South Downs Mercury

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Main Talk Tony Roberts "Astronomical Oddities - a look at the weird, wonderful and sometimes just wrong from the history of astronomy."
Tony Roberts has observed the heavens since a child in the sixties and is the current chair at both SAGAS and Croydon Astronomical Society**.**

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❖ Gargantuan black hole jets are biggest seen yet

The jumbo jets blast hot plasma well beyond their own host galaxy

Date: September 18, 2024
Source: California Institute of Technology

An artist's illustration of the longest black hole jet system ever observed. Nicknamed Porphyrion after a mythological Greek giant, these jets span roughly 7 megaparsecs, or 23 million light-years. That is equivalent to lining up 140 Milky Way galaxies back-to-back. Porphyrion dates back to a time when our universe was less than half its present age. During this early epoch, the wispy filaments that connect and feed galaxies, known as the cosmic web, were closer together than they are now. Consequently, this colossal jet pair extended across a larger portion of the cosmic web compared to similar jets in our nearby universe. Porphyrion's discovery thus implies that jets in the early universe may have influenced the formation of galaxies to a greater extent than previously believed

Astronomers have spotted the biggest pair of black hole jets ever seen, spanning 23 million light-years in total length. That's equivalent to lining up 140 Milky Way galaxies back-to-back.

"This pair is not just the size of a solar system, or a Milky Way; we are talking about 140 Milky Way diameters in total," says Martijn Oei, a Caltech postdoctoral scholar and lead author of a new *Nature* paper reporting the findings. "The Milky Way would be a little dot in these two giant eruptions."

The jet megastructure, nicknamed Porphyrion after a giant in Greek mythology, dates to a time when our universe was 6.3 billion years old, or less than half its present age of 13.8 billion years. These fierce outflows -- with a total power output equivalent to trillions of suns -- shoot out from above and below a supermassive black hole at the heart of a remote galaxy.

Prior to Porphyrion's discovery, the largest confirmed jet system was Alcyoneus, also named after a giant in Greek mythology. Alcyoneus, which was discovered in 2022 by the same team that found Porphyrion, spans the equivalent of around 100 Milky Ways. For comparison, the well-known Centaurus A jets, the closest major jet system to Earth, spans 10 Milky Ways.

The latest finding suggests that these giant jet systems may have had a larger influence on the formation of galaxies in the young universe than previously believed. Porphyrion existed during an early epoch when the wispy filaments that connect and feed galaxies, known as the cosmic web, were closer together than they are now. That means enormous jets like Porphyrion reached across a greater portion of the cosmic web compared to jets in the local universe.

"Astronomers believe that galaxies and their central black holes co-evolve, and one key aspect of this is that jets can spread huge amounts of energy that affect the growth of their host galaxies and other galaxies near them," says co-author George Djorgovski, professor of astronomy and data science at Caltech. "This discovery shows that their effects can extend much farther out than we thought."

Unveiling a Vast Population

The Porphyrion jet system is the biggest found so far during a sky survey that has revealed a shocking number of the faint megastructures: more than 10,000. This massive population of gargantuan jets was found using Europe's LOFAR (LOw Frequency ARray) radio telescope.

While hundreds of large jet systems were known before the LOFAR observations, they were thought to be rare and on average smaller in size than the thousands of systems uncovered by the radio telescope.

"Giant jets were known before we started the campaign, but we had no idea that there would turn out to be so many," says Martin Hardcastle, second author of the study and a professor of astrophysics at the University of Hertfordshire in England. "Usually when we get a new observational capability, such as LOFAR's combination of wide field of view and very high sensitivity to extended structures, we find something new, but it was still very exciting to see so many of these objects emerging."

Back in 2018, Oei and his colleagues began using LOFAR to study not black hole jets but the cosmic web of wispy filaments that crisscrossed the space between galaxies. As the team inspected the radio images for the faint filaments, they began to notice several strikingly long jet systems.

"When we first found the giant jets, we were quite surprised," says Oei, who is also affiliated with Leiden Observatory in the Netherlands. "We had no idea that there were this many."

To systematically search for more hidden jets, the team inspected the radio images by eye, used machine-learning tools to scan the images for signs of the looming jets, and enlisted the help of citizen scientists around the globe to eyeball the images further. A paper describing their most recent batch of giant outflows, containing more than 8,000 jet pairs, has been accepted for publication in the journal *Astronomy & Astrophysics*.

Lurking in the Past

To find the galaxy from which Porphyrion originated, the team used the Giant Metre wave Radio Telescope (GMRT) in India along with ancillary data from a project called Dark Energy Spectroscopic Instrument (DESI), which operates from Kitt Peak National Observatory in Arizona. The observations pinpointed the home of the jets to a hefty galaxy about 10 times more massive than our Milky Way.

The team then used the W. M. Keck Observatory in Hawai'i to show that Porphyrion is 7.5 billion light-years from Earth. "Up until now, these giant jet systems appeared to be a phenomenon of the recent universe," Oei says. "If distant jets like these can reach the scale of the cosmic web, then every place in the universe may have been affected by black hole activity at some point in cosmic time," Oei says.

The observations from Keck also revealed that Porphyrion emerged from what is called a radiative-mode active black hole, as opposed to one that is in a jet-mode state. When supermassive black holes become active -- in other words, when their immense forces of gravity tug on and heat up surrounding material -- they are thought to either emit energy in the form of radiation or jets. Radiative-mode black holes were more common in the young, or distant, universe, while jet-mode ones are more common in the present-day universe.

The fact that Porphyrion came from a radiative-mode black hole came as a surprise because astronomers did not know this mode could produce such huge and powerful jets. What is more, because Porphyrion lies in the distant universe where radiative-mode black holes abound, the finding implies there may be a lot more colossal jets left to be found. "We may be looking at the tip of the iceberg," Oei says. "Our LOFAR survey only covered 15 percent of the sky. And most of these giant jets are likely difficult to spot, so we believe there are many more of these behemoths out there."

Ongoing Mysteries

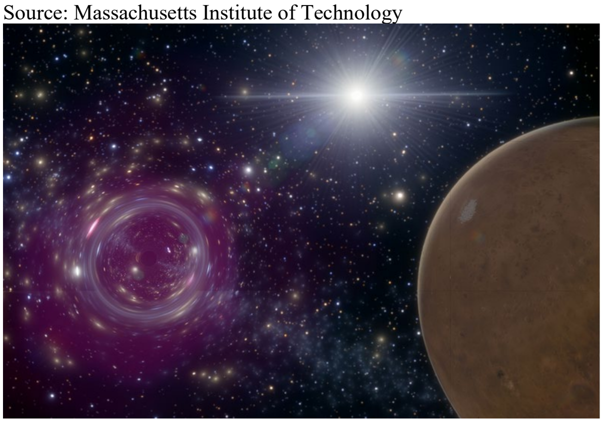
How the jets can extend so far beyond their host galaxies without destabilizing is still unclear. "Martijn's work has shown us that there isn't anything particularly special about the environments of these giant sources that causes them to reach those large sizes," says Hardcastle, who is an expert in the physics of black hole jets. "My interpretation is that we need an unusually long-lived and stable accretion event around the central, supermassive black hole to allow it to be active for so long -- about a billion years -- and to ensure that the jets keep pointing in the same direction over all of that time. What we're learning from the large number of giants

is that this must be a relatively common occurrence."
As a next step, Oei wants to better understand how these megastructures influence their surroundings. The jets spread cosmic rays, heat, heavy atoms, and magnetic fields throughout the space between galaxies. Oei is specifically interested in finding out the extent to which giant jets spread magnetism. "The magnetism on our planet allows life to thrive, so we want to understand how it came to be," he says. "We know magnetism pervades the cosmic web, then makes its way into galaxies and stars, and eventually to planets, but the question is: Where does it start? Have these giant jets spread magnetism through the cosmos?"

- A wobble from Mars could be sign of dark matter

Watching for changes in the Red Planet's orbit over time could be new way to detect passing dark matter

Date: September 17, 2024
Source: Massachusetts Institute of Technology



In a new study, MIT physicists propose that if most of the dark matter in the universe is made up of microscopic primordial black holes -- an idea first proposed in the 1970s -- then these gravitational dwarfs should zoom through our solar system at least once per decade. A flyby like this, the researchers predict, would introduce a wobble into Mars' orbit, to a degree that today's technology could actually detect.
Such a detection could lend support to the idea that primordial black holes are a primary source of dark matter throughout the universe.
"Given decades of precision telemetry, scientists know the distance between Earth and Mars to an accuracy of about 10 centimetres," says study author David Kaiser, professor of physics and the Germeshausen Professor of the History of Science at MIT. "We're taking advantage of this highly instrumented region of space to try and look for a small effect. If we see it, that would count as a real reason to keep pursuing this delightful idea that all of dark matter consists of black holes that were spawned in less than a second after the Big Bang and have been streaming around the universe for 14 billion years."
Kaiser and his colleagues report their findings today in the journal *Physical Review D*. The study's co-authors are lead author Tung Tran '24, who is now a graduate student at Stanford University; Sarah Geller '12, SM '17, PhD '23, who is now a postdoc at the University of California at Santa Cruz; and MIT Pappalardo Fellow Benjamin Lehmann.

Beyond particles

Less than 20 percent of all physical matter is made from visible stuff, from stars and planets, to the kitchen sink. The rest is composed of dark matter, a hypothetical form of matter that is invisible across the entire electromagnetic spectrum yet is thought to pervade the universe and exert a gravitational force large enough to affect the motion of stars and galaxies.
Physicists have erected detectors on Earth to try and spot dark matter and pin down its properties. For the most part, these experiments assume that dark matter exists as a form of exotic particle that might scatter and decay into observable particles as it passes through a given experiment. But so far, such particle-based searches have come up empty.
In recent years, another possibility, first introduced in the 1970s, has regained traction: Rather than taking on a particle form, dark matter could exist as microscopic, primordial black holes that formed in the first moments following the Big Bang. Unlike the astrophysical black holes that form from the collapse of old stars, primordial black holes would have formed from the collapse of dense pockets of gas in the very early universe and would have scattered across the cosmos as the universe expanded and cooled.
These primordial black holes would have collapsed an enormous amount of mass into a tiny space. The majority of these primordial black holes could be as small as a single atom and as heavy as the largest asteroids. It would be conceivable, then, that such tiny giants could exert a gravitational force that could explain at least a portion of dark matter. For the MIT team, this possibility raised an initially frivolous question.

"I think someone asked me what would happen if a primordial black hole passed through a human body," recalls Tung, who did a quick pencil-and-paper calculation to find that if such a black hole zinged within 1 meter of a person, the force of the black hole would push the person 6 meters, or about 20 feet away in a single second. Tung also found that the odds were astronomically unlikely that a primordial black hole would pass anywhere near a person on Earth.

Their interest piqued, the researchers took Tung's calculations a step further, to estimate how a black hole flyby might affect much larger bodies such as the Earth and the moon.

"We extrapolated to see what would happen if a black hole flew by Earth and caused the moon to wobble by a little bit," Tung says. "The numbers we got were not very clear. There are many other dynamics in the solar system that could act as some sort of friction to cause the wobble to dampen out."

Close encounters

To get a clearer picture, the team generated a relatively simple simulation of the solar system that incorporates the orbits and gravitational interactions between all the planets, and some of the largest moons.

"State-of-the-art simulations of the solar system include more than a million objects, each of which has a tiny residual effect," Lehmann notes. "But even modelling two dozen objects in a careful simulation, we could see there was a real effect that we could dig into."

The team worked out the rate at which a primordial black hole should pass through the solar system, based on the amount of dark matter that is estimated to reside in a given region of space and the mass of a passing black hole, which in this case, they assumed to be as massive as the largest asteroids in the solar system, consistent with other astrophysical constraints.

"Primordial black holes do not live in the solar system. Rather, they're streaming through the universe, doing their own thing," says co-author Sarah Geller. "And the probability is, they're going through the inner solar system at some angle once every 10 years or so."

Given this rate, the researchers simulated various asteroid-mass black holes flying through the solar system, from various angles, and at velocities of about 150 miles per second. (The directions and speeds come from other studies of the distribution of dark matter throughout our galaxy.) They zeroed in on those flybys that appeared to be "close encounters," or instances that caused some sort of effect in surrounding objects. They quickly found that any effect in the Earth or the moon was too uncertain to pin to a particular black hole. But Mars seemed to offer a clearer picture.

The researchers found that if a primordial black hole were to pass within a few hundred million miles of Mars, the encounter would set off a "wobble," or a slight deviation in Mars' orbit. Within a few years of such an encounter, Mars' orbit should shift by about a meter -- an incredibly small wobble, given the planet is more than 140 million miles from Earth. And yet, this wobble could be detected by the various high-precision instruments that are monitoring Mars today.

If such a wobble were detected in the next couple of decades, the researchers acknowledge there would still be much work needed to confirm that the push came from a passing black hole rather than a run-of-the-mill asteroid.

"We need as much clarity as we can of the expected backgrounds, such as the typical speeds and distributions of boring space rocks, versus these primordial black holes," Kaiser notes. "Luckily for us, astronomers have been tracking ordinary space rocks for decades as they have flown through our solar system, so we could calculate typical properties of their trajectories and begin to compare them with the very different types of paths and speeds that primordial black holes should follow."

To help with this, the researchers are exploring the possibility of a new collaboration with a group that has extensive expertise simulating many more objects in the solar system.

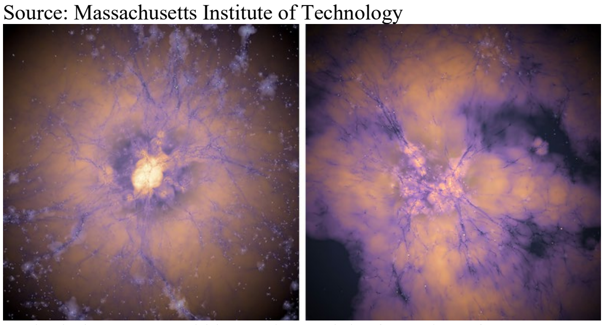
"We are now working to simulate a huge number of objects, from planets to moons and rocks, and how they're all moving over long-time scales," Geller says. "We want to inject close encounter scenarios, and look at their effects with higher precision."

This work was supported in part by the U.S. Department of Energy and the U.S. National Science Foundation, which includes an NSF Mathematical and Physical Sciences postdoctoral fellowship.

❖ Early dark energy could resolve cosmology's two biggest puzzles

In the universe's first billion years, this brief and mysterious force could have produced more bright galaxies than theory predicts

Date: September 13, 2024
Source: Massachusetts Institute of Technology



Early dark energy could have triggered the formation of numerous bright galaxies, very early in the universe, a new study finds. The mysterious unknown force could have caused early seeds of galaxies (depicted at left) to sprout many more bright galaxies (at right) than theory predicts.
Credits:
Image: Josh Borrow/Thesan Team

A new study by MIT physicists proposes that a mysterious force known as early dark energy could solve two of the biggest puzzles in cosmology and fill in some major gaps in our understanding of how the early universe evolved.

One puzzle in question is the "Hubble tension," which refers to a mismatch in measurements of how fast the universe is expanding. The other involves observations of numerous early, bright galaxies that existed at a time when the early universe should have been much less populated.

Now, the MIT team has found that both puzzles could be resolved if the early universe had one extra, fleeting ingredient: early dark energy. Dark energy is an unknown form of energy that physicists suspect is driving the expansion of the universe today. Early dark energy is a similar, hypothetical phenomenon that may have made only a brief appearance, influencing the expansion of the universe in its first moments before disappearing entirely.

Some physicists have suspected that early dark energy could be the key to solving the Hubble tension, as the mysterious force could accelerate the early expansion of the universe by an amount that would resolve the measurement mismatch.

The MIT researchers have now found that early dark energy could also explain the baffling number of bright galaxies that astronomers have observed in the early universe. In their new study, reported in the *Monthly Notices of the Royal Astronomical Society,* the team modelled the formation of galaxies in the universe's first few hundred million years. When they incorporated a dark energy component only in that earliest sliver of time, they found the number of galaxies that arose from the primordial environment bloomed to fit astronomers' observations.

"You have these two looming open-ended puzzles," says study co-author Rohan Naidu, a postdoc in MIT's Kavli Institute for Astrophysics and Space Research. "We find that in fact, early dark energy is a very elegant and sparse solution to two of the most pressing problems in cosmology."

The study's co-authors include lead author and Kavli postdoc Xuejian (Jacob) Shen, and MIT professor of physics Mark Vogelsberger, along with Michael Boylan-Kolchin at the University of Texas at Austin, and Sandro Tacchella at the University of Cambridge.

Big city lights

Based on standard cosmological and galaxy formation models, the universe should have taken its time spinning up the first galaxies. It would have taken billions of years for primordial gas to coalesce into galaxies as large and bright as the Milky Way.

But in 2023, NASA's James Webb Space Telescope (JWST) made a startling observation. With an ability to peer farther back in time than any observatory to date, the telescope uncovered a surprising number of bright galaxies as large as the modern Milky Way within the first 500 million years, when the universe was just 3 percent of its current age.

"The bright galaxies that JWST saw would be like seeing a clustering of lights around big cities, whereas theory predicts something like the light around more rural settings like Yellowstone National Park," Shen says. "And we don't expect that clustering of light so early on."

For physicists, the observations imply that there is either something fundamentally wrong with the physics underlying the models or a missing ingredient in the early universe that scientists have not accounted for. The MIT team explored the possibility of the latter, and whether the missing ingredient might be early dark energy.

Physicists have proposed that early dark energy is a sort of antigravitational force that is turned on only at very early times. This force would counteract gravity's inward pull and accelerate the early expansion of the universe, in a way that would resolve the mismatch in measurements. Early dark energy, therefore, is considered the most likely solution to the Hubble tension.

Galaxy skeleton

The MIT team explored whether early dark energy could also be the key to explaining the unexpected population of large, bright galaxies detected by JWST. In their new study, the physicists considered how early dark energy might affect the early structure of the universe that gave rise to the first galaxies. They focused on the formation of dark matter halos -- regions of space where gravity happens to be stronger, and where matter begins to accumulate.

"We believe that dark matter halos are the invisible skeleton of the universe," Shen explains. "Dark matter structures form first, and then galaxies form within these structures. So, we expect the number of bright galaxies should be proportional to the number of big dark matter halos."

The team developed an empirical framework for early galaxy formation, which predicts the number, luminosity, and size of galaxies that should form in the early universe, given some measures of "cosmological parameters." Cosmological parameters are the basic ingredients, or mathematical terms, that describe the evolution of the universe.

Physicists have determined that there are at least six main cosmological parameters, one of which is the Hubble constant -- a term that describes the universe's rate of expansion. Other parameters describe density fluctuations in the primordial soup, immediately after the Big Bang, from which dark matter halos eventually form.

The MIT team reasoned that if early dark energy affects the universe's early expansion rate, in a way that resolves the Hubble tension, then it could affect the balance of the other cosmological parameters, in a way that might increase the number of bright galaxies that appear at early times. To test their theory, they incorporated a model of early dark energy (the same one that happens to resolve the Hubble tension) into an empirical galaxy formation framework to see how the earliest dark matter structures evolve and give rise to the first galaxies.

"What we show is, the skeletal structure of the early universe is altered in a subtle way where the amplitude of fluctuations goes up, and you get bigger halos, and brighter galaxies that are in place at earlier times, more so than in our more vanilla models," Naidu says. "It means things were more abundant, and more clustered in the early universe."

"A priori, I would not have expected the abundance of JWST's early bright galaxies to have anything to do with early dark energy, but their observation that EDE pushes cosmological parameters in a direction that boosts the early-galaxy abundance is interesting," says Marc Kamionkowski, professor of theoretical physics at Johns Hopkins University, who was not involved with the study. "I think more work will need to be done to establish a link between early galaxies and EDE, but regardless of how things turn out, it's a clever -- and hopefully ultimately fruitful -- thing to try."

"We demonstrated the potential of early dark energy as a unified solution to the two major issues faced by cosmology. This might be evidence for its existence if the observational findings of JWST get further consolidated," Vogelsberger concludes. "In the future, we can incorporate this into large cosmological simulations to see what detailed predictions we get."

This research was supported, in part, by NASA and the National Science Foundation.

- Astronomers track bubbles on star's surface

Date: September 11, 2024
Source: ESO

For the first time, astronomers have captured images of a star other than the Sun in enough detail to track the motion of bubbling gas on its surface. The images of the star, R Doradus, were obtained with the Atacama Large Millimetre/submillimetre Array (ALMA), a telescope co-owned by the European Southern Observatory (ESO), in July and August 2023. They show giant, hot bubbles of gas, 75 times the size of the Sun, appearing on the surface and sinking back into the star's interior faster than expected.

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and sinking back into the star's interior faster than expected.
"This is the first time the bubbling surface of a real star can be shown in such a way,"* says Wouter Vlemmings, a professor at Chalmers University of Technology, Sweden, and lead author of the study published today in Nature. "We had never expected the data to be of such high quality that we could see so many details of the convection on the stellar surface."
Stars produce energy in their cores through nuclear fusion. This energy can be carried out towards the star's surface in huge, hot bubbles of gas, which then cool down and sink -- like a lava lamp. This mixing motion, known as convection, distributes the heavy elements formed in the core, such as carbon and nitrogen, throughout the star. It is also thought to be responsible for the stellar winds that carry these elements out into the cosmos to build new stars and planets.
Convection motions had never been tracked in detail in stars other than the Sun, until now. By using ALMA, the team were able to obtain high-resolution images of the surface of R Doradus over the course of a month. R Doradus is a red giant star, with a diameter roughly 350 times that of the Sun, located about 180 light-years away from Earth in the constellation Dorado. Its large size and proximity to Earth make it an ideal target for detailed observations. Furthermore, its mass is similar to that of the Sun, meaning R Doradus is likely fairly similar to how our Sun will look like in five billion years, once it becomes a red giant.
"Convection creates the beautiful granular structure seen on the surface of our Sun, but it is hard to see on other stars," adds Theo Khouri, a researcher at Chalmers who is a co-author of the study. "With ALMA, we have now been able to not only directly see convective granules -- with a size 75 times the size of our Sun! -- but also measure how fast they move for the first time."
The granules of R Doradus appear to move on a one-month cycle, which is faster than scientists expected based on how convection works in the Sun. "We don't yet know what is the reason for the difference. It seems that convection changes as a star gets older in ways that we don't yet understand," says Vlemmings. Observations like those now made of R Doradus are helping us to understand how stars like the Sun behave, even when they grow as cool, big and bubbly as R Doradus is.
"It is spectacular that we can now directly image the details on the surface of stars so far away, and observe physics that until now was mostly only observable in our Sun," concludes Behzad Bojnodi Arbab, a PhD student at Chalmers who was also involved in the study.
Notes
*Convection bubbles have been previously observed in detail on the surface of stars, including with the PIONIER instrument on ESO's Very Large Telescope Interferometer. But the new ALMA observations track the motion of the bubbles in a way that was not possible before.

- ❖ Organic matter on Mars was formed from atmospheric formaldehyde

Date: September 19, 2024
Source: Tohoku University

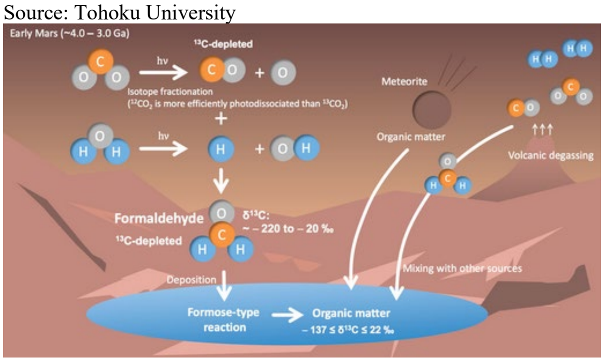


Diagram showing the processes of how organic matter was formed on early Mars. (Image: Shungo Koyama)

Although Mars is currently a cold, dry planet, geological evidence suggests that liquid water existed there around 3 to 4 billion years ago. Where there is water, there is usually life. In their quest to answer the burning question about life on Mars, researchers at Tohoku University created a detailed model of organic matter production in the ancient Martian atmosphere.
Organic matter refers to the remains of living things such as plants and animals, or the byproduct of certain chemical reactions. Whatever the case, the stable carbon isotope ratio ($^{13}C/^{12}C$) found in organic matter provides valuable clues about how these building blocks of life were originally formed, giving scientists a window into the past. As such, it has become a point of interest for Mars expeditions. For example, the Mars rover Curiosity (operated by NASA) revealed that organic matter found in sediments from that era on Mars are unusually depleted in ^{13}C. It was also discovered that the carbon isotope ratios varied significantly between samples.

However, the reason for this variability was a mystery.

To expand on these findings, a research group led by Shungo Koyama, Tatsuya Yoshida, and Naoki Terada from Tohoku University developed a Martian atmospheric evolution model. The model focused on formaldehyde (H_2CO), which members of this research team previously determined could feasibly be produced in the ancient Martian atmosphere. The reason for this choice is that formaldehyde can generate complex organic compounds such as sugars, which are essential for life. In other words, formaldehyde may be the missing factor that could explain the anomalous values of the Curiosity rover samples. It could also be a sign of past life.

This model combined a photochemical model with a climate model to estimate the changes in the carbon isotope ratio of formaldehyde on Mars, dating back 3 to 4 billion years. It revealed that the depletion of ^{13}C in formaldehyde is due to the photodissociation of CO_2 by solar ultraviolet radiation, which results in the preference of one stable isotope over another. The study also showed that the carbon isotope ratio varied based on factors such as the atmospheric pressure on Mars at the time, the fraction of light reflected by the planet's surface, the ratio of CO to CO_2, and the amount of hydrogen released by volcanic activity.

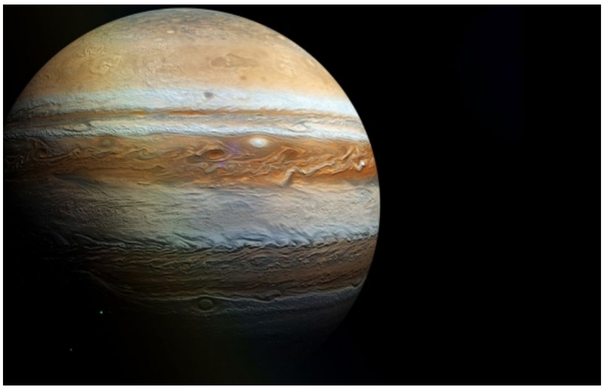
"This model provides a possible explanation for previously unexplained findings, such as why ^{13}C was mysteriously depleted." remarks Koyama, a graduate student at Tohoku University.

This discovery indicates that formaldehyde contributed to the formation of organic matter on ancient Mars, implying that bio-important molecules such as sugars and ribose (a component of RNA, which is present in all living cells) may have been produced on the planet.

These findings were published in *Scientific Reports* on September 17, 2024.

- ❖ Volcanoes may help reveal interior heat on Jupiter moon

Date: September 19, 2024
Source: Cornell University



By staring into the hellish landscape of Jupiter's moon Io -- the most volcanically active location in the solar system -- Cornell University astronomers have been able to study a fundamental process in planetary formation and evolution: tidal heating.

"Tidal heating plays an important role in the heating and orbital evolution of celestial bodies," said Alex Hayes, professor of astronomy. "It provides the warmth necessary to form and sustain subsurface oceans in the moons around giant planets like Jupiter and Saturn."

"Studying the inhospitable landscape of Io's volcanoes actually inspires science to look for life," said lead author Madeline Pettine, a doctoral student in astronomy.

By examining flyby data from the NASA spacecraft Juno, the astronomers found that Io has active volcanoes at its poles that may help to regulate tidal heating -- which causes friction -- in its magma interior.

The research published in *Geophysical Research Letters*.

"The gravity from Jupiter is incredibly strong," Pettine said. "Considering the gravitational interactions with the large planet's other moons, Io ends up getting bullied, constantly stretched and scrunched up. With that tidal deformation, it creates a lot of internal heat within the moon."

Pettine found a surprising number of active volcanoes at Io's poles, as opposed to the more-common equatorial regions. The interior liquid water oceans in the icy moons may be kept liquefied by tidal heating, Pettine said.

In the north, a cluster of four volcanoes -- Asis, Zal, Tonatiuh, one unnamed and an independent one named Loki -- were highly active and persistent with a long history of space mission and ground-based observations.

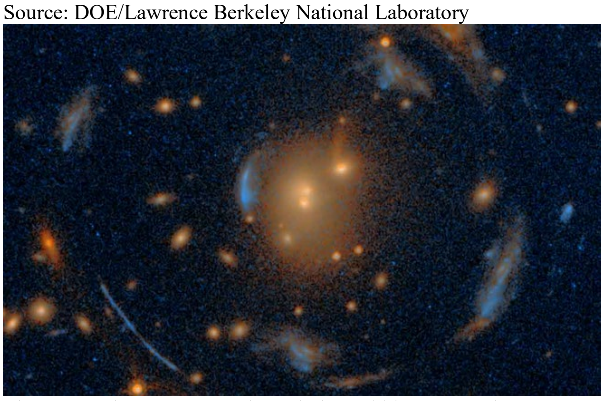
A southern group, the volcanoes Kanehekili, Uta and Laki-Oi demonstrated strong activity.

The long-lived quartet of northern volcanoes concurrently became bright and seemed to

respond to one another. "They all got bright and then dim at a comparable pace," Pettine said. "It's interesting to see volcanoes and seeing how they respond to each other.
This research was funded by NASA's New Frontiers Data Analysis Program and by the New York Space Grant.

❖ Magnifying deep space through the 'carousel lens'

Date: September 18, 2024
Source: DOE/Lawrence Berkeley National Laboratory



The Carousel Lens, as seen through the Hubble Space Telescope.
Credit: William Sheu/UCLA

In a rare and extraordinary discovery, researchers have identified a unique configuration of galaxies that form the most exquisitely aligned gravitational lens found to date. The Carousel Lens is a massive cluster-scale gravitational lens system that will enable researchers to delve deeper into the mysteries of the cosmos, including dark matter and dark energy.

"This is an amazingly lucky 'galactic line-up' -- a chance alignment of multiple galaxies across a line-of-sight spanning most of the observable universe," said David Schlegel, a co-author of the study and a senior scientist in Berkeley Lab's Physics Division. "Finding one such alignment is a needle in the haystack. Finding all of these is like eight needles precisely lined up inside that haystack."

The Carousel Lens is an alignment consisting of one foreground galaxy cluster (the 'lens') and seven background galaxies spanning immense cosmic distances and seen through the gravitationally distorted space-time around the lens. In the dramatic image below:

- The lensing cluster, located 5 billion light years away from Earth, is shown by its four brightest and most massive galaxies (indicated by La, Lb, Lc, and Ld), and these constitute the foreground of the image.
- Seven unique galaxies (numbered 1 through 7), appear through the lens. These are located far beyond, at distances from 7.6 to 12 billion light years away from Earth, approaching the limit of the observable universe.
- Each galaxy's repeated appearances (indicated by each number's letter index, e.g., a through d) show differences in shape that are curved and stretched into multiple "fun house mirror" iterations caused by the warped space-time around the lens.
- Of particular interest is the discovery of an Einstein Cross -- the largest known to date -- shown in galaxy number 4's multiple appearances (indicated by 4*a*, 4*b*, 4*c*, and 4*d*). This rare configuration of multiple images around the centre of the lens is an indication of the symmetrical distribution of the lens' mass (dominated by invisible dark matter) and plays a key role in the lens-modelling process.

Light traveling from far-distant space can be magnified and curved as it passes through the gravitationally distorted space-time of nearer galaxies or clusters of galaxies. In rare instances, a configuration of objects aligns nearly perfectly to form a strong gravitational lens. Using an abundance of new data from the Dark Energy Spectroscopic Instrument (DESI) Legacy Imaging Surveys, recent observations from NASA's Hubble Space Telescope, and the Perlmutter supercomputer at the National Energy Research Scientific Computing Centre (NERSC), the research team built on their earlier studies (in May 2020 and Feb 2021) to identify likely strong lens candidates, laying the groundwork for the current discovery.

"Our team has been searching for strong lenses and modelling the most valuable systems," explains Xiaosheng Huang, a study co-author and member of Berkeley Lab's Supernova Cosmology Project, and a professor of physics and astronomy at the University of San Francisco. "The Carousel Lens is an incredible alignment of seven galaxies in five groupings that line up nearly perfectly behind the foreground cluster lens. As they appear through the lens, the multiple images of each of the background galaxies form approximately concentric circular patterns around the foreground lens, as in a carousel. It's an unprecedented discovery, and the computational model generated shows a highly promising prospect for measuring the properties of the cosmos, including those of dark matter and dark energy."

The study also involved several Berkeley Lab student researchers, including the lead author, William Sheu, an undergraduate student intern with DESI at the beginning of this study, now a PhD student at UCLA and a DESI collaborator.

The Carousel Lens will enable researchers to study dark energy and dark matter in entirely new ways based on the strength of the observational data and its computational model.

"This is an extremely unusual alignment, which by itself will provide a testbed for cosmological studies," observes Nathalie Palanque-Delabrouille, director of Berkeley Lab's Physics Division. "It also shows how the imaging done for DESI can be leveraged for other scientific applications," such as investigating the mysteries of dark matter and the accelerating expansion of the universe, which is driven by dark energy.

- NASA's Webb provides another look into galactic collisions

Date: September 18, 2024
Source: NASA/Goddard Space Flight Centre

This composite image of Arp 107, created with data from the James Webb Sp

Smile for the camera! An interaction between an elliptical galaxy and a spiral galaxy, collectively known as Arp 107, seems to have given the spiral a happier outlook thanks to the two bright "eyes" and the wide semicircular "smile." The region has been observed before in infrared by NASA's Spitzer Space Telescope in 2005, however NASA's James Webb Space Telescope displays it in much higher resolution. This image is a composite, combining observations from Webb's MIRI (Mid-Infrared Instrument) and NIRCam (Near-Infrared Camera).

NIRCam highlights the stars within both galaxies and reveals the connection between them: a transparent, white bridge of stars and gas pulled from both galaxies during their passage. MIRI data, represented in orange-red, shows star-forming regions and dust that is composed of soot-like organic molecules known as polycyclic aromatic hydrocarbons. MIRI also provides a snapshot of the bright nucleus of the large spiral, home to a supermassive black hole.

The spiral galaxy is classified as a Seyfert galaxy, one of the two largest groups of active galaxies, along with galaxies that host quasars. Seyfert galaxies aren't as luminous and distant as quasars, making them a more convenient way to study similar phenomena in lower energy light, like infrared.

This galaxy pair is similar to the Cartwheel Galaxy, one of the first interacting galaxies that Webb observed. Arp 107 may have turned out very similar in appearance to the Cartwheel, but since the smaller elliptical galaxy likely had an off-centre collision instead of a direct hit, the spiral galaxy got away with only its spiral arms being disturbed.

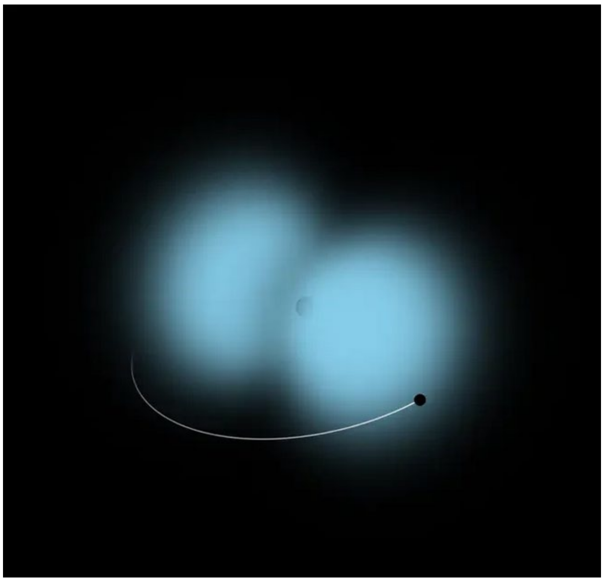
The collision isn't as bad as it sounds. Although there was star formation occurring before, collisions between galaxies can compress gas, improving the conditions needed for more stars to form. On the other hand, as Webb reveals, collisions also disperse a lot of gas, potentially depriving new stars of the material they need to form.

Webb has captured these galaxies in the process of merging, which will take hundreds of millions of years. As the two galaxies rebuild after the chaos of their collision, Arp 107 may lose its smile, but it will inevitably turn into something just as interesting for future astronomers to study.

Arp 107 is located 465 million light-years from Earth in the constellation Leo Minor.

- Black hole pairs may unveil new particles

Date: September 17, 2024
Source: Universiteit van Amsterdam



A gravitational atom. In the same way that electrons can orbit a nucleus in an atom, a cloud of so far undiscovered ultralight particles may orbit pairs of black holes. Image Credit: University of Amsterdam

In a paper published in *Physical Review Letters* this week, physicists from Amsterdam and Copenhagen argue that close observations of merging black hole pairs may unveil information about potential new particles. The research combines several new discoveries made by UvA scientists over the past six years.

Gravitational waves that are emitted by the merger of two black holes carry detailed information about the shape and evolution of the orbits of the components. A new study by physicists Giovanni Maria Tomaselli and Gianfranco Bertone from the University of Amsterdam (UvA), together with former UvA master student Thomas Spieksma, now at the Niels Bohr Institute in Copenhagen, suggests that a careful analysis of this information may reveal the existence of new particles in nature.

Superradiance

The mechanism that makes the detection of new particles possible is called *black hole superradiance*. When a black hole spins fast enough, it can shed some of its mass into a 'cloud' of particles around it. The black hole-cloud system is referred to as a 'gravitational atom', due to its similarity with the electron cloud around a proton. Since superradiance is only efficient if the particles are much lighter than the ones measured in experiments so far, this process provides the unique opportunity to probe the existence of new particles known as ultralight bosons, whose existence may resolve several puzzles in astrophysics, cosmology and particle physics.

The orbital evolution of binary black holes in the presence of ultralight boson clouds has been studied by UvA scientists in a series of influential papers over the past six years. One important new phenomenon that was discovered was that of resonant transitions, where the cloud 'jumps' from one state to another, similar to how an electron in an ordinary atom can jump between orbits. Another new phenomenon, again similar to the behaviour of ordinary atoms, is ionization, where part of the cloud is ejected. Both of these effects leave characteristic imprints on the emitted gravitational waves, but the details of such imprints depend on the -- so far unknown -- state of the particle cloud. In an effort to fill in these remaining details, the new study combines all the previous results, and follows the history of the system from the formation of the binary black hole to the black hole merger.

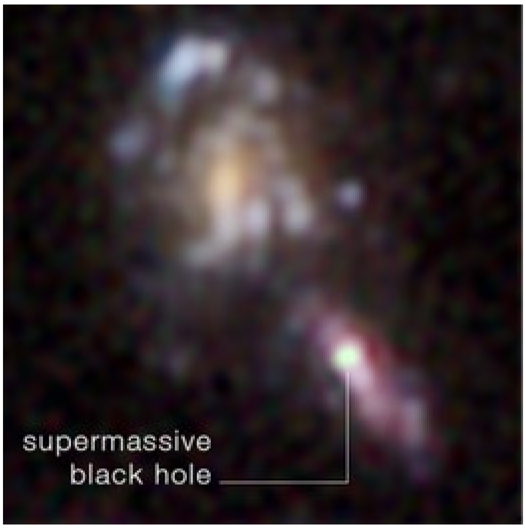
Two possibilities

The main conclusions substantially improve our understanding of the binary gravitational atoms. The researchers found that there were two possible outcomes of the evolution of such a system, both equally interesting. If the black holes and the cloud initially rotate in opposite directions, then the cloud survives in the state originally produced by superradiance, and it becomes detectable through its ionization, which leaves a clear signature on the gravitational waves. In all other cases, resonant transitions destroy the cloud altogether, and the binary's orbit acquires very specific values of eccentricity and inclination, which can be measured from the gravitational waves signal.

Thus, the new result provides a novel and solid search strategy for new particles, either via the detection of ionization effects in gravitational waveforms in one case, or in the other case via the observation of an anomalous excess of systems with the predicted values of eccentricity and inclination. For both cases, upcoming detailed gravitational wave observations will reveal very interesting information about the question whether new ultralight particles exist.

More black holes than expected in the early universe

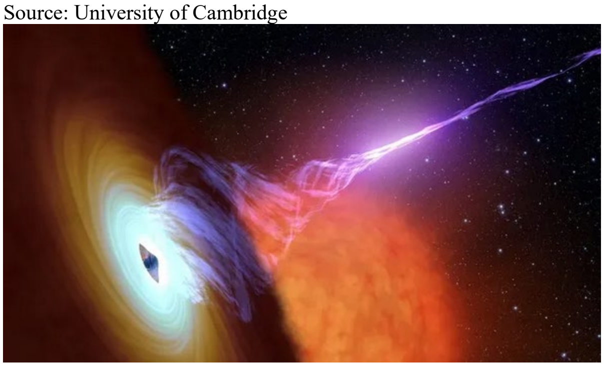
Date: September 17, 2024
Source: NASA/Goddard Space Flight Centre



With the help of NASA's Hubble Space Telescope, an international team of researchers led by scientists in the Department of Astronomy at Stockholm University has found more black holes in the early universe than has previously been reported. The new result can help scientists understand how supermassive black holes were created.
Currently, scientists do not have a complete picture of how the first black holes formed not long after the big bang. It is known that supermassive black holes, that can weigh more than a billion suns, exist at the centre of several galaxies less than a billion years after the big bang.
"Many of these objects seem to be more massive than we originally thought they could be at such early times -- either they formed very massive or they grew extremely quickly," said Alice Young, a PhD student from Stockholm University and co-author of the study published in *The Astrophysical Journal Letters*.
Black holes play an important role in the lifecycle of all galaxies, but there are major uncertainties in our understanding of how galaxies evolve. In order to gain a complete picture of the link between galaxy and black hole evolution, the researchers used Hubble to survey how many black holes exist among a population of faint galaxies when the universe was just a few percent of its current age.
Initial observations of the survey region were re-photographed by Hubble after several years. This allowed the team to measure variations in the brightness of galaxies. These variations are a telltale sign of black holes. The team identified more black holes than previously found by other methods.
The new observational results suggest that some black holes likely formed by the collapse of massive, pristine stars during the first billion years of cosmic time. These types of stars can only exist at very early times in the universe, because later-generation stars are polluted by the remnants of stars that have already lived and died. Other alternatives for black hole formation include collapsing gas clouds, mergers of stars in massive clusters, and "primordial" black holes that formed (by physically speculative mechanisms) in the first few seconds after the big bang. With this new information about black hole formation, more accurate models of galaxy formation can be constructed.
"The formation mechanism of early black holes is an important part of the puzzle of galaxy evolution," said Matthew Hayes from the Department of Astronomy at Stockholm University and lead author of the study. "Together with models for how black holes grow, galaxy evolution calculations can now be placed on a more physically motivated footing, with an accurate scheme for how black holes came into existence from collapsing massive stars."
Astronomers are also making observations with NASA's James Webb Space Telescope to search for galactic black holes that formed soon after the big bang, to understand how massive they were and where they were located.

- Astronomers detect black hole 'starving' its host galaxy to death

Date: September 16, 2024
Source: University of Cambridge



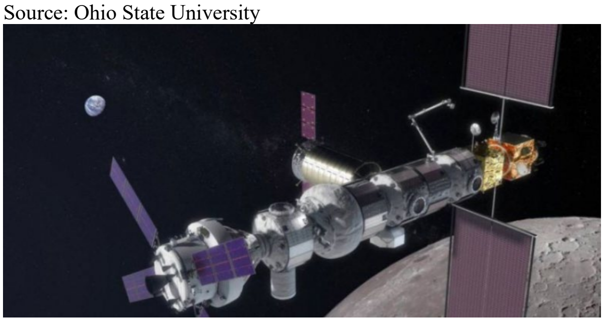
A purple glowing jet is released from a spinning black hole in space. (Image credit: NASA/JPL-Caltech)

Astronomers have used the NASA/ESA James Webb Space Telescope to confirm that supermassive black holes can starve their host galaxies of the fuel they need to form new stars.
The international team, co-led by the University of Cambridge, used Webb to observe a galaxy roughly the size of the Milky Way in the early universe, about two billion years after the Big Bang. Like most large

galaxies, it has a supermassive black hole at its centre. However, this galaxy is essentially 'dead': it has mostly stopped forming new stars.
"Based on earlier observations, we knew this galaxy was in a quenched state: it's not forming many stars given its size, and we expect there is a link between the black hole and the end of star formation," said co-lead author Dr Francesco D'Eugenio from Cambridge's Kavli Institute for Cosmology. "However, until Webb, we haven't been able to study this galaxy in enough detail to confirm that link, and we haven't known whether this quenched state is temporary or permanent."
This galaxy, officially named GS-10578 but nicknamed 'Pablo's Galaxy' after the colleague who decided to observe it in detail, is massive for such an early period in the universe: its total mass is about 200 billion times the mass of our Sun, and most of its stars formed between 12.5 and 11.5 billion years ago.
"In the early universe, most galaxies are forming lots of stars, so it's interesting to see such a massive dead galaxy at this period in time," said co-author Professor Roberto Maiolino, also from the Kavli Institute for Cosmology. "If it had enough time to get to this massive size, whatever process that stopped star formation likely happened relatively quickly."
Using Webb, the researchers detected that this galaxy is expelling large amounts of gas at speeds of about 1,000 kilometres per second, which is fast enough to escape the galaxy's gravitational pull. These fast-moving winds are being 'pushed' out of the galaxy by the black hole.
Like other galaxies with accreting black holes, 'Pablo's Galaxy' has fast outflowing winds of hot gas, but these gas clouds are tenuous and have little mass. Webb detected the presence of a new wind component, which could not be seen with earlier telescopes. This gas is colder, which means it's denser and -- crucially -- does not emit any light. Webb, with its superior sensitivity, can see these dark gas clouds because they block some of the light from the galaxy behind them.
The mass of gas being ejected from the galaxy is greater than what the galaxy would require to keep forming new stars. In essence, the black hole is starving the galaxy to death. The results are reported in the journal *Nature Astronomy*.
"We found the culprit," said D'Eugenio. "The black hole is killing this galaxy and keeping it dormant, by cutting off the source of 'food' the galaxy needs to form new stars."
Although earlier theoretical models had predicted that black holes had this effect on galaxies, before Webb, it had not been possible to detect this effect directly.
Earlier models had predicted that the end of star formation has a violent, turbulent effect on galaxies, destroying their shape in the process. But the stars in this disc-shaped galaxy are still moving in an orderly way, suggesting that this is not always the case.
"We knew that black holes have a massive impact on galaxies, and perhaps it's common that they stop star formation, but until Webb, we weren't able to directly confirm this," said Maiolino. "It's yet another way that Webb is such a giant leap forward in terms of our ability to study the early universe and how it evolved."
New observations with the Atacama Large Millimetre Submillimetre Array (ALMA), targeting the coldest, darkest gas components of the galaxy, will tell us more about if and where any fuel for star formation is still hidden in this galaxy, and what is the effect of the supermassive black hole in the region surrounding the galaxy.
The research was supported in part by the Royal Society, the European Union, the European Research Council, and the Science and Technology Facilities Council (STFC), part of UK Research and Innovation (UKRI).

- Keeping mould out of future space stations

Study models how dust, humidity creates problems for astronauts
Date: September 11, 2024
Source: Ohio State University



Mold can survive the harshest of environments, so to stop harmful spores from growing on future space stations, a new study suggests a novel way to prevent its spread. Researchers created a predictive approach for modelling unintended microbial growth in

critical spaces and applied it to life on the International Space Station.
An analysis of dust samples obtained from the space station found that repeated elevated humidity exposures for even a short time can lead to rapid microbial growth and composition changes in dust that make it easier for microbes, such as fungi, to thrive.
The study provides important insight into how healthy environments might be maintained during future missions, especially as the commercial space industry begins to prompt more people to live and work above Earth, said Karen Dannemiller, senior author of the study and an associate professor of civil, environmental and geodetic engineering and environmental health sciences at The Ohio State University.
"It's really important to understand the exposures that happen in the space environment in part because we see immune system changes in astronauts," she said. "People who are normally healthy individuals may be especially vulnerable to microbes in space, more so than on Earth."
The study was published in the journal *Microbiome.*
Historically, many spacecrafts have had issues with unintended microbial growth because, much like a typical home on Earth, they, too, are environments that tend to trap the moisture humans emit. On the ISS, dust is usually produced by people as they go about their daily activities, but left unchecked, these floating particles can cause a range of negative health issues for the crew, such as asthma or allergies, and degrade building materials and equipment.
To ensure that dust levels aboard the ISS are carefully controlled, every week astronauts must clean the protective screens that cover the filters of the space station's air ventilation system. In this study, four separate vacuum bag samples of the dust collected from these housekeeping chores were sent down to Dannemiller's team to be tested.
After incubating the samples for two weeks at different relative humidities to simulate a scenario where an unexpected event, such as a temporary air ventilation system failure, could cause bursts of moisture, analysis revealed that fungi and bacteria can grow in the same concentrated amounts as dust collected from residential homes on the ground.
"Spacecraft actually aren't that different from what we see on Earth in terms of having a unique indoor microbiome," said Nicholas Nastasi, lead author of the study and a postdoctoral researcher at Ohio State's Indoor Environmental Quality Laboratory. "If you put people in a space, there will always be microbes there, so it's important to prevent their spread because once it starts, it's often not too easy to get rid of."
Spacecraft are especially prone to microbial growth because they are enclosed environments where humans constantly exhale moisture. If that moisture builds up, Mold can begin to grow, as seen in past space stations such as *Mir*. Although the ISS has much improved controls for moisture, unexpected situations can still easily occur, said Nastasi.
Additionally, while Earth and space environments are complex in their own unique ways, the two more often than not contain similar core microbial communities, Nastasi said. Moreover, staying knowledgeable about the evolution of these communities will make certain that vulnerable individuals both on- and off-world have the information needed to maintain a healthy indoor microbiome on the space station.
"In designing some of our current space station systems, we've already learned a lot of really important lessons in terms of how to keep moisture under control," said Dannemiller. "Now we're learning even more that we can use to advance these systems in the future."
In general, the study also suggests that the team's research could later aid the development of planetary protection protocols aimed at preventing contamination of Earth or any other celestial bodies humans may visit.
Next, the team will likely work to discover what effect other untested spaceflight variables, such as microgravity, radiation and elevated carbon dioxide levels, have on microbial growth in similar working space stations, like NASA's lunar station Gateway or other imminent commercial projects. Many of their upcoming projects will also benefit from Ohio State's terrestrial analog of the George Washington Carver Science Park, a replica of Starlab space station science park that will allow researchers to conduct parallel missions on the ground.
"There's a lot of other unique spaceflight factors we can potentially add to these microbial models to make them more accurate and useful," said Nastasi. "We'll keep refining

what we do to maintain those healthy space environments and having unprecedented access to a platform such as Starlab will help immensely."

❖ Huge gamma-ray burst collection 'rivals 250-year-old Messier catalogue'

Date: September 13, 2024
Source: Royal Astronomical Society

Gamma-ray bursts (like the one depicted in this artist's impression) are the most violent explosions in the Universe, releasing more energy than the Sun would in 10 billion years.
Credit
NASA/Swift/Cruz deWilde

Hundreds of gamma-ray bursts (GRBs) have been recorded as part of an enormous global effort so extensive it "rivals the catalogue of deep-sky objects created by Messier 250 years ago," astronomers say.
GRBs are the most violent explosions in the Universe, releasing more energy than the Sun would in 10 billion years. They occur when either a massive star dies or two neutron stars merge.
The explosions are so formidable that if one were to erupt within a distance of 1,000 light-years from Earth -- which is predicted to happen every 500 million years -- the blast of radiation could damage our ozone layer and have devastating consequences for life. However, the chances of such an event occurring any time soon are extremely low.
First observed almost six decades ago, GRBs also have the potential to help us better understand the history of our Universe, from its earliest stars to how it looks today.
The latest research recorded 535 GRBs -- the nearest of which was 77 million light-years from Earth -- from 455 telescopes and instruments across the world.
It was led by Professor Maria Giovanna Dainotti, of the National Astronomical Observatory of Japan, and has been published today in the *Monthly Notices of the Royal Astronomical Society*.
The researchers likened their collection to the 110 deep-sky objects catalogued by the French astronomer Charles Messier in the 18th century. To this day the catalogue continues to provide astronomers -- both professional and amateur -- with a range of easy-to-find objects in the night sky.
"Our research enhances our understanding of these enigmatic cosmic explosions and showcases the collaborative effort across nations," said Professor Dainotti.
"The result is a catalogue akin to the one created by Messier 250 years ago, which classified deep-sky objects observable at that time."
It has been hailed by co-author Professor Alan Watson, of the National Autonomous University of Mexico, as a "great resource" that could help "push the frontiers of our knowledge forward."
Professors Watson and Dainotti were part of a team of more than 50 scientists who meticulously studied how GRB light reaches Earth over several weeks and, in some cases, even months after the explosion. The result, they say, is the largest catalogue ever assembled of GRBs observed in optical wavelengths with measured distances.
It includes 64,813 photometric observations collected over 26 years, with notable contributions from the Swift satellites, the RATIR camera, and the Subaru Telescope.
What the team found particularly interesting about their findings was that nearly a third of the GRBs recorded (28 per cent) did not change or evolve as the light from the explosions travelled across the cosmos.
Co-author Dr Rosa Becerra, of the University of Tor Vergata in Rome, said this suggests that some of the most recent GRBs behave in exactly the same way as those which occurred billions of years ago.
Such a finding is at odds with the big picture commonly seen in the Universe, where objects have continuously evolved from the Big Bang.
Professor Dainotti added: "This phenomenon could indicate a very peculiar mechanism for how these explosions occur, suggesting that the stars linked to GRBs are more primitive than those born more recently.
"However, this hypothesis still needs more investigation."
On the other hand, for the few GRBs where this optical evolution matches the X-ray evolution, a more straightforward explanation is possible.
"Specifically, we are observing an expanding plasma composed of electrons and positrons that cools over time, and like a hot iron rod

radiating redder and redder light as it cools, we do see a transition of the emission mechanism," said fellow researcher Professor Bruce Gendre, of the University of the Virgin Islands.
"In this case, this mechanism may be linked to the magnetic energy that powers these phenomena."
The researchers now want the astronomical community to help expand their GRB compilation further. They have made the data accessible through a user-friendly web app and have called on their peers to add to it, ideally by sharing findings in the same format.
"Adopting a standardised format and units, potentially linked to the International Virtual Observatory Alliance protocols, will enhance the consistency and accessibility of the data in this field," Professor Gendre said.
"Once the data are secured, additional population studies will be conducted, triggering new discoveries based on the statistical analysis of the current work."

- Simple shift could make low Earth orbit satellites high capacity

Date: September 13, 2024
Source: Princeton University, Engineering School
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Low-orbit satellites could soon offer millions of people worldwide access to high-speed communications, but the satellites' potential has been stymied by a technological limitation -- their antenna arrays can only manage one user at a time.
The one-to-one ratio means that companies must launch either constellations of many satellites, or large individual satellites with many arrays, to provide wide coverage. Both options are expensive, technically complex, and could lead to overcrowded orbits.
For example, SpaceX went the "constellation" route. Its network, StarLink, currently consists of over 6,000 satellites in low-Earth orbit, over half of which were launched in the past few years. SpaceX aims to launch tens of thousands more in the coming years.
Now, researchers at Princeton engineering and at Yang Ming Chiao Tung University in Taiwan have invented a technique that enables low-orbit satellite antennas to manage signals for multiple users at once, drastically reducing needed hardware.
In a paper published June 27 in *IEEE Transactions on Signal Processing*, the researchers describe a way to overcome the single-user limit. The strategy builds on a common technique to strengthen communications by positioning antenna arrays to direct a beam of radio waves precisely where it's needed. Each beam carries information, like texts or phone calls, in the form of signals. While antenna arrays on terrestrial platforms such as cell towers can manage many signals per beam, low-orbit satellites can only handle one.
The satellites' 20,000 miles-per-hour speed and constantly changing positions make it nearly impossible to handle multiple signals without jumbling them.
"For a cell tower to communicate with a car moving 60 miles per hour down the highway, compared to the rate that data is exchanged, the car doesn't move very much," said co-author H. Vincent Poor, the Michael Henry Strater University Professor in Electrical and Computer Engineering at Princeton. "But these satellites are moving very fast to stay up there, so the information about them is changing rapidly."
To deal with that limitation, the researchers developed a system to effectively split transmissions from a single antenna array into multiple beams without requiring additional hardware. This allows satellites to overcome the limit of a single user per antenna array.
Co-author Shang-Ho (Lawrence) Tsai, professor of electrical engineering at Yang Ming Chiao Tung University, compared the approach to shining two distinctive rays from a flashlight without relying on multiple bulbs. "Now, we only need one bulb," he said. "This means a huge reduction in cost and power consumption."
A network with fewer antennas could mean fewer satellites, smaller satellites, or both. "A conventional low Earth orbit satellite network may need 70 to 80 satellites to cover the United States alone," Tsai said. "Now, that number could be reduced to maybe 16."
The new technique can be incorporated into existing satellites that are already built, according to Poor. "But a key benefit is that you can design a simpler satellite," he said.
Impacts in space
Low-orbit satellites reside in the lower layer of Earth's atmosphere, between 100 and 1,200 miles from the surface. This region of space offers limited real estate. The more objects flying around, the more likely they are to crash, breaking apart and releasing smaller

fragments of debris that can then crash into other objects.
"The concern there isn't so much getting hit by a falling satellite," Poor said, "But about the long-term future of the atmosphere, and the orbit being clouded up with space debris causing problems."
Because the low-orbit satellite industry is gaining traction at a rapid pace, with companies including Amazon and OneWeb deploying their own satellite constellations to provide internet service, the new technique has the potential to reduce the risk of these hazards.
Poor said that while this paper is purely theoretical, the efficiency gains are real. "This paper is all mathematics," he said. "But in this field in particular, theoretical work tends to be very predictive."
Since publishing the paper, Tsai has gone on to conduct field tests using underground antennas and has shown that the math does, in fact, work. "The next step is to implement this in a real satellite and launch it into space," he said.

- ❖ Hair-thin wire to help simulate cosmic conditions

Date: September 12, 2024
Source: Helmholtz-Zentrum Dresden-Rossendorf

Extreme conditions prevail inside stars and planets. The pressure reaches millions of bars, and it can be several million degrees hot. Sophisticated methods make it possible to create such states of matter in the laboratory -- albeit only for the blink of an eye and in a tiny volume. So far, this has required the world's most powerful lasers, such as the National Ignition Facility (NIF) in California. But there are only a few of these light giants, and the opportunities for experiments are correspondingly rare. A research team led by the Helmholtz-Zentrum Dresden-Rossendorf (HZDR), together with colleagues from the European XFEL, has now succeeded in creating and observing extreme conditions with a much smaller laser. At the heart of the new technology is a copper wire, finer than a human hair, as the group reports in the journal *Nature Communications.*
So far, experts have been firing extremely high-energy laser flashes at a material sample, usually a thin foil. This causes the material on the surface to heat up suddenly. This creates a shock wave that races through the sample. It compresses the material and heats it up. For a few nanoseconds, conditions arise like those in the interior of a planet or in the shell of a star. The tiny time window is sufficient to study the phenomenon using special measuring techniques, such as the ultra-strong X-ray flashes of the European XFEL in Schenefeld near Hamburg, Germany.
Here, at Europe's most powerful X-ray laser, the HZDR leads an international user consortium called HIBEF -- Helmholtz International Beamline for Extreme Fields. Among other things, this consortium operates a laser at the High Energy Density (HED-HIBEF) experimental station, which generates ultra-short pulses that do not have particularly high energy -- only about one joule. However, at 30 femtoseconds, they are so short that they achieve an output of 100 terawatts. The research team used this laser at HED-HIBEF to fire at a thin copper wire, just 25 micrometres thick. "Then we were able to use the strong X-ray flashes from the European XFEL to observe what was happening inside the wire," explains Dr. Alejandro Laso Garcia, lead author of the paper. "This combination of short-pulse laser and X-ray laser is unique in the world. It was only thanks to the high quality and sensitivity of the X-ray beam that we were able to observe an unexpected effect."
Concentrated shock waves
In several series of measurements, the scientists systematically varied the time interval between the impact of the laser flash and the X-rays shining through. This made it possible to record a detailed "X-ray film" of the event: "First, the laser pulse interacts with the wire and generates a local shock wave that passes through the wire like a detonation and ultimately destroys it," explains HIBEF department head Dr. Toma Toncian. "But before that, some of the high-energy electrons created when the laser hits, race along the surface of the wire." These fast electrons heat up the surface of the wire quickly and generate further shock waves. These then run in turn from all sides to the centre of the wire. For a brief moment, all the shock waves collide there and generate extremely high pressures and temperatures.
The measurements showed that the density of the copper in the middle of the wire was briefly eight to nine times higher than in "normal," cold copper. "Our computer simulations suggest that we have reached a pressure of 800 megabars," says Prof. Thomas

Cowan, director of the HZDR Institute of Radiation Physics and initiator of the HIBEF consortium. "That corresponds to 800 million times atmospheric pressure and 200 times the pressure that prevails inside the earth." The temperature reached was also enormous by terrestrial standards: 100,000 degrees Celsius.

Perspectives for nuclear fusion

These are the conditions that are close to those in the corona of a white dwarf star. "Our method could also be used to achieve conditions like those in the interior of huge gas planets," emphasizes Laso Garcia. This includes not only well-known giants like Jupiter, but also a large number of distant exoplanets that have been discovered over the past few years. The research team has now also set its sights on wires made of other materials, such as iron and plastic. "Plastic is mainly made of hydrogen and carbon," says Toncian. "And both elements are found in stars and their corona."

The new measurement method should not only be useful for astrophysics, but also for another field of research. "Our experiment shows in an impressive way how we can generate very high densities and temperatures in a wide variety of materials," says Ulf Zastrau, who heads the HED group at the European XFEL. "This will take fusion research an important step further." Several research teams and start-ups around the world are currently working on a fusion power plant based on high-performance lasers.

The principle: Strong laser flashes hit a fuel capsule made of frozen hydrogen from all sides and ignite it, with more energy coming out than was put in. "With our method, we could observe in detail what happens inside the capsule when it is hit by the laser pulses," says Cowan, describing future experiments. "We expect that this can have a huge impact on basic research in this area."

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A lady in Eastergate is selling this Telescope it belonged to her late Husband. Contact me for details.


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