South Downs Mercury

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Main Talk. William Joyce "Volcanoes and Ice Volcanoes in the Solar System"

Bio

William has worked in space research at Leicester university with Earth remote sensing satellite instruments and in industry in laboratories, space software engineering and later in aerospace systems engineering. William changed career in the mid 2000's and obtained a degree in Earth and Planetary science and followed this with university teaching and astronomy work

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- The Sun's hidden poles could finally reveal its greatest secrets

Date: October 14, 2025
Source: Beijing Zhongke Journal Publishing Co. Ltd.

Schematic of the Solar Polar-orbit Observatory. Credit: Zhenyong Hou and Jiasheng Wang at Peking University

The Sun's polar regions remain one of the least explored areas in solar science. Space-based observatories and ground telescopes have given us extraordinary images of the Sun's surface, atmosphere, and magnetic fields, but nearly all of those observations come from within the ecliptic plane -- the narrow zone where Earth and most other planets orbit. This viewing angle limits what scientists can see of the Sun's high-latitude poles. Yet these regions are crucial, as their magnetic fields and dynamic activity help shape the solar magnetic cycle and supply the mass and energy that feed the fast solar wind, influencing solar behaviour and driving space weather throughout the solar system.

Why the Poles Matter

At first glance, the Sun's poles seem calm compared to the active mid-latitudes around ±35°, where sunspots, solar flares, and coronal mass ejections (CMEs) dominate. But appearances are deceiving. The magnetic fields at the poles are vital to the Sun's global dynamo process and may act as "seed fields" that shape the next solar cycle, defining the overall solar magnetic structure. Data from the Ulysses spacecraft showed that the fast solar wind originates mainly from vast coronal holes near the poles. Understanding these regions is therefore key to answering three of the most important questions in solar physics:

1. How does the solar dynamo operate and drive the magnetic cycle?

The Sun's magnetic cycle is a repeating pattern that lasts about 11 years, marked by fluctuations in sunspot numbers and a complete reversal of the Sun's magnetic poles. This process is driven by a complex dynamo mechanism powered by the Sun's internal motion. Differential rotation produces magnetic activity, while meridional circulation carries magnetic flux toward the poles. However, decades of Helio seismic studies have revealed conflicting information about how these flows behave deep inside the convection zone. Some evidence even points to poleward flows at the base of the zone, challenging traditional dynamo theories. Observations from high latitudes are needed to clarify these internal flow patterns and refine existing models.

2. What powers the fast solar wind?

The fast solar wind -- a supersonic stream of charged particles -- originates mainly in the Sun's polar coronal holes and fills most of the heliosphere, shaping conditions in interplanetary space. Yet scientists still do not fully understand how it begins. Does it emerge from dense plumes inside the coronal holes, or from the more diffuse regions

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between them? Are magnetic reconnection events, wave interactions, or both responsible for accelerating the flow? Only direct imaging of the poles and in-situ measurements can resolve these long-standing questions.

3. How do space weather events spread through the solar system?

Space weather refers to changes in the solar wind and solar eruptions that disturb the space environment. Extreme events such as powerful flares and CMEs can trigger geomagnetic and ionospheric storms on Earth, creating dazzling auroras but also threatening satellites, communication systems, and power grids. To improve forecasts, researchers must follow how solar material and magnetic structures evolve across the Sun and through space, not just from the limited perspective of Earth's orbital plane. Observing from outside the ecliptic would provide a crucial top-down view, helping scientists trace how CMEs and other disturbances travel through the solar system.

Past Efforts

Scientists have long recognized the importance of solar polar observations. The Ulysses mission, launched in 1990, was the first spacecraft to leave the ecliptic plane and sample the solar wind over the poles. Its in-situ instruments confirmed key properties of the fast solar wind but lacked imaging capability. More recently, the European Space Agency's Solar Orbiter has been gradually moving out of the ecliptic plane and is expected to reach latitudes of around 34° in a few years. While this represents a remarkable progress, it still falls far short of the vantage needed for a true polar view.

A number of ambitious mission concepts have been proposed over the past decades, including the Solar Polar Imager (SPI), the POLAR Investigation of the Sun (POLARIS), the Solar Polar ORbit Telescope (SPORT), the Solaris mission, and the High Inclination Solar Mission (HISM). Some envisioned using advanced propulsion such as solar sails to reach high inclinations. Others relied on gravity assists to incrementally tilt their orbits. Each of these missions would carry both remote-sensing and in-situ instruments to image the Sun's poles and measure key physical parameters above the poles.

The SPO Mission

The Solar Polar-orbit Observatory (SPO) is designed specifically to overcome the limitations of past and current missions. Scheduled for launch in January 2029, SPO will use a Jupiter gravity assist (JGA) to bend its trajectory out of the ecliptic plane. After several Earth flybys and a carefully planned encounter with Jupiter, the spacecraft will settle into a 1.5-year orbit with a perihelion of about 1 AU and an inclination of up to 75°. In its extended mission, SPO could climb to 80°, offering the most direct view of the poles ever achieved.

The 15-year lifetime of the mission (including an 7-year extended mission period) will allow it to cover both solar minimum and maximum, including the crucial period around 2035 when the next solar maximum and expected polar magnetic field reversal will occur. During the whole lifetime, SPO will repeatedly pass over both poles, with extended high-latitude observation windows lasting more than 1000 days.

The SPO mission aims at breakthroughs on the three scientific questions mentioned above. To meet its ambitious objectives, SPO will carry a suite of several remote-sensing and in-situ instruments. Together, they will provide a comprehensive view of the Sun's poles. The remote-sensing instruments include the Magnetic and Helio seismic Imager (MHI) to measure magnetic fields and plasma flows at the surface, the Extreme Ultraviolet Telescope (EUT) and the X-ray Imaging Telescope (XIT) to capture dynamic events in the solar upper atmosphere, the VISible-light CORonagraph (VISCOR) and the Very Large Angle CORonagraph (VLACOR) to track the solar corona and solar wind streams out to 45 solar radii (at 1 AU). The in-situ package includes a magnetometer and particle detectors to sample the solar wind and interplanetary magnetic field directly. By combining these observations, SPO will not only capture images of the poles for the first time but also connect them to the flows of plasma and magnetic energy that shape the heliosphere.

SPO will not operate in isolation. It is expected to work in concert with a growing fleet of solar missions. These include the STEREO Mission, the Hinode satellite, the Solar Dynamics Observatory (SDO), the Interface Region Imaging Spectrograph (IRIS), the Advanced Space-based Solar Observatory (ASO-S), the Solar Orbiter, the Aditya-L1 mission, the PUNCH mission, as well as the upcoming L5 missions (e.g., ESA's Vigil mission and China's LAVSO mission).

Together, these assets will form an unprecedented observational network. SPO's polar vantage will provide the missing piece, enabling nearly global 4π coverage of the Sun for the first time in human history.

Looking Ahead

The Sun is our nearest star, yet much about it remains unknown. The upcoming Solar Polar-orbit Observatory (SPO) mission is expected to change that by giving scientists an unprecedented look at the Sun's polar regions. These areas, which have long been hidden from direct view, will soon be observed in detail, offering new insight into the forces that shape our star and sustain life on Earth.

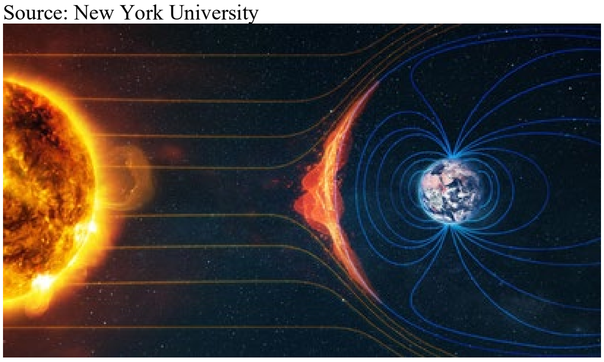
The importance of SPO goes far beyond pure scientific curiosity. By improving knowledge of the solar dynamo, the mission could lead to more accurate predictions of the solar cycle and, in turn, more reliable space weather forecasts. Understanding how the fast solar wind forms and behaves will also refine models of the heliosphere, which is vital for spacecraft engineering and astronaut safety. Most significantly, advances in tracking solar activity could strengthen our ability to safeguard critical technologies, including navigation and communication satellites, aviation systems, and power grids on Earth.

- ❖ This new AI can spot solar storms days before they strike

Breakthrough improves early warnings to protect satellites and power grids

Date: September 17, 2025

Source: New York University



NYU Abu Dhabi scientists developed an AI system that forecasts solar wind with 45% better accuracy than current models. This breakthrough strengthens defences against space weather that threatens satellites and critical infrastructure. Credit: Shutterstock

Scientists at NYU Abu Dhabi (NYUAD) have developed an artificial intelligence (AI) model that can forecast solar wind speeds up to four days in advance, significantly more accurately than current methods. The study is published in *The Astrophysical Journal Supplement Series.*

Solar wind is a continuous stream of charged particles released by the Sun. When these particles speed up, they can cause "space weather" events that disrupt Earth's atmosphere and drag satellites out of orbit, damage their electrons, and interfere with power grids. In 2022, a strong solar wind event caused SpaceX to lose 40 Starlink satellites, showing the urgent need for better forecasting.

The NYUAD team, led by Postdoctoral Associate Dattaraj Dhuri and Co-Principal Investigator at the Centre for Space Science (CASS) Shravan Hanasoge, trained their AI model using high-resolution ultraviolet (UV) images from NASA's Solar Dynamics Observatory, combined with historical records of solar wind. Instead of analysing text, like today's popular AI language models, the system analyses images of the Sun to identify patterns linked to solar wind changes. The result is a 45 percent improvement in forecast accuracy compared to current operational models, and a 20 percent improvement over previous AI-based approaches.

"This is a major step forward in protecting the satellites, navigation systems, and power infrastructure that modern life depends on," said Dhuri, lead author of the study. "By combining advanced AI with solar observations, we can give early warnings that help safeguard critical technology on Earth and in space."

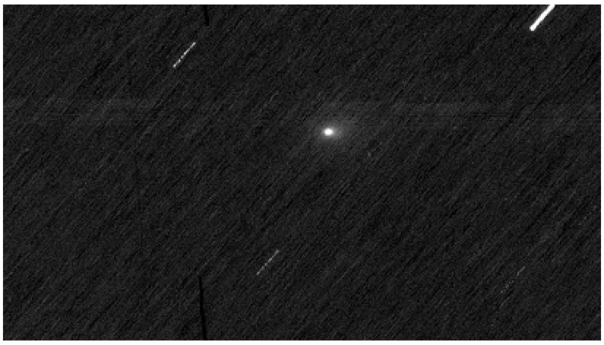
The breakthrough demonstrates how AI can solve one of space science's toughest challenges: predicting the solar wind. With more reliable forecasts, scientists and engineers can better prepare for space weather events, strengthening resilience against disruptions to critical infrastructure.

NYU Abu Dhabi has established more than 90 faculty labs and projects, producing over 9,200 internationally recognized research publications. Times Higher Education ranks NYU among the world's top 35 universities, making NYUAD the highest globally ranked university in the UAE.

- ❖ An interstellar visitor lights up the Red Planet’s sky

Date: October 12, 2025

Source: European Space Agency (ESA)


On October 3, ESA's ExoMars Trace Gas Orbiter (TGO) turned its eyes towards interstellar comet 3I/ATLAS as it passed close to Mars. It looked towards the interstellar interloper from 30 million km away during its closest approach to the Red Planet. ExoMars TGO used its dedicated Colour and Stereo Surface Imaging System (CaSSIS) to capture the comet, an instrument normally used to photograph the bright surface of Mars from a few hundred to a few thousand kilometres away. Comet 3I/ATLAS is the slightly fuzzy white dot towards the right of the image. Despite not being designed to capture something so far away, ExoMars TGO revealed the coma of gas and dust surrounding the icy-rocky nucleus. Credit: ESA/TGO/CaSSIS

Between October 1 and 7, ESA's ExoMars Trace Gas Orbiter (TGO) and Mars Express spacecraft turned their instruments toward interstellar comet 3I/ATLAS as it passed near Mars.

Of all ESA spacecraft, the two Mars orbiters had the best view of this rare visitor. During its closest approach to the Red Planet on October 3, the comet was about 30 million km away.

Both orbiters used their onboard cameras to track the comet's motion. These instruments are typically designed to capture Mars's bright surface from just a few hundred to a few thousand kilometres above it, so observing such a faint object at such a great distance presented a major challenge.

ExoMars TGO successfully recorded a series of images using its Colour and Stereo Surface Imaging System (CaSSIS). In the animation below, comet 3I/ATLAS appears as a faint white spot drifting downward near the centre. That small blur marks the heart of the comet, made up of its icy, rocky nucleus surrounded by a glowing cloud called the coma.

Because the comet was so distant, CaSSIS could not separate the nucleus from the coma. Detecting the nucleus itself would have been like trying to spot a mobile phone on the Moon from Earth.

The coma, however, is clearly visible. Stretching several thousand kilometres across, it forms as sunlight warms the comet, releasing gas and dust that collect into a hazy halo around the core.

CaSSIS could not measure the coma's full extent because its brightness fades rapidly with distance from the nucleus, eventually disappearing into background noise.

Usually, gas and dust from the coma stream away to create a long tail that can stretch for millions of kilometres as the comet nears the Sun. The tail is much dimmer than the coma, so it does not appear in the current images, but it could become visible in future observations as 3I/ATLAS heats up and sheds more ice.

Nick Thomas, Principal Investigator of the CaSSIS camera, said, "This was a very challenging observation for the instrument. The comet is around 10,000 to 100,000 times fainter than our usual target.

The work continues

So far, 3I/ATLAS has not been detected in the Mars Express images. One reason is that Mars Express can only take exposures of up to 0.5 seconds (its maximum limit), while ExoMars TGO was able to use five-second exposures.

Researchers are continuing to process the data from both orbiters. They plan to combine multiple Mars Express images to enhance the faint signal and improve their chances of detecting the comet.

The teams also attempted to study the comet's light spectrum using the OMEGA and SPICAM spectrometers on Mars Express and the NOMAD instrument on ExoMars TGO. It remains uncertain whether the coma and tail were bright enough to allow scientists to identify the comet's chemical composition.

Over the coming weeks and months, researchers will keep analysing the data to learn more about the materials that make up 3I/ATLAS and how it changes as it draws closer to the Sun.

Colin Wilson, Mars Express and ExoMars project scientist at ESA, said: "Though our Mars orbiters continue to make impressive contributions to Mars science, it's always extra exciting to see them responding to unexpected situations like this one. I look forward to seeing what the data reveals following further analysis."

A rare visitor

Originating from outside our Solar System, comet 3I/ATLAS is only the third interstellar comet ever seen, following 1I/'Oumuamua in 2017 and 2I/Borisov in 2019.

These comets are absolutely foreign. Every planet, moon, asteroid, comet and lifeform in our Solar System share a common origin. But interstellar comets are true outsiders, carrying clues about the formation of worlds far beyond our own.

Comet 3I/ATLAS was first spotted on July 1, 2025, by the Asteroid Terrestrial-impact Last Alert System (ATLAS) telescope in Río Hurtado, Chile. Since then, astronomers have used ground-based and space telescopes to monitor its progress and discover more about it.

Based on its trajectory, astronomers suspect that 3I/ATLAS could be the oldest comet ever observed. It may be three billion years older than the Solar System, which is itself already 4.6 billion years old.

What's next?

Next month, we will observe the comet with our Jupiter Icy Moons Explorer (Juice). Though Juice will be further from 3I/ATLAS than our Mars orbiters were last week, it will see the comet just after its closest approach to the Sun, meaning that it will be in a more active state. We don't expect to receive data from Juice's observations until February 2026 -- find out why in our FAQs.

Icy wanderers such as 3I/ATLAS offer a rare, tangible connection to the broader galaxy. To actually visit one would connect humankind with the Universe on a far greater scale. To this end, ESA is preparing the Comet Interceptor mission.

Comet Interceptor is due to launch in 2029 into a parking orbit, from where it will lie in wait for a suitable target -- a pristine comet from the distant Oort Cloud that surrounds our Solar System, or, unlikely but highly appealing, an interstellar object like 3I/ATLAS.

Michael Kueppers, Comet Interceptor project scientist expands: "When Comet Interceptor was selected in 2019, we only knew of one interstellar object -- 1I/'Oumuamua, discovered in 2017. Since then, two more such objects have been discovered, showing large diversity in their appearance. Visiting one could provide a breakthrough in understanding their nature."

While it remains improbable that we will discover an interstellar object that is reachable for Comet Interceptor, as a first demonstration of a rapid response mission that waits in space for its target, it will be a pathfinder for possible future missions to intercept these mysterious visitors.

- Harvard astrophysicist suggests mysterious interstellar object may be an alien probe

Date: October 15, 2025
Source: The Conversation

This is a Hubble Space Telescope image of the interstellar object 3I/ATLAS. Hubble photographed the comet on July 21 2025, when 3I/ATLAS was 365 million kilometres from Earth. Because Hubble was tracking the comet moving along a hyperbolic trajectory, the stationary background stars are streaked in the exposure. Credit: NASA, ESA, D. Jewitt (UCLA); Image Processing: J. DePasquale (STScI)

On July 1, astronomers detected a strange, fast-moving object racing toward the Sun. Named 3I/ATLAS, this unusual traveller immediately stood out for one remarkable reason: its orbital path revealed that it had come from beyond our Solar System.

This marked only the third time in history that scientists have identified an interstellar visitor entering our cosmic neighbourhood. And this one was particularly puzzling.

3I/ATLAS sets new records

Measurements show that 3I/ATLAS is moving at an incredible 245,000 kilometres per hour, making it the fastest known object ever observed within the Solar System.

It also appears to be enormous. Early estimates indicate that the body could span up to 20 kilometres in diameter, and researchers believe it may even predate the formation of the Sun itself.

Could it be alien?

Typically, when astronomers encounter a new object in space, they assume it is composed of rock, ice, or a combination of the two. However, 3I/ATLAS exhibits such strange characteristics that some scientists have begun to wonder whether it might be something more unusual.

Harvard astrophysicist Avi Loeb and his team recently posted a paper titled "Is the Interstellar Object 3I/ATLAS Alien Technology?" on the arXiv preprint server. (The paper has not yet been peer reviewed.)

Loeb, a well-known and sometimes divisive figure in the scientific community, previously argued that the first observed interstellar object, 1I/'Oumuamua, discovered in 2017, could have been an extraterrestrial spacecraft.

Among several features he considers potentially artificial, Loeb points out that 3I/ATLAS follows an orbit that takes it unusually close to Venus, Mars, and Jupiter -- an alignment he finds intriguing.

We've sent out our own alien probes

The idea of alien probes wandering the cosmos may sound strange, but humans sent out a few ourselves in the 1970s. Both Voyager 1 and 2 have officially left our Solar System, and Pioneer 10 and 11 are not far behind.

So, it's not a stretch to think that alien civilizations -- if they exist -- would have launched their own galactic explorers.

However, this brings us to a crucial question: short of little green men popping out to say hello, how would we actually know if 3I/ATLAS, or any other interstellar object, was an alien probe?

Detecting alien probes 101

The first step to determining whether something is a natural object or an alien probe is of course to spot it.

Most things we see in our Solar System don't emit light of their own. Instead, we only see them by the light they reflect from the Sun. Larger objects generally reflect more sunlight, so they are easier for us to see. So, what we see tends to be larger comets and asteroid, especially farther from Earth.

It can be very difficult to spot smaller objects. At present, we can track objects down to a size of ten or 20 metres out as far from the Sun as Jupiter.

Our own Voyager probes are about ten meters in size (if we include their radio antennas). If an alien probe was similar, we probably wouldn't spot it until it was somewhere in the asteroid belt between Jupiter and Mars.

If we did spot something suspicious, to figure out if it really were a probe or not, we would look for a few telltales.

First off, because a natural origin is most likely, we would look for evidence that no aliens were involved. One clue in this direction might be if the object were emitting a "tail" of gas in the way that comets do.

However, we might also want to look for hints of alien origin. One very strong piece of evidence would be any kind of radio waves coming from the probe as a form of communication. This is assuming the probe was still in working order, and not completely defunct.

We might also look for signs of electrostatic discharge caused by sunlight hitting the probe. Another dead giveaway would be signs of manoeuvring or propulsion. An active probe might try to correct its course or reposition its antennas to send and receive signals to and from its origin.

And a genuine smoking gun would be an approach to Earth in a stable orbit. Not to brag, but Earth is genuinely the most interesting place in the Solar System -- we have water, a healthy atmosphere, a strong magnetic field and life. A probe with any decision-making capacity would likely want to investigate and collect data about our interesting little planet.

We may never know

Without clear signs one way or the other, however, it may be impossible to know if some interstellar objects are natural or alien-made.

Objects like 3I/ATLAS remind us that space is vast, strange, and full of surprises. Most of them have natural explanations. But the strangest objects are worth a second look.

For now, 3I/ATLAS is likely just an unusually fast, old and icy visitor from a distant system. But it also serves as a test case: a chance to refine the way we search, observe and ask questions about the universe.

- ❖ The Moon’s south pole hides a 4-billion-year-old secret

Scientists now believe a massive asteroid struck the Moon from the north, reshaping its surface and exposing hidden interior layers.

Date: October 12, 2025
Source: University of Arizona

The South Pole-Aitken impact basin on the far side of the Moon formed in a southward impact (toward the bottom in the image). The basin has a radioactive “KREEP-rich” ejecta blanket on one side of the basin (bright red), containing material excavated from the lunar magma ocean. Artemis astronauts will land within this material at the south end of the basin (bottom in image). Credit: Jeff Andrews-Hanna/University of Arizona/NASA/NAOJ

When astronauts touch down near the moon's south pole in the coming years as part of NASA's Artemis program, they may discover a remarkable archive of clues about how the moon was born. That possibility comes from new research led by Jeffrey Andrews-Hanna, a planetary scientist at the University of Arizona.

The study, published Oct. 8 in *Nature*, paints a vivid picture of the moon's violent early history. It could also shed light on one of lunar science's enduring mysteries: why the far side of the moon is heavily cratered while the near side, which hosted the Apollo landings of the 1960s and 1970s, is comparatively smooth.

Around 4.3 billion years ago, when the solar system was still young, a massive asteroid struck the far side of the moon. The colossal impact carved out the South Pole-Aitken basin (SPA), an immense crater measuring roughly 1,200 miles from north to south and 1,000 miles from east to west. Its elongated, oval shape suggests the asteroid hit at an angle rather than head-on.

By comparing SPA with other giant impact sites across the solar system, Andrews-Hanna's team found a consistent pattern: these enormous craters narrow in the direction the impactor was traveling, forming a shape similar to a teardrop or avocado. Contrary to earlier assumptions that the asteroid came from the south, their analysis shows the SPA basin tapers toward the south, meaning the asteroid likely arrived from the north. The researchers determined that the southern, or down-range, rim should be buried under thick layers of debris blasted from deep within the moon, while the northern, up-range end should contain less of this material.

"This means that the Artemis missions will be landing on the down-range rim of the basin -- the best place to study the largest and oldest impact basin on the moon, where most of the ejecta, material from deep within the moon's interior, should be piled up," he said.

Further evidence for a north-to-south impact came from studying the moon's topography, crustal thickness, and surface chemistry. Together, these clues not only strengthen the case for the asteroid's northern origin but also reveal new details about the moon's inner structure and how it evolved over time.

Scientists have long believed that the early moon was once completely molten, forming a global "magma ocean." As it cooled, denser minerals sank to create the mantle, while lighter ones floated upward to form the crust. Some elements, however, failed to fit neatly into these solid layers and accumulated in the last remnants of molten material. Those residual ingredients included potassium, rare earth elements, and phosphorus -- collectively known as "KREEP," with the "K" representing potassium's chemical symbol. Andrews-Hanna noted that these elements are unusually concentrated on the moon's near side.

"If you've ever left a can of soda in the freezer, you may have noticed that as the water becomes solid, the high fructose corn syrup resists freezing until the very end and instead becomes concentrated in the last bits of liquid," he said. "We think something similar happened on the moon with KREEP."

As it cooled over many millions of years, the magma ocean gradually solidified into crust and mantle. "And eventually you get to this point where you just have that tiny bit of liquid left sandwiched between the mantle and the crust, and that's this KREEP-rich material," he said.

"All of the KREEP-rich material and heat-producing elements somehow became concentrated on the moon's near side, causing it to heat up and leading to intense volcanism that formed the dark volcanic plains that make for the familiar sight of the 'face' of the Moon from Earth, according to Andrews-Hanna.

However, the reason why the KREEP-rich material ended up on the nearside, and how that material evolved over time, has been a mystery.

"The moon's crust is much thicker on its far side than on its near side facing the Earth, an asymmetry that has scientists puzzled to this day. This asymmetry has affected all aspects of the moon's evolution, including the latest stages of the magma ocean," Andrews-Hanna said.

"Our theory is that as the crust thickened on the far side, the magma ocean below was squeezed out to the sides, like toothpaste being squeezed out of a tube, until most of it ended up on the near side," he said.

The new study of the SPA impact crater revealed a striking and unexpected asymmetry around the basin that supports exactly that scenario: The ejecta blanket on its western side is rich in radioactive thorium, but not in its eastern flank. This suggests that the gash left by the impact created a window through the moon's skin right at the boundary separating the crust underlain by the last remnants of the KREEP-enriched magma ocean from the "regular" crust.

"Our study shows that the distribution and composition of these materials match the predictions that we get by modelling the latest stages of the evolution of the magma ocean," Andrews-Hanna said. "The last dregs of the lunar magma ocean ended up on the near side, where we see the highest concentrations of radioactive elements. But at some earlier time, a thin and patchy layer of magma ocean would have existed below parts of the far side, explaining the radioactive ejecta on one side of the SPA impact basin."
Many mysteries surrounding the moon's earliest history still remains, and once astronauts bring samples back to Earth, researchers hope to find more pieces to the puzzle. Remote sensing data collected by orbiting spacecraft like those used for this study provide researchers with a basic idea of the composition of the moon's surface, according to Andrews-Hanna. Thorium, an important element in KREEP-rich material, is easy to spot, but getting a more detailed analysis of the composition is a heavier lift.
"Those samples will be analysed by scientists around the world, including here at the University of Arizona, where we have state - of-the-art facilities that are specially designed for those types of analyses," he said.
"With Artemis, we'll have samples to study here on Earth, and we will know exactly what they are," he said. "Our study shows that these samples may reveal even more about the early evolution of the moon than had been thought."

- Scientists stunned by wild Martian dust devils racing at hurricane speeds

Date: October 9, 2025
Source: University of Bern

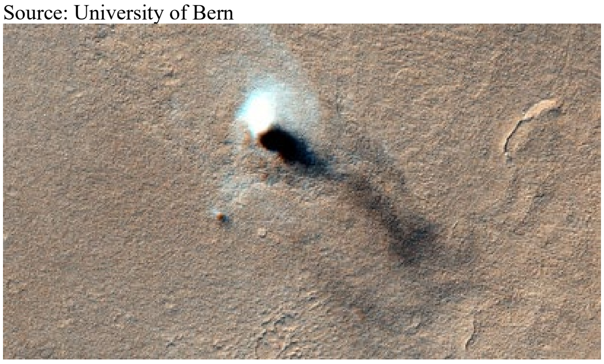


Image of a dust devil, whirlwind of dust that is blown across Mars' surface. Credit: CC BY SA 3.0 IGO ESA/TGO/CaSSIS for CaSSIS

Although Mars has an extremely thin atmosphere, it still experiences powerful winds that play a major role in shaping the planet's climate and in distributing its ever-present dust. These winds stir up dust into swirling columns called dust devils—rotating plumes of air and fine particles that sweep across the Martian surface. While the winds themselves are invisible, the dust devils they lift can be seen clearly in spacecraft images. Because they trace the flow of moving air, scientists use them as natural markers to study wind behaviour that would otherwise remain unseen.

A new study led by Dr. Valentin Bickel from the Centre for Space and Habitability at the University of Bern reveals that both dust devils and the winds driving them are much faster than scientists previously believed. These stronger winds may be responsible for much of the dust lofted into the Martian atmosphere, which has a major impact on the planet's weather and long-term climate. The research, conducted in collaboration with the University of Bern's Department of Space Research and Planetology, the Open University in the UK, and the German Aerospace Centre (DLR), was recently published in *Science Advances*.

Movement of dust devils studied with the help of deep learning

"Using a state-of-the-art deep learning approach, we were able to identify dust devils in over 50,000 satellite images," explains first author Valentin Bickel. The team used images from the Bern-based Mars camera CaSSIS (Colour and Stereo Surface Imaging System) and the stereo camera HRSC (High Resolution Stereo Camera). CaSSIS is on board the European Space Agency's (ESA) ExoMars Trace Gas Orbiter, while the HRSC camera is on board the ESA orbiter Mars Express. "Our study is therefore based exclusively on data from European Mars exploration," Bickel continues.
Next, the team studied stereo images of about 300 of these dust devils to determine their movement and speed. Co-author Nicolas Thomas, who led the development of the CaSSIS camera system at the University of Bern and whose work is funded by SERI's Swiss Space Office through ESA's PRODEX program, explains: "Stereo images are images of the same spot on the surface of Mars, but taken a few seconds apart. These images can therefore be used to measure the movement of dust devils."
Bickel emphasizes: "If you put the stereo images together in a sequence, you can observe how dynamically the dust devils move across the surface." (see the images on the website of the University of Bern)

Winds on Mars stronger than previously assumed

The results show that the dust devils and the winds surrounding them on Mars can reach speeds of up to 44 m/s, i.e. around 160 km/h, across the entire planet, which is much faster than previously assumed (previous measurements on the surface had shown that winds mostly remain below 50 km/h and - in rare cases - can reach a maximum of 100 km/h).

The high wind speed in turn influences the dust cycle on the Red Planet: "These strong, straight-line winds are very likely to bring a considerable amount of dust into the Martian atmosphere - much more than previously assumed," says Bickel. He continues: "Our data show where and when the winds on Mars seem to be strong enough to lift dust from the surface. This is the first time that such findings are available on a global scale for a period of around two decades."

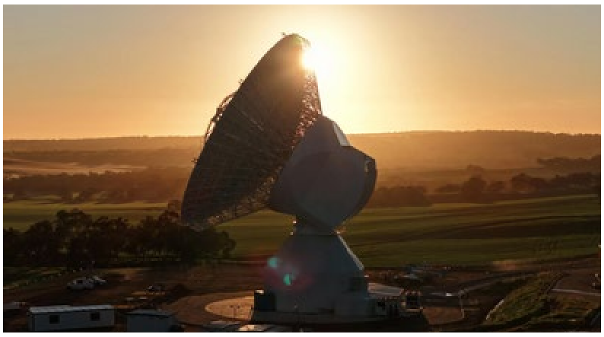
Future Mars missions can benefit from the research results

The results obtained are also particularly important for future Mars missions. "A better understanding of the wind conditions on Mars is crucial for the planning and execution of future landed missions," explains Daniela Tirsch from the Institute of Space Research at the German Aerospace Centre (DLR) and co-author of the study. "With the help of the new findings on wind dynamics, we can model the Martian atmosphere and the associated surface processes more precisely," Tirsch continues. These models are essential to better assess risks for future missions and adapt technical systems accordingly. The new study thus provides important findings for a number of research areas on Mars, such as research into the formation of dunes and slope streaks, as well as the creation of weather and climate models of Mars.

The researchers plan to further intensify the observations of dust devils and supplement the data obtained with targeted and coordinated observations of dust devils using CaSSIS and HRSC. "In the long term, our research should help to make the planning of Mars missions more efficient," concludes Bickel.

- ESA's chilling new "super antenna" in Australia reaches spacecraft billions of miles away

Date: October 6, 2025
Source: European Space Agency (ESA)



The European Space Agency (ESA) is expanding its deep space communication capabilities with the construction of a new 35-meter-deep space antenna – the fourth of its kind. It will be joining the existing one at New Norcia station, Australia, to help meet the Agency's fast increasing data download needs. When the new deep space antenna enters service in 2026, it will support ESA's current flagship missions flown as part of the Agency's scientific, exploration, and space safety fleets, including Juice, Solar Orbiter, BepiColombo, Mars Express, Euclid, ExoMars Trace Gas Orbiter, and Hera, and later upcoming missions including Plato, Envision, and Vigil. Credit: ESA

The European Space Agency (ESA) has strengthened its ability to communicate with spacecraft exploring the Solar System by unveiling a new 35-meter-wide deep space antenna, the fourth addition to its Estrack tracking network.

Situated in New Norcia, around 115 kilometres north of Perth in Western Australia, the "New Norcia 3" antenna will handle ESA's rapidly growing data transmission needs while reinforcing Europe's independence and leadership in space exploration.

At the inauguration on October 4, ESA Director General Josef Aschbacher said: "This strategic investment reinforces ESA's deep-space communication capabilities and maximizes the return of our missions' most valuable asset: data delivered from spacecraft voyaging far from Earth. New and exciting opportunities between the European and Australian space sectors are opening up with Australia announcing this week a mandate to begin negotiations on a cooperative agreement with ESA."

Supporting Missions Across the Solar System

Construction began in 2021 and was completed on schedule, reflecting close collaboration between ESA, European and Australian industries, and their partners. When it becomes operational in 2026, the antenna will support ESA's major scientific, exploration, and space safety missions including Juice, Solar Orbiter, BepiColombo, Mars Express, and Hera. It will also play a key role in future projects such as Plato, Envision, Ariel, Ramses, and Vigil.

In addition to ESA missions, the antenna will contribute to international cooperation.

Through cross-support agreements, it can assist other agencies such as NASA, Japan's JAXA, and India's ISRO, as well as commercial spacecraft operators. This collaboration enhances scientific return and operational efficiency for all partners involved.

Advanced Technology for Deep Space Communication

The new facility at New Norcia is ESA's most advanced deep space antenna to date. It features cutting-edge communication systems, including components cooled to approximately -263°C (near absolute zero) to detect extremely weak signals from spacecraft billions of kilometres away. A 20-kilowatt radio-frequency amplifier allows it to transmit commands across vast distances.

Precision timing systems and state-of-the-art radio frequency technologies make this antenna a cornerstone of deep space communication, maximizing the reliability and efficiency of contact with missions throughout the Solar System.

Strengthening Europe-Australia Space Cooperation

Opened in 2003, the New Norcia Estrack station highlights ESA's long-standing engagement in the Asia-Pacific region and its enduring partnership with Australia. The collaboration has brought significant scientific, economic, and technological benefits to both sides, laying the groundwork for future joint projects in communications, mission operations, and space safety.

Enrico Palermo, Head of the Australian Space Agency (ASA), said: "Australia is well known as a trusted, experienced and capable operator in deep-space communications. This investment by ESA and the Australian Government will unlock millions of dollars in local economic value as well as employment over the projected lifetime of 50 years."

"It's another chapter in the story of Australian and European partnership in space, which we will grow further as we begin to negotiate a new Cooperation Agreement between Australia and ESA," he added.

Construction, Industry, and Investment

The inauguration event was led by Josef Aschbacher alongside Enrico Palermo and Rolf Densing, ESA's Director of Operations, with Western Australian ministers Stephen Dawson and Sabine Winton among those present.

The total cost of the antenna is estimated at EUR 62.3 million, covering construction, upgrades to site infrastructure, and facility services. The Australian Space Agency contributed EUR 3 million toward the evolution of the New Norcia station.

European contractors Thales Alenia Space (France) and Schwartz Hautmont Construcciones Metálicas (Spain) led construction efforts, with major Australian participation from TIAM Solutions, Thales Australia, Fredon, and Westforce Construction.

"This new deep-space antenna is a cornerstone for European and Australian space industries," said Hervé Derrey, CEO of Thales Alenia Space. "Its inauguration demonstrates our capacity to build strategic, world-class space infrastructure anywhere. It required implementing advanced technologies and shows we are able to deliver the mission operations infrastructure that enables European scientists to go where they wish to explore. Alongside Schwartz Hautmont and mtex antenna technology, we are very proud of this first major success for the E-DSA^2 consortium."

A Strategic Site for Global Connectivity

New Norcia's location provides an ideal position for around-the-clock tracking of deep space missions and complements ESA's other ground stations in Malargüe (Argentina) and Cebreros (Spain). Once operational, it will be the first ESA site equipped with two deep space antennas.

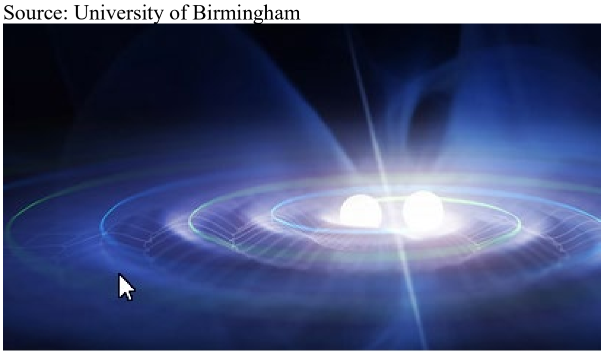
The station is operated locally by CSIRO, Australia's national science agency, which also manages NASA's deep space network facility at Tidbinbilla near Canberra.

Western Australia's location also serves ESA's launch monitoring needs. Payloads launched from Europe's Spaceport in Kourou, French Guiana, pass over the region after separating from their rockets. A nearby 4.5-meter antenna tracks Vega-C and Ariane 6 launchers, collecting essential flight data.

Additionally, the site hosts a custom-built transponder antenna for ESA's Biomass mission (launched in 2025). This system helps calibrate satellite instruments as part of a five-year study of Earth's forests, with the Biomass spacecraft passing over the site several times each year.

- ❖ A tiny detector could unveil gravitational waves we've never seen before

Date: October 3, 2025
Source: University of Birmingham



A lab-scale gravitational wave detector could finally unlock the long-missing milli-Hertz band. Using optical cavity and atomic clock tech, it may reveal hidden black hole mergers and relics of the early universe years ahead of schedule. Credit: Shutterstock

Scientists have unveiled a new approach to detecting gravitational waves in the milli-Hertz frequency range, providing access to astrophysical and cosmological phenomena that are not detectable with current instruments.

Gravitational waves—ripples in spacetime predicted by Einstein—have been observed at high frequencies by ground-based interferometers such as LIGO and Virgo, and at ultra-low frequencies by pulsar timing arrays. However, the mid-band range has remained a scientific blind spot.

Developed by researchers at the Universities of Birmingham and Sussex, the new detector concept uses cutting-edge optical cavity and atomic clock technologies to sense gravitational waves in the elusive milli-Hertz frequency band (10^{-5} – 1 Hz).

Publishing their proposal today (Oct. 3) in *Classical and Quantum Gravity*, the scientist reveal a detector that uses advances in optical resonator technology, originally developed for optical atomic clocks, to measure tiny phase shifts in laser light caused by passing gravitational waves. Unlike large-scale interferometers, these detectors are compact, relatively immune to seismic and Newtonian noise.

Co-author Dr Vera Guarrera, from the University of Birmingham, commented: "By using technology matured in the context of optical atomic clocks, we can extend the reach of gravitational wave detection into a completely new frequency range with instruments that fit on a laboratory table. This opens the exciting possibility of building a global network of such detectors and searching for signals that would otherwise remain hidden for at least another decade."

The milli-Hertz frequency band - sometimes called the 'mid-band' - is expected to host signals from a variety of astrophysical and cosmological sources, including compact binaries of white dwarfs and black hole mergers. Ambitious space missions such as LISA also target this frequency band, but they are scheduled for launch in the 2030s. The proposed optical resonator detectors could begin exploring this territory now.

Co-author Professor Xavier Calmet, from the University of Sussex, commented: "This detector allows us to test astrophysical models of binary systems in our galaxy, explore the mergers of massive black holes, and even search for stochastic backgrounds from the early universe. With this method, we have the tools to start probing these signals from the ground, opening the path for future space missions."

While future space-based missions like LISA will offer superior sensitivity, their operation is over a decade away. The proposed optical cavity detectors provide an immediate, cost-effective means to explore the milli-Hz band.

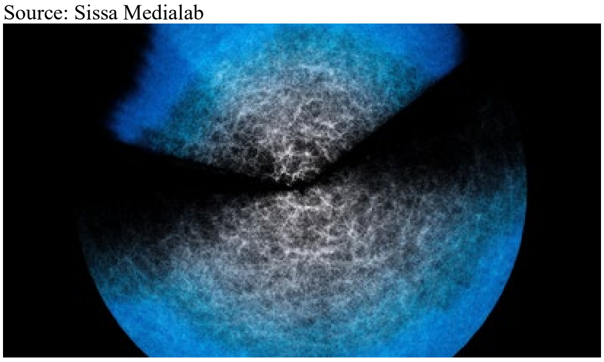
The study also suggests that integrating these detectors with existing clock networks could extend gravitational wave detection to even lower frequencies, complementing high-frequency observatories like LIGO.

Each unit consists of two orthogonal ultra stable optical cavities and an atomic frequency reference, enabling multi-channel detection of gravitational wave signals. This configuration not only enhances sensitivity but also allows for the identification of wave polarisation and source direction.

- ❖ Cosmic simulations that once needed supercomputers now run on a laptop

Effort.jl, a powerful new emulator, can match complex models with astonishing speed and accuracy, running on something as ordinary as a laptop.

Date: September 18, 2025
Source: Sissa Medialab



Two 'fans' corresponding to the two main areas DESI has observed, above and below the plane of our Milky Way (see this map). DESI is mounted on the U.S. National Science Foundation Nicholas U.

Mayall 4-meter Telescope at Kitt Peak National Observatory (KPNO), a Program of NSF NOIRLab. DESI has made the largest 3D map of our Universe to date and uses it to study dark energy. Earth is at the centre of the two fans, where bluer points indicate more distant objects. This is a still from an animated rotation of the DESI Year-3 data map. Credit: DESI Collaboration/DOE/KPNO/NOIRLab/NSF/AURA/R. Proctor

If you think a galaxy is big, compare it to the size of the Universe: it's just a tiny dot which, together with a huge number of other tiny dots, forms clusters that aggregate into superclusters, which in turn weave into filaments threaded with voids -- an immense 3D skeleton of our Universe.

If that gives you vertigo and you're wondering how one can understand or even "see" something so vast, the answer is: it isn't easy. Scientists combine the physics of the Universe with data from astronomical instruments and build theoretical models, such as EFTofLSS (Effective Field Theory of Large-Scale Structure). Fed with observations, these models describe the "cosmic web" statistically and allow its key parameters to be estimated.

Models like EFTofLSS, however, demand a lot of time and computing resources. Since the astronomical datasets at our disposal are growing exponentially, we need ways to lighten the analysis without losing precision. This is why emulators exist: they "imitate" how the models respond, but operate much faster.

Since this is a kind of "shortcut," what's the risk of losing accuracy? An international team including, among others, INAF (Italy), The University of Parma (Italy) and the University of Waterloo (Canada) has published in the Journal of Cosmology and Astroparticle Physics (JCAP) a study testing the emulator Effort.jl, which they designed. It shows that Effort.jl delivers essentially the same correctness as the model it imitates -- sometimes even finer detail -- while running in minutes on a standard laptop instead of a supercomputer.

"Imagine wanting to study the contents of a glass of water at the level of its microscopic components, the individual atoms, or even smaller: in theory you can. But if we wanted to describe in detail what happens when the water moves, the explosive growth of the required calculations makes it practically impossible," explains Marco Bonici, a researcher at the University of Waterloo and first author of the study. "However, you can encode certain properties at the microscopic level and see their effect at the macroscopic level, namely the movement of the fluid in the glass. This is what an effective field theory does, that is, a model like EFTofLSS, where the water in my example is the Universe on very large scales and the microscopic components are small-scale physical processes."

The theoretical model statistically explains the structure that gives rise to the data collected: the astronomical observations are fed to the code, which computes a "prediction." But this requires time and substantial compute. Given today's data volume -- and what is expected from surveys just begun or coming soon (such as DESI, which has already released its first batch of data, and Euclid) -- it's not practical to do this exhaustively every time.

"This is why we now turn to emulators like ours, which can drastically cut time and resources," Bonici continues. An emulator essentially mimics what the model does: its core is a neural network that learns to associate the input parameters with the model's already-computed predictions. The network is trained on the model's outputs and, after training, can generalize to combinations of parameters it hasn't seen. The emulator doesn't "understand" the physics itself: it knows the theoretical model's responses very well and can anticipate what it would output for a new input. Effort.jl's originality is that it further reduces the training phase by building into the algorithm knowledge we already have about how predictions change when parameters change: instead of making the network "re-learn" these, it uses them from the start. Effort.jl also uses gradients -- i.e., "how much and in which direction" predictions change if you tweak a parameter by a tiny amount -- another element that helps the emulator learn from far fewer examples, cutting compute needs and allowing it to run on smaller machines.

A tool like this needs extensive validation: if the emulator doesn't know the physics, how sure are we that its shortcut yields correct answers (i.e., the same ones the model would give)? The newly published study answers exactly this, showing that Effort.jl's accuracy -- on both simulated and real data -- is in close agreement with the model. "And in some cases, where with the model you have to trim part of the analysis to speed things up, with Effort.jl we were able to include those missing pieces as well," Bonici concludes. Effort.jl thus emerges as a valuable ally for analysing

upcoming data releases from experiments like DESI and Euclid, which promise to greatly deepen our knowledge of the Universe on large scales.
The study "Effort.jl: a fast and differentiable emulator for the Effective Field Theory of the Large-Scale Structure of the Universe" by Marco Bonici, Guido D'Amico, Julien Bel and Carmelita Carbone is available in the *Journal of Cosmology and Astroparticle Physics (JCAP)*.

- The Moon could finally reveal dark matter

Date: September 18, 2025
Source: Kavli Institute for the Physics and Mathematics of the Universe

A NASA artist's illustration of Artemis astronauts working on the Moon. Credit: NASA

An international research collaboration has used advanced computer simulations to investigate how faint radio signals from the early Universe, soon to be observed from missions on the far side of the Moon, could shed light on the fundamental properties of dark matter, reports a new study published in *Nature Astronomy* on September 16, 2025.
Ordinary matter, which makes up the stars, planets, and everything we can see, makes up only about 20 per cent of all matter in the Universe. The remaining 80 per cent is believed to be dark matter: a mysterious substance that does not emit, absorb, or reflect light, and whose true nature remains one of the greatest unsolved problems in modern physics. Despite its invisibility, dark matter is known to play a vital role in the formation of galaxies, such as the Milky Way, and in shaping the large-scale structure of the Universe.
One of the key properties of dark matter is the mass of its constituent particles. If these particles are relatively light, such as less than about 5 per cent of electron mass, then dark matter is considered warm and would inhibit the formation of structures smaller than galaxies. However, if the particles are heavier, dark matter is classified as cold, which would promote the growth of smaller-scale structures.
Astronomers have long sought to determine the dark matter particle mass by studying small-scale structures composed of gas and stars because this information is crucial for particle physicists to develop theoretical models of dark matter.
A new study led by The University of Tsukuba Postdoctoral Fellow Hyunbae Park, who carried out this study during his time as a University of Tokyo Kavli Institute for the Physics and Mathematics of the Universe (Kavli IPMU, WPI) Project Researcher, and including Kavli IPMU Professor and Max Planck Insitute for Astrophysics Visiting Scientist Naoki Yoshida, focused on small gas clouds that existed during the cosmic Dark Ages, the first 100 million years after the Big Bang before the formation of stars and galaxies. Because the formation and evolution of stars and galaxies involve complex and poorly understood processes, simulating their behaviour accurately remains a major challenge in modern computational astrophysics. By targeting an era before these complexities arose, the researchers were able to simulate early cosmic structures with unprecedented precision.
The simulation results revealed how gas gradually cooled as the Universe expanded while developing small gas clumps via gravitational interaction with dark matter during the Dark Ages. The gas in these clumps became much denser than in the average Universe and heated up due to compression. This variation in density and temperature was imprinted in the 21-centimeter radio emission from hydrogen atoms. The team modelled this ancient signal from the primordial gas clouds and found that its sky-averaged strength depends sensitively on whether dark matter is warm or cold.
According to the researchers, this difference could allow future lunar experiments to distinguish between competing dark matter scenarios.
The Dark Ages signal is expected to appear at frequencies around 50 MHz or lower with a characteristic frequency modulation, and the difference between the two dark matter scenarios is less than a milli-kelvin in brightness temperature. These frequencies are heavily contaminated by human-made signals on Earth, and further obscured by the ionosphere making it virtually impossible to

detect the signal from ground-based observatories. In contrast, the far side of the Moon offers a radio-quiet environment, shielded from terrestrial interference, and is considered an ideal location for detecting the elusive Dark Ages signal.

Although building radio observatories on the Moon poses major technological and financial challenges, an increasing number of nations are pursuing such missions as part of the new space race, combining scientific ambition with technological advancement. With this growing international momentum, it is now considered feasible to determine the mass of dark matter particles through lunar-based observations in the coming decades. Among these nations, Japan is actively developing the Tsukuyomi project, which plans to deploy radio antennas on the Moon.

The team's research provides essential theoretical guidance for these near-future missions to maximize their scientific return.

- Rapid rocket growth raises alarm over Earth's fragile ozone layer

Date: September 15, 2025
Source: ETH Zurich

Falcon Heavy, a reusable heavy-lift launch vehicle from SpaceX, in flight for the first time on 6th February 2018. Credit: SpaceX / Keystone

The rapid rise in global rocket launches could slow the recovery of the vital ozone layer, says Sandro Vattioni. The problem is being underestimated - yet it could be mitigated by forward-looking, coordinated action.

In recent years, the night sky has filled with satellites from rapidly expanding constellations in low Earth orbit, driven by a booming space industry. While this development brings exciting opportunities, it also raises new environmental concerns. Rocket launches and re-entering space debris release pollutants into the middle atmosphere, where they can damage the ozone layer which protects life on Earth from harmful UV radiation -- a growing concern that scientists are only beginning to understand.

Research on the effects of rocket emissions on the ozone layer began over 30 years ago, but for a long time, these effects were considered small.[1] This perception is starting to change as launch activity accelerates. In 2019, there were just 97 orbital space rocket launches globally. By 2024, that number had surged to 258, and is expected to keep rising rapidly.[2]

A long-underestimated concern

In the middle and upper atmosphere, emissions from rockets and re-entering space debris can remain up to 100 times longer than emissions from ground-based sources due to the absence of removal processes such as cloud-driven washout. While most launches occur in the Northern Hemisphere, atmospheric circulation spreads these pollutants globally.

To better understand the long-term impact of increasing rocket emissions, we collaborated with an international research team led by Laura Revell from the University of Canterbury. Using a chemistry climate model developed at ETH Zurich and the Physical Meteorological Observatory in Davos (PMOD/WRC) we simulated how projected rocket emissions will affect the ozone layer by 2030.[3]

Assuming a growth scenario with 2,040 annual launches in 2030 -- about eight times the figure for 2024 -- global average ozone thickness would decline by almost 0.3%, with seasonal reductions of up to 4% over Antarctica, where the ozone hole still forms each spring.

While these numbers may seem modest at first sight, it's important to remember that the ozone layer is still recovering from past damage caused by long-lived chlorofluorocarbons (CFCs), which were successfully banned by the Montreal Protocol in 1989. Yet today, the thickness of the global ozone layer is still roughly 2% below pre-industrial levels and is not expected to fully recover until around 2066.[4] Our findings indicate that emissions from rockets -- currently unregulated -- could delay this recovery by years or decades, depending on the rocket industry growth.

With rockets, too, the choice of fuel matters

The main contributors to ozone depletion from rocket emissions are gaseous chlorine and soot particles. Chlorine catalytically destroys ozone molecules, while soot particles warm the middle atmosphere, accelerating ozone-depleting chemical reactions.

While most rocket propellants emit soot, chlorine emissions primarily come from solid rocket motors. Currently, the only propulsion systems that have a negligible effect on the ozone layer are those which use cryogenic fuels such as liquid oxygen and hydrogen. However, due to the technological complexity of handling cryogenic fuels, only about 6% of rocket launches currently use this technology.[5]

Re-entry effects are still uncertain

We would like to mention that our study only considered emissions released from rockets during ascent into space. But this is only part of the picture. Most satellites in low Earth orbit re-enter the atmosphere at the end of their operational life, burning up in the process.

This process generates additional pollutants, including various metal particles and nitrogen oxides, due to the intense heat generated upon re-entry. While nitrogen oxides are known to deplete ozone catalytically, metal particles may contribute to forming polar stratospheric clouds or serve as reaction surfaces themselves, both of which can intensify ozone loss.

These re-entry effects are still poorly understood and not yet incorporated into most atmospheric models. From our point of view, it is clear that with increasing satellite constellations, re-entry emissions will become more frequent, and the total impact on the ozone layer is likely to be even higher than current estimates. Science is called upon to fill these gaps in our understanding.[6]

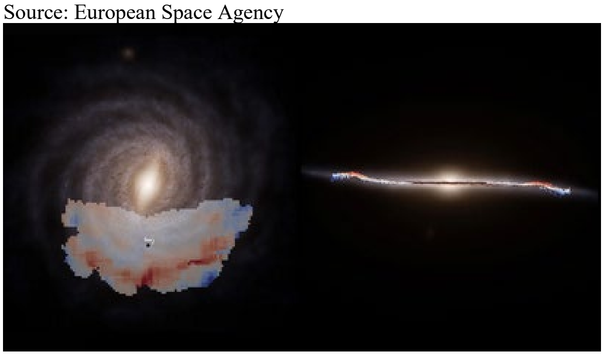
Needed: Foresight and coordinated action

But that alone will not be enough. The good news: We believe a launch industry that avoids ozone damaging effects is entirely possible: Monitoring rocket emissions, minimizing the usage of chlorine and soot-producing fuels, promoting alternative propulsion systems, and implementing the necessary and appropriate regulations are all key to ensuring that the ozone layer continues its recovery.[4] This will take coordinated efforts between scientists, policymakers, and industry.

The Montreal Protocol successfully demonstrated that even planetary-scale environmental threats can be addressed through global cooperation. As we enter a new era of space activity, the same kind of foresight and international coordination will be needed to avoid harmful effects on the ozone layer - one of the Earth's most vital natural shields

- A giant wave is rippling through the Milky Way, and scientists don't know why

Date: October 22, 2025
Source: European Space Agency



The Gaia space telescope has revealed that our Milky Way galaxy has a giant wave rippling outwards from its centre, as illustrated in this figure. Here the positions of thousands of bright stars are shown, overlaid on Gaia's maps of the Milky Way. Credit: ESA/Gaia/DPAC, S. Payne-Wardenaar, E. Poggio et al (2025)

Our Milky Way is constantly in motion: it spins, it tilts, and, as new observations reveal, it ripples. Data collected by the European Space Agency's Gaia space telescope show that our galaxy is not only rotating and wobbling but also sending out a vast wave that travels outward from its centre.

For about a century, astronomers have known that the Milky Way's stars orbit its core, and Gaia has precisely tracked their speeds and trajectories. Since the 1950s, scientists have also recognized that the galactic disc is not flat but warped. Then in 2020, Gaia uncovered that this warped disc slowly oscillates over time, similar to the motion of a spinning top.

Now, researchers have identified an enormous wave that moves through the Milky Way, influencing stars tens of thousands of light-years from the Sun. The phenomenon is like a rock dropped into a pond, where the resulting ripples spread outward -- only here, the "ripples" are made of stars, stretching across the galaxy's outer regions.

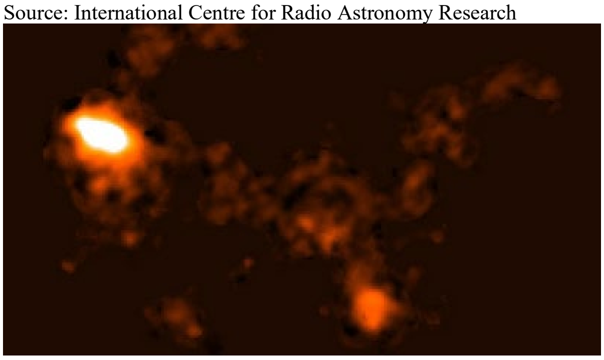
The newly revealed wave is illustrated in the figure above. Thousands of bright stars, shown in red and blue, are overlaid on Gaia's detailed map of the Milky Way.

In the image on the left, we see our galaxy from a top-down perspective. The right panel shows a side view, cutting vertically through the galactic plane. From this angle, the left portion of the galaxy curves upward while the right-side bends downward (this is the warp of the disc). The red and blue regions mark the newly discovered wave: red areas indicate stars located above the warped plane, while blue areas show stars lying below it.

Although no spacecraft can venture beyond the galaxy, Gaia's remarkably precise measurements -- covering all three spatial dimensions (3D) and three components of motion (toward and away from us, and across the sky) -- allow scientists to construct these top-down and edge-on views of the Milky Way.
These maps reveal that the wave extends over a vast section of the disc, affecting stars located about 30,000 to 65,000 light-years from the galactic centre (the Milky Way itself measures about 100,000 light-years across).
"What makes this even more compelling is our ability, thanks to Gaia, to also measure the motions of stars within the galactic disc," says Eloisa Poggio who is an astronomer at the Istituto Nazionale di Astrofisica (INAF) in Italy, and led the team of scientists that discovered the wave.
"The intriguing part is not only the visual appearance of the wave structure in 3D space, but also its wave-like behaviour when we analyse the motions of the stars within it."
In the edge-on view of the Milky Way linked below ("The Milky Way's great wave in motion"), white arrows show how the stars move. The vertical motion of the stars (represented by these arrows) is slightly shifted sideways compared to the pattern of their positions (shown by the red and blue colours).
"This observed behaviour is consistent with what we would expect from a wave," Eloisa explains.
She compares the phenomenon to a stadium crowd performing a wave. If we could freeze that moment in time, some people would be standing upright, others would just have sat down (after the wave passed), and some would be about to stand (as the wave approaches). Galactic timescales are far longer, but the principle is similar.
In this comparison, the people standing upright correspond to the red regions in Gaia's maps, while those about to rise -- moving upward with the greatest vertical speed -- are represented by the longest white arrows pointing up, just ahead of the wave's crest.
Eloisa and her team detected this remarkable motion by carefully studying young giant stars and Cepheid stars, both of which vary in brightness in predictable ways that make them easy for Gaia to observe across large distances.
Because these stars seem to move with the wave, the researchers suspect that gas in the galactic disc may also participate in this large-scale motion. Newly formed stars could retain information from the gas they were born from, preserving a kind of "memory" of the wave.
The cause of the galaxy's vast oscillations is still uncertain. One possibility is that the Milky Way experienced a past encounter or collision with a smaller, dwarf galaxy, but further analysis is needed to confirm this.
This newly found "great wave" might also have some link to a smaller undulating structure known as the Radcliffe Wave, which lies roughly 500 light-years from the Sun and extends about 9,000 light-years across.
"However, the Radcliffe Wave is a much smaller filament, and located in a different portion of the galaxy's disc compared to the wave studied in our work (much closer to the Sun than the great wave). The two waves may or may not be related. That's why we would like to do more research," Eloisa adds.
"The upcoming fourth data release from Gaia will include even better positions and motions for Milky Way stars, including variable stars like Cepheids. This will help scientists to make even better maps, and thereby advance our understanding of these characteristic features in our home galaxy," says Johannes Sahlmann, ESA's Gaia Project Scientist.

- Astronomers discover a gigantic bridge of gas connecting two galaxies

Astronomers have made a groundbreaking discovery of a colossal bridge of neutral hydrogen gas linking two dwarf galaxies.
Date: October 19, 2025
Source: International Centre for Radio Astronomy Research



Radio galaxy image of neutral hydrogen in and around the NGC 4532 / DDO 137 using ASKAP. Credit: ICRAR

Scientists at The University of Western Australia's node of the International Centre for Radio Astronomy Research (ICRAR) have made a remarkable discovery: a massive structure stretching about 185,000 light-years between two galaxies, NGC 4532 and DDO

137, located some 53 million light-years from Earth.
According to a study published in the *Monthly Notices of the Royal Astronomical Society*, the team also detected a huge tail of gas extending another 1.6 million light-years beyond the bridge, making it the largest feature of its kind ever recorded.
Lead researcher Professor Lister Staveley-Smith from ICRAR UWA explained that the finding provides an important new insight into how galaxies influence each other.
"Our modelling showed that the tidal forces acting between these galaxies, alongside their proximity to the massive Virgo cluster of galaxies, played a crucial role in the gas dynamics we observed," Professor Staveley-Smith said.
He added that as the galaxies orbited one another and moved toward the superheated gas cloud surrounding the Virgo cluster, which reaches temperatures about 200 times hotter than the Sun's surface, they experienced "ram pressure." This effect stripped gas from the galaxies and heated it as they passed through the dense environment.
"The process is akin to atmospheric burn-up when a satellite re-enters the Earth's upper atmosphere, but has extended over a period of a billion years," he said.
"The density of electrons and the speed at which galaxies are falling into the hot gas cloud are enough to explain why so much gas has been pulled away from the galaxies and into the bridge and surrounding areas."
The discovery was made as part of the Widefield ASKAP L-band Legacy All-sky Survey (WALLABY), a large-scale project that maps hydrogen gas throughout the Universe using the ASKAP radio telescope, owned and operated by CSIRO, Australia's national science agency.
Co-author Professor Kenji Bekki of ICRAR UWA said the team identified the enormous gas structures through high-resolution observations of neutral hydrogen, a key ingredient in star formation.
"Neutral hydrogen plays a crucial role in the formation of stars, making this finding fundamental to understanding how galaxies interact and evolve, particularly in dense environments," Professor Bekki said.
Professor Staveley-Smith said the system had strong similarities with our own Milky Way and Magellanic System, providing a unique opportunity to study such interactions in detail.
"Understanding these gas bridges and their dynamics provides critical insights into how galaxies evolve over time, how galactic gas is redistributed, and the varying conditions under which galaxies may or may not form stars," he said.
"This contributes to our broader understanding of the most massive structures in the Universe and their life cycles, which helps us grasp more about their vast complexities and history of star formation."