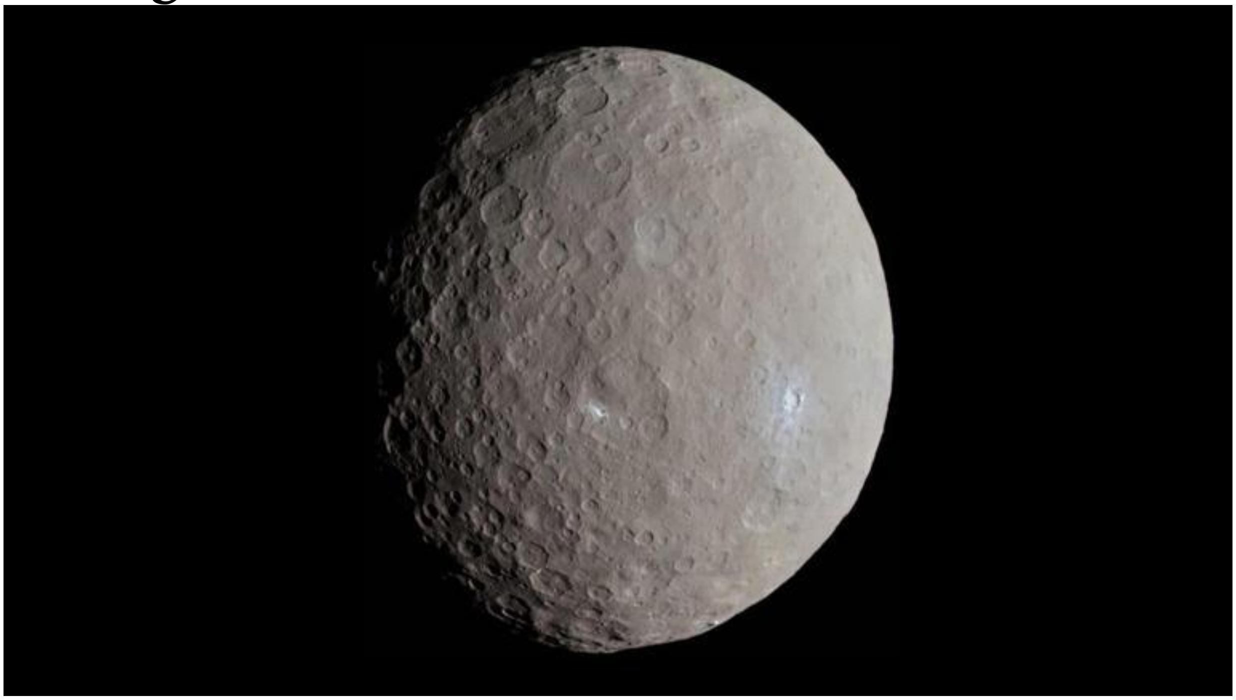
SPACE TECH VOL 4

Second Most Water-Rich World In The Inner Solar System Has More Organic Material Than Thought



Ceres, as seen by NASA's Dawn. - Image credit: NASA / JPL-Caltech / UCLA / MPS / DLR / IDA / Justin Cowart© IFL Science

Ceres, a dwarf planet and queen of the Asteroid Belt, continues to be a fascinating world. When it was visited by NASA's Dawn, signs of geological activity – including ice volcanoes – were abundant. The spacecraft also reported the presence of several organic-rich regions. The assumption was that comets and asteroids brought those to the Cererian surface. New work challenges that assumption.

Ceres is a big sphere of ice and rock. It is unlikely to have an ocean underneath but it is possible that it possesses a briny interior that flows, and that occasionally erupts into cryovolcanoes like Ahuna Mons. In the inner Solar System, it is second only to Earth for its amount of water. New analysis of Dawn's data has revealed more regions rich in organic materials, which disfavor the idea that these materials have an exogenous source – they were not brought here by collision.

There is another piece of evidence in support of endogenous production. Researchers conducted lab experiments to see how long it would take these deposits to degrade. They estimate that Ceres had between twice and as many as 30 times more organic material than detected today; that is much more than could be brought by an asteroid. Internal production is more likely according to these results, with potentially big consequences.

"The significance of this discovery lies in the fact that, if these are endogenous materials, it would confirm the existence of internal energy sources that could support biological processes," lead author Juan Luis Rizos, a researcher at the Instituto de Astrofísica de Andalucía, said in a translated statement.

The team found 11 new regions with characteristics that suggest the presence of organic compounds. Among the candidate regions are the Urvara and Yalode basins. They had the strongest signature of organics, suggesting that maybe the organics come from the subsurface and are only exposed during the dramatic excavation caused by an impact.

"These impacts were the most violent Ceres has experienced, so the material must originate from deeper regions than the material ejected from other basins or craters," explained Rizos. "If the presence of organics is confirmed, their origin leaves little doubt that these compounds are endogenous materials."

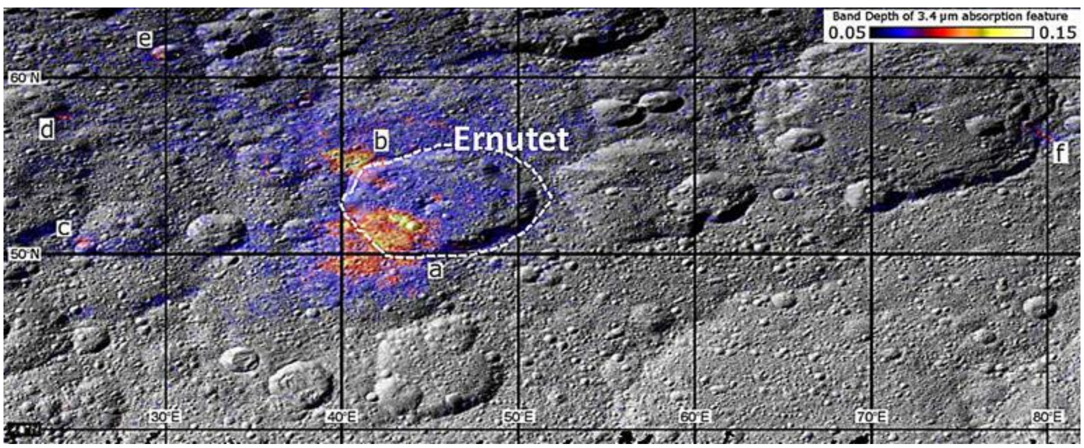
Six years on since the end of the mission, Dawn's data continues to be analyzed, revealing new insights into the largest body in the asteroid belt and the only dwarf planet in the inner Solar System. These findings, though, might have a broader impact.

"The idea of an organic reservoir in such a remote and seemingly inert location like Ceres raises the possibility that similar conditions could exist on other Solar

System bodies. Without a doubt, Ceres will be revisited by new probes in the near future, and our research will be key in defining the observational strategy for these missions," Rizos concluded.

The two papers on this work are published in The Planetary Science Journal and in Science.

New evidence of organic material identified on Ceres, the inner solar system's most water-rich object after Earth



Data from the Dawn spacecraft show the areas around Ernutet crater where organic material has been discovered (labeled 'a' through 'f'). The intensity of the organic absorption band is represented by colors, where warmer colors indicate higher concentrations. Credit: NASA/JPL-Caltech/UCLA/ASI/INAF/MPS/DLR/IDA

Six years ago, NASA's Dawn mission communicated with Earth for the last time, ending its exploration of Ceres and Vesta, the two largest bodies in the asteroid belt. Since then, Ceres —a water-rich dwarf planet showing signs of geological activity— has been at the center of intense debates about its origin and evolution.

Now, a study led by IAA-CSIC, using Dawn data and an innovative methodology, has identified 11 new regions suggesting the existence of an internal reservoir of organic materials in the dwarf planet. The results, published in *The Planetary*

Science Journal, provide critical insights into the potential nature of this celestial body.

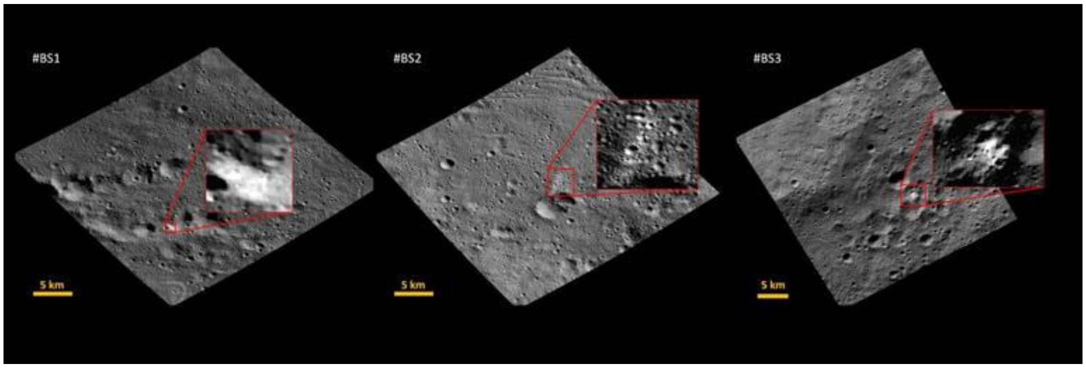
In 2017, the Dawn spacecraft detected organic compounds near the Ernutet crater in Ceres' northern hemisphere, sparking discussions about their origin. One leading hypothesis proposed an exogenous origin, suggesting these materials were delivered by recent impacts of organic-rich comets or asteroids.

This new research, however, focuses on a second possibility: that the organic material formed within Ceres and has been stored in a reservoir shielded from solar radiation.

"The significance of this discovery lies in the fact that, if these are endogenous materials, it would confirm the existence of internal energy sources that could support biological processes," explains Juan Luis Rizos, a researcher at the Instituto de Astrofísica de Andalucía (IAA-CSIC) and the lead author of the study.

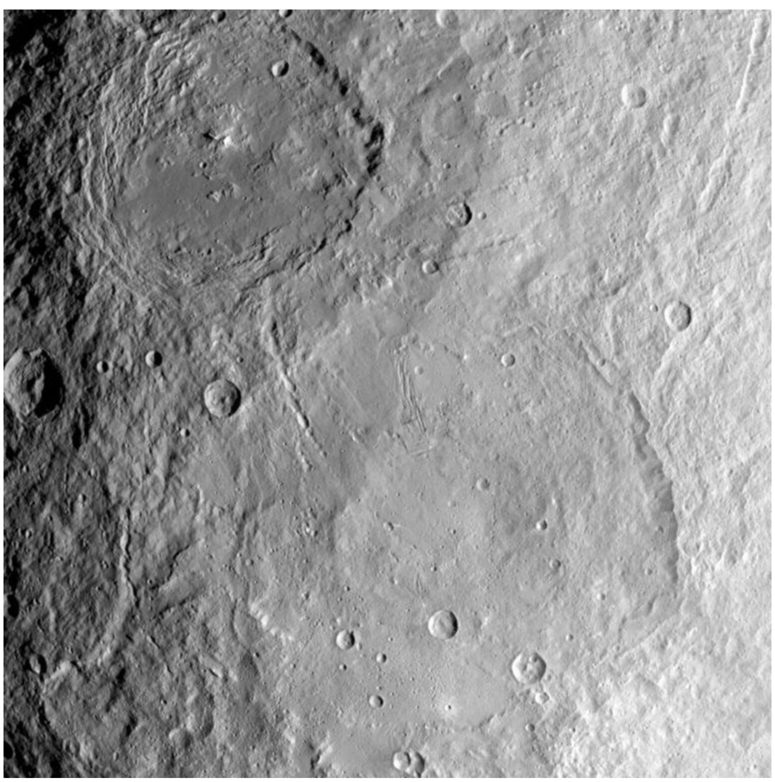
This color composite image, made with data from the framing camera aboard NASA's Dawn spacecraft, shows the area around Ernutet crater. The bright red parts appear redder than the rest of Ceres. Credit: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA

A potential witness to the dawn of the solar system



BS1,2 and 3 are images with the FC2 camera filter in the areas of highest abundance of these possible organic compounds. Credit: Juan Luis Rizos

With a diameter exceeding 930 kilometers, Ceres is the largest object in the main asteroid belt. This dwarf planet—which shares some characteristics with planets but doesn't meet all the criteria for planetary classification—is recognized as the most water-rich body in the inner solar system after Earth, placing it among the ocean worlds with potential astrobiological significance.



This image from NASA's Dawn spacecraft shows the large craters Urvara (top) and Yalode (bottom) on the dwarf planet Ceres. The two giant craters formed at different times. Urvara is about 120-140 million years old and Yalode is almost a billion years old. Credit: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA

Additionally, due to its physical and chemical properties, Ceres is linked to a type of meteorite rich in carbon compounds: carbonaceous chondrites. These meteorites are considered remnants of the material that formed the solar system approximately 4.6 billion years ago.

"Ceres will play a key role in future space exploration. Its water, present as ice and possibly as liquid beneath the surface, makes it an intriguing location for resource exploration," says Rizos (IAA-CSIC). "In the context of space colonization, Ceres could serve as a stopover or resource base for future missions to Mars or beyond."

The ideal combination of high-quality resolutions

To explore the nature of these organic compounds, the study employed a novel approach, allowing for the detailed examination of Ceres' surface and the analysis of the distribution of organic materials at the highest possible resolution.

First, the team applied a Spectral Mixture Analysis (SMA) method—a technique used to interpret complex spectral data—to characterize the compounds in the Ernutet crater.

Using these results, they systematically scanned the rest of Ceres' surface with high spatial resolution images from the Dawn spacecraft's Framing Camera 2 (FC2). This instrument provided high-resolution spatial images but low spectral resolution. This approach led to the identification of eleven new regions with characteristics suggesting the presence of organic compounds.

Most of these areas are near the equatorial region of Ernutet, where they have been more exposed to solar radiation than the organic materials previously identified in the crater. Prolonged exposure to solar radiation and the solar wind likely explains the weaker signals detected, as these factors degrade the spectral features of organic materials over time.

Next, the researchers conducted an in-depth spectral analysis of the candidate regions using the Dawn spacecraft's VIR imaging spectrometer, which offers high spectral resolution, though at lower spatial resolution than the FC2 camera. The combination of data from both instruments was crucial for this discovery.

Among the candidates, a region between the Urvara and Yalode basins stood out with the strongest evidence for organic materials. In this area, the organic compounds are distributed within a geological unit formed by the ejection of material during the impacts that created these basins.

"These impacts were the most violent Ceres has experienced, so the material must originate from deeper regions than the material ejected from other basins or craters," clarifies Rizos (IAA-CSIC). "If the presence of organics is confirmed, their origin leaves little doubt that these compounds are endogenous materials."

These findings are supported by a related study by Italian collaborators who also participated in this work. Through laboratory experiments, the team demonstrated that organic compounds degrade more rapidly under solar radiation than previously estimated.

Given the detected quantities and observed degradation levels, the study suggests that organic material must exist in large quantities beneath Ceres' surface.

"The idea of an organic reservoir in such a remote and seemingly inert location like Ceres raises the possibility that similar conditions could exist on other solar system bodies. Without a doubt, Ceres will be revisited by new probes in the near future, and our research will be key in defining the observational strategy for these missions," concludes Rizos.

More information: J. L. Rizos et al, New Candidates for Organic-rich Regions on Ceres, *The Planetary Science Journal* (2024). DOI: 10.3847/PSJ/ad86ba

Maria Cristina De Sanctis et al, Recent replenishment of aliphatic organics on Ceres from a large subsurface reservoir, *Science Advances* (2024). DOI: 10.1126/sciadv.adp3664

Provided by Instituto de Astrofísica de Andalucía

'We know so little': Bizarre 'runaway' planets discovered by James Webb telescope may be failed stars in disguise

A colorized image of a nebula© ESA/Webb, NASA, CSA, Mahdi Zamani (ESA/Webb), PDRs4ALL ERS Team

Mysterious pairs of "rogue," Jupiter-size objects may have arisen from embryonic stars, a new study suggests. The theory could explain some characteristics of these Jupiter-mass binary objects (JuMBOs), such as why members of each pair are so widely separated, but more data is needed to confirm the idea.

The James Webb Space Telescope spotted these JuMBOs in the trapezoid zone of the Orion Nebula. Each JuMBO pair comprises two gas giants, each between 0.7 and 30 times the mass of Jupiter. These "rogue" planet partners have been found orbiting each other — but not a parent star — at a distance of about 25 to 400 astronomical units, or 25 to 400 times the average distance between Earth and the sun.

Astronomers have proposed several ideas for how these mysterious duos form. One theory is that they were flung simultaneously from their home systems by a passing star, although some scientists believe this is very unlikely. Another idea is that JuMBOs emerged around a star but their gravities tug them toward each other and out of orbit during close encounters.

However, all of these theories assume that JuMBOs originate from planets that have already formed. In contrast, the new study proposes a radically different idea: that the Orion Nebula's JuMBOs aren't preexisting pairs of planets but rather the hearts of embryonic stars.

A star forms from a massive and dense cloud of gas and dust called a pre-stellar core. As a core grows, it collapses under its own weight, forming a baby star called a protostar; if the core fragments, it could form twin or even triplet stars.But such nurseries aren't serene places. They could be surrounded by massive stars — just as the Orion Nebula is — which produce incredibly high-energy radiation. Twenty years ago, the astronomers Anthony Whitworth and Hans Zinnecker had theoretically shown that these powerful photons could pummel pre-stellar cores, stripping away their outer layers. At almost the same time, a compression wave would push against the core's center, compacting it into a smaller-mass object. The result was that the star itself transformed into a planet or a brown dwarf, which is sometimes called a "failed star" because it's not massive enough to fuse hydrogen to helium.

The new study's authors knew of Whitworth and Zinnecker's study and wondered whether the same mechanism could create JuMBOs, too. They "noticed that the JuMBOs['] separations were similar to those of stellar binary systems with two stars of similar or higher mass to the Sun," Richard Parker, a senior lecturer in astrophysics at the University of Sheffield in the U.K. and senior author of the new study, told Live Science in an email.

That makes them unlike most brown dwarf twins elsewhere in the Milky Way, which are separated by only a few Earth-sun distances, Parker said, so a different mechanism must be involved. "We supposed that the core was already fragmenting to produce a stellar binary, but then the radiation from the massive star removed a lot of the mass," he added.

To test this idea, Parker and Jessica Diamond, a graduate student at the University of Sheffield and lead author of the study, turned to theory. First, they created a bunch of virtual pre-stellar cores, each with a mass within the range spotted in nature. They also assumed the core would split into two, and selected a value for the spacing between the siblings — again, from values observed among star pairs. Then, they applied Whitworth and Zinnecker's calculations to the virtual cores. This essentially pounded them with high-energy radiation from a nearby massive star, eroded the core's cloak and compressed its center.

Diamond and Parker found that the resulting paired objects had masses and separation distances very similar to the JuMBOs'. The findings suggest that, with a strong push of radiation from neighbouring stars, developing binary stars could become pairs of rogue planets, providing an explanation for how the JuMBO pairs formed. The results of their study were published Nov. 5 in The Astrophysical Journal.

More data, such as evidence of JuMBOs in other star-forming complexes with massive stars, would help to confirm the hypothesis, Parker said. In his opinion, one example of such a place is the Scorpius-Centaurus association, a conglomeration of thousands of stars that make up parts of the constellations Scorpius and Centaurus.

In any case, Parker doesn't rule out JuMBO formation through other routes. "I always have a hard time in thinking there is only one way to form objects like these," Parker said. "We know so little about them that it's feasible they may form from a variety of ways."

Massive cosmic water reservoir discovered : 140 trillion times Earth's water supply

Massive cosmic water reservoir discovered : 140 trillion times Earth's water supply© Daily Galaxy

The identification of this massive water reservoir marks a significant milestone in astronomical research. **Surrounding the quasar APM 08279+5255, this aqueous expanse stretches across hundreds of light-years**, showcasing the pervasive nature of water throughout the cosmos. Matt Bradford, a scientist at NASA's Jet Propulsion Laboratory and lead researcher on one of the teams behind this discovery, emphasizes the uniqueness of this environment and its implications for our understanding of the universe's composition.

The sheer scale of this water reservoir is mind-boggling :

- 140 trillion times more water than Earth's oceans
- Spans hundreds of light-years
- Located over 12 billion light-years from Earth

This finding not only highlights the abundance of water in the cosmos but also provides a glimpse into the conditions present in the early universe. The research, partially funded by NASA, has been published in the Astrophysical Journal Letters, solidifying its significance in the scientific community.

Quasars : cosmic powerhouses and their watery secrets

At the heart of this aqueous marvel lies a quasar, one of the most energetic phenomena in the universe. **Quasars are powered by supermassive black holes, voraciously consuming surrounding matter and emitting colossal amounts of energy**. The quasar APM 08279+5255 hosts a black hole 20 billion times more massive than our sun, generating energy equivalent to a thousand trillion suns.

The presence of such a vast amount of water vapor around this quasar offers crucial insights into the conditions of the early universe. While water vapor has been detected in our Milky Way, the quantity found in this distant quasar is 4,000 times greater. This stark contrast underscores the unique nature of this cosmic environment and its potential implications for our understanding of galaxy formation and evolution.

The role of water vapor as a trace gas in this distant quasar cannot be overstated. It provides valuable information about the physical conditions in the quasar's vicinity :

Unveiling cosmic secrets : observational techniques and future implications

The discovery of this massive water reservoir was made possible through the use of advanced observational techniques and instruments. Bradford's team utilized the "Z-Spec" instrument at the California Institute of Technology's Submillimeter Observatory, a 33-foot telescope perched atop Mauna Kea in Hawaii. Further observations were conducted using the Combined Array for Research in Millimeter-Wave Astronomy (CARMA) in California's Inyo Mountains.

This groundbreaking research not only pushes the boundaries of our understanding of water's prevalence in the universe but also opens up new avenues for exploring the interactions between dark matter and regular matter. The presence of such vast quantities of water in the early universe raises intriguing questions about the role of water in cosmic evolution and the potential for life beyond our planet.

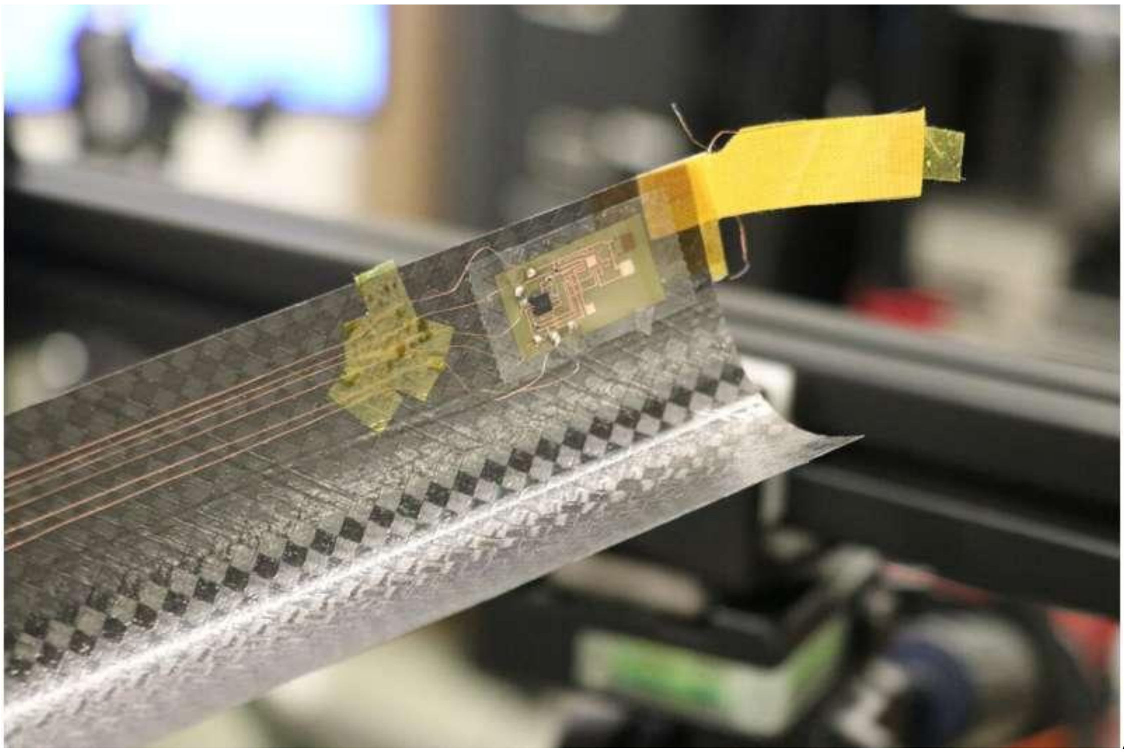
The implications of this discovery extend far beyond the realm of astronomy. By studying the composition and distribution of water in the distant universe, scientists gain valuable insights into the processes that shaped our own solar system and potentially other planetary systems. This research complements ongoing efforts to detect and study brown dwarfs and other celestial objects beyond the Milky Way, further expanding our cosmic perspective.

As we continue to explore the vast expanses of the universe, discoveries like this massive water reservoir remind us of the wonders that await our exploration. *The presence of water, a fundamental building block of life as we know it, in such abundance in the early universe, opens up exciting possibilities for future research and exploration*. It challenges our understanding of cosmic evolution and invites us to contemplate the potential for life in the most distant reaches of space.

JANUARY 9, 2025

Flexible electronics integrated with paper-thin structure for use in space

by University of Illinois at Urbana-Champaign


A close-up of the extended boom showing a lightweight, flexible electronics patch with a motion sensor, and a temperature sensor mounted on the boom tip. Credit: University of Illinois at Urbana-Champaign

Being lightweight is essential for space structures, particularly for tools used on already small, lightweight satellites. The ability to perform multiple functions is a bonus. To address these characteristics in a new way, researchers at the University of Illinois Urbana-Champaign successfully integrated flexible electronics with a three-ply, self-deployable boom that weighs only about 20 grams.

The study, "Multifunctional bistable ultrathin composite booms with flexible electronics," by Yao Yao and Xin Ning from Illinois, Juan Fernandez from NASA Langley Research Center and Sven Bilén at Penn State, is published in *Extreme Mechanics Letters*.

"It's difficult to get commercial electronics integrated into these super thin structures," said Xin Ning, an aerospace professor in The Grainger College of Engineering at U. of I. "There were a lot of engineering constraints adding to the challenge of making the electronics able to withstand the harsh environment of space."

Ning said the concept for the work began at a conference about two years ago. He presented his unique expertise in making multifunctional space structures that integrate lightweight, flexible electronics.

"It got the attention of Juan Fernandez from NASA Langley Research Center. He was making a boom structure for a Virginia Tech CubeSat project and saw the opportunity to collaborate and add multi-functional devices to the structures instead of just a pure structure," Ning said.

Ultimately, the boom to contain the electronics was made at NASA Langley Research Center, Ning said. It is a three-ply carbon fiber and epoxy composite material designed to be extremely thin—about as thick as a sheet of paper. It is rolled up like a tape measure with stored energy in its coils until it unfurls on its own in space.

"Virginia Tech had specific requirements for us to follow, some that created challenges," Ning said. "One was the length. They wanted to have power and data lines over a meter in length embedded in a paper-thin composite material. We tried different materials and different technologies.

"Eventually, we went with thin commercial wires coated with insulation and it worked. I think we were overthinking it at the beginning. We tried more difficult, fancier approaches, but they failed. This was a simple and reliable solution using off-the-shelf, readily available wires."

Another key component is a lightweight, flexible electronics patch with a motion sensor, a temperature sensor, and a blue LED, all mounted on the boom tip. Ning explained that the electronics needed to endure the harsh thermal-vacuum conditions of space while remaining flexible enough to withstand the sudden unfurling of the coiled boom. The motion sensor monitors the deployment and vibration of the boom, and the blue LED assists CubeSat cameras in seeing the structure in space once deployed.

Ning's team conducted comprehensive on-ground experiments and simulations to explore the mechanics of the bistable boom with flexible electronics, as well as its deployment and vibration behavior. Ning said that these fundamental studies could offer valuable insights for future designs of multifunctional space structures.

The Virginia Tech three-unit CubeSat with the multifunctional boom is aiming for launch in 2025.

"We are also working on making the flexible electronics more durable in space—ways to protect the electronics so they will be operational longer in the space environment."

More information: Yao Yao et al, Multifunctional bistable ultrathin composite booms with flexible electronics, *Extreme Mechanics Letters* (2024). DOI: 10.1016/j.eml.2024.102247
Provided by University of Illinois at Urbana-Champaign

First man-made biological leaf to make oxygen for space travel

PTI

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An inventor in the UK has developed the world's first synthetic biological leaf that absorbs water and carbon dioxide to produce oxygen just like a plant, and it could enable long-distance space travel. Photo courtesy: Dezeen

An inventor in the UK has developed the world's first synthetic biological leaf that absorbs water and carbon dioxide to produce oxygen just like a plant, and it could enable long-distance space travel.

The leaf, created by Royal College of Art student Julian Melchiorri, consists of chloroplasts suspended in a matrix made out of silk protein. "The material is extracted directly from the fibres of silk," Melchiorri said.

"This material has an amazing property of stabilising molecules. I extracted chloroplasts from plant cells and placed them inside this silk protein. As an outcome I have the first photosynthetic material that is living and breathing as a leaf does," he said.

Like the leaves of a plant, Melchiorri's Silk Leaf needs light and a small amount of water to produce oxygen, 'Dezeen' reported.

"Silk Leaf is the first man-made biological leaf. It's very light, low energy-consuming, it's completely biological," Melchiorri said.

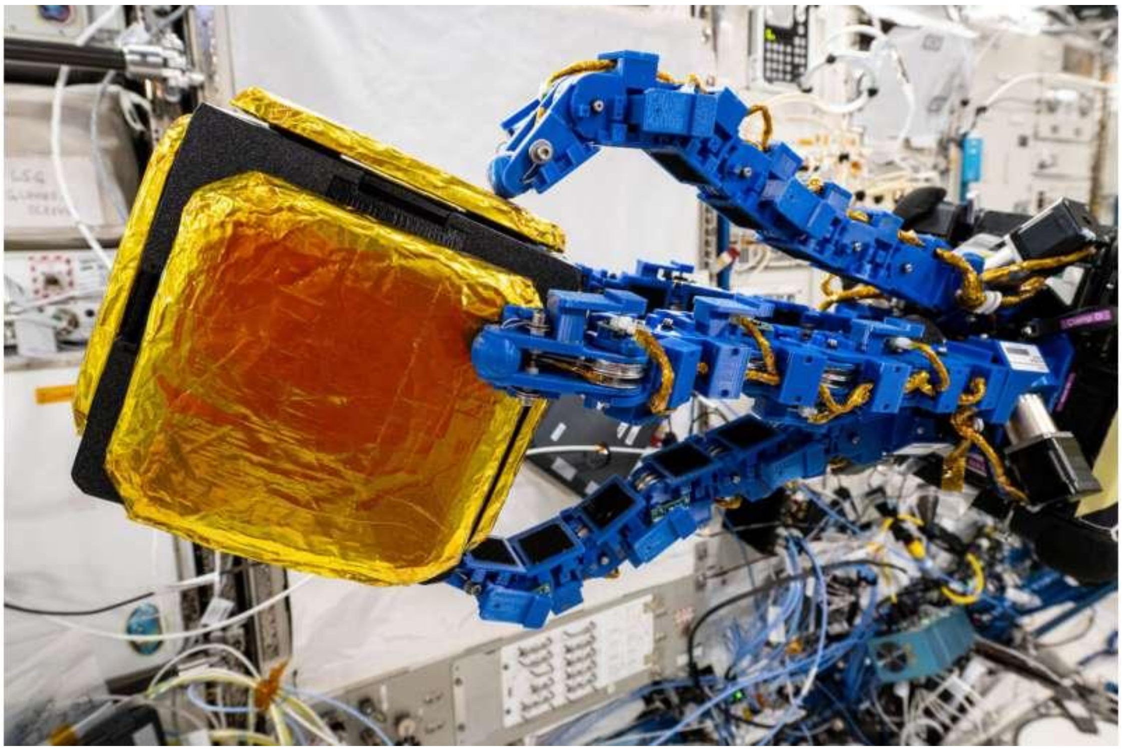
"Plants don't grow in zero gravity. NASA is researching different ways to produce oxygen for long-distance space journeys to let us live in space. This material could allow us to explore space much further than we can now," said Melchiorri.

The Silk Leaf project was developed as part of the Royal College of Art's Innovation Design Engineering course in collaboration with Tufts University silk lab. Melchiorri said the leaf could also be used for outdoor applications.

"So facades, ventilation systems. You can absorb air from outside, pass it through these biological filters and then bring oxygenated air inside," he said.

FEBRUARY 7, 2025

Robot grippers could be used to remove space debris



Credit: NASA/Suni Williams
Blue tentacle-like arms attached to an Astrobee free-flying robot grab onto a "capture cube" in this image from Feb. 4, 2025. The experimental grippers demonstrated autonomous detection and capture techniques that may be used to remove space debris and service satellites in low Earth orbit.

The Astrobee system was designed and built at NASA's Ames Research Center in Silicon Valley for use inside the International Space Station. The system consists of three cube-shaped robots (named Bumble, Honey, and Queen), software, and a docking station used for recharging.

The robots use electric fans as a propulsion system that allows them to fly freely through the microgravity environment of the station. Cameras and sensors help them to "see" and navigate their surroundings. The robots also carry a perching arm that allows them to grasp station handrails to conserve energy or to grab and hold items.

Provided by NASA

Milky Way May Be Larger Than Thought, Study Reveals

Our home galaxy might be larger than we first assumed, astronomers have found.

A new model of the Milky Way has revealed that our galaxy is wider than we thought, according to a new paper in the journal *Nature Astronomy*.

The researchers found that the bulge at the center of our galaxy is less densely packed with stars than they expected.

"...we obtained a significantly larger 'size' (defined as the half-light radius) for the Milky Way than that expected," the researchers wrote in the paper.

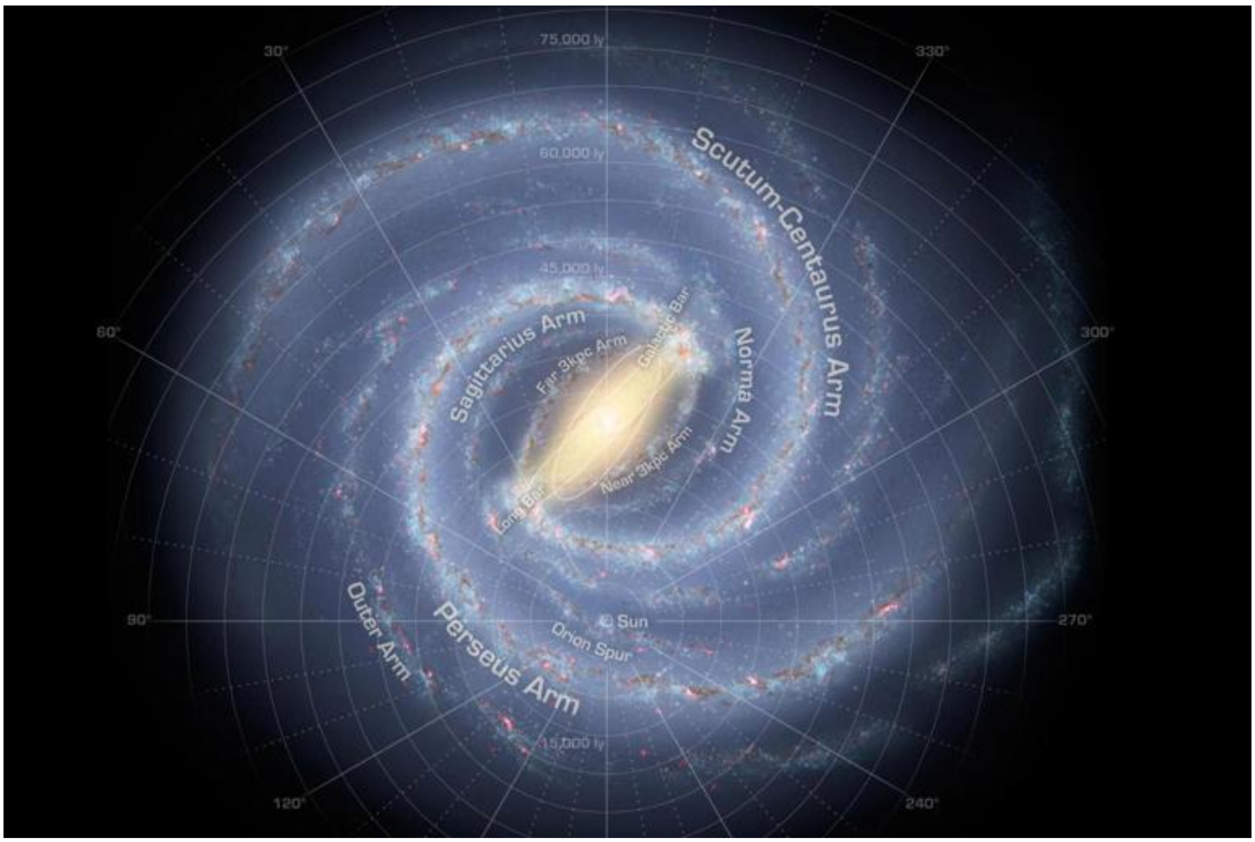
The Milky Way is a barred spiral galaxy with a central bar-shaped structure and several spiral arms extending from the center. The galaxy has a dense central bulge around the Galactic Center, which is thought to contain a supermassive black hole named Sagittarius A*. The Milky Way contains between 100 billion and 400 billion stars, but the exact number is difficult to determine due to the galaxy's vast size and the presence of dust that obscures our view.

"Our understanding of the Milky Way's structure has improved tremendously through the advancement of galactic observations over recent decades. Thanks to the proximity to our home galaxy, we are able to study the Milky Way's substructures (for example, disk scale heights, spiral arms and bar/X-shape) in great detail. For the same reason, however, a global picture of the galactic structure is still incomplete," the researchers wrote in the paper.

"The sun's position embedded in the disk results in high line-of-sight extinction towards the densest region in the galaxy, and thus, collecting data from large samples of stars over a wide spatial range is costly in terms of observing time. For instance, a surface brightness radial profile across a galaxy, a basic observable of galaxies that contains rich information about their assembly histories and is easily obtainable from their images, has long been missing for the Milky Way galaxy."

In the paper, the researchers describe how they measured the brightness of all parts of our galaxy, and conducted a census of the red giants dotted across the Milky Way. They found that the bulge in the center of the galaxy is not as densely packed as first thought and is also flatter; the Milky Way thus has a greater half-light radius than we knew.

The half-light radius is a measure used in astronomy to describe the size of an astronomical object, defined as the radius within which half of the total light (or luminosity) of the object is emitted. In other words, it is the distance from the center of the object to the point where half of the total light from the object is contained within a sphere of that radius.



NASA illustration of the Milky Way from above. The bulge at the center may be less dense than we first thought.
NASA© NASA

"Because the inner disk profile flattens, the half-light radius of the Milky Way is significantly larger than that expected from a picture of the Milky Way's structure with a bulge and single-exponential thick and thin disk components," they wrote.

"We also confirm that the size growth history of the Milky Way is broadly consistent with high-redshift galaxies but with systematically smaller sizes. Our results suggest that the Milky Way has a more complex radial structure and larger size than previously expected."

Largest structure in known universe discovered, 13,000 times longer than Milky Way

Largest structure in known universe discovered, 13,000 times longer than Milky Way

Astronomers have identified what could be the largest structure ever observed in the known universe—a vast network of galaxy clusters and superclusters containing an astonishing 200 quadrillion solar masses. Named Quipu, the structure takes inspiration from the ancient Incan system of recording numbers using knotted cords.

Much like a Quipu cord, the structure is intricate, consisting of a central filament with multiple branching strands. Spanning approximately 1.3 billion light-years—over 13,000 times the length of the Milky Way—it may be the longest known structure in the universe, surpassing previous record-holders like the Laniākea supercluster.

A vast filament structure rivaling known superclusters

According to the scientific team which made the discovery, Quipu stands out as a highly prominent structure that is easily visible in a sky map of galaxy clusters within the target redshift range, even without specialized detection methods.

The research is part of an ongoing effort to map the universe's matter distribution across different wavelengths of light. Distant cosmic structures appear shifted toward the red part of the spectrum, a phenomenon called redshift. While objects with a redshift up to 0.3 are well-mapped, this study focuses on those between 0.3 and 0.6—meaning even farther away.

The largest superstructure discovered in the researchers' datasets was Quipu, but they also found four other massive structures. The Shapley supercluster, once considered the largest, has now been overtaken by Quipu and three others: the Serpens-Corona Borealis superstructure, the Hercules supercluster, and the Sculptor-Pegasus superstructure, which stretches between the two constellations.

The structures in the new study were found between 425 million and 815 million light-years from Earth. Previous research suggests that even larger structures may exist farther out in the universe. Currently, the Hercules Corona-Borealis Great Wall, a massive concentration of matter about 10 billion light-years away, holds the title for the largest known structure, though its existence is still debated.

Superstructures affect the universe's expansion and bend light

Researchers also observed how these superstructures influence the broader universe. They affect the cosmic microwave background (CMB), the radiation leftover from the Big Bang, which is spread evenly across space.

The team found that the velocity of galaxy streams in these superstructures can distort measurements of the universe's expansion, known as the Hubble constant. Additionally, the immense gravitational pull of these structures can cause gravitational lensing, bending light and distorting distant sky images.

The study noted that future research could explore how these large-scale structures have influenced galaxy evolution. While these structures are temporary, as the universe's expansion gradually pulls clusters apart, their immense size makes them significant.

"In the future cosmic evolution, these superstructures are bound to break up into several collapsing units. They are thus transient configurations. But at present they are special physical entities with characteristic properties and special cosmic environments deserving special attention," the researchers observed.

Thus, the five superstructures also account for 45% of the galaxy clusters, 30% of the galaxies, and 25% of the matter in the observable universe, making up 13% of the universe's total volume.

Enormous Galaxy Clusters Found to be 1.3 Billion Light-Years Wide, Deemed to be The Largest Known Structure

Enormous Galaxy Clusters Found to be 1.3 Billion Light-Years Wide, Deemed to be The Largest Known Structure© Knewz

Enormous Galaxy Clusters Found to be 1.3 Billion Light-Years Wide, Deemed to be The Largest Known Structure

In a monumental discovery, astronomers identified the largest known structure in the universe, dubbed 'Quipu' after the ancient Incan recording and counting system. The revelations of space were of great interest to researchers as it was a vast unknown with much to reveal. Galaxies and Universes held several phenomena with frequent discoveries, and recently, experts mapped a nearby universe that was about 425 million to 800 million light-years away. They examined the largest object there, as accepted by the journal *Astronomy and Astrophysics*. A massive 'cluster of galaxies containing galaxies with clusters' was found, a wormhole of branching galaxies that spread massively.

Like a Quipu cord, the structure was complex and was made up of one long filament and multiple side filaments. It spanned around 1.3 billion light-years, which was more than 13,000 times the length of the Milky Way. This made it possibly the largest known object in the universe in terms of length, as per LiveScience. The cluster also contained enormous 200 quadrillion solar masses. "Quipu is a prominent structure readily noticeable by eye in a sky map of clusters in the target redshift range, without the help of a detection method," the team wrote in the paper. The research was part of a long-running effort to map the matter distribution of the universe at different wavelengths of light.

Knewz.com noted that studying Quipu and its brethren would help to understand how galaxies evolved. It could also improve the cosmological models and accuracy of astronomers' cosmological measurements. "For a precise determination of cosmological parameters, we need to understand the effects of the local large-scale structure of the Universe on the measurements," the authors write. "They include modifications of the cosmic microwave background, distortions of sky images by large-scale gravitational lensing, and the influence of large-scale streaming motions on measurements of the Hubble constant," as per ScienceAlert. Quipu and the other four superstructures found contained 45 percent of the galaxy clusters.

The Sloan Great Wall was another superstructure identified in 2003 and was the largest observed structure in the universe at the time, as per Smithsonian Magazine. "The Quipu superstructure, end to end, is slightly longer than the Sloan Great Wall," J. Richard Gott III, an astrophysicist at Princeton University, commented. Based on the data from the German ROSAT X-ray satellite, the team used a "friends-of-friends" algorithm, which established a maximum distance between clusters to be considered as part of the same structure. Hans Böhringer of the Max Planck Institute led the study into this discovery. Quipu and the other superstructures might eventually pull apart as the cosmos evolve.

The expansion of the universe distorted the light that traveled from distant objects, increasing their wavelengths and shifting them closer to the red part of the visible light spectrum. This phenomenon called redshift indicated that the farther away an object was, the higher the redshift. The research team focused on matters within a less-known redshift region, officially between redshift 0.03 and 0.06. Their survey called the CLASSIX cluster survey, covered about 86% of the sky, and the missing region was called the Zone of Avoidance, known as the Milky Way, as per EarthSky. There were 185 galaxy clusters within the five superstructures, and Quipu alone contained 68 galaxy cluster

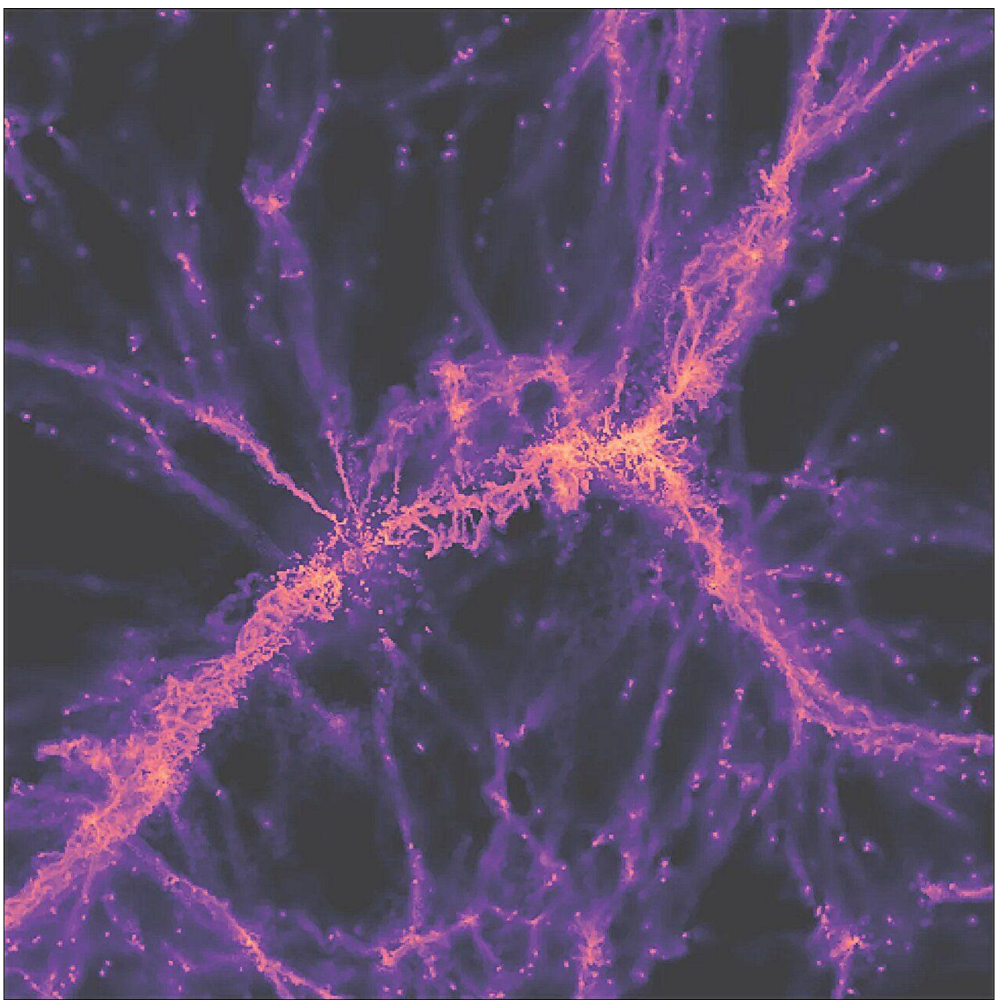
This unprecedented image reveals a filament of the cosmic web

Published by Adrien, February 12, 2025 at 01:00 AM

Source: Nature Astronomy

An international team has captured an unprecedented image of a cosmic filament connecting two galaxies. This discovery sheds light on the structure of the cosmic web and its role in galaxy formation.

After hundreds of hours of observations, researchers obtained a high-definition image of a cosmic filament. This filament, dating back to when the Universe was about 2 billion years old, connects two actively forming galaxies. This observation was made possible by the MUSE instrument installed on the Very Large Telescope in Chile.



The diffuse gas (yellow to purple) contained in the cosmic filament connecting two galaxies, spanning a vast distance of 3 million light-years.
Credit: Davide Tornotti/University of Milan-Bicocca

The cosmic web, composed of dark matter filaments, serves as the framework of the Universe. Galaxies form at the intersections of these filaments, where intergalactic gas fuels star formation. This study, published in *Nature Astronomy*, marks a major breakthrough in understanding galaxy formation.

The team used computer simulations to compare their observations with theoretical predictions. The results show remarkable agreement between current cosmological models and observed data. This validation strengthens our understanding of gas distribution in the Universe.

Davide Tornotti, a PhD student at the University of Milano-Bicocca, explains that this observation allows for precise characterization of the filament's shape. For the first time, researchers were able to directly measure the boundary between the gas in galaxies and that of the cosmic web.

This discovery opens new perspectives for studying the gaseous environment around galaxies. Fabrizio Arrigoni Battaia, a scientist at the Max Planck Institute for Astrophysics, emphasizes the importance of continuing these observations to obtain a comprehensive view of gas distribution in the cosmic web.

Researchers plan to collect more data to discover other similar structures. This work could revolutionize our understanding of galaxy formation and evolution by revealing how gas flows through the Universe.

What is the cosmic web?

The cosmic web is a large-scale structure of the Universe, composed of dark matter filaments and gas. These filaments connect galaxies, forming a complex network. The intersections of these filaments host galaxy clusters, where matter density is highest.

Dark matter, invisible but detectable through its gravitational effects, constitutes about 85% of the total matter in the Universe. It plays a crucial role in the formation of the cosmic web by attracting intergalactic gas that fuels star formation.

Recent observations, like those in this study, allow for a better understanding of gas distribution in these filaments. These data are essential for validating cosmological models and understanding how galaxies form and evolve.

By studying the cosmic web, scientists hope to unravel the mysteries of the early Universe and better understand the processes that led to the formation of the structures we observe today.

How are cosmic filaments observed?

Observing cosmic filaments is a major technical challenge. Intergalactic gas is very diffuse and emits extremely faint light. Traditional instruments cannot directly detect this light, making filament observation difficult.

To overcome this problem, astronomers use indirect techniques, such as the absorption of quasar light by intergalactic gas. However, these methods do not provide direct images of the filaments.

The MUSE instrument, installed on the Very Large Telescope, has enabled the capture of a high-definition image of a cosmic filament. Thanks to its advanced spectroscopic capabilities, MUSE was able to detect the faint light emitted by intergalactic gas.

This observation required hundreds of hours of observation time, making it one of the most ambitious campaigns ever conducted with this instrument. The results open new perspectives for the direct study of cosmic filaments.

Twisted magnetic fields in space sculpt the jets of black holes and baby stars

At first glimpse, it may seem like infant stars and supermassive black holes have very little in common.

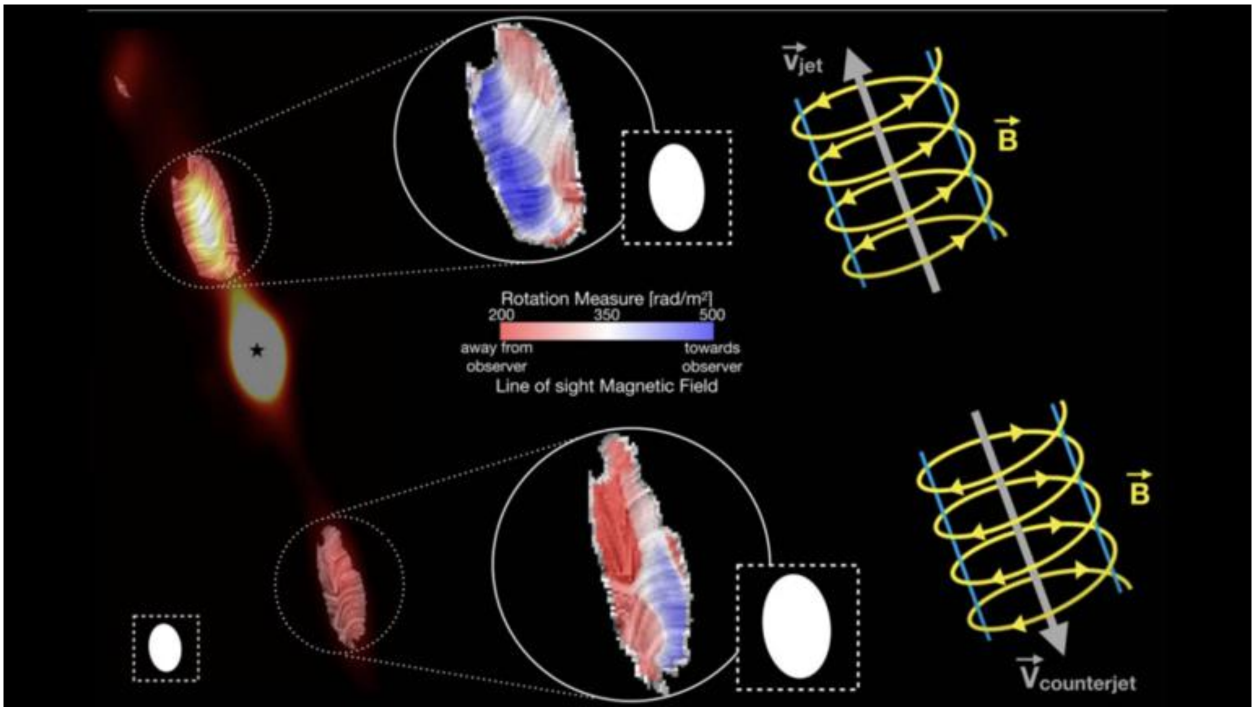
Infant stars, or "protostars," haven't yet gathered enough mass to trigger the nuclear fusion of hydrogen to helium in their cores, the process which defines what a main sequence star is. Supermassive black holes, on the other hand, have masses equivalent to millions, or even billions, of suns crammed into a space no more than a few billion miles wide. For context, the solar system is estimated to be 18.6 *trillion* miles wide.

Yet, protostars and supermassive black holes *do* have at least one thing in common: They both launch high-speed astrophysical jets from their poles while gathering mass to increase in size. And new research suggests the mechanism creating these jets may be the same for these objects at opposite ends of the astrophysical spectrum.

The team behind this research reached that conclusion when they detected a helix-shaped magnetic field within a protostellar jet designated HH 80-81.

HH 80-81 is the fastest protostellar jet ever seen, erupting from a star that sits at the heart of a natal cloud of gas and dust called IRAS 18162-204. This cloud is located around 5,540 light-years away. Moreover, the helical magnetic fields in the observed jets are similar to such structures seen in jets erupting from supermassive black holes.

"This is the first solid evidence that helical magnetic fields can explain astrophysical jets at different scales, supporting the universality of the collimation mechanism," Adriana Rodríguez-Kamenetzky, team leader and a researcher at the Institute of Theoretical Experimental Astronomy (IATE), said in a statement.



Analysis of the HH80-81 jet. On the left is a streamlined image of the component of the magnetic field parallel to the plane of the sky. In the middle, a color scale shows the direction of the magnetic field along the line of sight (red, away from the observer, and blue, towards the observer). On the right, the 3D configuration of the magnetic field showing a helix shape. (Image credit: Rodríguez-Kamenetzky et al. 2025, The Astrophysical Journal.)

This isn't the first time scientists have connected the mechanisms launching jets from supermassive black holes and those emerging from protostars — however, there has never before been definitive evidence of helical magnetic fields in protostellar jets.

This evidence has been difficult to obtain because the light emitted by these jets is mostly thermal. That makes it difficult to detect magnetic field structures.

"Back in 2010, we used the Very Large Array (VLA) to detect non-thermal emission and the presence of a magnetic field, but we couldn’t study its 3D structure," Carlos Carrasco-González, team member and a researcher at the Institute of Radio Astronomy and Astrophysics (IRyA), said in the statement.

Upgrades to the VLA, a radio telescope that's about a 2-hour drive from Albuquerque, have now allowed these limitations to be overcome. As a result, the team was able to conduct a highly detailed Rotation Measure (RM) analysis of the HH 80-81 jet. The RM analysis enabled the scientists to correct for the rotation of light polarization as it passes through magnetized plasma. With this so-called "Faraday rotation" accounted for, the researcherscould discover the true orientation of the HH 80-81's magnetic field.

“For the first time, we were able to study the 3D configuration of the magnetic field in a protostellar jet," Alice Pasetto, team member and a scientist at IRyA, said in the statement.

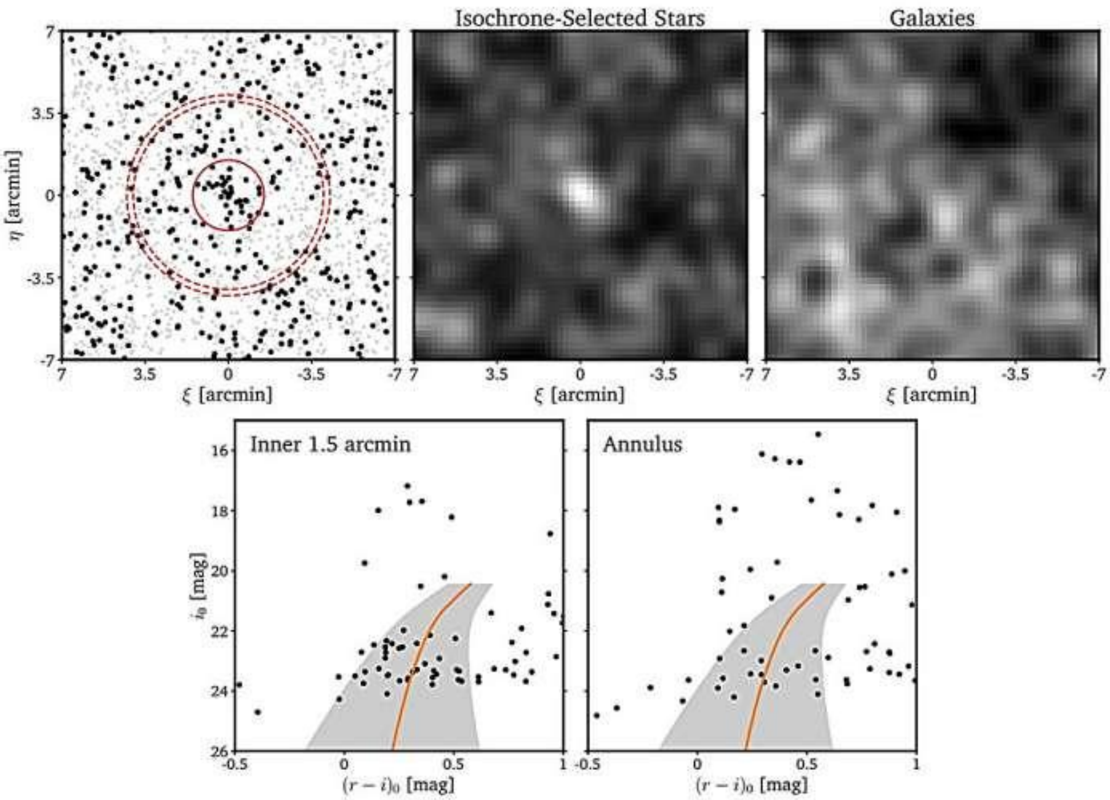
The first application of RM analysis to a protostellar jet revealed a definite helical magnetic field within HH 80-81. This suggests these twisted magnetic fields are indeed a universal mechanism for the launch of astrophysical jets.

The team's research was published on Jan. 7 in the Astrophysical Journal Letters.

FEBRUARY 25, 2025

New dwarf galaxy discovered in the halo of Andromeda galaxy

by Tomasz Nowakowski , Phys.org



A series of plots showing the tentative detection of a candidate stellar overdensity (Pegasus VII) in the UNIONS photometric catalogs. Credit: *arXiv* (2025). DOI: 10.48550/arxiv.2502.09792

An international team of astronomers reports the discovery of a new dwarf galaxy, which they have named Pegasus VII. The newfound galaxy, which lies about 2.4 million light years away, was identified in the Ultraviolet Near-Infrared Optical Northern Survey (UNIONS). The discovery was detailed in a research paper published Feb. 13 on the *arXiv* preprint server.

Dwarf galaxies are low-luminosity and low-mass stellar systems, usually containing a few billion stars. Their formation and activity are thought to be heavily influenced by interactions with larger galaxies.

One of the great places to look for dwarf galaxies is the halo of the Andromeda galaxy (also known as Messier 31, or M31 for short), due to its relative proximity. UNIONS is so far the deepest available survey for exploring the far reaches of this galaxy's halo and now a team of astronomers led by Simon E. T. Smith of the University of Victoria in Canada, has found another such dwarf.

"We present the newly discovered dwarf galaxy Pegasus VII (Peg VII), a member of the M31 sub-group which has been uncovered in the ri photometric catalogs from the Ultraviolet Near-Infrared Optical Northern Survey and confirmed with follow-up imaging from both the Canada-France-Hawaii Telescope and the Gemini-North Telescope," the researchers wrote in the paper.

Pegasus VII was identified at a separation of about 1.08 million light years from the Andromeda galaxy. Therefore, Pegasus VII is just about to cross the virial radius of Andromeda and has likely been isolated up until this point.

According to the study, Pegasus VII has an absolute V-band magnitude of −5.7 mag, a central surface of 27.3 mag/arcsec^2, and a physical half-light radius of approximately 577 light years. This means that Pegasus VII is the faintest known dwarf galaxy satellite of Andromeda and roughly five times larger than the most extended globular clusters in this galaxy.

The study found that Pegasus VII has an ellipticity at a level of 0.5 and this projected elongation is aligned within 18 degrees of the projected direction towards Andromeda. The astronomers suppose that the source of this elongation is a previous tidal interaction with the gravitational potential of the Andromeda galaxy.

Furthermore, the researchers calculated that Pegasus VII has a total stellar mass of 26,000 solar masses and its metallicity is at a level of -2.0 dex. The age of the dwarf galaxy was estimated to be around 10 billion years.

Summing up the results, the authors of the paper concluded that they hope to find many more dwarf galaxies in the halo of Andromeda.

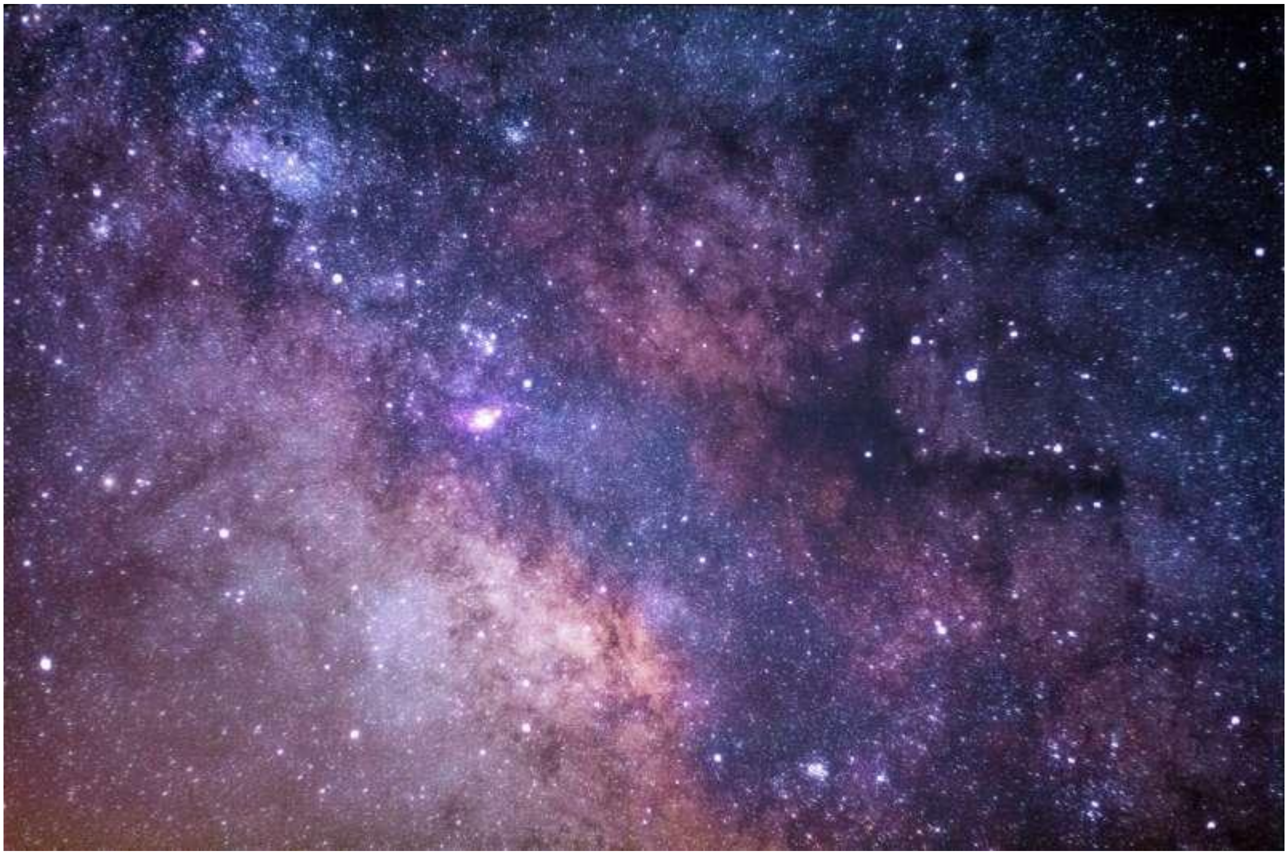
"The discovery of Pegasus VII complements both the empirical and theoretical claim that a wealth of dwarf galaxy satellites remain undetected towards M31," the scientists wrote.

More information: Simon E. T. Smith et al, Deep in the Fields of the Andromeda Halo: Discovery of the Pegasus VII dwarf galaxy in UNIONS, *arXiv* (2025). DOI: 10.48550/arxiv.2502.09792
Journal information: arXiv

FEBRUARY 26, 2025

What's the shape of the universe? Mathematicians use topology to study its shape and everything in it

by John Etnyre, The Conversation



Credit: Pixabay/CC0 Public Domain

When you look at your surrounding environment, it might seem like you're living on a flat plane. After all, this is why you can navigate a new city using a map: a flat piece of paper that represents all the places around you. This is likely why some people in the past believed the Earth to be flat. But most people now know that is far from the truth.

You live on the surface of a giant sphere, like a beach ball the size of the Earth with a few bumps added. The surface of the sphere and the plane are two possible 2D spaces, meaning you can walk in two directions: north and south or east and west.

What other possible spaces might you be living on? That is, what other spaces around you are 2D? For example, the surface of a giant doughnut is another 2D space.

Through a field called geometric topology, mathematicians like me study all possible spaces in all dimensions. Whether trying to design secure sensor networks, mine data or use origami to deploy satellites, the underlying language and ideas are likely to be that of topology.

The shape of the universe

When you look around the universe you live in, it looks like a 3D space, just like the surface of the Earth looks like a 2D space. However, just like the Earth, if you were to look at the universe as a whole, it could be a more complicated space, like a giant 3D version of the 2D beach ball surface or something even more exotic than that.

While you don't need topology to determine that you are living on something like a giant beach ball, knowing all the possible 2D spaces can be useful. Over a century ago, mathematicians figured out all the possible 2D spaces and many of their properties.

In the past several decades, mathematicians have learned a lot about all of the possible 3D spaces. While we do not have a complete understanding like we do for 2D spaces, we do know a lot. With this knowledge, physicists and astronomers can try to determine what 3D space people actually live in.

While the answer is not completely known, there are many intriguing and surprising possibilities. The options become even more complicated if you consider time as a dimension.

To see how this might work, note that to describe the location of something in space—say a comet—you need four numbers: three to describe its position and one to describe the time it is in that position. These four numbers are what make up a 4D space.

Now, you can consider what 4D spaces are possible and in which of those spaces you do live.

Topology in higher dimensions

At this point, it may seem like there is no reason to consider spaces that have dimensions larger than four, since that is the highest imaginable dimension that might describe our universe. But a branch of physics called string theory suggests that the universe has many more dimensions than four.

There are also practical applications of thinking about higher-dimensional spaces, such as robot motion planning. Suppose you are trying to understand the motion of three robots moving around a factory floor in a warehouse. You can put a grid on the floor and describe the position of each robot by their x and y coordinates on the grid. Since each of the three robots requires two coordinates, you will need six numbers to describe all of the possible positions of the robots. You can interpret the possible positions of the robots as a 6D space.

As the number of robots increases, the dimension of the space increases. Factoring in other useful information, such as the locations of obstacles, makes the space even more complicated. In order to study this problem, you need to study high-dimensional spaces.

There are countless other scientific problems where high-dimensional spaces appear, from modeling the motion of planets and spacecraft to trying to understand the "shape" of large datasets.

Tied up in knots

Another type of problem topologists study is how one space can sit inside another.

For example, if you hold a knotted loop of string, then we have a 1D space (the loop of string) inside a 3D space (your room). Such loops are called mathematical knots.

The study of knots first grew out of physics but has become a central area of topology. They are essential to how scientists understand 3D and 4D spaces and have a delightful and subtle structure that researchers are still trying to understand.

In addition, knots have many applications, ranging from string theory in physics to DNA recombination in biology to chirality in chemistry.

What shape do you live on?

Geometric topology is a beautiful and complex subject, and there are still countless exciting questions to answer about spaces.

For example, the smooth 4D Poincaré conjecture asks what the "simplest" closed 4D space is, and the slice-ribbon conjecture aims to understand how knots in 3D spaces relate to surfaces in 4D spaces.

Topology is currently useful in science and engineering. Unraveling more mysteries of spaces in all dimensions will be invaluable to understanding the world in which we live and solving real-world problems.

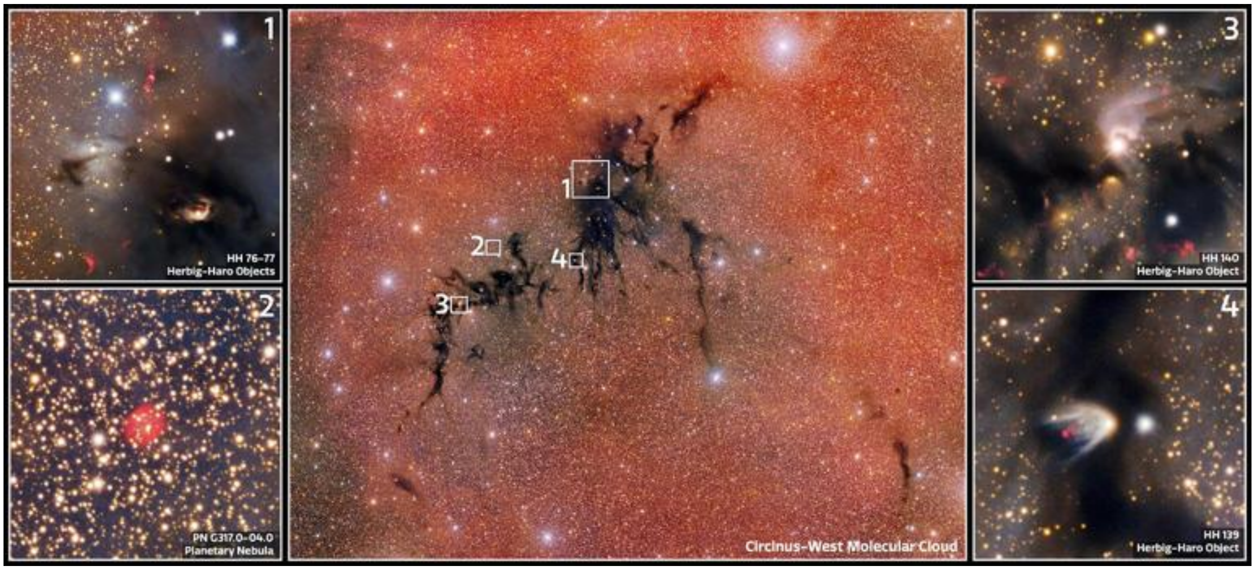
Provided by The Conversation

Astronomers gaze into 'dark nebula' 60 times the size of the solar system

Astronomers have discovered a dense stellar nursery packed with infant stars in a vast "cosmic ink blot."

The team made the discovery using one of the most powerful digital cameras in the world: the Dark Energy Camera (DECam) mounted on the Víctor M. Blanco 4-meter telescope at Cerro Tololo Inter-American Observatory in Chile.

The dark shadow overlaid on a starry background is known as the Circinus West molecular cloud. Circinus West is a cold, dense cloud of gas and dust that stretches out for 180 light-years, around 60 times the size of our solar system. Nebulas like this are so dense that light cannot pass through them, resulting in their dark, ink-like appearance and the fitting nickname "dark nebulas."



The features of the Circinus West molecular cloud, a celestial shadow investigated by the DECam. (Image credit: CTIO/NOIRLab/DOE/NSF/AURAImage Processing: T.A. Rector (University of Alaska Anchorage/NSF NOIRLab), D. de Martin & M. Kosari (NSF NOIRLab))

With a mass around 250,000 times that of the sun, the Circinus West molecular cloud, located 2500 light-years from Earth in the constellation Circinus, is jam-packed with the raw material for star formation.

Despite being a "dark nebula," the Circinus West molecular cloud isn't so dark that it can completely hide its young stellar population, however. The team zoomed in on this region with the powerful DECam instrument to see these stellar infants and their associated phenomena in greater detail.

A close-up of two Herbig-Haro (HH) objects found in the Circinus West molecular cloud: HH 76 (above center of image) and HH 77 (lower left) as seen by the DECam. (Image credit: CTIO/NOIRLab/DOE/NSF/AURAImage Processing: T.A. Rector (University of Alaska Anchorage/NSF NOIRLab), D. de Martin & M. Kosari (NSF NOIRLab))

One dead giveaway of newborn stars is occasional pockets of light punctuating the inky tendrils of the molecular cloud.

These are created during star formation when so-called "protostars"—stars that haven't yet gathered enough material to trigger the fusion of hydrogen to helium in their cores— launch jets of material into space, carving cavities in the dense molecular gas and dust.

Astronomers find these high-energy outflows are easier to see than the protostars that launch them. That is because protostars are still wrapped in natal blankets of gas and dust from which they continue to gather mass on their journey to becoming main-sequence stars like the sun.

This makes these outflows and cavities a great indicator of the location of protostars.

A collection of Herbig-Haro (HH) objects found in the Circinus West molecular cloud. (Image credit: CTIO/NOIRLab/DOE/NSF/AURAImage Processing: T.A. Rector (University of Alaska Anchorage/NSF NOIRLab), D. de Martin & M. Kosari (NSF NOIRLab))

Multiple outflows can be seen in the central black tendril of the Circinus West molecular cloud, named the Cir-MMS region.

At the heart of the Cir-MMS region is a large cavity that is being cleared by radiation blasting out for an infant star. Another stellar newborn is clearing a similar cavity at the bottom left of the Cir-MMS region.

The abundance of "Herbig-Haro" (HH) objects in Circinus West is another indication of active star formation.

HH objects are glowing red patches of nebulous gas and dust commonly found near newborn stars. They are created when fast-moving gas ejected by stars slams into slower-moving surrounding gas. Circinus West is packed with such objects, punctuating the dark lanes of gas and dust.

A planetary nebula found in the Circinus West molecular cloud as seen by the DECam (Image credit: CTIO/NOIRLab/DOE/NSF/AURAImage Processing: T.A. Rector (University of Alaska Anchorage/NSF NOIRLab), D. de Martin & M. Kosari (NSF NOIRLab))

It isn't just newborn stars that populate Circinus West. This molecular cloud is also home to many stars at the other end of the stellar cycle of life and death.

Planetary nebulas, seen by the DECam in Circinus West as red blotches, are the remains of red giant stars, stellar bodies that have reached the end of their hydrogen supplies and their main sequence lifetimes.

At this point, they shed their outer layers, with this material dispersing and cooling, creating a planetary nebula (which somewhat confusingly actually have nothing to do with planets).

The team behind this research hopes that by studying the infant and aging stars of Circinus West and their outflows can reveal more about how they shape their immediate environments

Ultimately, this could reveal the processes that govern the evolution of galaxies like the Milky Way.

The Great Attractor: Our Galaxy Is Being Pulled Toward Something We Cannot See

Astronomers noticed 400 galaxies, including our own, were being pulled in the same direction.

The great attractor is beyond this region of sky.

1929 brought the discovery that how redshifted a galaxy is is proportional to its distance, giving us a way to measure distant galaxies, leading to the discovery that the majority are moving away from us (and giving support to the idea of an expanding universe).

This knowledge, as well as helping us learn about the shape of the universe and its expansion, eventually led to a slightly unsettling discovery. As they continued to map the observable universe, astronomers looking at 400 elliptical galaxies noticed that they were moving towards something we cannot see, as it is in the "Zone of Avoidance", or the area of sky obscured by our own galaxy's galactic plane and the cosmic dust within it. Whatever it was, to move a large number of galaxies requires a lot of mass. We can't see it, but we are being dragged towards something gigantic.

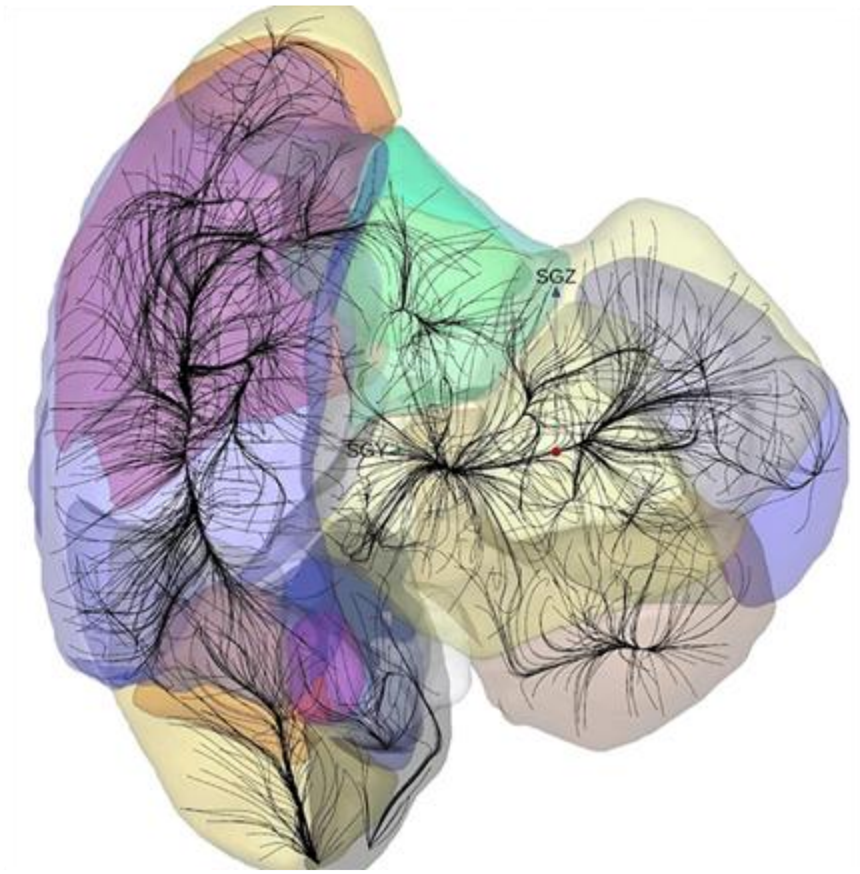
So, is it time to crack each others' heads open and feast on the goo inside? No. While continuing to be largely obscured by the Zone of Avoidance, we have a fairly good idea of what we're (not) looking at. Observing other galaxies in the sky has shown us that galaxies clump together to form "superclusters", with 90 percent of galaxies thought to reside within them.

By looking at the flow of galaxies, a team in 2014 found the Milky Way, already part of the Virgo Supercluster, is likely within an even larger structure containing around 100,000 galaxies.

"Local flows within the region converge toward the Norma and Centaurus clusters in good approximation to the location of what has been called the ‘Great Attractor’," the team wrote in their paper. "The region deserves a name. In the Hawaiian language 'lani' means 'heaven' and 'akea' means 'spacious, immeasurable'. We propose that we live in the Laniakea Supercluster of galaxies."

The Great Attractor, rather than anything to be afraid of, is where our local galaxies are heading to hang out, the central gravitational point of our local area of the universe. Unfortunately for any lonely galaxies hoping to meet other singles in their area, the expansion of the universe will eventually rip us all apart from the cluster's influence, as is the fate of the other superclusters out there.

Our Galaxy Appears To Be Part Of Structure So Large It Challenges Our Models Of Cosmology



The map of the basin of attraction. - Image credit: University of Hawai'i at Mānoa© IFL Science

Astronomers have found that our galaxy, the Milky Way, may be a tiny part of an even larger local structure than we thought. The research, if confirmed by further observations and studies, may be evidence that we haven't quite nailed down our model of the evolution of the universe.

As we study the universe more, we have found ourselves to be part of much larger structures, formed by gravitational interactions. We orbit the Sun, the Sun is part of the Milky Way, and the Milky Way is part of the Local Group, which includes several small galaxies as well as Andromeda, of "it may collide with us" fame.

But it doesn't stop there. The Local Group is on the outer edge of the Virgo Supercluster, which is itself part of a giant basin known as Laniakea. According to the new study, Laniakea too resides within a larger "basin of attraction" (BoA) potentially 10 times its volume.

"The entire Universe can be considered a patchwork of abutting BoA, just as the terrestrial landscape is separated into watersheds," the team explains in their paper. "A BoA is generally not gravitationally bound because the relative motion of distant points within it is usually dominated by cosmic expansion."

The basins of attraction are enormous structures, so much so that gravity is not the dominant force, but there is nevertheless evidence of common flow. The team looked at the motions of 56,000 galaxies, and attempted to make a "probabilistic map" of the local universe, given errors that occur when attempting to measure the velocity and motion of galaxies. In doing so, they hoped to narrow down the possibility of the existence of these basins of attraction.

“Our universe is like a giant web, with galaxies lying along filaments and clustering at nodes where gravitational forces pull them together,” University of Hawai'i at Manoa astronomer R. Brent Tully explained in a statement. “Just as water flows within watersheds, galaxies flow within cosmic basins of attraction. The discovery of these larger basins could fundamentally change our understanding of cosmic structure.”

Running simulations on the data, they found that the BoA encompassed many gigantic structures, including the mysterious Great Attractor.

"Nearby, evidence emerges for a BoA centred in proximity to the highly obscured Ophiuchus cluster that lies behind the centre of the Milky Way Galaxy," the team explained. "This BoA may include the so-called Great Attractor region and the entity Laniakea, including ourselves. In the extension [...] the Sloan Great Wall and the associated structure are overwhelmingly dominant."

Creating such maps of the universe is a messy business, tracking the movement of galaxies and their effect on each other in order to model these cosmic "currents" and flows. As such, there is a lot of uncertainty. According to the team's simulations, there is a 60 percent chance that our own Milky Way is in fact not in Laniakea, but in the Shapley concentration.

As well as being nice to really nail down our home address, the study could have much larger implications for our models of the universe, if the same structure continues to be found with further observation and analysis. Simply put, structures of gargantuan size challenge our understanding of the cosmos.

Given what we see in the cosmic microwave background, the first light we can detect after the inflation of the universe, structures can only grow so large within our current models. Yet this, and other similar discoveries, appear to be larger than our current models predict. For now, the team plans to continue mapping the largest structures in the cosmos.

"It is perhaps unsurprising that the further into the cosmos we look, we find that our home supercluster is more connected and more extensive than we thought," Noam Libeskind, astronomer at the Leibniz Institute for Astrophysics Potsdam, said in a separate statement. "Discovering that there is a good chance that we are part of a much larger structure is exciting. At the moment it’s just a hint: more observations will have to be made to confirm the size of our home supercluster."

The study is published in Nature Astronomy.

MAY 2, 2025

SPHEREx space telescope begins capturing entire sky

by NASA

NASA’s SPHEREx mission is observing the entire sky in 102 infrared colors, or wavelengths of light not visible to the human eye. This image shows a section of sky in one wavelength (3.29 microns), revealing a cloud of dust made of a molecule similar to soot or smoke. Credit: NASA

Launched on March 11, NASA's SPHEREx space observatory has spent the last six weeks undergoing checkouts, calibrations, and other activities to ensure it is working as it should. Now it's mapping the entire sky—not just a large part of it—to chart the positions of hundreds of millions of galaxies in 3D to answer some big questions about the universe.

On May 1, the spacecraft began regular science operations, which consist of taking about 3,600 images per day for the next two years to provide new insights about the origins of the universe, galaxies, and the ingredients for life in the Milky Way.

"Thanks to the hard work of teams across NASA, industry, and academia that built this mission, SPHEREx is operating just as we'd expected and will produce maps of the full sky unlike any we've had before," said Shawn Domagal-Goldman, acting director of the Astrophysics Division at NASA Headquarters in Washington.

"This new observatory is adding to the suite of space-based astrophysics survey missions leading up to the launch of NASA's Nancy Grace Roman Space Telescope. Together with these other missions, SPHEREx will play a key role in answering the big questions about the universe we tackle at NASA every day."

From its perch in Earth orbit, SPHEREx peers into the darkness, pointing away from the planet and the sun. The observatory will complete more than 11,000 orbits over its 25 months of planned survey operations, circling Earth about 14½ times a day.

It orbits Earth from north to south, passing over the poles, and each day it takes images along one circular strip of the sky. As the days pass and the planet moves around the sun, SPHEREx's field of view shifts as well, so that after six months, the observatory will have looked out into space in every direction.

When SPHEREx takes a picture of the sky, the light is sent to six detectors that each produces a unique image capturing different wavelengths of light. These groups of six images are called an exposure, and SPHEREx takes about 600 exposures per day.

When it's done with one exposure, the whole observatory shifts position—the mirrors and detectors don't move as they do on some other telescopes. Rather than using thrusters, SPHEREx relies on a system of reaction wheels, which spin inside the spacecraft to control its orientation.

Hundreds of thousands of SPHEREx's images will be digitally woven together to create four all-sky maps in two years. By mapping the entire sky, the mission will provide new insights about what happened in the first fraction of a second after the big bang. In that brief instant, an event called cosmic inflation caused the universe to expand a trillion-trillion-fold.

"We're going to study what happened on the smallest-sized scales in the universe's earliest moments by looking at the modern universe on the largest scales," said Jim Fanson, the mission's project manager at NASA's Jet Propulsion Laboratory in Southern California. "I think there's a poetic arc to that."

This video shows SPHEREx’s field of view as it scans across one section of sky inside the Large Magellanic Cloud, with rainbow colors representing the infrared wavelengths the telescope’s detectors see. The view from one detector array moves from purple to green, followed by the second array’s view, which changes from yellow to red. The images are looped four times. Credit: NASA/JPL-Caltech
Cosmic inflation subtly influenced the distribution of matter in the universe, and clues about how such an event could happen are written into the positions of galaxies across the universe. When cosmic inflation began, the universe was smaller than the size of an atom, but the properties of that early universe were stretched out and influence what we see today.

No other known event or process involves the amount of energy that would have been required to drive cosmic inflation, so studying it presents a unique opportunity to understand more deeply how our universe works.

"Some of us have been working toward this goal for 12 years," said Jamie Bock, the mission's principal investigator at Caltech and JPL. "The performance of the instrument is as good as we hoped. That means we're going to be able to do all the amazing science we planned on and perhaps even get some unexpected discoveries."

Color field

The SPHEREx observatory won't be the first to map the entire sky, but it will be the first to do so in so many colors. It observes 102 wavelengths, or colors, of infrared light, which are undetectable to the human eye. Through a technique called spectroscopy, the telescope separates the light into wavelengths—much like a prism creates a rainbow from sunlight—revealing all kinds of information about cosmic sources.

For example, spectroscopy can be harnessed to determine the distance to a faraway galaxy, information that can be used to turn a 2D map of those galaxies into a 3D one. The technique will also enable the mission to measure the collective glow from all the galaxies that ever existed and see how that glow has changed over cosmic time.

And spectroscopy can reveal the composition of objects. Using this capability, the mission is searching for water and other key ingredients for life in these systems in our galaxy. It's thought that the water in Earth's oceans originated as frozen water molecules attached to dust in the interstellar cloud where the sun formed.

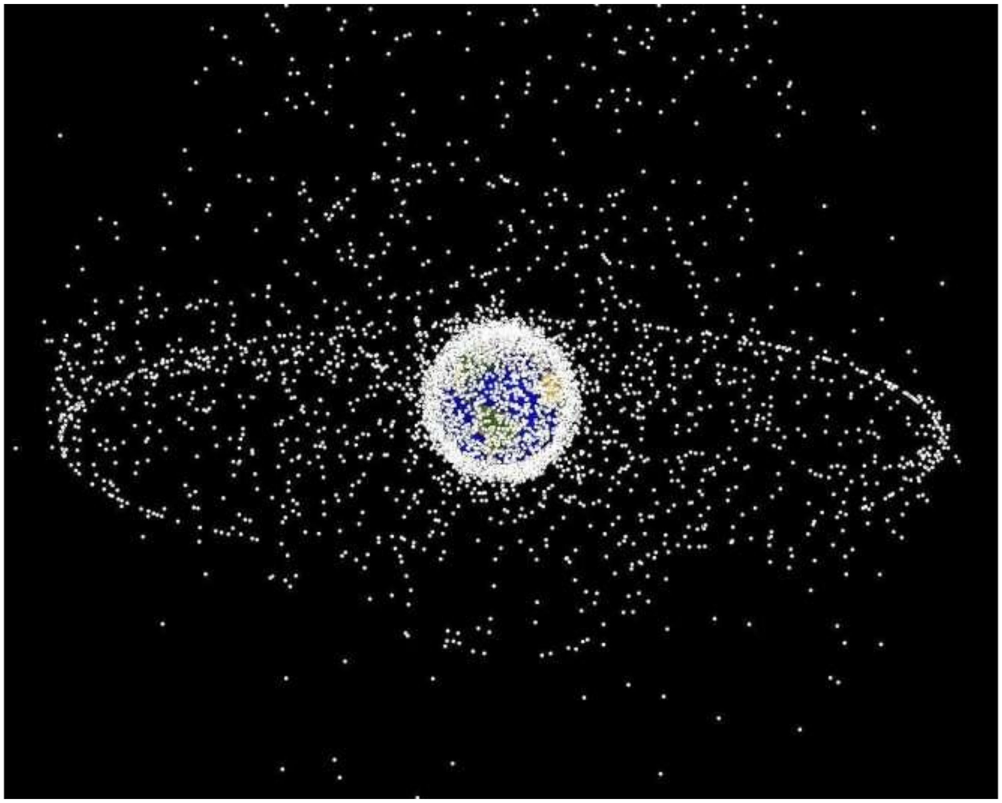
The SPHEREx mission will make over 9 million observations of interstellar clouds in the Milky Way, mapping these materials across the galaxy and helping scientists understand how different conditions can affect the chemistry that produced many of the compounds found on Earth today.

Provided by NASA

MAY 2, 2025

Space junk falling to Earth needs to be tracked—meteoroid sounds can help

by Asmae Ourkiya , European Geosciences Union



Credit: Pixabay/CC0 Public Domain

Space junk and meteoroids are falling to Earth every year, posing a growing risk as they re-enter the atmosphere at high speeds. Researchers are using infrasound sensors to track these objects, including bolides, which are meteoroids breaking apart in the sky.

New research presented at the EGU General Assembly (EGU25) shows that infrasound signals can help track these objects, but the trajectory needs to be considered, especially for objects entering at shallow angles. This study highlights the importance of improving monitoring techniques for planetary defense and space junk management.

Every year, Earth gets a bit bigger. Thousands of metric tons of space dust fall from the sky, while about 50 tons per year of meteorites crash land somewhere on the surface. Since the 1960s, space junk has also occasionally returned to Earth, falling from a hazy sphere of trash encircling the planet. Remnants of rockets, tools lost by space-walking astronauts, defunct satellites, and more fly through lower Earth orbit, reaching speeds of 18,000 miles per hour.

When any item—whether space rock or space junk—enters the atmosphere, scientists try to track its path to estimate where it will land. Will the item in question plunk straight down, or will it fly along at an angle before skittering to a halt?

In a new study to be presented at the General Assembly of the European Geosciences Union, Elizabeth Silber, a scientist at Sandia National Laboratories, will consider how infrasound sensors—instruments that detect sounds at lower frequencies than humans can hear—listen for bolides. Bolides are the bright flashes and booms from large meteoroids breaking apart high in the sky. These events release huge amounts of energy, creating shock waves that travel as infrasound signals across thousands of kilometers.

But here's the challenge: Bolides aren't like explosions that happen in one place. They are moving, generating sound along their path as they travel through the sky. This movement matters, especially for meteoroids and space debris that enter shallow angles. In those cases, different infrasound stations might pick up signals coming from different directions, making it harder to pinpoint the source.

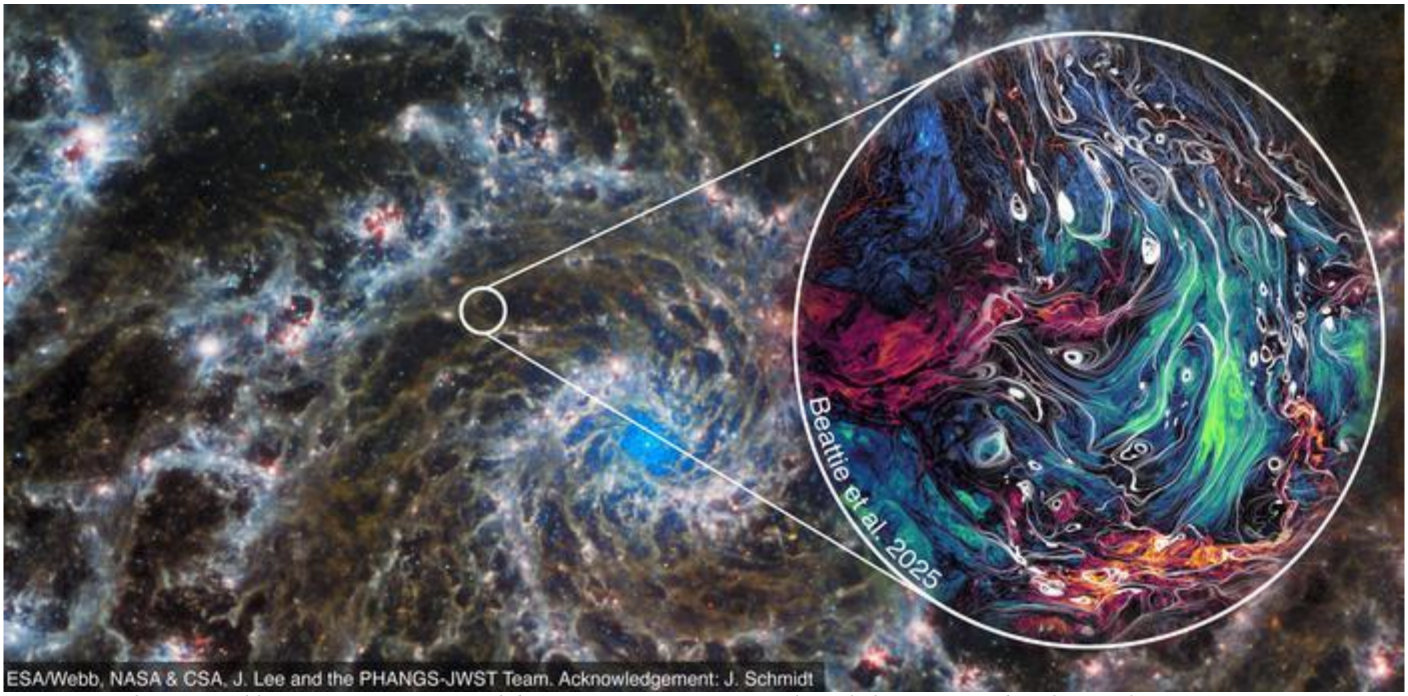
Motivated by this problem, Silber used a network of infrasound sensors around the world maintained by the Comprehensive Test Ban Treaty Organization (CTBTO), an organization tasked with listening for illicit explosions. These instruments also record anything else that claps or booms, from thunder to supersonic aircraft. Using signals specifically from bolides, Silber isolated the purely geometric component for her analysis.

She found that if a bolide enters Earth's atmosphere at a relatively steep angle—greater than 60°—analysis of the infrasound signal gets the trajectory right. But when it comes more horizontally, the uncertainty increases.

"Infrasound from a bolide is more like a sonic boom stretched across the sky than a single bang," Silber says. "You must account for the fact that the sound is being generated along the flight path."

And so, this study highlights a critical need: to consider the trajectory of an object when interpreting infrasound data. Infrasound instruments are indispensable for planetary defense, according to Silber, and the findings are relevant to Earth-bound space junk. If you don't know where something is going, then you have a hard time preparing for it.

More information: Elizabeth Silber, Reducing uncertainties in bolide and space debris detection: The role of entry geometry in infrasound analysis (2025). DOI: 10.5194/egusphere-egu25-4030
Provided by European Geosciences Union



Credit: ESA/Webb, NASA & CSA, J. Lee and the PHANGS-JWST Team; Acknowledgement: J. Schmidt; Simulation: J. Beattie.

NEW MILKY WAY MODEL EXPLORES WHAT LIES BETWEEN THE STARS WITH SURPRISING REVELATIONS

RYAN WHALEN·MAY 15, 2025

An innovative new computer model describing the expanse of charged particles and gas between stars reveals the Milky Way Galaxy's magnetic turbulence, challenging the current understanding of astrophysical turbulence.

Known as interstellar mass, this cosmic medium filling the space between planets in the Milky Way has never been described in such detail. The team behind the achievement required the ultra-powerful SuperMUC-NG supercomputer housed at Germany's Leibniz Supercomputing Centre to run their unprecedented model.

WHAT FILLS THE VOID

Even ultra-high vacuum experiments on Earth contain many more particles than the ocean of interstellar space. Yet, even those few cosmic particles manage to create a magnetic field similar to Earth's core. With the sparseness of particles generating the field, its strength is millions of times below that of even refrigerator magnets, yet still enough to impact the universe around it, creating turbulence for objects traversing the cosmos. The behavior of that turbulence has been an unsettled problem for modern physics.

"This is the first time we can study these phenomena at this level of precision and at these different scales," said lead author James Beattie.

"Turbulence remains one of the greatest unsolved problems in classical mechanics," added Beattie. "This despite the fact that turbulence is ubiquitous: from swirling milk in our coffee to chaotic flows in the oceans, solar wind, interstellar medium, even the plasma between galaxies."

A NEW MODEL OF THE MILKY WAY

The model was so computation-heavy that it required power equal to 140,000 computers operating at once to run.

"To put these massive simulations into perspective: if we had started one on a single laptop when humans first domesticated animals, it would just be finishing now," said Beattie. "Luckily, utilizing the amazing resources from the Leibniz Supercomputing Centre, we can distribute the workload across thousands of computers to accelerate the calculations."

The model is highly scalable, from a cube of 10,000 units per dimension, representing 30 light-years aside, to a version reduced by a factor of 5000. The largest scale provides insight into the Milky Way's entire magnetic fields, while the smaller end provides the granularity needed for researchers to investigate how solar winds impact the Earth.

MILKY WAY MODEL REVELATIONS

In the new model, magnetic fields affect energy traveling through interstellar mass by surpassing small-scale motions and increasing Alfvén waves, a type of wave-like disturbance. These findings conflict with decades of astrophysical theory, potentially altering how turbulence, high-energy particle transport, and star formation are understood.

“We are a step closer to uncovering the true nature of astrophysical and space turbulence, from chaotic plasma near Earth to the vast motions within our Galaxy and beyond,” said Beattie, “The dream is to discover universal features in turbulence across the Universe, and we’ll continue pushing the limits of the next-generation of simulations to test that idea.”

WHAT SCIENTISTS HOPE TO LEARN

With their new model, the researchers hope to illuminate many cosmic matters, such as the Milky Way’s magnetism, star formation, cosmic ray propagation, and interstellar mass.

“We know that magnetic pressure opposes star formation by pushing outward against gravity as it tries to collapse a star-forming nebula,” explained Beattie. “Now we can quantify in detail what to expect from magnetic turbulence on those kinds of scales.”

One of the team’s most significant achievements is its model’s ability to represent density changes across the interstellar mass, which can vary greatly and peak in star-forming nebulae. Crucially, a more dynamic understanding of interstellar mass will be of tremendous use to future space navigation, as crewed missions set their sights on Mars and beyond.

“The research has implications for predicting and monitoring space weather to better understand the plasma environment around satellites and future space missions, and also the acceleration of highly energetic particles, which damage everything, and could endanger human beings in space," said co-author Amitava Bhattacharjee.

"A lot of these fundamental plasma turbulence questions are objects of missions now launched by NASA and have implications for understanding the origin of cosmic magnetic fields. Simulations like these would give us insights into how to interpret satellite and ground-based measurements," added Bhattacharjee.

THE RESEARCH CYCLE CONTINUES

Beatie's team is not finished yet, though. They are continuing to push the model to an even higher resolution while testing their simulation against real-world data.

"We've already begun testing whether the model matches existing data from the solar wind and the Earth — and it's looking very good," says Beattie. "This is very exciting because it means we can learn about space weather with our simulation. Space weather is very important because we're talking about the charged particles that bombard satellites and humans in space and have other terrestrial effects."

Fortunately, new observation platforms provide plenty of data to check the model against and new details that require expanded frameworks to interpret. One prime example is the Square Kilometre Array in South Africa, which can precisely measure the galaxy's turbulent magnetic fields.

"There's something very romantic about how it appears at all these different levels and I think that's very exciting," Beattie concluded about the universal applicability of the team's turbulence research.

The Milky Way was on a collision course with a neighboring galaxy. Not anymore

The paper "The Spectrum of Magnetized Turbulence in the Interstellar Medium" appeared on May 13, 2025 in *Nature Astronomy.*

More than a decade ago, scientists predicted our Milky Way galaxy and neighboring Andromeda would collide in four billion years, resulting in a "makeover" of our solar system.

Now, that is unlikely — at least within the expected timeframe.

"We see external galaxies often colliding and merging with other galaxies, sometimes producing the equivalent of cosmic fireworks when gas, driven to the center of the merger remnant, feeds a central black hole emitting an enormous amount of radiation, before irrevocably falling into the hole," explained Durham University Professor Carlos Frenk.

"Until now we thought this was the fate that awaited our Milky Way galaxy," he said in a statement. "We now know that there is a very good chance that we may avoid that scary destiny."

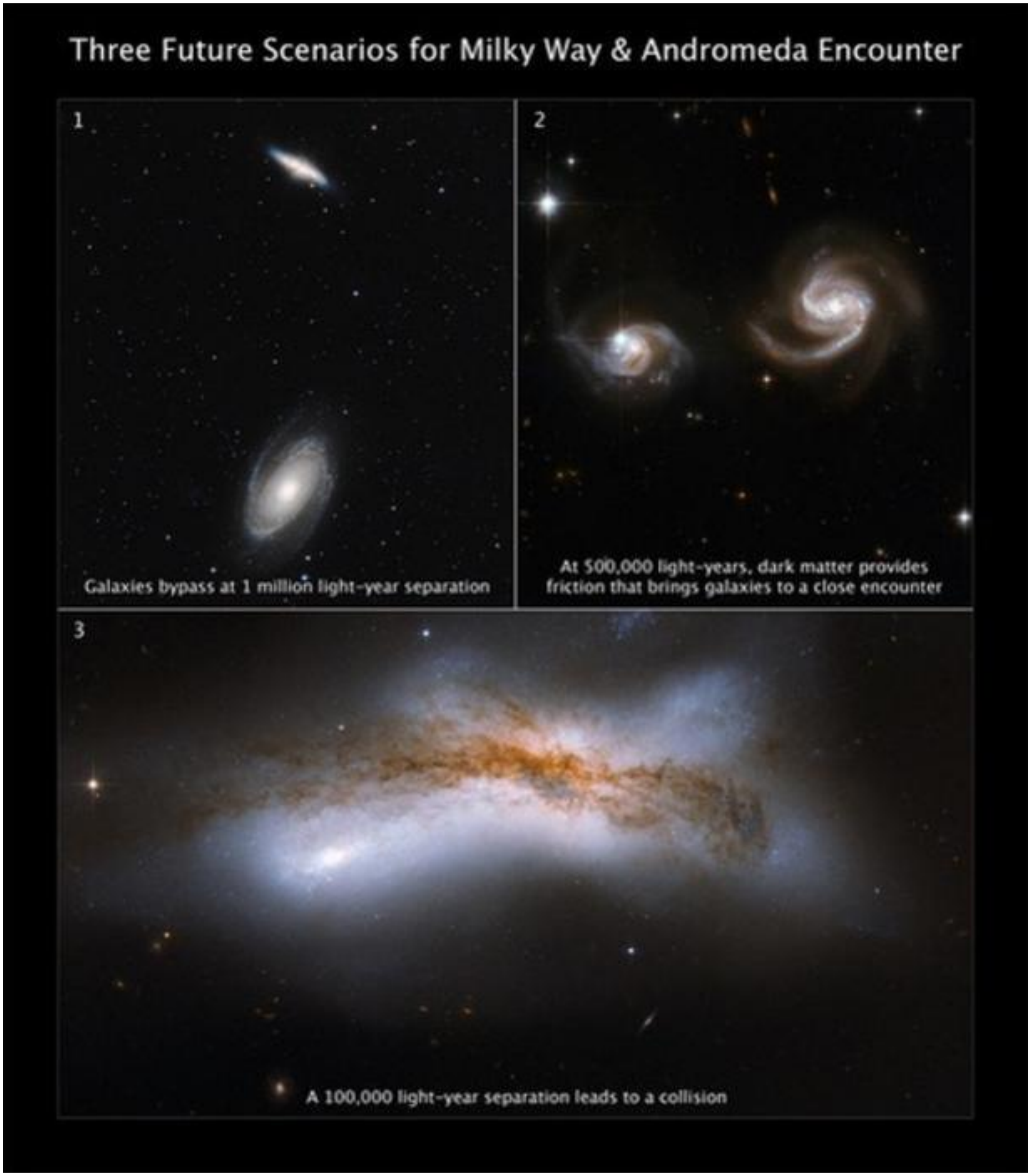
Previous research from NASA astronomers had found that the collision with our closest neighbor galaxy would fling the sun to a new region of space, although the Earth would not be destroyed. The stars would be sent into different orbits. Right now, the galaxies are heading toward each other with a speed of approximately 62 miles per second.

But, following 100,000 simulations of both galaxies based on the latest observational data from NASA's Hubble and the European Space Agency's Gaia space telescopes, the authors of the study that was published in the journal *Nature Astronomy* found just a 2 percent probability that the Milky Way and Andromeda would crash into each other over the course of the next five billion years.

In more than half of the scenarios, the galaxies experienced at least one close encounter before they lost enough orbital energy to collide and merge. However, that would occur in some eight-to-10 billion years. By that time, the sun may have burnt itself out when it runs out of hydrogen, consuming the Earth.

But, in most other cases, the galaxies pass each other by without incident, although there is room for uncertainty.

Furthermore, the authors assert that previous research was not incorrect, but that they were able to incorporate more variables in their simulations.



This graphic shows three future scenarios for an encounter between the Milky Way and Andromeda galaxies. In scenario one, they bypass. In the second, they have a close encounter. In the third, they collide. (NASA/ESA)

"While some earlier works had focused on the interaction between the Milky Way, Andromeda, and the Triangulum galaxy, we also include the effect of the Large Magellanic Cloud," lead author Dr. Till Sawala, of the University of Helsinki, said. The cloud is a dwarf galaxy that orbits the Milky Way. "Although its mass is only around 15 percent of the Milky Way's, its gravitational pull directed perpendicular to the orbit with Andromeda perturbs the Milky Way's motion enough to significantly reduce the chance of a merger with the Andromeda galaxy."

However, the authors are already looking to update their findings with new data. The European Space Agency's Gaia space telescope will soon provide more precise measurements of crucial factors within the galaxies, including the motion of Andromeda. Still, Frenk said the results are a "testimony" to the power of large supercomputers.

"When I see the results of our calculations, I am astonished that we are able to simulate with such precision the evolution of gigantic collections of stars over billions of years and figure out their ultimate fate," he added.

JUNE 12, 2025

NASA's Roman to peer into cosmic 'lenses' to better define dark matter

by Claire Blome, Christine Pulliam, Space Telescope Science Institute

edited by Gaby Clark, reviewed by Andrew Zinin

This image shows a simulated observation from NASA's Nancy Grace Roman Space Telescope with an overlay of its Wide Field Instrument's field of view. More than 20 gravitational lenses, with examples shown at left and right, are expected to pop out in every one of Roman's vast observations. A journal paper led by Bryce Wedig, a graduate student at Washington University in St. Louis, Missouri, estimates that of those Roman detects, about 500 from the telescope's High-Latitude Wide-Area Survey will be suitable for dark matter studies. By examining such a large population of gravitational lenses, the researchers hope to learn a lot more about the mysterious nature of dark matter. Credit:

Science: NASA, Bryce Wedig (Washington University in St. Louis), Tansu Daylan (Washington University in St. Louis). Image: Joseph DePasquale (STScI)
Dark matter affects how stars move within galaxies, how galaxies build up over time, and how everything in the universe is held together—but no existing tool has directly detected it. While dark matter does not reflect, absorb, or emit light, it can still be indirectly observed by telescopes.

To better characterize dark matter, astronomers look for its influence on the light they can observe. Dark matter possesses mass, therefore it can distort light traveling through the cosmos in a process known as gravitational lensing.

The Nancy Grace Roman Space Telescope, set to survey the sky following its launch, will turn up hundreds of gravitational lenses where a massive galaxy in the foreground magnifies and distorts light from the background galaxy into arcs and swoops. Researchers will use Roman's data to measure tiny deviations in the repeated imagery of the background galaxies, which will help them measure the effects of dark matter on incredibly small scales and better pinpoint what it is.

A funky effect Einstein predicted, known as gravitational lensing—when a foreground galaxy magnifies more distant galaxies behind it—will soon become common when NASA's Nancy Grace Roman Space Telescope begins science operations in 2027 and produces vast surveys of the cosmos.

A particular subset of gravitational lenses, known as strong lenses, is the focus of a new paper published in the *Astrophysical Journal* led by Bryce Wedig, a graduate student at Washington University in St. Louis.

The research team has calculated that over 160,000 gravitational lenses, including hundreds suitable for this study, are expected to pop up in Roman's vast images. Each Roman image will be 200 times larger than infrared snapshots from NASA's Hubble Space Telescope, and its upcoming "wealth" of lenses will vastly outpace the hundreds studied by Hubble to date.

Roman will conduct three core surveys, providing expansive views of the universe. This science team's work is based on a previous version of Roman's now fully defined High-Latitude Wide-Area Survey. The researchers are working on a follow-up paper that will align with the final survey's specifications to fully support the research community.

"The current sample size of these objects from other telescopes is fairly small because we're relying on two galaxies to be lined up nearly perfectly along our line of sight," Wedig said. "Other telescopes are either limited to a smaller field of view or less precise observations, making gravitational lenses harder to detect."

Gravitational lenses are made up of at least two cosmic objects. In some cases, a single foreground galaxy has enough mass to act like a lens, magnifying a galaxy that is almost perfectly behind it. Light from the background galaxy curves around the foreground galaxy along more than one path, appearing in observations as warped arcs and crescents. Of the 160,000 lensed galaxies Roman may identify, the team expects to narrow that down to about 500 that are suitable for studying the structure of dark matter at scales smaller than those galaxies.

"Roman will not only significantly increase our sample size—its sharp, high-resolution images will also allow us to discover gravitational lenses that appear smaller on the sky," said Tansu Daylan, the principal investigator of the science team conducting this research program. Daylan is an assistant professor and a faculty fellow at the McDonnell Center for the Space Sciences at Washington University in St. Louis.

"Ultimately, both the alignment and the brightness of the background galaxies need to meet a certain threshold so we can characterize the dark matter within the foreground galaxies."

This video shows how a background galaxy's light is lensed or magnified by a massive foreground galaxy, seen at center, before reaching NASA's Roman Space Telescope. Light from the background galaxy is distorted, curving around the foreground galaxy and appearing more than once as warped arcs and crescents. Researchers studying these objects, known as gravitational lenses, can better characterize the mass of the foreground galaxy, which offers clues about the particle nature of dark matter. Credit: NASA, STScI, Joseph Olmsted (STScI)

What is dark matter?

Not all mass in galaxies is made up of objects we can see, like star clusters. A significant fraction of a galaxy's mass is made up of dark matter, so called because it doesn't emit, reflect, or absorb light. Dark matter does, however, possess mass, and like anything else with mass, it can cause gravitational lensing.

When the gravity of a foreground galaxy bends the path of a background galaxy's light, its light is routed onto multiple paths. "This effect produces multiple images of the background galaxy that are magnified and distorted differently," Daylan said. These "duplicates" are a huge advantage for researchers—they allow multiple measurements of the lensing galaxy's mass distribution, ensuring that the resulting measurement is far more precise.

Roman's 300-megapixel camera, known as its Wide Field Instrument, will allow researchers to accurately determine the bending of the background galaxies' light by as little as 50 milliarcseconds, which is like measuring the diameter of a human hair from the distance of more than two and a half American football fields or soccer pitches.

The amount of gravitational lensing that the background light experiences depends on the intervening mass. Less massive clumps of dark matter cause smaller distortions. As a result, if researchers are able to measure tinier amounts of bending, they can detect and characterize smaller, less massive dark matter structures—the types of structures that gradually merged over time to build up the galaxies we see today.

With Roman, the team will accumulate overwhelming statistics about the size and structures of early galaxies. "Finding gravitational lenses and being able to detect clumps of dark matter in them is a game of tiny odds. With Roman, we can cast a wide net and expect to get lucky often," Wedig said. "We won't see dark matter in the images—it's invisible—but we can measure its effects."

"Ultimately, the question we're trying to address is: What particle or particles constitute dark matter?" Daylan added. "While some properties of dark matter are known, we essentially have no idea what makes up dark matter. Roman will help us to distinguish how dark matter is distributed on small scales and, hence, its particle nature."

Preparations continue

Before Roman launches, the team will also search for more candidates in observations from ESA's (the European Space Agency's) Euclid mission and the upcoming ground-based Vera C. Rubin Observatory in Chile, which will begin its full-scale operations in a few weeks. Once Roman's infrared images are in hand, the researchers will combine them with complementary visible light images from Euclid, Rubin, and Hubble to maximize what's known about these galaxies.

"We will push the limits of what we can observe, and use every gravitational lens we detect with Roman to pin down the particle nature of dark matter," Daylan said.

More information: Bryce Wedig et al, The Roman View of Strong Gravitational Lenses, *The Astrophysical Journal* (2025). DOI: 10.3847/1538-4357/adc24f
Journal information: Astrophysical Journal
Provided by Space Telescope Science Institute