South Downs Mercury

The monthly circular of South Downs Astronomical Society
Issue: 603 – January 9th 2026 Editor: Roger Burgess

Main Talk. Michael Foulkes **"'Herschel's Planet' This is on Uranus"**
This talk discusses the most famous of transit events, I.e transits of Mercury and Venus. It looks at the history of Venus transits and the attempts to use these events to measure the distance between the Earth to the Sun. It also discusses other types of transit phenomena including how transits have been used to find exo planets.
Michael is the Director of the BAA Saturn, Uranus and Neptune Section

Please support a raffle we are organizing this month.
AGM this the one meeting during the year when the Trustees of the South Downs AS run the first half of the meeting. We have to appoint a new committee; anyone wishing to put their name forward can do so at the beginning of the meeting. If you know someone who might be able to serve on the committee, please ask them before nominating them. Being a committee member does not involve too much time or effort, the main thing is to be willing to take on some quite simple tasks, such as meet and greet at the main meetings, attend around six committee meetings each year.

- What are asteroids really made of? New analysis brings space mining closer to reality

By studying rare meteorites, scientists are uncovering which asteroids might someday fuel humanity's expansion into space.
Date: December 25, 2025
Source: Spanish National Research Council (CSIC)

Ancient carbon-rich asteroids could one day supply water and other resources needed for deep-space missions. Credit: AI/ScienceDaily.com

Scientists still have much to learn about what small asteroids are made of. These rocky bodies may contain valuable metals, ancient material left over from the formation of the solar system, and chemical clues that reveal the history of their original parent bodies. Because of this, they are increasingly viewed as possible sources of future space resources. A research team led by the Institute of Space Sciences (ICE-CSIC) examined samples linked to C-type asteroids, carbon rich objects that are believed to be the original sources of carbonaceous chondrites. Their results, published in the Monthly Notices of the Royal Astronomical Society, strengthen the case that these asteroids could serve as important material reservoirs. The findings also help scientists identify where these meteorites came from and support planning for future space missions and resource extraction technologies.

Rare Meteorites From Ancient Asteroids

Carbonaceous chondrites arrive on Earth naturally, but they account for only about 5% of all meteorite falls. Many are extremely fragile and break apart before they can be recovered, which makes them especially rare. When they are found, it is often in desert environments such as the Sahara or Antarctica, where preservation conditions are favourable.

"The scientific interest in each of these meteorites is that they sample small, undifferentiated asteroids, and provide valuable information on the chemical composition and evolutionary history of the bodies from which they originate," says Josep M. Trigo-Rodríguez, the study's lead author and an astrophysicist at ICE-CSIC, affiliated to the Institute of Space Studies of Catalonia (IEEC).

Measuring the Building Blocks of Asteroids

To carry out the study, the ICE-CSIC team selected and carefully characterized asteroid related samples before sending them for detailed chemical analysis. The measurements

were performed using mass spectrometry at the University of Castilla-La Mancha by Professor Jacinto Alonso-Azcárate. This work allowed the researchers to determine the precise chemical makeup of the six most common types of carbonaceous chondrites and assess whether extracting materials from their parent asteroids could one day be practical.

The Asteroids, Comets, and Meteorites research group at ICE-CSIC has spent more than a decade studying the physical and chemical properties of asteroid and comet surfaces. "At ICE-CSIC and IEEC, we specialize in developing experiments to better understand the properties of these asteroids and how the physical processes that occur in space affect their nature and mineralogy," Trigo-Rodríguez explains.

He also notes that ICE-CSIC serves as the international repository for NASA's Antarctic meteorite collection. Over the past ten years, he has helped select and request several of the carbonaceous chondrites used in this study and has designed multiple experiments around them. "The work now being published is the culmination of that team effort," he says.

Are Asteroid Resources Worth Extracting?

"Studying and selecting these types of meteorites in our clean room using other analytical techniques is fascinating, particularly because of the diversity of minerals and chemical elements they contain. However, most asteroids have relatively small abundances of precious elements, and therefore the objective of our study has been to understand to what extent their extraction would be viable," says Pau Grèbol Tomás, a predoctoral researcher at ICE-CSIC.

Jordi Ibáñez-Insa, a co-author of the study and researcher at Geosciences Barcelona (GEO3BCN-CSIC), points out that while many small asteroids are covered in loose surface material known as regolith, collecting small samples is very different from extracting resources at scale. "Although most small asteroids have surfaces covered in fragmented material called regolith -and it would facilitate the return of small amounts of samples-, developing large-scale collection systems to achieve clear benefits is a very different matter. In any case, it deserves to be explored because the search for resources in space could be susceptible to minimizing the impact of mining activities on terrestrial ecosystems," he says.

Choosing the Right Asteroids for the Future

The main asteroid belt contains an enormous range of objects, and understanding what resources they hold requires careful classification. According to Trigo-Rodríguez, asteroid composition varies widely due to their long and complex histories. "They are small and quite heterogeneous objects, heavily influenced by their evolutionary history, particularly collisions and close approaches to the Sun. If we are looking for water, there are certain asteroids from which hydrated carbonaceous chondrites originate, which, conversely, will have fewer metals in their native state. Let's not forget that, after 4.56 billion years since their formation, each asteroid has a different composition, as revealed by the study of chondritic meteorites."

One key conclusion of the research is that mining undifferentiated asteroids -- the primordial remnants of the solar system's formation considered the progenitor bodies of chondritic meteorites -- remains impractical for now. However, the team identifies a different class of relatively pristine asteroids that display olivine and spinel signatures as more promising mining targets.

To confidently identify such candidates, the researchers emphasize the importance of detailed chemical studies of carbonaceous chondrites combined with new sample return missions. These missions would help confirm which asteroids are truly linked to the meteorites studied on Earth.

Technology, Water, and Long-Term Exploration

"Alongside the progress represented by sample return missions, companies capable of taking decisive steps in the technological development necessary to extract and collect these materials under low-gravity conditions are truly needed. The processing of these materials and the waste generated would also have a significant impact that should be quantified and properly mitigated," Trigo-Rodríguez adds.

The team expects progress in the near future, especially as in situ resource use becomes increasingly important for long duration missions to the Moon and Mars. Using materials found in space could significantly reduce the need for supplies launched from Earth. If water is the primary target, the researchers stress that asteroids altered by

water and rich in water bearing minerals should be prioritized.

Extracting resources in low gravity environments will require entirely new approaches. "It sounds like science fiction, but it also seemed like science fiction when the first sample return missions were being planned thirty years ago," says Pau Grèbol Tomàs.

From Planetary Defence to Space Resources

Globally, several concepts are already being discussed, including capturing small asteroids that pass close to Earth and placing them into circumlunar orbit for study and resource use. Trigo-Rodríguez highlights that water rich carbonaceous asteroids may be especially attractive targets. "For certain water-rich carbonaceous asteroids, extracting water for reuse seems more viable, either as fuel or as a primary resource for exploring other worlds. This could also provide science with greater knowledge about certain bodies that could one day threaten our very existence. In the long term, we could even mine and shrink potentially hazardous asteroids so that they cease to be dangerous," he explains.

- ❖ Subaru Telescope reveals a hidden giant planet

Date: December 22, 2025
Source: National Institutes of Natural Sciences

Astronomers have spotted a massive exoplanet and a rare brown dwarf by tracking tiny stellar motions and then imaging the hidden companions directly. One of the finds gives NASA's Roman Space Telescope its first perfect target for testing planet-hunting technology meant to reveal Earth-like worlds. Credit: AI/ScienceDaily.com

Astronomers working with the Subaru Telescope in Hawai‘i have identified two remarkable objects circling distant stars: a giant planet and a brown dwarf. These findings mark the first successes of OASIS (Observing Accelerators with SCExAO Imaging Survey), a project that pairs precise space-based data with Subaru's powerful imaging systems to uncover worlds that are otherwise extremely difficult to see. The discoveries also provide an important stepping stone for NASA's upcoming Roman Space Telescope, which will test new tools designed to image Earth-like planets.

Only about 1 percent of stars are known to host massive planets or brown dwarfs that can be directly photographed with today's telescopes. Even when these objects are young and still glowing from the heat of their formation, they remain vastly dimmer than the stars they orbit. As a result, their faint light is often overwhelmed by the intense brightness of their host stars. For astronomers, the long-standing challenge has not just been how to see these objects, but knowing where to search in the first place.

How OASIS Pinpoints Hidden Companions

OASIS [Principal Investigator (PI): Thayne Currie / Deputy-PI: Masayuki Kuzuhara] addresses this challenge by narrowing down the most promising targets. The survey analyses measurements from two European Space Agency missions -- Hipparcos and Gaia -- which track tiny motions in stars caused by the gravitational pull of unseen companions. Once a star shows signs of being tugged by an invisible object, OASIS turns the Subaru Telescope toward it. Using the Subaru Coronagraphic Extreme Adaptive Optics (SCExAO) system, astronomers can then capture extremely sharp images that make it possible to directly photograph these hidden worlds.

A Giant Planet Revealed in Leo

One of the new discoveries is a planet known as HIP 54515 b, which orbits a star located 271 light-years away in the constellation Leo. This planet has nearly 18 times the mass of Jupiter and travels around its star at a distance similar to that of Neptune in our own solar system. From Earth, however, the planet and its star appear incredibly close together. The separation is comparable to spotting a baseball from 100 km away. Thanks to the precision of the SCExAO system, astronomers were able to resolve the planet clearly despite this challenge.

A Rare Brown Dwarf With Special Potential

The second object, HIP 71618 B, is a brown dwarf with a mass about 60 times that of Jupiter. It lies 169 light-years away in the constellation Bootes. Brown dwarfs are often referred to as "failed stars" -- because they form in a similar way to stars but never grow massive enough to ignite nuclear fusion in their cores.

A Perfect Test Target for NASA's Roman Telescope

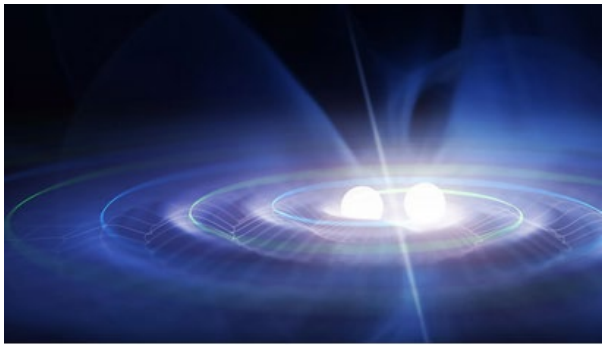
HIP 71618 B stands out because it is exceptionally well suited for study by NASA's Roman Space Telescope. Roman is scheduled to conduct a technology demonstration that will test advanced coronagraph systems. These instruments are essential for future missions that aim to directly image Earth-like planets around other stars, objects that can be ten billion times fainter than the stars they orbit. Until now, astronomers had not identified a single confirmed target that met all the strict criteria for this test. HIP 71618 B fills that gap. Its host star is bright, the brown dwarf sits at an ideal position, and at the Roman Coronagraph's operating wavelengths it will appear faint enough relative to its star to properly evaluate the new technology.

A New Era of Teamwork in Planet Hunting

Together, these discoveries highlight the power of combining precise measurements from space with advanced imaging from the ground. This coordinated approach allows astronomers to find planets and brown dwarfs that would otherwise remain hidden in starlight. The success of OASIS demonstrates that the Subaru Telescope will continue to play a leading role in astronomical discovery, even as a new generation of powerful telescopes comes online.

- ❖ Gravitational waves may reveal hidden dark matter around black holes

Date: December 19, 2025
Source: Universiteit van Amsterdam



Black hole gravitational waves could become a powerful new tool for uncovering the hidden structure of dark matter. Credit: Shutterstock

Scientists at the University of Amsterdam have developed a new way to use gravitational waves from black holes to uncover the presence of dark matter and learn more about its behaviour. Their approach relies on a detailed theoretical model grounded in Einstein's theory of general relativity. This model carefully describes how a black hole interacts with material in its immediate environment, including dark matter that cannot be seen directly.

The research was carried out by Rodrigo Vicente, Theophanes K. Karydas and Gianfranco Bertone from the UvA Institute of Physics (IoP) and the GRAPPA centre of excellence for Gravitation and Astroparticle Physics Amsterdam. Their findings were published in the journal *Physical Review Letters*. In the study, the team presents a more advanced method for calculating how dark matter surrounding black holes subtly alters the gravitational waves those systems produce.

Extreme Mass Ratio Inspirals and Long Gravitational Signals

The study concentrates on a class of systems known as extreme mass-ratio inspirals, or EMRIs. These occur when a small, dense object -- such as a black hole created by the collapse of a single star -- moves in orbit around a much larger black hole, usually one located at the centre of a galaxy. Over time, the smaller object gradually spirals inward, emitting gravitational waves throughout this slow descent.

Upcoming space missions, including the European Space Agency's LISA space antenna scheduled for launch in 2035, are expected to observe these signals for very long periods. Some EMRI events may be tracked for months or even years, covering hundreds of thousands to millions of individual orbits. When scientists can model these signals with high precision, the resulting data act like detailed "cosmic fingerprints" that reveal how matter is arranged near massive black holes. This includes dark matter, which is believed to make up most of the matter in the Universe.

Why a Fully Relativistic Model Matters

Before observatories like LISA begin collecting data, researchers must understand in advance what kinds of gravitational wave patterns they should expect and how to interpret them. Until now, many studies have used simplified models that only roughly describe how the surrounding environment influences EMRIs. According to the authors, these approximations leave out important physical effects.

The new work addresses this limitation by introducing the first fully relativistic framework for a wide range of possible environments. This means the calculations rely entirely on Einstein's theory of gravity

rather than simplified Newtonian approximations. As a result, the model can more accurately describe how matter around a massive black hole changes the orbit of the smaller object and reshapes the gravitational waves that are emitted.

Dark Matter Spikes and Detectable Imprints

A key focus of the study is on dense regions of dark matter that may form around massive black holes. These concentrations are often referred to as "spikes" or "mounds." By incorporating their relativistic model into modern gravitational waveform calculations, the researchers demonstrate that such dark matter structures would leave distinct, measurable signatures in the signals detected by future observatories.

The authors describe this research as an essential step toward a larger scientific goal. Over time, they hope gravitational waves can be used to chart how dark matter is distributed throughout the Universe and provide new insight into its fundamental nature.

- Scientists prove “impossible” Earth-to-space quantum link is feasible

Quantum satellites may soon rely on Earth-based transmitters instead of generating signals in space.

Date: December 17, 2025
Source: University of Technology Sydney

Scientists just flipped quantum satellite communication upside down—sending entanglement up from Earth could power a future quantum internet. Credit: Shutterstock

Quantum satellites are best known for sending entangled particles of light from orbit down to ground stations, a method used to create extremely secure communication links. New research now shows that the process can also work in reverse, with quantum signals sent from Earth up to a satellite, an approach long considered impractical.

This finding removes several major limitations facing today's quantum satellite systems. Equipment on the ground can draw on far more power, is simpler to service, and can produce much stronger signals. These advantages could be critical for building future networks that link quantum computers through satellites acting as relays.

Study Details and Recent Milestones

The research, titled "Quantum entanglement distribution via uplink satellite channels," by Professor Simon Devitt, Professor Alexander Solntsev and a research team from the University of Technology Sydney (UTS), was recently published in the journal *Physical Review Research*.

Quantum satellite communication has already seen important advances. China's Micius satellite, launched in 2016, enabled the first demonstrations of quantum-encrypted data sent from space. In 2025, the Jinan-1 microsatellite pushed this work further by establishing a 12,900 km quantum connection between China and South Africa.

Why Uplink Quantum Communication Was Dismissed

"Current quantum satellites create entangled pairs in space and then send each half of the pair down to two places on Earth -- called a 'downlink'," said Professor Solntsev. "It's mostly used for cryptography, where only a few photons (particles of light) are needed to generate a secret key."

Scientists largely ignored the opposite approach, in which entangled photons are produced on Earth and transmitted upward. This idea was seen as unrealistic because of expected losses, interference, and the scattering of light as it travels through the atmosphere.

Modelling the "Impossible" Scenario

"The idea is to fire two single particles of light from separate ground stations to a satellite orbiting 500 km above Earth, traveling at about 20,000 km per hour, so that they meet so perfectly as to undergo quantum interference. Is this even possible?" said Professor Devitt.

According to the researchers, careful modelling suggests the answer is yes. "Surprisingly, our modelling showed that an uplink is feasible. We included real-world effects such as background light from the Earth and sunlight reflections from the Moon, atmospheric effects and the imperfect alignment of optical systems," he said.

Toward a Scalable Quantum Internet

The team says the idea could be tested soon using drones or balloon-mounted receivers, providing a stepping stone toward large-scale quantum networks that span nations and

continents using small satellites in low Earth orbit.

"A quantum internet is a very different beast from current nascent cryptographic applications. It's the same primary mechanism but you need significantly more photons -- more bandwidth -- to connect quantum computers," said Professor Devitt.

The uplink strategy may offer a practical solution. "The uplink method could provide that bandwidth. The satellite only needs a compact optical unit to interfere incoming photons and report the result, rather than quantum hardware to produce the trillions upon trillions of photons per second needed to overcome losses to the ground, allowing for a high-bandwidth quantum link. That keeps costs and size down and makes the approach more practical."

Quantum Entanglement as Everyday Infrastructure

Professor Devitt compares the long-term vision to modern electricity. "In the future, quantum entanglement is going to be a bit like electricity. A commodity that we talk about that power's other things. It's generated and transmitted in a way that is often invisible to the user; we just plug in our appliances and use it. This will ultimately be the same for large quantum entanglement networks. There will be quantum devices that plug into an entanglement source as well as a power source, utilizing both to do something useful," he said.

The project combines expertise from the UTS Faculty of Engineering and IT and the Faculty of Science, bringing together specialists in quantum networking, systems modelling, and photonics. It demonstrates how collaboration across disciplines at UTS is helping address some of the most demanding challenges in emerging technology.

- ❖ Scientists are turning Earth into a giant detector for hidden forces shaping our Universe

Date: December 6, 2025
Source: Science China Press

A high-speed space-based quantum sensor network poised to uncover new physics lurking in the cosmos. Credit: AI/ScienceDaily.com

By placing ultra-sensitive quantum spin sensors in orbit, SQUIRE gains orders-of-magnitude improvements in detecting exotic physics signals.

This approach lays the groundwork for a global and interplanetary sensing system that could reveal hidden particles and forces.

Understanding SQUIRE and Its Space-Based Quantum Strategy

Exotic-boson-mediated interactions fall into 16 categories. Of these, 15 depend on particle spin and 10 depend on relative velocity. These interactions can produce small shifts in atomic energy levels, and quantum spin sensors detect those shifts as pseudomagnetic fields. The SQUIRE mission intends to place such sensors on space platforms, including the China Space Station, to look for pseudomagnetic fields generated by exotic interactions between the sensors and Earth's geoelectrons. By combining space access with quantum precision tools, SQUIRE avoids a major limitation of ground experiments, which struggle to increase both relative velocity and the total number of polarized spins at the same time.

Why Low Earth Orbit Greatly Improves Sensitivity

Several features of the orbital environment provide strong advantages.

1. The China Space Station travels in low Earth orbit at 7.67 km/s relative to Earth, nearly the first cosmic velocity and about 400 times faster than typical moving sources used in laboratory tests.
2. Earth acts as an enormous natural source of polarized spins. Unpaired geoelectrons within the mantle and crust, aligned by the geomagnetic field, supply roughly 10^{42} polarized electrons, exceeding the capabilities of $SmCo_5$ laboratory spin sources by approximately 10^{17}.
3. Orbital motion turns exotic interaction signatures into periodic signals. For the China Space Station (orbital period ~1.5 hours), this produces modulation near 0.189 MHz, a region with lower intrinsic noise than DC measurement bands.

Projected Performance Gains in Orbit

With these space-enabled benefits, the SQUIRE concept allows exotic field amplitudes to reach up to 20 pT even under

strict current limits on coupling constants. This is dramatically higher than the best terrestrial detection threshold of 0.015 pT. For velocity-dependent interactions with force ranges $>10^6$ m, the projected sensitivity improves by 6 to 7 orders of magnitude.

Building a Space-Ready Quantum Spin Sensor

Developing the prototype quantum sensor is essential for putting SQUIRE into operation. The instrument must remain extremely sensitive and stable over long periods while operating in a challenging orbital environment. In space, spin sensors encounter three dominant sources of interference: variations in the geomagnetic field, mechanical vibrations of the spacecraft, and cosmic radiation.

Reducing Noise and Increasing Stability

To overcome these challenges, the SQUIRE team created a prototype using three major innovations.

1. Dual Noble-Gas Spin Sensor: The device uses ^{129}Xe and ^{131}Xe isotopes with opposite gyromagnetic ratios, which allows it to cancel shared magnetic noise while remaining responsive to SSVI signals. This approach provides 10^4-fold noise suppression. With multilayer magnetic shielding, geomagnetic disturbances fall to the sub-femtotesla level.
2. Vibration Compensation Technology: A fibre-optic gyroscope tracks spacecraft vibrations and enables active correction, bringing vibration noise to roughly 0.65 fT.
3. Radiation-Hardened Architecture: A 0.5 cm aluminium enclosure and triple modular redundancy in its control electronics protect the system from cosmic rays. The design can continue functioning even if two of the three modules fail, reducing radiation-related interruptions to fewer than one per day.

On-Orbit Sensitivity and Scientific Readiness

By combining these technologies, the prototype achieves a single-shot sensitivity of 4.3 fT @ 1165 s, which is well matched to detecting SSVI signals that follow the 1.5-hour orbital period. This capability establishes a strong technological basis for precision dark matter searches conducted directly in orbit.

Expanding Toward a Space-Ground Quantum Sensing Network

Quantum spin sensors aboard the China Space Station can do far more than search for exotic interactions. SQUIRE proposes a "space-ground integrated" quantum sensing network that links orbital detectors with those on Earth, enabling far greater sensitivity across many dark matter models and other beyond-Standard-Model possibilities. These include additional exotic interactions, Axion halos, and CPT violation studies.

Future Opportunities Across the Solar System

The high-speed motion of orbiting sensors increases the coupling between axion halos and nucleon spins, producing a tenfold sensitivity improvement compared with Earth-based dark matter searches. As China expands deeper into the solar system, the SQUIRE approach may eventually employ distant planets such as Jupiter and Saturn (e.g., planets rich in polarized particles) as large natural spin sources. This long-term vision opens the door to exploring physics across much broader cosmic scales.

- ❖ Space is filling with junk and scientists have a fix

Date: December 3, 2025
Source: Cell Press

A new push to repair, reuse, and recycle spacecraft could help rescue Earth's orbit from a growing tide of debris. Credit: Shutterstock

Each rocket launch sends valuable materials into the sky that cannot be recovered, while also releasing large amounts of greenhouse gases and chemicals that damage the ozone layer. A new paper published December 1 in the Cell Press journal Chem Circularity examines how familiar ideas like reducing, reusing, and recycling could be built into the way satellites and spacecraft are designed, repaired in orbit, and handled at the end of their service lives.

"As space activity accelerates, from mega-constellations of satellites to future lunar and Mars missions, we must make sure exploration doesn't repeat the mistakes made

on Earth," says senior author and chemical engineer Jin Xuan of the University of Surrey. "A truly sustainable space future starts with technologies, materials and systems working together."

Growing debris and the problem of abandoned satellites

The environmental toll continues long after launch. Most spacecraft and satellites are never recycled, which means that large amounts of material are permanently lost when missions end. Many older satellites are shifted into "graveyard orbits," while others become drifting orbital debris that can disrupt the operation of active systems.

The authors argue that this approach cannot continue, especially with the increasing pace of private space missions. They highlight the need for a circular space economy, a model in which materials and equipment are created with reuse, repair, and recycling in mind. They also note that industries such as personal electronics and automotive manufacturing have already adopted similar ideas with considerable success.

"Our motivation was to bring the conversation about circularity into the space domain, where it's long overdue," says Xuan. "Circular economy thinking is transforming materials and manufacturing on Earth, but it's rarely applied to satellites, rockets, or space habitats."

Applying the 3 Rs to spacecraft, satellites, and space stations

According to the team, the foundation of a circular space economy lies in the 3 Rs: reduce, reuse, and recycle. Reducing waste would begin with building satellites and spacecraft that last longer and can be fixed more easily in space. They also suggest turning space stations into multifunctional centres where spacecraft can refuel, undergo repairs, or even have new components manufactured, which could cut down on the number of launches required.

The authors add that bringing spacecraft and space stations safely back to Earth for reuse would require better recovery systems, including technologies such as parachutes and airbags. They point out that equipment in space experiences significant wear because of extreme temperatures and radiation, so any part intended for reuse would need to pass strict safety checks.

Recovering orbital debris and using advanced technology for safer space operations

The researchers also recommend new efforts to gather orbital debris, such as using robotic arms or nets to collect fragments so the materials can be recycled. This would also help prevent collisions that create even more debris.

Data-driven tools will play an important role in this transition, the authors say. Information gathered from spacecraft could guide improvements in design and help limit waste, while simulation tools may reduce the need for expensive physical testing. They add that AI systems could help spacecraft and satellites avoid dangerous debris in real time.

Transforming the entire space system through innovation and global cooperation

The authors emphasize that a circular space economy represents a major shift in how the space sector works. Instead of focusing on single pieces of hardware, the entire system needs to be considered at once, from the materials used to how spacecraft are operated and retired.

"We need innovation at every level, from materials that can be reused or recycled in orbit and modular spacecraft that can be upgraded instead of discarded, to data systems that track how hardware ages in space," says Xuan.

"But just as importantly, we need international collaboration and policy frameworks to encourage reuse and recovery beyond Earth. The next phase is about connecting chemistry, design, and governance to turn sustainability into the default model for space."

This research received support from the UK Engineering and Physical Sciences Research Council, the Leverhulme Trust, and the Surrey-Adelaide Partnership Fund.

- ❖ New state of quantum matter could power future space tech

Date: December 2, 2025
Source: University of California, Irvine

A newly discovered quantum phase may fuel the next generation of

ultra-durable, spin-powered space computers. Credit: AI/ScienceDaily.com

Researchers at the University of California, Irvine have identified a previously unobserved form of quantum matter. According to the team, this state arises inside a specially engineered material that may one day support self-charging computers and technologies capable of operating in the harsh environment of deep space.

"It's a new phase of matter, similar to how water can exist as liquid, ice or vapor," said Luis A. Jauregui, professor of physics & astronomy at UC Irvine and corresponding author of the new *Physical Review Letters*. "It's only been theoretically predicted -- no one has ever measured it until now."

Exotic Electron Behaviour and Exciton Formation

In this phase, electrons and positively charged "holes" come together to form a fluid-like mixture that creates unusual structures known as excitons. What makes this discovery especially striking is that the electrons and holes rotate in the same direction. "It's its own new thing," Jauregui said. "If we could hold it in our hands, it would glow a bright, high-frequency light."

The phenomenon was found in a material produced at UC Irvine by postdoctoral researcher Jinyu Liu, the study's first author. Jauregui's group detected the phase at the Los Alamos National Laboratory (LANL) in New Mexico while studying the material under intense magnetic conditions.

Magnetic Fields Trigger the New Quantum Phase

Creating this quantum state required exposing the material to magnetic fields of up to 70 Teslas (by comparison, the magnetic field from a strong fridge magnet is around 0.1 Teslas). The team refers to the material as hafnium pentatelluride.

As the magnetic field increased, the researchers observed a sharp drop in the material's electrical conductivity. Jauregui explained that this sudden change indicated the system had shifted into the exotic exciton state. "This discovery is important because it may allow signals to be carried by spin rather than electrical charge, offering a new path toward energy-efficient technologies like spin-based electronics or quantum devices."

Radiation-Resistant Properties for Space Exploration

This newly observed quantum matter is not affected by radiation, a trait that sets it apart from many materials used in today's electronic devices. The team believes this could be significant for space applications.

"It could be useful for space missions," Jauregui said. "If you want computers in space that are going to last, this is one way to make that happen."

Companies such as SpaceX are working toward future human missions to Mars, and any long-duration spaceflight will require electronics that can handle continuous radiation exposure.

"We don't know yet what possibilities will open as a result," Jauregui said.

The material was synthesized, characterized and incorporated into testable devices at UC Irvine by Jinyu Liu with assistance from graduate students Robert Welser and Timothy McSorley, and undergraduate researcher Triet Ho. Theoretical modelling and interpretation were contributed by Shizeng Lin, Varsha Subramanyan, and Avadh Saxena at LANL. High-magnetic-field experiments were carried out with support from Laurel Winter and Michael T. Pettes at LANL and David Graf at the National High Magnetic Field Laboratory in Florida.

- ❖ Solar Superstorm Gannon crushed Earth’s plasmasphere to a record low

A rare solar superstorm collapsed Earth’s plasma shield and exposed the hidden processes that slow its recovery.

Date: November 23, 2025

Source: Nagoya University

Scientists have captured the first detailed observations of how a superstorm compresses Earth’s plasmasphere and reveal why recovery took more than four days, affecting navigation and communication systems. Credit: Institute for Space-Earth Environmental Research (ISEE), Nagoya University

A geomagnetic superstorm is one of the most extreme forms of space weather, created when the Sun sends enormous bursts of energy and charged particles toward Earth. These powerful events rarely occur, typically appearing only once every 20-25 years. On May 10-11, 2024, Earth was hit by the strongest event of this kind in more than two

decades, known as the Gannon storm or Mother's Day storm.

A research effort led by Dr. Atsuki Shinbori of Nagoya University's Institute for Space-Earth Environmental Research gathered direct observations during the storm and produced the first detailed view of how such an event squeezes Earth's plasmasphere (a protective region of charged particles surrounding the planet). The results, published in *Earth, Planets and Space*, show how both the plasmasphere and the ionosphere respond during intense solar disturbances and offer insight that can improve predictions of satellite disruptions, GPS problems, and communication issues caused by extreme space weather.

Arase Satellite Captures a Rare Plasmasphere Collapse

Launched by the Japan Aerospace Exploration Agency (JAXA) in 2016, the Arase satellite travels through Earth's plasmasphere and measures plasma waves and magnetic fields. During the May 2024 superstorm, it happened to be in an ideal position to record the severe compression of the plasmasphere and the long, slow recovery that followed. This marked the first time scientists had continuous, direct data showing the plasmasphere contracting to such a low altitude during a superstorm.

"We tracked changes in the plasmasphere using the Arase satellite and used ground-based GPS receivers to monitor the ionosphere -- the source of charged particles that refill the plasmasphere. Monitoring both layers showed us how dramatically the plasmasphere contracted and why recovery took so long," Dr. Shinbori explained.

Superstorm Pushes Plasmasphere to Record-Low Altitudes

The plasmasphere works with Earth's magnetic field to help block harmful charged particles from the Sun and deep space, offering natural protection for satellites and other technology. Under normal conditions, this region stretches far from Earth, but the May storm forced its outer edge inward from about 44,000 km above the surface to only 9,600 km.

The storm formed after several major eruptions on the Sun released billions of tons of charged particles toward Earth. Within just nine hours, the plasmasphere was compressed to roughly one-fifth of its usual size. Its recovery was unusually slow, requiring more than four days to refill, which is the longest recovery time recorded since Arase began monitoring the region in 2017.

"We found that the storm first caused intense heating near the poles, but later this led to a big drop in charged particles across the ionosphere, which slowed recovery. This prolonged disruption can affect GPS accuracy, interfere with satellite operations, and complicate space weather forecasting," Dr. Shinbori noted.

Superstorm Pushes Auroras Farther Toward the Equator

During the peak of the storm, the Sun's activity compressed Earth's magnetic field so strongly that charged particles were able to travel much farther along magnetic field lines toward the equator. As a result, vivid auroras appeared in places that rarely experience them.

Auroras normally occur near the poles because Earth's magnetic field channels solar particles into the atmosphere there. This storm was powerful enough to shift the auroral zone far beyond its usual location near the Arctic and Antarctic circles, producing displays in mid-latitude regions such as Japan, Mexico, and southern Europe -- areas where auroras are seldom seen. Stronger geomagnetic storms allow the lights to reach increasingly equatorial regions.

Negative Storms Slow the Plasmasphere's Return to Normal

About an hour after the superstorm arrived, charged particles surged through Earth's upper atmosphere at high latitudes and flowed toward the polar cap. As the storm weakened, the plasmasphere began to replenish with particles supplied by the ionosphere.

This refill process usually takes only a day or two, but in this case the recovery stretched out to four days because of a phenomenon known as a negative storm. In a negative storm, particle levels in the ionosphere drop sharply over large areas when intense heating alters atmospheric chemistry. This reduces oxygen ions that help create hydrogen particles needed to restore the plasmasphere. Negative storms are invisible and can only be detected using satellites.

"The negative storm slowed recovery by altering atmospheric chemistry and cutting off the supply of particles to the plasmasphere. This link between negative storms and delayed recovery had never been clearly observed before," Dr. Shinbori said.

Why These Findings Matter for Space Weather and Technology

These results provide a clearer understanding of how the plasmasphere changes during a severe solar storm and how energy moves through this region of space. Several satellites experienced electrical problems or stopped transmitting data during the event, GPS signals became less accurate, and radio communications were disrupted. Knowing how long Earth's plasma layer takes to recover from such disturbances is essential for predicting future space weather and for protecting the technology that relies on stable conditions in near-Earth space.

- ❖ Japanese spacecraft faces a massive challenge from a house-size asteroid

Date: November 21, 2025
Source: ESO

An artist's impression of Japan's Hayabusa2 space mission touching down on the surface of the asteroid 1998 KY26. New observations with ESO's Very Large Telescope (VLT) have revealed that 1998 KY26 is just 11 m wide, almost three times smaller than previously thought, and is spinning once every 5 minutes, which is much faster than expected. The image above shows an updated size comparison between the asteroid and spacecraft. Credit: ESO/M. Kornmesser. Asteroid: T. Santana-Ros et al. Hayabusa2 model: SuperTKG (CC-BY-SA).

Astronomers have gathered new data on the asteroid 1998 KY26 using observatories across several continents, including the European Southern Observatory's Very Large Telescope (ESO's VLT). These coordinated observations show that the asteroid is almost three times smaller than earlier estimates and rotates far more rapidly. The object is the planned 2031 destination for Japan's Hayabusa2 extended mission, and the updated measurements provide essential details for planning spacecraft operations only six years before the encounter.

"We found that the reality of the object is completely different from what it was previously described as," says astronomer Toni Santana-Ros of the University of Alicante, Spain, who led the Nature Communications study. By combining the new results with earlier radar data, the team determined that the asteroid is only 11 meters across, small enough to fit inside the dome of the VLT unit telescope used during the observations. They also discovered that the asteroid completes a rotation in roughly five minutes. Previous work suggested a diameter of about 30 meters and a rotation period closer to ten minutes.

A Smaller and Faster Asteroid Raises Mission Challenges

"The smaller size and faster rotation now measured will make Hayabusa2's visit even more interesting, but also even more challenging," says co-author Olivier Hainaut, an astronomer at ESO in Germany. The rapid spin and tiny size mean that performing a touchdown manoeuvre, in which the spacecraft briefly makes contact with the surface, will be more difficult than mission teams originally expected.

1998 KY26 is planned as the final target of the Japanese Aerospace eXploration Agency (JAXA)'s Hayabusa2 spacecraft. During its primary mission, Hayabusa2 visited the 900-meter-diameter asteroid 162173 Ryugu in 2018 and returned samples to Earth in 2020. With sufficient fuel remaining, the spacecraft was assigned an extended mission ending in 2031, when it will reach 1998 KY26 to investigate very small asteroids. This encounter will mark the first time a spacecraft visits an asteroid of such tiny size, as all previous missions have explored bodies hundreds or thousands of meters wide.

Ground Telescopes Capture Rare Details of a Tiny Target

To support mission planning, Santana-Ros and colleagues observed 1998 KY26 from Earth. Because the asteroid is both extremely small and faint, the team needed to wait until the object made a relatively close pass by Earth and then rely on some of the largest available telescopes, including ESO's VLT in the Atacama Desert of northern Chile.

The observations indicate that the asteroid has a bright surface and is probably a solid piece of rock, possibly originating from a fractured planet or another asteroid. Even so, the researchers cannot completely rule out that it might instead be a cluster of loosely bound debris. "We have never seen a ten-meter-size asteroid in situ, so we don't really know what to expect and how it will look," says Santana-Ros, who is also affiliated with the University of Barcelona.

Insights for Future Exploration and Planetary Defence

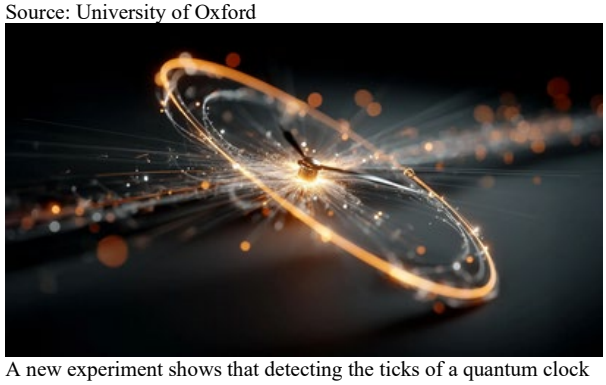
"The amazing story here is that we found that the size of the asteroid is comparable to the size of the spacecraft that is going to visit it! And we were able to characterize such a small object using our telescopes, which means that we can do it for other objects in the future," says Santana-Ros. "Our methods could have an impact on the plans for future near-Earth asteroid exploration or even asteroid mining."
"Moreover, we now know we can characterize even the smallest hazardous asteroids that could impact Earth, such as the one that hit near Chelyabinsk, in Russia in 2013, which was barely larger than KY26," concludes Hainaut.

The findings appear in the paper titled "Hayabusa2♯ mission target 1998 KY26 preview: decametre size, high albedo and rotating twice as fast" published in *Nature Communications*.

The research team includes T. Santana-Ros (Departamento de Física, Ingeniería de Sistemas y Teoría de la Señal, Universidad de Alicante, and Institut de Ciències del Cosmos (ICCUB), Universitat de Barcelona (IEEC-UB), Spain), P. Bartczak (Instituto Universitario de Física Aplicada a las Ciencias y a las Tecnologías, Universidad de Alicante, Spain and Astronomical Observatory Institute, Faculty of Physics and Astronomy, A. Mickiewicz University, Poland [AOI AMU]), K. Muinonen (Department of Physics, University of Helsinki, Finland [Physics UH]), A. Rożek (Institute for Astronomy, University of Edinburgh, Royal Observatory Edinburgh, UK [IfA UoE]), T. Müller (Max-Planck-Institut für extraterrestrische Physik, Germany), M. Hirabayashi (Georgia Institute of Technology, United States), D. Farnocchia (Jet Propulsion Laboratory, California Institute of Technology, USA [JPL]), D. Oszkiewicz (AOI AMU), M. Micheli (ESA ESRIN / PDO / NEO Coordination Centre, Italy), R. E. Cannon (IfA UoE), M. Brozovic (JPL), O. Hainaut (European Southern Observatory, Germany), A. K. Virkki [Physics UH], L. A. M. Benner (JPL), A. Cabrera-Lavers (GRANTECAN and Instituto de Astrofísica de Canarias, Spain), C. E. Martínez-Vázquez (International Gemini Observatory/NSF NOIRLab, USA), K. Vivas (Cerro Tololo Inter-American Observatory/NSF NOIRLab, Chile).

- This tiny quantum clock packs a billion-fold energy mystery

Date: November 17, 2025
Source: University of Oxford



A new experiment shows that detecting the ticks of a quantum clock uses far more energy than producing them. This dramatic imbalance reveals that observation itself is what forces time to flow forward. Credit: AI/ScienceDaily.com

`measurement itself. In findings published on November 14 in *Physical Review Letters*, the researchers show that the energy required to read a quantum clock is far greater than the energy needed to run it. Their results point to new challenges and opportunities for developing next-generation quantum technologies.

Traditional clocks, from pendulums to atomic oscillators, depend on irreversible processes to track time. At the quantum level, these processes become extremely weak or may barely occur at all, which makes reliable timekeeping far more complicated. Devices such as quantum sensors and navigation systems, which rely on precise timing, will need internal clocks that use energy sparingly. Until now, the thermodynamic behaviour of these systems has remained largely unknown.

Investigating the Real Energy Cost of Time

The researchers set out to determine the true thermodynamic burden of keeping time in the quantum realm and to separate how much of that cost is caused by the act of measurement. To explore this, they built a tiny clock that uses single electrons hopping between two nanoscale regions (known as a double quantum dot). Each hop serves as a clock-like tick. The team then monitored these ticks using two different techniques; one measured extremely small electric currents, while the other used radio waves to detect subtle changes in the system. In both approaches, the detectors convert quantum events (electron jumps) into classical information that can be recorded: a quantum-to-classical transition.

A Billion-Fold Measurement Energy Surprise

The team calculated the entropy (amount of energy dissipated) generated both by the clock itself (i.e., the double quantum dot) and by the

measurement devices. They found that the energy required to read the quantum clock (i.e., to convert its tiny signals into something measurable) can be up to a billion times larger than the energy used by the clockwork. This result challenges the long-held belief that measurement costs in quantum physics are negligible. It also reveals something striking: observation introduces irreversibility, which is what gives time its forward direction.
This finding overturns the usual expectation that improving quantum clocks requires better quantum components. Instead, the researchers argue that future progress depends on designing measurement methods that gather information more efficiently.

Rethinking Efficiency in Quantum Clock Design

Lead author Professor Natalia Ares (Department of Engineering Science, University of Oxford) said: "Quantum clocks running at the smallest scales were expected to lower the energy cost of timekeeping, but our new experiment reveals a surprising twist. Instead, in quantum clocks the quantum ticks far exceed that of the clockwork itself."
According to the researchers, this imbalance might actually offer an advantage. The additional energy used during measurement can provide richer information about the clock's behaviour, not only counting ticks but capturing every minor fluctuation. This could make it possible to build highly precise clocks that operate more efficiently.
Co-author Vivek Wadhia (PhD student, Department of Engineering Science) said: "Our results suggest that the entropy produced by the amplification and measurement of a clock's ticks, which has often been ignored in the literature, is the most important and fundamental thermodynamic cost of timekeeping at the quantum scale. The next step is to understand the principles governing efficiency in nanoscale devices so that we can design autonomous devices that compute and keep time far more efficiently, as nature does."
Co-author Florian Meier (PhD student, Technische Universität Wien) said: "Beyond quantum clocks, the research touches on deep questions in physics, including why time flows in one direction. By showing that it is the act of measuring -- not just the ticking itself -- that gives time its forward direction, these new findings draw a powerful connection between the physics of energy and the science of information."
The study also involved researchers from TU Wien and Trinity College Dublin.

- ❖ AI creates the first 100-billion-star Milky Way simulation

Date: November 16, 2025
Source: RIKEN

A new AI-enhanced simulation models every star in the Milky Way with unprecedented speed and detail. The technique unlocks galaxy-scale realism while also promising major advances in climate and weather modelling. Credit: Shutterstock

Researchers led by Keiya Hirashima at the RIKEN Centre for Interdisciplinary Theoretical and Mathematical Sciences (iTHEMS) in Japan, working with partners from The University of Tokyo and Universitat de Barcelona in Spain, have created the first Milky Way simulation capable of tracking more than 100 billion individual stars across 10 thousand years of evolution. The team achieved this milestone by pairing artificial intelligence (AI) with advanced numerical simulation techniques. Their model includes 100 times more stars than the most sophisticated earlier simulations and was generated more than 100 times faster.
The work, presented at the international supercomputing conference SC '25, marks a major step forward for astrophysics, high-performance computing, and AI-assisted modelling. The same strategy could also be applied to large-scale Earth system studies, including climate and weather research.

Why Modelling Every Star Is So Difficult

For many years, astrophysicists have aimed to build Milky Way simulations detailed enough to follow each individual star. Such models would allow researchers to compare theories of galactic evolution, structure, and star formation directly to observational data. However, simulating a galaxy accurately requires calculating gravity, fluid behaviour, chemical element formation, and supernova activity across enormous ranges of time and space, which makes the task extremely demanding.

Scientists have not previously been able to model a galaxy as large as the Milky Way while maintaining fine detail at the level of single stars. Current cutting-edge simulations can represent systems with the equivalent mass of about one billion suns, far below the more than 100 billion stars that make up the Milky Way. As a result, the smallest "particle" in those models usually represents a group of roughly 100 stars, which averages away the behaviour of individual stars and limits the accuracy of small-scale processes.
The challenge is tied to the interval between computational steps: to capture rapid events such as supernova evolution, the simulation must advance in very small-time increments. Shrinking the timestep means dramatically greater computational effort. Even with today's best physics-based models, simulating the Milky Way star by star would require about 315 hours for every 1 million years of galactic evolution. At that rate, generating 1 billion years of activity would take over 36 years of real time. Simply adding more supercomputer cores is not a practical solution, as energy use becomes excessive and efficiency drops as more cores are added.

A New Deep Learning Approach

To overcome these barriers, Hirashima and his team designed a method that blends a deep learning surrogate model with standard physical simulations. The surrogate was trained using high-resolution supernova simulations and learned to predict how gas spreads during the 100,000 years following a supernova explosion without requiring additional resources from the main simulation. This AI component allowed the researchers to capture the galaxy's overall behaviour while still modelling small-scale events, including the fine details of individual supernovae. The team validated the approach by comparing its results against large-scale runs on RIKEN's Fugaku supercomputer and The University of Tokyo's Miyabi Supercomputer System.
The method offers true individual-star resolution for galaxies with more than 100 billion stars, and it does so with remarkable speed. Simulating 1 million years took just 2.78 hours, meaning that 1 billion years could be completed in approximately 115 days instead of 36 years.

Broader Potential for Climate, Weather, and Ocean Modelling

This hybrid AI approach could reshape many areas of computational science that require linking small-scale physics with large-scale behaviour. Fields such as meteorology, oceanography, and climate modelling face similar challenges and could benefit from tools that accelerate complex, multi-scale simulations.
"I believe that integrating AI with high-performance computing marks a fundamental shift in how we tackle multi-scale, multi-physics problems across the computational sciences," says Hirashima. "This achievement also shows that AI-accelerated simulations can move beyond pattern recognition to become a genuine tool for scientific discovery -- helping us trace how the elements that formed life itself emerged within our galaxy."

- ❖ Dark matter acts surprisingly normal in a new cosmic test

Dark matter may be the Universe’s great unknown, but scientists just pulled off one of the sharpest tests yet of how it actually behaves.

Date: November 16, 2025
Source: Université de Genève

Dark matter seems to follow the same gravitational rules as ordinary matter, based on galactic motion across cosmic structures. Yet scientists can’t rule out a subtle fifth force that may emerge with upcoming high-precision observations. Credit: AI/ScienceDaily.com

Does dark matter behave according to the same physical rules that apply to ordinary matter? This question remains one of the major puzzles in modern cosmology, since this invisible form of matter (which neither emits nor reflects any light) is still hypothetical and extremely difficult to study directly. Researchers from the University of Geneva (UNIGE) and collaborating institutions aimed to see whether dark matter follows familiar behaviour on the largest scales, or whether other forces might influence it. Their study, published in Nature Communications, indicates that dark matter appears to act much like ordinary matter, although they cannot yet rule out the possibility of an additional, previously unknown interaction. Because dark matter is thought to be five times more common than

ordinary matter, even a small new insight helps clarify its role in shaping the Universe. Ordinary matter is affected by four known fundamental forces: gravity, electromagnetism, and the strong and weak forces within atoms. The question is whether dark matter responds to the same set of forces. While dark matter is invisible and difficult to detect, it may still follow these familiar laws or possibly be influenced by a fifth force that scientists have not yet identified.

Investigating How Dark Matter Moves Through Gravitational Wells

To explore this possibility, the UNIGE-led team examined whether dark matter sinks into gravitational wells the way ordinary matter does on cosmic scales. Massive objects distort the structure of space, forming these wells. Ordinary matter -- planets, stars and galaxies -- falls into them according to established physical principles that include Einstein's general relativity and Euler's equations. The team wanted to know whether dark matter behaves in the same predictable way.

"To answer this question, we compared the velocities of galaxies across the Universe with the depth of gravitational wells," explains Camille Bonvin, associate professor in the Department of Theoretical Physics at UNIGE's Faculty of Science and co-author of the study. "If dark matter is not subject to a fifth force, then galaxies -- which are mostly made of dark matter -- will fall into these wells like ordinary matter, governed solely by gravity. On the other hand, if a fifth force acts on dark matter, it will influence the motion of galaxies, which would then fall into the wells differently. By comparing the depth of the wells with the galaxies' velocities, we can therefore test for the presence of such a force."

Dark Matter Appears to Follow Euler's Equations

Using this method on modern cosmological data, the researchers found that dark matter moves into gravitational wells in the same manner as ordinary matter, meaning it is consistent with Euler's equations. "At this stage, however, these conclusions do not yet rule out the presence of an unknown force. But if such a fifth force exists, it cannot exceed 7% of the strength of gravity -- otherwise it would already have appeared in our analyses," says Nastassia Grimm first author of the study and former postdoctoral researcher at the Department of Theoretical Physics at UNIGE's Faculty of Science who has recently joined the Institute of Cosmology and Gravitation at the University of Portsmouth.

What Comes Next in the Search for New Physics

These early findings represent an important step in refining our understanding of dark matter. The next key objective is to determine whether a subtle fifth force truly affects it. "Upcoming data from the newest experiments, such as LSST and DESI, will be sensitive to forces as weak as 2% of gravity. They should therefore allow us to learn even more about the behaviour of dark matter," concludes Isaac Tutusaus, researcher at ICE-CSIC and IEEC and associate professor at IRAP, Midi-Pyrénées observatory, University of Toulouse, co-author of the study.

- ❖ Most distant supernova: James Webb sees a star explode at cosmic dawn

JWST has revealed a stellar explosion from the universe’s childhood, and it looks astonishingly familiar.

Date: December 28, 2025
Source: UCD Research & Innovation

This is an artist's concept of one of brightest explosions ever seen in space. Credit: NASA, ESA, NSF's NOIRLab, Mark Garlick, Mahdi Zamani

Astronomers from around the world have reached a major milestone in studying the early universe. Using the James Webb Space Telescope (JWST), they identified a supernova, the explosive death of a massive star, at a distance never observed before. The blast, known as SN in GRB 250314A, occurred when the universe was only about 730 million years old. This places it firmly within the era of reionisation, a period when the first stars and galaxies were beginning to emerge. The observation offers a rare and direct view of how massive stars ended their lives during this formative stage of cosmic history.

A Gamma Ray Burst Leads the Way

The discovery was first reported in the academic paper 'JWST reveals a supernova

following a gamma-ray burst at z ≃ 7.3,' (Astronomy & Astrophysics, 704, December 2025). The event initially drew attention after a powerful flash of high energy radiation, called a long duration Gamma Ray Burst (GRB), was detected on March 14, 2025 by the space based multi band astronomical Variable Objects Monitor (SVOM). Astronomers then used the European Southern Observatory's Very Large Telescope (ESO/VLT) to confirm that the source was located at an extreme distance.

JWST Separates the Explosion From Its Host Galaxy

The decisive observations came about 110 days after the burst, when JWST targeted the region using its Near Infrared Camera (NIRCAM). These images allowed researchers to isolate the fading light of the supernova from the much dimmer glow of its host galaxy, a critical step in confirming the nature of the explosion.

Coauthor and UCD School of Physics astrophysicist Dr. Antonio Martin Carrillo explained the importance of the finding: "The key observation, or smoking gun, that connects the death of massive stars with gamma-ray bursts is the discovery of a supernova emerging at the same sky location. Almost every supernova ever studied has been relatively nearby to us, with just a handful of exceptions to date. When we confirmed the age of this one, we saw a unique opportunity to probe how the Universe was there and what type of stars existed and died back then.

"Using models based on the population of supernovae associated with GRBs in our local universe, we made some predictions of what the emission should be and used it to proposed a new observation with the James Webb Space Telescope. To our surprise, our model worked remarkably well and the observed supernova seems to match really well the death of stars that we see regularly. We were also able to get a glimpse of the galaxy that hosted this dying star."

An Unexpectedly Familiar Explosion

Measurements show that this distant supernova closely matches the brightness and spectral features of SN 1998bw, a well-known supernova linked to a gamma ray burst that exploded much closer to Earth. This resemblance suggests that the star behind GRB 250314A was not dramatically different from massive stars that produce similar explosions in the nearby universe.

Despite forming in an environment with very different conditions, including much lower metallicity, the star appears to have died in a familiar way. The data also rule out a far brighter type of explosion, such as a Super luminous Supernova (SLSN).

Rethinking the First Generations of Stars

These results challenge the long-held idea that the earliest stars would produce explosions that were distinctly brighter or bluer than those seen today. Instead, the findings point to a surprising consistency in how massive stars end their lives across cosmic time.

While the discovery provides an important reference point for understanding stellar evolution in the early universe, it also raises new questions about why these explosions appear so uniform.

The team plans to conduct another round of JWST observations within the next one to two years. By then, the supernova should have faded by more than two magnitudes, making it easier to fully study the faint host galaxy and confirm exactly how much light came from the supernova itself.

- ❖ Scientists may have found the best place for humans to land on Mars

Hidden ice beneath Mars' surface may mark the spot where humanity first sets foot on the Red Planet.

Date: December 27, 2025
Source: University of Mississippi

Researchers have discovered signs of shallow water ice on Mars in a region ideal for human exploration. The ice could support future missions—and possibly preserve evidence of ancient life. Credit: Shutterstock

Before humans can make the long trip to another world, scientists must identify a safe and practical place to land. New research led by a University of Mississippi scientist suggests one region on Mars may meet many of the requirements for future human missions.

Erica Luzzi, a planetary geologist and postdoctoral researcher with the Mississippi Mineral Resources Institute, led a study that uncovered signs of water ice located just below the Martian surface. The research,

published in the *Journal of Geophysical Research: Planets*, points to a possible local water supply that astronauts could rely on during extended stays on Mars.

"If we're going to send humans to Mars, you need H_2O and not just for drinking, but for propellant and all manner of applications," Luzzi said. She carried out the work during her postdoctoral research at the Bay Area Environmental Research Institute within NASA Ames Research Centre.

She explained that ice close to the surface is especially valuable because it could be accessed more easily than deeply buried deposits. This approach, known as in situ resource utilization, allows explorers to use materials already available on another planet rather than transporting everything from Earth.

Ice Just Beneath the Martian Surface

By studying high resolution orbital images, the research team examined the Martian landscape and found signs of ice less than 1 meter below the surface in Amazonis Planitia. This area lies in Mars' mid latitudes and is already being considered as a possible destination for future human landings.

"The mid-latitudes offer the perfect compromise -- they get enough sunlight for power, but they're still cold enough to preserve ice near the surface," Luzzi said. "That makes them ideal for future landing sites."

The team used images from HiRISE, the most detailed camera ever sent to another planet. These images revealed craters that expose ice, patterned ground known as polygonal terrain, and other surface features that often indicate ice just below the surface.

Why Water Ice Matters for Astronauts

Accessible water ice would allow astronauts to produce drinking water, breathable oxygen, fuel, and other essentials needed to survive and work on Mars for long periods.

"For the moon, it would take us one week, more or less, to go back and forth to Earth for resupply," said Giacomo Nodjoumi, a postdoctoral researcher at the Space Science Data Centre of the Italian Space Agency and a coauthor of the study. "But for Mars, it would take months. So, we have to be prepared for not having resupply from Earth for extended periods of time.

"The most important resources are oxygen to breathe and water to drink. That's what makes our candidate landing site really promising."

Clues to Mars' Past and Present Habitability

The presence of ice could also help scientists search for signs of life. According to the researchers, ice has the potential to preserve evidence of biological activity.

"This also has astrobiological implications," Luzzi said. "On Earth, ice can preserve biomarkers of past life, and it can also host microbial populations. So, it could tell us if Mars was ever habitable."

Next Steps Toward Confirmation

Collecting direct samples of the ice would require sending a robotic mission to the region.

"The next step would be radar analyses to better understand the depth and patchiness of the ice," Luzzi said. "The lag deposit, material on top of the ice, might vary, which affects whether the ice is preserved.

"Understanding that will help us decide where a robotic precursor should land."

A rover or future human mission would also be needed to confirm whether the ice is made entirely of water or mixed with other materials.

"We will never be sure of something if we don't have a rover, a lander or a human to take real measurements," Nodjoumi said. "We have strong evidence to suggest that this is water ice, but until we go there and measure it, we won't be 100% sure."

Although human exploration of Mars remains years away, this research helps narrow down where astronauts might one day touch down on the Red Planet.

- ❖ Something fundamental about black holes may be changing

Date: December 27, 2025
Source: Royal Astronomical Society

Supermassive black holes may not have played by the same rules throughout cosmic history—and quasars are revealing the surprise. Credit: AI/ScienceDaily.com

An international group of astronomers has uncovered strong evidence suggesting that the material surrounding supermassive black holes has not remained the same throughout the history of the universe. The findings

indicate that the structure and behaviour of this matter may have shifted over billions of years.

Led by researchers at the National Observatory of Athens, the study was published in *Monthly Notices of the Royal Astronomical Society*. If confirmed, the results would challenge a foundational idea in astronomy that has guided research for nearly 50 years.

What Makes Quasars So Bright

Quasars, first identified in the 1960s, rank among the most luminous objects known. They shine so intensely because they are powered by supermassive black holes pulling in surrounding matter. As this material spirals inward under immense gravity, it forms a rotating, disk-shaped structure before falling into the black hole.

Friction within this disk heats the matter to extreme temperatures. As a result, it can emit 100 to 1,000 times lighter than an entire galaxy made up of about 100 billion stars. This overwhelming brightness allows quasars to outshine their host galaxies and makes them visible to telescopes across vast cosmic distances.

From Ultraviolet Light to Powerful X-Rays

The glowing disk around a black hole produces enormous amounts of ultraviolet light. Scientists believe this light plays a key role in generating the even more energetic X-rays emitted by quasars. As ultraviolet rays travel outward, they pass through clouds of highly energized particles located very close to the black hole, a region known as the "corona."

When ultraviolet light interacts with these particles, it gains energy and transforms into intense X-ray radiation. These X-rays can then be detected by space-based observatories.

A Long-Standing Cosmic Relationship Under Question

Because both types of light originate near the same black hole, astronomers have long known that ultraviolet and X-ray emissions from quasars are closely linked. Typically, brighter ultraviolet light goes hand in hand with stronger X-ray output. This relationship, identified almost five decades ago, has offered critical clues about the physical conditions near supermassive black holes.

The new study challenges the assumption that this connection is universal. That assumption suggests that the structure of matter around black holes is essentially the same everywhere and at all times in the universe.

Instead, the researchers found that when the universe was younger (about half its present age), the relationship between ultraviolet and X-ray light looked noticeably different from what astronomers see in nearby quasars today. This points to changes in how the accretion disk and corona interact over roughly the last 6.5 billion of years.

"Confirming a non-universal X-ray-to-ultraviolet relation with cosmic time is quite surprising and challenges our understanding of how supermassive black holes grow and radiate," said Dr. Antonis Georgakakis, one of the study's authors.

"We tested the result using different approaches, but it appears to be persistent."

How the Researchers Made the Discovery

To reach their conclusions, the team combined fresh X-ray observations from the eROSITA X-ray telescope with archival data from the European Space Agency's XMM-Newton X-ray observatory. Together, these datasets allowed scientists to analyse the X-ray and ultraviolet emissions of an exceptionally large sample of quasars.

The broad and consistent sky coverage provided by eROSITA proved especially important. It enabled the team to examine quasar populations on a scale that was not possible before.

Why the Findings Matter for Cosmology

The idea that the ultraviolet and X-ray relationship in quasars is universal underlies some methods that use quasars as (standard candles) to map the shape of the universe and study dark matter and dark energy. The new results suggest scientists need to be cautious, since the assumption of an unchanging black hole environment over cosmic time may not hold.

"The key advance here is methodological," said postdoctoral researcher Maria Chira of the National Observatory of Athens, who led the study.

"The eROSITA survey is vast but relatively shallow -- many quasars are detected with only a few X-ray photons. By combining these data in a robust Bayesian statistical framework, we could uncover subtle trends that would otherwise remain hidden."

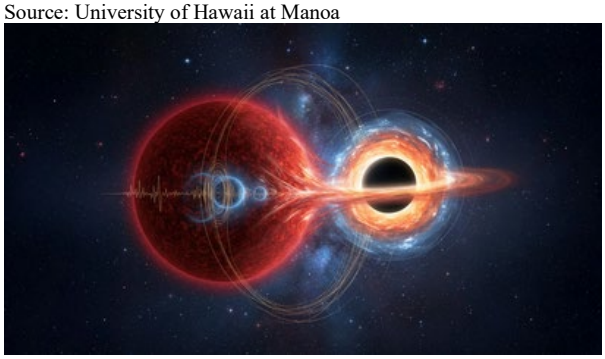
What Comes Next

Upcoming eROSITA all-sky scans will allow astronomers to observe even fainter and more distant quasars. By combining these future

observations with next-generation X-ray and multiwavelength surveys, researchers hope to determine whether the observed changes reflect real physical evolution or are influenced by how the data were collected. These efforts promise deeper insight into how supermassive black holes power the brightest objects in the universe and how their behaviour has transformed over cosmic time.

- ❖ A strange star near a black hole is defying expectations

Date: December 26, 2025
Source: University of Hawaii at Manoa



AI-generated image of red giant star orbiting a quiet black hole in the Gaia BH2 system. Credit: ESO/L. Calçada/Space Engine, edited

Astronomers at the University of Hawai‘i Institute for Astronomy (IfA) have pieced together the dramatic history of a distant red giant by studying subtle changes in its light. Tiny fluctuations in brightness reveal that the star may have collided and merged with another star long ago, a violent event that likely left it spinning much faster than normal. Today, this unusual star circles a quiet black hole in a system known as Gaia BH2.

Using observations from NASA's Transiting Exoplanet Survey Satellite (TESS), the team detected faint vibrations known as "starquakes" moving through the red giant, which is the companion to the black hole. Gaia BH2 itself was first identified in 2023 by the European Space Agency's Gaia mission. Much like earthquakes help scientists explore Earth's interior, these stellar tremors allowed astronomers to probe deep inside the star and precisely measure properties of its core. The results of this work were recently published in *Astronomical Journal*.

"Just like seismologists use earthquakes to study Earth's interior, we can use stellar oscillations to understand what's happening inside distant stars," said IfA research scientist Daniel Hey, lead author of the study. "These vibrations told us something unexpected about this star's history."

A Star That Appears Older Than It Is

One of the most surprising findings came from the star's chemical composition. The red giant is described as "alpha-rich," meaning it contains large amounts of heavy elements that are typically found in very old stars. Based on its chemistry alone, the star should be ancient. However, analysis of its internal vibrations told a different story. The star is actually about 5 billion years old, far younger than its chemical makeup would suggest. That mismatch presents a puzzle for astronomers trying to understand how the star formed.

"Young, alpha-rich stars are quite rare and puzzling," explained Hey. "The combination of youth and ancient chemistry suggests this star didn't evolve in isolation. It likely acquired extra mass from a companion, either through a merger or by absorbing material when the black hole formed."

Spinning Faster Than Expected

Additional clues came from long-term monitoring with ground-based telescopes. These observations show the star completes one full rotation every 398 days, which is unusually fast for a red giant of its age that evolved alone.

"If this rotation is real, it can't be explained by the star's birth spin alone," said co-author Joel Ong, a NASA Hubble Fellow at IfA. "The star must have been spun up through tidal interactions with its companion, which further supports the idea that this system has a complex history."

Comparing Quiet Black Hole Systems

The researchers also studied Gaia BH3, another black hole system with an even stranger companion star. Existing models predicted that this star should display strong oscillations, yet none were observed. This unexpected result suggests that current theories about stars with extremely low metal content may need to be revised.

Both Gaia BH2 and Gaia BH3 belong to a class of dormant black hole systems. These black holes are not actively pulling in material from their companion stars, which means they do not emit X-rays. Instead, astronomers discovered them by carefully tracking the motion of nearby stars. These findings are changing how scientists search for and study black holes within the Milky Way.

What Comes Next

Future observations from TESS will allow astronomers to study Gaia BH2's stellar vibrations in even greater detail. With more data, the team hopes to confirm whether the

red giant truly formed through a past stellar merger and to better understand how these quiet black hole pairs develop over time.

- How Earth endured a planet-wide inferno: The secret water vault under our feet

Date: December 26, 2025
Source: Chinese Academy of Sciences Headquarters

Earth’s oceans may have survived the planet’s fiery birth by hiding deep underground until the surface was ready. Credit: AI/ScienceDaily.com

Around 4.6 billion years ago, Earth looked nothing like the calm, blue world we see today. Repeated and powerful impacts from space kept the planet's surface and interior in a turbulent, molten state. Much of Earth was covered by a global ocean of magma, with temperatures so extreme that liquid water could not survive. The young planet more closely resembled a blazing furnace than a place capable of supporting oceans or life.
Today, however, oceans cover about 70% of Earth's surface. How water managed to endure the transition from this molten early phase to a largely solid planet has long puzzled scientists and driven decades of research.

Water Hidden Deep Inside the Planet

A recent study led by Prof. Zhixue Du of the Guangzhou Institute of Geochemistry of the Chinese Academy of Sciences (GIGCAS) offers a new explanation. The team found that large amounts of water could have been stored deep within Earth's mantle as it cooled and crystallized from molten rock.
Their results, published in *Science* on December 11, are changing how scientists think about water storage deep inside the planet. The researchers showed that bridgmanite, the most abundant mineral in Earth's mantle, can function like a microscopic "water container." This ability may have allowed early Earth to trap significant amounts of water below the surface as the planet solidified.
According to the team, this early reservoir of water may have played a key role in Earth's transformation from a hostile, fiery world into one capable of supporting life.

Testing Water Storage Under Extreme Conditions

Earlier experiments suggested that bridgmanite could only hold small amounts of water. Those studies, however, were conducted at relatively low temperatures. To revisit the question, the researchers had to overcome two major hurdles. They needed to recreate the intense pressures and temperatures found more than 660 kilometres beneath Earth's surface, and they had to detect extremely small traces of water in mineral samples, some thinner than one tenth the width of a human hair and containing only a few hundred parts per million of water.
To meet these challenges, the team built a diamond anvil cell system combined with laser heating and high-temperature imaging. This custom-designed setup allowed them to push temperatures as high as ~4,100 °C. By reproducing deep mantle conditions and accurately measuring equilibrium temperatures, the researchers were able to explore how heat affects the way minerals absorb water.

Advanced Tools Reveal Hidden Water

Using the advanced analytical facilities at GIGCAS, the scientists applied techniques including cryogenic three-dimensional electron diffraction and NanoSIMS. Working with Prof. LONG Tao from the Institute of Geology of the Chinese Academy of Geological Sciences, they also incorporated atom probe tomography (APT).
Together, these methods acted like ultra-high-resolution "chemical CT scanners" and "mass spectrometers" for the microscopic world. This approach allowed the team to map how water is distributed inside tiny samples and confirm that water is structurally dissolved within bridgmanite itself.

A Much Wetter Deep Mantle Than Expected

The experiments revealed that bridgmanite's ability to trap water, measured by its water partition coefficient, increases sharply at higher temperatures. During Earth's hottest magma ocean phase, newly formed bridgmanite could have stored far more water than scientists once believed. This finding challenges the long-standing assumption that the lower mantle is almost completely dry.
Using these results, the team modelled how Earth's magma ocean cooled and crystallized. Their simulations suggest that, because bridgmanite held water so efficiently under

extreme heat, the lower mantle became the largest water reservoir within the solid Earth after the magma ocean cooled. The model indicates that this reservoir could be five to 100 times larger than earlier estimates, with total water amounts ranging from 0.08 to 1 time the volume of today's oceans.

How Deep-Water Shaped Earth's Evolution

This deeply stored water did not simply remain trapped. Instead, it acted as a "lubricant" for Earth's internal engine. By lowering the melting point and viscosity of mantle rocks, the water helped drive internal circulation and plate motion, giving the planet long-term geological energy.

Over vast spans of time, some of this water was slowly returned to the surface through volcanic and magmatic activity. This process contributed to the formation of Earth's early atmosphere and oceans. The researchers suggest that this buried "spark of water" may have been a decisive factor in turning Earth from a molten inferno into the blue, life-friendly planet we know today.