SPACE TECH NEWS VOL 3

James Webb Telescope Unlocks Hidden Secrets of Failed Stars in the Orion Nebula

The James Webb Space Telescope (JWST) is shedding light on mysteries surrounding brown dwarfs, following decades of questions left unresolved by earlier missions. Astronomers have long wondered if these so-called "**failed stars**" could be surrounded by protoplanetary discs after their formation. Now, new observations in the Orion Nebula provide fascinating answers.

Breakthrough in Studying Brown Dwarfs

The **Orion Nebula**, located 1,300 light-years away from Earth, has long been a target for astronomers. This star-forming region, close to our Solar System, offers ideal conditions for observing stellar nurseries. For years, the Hubble Space

Telescope provided remarkable insights, especially in the 1990s, confirming theories about the origins of our Solar System.

Hubble’s observations showed protoplanetary discs, called proplyds, around young stars, illuminated and ionized by intense ultraviolet radiation. This initial research documented **about 180 proplyds**, but mysteries lingered about their true nature.

Hubble’s Limitations and New Hope with JWST

Despite its many successes, Hubble struggled to detect certain faint objects, especially those emitting primarily in the infrared spectrum. This gap left astronomers questioning if some proplyds belonged to **protostars or brown dwarfs**.

Brown dwarfs, larger than gas giants like Jupiter but too small for sustained nuclear fusion, only briefly burn deuterium, a heavy hydrogen isotope formed in the Big Bang. These elusive objects required more sensitive technology for proper investigation.

James Webb Telescope's Revolutionary Findings

Enter the James Webb Space Telescope. Equipped with advanced infrared capabilities, JWST successfully tackled challenges where Hubble fell short. Using the **Webb near-infrared spectrograph**, researchers analyzed several candidate brown dwarfs in the Orion Nebula. These measurements revealed crucial details:

・**Twenty objects** were confirmed as brown dwarfs, with the smallest having only 0.5% of the Sun’s mass, equivalent to five Jupiter masses.

・Two other objects had masses close to the minimum required for fusion, blurring the line between small stars and large brown dwarfs.

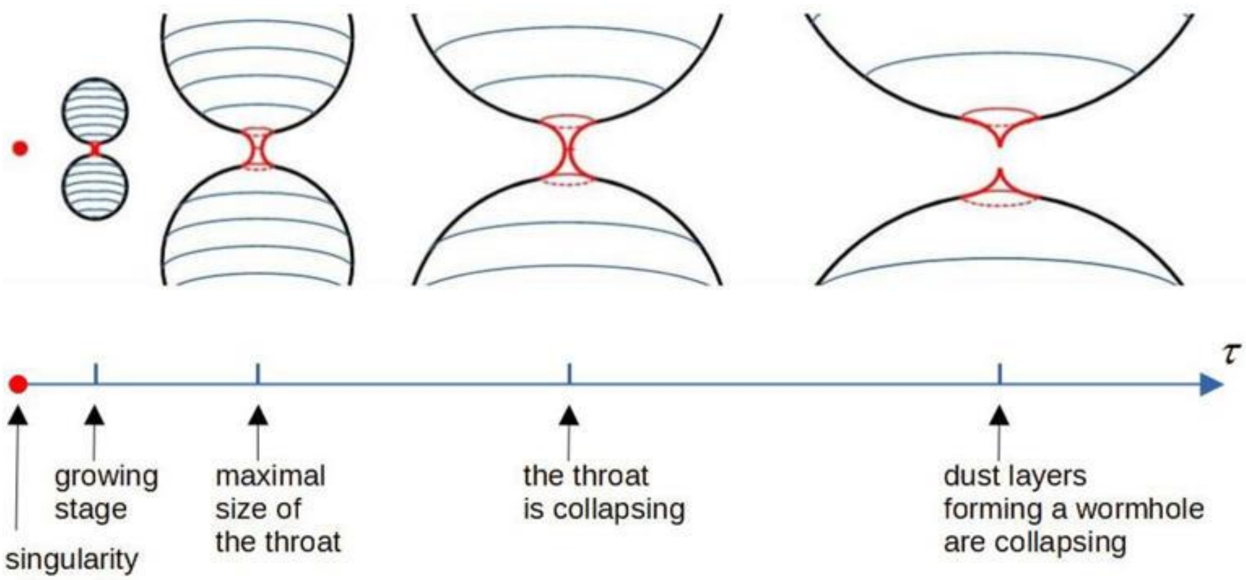
・Among the findings were **two faint proplyds** initially detected by Hubble in the 1990s, now identified as some of the least massive and coolest proplyds ever found.

Filling the Gaps in our Knowledge

Kevin Luhman, a professor of astronomy and astrophysics at Penn State and a leader of this research, highlighted the significance of these findings. He noted that Webb's initial observations are just scratching the surface. **"The nebula contains a few hundred faint objects that could be brown dwarfs,"** Luhman explained, adding that these objects are ripe for further study using spectroscopy.

Future JWST observations could identify many more brown dwarfs surrounded by protoplanetary discs. **This research promises to deepen our understanding of brown dwarf formation and their connections to stars and planets**, helping scientists refine models of stellar and planetary evolution.

Astrophysicists offer theoretical proof of traversable wormholes in the expanding universe



An evolving wormhole connecting two Friedmann universes. Credit: Universe (2023). DOI: 10.3390/universe9110465© Provided by Phys.org

The expansion of the universe at some stage of evolution is well described by the Friedmann model. It was derived from general relativity a hundred years ago, but it is still considered one of the most important and relevant cosmological models.

RUDN University astrophysicists have now proven the theoretical possibility of the existence of traversable wormholes in the Friedmann universe. The research is published in the journal *Universe*.

"A wormhole is a type of highly curved geometry. It resembles a tunnel either between distant regions of the same universe or between different universes. Such structures were first discussed in the framework of solutions to the gravitational field equations a hundred years ago. But the wormholes considered then turned out to be non-traversable even for photons—they could not move from one 'end of the tunnel' to the other, not to mention going back," said Kirill Bronnikov, doctor of physical and mathematical sciences, professor of RUDN University.

"Others are now being considered—traversable wormholes in various theories of gravity and the presence of various types of matter. We investigated possible traversable wormholes in the general theory of relativity, which are supported by dustlike matter," Bronnikov added.

The astrophysicists investigated a generalized form of the famous Lemaître–Tolman–Bondi solution, which describes the evolution of spherically symmetric distributions of electrically neutral dust in general relativity. The researchers generalized it to the case of when there is an external source of an electric or magnetic field and a non-zero cosmological constant. They aimed to find mathematical conditions under which traversable wormholes could exist in such a setting, and then give a cosmological explanation for this.

The researchers obtained numerical solutions that describe the movement of photons through wormholes connecting different Friedmann universes or different parts of the same universe. Whether it will be possible to pass through a wormhole depends on the parameters of its "entrance" and the initial conditions. The physicists generalized the case of one universe to the case of multiple universes. In this case, the "mother" universe has several "entrances" to wormholes that connect it with the "daughter" universe.

"A charge on one 'pole' inevitably leads to an opposite charge on the other. At this other pole there might be a similar wormhole mouth, and beyond that another universe, and so on. The whole picture will resemble churchkhela, a wonderful Georgian dessert. Some of the wormholes can connect different parts of the same universe," Bronnikov explained.

"Possible observational signs of such objects, in particular, the properties of the cosmic microwave background and magnetic fields, may be the subject of further research. It is especially interesting to compare the characteristics of our wormhole models with the observed parameters of cosmic voids and other inhomogeneities in our universe," Bronnikov concluded.

More information: Kirill A. Bronnikov et al, Possible Wormholes in a Friedmann Universe, *Universe* (2023). DOI: 10.3390/universe9110465

New study suggests black holes may be sources of dark energy driving universe's expansion

Black hole collision and merger releasing gravitational waves by Simulating eXtreme Spacetimes Lensing (SXS) is licensed under CC BY-SA 4.0.© (photo credit: Wikimedia Commons)

In a groundbreaking new study published in the journal Cosmology and Astrophysical Particle Physics, researchers from the University of Michigan and Arizona State University have proposed a profound connection between dark energy and black holes, suggesting that black holes could be sources of dark energy influencing cosmic evolution. The study introduces the concept of "cosmological coupling," a new idea that suggests black holes are not only passive objects but might play an active role in dark energy interactions.

Astrophysicist Kevin Croker of Arizona State University and his colleagues investigated the link between black holes and dark energy at the time of black hole formation. "If black holes contain dark energy, they can couple to and grow with the expanding universe, causing its growth to accelerate," Croker explained. "We can't get the details of how this is happening, but we can see evidence that it is happening," he added.

The research team utilized the Dark Energy Spectroscopic Instrument (DESI) mounted on the Nicholas U. Mayall 4-meter Telescope in Arizona to search for evidence of dark energy from black holes. Equipped with 5,000 robotic sensors designed to scan the skies for dark energy, DESI provided precise measurements, enabling researchers to calculate the universe’s expansion rate with remarkable accuracy, consistent with current measurements.

By analyzing data throughout the age of the universe, the team estimated the amount of dark energy and found a match between the increasing density of dark energy and the growing mass of black holes as the universe aged. This provided a compelling clue supporting the idea of what dark energy is. "The two phenomena were consistent with each other—as new black holes were made in the deaths of massive stars, the amount of dark energy in the universe increased in the right way," noted Duncan Farrah, a co-author of the study. "This makes it more plausible that black holes are the source of dark energy."

Physicist Gregory Tarlé of the University of Michigan offered further insight into the findings. "If you ask yourself the question, 'Where in the later Universe do we see gravity as strong as it was at the beginning of the Universe?' the answer is at the center of black holes," Tarlé explained. He described the process as "reverse inflation," where the collapse of a massive star could generate dark energy, acting like the Big Bang reversed. Tarlé emphasized, "Fundamentally, whether black holes are dark energy, coupled to the universe they inhabit, has ceased to be just a theoretical question. This is an experimental question now."

The study found that black holes formed from the collapse of massive stars may contribute to dark energy as they grow. By comparing the black hole formation rate with the expansion of the universe, the researchers observed that as more black holes form, the amount of dark energy increases in a manner consistent with observations of the universe's accelerating expansion. This suggests that black holes could be sources of dark energy linked to the expansion of the universe.

The concept of cosmological coupling emerged from attempts to resolve black hole weirdness with interpretations of general relativity. Any growth demonstrated by black holes in galaxies that have stopped forming new stars could not be attributed to normal growth mechanisms but to cosmological coupling. The research team found signs of growth in the black holes of these "dead" galaxies, which they felt validated their idea of cosmological coupling.

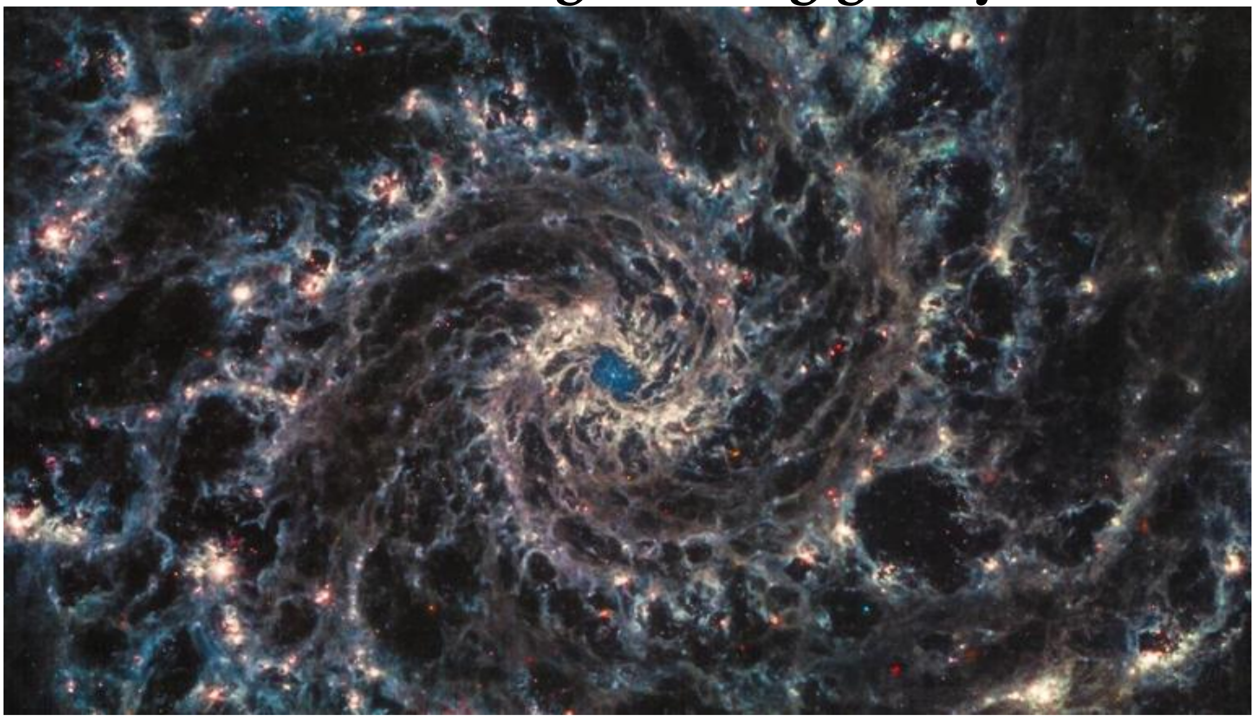
"If the hypothesis that black holes are related to dark energy is proven correct, it would revolutionize conventional knowledge about black holes and dark energy," the researchers stated. The potential implications of this study extend to solving the Hubble tension, a problem in cosmology where different parts of the universe appear to be expanding at different speeds, creating contradictions in current models. The concept suggests that black holes could influence these contradictions.

Despite the promising evidence, the team emphasizes that further research using tools like DESI will be necessary to confirm these initial observations. "Researchers hope that similar observations with tools such as DESI will further improve this knowledge in the future," they noted. "Scientists have not provided enough evidence to support the hypothesis that black holes have something to do with dark energy."

The research offers solutions to several outstanding questions about dark energy and the universe's expansion, representing a new chapter in our understanding of black holes and the forces that shape the universe. As Tarlé concluded, "Fundamentally, whether black holes are dark energy, coupled to the universe they inhabit, has ceased to be just a theoretical question. This is an experimental question now."

Sources: News18, ScienceAlert, Al Youm Al Saba

Webb confirms a longstanding galaxy model



WST image of the grand design spiral galaxy NGC 628. Credit: NASA / ESA / CSA / Judy Schmidt (CC BY 2.0)

Perhaps the greatest tool astronomers have is the ability to look backward in time. Since starlight takes time to reach us, astronomers can observe the history of the cosmos by capturing the light of distant galaxies.

This is why observatories such as the James Webb Space Telescope (JWST) are so useful. With it, we can study in detail how galaxies formed and evolved. We are now at the point where our observations allow us to confirm long-standing galactic models, as a recent study shows.

This particular model concerns how galaxies become chemically enriched. In the early universe, there was mostly just hydrogen and helium, so the first stars were massive creatures with no planets. They died quickly and spewed heavier elements, from which more complex stars and planets could form.

Each generation adds more elements to the mix. But as a galaxy nurtures a menagerie of stars from blue supergiants to red dwarfs, which stars play the greatest role in chemical enrichment?

One model argues that it is the most massive stars. This makes sense because giant stars explode as supernovae when they die. They toss their enriched outer layers deep into space, allowing the material to mix within great molecular clouds from which new stars can form. But about 20 years ago, another model argued that smaller, more sunlike stars played a greater role.

The Cat's Eye nebula is a remnant of an AGB star. Credit: ESA, NASA, HEIC and the Hubble Heritage Team, STScI/AURA

Stars like the sun don't die in powerful explosions. Billions of years from now, the sun will swell into a red giant star. In a desperate attempt to keep burning, the core of a sun-like star heats up significantly to fuse helium, and its diffuse outer layers swell.

On the Hertzsprung-Russell diagram, they are known as asymptotic giant branch (AGB) stars. While each AGB star might toss less material into interstellar space, they are far more common than giant stars. So, the model argues, AGB stars play a greater role in the enrichment of galaxies.

Both models have their strengths, but proving the AGB model over the giant star model would prove difficult. It's easy to observe supernovae in galaxies billions of light years away. Not so much with AGB stars. Thanks to the JWST, we can now test the AGB model.

Using JWST, the study, published in *Nature Astronomy*, looked at the spectra of three young galaxies. Since the Webb's NIRSpec camera can capture high-resolution infrared spectra, the team could see not just the presence of certain elements but their relative abundance.

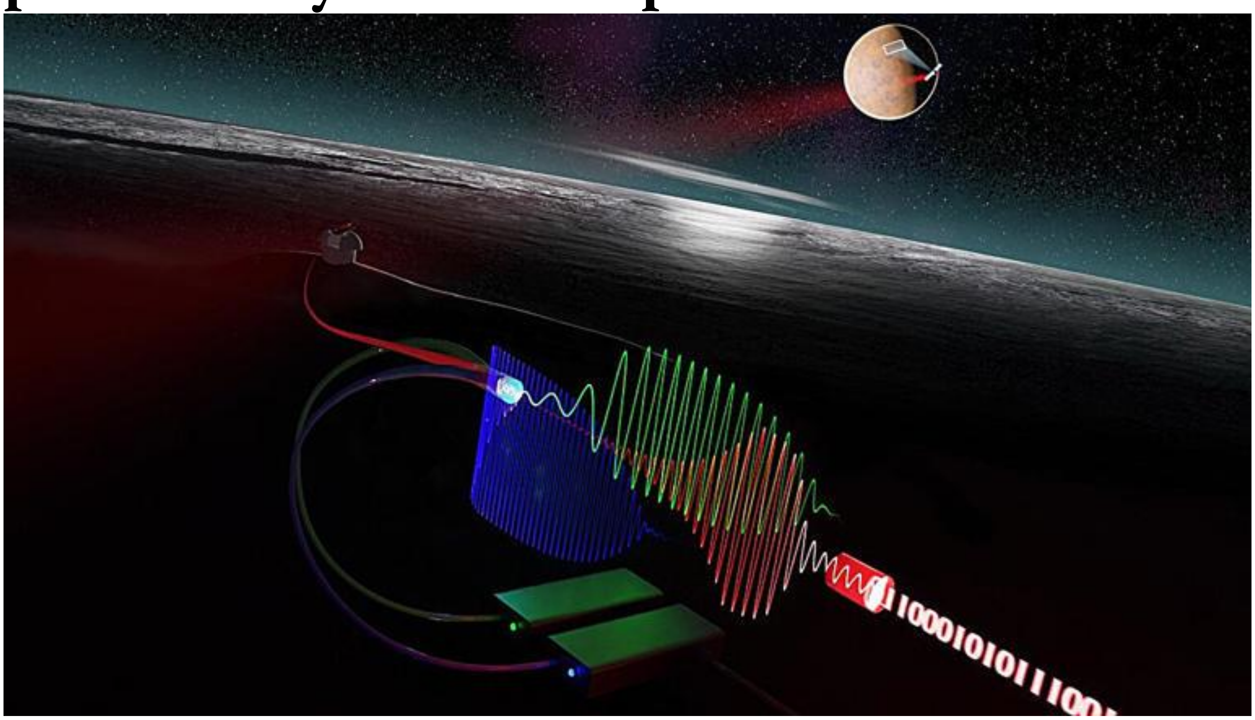
They found a strong presence of carbon and oxygen bands, which is common for AGB remnants, but also the presence of more rare elements such as vanadium and zirconium. Taken altogether, this points to a type of AGB star known as thermally pulsing AGBs, or TP-AGBs.

Many red giant stars enter a pulsing phase at the end of their lives. The hot core swells the outer layers, things cool down a bit, and gravity compresses the star a bit, which heats the core, and the whole process starts over. This study indicates that TP-AGBs are particularly efficient at enriching galaxies, thus confirming the 20-year-old model.

More information: Shiying Lu et al, Strong spectral features from asymptotic giant branch stars in distant quiescent galaxies, *Nature Astronomy* (2024). DOI: 10.1038/s41550-024-02391-9

Provided by Universe Today

Optical amplifier and record-sensitive receiver pave the way for faster space communication



In the new communication system from researchers at Chalmers University of Technology, in Sweden, a weak optical signal (red) from the spacecraft's transmitter can be amplified noise-free when it encounters two so-called pump waves (blue and green) of different frequencies in a receiver on Earth. Thanks to the researchers' noise-free amplifiers in the receiver, the signal is kept undisturbed and the reception on Earth becomes record-sensitive, which in turn paves the way for a more error-free and faster data transmission in space in the future. Credit: Chalmers University of Technology | Rasmus Larsson

In space exploration, long-distance optical links can now be used to transmit images, films and data from space probes to Earth using light. But in order for the signals to reach all the way and not be disturbed along the way, hypersensitive receivers and noise-free amplifiers are required.

Now, researchers at Chalmers University of Technology, in Sweden, have created a system that, with a silent amplifier and record-sensitive receiver, paves the way for faster and improved space communication.

Their study, "Ultralow noise preamplified optical receiver using conventional single wavelength transmission," is [published](#) in *Optica*.

Space communication systems are increasingly based on optical laser beams rather than radio waves, as the signal loss has been shown to be less when light is used to carry information over very long distances. But even information carried by light loses its power during the journey, and optical systems for space communication therefore require extremely sensitive receivers capable of sensing signals that have been greatly weakened before they finally reach Earth.

The Chalmers researchers' concept of optical space communication opens up new communication opportunities—and discoveries—in space.

"We can demonstrate a new system for optical communication with a receiver that is more sensitive than has been demonstrated previously at high data rates. This means that you can get a faster and more error-free transfer of information over very long distances, for example when you want to send high-resolution images or videos from the moon or Mars to Earth," says Peter Andrekson, Professor of Photonics at Chalmers and one of the lead authors of the study.

Silent amplifier with simplified transmitter improves communication

The researchers' communication system uses an optical amplifier in the receiver that amplifies the signal with the least possible noise so that its information can be recycled.

Just like the glow of a flashlight, the light from the transmitter widens and weakens with distance. Without amplification, the signal is so weak after the space flight that it is drowned out by the electronic noise of the receiver.

After 20 years of struggling with disturbing noise that impaired the signals, the research team at Chalmers was able to demonstrate a noise-free optical amplifier a few years ago. But until now, the silent amplifier has not been able to be used practically in optical communication links, as it has placed completely new, significantly more complex, demands on both transmitter and receiver.

Due to the limited resources and minimal space on board a space probe, it is important that the transmitter is as simple as possible.

By allowing the receiver on Earth to generate two of the three light frequencies needed for noise-free amplification, and at the same time allowing the transmitter to generate only one frequency, the Chalmers researchers were able to implement the noise-free amplifier in an optical communication system for the first time. The results show outstanding sensitivity, while complexity at the transmitter is modest.

"This phase-sensitive optical amplifier does not, in principle, generate any extra noise, which contributes to a more sensitive receiver and that error-free data transmission is achieved even when the power of the signal is lower," says Rasmus Larsson, Postdoctoral Researcher in Photonics at Chalmers and one of the lead authors of the study.

"By generating two extra waves of different frequencies in the receiver, rather than as previously done in the transmitter, a conventional laser transmitter with one wave can now be used to implement the amplifier. Our simplification of the transmitter means that already existing optical transmitters on board satellites and probes could be used together with the noise-free amplifier in a receiver on Earth."

Can solve problematic bottleneck

The progress means that the researchers' silent amplifiers can eventually be used in practice in communication links between space and Earth. The system is thus poised to contribute to solving a well-known bottleneck problem among space agencies today.

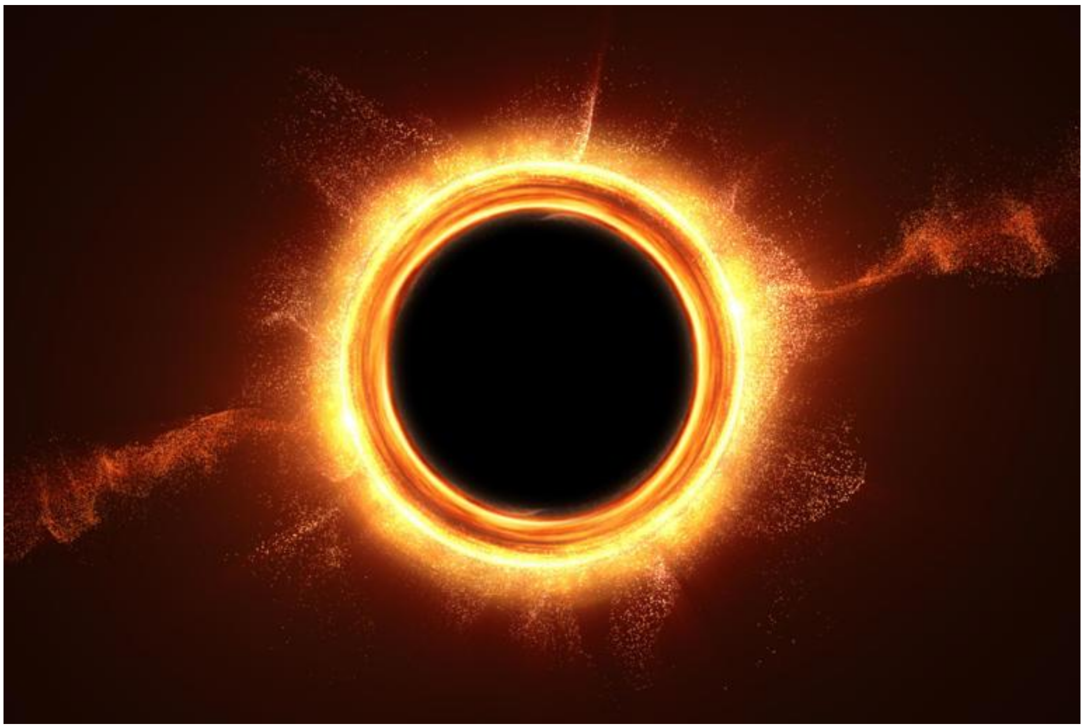
"NASA talks about 'the science return bottleneck,' and here the speed of the collection of scientific data from space to Earth is a factor that constitutes an obstacle in the chain. We believe that our system is an important step forward towards a practical solution that can resolve this bottleneck," says Peter Andrekson.

The next step for the researchers is to test the optical communication system with the implemented amplifier during field studies on Earth, and later also in communication links between a satellite and Earth.

More information: Rasmus Larsson et al, Ultralow-noise preamplified optical receiver using conventional single-wavelength transmission, *Optica* (2024). DOI: 10.1364/OPTICA.539544

Provided by Chalmers University of Technology

A Supermassive Black Hole At The Center Of The Milky Way Was Born From A Cataclysmic Merger With Another Giant Black Hole Billions Of Years Ago



Kittiphat – stock.adobe.com – illustrative purposes only

At the center of the Milky Way, there is a supermassive black hole named Sagittarius A* that is located 26,000 light-years away.

It is 14.6 million miles wide and is four million times the mass of the sun. The black hole spins incredibly fast, at an angle that does not align with the rest of the galaxy.

For a long time, astronomers didn't know why that was, but new data from the Event Horizon Telescope has revealed a clue about the black hole's past.

Billions of years ago, Sagittarius A* was born from a cataclysmic merger with another giant black hole. To this day, it still shows the effects of the aftermath of the collision.

"This discovery paves the way for our understanding of how supermassive black holes grow and evolve," said Yihan Wang, the lead author of the study and an astrophysicist at the University of Nevada, Las Vegas.

"The misaligned high spin of Sgr A* indicates that it may have merged with another black hole, dramatically altering its amplitude and orientation of spin."

Sagittarius A* only consists of 0.0003 percent of the Milky Way's mass. Every so often, it sucks in matter and spits it out at high speeds, shaping our galaxy.

Scientists believe the black hole started out just like any other. It was born from the collapse of a giant star or gas cloud and consumed anything that got too close to it. After expanding to a gargantuan size, it fed on other supermassive black holes.

When whole galaxies merge together, supermassive black holes occur. In the Milky Way's disk, there are bumps and kinks that suggest it collided with at least a dozen galaxies over the past 12 billion years.

However, the importance of black hole mergers is still unclear when it comes to the creation of supermassive black holes. Astronomers also aren't sure whether black holes can grow that large just by consuming dust and gas.

So, to figure out where Sagittarius A* originated, the researchers behind the study used data from the Event Horizon Telescope to construct a model of the black hole's behavior throughout time.

After looking at multiple simulations, the research team found that the black hole's spin was best explained by a merger event with the supermassive black hole of another galaxy.

"This merger likely occurred around 9 billion years ago, following the Milky Way's merger with the Gaia-Enceladus galaxy," Bing Zhang, a co-author of the study and a professor of physics and astronomy at UNLV, said.

Zhang added that the merger supports the idea that black holes can grow larger than ever by consuming other black holes and provides "insights into the dynamic history of our galaxy."

The researchers are now waiting for the construction of space-based gravitational wave telescopes to be completed so they can uncover more evidence of giant black hole mergers across the universe.

The study was published in the journal *Nature Astronomy*.

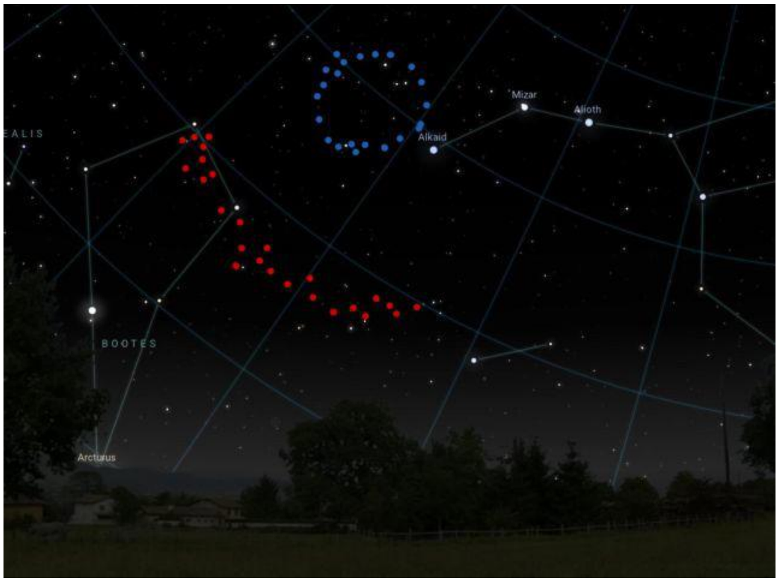
A Giant Structure in Space Challenges Our Understanding of The Universe

A colossal structure in the distant Universe is defying our understanding of how the Universe evolved.

In light that has traveled for 6.9 billion years to reach us, astronomers have found a giant, almost perfect ring of galaxies, some 1.3 billion light-years in diameter. It doesn't match any known structure or formation mechanism.

The Big Ring, as the structure has been named, could mean that we need to amend the standard model of cosmology.

The discovery, led by astronomer Alexia Lopez of the University of Central Lancashire, was presented at the 243rd meeting of the American Astronomical Society in January, and has been published in the *Journal of Cosmology and Astroparticle Physics*.



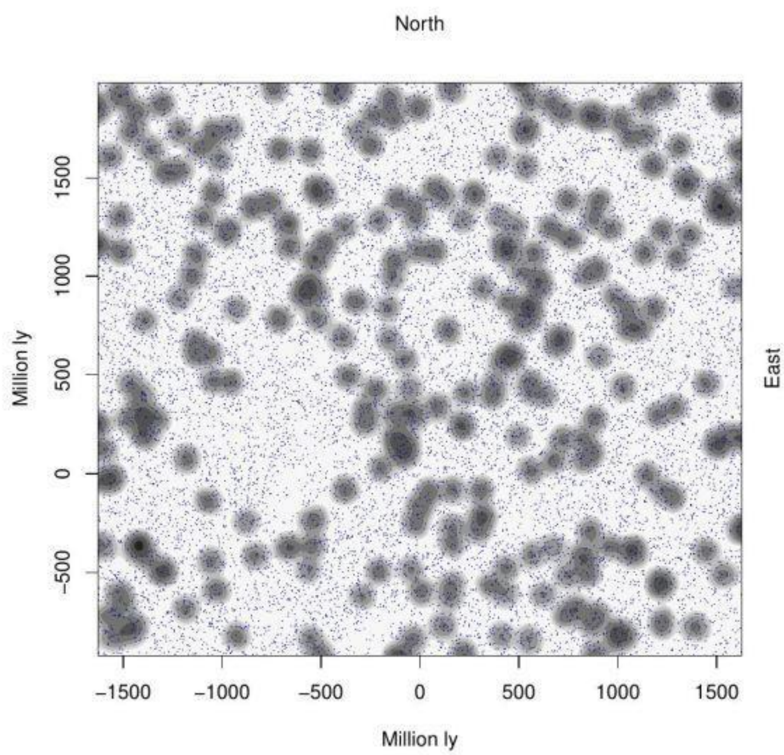
The Big Ring (blue) and Giant Arc (red). (University of Central Lancashire)

It's the second giant structure discovered by Lopez and her colleagues. The first, called the Giant Arc, is actually in the same part of the sky, at the same distance away. When the arc's discovery was announced in 2021, it puzzled astronomers. The Big Ring only deepens the mystery.

"Neither of these two ultra-large structures is easy to explain in our current understanding of the universe," Lopez said in January.

"And their ultra-large sizes, distinctive shapes, and cosmological proximity must surely be telling us something important – but what exactly?"

The most immediate link seems to be with something called a Baryon Acoustic Oscillation (BAO). These are giant, circular arrangements of galaxies found all throughout space. They're actually spheres, the fossils of acoustic waves that propagated through the early Universe, and then froze when space became so diffuse acoustic waves could no longer travel.



A plot of galaxies, showing the Big Ring, roughly centered on 0 on the x-axis. (University of Central Lancashire)

Which leaves the very unanswered question: What the heck is it? And what does it mean for the Cosmological Principle, which states that, in all directions, any given patch of space should look pretty much the same as all other patches of space?

"We expect matter to be evenly distributed everywhere in space when we view the universe on a large scale, so there should be no noticeable irregularities above a certain size," Lopez explained.

"Cosmologists calculate the current theoretical size limit of structures to be 1.2 billion light-years, yet both of these structures are much larger – the Giant Arc is almost three times bigger and the Big Ring's circumference is comparable to the Giant Arc's length."

But the size is just one of the problems. The other is what it means for cosmology, the study of the evolution of the Universe. The current model is the one that currently fits the best with what we observe, but there are some features that are challenging to explain under its framework.

There are other models that have been put forward to address these features. Under one such model, Roger Penrose's conformal cyclic cosmology, in which the Universe goes through endless Big Bang expansion cycles, ring structures are expected – although it's worth noting that conformal cyclic cosmology has significant problems of its own.

Another possibility is that the structures are a type of topological defect in the fabric of space-time known as cosmic strings. These are thought to be like proton-wide wrinkles that emerged in the early Universe as space-time stretched, then froze into place.

We've not found much physical evidence of cosmic strings, but the theoretical evidence is pretty promising.

At the moment, nobody knows for sure what the Big Ring and the Giant Arc signify. They could just be chance arrangements of galaxies twirling across the sky, although the likelihood of that seems pretty small.

The best hope would be to find more such arrangements of galaxies, scattered throughout the Universe, hiding in plain sight.

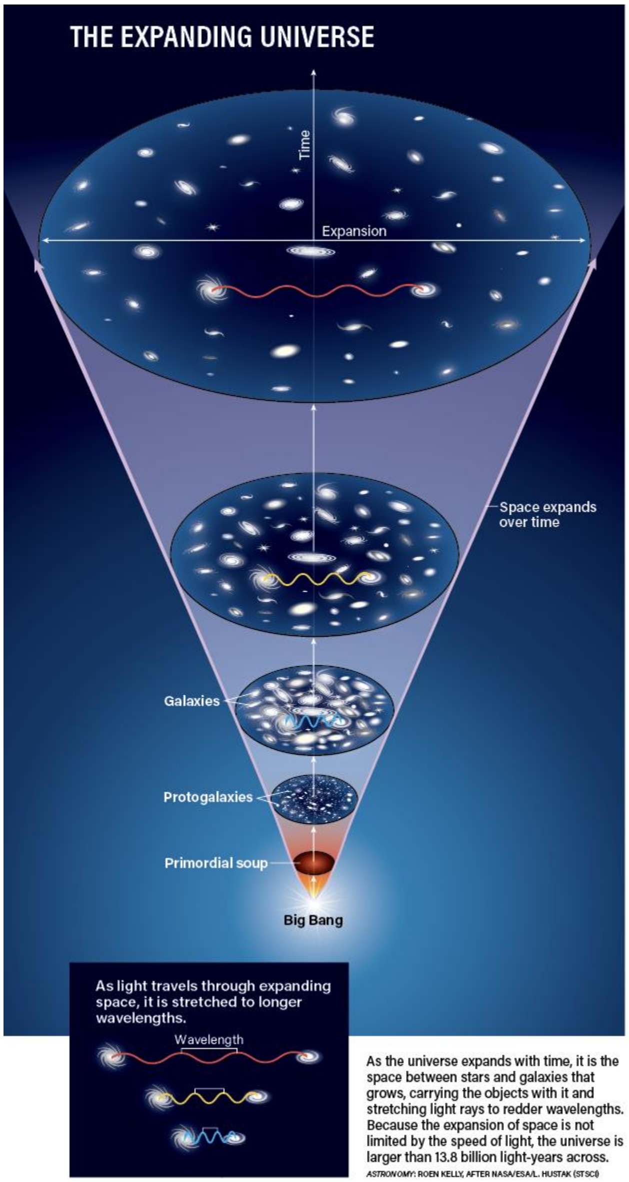
"From current cosmological theories we didn't think structures on this scale were possible," Lopez said.

"We could expect maybe one exceedingly large structure in all our observable Universe. Yet, the Big Ring and the Giant Arc are two huge structures and are even cosmological neighbors, which is extraordinarily fascinating."

The findings are reported in the *Journal of Cosmology and Astroparticle Physics*.

An earlier version of this article was published in January 2024.

How can the visible universe be 46 billion light-years in radius when the universe is only 13.8 billion years old?



How can the visible universe be 46 billion light-years in radius when the universe is only 13.8 billion years old?© Provided by Astronomy

How can the visible universe be 46 billion light-years in radius when the universe is only 13.8 billion years old? And how can we detect light 46 billion light-years away when the universe has been in existence for a fraction of that time?

Joe Murchison

Placerville, California

Astronomers widely accept that the universe formed in the Big Bang approximately 13.8 billion years ago. It has been expanding ever since. This expansion explains how a 13.8-billion-year-old universe can be so much larger than 13.8 billion light-years across.

First of all, we should explain that the light-speed limit that relativity imposes on objects within the universe doesn't apply to the universe itself. In fact, we can't refer to an absolute expansion speed of the universe because we can't measure it in reference to anything external. We can only gauge the "speeds" of distant galaxies that are receding from us relative to our own position. Apart from those that are gravitationally bound (such as, say, the Milky Way and Andromeda galaxies), all galaxies appear to be moving away from each other as the space-time in which they're embedded expands. The more distant the galaxy, the faster its recession velocity, as noted by the Hubble Law. As a consequence of this expansion, a galaxy's location changes considerably during the period of time that its light requires to travel to us.

Let's couch this in human terms: You are tossing a ball to a friend from a set distance, say 50 feet (15 meters). Provided both of you remain stationary (and you aim properly), the ball's 50-foot path will always equal the distance that separates you and your friend. But now let's assume that instead of remaining in place, you back away 10 feet (3 m) each time you toss the ball. In that case, by the time the ball reaches your friend, its travel distance will be less than the distance that now separates the two of you.

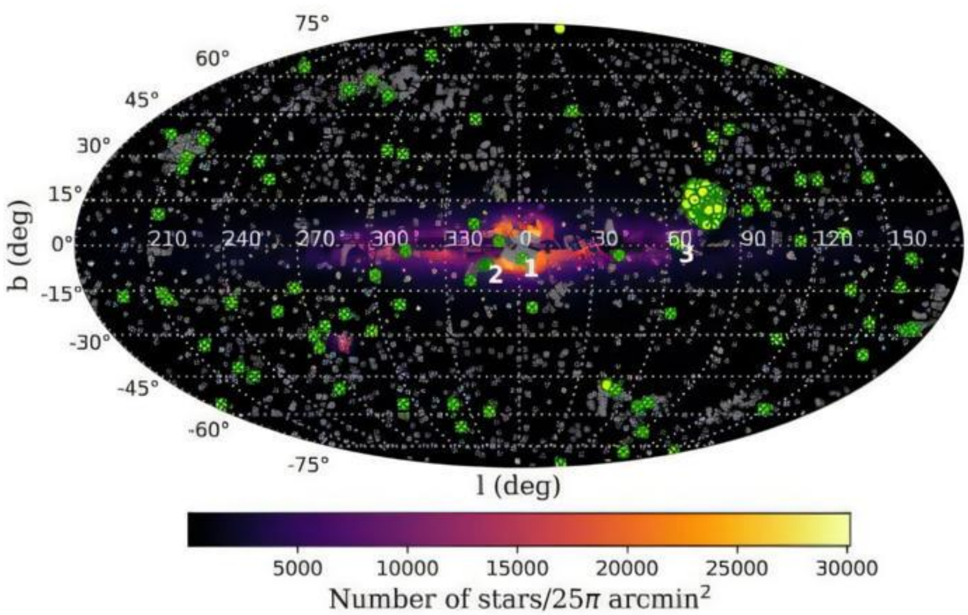
In the same way, the light we're seeing from an object 13 billion light-years away required 13 billion years to move from it to us, but during that period, the amount of space separating us from that object has increased substantially. Calculations show that this expansion would cause the current radius of the universe to be about 46 billion light-years.

Edward Herrick-Gleason

Planetarium Director, Southworth Planetarium,

University of Southern Maine, Portland, Maine

Examining how stellar threats impact the habitable zone of exoplanets



This image from the research shows the sky positions of exoplanet-hosting stars projected on a Molleweide map. HZS are denoted by yellow-green circles, while the remaining population of exoplanets is represented by gray circles. The studied sample of 84 HZS, located within 220 pc of the Sun, is represented by crossed yellow-green circles. The three high-density HZS located near the galactic plane are labeled 1, 2 and 3 in white. The colour bar represents the stellar density, i.e., the number of stars having more than 15 stars within a radius of 5 arc mins. Credit: arXiv (2024). DOI: 10.48550/arxiv.2410.22396

When we think of exoplanets that may be able to support life, we home in on the habitable zone. A habitable zone is a region around a star where planets receive enough stellar energy to have liquid surface water. It's a somewhat crude but helpful first step when examining thousands of exoplanets.

However, there's a lot more to habitability than that.

In a dense stellar environment, planets in habitable zones have more than their host star to contend with. Stellar flybys and exploding supernovae can eject habitable zone exoplanets from their solar systems and even destroy their atmospheres or the planets themselves.

New research examines the threats facing the habitable zone planets in our stellar neighborhood. The study is titled "The 10 pc Neighborhood of Habitable Zone Exoplanetary Systems: Threat Assessment from Stellar Encounters & Supernovae," and it has been accepted for publication in *The Astronomical Journal*. It currently appears on the *arXiv* preprint server. The lead author is Tisyagupta Pyne from the Integrated Science Education And Research Center at Visva-Bharati University in India.

The researchers examined the 10-parsec regions around the 84 solar systems with habitable zone exoplanets. Some of these habitable zone systems (HZS) face risks from stars outside of the solar systems. How do these risks affect their habitability? What does it mean for our notion of the habitable zone?

"Among the 4,500+ exoplanet-hosting stars, about 140+ are known to host planets in their habitable zones," the authors write. "We assess the possible risks that the local stellar environment of these HZS pose to their habitability."

We have more than 150 confirmed exoplanets in habitable zones, and as exoplanet science advances, scientists are developing a more detailed understanding of what "habitable zone" means. Scientists increasingly use the terms "conservative habitable zone" and "optimistic habitable zone."

The optimistic habitable zone is defined as regions that receive less radiation from their star than Venus received 1 billion years ago and more than Mars did 3.8 billion years ago. Scientists think that recent Venus (RV) and early Mars (EM) both likely had surface water.

The conservative habitable zone is a more stringent definition. It's a narrower region around a star where an exoplanet could have surface water. It's defined by an inner runaway greenhouse edge where stellar flux would vaporize surface water and an outer maximum greenhouse edge where the greenhouse effect of carbon dioxide is dominated by Rayleigh scattering.

Those are useful scientific definitions as far as they go. But what about habitable stellar environments? In recent years, scientists have learned a lot about how stars behave, the characteristics of exoplanets, and how the two are intertwined.

"The discovery of numerous extrasolar planets has revealed a diverse array of stellar and planetary characteristics, making systematic comparisons crucial for evaluating habitability and assessing the potential for life beyond our solar system," the authors write.

To make these necessary systematic comparisons, the researchers developed two metrics: the Solar Similarity Index (SSI) and the Neighborhood Similarity Index (NSI). Since main sequence stars like our sun are conducive to habitability, the SSI compares our solar system's properties with those of other HZs. The NSI compares the properties of stars in a 10-parsec region around the sun to the same size region around other HZSs.

These indices put habitable zones in a larger context.

"While the concept of HZ is vital in the search for habitable worlds, the stellar environment of the planet also plays an important role in determining longevity and maintenance of habitability," the authors write. "Studies have shown that a high rate of catastrophic events, such as supernovae and close stellar encounters in regions of high stellar density, is not conducive to the evolution of complex life forms and the maintenance of habitability over long periods."

When radiation and high-energy particles from a distant source reach a planet in a habitable zone, they can cause severe damage to Earth-like planets. Supernovae are a dangerous source of radiation and particles, and if one were to explode close enough to Earth, that would be the end of life. Scientists know that ancient supernovae have left their mark on Earth, but none of them were close enough to destroy the atmosphere.

"Our primary focus is to investigate the effects of SNe on the atmospheres of exoplanets or exomoons assuming their atmospheres to be Earth-like," the authors write.

The first factor is stellar density. The more stars in a neighborhood, the greater the likelihood of supernova explosions and stellar flybys.

"The astrophysical impacts of the stellar environment is a 'low-probability, high-consequence' scenario for the continuation of habitability of exoplanets," the authors write. Though disruptive events like supernova explosions or close stellar flybys are unlikely, the consequences can be so severe that habitability is completely eliminated.

When it came to the supernova threat, the researchers looked at high-mass stars in stellar neighborhoods since only massive stars explode. Pyne and her colleagues found high-mass stars with more than eight solar masses in the 10-parsec neighborhoods of two HZS: TOI-1227 and HD 48265.

"These high-mass stars are potential progenitors for supernova explosions," the authors explain.

Only one of the HZS is at risk of a stellar flyby. HD 165155 has an encounter rate of ≥1 in 5 Gyr period. That means it's at greater risk of an encounter with another star that could eject planets from its habitable zone.

The team's pair of indices, the SSI and the NSI, produced divergent results: "... we find that the stellar environments of the majority of HZS exhibit a high degree of similarity (NSI> 0.75) to the solar neighborhood," the researchers explain. However, because of the wide variety of stars in HZS, comparing them to the sun results in a wide range of SSI values.

We know the danger supernova explosions pose to habitability. The initial burst of radiation could kill anything on the surface of a planet too close. The ongoing radiation could strip away the atmospheres of some planets further away and could also cause DNA damage in any lifeforms exposed to it.

For planets that are further away from the blast, the supernova could alter their climate and trigger extinctions. There's no absolutely certain understanding of how far away a planet must be to avoid devastation, but many scientists say that within 50 light-years, a planet is probably toast.

We can see the results of some of the stellar flybys the authors are considering. Rogue planets, or free-floating planets (FPPs), are likely in their hapless situations precisely because a stellar interloper got too close to their HZS and disrupted the gravitational relationships between the planets and their stars.

We don't know how many of these FPPs are in the Milky Way, but there could be many billions of them. Future telescopes like the Nancy Grace Roman Space Telescope will help us understand how many there truly are.

Habitability may be fleeting, and our planet may be the exception. It's possible that life appears on many planets in habitable zones but can't last long due to various factors. From a great distance away, we can't detect all the variables that go into exoplanet habitability.

However, we can gain an understanding of the stellar environments in which potentially habitable exoplanets exist, and this research shows us how.

More information: Tisyagupta Pyne et al, The 10 pc Neighborhood of Habitable Zone Exoplanetary Systems: Threat Assessment from Stellar Encounters & Supernovae, *arXiv* (2024). DOI: 10.48550/arxiv.2410.22396

Provided by Universe Today

Traces Of The Milky Way's Original Disk Show Our Galaxy Is Unexpectedly Ancient

The galaxy J04542829-6625280 bears a considerable resemblance to the Milky Way, but may have developed through a quite different path. - Image Credit: NASA/Goddard Space Flight Center© IFL Science

A population of stars more than 13 billion years old represents the original disk from which the Milky Way formed, a team of astronomers claim. By studying this population's movements, the authors have reconstructed what they think is the shape of the proto-Milky Way, which they say is a relatively unusual starting point for galaxies like ours.

Our Milky Way galaxy is no giant, but it is much larger than the average galaxy in our part of the universe, a status it has achieved by consuming smaller collections of stars. The Gaia Space Telescope's mapping of millions of stars' locations and movements has enabled astronomers to detect collections of stars that were once part of these cannibalized galaxies, even when they have long been separated from their companions.

As impressive as this is, the ultimate step in understanding our galaxy's development is to identify the original disk structure the Milky Way developed, before all these subsequent events. That's a challenge since all the most massive, and therefore brightest, stars from that time have long since burned out. Moreover, the smaller stars that have survived would be well mixed.

Nevertheless, a team led by Dr Maosheng Xiang of the Chinese Academy of Sciences think they have done it, tracking the galaxy's oldest stars and identifying differences between those more than 13 billion years old, and the relative youngsters born after 12.5 billion years ago. They have named the disk containing the 13+ billion-year-old stars PanGu.

Astronomers are on a quest to identify when the first stars appeared, but it was probably within 400 million years of the Big Bang, ie about 13.4 billion years ago. However, these early stars were not necessarily part of well-structured galaxies, instead being just dots of light within relatively amorphous gas. The Milky Way's original structure has been thought to have emerged 12.5 billion years ago.

Xiang and colleagues challenge that. They argue that PanGu had stars with a combined mass of about 3.7 billion times the Sun's, produced at a relatively steady rate over several hundred million years. Of these, 2.2 billion solar masses survive, the rest having blown up in supernova explosions, with 2 billion still in the disk. That represents just 0.2 percent of the Milky Way's current mass, but is much more than dwarf galaxies such as the Sagittarius Dwarf Galaxy.

The team concludes the Milky Way achieved a peak in star formation around 11 billion years ago, when it was making new stars with a combined mass of 11 Suns each year. That's a rather unusual path for galaxies that end up looking like our own, they say.

Previous studies of galaxy development showed a marked change around 8 billion years ago. Stars formed before that time have distinctly different chemistry and paths from those formed more recently. Breaking down those early stars into finer subgroups has been more difficult. If Xiang and colleagues are right, the majority of those early stars were formed during the peak they identified 11 billion years ago.

The component stars' motion suggests the original disk wasn't all that disk-shaped, starting out almost as high as it was wide. However, over time it flattened down to around a 10th of its original height, while barely changing in length and width.

Simulations suggest most early galaxy development occurs through violent mergers that disrupt the formation of well-structured disks, but that doesn't seem to have been the case for the Milky Way. Similarly, attempts to trace the formation of spiral galaxies like our own indicate that less than one-sixth followed a similar path, the rest having suffered greater disruption.

The Sun did not form until long after these early developments had passed. We're not aware of any way they could have left an imprint on the galaxy that led to different outcomes for us and our star compared to formation in a galaxy with a more violent history. Nevertheless, this is not a topic that is currently well understood.

PanGu is a doubly appropriate name. Individually, the character Pan means disk and Gu means old. Meanwhile, PanGu was a god in Chinese mythology responsible for separating heaven and Earth.

The paper is open access in Nature Astronomy.

Breaking the Limits: New Supermassive Black Hole Defies Theories

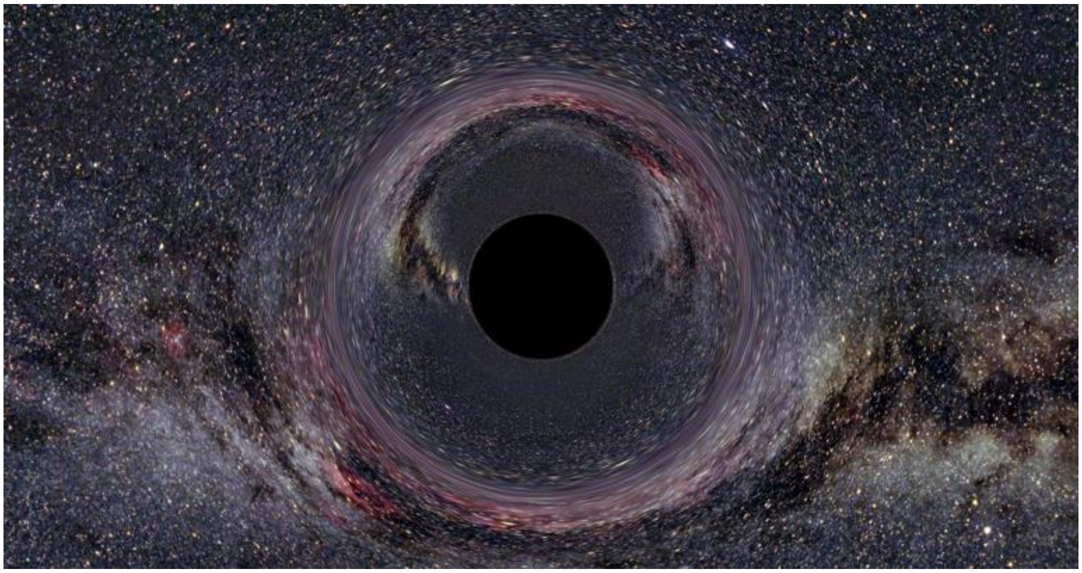


Photo: Wikimedia Commons© Photo: Wikimedia Commons

Astronomers have discovered a supermassive black hole in a distant galaxy that is defying conventional understanding.

Growing 40 times faster than current theories allow, this discovery could reshape our knowledge of how black holes form and evolve — especially in the early universe. This was reported by *Illustrated Science*.

The black hole, dubbed LID-568, was identified by astronomers at the Gemini Observatory using the James Webb Space Telescope's NIRSpec instrument.

This rapid growth rate challenges the Eddington limit, a theoretical cap on how quickly black holes can absorb matter.

According to this limit, outward radiation pressure from a black hole's core should counteract gravitational pull, preventing excessive growth.

Also read

[Galaxy Similar to Milky Way Discovered Where it Shouldn’t Exist]

Yet, LID-568 somehow bypasses this restriction, raising questions about how black holes might have developed during the universe's formative years.

"This discovery of a supermassive black hole in the early universe challenges our current models of black hole formation and growth," said Hyewon Suh, an astronomer at the Gemini Observatory.

Black Holes in Three Classes

Astronomers categorize black holes into three general mass classes:

- **Stellar-mass black holes** (lightweight), formed from collapsing stars, range from about three to 100 solar masses.
- **Intermediate black holes** (medium), with masses between 100 and one million solar masses, are difficult to locate but could represent a transitional phase between stellar-mass and supermassive black holes.
- **Supermassive black holes** (heavyweight), found at the center of galaxies like the Milky Way, range from millions to billions of solar masses, though their formation process remains mysterious.

The discovery of LID-568 suggests that certain black holes may have mechanisms allowing them to surpass known growth limits. This insight could be crucial in understanding the origins and evolution of supermassive black holes.

"While we don’t yet know how LID-568 crosses the Eddington limit, further investigation is planned with Webb to gather more data," Suh noted. This research could provide new clues to the complex puzzle of black hole growth in the early cosmos.

3D map reveals our solar system's local bubble has an 'escape tunnel'

Using data from the eROSITA All-Sky Survey, astronomers have created a 3D map of the low-density bubble of X-ray-emitting, million-degree hot gas that surrounds the solar system.

The investigation has revealed a large-scale temperature gradient within this bubble, called the Local Hot Bubble (LHB), meaning it contains both hot and cold spots. The team suspects that this temperature gradient may have been caused by exploding massive stars detonating in supernovas, causing the bubble to be reheated. This reheating would cause the pocket of low-density gas to expand.

The researchers also found what seems to be an "interstellar tunnel," a channel between stars directed towards the constellation Centaurus. This tunnel may link the solar system's home bubble with a neighboring superbubble and could have been carved out by erupting young stars and powerful and high-speed stellar winds.

Scientists have been aware of the LHB concept for at least five decades. This cavity of low-density gas was first suggested to explain background measurements of relatively low-energy, or "soft," X-rays. These photons, with an energy of around 0.2 electronvolts (eV), can't travel very far through interstellar space before being absorbed.

The fact that our immediate solar neighborhood is devoid of large quantities of interstellar dust that could emit these photons suggested the existence of soft X-ray emitting plasma that displaces neutral materials around the solar system in a "Local Hot Bubble." Thus, theories of the LHB were born.

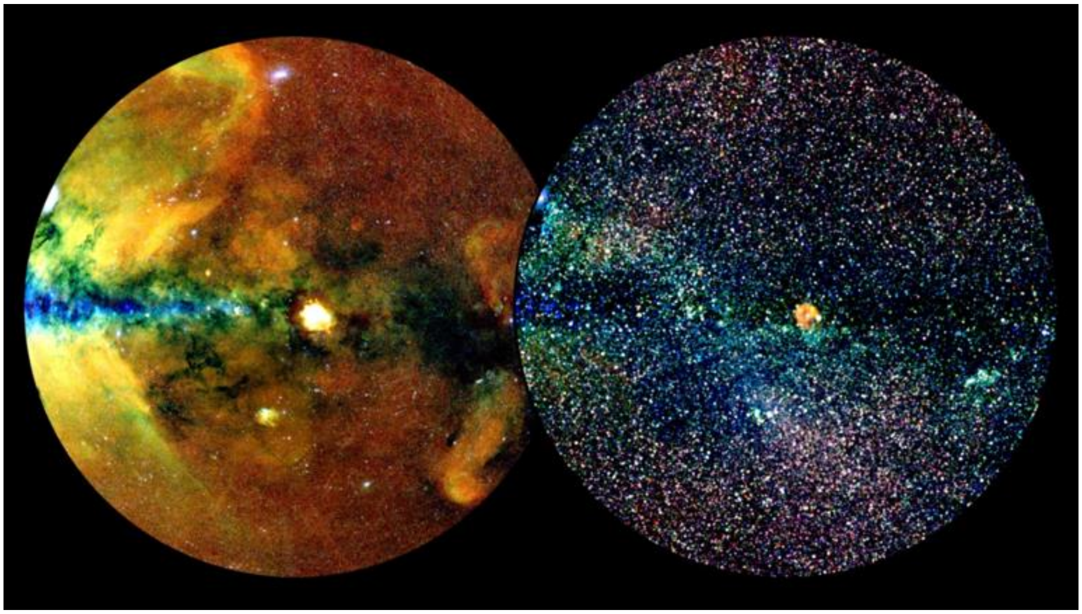
One of the major problems with this theory emerged in 1996, when scientists found that exchanges between the solar wind, a stream of charged particles blown out by the sun, and particles in Earth's "geocorona," the outermost layer of our planet's atmosphere, emit X-ray photons with energies similar to those proposed to originate from the LHB.

Understanding the solar system's local bubble

The eROSITA telescope, the primary instrument of the Spectrum-Roentgen-Gamma (SRG) mission launched in 2019, is the ideal instrument to tackle this conundrum. At 1 million miles (1.5 million kilometers) from Earth, eROSITA is the first X-ray telescope to observe the universe from outside Earth's geocorona, meaning potential X-ray "noise" can be ruled out of observations of photons from the LHB.

Additionally, eROSITA's All-Sky Survey (eRASS1) collected data during a lull in the sun's 11-year solar cycle when solar winds are weak, called the "solar minimum." This reduced the amount of contamination coming from solar wind exchange.

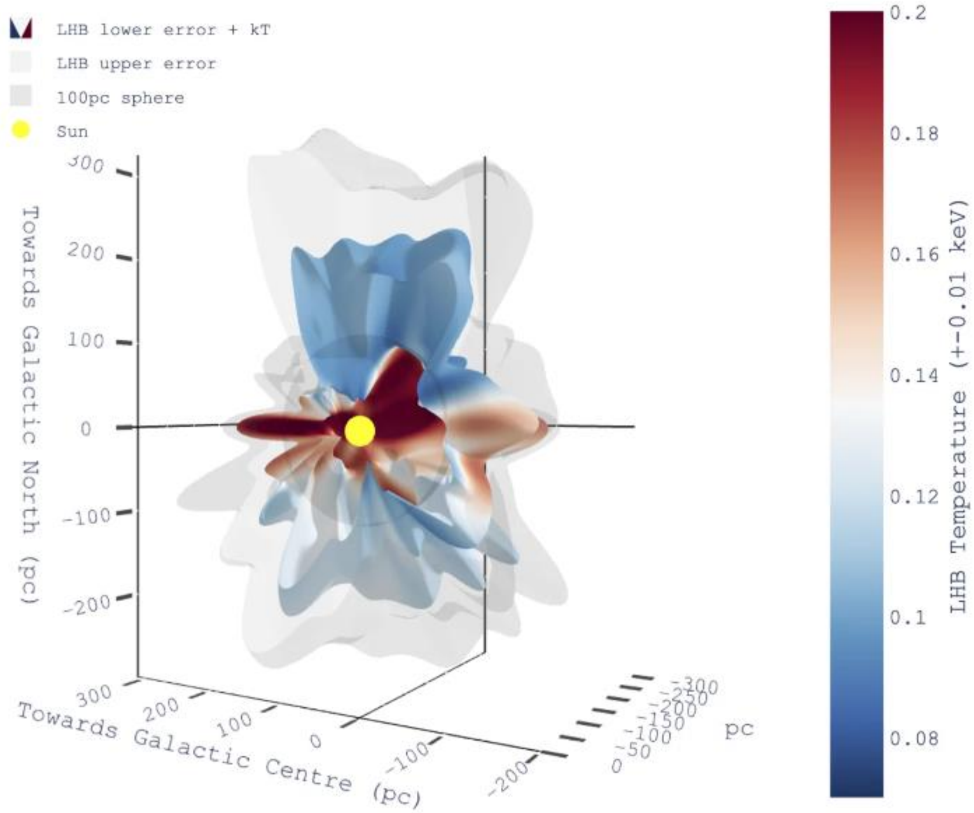
"In other words, the eRASS1 data released to the public this year provides the cleanest view of the X-ray sky to date, making it the perfect instrument for studying the LHB," team leader Michael Yeung, a researcher at Max Planck Institute of Physics (MPE), said in a statement.



Two versions of eRosita All-Sky Survey Catalogue (eRASS1) data (Right) the X-ray sky over earth (right) X-ray sources. (Image credit: MPE, J. Sanders für das eROSITA-Konsortium)© Provided by Space

After dividing the hemisphere of the Milky Way into 2,000 distinct regions, Yeung and colleagues analyzed the light from all these regions. What they discovered was a clear disparity in temperatures in the LHB, with the Galactic North cooler than the Galactic South.

The same team had already established that the hot gas of the LHB is relatively uniform in terms of its density. Comparing this to the gas in cool and dense molecular clouds at the edge of the LHB, the team was able to create a detailed 3D map of the LHB.



3D structure of the Milky Way's local bubble created using data from eROSITA. (Image credit: Michael Yeung/MPE)

This revealed that the LHB is stretched toward the poles of the galactic hemisphere. Hot gas expands in the direction that offers the least resistance, which, in this case, is away from the galactic disk. Thus, this wasn't a huge surprise to the researchers as it is also finding that had been revealed by eROSITA's predecessor, ROSAT, around 3 decades ago.

But, the new 3D map did reveal something hitherto unknown.

"What we didn't know was the existence of an interstellar tunnel towards Centaurus, which carves a gap in the cooler interstellar medium," team member and MPE physicist Michael Freyberg said in the statement. "This region stands out in stark relief thanks to the much-improved sensitivity of eROSITA and a vastly different surveying strategy compared to ROSAT."

The nebula L1527 and its erupting protostar put on a celestial fireworks display, captured by the JWST. Feedback like this could help carve out a network of "tunnels" between stars. (Image credit: NASA, ESA, CSA, STScI)

Excitingly, the team suspects that the Centaurus tunnel in the LHB may just be a part of a network of hot gas tunnels that bore their way between the cool gas of the interstellar medium between stars.

This interstellar medium network would be maintained and sustained by the influence of stars in the form of stellar winds, the supernovas that mark the death of massive stars, and jets blasting out from newly formed stars or "protostars."

These phenomena are collectively referred to as "stellar feedback," and they are believed to sweep across the Milky Way, thereby shaping it.

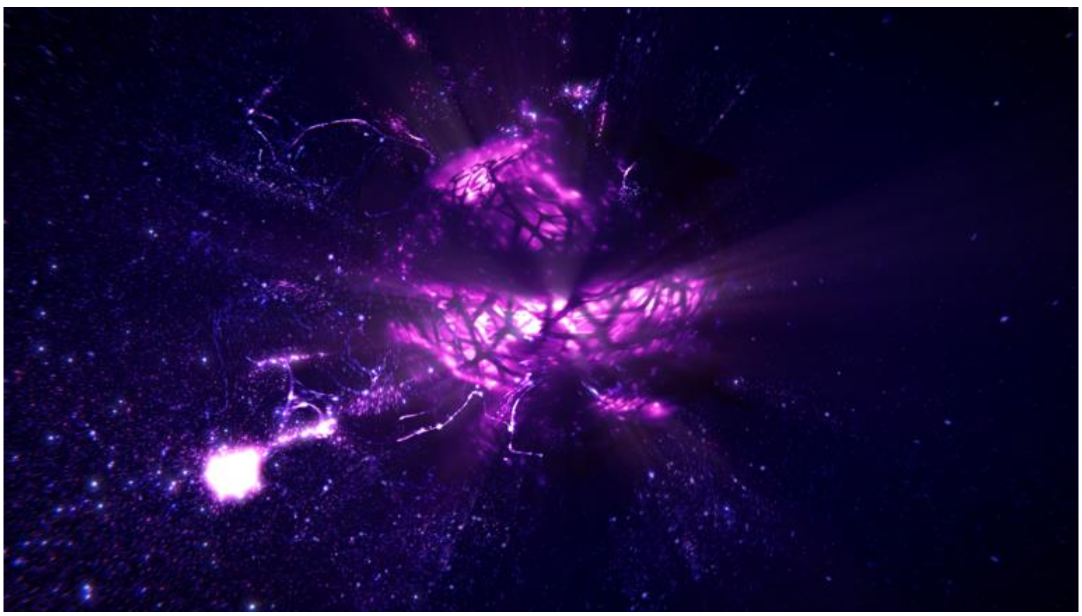
In addition to the 3D map of the LHB, the team also created a census of supernova wreckage, superbubbles, and dust, which they incorporated into the map to build a 3D interactive model of the solar system's cosmic neighborhood.

This included another previously known interstellar medium tunnel called the Canis Majoris tunnel. This is thought to stretch between the LHB and the Gum nebula or between the LHB and GSH238+00+09, a more distant superbubble.

They also mapped dense molecular clouds at the edge of the LHB that are racing away from us. These clouds could have been built when the LHB was "cleared" and denser material was swept to its extremities. This could also give a hint as to when the sun entered this local low-density bubble.

"Another interesting fact is that the sun must have entered the LHB a few million years ago, a short time compared to the age of the sun [4.6 billion years]," team member and MPE scientist Gabriele Ponti said. "It is purely coincidental that the sun seems to occupy a relatively central position in the LHB as we continuously move through the Milky Way."

Rare glimpse of 'ghostly' neutrino fog detected by dark matter experiments in a first



Rare glimpse of 'ghostly' neutrino fog detected by dark matter experiments in a first

Do you know which are the most abundant particles in the universe? It is neutrinos — small, chargeless, and nearly massless subatomic particles that either don't interact with matter at all or interact very weakly.

They are so lightweight that even an electron is six million times heavier than a neutrino. Also, since they barely interact with matter, they have the uncanny ability to pass through any object without being detected. This is why they're also called ghost particles.

However, for the first time, two dark matter experiments have detected a neutrino fog, a dense cloud of neutrinos. This discovery is reported by researchers from XENON and PandaX — two scientific experiments that aim to detect dark matter, operating independently in Italy and China respectively.

"This is the first measurement of astrophysical neutrinos with a dark matter experiment," Fei Gao, a scientist involved in the Xenon experiment, said.

Spotting a cloud of neutrinos

Neutrinos are typically detected through coherent elastic neutrino-nucleus scattering (CEvNS), a process in which neutrinos interact with the entire nucleus rather than just a proton or electron.

This wholesome interaction distributes the neutrino's energy evenly across the nucleus, causing it to recoil. Scientists then measure the energy from the CEvNS process to detect the presence of neutrinos.

Generally, CEvNS detection involves the use of particle accelerators. However, a much weaker CEvNS signal from solar neutrinos, rather than those produced by accelerators, is observed by both the PandaX and XENON experiments.

Both these dark matter experiments use liquid xenon detectors to look for dark matter particles or neutrinos by studying how these particles interact with xenon atoms within the liquid. This allows them to potentially detect even faint signals from these elusive particles.

During their study, the researchers went through two years of data from the experiments. Their analysis revealed CEvNS signals from the radioactive beta decay of Boron-8 in the Sun's core.

While the XENON team reported 11 CEvNS signals, PandaX identified 75 signals. However, the statistical confidence (reliability of the results) for both experiments was almost similar i.e. 2.64 sigma (for PandaX) and 2.73 sigma (for XENON).

"I think that most people, including myself, are pretty confident that both collaborations have measured the neutrino fog," Kate Scholberg, a professor of physics at Duke University, said.

This makes the search for dark matter more challenging

While neutrino fog detection via dark matter experiments is fascinating, the presence of dense neutrino clouds around the dark matter makes our quest for the mysterious and elusive dark matter more difficult.

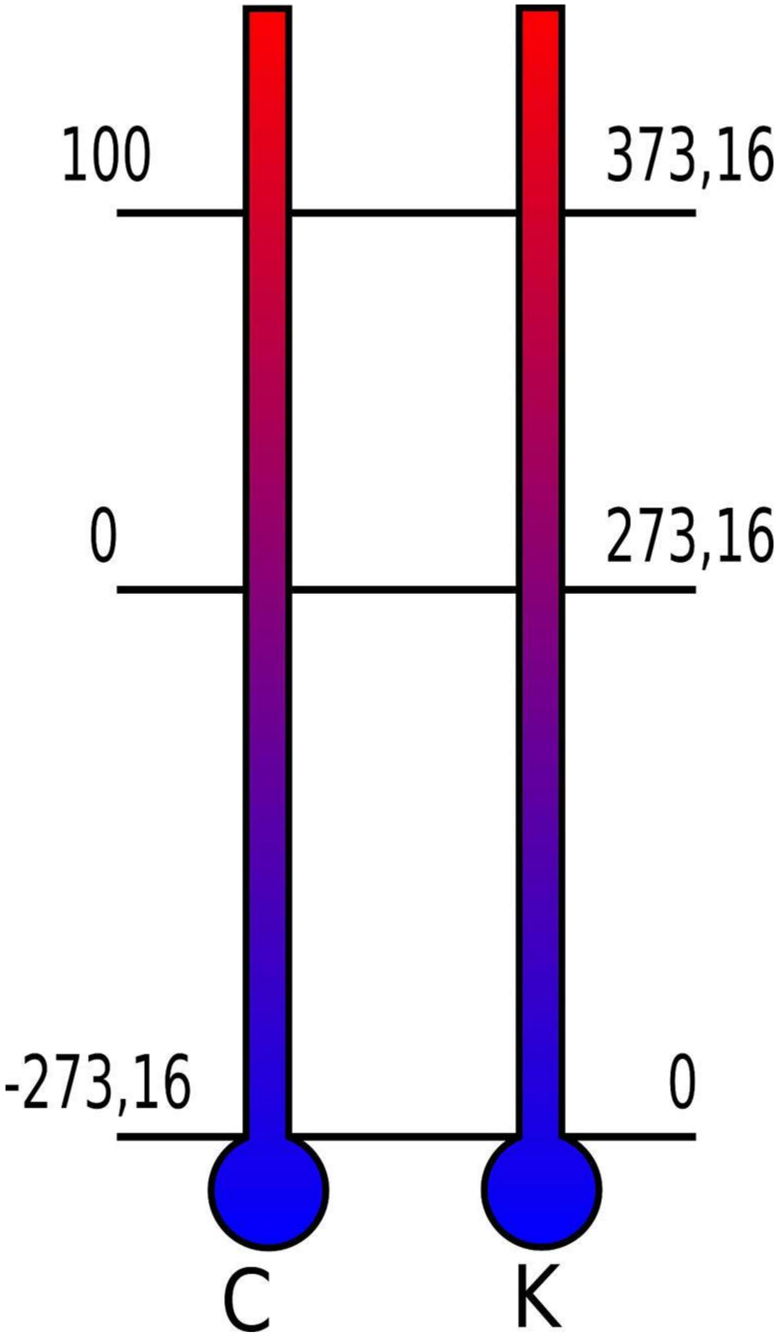
This is because neutrinos are themselves hardly detectable. Their abundant presence in the universe can create background noise that can derail the attempts to detect dark matter.

For instance, in experiments designed to find dark matter, such as those looking for rare interactions with nuclei, the neutrinos in the fog can produce signals that resemble those from dark matter interactions, making it harder to distinguish between the two.

However, "The perceived 'existential threat' posed by the neutrino fog is likely overstated. There is still a lot to be done before this background prevents us from making further progress," Elisabetta Barberio, who wasn't involved in any of the experiments but is an expert in dark matter particle physics at the University of Melbourne, said.

The PandaX and XENON studies are published in the journal *Physical Review Letters*.

Lord Kelvin: How the 19th century scientist combined research and innovation to change the world



Credit: Pixabay/CC0 Public Domain

"What got you into astrophysics?" It's a question I'm often asked at outreach events, and I answer by pointing to my early passion for exploring the biggest questions about our universe. Well, along with seeing Star Wars at an impressionable age.

This fascination with the fundamental is a well-trodden path for many budding scientists. Learning about mindboggling fields such as general relativity, which describes the universe on large scales, and quantum physics, which rules the microworld of atoms and particles, can be a powerful way to stimulate young minds.

For many others, however, the road to physics (like hell) is paved with good intentions. What drives their passion is not so much the esoteric secrets of the cosmos, but applying the latest science to solve societal problems and global challenges—from health inequalities to the climate emergency. Both motivations are valid, maybe even essential, helping to form a virtuous circle between "blue sky" research and innovation.

Yet this dual-track approach to research and innovation—core to the contemporary mission of research councils and funding agencies across the globe—isn't as modern as it may seem. This year marks the bicentenary of the birth of William Thomson, aka Lord Kelvin, arguably the most influential scientist of the 19th century, and perhaps beyond. He was a master at combining fundamental discovery with societal and commercial impact.

Cornerstone of physics

Thomson was professor of natural philosophy at Glasgow University for 53 years, making revolutionary contributions to physics, mathematics and engineering that still resonate today.

He is probably best known for his work on energy and the laws of thermodynamics, the science of heat and work, which are often hailed as the most unbreakable laws of nature. The British astrophysicist Arthur Eddington is reported to have declared in the 1920s that thermodynamics holds "the supreme position among the laws of nature", adding: "If your theory is found to be against the second law of thermodynamics I can give you no hope; there is nothing for it but to collapse in deepest humiliation."

Thermodynamics still plays a central role in modern physics, underpinning research in information science, quantum mechanics, cosmology and even theories of life and consciousness. In fact, it is as much a cornerstone of modern physics as general relativity and quantum mechanics. Any final "theory of everything" will need to be consistent with the laws of thermodynamics.

Perhaps Thomson's most well known discovery is the concept of absolute zero on the temperature scale, which is named Kelvin in honor of the title he would receive in 1892. But when we look beyond his work on thermodynamics, his achievements are remarkable not just for their breadth, but also for their diversity. They range from theoretical breakthroughs addressing the biggest research questions of the day to practical inventions driving industrial and commercial innovation.

Kelvin's key attributes

What made Thomson so successful? There are three key aspects of his approach to research and discovery that I believe marked him out as a scientist for the ages.

First, there was his outstanding mathematical prowess. This allied with his deep appreciation of the power of math for explaining the natural world—a power upon which he drew heavily throughout his career. This is captured in a profound quote that has been attributed to Thomson: "The fact that mathematics does such a good job of describing the universe is a mystery that we don't understand, and a debt that we will probably never be able to repay."

But Thomson was much more than a mathematician par excellence. He also understood that precise measurement and quantification were essential tools for scientific progress—an idea we find expressed in his 1889 book Popular Lectures and Addresses. "When you can measure what you are speaking about and express it in numbers you know something about it," he wrote.

Thomson's lifelong talent for inventing ingenious scientific instruments secured him 70 patents, enabled dozens of scientific breakthroughs and made him a highly successful entrepreneur.

Third, there was Thomson's outstanding ability to think "out of the box", to look at a problem in a completely novel way. For me, there is no better example of that visionary thinking than Thomson's work on laying the first transatlantic telegraph cable. This was an immense technological challenge that has been described as the "Apollo project" of the 1800s.

It revolutionized the Victorian world as profoundly as the internet and mobile communications have changed ours.

After failed attempts in the 1850s, Thomson's genius was instrumental (quite literally) to the first successful cable-laying expedition in 1865. His understanding of the similarities between heat transfer and electrical transport allowed Thomson to model how electrical impulses would be distorted as they traveled along undersea cables.

But Thomson's experimental breakthroughs were also key. Instead of using a stronger signal, requiring a much heavier and costlier cable, he invented instruments that could precisely measure extremely weak electrical signals, transmitted as Morse code. They were known as the mirror galvanometer and, later, the siphon recorder. These were essentially a precursor of a modern inkjet printer.

These inventions were game-changers and, as a result, global communications were transformed for ever. As my late colleague David Saxon wrote in 2007, "the transatlantic cable shrank the world more than anything before or since."

For all of this, Thomson was first knighted in 1866, then later ennobled as Lord Kelvin in 1892—the first ever scientist so honored. And Thomson's elegant combination of ultra-precision technology and cutting-edge theory to detect extremely faint signals resonates strongly with the story of our LIGO laser interferometers, the most sensitive scientific instruments ever built. It was just such a combination that enabled the 2015 Nobel prizewinning discovery of ripples in spacetime known as gravitational waves.

The science and technology of black holes and gravitational waves belong firmly to the post-Kelvin domain of Einsteinian physics. But I believe that domain—and the transformative quantum technology it has enabled—draws inspiration from the pioneering example of William Thomson, who combined fundamental research and innovation to change the world.

The ultimate cosmic question: How fast is the universe expanding?

The universe is expanding. But how fast? Why is this happening? And what will be the universe's ultimate fate?

These are big, literally cosmic questions, and astronomers continue to struggle to nail down the answers. Different techniques for measuring what is called the Hubble Constant — the rate at which the universe is expanding — keep coming up with different estimates.

The cosmologists have given a name to this conundrum: the Hubble Tension.

In August, a research paper from University of Chicago astronomers, posted online and not yet peer-reviewed, reported that three observational techniques had produced estimates for the Hubble Constant ranging from 68 to 72 kilometers per second per megaparsec.

Days later, another research team led by cosmologist Adam Riess, a Nobel laureate at Johns Hopkins University, posted online a paper estimating the Hubble Constant at 73.

These numbers may seem, to the average nonscientist, close enough. Not for cosmologists — and certainly not for Riess, who has devoted his career to measuring the cosmic expansion.

“We're stuck,” Riess said on a recent morning in his Johns Hopkins office, where he keeps a replica of the gold medal he was given in Stockholm.

The Hubble Tension flared in the past decade. One observational technique is based on analysis of the oldest light in the universe, known as the Cosmic Microwave Background radiation, or CMB. That analysis estimated the Hubble Constant at 67.

But Riess and his colleagues used the Hubble Space Telescope to study exploding stars (supernovae) in distant galaxies and came up with the speedier estimate of 73, and more recent observations by the James Webb Space Telescope reached a similar result.

The lead author of the University of Chicago paper, Wendy Freedman, said the Hubble Tension may be no big deal, that the scientific community may merely need to improve the way it estimates the distances between galaxies and thus the speed they recede from one another. If that happens, the Hubble Tension could be resolved without the requirement of revolutionary theories.

“We really will get to the bottom of this,” Freedman vows.

The debate — the tension — is simultaneously esoteric and fundamental. It’s esoteric in that the universe evolves on billion-year time scales. The Hubble Constant has no effect on any human being. Cosmic expansion occurs in intergalactic space, not down here on the ground where we all live. “Who cares?” is a reasonable reaction to this entire discussion.

But physicists and cosmologists care very much, because it concerns the fundamental nature of the universe. If the scientists can’t reconcile their estimates, it could mean there’s something going on in the universe that demands dramatic revisions to cosmological orthodoxy.

The rate of cosmic expansion tells us how old the universe is — about 13.8 billion years according to the current estimate based on the background radiation. And cosmic expansion will ultimately determine the future of everything there is. What will be the fate of the universe?

Scientific questions don’t get any bigger than that.

Far, far away

Space has the nice feature of being generally transparent. But it’s still very hard for astronomers to measure the distance to faraway stars and galaxies. This, in turn, makes it hard to tell how rapidly galaxies are moving away from one another as the space between them expands.

Every time scientists think they’re converging on a consensus, the universe scrambles the narrative, sending astronomers back to their telescopes and theorists back to their chalkboards.

The Hubble Constant is named for pioneering astronomer Edwin Hubble, who in the 1920s discovered that the light from many galaxies is red-shifted, a sign the galaxies are moving away from us. Moreover, the red shift increased with their distance. (This is why the Hubble Constant is traditionally described with the ungainly metric of “kilometers per second per megaparsec.” A megaparsec is a distance equal to about 3 million light-years. The farther away a galaxy, the faster it is receding from us.)

The theoretical implication of Hubble’s discovery was stunning: The universe is not static and eternal. It is dynamic. The space between the galaxies, except those bound to one another by gravity, is expanding. This is a key element of the big bang theory. The universe is today a vast, cold, thin soup of matter and energy, but long ago, it was unimaginably hot and dense.

Riess, 54, has devoted his career to understanding cosmic expansion. He and two other scientists shared the Nobel for their 1998 discovery that the universe is not only expanding, it’s doing so at an accelerating rate.

“What we’ve discovered is the universe is fairly complicated,” Riess said. “We keep getting little surprises.”

As the Hubble Tension debate continues, there’s another head-scratching development on the cosmic expansion front. A project called the Dark Energy Spectroscopic Instrument (DESI) survey is using a telescope at Kitt Peak in

Arizona to scrutinize millions of galaxies and create a time-lapse movie of cosmic expansion during many billions of years.

The first batch of DESI data was published this year. Surprise! The acceleration of the universe — the discovery Riess won his Nobel for — appeared in the DESI data to have eased up the last billion years or so, as if someone had taken a foot off the gas pedal.

This provisional result has the potential to dynamite an assumption about dark energy, the hypothetical (and still very mysterious) energy field assumed to be driving the acceleration. Scientists have generally regarded dark energy as a "cosmological constant," retaining its density in any given volume of space even as the universe expands. But the DESI data suggests it may not be a constant after all.

"If this result stands, this is the most important finding about dark energy since the discovery of cosmic acceleration in 1998," said astrophysicist Mustapha Ishak, a professor at the University of Texas at Dallas and co-lead of DESI cosmological analysis.

By the way, this could change the fate of the universe.

Since the discovery of the acceleration, theorists have calculated that the universe will continue to expand faster and faster — until the cosmos becomes (trillions of years later) utterly cold, dark and inhospitable to life. That bleak future may never arrive, however, if the expansion slows.

In fact, in one scenario, the universe could even re-collapse. There's a name for that: the "Big Crunch."

Astronomers have revealed amazing wonders in our universe, but some of the most basic questions remain difficult to answer, and possibly beyond the reach of science. For example: Is the universe finite or infinite? Scientists don't know. It could be either, they say. There may be no way to answer the question definitively. This is why it's imprecise to say the expanding universe is "getting bigger." If it's infinite, that's as big as it gets.

Stephen Hawking's best-selling 1988 book, "A Brief History of Time," posed big questions that remain unanswered 36 years later: "Where did the universe come from, and where is it going? Did the universe have a beginning, and if so, what happened *before* then? What is the nature of time? Will it ever come to an end?"

Here's another stumper: No one knows what the universe — including "empty space" — is made of at the most fundamental level. The physicist Brian Greene, in an email, framed that question like this: "What threads stitch the fabric of space?"

Scientists in recent decades have calculated that roughly one-fourth of the universe's "energy budget" (which includes matter and energy) is in the form of dark matter. No one knows what dark matter is. That's why they call it "dark."

Finally — here we get back to this DESI survey — there's dark energy. It is estimated to constitute about 70 percent of the universe. Only about 4 percent of the universe is composed of the ordinary matter, like protons and neutrons and electrons and the other particles that provide us with stars, planets, rocks, trees, anteaters, toasters, etc.

"The universe is dominated by dark matter and dark energy, neither of which we understand. It's bizarre," said Jane Rigby, senior scientist for the Webb telescope. "It bothers us all."

Still in the dark

Riess was still a young postdoc when he joined an effort, led by astronomer Brian Schmidt, to study supernovae to discern changes in the expansion rate of the universe. A second team led by astronomer Saul Perlmutter had a similar goal, and the two teams raced to get the answer first.

The assumption was that gravity would cause the expansion to slow down. But in 1997, Riess kept slamming into something peculiar: The supernovae observations and the equations for cosmic expansion made sense only if the universe had *negative mass*. That was absurd. There's no such thing as negative mass.

Riess had a revelation: The equations would make sense if the universe wasn't slowing down, as everyone assumed, but rather was *accelerating* in its expansion.

He and his colleagues exchanged a flurry of excited but wary emails. This was an extraordinary claim. What if they were wrong? Riess urged his colleagues to be confident: "Approach these results not with your heart or head but with your eyes. We are observers after all!"

The two rival teams wound up reporting the same stunning result, and shared Nobel Prize glory.

Scientists then had the task of figuring out what, exactly, was causing the cosmic acceleration. They began flinging around a new term: dark energy, which appears to be a property of space, a repulsive force, kind of like antigravity.

Dark energy "is a new fluid that we know nothing about. It's not matter, it's not photons, it's something else that has negative pressure," said Nathalie Palanque-Delabrouille, physics division director at the Lawrence Berkeley National Laboratory and a spokesperson for the DESI survey.

"I said it 25 years ago, and I still believe it: Dark energy is the most profound problem in all of science," Michael Turner, a cosmologist at the University of Chicago who coined the term "dark energy" and is not part of the DESI team, said in an email. The DESI results, he said, "could be the breakthrough we need."

The DESI results suggesting dark energy isn't a constant are preliminary. The leader of the survey, Michael Levi, a physicist at the national laboratory, notes that the data released so far cover only one year of observations.

"We think this is intriguing, but I don't think we are anywhere near the D-word — discovery," Levi said.

U.S. taxpayers are funding multiple efforts to solve the dark energy mystery. NASA is developing the Nancy Grace Roman Space Telescope, slated for launch in 2027. It is the same size as the Hubble but will have a much wider field of view and should offer more data on the evolution of the universe. A European mission, Euclid, is also dedicated to mapping the universe over time and studying the role of dark energy.

Track the last century of cosmology, and you see a static universe becoming an expanding one, and then an accelerating one, and then maybe shifting gears again. Riess is among those who thinks his profession could be on the verge of another major discovery.

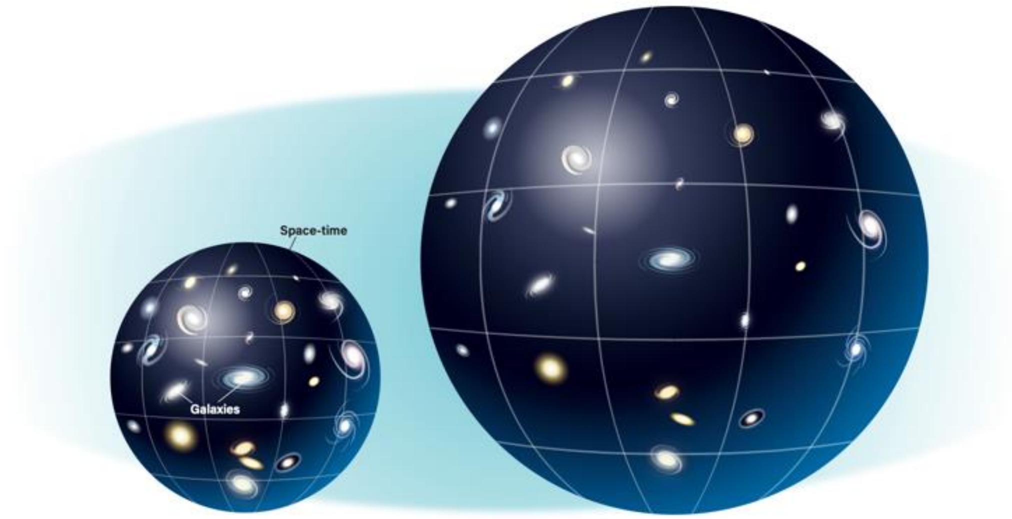
"We're starting to see more tensions, or maybe perhaps oddities," he said. "Do we have the right physical description of the universe?"

With so much scientific uncertainty about cosmic expansion, the future is very much in play. So, for that matter, is the past. It's possible, Riess noted, that the universe is cyclical. A big bang could be followed by a big crunch and then another big bang, on and on. For eternity.

"I've always preferred if it was a cyclical universe," Riess said.

But that's just his preference. The universe is going to do whatever it's going to do. The fate of the cosmos won't be decided by a show of hands.

What is the universe expanding into?



What is the universe expanding into?

What is the universe expanding into?

Euan Tobin

Edinburgh, Scotland

This excellent question forces us to confront a region beyond the bounds of our intuition, so please bear with me. When you inflate a balloon, the balloon's membrane moves outward, closer to the boundaries of whatever room encloses it. You can easily visualize this expansion because one object is inflating relative to a fixed enclosure.

The notion of the expansion of the universe is more problematic because the universe contains everything - it is a closed space-time system. One could say that the universe isn't expanding into anything because the question implies that something exists "outside" the universe, which is nonsensical, as "outside" is a spatially relative term.

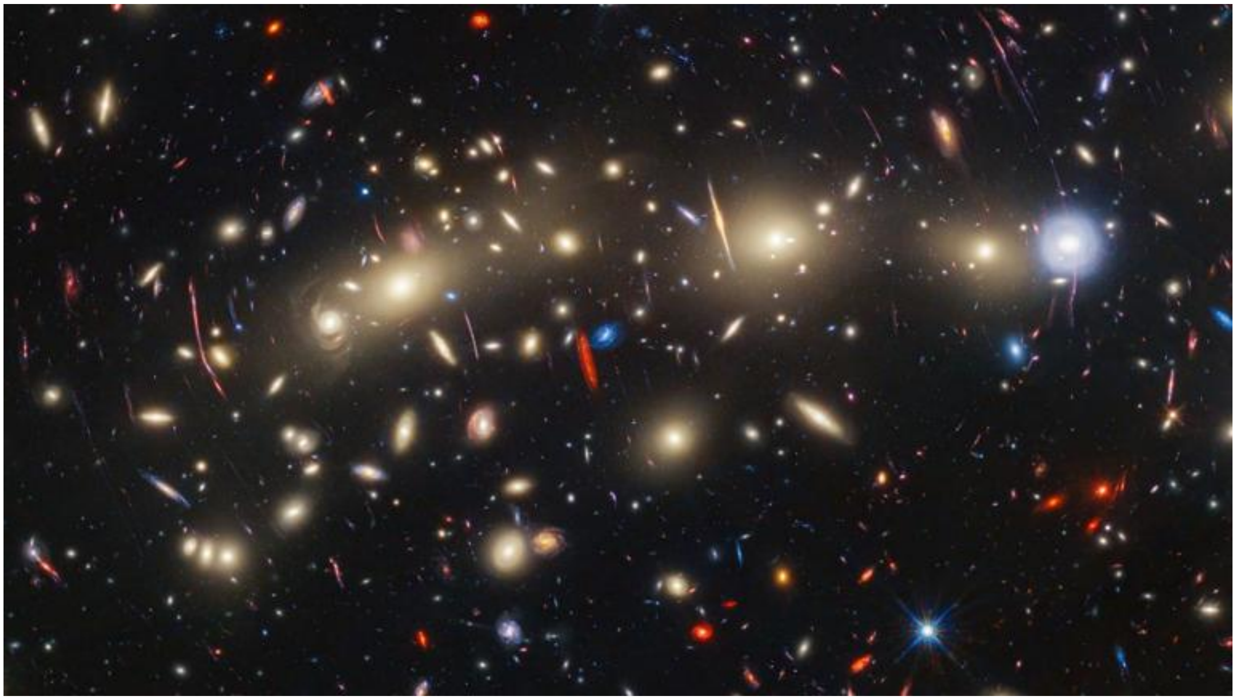
However, such an answer is unsatisfactory. Let's return to the balloon. This time, let's draw a series of black dots along the membrane. As the balloon inflates, the dots appear to be moving away from each other. From the perspective of one dot, the more distant dots move away more quickly than those closer to it. As the membrane expands, the dots grow farther apart. In this example, the dots represent the galaxies, while the membrane represents the finite yet unbounded universe. You could travel along the balloon but never come to the "end," as it is literally unbounded. And though the balloon's surface might not be infinite in extent, it is not defined by an outer boundary. (Note that a shortcoming of this balloon analogy is that it tries to represent three-dimensional reality along a two-dimensional shell.)

Universal expansion causes galaxies to recede from each other. Galaxies close to us recede at a slower rate than those farther away. As demonstrated by the balloon model, the space-time "fabric" is what is expanding, and the material embedded within it - namely galaxies - moves apart in response to this expansion. We cannot truly say that the universe is expanding "into" anything else. There is no fixed center, nor is there any rigid outer boundary. It is merely expanding, just as the balloon membrane expands - albeit in three spatial dimensions instead of two.

Edward Herrick-Gleason

Astronomy Educator, St. John's, Newfoundland and Labrador

How many galaxies are in the universe?



How many galaxies are in the universe?© NASA, ESA, CSA, STScI, J. Diego (Instituto de Física de Cantabria, Spain), J. D'Silva (U. Western Australia), A. Koekemoer (STScI), J. Summers & R. Windhorst (ASU), and H. Yan (U. Missouri)

The Milky Way is just a speck in a universe filled with an untold number of galaxies. But if we had to take an educated guess, how many galaxies are in the universe?

That sounds like a simple question, but it's anything but. The first problem is that even with our most powerful telescopes, we can see only a tiny fraction of the universe.

"The observable universe is only that part of the universe from which the light has had time to reach us," astrophysicist Kai Noeske, now outreach officer at the European Space Agency, told Live Science.

The universe is 13.8 billion years old, but the observable universe stretches more than 13.8 light-years in every direction. That's because the universe is expanding and light got a head start early on, when the universe was smaller.

"Now, the total size in each direction is about 46 billion light-years," Noeske said.

That's much smaller than even our smallest estimates of the entire universe. "We see at most 3% of the universe," Pamela Gay, a senior scientist at the Planetary Science Institute, told Live Science.

Related: Why are galaxies different shapes?

The second problem is that there are so many galaxies that we can only make estimates of the total number based on what we can observe in small regions of the universe.

"You look at a small patch of the sky, and you count everything in that small patch and then multiply over the size of the sky," Gay said.

But even that requires a cutoff. "What do we define [as] a galaxy?" Noeske said. "We have really giant galaxies that have to have a factor of 10 more" the mass of our galaxy, "and we have a lot of small galaxies, from lower-mass galaxies that have about 10 times less mass ... down all the way to dwarf galaxies."

At some point, scientists need to define a minimum mass for a galaxy to make estimates possible.

"If we set a mass cutoff and try to make this conservative, like a million solar masses, we end up with an average number of galaxies in the universe from the beginning to today of about 1 to 2 trillion," Noeske said. Scientists think there were more galaxies earlier in the universe's history than there are today, which is why galaxy estimates are an average over time.

"But those results come from the Hubble [telescope] — the James Webb Space Telescope is starting to speak to these results — which are near Earth, inside of our solar system, and are limited on what they can see by all the stuff in our solar system that adds light to the sky," Gay said. "We do have one spacecraft with a camera that has gotten beyond all the garbage within our solar system, and that's the New Horizons spacecraft."

A 2021 study used the camera aboard New Horizons to measure the total amount of light in various patches of sky and estimated how many galaxies would be needed to create that much light.

"And suddenly, as they're outside of all the light sources in our solar system, they realize we don't need as many galaxies as we thought," Gay said. "And so their estimates put us at, like, 200 billion, maybe even 100 billion galaxies in the visible universe.

"So somewhere between 2 trillion galaxies at the top edge and 100 billion at the lower edge is the number of galaxies in our observable universe," she said.

If you assume that's 3% — at most — of our universe, you can multiply that range of galaxies to get the total number of galaxies in the universe. If we're seeing less of the universe than we think, there will be a smaller total number of galaxies.

But considering we don't actually know the size of the universe, those estimates are murky. "If it's an infinite universe, you're going to have infinite galaxies," Gay said.

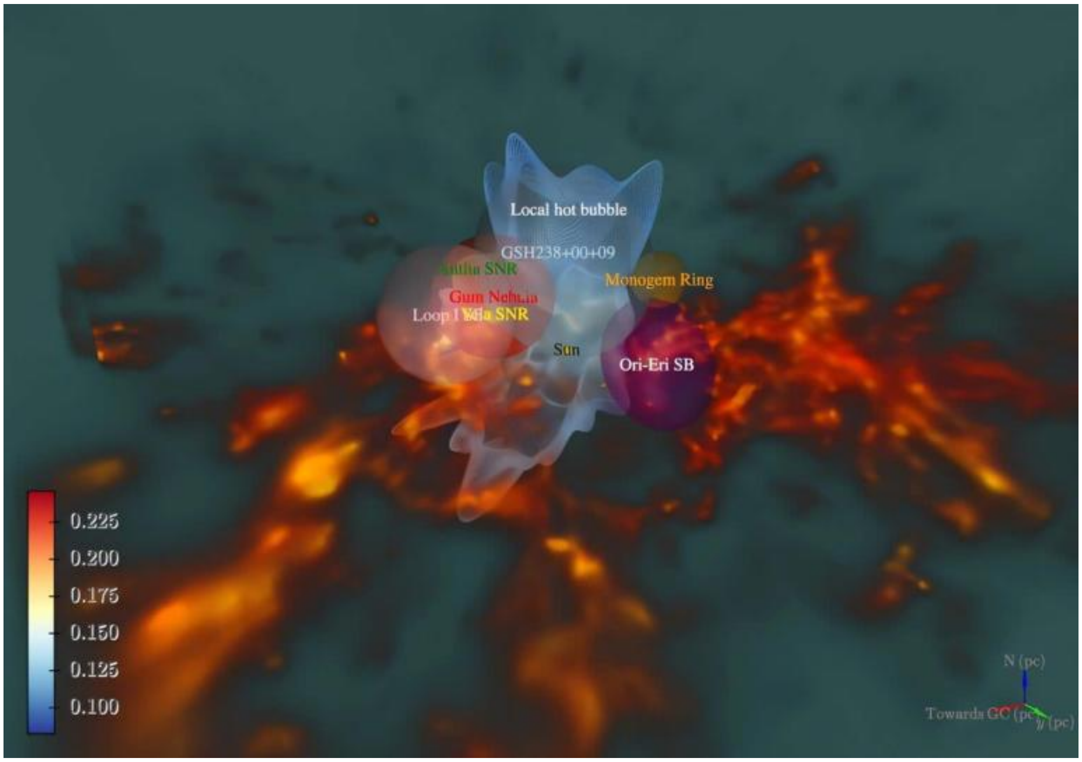
Interstellar tunnel discovered near our solar system - could lead to other star systems

Our solar system resides in a unique low-density bubble called the Local Hot Bubble (LHB). Stretching at least 1,000 light-years, this region glows in X-rays due to its million-degree temperature. However, because its atoms are so sparse, this extreme heat barely affects the matter inside. It’s fortunate for life on Earth, but this enigmatic bubble has long puzzled astronomers.

Theories suggest that the LHB was carved out millions of years ago by supernova explosions. A chain of these stellar detonations likely blew away the interstellar medium, creating this expansive cavity. Recent breakthroughs from the Max Planck Institute for Extraterrestrial Physics (MPE) have shed light on the LHB's true nature and its intricate structure.

Charting the Bubble

Astrophysicist Michael Yeung and his team used eROSITA, a powerful X-ray telescope aboard a space observatory, to map the LHB in unprecedented detail. Unlike Earth-based observatories or those influenced by our planet's halo of hydrogen, eROSITA operates 1.5 million kilometers from Earth. This unique vantage point offers an untainted view of the X-ray sky.



3D model of the solar neighborhood. The color bar represents the temperature of the LHB as colored on the LHB surface. The direction of the Galactic Center (GC) and Galactic North (N) is shown in the bottom right. (CREDIT: Michael Yeung / MPE)© The Brighter Side of News

By dividing the sky into 2,000 sections, researchers analyzed the X-ray light in each area. They discovered that the LHB is not a uniform sphere but expands more readily perpendicular to the galactic plane. This makes sense—there's less resistance in the vertical direction compared to the horizontal galactic disk.

Michael Freyberg, another key member of the MPE team, noted that the bubble's shape resembles a bipolar nebula, though spikier and bumpier. This irregular structure wasn't the only revelation. "What we didn't know was the existence of an interstellar tunnel towards Centaurus, which carves a gap in the cooler interstellar medium," Freyberg explained.

A Tunnel to the Stars?

This tunnel could connect the LHB to a neighboring superbubble or other cosmic structures like the Gum Nebula. Its discovery lends credence to a 1974 theory proposing that the galaxy consists of interconnected hot bubbles and tunnels.

Though evidence for such a network has been scarce, this finding could be a crucial piece of the puzzle.

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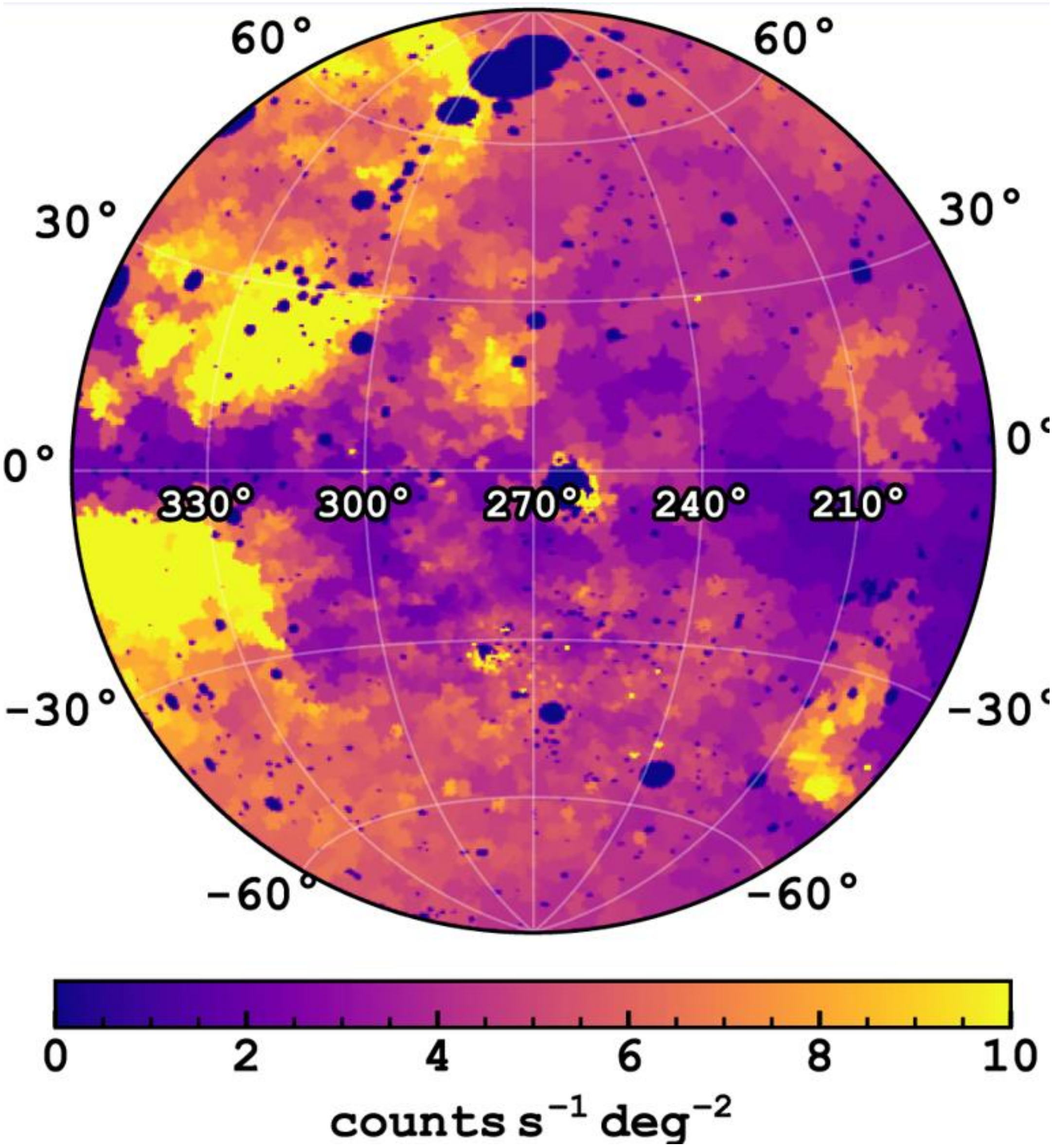
The tunnel isn't just an isolated feature. The team's model revealed a temperature gradient within the LHB, with the northern region being hotter than the southern. This suggests that recent supernova events may have reheated parts of the bubble within the last few million years.

Living in the Bubble

The LHB has fascinated astronomers since its existence was proposed over fifty years ago. Initially, scientists used the bubble to explain mysterious X-ray emissions that shouldn't have reached us through the dense interstellar medium. The theory gained traction as observations revealed a relative void of interstellar dust near our solar system.

Challenges emerged in the 1990s when scientists discovered that solar wind interactions with Earth's geocorona could also produce X-rays. But recent data from eROSITA, which observed the sky during a solar minimum, confirmed the LHB's role in these emissions.



Contour-binned eRASS1 0.2–0.6 keV band surface brightness map in zenithal equal-area projection. (CREDIT: Astronomy & Astrophysics)© The Brighter Side of News

Michael Yeung highlighted eROSITA's contribution, stating, "eRASS1 data provides the cleanest view of the X-ray sky to date, making it the perfect instrument for studying the LHB."

Connecting the Cosmic Dots

The detailed 3D model constructed by Yeung's team paints a vivid picture of our cosmic neighborhood. It includes known supernova remnants, molecular clouds, and even other tunnels, like the Canis Majoris tunnel, potentially linking the LHB to the Gum Nebula.

Some dense molecular clouds near the bubble's edge have velocities suggesting they formed from material swept up during the bubble's early formation. Co-author Gabriele Ponti noted, "The sun must have entered the LHB a few million years ago—a short time compared to the age of the sun."

3D structure of the LHB with colours indicating its temperature. The two surfaces indicate the measurement uncertainty of the LHB extent: the most probable extent most likely lies between the two. The location of the Sun and a sphere of 100 parsec radius are marked for comparison. (CREDIT: Michael Yeung / MPE)© The Brighter Side of News

This central positioning of the Sun within the LHB is purely coincidental. As the solar system moves through the Milky Way, we're likely just passing through this cosmic cavity.

Future Exploration

The discovery of the Centaurus tunnel could mark the beginning of a new chapter in galactic exploration. If the Milky Way is indeed a vast network of hot bubbles and tunnels, studying these structures could reveal the galaxy's dynamic history.

The study, published in Astronomy & Astrophysics, emphasizes how stellar feedback—energy released by dying stars—shapes the interstellar medium. As researchers continue to analyze eROSITA's data, we may soon uncover more secrets hidden in the vast expanse of space.

Note: Materials provided above by The Brighter Side of News. Content may be edited for style and length.

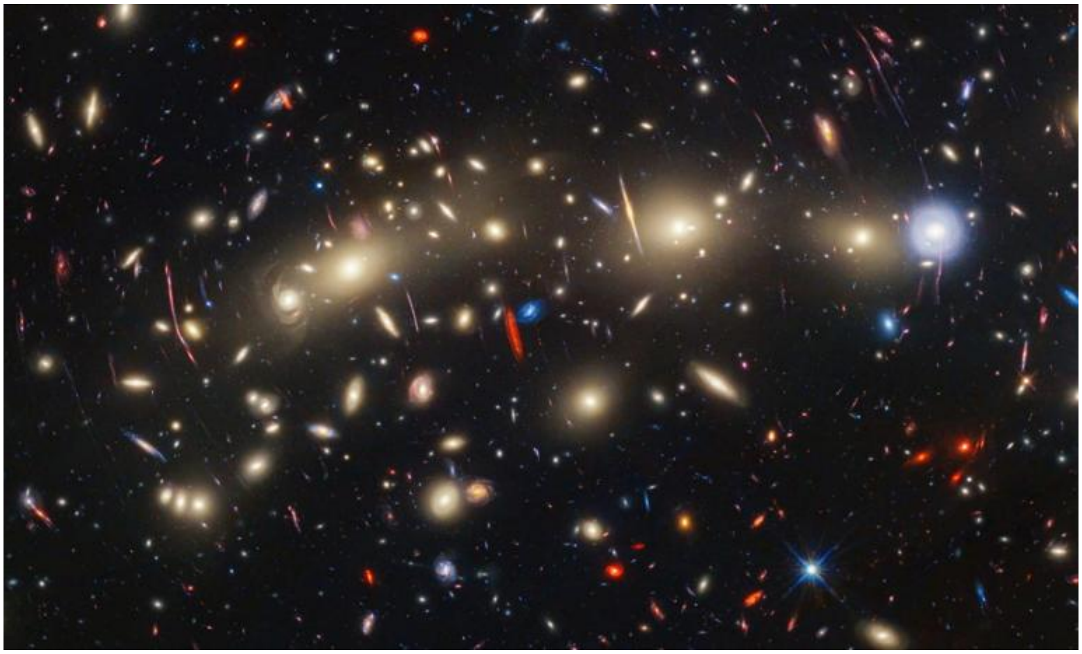
Like these kind of feel good stories? Get The Brighter Side of News' newsletter.

Groundbreaking new research finds that gravity can exist without mass

Dark matter, a mysterious substance thought to make up most of the universe's mass, has puzzled scientists for nearly a century. First proposed by Dutch astronomer Jan Oort in 1932 to explain the "missing mass" needed for galaxies to stay together, it remains undetected despite decades of research. However, a recent study by Dr. Richard Lieu at The University of Alabama in Huntsville (UAH) offers an intriguing alternative to dark matter.

In his paper published in the Monthly Notices of the Royal Astronomical Society, Lieu presents a theory that suggests gravity can exist without mass. This groundbreaking idea could potentially eliminate the need for dark matter to explain certain gravitational effects.

“My own inspiration came from my pursuit for another solution to the gravitational field equations of general relativity — the simplified version of which, applicable to the conditions of galaxies and clusters of galaxies, is known as the Poisson equation — which gives a finite gravitation force in the absence of any detectable mass,” says Lieu, a distinguished professor of physics and astronomy at UAH. “This initiative is in turn driven by my frustration with the status quo, namely the notion of dark matter's existence despite the lack of any direct evidence for a whole century.”


Panchromatic view of galaxy cluster MACS0416 was created by combining infrared observations from the NASA/ESA/CSA James Webb Space Telescope with visible-light data from the NASA/ESA Hubble Space Telescope. (CREDIT: NASA/ESA/CSA/STScI)© The Brighter Side of News

Lieu's theory revolves around topological defects in the cosmos, which may have formed during a phase transition in the early universe. A cosmological phase transition involves a widespread change in the state of matter. According to Lieu, these defects, which he describes as shell-like structures, could create the "excess" gravity needed to bind galaxies and clusters together.

“It is unclear presently what precise form of phase transition in the universe could give rise to topological defects of this sort,” Lieu says. “Topological defects are very compact regions of space with a very high density of matter, usually in the form of linear structures known as cosmic strings, although 2-D structures such as spherical shells are also possible."

"The shells in my paper consist of a thin inner layer of positive mass and a thin outer layer of negative mass; the total mass of both layers — which is all one could measure, mass-wise — is exactly zero, but when a star lies on this shell it experiences a large gravitational force pulling it towards the center of the shell,” Lieu continued.

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Scientists discover massive 'Gravity Hole' in the Indian Ocean Profound new findings could redefine our understanding of dark matter and gravity Scientists have discovered a potential “cosmic glitch” in gravity

Gravitational force, which involves the warping of space-time, affects all objects, whether they have mass or not. Even massless photons are influenced by gravity from astronomical objects.

“Gravitational bending of light by a set of concentric singular shells comprising a galaxy or cluster is due to a ray of light being deflected slightly inwards — that is, towards the center of the large-scale structure, or the set of shells — as it passes through one shell,” Lieu notes. “The sum total effect of passage through many shells is a finite and measurable total deflection which mimics the presence of a large amount of dark matter in much the same way as the velocity of stellar orbits.

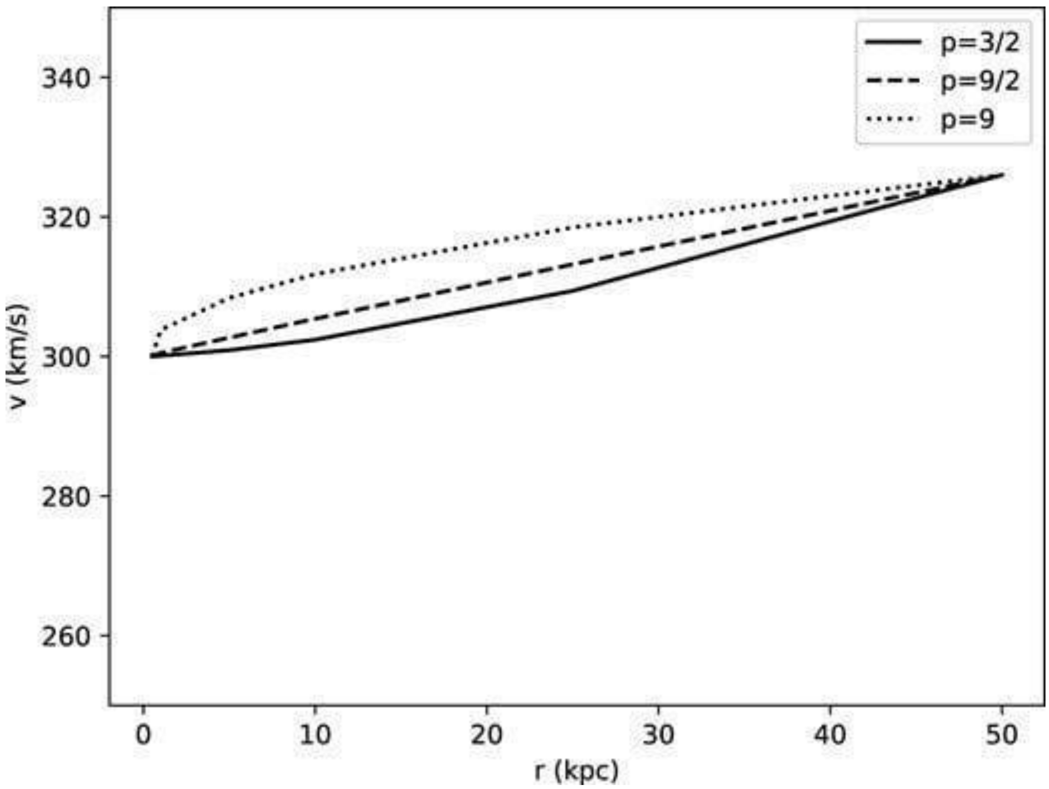
“Both the deflection of light and stellar orbital velocities is the only means by which one gauges the strength of the gravitational field in a large-scale structure, be it a galaxy or a cluster of galaxies. The contention of my paper is that at least the shells it posits are massless. There is then no need to perpetuate this seemingly endless search for dark matter.”

Dr. Richard Lieu, distinguished professor of physics and astronomy at UAH. (CREDIT: UAH)© The Brighter Side of News

Lieu acknowledges that further research is needed to understand how galaxies or clusters form from these shells and how they evolve.

“This paper does not attempt to tackle the problem of structure formation. A contentious point is whether the shells were initially planes or even straight strings, but angular momentum winds them up. There is also the question of how to confirm or refute the proposed shells by dedicated observations.

Of course, the availability of a second solution, even if it is highly suggestive, is not by itself sufficient to discredit the dark matter hypothesis — it could be an interesting mathematical exercise at best," Lieu concludes. "But it is the first proof that gravity can exist without mass."



Circular velocity of stars in a galaxy, taking into account the extra centrifugal acceleration provided by the gravitational pull of the underlying baryons, as well as the singular shell. (CREDIT: Monthly Notices of the Royal Astronomical Society)© The Brighter Side of News

Lieu's research opens new avenues for understanding the universe's gravitational forces. If proven correct, it could revolutionize the way we perceive and study the cosmos, challenging the long-held belief in dark matter's existence.

How Astronomers Define Where a Galaxy Ends and Interstellar Space Begins


How Astronomers Define Where a Galaxy Ends and Interstellar Space Begins

For us, galaxies are where most of the interesting stuff happens in the cosmos.

Stars, planets, and black holes are all usually found inside these bustling cosmic neighborhoods. But space isn't just galaxies. In between galaxies are vast expanses of interstellar space - galactic deserts where you might be lucky to stumble across a few hydrogen atoms or, at best, a wandering rogue planet ejected from its home galaxy.

So, where does a galaxy end and interstellar space begin? There seem to be a number of plausible ways astronomers might define the 'edge' of a galaxy - perhaps where concentrations of gas and dust drop below a certain threshold or even via a galaxy's gravitational influence.

Defining the Edge of a Galaxy

Nushkia Chamba is a postdoctoral fellow at NASA's Ames Research Center who specializes in studying the outskirts of galaxies, as well as galaxy formation and evolution in general. Here, she helps explain how astronomers have defined the edge of a galaxy and what factors contribute to where a given galaxy's edge is likely to be situated.

"The short answer is that the ‘boundary' of a galaxy has been traditionally defined using fixed levels of brightness (or technically called surface brightness isophotes)," says Chamba. However, Chamba has spearheaded recent efforts to more robustly define the edge of a galaxy. "Our work in 2020 and 2022 was the first to discuss an alternative idea of "edge of a galaxy" as a definition of size."

Specifically, Chamba and her team developed a physically motivated criteria for the boundary of a galaxy based on the required gas density for star formation. This means the outermost region of a galaxy where star formation is still, or likely to take place, is where Chamba and her colleagues have defined the 'edge' of a galaxy.

It's kind of like defining the edge of a city where new housing is still being developed - implying that this 'edge' is a shifting, dynamic thing.

Read More: How Many Galaxies Are There? Astronomers Are Revealing the Enormity of the Universe

How Star Formation Sets the Boundaries of Galaxies

Since the boundary of a galaxy is defined as a function of where star formation can occur, astronomers have been interested in how a galaxy's location with respect to other galaxies might influence its size and, therefore, its ability to sustain star formation in its outer regions.

"We have been trying to understand how galaxies regulate their size during their life and how their environment impacts their growth, depending on if they are located in a crowded cluster with 1000s of galaxies or are nearly isolated," says Chamba.

Chamba was part of a team that, this year, found that galaxies in crowded environments were up to 50 percent smaller in size than those in near isolation.

"This is consistent with our current understanding of how galaxies undergo gas removal due to environmental interactions and processes which can stop their star formation and growth, compared to more isolated galaxies that can retain their gas for longer periods of time," she says.

"Many factors can influence the edge of a galaxy, the environment, the morphology (shape and size), the mass of a galaxy in stars (we are yet to investigate how the dark matter affects star formation, which is an open question in astrophysics), but also at which epoch most of the star formation of a galaxy occurred, as the edge of a galaxy not only changes due to their inherent structure and environment but it also changes with time," Chamba explains.

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A Closer Look at Dwarf Galaxies

When it comes to small, or 'dwarf' galaxies, they are more impacted by their environment, where they are more likely to lose material - gas and dust - as they move through a crowded galactic neighborhood, which in turn affects the galaxy's ability to support new star formation.

Recent research by Chamba and colleagues has also shed light on the role that supernovas might play in the dispersion of gas within a galaxy - where 'stellar feedback' can influence the inflows and outflows of gas in a galaxy which either supports or negates star formation.

The ability for astronomers to observe concentrations of gas, and therefore where star formation is possible, in far-off galaxies has been made possible by the development of deep imaging techniques, where telescopes such as the James Webb Space Telescope have been optimized for observing very faint light.

Read More: How Galaxies Live, Breathe and Die

Future Research of Galaxy Formation

Chamba says that researchers are working on how more mysterious mechanisms, such as the dispersion of dark matter, might influence star formation in galaxies. Based on the current cosmological framework, it is generally agreed that the size of galaxies - how much material they are composed of - would be set by the properties of the dark matter halo, as it exerts its gravitational influence on surrounding baryonic matter - the stuff we are made of.

There is still a lot to learn about the factors that drive the evolution of galaxies through time, and Chamba is at the forefront of that endeavor.

Read More: Black Hole Theory Finally Explains How Galaxies Form

Article Sources

Our writers at Discovermagazine.com use peer-reviewed studies and high-quality sources for our articles, and our editors review for scientific accuracy and editorial standards. Review the sources used below for this article:

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- Astronomy & Astrophysics. The edges of galaxies: Tracing the limits of star formation
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NASA Webb Revelations Challenge Traditional Theory of Gravity

Observations of the early universe made by NASA's flagship James Webb Space Telescope are challenging the traditional theory of gravity and how the first galaxies formed.

This is the conclusion of a new study by astrophysicist Stacy McGaugh—of Ohio's Case Western Reserve University—and his colleagues.

According to the team, the standard model of early galaxy formation predicted that, staring at the distant (and therefore, given how light takes time to travel, young) universe, Webb should have seen only dim signals from small and primitive galaxies 13 billion years ago, when the universe was less than half-a-billion years old.

"The expectation was that every big galaxy we see in the nearby universe would have started from these itty-bitty pieces," McGaugh said in a statement.

What astronomers have observed instead, however, is that these early galaxies are large and bright—meaning something is amiss in our understanding of the universe's evolution.

Protogalaxies as seen by NASA's James Webb Space Telescope. The signals are far brighter and larger than predicted by the conventional theory of gravity. NASA© NASA

The largest and most powerful space telescope ever built, Webb's infrared instruments are capable of seeing objects so distant the light from them takes up to 13.5 billion years to reach us, effectively providing a window back into the infancy of the universe.

This has allowed us to see, for the first time, how the first stars and galaxies formed — and test the hypothesis that invisible "dark matter" helped normal matter clump together bit by bit, building up increasingly large structures until galaxies formed.

"Astronomers invented dark matter to explain how you get from a very smooth early universe to big galaxies with lots of empty space between them that we see today," said McGaugh.

However, he said: "What the theory of dark matter predicted is not what we see."

Pictured: astrophysicist Stacy McGaugh of Ohio's Case Western Reserve University. McGaugh told Newsweek that if MOND is the correct theory of gravity, "then the broader implications are enormous." CWRU© CWRU

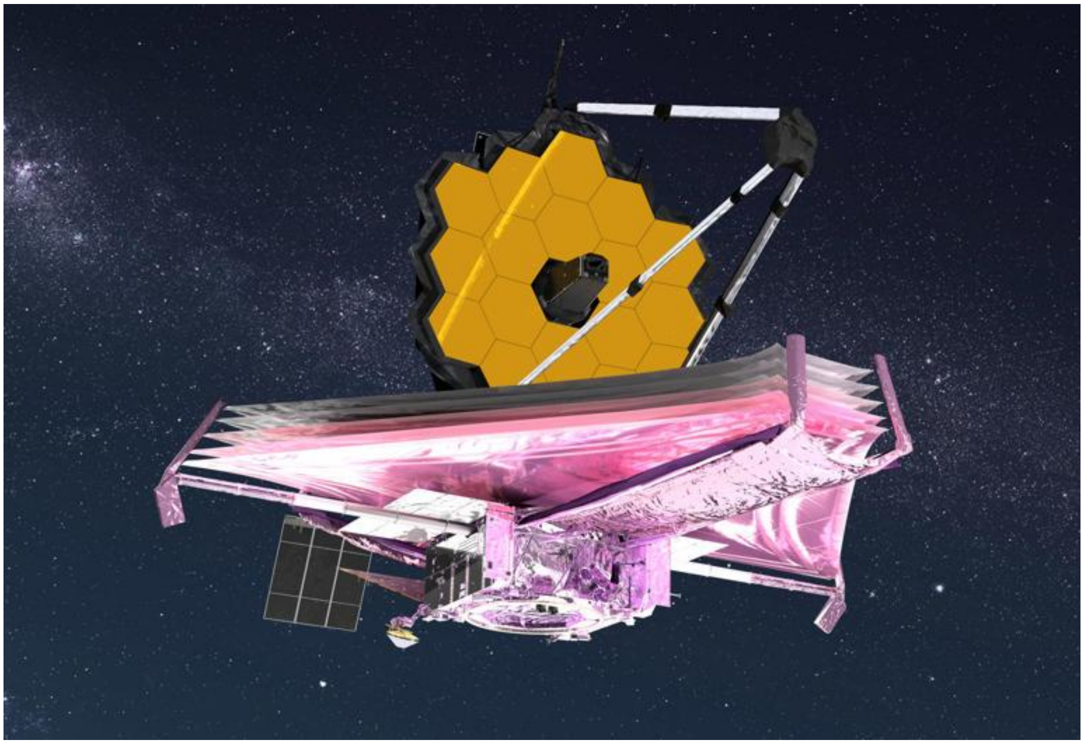
The large, bright signals that Webb keeps seeing, even as it looks deeper and deeper into the universe's past, are, however, compatible with another theory: Modified Newtonian Dynamics, or "MOND", for short.

"If MOND is indeed the correct theory—the status we usually confer to theories that get so many a priori predictions right—then the broader implications are enormous," McGaugh told *Newsweek*.

"For one, it implies that we have been barking up the wrong tree with dark matter. The reason we haven't detected dark matter in the laboratory despite decades of dedicated searches is because it is not there."

"The discrepancies we attribute to invisible dark matter are in fact due to a change in the force law. That in turn implies that our theory of gravity is incomplete."

Filling in these potential gaps, McGaugh added, will require a "major change in thinking" of the likes physics hasn't seen since the development of quantum mechanics a century ago.


An artist's impression of the James Webb Space Telescope. Webb is the largest and most powerful space telescope ever built—capable of peering back 13.5 billion years through time to the early universe. NASA© NASA

The standard cosmological model invokes invisible dark matter to explain why galaxies appear to spin faster than they should based on what they can be seen to contain.

In MOND, meanwhile, this discrepancy is explained away by suggesting that Newton's law of gravity breaks down in situations where the pull of gravity is very weak—such as, for example, in the outer regions of galaxies.

Models suggest that in a MOND universe, cosmic structures like burgeoning galaxies would be built up much faster—first expanding outward with the rest of the universe, before collapsing in on itself under a stronger force of gravity to form a galaxy.

This would produce the same large and bright structures seen now by Webb, proponents of MOND first argued more than 25 years ago.

"The bottom line is: 'I told you so'," said McGaugh. He added: "I was raised to think that saying that was rude, but that's the whole point of the scientific method: make predictions and then check which come true."

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Reference

McGaugh, S. S., Schombert, J. M., Lelli, F., & Franck, J. (2024). Accelerated Structure Formation: the Early Emergence of Massive Galaxies and Clusters of Galaxies. *The Astrophysical Journal*. https://doi.org/10.3847/1538-4357/ad834d

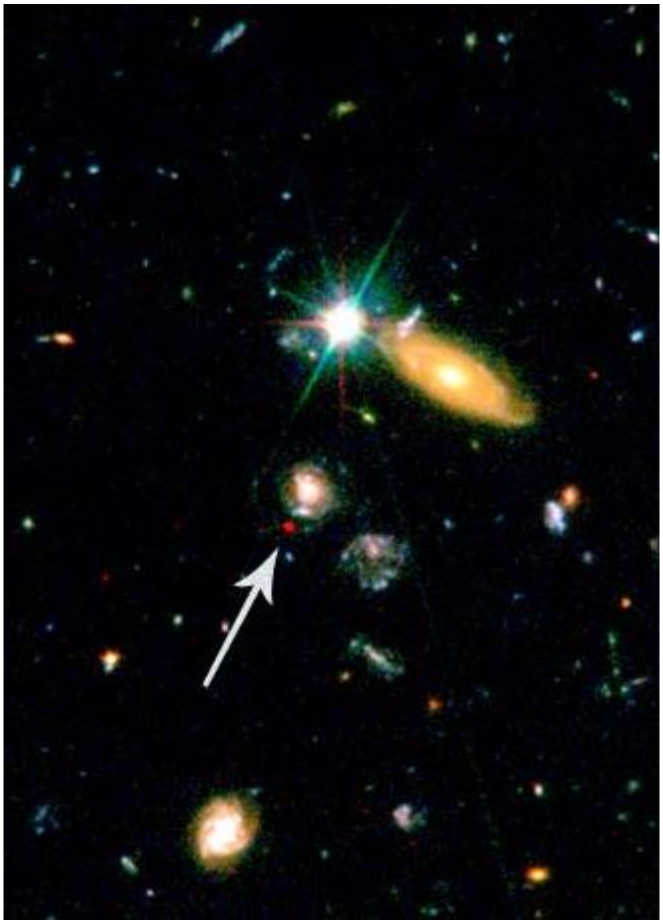
Related Articles

What is dark energy?

In a 1998 research breakthrough, Saul Perlmutter of the University of California, Berkeley, and his colleagues in the Supernova Cosmology Project found the expansion rate of the universe is accelerating.

Perlmutter and his team made the discovery by observing distant type Ia supernovae, whose brightnesses are well known, at different distances. His team made observations in conjunction with a team led by Brian Warner of the Mt. Stromlo-Siding Spring Observatories. This astonishing finding contradicts conventional wisdom, which suggests the universal expansion rate of galaxies away from each other is constant. Several implications follow the new finding, the most significant of which has turned cosmology on its head.

In May 1999, Perlmutter and his colleagues published a paper in *Science* that outlined their ideas about a newly understood force in the universe - dark energy. "The universe is made up mostly of dark matter and dark energy," wrote Perlmutter. Astronomers now think 68.3 percent of the mass-energy content of the cosmos consists of this dark energy and that it is the force accelerating the universe's expansion. If dark energy is as dominant as astronomers believe it is, it will eventually force the universe into a cold, dark, ever-expanding end to space and time - the universe will end with a whimper, not with a bang.



A distant supernova (indicated with an arrow) in this Hubble Wide-Field Planetary Camera 2 image added more weight to the dark energy argument. Credit: NASA and J. Blakeslee (JHU)

Dark energy, now that it is known to exist, has come to the fore as one of science's great mysteries. Although astronomers don't yet know exactly what it is, three leading contenders offer possible explanations.

The first is the cosmological constant, or a static field of fixed energy, proposed by Albert Einstein (and which he later declared his biggest blunder). A second possibility is quintessence, a dynamic, scalar field of energy that varies through time and space.

The third possibility is that dark energy doesn't exist; what astronomers observe with distant supernovae represents a breakdown of Einsteinian gravitational physics that has yet to be explained. A fourth possibility could be something we don't yet understand.

Determining what dark energy is will be far more complex than the discovery of the accelerating universe. Astronomers are using the Hubble Space Telescope to "push back to higher redshifts to measure the onset of acceleration," says Adam Riess of the Space Telescope Science Institute in Baltimore. One important moment to focus on is the so-called transition point, the time when dark-energy acceleration overtook the normal pull of gravity and became the dominant force in the universe. This probably happened about 5 billion years ago, according to Riess.

Research on type Ia supernovae must continue to get a handle on this question. Could the reliability of type Ia supernovae come into question? The fact that not as many heavy metals existed in the very early universe could influence the brightnesses of these objects and throw astronomers' observations off the mark.

Other techniques will also come into play. Astronomers will observe galaxy clusters to see how their densities vary with distance. This could relate to whether gravity or dark energy dominated at certain times in the cosmos' past. Cosmologists will also study gravitational lenses for clues to dark energy's existence in the distortion patterns visible in these optical illusions. This pioneering technique, developed by the University of Pennsylvania's Gary Bernstein, is in its infancy. "Right now," says Bernstein, "we're just starting to measure dark energy, but the more galaxies we get, the better we'll do. The goal is to see as much sky as possible."

The era of dark energy has just begun. Although no one yet knows what it is, astronomers think it represents an essential part of understanding the universe. Vast amounts of research will focus on dark energy in the years to come.

This article was originally published online on July 1, 2019.

The post [What is dark energy?] appeared first on [Astr]

New research challenges dark matter theory in galaxy formation

The standard model for how galaxies formed in the early universe predicted that the James Webb Space Telescope (JWST) would see dim signals from small, primitive galaxies. But data are not confirming the popular hypothesis that invisible dark matter helped the earliest stars and galaxies clump together.

Instead, the oldest galaxies are large and bright, in agreement with an alternate theory of gravity, according to new research from Case Western Reserve University published November 12 in *The Astrophysical Journal*. The results challenge astronomers' understanding of the early universe.

"What the theory of dark matter predicted is not what we see," said Case Western Reserve astrophysicist Stacy McGaugh, whose paper describes structure formation in the early universe.

McGaugh, professor and director of astronomy at Case Western Reserve, said instead of dark matter, modified gravity might have played a role. He says a theory known as MOND, for Modified Newtonian Dynamics, predicted in 1998 that structure formation in the early universe would have happened very quickly—much faster than the theory of Cold Dark Matter, known as lambda-CDM, predicted.

JWST was designed to answer some of the biggest questions in the universe, such as how and when did stars and galaxies form? Until it was launched in 2021, no telescope was able to see that deeply into the universe and far back in time.

Lambda-CDM predicts that galaxies were formed by gradual accretion of matter from small to larger structures, due to the extra gravity provided by the mass of dark matter.

"Astronomers invented dark matter to explain how you get from a very smooth early universe to big galaxies with lots of empty space between them that we see today," McGaugh said.

The small pieces assembled in larger and larger structures until galaxies formed. JWST should be able to see these small galaxy precursors as dim light.

"The expectation was that every big galaxy we see in the nearby universe would have started from these itty-bitty pieces," he said.

But even at higher and higher redshift—looking earlier and earlier into the evolution of the universe—the signals are larger and brighter than expected.

MOND predicted that the mass that becomes a galaxy assembled rapidly and initially expands outward with the rest of the universe. The stronger force of gravity slows, then reverses, the expansion, and the material collapses on itself to form a galaxy. In this theory, there is no dark matter at all.

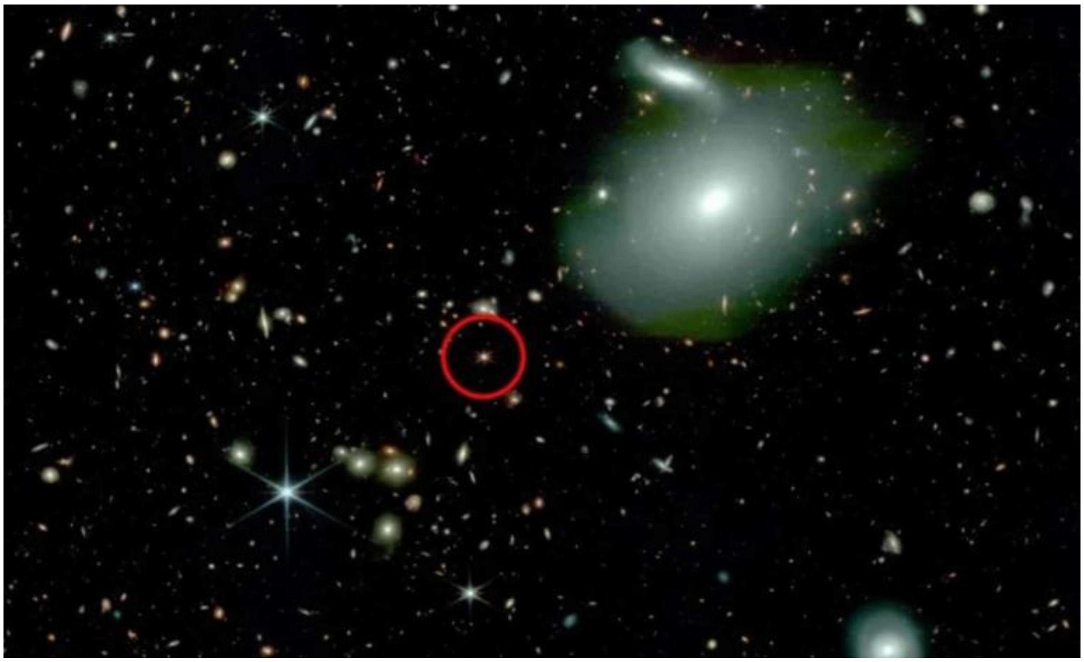
The large and bright structures seen by JWST very early in the universe were predicted by MOND over a quarter century ago, McGaugh said. He co-authored the paper with former Case Western Reserve postdoctoral researcher Federico Lelli, now at INAF—Arcetri Astrophysical Observatory in Italy, and former graduate student Jay Franck. The fourth co-author is James Schombert from the University of Oregon.

"The bottom line is, 'I told you so,'" McGaugh said. "I was raised to think that saying that was rude, but that's the whole point of the scientific method: make predictions and then check which come true." He added that finding a theory compatible with both MOND and General Relativity is still a great challenge.

More information: Stacy S. McGaugh et al, Accelerated Structure Formation: the Early Emergence of Massive Galaxies and Clusters of Galaxies, *The Astrophysical Journal* (2024). On *arXiv*: DOI: 10.48550/arxiv.2406.17930

Provided by Case Western Reserve University

JWST Finds Quasars in Unexpected Places, Shaking Up Our Understanding of Early Universe Evolution



JWST Finds Quasars in Unexpected Places, Shaking Up Our Understanding of Early Universe Evolution© Daily Galaxy

Astronomers using the James Webb Space Telescope (JWST) have made a startling discovery that challenges long-held theories about the early universe.

In a new study, the JWST captured images of **quasars**—the intensely bright centers of galaxies powered by supermassive black holes—existing in unexpected regions of space. These quasars, some of the oldest and most distant ever observed, appear to be isolated, with very few neighboring galaxies. This finding raises critical questions about how such **supermassive black holes** could have formed and grown so large in the first few hundred million years after the **Big Bang** without an abundant supply of nearby matter.

Unexpected Discovery: Lonely Quasars

The **JWST**has the ability to peer back over **13 billion years**, providing scientists with an unprecedented view of the early universe. In their study, astronomers focused on five quasars that formed between **600 to 700 million years** after the Big Bang. Quasars are usually expected to form in dense regions of space filled with galaxies that provide the black holes with enough matter to fuel their rapid growth. However, the **five quasars** identified by JWST exist in what appear to be **sparsely populated regions**, with very few neighboring galaxies in sight.

"Contrary to previous belief, we find on average, these quasars are not necessarily in those highest-density regions of the early universe. Some of them seem to be sitting in the middle of nowhere," said **Anna-Christina Eilers**, lead author of the study and a professor at **MIT**. **"It's difficult to explain how these quasars could have grown so big if they appear to have nothing to feed from."**

The discovery challenges the established model of how **supermassive black holes** grow. In denser regions of space, black holes are thought to accumulate mass by consuming gas, dust, and other material provided by nearby galaxies. But the newfound quasars seem to lack these essential materials, raising the question of how they managed to grow into some of the most massive objects in the universe so early in cosmic history.

How Quasars Defy Formation Theories

The most striking aspect of the study is the significant variation between the environments of the quasars. One quasar was found surrounded by nearly **50 neighboring galaxies**, while another had only **two galaxies** nearby. Despite these dramatic differences, all the quasars shared similar sizes, luminosities, and ages, suggesting they formed around the same time and under the same cosmic conditions. **"That was really surprising to see,"** Eilers remarked, **"For instance, one quasar has almost 50 galaxies around it, while another has just two."**

This variation introduces new uncertainties into the standard model of **black hole formation**. Current theories suggest that **dark matter filaments** in the early universe acted like gravitational highways, pulling in gas and dust that fed the growth of stars and galaxies. Quasars, which are thought to emerge in these dense regions, would have required large amounts of nearby matter to sustain their rapid growth. However, the "lonely" quasars identified by JWST contradict this, suggesting that some supermassive black holes may have formed in isolation, with little nearby matter to sustain them.

"Our results show that there's still a significant piece of the puzzle missing of how these supermassive black holes grow," Eilers added. **"If there's not enough material around for some quasars to be able to grow continuously, that means there must be some other way that they can grow, that we have yet to figure out."**

Implications for Understanding the Early Universe

The discovery of these isolated quasars could significantly reshape our understanding of the **early universe**. The prevailing cosmological model, which predicts that quasars form in the densest regions of the universe, may need to be revised to account for these findings. The presence of these quasars in seemingly empty regions of space raises the possibility that **supermassive black holes** can grow in ways that are not yet fully understood.

JWST's ability to observe these distant quasars in such detail is a major leap forward for astronomy. **"It's just phenomenal that we now have a telescope that can capture light from 13 billion years ago in so much detail,"** Eilers commented. The team's findings, published in **The Astrophysical Journal**, may provide new clues about how the earliest galaxies and black holes formed, potentially unveiling new pathways for the growth of supermassive black holes in the early universe.

This research also opens the door to further studies, as scientists work to understand the precise mechanisms that allowed these quasars to form in seemingly **barren regions** of space. Future observations, including more detailed studies of these quasars' surroundings, could help astronomers solve one of the most puzzling mysteries of modern cosmology.

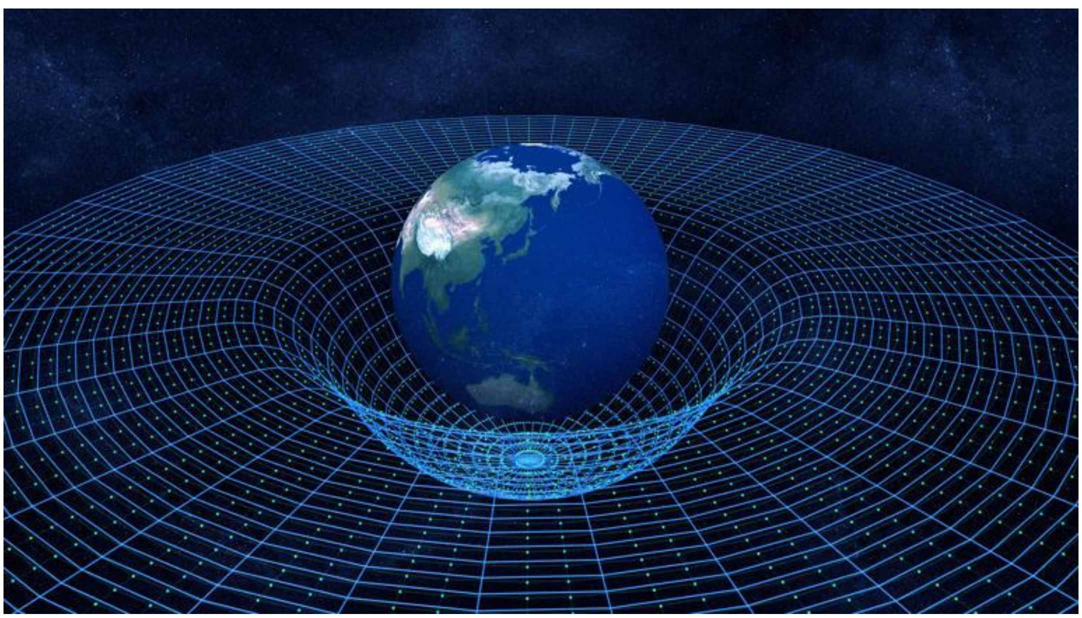
Einstein's Theory of General Relativity Faces Challenge

Albert Einstein's theory of general relativity—which explains gravity as the product of the distortion of space and time—may not be universally applicable.

This is the conclusion of physicists from the University of Geneva (UNIGE), Switzerland, and the Paul Sabatier University in Toulouse, France, who studied data from a survey mapping the shape of hundreds of millions of galaxies from various points of cosmic history.

When the team analyzed how the mass of these galaxies distorts space-time, they found a slight deviation from Einstein's predictions that they emerged between 5–6 million years ago.

This change coincides with an acceleration in the rate of expansion of the universe, and so may help shine a light on this puzzling phenomena.



An artist's impression of Earth's gravity well. The idea that gravity is the result of the curvature of spacetime is a core principle of Einstein's theory of general relativity. DesignCells/iStock / Getty Images Plus© DesignCells/iStock / Getty Images Plus

Under Einstein's theory of general relativity, objects with mass distort space and time—much like how your mattress would deform if you placed a bowling ball on your bed.

This deformation of the fabric of the universe, the physicist proposed, is what we experience as gravity.

The space-time distortions around objects—like, for example, planets or stars—sit in their own little "gravitational wells".

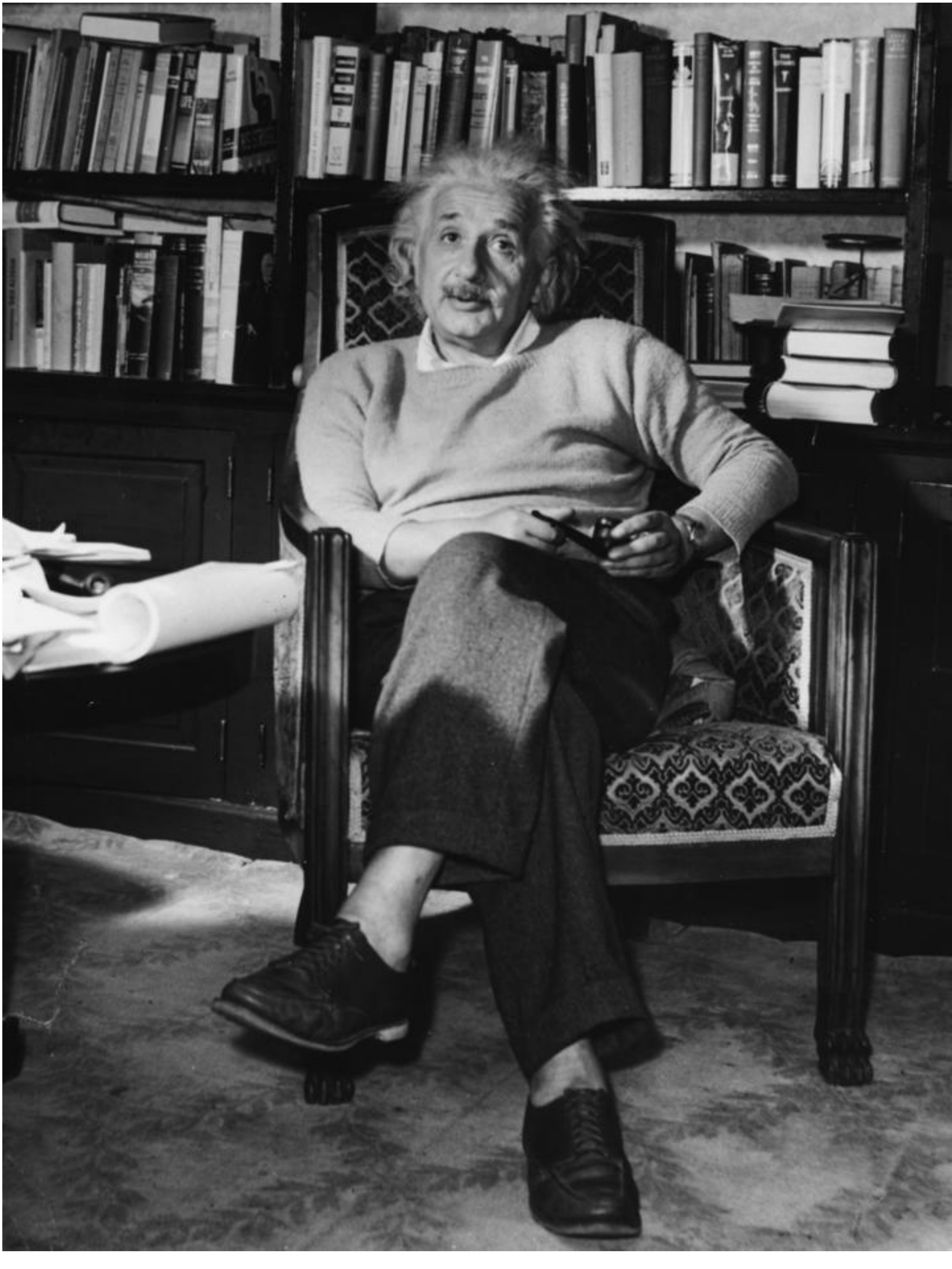
And when light passes through these wells, it is bent as if passing through a magnifying glass, in a process known as gravitational lensing.

This aspect of general relativity was verified in 1919, four years after the concept was published, via experiments partly undertaken during a solar eclipse.

British astronomers Arthur Stanley Eddington and Frank Watson Dyson showed that the sun's gravity well deflected light from distant stars (which were visible while the sun was blocked out during the eclipse) exactly as general relativity predicted.

This was around twice that of the deflection anticipated by Newtonian physics, which did not account for the curvature of time as well as of space.

The question remains, however, as to whether Einstein's predictions remain correct on a universal scale.



Pictured: Albert Einstein. The theoretical physicist published his theory of general relativity in 1919. Lucien Aigner/The Image Bank Unreleased© Lucien Aigner/The Image Bank Unreleased

In their study, the researchers used data from the Dark Energy Survey. This project is measuring the accelerating expansion of the universe, which is thought to be driven by a mysterious, invisible force dubbed dark energy.

"Until now, Dark Energy Survey data have been used to measure the distribution of matter in the Universe," said paper author and UNIGE cosmologist professor Camille Bonvin in a statement.

"In our study, we used this data to directly measure the distortion of time and space, enabling us to compare our findings with Einstein's predictions."

As light takes time to travel across space, looking far out into the distant universe is the same as looking back billions of years into time.

Taking advantage of this fact, the researchers analyzed 100 million galaxies from four different points in the universe's life span: 3.5, 5, 6 and 7 billion years ago—allowing them to explore how gravitational wells have changed over more than half of cosmic history.

Pictured: The Víctor M. Blanco Telescope at the Cerro Tololo Inter-American Observatory in Chile. It it from here that the Dark Energy Survey is conducted. TimAbbott/iStock / Getty Images Plus© TimAbbott/iStock / Getty Images Plus

"We discovered that in the distant past—6 and 7 billion years ago—the depth of the wells aligns well with Einstein's predictions," said paper author and astrophysicist professor Isaac Tutusaus of the Paul Sabatier University in a statement.

"However, closer to today—3.5 and 5 billion years ago—they are slightly shallower than predicted by Einstein."

It is during the second period, the researchers note, that the universe's expansion began to accelerate.

Accordingly it is possible that both mysteries have the same cause—specifically, that gravity may operate slightly differently at large scale than Einstein's theory predicted.

"Our results show that Einstein's predictions have an incompatibility of 3 sigma with measurements," said paper author and UNIGE theoretical physicist Nastassia Grimm in a statement.

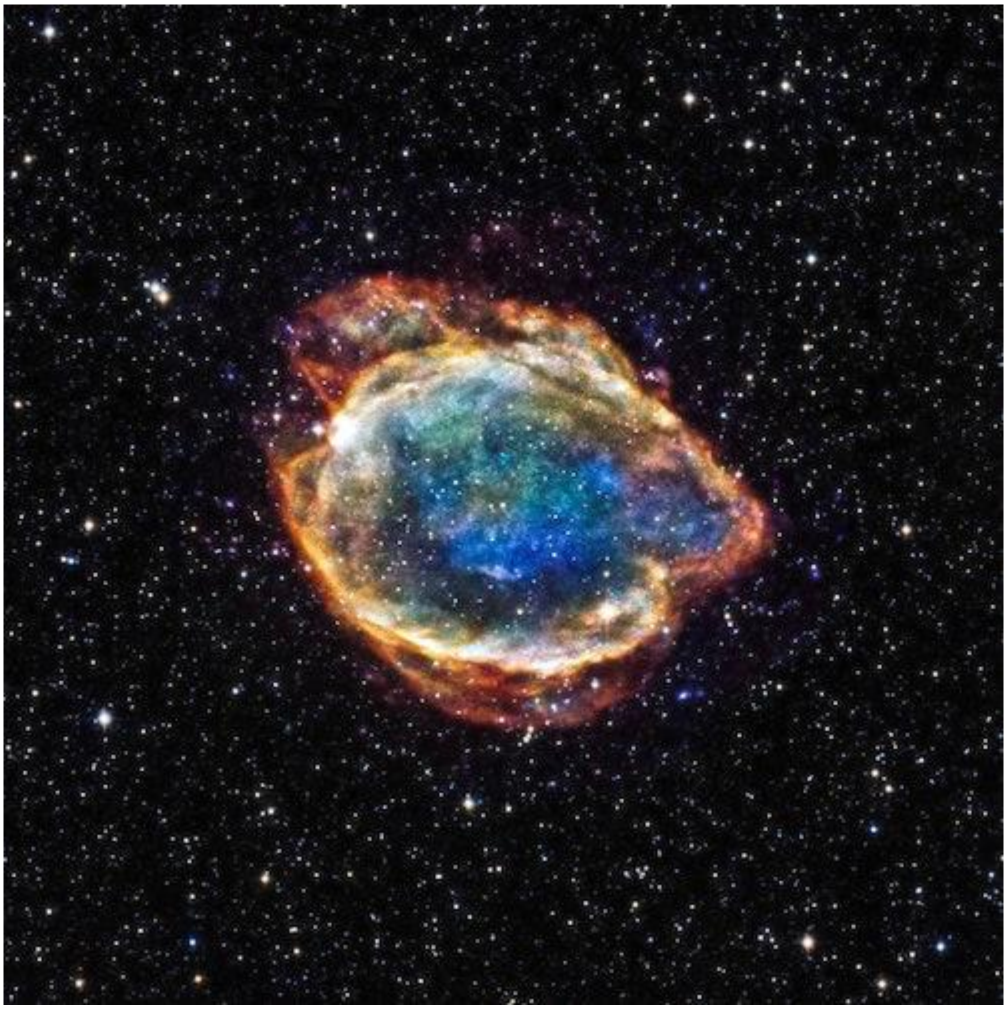
What "3 sigma" means, Grimm explained, is that the difference is interesting and merits further investigation. However, she added, "this incompatibility is not large enough, at this stage, to invalidate Einstein's theory.

"For that to happen, we would need to reach a threshold of 5 sigma. It is therefore essential to have more precise measurements to confirm or refute these results, and to find out whether this theory remains valid in our universe at very large distances."

With their initial study complete, the team are getting ready to analyze data from the European Space Agency's Euclid space telescope, launched last year, which will provide more precise measurements of gravitational lensing.

Tutusaus, I., Bonvin, C., & Grimm, N. (2024). Measurement of the Weyl potential evolution from the first three years of dark energy survey data. *Nature Communications*, *15*(1), 9295. https://doi.org/10.1038/s41467-024-53363-6

Einstein's "Greatest Mistake" Could Actually Help Explain Why the Universe Is Expanding So Quickly



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What is the universe made of? This question has driven astronomers for hundreds of years.

For the past quarter of a century, scientists have believed "normal" stuff like atoms and molecules that make up you, me, Earth, and nearly everything we can see only accounts for 5 percent of the universe. Another 25 percent is "dark matter," an unknown substance we can't see but which we can detect through how it affects normal matter via gravity.

The remaining 70 percent of the cosmos is made of “dark energy.” Discovered in 1998, this unknown form of energy is believed to be making the universe expand at an ever-increasing rate.

In a new study soon to be published in the Astronomical Journal, we have measured the properties of dark energy in more detail than ever before. Our results show it may be a hypothetical vacuum energy first proposed by Einstein — or it may be something stranger and more complicated that changes over time.

What is dark energy?

When Einstein developed the General Theory of Relativity over a century ago, he realized his equations showed the universe should either be expanding or shrinking. This seemed wrong to him, so he added a “cosmological constant” — a kind of energy inherent in empty space — to balance out the force of gravity and keep the universe static.

Later, when the work of Henrietta Swan Leavitt and Edwin Hubble showed the universe was indeed expanding, Einstein did away with the cosmological constant, calling it his “greatest mistake.”

However, in 1998, two teams of researchers found the expansion of the universe was actually accelerating. This implies that something quite similar to Einstein’s cosmological constant may exist after all — something we now call dark energy.

Since those initial measurements, we’ve been using supernovae and other probes to measure the nature of dark energy. Until now, these results have shown the density of dark energy in the universe appears to be constant.

This means the strength of dark energy remains the same, even as the universe grows — it doesn’t seem to be spread more thinly as the universe gets bigger. We measure this with a number called w. Einstein’s cosmological constant, in effect, set w to -1, and earlier observations have suggested this was about right.

Exploding stars as cosmic measuring sticks

How do we measure what is in the universe and how fast it is growing? We don't have enormous tape measures or giant scales, so instead, we use "standard candles": objects in space whose brightness we know.

Imagine it is night, and you are standing on a long road with a few light poles. These poles all have the same light bulb, but the poles further away are fainter than the nearby ones.

This is because light fades proportionately to distance. If we know the power of the bulb and can measure how bright the bulb appears to be, we can calculate the distance to the light pole.

For astronomers, a common cosmic light bulb is a kind of exploding star called a Type Ia supernova. These are white dwarf stars that often suck in matter from a neighboring star and grow until they reach 1.44 times the mass of our Sun, at which point they explode. By measuring how quickly the explosion fades, we can determine how bright it was and, hence, how far away from us.

The Dark Energy Survey

The Dark Energy Survey is the largest effort yet to measure dark energy. More than 400 scientists across multiple continents have worked together for nearly a decade to repeatedly observe parts of the southern sky.

Repeated observations let us look for changes, like new exploding stars. The more often you observe, the better you can measure these changes, and the larger the area you search, the more supernovae you can find.

The first results indicating the existence of dark energy used only a couple of dozen supernovae. The latest results from the Dark Energy Survey use around 1,500 exploding stars, giving much greater precision.

Using a specially built camera installed on the 4-metre Blanco Telescope at the Cerro-Tololo Inter-American Observatory in Chile, the survey found thousands of supernovae of different types. To work out which ones were Type Ia (the kind we need for measuring distances), we used the 4-meter Anglo-Australian Telescope at Siding Spring Observatory in New South Wales.

The Anglo-Australian Telescope took measurements that broke up the colors of light from the supernovae. This lets us see a “fingerprint” of the individual elements in the explosion.

Type Ia supernovae have some unique features, like containing no hydrogen and silicon. And with enough supernovae, machine learning allowed us to classify thousands of supernovae efficiently.

More complicated than the cosmological constant

Finally, after more than a decade of work and studying around 1,500 Type Ia supernovae, the Dark Energy Survey has produced a new best measurement of w. We found $w = –0.80 \pm 0.18$, so it’s somewhere between –0.62 and –0.98.

This is a very interesting result. It is close to –1, but not quite exactly there. To be the cosmological constant or the energy of empty space, it would need to be exactly –1.

Where does this leave us? With the idea that a more complex model of dark energy may be needed, perhaps one in which this mysterious energy has changed over the life of the universe.

Dark matter has a firm grip on these galaxies

NGC 1270 is just one member of the Perseus Cluster, a group of thousands of galaxies that lies about 240 million light-years from Earth in the constellation Perseus. This image, taken with the Gemini Multi-Object Spectrograph (GMOS) on the Gemini North telescope, one half of the International Gemini Observatory, captures a dazzling collection of galaxies in the central region of this enormous cluster. Credit: International Gemini Observatory/NOIRLab/NSF/AURA/ Image Processing: J. Miller & M. Rodriguez (International Gemini Observatory/NSF NOIRLab), T.A. Rector (University of Alaska Anchorage/NSF NOIRLab), M. Zamani (NSF NOIRLab) Acknowledgements: PI: Jisu Kang (Seoul National University)

The elliptical galaxy NGC 1270 lies about 240 million light-years away. But it's not alone. It's part of the Perseus Cluster (Abell 426), the brightest X-ray object in the sky and one of the most massive objects in the universe.

NGC 1270 plays a starring role in a new image from the Gemini North telescope. However, the image doesn't show the dark matter that has a firm grip on the galaxy and the rest of the galaxies in the Perseus Cluster.

Ancient astronomers would be astounded by what we've learned about the universe. Even astronomers like Edwin Hubble from the 20th would be amazed at the power of our modern telescopes and what they've shown us. At that time, distant galaxies appeared fuzzy and were called nebulae.

Even the nature of Andromeda, our closest galactic neighbor, was uncertain. In 1920, Hubble and others were debating whether Andromeda and other objects they were seeing were small objects in the Milky Way's outer regions, nebulae, or other galaxies.

German philosopher and Enlightenment thinker Immanuel Kant coined the term "island universes" to describe all these fuzzy objects, hinting at their true nature. The idea of other galaxies beyond our own dates back a long way, but there was no way to test it. Then, in 1924, Edwin Hubble ended the debate. He was able to show that individual stars in some of these so-called "nebulae" were actually far beyond the Milky Way.

The discovery was decisive, and we now know that the universe is populated by hundreds of billions or even trillions of other galaxies like our own Milky Way.

Now, astronomers use powerful telescopes to examine other galaxies in great detail. They've even used the James Webb Space Telescope to peer back in time at the universe's earliest galaxies. Anyone can quickly examine hundreds of amazing images of other galaxies of all types.

Enormous objects like the Perseus Cluster alert us to the presence of something even more mysterious and challenging to understand than the nature of galaxies. Something binds these individual galaxies together into a coherent group, and we call that dark matter.

There's a growing chorus of scientific voices suggesting we stop calling it dark matter and instead use the more accurate term invisible matter. But whatever we decide to call it, dark matter makes up most of the matter in the universe and dwarfs the "normal" matter that interacts with light and makes up stars, planets, and us.

As cosmology has progressed, scientists have mapped the universe's large-scale structure. These maps show how galaxies and their groups are organized along filaments of dark matter that act as scaffolds. The Perseus Cluster is associated with the Perseus-Pegasus Filament, a long, thin structure of galaxies that stretches over a billion light-years.

If there were no dark matter, scientists think that the universe would be far more homogenous. The galaxies would be spread more evenly throughout space. But that's not what we see, and NGC 1270 and the rest of the Perseus Cluster show it clearly.

Currently, scientific theory suggests that a web of invisible dark matter draws galaxies together. They're situated where dark matter's massive tendrils intersect. That's where its gravitational pull is strongest.

In short, the Perseus Cluster and NGC 1270 wouldn't be where they are and wouldn't be grouped together without dark matter. The cluster, and all other groups, clusters, and super-clusters, are firmly in dark matter's grip.

American astronomer Vera Rubin played a huge role in our modern understanding of dark matter. She observed that stars and gas at a galaxy's outer edge were moving much faster than predicted by the visible mass of the galaxy. Newtonian physics suggests they should be moving slower.

Rubin and her colleagues thought that there must be a large amount of invisible matter beyond the visible edges of galaxies. Eventually, she figured out that there must be six times more dark matter than visible matter in galaxies.

Rubin faced many obstacles in getting her results accepted. As a woman, she wasn't part of the male-dominated world of 1970s astronomy. She was denied access to some facilities early in her career, which slowed her progress. Now, she's given full credit and mentioned alongside Hubble and other influential figures in astronomy. One of the most powerful and unique observatories ever conceived is named after her.

Regardless of what we call it and who discovered it, our universe is dominated by something we don't fully understand.

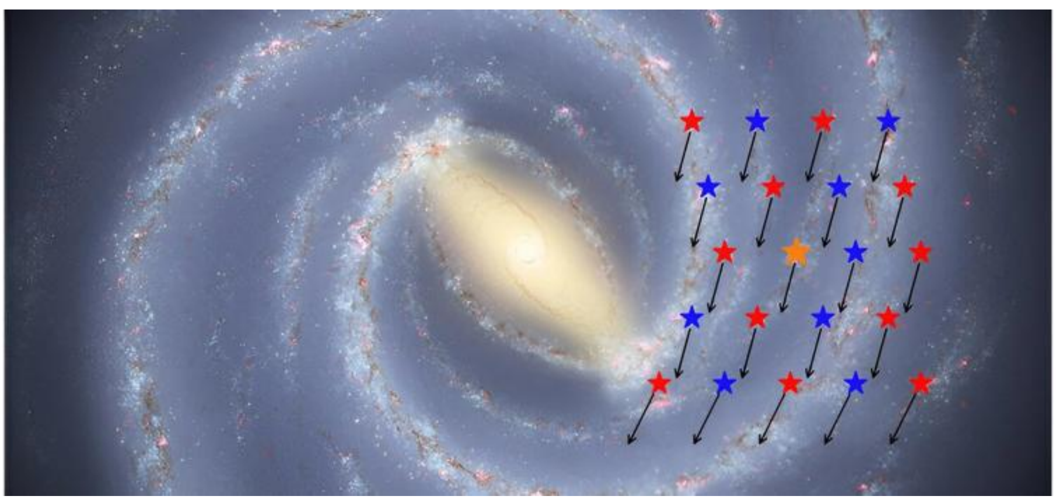
It's remarkable that scientists can map invisible matter by its inference alone, without knowing what it is. The most widely accepted understanding of dark matter is in the Lambda Cold Dark Matter (Lambda-CDM) model of cosmology, also called the Standard Model of Big Bang Cosmology. It successfully recreates many things that we observe in the universe, including how galaxies form, how the universe expands, and, of course, the large-scale structure of the universe.

But even Lambda-CDM can't tell us what dark matter is. Most think it's some type of particle, but if it is, it's extremely elusive.

That doesn't stop us from seeing its effect when we observe objects like NGC 1270 and the Perseus Cluster.

Provided by Universe Today

Discovery of ancient stars on the stellar thin disk of the Milky Way



Rotational motion of young (blue) and old (red) stars similar to the Sun (orange). Credit: Background image by NASA/JPL-Caltech/R. Hurt (SSC/Caltech)© Provided by Phys.org

A surprising discovery about the evolution of our galaxy using data from the Gaia mission found a large number of ancient stars on orbits similar to that of our sun. They formed the Milky Way's thin disk less than 1 billion years after the Big Bang, several billion years earlier than previously believed.

The Milky Way galaxy has a large halo, a central bulge and bar, a thick disk and a thin disk. Most stars are located in the so-called thin disk of our Milky Way and follow an organized rotation around the galactic center. Middle-aged stars such as our 4.6-billion-year-old sun belong to the thin disk, which was generally thought to have started forming around 8 to 10 billion years ago.

Understanding how the Milky Way was formed is a major goal of galactic archaeology. To achieve this, detailed maps of the galaxy that show the ages, chemical compositions, and movements of stars are needed. These maps, known as chrono-chemo-kinematical maps, help to piece together the history of our galaxy. Creating these detailed maps is challenging because it requires large datasets of stars with accurately known ages.

One common approach to overcome this challenge is to study very metal-poor stars, which are old, to provide a window into the early Milky Way. Very metal-poor stars are known to be old because they were among the first stars to form when the universe was still largely composed of hydrogen and helium, before many of the heavier elements were created and distributed by successive generations of stars.

Using a data set from the European Space Agency (ESA) Gaia Mission, an international team led by astronomers from the Leibniz Institute for Astrophysics Potsdam (AIP) studied stars in the solar neighborhood, about 3,200 light years around the sun. They discovered a surprising number of very old stars in thin disk orbits; the majority of these are older than 10 billion years, some of them even older than 13 billion years.

These ancient stars show a wide range of metal compositions: some are very metal-poor (as expected), while others have twice the metal content of our much younger sun, indicating that a rapid metal enrichment took place in the early phase of the Milky Way's evolution.

"These ancient stars in the disk suggest that the formation of the Milky Way's thin disk began much earlier than previously believed, by about 4–5 billion years," explains Samir Nepal from AIP and first author of the study, which has been accepted for publication by *Astronomy and Astrophysics* and is available on the *arXiv* preprint server.

"This study also highlights that our galaxy had an intense star formation at early epochs leading to very fast metal enrichment in the inner regions and the formation of the disk. This discovery aligns the Milky Way's disk formation timeline with those of high-redshift galaxies observed by the James Webb Space Telescope (JWST) and Atacama Large Millimeter Array (ALMA) Radio Telescope.

"It indicates that cold disks can form and stabilize very early in the universe's history, providing new insights into the evolution of galaxies."

"Our study suggests that the thin disk of the Milky Way may have formed much earlier than we had thought, and that its formation is strongly related to the early chemical enrichment of the innermost regions of our galaxy," explains Cristina Chiappini. "The combination of data from different sources and the application of advanced machine learning techniques have enabled us to increase the number of stars with high quality stellar parameters, a key step to lead our team to these new insights."

The results were made possible by the third data release of the Gaia mission. The team analyzed the stellar parameters of more than 800,000 stars using a novel machine learning method that combines information from different types of data to provide improved stellar parameters with high precision. These precise measurements include gravity, temperature, metal content, distances, kinematics and the age of the stars.

In the future, a similar machine learning technique will be used to analyze millions of spectra, collected by the 4MIDABLE-LR survey with the 4-meter Multi-Object Spectroscopic Telescope (4MOST), starting operations in 2025.

More information: Samir Nepal et al, Discovery of the local counterpart of disc galaxies at z > 4: The oldest thin disc of the Milky Way using Gaia-RVS, *arXiv* (2024). DOI: 10.48550/arxiv.2402.00561

Provided by Leibniz Institute for Astrophysics Potsdam

Astronomers detect ancient lonely quasars with murky origins

This image, taken by NASA's James Webb Space Telescope, shows an ancient quasar (circled in red) with fewer than expected neighboring galaxies (bright blobs), challenging physicists' understanding of how the first quasars and supermassive black holes formed. Credit: Christina Eilers/EIGER team

A quasar is the extremely bright core of a galaxy that hosts an active supermassive black hole at its center. As the black hole draws in surrounding gas and dust, it blasts out an enormous amount of energy, making quasars some of the brightest objects in the universe. Quasars have been observed as early as a few hundred million years after the Big Bang, and it's been a mystery as to how these objects could have grown so bright and massive in such a short amount of cosmic time.

Scientists have proposed that the earliest quasars sprang from overly dense regions of primordial matter, which would also have produced many smaller galaxies in the quasars' environment. But in a new MIT-led study, astronomers observed some ancient quasars that appear to be surprisingly alone in the early universe.

The astronomers used NASA's James Webb Space Telescope (JWST) to peer back in time, more than 13 billion years, to study the cosmic surroundings of five known ancient quasars. They found a surprising variety in their neighborhoods, or "quasar fields." While some quasars reside in very crowded fields with more than 50 neighboring galaxies, as all models predict, the remaining quasars appear to drift in voids, with only a few stray galaxies in their vicinity.

These lonely quasars are challenging physicists' understanding of how such luminous objects could have formed so early on in the universe, without a significant source of surrounding matter to fuel their black hole growth.

"Contrary to previous belief, we find on average, these quasars are not necessarily in those highest-density regions of the early universe. Some of them seem to be sitting in the middle of nowhere," says Anna-Christina Eilers, assistant professor of physics at MIT. "It's difficult to explain how these quasars could have grown so big if they appear to have nothing to feed from."

There is a possibility that these quasars may not be as solitary as they appear, but are instead surrounded by galaxies that are heavily shrouded in dust and therefore hidden from view. Eilers and her colleagues hope to tune their observations to try and see through any such cosmic dust, in order to understand how quasars grew so big, so fast, in the early universe.

Eilers and her colleagues report their findings in a paper appearing in *The Astrophysical Journal*. The MIT co-authors include postdocs Rohan Naidu and Minghao Yue; Robert Simcoe, the Francis Friedman Professor of Physics and director of MIT's Kavli Institute for Astrophysics and Space Research; and collaborators from institutions including Leiden University, the University of California at Santa Barbara, ETH Zurich, and elsewhere.

Galactic neighbors

The five newly observed quasars are among the oldest quasars observed to date. More than 13 billion years old, the objects are thought to have formed between 600 to 700 million years after the Big Bang. The supermassive black holes powering the quasars are a billion times more massive than the sun, and more than a trillion times brighter. Due to their extreme luminosity, the light from each quasar is able to travel over the age of the universe, far enough to reach JWST's highly sensitive detectors today.

"It's just phenomenal that we now have a telescope that can capture light from 13 billion years ago in so much detail," Eilers says. "For the first time, JWST enabled us to look at the environment of these quasars, where they grew up, and what their neighborhood was like."

The team analyzed images of the five ancient quasars taken by JWST between August 2022 and June 2023. The observations of each quasar comprised multiple "mosaic" images, or partial views of the quasar's field, which the team effectively stitched together to produce a complete picture of each quasar's surrounding neighborhood.

The telescope also took measurements of light in multiple wavelengths across each quasar's field, which the team then processed to determine whether a given object in the field was light from a neighboring galaxy, and how far a galaxy is from the much more luminous central quasar.

"We found that the only difference between these five quasars is that their environments look so different," Eilers says. "For instance, one quasar has almost 50 galaxies around it, while another has just two. And both quasars are within the same size, volume, brightness, and time of the universe. That was really surprising to see."

Growth spurts

The disparity in quasar fields introduces a kink in the standard picture of black hole growth and galaxy formation. According to physicists' best understanding of how the first objects in the universe emerged, a cosmic web of dark matter should have set the course. Dark matter is an as-yet unknown form of matter that has no other interactions with its surroundings other than through gravity.

Shortly after the Big Bang, the early universe is thought to have formed filaments of dark matter that acted as a sort of gravitational road, attracting gas and dust along its tendrils. In overly dense regions of this web, matter would have accumulated to form more massive objects. And the brightest, most massive early objects, such as quasars, would have formed in the web's highest-density regions, which would have also churned out many more, smaller galaxies.

"The cosmic web of dark matter is a solid prediction of our cosmological model of the universe, and it can be described in detail using numerical simulations," says co-author Elia Pizzati, a graduate student at Leiden University. "By comparing our observations to these simulations, we can determine where in the cosmic web quasars are located."

Scientists estimate that quasars would have had to grow continuously with very high accretion rates in order to reach the extreme mass and luminosities at the times that astronomers have observed them, fewer than 1 billion years after the Big Bang.

"The main question we're trying to answer is, how do these billion-solar-mass black holes form at a time when the universe is still really, really young? It's still in its infancy," Eilers says.

The team's findings may raise more questions than answers. The "lonely" quasars appear to live in relatively empty regions of space. If physicists' cosmological models are correct, these barren regions signify very little dark matter, or starting material for brewing up stars and galaxies. How, then, did extremely bright and massive quasars come to be?

"Our results show that there's still a significant piece of the puzzle missing of how these supermassive black holes grow," Eilers says. "If there's not enough material around for some quasars to be able to grow continuously, that means there must be some other way that they can grow, that we have yet to figure out."

More information: Anna-Christina Eilers et al, EIGER. VI. The Correlation Function, Host Halo Mass, and Duty Cycle of Luminous Quasars at $z \gtrsim 6$, *The Astrophysical Journal* (2024). DOI: 10.3847/1538-4357/ad778b

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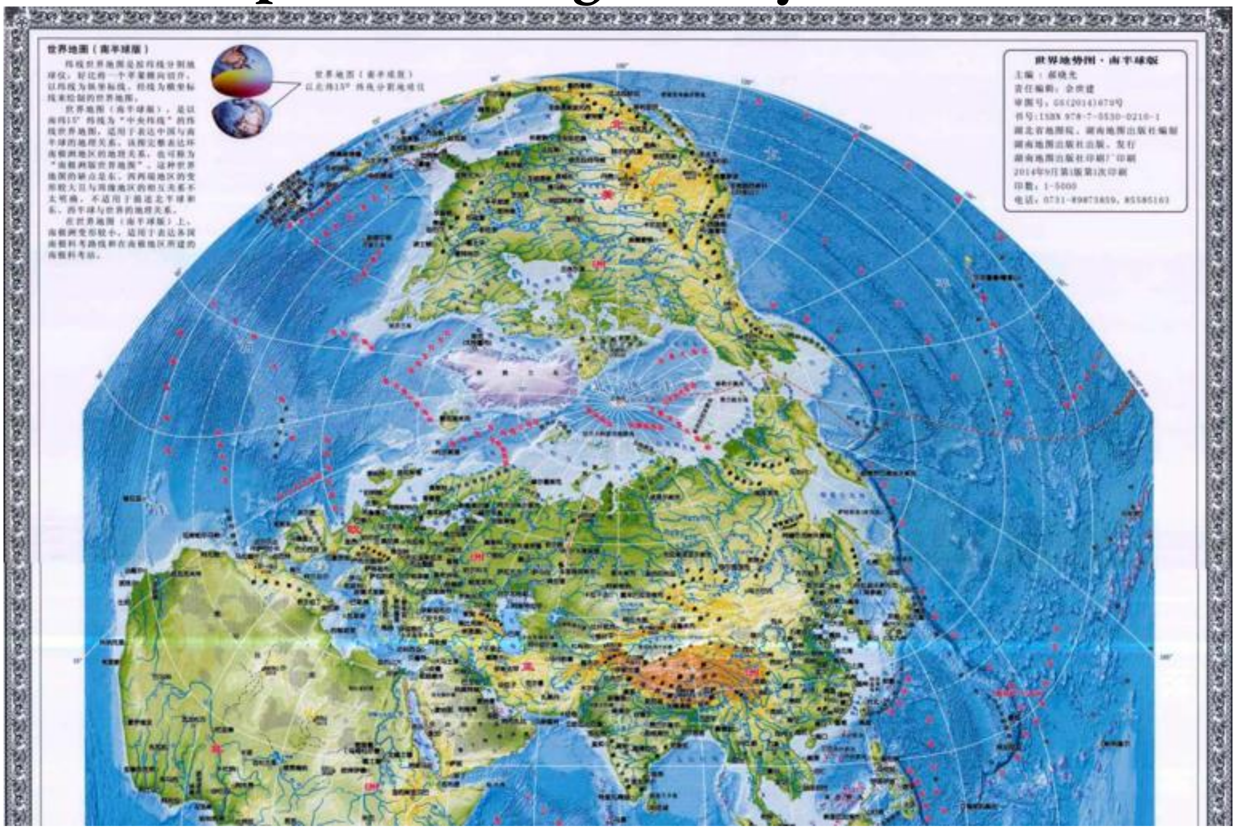
Provided by Massachusetts Institute of Technology

These maps will change how you see the world



Part of Hao Xiaoguang's vertical world map TopPhoto via AP Images/Alamy

Alastair Bonnett has an unusual pastime for an expert in mapping: he likes to get lost. A geographer at Newcastle University, UK, Bonnett sees this as a necessary corrective for a society dependent on maps for basic daily activities. "We're increasingly not good at dealing with not knowing where things are," he says. "Sometimes it feels like we're in control; sometimes it feels like the map is in control."

This ubiquity of maps makes the 21st century a golden era for cartography, says Bonnett. Maps are everywhere, used for everything from tracking the spread of disease to finding where to get your groceries. They have also become an ever-more essential tool in many scientific fields. But Bonnett is concerned that despite our obsession with maps, we don't always know what makes for a good one, or how people have used them over the centuries. "We need to use this moment to think about the lost traditions of cartography," he says.

In *40 Maps That Will Change How You See The World*, out on 26 September, Bonnett aims to do just that, putting together a tour of diverse cartographic traditions, from the wooden ocean maps of the Marshall Islands to a 500-year-old Aztec depiction of the descendants of regional leader Lord-11 Quetzalecatzin.

Some of the selections, most of which Bonnett came upon by chance and saved for the collection, illustrate rapid planetary change or geopolitical tension. Others – from a map of neurons to a map of smells – challenge the definition of what a map can be. All of them, in his words, “disorient and reorient” us to discover new ways of finding our place in the universe.

A map of the Laniakea Supercluster MARK GARLICK/SCIENCE PHOTO LIBRARY

This is literally true of the first example from his book, a map of the Laniakea Supercluster, a collection of more than 100,000 galaxies including the Milky Way. The red dot marks Earth’s current location among them as part of the Virgo cluster. The migratory routes of the galaxies as they are pulled along by gravity and shaped by the expanding universe are depicted by the glowing lines. The researchers who made the map compare the way they flow together to form a supercluster to the way water flows within a watershed. Our supercluster, named using the Hawaiian word for “immense heaven”, is around 520 million light years across.

The “Map of the Tracks of Yu” Alamy Stock Photo

The rational organisation of space that defines most maps in use today has a much longer history. This “Map of the Tracks of Yu” from 12th-century China is what Bonnett calls the first modern map. This is because of the way it represents space on a grid, enabling a reasonably accurate depiction of China’s great rivers and waterways. “Yu” refers to “Yu the Great”, a legendary civil engineer and king said to be responsible for opening up the rivers to navigation. The map was chiselled into stone, which enabled people to make rubbings of it.

This map was purported to show the world as known to Chinese geographers in 1418

China, with a mapping culture extending back millennia, is the source of a number of maps in Bonnett's book. This one was discovered in 2001 by an amateur historian and was purported to show the world as known to Chinese geographers in 1418. The detailed view of global coastlines, including Australia, decades before Columbus set sail would be extraordinary if genuine, but according to Bonnett it is almost certainly a fake; it doesn't resemble any other maps from the period and there are no records of the global voyages needed to make it. Still, it is true that "China is home to the most impressive ancient map-making tradition in the world", he writes.

世界地图（南半球版）

纬线世界地图是按纬线分割地球仪，好比将一个苹果横向切开，以纬线为纵坐标线，经线为横坐标线来绘制的世界地图。

世界地图（南半球版），是以南纬13°纬线为"中央纬线"的纬线世界地图，适用于表达中国与南半球的地理关系。该图完整表达出南极洲地区的地理关系，也可称为"南极洲版世界地图"。这种世界地图的缺点是东、西两端地区的变形较大且与周缘地区的相互关系不太明确，不适用于描述北半球和东、西半球与世界的地理关系。

在世界地图（南半球版）上，南极洲变形较小，适用于表达各国南极科考路线和在南极地区所建的南极科考站。

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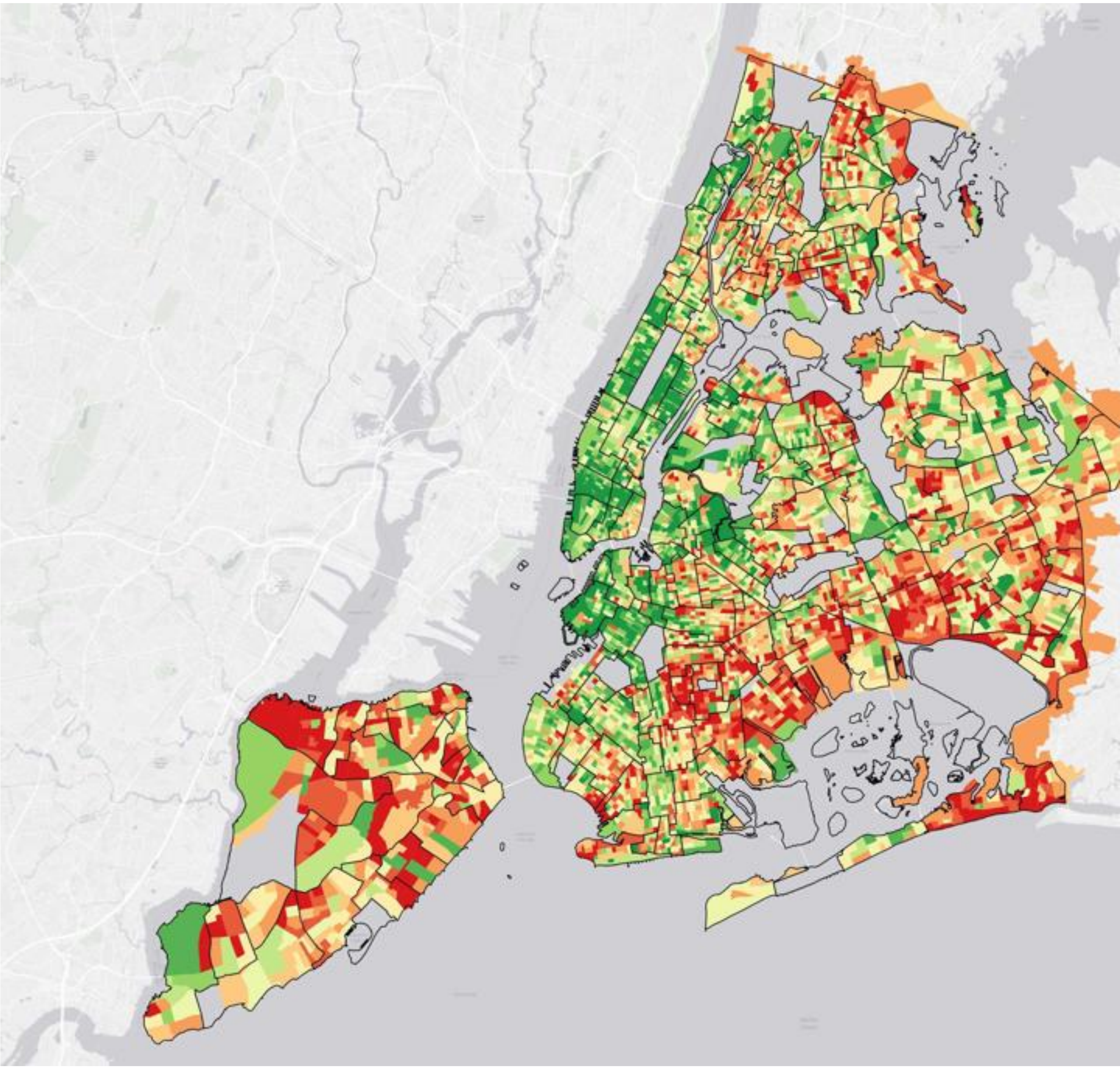
Hao Xiaoguang's vertical world map Associated Press / Alamy Stock Photo

Geopolitics is also at play in this modern Chinese map from 2013. The vertical depiction shows Asia at the centre of the world, also highlighting the poles as opposed to hiding them away in the usual manner like “some embarrassing great aunt”, says Bonnett. The effect is to emphasise Asia as the seat of global power and to mark increasingly ice-free polar waters as sites for economic opportunity. Political boundaries have always changed, says Bonnett. However, that is increasingly true of natural features as well. “I don’t think we’ve ever lived at a time where the physical natural map of the world is changing so fast,” he says.

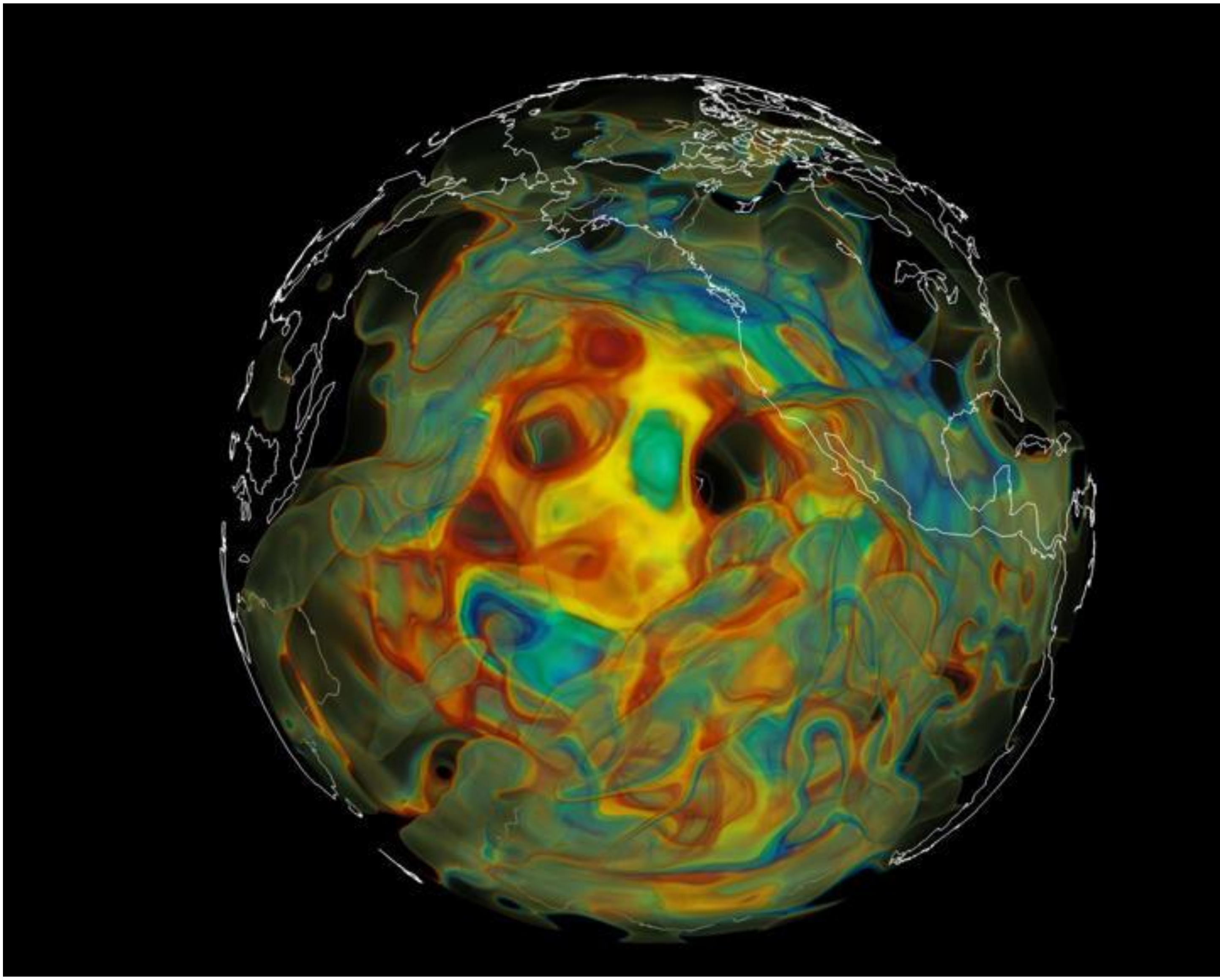
A 16th-century American map, shown in part Library of Congress

This detail from a map from 1593 shows the Aztec leader Lord-11 Quetzalcatzin (in red) surrounded by his descendants asserting land rights over what is now Mexico’s Puebla and Oaxaca regions. Bonnett calls it “one of the most important maps in the history of the Americas” because it captures a point of cultural transition between Indigenous and post-colonial societies, with elements of the cartographic traditions of both.



Walkability for Women in New York City, 2021 Gorrini, A., Presicce, D., Choubassi, R., Sener, I.N. (2021)

This thoroughly modern map depicts New York neighbourhoods coloured by a "walkability for women" index, with greener areas more walkable and redder areas less so. This was created by a team of researchers based on surveys of women on where they feel safe, along with data on infrastructure and crime. In general, richer parts of the city scored higher than poorer parts. This shouldn't just be taken at face value, writes Bonnett, but as an illustration of how maps can reproduce existing inequalities. "Maps of walkability are also maps of well-being, sociability and connection."



This map shows the structure of the planet's mantle below the Pacific Ocean based on reflected seismic waves
Princeton University

Maps can extend from above Earth to below it. This tangle of colours indicates the structure of the planet's mantle below the Pacific Ocean based on reflected seismic waves rippling through this region. Produced in [2015 by a team of geoscientists] using a supercomputer to crunch the numbers from thousands of earthquakes, it depicts the speed of the waves as they move through different materials that are at different pressures and temperatures within the planet. The slowest speeds are in red and orange, while the fastest are in green and blue. A particular area of interest for Bonnett is the ring of blue on the left side of the map marking the fast-moving tectonic feature known as the Tonga microplate. This image is just one view of a larger project to create a 3D map of Earth's entire mantle.

***40 Maps That Will Change How You See The World* by Alastair Bonnett is published by Ivy Press on 26 September in the UK, and on 17 September in the US**

2R0BH12 The Fra Mauro map, ca 1450 by the Venetian cartographer Fra Mauro

The magnificent medieval map that made cartography into a science

Some 550 years ago, a Venetian monk named Fra Mauro set out to create a world map. Rather than myth and religion, it was based on solid evidence for the first time

Newly Discovered “Hedgehog" Galaxy Might Be The Loneliest In The Known Universe

NGC 5068 is a fairly ordinary, if releatively close, spiral galaxy, but in looking for dwarf galaxies around it astronomers found something much more significant. - Image Credit: By Donald Pelletier - Own work, (CC BY-SA 4.0)© IFL Science

At just 7.8 million light-years away, the newly discovered dwarf galaxy dw1322m2053 is remarkable for its isolation and lack of star-forming activity. If that wasn't enough to make you anthropomorphize it and feel sorry for its lonely status, the astronomers who found it have nicknamed it "Hedgehog".

We have detected galaxies billions of light-years away, so one might expect the local universe out to at least 10 million light-years would be thoroughly mapped out. For a variety of reasons, however, that is not the case, and galaxies like Hedgehog have remained unnoticed until now. Although relatively nearby dwarf galaxies are discovered now and then, finding one as distinctive as Hedgehog is a different matter.

Exposure to the gravity of larger galaxies frequently disrupts the gas in dwarf galaxies. Some undergo dramatic bursts of star formation that can exceed activity in many larger galaxies. It's not entirely a coincidence that we saw a supernova in the Large Magellanic Cloud (LMC) far more recently than one in the Milky Way, and the most massive stars we know are also overwhelmingly in the LMC.

Hedgehog, however, is at the other extreme. Instead of just a few Milky Way-lengths away, like the Magellanic Clouds, Hedgehog is 3.3 million light years from the nearest galaxy, and 2.2 million more from a galactic group.

Many dwarf galaxies are quiescent (have stopped forming stars) because the gas that would have been the raw material for star formation was stripped in encounters with larger galaxies, or used up in previous bursts.

On the other hand, just 6 in 10,000 known isolated dwarf galaxies are quiescent. With nothing nearby to cause such violent disruption, they usually just keep on forming stars at a relatively steady rate. Then again, we may have a skewed sample – if a dwarf galaxy is both small and lacking in hot young stars, we might just be overlooking it.

Princeton University graduate student Jiaxuan Li () was part of a team seeking dwarf galaxies orbiting the spiral galaxy NGC 5068 when they discovered Hedgehog. At an estimated 17 million light-years away, NGC 5068 is a good distance to have undiscovered dwarf companions that are still close enough for in-depth study.

Despite being in the right direction, dw1322m2053 didn't seem to fit, and the team thought its strange patterns might mean it was close enough we were seeing individual stars or clusters. Examination with a larger instrument revealed dw1322m2053 produced an estimate of, just 7.8 million light years away.

Our local group of galaxies are not dw1322m2053's nearest neighbors, that status goes to fellow dwarf KKs 53 at the edge of the group containing the huge elliptical galaxy Centaurus A.

Dw1322m2053 appears invisible in the ultraviolet part of the spectrum, indicating an absence of young stars, and no dust lanes behind which such stars could be lurking were detected. In fact, Li and colleagues think there has been no new star formation in Hedgehog for at least 100 million years, and possibly five billion. The last time this galaxy formed a star not only were there no hedgehogs, there were barely mammals, and it's even possible there was no life on Earth.

The immediate thing astronomers want to know is why Hedgehog is quiescent. Li and colleagues think it is most likely a "backsplash galaxy,", one that passed through a group and had most of its gas stripped away, leaving it with little material to form new stars. The remnants were then flung into the void by the gravity of larger objects.

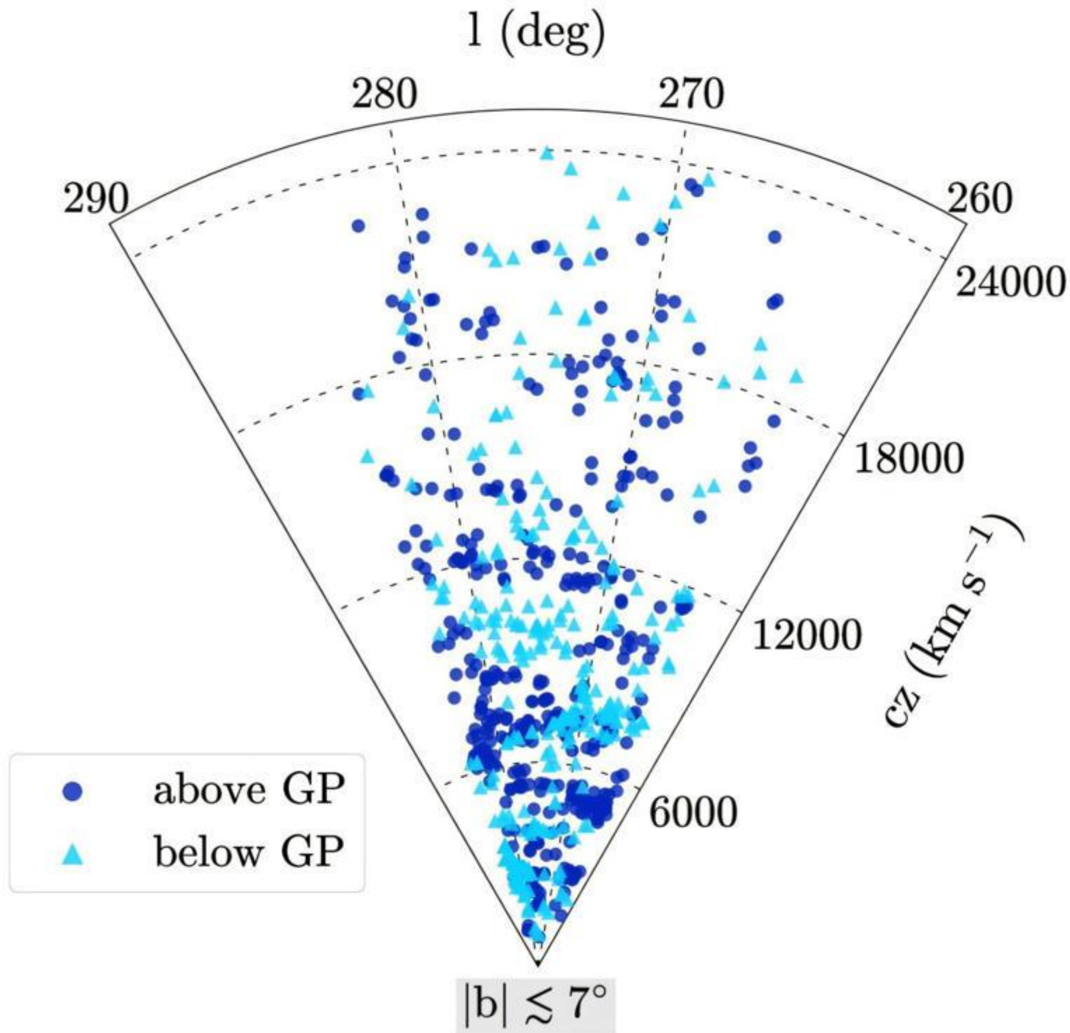
If this sounds like the behavior of a cosmic tyrant, be warned: Centaurus A is the prime suspect for such bullying, but the Milky Way isn't that much more distant, so any "cruelty to galactic hedgehogs" inspectors might not cross us off the list. Further research on Hedgehog's age and movements will be necessary to determine if it's a backsplash galaxy, and if so, who is responsible. It's estimated that if expelled by the Centaurus A group of galaxies, it would have taken 4-6 billion years to reach its current location.

It's also possible dw1322m2053 is so small (around 630,000 solar masses) that it lost its gas in some other way, such as a small number of supernovae driving remnant gas out a long time ago.

Either way, its distinctiveness makes Hedgehog worth studying as a point of comparison, so it's handy it is so close - 12 times closer than another recently discovered isolated quiescent dwarf galaxy.

If you're wondering about the name, it's not because dw1322m2053 looks like a hedgehog. Frankly, it doesn't look like anything much. The authors say it is because hedgehogs are "small and solitary animals."

Astronomers defy the zone of avoidance to find hundreds of new galaxies



Observed galaxies within the Vela supercluster. Credit: Sambatriniaina H. A. Rajohnson, et al

There is a region of the sky where astronomers fear to look. Filled with dark clouds of dust, it hides an unseen mass. A mass so large it is pulling the Milky Way and other galaxies toward it.

Okay, maybe that's overdramatic, but it is true. The region is known as the Zone of Avoidance, and it happens to be in the general direction of the galactic center. Our view of the universe isn't as perfect as we'd like. The sun is located within the galactic plane of the Milky Way, about 30,000 light-years from its center. If we look to the north or south of the galactic plane, we get a pretty normal view of the cosmos. We can peer deep into the sky and see distant galaxies.

But if we look toward the galactic center, we don't have a clear view. Instead, we see a bunch of stars, gas, and dust. This is fine if you want to study stars, gas, and dust, but it means our view of the distant universe is obscured in that direction. If you want to get an unbiased view of the cosmos, you avoid that region, hence the term.

It's also true that we're being pulled in that direction. There happens to be a supercluster of galaxies that way, called the Great Attractor. We can map it out a bit by studying the relative motion of nearby galaxies, and we can observe X-rays from the supercluster, so we know it's out there. But with all the gas and dust in the Zone of Avoidance, we can't study it in the optical. One thing we know so far is that the Great Attractor actually consists of multiple clusters. The closest one is known as the Norma cluster, while a larger and more distant one is called the Vela supercluster. Still, there is much we don't know about the region.

Fortunately, radio light can penetrate the dust of the Zone, so radio astronomers have tried to map the region. One downside is that radio telescopes often don't have a large field of view, so it's difficult to map the region. But a new work is making progress. The paper is published on the *arXiv* preprint server.

The new study uses data from the MeerKAT array telescope in South Africa. MeerKAT is particularly sensitive to the radio emissions of neutral hydrogen, known as the HI or [21-centimeter] line. Since hydrogen is so abundant in the universe, the distribution of hydrogen tells us the distribution of galaxies and clusters.

The study mapped the region of the Zone in the direction of the Vela supercluster with enough resolution to distinguish individual pockets of neutral hydrogen, each surrounding a galaxy. In this way, the team was able to discover 719 galaxies within the Vela cluster. Less than a third of them had been known previously.

This was just the first detailed survey of the Vela supercluster by MeerKAT, and it shows the real power of this relatively new observatory. Future studies should give us an even better understanding of the zone astronomers so often avoid.

More information: Sambatriniaina H. A. Rajohnson et al, Revealing hidden structures in the Zone of Avoidance -- a blind MeerKAT HI Survey of the Vela Supercluster, *arXiv* (2024). [DOI: 10.48550/arxiv.2411.07084](https://dx.doi.org/10.48550/arxiv.2411.07084)

Provided by Universe Today

Scientists propose “DNA of the universe” is gap in Einstein’s hunt for unified physics theory

DNA double helix among the stars Getty Images/PASIEKA© Getty Images/PASIEKA

When molecular biologist Francis Crick tripped on the psychedelic drug LSD in 1953, his mind famously pulled together all of his previous research on human DNA to conceive of the image of a double helix. More than seven decades later, mathematician Robert Monjo believes he has discovered a similarly significant double helix — but this time not as the structure of human DNA, but as the structure of spacetime itself.

"Our study completes the work of Albert Einstein in his attempt to relate gravity and electromagnetism forces in the same geometric theory," Monjo, a professor of mathematics at Saint Louis University in Spain, told Salon. While it may seem like an odd coincidence for spacetime to follow an analogous engineering blueprint as the human body, Monjo argues this is perfectly logical.

"The actual connection between physics and molecular biology is that curvature and torsion are the most probable solutions (minimum energy when forces are acting) for particle paths and for designing stable structures," Monjo said. "The simile with the DNA is more a metaphor but in some way, there exists the connection as mentioned for solving paths."

Working with Dr. Rutwig Campoamor-Stursberg and mathematics colleague Álvaro Rodríguez Abella, Monjo performed extensive algebraic and other mathematical calculations — much of it drawing from existing research on theoretical physics — in order to arrive at their conclusions. Their study was published in the journal General Relativity and Gravitation in October.

Monjo's theory helps unify scientific concepts of Newtonian gravity with our knowledge of electromagnetism. Einstein was convinced that such a unified theory exists, and during his own lifetime demonstrated that his theory of relativity applies to Newtonian mechanics as well as other important concepts involving electromagnetism, optics, electric and magnetic circuits.

"That was already a first unification of the transformations of mechanics, since until then physics were considered two different worlds," Monjo explained, contrasting physicist Isaac Newton's concepts of physics with those advanced by a similarly foundational physicist, James Clerk Maxwell. "Einstein then generalized his idea to the relativity of the gravitational force (General Relativity, in 1915-

1916) and worked more than a decade to improve it, but he was unable to finish the work for the electromagnetic force. Our work addresses precisely that point: we can perform transformations of motion so that gravity and electromagnetism can be deduced from the same equation of spacetime."

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Dr. Djordje Minic, a professor of physics and particle and string theory at the University of Texas at Austin, isn't so sure about these conclusions. He noted that teleparallel gravity — the conceptual unified theory imagined by Einstein — has "various problems," starting with local Lorentz symmetry, or the theory that in physics the laws are the same for all observers moving relative to each other.

"Saying that matter interactions all come from the metric of classical spacetime means, at least naïvely, that quantum spacetime — whatever that means empirically — does not really have any role, or that the foundational questions in quantum theory are simply irrelevant in quantum theory of gravity and matter," Minic said. Matter is quantum as we know, and if matter comes from the spacetime metric then, what happens to the observed distinction between quantum and classical correlations - for example quantum probabilities interfere, classical do not."

"Now, the authors say that spacetime coordinates are matrices, but what does that mean for the experimentally tested Standard Model whose quantum fields live in classical spacetime?" Minic went on. "What is the consequence of this approach for the observed vacuum energy (cosmological constant) and the observed masses of elementary particles?" The term "vacuum energy" refers to the energy background that permeates the entire universe, within or outside of a vacuum. A cosmological constant is a famous part of Einstein's General Relativity theory, and refers to an arbitrary constant that is present in all related field equations. Finally elementary particles are protons, electrons, neutrons and all other particles that are smaller than an atom.

While the authors argue that spacetime coordinates are matrices, Minic said "I do not see any deep consequences of that statement! What happens to quantum correlations in that matrix valued spacetime? Do they satisfy the quantum Bell bound? How is the quantum probability computed? Is the Born rule still valid? Are there any new testable predictions?"

The Bell theorem refers to how entangled electrons are predicted by quantum mechanics, making them non-local — often referred to as “spooky action at a distance.” The Born rule bridges the math of quantum theory to the outcomes of experiments, which makes the field a legitimate scientific discipline in the first place. It seems this new theory of the universe still has a lot to explain. Minic instead argued that the quantum theory behind Einstein's gravity and standard model for matter is gravitized quantum theory.

“In this approach the currently fixed geometry of quantum theory, tied to the Born rule for quantum probabilities, becomes dynamical, in analogy with dynamical spacetime metric of general relativity,” Minic said. “This ultimately connects to metastring theory, an intrinsically non-commutative and phase-space-like formulation of string theory.” Their approach attempts to illuminate a cosmological constant as well as the properties of leptons and quarks.

“There is a new prediction that has to do with intrinsic triple (and higher order) quantum interference and a dynamical Born rule that can be experimentally tested,” Minic said. “In general, we need experiments in quantum gravity, not just theories. With experiments, we will have real science, which is what we all want in our quest to understand the universe a bit better and a bit more completely.”

In contrast to Minic, Dr. Avi Loeb, a theoretical physics professor at Harvard University, praised the paper as “highly technical and offers a novel mathematical way to describe interactions among particles in a unified geometric way, including gravity and electromagnetism.” Adding that its results can be used to create a new unification scheme of quantum mechanics and gravity, Loeb said the deeper significance of the double helix structure isthat it “is simply a mathematical result that has nothing to do with biology. The fact that it appears here and in the human DNA is a remarkable coincidence.”

New discovery challenges Einstein's theory of general relativity

The accelerating expansion of the Universe has puzzled scientists since its discovery in 1998. This phenomenon, one of the most profound mysteries in physics, challenges our understanding of the cosmos.

Some theories suggest that this acceleration is driven by a cosmological constant, while others point to dynamic dark energy or even modifications of Einstein's general relativity. To test these possibilities, researchers rely on large-scale structure surveys that map the distribution of matter and galaxies in the Universe.

New Approaches to Cosmic Mystery

Traditional models like ΛCDM have provided a strong foundation for understanding the Universe, but their limitations are becoming apparent. As a result, scientists have developed two key approaches to testing theories beyond ΛCDM.

Einstein's equations by introducing two functions, μ and η, which describe changes in gravity and metric distortions. (CREDIT: Nicolle Fuller/National Science Foundation)© The Brighter Side of News

One focuses on broad categories of theories, such as Horndeski theories, which unify scalar-tensor models with second-order equations of motion. This method directly ties observable data to theoretical components but suffers from significant degeneracies among the functions involved, limiting its effectiveness with current data.

The second approach takes a more direct, phenomenological route. It modifies Einstein's equations by introducing two functions, μ and η, which describe changes in gravity and metric distortions.

μ addresses alterations in Poisson's equation, while η captures differences in time and spatial distortions. These parameters are invaluable for analyzing gravitational lensing data from projects like the Dark Energy Survey (DES) and galaxy clustering measurements from BOSS and eBOSS.

Related Stories

Revolutionary new theory finally unites quantum mechanics and Einstein's theory of general relativity Scientists are uniting quantum mechanics with general relativity through 'Quantum gravity' Scientists rework Schrödinger's cat equation to unite Einstein's relativity and quantum mechanics

However, this approach has its challenges. The constraints on μ and η are interdependent across different redshifts, requiring either a fixed evolution model or sophisticated reconstruction techniques. Moreover, the framework assumes the validity of Euler's equation for dark matter, which introduces potential degeneracies that complicate data interpretation.

Pushing the Boundaries of General Relativity

Einstein's general relativity revolutionized our understanding of gravity, depicting the Universe as a flexible fabric deformed by massive objects. This theory, confirmed by the 1919 solar eclipse, predicted the deflection of light by gravity, a phenomenon known as gravitational lensing. By studying how light bends around celestial bodies, scientists gain critical insights into the Universe's structure and expansion.

Gravitational lensing of distant galaxies by the galaxy cluster Abell 2390, observed by the Euclid satellite. (CREDIT: ESA/Euclid/Euclid Consortium/NASA, image processing by J.-C. Cuillandre (CEA Paris-Saclay), G. Anselmi)© The Brighter Side of News

But are Einstein's equations valid on the largest cosmic scales? Researchers from the University of Geneva (UNIGE) and Toulouse III – Paul Sabatier have sought to answer this question. Using DES data, they analyzed the distortion of time and space, comparing their findings to Einstein's predictions.

Camille Bonvin, an associate professor at UNIGE, highlights the novelty of this approach: "Until now, Dark Energy Survey data have been used to measure the distribution of matter in the Universe. In our study, we used this data to directly measure the distortion of time and space, enabling us to compare our findings with Einstein's predictions."

A Universe Slightly Out of Sync

The DES provided data on 100 million galaxies across four time periods: 3.5, 5, 6, and 7 billion years ago. These measurements revealed how gravitational wells—regions where gravity deforms space-time—evolved.

Measured values of \(\hat{J}\) with 1 standard deviation error bars at the mean redshifts of the MAGLIM sample. (CREDIT: Nature Communications)© The Brighter Side of News

According to Isaac Tutusaus, lead author of the study, "We discovered that in the distant past — 6 and 7 billion years ago — the depth of the wells aligns well with Einstein’s predictions. However, closer to today, 3.5 and 5 billion years ago, they are slightly shallower than predicted by Einstein."

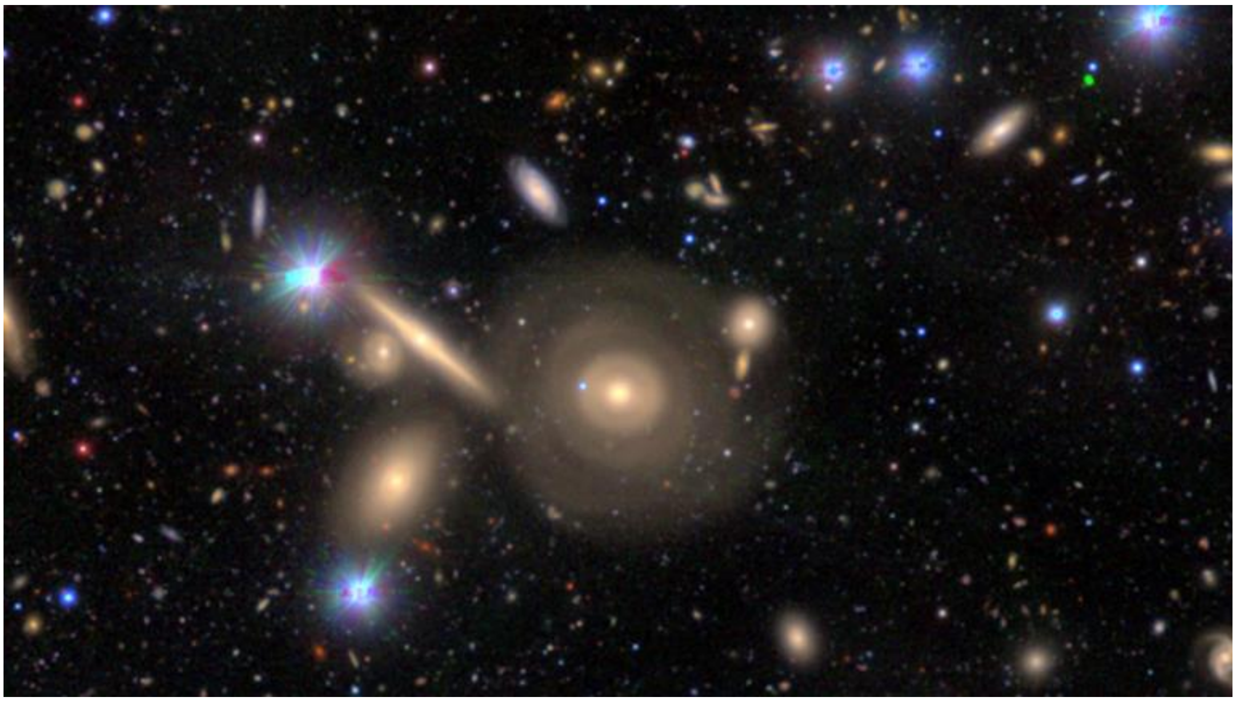
This discrepancy coincides with the period when the Universe’s expansion began accelerating. The data hint at a possible link between the two phenomena, suggesting that gravity might operate differently on cosmic scales. Tutusaus notes, "The slower growth of gravitational wells and the accelerating expansion might share the same underlying cause."

The 3-Sigma Challenge

The study found a 3-sigma level of incompatibility between Einstein’s predictions and the observed data. While this is significant, it falls short of the 5-sigma threshold needed to definitively challenge the theory. Nastassia Grimm, a co-author and postdoctoral researcher at UNIGE, explains, "Such an incompatibility threshold arouses our interest and calls for further investigations. But this incompatibility is not large enough, at this stage, to invalidate Einstein’s theory."Further research is necessary to confirm these findings. The team is turning to the Euclid space telescope, launched last year, which promises more precise gravitational lensing data. Over its six-year mission, Euclid will observe 1.5 billion galaxies, offering unprecedented insights into the Universe's history and allowing scientists to test Einstein’s equations more rigorously.

As cosmologists delve deeper into the mysteries of the Universe, the boundaries of established theories are being pushed. The work of the UNIGE and Toulouse teams represents a critical step in this journey. With upcoming data from Euclid, the scientific community is poised to refine its understanding of gravity and cosmic expansion. These efforts may ultimately reshape our perception of the Universe, bringing us closer to solving one of science’s greatest enigmas.

Researchers spot rare 'triple-ring' galaxy that defies explanation



Researchers spot rare 'triple-ring' galaxy that defies explanation© Subaru Telescope / National Astronomical Observatory of Japan

No, that's not an interstellar bull's-eye. This remarkable image, captured by Japan's Subaru Telescope on Mauna Kea in Hawaii, actually shows something much more special: an extremely rare triple-ring galaxy located about 800 million light-years from Earth, officials from the National Astronomical Observatory of Japan wrote in a statement. How it formed remains a cosmic mystery.

Under the standard Hubble sequence method of classification, galaxies typically fall into one of four categories: elliptical, lenticular, spiral and irregular. Elliptical galaxies appear fairly smooth and egg-shaped through a telescope, with an even distribution of stars. Lenticular galaxies look a bit like flattened ellipses with a bulge in the center — imagine viewing a fried egg from the side. Spiral galaxies, such as our Milky Way, have a similar central bulge, but instead of an outer disk, they have swirling stellar "arms." And irregular galaxies, as their name suggests, lack a predictable, organized shape.

But ring galaxies don't fit into these neat categories. This has led some researchers and citizen scientists to argue that the Hubble sequence — the most widely used method of categorizing galaxies — needs a serious update.

While Hubble sequence galaxies tend to follow one of two predictable evolutionary paths, nobody knows for certain how ring galaxies form. One of the leading hypotheses is that they result from collisions between galaxies. When another galaxy hits the center of a spiral galaxy, it creates ripples of gas and dust that radiate like a shock wave, producing a ring, the theory suggests.

Another hypothesis is that galactic rings result from natural resonance phenomena. As the interstellar gas within a galaxy moves, it tends to congregate in certain regions because of gravitational effects. Under certain circumstances, this could produce a distinctive ring shape around the galaxy — or even more than one.

Galaxy Cruise, the citizen science project in charge of classifying Subaru images, currently regards ring galaxies as the result of collisions. Whether this triple-ring galaxy was formed through multiple collisions, a single collision or some other means is still unknown. But one thing is certain: Finding oddballs like this helps us refine our overall understanding of the universe and galactic formation

How many galaxies orbit the Milky Way?

The number of known galaxies circling the Milky Way is increasing as we develop new powerful telescopes.

The Milky Way is a large galaxy. So how many smaller "satellite galaxies" orbit it? (Image credit: MARK GARLICK/SCIENCE PHOTO LIBRARY via Getty Images)

In space, the gravitational pull of massive objects is irresistible to smaller ones. Moons are locked in orbit around planets. Planets, asteroids and comets orbit more massive stars, and stars collect around supermassive black holes, forming galaxies.

Large galaxies, like the Milky Way, attract smaller galaxies. Our solar system's cosmic neighborhood spans 100,000 light-years and contains between 100 billion and 400 billion stars. The Milky Way is so big that, over billions of years, its mass has captured numerous dwarf galaxies, which contain no more than a few billion stars, as satellites.
But how many satellite galaxies does the Milky Way have?
The count is continually changing as new telescopes and sky surveys reveal ever-fainter galaxies. But let's start with the ones we can see easily. Two of Milky Way's prominent satellite galaxies are the Large Magellanic Cloud and the Small Magellanic Cloud. They orbit the Milky Way at a distance of about 160,000 light-years and are visible from the Southern Hemisphere without a telescope, according to NASA's Goddard Space Flight Center.
However, such highly visible satellites are the exception, not the rule. Most satellite galaxies are so small and dim that they are invisible to all but the most powerful telescopes.
Scientists find dwarf galaxies by using instruments with a wide field of view to capture as much of the sky as possible, said Or Graur, an associate professor of astrophysics at the University of Portsmouth in the U.K.
"The bigger telescopes get and the better our instruments get, we can drill down to fainter and fainter dwarf galaxies, down to what is now called ultra-faint dwarfs," which have just a few hundred thousand stars, Graur told Live Science.

Confirming if a nearby dwarf galaxy is a Milky Way satellite involves spectroscopy — analysis of the light it emits — to determine its motion and direction, said Marla Geha, a professor of astronomy and physics at Yale University.

"Then you can tell whether the object is gravitationally bound to itself, and if that ensemble is going around the Milky Way," Geha told Live Science. "A satellite galaxy is currently — and will always go around — the larger galaxy."

A recent census, published in 2020 in The Astrophysical Journal, estimated that there were about 60 satellites orbiting the Milky Way within a distance of 1.4 million light-years. Yet the precise number of the Milky Way's satellite galaxies is tricky to pin down, in part because not all of the proposed satellite galaxies have been spectroscopically confirmed to be orbiting the Milky Way.

"There are probably five to eight objects that don't yet have spectroscopy or have ambiguous spectroscopy," Geha said. What's more, new satellite candidates are still being discovered, she added.

Geha studies the origin and evolution of dwarf galaxies, and when she started her research more than two decades ago, the Milky Way had only 11 known satellites. That changed when the Sloan Digital Sky Survey began collecting data in the early 2000s, Geha said. Sloan produced the first digital map covering more than one-third of the night sky, and its digital camera improved astronomers' chances of spotting dim dwarf galaxies. Their faint luminescence is often obscured by brighter stars that are closer to Earth.

Using Sloan's digital images, researchers could algorithmically subtract foreground stars — something that was much harder to do with analog photographs and photographic plates, Geha said. This revealed faint dwarf galaxies that were previously hidden.

"Each of the big new imaging surveys has been a game-changer," Geha said. "Technology is really driving all of these upticks and the number of satellites that we know about."

From Sloan in the 2000s to the Dark Energy Survey in the 2010s, each survey revealed dozens more satellite galaxies orbiting the Milky Way. The Vera C. Rubin Observatory in Chile will likely find hundreds more satellites, Geha said — that is, if the Milky Way doesn't eat those galaxies first.

"Satellite galaxies are gravitationally bound to the Milky Way," Graur said. "The Milky Way keeps pulling on them gravitationally. Slowly, it pulls them in. And as it pulls them in, it starts to tear them apart and consume them."

One such victim was a dwarf galaxy now known as Gaia Enceladus, which was shredded and devoured by the Milky Way and whose stars now glimmer in the Milky Way's halo, Graur said. Eventually, the satellite galaxies that are visible today will likely suffer the same fate, Geha added.

"If we waited a super long time, billions and billions of years," she said, "those satellite galaxies will fall into the parent and merge, and create an even bigger central galaxy."

Celestial staredown: Galaxies appear to be looking at us

The palette of these galaxies is owed to a mix of mid-infrared light from NASA’s James Webb Space Telescope and visible and ultraviolet light from NASA’s Hubble Space Telescope. (NASA, ESA, CSA, STScI via SWNS)

An unsettling new space picture shows the universe seemingly staring back at us.

NASA's James Webb and Hubble telescopes have been examining a pair of galaxies that resemble cosmic eyes.

By teaming up, the two telescopes have delivered the highest resolution image of IC 2163 and NGC 2207 to date in a combination of mid-infrared, visible, and ultraviolet light.

Hubble's ultraviolet- and visible-light observation of spiral galaxies IC 2163 and NGC 2207, left, shows bright blue glowing arms and the galaxies cores in orange. In the James Webb Space Telescope's mid-infrared observation, right, cold dust takes center stage, casting the galaxies arms in white. (NASA, ESA, CSA, STScI via SWNS)

NASA JPL said: “The long, ghastly “stare” of their searing eye-like cores shines out into the supreme cosmic darkness.”

They added: “The smaller galaxy to the left, IC 2163, has ‘slithered’ behind the larger one at right, NGC 2207, millions of years ago. Though we can’t wait around for millions of years to see what may happen next, researchers can use this crisp combination of mid-infrared light from Webb, and ultraviolet and visible light from Hubble to learn more about the pair, and improve models that may preview the galaxies’ upcoming ‘thrills’.”

New way to calculate probability of intelligent alien life in universe

The NASA Hubble Space Telescope image captures a triple-star star system. (NASA, ESA, G. Duchene (Universite de Grenoble I) via SWNS)

By Stephen Beech via SWNS

Scientists are working on an accurate way of calculating the probability of finding alien life elsewhere in the universe.

Astrophysicists have developed a theoretical model that could be used to estimate how likely it is for intelligent life to emerge on other planets.

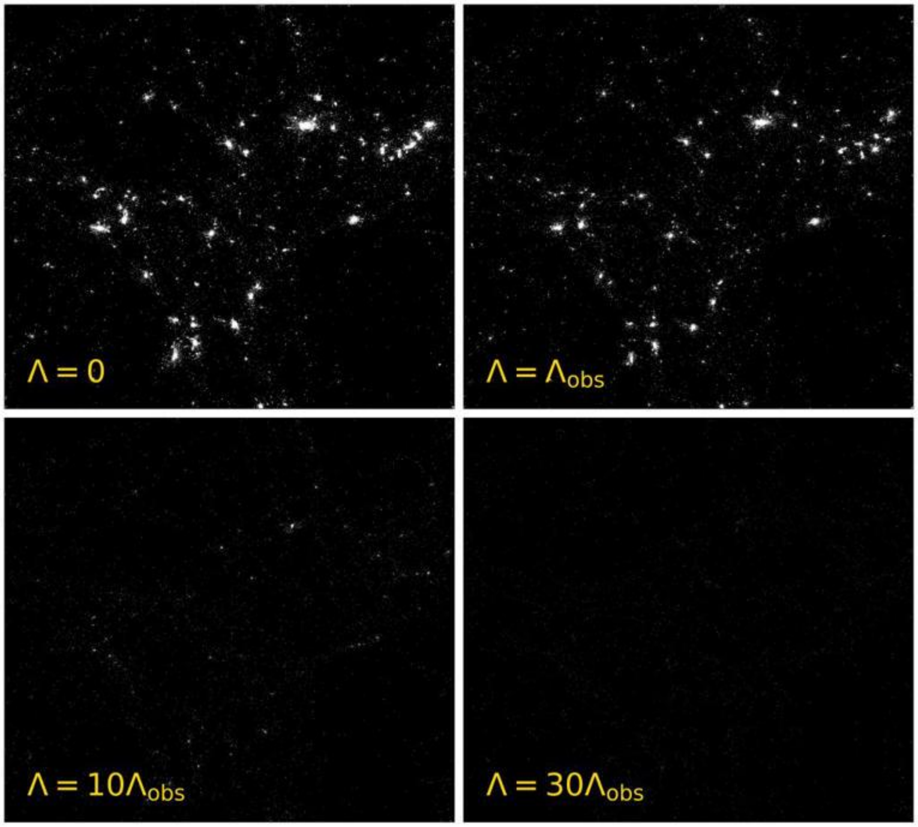
American astronomer Dr. Frank Drake came up with an equation in the 1960s to calculate the number of detectable extraterrestrial civilizations in our Milky Way galaxy.

Now, more than 60 years on, researchers led by Durham University's Institute for Computational Cosmology, have produced a new model based on the conditions created by the acceleration of the universe's expansion and the amount of stars formed instead.

It is believed that the expansion is being driven by a mysterious form of energy - called "dark energy" - that permeates space and makes up over two-thirds of the universe.

The new research, published in the journal Monthly Notices of the Royal Astronomical Society, has calculated the fraction of ordinary matter converted into stars over the entire history of the universe, for different dark energy densities.

The model predicts that fraction would be around 27% in a universe that is most efficient at forming stars, compared to 23% in our universe.



Amount of stars (white) produced in universes with different dark energy densities. The images are generated from a suite of cosmological simulations and show how the same region of the universe would look for different values of the dark energy density. Clockwise from the upper-left panel: no dark energy, same dark energy density as in our Universe, 30 and 10 times the dark energy density in our Universe. (Courtesy of Oscar Veenema via SWNS)

Scientists say the model could allow them to understand the effects of differing densities of dark energy on the formation of structures in the universe and the conditions for life to develop in the cosmos.

It also takes into account the fact alien lifeforms may develop deep into the future that do not currently exist.

Lead researcher Dr. Daniele Sorini, of the Institute for Computational Cosmology, Durham University, said: “Understanding dark energy and its impact on our universe is one of the biggest challenges in cosmology and fundamental physics.

“The parameters that govern our universe, including the density of dark energy, could explain our own existence.

“Surprisingly, though, we found that even a significantly higher dark energy density would still be compatible with life, suggesting we may not live in the most likely of universes.”

Dr. Sorini says that at present, there is no satisfactory explanation of what dark energy is and of its abundance in the universe.

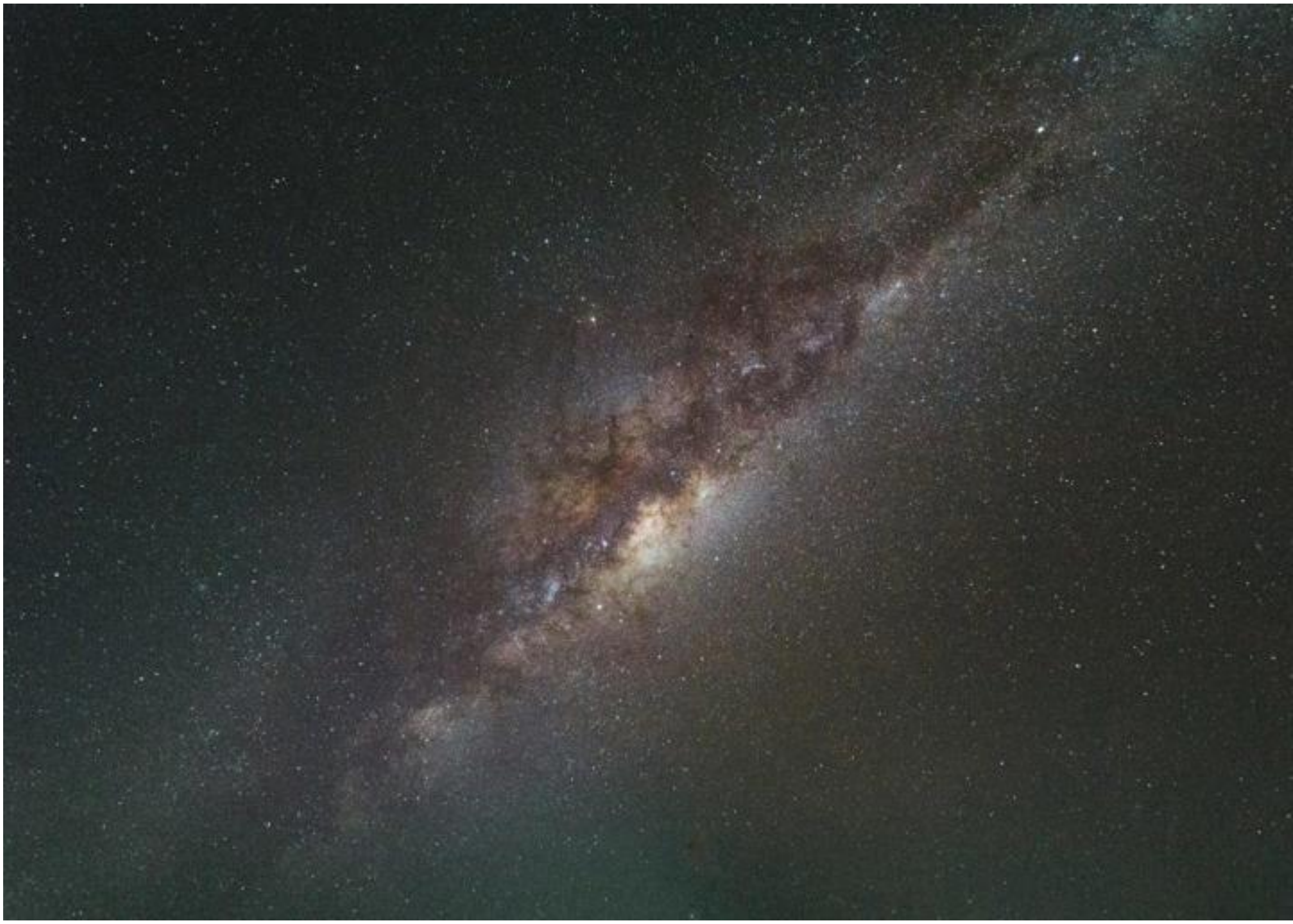
He explained that dark energy makes the universe expand faster, balancing gravity’s pull and creating a universe where both expansion and structure formation are possible.

However, for life to develop, there would need to be regions where matter can clump together to form stars and planets, and it would need to remain stable for billions of years to allow life to evolve.

Since stars are a precondition for the emergence of life as we know it, Dr Sorini says the new calculation could be used to estimate the probability of generating intelligent life in our universe and in a multiverse scenario of hypothetical different universes.

The study suggests that the astrophysics of star formation and the evolution of the large-scale structure of the universe combine in a "subtle" way to determine the optimal value of the dark energy density needed for the generation of intelligent life.

The new research does not attempt to calculate the absolute number of "observers" - i.e. intelligent life - in the universe, but instead considers the relative probability of a randomly chosen observer inhabiting a universe with particular properties.


(Photo by Yong Chuan Tan via Unsplash)

It concludes that a typical observer would expect to experience a "substantially larger" density of dark energy than is seen in our own universe – suggesting the ingredients it possesses make it a rare and unusual case in the multiverse.

The research also involved scientists at the University of Edinburgh and the University of Geneva in Switzerland.

Study co-author Professor Lucas Lombriser, of the University of Geneva, said: “It will be exciting to employ the model to explore the emergence of life across different universes and see whether some fundamental questions we ask ourselves about our own universe must be reinterpreted.”

Dr. Sorini added: "I cannot give you a number or a percentage chance of finding intelligent life at this stage as the model is just one step in the process.

"We should be able to give a more accurate figure in the future.

"We are not restricting on when life could emerge past, present or future.

"It could be that many lifeforms could emerge much later in the life of the universe."

Why It's So Difficult For Scientists To Measure The Age Of Stars

Tarantula Nebula© X-ray: NASA/CXC/Penn State Univ./L. Townsley et al.; IR: NASA/ESA/CSA/STScI/JWST ERO Production Team

With the evolving technology of space telescopes allowing us to peer out beyond our solar system and see distant planets, black holes, and even some of the oldest galaxies to exist, you might imagine that stars would be fairly simple to understand. Astronomers have observed thousands of stars, of all different types, both in our galaxy and beyond. They can often tell how big a star is, how brightly it shines, and what it is composed of. However, there's one aspect of stars that is still surprisingly hard to determine: how old a given star is.

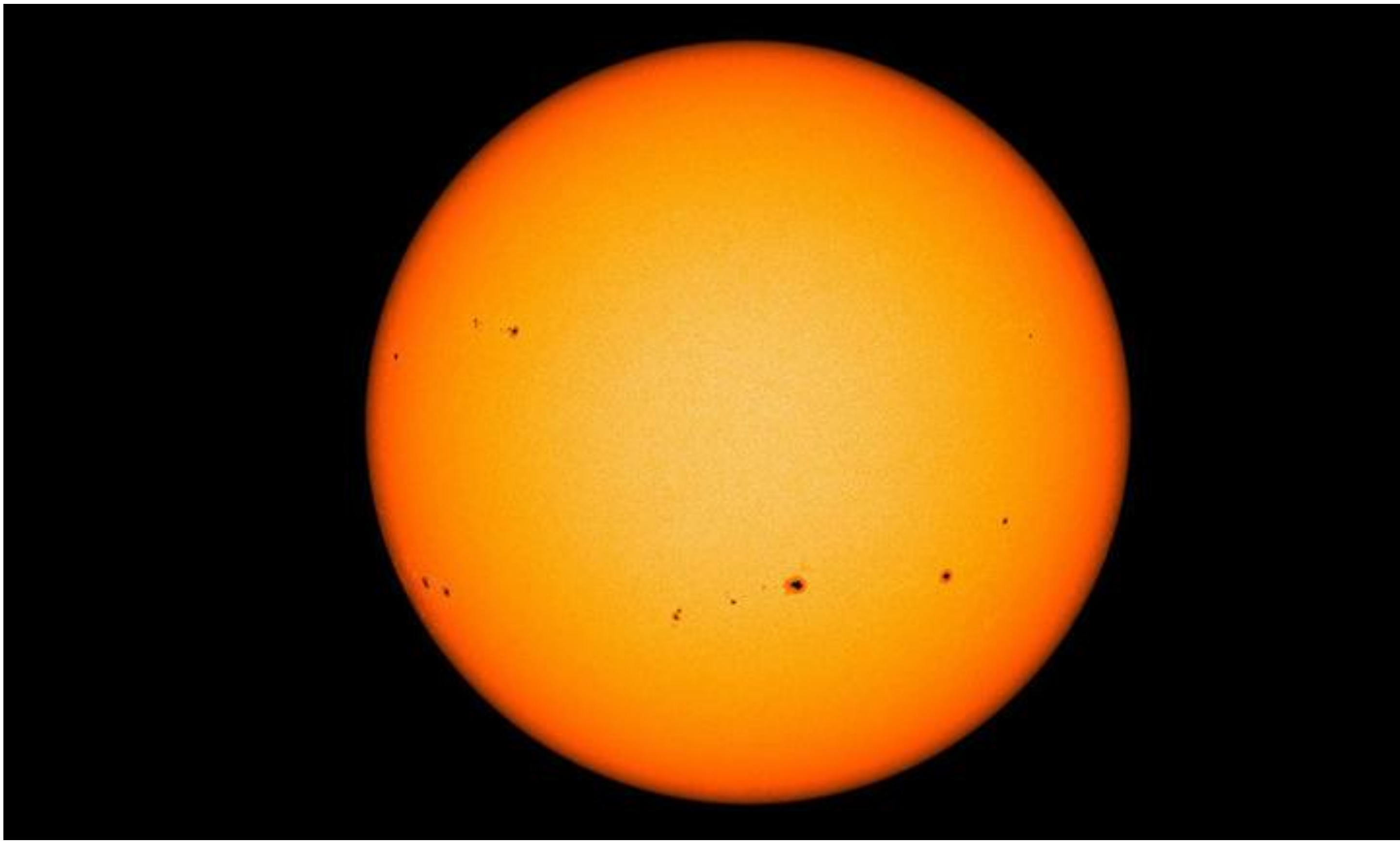
The basic life cycle of stars is well understood. They have a bright, chaotic phase as youngsters, before settling into a long, more moderate phase as adults — also known as main sequence stars, like our sun. When they eventually run out of fuel, they can puff up and become dim and cool, before eventually collapsing to a core.

However, during that long period of maturity, when the star is in its middle age, it's hard to tell how old it is. Stars tend to be stable during this time, so there aren't many obvious differences between stars that are 1 billion years old and those that are 10 billion years old, or even older. What astronomers do know is that more massive stars tend to burn through their material more quickly, so they have shorter lives.

Looking at a particular star in the sky, and then figuring out how old it is, remains a challenge. But astronomers have a plan for figuring this out.

Read more: The 10 Most Iconic Airplanes In Aviation History, Ranked

Using Rotation To Figure Out Stellar Ages



Sunspots© NASA

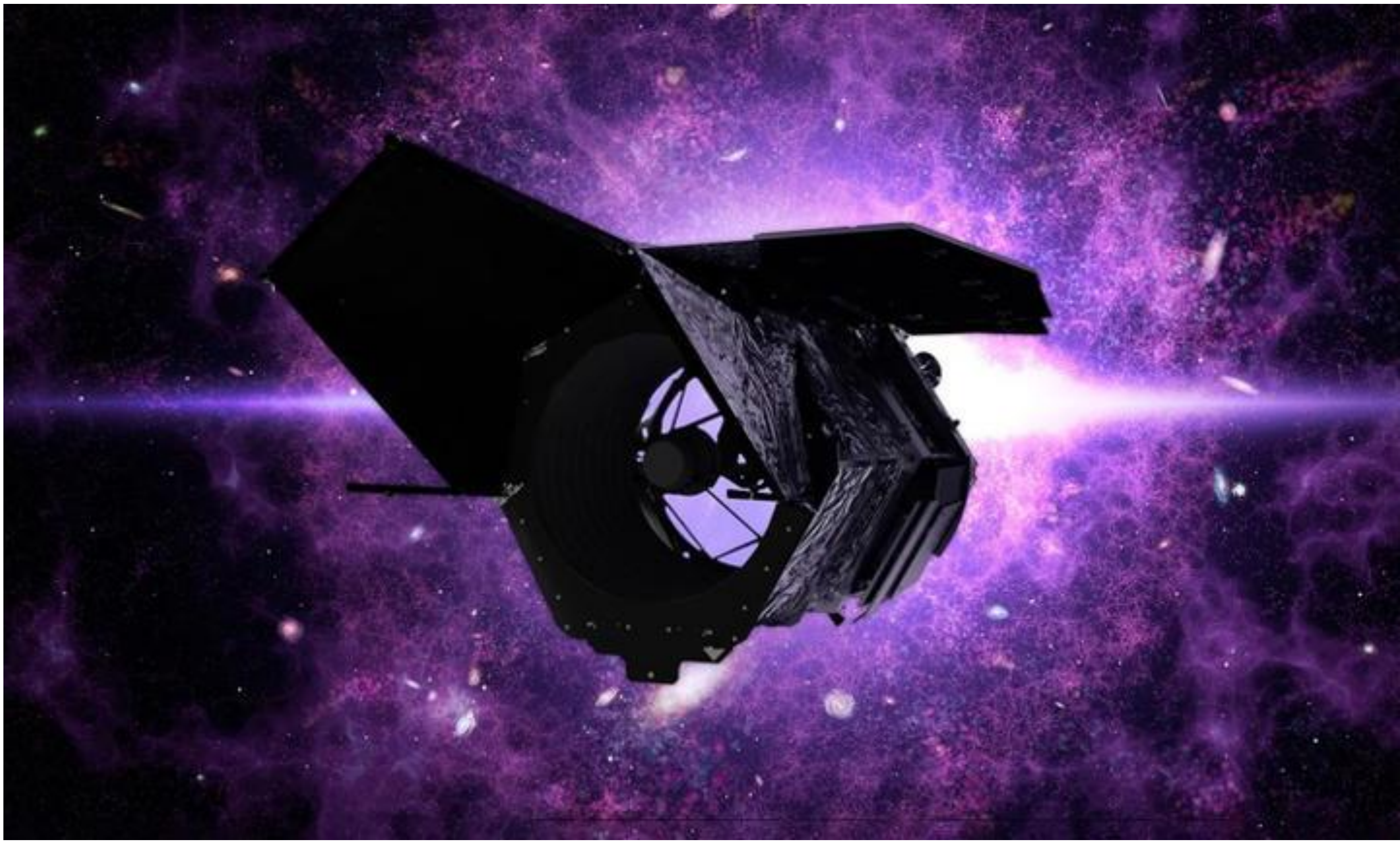
One potential way to determine a star's age is to look at the speed at which it rotates. When stars are born, they rotate very quickly, but over time they slow down. This happens because the star gives off charged particles, called stellar winds, which interact with the magnetic field. As these two interact, they cause the star to gradually slow rotation in an effect called "magnetic braking."

The effect isn't simple, though. A star that spins very fast will have a strong magnetic field, and it will slow down faster. However, over time stars tend to follow a similar evolution, so by the time a star is one billion years old, it will spin at around the same rate as other stars of a similar mass and a similar age.

This means that if scientists can measure both the rotation speed and the mass of a star, they can estimate its age. To measure rotation, they look at dips in brightness caused by cooler regions on a star called star spots (like sun spots on our sun).

Scientists, like Zachary Claytor from the University of Florida, are working on a program to identify a star's rotation time using AI. First, they had to train a neural network on simulated data, so it can analyze real data in the future. "This program lets the user set a number of variables, like the star's rotation rate, the number of spots, and spot lifetimes," Claytor explained. "Then it will calculate how spots emerge, evolve, and decay as the star rotates and convert that spot evolution to a light curve -- what we would measure from a distance."

Using The Nancy Grace Roman Space Telescope To Figure Out Stellar Ages



Nancy Grace Roman Space Telescope© NASA

To measure real star rotations, scientists will need a powerful instrument. And this is what astronomers want to do with a new telescope to be launched in 2027, the Nancy Grace Roman Space Telescope (known as Roman).

Roman will observe millions of stars in a huge survey, looking toward the bulge at the center of our galaxy which is full of stars. It will look for changes in brightness in these stars — which could indicate many things, from the presence of an exoplanet to a star spot which can be used to learn about rotation.

By combining data from Roman with AI models like the one Claytor is working on, researchers hope to get data on stellar rotation at a large scale.

"We can test which things matter and what we can pull out of the Roman data depending on different survey strategies. So when we actually get the data, we'll already have a plan," said Jamie Tayar of the University of Florida, who is also working on the program for identifying light curves that can be used to measure rotation. "We have a lot of the tools already, and we think they can be adapted to Roman."

The Milky Way may reside at the center of a 2 billion light-year wide cosmic void

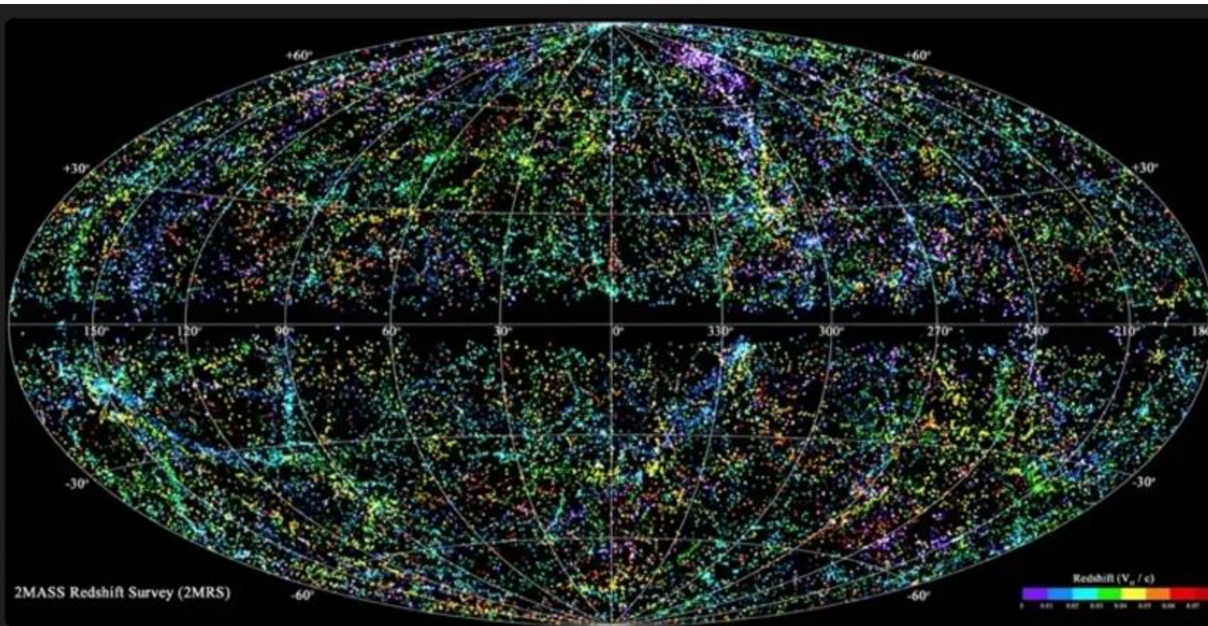
Cosmologists are unraveling a perplexing mystery: the universe appears to be expanding faster than predicted. Known as the Hubble tension, this discrepancy challenges the cornerstone of modern cosmology, the [Lambda Cold Dark Matter (ΛCDM) model].

Measurements of the Hubble constant, H0H_0H0, vary depending on where and how they're taken. Local observations using nearby supernovae and Cepheid variables yield values roughly 10% higher than predictions based on the cosmic microwave background (CMB).

These divergent results could imply either a fundamental flaw in ΛCDM or a previously unrecognized [cosmic feature] influencing our measurements.

The Nature of the Hubble Tension

The Hubble tension is more than a minor inconsistency. If local measurements are accurate, the universe could be about 10% younger than previously calculated. Yet, this contradicts the established ages of the [oldest stars].



The 2MASS Redshift Survey (2MRS) has catalogued more than 43,000 galaxies within 380 million light-years from Earth (z). (CREDIT: T.H. Jarrett (IPAC/SSC)

Nobel laureate Adam Riess, a leading figure in the debate, remarked, “Our measurements keep getting more precise, and the tension doesn’t go away.”

The persistence of this conflict has prompted researchers to seek explanations beyond the standard model, and one of the most intriguing hypotheses involves a vast underdensity in the cosmic structure known as the KBC void.

The KBC Void: A Gigantic Cosmic Underdensity

Proposed in 2013, the KBC void is an enormous region of space spanning two billion light-years, making it the largest void ever observed.

Related Stories

Scientists discover the origin of Milky Way’s central supermassive black hole Cosmic dust could spread life from planet to planet across the Milky Way Astronomers discovered why spiral galaxies like our Milky Way are so rare

Named after astronomers Keenan, Barger, and Cowie, who first identified it, this underdensity exhibits a matter density about 20% lower than surrounding regions.

If the void exists, it could mean that the Milky Way and its neighbors reside in a uniquely sparse region of the universe. This would challenge the cosmological principle, which holds that the universe should appear homogeneous and isotropic on large scales.

Evidence supporting the KBC void comes from various observations across multiple wavelengths, including optical, infrared, X-ray, and radio. Recent studies, such as those by Indranil Banik of the University of St. Andrews, suggest that the void might be the key to resolving the Hubble tension.

“By now, it's pretty clear that we are in a significant underdensity,” Banik said. His work, published in the Monthly Notices of the Royal Astronomical Society, proposes that our local measurements of H0H_0H0 are inflated due to the void’s influence.

KBC Void in an immense, comparatively empty region of space containing the Local Group, and a large part of the Laniakea Supercluster - 2,000 million ly diameter sphere with its center about 250 million ly away - Galaxies inside the void experience a gravitational pull from outside yielding a larger local value for the Hubble constant (redshift). (CREDIT: Wikipedia / Pablo Carlos Budassi)© The Brighter Side of News

How the Void Could Explain Faster Expansion

Galaxies within the KBC void experience a gravitational pull toward denser regions beyond its borders. This outflow causes a local acceleration in the expansion rate, resulting in a higher observed H0H_0H0. Banik’s calculations estimate that the void could account for an 11% increase in the locally measured Hubble constant, bringing it in line with observations.

However, this explanation poses challenges for the ΛCDM model. Simulations suggest that a void as large and underdense as the KBC void is improbable within ΛCDM without invoking highly unlikely early density fluctuations. To form such a structure naturally, the model would require a 10σ deviation from the expected density, an extremely rare occurrence.

Bulk Flows: Testing the Void Hypothesis

To further test the void hypothesis, scientists have turned to bulk flows—large-scale movements of galaxies. These flows provide insight into the distribution of matter and the gravitational landscape of the universe.

Bulk flows in spheres of different radii around an observer with a suitable CMB-frame velocity for the Maxwell–Boltzmann, Gaussian, and Exponential density profiles (green, red, and blue curves, respectively). (CREDIT: Monthly Notices of the Royal Astronomical Society)© The Brighter Side of News

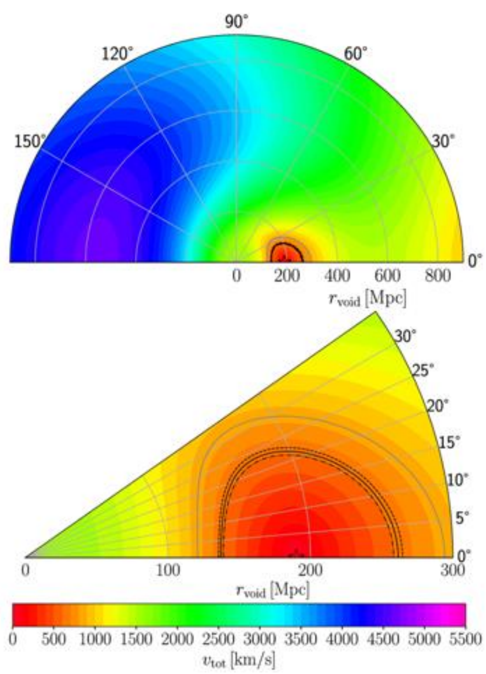
Using data from the CosmicFlows-4 galaxy catalog, recent studies by Watkins et al. (2023) have revealed bulk flows exceeding 400 km/s on scales of 300 million light-years. Such high velocities are in stark tension with ΛCDM, which predicts much slower flows on these scales.

Banik's νHDM model, an alternative to ΛCDM, accurately predicts these bulk flows. Unlike ΛCDM, νHDM incorporates Milgromian dynamics (MOND), which modifies gravitational laws at low accelerations. This model includes an additional type of sterile neutrino that aids in matching observed galactic phenomena and large-scale structures.

"The νHDM framework provides a consistent explanation for both the KBC void and the observed bulk flows," Banik explains.

Implications for Cosmology

If the KBC void and νHDM model hold, they could revolutionize cosmology. Brian Keating, a cosmologist at UC San Diego, supports exploring this direction.



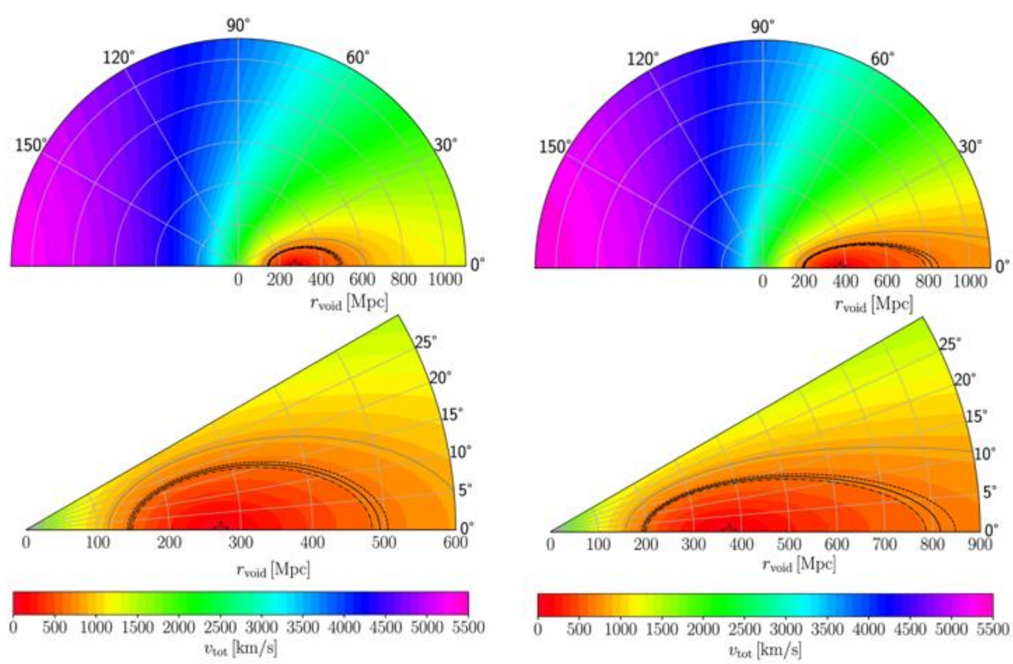
Map of the total velocity v tot in the CMB frame resulting from the Maxwell–Boltzmann void density profile. (CREDIT: Monthly Notices of the Royal Astronomical Society)© The Brighter Side of News

“The hypothesis that a local void could explain the Hubble tension by inducing significant outflows seems sound in principle,” he says. However, Keating cautions that such a solution might only address local discrepancies. “If the local void isn’t representative of the wider cosmos, this may only provide a local solution, not a global one.”

Another intriguing aspect of the KBC void involves peculiar velocities—deviations from the expected motion due to the universe’s overall expansion. The Milky Way’s peculiar velocity is relatively low, around 627 km/s, a fact that νHDM can naturally account for through gravitational interactions between nearby and distant structures.

While the void hypothesis offers a compelling narrative, it is not the only contender. Some researchers propose that early dark energy—an additional energy component in the universe’s infancy—might explain the higher local H0H_0H0 values.

This theory suggests that an early burst of accelerated expansion could alter the universe’s expansion history, reconciling the CMB and local measurements. However, this model introduces its own challenges, such as potential conflicts with the observed ages of ancient stars.



Map of the total velocity v tot in the CMB frame resulting from the Gaussian and Exponential density profiles. (CREDIT: Monthly Notices of the Royal Astronomical Society)© The Brighter Side of News

Banik remains focused on testing his void model further. His next research aims to analyze supernova data beyond the void's boundaries. If the Hubble constant aligns with standard predictions outside the void, it would provide strong evidence for the local void hypothesis.

Broader Implications

The resolution of the Hubble tension has implications for our understanding of the universe's age, composition, and fundamental laws.

If voids like KBC are rare but significant contributors to local discrepancies, they could redefine how cosmologists interpret observational data. Conversely, if new physics such as νHDM or early dark energy is required, it would signal a paradigm shift in cosmology.

Regardless of the outcome, the Hubble tension underscores the dynamic and evolving nature of scientific inquiry. As Banik puts it, "Each new observation brings us closer to unraveling the complexities of our universe."

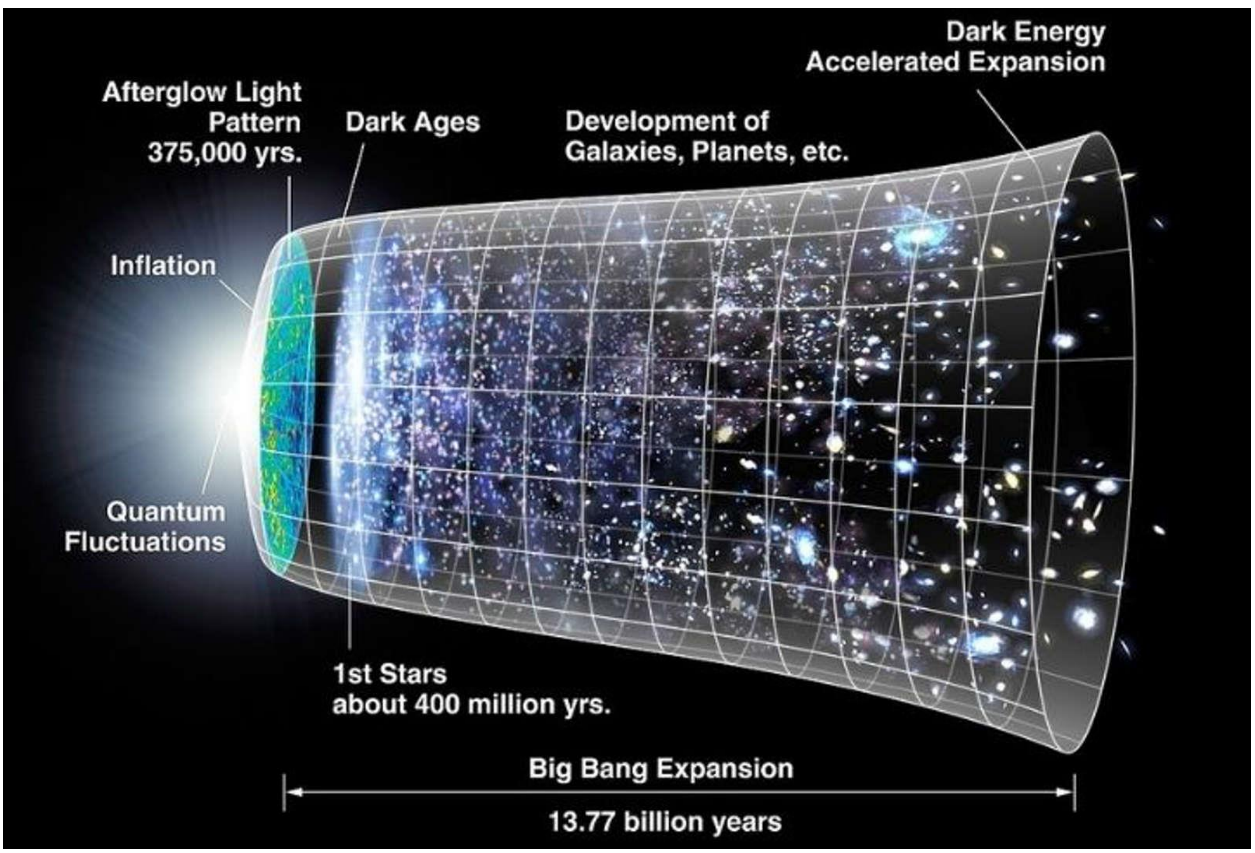
The KBC void and the Hubble tension highlight the interconnectedness of local and global cosmic phenomena. Whether these puzzles find resolution within existing models or demand entirely new frameworks, they serve as a testament to the ingenuity and persistence of the scientific community.

The Hidden History of the Universe Before the Big Bang

Scientists have long wondered about the origins of our universe. And even though the Big Bang theory was widely accepted, it left many questions unanswered. Now, groundbreaking research suggests there might have been a "secret life" in the universe before this cosmic explosion. This discovery has the potential to give us a better understanding of the cosmos and its beginnings.

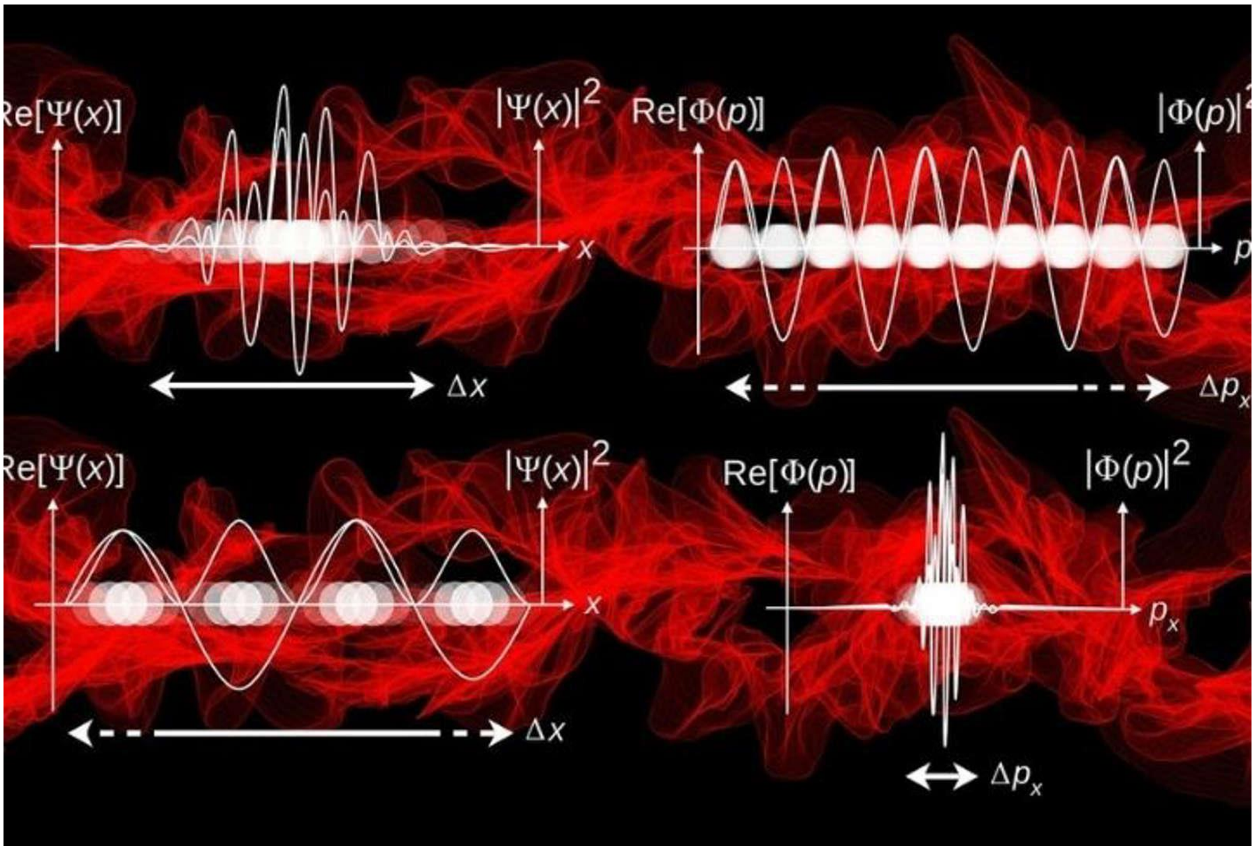
The Big Bang Puzzle

For decades, scientists thought the Big Bang marked the start of everything. But this theory had gaps. It couldn't explain what came before or why the universe began expanding. These questions pushed researchers to look beyond the Big Bang and find clues in the cosmos' earliest moments.



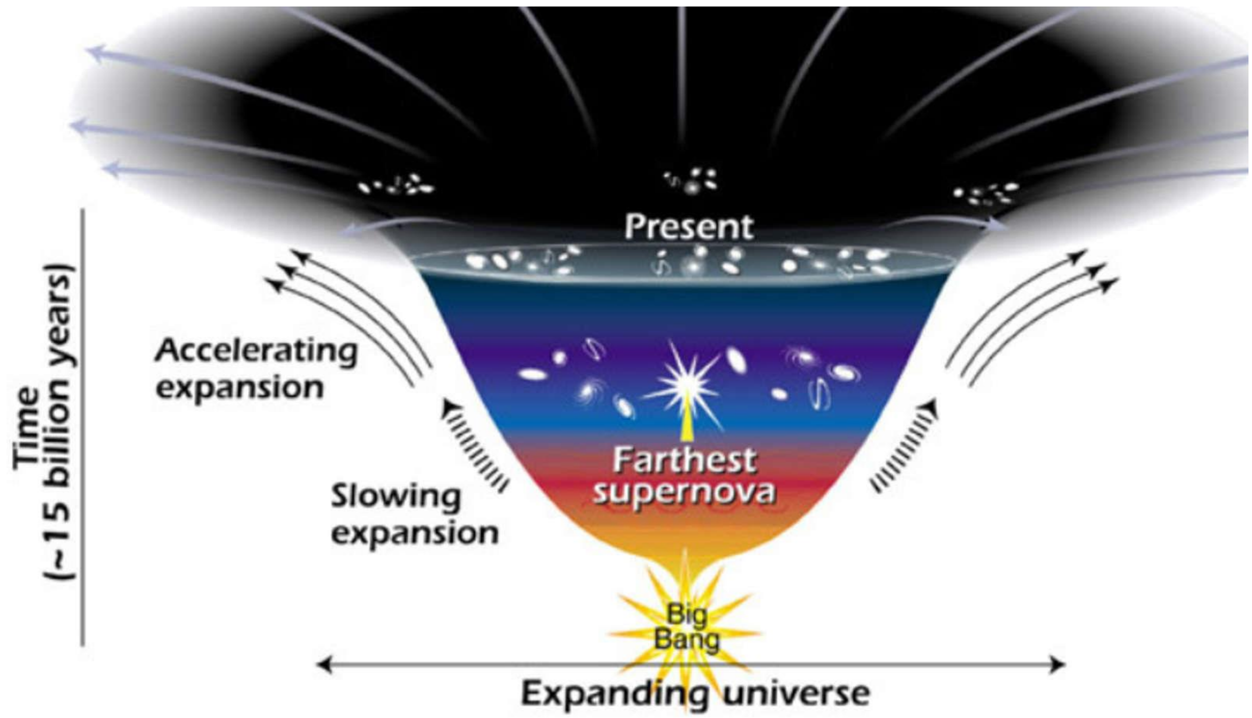
Quantum Fluctuations

New studies focus on quantum fluctuations, which consist of tiny changes in energy that might have existed before the Big Bang. These fluctuations could have set the stage for the universe we know today. However, scientists use advanced math and physics to model these pre-Big Bang conditions.



The Role of Dark Energy

The universe's rapid expansion is a mystery. Dark energy may be the culprit, a mysterious force permeating space itself. However, scientists are studying how this invisible energy could drive the accelerating expansion, potentially revealing secrets about the universe's past and future.



String Theory Insights

String theory, which sees the universe as made up of tiny vibrating strings, offers another perspective. It hints at the possibility of multiple universes or dimensions existing before and alongside our own. Perhaps this explains how our universe came to be.

Cosmic Microwave Background

We can learn a great deal from the cosmic microwave background, a remnant of radiation from the early universe. Scientists are studying tiny variations in this radiation. Consequently, these patterns might contain hidden messages about conditions before the Big Bang, acting like a cosmic time capsule.

Black Hole Clues

Black holes might offer insights into pre-Big Bang physics. As matter falls into these cosmic giants, it behaves similarly to how the universe might have acted in its earliest moments. Ultimately, studying black holes could tell us more secrets about the universe's birth.

Time Before Time

The concept of time before the Big Bang challenges our understanding of the universe, as some theories suggest time didn't exist before this event. Quantum gravity theories propose cyclical universes or a multiverse, which raises questions about whether time is a fundamental construct or tied to the universe's existence.

Multiverse Theories

There is a growing interest in the concept of a multiverse—the theory of many universes existing simultaneously. Our universe might have emerged from a different, older universe. This concept opens up even newer ways of thinking about what came before the Big Bang.

Advanced Computer Simulations

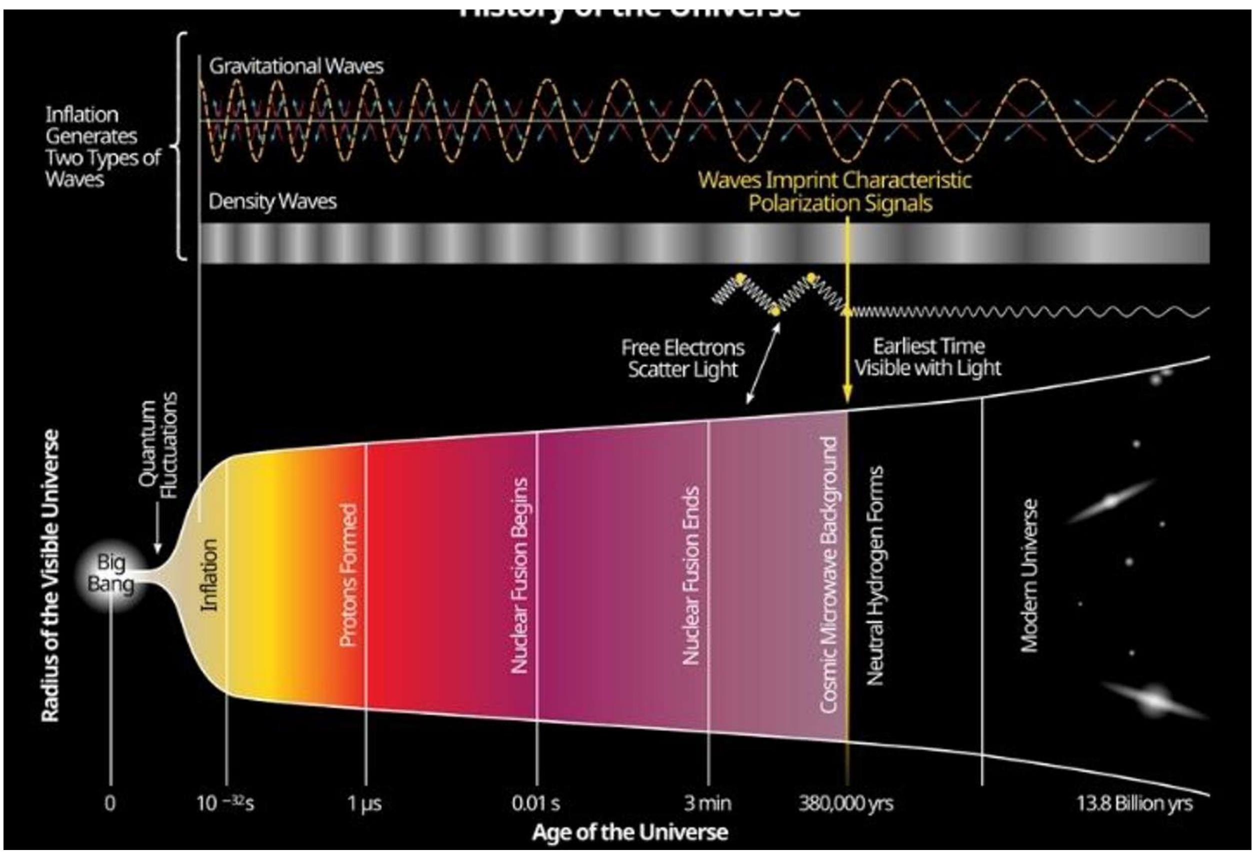
Powerful computers allow scientists to explore pre-Big Bang scenarios and to test various theories about the universe's behavior before its expansion. These models expand our understanding of cosmology by pushing the limits of what we know about the origins and early conditions of the universe.

Gravitational Waves

Gravitational waves, tiny ripples in space-time, could carry whispers from before the Big Bang. Scientists are working hard to develop more sensitive detectors, hoping to catch these faint signals. If successful, we might finally "listen in" to the universe's first moments and get hold of the mysteries of its earliest days.

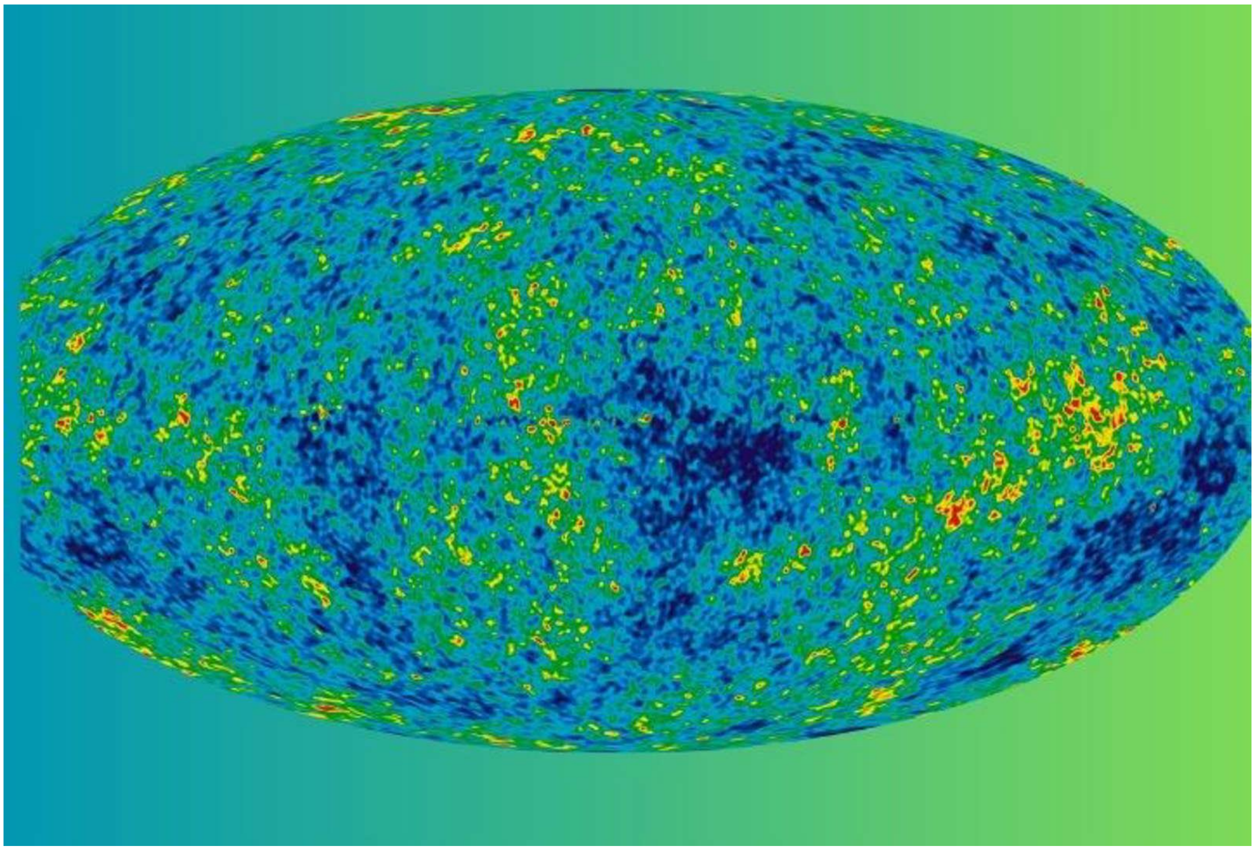
Matter-Antimatter Asymmetry

The mystery of why there's more matter than antimatter in the universe has puzzled scientists for years. Some believe the answer could lie in conditions before the Big Bang. Figuring out this imbalance might help explain why the universe exists in its current form, filled with stars, planets, and life.



Quantum Gravity

Quantum gravity seeks to reconcile quantum mechanics with general relativity, two theories that clash in extreme conditions, like black holes or the early universe. This unification could reveal pre-Big Bang physics and cosmic origins. While string theory and loop quantum gravity offer promising approaches, experimental validation remains elusive.



Eternal Inflation Theory

This theory proposes our universe as one bubble in an infinite, ever-expanding multiverse. It suggests our cosmic bubble emerged from a pre-existing inflationary state and gives a perspective on what might have preceded our universe's formation. It challenges traditional notions of cosmic origins and singularity.

Philosophical Implications

These discoveries raise big questions about existence itself. The possibility of a "before" the Big Bang questions long-held assumptions about reality, time, and causality. In light of this intersection between science and philosophy, we can reflect deeply on the fundamental nature of our universe and how we might find other multiverses.

Future Research Directions

Scientists are planning new experiments to explore cosmic origins using advanced technology like space telescopes and particle accelerators. Researchers can test theories about the universe's beginnings with these tools. This scientific pursuit is driven by a desire to understand our cosmic origins.

The Milky Way's stunning spiral structure appears to be an anomaly. But why?

If you were to spring from Earth so high you could glance down at the entire Milky Way, our home galaxy would look like a spinning pinwheel. In it, some 100 billion stars are sprinkled across some 100,000 light-years, accompanied by unfathomable amounts of gas and dust. Together, these galactic components swirl around in a stellar disk, spilling into four giant spiral arms emanating from the galaxy's blinding center, the home of a supermassive black hole.

We've come to really identify our galaxy with its spiral structure (although its exact number of galactic arms is still being debated). Yet, astronomers have long puzzled over why spiral galaxies such as ours appear to be strikingly scarce in our crowded pocket of the universe. The pancake-like supergalactic plane in which the Milky Way is embedded, spanning 1.4 billion years in width, is instead dominated by clumpy, somewhat rounded, galaxies known as ellipticals.

Now, a new supercomputer simulation of the 13.8 billion-year-long evolution of the universe suggests this scarcity is thanks to naturally occurring, frequent interactions among galaxies in the supergalactic plane that smooth out any potential spiral arms, leading to formation of the elliptical galaxies we see.

Stars in spiral galaxies like the Milky Way float around their galaxy centers in mostly circular orbits. However, when two galaxies of comparable mass are near each other, these ordered motions become disordered.

"The stellar orbits become reshuffled or randomized," Till Sawala, an astrophysicist at the University of Helsinki in Finland and co-author of a study on the findings, told Space.com. "This removes any ordered features, such as the appearance of a stellar disk, and therefore also removes the appearance of spiral arms."

The consequences of large galaxies merging together are also manifold. In addition to randomizing the orbits of numerous stars, consequent interactions can sometimes lead to a starburst as well, an event in which many new stars are born.

Additionally, the supermassive black holes that reside at the centers of most large galaxies "can get triggered — become active — during mergers," Sawala said. "This can change, and generally reduces the amount of new stars that the new galaxy can grow after the merger."

In turn, that makes the new galaxy even more elliptical.

Our Milky Way itself has grown over time by swallowing galaxies smaller than itself, known as dwarf galaxies. Due to their petite sizes, however, those galaxies did not influence the shape of our galaxy. Although, the Milky Way's predicted head-on collision with the Andromeda galaxy, expected to take place four billion years from now, may affect its structure at last. Andromeda boasts a similar, if not higher, mass than our galaxy exhibits.

An elliptical galaxy (left) and a spiral galaxy (right). (Image credit: NASA, ESA, CSA, Rogier Windhorst (ASU), William Keel (University of Alabama), Stuart Wyithe (University of Melbourne), JWST PEARLS Team, Alyssa Pagan (STScI))© Provided by Space

As for whether a spiral galaxy that was stripped of its arms and transformed into an elliptical can return to its original shape, well, probably not, Sawala says.

Though galaxies that contain sufficient reservoirs of gas can form new stars, which may spread out into spiral arms, that wouldn't apply to elliptical galaxies, as they tend to be gas-poor.

"An elliptical galaxy will never turn back into a disk galaxy," Sawala said. "Because disk galaxies represent a state of order, and elliptical galaxies represent a state of disorder, it is generally not possible to reverse the process."

Sawala said his team is now working on improving the simulations to make them more accurate, so the researchers can further compare what we know of fundamental physical processes with telescopic observations of the local universe.

"This either lets us improve our understanding of what we observe, or — even better — discover a gap or error in our knowledge," Sawala said. "In the work we just published, we found that the simulation produced exactly what was observed."

"Personally, I am hoping that next time, we discover a real anomaly!"

This research was described in a paper published Monday (Nov. 20) in the journal Nature Astronomy.

Earliest Galaxies Formed By The Big Bang Discovered And It Changes Everything

According to a new study published in the scientific journal Nature, researchers have located some of the earliest galaxies ever formed, helping them to garner a better understanding of the Big Bang. Using the James Webb Space Telescope, a team out of Stockholm University were able to determine some visually and chemically distinct differences between modern galaxies and those which formed at the onset of the universe's creation.

As scientists continue to dissect these new findings, the results could completely change the way we view interstellar studies.

Millions Of Stars In Baby Galaxies

The study was responsible for locating five incredibly dense star clusters that formed along an extremely thin arc in the distant reaches of outer space.

These galaxies could potentially be the earliest ever formed in the history of the universe, and are certainly the earliest we've laid eyes on. The galaxies in question have been classified as proton-globular clusters, meaning they contain millions of individual stars, each bound by the extreme gravitational force of the galactic core.

Time Dilation Lets Scientists View The Past

If you're an avid fan of space discoveries, you likely already know that peering deeper and deeper into the vacuum of space allows scientists to look further and further back in time. This is due to the amount of time that it takes for light to reach from these distant corners of the universe to the James Webb or other comparable devices. Essentially, by searching further from Earth than ever before, scientists can discover galaxies that date back billions of years.

From The First 500 Million Years Of Existence

The galaxies located in this latest discovery are said to have formed within the first 500 million years of the formation of the universe. While this may sound like an incredibly massive stretch of time, it's actually minute in a cosmic sense, and serves as the closest we've gotten to observing early-universe structures. The universe itself is said to have formed nearly 14 billion years ago, while Earth only just arrived on the scene 4.5 billion years ago.

Calls Prior Research Into Question

Furthermore, that 500 million-year estimate puts this cluster of galaxies smack-dab in the middle of the cosmic dawn, encompassing the first billion years to follow the Big Bang. Existing studies indicate that the Epoch of Reionization didn't kick off until about 400 million years after the cosmic jump-start, leading to the eventual formation of galaxies as a concept. Therefore, the newly discovered crescent of stars seemingly proves that galaxies form much faster and shine much brighter than previously believed.

Primordial Space Mystery

The cluster of galaxies located by the Stockholm team, led by Angela Adamo, has been nicknamed the Cosmic Gems due to their bright, shining appearance. The incredibly luminous structures are said to be magnified and distorted by their crescent-shaped arc, which amplifies the blinding light as the stars refract off of one another. Researchers call the region the most highly magnified discovery they've ever seen, fully reshaping our understanding of primordial space discoveries.

New Discoveries Thanks To The James Webb Telescope

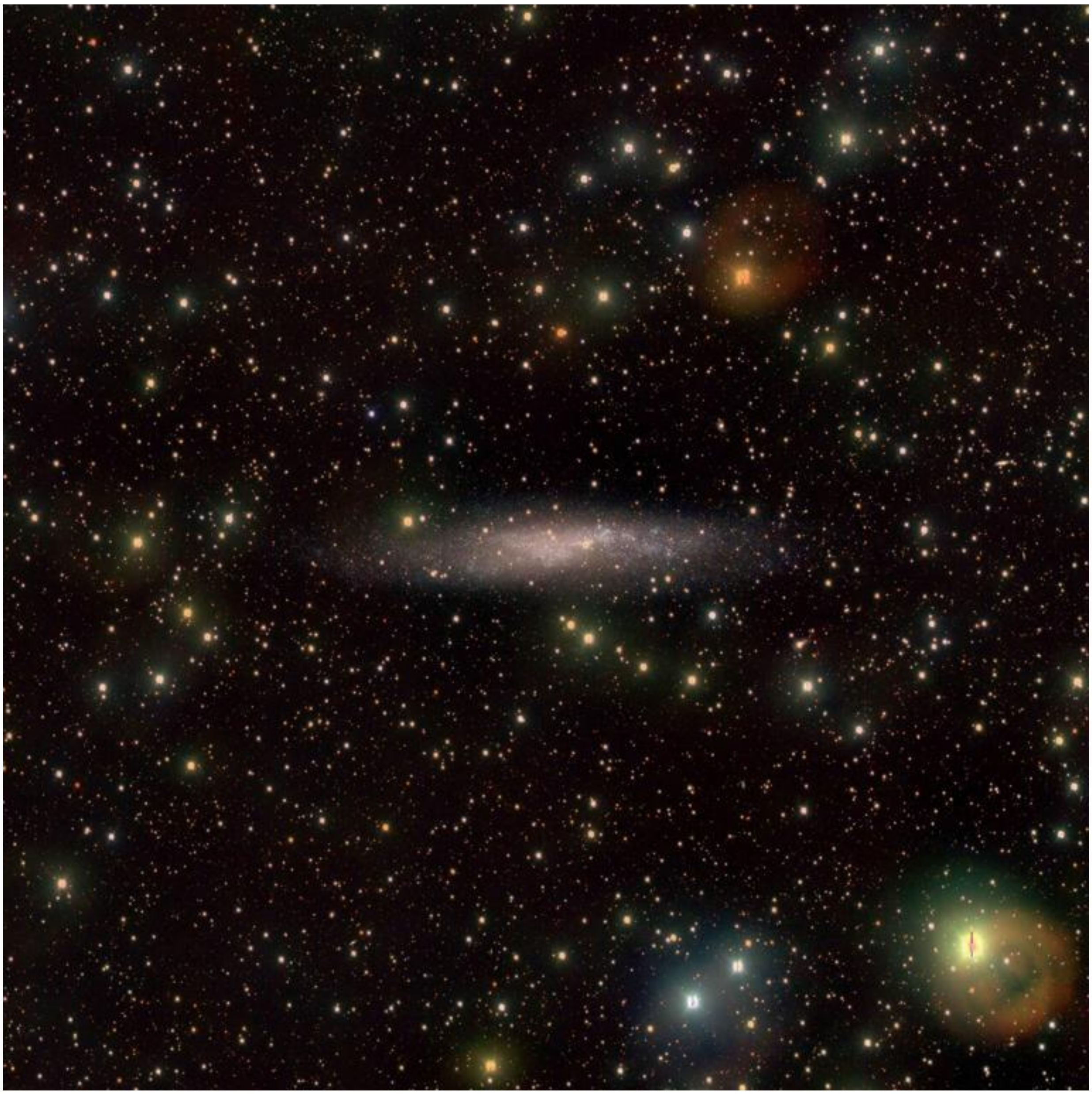
As researchers continue to dig deeper into the reaches of outer space with the James Webb Space Telescope, discoveries of this kind are sure to continue revealing new and exciting information. The fact is, human beings may have actually laid eyes on the earliest possible galaxies ever produced, meaning we're several steps closer to fully mapping to the dawn of existence.

Survey captures image sequence of galactic neighbors in the local universe

Credit: National Institute for Astrophysics The Southern Pinwheel, a spiral galaxy about 15 million light-years away, imaged by the Vst. Credit: Inaf/Vst-Smash/C. Tortora et al. 2024

The National Institute for Astrophysics (INAF) has released images of five galaxies in the local universe, taken with the Italian VST (VLT Survey Telescope) managed by INAF in Chile. The new images show these iconic galaxies in great detail, immortalizing their shape, colors and distribution of stars up to great distances from the center.

Two of them, the irregular galaxy NGC 3109 and the irregular dwarf Sextant A , are located on the edge of the so-called Local Group, which also includes our galaxy, the Milky Way, and are about 4 million light-years away. Two other galaxies, the splendid spiral galaxy known as the Southern Pinwheel (but also NGC 5236 or M 83) and the irregular NGC 5253 are located, respectively, about 15 and 11 million light-years away from ours, while the fifth and most distant, the spiral galaxy IC 5332 , is about 30 million light-years away.



The irregular galaxy NGC 3109, about 4 million light-years away, imaged by the VST. Credit: Inaf/VST-Smash/C. Tortora et al. 2024

The observations were made in three filters, or colors, as part of the VST-SMASH survey (VST Survey of Mass Assembly and Structural Hierarchy), a project led by Crescenzo Tortora , a researcher at INAF in Naples, to understand the mechanisms that lead to the formation of the many different galaxies that populate the cosmos.

The five galaxies are part of a sample of 27 galaxies that the team is studying with the VST, a telescope with a 2.6-meter diameter mirror, built in Italy and hosted since 2012 at the ESO Observatory on Cerro Paranal, in Chile. These galaxies were carefully selected in the portion of the sky that, over the next few years, will also be observed by the European Space Agency's Euclid satellite (ESA) to provide a more detailed optical counterpart (up to blue wavelengths) to the space data collected by the VIS instrument (at red wavelengths) and the NISP instrument in the near-infrared.

The irregular dwarf galaxy Sextans A, about 4 million light-years away, imaged by the Vst. Credit: Inaf/Vst-Smash/C. Tortora et al. 2024

The group presented the survey in a paper published in *The Messenger* journal.

"We are trying to understand how galaxies form, as a function of their mass and morphological type. This means asking how stars form in situ, inside galaxies, but also how they are accumulated (ex situ) through merging processes, that is, fusion, with other galaxies" explains Tortora, who leads an international team that involves many researchers from various INAF sites.

"To do this, we need to trace the colors of these galaxies up to the peripheral regions, to be able to investigate the presence of very faint structures belonging to these galaxies, and populations of dim galaxies orbiting around them. This is useful to be able to trace the residues of galactic interactions, and therefore constrain the hierarchical process of cosmic structure formation."

The analysis of the collected data is still in its early stages, but the observations have already proven effective, allowing the team to examine the galaxies down to very low surface brightnesses, which until a few years ago were difficult to observe.

The VST telescope, with its large field of view of one degree squared, equal to about four times the area of the full moon in the sky, was the key instrument that allowed these images to be made in a relatively short time—observing the field around these galaxies, in the three filters, with 10 hours of observations per degree squared. In comparison, making just one of these images with the Hubble Space Telescope would have required many consecutive exposures.

"This is the first time that all these galaxies have been observed in such a deep and detailed way, and with homogeneous data," adds Tortora. "In the years to come, only Euclid will reach our optical depths, but it will not be able to count on the vast coverage in the optical lengths of the VST.

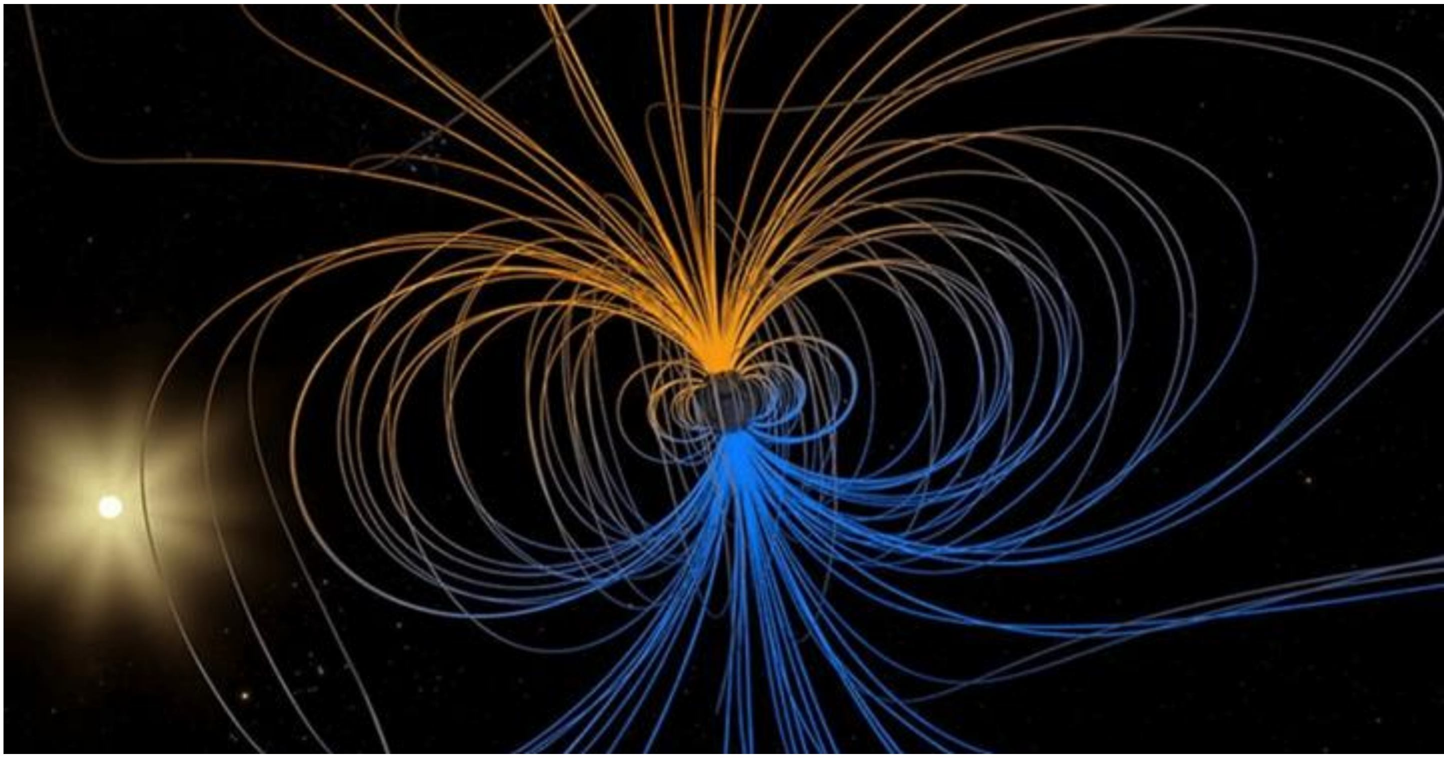
The irregular galaxy NGC 5253, about 11 million light-years away (left), and the spiral galaxy IC 5332, about 30 million light-years away (right), imaged by the VST. Credit: Inaf/VST-Smash/C. Tortora et al. 2024

"The Vera Rubin Observatory, on the other hand, although observing in spectral regions similar to ours, will reach similar depths only after many years of observation. This makes VST an instrument that can still have its say, and gives hope for interesting results within our survey," he concludes.

More information: Crescenzo Tortora et al, VST-SMASH: the VST Survey of Mass Assembly and Structural Hierarchy, *The Messenger* (2024). DOI: 10.18727/0722-6691/5366

Provided by National Institute for Astrophysics

Why Is Earth's Magnetic North Pole Moving Eastwards Across The Globe?



An illustration of Earth's magnetic pole fields with the Sun chilling out in the background. - Image credit: NASA© IFL Science

Earth’s magnetic poles aren’t set in stone (or ice). Over the past centuries,

Earth's magnetic north has been drifting east at an accelerating pace, shifting thousands of kilometers across the globe. The massive, compass-wobbling trend is being driven by vast oceans of liquid metal in Earth’s interior and some fundamental principles of electromagnetism.

Since the 1830s, the north magnetic pole of Earth has relocated some 2,250 kilometers (1,400 miles) across the upper stretches of the Northern Hemisphere from Canada towards Siberia.

The magnetic north pole's travel seems to be accelerating too. Between 1990 and 2005, the rate of pole movement increased from less than 15 kilometers (9.3 miles) per year to around 50 to 60 kilometers (31 to 37 miles) per year, according to a 2020 study.

If it continues at this pace, the north magnetic pole will travel up to 660 kilometers (410 miles) toward Siberia over the next decade. The effect is so profound that scientists at the British Geological Survey (BGS) have previously said that all compasses will "probably point eastward of true north" by 2040.

On the other side of the planet, Earth's south magnetic pole also appears to be on the move, drifting eastwards over Antarctica's coast. These changes may seem extreme, but bigger shifts are possible. Every 300,000 years or so on average, Earth's magnetic poles swap entirely; the north pole is transformed into the south pole and the south pole becomes the north pole. Since the last pole swap was 780,000 years ago, some think we're long overdue for a switch-up.

Earth's magnetic poles are the result of molten iron and nickel sloshing around its outer core. These liquid metals are conductive and in constant motion due to the planet's rotation and heat-driven convection. In tune with the principles of electromagnetism, the movement creates electric currents, which generate a magnetic field.

This is known as Earth's geodynamo system or the dynamo theory. As we've seen in recent shifts, the magnetic poles aren't constant and the geodynamo system can appear fairly chaotic.

As explained by the 2020 study mentioned above, the recent shift towards Siberia is possibly caused by a change in the pattern of flow in Earth's interior that occurred between 1970 and 1999. The change resulted in the Canadian "blob" becoming elongated and losing its influence on the magnetosphere, causing the pole to slip toward Siberia.

At least, that's one current theory.

"We know there are irregular changes in the planet's liquid outer core and that the magnetic field is also weakening under Canada, but it's not yet possible to say exactly for sure why magnetic north is changing so fast," Ciarán Beggan, BGS Geophysicist, said in a 2019 statement.

The shifting pole will have minimal impact on your day-to-day life (unless you're a pre-modern sailor navigating uncharted seas). However, scientists must keep an eye on its movement as the Global Positioning System (GPS) and other satellite-based radio navigation systems will need to be recalibrated with the shift in mind

DESI confirms Einstein's relativity on cosmic scales with unprecedented precision.

Sparring antennae galaxies.© (photo credit: NASA Goddard Photo and Video is licensed under CC BY 2.0. Via NASA)

An international team of astronomers confirmed that Albert Einstein's theory of general relativity holds true on cosmic scales, following an extensive survey conducted by the Dark Energy Spectroscopic Instrument (DESI). The study analyzed nearly six million galaxies and quasars, spanning 11 billion years of cosmic history, offering new perspectives on the growth of cosmic structures, the mass of neutrinos, and the distribution of dark matter and energy.

Scientists used DESI, a state-of-the-art spectroscopic instrument installed on the Nicholas U. Mayall Telescope at Kitt Peak National Observatory in Arizona, to map how these galaxies cluster across time, aligning with Einstein's predictions and confirming general relativity on cosmic scales. This study represents the most accurate large-scale test of gravity in history, spanning most of the 13.8-billion-year history of the universe and strengthening the foundations of general relativity.

"General relativity has been very well tested at the scale of solar systems, but we also needed to test that our assumption works on much larger scales," said cosmologist Pauline Zarrouk from the French National Centre for Scientific Research, according to Science Alert. Zarrouk co-directed the new analysis alongside Héctor Gil Marín from the University of Barcelona.

The findings reveal that the way galaxies cluster and evolve over billions of years is consistent with Einstein's predictions, aligning with general relativity at cosmological scales. "Studying the speed at which galaxies formed allows us to directly test our theories, and so far, we are aligning with what general relativity predicts on cosmological scales," Zarrouk stated, as reported by Scienze Notizie.

The DESI collaboration involves more than 900 researchers from over 70 institutions worldwide and is managed by the U.S. Department of Energy's Lawrence Berkeley National Laboratory. DESI can capture light from 5,000 galaxies simultaneously and will eventually observe roughly 40 million galaxies and quasars, providing important contributions to the understanding of the universe over the last 11 billion years.

Space.com, New Scientits, and India Today were among the websites that reported on the study.

"Both our BAO results and the full-shape analysis are spectacular," said Professor Dragan Huterer of the University of Michigan, co-lead of DESI's group interpreting the cosmological data, according to Phys.org. "We're showing a tremendous new ability to probe modified gravity and improve constraints on models of dark energy. And it's only the tip of the iceberg."

The new analysis, called a "full-shape analysis," has expanded the possibilities of extracting information from the data, allowing the study of the distribution of galaxies and matter on different scales in space. This analysis has allowed researchers to explore up to 11 billion years into the past. Conducting this study required months of additional work and rigorous cross-checks.

Gravity plays a fundamental role in the functioning of the Universe, acting as the glue that holds cosmic structures together. The cosmic web, an intricate network of filaments and voids, represents the large-scale structure of matter formed by the gravitational pull of galaxies and dark matter. The way gravity clumps galaxies together along strands of the cosmic web against the outward pull of the expansion of the Universe is consistent with predictions made by Einstein's theory of general relativity.

"Einstein's theory of general relativity describes the motion of massive objects in a gravitational field that they create. It is one of the most successful physical theories that we have," said Huterer, as reported by Space.com.

The findings also place tighter constraints on alternative theories of modified gravity, which have been proposed to explain unexpected observations, including the accelerating expansion of the universe. These alternatives are generally referred to as "modified theories of gravity" and aim to explain observations of the universe without the need to introduce an unknown like dark energy.

"Our DESI data shows that it is in agreement with Einstein's theory of gravity but still favors a dynamical dark energy—and finding these simultaneously is new," noted Mustapha Ishak-Boushaki, an astrophysicist from the University of Texas at Dallas, according to New Scientist.

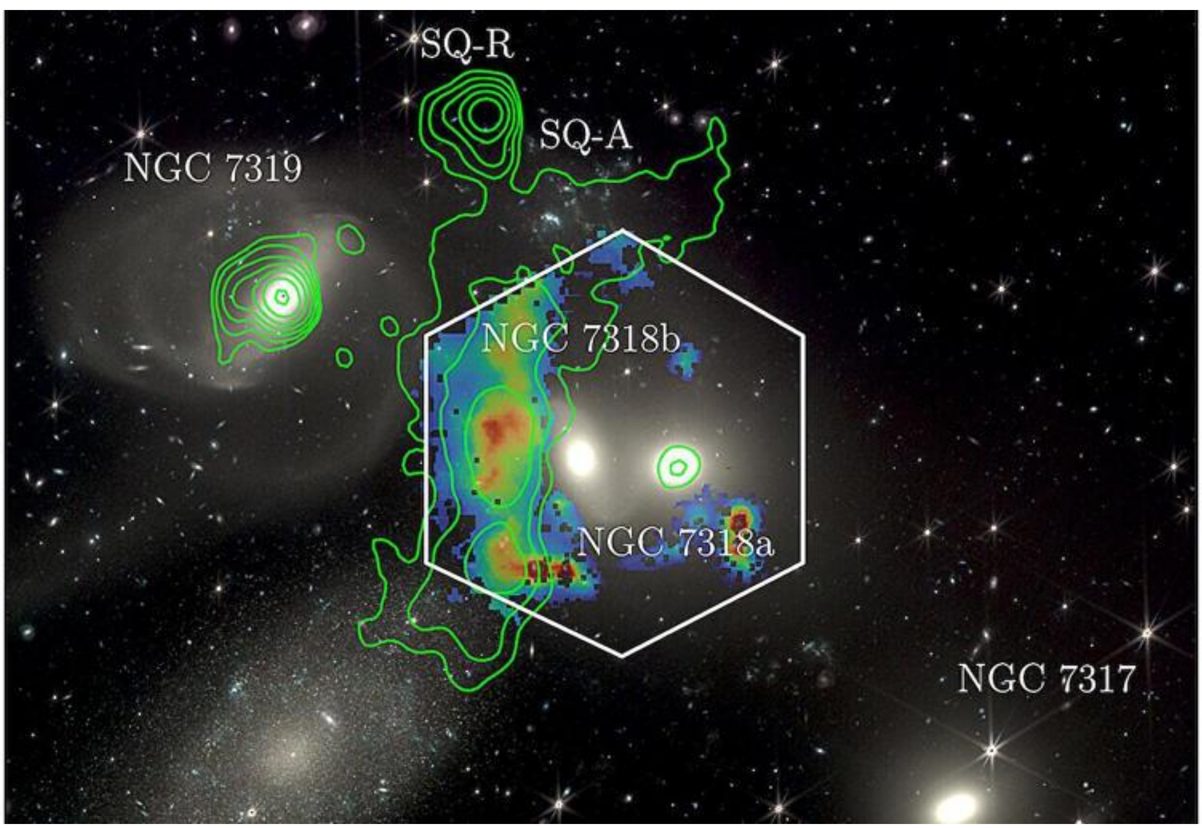
The study also provided new upper limits on the mass of neutrinos, the only fundamental particles whose masses have not yet been precisely measured in the laboratory. DESI's results indicate that the sum of the neutrino masses should be less than 0.071 eV/c^2, leaving a narrow window for neutrino masses.

"Remarkably, the galaxy clustering also sets upper limits on the yet unknown mass of tiny particles called neutrinos, as their presence affects the growth of structure," said Professor Ofer Lahav from UCL Physics & Astronomy, a DESI collaborator and a member of its Executive Committee, as reported by Mirage News.

Despite ongoing data collection, DESI has already achieved the most precise measurement of cosmic structure growth, focusing on how galaxies cluster and offering new insights into dark matter and dark energy. Further results from the second and third years of DESI operations are expected to be released in Spring 2025, with takeaways from the first three years of observations to be shared in March 2025.

"The idea that we can take pictures of the universe and tackle these big, fundamental questions is mind-blowing," said Mark Maus, a PhD student at Berkeley Lab and UC Berkeley, as reported by Space.com.

2 million mph galaxy smash-up seen in unprecedented detail



WEAVE data overlaid on a James Webb Space Telescope image of Stephan's Quintet, with green contours showing radio data from the Low Frequency Array (LOFAR) radio telescope. The orange and blue colors follow the brightness of Hydrogen-alpha obtained with the WEAVE LIFU, which trace where the intergalactic gas is ionized. The hexagon denotes the approximate coverage of the new WEAVE observations of the system, which is 36 kpc wide (similar in size to our own galaxy, the Milky Way). Credit: University of Hertfordshire

A massive collision of galaxies sparked by one traveling at a scarcely-believable 2 million mph (3.2 million km/h) has been seen in unprecedented detail by one of Earth's most powerful telescopes.

The dramatic impact was observed in Stephan's Quintet, a nearby galaxy group made up of five galaxies first sighted almost 150 years ago.

It sparked an immensely powerful shock akin to a "sonic boom from a jet fighter"—the likes of which are among the most striking phenomena in the universe.

Stephan's Quintet represents "a galactic crossroad where past collisions between galaxies have left behind a complex field of debris", which has now been reawakened by the passage of the galaxy, NGC 7318b.

The collision was spotted by a team of scientists using the first observations from the new 20-million Euro (£16.7million) William Herschel Telescope Enhanced Area Velocity Explorer (WEAVE) wide-field spectrograph in La Palma, Spain.

This cutting-edge, next generation science facility will not only reveal how our Milky Way galaxy was built up over billions of years, but also offer new insights into millions of other galaxies across the universe.

The discovery of NGC 7318b smashing through Stephan's Quintet was observed by a team of more than 60 astronomers and has been published in *Monthly Notices of the Royal Astronomical Society*.

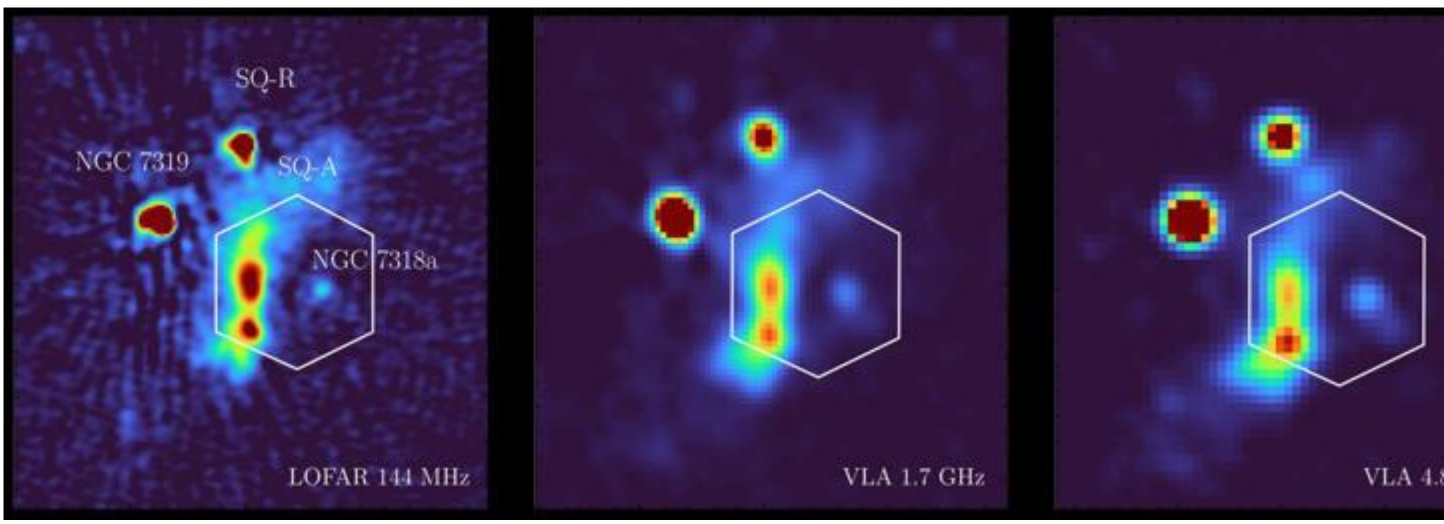
The system is an ideal laboratory to understand the chaotic and often violent relationship between galaxies, which is why it was the focus of the first-light observation by the WEAVE Large Integral Field Unit (LIFU).

Lead researcher Dr. Marina Arnaudova, of the University of Hertfordshire, said, "Since its discovery in 1877, Stephan's Quintet has captivated astronomers, because it represents a galactic crossroad where past collisions between galaxies have left behind a complex field of debris.

"Dynamical activity in this galaxy group has now been reawakened by a galaxy smashing through it at an incredible speed of over 2 million mph (3.2 million km/h), leading to an immensely powerful shock, much like a sonic boom from a jet fighter."

The international team has uncovered a dual nature behind the shock front, previously unknown to astronomers.

"As the shock moves through pockets of cold gas, it travels at hypersonic speeds—several times the speed of sound in the intergalactic medium of Stephan's Quintet—powerful enough to rip apart electrons from atoms, leaving behind a glowing trail of charged gas, as seen with WEAVE," Dr. Arnaudova said.

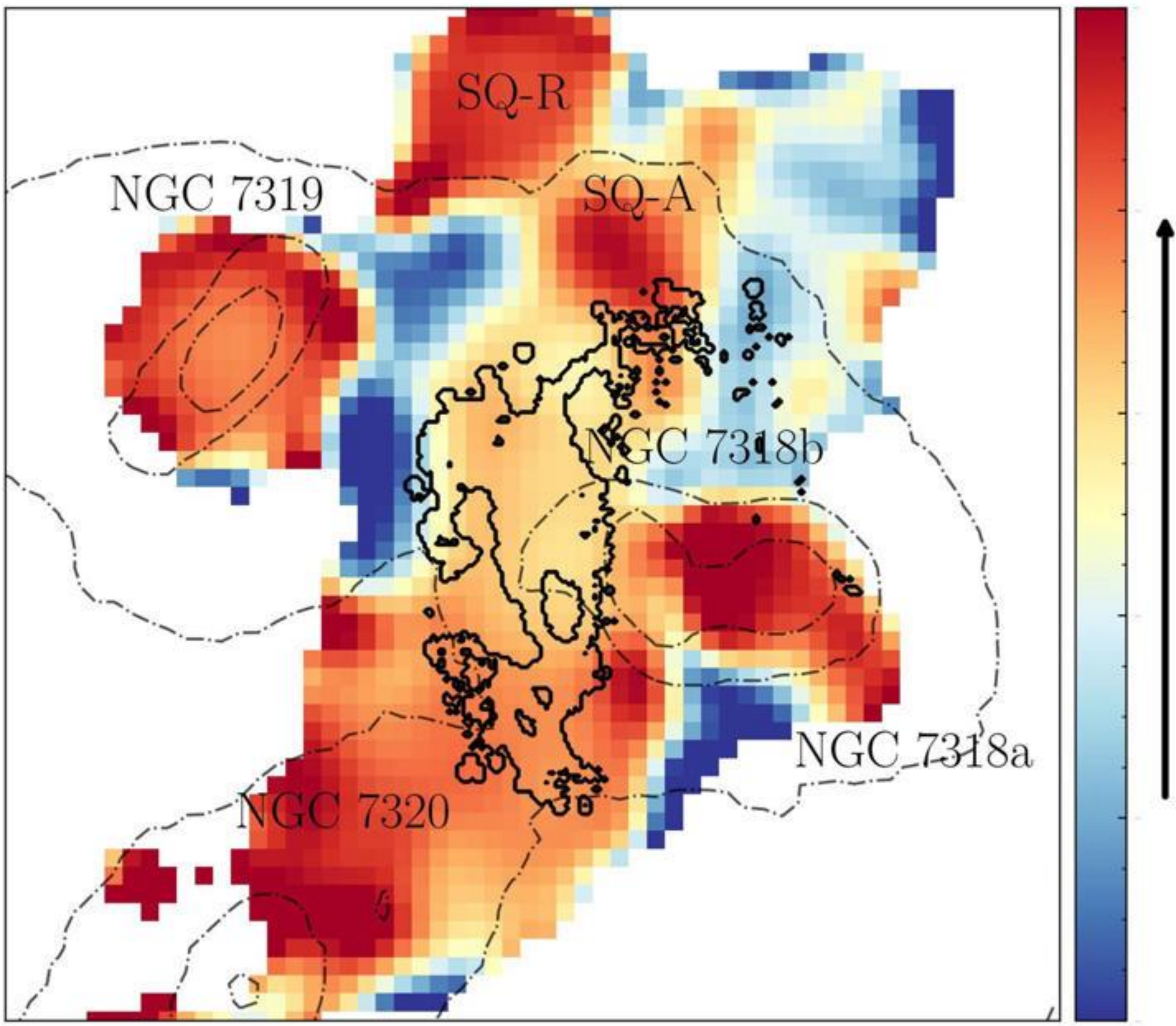


Radio observations of Stephan's Quintet at different frequencies, taken by the Low Frequency Array (LOFAR) and the Very Large Array (VLA). The red colors indicate strong radio emission coming from the shock front, as well as from some of the galaxies in the group and beyond. Credit: University of Hertfordshire

However, when the shock passes through the surrounding hot gas, it becomes much weaker, according to Ph.D. student Soumyadeep Das, of the University of Hertfordshire.

He added, "Instead of causing significant disruption, the weak shock compresses the hot gas, resulting in radio waves that are picked up by radio telescopes like the Low Frequency Array (LOFAR)."

The new insight and unprecedented detail came from WEAVE's LIFU, combining data with other cutting-edge instruments such as the LOFAR, the Very Large Array (VLA), and the James Webb Space Telescope (JWST).



An image revealing the age of high-energy plasma in Stephan's Quintet, as captured by radio observations with the VLA and LOFAR. The blue colors indicate older, low-energy plasma, while the orange and yellow areas mark regions that are being actively energized. The thin, dashed lines outline the location of the galaxies in the group, while the black solid lines trace the shock region identified with WEAVE data, which perfectly matches the areas where this plasma is being re-accelerated by the collision between NGC 7318b and the group. Credit: University of Hertfordshire

WEAVE is a state-of-the-art super-fast mapping device that has been connected to the William Herschel Telescope to analyze the composition of stars and gas both in the Milky Way and in distant galaxies.

This is done with the help of a spectroscope, which reveals the elements that stars are made of by generating a bar code-style pattern within a prism of colors that make up a source of light.

It was designed and built following a multi-lateral agreement by France, Italy and the countries of the Isaac Newton Group of Telescopes partnership (the UK, Spain and the Netherlands).

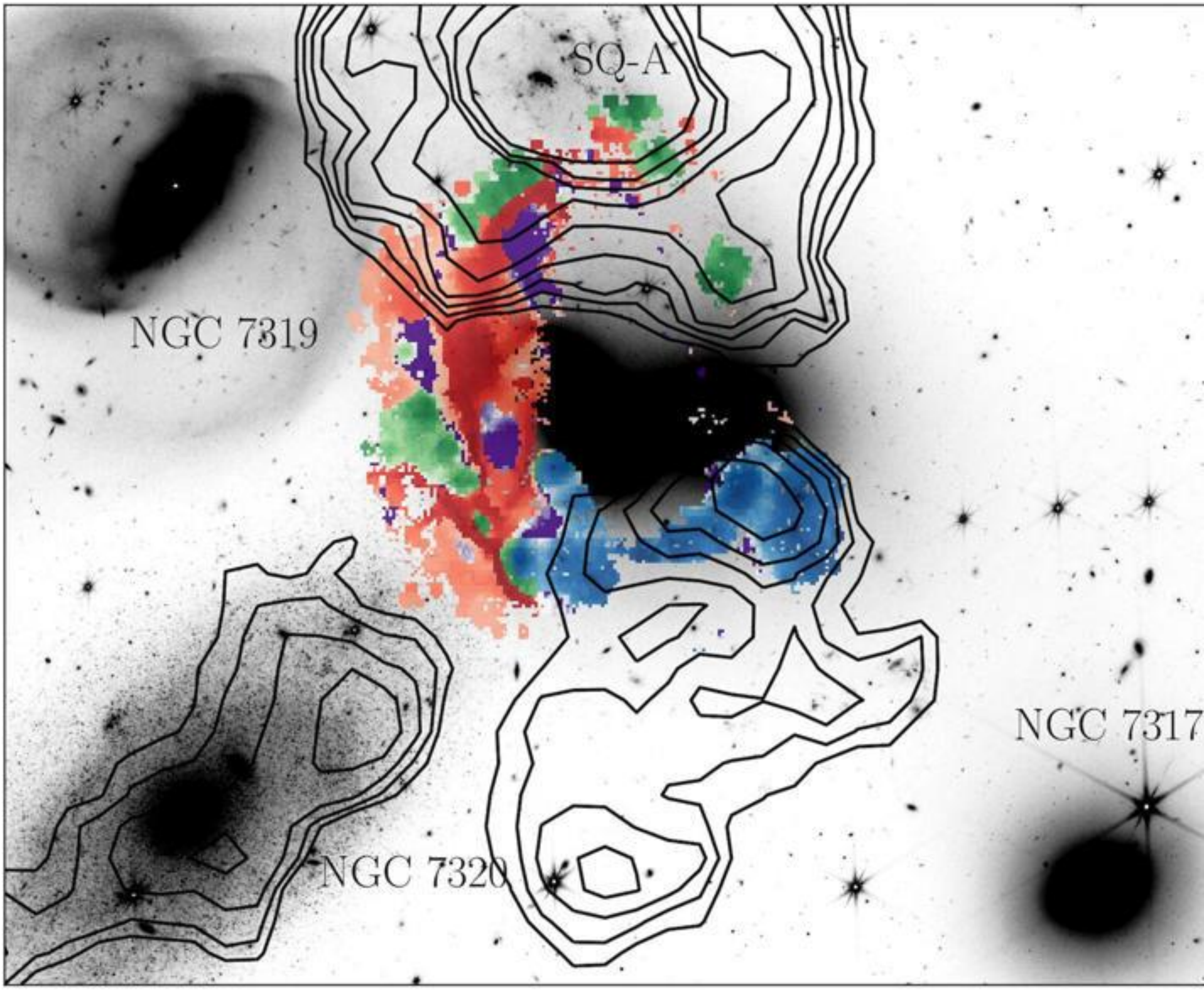
Astronomers hope that WEAVE will help reveal how our galaxy formed in unprecedented detail and revolutionize our understanding of the universe.

Dr. Daniel Smith, of the University of Hertfordshire, said, "It's really neat work that Marina has put together with this large team, but this first WEAVE science paper also represents just a taste of what is to come over the next five years now that WEAVE is becoming fully operational."

Professor Gavin Dalton, WEAVE principal investigator at RAL Space and the University of Oxford, said, "It's fantastic to see the level of detail uncovered here by WEAVE.

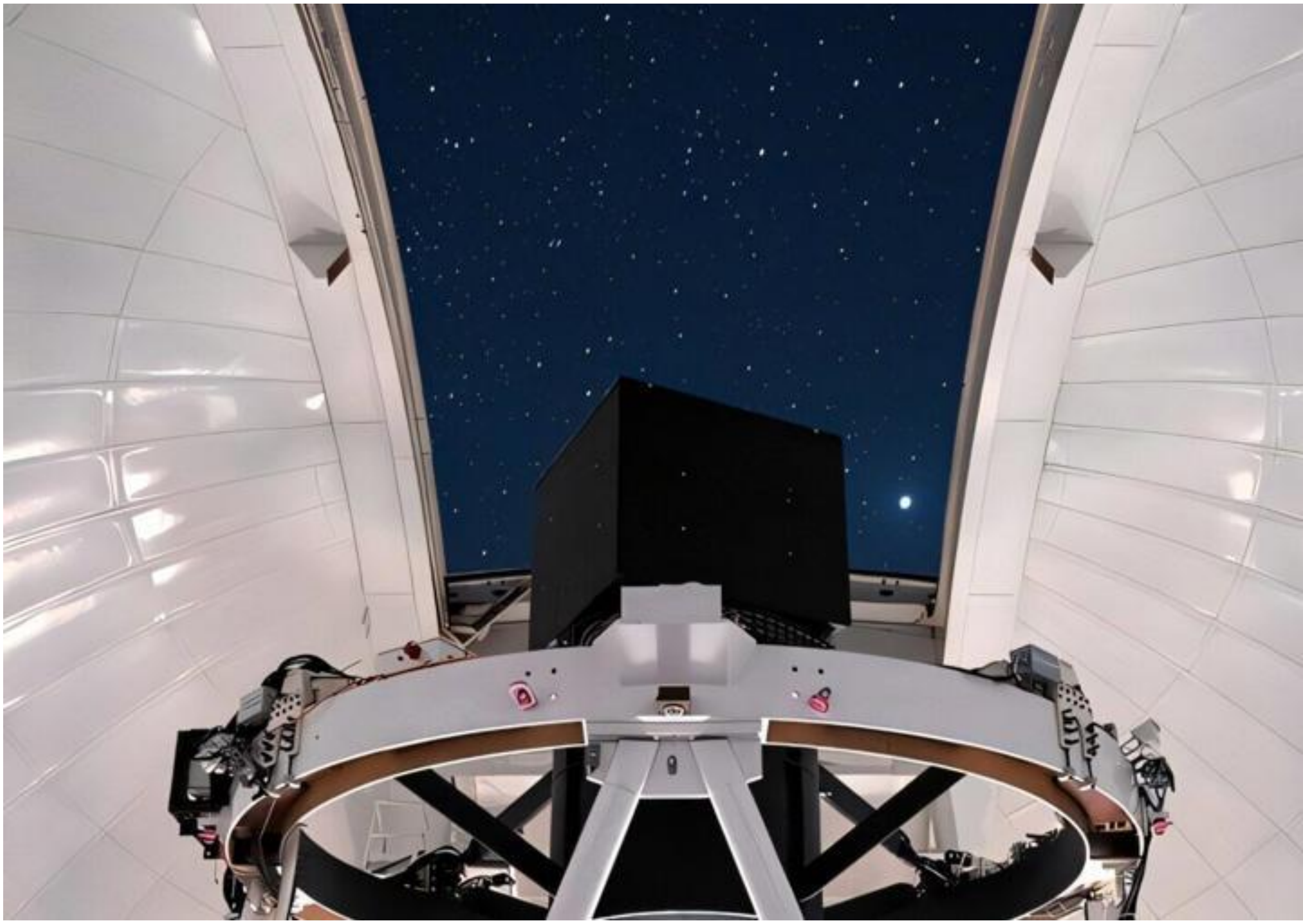
"As well as the details of the shock and the unfolding collision that we see in Stephan's Quintet, these observations provide a remarkable perspective on what may be happening in the formation and evolution of the barely resolved faint galaxies that we see at the limits of our current capabilities."

Dr. Marc Balcells, director of the Isaac Newton Group of Telescopes, said, "I'm excited to see that the data gathered at the WEAVE first light already provide a high-impact result, and I'm sure this is just an early example of the types of discoveries that will be made possible with WEAVE on the William Herschel Telescope in the coming years."



WEAVE decomposition of gas in Stephan's Quintet, overlaid on a JWST image. The red highlights gas shocked by the collision, while green and blue shows star-forming regions. The purple areas represent bubbles with an unknown origin. The black contours show neutral Hydrogen, and its location relative to the shocked gas (in red) suggests that is where it comes from. Credit: University of Hertfordshire

More information: M I Arnaudova et al, WEAVE First Light Observations: Origin and Dynamics of the Shock Front in Stephan's Quintet, *Monthly Notices of the Royal Astronomical Society* (2024). DOI: 10.1093/mnras/stae2235

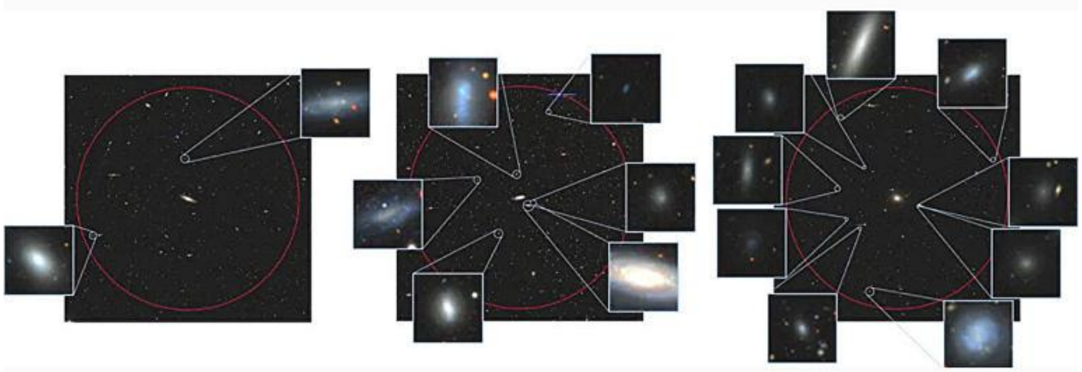

The WEAVE prime-focus corrector and positioner at the William Herschel telescope in La Palma, Spain. Credit: ING

Provided by Royal Astronomical Society

The Milky Way represents an outlier among similar galaxies, universe survey data shows

For decades, scientists have used the Milky Way as a model for understanding how galaxies form. But three new studies raise questions about whether the Milky Way is truly representative of other galaxies in the universe.

"The Milky Way has been an incredible physics laboratory, including for the physics of galaxy formation and the physics of dark matter," said Risa Wechsler, the Humanities and Sciences Professor and professor of physics in the School of Humanities and Sciences. "But the Milky Way is only one system and may not be typical of how other galaxies formed. That's why it's critical to find similar galaxies and compare them."



The SAGA Survey identified 101 Milky Way-like galaxies that have small satellite galaxies. These three examples contain two, six, and nine satellite galaxies, respectively. Credit: Yasmeen Asali (Yale), with images from the DESI Legacy Surveys Sky Viewer

To achieve that goal, Wechsler cofounded the Satellites Around Galactic Analogs (SAGA) Survey dedicated to comparing galaxies similar in mass to the Milky Way.

After more than a decade of scanning the universe, the SAGA team identified and studied 101 Milky Way-like analogs as a first step in its ongoing research. The results, published in three studies in the Nov. 18 issue of *The Astrophysical Journal*, reveal that, in many ways, the evolutionary history of the Milky Way is different from other comparable-sized galaxies.

"Our results show that we cannot constrain models of galaxy formation just to the Milky Way," said Wechsler, who is also professor of particle physics and astrophysics at the SLAC National Accelerator Laboratory. "We have to look at that full distribution of similar galaxies across the universe."

In addition to Wechsler, the SAGA project is led by Professor Marla Geha at Yale University and Yao-Yuan Mao, Wechsler's former doctoral student at Stanford, now an assistant professor at the University of Utah. All three co-authored the newly published studies.

Dark matter mystery

The Milky Way is made of ordinary atomic matter, like hydrogen and iron. But ordinary matter only accounts for about 15% of matter in the universe. The remaining 85% is mysterious, invisible dark matter.

"No one knows what dark matter is made of," Wechsler said. "It doesn't interact with ordinary matter or light. There's probably dark matter running through you right now and you don't even know it."

Studies show that galaxies form inside massive regions of dark matter called halos. A dark matter halo may be invisible, but its enormous size creates a gravitational force strong enough to pull in ordinary matter from space and transform it into stars and galaxies.

A key objective of the SAGA Survey is to determine how dark matter halos impact galactic evolution. To begin, the SAGA team focused on galactic satellites—small galaxies that orbit much larger host galaxies like the Milky Way.

The researchers identified four of the Milky Way's brightest satellite galaxies, including the two biggest, known as the Large and Small Magellanic Clouds (LMC and SMC). The scientists then conducted a painstaking search for satellites around other host galaxies similar in mass. Using telescopic imaging, they eventually identified 378 satellite galaxies surrounding 101 Milky Way-like hosts.

"There's a reason no one ever tried this before," Wechsler said. "It's a really ambitious project. We had to use clever techniques to sort those 378 orbiting galaxies from thousands of objects in the background. It's a real needle-in-the-haystack problem."

New findings

In one of the three new SAGA studies, researchers found that the number of satellites per host galaxy ranges from 0 to 13. The Milky Way's four observable satellites fit within that range.

The study also revealed that host galaxies with large satellites, similar in size to the Milky Way's massive LMC and SMC galaxies, tend to have more satellites overall. But the Milky Way actually hosts fewer satellites than similar galaxies, making it an outlier among its peers.

A second study focused on star formation in satellite galaxies—an important metric for understanding how galaxies evolve. The study found that in a typical host galaxy, smaller satellites are still forming stars. But in the Milky Way, star formation only occurs in the massive LMC and SMC satellites. All the smaller satellites have stopped forming stars.

"Now we have a puzzle," Wechsler said. "What in the Milky Way caused these small, lower-mass satellites to have their star formation quenched? Perhaps, unlike a typical host galaxy, the Milky Way has a unique combination of older satellites that have ceased star formation and newer, active ones—the LMC and SMC—that only recently fell into the Milky Way's dark matter halo."

The study also found that star formation typically stops in satellite galaxies located closer to the host, perhaps because of the gravitational pull of dark matter halos in and around the host galaxy.

"To me, the frontier is figuring out what dark matter is doing on scales smaller than the Milky Way, like with the smaller dark matter halos that surround these little satellites," Wechsler said.

The third study, led by Stanford doctoral scholar Yunchong "Richie" Wang, compares the new data to computer simulations and calls for the development of a new model of galaxy formation based in part on the SAGA Survey.

"SAGA provides a benchmark to advance our understanding of the universe through the detailed study of satellite galaxies in systems beyond the Milky Way," Wechsler said. "Although we finished our initial goal of mapping bright satellites in 101 host galaxies, there's a lot more work to do."

More information: Yao-Yuan Mao et al, The SAGA Survey. III. A Census of 101 Satellite Systems around Milky Way–mass Galaxies, *The Astrophysical Journal* (2024). DOI: 10.3847/1538-4357/ad64c4

Marla Geha et al, The SAGA Survey. IV. The Star Formation Properties of 101 Satellite Systems around Milky Way–mass Galaxies, *The Astrophysical Journal* (2024). DOI: 10.3847/1538-4357/ad61e7

Yunchong Wang et al, The SAGA Survey. V. Modeling Satellite Systems around Milky Way–Mass Galaxies with Updated UniverseMachine, *The Astrophysical Journal* (2024). DOI: 10.3847/1538-4357/ad7f4c

Provided by Stanford University

What human-made object is the farthest from Earth?

During the decades that humanity has collectively been exploring space we've sent up a lot of stuff. Much of it has stayed up there, orbiting the planet or eventually falling back to Earth and burning up in the atmosphere (or sometimes not). To really send something far out into space, though, you've got to put […]

During the decades that humanity has collectively been exploring space we've sent up a lot of stuff. Much of it has stayed up there, orbiting the planet or eventually falling back to Earth and burning up in the atmosphere (or sometimes not).

To really send something far out into space, though, you've got to put more effort in. Rocket-fueled effort. The spacecraft that's been launched to explore the outer reaches of the solar system needed a boost to get there, and then further help from the gravity of the planets they passed. Thanks to the general lack of friction in space combined with the abundance of *open* space, these projectiles can just keep going. The man-made object that is farthest away from Earth and will continue to hold the title is the Voyager 1 spacecraft, followed by Voyager 2.

Voyager 1 was launched a couple weeks after Voyager 2, both in 1977. Voyager 1 was so named because it was on a faster trajectory to reach Jupiter and thus would be the first Voyager to see that planet. It is currently more than 15 billion miles away from Earth. Voyager 2 is more than 12 billion miles from home.

The probes will celebrate 47 years of operation this year and are NASA's longest operating spacecraft. Both Voyager probes have flown past Jupiter and Saturn. Voyager 2 has also flown past Uranus and Neptune.

[Related: Carl Sagan in 1986: 'Voyager has become a new kind of intelligent being—part robot, part human']

These are the only two spacecraft, according to NASA, to "directly sample interstellar space." Interstellar space is the region outside the heliosphere–the protective bubble created by solar winds. That protective bubble drops off when the force of the solar winds is counteracted by interstellar winds. Voyager 1 and 2 both left the heliosphere and are now in interstellar space. Technically, both are still within the solar system, and will be for a while. The probes will have left the solar system when they pass beyond the Oort Cloud. Voyager 1 will reach the leading edge of the Oort Cloud in roughly 300 years.

Engineers are still sending commands to Voyager 1 and receiving usable information from the spacecraft. Because of the vast distance it's traveled, NASA says it takes more than 22 and 1/2 hours for light from Earth to reach the spacecraft and the same amount for signals from Voyager 1 to return to Earth. When engineers send a command to Voyager 1 they need to wait two days to find out if it worked.

In May of 2024, Voyager 1 resumed sending scientific data from two of its four instruments after a computer issue took the instrumentation out of commission in November 2023. In June of 2024 Voyager 1 was back to conducting normal scientific operation with all four instruments after troubleshooting efforts by NASA. The four instruments study "plasma waves, magnetic fields, and particles," according to NASA's description of the probe.

Voyager 1 was responsible for one of the most iconic space photos in the history of the space program. In 1990, while still at a relatively close 3.7 billion miles away from Earth, the space probe took the image now immortalized as the "pale blue dot."

A small pinprick of light–Earth, only a pixel in size–hangs as if suspended in a ray of sunshine. The image was composed from a series of 60 images taken by Voyager as it passed beyond Neptune. Team managers instructed the probe to look backwards toward home and take a final series of images. According to NASA, Voyager 1 is one of only three spacecraft that could ever have taken such an image (Voyager 2 and New Horizons are the others). Also captured in the Solar System Family Portrait were Neptune, Uranus, Saturn, Jupiter, and Venus.

The images that formed the basis for the iconic photo were taken barely half an hour before the probe's cameras were permanently shut down in February 1990. It wasn't until May of that same year, that all of the file data was received back on Earth and could be processed.

Voyager 1 and Voyager 2 continue on their outward trajectories, slowly losing power and capabilities until they're truly shut down and out of range. Scientific data may be sent back to Earth for several more years after the crafts' instruments have shut down, depending on how much power is available.

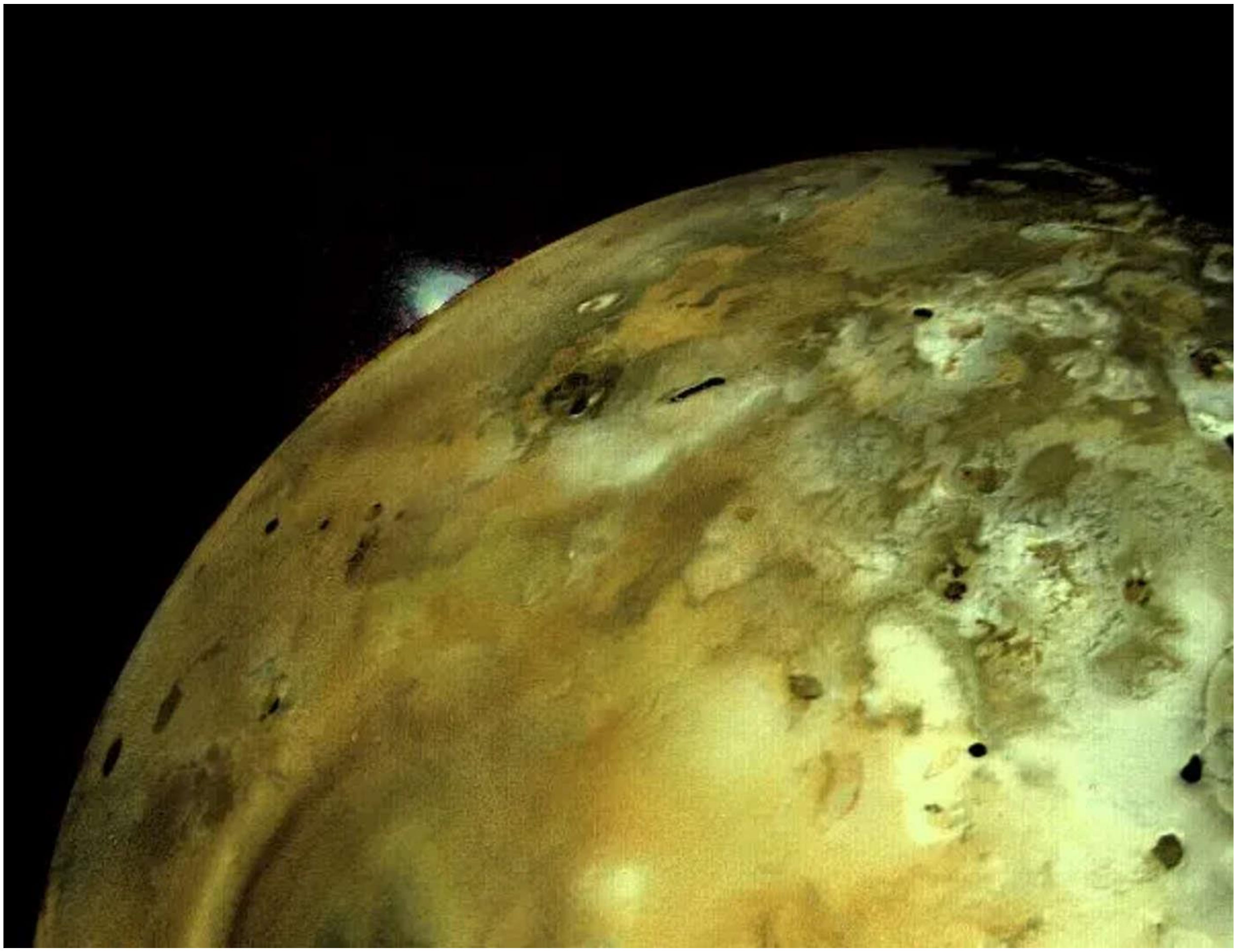
Astonishing Images: What Voyager 1 Really Saw in its 47-Year-Journey to Interstellar Space.

Earth and the Moon – A Distant View

Taken on September 18, 1977, Voyager 1 became the first spacecraft to capture both Earth and its Moon in a single frame. At a distance of 7.25 million miles from Earth, this iconic image shows the Moon floating beyond our home planet, emphasizing the vastness of space.

Jupiter's Great Red Spot

In early 1979, Voyager 1 provided a close-up of Jupiter’s Great Red Spot, a storm larger than Earth. This swirling mass of clouds, first observed centuries ago, gave scientists new insight into Jupiter’s turbulent atmosphere, thanks to the detailed images captured by Voyager.



Active Volcanism on Io

During its flyby of Jupiter's moon Io, Voyager 1 discovered something unprecedented-active volcanoes. This was the first observation of volcanic activity on another celestial body besides Earth. Voyager detected plumes erupting miles into space, revealing Io’s fiery surface.

Saturn's Breathtaking Rings

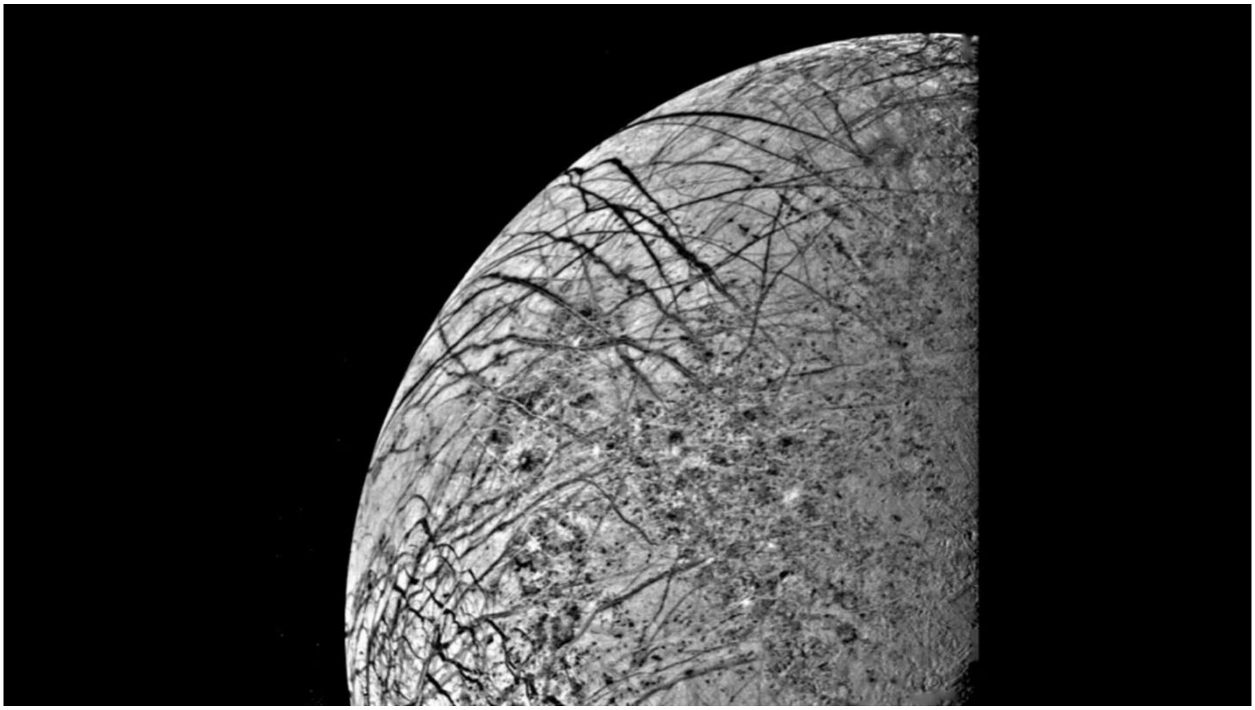
Voyager 1 reached Saturn in 1980, capturing stunning images of its intricate ring system. Saturn’s rings, composed of countless ice and rock particles, revealed a beauty never before seen. Voyager even discovered a new, faint G-ring and enigmatic spokes in the B-ring.

Titan's Hazy Atmosphere

As Voyager 1 flew past Saturn's largest moon, Titan, it detected a thick atmosphere primarily composed of nitrogen. Titan's opaque haze left its surface hidden, fueling speculation about the moon's geological secrets. This image offered a glimpse into one of the most mysterious moons in our solar system.

The Pale Blue Dot

Perhaps the most famous image Voyager 1 ever captured is the “Pale Blue Dot,” taken on February 14, 1990, from 3.7 billion miles away. In this image, Earth appears as a tiny speck, less than a pixel in size, suspended in a sunbeam. Carl Sagan's reflections on this image remind us of our small place in the vast universe.



Close-up of Europa

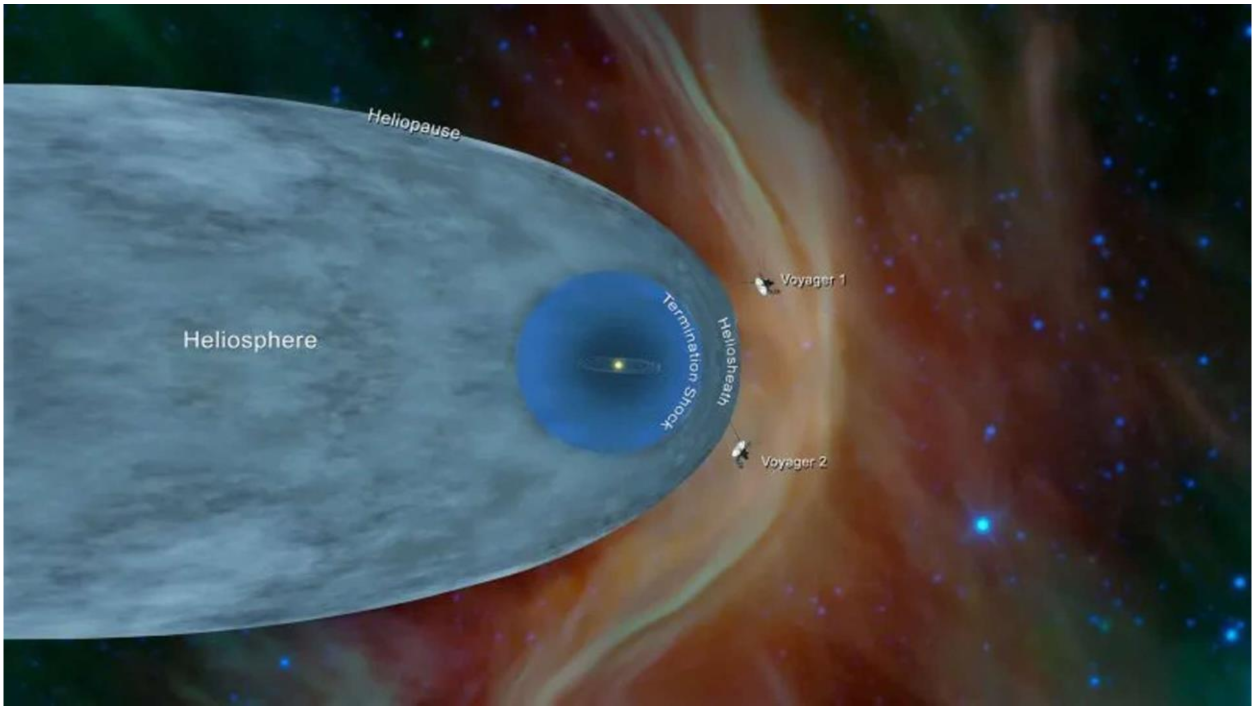
Voyager 1 also flew by Jupiter's moon Europa, capturing images of its icy surface. The close-up showed evidence of potential subsurface oceans, raising the possibility of life beneath its frozen crust. These images set the stage for future missions to study Europa more closely.

Saturn's Moons – Tethys, Dione, and Rhea

Voyager 1 captured images of Saturn's moons Tethys, Dione, and Rhea in 1980, showcasing their cratered surfaces and icy landscapes. These moons, though small, are integral parts of Saturn's complex system of rings and satellites.

The F Ring of Saturn

One of the discoveries made by Voyager 1 was the narrow, braided F ring of Saturn. This stunning image shows the intricacies of the ring's structure, including its twists and clumps, revealing a dynamic system shaped by gravitational interactions with Saturn's moons.

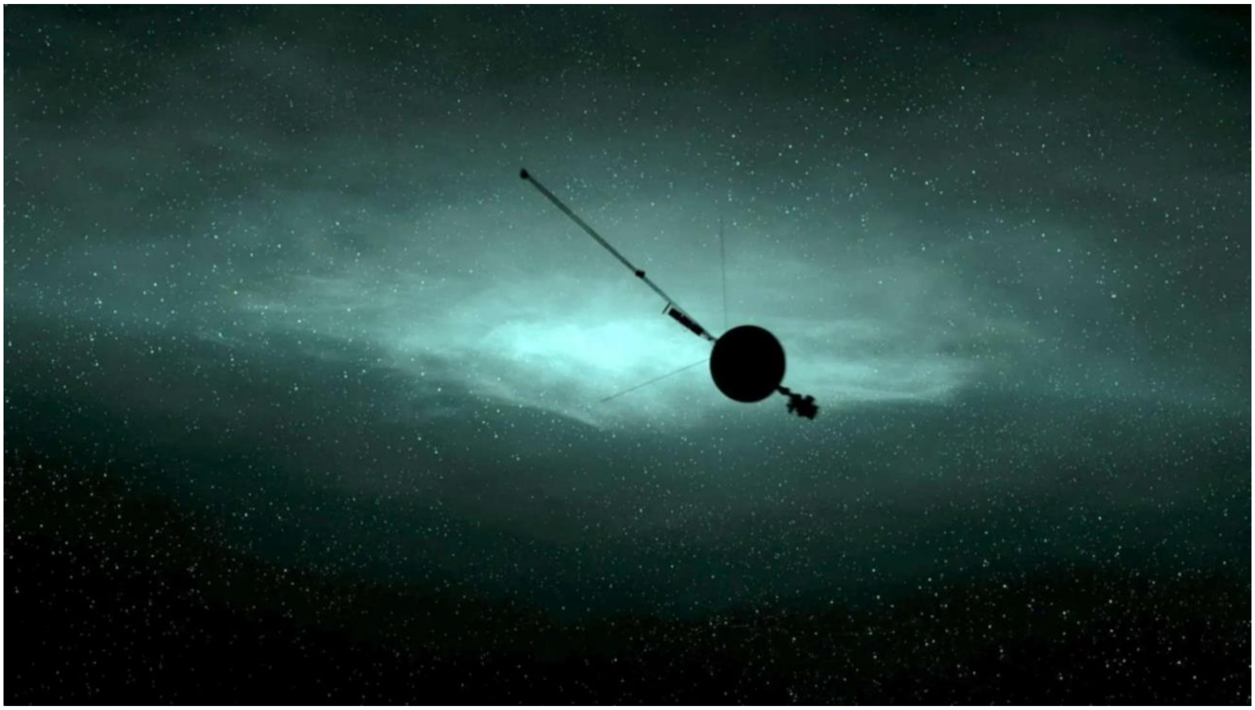


Entering Interstellar Space

In 2012, Voyager 1 became the first human-made object to enter interstellar space, crossing the heliopause-the boundary between the solar wind and interstellar medium. The spacecraft's data showed a steep drop in solar particles and a rise in cosmic rays, confirming this historic milestone.

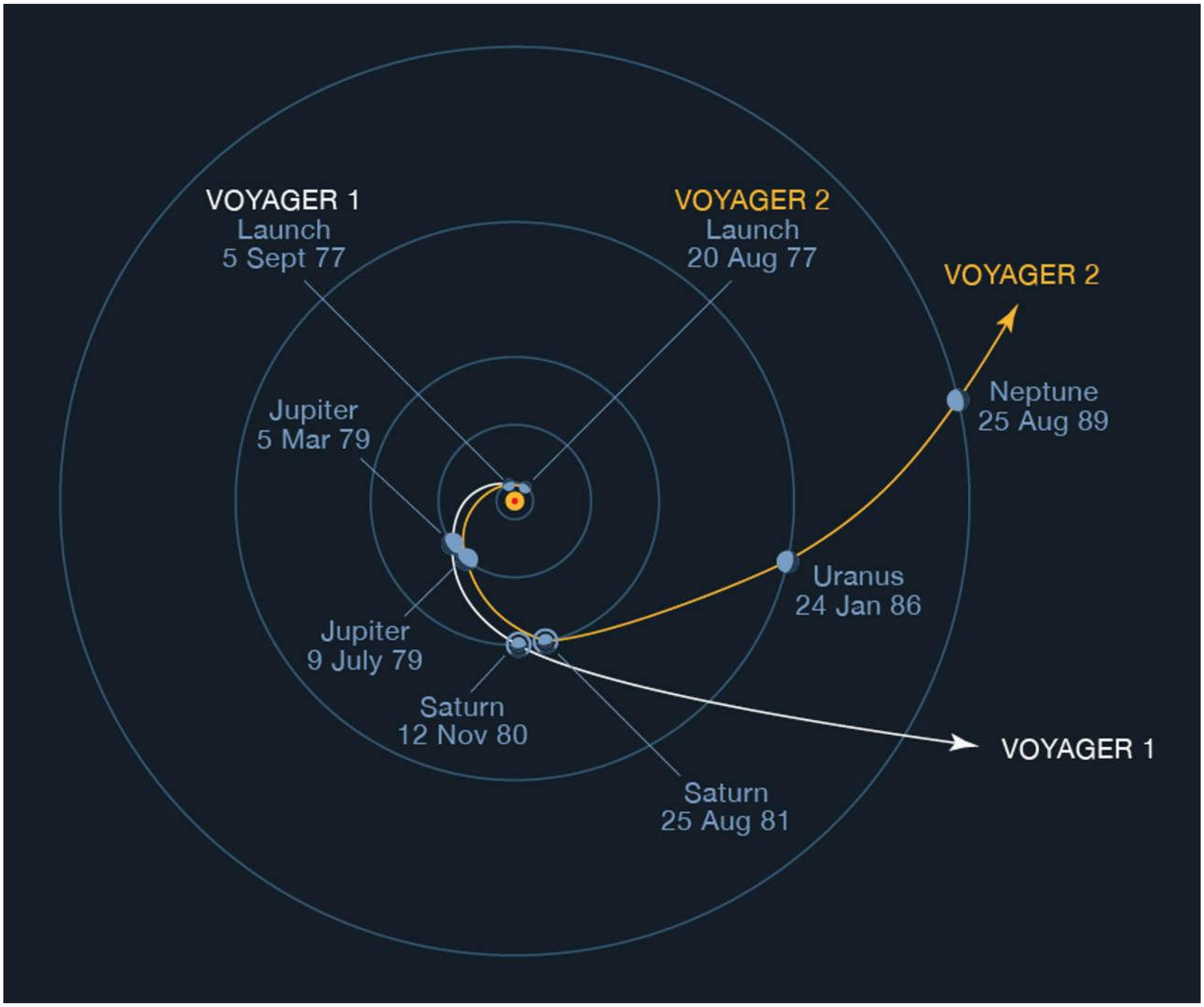
A Golden Message to the Cosmos

Voyager 1 carries the Golden Record, a 12-inch disc containing sounds and images from Earth. This record, curated by Carl Sagan and his team, serves as a message to any intelligent life that might find it, showcasing humanity's diversity and curiosity.



Beyond the Solar System

Voyager 1's journey continues today, traveling at 38,000 miles per hour into interstellar space. Though its power is diminishing, the data it sends back from beyond the solar system gives us unprecedented insight into the universe beyond the Sun's influence.

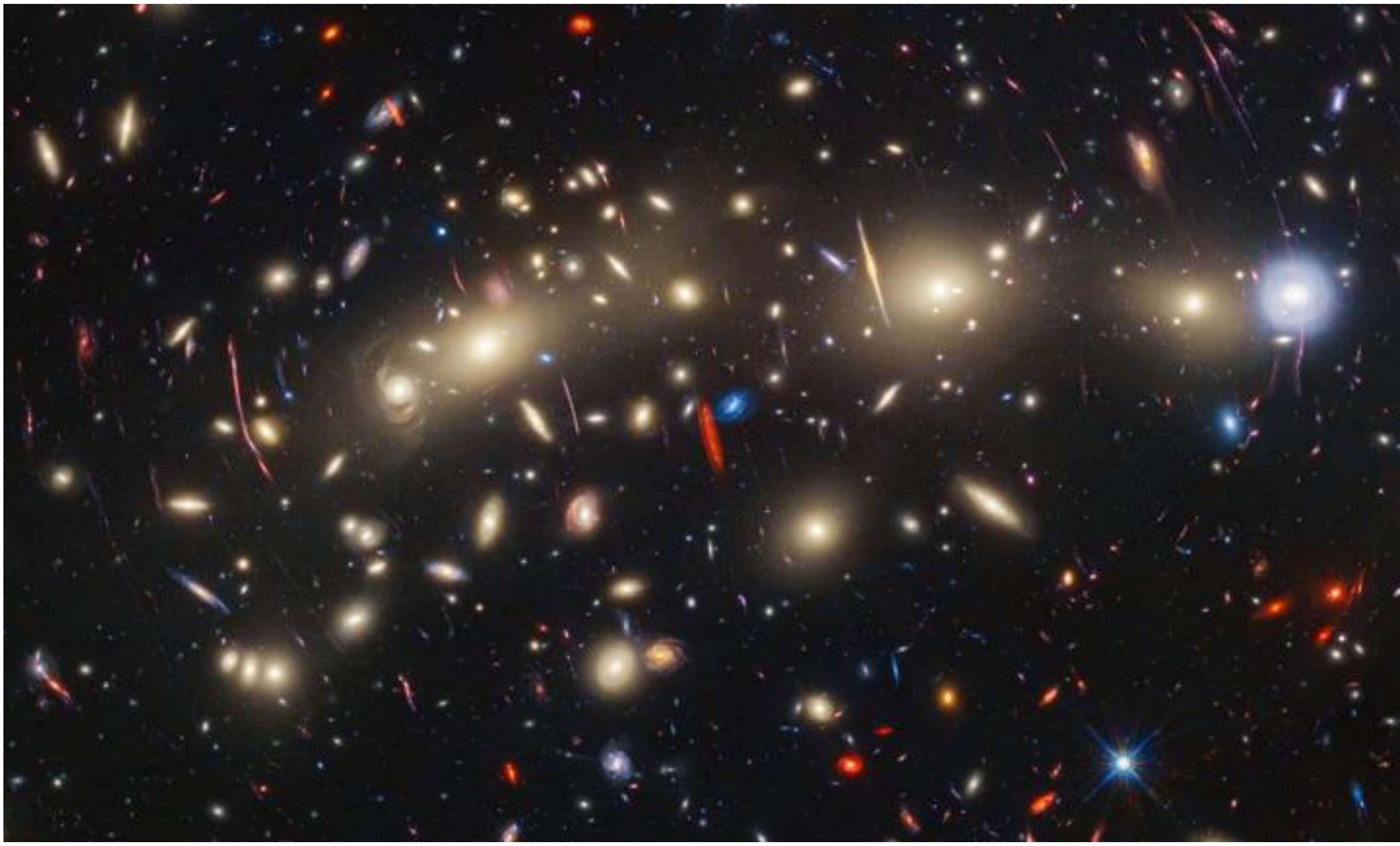


Conclusion

Voyager 1's images, from the close-up of Jupiter's Great Red Spot to the distant Pale Blue Dot, have changed our understanding of the cosmos. As it continues its journey through interstellar space, this remarkable spacecraft reminds us of humanity's quest for discovery beyond the stars.

1. "*Astonishing Images: What Voyager 1 Really Saw in its 47-Year-Journey to Interstellar Space.*." Secrets of Universe. Rishabh Nakra.
2. "*Voyager: 15 incredible images of our solar system captured by the twin probes (gallery).*" Space. Daisy Dobrijevic and Mike Wall. September 22, 2022.

How many galaxies are in the universe?



How many galaxies are in the universe?© NASA, ESA, CSA, STScI, J. Diego (Instituto de Física de Cantabria, Spain), J. D'Silva (U. Western Australia), A. Koekemoer (STScI), J. Summers & R. Windhorst (ASU), and H. Yan (U. Missouri)

The Milky Way is just a speck in a universe filled with an untold number of galaxies. But if we had to take an educated guess, how many galaxies are in the universe?

That sounds like a simple question, but it's anything but. The first problem is that even with our most powerful telescopes, we can see only a tiny fraction of the universe.

"The observable universe is only that part of the universe from which the light has had time to reach us," astrophysicist Kai Noeske, now outreach officer at the European Space Agency, told Live Science.

The universe is 13.8 billion years old, but the observable universe stretches more than 13.8 light-years in every direction. That's because the universe is expanding and light got a head start early on, when the universe was smaller.

"Now, the total size in each direction is about 46 billion light-years," Noeske said.

That's much smaller than even our smallest estimates of the entire universe. "We see at most 3% of the universe," Pamela Gay, a senior scientist at the Planetary Science Institute, told Live Science.

Related: Why are galaxies different shapes?

The second problem is that there are so many galaxies that we can only make estimates of the total number based on what we can observe in small regions of the universe.

"You look at a small patch of the sky, and you count everything in that small patch and then multiply over the size of the sky," Gay said.

But even that requires a cutoff. "What do we define [as] a galaxy?" Noeske said. "We have really giant galaxies that have to have a factor of 10 more" the mass of our galaxy, "and we have a lot of small galaxies, from lower-mass galaxies that have about 10 times less mass ... down all the way to dwarf galaxies."

At some point, scientists need to define a minimum mass for a galaxy to make estimates possible.

"If we set a mass cutoff and try to make this conservative, like a million solar masses, we end up with an average number of galaxies in the universe from the beginning to today of about 1 to 2 trillion," Noeske said. Scientists think there were more galaxies earlier in the universe's history than there are today, which is why galaxy estimates are an average over time.

"But those results come from the Hubble [telescope] — the James Webb Space Telescope is starting to speak to these results — which are near Earth, inside of our solar system, and are limited on what they can see by all the stuff in our solar system that adds light to the sky," Gay said. "We do have one spacecraft with a camera that has gotten beyond all the garbage within our solar system, and that's the New Horizons spacecraft."

A 2021 study used the camera aboard New Horizons to measure the total amount of light in various patches of sky and estimated how many galaxies would be needed to create that much light.

"And suddenly, as they're outside of all the light sources in our solar system, they realize we don't need as many galaxies as we thought," Gay said. "And so their estimates put us at, like, 200 billion, maybe even 100 billion galaxies in the visible universe.

"So somewhere between 2 trillion galaxies at the top edge and 100 billion at the lower edge is the number of galaxies in our observable universe," she said.

If you assume that's 3% — at most — of our universe, you can multiply that range of galaxies to get the total number of galaxies in the universe. If we're seeing less of the universe than we think, there will be a smaller total number of galaxies.

But considering we don't actually know the size of the universe, those estimates are murky. "If it's an infinite universe, you're going to have infinite galaxies," Gay said.

What Does the Edge of the Universe Look Like?

Our journey to comprehend the Universe's edge begins with the concept of the *observable Universe*. This term refers to the portion of the cosmos that we can theoretically detect from Earth. The observable Universe is vast, spanning an estimated **93 billion light-years in diameter**.

The limitations of our observations are not due to technological constraints but rather to the fundamental properties of light and time. Light travels at a finite speed of 299,792,458 meters per second, which means that distant objects' light takes significant time to reach us. Consequently, when we peer into deep space, we're essentially looking back in time.

This cosmic horizon presents a paradox : the farther we look, the older the light we observe. The most distant objects we can detect are those whose light has had just enough time to reach Earth since the beginning of the Universe. Beyond this point lies the cosmic microwave background radiation, the oldest light in the Universe, emanating from about 380,000 years after the Big Bang.

Theories and speculations on cosmic boundaries

While the observable Universe has definable limits, the true extent of the cosmos remains a subject of intense debate and speculation. Several theories attempt to explain what might exist beyond our cosmic horizon :

- Infinite Universe : Some scientists propose that the Universe extends infinitely in all directions, with no discernible edge or boundary.
- Multiverse : This theory suggests that our Universe might be one of many, existing alongside countless others in a vast multiverse.

- Curved Space : In this model, the Universe might curve back on itself, similar to how the surface of a sphere has no edge.

- Black Hole Universe : A fascinating hypothesis posits that our entire Universe could be contained within a black hole, challenging traditional Big Bang models.

These theories highlight the complexity of defining cosmic boundaries and underscore the limitations of our current understanding. As we continue to explore and gather data, new insights may reshape our perception of the Universe’s edge.

Cosmic expansion and the illusion of boundaries

One of the most perplexing aspects of cosmology is the ongoing expansion of the Universe. Edwin Hubble’s groundbreaking observations in the 1920s revealed that galaxies are moving away from each other, with more distant galaxies receding faster. This discovery led to the concept of cosmic expansion, which significantly impacts our understanding of the Universe’s structure and potential boundaries.

The expansion of space itself creates an interesting phenomenon : as the Universe grows, so does the observable Universe. This expansion means that the cosmic horizon is not a fixed boundary but a dynamic limit that changes over time. Paradoxically, some regions of space are now moving away from us faster than the speed of light due to this expansion, making them forever unobservable from Earth.

This cosmic expansion raises intriguing questions about the nature of space and time. Could the expansion continue indefinitely, or might it eventually slow down or reverse ? The answers to these questions could profoundly affect our understanding of cosmic boundaries and the ultimate fate of the Universe.

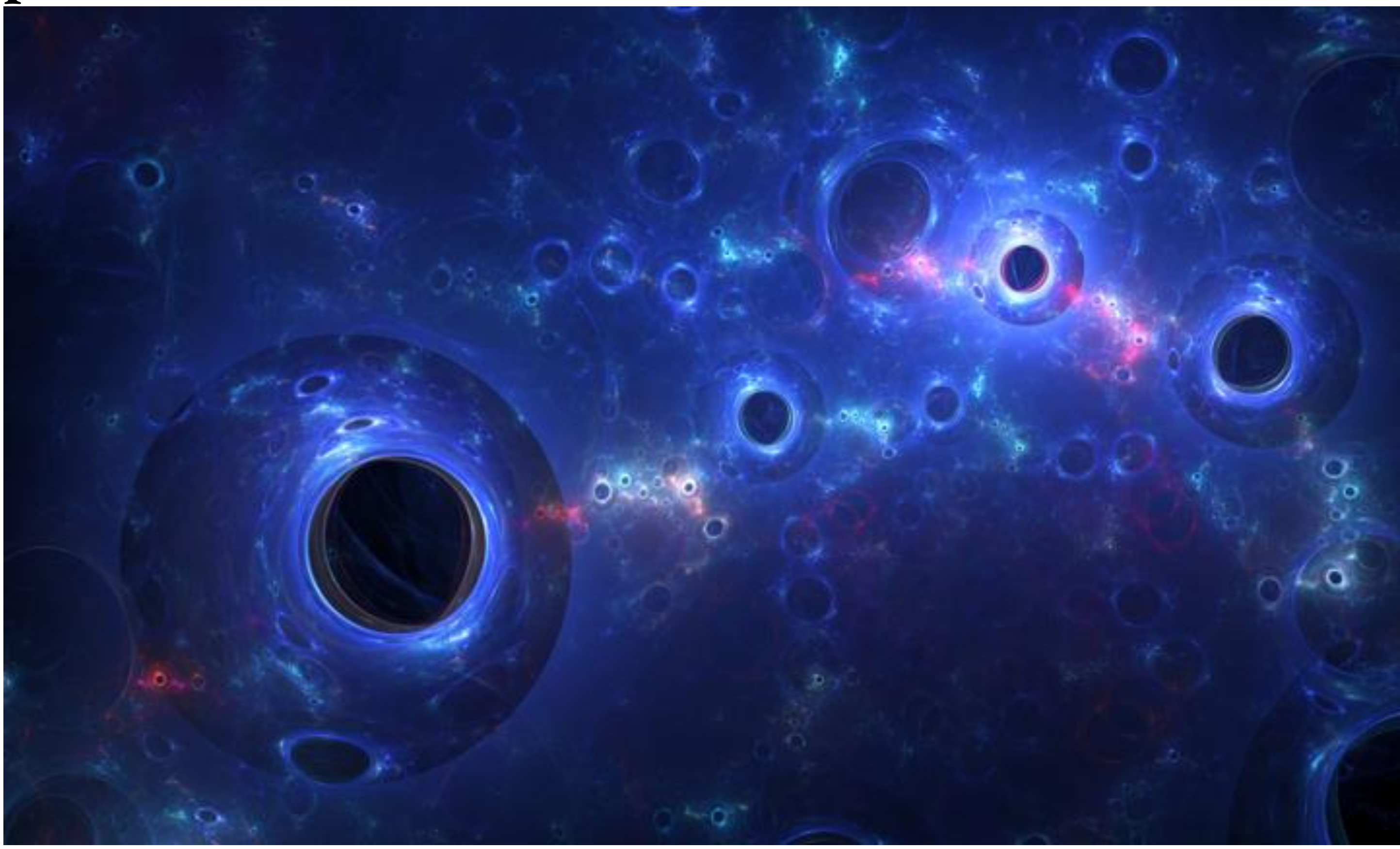
The quest for cosmic understanding

As we continue to probe the depths of space, our understanding of the Universe's structure and limits evolves. Advanced telescopes like the James Webb Space Telescope provide unprecedented views of distant galaxies and cosmic phenomena, pushing the boundaries of our observable Universe.

These observations not only expand our knowledge but also raise new questions. For instance, the Butterfly Effect theory suggests that minute changes in initial conditions could lead to vastly different outcomes, potentially creating entire universes within black holes.

While we may never directly observe the edge of the Universe, if it exists, the pursuit of this knowledge drives scientific innovation and philosophical inquiry. As we stand on the brink of new discoveries, the mysteries of cosmic boundaries continue to inspire and challenge our understanding of reality itself.

Just before the Big Bang, a ‘freeze-in’ event produced dark matter



Just before the Big Bang, a ‘freeze-in’ event produced dark matter

Researchers from the University of Texas at Austin (UT Austin) have proposed a new model to explain the origin of dark matter. It suggests that dark matter originated during the infinitesimally short span before the Big Bang when the Universe suddenly expanded to a large extent.

In 1981, physicist Alan Guth proposed the theory of cosmic inflation. It suggests that during the earliest moments of the universe, it expanded 10^{26} times within 10^{-36} seconds. The universe continues to spread even after the inflation but not at such an unprecedented rate.

Cosmic inflation was an important event because it eliminated all the irregularities in the structure of the universe. This is why despite so much vastness and continuous expansion, the universe appears uniform and homogenous.

In their new study, the researchers propose that inflation also played a role in the formation of dark matter through the freeze-in scenario.

“The thing that’s unique to our model is that dark matter is successfully produced during inflation. In most (other) models, anything that is created during inflation is then ‘inflated away’ by the exponential expansion of the universe, to the point where there is essentially nothing left,” Katherine Freese, lead researcher and professor of physics at UT Austin, said.

Did dark matter freeze out or freeze in?

According to the study authors, dark matter likely originated from the thermal bath during warm inflation. Thermal bath refers to the particles (like radiation and matter) that interact with each other while maintaining a certain temperature during the formation of the universe.

This thermal energy was sustained by the inflaton field (the field driving inflation) through its interactions, ensuring a warm environment during inflation (this is why referred to as warm inflation). However, there are two different possibilities for the birth of dark matter from the thermal bath.

For instance, it is possible that in the early universe, dark matter particles were in thermal equilibrium with regular matter. As the universe expanded and cooled, these particles froze out—-meaning they stopped interacting with regular matter, and their density became fixed. This is called the freeze-out scenario.

The researchers ruled out this possibility because, in a dynamic environment surrounded by intense events such as inflation and the Big Bang, thermal equilibrium would likely have been disrupted. This makes it unlikely that dark matter particles remained in equilibrium long enough for freeze-out to occur.

Another possibility called the freeze-in, implies that dark matter particles were never in thermal equilibrium. Instead, they were produced as a result of rare high-energy interactions like those involving UV radiation in the early universe.

The researchers suggest that during warm inflation, the quantum field that triggered the inflation lost a chunk of its energy to UV radiation, and this interaction caused the production of dark matter particles that eventually "froze in" as the universe cooled.

"We demonstrated that in a warm inflation setting the persistent thermal bath can source a sizable dark matter abundance via the nonrenormalizable interaction characteristic of UV freeze-in," the study authors note.

But it was all pre-Big Bang

You may have not noticed but there is a twist in the version of freeze-in that the UT Austin team proposed.

While many scientists believe inflation and freeze-in happened after the Big Bang, according to the proposed warm inflation via ultraviolet freeze-in (WIFI) model —- dark matter production occurred before the Big Bang in the short time when the universe exponentially expanded due to cosmic inflation.

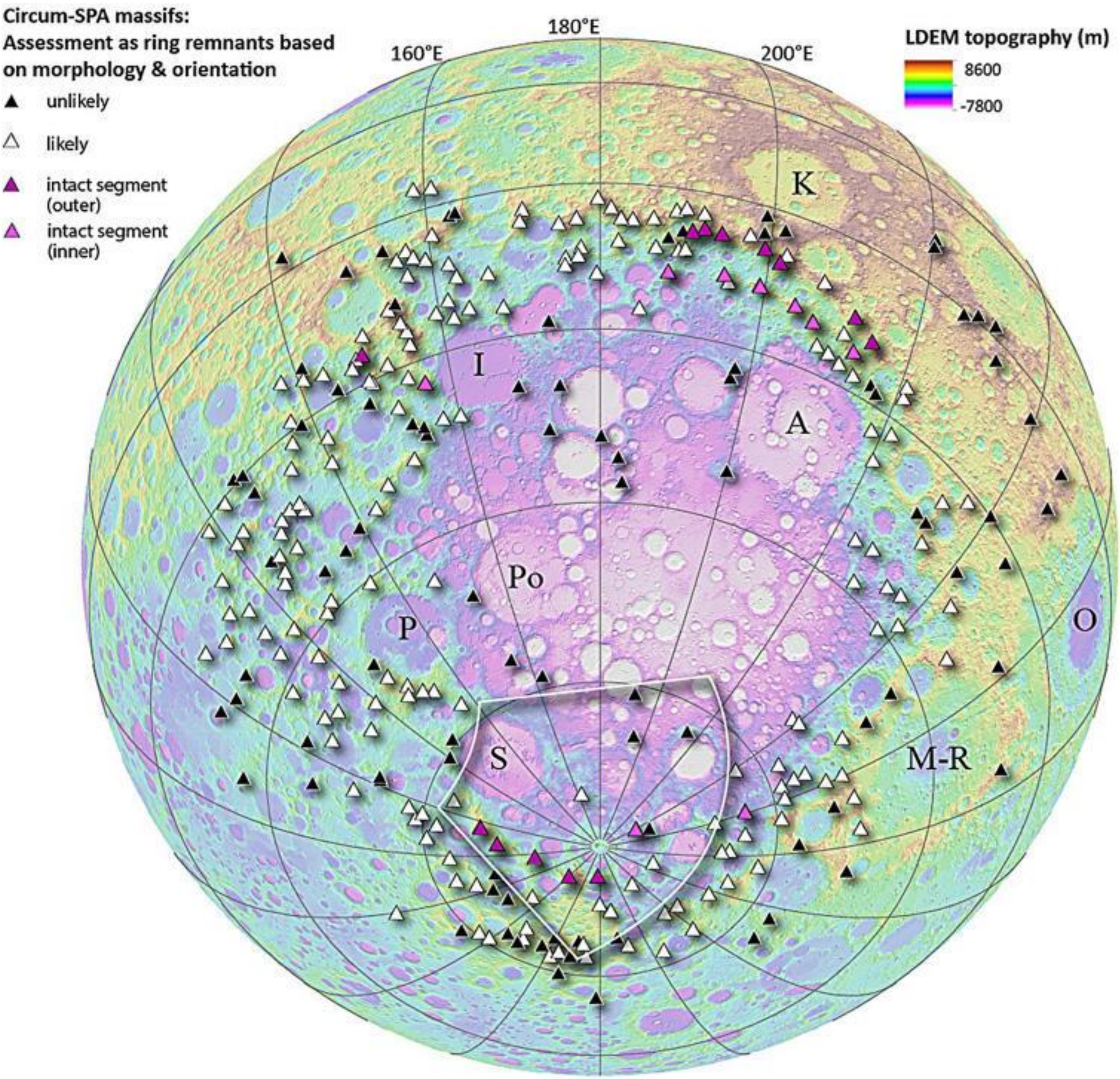
This new perspective on cosmic inflation could influence many existing theories that explain the origin of our universe.

Moreover, "WIFI suggests a broader applicability such as the production of other particles that could play a crucial role in the early universe's evolution. This highlights new opportunities for exploration in future research," Barmak Shams, one of the study authors, said.

However, the current findings still represent a theory. The study authors are required to validate their WIFI model through observations which could take many years. The study is published in the journal *Physical Review Letters*.

The moon's biggest and most ancient crater is more circular than previously thought

A topographic model of the moon using a color-scale from purple (low) to red (high) based on data collected by



NASA's Lunar Reconnaissance Orbiter and Kaguya by the Japanese Space Agency. This is a global view to show the entirety of the South Pole-Aitken basin (SPA). The triangles mark mountain-like features that can be found all around SPA. Credit: Hannes Bernhardt

The South Pole-Aitken basin is the moon's oldest and largest visible crater—a massive geological wound 4 billion years old that preserves secrets about the moon's early history, much like a lunar time capsule.

Based on some features of the basin, researchers thought that the crater was shaped like an oval or ellipse. For years, scientists believed this enormous crater was formed by an object striking the moon from a shallow angle, possibly as extreme as a rock skipping across water. Under this theory, very little debris from the impact would have sprayed across the lunar South Pole, which is the landing region for the upcoming Artemis missions to return humans to the lunar surface.

But a new University of Maryland-led study published in the journal *Earth and Planetary Science Letters* suggests that the impact may have been much more direct, leading to a much rounder crater—a finding that challenges our current understanding of the moon's history, with significant implications for NASA's future missions to the moon.

"It's challenging to study the South Pole-Aitken basin holistically due to its sheer enormousness, which is why scientists are still trying to learn its shape and size. In addition, 4 billion years have passed since the basin was originally formed and many other impacts have obscured its original appearance," explained the study's lead author, Hannes Bernhardt, an assistant research scientist in UMD's Department of Geology.

"Our work challenges many existing ideas about how this massive impact occurred and distributed materials, but we are now a step closer to better understanding the moon's early history and evolution over time."

Using high-resolution data from NASA's Lunar Reconnaissance Orbiter, Bernhardt and his team developed an innovative approach to understanding the South Pole-Aitken basin's complex structure. They identified and analyzed more than 200 mountain formations scattered around the basin, geologic features that the team suspected were ancient remnants of the original impact.

From the distribution and shapes of those mountain-like features, the team realized that the impact should have created a more circular crater from which significant chunks of planet-forming material were dispersed across the moon's surface, including the South Pole region.

"A rounder, more circular shape indicates that an object struck the moon's surface at a more vertical angle, possibly similar to dropping a rock straight down onto the ground," Bernhardt said. "This circular impact implies that debris from the impact is more equally distributed around it than was originally thought, which means that Artemis astronauts or robots in the South Pole region may be able to closely study rocks from deep within the moon's mantle or crust—materials that are typically impossible for us to access."

These lunar rocks could provide crucial insights into the moon's chemical composition and help validate theories about how the moon may have been created from a massive collision between Earth and another planet-sized object.

Recently, India's Chandrayaan 3 rover detected minerals indicative of impact debris coming from the mantle close to the South Pole, supporting the UMD team's theory about a more vertical impact forming a circular basin that would be required to spray such material in that area.

Bernhardt believes that his team's research provides critical information for future moon missions, helping mission planners and astronauts identify areas to explore and what materials they may encounter. A thick layer rich in materials from the lower crust and upper mantle could offer unprecedented access to the moon's complex geological history, potentially shedding light not just on the moon's formation but also the transformative events that shaped our solar system.

"One of the most exciting implications of our research is how it is applicable to missions to the moon and beyond," Bernhardt said. "Astronauts exploring the lunar South Pole might have easier access to ancient lunar materials that could help us understand how the moon and our solar system came to be."

More information: Hannes Bernhardt et al, Numeric ring-reconstructions based on massifs favor a non-oblique south pole-Aitken-forming impact event, *Earth and Planetary Science Letters* (2024). DOI: 10.1016/j.epsl.2024.119123

Provided by University of Maryland

The Hungriest Black Hole In The Early Universe Is Defying Laws Of Physics, Devouring Matter 40 Times Quicker Than Scientists Believed Was Possible

Quality Stock Arts – stock.adobe.com – illustrative purposes only – pictured above is a black hole

When astronomers used the James Webb Space Telescope (JWST) to get a closer look at ancient galaxies, they found a supermassive black hole that was breaking the rules of physics by gobbling up matter at a rate more than 40 times what scientists thought possible.

The black hole is named LID-568 and was in action when the universe was just 1.5 billion years old. To put that into perspective, the universe is now about 13.8 billion years old.

The discovery could provide insight into why some monstrous black holes seem to be growing too big and too fast for current cosmological models to explain.

Black holes have what's called an Eddington limit, which determines how quickly they can devour matter before they become unstable.

The newly discovered black hole is going way beyond its limit by consuming matter at 40 times the expected rate. It has been dubbed the hungriest black hole in the early universe.

"This black hole is having a feast," said Julia Scharwächter, a co-author of the study and an astronomer with the International Gemini Observatory and the National Science Foundation's NOIRLab.

"This extreme case shows that a fast-feeding mechanism above the Eddington limit is one of the possible explanations for why we see these very heavy black holes so early in the universe."

The research team, led by astronomer Hyewon Suh, identified LID-568 through X-ray observations, which showed that it was abnormally bright. The black hole was invisible in regular light, so JWST's infrared vision was needed to observe it.

"Owing to its faint nature, the detection of LID-568 would be impossible without JWST. Using the integral field spectrograph was innovative and necessary for getting our observation," said Emanuele Farina, a study co-author.

The observations revealed outflows of gas surrounding the black hole unlike anything ever seen before.

The power, speed, and size of these outflows suggested that much of the black hole's growth may have occurred during a single black hole feeding episode.

Instead of growing steadily over time, it had a sort of cosmic growth spurt, gaining most of its mass in one big binge.

It has a mass of around 7.2 million solar masses. Perhaps all unexplainably large black holes undergo phases of super-Eddington activity to enable faster growth.

Overall, the discovery shows that black holes are capable of exceeding their Eddington limits and marks another breakthrough in scientific understanding of the early universe.

The research team plans to use JWST to conduct further investigations to learn more about how the supermassive black hole can maintain such a rapid feeding rate without becoming unstable.

Hopefully, their findings will help solve the mystery of how the largest black holes in the universe came to exist.

The details of the study were published in the journal *Nature Astronomy*.