Tranquillitatis pit] is a promising site for a lunar base, as it offers shelter from the harsh surface environment and could support long-term human exploration of the Moon,” the authors write.

### HOW TO SETTLE A MOON CAVE

In the near term, NASA’s plans for the Artemis program call for landing and establishing a base near the lunar south pole, where astronauts can access water ice within permanently shadowed craters. But underground caves and lava tubes are a natural next step for a permanent, sheltered lunar base.

If a stable, suitable lava tube can be identified, a habitat solution may already be at hand. An inflatable module dubbed the Bigelow Expandable Activity Module (BEAM) has been attached to the International Space Station since 2016 for long-term testing. Instead of sealing off and pressurizing the entire lava tube, it may be more practical to deploy a similar inflatable habitat within the lava tube’s shelter. Additional data returned by LRO’s Diviner Lunar Radiometer Experiment show the temperature within the Tranquillitatis skylight is a benign 63 F (17 C), which would simplify the design of an inflatable habitat.

It would be ironic if, after 30 millennia of evolution, humankind were to revert off-world to being cave-dwellers once again — but lunar lava tubes show real promise to shelter future astronauts.

— ROBERT REEVES

### MARTIAN MOSS

The desert moss *Syntrichia caninervis* — found in the Mojave Desert, Antarctica, and elsewhere — is so hardy it could help terraform Mars, a Chinese team has found. Tests show the plant can survive extreme desiccation, gamma radiation, and five years at a temperature of -112 F (-80 C).

### SPACEPLANE MASTER

X-15 pilot and astronaut Joe Engle died July 10 at 91. Due to fly on Apollo 17, he was passed over by NASA in favor of geologist Harrison Schmitt. He later commanded two space shuttle missions, becoming the only person to fly both the X-15 and the shuttle to space.

### LOOKING UP

On June 19, Kosovo opened its first national observatory and planetarium, an effort spearheaded by Pranvera Hyseni, a Kosovo native and a Ph.D. candidate at the University of California, Santa Cruz. The primary telescope is a C14 donated by Celestron.

### LUNAR ARK

Scientists have proposed building a repository on the Moon to safely store genetic samples of most of Earth’s species. Crater floors near the poles that lie permanently in shadow are cold enough to serve as natural cryogenic freezers, says a July 31 paper in *BioScience*.

### FIRST FLIGHT

Europe’s new heavy-lift Ariane 6 rocket made its first demonstration flight July 9, launching to low Earth orbit from French Guiana. The launch system replaces the Ariane 5, which was retired in 2017.

### CLOUDY ORIGINS

Our solar system may have passed through a dense molecular cloud 2 million to 3 million years ago, shrinking the Sun’s magnetic field and leaving Earth exposed to the cloud, a *Nature Astronomy* study suggests. This could have resulted in climate change that led to the rise of humans. — MARK ZASTROW

## Vera C. Rubin Observatory’s secondary mirror now in place

On July 24, 2024, the 3.4-meter secondary mirror of the Vera C. Rubin Observatory’s Simonyi Survey Telescope in Chile was installed — the first permanent piece of the telescope’s optical system to be put in place. The secondary had been shipped to Chile in 2018 from Rochester, New York, and stored there while the telescope’s mount was completed over the last few years. To install the mirror, a team used a cart to rotate it vertically and then lifted it onto the mount, taking care to not stress the glass.

Following the telescope’s primary mirror installation, slated for August, will come the integration of the Legacy Survey of Space and Time (LSST) camera. Once the system is complete, the decade-long LSST is set to start in 2025.

— ELIZABETH GAMILLO



RUBIN OBSERVATORY/NSF/AURA/E. MUNKOZ/ARANCIBIA