South Downs Mercury

The monthly circular of South Downs Astronomical Society
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Main Talk **JULIAN ONIONS** Aperture Fever - does my mirror look big in this?

After a very brief review of how telescopes work, we look at some of the existing telescopes, both visible and other wavebands, and consider why they are so big, what they can and can't see and what the telescopes planned for the next few years will deliver.

Julian has always had an interest in astronomy, and after many years as an amateur studied for a PhD in astrophysics at the University of Nottingham. There he studies computer models of galaxy formation using some of the biggest computers in the world, building model universes using mostly dark matter. He also helps out with undergraduate teaching and various outreach activities.

Please support a raffle we are organizing this month.

- Gulf of Mars: Rover finds evidence of 'vacation-style' beaches on Mars

Date: February 24, 2025
Source: Penn State

A vast ocean may have once existed in the northern pole of Mars for millions of years. **Credit: Björn Schreiner / FU Berlin / ESA**

Mars may have once been home to sun-soaked, sandy beaches with gentle, lapping waves according to a new study published today (Feb. 24) in the *Proceedings of the National Academy of Sciences* (*PNAS*).

An international team of scientists, including Penn State researchers, used data from the Zhurong Mars rover to identify hidden layers of rock under the planet's surface that strongly suggest the presence of an ancient northern ocean. The new research offers the clearest evidence yet that the planet once contained a significant body of water and a more habitable environment for life, according to Benjamin Cardenas, assistant professor of geology at Penn State and co-author on the study.

"We're finding places on Mars that used to look like ancient beaches and ancient river deltas," Cardenas said. "We found evidence for wind, waves, no shortage of sand -- a proper, vacation-style beach."

The Zhurong rover landed on Mars in 2021 in an area known as Utopia Planitia and sent back data on the geology of its surroundings in search of signs of ancient water or ice. Unlike other rovers, it came equipped with rover-penetrating radar, which allowed it to explore the planet's subsurface, using both low and high-frequency radar to penetrate the Martian soil and identify buried rock formations.

By studying the underground sedimentary deposits, scientists are able to piece together a more complete picture of the red planet's history, Cardenas explained. When the team reviewed radar data, it revealed a similar layered structure to beaches on Earth: formations called "foreshore deposits" that slope downwards towards oceans and form when sediments are carried by tides and waves into a large body of water.

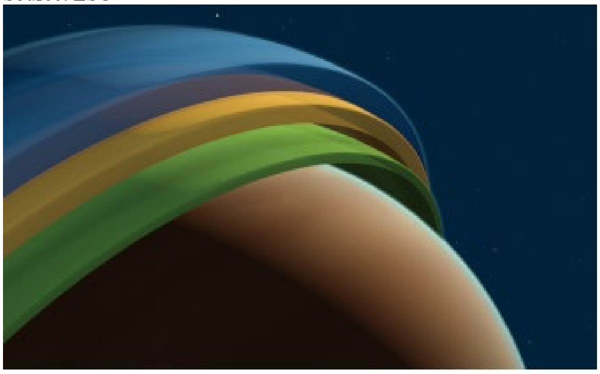
"This stood out to us immediately because it suggests there were waves, which means there was a dynamic interface of air and water," Cardenas said. "When we look back at where the earliest life on Earth developed, it was in the interaction between oceans and land, so this is painting a picture of ancient habitable environments, capable of harbouring conditions friendly toward microbial life."

When the team compared the Martian data with radar images of coastal deposits on Earth, they found striking similarities, Cardenas said. The dip angles observed on

Mars fell right within the range of those seen in coastal sedimentary deposits on Earth.
The researchers also ruled out other possible origins for the dipping reflectors, such as ancient river flows, wind or ancient volcanic activity. They suggested that the consistent dipping shape of the formations as well as the thickness of the sediments point to a coastal origin.
"We're seeing that the shoreline of this body of water evolved over time," Cardenas said. "We tend to think about Mars as just a static snapshot of a planet, but it was evolving. Rivers were flowing, sediment was moving, and land was being built and eroded. This type of sedimentary geology can tell us what the landscape looked like, how they evolved, and, importantly, help us identify where we would want to look for past life."
The discovery indicates that Mars was once a much wetter place than it is today, further supporting the hypothesis of a past ocean that covered a large portion of the northern pole of the planet, Cardenas explained. The study also provided new information on the evolution of the Martian environment, suggesting that a life-friendly warm and wet period spanned potentially tens of millions of years.
"The capabilities of the Zhurong rover have allowed us to understand the geologic history of the planet in an entirely new way," said Michael Manga, professor of Earth and planetary science at the University of California, Berkeley, and a corresponding author on the paper. "Its ground-penetrating radar gives us a view of the subsurface of the planet, which allows us to do geology that we could have never done before. All these incredible advancements in technology have made it possible to do basic science that is revealing a trove of new information about Mars."
The other corresponding authors on the paper are Hai Liu of Guangzhou University and Guangyou Fang of the Chinese Academy of Sciences. The other Penn State co-author is Derek Elsworth, the G. Albert Shoemaker Chair and professor of energy and mineral engineering and geosciences. The other authors are Jianhui Li, Xu Meng, Diwen Duan and Haijing Lu of Guangzhou University; Jinhai Zhang and Bin Zhou of the Chinese Academy of Sciences; and Fengshou Zhang of Tongji University in Shanghai, China.

- Out of science fiction': First 3D observations of an exoplanet's atmosphere reveal a unique climate

Date: February 18, 2025
Source: ESO


Credit: ESO/M. Kornmesser

Astronomers have peered through the atmosphere of a planet beyond the Solar System, mapping its 3D structure for the first time. By combining all four telescope units of the European Southern Observatory's Very Large Telescope (ESO's VLT), they found powerful winds carrying chemical elements like iron and titanium, creating intricate weather patterns across the planet's atmosphere. The discovery opens the door for detailed studies of the chemical makeup and weather of other alien worlds.
"This planet's atmosphere behaves in ways that challenge our understanding of how weather works -- not just on Earth, but on all planets. It feels like something out of science fiction," says Julia Victoria Seidel, a researcher at the European Southern Observatory (ESO) in Chile and lead author of the study, published today in Nature.
The planet, WASP-121b (also known as Tylos), is some 900 light-years away in the constellation Puppis. It's an ultra-hot Jupiter, a gas giant orbiting its host star so closely that a year there lasts only about 30 Earth hours. Moreover, one side of the planet is scorching, as it is always facing the star, while the other side is much cooler.
The team has now probed deep inside Tylos's atmosphere and revealed distinct winds in separate layers, forming a map of the atmosphere's 3D structure. It's the first-time astronomers have been able to study the atmosphere of a planet outside our Solar System in such depth and detail.
"What we found was surprising: a jet stream rotates material around the planet's equator, while a separate flow at lower levels of the atmosphere moves gas from the hot side to the cooler side. This kind of climate has never been seen before on any planet," says Seidel,

who is also a researcher at the Lagrange Laboratory, part of the Observatoire de la Côte d'Azur, in France. The observed jet stream spans half of the planet, gaining speed and violently churning the atmosphere high up in the sky as it crosses the hot side of Tylos. "Even the strongest hurricanes in the Solar System seem calm in comparison," she adds.
To uncover the 3D structure of the exoplanet's atmosphere, the team used the ESPRESSO instrument on ESO's VLT to combine the light of its four large telescope units into a single signal. This combined mode of the VLT collects four times as much light as an individual telescope unit, revealing fainter details. By observing the planet for one full transit in front of its host star, ESPRESSO was able to detect signatures of multiple chemical elements, probing different layers of the atmosphere as a result.
"The VLT enabled us to probe three different layers of the exoplanet's atmosphere in one fell swoop," says study co-author Leonardo A. dos Santos, an assistant astronomer at the Space Telescope Science Institute in Baltimore, United States. The team tracked the movements of iron, sodium and hydrogen, which allowed them to trace winds in the deep, mid and shallow layers of the planet's atmosphere, respectively. "It's the kind of observation that is very challenging to do with space telescopes, highlighting the importance of ground-based observations of exoplanets," he adds.
Interestingly, the observations also revealed the presence of titanium just below the jet stream, as highlighted in a companion study published in Astronomy and Astrophysics. This was another surprise since previous observations of the planet had shown this element to be absent, possibly because it's hidden deep in the atmosphere.
"It's truly mind-blowing that we're able to study details like the chemical makeup and weather patterns of a planet at such a vast distance," says Bibiana Prinoth, a PhD student at Lund University, Sweden, and ESO, who led the companion study and is a co-author of the Nature paper.
To uncover the atmosphere of smaller, Earth-like planets, though, larger telescopes will be needed. They will include ESO's Extremely Large Telescope (ELT), which is currently under construction in Chile's Atacama Desert, and its ANDES instrument. "The ELT will be a game-changer for studying exoplanet atmospheres," says Prinoth. "This experience makes me feel like we're on the verge of uncovering incredible things we can only dream about now."
The companion research, uncovering the presence of titanium, was published in the journal *Astronomy & Astrophysics* in a paper titled "Titanium chemistry of WASP-121 b with ESPRESSO in 4-UT mode" (doi: 10.1051/0004-6361/202452405)

- First detection of an ultra-high-energy neutrino

Date: February 12, 2025
Source: CNRS

Seeing the light KM3NeT detectors being readied for deployment at sea. (Courtesy: Marco Kraan/Nikhef)

An extraordinary event consistent with a neutrino with an estimated energy of about 220 PeV (220 x 1015 electron volts or 220 million billion electron volts), was detected on February 13, 2023, by the ARCA detector of the kilometre cubic neutrino telescope (KM3NeT) in the deep sea. This event, named KM3-230213A, is the most energetic neutrino ever observed and provides the first evidence that neutrinos of such high energies are produced in the Universe. After long and meticulous work to analyse and interpret the experimental data, today, February 12, 2025, the international scientific collaboration of KM3NeT reports the details of this amazing discovery in an article published in *Nature.*
The detected event was identified as a single muon which crossed the entire detector, inducing signals in more than one third of the active sensors. The inclination of its trajectory combined with its enormous energy provides compelling evidence that the muon originated from a cosmic neutrino interacting in the vicinity of the detector.
"KM3NeT has begun to probe a range of energy and sensitivity where detected neutrinos may originate from extreme astrophysical phenomena. This first ever detection of a neutrino of hundreds of PeV opens a new chapter in neutrino astronomy and a new observational window on the Universe," comments Paschal Coyle, KM3NeT Spokesperson at the time of the detection, and researcher at CNRS Centre National de la

Recherche Scientifique -- Centre de Physique des Particules de Marseille, France.

The high-energy universe is the realm of cataclysmic events such as accreting supermassive black holes at the centre of galaxies, supernova explosions, gamma ray bursts, all as yet not fully understood. These powerful cosmic accelerators, generate streams of particles called cosmic rays. Some cosmic rays may interact with matter or photons around the source, to produce neutrinos and photons. During the travel of the most energetic cosmic rays across the Universe, some may also interact with photons of the cosmic microwave background radiation, to produce extremely energetic "cosmogenic" neutrinos.

"Neutrinos are one of the most mysterious of elementary particles. They have no electric charge, almost no mass and interact only weakly with matter. They are special cosmic messengers, bringing us unique information on the mechanisms involved in the most energetic phenomena and allowing us to explore the farthest reaches of the Universe," explains Rosa Coniglione, KM3NeT Deputy-Spokesperson at the time of the detection, researcher at the INFN National Institute for Nuclear Physics, Italy.

Although neutrinos are the second most abundant particle in the Universe after photons, their weak interaction with matter makes them very hard to detect and requires enormous detectors. The KM3NeT neutrino telescope, currently under construction, is a giant deep-sea infrastructure distributed across two detectors ARCA and ORCA. In its final configuration, KM3NeT will occupy a volume of more than one cubic kilometre. KM3NeT uses sea water as the interaction medium for neutrinos. Its high-tech optical modules detect the Cherenkov light, a bluish glow that is generated during the propagation through the water of the ultra-relativistic particles produced in neutrino interactions.

"To determine the direction and energy of this neutrino required a precise calibration of the telescope and sophisticated track reconstruction algorithms. Furthermore, this remarkable detection was achieved with only one tenth of the final configuration of the detector, demonstrating the great potential of our experiment for the study of neutrinos and for neutrino astronomy," comments Aart Heijboer, KM3NeT Physics and Software Manager at the time of the detection, and researcher at Nikhef National Institute for Subatomic Physics, The Netherlands.

The KM3NeT/ARCA (Astroparticle Research with Cosmics in the Abyss) detector is mainly dedicated to the study of the highest energy neutrinos and their sources in the Universe. It is located at 3450 m depth, about 80 km from the coast of Portopalo di Capo Passero, Sicily. Its 700 m high detection units (DUs) are anchored to the seabed and positioned about 100 m apart. Every DU is equipped with 18 Digital Optical Modules (DOM) each containing 31 photomultipliers (PMTs). In its final configuration, ARCA will comprise 230 DUs. The data collected are transmitted via a submarine cable to the shore station at the INFN Laboratori Nazionali del Sud.

The KM3NeT/ORCA (Oscillation Research with Cosmics in the Abyss) detector is optimised to study the fundamental properties of the neutrino itself. It is located at a depth of 2450 m, about 40 km from the coast of Toulon, France. It will comprise 115 DUs, each 200 m high and spaced by 20 m. The data collected by ORCA are sent to the shore station at La Seyne Sur Mer.

"The scale of KM3NeT, eventually encompassing a volume of about one cubic kilometre with a total of about 200,000 photomultipliers, along with its extreme location in the abyss of the Mediterranean Sea, demonstrates the extraordinary efforts required to advance neutrino astronomy and particle physics. The detection of this event is the result of a tremendous collaborative effort between many international teams of engineers, technicians and scientists," comments Miles Lindsey Clark, KM3NeT Technical Project Manager at the time of the detection, and research engineer at the CNRS -- Astroparticle and Cosmology laboratory, France.

This ultra-high energy neutrino may originate directly from a powerful cosmic accelerator. Alternatively, it could be the first detection of a cosmogenic neutrino. However, based on this single neutrino it is difficult to conclude on its origin. Future observations will focus on detecting more such events to build a clearer picture. The ongoing expansion of KM3NeT with additional detection units and the acquisition of additional data will improve its sensitivity and enhance its ability to pinpoint cosmic neutrino sources, making it a leading contributor to multi-messenger astronomy.

The KM3NeT Collaboration brings together more than 360 scientists, engineers, technicians and students of 68 institutions from 21 countries all over the world.

KM3NeT is included in the roadmap of the European Strategy Forum on Research Infrastructures, which recognises KM3NeT as a priority research infrastructure for Europe. In addition to the funding provided by research agencies in several countries, KM3NeT has benefitted from various fundings through the European research and innovation programmes as well as the European Regional Development Fund.

- Why is Mars red? Scientists may finally have the answer

Date: February 25, 2025
Source: Brown University

Martin Holverda//Getty Images

Mars has captivated scientists and the public alike for centuries. One of the biggest reasons is the planet's reddish hue, earning the fourth rock from the sun one its most popular nicknames -- the "Red Planet." But what exactly gives the planet its iconic colour? Scientists have wondered this for as long as they've studied the planet. Today, they may finally have a concrete answer, one that ties into Mar's watery past.

Results from a new study published in the journal *Nature Communications* and led by researchers from Brown University and the University of Bern suggest that the water-rich iron mineral ferrihydrite may be the main culprit behind Mars' reddish dust. Their theory -- which they reached by analysing data from Martian orbiters, rovers and laboratory simulations -- runs counter to the prevailing theory that a dry, rust-like mineral called hematite is the reason for the planet's colour.

"The fundamental question of why Mars is red has been thought of for hundreds if not for 1000s of years," said Adomas (Adam) Valantinas, a postdoctoral fellow at Brown who started this work as a Ph.D. student at the University of Bern. "From our analysis, we believe ferrihydrite is everywhere in the dust and also probably in the rock formations, as well. We're not the first to consider ferrihydrite as the reason for why Mars is red, but it has never been proven the way we proved it now using observational data and novel laboratory methods to essentially make a Martian dust in the lab."

Ferrihydrite is an iron oxide mineral that forms in water-rich environments. On Earth, it is commonly associated with processes like the weathering of volcanic rocks and ash. Until now, its role in Mars' surface composition was not well understood, but this new research suggests that it could be an important part of the dust that blankets the planet's surface.

The finding offers a tantalizing clue to Mars' wetter and potentially more habitable past because unlike hematite, which typically forms under warmer, drier conditions, ferrihydrite forms in the presence of cool water. This suggests that Mars may have had an environment capable of sustaining liquid water -- an essential ingredient for life -- and that it transitioned from a wet to a dry environment billions of years ago.

"What we want to understand is the ancient Martian climate, the chemical processes on Mars -- not only ancient -- but also present," said Valantinas, who is working in the lab of Brown planetary scientist Jack Mustard, a senior author on the study. "Then there's the habitability question: Was there ever life? To understand that, you need to understand the conditions that were present during the time of this mineral formation. What we know from this study is the evidence points to ferrihydrite forming, and for that to happen there must have been conditions where oxygen, from air or other sources, and water could react with iron. Those conditions were very different from today's dry, cold environment. As Martian winds spread this dust everywhere, it created the planet's iconic red appearance."

The researchers analysed data from multiple Mars missions, combining orbital observations from NASA's Mars Reconnaissance Orbiter and the European Space Agency's Mars Express and Trace Gas Orbiter with ground-level measurements from rovers like Curiosity, Pathfinder and Opportunity.

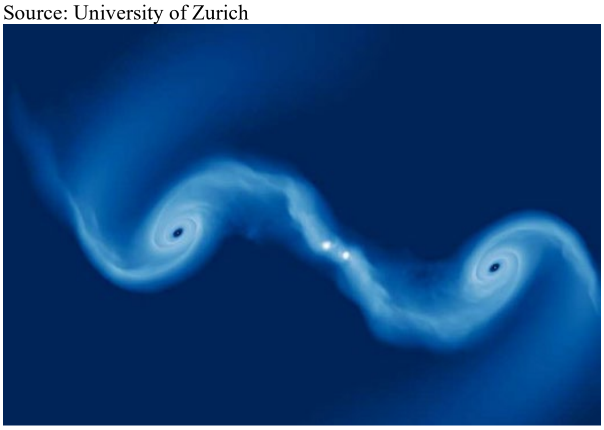
Instruments on the orbiters and rovers provided detailed spectral data of the planet's dusty surface. These findings were then compared to laboratory experiments, where the team tested how light interacts with ferrihydrite particles and other minerals under simulated Martian conditions.

"Martian dust is very small in size, so to conduct realistic and accurate measurements we simulated the particle sizes of our mixtures to fit the ones on Mars," Valantinas said. "We used an advanced grinder machine which reduced the size of our ferrihydrite and basalt to submicron sizes. The final size was 1/100th

of a human hair and the reflected light spectra of these mixtures provide a good match to the observations from orbit and red surface on Mars."
As exciting as these new findings are, the researchers are well aware none of it can be confirmed until samples from Mars are brought back to Earth, leaving the mystery of the Red Planet's past just out of reach.
"The study is a door opening opportunity," Mustard said. "It gives us a better chance to apply principles of mineral formation and conditions to tap back in time. What's even more important though is the return of the samples from Mars that are being collected right now by the Perseverance rover. When we get those back, we can actually check and see if this is right."

- Young star clusters give birth to rogue planetary-mass objects

Date: February 27, 2025
Source: University of Zurich



The formation of binary PMOs via circumstellar disk encounters.
Credit: Deng Hongping

How do rogue planetary-mass objects -- celestial bodies with masses between stars and planets -- form? An international team of astronomers, including the University of Zurich, has used advanced simulations to show that these enigmatic objects are linked to the chaotic dynamics of young star clusters.
Planetary-mass objects (PMOs) are cosmic nomads: they drift freely through space, unbound to any star, and weigh less than 13 times the mass of Jupiter. While they have been spotted in abundance in young star clusters such as the Trapezium Cluster in Orion, their origin has puzzled scientists. Traditional theories have suggested that they might be failed stars or planets ejected from their solar systems.
An international team of astronomers, in collaboration with the University of Zurich (UZH), has used advanced simulations to demonstrate that these enigmatic objects can form directly from the violent interactions of disks around young stars. "PMOs don't fit neatly into existing categories of stars or planets," said Lucio Meyer from the UZH, corresponding author of the study. "Our simulations show they are probably formed by a completely different process."

How disks collide to create PMOs

Using high-resolution hydrodynamic simulations, the team from the University of Zurich, the University of Hong Kong, the Shanghai Astronomical Observatory, and the University of California Santa Cruz, recreated close encounters between two circumstellar disks -- rotating rings of gas and dust that surround young stars. When these disks pass close to each other, their gravitational interactions stretch and compress the gas into elongated "tidal bridges."
The simulations revealed that these bridges collapse into dense filaments, which further fragment into compact cores. When the mass of the filaments exceeds a critical threshold for stability, they produce PMOs with masses of about 10 Jupiters. Up to 14% of PMOs form in pairs or triples, which explains the high rate of PMO binaries in some clusters. Frequent disk encounters in dense environments such as the Trapezium Cluster could generate hundreds of PMOs.

Why PMOs are unique

PMOs form along stars, inheriting material from the outer edges of circumstellar disks. PMOs move in synchrony with the stars in their host cluster, unlike ejected planets. Many PMOs retain gas disks, suggesting the potential for moon or even planet formation around these nomads.
"This discovery partly reshapes how we view cosmic diversity," said co-author Lucio Mayer. "PMOs may represent a third class of objects, born not from the raw material of star forming clouds or via planet-building processes, but rather from the gravitational chaos of disk collisions."

- The International Space Station is overly sterile; making it 'dirtier' could improve astronaut health

Date: February 27, 2025
Source: Cell Press

Photograph: Kayla Barron/AP

Astronauts often experience immune dysfunction, skin rashes, and other inflammatory conditions while traveling in space. A new study publishing February 27 in the Cell Press journal *Cell* suggests that these issues could be due to the excessively sterile nature of spacecraft. The study showed that the International Space Station (ISS) has a much lower diversity of microbes compared to human-built environments on Earth, and the microbes that are present are mostly species carried by humans onto the ISS, suggesting that the presence of more microbes from nature could help improve human health in the space station.

"Future built environments, including space stations, could benefit from intentionally fostering diverse microbial communities that better mimic the natural microbial exposures experienced on Earth, rather than relying on highly sanitized spaces," says co-first author Rodolfo Salido of the University of California, San Diego (UC San Diego).

The researchers collaborated with astronauts who swabbed 803 different surfaces on the ISS -- around 100 times more samples than were taken in previous surveys. Back on Earth, the researchers identified which bacterial species and chemicals were present in each sample. Then, they created three-dimensional maps illustrating where each was found on the ISS and how the bacteria and chemicals might be interacting.

The team found that overall, human skin was the main source of microbes throughout the ISS. Chemicals from cleaning products and disinfectants were present ubiquitously throughout the station. They also found that different "modules" or rooms within the ISS hosted different microbial communities and chemical signatures, and these differences were determined by the module's use. For example, dining and food preparation areas contained more food-associated microbes, whereas the space toilet contained more urine- and fecal-associated microbes and metabolites.

"We noticed that the abundance of disinfectant on the surface of the International Space Station is highly correlated with the microbiome diversity at different locations on the space station," says co-first author Nina Zhao of UC San Diego.

When they compared the ISS to different human-built environments on Earth, the researchers found that the ISS microbial communities were less diverse than most of the samples from Earth and were more similar to samples from industrialized, isolated environments, such as hospitals and closed habitats, and homes in urbanized areas.

Compared to most of the Earth samples, the ISS surfaces were lacking in free-living environmental microbes that are usually found in soil and water. Intentionally incorporating these microbes and the substrates they live in into the ISS could improve astronaut health without sacrificing hygiene, the researchers say. The researchers compare their suggestion to the well-studied beneficial impacts of gardening on the immune system.

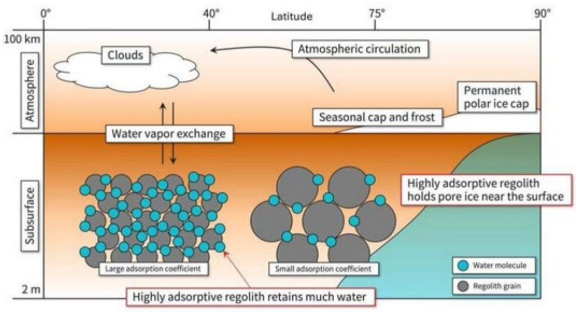
"There's a big difference between exposure to healthy soil from gardening versus stewing in our own filth, which is kind of what happens if we're in a strictly enclosed environment with no ongoing input of those healthy sources of microbes from the outside," says Knight.

In the future, the researchers hope to refine their analyses to be able to detect potentially pathogenic microbes and signals of human health from environmental metabolites. They say that these methods could also help improve the health of people living and working in similarly sterile environments on Earth.

"If we really want life to thrive outside Earth, we can't just take a small branch of the tree of life and launch it into space and hope that it will work out," says Salido. "We need to start thinking about what other beneficial companions we should be sending with these astronauts to help them develop ecosystems that will be sustainable and beneficial for all."

- Adsorptive regolith on Mars soaks up water, researchers reveal

Date: February 26, 2025
Source: Tohoku University



The schematic diagram of the model and results. Credit: Mirai Kobayashi

Mars, the next frontier in space exploration, still poses many questions for scientists. The planet was once more hospitable, characterized by a warm and wet climate with liquid oceans. But today Mars is cold and dry, with most water now located below the surface. Understanding how much water is stored offers critical information for energy exploration, as well as life sustainability on the planet.

A research group from Tohoku University has helped shed light on this by improving an existing Mars climate model. The enhanced model accommodates the various properties of Martian regolith, or the loose deposits of solid rock that comprise Martian soil.

Mirai Kobayashi says current models fail to account for the fact that laboratory experiments have demonstrated that the water-holding capacity of the regolith is strongly influenced by its adsorption coefficient.

"Models to date that estimate the distribution of surface and subsurface water on Mars assume that its regolith properties are uniform. This contrasts with observations made by orbiters and landers, which suggest that Martian regolith has globally non-uniform physical properties."

The model estimated Mars's subsurface water distribution down to 2 meters from the surface. Like a sponge, highly absorptive regolith in Mars's mid- and low latitudes retains substantial amounts of absorbed water. Some of this water, the findings showed, remains on the surface of the regolith as stable adsorbed water.

The study also showed that the soil on Mars could keep ice near the surface in the middle and lower areas because water vapor moves more slowly there. This means the soil helps trap water for a long time by slowing down how water vapor spreads, which is important for understanding the change in water on Mars over time.

"Our study stresses the importance of incorporating absorption and inhomogeneity of Martian regolith in forecasting Mars's surface water," says Takeshi Kuroda, who led the team alongside Kobayashi, Arihiro Kamada and Naoki Terada. "The model can also be used to study how water on Mars has changed, and how it may have moved deeper underground near the planet's mantle."

With several Mars exploration missions underway, including the Japan-led Martian Moons eXploration (MMX) and the international Mars Ice Mapper (MIM) projects, the model is expected to complement further studies that can lead to subsurface water maps of Mars.

❖ ESO observations help almost fully rule out 2024 YR4 asteroid impact

Date: February 25, 2025
Source: ESO

Artist's impression of asteroid 2024 YR4. Concerns about a potential impact have dissipated as more observational data comes in. Credit: ESA

New observations of 2024 YR4 conducted with the European Southern Observatory's Very Large Telescope (ESO's VLT) and facilities around the world have all but ruled out an impact of the asteroid with our planet. The asteroid has been closely monitored in the past couple of months as its odds of impacting Earth in 2032 rose to around 3%, the highest impact probability ever reached for a sizable asteroid. After the latest observations, the odds of impact dropped to nearly zero.

The asteroid 2024 YR4, estimated to be about 40 to 90 metres in diameter, was discovered in late December last year on an orbit that could cause it to collide with Earth on 22 December 2032. Because of its size and likelihood of impact, the asteroid quickly rose to the top of the European Space Agency's (ESA) risk list, a catalogue of all space rocks with any chance of impacting Earth.

ESO's VLT was used to observe 2024 YR4 in mid-January, giving astronomers the crucial data they needed to more precisely calculate its orbit. Combined with data from other observatories, the very precise measurements from the VLT improved our knowledge of the asteroid's orbit, leading to an impact probability exceeding 1% -- a key threshold to trigger disaster mitigation. More observations were triggered and the International Asteroid Warning Network issued a potential asteroid impact notification, alerting planetary defence groups, including the Space Mission Planning Advisory Group, about the possible impact. With multiple telescopes around the world observing the asteroid, and astronomers modelling its orbit, the impact probability rose to around 3% on 18 February, the highest impact probability ever recorded for an asteroid larger than 30 metres. However, just the next day, new observations made with ESO's VLT cut the impact risk in half.

This rise and fall of the asteroid's impact probability follows an expected and understood pattern. To know where the asteroid will be in 2032, astronomers extrapolate from the small bit of the orbit measured thus far. ESO Astronomer Olivier Hainaut makes an analogy: "Because of the uncertainties, the orbit of the asteroid is like the beam of a flashlight: getting broader and broader and fuzzier in the distance. As we observe more, the beam becomes sharper and narrower. Earth was getting more illuminated by this beam: the probability of impact increased."

The new VLT observations, together with data from other observatories, have allowed astronomers to constrain the orbit enough to all but rule out an impact with Earth in 2032. "The narrower beam is now moving away from Earth," Hainaut says. At the time of writing, the impact probability reported by ESA's Near-Earth Objects Coordination Centre is around 0.001% and the asteroid no longer tops ESA's risk list.

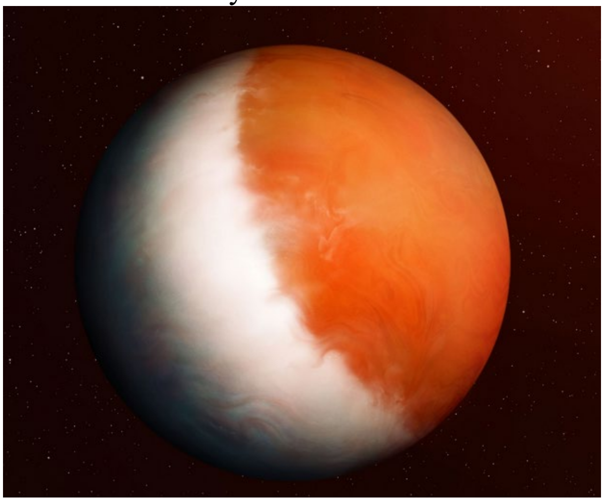
As 2024 YR4 is moving away from Earth, it has become increasingly faint and difficult to observe it with all but the largest telescopes. ESO's VLT has been instrumental in observations of this asteroid because of its mirror size and superb sensitivity, as well as the excellent dark skies at ESO's Paranal Observatory in Chile, where the telescope is located. This makes it ideal to track faint objects such as 2024 YR4 and other potentially dangerous asteroids.

Unfortunately, the same Paranal's pristine dark skies that made these crucial measurements possible are currently under threat by the industrial megaproject INNA by AES Andes, a subsidiary of the US power company AES Corporation. The project is planned to cover an area similar in size to that of a small city and be located, at the closest point, about 11 km from the VLT. Due to its size and proximity, INNA would have devastating effects on the quality of the skies at Paranal, especially due to light pollution from its industrial facilities. With a brighter sky, telescopes like the VLT will lose their ability to detect some of the faintest cosmic targets.

Hainaut warns: "With that brighter sky, the VLT would lose the faint 2024 YR4 about one month earlier, which would make a huge difference in our capability to predict an impact, and prepare mitigation measures to protect Earth."

❖ Today's forecast: Partially cloudy skies on an 'ultra-hot Neptune'

Date: February 25, 2025
Source: University of Montreal



The exotic atmosphere of LTT 9779 b, a rare "ultra-hot Neptune," is coming to light thanks to observations via the James Webb Space Telescope led by Louis-Philippe Coulombe, a graduate student at Université de Montréal's Trottier Institute for Research on Exoplanets (IREx).

Published today in *Nature Astronomy*, the observations by Coulombe and his team, offer new insights into the extreme weather patterns and atmospheric properties of this fascinating exoplanet.

Orbiting its host star in less than a day, LTT 9779 b is subjected to searing temperatures reaching almost 2,000°C on its dayside. The planet is tidally locked (similar to Earth's Moon), meaning one side constantly faces its star while the other remains in perpetual darkness.

Despite these extremes, Coulombe's team discovered that the exoplanet's dayside hosts reflective clouds on its cooler western hemisphere, creating a striking contrast to the hotter eastern side.

"This planet provides a unique laboratory to understand how clouds and the transport of heat interact in the atmospheres of highly irradiated worlds," said Coulombe.

Asymmetry on the dayside

Using the James Webb Space Telescope (JWST), his team uncovered an asymmetry in the planet's dayside reflectivity. They propose that the uneven distribution of heat and clouds is driven by powerful eastward winds that transport heat around the planet.

These findings help refine models describing how heat is transported across a planet and cloud formation in exoplanet atmospheres, thereby also bridging the gap between theory and observation.

The research team studied the atmosphere in detail by analysing both the heat emitted by the
planet and the light it reflects from its star. To create a clearer picture, they observed the planet at multiple positions in its orbit and analysed its properties at each phase individually.

They discovered clouds made of materials like silicate minerals, which form on the slightly cooler western side of the planet's dayside. These reflective clouds help explain why this planet is so bright at visible wavelengths, bouncing back much of the star's light.

By combining this reflected light with heat emissions, the team was able to create a detailed model of the planet's atmosphere. Their findings reveal a delicate balance between intense heat from the star and the planet's ability to redistribute energy.

The study also detected water vapour in the atmosphere, providing important clues about the planet's composition and the processes that govern its extreme environment.

"By modelling LTT 9779 b's atmosphere in detail, we're starting to unlock the processes driving its alien weather patterns," said Coulombe's research advisor Björn Benneke, an UdeM professor of astronomy and co-author of the study.

An incredibly powerful telescope

With this study, the JWST has once again demonstrated its incredible power, allowing scientists to study the atmosphere of LTT 9779 b in unprecedented detail.

Its Canadian instrument, the Near Infrared Imager and Slit less Spectrograph (NIRISS), was used to observe the planet for nearly 22 hours. The data captured the planet's full orbit around its star, including two secondary eclipses (when the planet passes behind its star) and a primary transit (when the planet passes in front of its star).

For an exoplanet like LTT 9779 b, which is tidally locked to its star, the amount and type of light that's observed changes as the planet rotates, showing us different parts of its surface. The dayside reflects and emits more light due to intense heating, while the cooler nightside emits less light. By capturing spectra at various phases, researchers can map out variations in temperature, composition and even cloud coverage across the planet's surface.

Michael Radica, a former PhD student at UdeM and now a postdoctoral researcher at the University of Chicago, was the second author of this study. Earlier this year, he published
a detailed analysis of the planet's light spectrum during transit. "It's remarkable that both types of analyses paint such a clear and consistent picture of the planet's atmosphere," he noted.

The research was conducted as part of the NEAT (NIRISS Exploration of Atmospheric Diversity of Transiting Exoplanets) Guaranteed Time Observation program, led by IREx's David Lafrenière, an UdeM astrophysics professor.

The study highlights the importance of JWST's ability to observe exoplanets across a wide wavelength range, allowing scientists to disentangle the contributions of reflected light and thermal emission, he said.

"This is exactly the kind of groundbreaking work JWST was designed to enable."

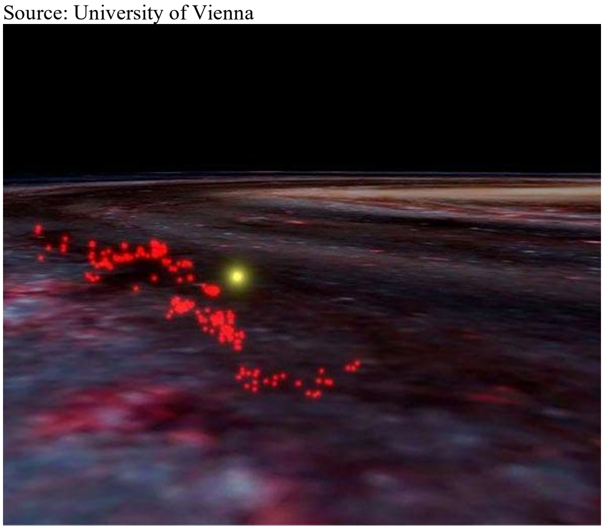
Remarkably rare hot Neptunes

LTT 9779 b resides in the "hot Neptune desert," where exceptionally few such planets are known to exist. While giant planets orbiting very close to their host stars -- often called "hot Jupiters" -- are commonly detected using current exoplanet-finding methods,

ultra-hot Neptunes like LTT 9779 b remain remarkably rare.
"Finding a planet of this size so close to its host star is like finding a snowball that hasn't melted in a fire," said Coulombe. "It's a testament to the diversity of planetary systems and offers a window into how planets evolve under extreme conditions."
This rare planetary system continues to challenge scientists' understanding of how planets form, migrate, and endure in the face of unrelenting stellar forces. LTT 9779 b's reflective clouds and high metallicity may shed light on how atmospheres evolve in extreme environments, too.
LTT 9779 b is a remarkable laboratory for exploring these questions, offering insights into the broader processes that shape the architecture of planetary systems across the galaxy, said Coulombe.
"These findings give us a new lens for understanding atmospheric dynamics on smaller gas giants. This is just the beginning of what JWST will reveal about these fascinating worlds."

- ❖ The galactic journey of our solar system

Our sun and its planets crossed the Radcliffe Wave in the well-known Orion complex
Date: February 25, 2025
Source: University of Vienna



An international research team led by the University of Vienna has discovered that the Solar System traversed the Orion star-forming complex, a component of the Radcliffe Wave galactic structure, approximately 14 million years ago. This journey through a dense region of space could have compressed the heliosphere, the protective bubble surrounding our solar system, and increased the influx of interstellar dust, potentially influencing Earth's climate and leaving traces in geological records. The findings, published in *Astronomy & Astrophysics*, offer a fascinating interdisciplinary link between astrophysics, paleoclimatology, and geology.
The Solar System's journey around the Milky Way's centre takes it through varying galactic environments. "Imagine it like a ship sailing through varying conditions at sea," explains Efrem Maconi, lead author and doctoral student at the University of Vienna. "Our Sun encountered a region of higher gas density as it passed through the Radcliffe Wave in the Orion constellation."
Using data from the European Space Agency's (ESA) Gaia mission and spectroscopic observations, the team pinpointed the Solar System's passage through the Radcliffe Wave in the Orion region about 14 million years ago. "This discovery builds upon our previous work identifying the Radcliffe Wave," says João Alves, professor of astrophysics at the University of Vienna and co-author of the study. The Radcliffe Wave is a vast, thin structure of interconnected star-forming regions, including the renowned Orion complex, which the Sun traversed, as established in this study.
"We passed through the Orion region as well-known star clusters like NGC 1977, NGC 1980, and NGC 1981 were forming," Alves notes. "This region is easily visible in the winter sky in the Northern Hemisphere and summer in the Southern Hemisphere. Look for the Orion constellation and the Orion Nebula (Messier 42) -- our solar system came from that direction!"
The increased dust from this galactic encounter could have had several effects. It may have penetrated the Earth's atmosphere, potentially leaving traces of radioactive elements from supernovae in geological records. "While current technology may not be sensitive enough to detect these traces, future detectors could make it possible," Alves suggests.
The team's research indicates the Solar System's passage through the Orion region occurred between approximately 18.2 and 11.5 million years ago, with the most likely time between 14.8 and 12.4 million years ago. This timeframe aligns well with the Middle Miocene Climate Transition, a significant shift from a warm variable climate to a cooler climate, leading to the establishment of a continental-scale prototype Antarctic ice sheet

configuration. While the study raises the possibility of a link between the past traverse of the solar system through its galactic neighbourhood and Earth's climate via interstellar dust, the authors emphasize that a causal connection requires further investigation.

Not comparable to the current human-made Climate Change

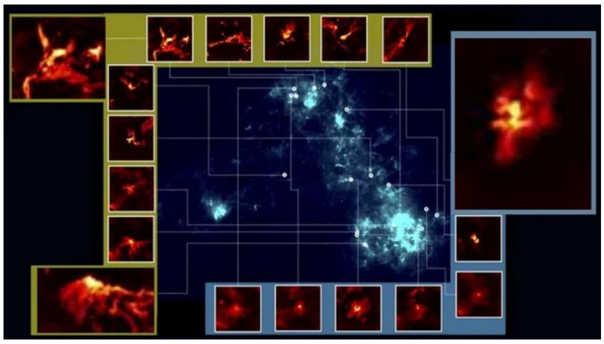
"While the underlying processes responsible for the Middle Miocene Climate Transition are not entirely identified, the available reconstructions suggest that a long-term decrease in the atmospheric greenhouse gas carbon dioxide concentration is the most likely explanation, although large uncertainties exist. However, our study highlights that interstellar dust related to the crossing of the Radcliffe Wave might have impacted Earth's climate and potentially played a role during this climate transition. To alter the Earth's climate the amount of extraterrestrial dust on Earth would need to be much bigger than what the data so far suggest," says Maconi. "Future research will explore the significance of this contribution. It's crucial to note that this past climate transition and current climate change are not comparable since the Middle Miocene Climate Transition unfolded over timescales of several hundred thousand years. In contrast, the current global warming evolution is happening at an unprecedented rate over decades to centuries due to human activity."

This study is important because it adds a small puzzle piece to the recent history of the Solar System, helping to place it in the context of the Milky Way. "We are inhabitants of the Milky Way," says Alves, "The European Space Agency's Gaia Mission has given us the means to trace our recent route in the Milky Way's interstellar sea, allowing astronomers to compare notes with geologists and paleoclimatologists. It's very exciting." In the future, the team led by João Alves plans to study in more detail the Galactic environment encountered by the Sun while sailing through our Galaxy.

- In ancient stellar nurseries, some stars are born of fluffy clouds

Observations of the Small Magellanic Cloud: insights into star formation in early-universe-like environments

Date: February 20, 2025
Source: Kyushu University



A far infrared image of the Small Magellanic Cloud as observed by the European Space Agency's (ESA) Herschel Space Observatory. (Image credit: ALMA (ESO/NAOJ/NRAO), Tokuda et al., ESA/Herschel)

How are stars born, and has it always been this way?

Stars form in regions of space known as stellar nurseries, where high concentrations of gas and dust coalesce to form a baby star. Also called molecular clouds, these regions of space can be massive, spanning hundreds of light-years and forming thousands of stars. And while we know much about the life cycle of a star thanks to advances in technology and observational tools, precise details remain obscure. For example, did stars form this way in the early universe?

Publishing in *The Astrophysical Journal*, researchers from Kyushu University, in collaboration with Osaka Metropolitan University, have found that in the early universe, some stars may have formed in "fluffy" molecular clouds. The results were obtained from observations of the Small Magellanic Cloud and may provide a new perspective on star formation throughout the history of the universe.

In our Milky Way galaxy, the molecular clouds that facilitate star formation have an elongated "filamentary" structure about 0.3 light-years wide. Astronomers believe that our Solar System was formed in the same way, where a large filamentary molecular cloud broke apart to form a stellar egg, also called a molecular cloud core. Over hundreds of thousands of years, gravity would attract gases and matter into the cores to create a star.

"Even today our understanding of star formation is still developing, comprehending how stars formed in the earlier universe is even more challenging," explains Kazuki Tokuda, a Post? Doctoral Fellow at Kyushu University's Faculty of Science and first author of the study. "The early universe was quite different from today, mostly populated by hydrogen and helium. Heavier elements formed later in high-mass stars. We can't go back in time to study star formation in the early universe, but we can observe parts of the universe with environments similar to the early universe."

The team set their sights on the Small Magellanic Cloud (SMC), a dwarf galaxy near the Milky Way about 20,000 light-years from Earth. The SMC contains only about one-fifth of the heavy elements of the Milky Way, making it very close to the cosmic environment of the early universe, about 10 billion years ago. However, the spatial resolution for observing the molecular clouds in the SMC was often insufficient, and it was unclear whether the same filamentary structure could be seen at all.

Fortunately, the ALMA radio telescope in Chile was powerful enough to capture higher-resolution images of the SMC and determine the presence or absence of filamentary molecular clouds.

"In total, we collected and analysed data from 17 molecular clouds. Each of these molecular clouds had growing baby stars 20 times the mass of our Sun," continues Tokuda. "We found that about 60% of the molecular clouds we observed had a filamentary structure with a width of about 0.3 light-years, but the remaining 40% had a 'fluffy' shape. Furthermore, the temperature inside the filamentary molecular clouds was higher than that of the fluffy molecular clouds."

This temperature difference between filamentary and fluffy clouds is likely due to how long ago the cloud was formed. Initially, all clouds were filamentary with high temperatures due to the clouds colliding with each other. When the temperature is high, the turbulence in the molecular cloud is weak. But as the temperature of the cloud drops, the kinetic energy of the incoming gas causes more turbulence and smoothens the filamentary structure, resulting in the fluffy cloud.

If the molecular cloud retains its filamentary shape, it is more likely to break up along its long "string" and form many stars like our Sun, a low-mass star with planetary systems. On the other hand, if the filamentary structure cannot be maintained, it may be difficult for such stars to emerge.

"This study indicates that the environment, such as an adequate supply of heavy elements, is crucial for maintaining a filamentary structure and may play an important role in the formation of planetary systems," concludes Tokuda. "In the future, it will be important to compare our results with observations of molecular clouds in heavy-element-rich environments, including the Milky Way galaxy. Such studies should provide new insights into the formation and temporal evolution of molecular clouds and the universe."

- 300 new intermediate-mass black holes plus 2500 new active black holes in dwarf galaxies discovered

Date: February 19, 2025
Source: Association of Universities for Research in Astronomy (AURA)

This artist's illustration depicts a dwarf galaxy that hosts an active galactic nucleus — an actively feeding black hole. In the background are many other dwarf galaxies hosting active black holes, as well as a variety of other types of galaxies hosting intermediate-mass black holes. (Credit: NOIRLab/NSF/AURA/J. da Silva/M. Zamani)

Using early data from the Dark Energy Spectroscopic Instrument (DESI), a team of scientists have compiled the largest sample ever of dwarf galaxies that host an actively feeding black hole, as well as the most extensive collection of intermediate-mass black hole candidates to date. This dual achievement not only expands scientists' understanding of the black hole population in the Universe, but also sets the stage for further explorations regarding the formation of the first black holes to form in the Universe and their role in galaxy evolution.

DESI is a state-of-the-art instrument that can capture light from 5000 galaxies simultaneously. It was constructed, and is operated, with funding from the Department of Energy (DOE) Office of Science. DESI is mounted on the U.S. National Science Foundation (NSF) Nicholas U. Mayall 4-meter Telescope at the NSF Kitt Peak National Observatory, a Program of NSF NOIRLab. The program is now in its fourth of five years surveying the sky and is set to observe roughly 40 million galaxies and quasars by the time the project ends.

The DESI project is an international collaboration of more than 900 researchers from over 70 institutions around the world and is managed by DOE's Lawrence Berkeley National Laboratory (Berkeley Lab).

With DESI's early data [1], which include survey validation and 20% of the first year of operations, the team, led by University of Utah postdoctoral researcher Ragadeepika Pucha, was able to obtain an unprecedented dataset that includes the spectra of 410,000 galaxies [2], including roughly 115,000 dwarf galaxies -- small, diffuse galaxies containing thousands to several billions of stars and very little gas. This extensive set would allow Pucha and her team to explore the complex interplay between black hole evolution and dwarf galaxy evolution.

While astrophysicists are fairly confident that all massive galaxies, like our Milky Way, host black holes at their centres, the picture becomes unclear as you move toward the low-mass end of the spectrum. Finding black holes is a challenge in itself, but identifying them in dwarf galaxies is even more difficult, owing to their small sizes and the limited ability of our current instruments to resolve the regions close to these objects. An actively feeding black hole, however, is easier to spot.

"When a black hole at the centre of a galaxy starts feeding, it unleashes a tremendous amount of energy into its surroundings, transforming into what we call an active galactic nucleus," says Pucha. "This dramatic activity serves as a beacon, allowing us to identify hidden black holes in these small galaxies."

From their search the team identified an astonishing 2500 candidate dwarf galaxies hosting an active galactic nucleus (AGN) -- the largest sample ever discovered. The significantly higher fraction of dwarf galaxies hosting an AGN (2%) relative to previous studies (about 0.5%) is an exciting result and suggests scientists have been missing a substantial number of low-mass, undiscovered black holes.

In a separate search through the DESI data, the team identified 300 intermediate-mass black hole candidates -- the most extensive collection to date. Most black holes are either lightweight (less than 100 times the mass of our Sun) or supermassive (more than one million times the mass of our Sun). The black holes in between the two extremes are poorly understood, but are theorized to be the relics of the very first black holes formed in the early Universe, and the seeds of the supermassive black holes that lie at the centre of large galaxies today. Yet they remain elusive, with only around 100-150 intermediate-mass black hole candidates known until now. With the large population discovered by DESI, scientists now have a powerful new dataset to use to study these cosmic enigmas.

"The technological design of DESI was important for this project, particularly its small fibre size, which allowed us to better zoom in on the centre of galaxies and identify the subtle signatures of active black holes," says Stephanie Juneau, associate astronomer at NSF NOIRLab and co-author of the paper. "With other fibre spectrographs with larger fibres, more starlight from the galaxy's outskirts comes in and dilutes the signals we're searching for. This explains why we managed to find a higher fraction of active black holes in this work relative to previous efforts."

Typically, black holes found in dwarf galaxies are expected to be within the intermediate-mass regime. But intriguingly, only 70 of the newly discovered intermediate-mass black hole candidates overlap with dwarf AGN candidates. This adds another layer of excitement to the findings and raises questions about black hole formation and evolution within galaxies.

"For example, is there any relationship between the mechanisms of black hole formation and the types of galaxies they inhabit?" Pucha said. "Our wealth of new candidates will help us delve deeper into these mysteries, enriching our understanding of black holes and their pivotal role in galaxy evolution."

Notes

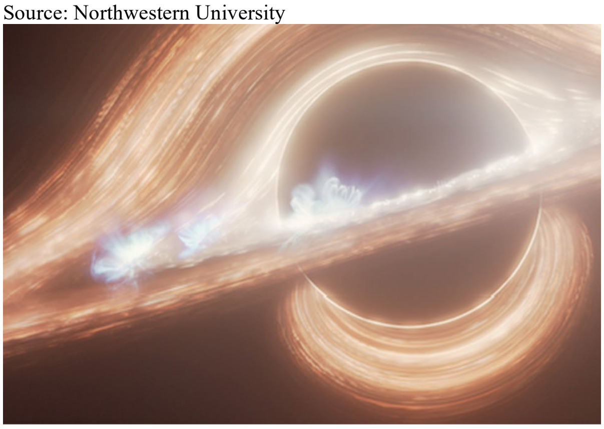
[1] DESI early data is available as files via the DESI collaboration and as searchable databases of catalogues and spectra via the Astro Data Lab and SPARCL at the Community Science and Data Centre, a Program of NSF NOIRLab.

[2] DESI's early data contain nearly 3.5 million unique galaxy spectra. The sample used in this work was selected based on redshift (distance) and accurate detection of emission lines.

- Flickers and flares: Milky Way's central black hole constantly bubbles with light

James Webb Space Telescope reveals ongoing, rapid-fire light show

Date: February 18, 2025
Source: Northwestern University



This artist's concept portrays the supermassive black hole at the centre of the Milky Way galaxy. Several flaring hot spots that resemble solar flares, but on a more energetic scale, are seen in the disk. Image by NASA, ESA, CSA, Ralf Crawford (STScI)

The supermassive black hole at the centre of the Milky Way appears to be having a party -- and it is weird, wild and wonderful.

Using NASA's James Webb Space Telescope (JWST), a Northwestern University-led team of astrophysicists has gained the longest, most detailed glimpse yet of the void that lurks in middle of our galaxy.

The swirling disk of gas and dust (or accretion disk) orbiting the central supermassive black hole, called Sagittarius A*, is emitting a constant stream of flares with no periods of rest, the researchers found. While some flares are faint flickers, lasting mere seconds, other flares are blindingly bright eruptions, which spew daily. There also are even fainter flickers that surge for months at a time. The level of activity occurs over a wide range of time -- from short interludes to long stretches.

The new findings could help physicists better understand the fundamental nature of black holes, how they interact with their surrounding environments and the dynamics and evolution of our own galactic home.

The study will be published on Tuesday (Feb. 18) in T*he Astrophysical Journal Letters.*

"Flares are expected to happen in essentially all supermassive black holes, but our black hole is unique," said Northwestern's Farhad Yusef-Zadeh, who led the study. "It is always bubbling with activity and never seems to reach a steady state. We observed the black hole multiple times throughout 2023 and 2024, and we noticed changes in every observation. We saw something different each time, which is really remarkable. Nothing ever stayed the same."

An expert on the Milky Way's centre, Yusef-Zadeh is a professor of physics and astronomy at Northwestern's Weinberg College of Arts and Sciences. The international team of coauthors includes Howard Bushouse of the Space Telescope Science Institute, Richard G. Arendt of NASA, Mark Wardle of Macquarie University in Australia, Joseph Michail of Harvard & Smithsonian and Claire Chandler of the National Radio Astronomy Observatory.

Random fireworks

To conduct the study, Yusef-Zadeh and his team used the JWST's near infrared camera (NIRCam), which can simultaneously observe two infrared colours for long stretches of time. With the imaging tool, the researchers observed Sagittarius A* for a total of 48 hours -- in 8-to-10-hour increments across one year. This enabled scientists to track how the black hole changed over time.

While Yusef-Zadeh expected to see flares, Sagittarius A* was more active than he anticipated. Simply put: the observations revealed ongoing fireworks of various brightness and durations. The accretion disk surrounding the black hole generated five to six big flares per day and several small sub-flares in between.

"In our data, we saw constantly changing, bubbling brightness," Yusef-Zadeh said. "And then boom! A big burst of brightness suddenly popped up. Then, it calmed down again. We couldn't find a pattern in this activity. It appears to be random. The activity profile of the black hole was new and exciting every time that we looked at it."

Two separate processes at play

Although astrophysicists do not yet fully understand the processes at play, Yusef-Zadeh suspects two separate processes are responsible for the short bursts and longer flares. If the accretion disk is a river, then the short, faint flickers are like small ripples that fluctuate randomly on the river's surface. The longer, brighter flares, however, are more like tidal waves, caused by more significant events.

Yusef-Zadeh posits that minor disturbances within the accretion disk likely generate the faint flickers. Specifically, turbulent fluctuations within the disk can compress plasma (a hot, electrically charged gas) to cause a temporary burst of radiation. Yusef-Zadeh likens the event to a solar flare.

"It's similar to how the sun's magnetic field gathers together, compresses and then erupts a solar flare," he explained. "Of course, the

processes are more dramatic because the environment around a black hole is much more energetic and much more extreme. But the sun's surface also bubbles with activity."
Yusef-Zadeh attributes the big, bright flares to magnetic reconnection events -- a process where two magnetic fields collide, releasing energy in the form of accelerated particles. Traveling at velocities near the speed of light, these particles emit bright bursts of radiation. "A magnetic reconnection event is like a spark of static electricity, which, in a sense, also is an 'electric reconnection,'" Yusef-Zadeh said.

Double vision

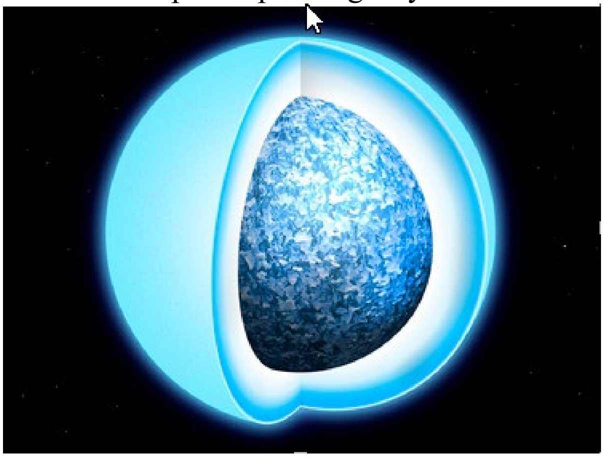
Because the JWST's NIRCam can observe two separate wavelengths (2.1 and 4.8 microns) at the same time, Yusef-Zadeh and his collaborators were able to compare how the flares' brightness changed with each wavelength. Yusef-Zadeh said capturing light at two wavelengths is like "seeing in colour instead of black and white." By observing Sagittarius A* at multiple wavelengths, he captured a more complete and nuanced picture of its behaviour.
Yet again, the researchers were met with a surprise. Unexpectedly, they discovered events observed at the shorter wavelength changed brightness slightly before the longer-wavelength events.
"This is the first time we have seen a time delay in measurements at these wavelengths," Yusef-Zadeh said. "We observed these wavelengths simultaneously with NIRCam and noticed the longer wavelength lags behind the shorter one by a very small amount -- maybe a few seconds to 40 seconds."
This time delay provided more clues about the physical processes occurring around the black hole. One explanation is that the particles lose energy over the course of the flare -- losing energy quicker at shorter wavelengths than at longer wavelengths. Such changes are expected for particles spiralling around magnetic field lines.

Aiming for an uninterrupted look

To further explore these questions, Yusef-Zadeh hopes to use the JWST to observe Sagittarius A* for a longer period of time. He recently submitted a proposal to observe the black hole for an uninterrupted 24 hours. The longer observation run will help reduce noise, enabling the researchers to see even finer details.
"When you are looking at such weak flaring events, you have to compete with noise," Yusef-Zadeh said. "If we can observe for 24 hours, then we can reduce the noise to see features that we were unable to see before. That would be amazing. We also can see if these flares show periodicity (or repeat themselves) or if they are truly random."
The study, "Non-stop variability of Sgr A* using JWST at 2.1 and 4.8 micron wavelengths: Evidence for distinct populations of faint and bright variable emission," was supported by NASA and the National Science Foundation.

- Einstein Probe catches X-ray odd couple

Date: February 18, 2025
Source: European Space Agency



Artist's impression of crystallisation in white dwarf

The odd celestial couple consists of a big, hot star, more than 10 times larger than our Sun, and a small compact white dwarf, with a mass similar to our star. Only a handful of these systems have been found so far. And this the first-time scientists could track the X-ray light coming from such a curious pair from its initial sudden flare-up to its fading away.
On 27 May 2024, the Wide-field X-ray Telescope (WXT) on Einstein Probe spotted X-rays coming from within our neighbour galaxy, the Small Magellanic Cloud (SMC). To uncover the origin of this new celestial beacon, labelled EP J0052, scientists pointed Einstein Probes's Follow-up X-ray Telescope in that direction.
WXT's observations also triggered NASA's Swift and NICER X-ray telescopes to point to the newly discovered object. ESA's XMM-Newton followed up 18 days after the trigger. "We were chasing fleeting sources, when we came across this new spot of X-ray light in the SMC. We realised that we were looking at something unusual, that only Einstein Probe could catch," says Alessio Marino, a postdoctoral researcher at the Institute of

Space Sciences (ICE-CSIC), Spain and lead author of the new study published today. "This is because, among current telescopes monitoring the X-ray sky, WXT is the only one that can see lower energy X-rays with sufficient sensitivity to catch the novel source."

Initially, the scientists thought EP J0052 might be a well-known type of binary system that shines in X-rays. These pairs consist of a neutron star devouring up material from a massive star companion. Yet, there was something in the data telling a different story…

A rare discovery

Thanks to Einstein Probe catching the novel source right from its initial flash, scientists could analyse batches of data from different instruments. They examined how the light varied across a range of X-ray wavelengths, over six days, and teased out some of the elements present in the exploding material, such as nitrogen, oxygen and neon. The analysis delivered crucial clues.

"We soon understood that we were dealing with a rare discovery of a very elusive celestial couple" explains Alessio. "The unusual duo consists of a massive star that we call a Be star, weighting 12 times the Sun, and a stellar 'corpse' known as a white dwarf, a compact and hyper-dense object, with a mass similar to that of our star."

The two stars closely orbit each other, and the white dwarf's intense gravitational field pulls matter from its companion. As more and more material (mainly hydrogen) rains down on the compact object, its strong gravitation compresses it, until a runaway nuclear explosion is initiated. This creates a bright flash of light across a wide range of wavelengths from visible light to UVs and X-rays.

At first sight, the existence of this duo is puzzling. Massive stars of type Be burn fast through their reserve of nuclear fuel. Their lives are fierce and short, spanning about 20 million years. Its companion is (usually) the collapsed remnant of a star similar to our Sun that in isolation would live for several billions of years.

Since binary stars typically form together, how can the supposedly short-lived star still be shining bright, while the alleged long-lived one has already died?

There is an explanation.

A tale of two stars

Scientists think that the couple started off together, as a better-matched binary pair consisting of two rather big stars, six and eight times more massive than our Sun.

The bigger star exhausted its nuclear fuel earlier and started to expand, shedding matter to its companion. First, gas in its puffed-up outer layers got pulled in by the companion; then its remaining outer shells got ejected, forming an envelope around the two stars, which later became a disc, and finally dissolved.

By the end of this drama, the companion star had grown to be 12 times the mass of the Sun, while the outstripped core of the other had collapsed to become a white dwarf of just over one solar mass. Now, it is the turn of the white dwarf to steal and gobble up material from the outer layers of the Be star.

"This study gives us new insights into a rarely observed phase of stellar evolution, which is the result of a complex exchange of material that must have happened among the two stars," remarks Ashley Chrimes, research fellow and X-ray astronomer at ESA. "It's fascinating to see how an interacting pair of massive stars can produce such an intriguing outcome."

ESA's XMM-Newton mission's follow-up observation in the direction of EP J0052, 18 days after Einstein Probe's first look, did not see the signal anymore. This sets a limit on the duration of the flare, showing it to be relatively brief.

The duration of the short burst, and the presence of neon and oxygen, hint at a rather heavy type of white dwarf, likely 20% more massive than the Sun. Its mass is close to the level, called Chandrasekhar limit, above which the star would continue to implode, and become an even denser neutron star, or explode as a supernova.

Game-changing monitor

"Outbursts from a Be-white dwarf duo have been extraordinarily hard to catch, as they are best observed with low energy X-rays. The advent of Einstein Probe offers the unique chance to spot these fleeting sources and test our understanding of how massive stars evolve," remarks Erik Kuulkers, ESA Project Scientist for Einstein Probe.

"This discovery showcases the game-changing capabilities of this mission."

About Einstein Probe

Einstein Probe is a mission of the Chinese Academy of Science (CAS) working in partnership with the European Space Agency (ESA), the Max-Planck-Institute for extraterrestrial Physics (MPE), Germany, and the Centre National d'Études Spatiales (CNES), France. It was launched from the Xichang Satellite Launch Centre in China on 9 January 2024, and carries two instruments. The Wide-field X-ray Telescope (WXT) constantly monitors a large portion of the sky for unexpected X-rays, and the Follow-up X-ray Telescope (FXT) that homes in on the X-ray sources found by WXT for a more detailed lo