

# Sun science has a bright future on the moon

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Image of the Moon transiting across the Sun, using a blend of 171 ångstrom extreme ultraviolet light and visible light imagery from NASA's Solar Dynamics Observatory from August 21, 2017. Credit: NASA/SDO

There are many reasons NASA is pursuing the Artemis mission to land astronauts on the moon by 2024: It's a crucial way to study the moon itself and to pave a safe path to Mars. But it's also a great place to learn more about protecting Earth, which is just one part of the larger Sun-Earth system.

Heliophysicists—scientists who study the Sun and its influence on Earth—will also be sending up their own NASA missions as part of Artemis. Their goal is to better understand the complex space environment surrounding our planet, much of which is driven by our Sun. The more we understand that system, the more we can protect

[space technology](#), radio communications, and utility grids from the wrath of our closest star.

Here are five reasons that heliophysicists are over the moon about lunar opportunities.

## **1. It's a Steady Satellite**

The first advantage of moon-based science concerns satellite jitter, which rattles space scientists of every stripe.

Satellites are shakier than you might think. They're made of metals that expand and contract with temperature changes. They carry telescopes that constantly pivot to stay pointed at targets. They fire boosters and spin reaction wheels to stay in orbit. Each of these maneuvers causes jitter, which can throw off measurements that demand precision.

But the moon—Earth's only natural satellite—is a much smoother ride.

"The moon is a nice stable place—it doesn't shake or jitter like a spacecraft," said David Sibeck, a heliophysicist at NASA's Goddard Space Flight Center in Greenbelt, Maryland. "Anyone trying to do high-resolution measurements will be happy to not have to worry about jitter."

A jitter-free environment is a plus for all space sciences, but there are added bonuses for heliophysicists who study the aurora. At an average of 238,855 miles from Earth, the moon has a great view of Earth's aurora when they move equatorward during large geomagnetic storms. In addition, since the same side of the moon always faces Earth, telescopes don't need to be adjusted nearly as much. Plant them on its surface, and the moon keeps them pointed for you.

## 2. Prime Eclipse Viewing, On Demand

Long before the space age, scientists relied on the moon to help them study the Sun. Patient observers waited for total solar eclipses, when the moon blocks out the Sun's bright surface. Only then could they see its tenuous outer atmosphere, known as the corona.

But the waits could be long. A [total solar eclipse](#) happens somewhere on Earth once every 18 months. For any specific location, it's more like once every four centuries.

"We get fantastic results out of eclipses," said John Cooper, a heliophysicist at Goddard. "But we don't get them every day."

But a Sun-watching telescope, in the right sort of orbit around the moon, could generate eclipses "on demand." Instead of waiting for the moon to move across your telescope's line of view, Cooper explains, you move your line of view behind the moon.

"Basically you are using the knife edge of the lunar limb against the deep dark, black sky," said Cooper. Since the moon has no image-distorting atmosphere to look through, the measurements would be even crisper than those made on Earth.

From its up-close orbit, such a telescope wouldn't generate total solar eclipses—it would study one part of the Sun's limb would at a time. But Cooper estimates you could see both the eastern and western limbs of the Sun once each orbit—two high-resolution views, every single day.

## 3. It's Outside Earth's Magnetic Field

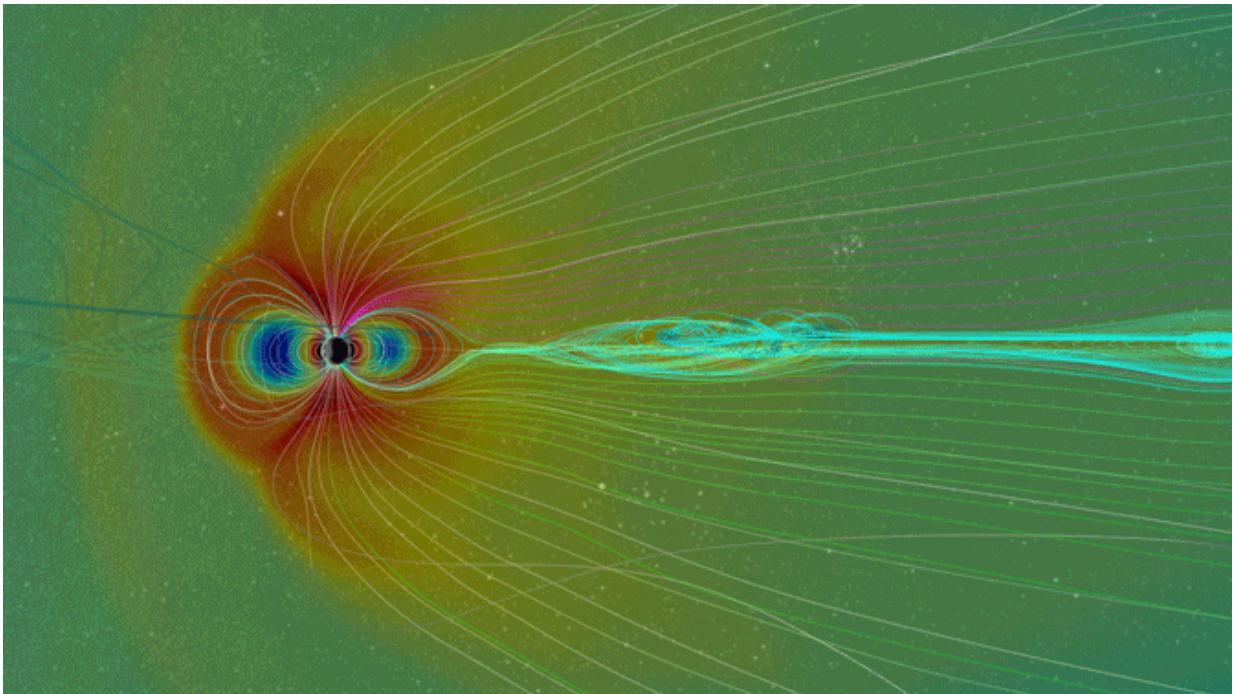
Space weather is a part of heliophysics where pure science gets real-time

application. Space weather scientists study the Sun—including its constant stream of solar wind—and their impacts on Earth. These applied researchers have to get that fundamental physics right to keep our valuable communications and GPS satellites safe. But determining whether a satellite is in danger can be tricky.

A satellite's safety depends, in part, on whether it is inside or outside of Earth's magnetopause. The magnetopause is a shifting no-man's-land where Earth's magnetic shield ends and the full brunt of space weather begins. Inside, you're largely safe. Outside, you're not.

But right now, the only way to know where that boundary is, is to fly through it.

"Sometimes there's a wiggle in the data, and you can see the boundary crossed you," said Sibeck. "Sometimes you see ten wiggles."



A simulated coronal mass ejection hits Earth's magnetic field. Credits: NASA's Goddard Space Flight Center/Scientific Visualization Studio/Community-Coordinated Modeling Center

But there's another way to find the magnetopause if you can get far enough outside Earth's magnetic shield. When the solar wind hits Earth's atmosphere just outside the magnetopause, it emits X-rays. A properly-placed X-ray telescope could capture that light and track the location of the magnetopause.

That's why Sibeck is on a team, led by space scientist Brian Walsh at Boston University, that is putting an X-ray telescope on the moon.

"Nobody's taken these global pictures, and the moon has a good vantage point from outside Earth's magnetic field," said Sibeck.

The Lunar Environment heliospheric X-ray Imager, or LEXI mission, will be planted on the lunar surface to take real-time, global pictures of the magnetopause. On July 1, 2019, NASA announced that LEXI will be among the first lunar payloads to take part in the Artemis mission. They expect to be on the moon's surface as soon as 2022.

LEXI is a little more than a yard long, but the lunar surface can accommodate much larger X-ray telescopes. That's good news, because X-rays are hard to focus; longer telescopes get much higher-resolution images. The requirement to be large has posed a problem; some satellites just aren't big enough to carry them. "But on the moon, things can be really big," said Sibeck.

## **4. You Can Dig Up the Sun's History**

The answer to some questions in heliophysics lie buried on the moon itself.

"The moon is like a time capsule," said Steve Clarke, Deputy Associate Administrator for Exploration at NASA. "Because it was formed at the same time as the Earth, it's got the history of the solar system on its surface."

During its first billion years, the Sun likely spun faster than it does today, shooting out a higher volume of solar eruptions and electrifying the very space that formed the planets. But to know for sure what that first billion years was like, we need evidence for things that happened long, long ago.

The moon—which has no atmosphere, no liquid water, and no plate tectonics—provides just such a historical record. Solar eruptions from billions of years ago leave undisturbed traces in lunar dust.

A recent paper looked to lunar dust to study the amount of volatiles—elements like sodium and potassium, with low boiling points—that remained in lunar samples. These volatiles are kicked off the moon when energetic solar particles strike the lunar surface. By looking at how much of these elements have been depleted over time, scientists saw our Sun's first billion years in a broader context. Though it used to spin faster than it does today, compared to others it was still a "slow rotator," spinning slower than 50% of similar stars—and erupting far less often than it might have.

"It could have been a much harsher environment," said Prabal Saxena, lead author of the study and an astronomer at Goddard.

There's still more ancient history to learn from lunar dust. The moon does not have a global magnetic field—but it may have had one in the past. Samples from the moon's poles, where the upcoming Artemis

mission plans to land, could show whether a historical magnetic field changed the pattern of volatiles left behind.

## **5. It's a Testbed for Mars**

For future astronauts on the moon and Mars, space weather will require constant attention. The Sun dishes up plenty to worry about—and it travels fast.

On the moon, X-ray light from solar flares reaches the surface within eight minutes. Coronal mass ejections—giant clouds of hot, charged particles—can reach it within a day. Solar energetic particles, or SEPs, are rarer but even faster and more dangerous.

"SEPs come at 10, 20% the speed of light, reaching us within an hour," said Karin Muglach, a solar physicist at Goddard's Space Weather Lab. "These things are like bullets."

Because the moon is a mere light-second away, warning systems on Earth should serve well enough to protect astronauts on the moon. "But if you go out to Mars, communication can be quite delayed," said Muglach.

Testing such protection systems nearby is one of the reasons NASA is going to the moon before going to Mars.

## **To the Moon and Beyond**

As NASA goes forward to the [moon](#) and on to Mars, new opportunities to learn about the Sun-Earth connection abound. But it's not just basic science. The Sun's influence fills the space around us—the very space that future astronauts will have to navigate and understand.



"Not all sciences get to have that really practical aspect," said Jim Spann, lead [space](#) weather scientist at NASA Headquarters in Washington, D.C. "I think that that's pretty cool."

Provided by NASA's Goddard Space Flight Center

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