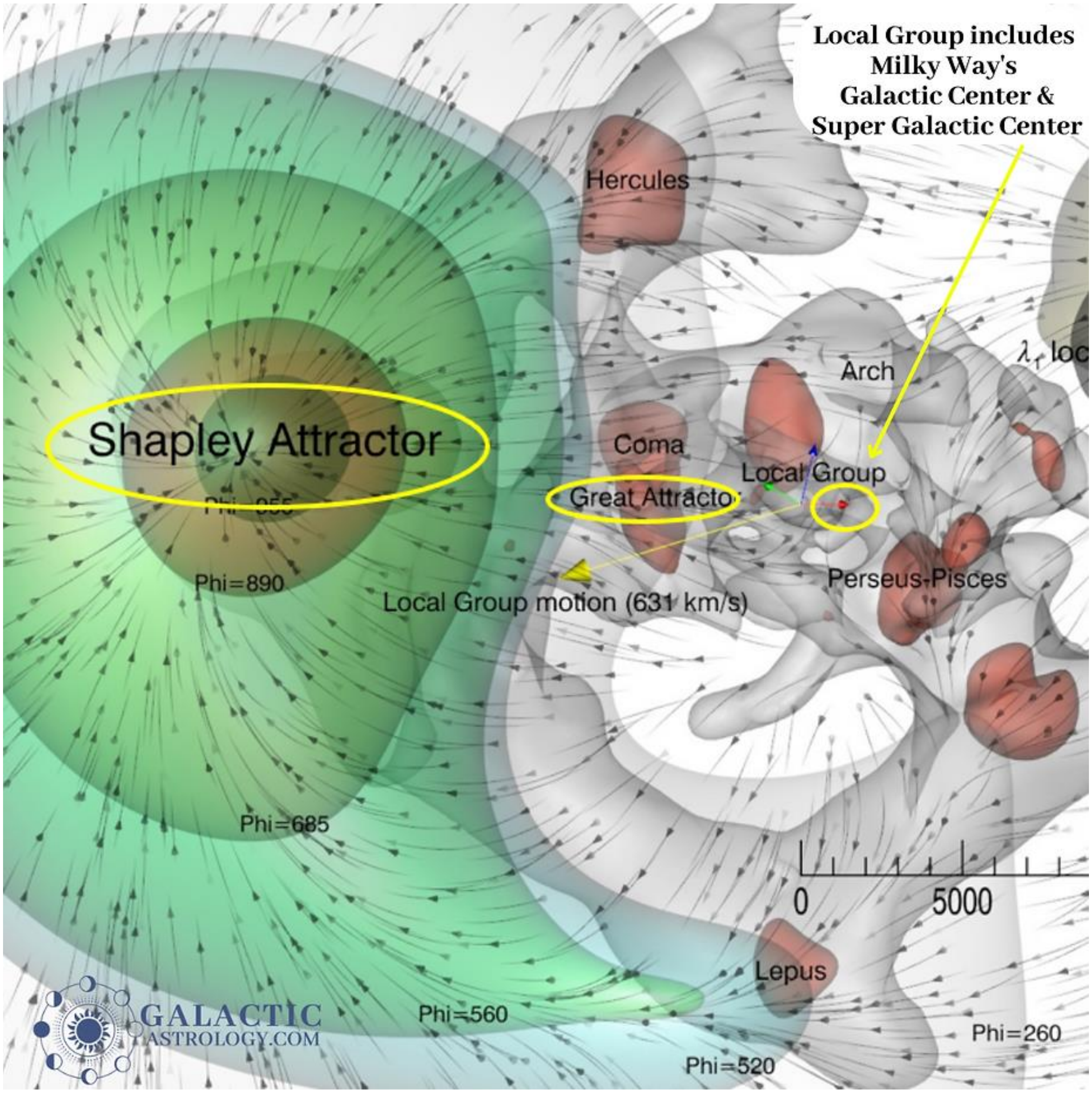
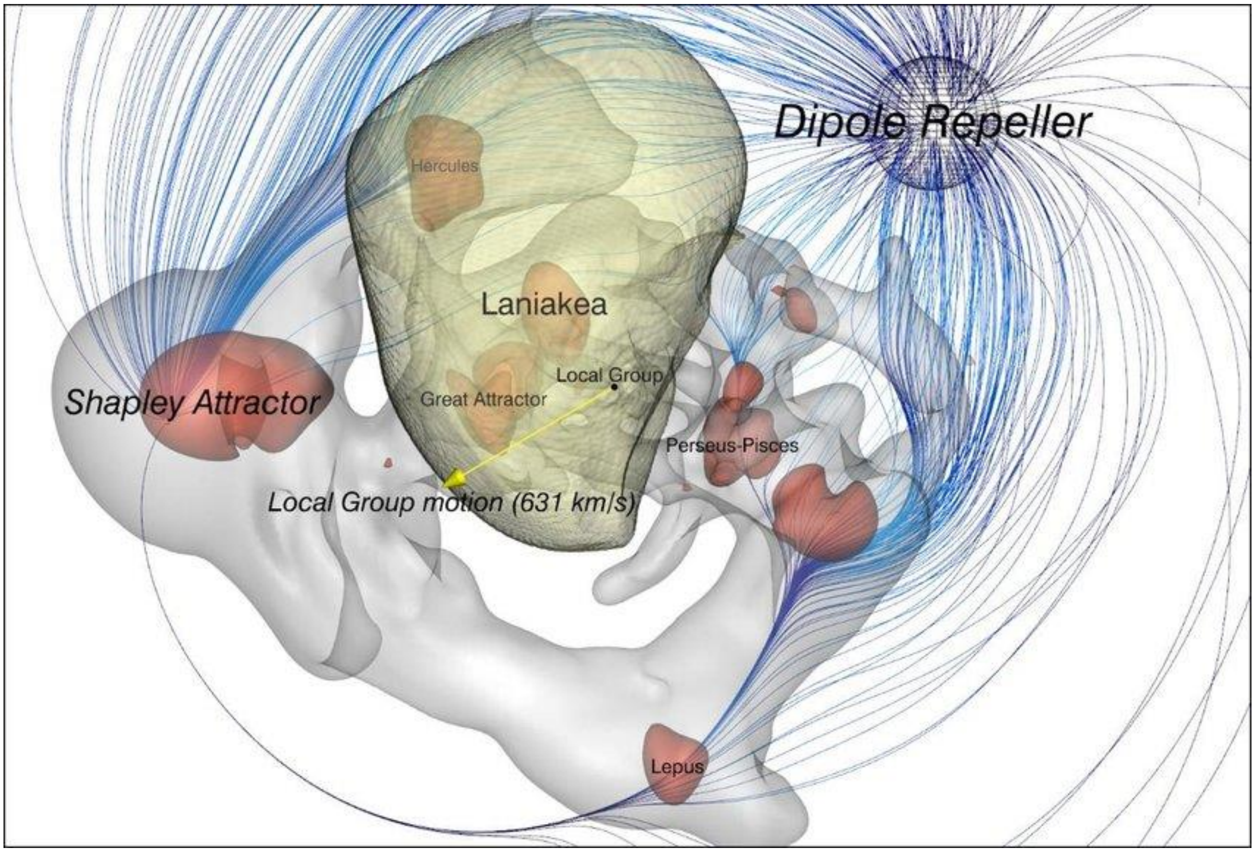
SPACE TECH NEWS VOL 2



The Shapley Cluster is the largest concentration of galaxies in our nearby universe that forms a gravitationally interacting unit, pulling itself together instead of expanding with the universe. To give you a visual:



The **Great Attractor** is a region of gravitational attraction in intergalactic space and the apparent central gravitational point of the Laniakea Supercluster of galaxies that includes the Milky Way galaxy, as well as about 100,000 other galaxies.

The observed attraction suggests a localized concentration of mass having the order of 10^{16} solar masses.[1] However, it is obscured by the Milky Way's galactic plane, lying behind the Zone of Avoidance (ZOA), so that in visible light wavelengths, the Great Attractor is difficult to observe directly.[2]

The attraction is observable by its effect on the motion of galaxies and their associated clusters over a region of hundreds of millions of light-years across the universe. These galaxies are observable above and below the Zone of Avoidance; all are redshifted in accordance with the Hubble flow, indicating that they are receding relative to the Milky Way and to each other, but the variations in their redshifts are large enough and regular enough to reveal that they are slightly drawn towards the attraction. The variations in their redshifts are known as *peculiar velocities*, and cover a range from about +700 km/s to −700 km/s, depending on the angular deviation from the direction to the Great Attractor. The Great Attractor itself is moving towards the Shapley Supercluster.[2]

History

The **Great Attractor** was named by Alan Dressler in 1987,[3][4] following decades of redshift surveys that built up a large dataset of redshift values. The redshift values and distance measurements independent of redshift measurements were then combined to create maps of peculiar velocity.[4]:274

Through a series of peculiar velocity tests, astrophysicists found that the Milky Way was moving in the direction of the constellation of Centaurus at about 600 km/s. [*citation needed*] Then, the discovery of cosmic microwave background (CMB) dipoles was used to reflect the motion of the Local Group of galaxies towards the Great Attractor.[5] The 1980s brought many discoveries about the Great Attractor, such as the fact that the Milky Way is not the only galaxy impacted. Approximately 400 elliptical galaxies are moving toward the Great Attractor beyond the Zone of Avoidance caused by the Milky Way galaxy light.

Intense efforts to work through the difficulties caused by the occlusion by the Milky Way during the late 1990's identified the Norma Cluster at the center of the Great Attractor region.[1]

Location

The first indications of a deviation from uniform expansion of the universe were reported in 1973 and again in 1978. The location of the Great Attractor was finally determined in 1986: It is situated at a distance of somewhere between 150 and 250 Mly (million light-years) (47–79 Mpc), the larger being the most recent estimate, away from the Milky Way, in the direction of the constellations Triangulum Australe (The Southern Triangle) and Norma (The Carpenter's Square).[6] While objects in that direction lie in the Zone of Avoidance (the part of the night sky obscured by the Milky Way galaxy) and are thus difficult to study with visible wavelengths, X-ray observations have revealed that region of space to be dominated by the Norma Cluster (ACO 3627),[7][8] a massive cluster of galaxies containing a preponderance of large, old galaxies, many of which are colliding with their neighbours and radiating large amounts of radio waves.

Debate over apparent mass

In 1992, much of the apparent signal of the Great Attractor was attributed to a statistical effect called *Malmquist bias*.[9] In 2005, astronomers conducting an X-ray survey of part of the sky known as the *Clusters in the Zone of Avoidance* (CIZA) project reported that the Great Attractor was actually only one tenth the mass that scientists had originally estimated. The survey also confirmed earlier theories that the Milky Way galaxy is in fact being pulled toward a much more massive cluster of galaxies near the Shapley Supercluster, which lies beyond the Great Attractor, and which is called the Shapley Attractor.[10]

Norma Wall

A massive galaxy filament, called the Norma Wall (also called Great Attractor Wall[11]) is located at the center of the supposed position of the Great Attractor. The Norma Wall contains the clusters Pavo II, Norma, Centaurus-Crux and CIZA J1324.7−5736. The most massive cluster in this region is the Norma supercluster.[12] Later studies found that the wall continues over to the constellations of Centaurus and Vela.[11]

Laniakea Supercluster

Main article: Laniakea Supercluster

The proposed Laniakea Supercluster is defined as the Great Attractor's basin. It covers approximately four main galaxy superclusters, including superclusters of Virgo and Hydra–Centaurus, and spans across 500 million light years. Because it is not dense enough to be gravitationally bound, it should be dispersing as the universe expands, but it is instead anchored by a gravitational focal point. Thus the Great Attractor would be the core of the new supercluster. The local flows of the Laniakea supercluster converge in the region of the Norma and Centaurus Clusters, approximately at the position of the Great Attractor.[13]

See also

- CfA2 Great Wall – Immense galaxy filament
- Dark flow – A possible non-random component of the peculiar velocity of galaxy clusters
- Dark matter – Concept in cosmology
- Dipole repeller – Center of effective repulsion in the large-scale flow of galaxies near the Milky Way
- Hercules–Corona Borealis Great Wall – Largest known structure in the observable universe
- Shapley Supercluster – Largest concentration of galaxies in our local universe
- South Pole Wall – Massive cosmic structure

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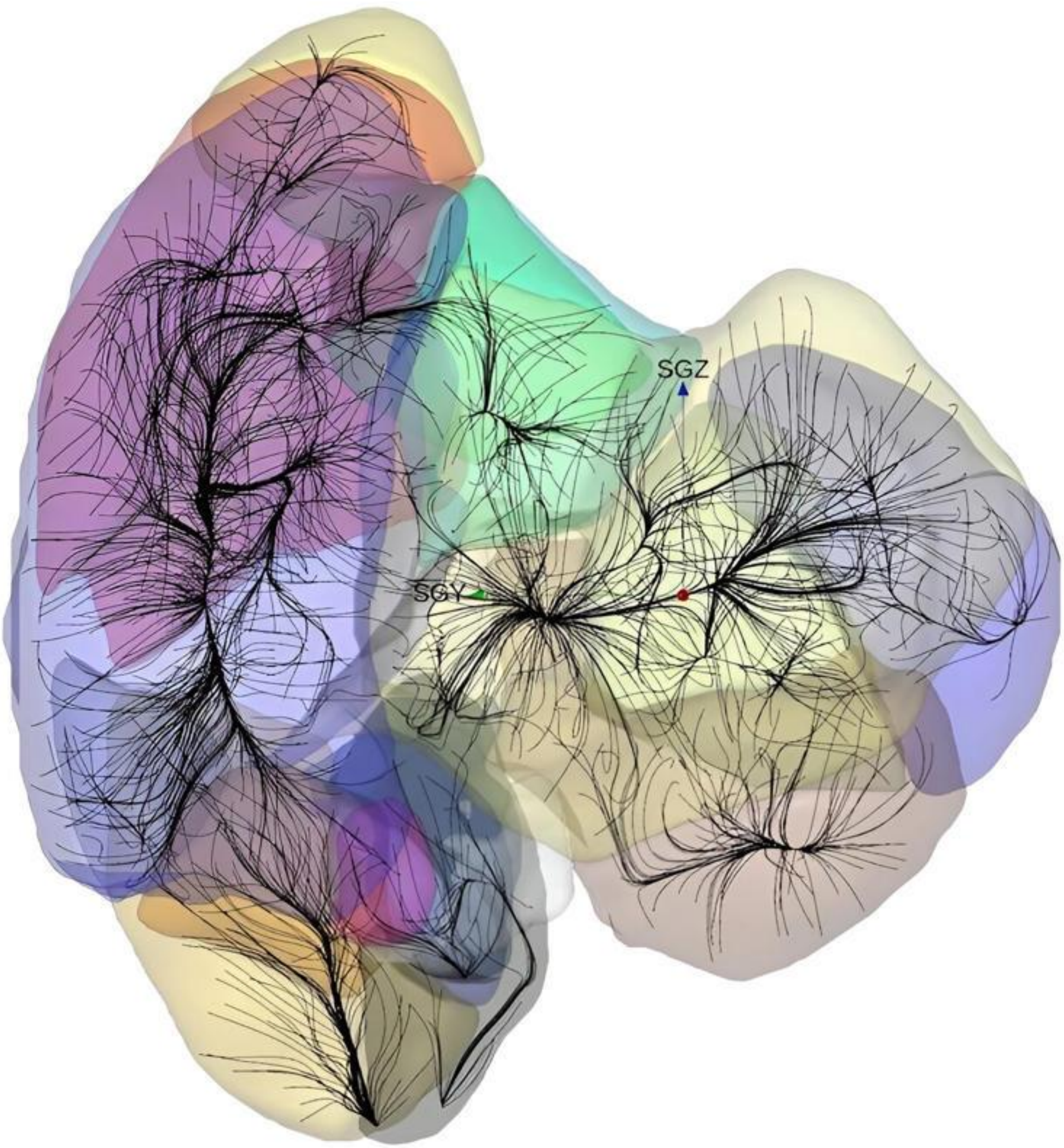
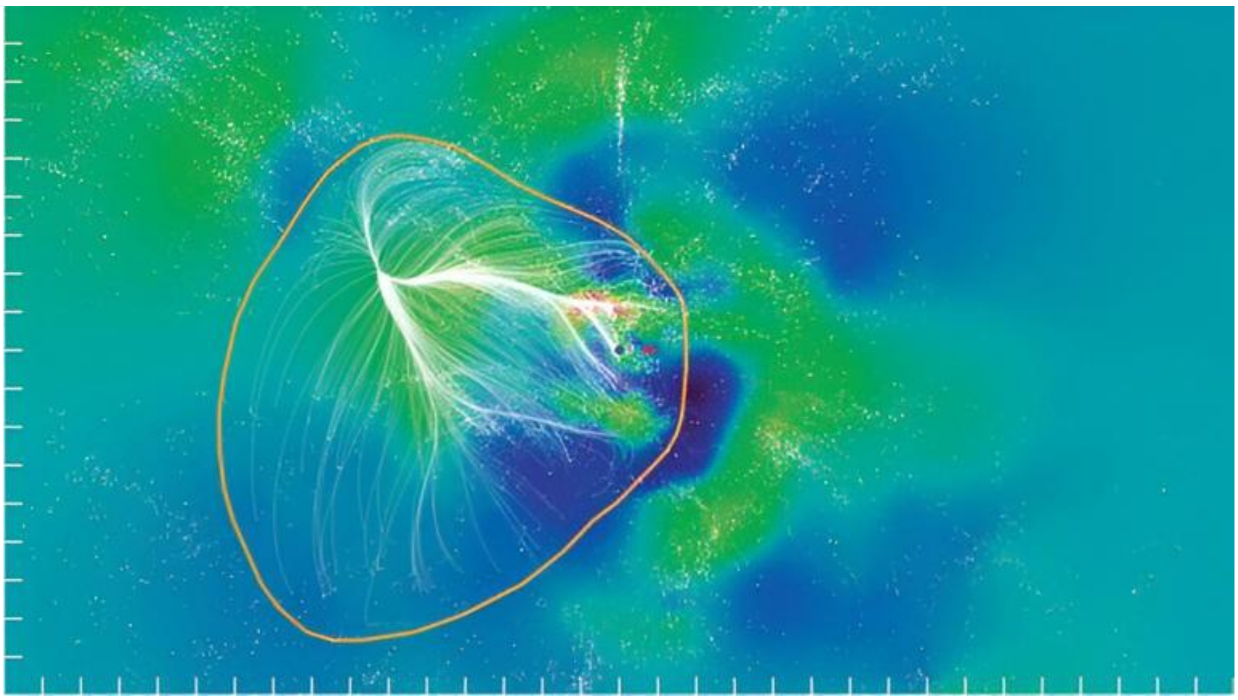
- *Cosmography of the Local Universe. Vimeo (video).* – video clip showing the Great Attractor

The Milky Way might be part of an even larger structure than Laniakea



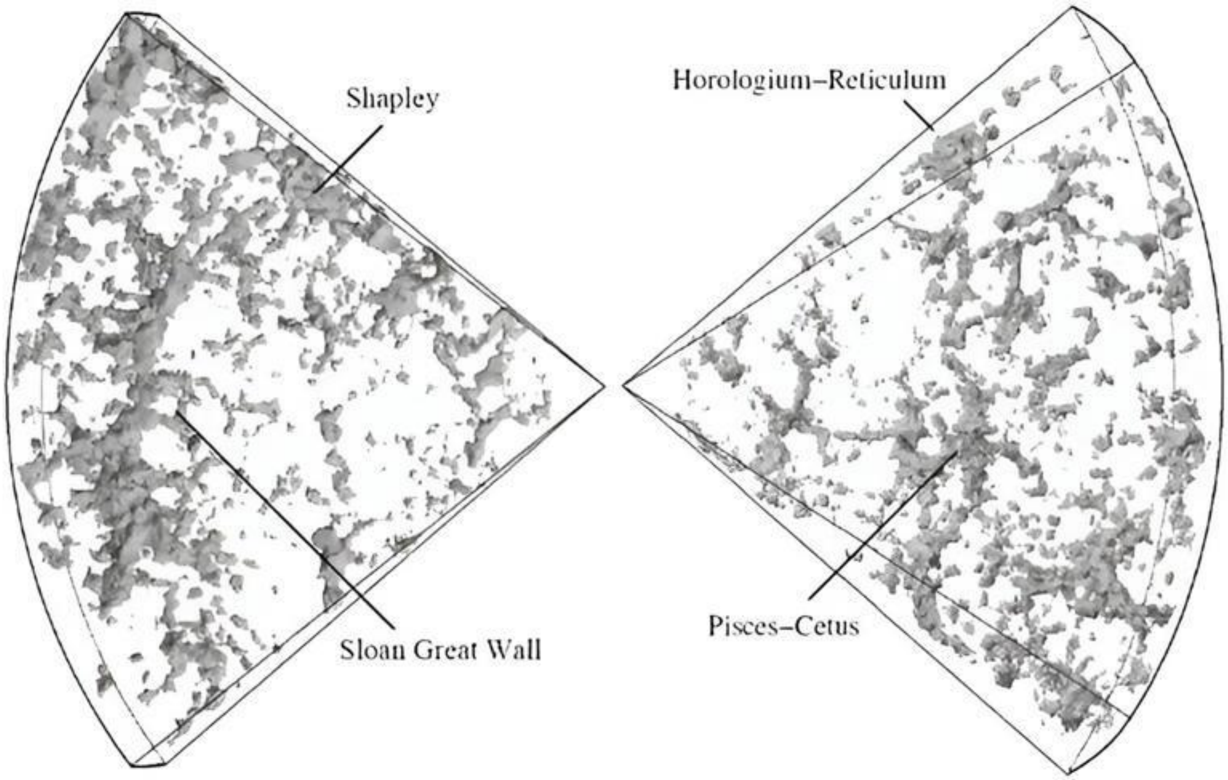
A data visualization of the motions of galaxies in structures called basins of attraction. The Milky Way is the red dot.
Credit: University of Hawai'i

If you want to pinpoint your place in the universe, start with your cosmic address. You live on Earth->Solar System->Milky Way Galaxy->Local Cluster->Virgo Cluster->Virgo Supercluster->Laniakea. Thanks to new deep sky surveys, astronomers now think all those places are part of an even bigger cosmic structure in the "neighborhood" called The Shapley Concentration.



A slice of the Laniakea Supercluster, a local basin of attraction. This structure contains many galaxies and clusters, including our own Milky Way Galaxy. Credit: SDvision interactive visualization software by DP at CEA/Saclay, France

Astronomers refer to the Shapley Concentration as a "basin of attraction." That's a region loaded with mass that acts as an "attractor." It's a region containing many clusters and groups of galaxies and comprises the greatest concentration of matter in the local universe. All those galaxies, plus dark matter, lend their gravitational influence to the Concentration.



Several superclusters were revealed by the 2dF Galaxy Redshift Survey. This contains the structure known as the "Sloan Great Wall." Credit: 2dF Galaxy Redshift Survey

There are many of these basins in the universe, including Laniakea. Astronomers are working to survey them more precisely, which should help provide a more precise map of the largest structures in the universe.

One group, led by astronomer R. Brent Tully of the University of Hawai'i measured the motions of some 56,000 galaxies to understand these basins and their distribution in space. "Our universe is like a giant web, with galaxies lying along filaments and clustering at nodes where gravitational forces pull them together," said Tully.

"Just as water flows within watersheds, galaxies flow within cosmic basins of attraction. The discovery of these larger basins could fundamentally change our understanding of cosmic structure." The paper is published in the journal *Nature Astronomy*.

Cosmic flows and mapping structures

Tully's team is called CosmicFlows and they study the motions through space of those distant galaxies. The team's "redshift" surveys revealed a possible shift in the size and scale of our local galactic basin of attraction. We already know that we "live" in Laniakea, which is about 500 million light-years across. However, the motions of other clusters indicate there's a larger "attractor" directing the cluster flow.

The CosmicFlows data suggest that we could be part of the Shapley Concentration, which could be 10 times the volume of Laniakea. It's about half the volume of the largest structure in space, known as "the Great Wall," which is a string of galaxies stretching across 1.4 billion light-years.

The Shapley Concentration was first observed by astronomer Harlow Shapley in the 1930s as a "cloud" in the constellation Centaurus. This supercluster appears along the direction of motion of the Local Group of galaxies (where we live). Because of that, scientists speculated that it could be influencing our galaxy's peculiar motion.

Interestingly, the Virgo Supercluster (and the Local Group and Milky Way galaxy) appears to be moving toward the Shapley Concentration. The surveys that Tully and others are doing should confirm that motion toward whatever is attracting them.

Exploring ever-larger structures in the universe

Where do these basins of attraction come from? In one sense, they're as old as the universe and its cosmic web of matter that Tully references. The seeds for the web and those basins of attraction were planted some 13.8 billion years ago. After the Big Bang, the infant universe was in a hot dense state. As it expanded and cooled, the density of matter started to fluctuate.

There were tiny differences in those density fluctuations. Think of them as the earliest "seeds" of galaxies, galaxy clusters, and even vaster structures that we see in today's universe.

As astronomers survey the sky, they find evidence for all those different structures. Now, they have to explain them. The idea that the Shapley Concentration is the large basin that our Laniakea belongs to means that current cosmological models don't quite explain its existence.

"This discovery presents a challenge: our cosmic surveys may not yet be large enough to map the full extent of these immense basins," said UH astronomer Ehsan Kourkchi. "We are still gazing through giant eyes, but even these eyes may not be big enough to capture the full picture of our universe."

Measuring the attractors

The main actor in all these galaxies, clusters, and superclusters, is gravity. The more mass, the more gravity influences motions and matter distribution. For these basins of attraction, Tully's research team examined their impact on galaxy motions in the region. The basins exert a sort of "tug of war" on galaxies that lie between them. That influences their motions.

In particular, redshift surveys like Tully's team is doing will map the radial motion (along the line of sight), velocities (how fast they're moving), and other related motions. By mapping the velocities of galaxies throughout our local universe, the team can define the region of space where each supercluster dominates.

Of course, these motions are tricky to define. That's why the team does different types of measurements. They aren't mapping just the luminous material in galaxies. They also have to take into account the inferred existence of dark matter.

There are other complications as well. For example, not all galaxies are the same—that is, they differ in their shapes (morphology) and matter density. Astronomers can get around this by measuring something called "galaxy peculiar velocity." That's the difference between its actual velocity and the expected "Hubble flow" velocity (which reflects gravitational interactions between galaxies).

The results of the Tully team surveys should provide ever more precise 3D maps of these regions of space. That includes their structures as well as their motions and velocities. Those maps, in turn, should give greater insight into the distribution of all matter (including cold dark matter) throughout the universe.

More information: A. Valade et al, Identification of basins of attraction in the local Universe, *Nature Astronomy* (2024). DOI: 10.1038/s41550-024-02370-0

Provided by Universe Today

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

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

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

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

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

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

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

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

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

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

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

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

The study is published in Nature Astronomy.

The universe had a secret life before the Big Bang, new study hints

The Big Bang may not have been the beginning of the universe, according to a theory of cosmology that suggests the universe can "bounce" between phases of contraction and expansion. If that theory is true, then it could have profound implications about the nature of the cosmos, including two of its most mysterious components: black holes and dark matter.

With this in mind, a recent study suggests that dark matter could be composed of black holes formed during a transition from the universe's last contraction to the current expansion phase, which occurred before the Big Bang. If this hypothesis holds, the gravitational waves generated during the black hole formation process might be detectable by future gravitational wave observatories, providing a way to confirm this dark matter generation scenario.

Observations of stellar movements in galaxies and the cosmic microwave background — an afterglow of the Big Bang — indicate that about 80% of all matter in the universe is dark matter, a substance that doesn't reflect, absorb or emit light. Despite its abundance, scientists have not yet identified what dark matter is made of.

In the new study, researchers explored a scenario where dark matter consists of primordial black holes formed from density fluctuations that occurred during the universe's last contraction phase, not long before the period of expansion that we observe now. They published their findings in June in the Journal of Cosmology and Astroparticle Physics.

The bouncing cosmos

The traditional cosmological view of the universe suggests that it started from a singularity, followed by a short period of extremely rapid expansion, called inflation. However, the authors behind the new study analyzed a more exotic theory, known as non-singular matter bouncing cosmology, which posits that the universe first underwent a contraction phase. This phase ended with a rebound due to the increasing density of matter, leading to the Big Bang and the accelerated expansion we observe today.

Related: The universe could stop expanding 'remarkably soon', study suggests

In this bouncing cosmology, the universe contracted to a size about 50 orders of magnitude smaller than it is today. After the rebound, photons and other particles were born, marking the Big Bang. Near the rebound, the matter density was so high that small black holes formed from quantum fluctuations in the matter’s density, making them viable candidates for dark matter.

"Small primordial black holes can be produced during the very early stages of the universe, and if they are not too small, their decay due to Hawking radiation [a hypothetical phenomenon of black holes emitting particles due to quantum effects] will not be efficient enough to get rid of them, so they would still be around now," Patrick Peter, director of research at the French National Centre for Scientific Research (CNRS), who was not involved in the study, told Live Science in an email. "Weighing more or less the mass of an asteroid, they could contribute to dark matter, or even solve this issue altogether."

The scientists' calculations show that this universe mode's properties, such as the curvature of space and the microwave background, match current observations, supporting their hypothesis.

To further test their predictions, the researchers hope to make use of next-generation gravitational wave observatories.The scientists calculated the properties of the gravitational waves produced during black hole formation in their model and found that they could be detected by upcoming gravitational observatories like the Laser Interferometer Space Antenna (LISA) and the Einstein Telescope. These detections could confirm whether primordial black holes are indeed dark matter; however, it could take more than a decade before either facility sees first light.

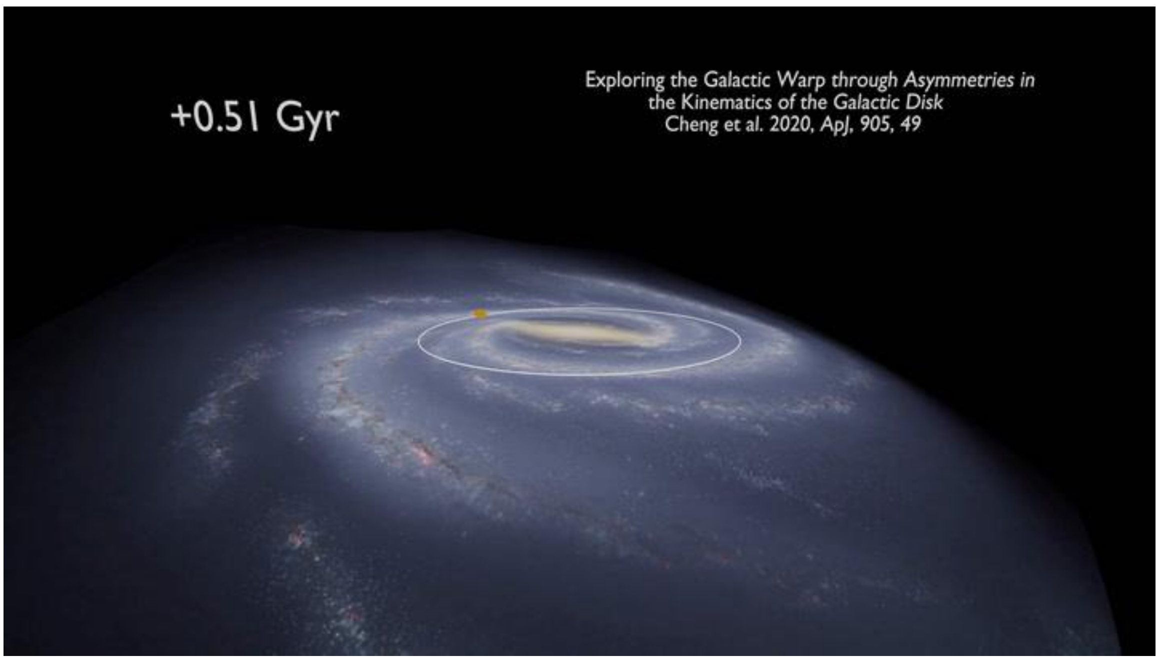
"This work is important in the sense that it provides a natural way of forming small yet still present black holes forming dark matter in a framework which is not the usual one based on inflation," Peter said. "Other works currently investigate the behavior of such tiny black holes around stars, potentially leading to a way of detecting them in the future."

If you've ever attended a star party, it's more than likely that the astronomer on site pointed out the Andromeda Galaxy (M31) - currently around 2.5 million light-years away - and mentioned that it's expected to collide with the Milky Way Galaxy in about 4.5 billion years. But recently, an international team of astronomers posted a study on the arXiv preprint server stating that the merger of the two galaxies is far from guaranteed.

The team, led by Till Sawala of the University of Helsinki, ran simulations including four of the largest galaxies in the Local Group: Andromeda, the Milky Way, the Triangulum Galaxy (M33), and the Large Magellanic Cloud (LMC). Each combination of the multi-body system produced different results for the merger. The data came from the most updated measurements of each galaxy's mass and proper motions made by Gaia and the Hubble Space Telescope.

Not so fast

Before Edwin Hubble determined that Andromeda was far outside the Milky way and a galaxy in its own right, it was one of many so-called spiral nebulae believed to lie within the Milky Way. But even before this discovery, astronomers had already realized that Andromeda was moving toward us. Since then, huge efforts have been made to produce the most accurate measurements of the galaxy's properties and, in the past few decades, develop computer models to predict its titanic crash into our galaxy. Some say the first close encounter will happen in less than four billion years, while others say it'll be after 4.5 billion years. But over the past decade or so, the consensus has hewed overwhelmingly toward a crash being inevitable.

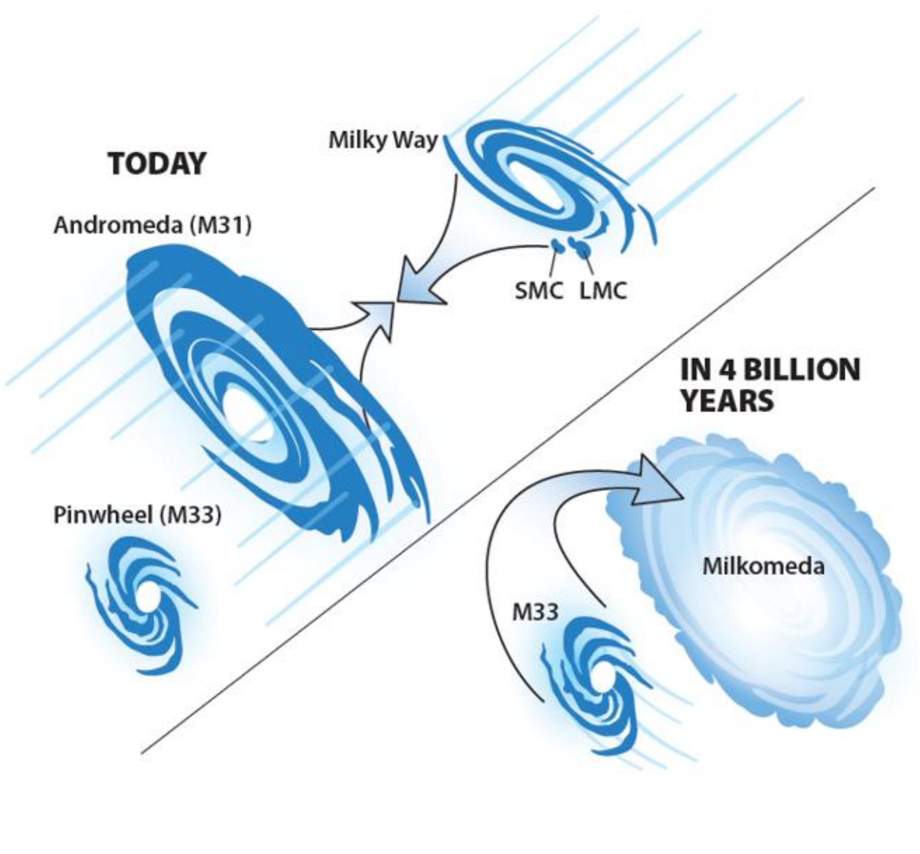


Not so fast, Sawala's group says. The probability of the crash occurring at all - resulting in an elliptical galaxy dubbed Milkomeda - varies greatly depending on the inclusion or exclusion of either of the two other Local Group galaxies mentioned above.

The researchers chose to use a simulation developed by the Institute for Computational Cosmology at Durham University in England. The galaxies residing in the Local Group are gravitationally bound, so apart from each member's individual parameters, the model also needs to include gravitational forces and dynamical friction - the transfer of energy through gravitational interactions, which is the dominating factor as the collision gets closer and leads to the decay of galactic orbits. However, it is important to note that even the "most accurate" measurements still have a wide range of uncertainty, so the team used a method known as Monte Carlo sampling to test tens of thousands of possibilities within those uncertainties.

It is this range of uncertainty, compounded by the inclusion of four different galaxies, that led Sawala's group to throw up a yellow flag on a Milkomeda future.

Every little bit counts



Our Milky Way Galaxy and the Andromeda Galaxy are (likely) destined to collide nearly head on in a few billion years. In one possible scenario, the smaller Pinwheel Galaxy (M33) misses the action during the initial smashup; if so, M33 may later merge with the result of the Milky Way-Andromeda collision, dubbed "Milkomeda." Ultimately, the collision’s fate depends on many factors, including contributions from M33, the LMC, and more. Credit: Astronomy : Roen Kelly.

Sawala's team first ran the model with only the Milky Way and Andromeda, with masses of one trillion and 1.3 trillion solar masses, respectively. It showed that the two galaxies merged in less than half of the cases, mostly during the second-closest encounter. And depending on the closeness of that encounter, the time of collision was either 7.6 or eight billion years from now. "Based on the best current data, both outcomes are almost equally likely," said the study.

To up the ante, they used a three-body system including the Triangulum Galaxy, and found that this increased the chances of collision to about two-thirds with a similar time frame as the two-body system. The model showed that M33 slowed Andromeda's velocity relative to our galaxy, meaning that Andromeda wasn't moving away fast enough to avoid merging.

But adding in the LMC changed things yet again, with or without M33. The simulation with just the Milky Way, Andromeda, and the LMC resulted in mergers in only a third of all the cases. But when all four of the galaxies were included in the model, the collision rate went back up to a coin toss occurring within the next 10 billion years.

Gravity - and time - will tell

Uncertainty is the biggest factor in, well, the uncertainty. The mass of the Milky Way is only known to within roughly 20 percent, and it's only known to within 30 percent for the two smaller galaxies. Furthermore, while the individual contributions from the Local Group of galaxies' smaller members is close to negligible, they are not when taken together, and calculating that effect is a daunting computational task - one not yet covered by Sawala's team.

Weighing entire galaxies - their stars, dust, and invisible dark matter - and measuring their motions is a basic but still monumental task in astronomy. Gaia's fourth data release, due in 2026, along with other new or updated surveys will help, but only to a point.

In spinning the possibilities out over eons of future time, even small ripples in the cosmic stream can have large effects. The only way to be sure might be to wait 10 billion years.

The post The Milky Way and Andromeda may not merge, after all appeared first on Astronomy Magazine.

NASA plans to establish a Coordinated Lunar Time (LTC) in order to support future moon and space exploration, the agency announced earlier this month. The announcement follows a White House policy directive issued in April, and aims to create a standardized timekeeping system for the moon.

Led by NASA's Space Communication and Navigation (SCaN) program, the initiative could eventually extend to other celestial bodies across the solar system. As humanity prepares to return to the Moon, LTC will be essential in developing a sustainable lunar ecosystem and ensuring the safety of future missions.

"The existence of a common time reference is the basis of our everyday life activities on Earth, and the same will be true on the Moon with the development of a lunar economy and the expansion of lunar exploration," Javier Ventura-Traveset, Moonlight Project navigation manager at the European Space Agency (ESA), told *Newsweek*.

"In a very short term, for example, we may need to define a common lunar reference time to ensure that different space agencies' planned lunar-based communication and navigation infrastructures remain interoperable; to establish growing lunar telecommunication networks; to precisely time-stamp some scientific experiments; to synchronize astronomical observations from lunar-based telescopes; or to coordinate time-sensitive operations such as spacecraft docking."

The full moon rises above the night sky in Shanghai on Sept. 17, 2024. NASA will coordinate with U.S. government stakeholders, partners, and international standards organizations to establish a Coordinated Lunar Time (LTC) following a policy directive from the White House in April. HECTOR RETAMAL/Getty© HECTOR RETAMAL/Getty

Similar to Earth's Coordinated Universal Time (UTC), the lunar time will be calculated using a weighted average of atomic clocks placed on the Moon.

However, establishing LTC isn't without its challenges. For one thing, accounting for the effects of Einstein's theories of special and general relativity is a tricky business. Current analysis shows that atomic clocks on the lunar surface appear to tick faster by microseconds per day due to differences in gravitational effects.

"If you place two clocks, one on the Earth's surface and one on the lunar surface, and start them running at exactly the same time, after 24 Earth hours, the clock on the Moon will be ahead by about 56 microseconds, with some additional smaller periodic variations," Ventura-Traveset said.

This difference may appear small, but its effects could be huge in the precise world of space exploration.

"For something traveling at the speed of light, 56 microseconds is enough time to travel the distance of approximately 168 football fields," Cheryl Gramling, lead on lunar position, navigation, timing, and standards at NASA Headquarters in Washington, said in a statement.

"If someone is orbiting the Moon, an observer on Earth who isn't compensating for the effects of relativity over a day would think that the orbiting astronaut is approximately 168 football fields away from where the astronaut really is."

As NASA's Artemis program advances toward landing astronauts on the lunar surface by September 2026 and aims to establish a sustained presence on and around the Moon, the need for a standardized lunar time system is becoming increasingly vital.

Ben Ashman, navigation lead for lunar relay development, emphasized that "a shared definition of time is an important part of safe, resilient, and sustainable operations" as more nations and commercial entities become active in lunar exploration.

The development of LTC is not just about the Moon. NASA envisions this timekeeping system as a stepping stone for future Mars missions and exploration of other parts of our solar system. By addressing the complexities of time in space now, NASA is laying the groundwork for long-duration exploration missions in the future.

The White House has set a deadline of December 31, 2026, for NASA to deliver a strategy for LTC's implementation.

This artist's impression shows Barnard b, a sub-Earth-mass planet that was discovered orbiting Barnard's star. Its signal was detected with the ESPRESSO instrument on ESO's Very Large Telescope (VLT), and astronomers were able to confirm it with data from other instruments. An earlier promising detection in 2018 around the same star could not be confirmed by these data. On this newly discovered exoplanet, which has at least half the mass of Venus but is too hot to support liquid water, a year lasts just over three Earth days. Credit: ESO/M. Kornmesser

Using the European Southern Observatory's Very Large Telescope (ESO's VLT), astronomers have discovered an exoplanet orbiting Barnard's star, the closest single star to our sun. On this newly discovered exoplanet, which has at least half the mass of Venus, a year lasts just over three Earth days. The team's observations also hint at the existence of three more exoplanet candidates, in various orbits around the star.

Located just six light-years away, Barnard's star is the second-closest stellar system—after Alpha Centauri's three-star group—and the closest individual star to us. Owing to its proximity, it is a primary target in the search for Earth-like exoplanets. Despite a promising detection back in 2018, no planet orbiting Barnard's star had been confirmed until now.

The discovery of this new exoplanet—announced in a paper published today in the journal *Astronomy & Astrophysics*—is the result of observations made over the last five years with ESO's VLT, located at Paranal Observatory in Chile. "Even if it took a long time, we were always confident that we could find something," says Jonay González Hernández, a researcher at the Instituto de Astrofísica de Canarias in Spain, and lead author of the paper.

The team were looking for signals from possible exoplanets within the habitable or temperate zone of Barnard's star—the range where liquid water can exist on the planet's surface. Red dwarfs like Barnard's star are often targeted by astronomers since low-mass rocky planets are easier to detect there than around larger sun-like stars.

Related video: This is the Moment a Star Expands to Eat One of its Orbiting Planets (Dailymotion)

Barnard b, as the newly discovered exoplanet is called, is twenty times closer to Barnard's star than Mercury is to the sun. It orbits its star in 3.15 Earth days and has a surface temperature around 125 °C.

"Barnard b is one of the lowest-mass exoplanets known and one of the few known with a mass less than that of Earth. But the planet is too close to the host star, closer than the habitable zone," explains González Hernández. "Even if the star is about 2500 degrees cooler than our sun, it is too hot there to maintain liquid water on the surface."

For their observations, the team used ESPRESSO, a highly precise instrument designed to measure the wobble of a star caused by the gravitational pull of one or more orbiting planets. The results obtained from these observations were confirmed by data from other instruments also specialized in exoplanet hunting: HARPS at ESO's La Silla Observatory, HARPS-N and CARMENES. The new data do not, however, support the existence of the exoplanet reported in 2018.

In addition to the confirmed planet, the international team also found hints of three more exoplanet candidates orbiting the same star. These candidates, however, will require additional observations with ESPRESSO to be confirmed.

"We now need to continue observing this star to confirm the other candidate signals," says Alejandro Suárez Mascareño, a researcher also at the Instituto de Astrofísica de Canarias and co-author of the study. "But the discovery of this planet, along with other previous discoveries such as Proxima b and d, shows that our cosmic backyard is full of low-mass planets."

ESO's Extremely Large Telescope (ELT), currently under construction, is set to transform the field of exoplanet research. The ELT's ANDES instrument will allow researchers to detect more of these small, rocky planets in the temperate zone around nearby stars, beyond the reach of current telescopes, and enable them to study the composition of their atmospheres.

More information: A sub-Earth-mass planet orbiting Barnard's star*Astronomy and Astrophysics* (2024). DOI: 10.1051/0004-6361/202451311. www.aanda.org/10.1051/0004-6361/202451311

Provided by ESO

Graphic depicting the various uses of biofilms. Credit: NASA

As humans spread into the cosmos, we will take a plethora of initially Earth-bound life with us for the ride. Some might be more beneficial or potentially harmful than others. And there is no lifeform more prevalent on Earth than bacteria. These tiny creatures and fungi, their long-lost cousins on the evolutionary tree, have a habit of clumping together to form a type of structure known as a biofilm.

Biofilms are ubiquitous in Earth-bound environments and have been noticed on space missions for decades. But what potential dangers do they pose? More interestingly, what possible problems can they solve?

A paper from a group of scientists focused on life support systems in the journal *Biofilm* provides a high-level overview of the state of the science of understanding how biofilms work in space and where it might need to go for us to establish a permanent human presence off-world.

The paper is divided into five sub-sections, each of which examines how biofilms might impact them. The first two sub-sections focus on wet and dry areas of an object in space, while the third focuses on the potential impact on human health. Further sections include a focus on in-situ resource utilization (fourth) and biosensors (fifth). Let's examine each one in turn.

Wet surfaces are probably the place most people would expect to see a biofilm. They are ubiquitous in uncleaned toilets and other areas where a continual source of nutrients and water are available. Unfortunately, space stations and crewed spaceships have the same necessary biological plumbing and could suffer from the same problem if not managed.

However, they also have wet storage areas, like the water reclamation system or fuel tanks, that aren't necessary for Earth-based systems. All that means there are plenty of areas where biofilms can pollute these systems and cause significant problems either mechanically or biologically for the crew.

Dry surfaces are essentially the same, though tracing the spread of the bacteria is trickier as typical deposition systems, like the settling of an aerosol from a person breathing, which happens to contain thousands of bacteria, isn't as much of a problem in space. However, astronauts still touch surfaces which deposits bacteria as well, and their breath has to be recycled in air cleaners, which could lead to deposits near or even on the HEPA filters that keep the air in the craft fresh.

Either way, those biofilms could prove problematic to the human occupants of any spacecraft.

There are two main ways they can create problems—either through infections, especially if the astronauts drink contaminated water, or through allergies, which could be caused by things like black mold. Unfortunately, we don't understand what, if any, impact microgravity has on all of these processes, including fundamentals like how virulent pathogens might become.

However, it's not all doom and gloom regarding biofilms in space exploration. Some biofilms can be helpful—especially by filtering valuable materials. Biofilm reactors are becoming more common in Earth-bound processes, whereby they can capture valuable materials like platinum from wastewater streams of mines or recycling plants.

A similar tactic could work on Mars, where bioreactors could filter out useful molecules like nitrogen from the atmosphere and allow human-made systems to access those resources.

However, such systems would be useless if they weren't controlled, and developing biosensors to monitor the health of biofilms —or lack thereof if they happen to be dangerous—will be a crucial innovation for future permanent space exploration missions.

Several sensors are coming on the market that could fill that need, but more experimentation is needed to see how effective they are in microgravity.

Ultimately, humans will have to learn to live to co-exist with biofilms in space, just like we do down on Earth. Whether that relationship is adversarial, symbiotic, or some combination of both will be primarily up to us.

But, as mentioned in the paper, and that holds for most things in the realm of science, it would be good if we had a better understanding of how these systems work in this new environment. Otherwise, we might be setting ourselves up for a very avoidable disaster.

More information: Yo-Ann Vélez Justiniano et al, Mitigation and use of biofilms in space for the benefit of human space exploration, *Biofilm* (2023). DOI: 10.1016/j.bioflm.2022.100102

Provided by Universe Today

The universe, vast and intricate, holds mysteries that continuously challenge our understanding. A recent study led by the University of Hawaiʻi Institute for Astronomy has uncovered findings that could potentially redefine the boundaries of our cosmic neighborhood.

By studying the movement of thousands of galaxies, researchers are suggesting that our corner of the universe might be far more expansive than previously thought.

An international team, known as the Cosmicflows group, has been analyzing the movements of over 56,000 galaxies. Their work points toward the possibility that the galactic basin containing our Milky Way, named Laniākea, may be part of an even more enormous cosmic structure.

Laniākea, a basin of attraction spanning 500 million light-years, was previously believed to encompass our galactic neighborhood. However, new evidence suggests that this basin may extend into something ten times larger, potentially centered around a region known as the Shapley concentration.

This area is known for its immense mass and gravitational pull, which affects surrounding galaxies. The recent findings, published in Nature Astronomy, indicate a 60% probability that our cosmic basin stretches into this much larger structure.

According to R. Brent Tully, a leading researcher from the University of Hawaiʻi, the universe can be visualized like a giant web, with galaxies spread along filaments and clustering at intersections where gravity pulls them together. "Just as water flows within watersheds, galaxies flow within cosmic basins of attraction," Tully explained.

Major discovery about the origins of matter in the universe The universe is significantly older than scientists previously imagined Astronomers found the largest water reservoir in the universe - 140 trillion times more water than on Earth

This idea of larger basins suggests that our understanding of the universe's architecture might need significant revision. Such a shift in perspective would mean that the initial seeds of cosmic structures could be far larger than the current models suggest, reflecting a more expansive interconnected universe.

The origin of our universe dates back around 13 billion years, when small variations in density began to grow under gravity, leading to the vast structures observed today. If Laniākea, whose name means "immense heaven" in Hawaiian, is indeed part of a much larger basin of attraction, it challenges current views on how cosmic structures formed and evolved. It suggests that these structures began growing even more extensively than previously estimated.

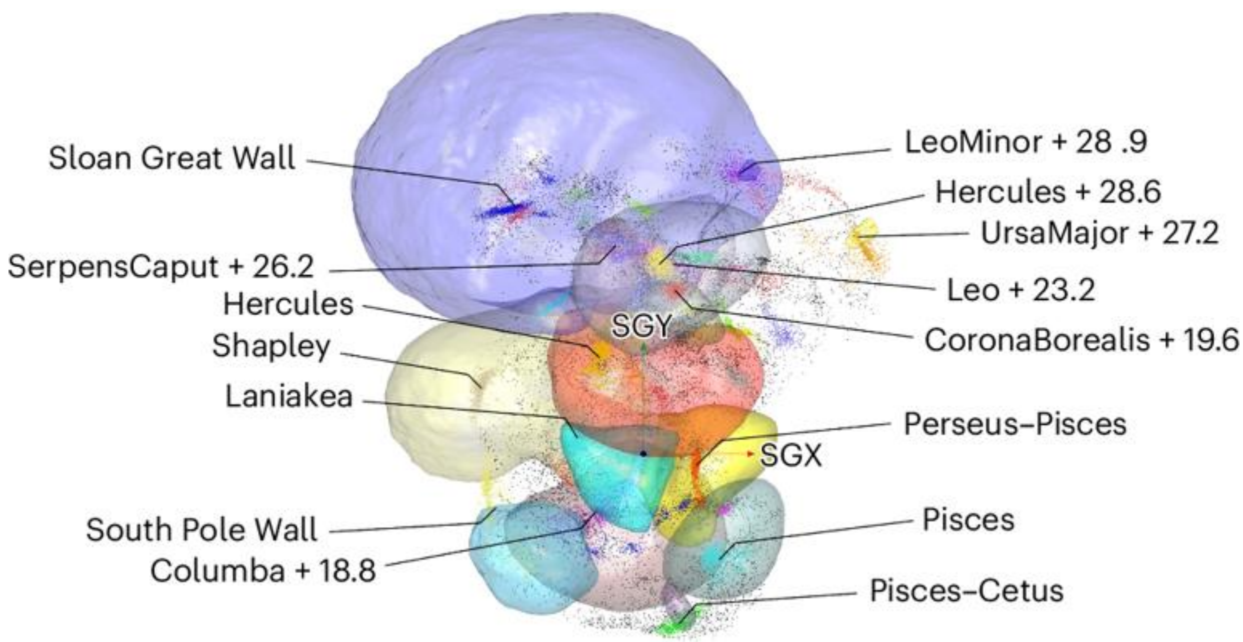
“This discovery presents a challenge: our cosmic surveys may not yet be large enough to map the full extent of these immense basins,” stated Ehsan Kourkchi, a co-author of the study.

Although modern astronomical tools provide impressive views of the cosmos, there is still a possibility that their reach may be insufficient for capturing the complete picture. Researchers, like Kourkchi, believe we are still seeing the universe with eyes that may not be big enough to grasp its entirety, pushing us to explore even further.

To understand these enormous cosmic structures, researchers observe the gravitational effects on the movement of galaxies. In regions where multiple basins overlap, galaxies are caught in a gravitational tug-of-war, with their movements influenced by surrounding massive structures. By charting the velocity of these galaxies, the researchers can determine where one supercluster ends and another begins, mapping the flow of galaxies throughout our local universe.

Tully and his team have made strides in understanding these structures, but their work is far from over. They are motivated by the idea that our universe might be part of a more expansive and interconnected cosmic system. This ongoing research could have a significant impact on how we view our place in the cosmos, possibly linking our galaxy to structures that are far grander than ever imagined.

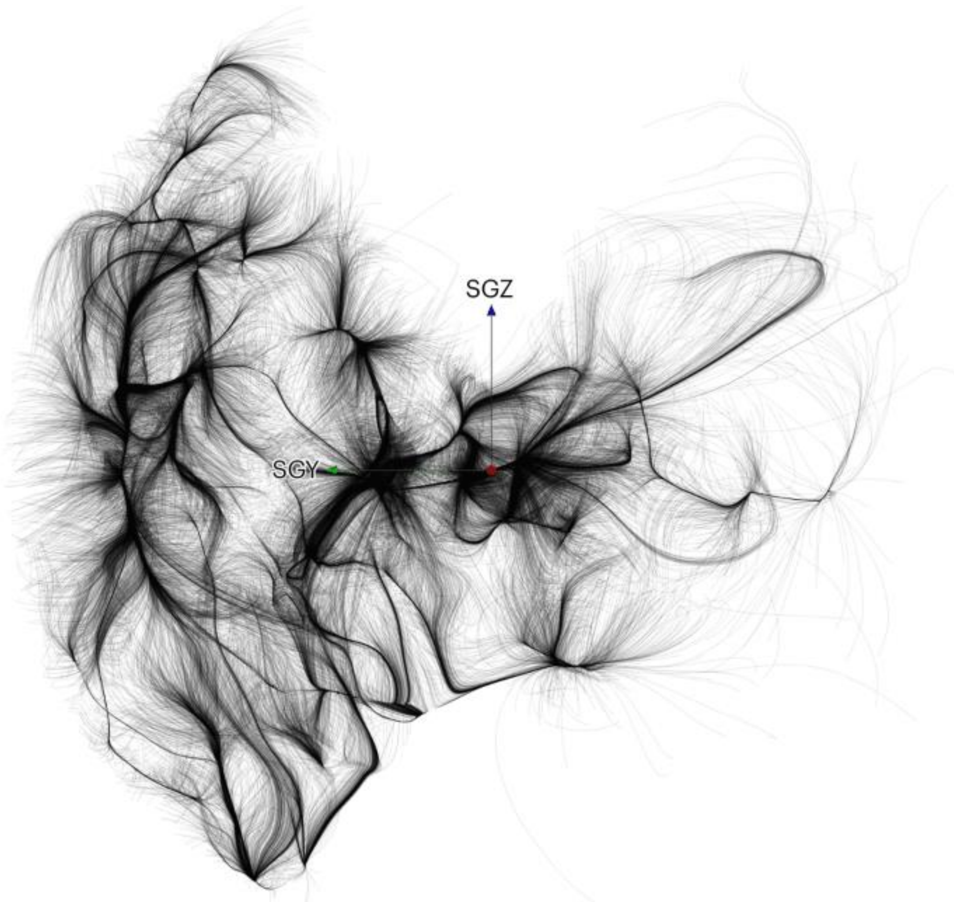
The team behind this study includes notable international astronomers. Besides Tully and Kourkchi from the University of Hawai'i, it also features researchers like Aurelien Valade, Noam Libeskind, and Simon Pfeifer from the Leibniz Institute for Astrophysics Potsdam, Daniel Pomarede from the University of Paris-Saclay, and Yehuda Hoffman from the Hebrew University.



Envelopes of major BoA superimposed on the sinks of HMC trials shown in the previous figure. (CREDIT: Nature Astronomy)© The Brighter Side of News

Mapping the universe is a daunting task, with the sheer scale of space presenting both opportunities and challenges. The discovery that the Milky Way might be part of a much larger basin of attraction calls for a reassessment of existing cosmic surveys and models. This realization not only highlights the vastness of the universe but also underscores our limitations in observing it.

Much like the way Earth's geography is shaped by watersheds that guide the flow of rivers, the universe is structured by gravitational basins of attraction that guide galaxies into clusters. However, the universe's structures are on a scale that



dwarfs anything on Earth. If Laniākea is merely a piece of an even larger basin, the implications for our understanding of cosmic evolution are enormous.

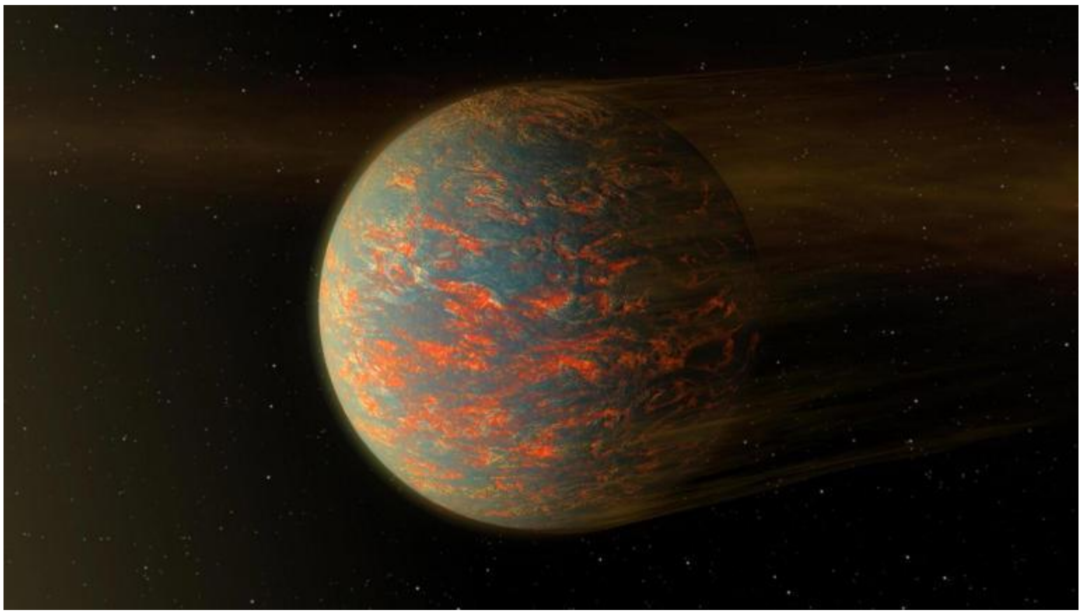
The Cosmicflows team's work reflects the dedication of scientists to continually expand the boundaries of knowledge, questioning what we think we know about our universe. With every new discovery, the universe seems to grow larger, moreintricate, and more mysterious.

Streamlines constructed from the mean HMC velocity field. (CREDIT: Nature Astronomy)© The Brighter Side of News

Researchers like Tully and his colleagues remind us that exploration is an ongoing endeavor, and with advanced surveys and new technologies, we are getting closer to unveiling the full grandeur of our cosmic neighborhood.

Far beyond the eight familiar planets in our solar system, countless bizarre and extreme worlds await discovery — and some have already been found.

Thanks to rapidly advancing telescope technology, astronomers have detected more than 5,600 planets outside our solar system. These exoplanets, as scientists call them, are worlds of lava, and worlds of water. They're worlds being ravaged by the heat of their stars, and worlds locked in eternal night. There are worlds that look like they were stolen straight from "Star Wars," and worlds that may hold exotic forms of life never dreamed up in science fiction.



Join us as we tour some of the strangest and most fascinating exoplanets in our ever-surprising universe.

The "hell planet" where it rains lava

((Image credit: NASA/JPL-Caltech))

55 Cancri e is a rocky world about eight times the size of Earth, making it a type of exoplanet known as a "super Earth." Despite its ample size, nothing is "super" about the living conditions here. Often nicknamed the "hell planet," 55 Cancri e is completely covered in flowing seas of lava, and it may even rain lava there as well. The exoplanet is located 41 light-years from Earth, making it a popular target for studies (but not for summer getaways).

The water world with (potentially) living oceans

K2-18 b is a large world located about 120 light-years from the sun. It inhabits the "Goldilocks zone" around its star, meaning that liquid water (and potentially life) could exist there. A recent analysis with the James Webb Space Telescope (JWST) supports the idea that the exoplanet may have its own liquid water ocean — and that the ocean may be home to living creatures. In the study, JWST detected possible traces of dimethyl sulfide, a chemical known to be emitted only by phytoplankton on Earth, in the exoplanet's atmosphere.

The real-world "Tatooine"

Luke Skywalker would feel right at home on Kepler-16b. This exoplanet is the first known circumbinary planet — a planet that orbits two stars at the same time, just like Tatooine from the Star Wars franchise. However, because this huge planet has a gassy surface similar to Saturn's, even a Jedi would have a hard time finding their footing on this exoplanet, which is located about 200 light-years from the sun.

The rule-breaking behemoth

The giant exoplanet LHS 3154b has scientists scratching their heads, because it seems far too large for its tiny star. This planet, which is about 13 times more massive than Earth but orbits a star nine times *less massive* than the sun, doesn't seem like it could exist, researchers said upon its discovery in 2023. Future studies of this "impossible" world could upend the known rules of planet formation.

The largest exoplanet in the known universe?

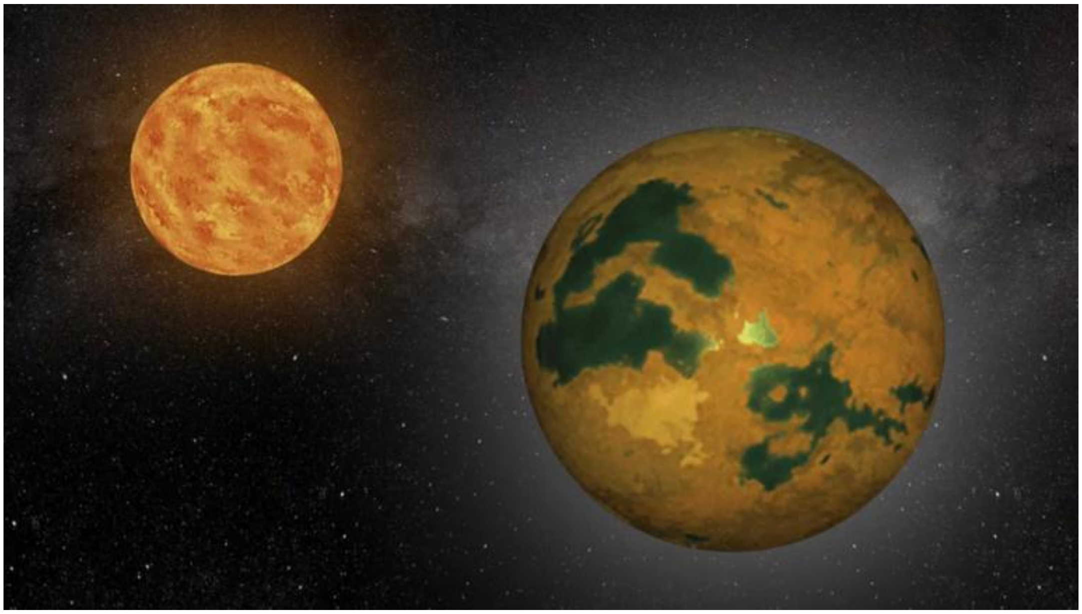
With twice the radius of Jupiter, the exoplanet HAT-P-67 b may be the largest known planet in the universe, in terms of width. But despite its monumental girth, there are more *massive* worlds out there. This honkin' world, located about 1,200 light-years from Earth, has a very low density, giving it only about one-third the mass of Jupiter.

The "fluffy" planet where it rains sand

(Image credit: Illustration: LUCA School of Arts, Belgium/ Klaas Verpoest (visuals), Johan Van Looveren (typography). Science: Achrène Dyrek (CEA and Université Paris Cité, France), Michiel Min (SRON, the Netherlands), Leen Decin (KU Leuven, Belgium) / European MIRI EXO GTO team / ESA / NASA)

Located 200 light-years from Earth, the exoplanet WASP-107b also has a very low density, making it appear "fluffy" in telescope observations. A recent JWST study of the planet revealed clouds potentially made of fine-grained silicate particles, meaning it may literally rain sand on this puffed-up world

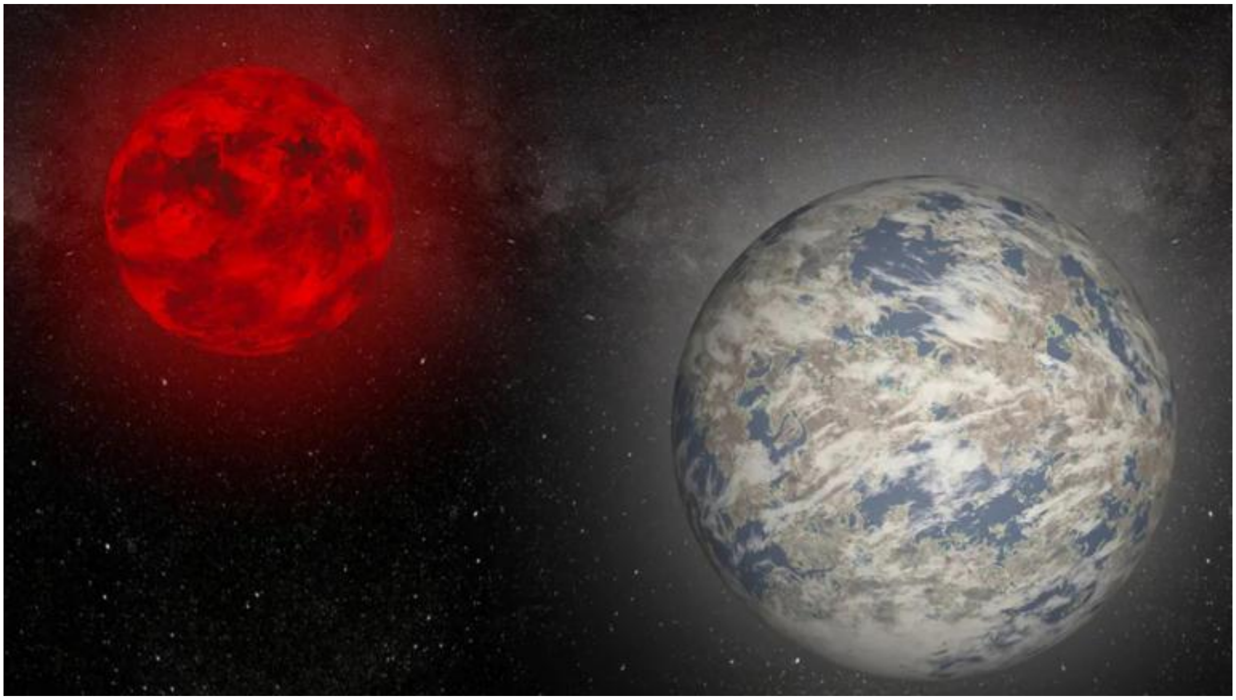
The "Vulcan planet" that may not exist



(Image credit: NASA/Robert Lea (created with Canva))

In a remarkable case of science fiction reflected in reality, scientists have reported the discovery of a planet similar to Vulcan, the home world of Dr. Spock in the Star Trek franchise. The planet was discovered in 2018 around the real star 40 Eridani A — the very same star that hosts Spock's home planet in the famous sci-fi series. However, recent follow-up observations of the star have called the planet's existence into question; subtle wobbles in the star's light signature may result not from a nearby planet's tugging on it but rather from regular eruptions on the star's surface. The existence of the Vulcan planet, named HD 26965 b, now seems in doubt.

The Earth-like planet around a small, red star



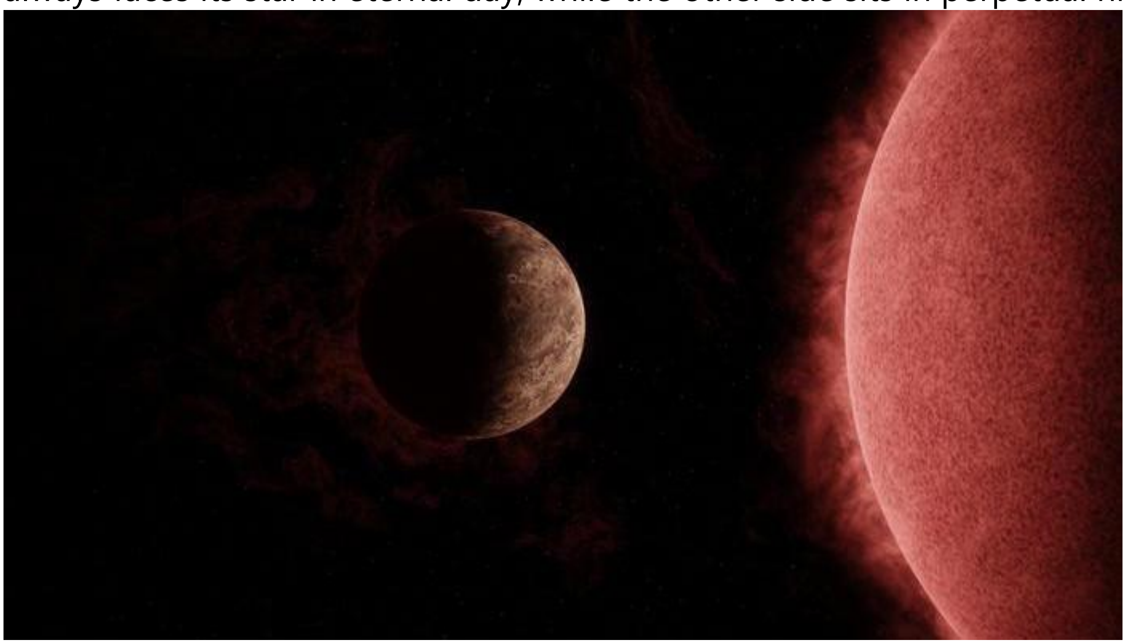
(Image credit: Robert Lea (created with Canva))

Earth may have a long-lost twin in a nearby star system. Named Gliese 12 b, the planet orbits a hot, red star in a system roughly 40 light-years from Earth. Remarkably, the exoplanet appears to have a width 1.1 times that of Earth, giving it similar properties to our own planet. And while Gliese 12 b orbits its home star much more closely than our planet does the sun (one year there lasts about 13 Earth days), that star is also much smaller, keeping the planet in the habitable zone where liquid water can form on the planet's surface. That means our distant twin may even have its own version of life.

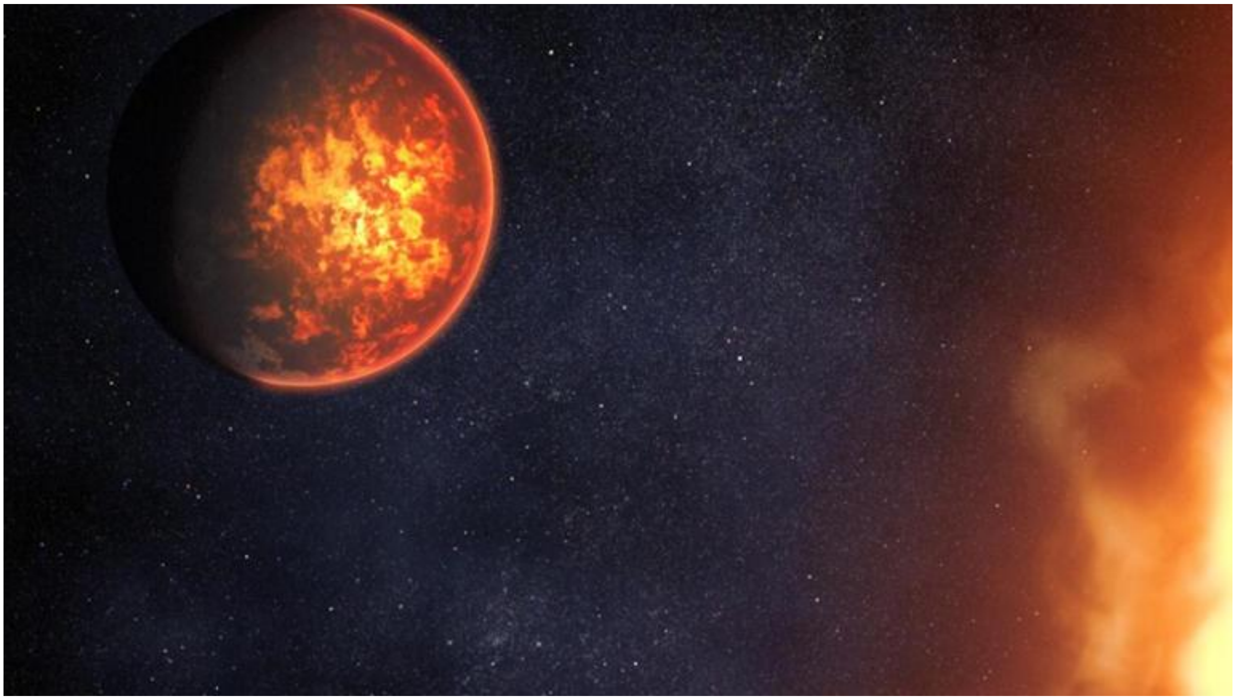
The Earth-size planet with eternal night

((Image credit: Lionel Garcia))

Not all Earth-size planets are lucky enough to be habitable. Take SPECULOOS-3 b, a rocky, Earth-like world whose orbit around its red dwarf star is a little too close for comfort. Completing an orbit every 17 hours, the rocky world is exposed to so much radiation that its atmosphere was likely blasted away long ago, leaving the unlucky planet totally barren. The roasting temperatures aren't a global phenomenon, however; this planet is tidally locked, meaning one side always faces its star in eternal day, while the other side sits in perpetual night.



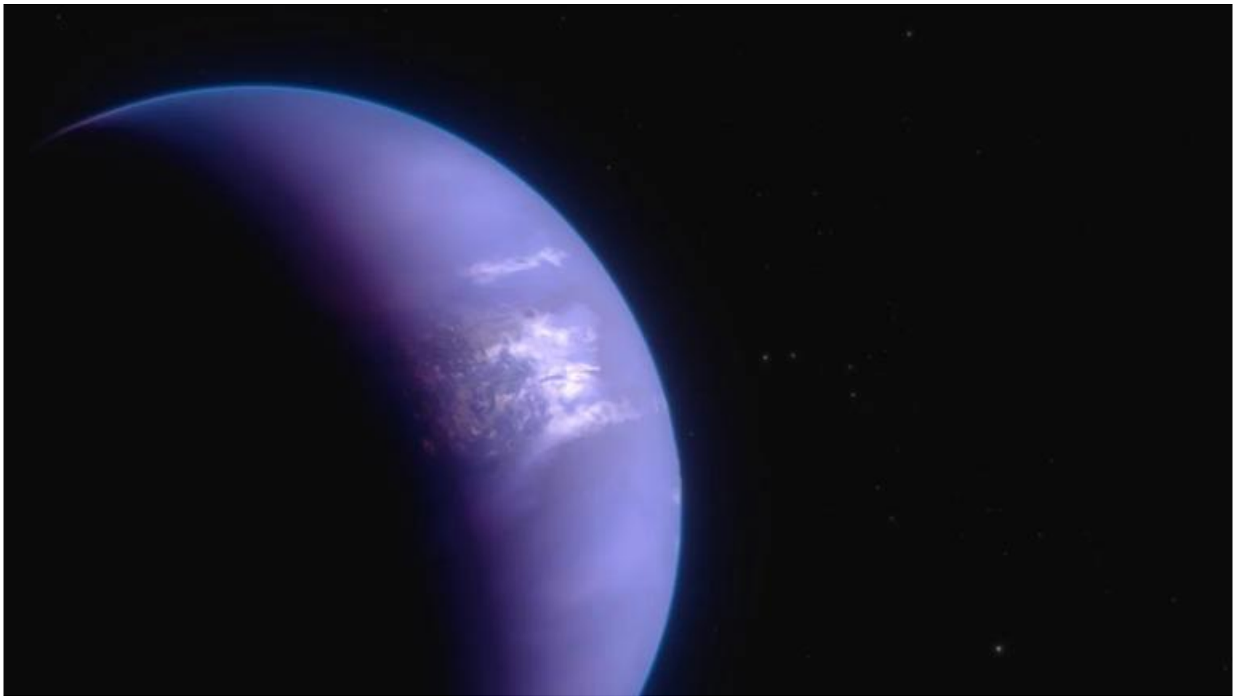
The red volcano world that's "melting from within"



((Image credit: NASA, ESA, CSA, Dani Player))

Astronomers have discovered a planet in a distant star system that appears to be erupting with so many volcanoes, the world literally glows red when seen through telescopes. The smoldering exoplanet, named TOI-6713.01, is located roughly 66 light-years from Earth and orbits its star closely, completing a loop every 2.2 Earth days. Observations suggest the planet is covered in molten lava, released by hundreds of active volcanoes. The planet is also subject to incredible internal friction from the gravity of its star and its neighboring planets, which may be causing the world to literally melt from within.

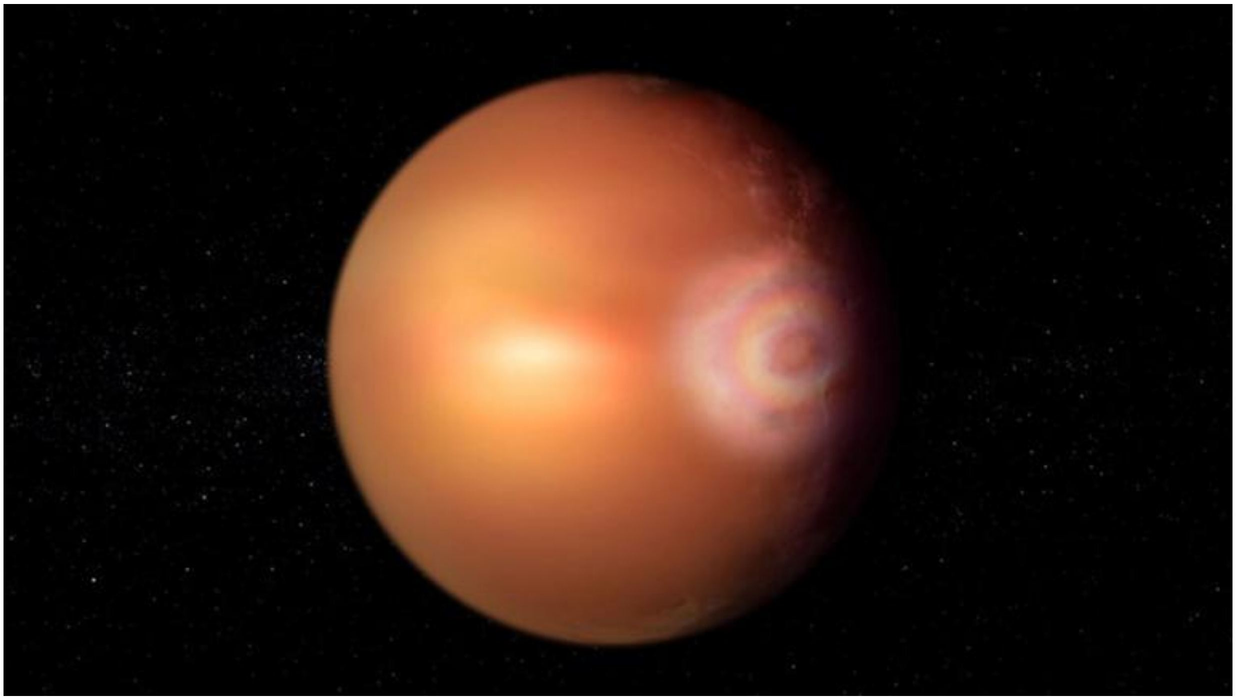
The gas giant with bullet-like wind



(Image credit: NASA, ESA, CSA, Ralf Crawford (STScI))

Scientists have mapped the weather on an enormous exoplanet 280 light-years from Earth, and the forecast looks grim. The planet, named WASP-43b, is tidally locked, with one massive face always pointing toward its star and the other cloaked in eternal darkness. Significant temperature differences between the two sides drive fierce winds, which scientists estimated to blow at up to 5,600 mph (9,000 km/h) — several times faster than a speeding bullet.

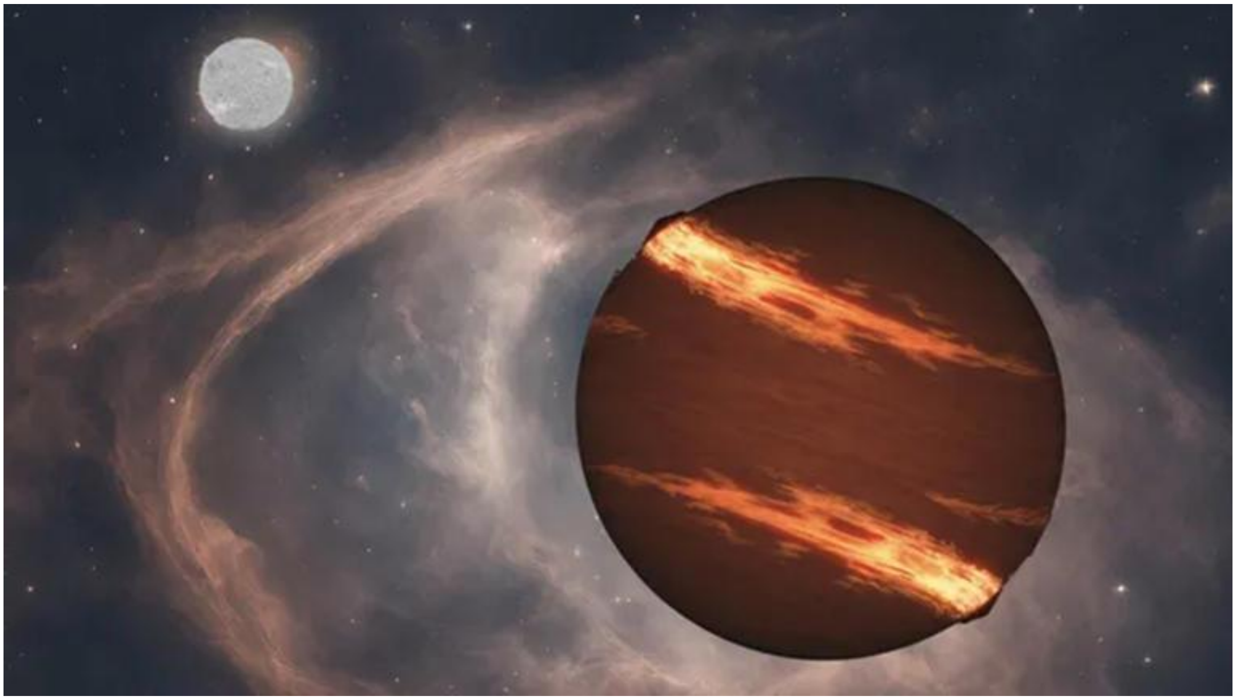
The hellish world with glorious rainbows



((Image credit: ESA))

The exoplanet WASP-76 b — located about 637 light-years from Earth — is not the type of place you'd want to vacation. Orbiting 20 times closer to its home star than Mercury orbits the sun, the planet's dayside is estimated to reach 4,350 degrees Fahrenheit (2,400 degrees Celsius), making it a true hell world. There is one draw, however: A strange bright spot observed on the planet's surface, right where the day and night sides meet, could be a "glory" — a rare visual phenomenon, sometimes seen on Earth, made up of concentric rainbow rings forming a giant circle.

The giant planets orbiting dead stars



(Image credit: Robert Lea (created with Canva))

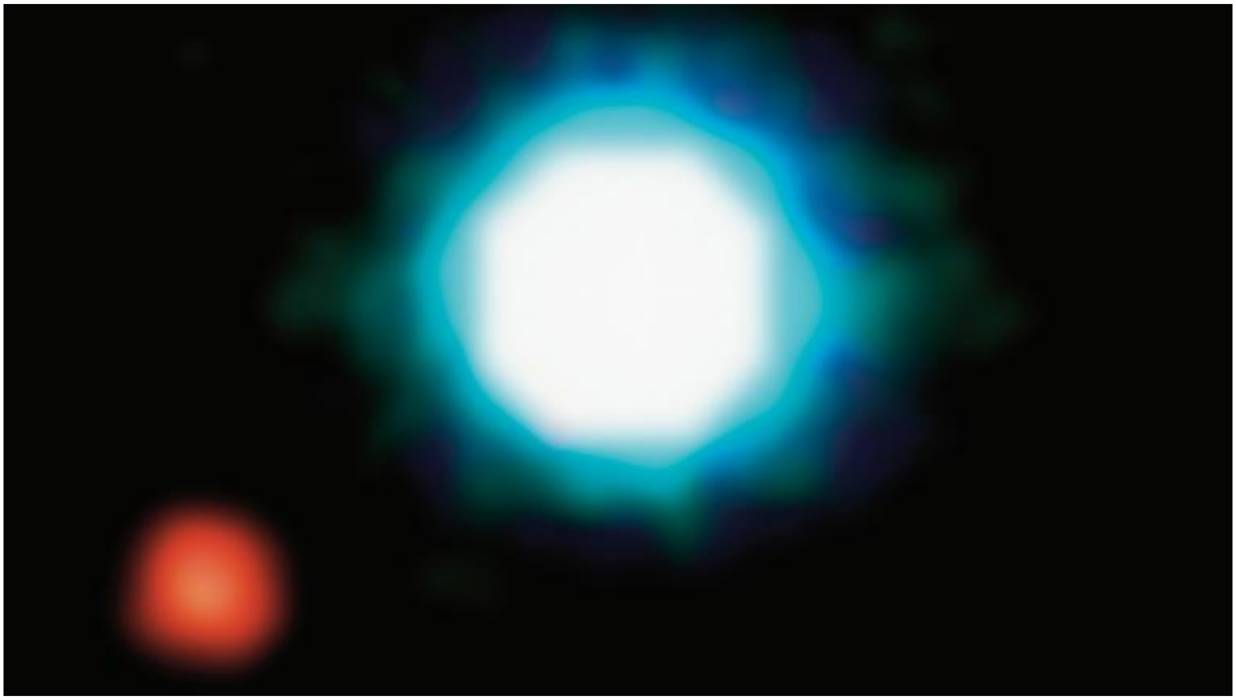
One day, the sun will die — but some planets in our solar system may live on. Scientists made this inference after discovering two enormous planets orbiting "dead" white dwarf stars in distant star systems. Named WD 1202-232 and WD 2105-82, the planets are estimated to be between one and seven times as massive as Jupiter, and both orbit small, dead stars at distances of at least 11.5 times that between Earth and the sun. Their discovery, if confirmed, hints that our solar system's comparable planets, Jupiter and Saturn, may be able to survive the inevitable death of the sun one day. (Earth, sadly, is likely to be swallowed up during our star's final expansion.)

The "rogue" planets of Orion

((Image credit: NASA, ESA, CSA / Science leads and image processing: M. McCaughrean, S. Pearson, CC BY-SA 3.0 IGO))

Most known planets orbit stars, but there may be countless others that don't. Scientists using the JWST have discovered hundreds of free-floating "rogue planets" zooming through the Orion Nebula, untethered to any star. Strangely, about 80 of these rogue worlds are trapped in binary orbits with each other, tumbling through space in pairs. Scientists are not certain how these worlds got ejected from their home star systems or why they are trapped in binary orbits. Given that these planets are roughly as massive as Jupiter, scientists have dubbed them Jupiter-mass binary objects — or JuMBOs, for short.

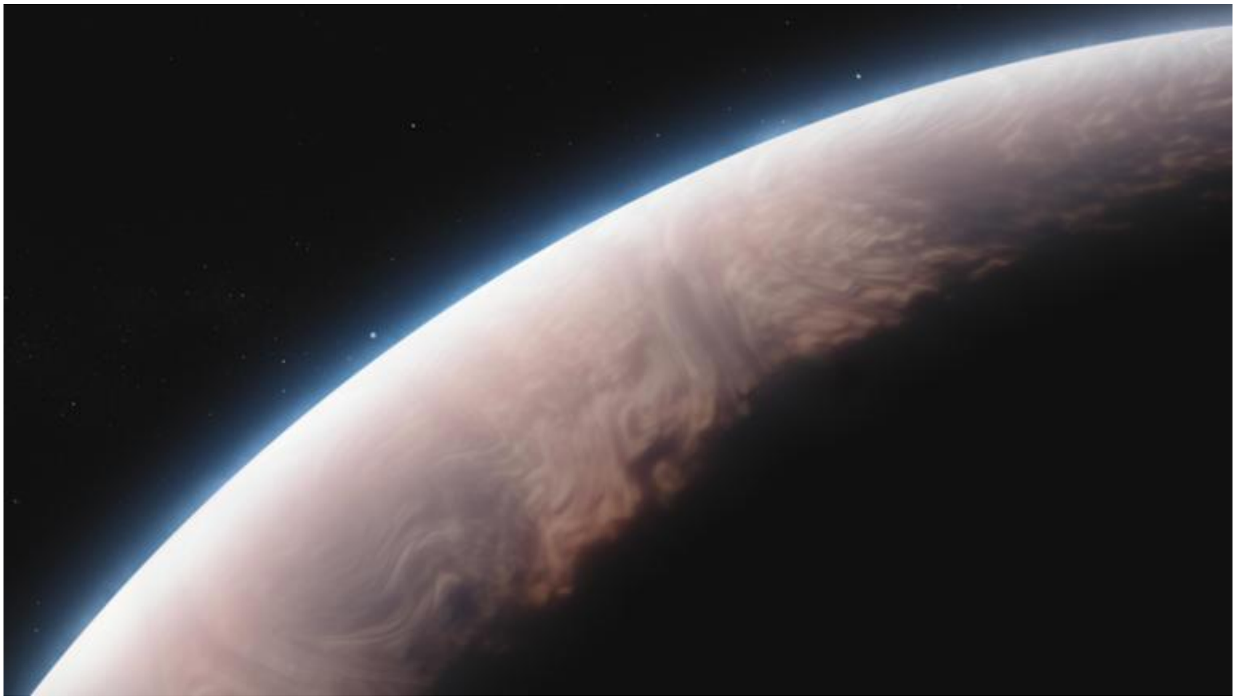
The distant planet we can actually see



((Image credit: ESO))

Scientists detect most exoplanets indirectly, by watching changes in the light emitted by distant stars. But in 2004, researchers got direct visual confirmation of an alien world for the first time ever. Called 2M1207b, the exoplanet is located about 170 light-years away, in the constellation Centaurus, and is a gas giant about five times more massive than Jupiter. The team spotted the distant world by looking at it in three different infrared wave bands, which helped reveal the planet's heat while blocking the light of its home star. Since this groundbreaking discovery, roughly 200 exoplanets have been discovered through direct imaging, while more than 5,000 others have been revealed through other means.

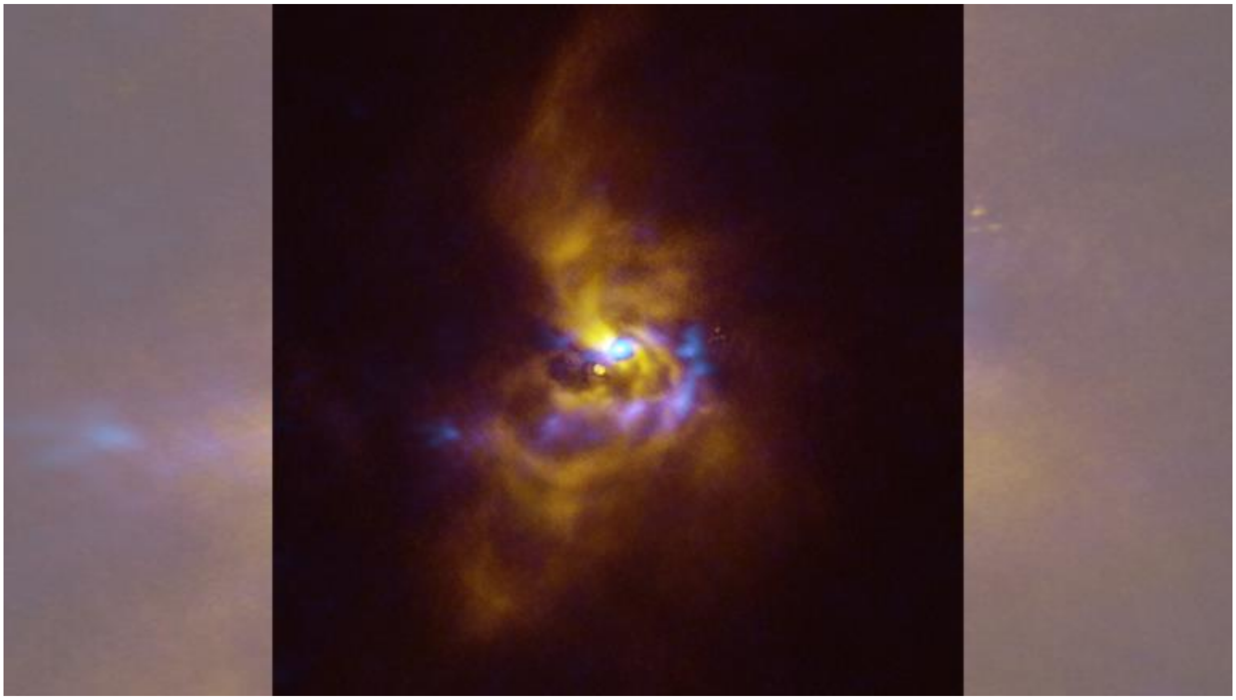
The planet with clouds of quartz



(Image credit: NASA, ESA, CSA, and R. Crawford (STScI))

Can you imagine a sunset filtered through a crystal sky? That may be a reality on the exoplanet WASP-17b, a Jupiter-like gas giant that's so hot that its clouds are made of quartz crystals, observations with JWST suggest. The planet orbits extremely close to its home star, giving it an atmosphere with temperatures reaching a blistering 2,700 F (1,500 C). This heat forms tiny, sand-size silica particles in the planet's atmosphere, which may coalesce into clouds of pure quartz, researchers suggest.

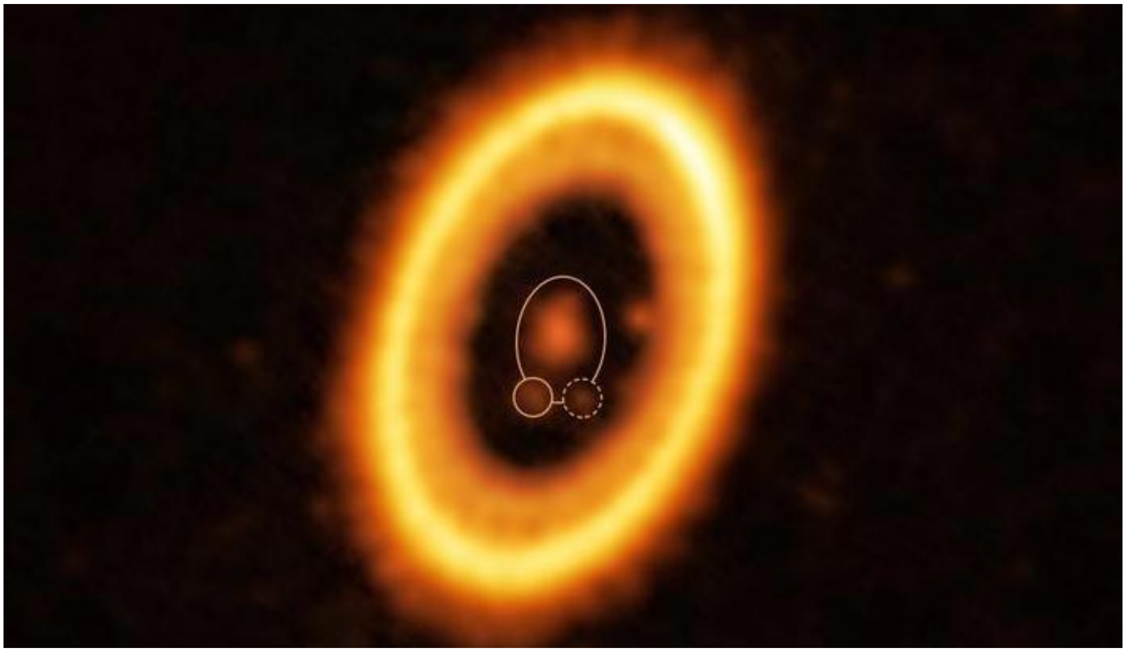
The baby Jupiter about to be born



(Image credit: ESO/ALMA (ESO/NAOJ/NRAO)/Weber et al.)

Exoplanet-hunting scientists zoom in on not just existing worlds but also worlds that are about to be born. While studying the region around the star V960 Mon, located about 5,000 light-years from Earth, scientists spotted a clumpy field of gas where two tendrils of material are apparently being funneled into distinct, planet-like lumps. According to the researchers, who made the discovery using the European Southern Observatory's Very Large Telescope and the Atacama Large Millimeter/submillimeter Array, this is the first time scientists have imaged a young star system on the verge of birthing its first giant planets.

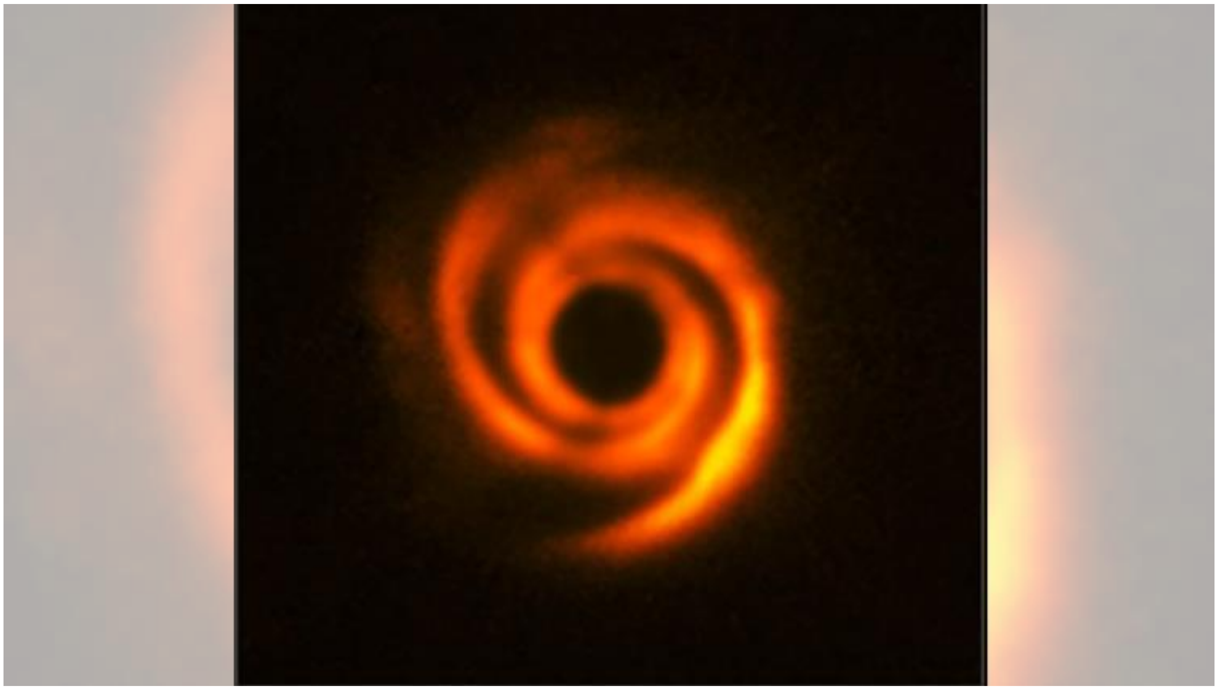
The sibling planets dancing in lockstep



(Image credit: ALMA (ESO/NAOJ/NRAO)/Balsalobre-Ruza et al.)

Around the distant star PDS 70, located 370 light-years from Earth, resides an incredibly rare pair of sibling planets. One fully formed world roughly the size of Jupiter appears to swirl around its host star; behind it, in the same orbit, is an enormous cloud of gas and dust that researchers suspect may be the planet's partially formed sibling. Although only one of the objects seems to be a full-fledged planet, the pair is the first evidence of rare "Trojan planets" — two worlds that formed at nearly the same time, in roughly the same place around their home star, moving in the exact same orbit.

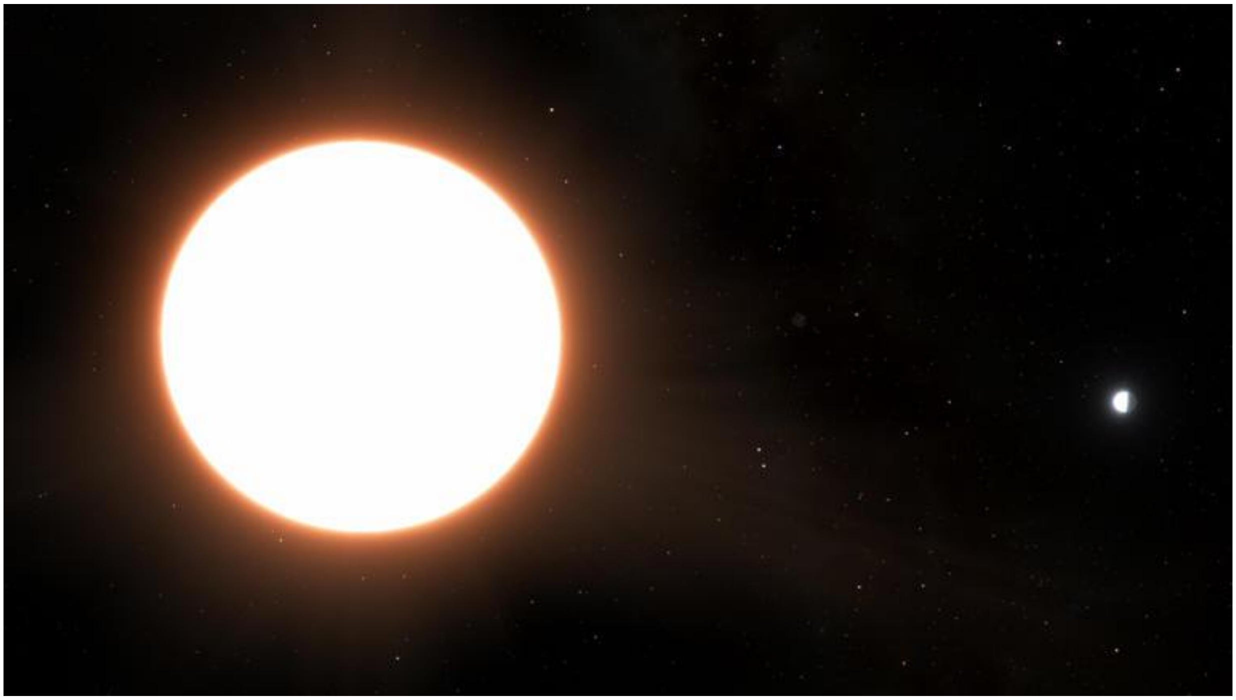
The planet turning its star into a "spiral galaxy"



((Image credit: ESO))

About 500 million light-years from Earth is a star system that looks suspiciously familiar. Wrapped in two dusty spiral arms, it resembles our own Milky Way galaxy — although on a much, much smaller scale. The reason for this star's galactic appearance? Astronomers suspect it's because of a hidden, Jupiter-size planet dubbed MWC 758 c, which used its massive gravitational pull to sculpt the star's sheath of dust into spectacular spiral arms. The planet has yet to be fully confirmed, but simulations show it's a likely cause of its home star's odd look.

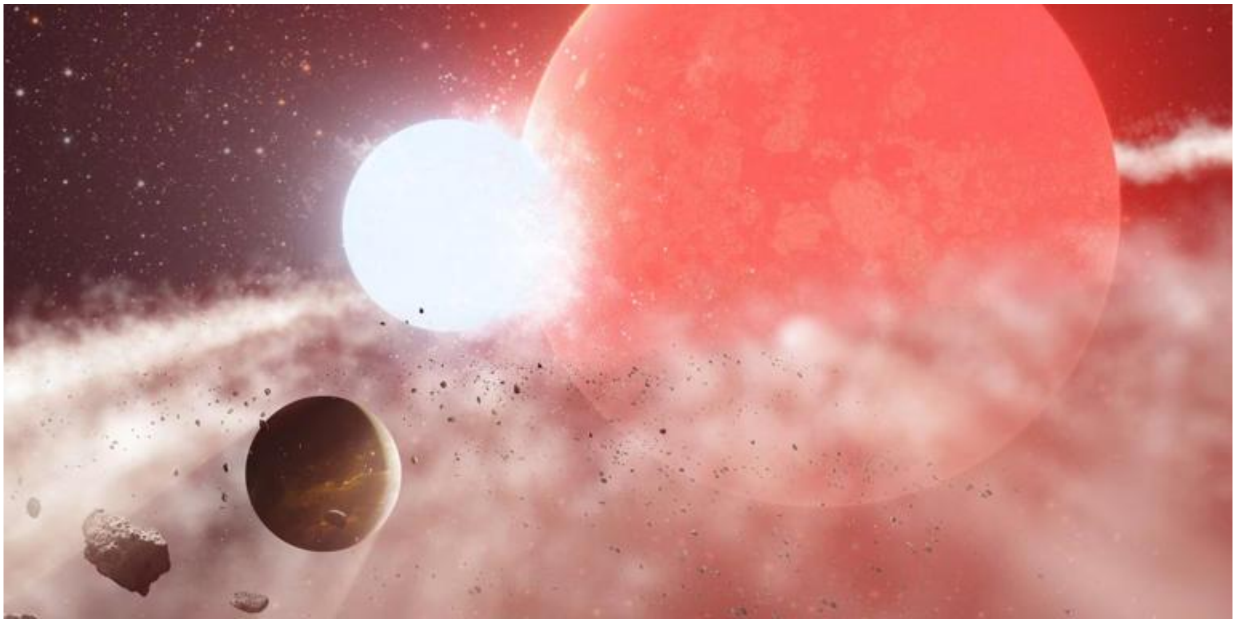
The mirror world that shouldn't exist



((Image credit: ESA/Cheops))

Most planets reflect at least a bit of their home star's light. But the exoplanet LTT9779 b reflects a whopping 80% of its star's incoming rays — the highest reflectiveness of any planet ever discovered. The key to the planet's impressive albedo is a layer of metallic clouds that surrounds it. Scientists suspect the Neptune-size world's sky is mostly full of silicate, or glass, and titanate, a salt containing titanium — turning the planet's atmosphere into a veritable mirror. The planet's existence poses a puzzle for scientists: The world orbits so closely to its star that its atmosphere should have been blown away by now. The key to its survival may be the metal in the planet's skies, which may be too heavy for solar wind to blast it away.

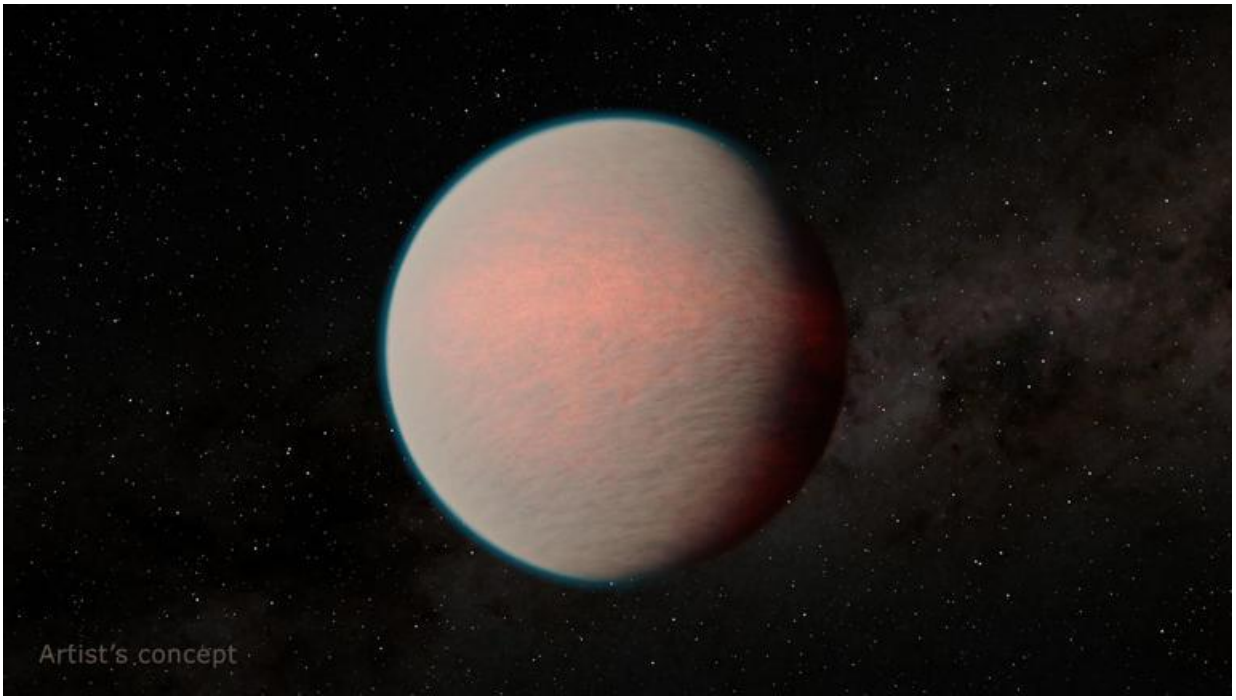
The "zombie" planet that survived its star's death



((Image credit: W. M. Keck Observatory/Adam Makarenko))

The exoplanet 8 Ursae Minoris b, also known as Halla, is a hot, Jupiter-like world located 520 light-years from Earth. Observations suggest the massive world should have been completely incinerated by its home star, which has already entered its red giant phase and appears to have long since ballooned outward into its system, scorching everything in its path, before shrinking back to its current size. The fact that Halla orbits relatively close to the star suggests it was either born after the star shrank again or the star that's visible today is one of two binary stars that merged, preventing either one from expanding on its path of destruction.

The water world with a steam atmosphere



(Image credit: NASA/JPL-Caltech/R. Hurt (IPAC))

The exoplanet GJ 1214b is located just 40 light-years from Earth, but it's coated in so many thick clouds that scientists had a hard time studying it until recently. Using JWST's infrared vision to peer through the clouds, scientists analyzed the planet and saw what appeared to be an atmosphere made of steam, suggesting the world below may contain significant amounts of water.

The Earth-like planet with no atmosphere

(Image credit: NASA, ESA, CSA, J. Olmsted (STScI))

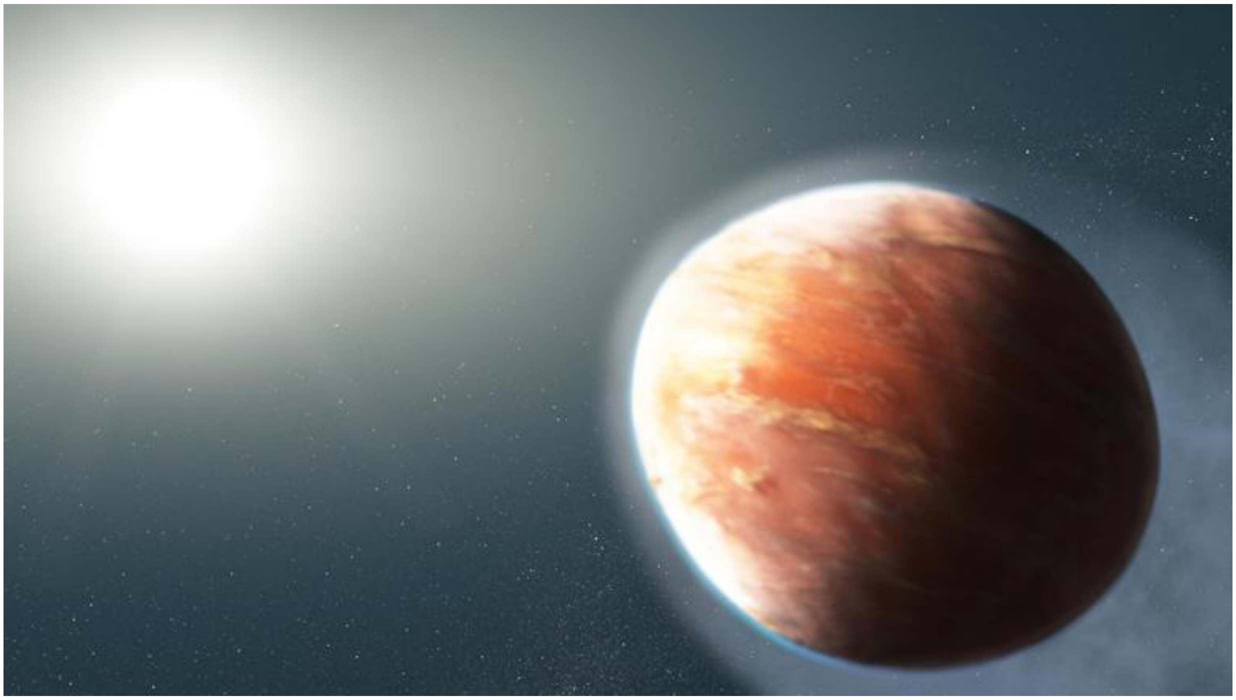
Around the distant star TRAPPIST-1, seven rocky, Earth-size planets swirl through the star's habitable zone. Whether any of these planets contain the right conditions for life is a question astronomers are eagerly investigating. But one of them, TRAPPIST-1b, may be officially out of the running. JWST's observations of the rocky, Earth-like world reveal that the planet is about as hot as an oven — a whopping 450 F (232 C) — and almost certainly doesn't have an atmosphere. Some of the scorching world's neighbors may be better positioned for life to emerge, but more research is needed to know for sure.

The extraterrestrial sandstorm planet

(Image credit: NASA, ESA, CSA, Joseph Olmsted (STScI))

Scientists using JWST have spotted a gargantuan sandstorm raging on the exoplanet VHS 1256 b, located roughly 40 light-years from Earth. An enormous world that's far from its star, the "super-Jupiter" takes about 10,000 years to complete a single orbit. That large distance means scientists can see the planet's atmosphere relatively clearly, without too much starlight getting in the way. Recent observations showed incredibly hot clouds made of silicate particles swirling through the planet's atmosphere. According to the researchers, this may be evidence of a gargantuan dust storm.

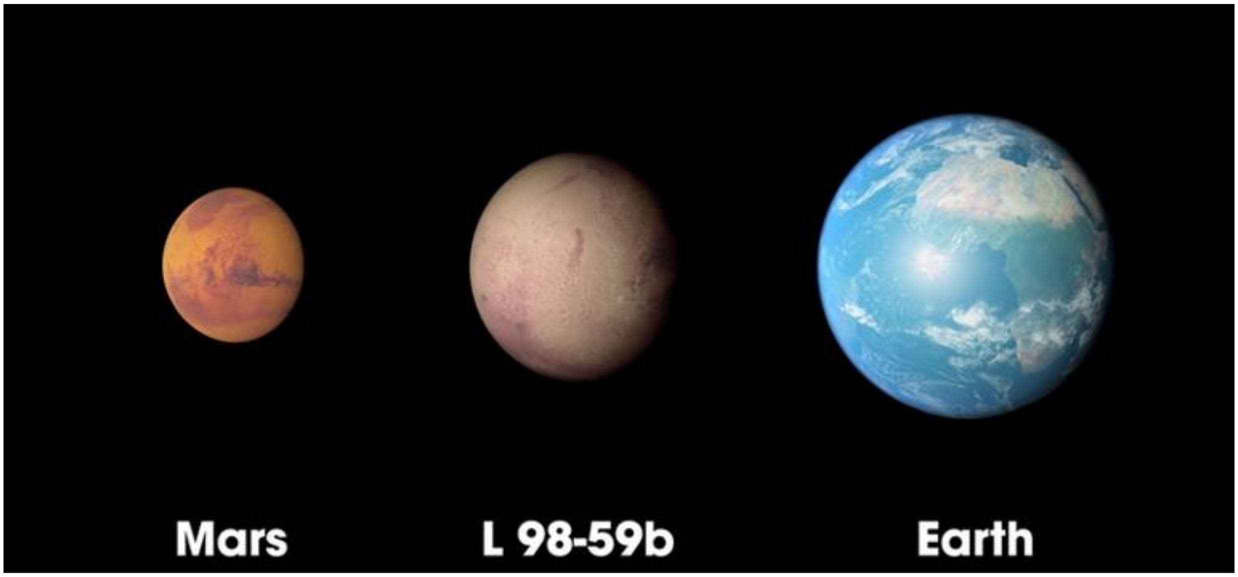
The toxic football planet



(Image credit: NASA, ESA, and J. Olmsted (STScI))

Located about 900 light-years from Earth, the [exoplanet WASP-121b] is so hot that heavy metals are constantly boiling through its atmosphere and venting into space. Scientists spotted iron and magnesium molecules so high above the planet's surface that they could escape the pull of gravity and drift away. The extreme heat comes from the planet's ultraclose proximity to its host star. The planet is so close, in fact, that tidal forces generated by the star's gravity have stretched the planet into a football shape that distinguishes it from the spherical worlds most often discovered.

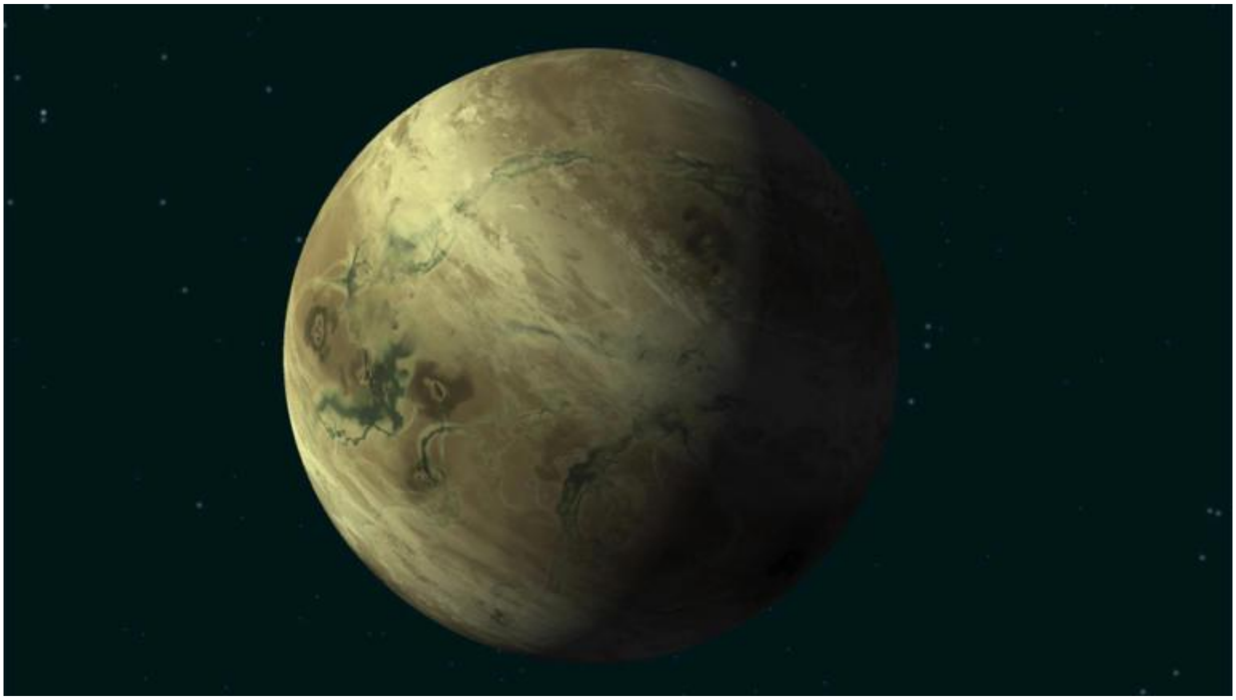
The ultrasmall world moving at breakneck speed



((Image credit: NASA))

Located 35 light-years from Earth, L 98-59b is one of the smallest exoplanets ever discovered, with a mass just 0.4 times that of Earth. The tiny world also rockets around its home star at breakneck speed, completing an orbit in just two days, six hours. Because of this, the planet receives roughly 22 times as much energy from its home star as Earth does from the sun, almost certainly rendering the tiny, fast-moving planet uninhabitable.

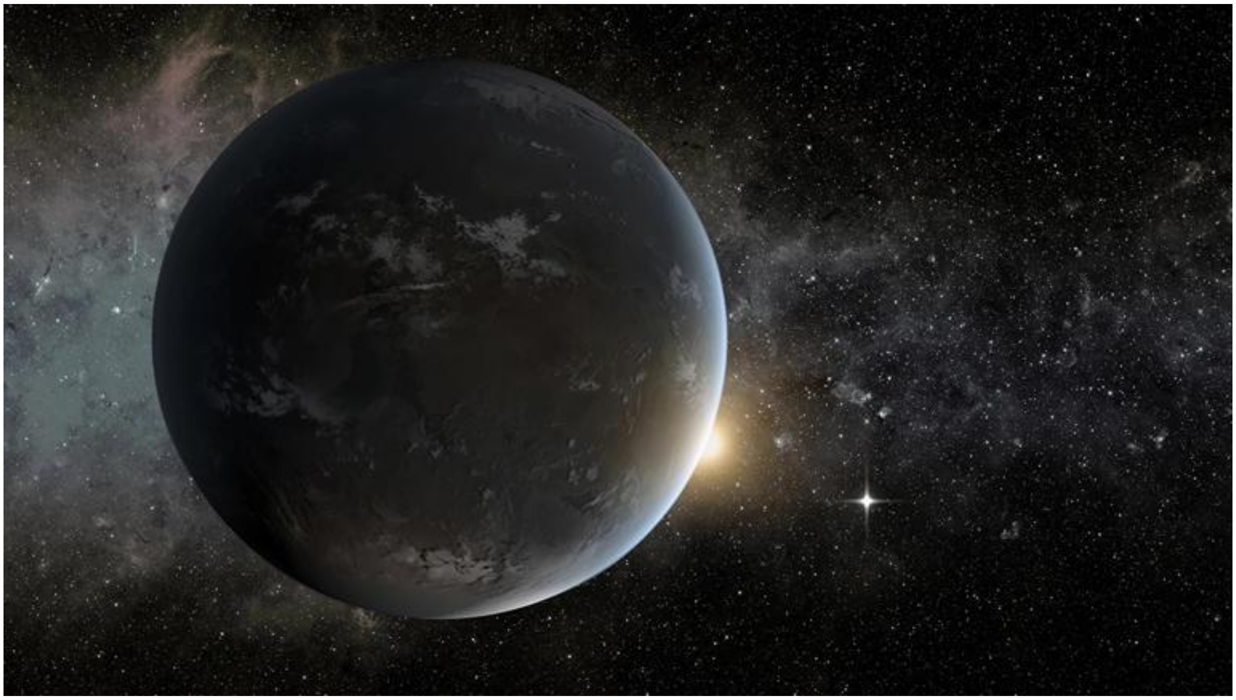
Earth's "older cousin"



((Image credit: NASA))

The exoplanet Kepler-452 b appears so similar to our home planet that NASA has dubbed the world "Earth's older cousin." The rocky exoplanet orbits a sunlike star at virtually the same distance that our planet orbits the sun, with a year there lasting about 384 days. That puts the planet firmly in the habitable zone, where liquid water could form on its surface. Sadly, our cousin will remain estranged for a good while longer: At nearly 1,800 light-years from Earth, the planet would take at least 30 million years to reach by spacecraft.

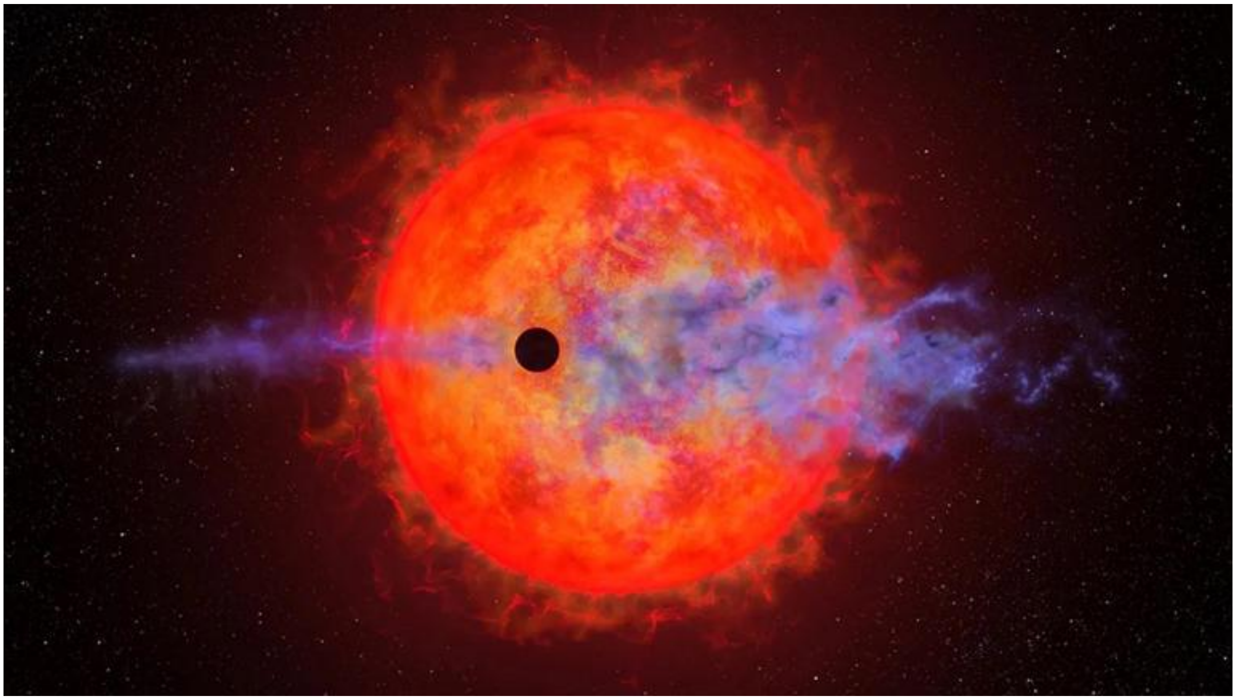
The bizarrely close sibling planets



((Image credit: NASA))

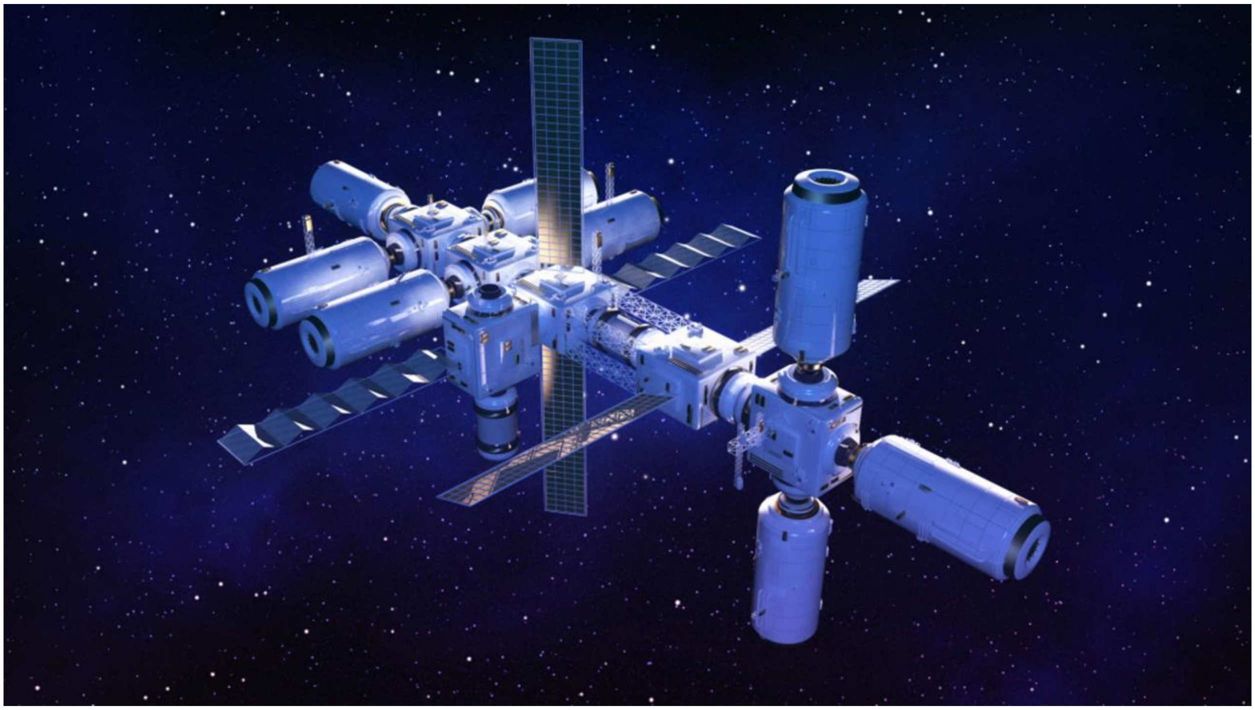
The exoplanet Kepler-36b is a rocky world that's about 1.5 times the size of Earth and orbits bizarrely close to its neighboring world, the Neptune-like exoplanet Kepler-36c. The two alien worlds make extremely close approaches to each other every 97 days, on average; during those cosmic family reunions, the two planets are separated by less than five Earth-moon distances. These ultraclose encounters exert tremendous tidal forces on the sibling planets, possibly promoting active volcanism on the rocky Kepler-36b.

The unlucky planet around a toddler star



(Image credit: NASA, ESA, Joseph Olmsted (STScI))

The exoplanet AU Microscopii b, located about 32 light-years from Earth, is unlucky enough to have formed a scant 6 million miles (9.6 million km) from its host star — an extremely young, hot, temperamental red dwarf. Estimated to be just 23 million years old, the star is a mere toddler in cosmic terms. (The sun, by comparison, is 4.6 billion years old.) The young star routinely erupts with blasts of radiation thousands of times stronger than the worst solar flares the sun can spit out — and poor AU Microscopii b is often in the firing line. Astronomers have noticed huge globs of planetary material orbiting near the distant world, suggesting that the temperamental star is blasting away pieces of the planet's atmosphere bit by bit.



Axiom Station: The Future of Space

© Image: Innovation News Network

The **Axiom Station** is set to become the first commercial space station, with construction already underway. This ambitious project aims to replace the International Space Station as it nears the end of its operational life. Axiom will consist of multiple modules, including research and habitation spaces, and is expected to launch in 2026.

As the first commercial space station, Axiom represents a significant step forward in space exploration and research. With plans for pharmaceutical production and other advanced facilities, this station will pave the way for future endeavors in space.

Scientists have found a “weird” galaxy that could help explain how the universe we know began.

It was spotted by scientists using Nasa’s James Webb Space Telescope, who noted that one galaxy had an odd light signature, which seemed to suggest its gas was shining brighter than its stars. No such galaxy has ever been seen before.

The galaxy existed around a billion years after the big bang. And researchers believe that it could be a missing part of galactic evolution, showing the time between the first stars in the universe and the well-established galaxies that we know.

“My first thought in looking at the galaxy’s spectrum was, ‘that’s weird,’ which is exactly what the Webb telescope was designed to reveal: totally new phenomena in the early universe that will help us understand how the cosmic story began,” said lead researcher Alex Cameron of the University of Oxford.

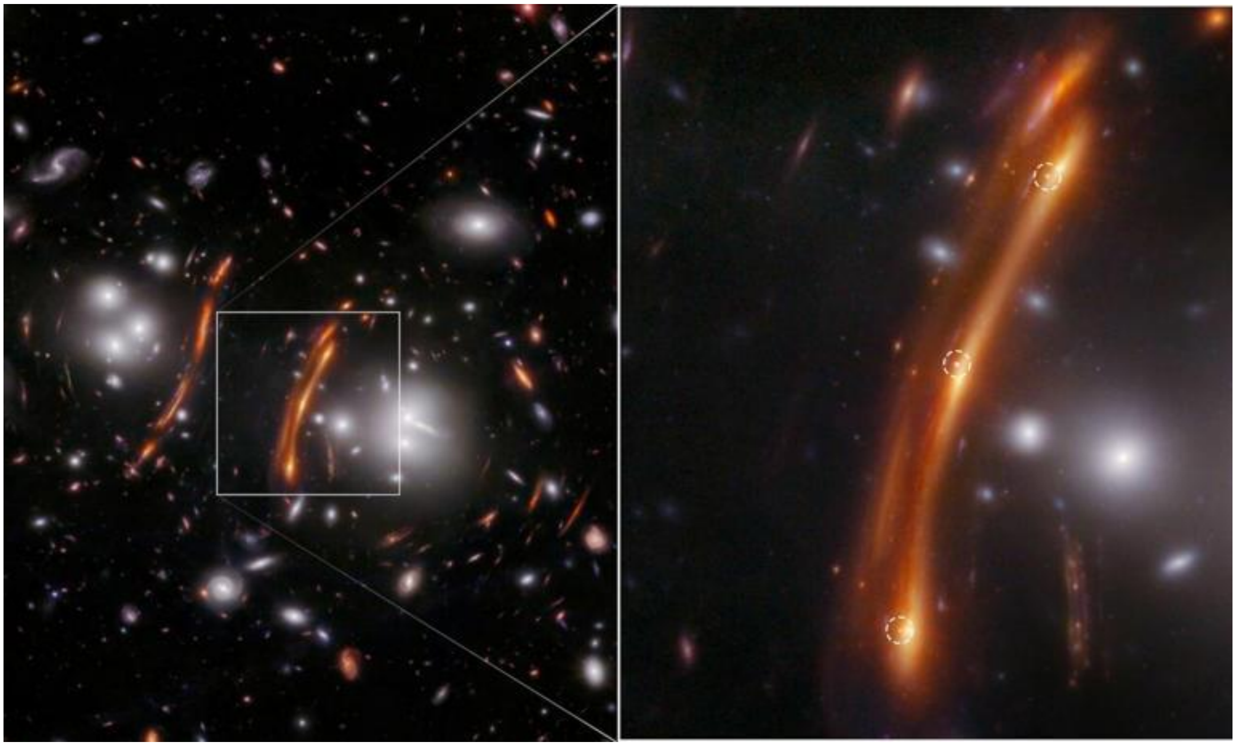
Examining the data, the team created computer models of what would happen if cosmic gas clouds were being heated by very hot, massive stars, so that the gas outshone the stars themselves. Those models matched the observations from the Webb telescope almost exactly.

Researchers believe that the galaxy is intensely forming stars inside a cloud of gas. That cloud is hit by so much light from the stars being created that it shines brightly across the universe so that researchers can see it.

The newly discovered galaxy – which has been named galaxy 9422 – remains a mystery in many ways. It is not clear how representative of galaxies at this point of the universe it is, for instance, or how it might emerge from galaxies at even earlier points in their evolution.

“It’s a very exciting time, to be able to use the Webb telescope to explore this time in the universe that was once inaccessible,” said Cameron. “We are just at the beginning of new discoveries and understanding.”

The research is described in a new paper, ‘Nebular dominated galaxies: insights into the stellar initial mass function at high redshift’, published in the *Monthly Notices of the Royal Astronomical Society*.



Webb image showing the appearances of a lensed supernova. Credit: NASA, ESA, CSA, STScI

We've known the universe is expanding for a long time. The first solid paper demonstrating cosmic expansion was published by Edwin Hubble in 1929, based on observations made by Vesto Slipher, Milton Humason, and Henrietta Leavitt.

Because of this, the rate of cosmic expansion is known as the Hubble constant, or Hubble parameter, H_0. From this parameter, you can calculate things such as the age of the universe since the Big Bang, so knowing the value of H_0 is central to our understanding of modern cosmology.

Early on, the measured value of the Hubble parameter varied widely. Hubble's initial value was on the order of 500 (km/s)/Mpc. By the 1960s, the value settled down to between 50 and 90 (km/s)/Mpc, where it stayed for most of the 20th century. It was difficult to get more precise because our methods of calculating it were limited.

All of these were based on the cosmic distance ladder, which uses a series of observations to calculate ever greater cosmic distances, each building on the previous method. But in the past few decades we got pretty good at it, and the Hubble value seemed to settle around 70 (km/s)/Mpc. After that, things started to get…problematic.

With satellites such as WMAP and Planck we started to get high-resolution maps of the cosmic microwave background. From fluctuations in this background we have a new way to measure H_0 and get a value of 67–68 (km/s)/Mpc. At the same time, observations of distant supernovae and the cosmic distance ladder pin down the value to 73–75 (km/s)/Mpc.

Both methods are quite precise, and yet they entirely disagree. This disagreement is now known as the Hubble tension problem, and it is the most bothersome mystery in cosmology.

We aren't sure what causes the Hubble tension. It might mean that one or more of our observation methods are fundamentally flawed, or it might mean there is something about dark energy and cosmic expansion that we really don't understand.

But astronomers generally agree that one way to address this mystery is to look for ways to measure H_0 that are independent of both the cosmic background and the cosmic distance ladder. One such method involves gravitational lensing.

Gravitational lensing occurs because gravity warps space, meaning that the path of light can be deflected by the presence of a large mass. So, for example, if a distant galaxy happens to be behind a closer galaxy from our vantage point, we see a gravitationally distorted view of the distant galaxy or even multiple images of the galaxy.

The interesting thing about the multiple image effect is that the light from each image travels a different path around the closer galaxy, each with a different distance. Since the speed of light is finite, this means each image gives us a view of the galaxy at different times in history.

This doesn't matter much for galaxies, but for supernovae it means gravitational lensing can let us observe the same supernova multiple times. By calculating the path of each supernova image we can determine the relative distance of each path, and by timing the appearance of each image we can determine the actual distance. This gives us a measurement that is independent of the cosmic distance ladder, giving us a new way to measure the Hubble parameter.

This method has been used a couple of times, but the uncertainties of their Hubble values weren't small enough to address the Hubble tension. However, a new study using this method is precise enough. The work is published on the *arXiv* preprint server.

The study is based on JWST images of a Type Ia supernova named SN H0pe. It is one of the most distant supernovae ever observed, and thanks to the less-distant galaxy cluster G165, the team captured three lensed images of SN H0pe. With their timing, observed brightness, and calculated paths, the team calculated H_0 to be 70–83 (km/s)/Mpc. This still has a higher uncertainty than other methods, but it agrees with the usual distance ladder method. It also clearly disagrees with the cosmic microwave background method.

Despite H0pe, the Hubble tension is very real. If anything, this new result makes the issue even more troublesome. There is something about cosmic expansion we don't understand, and it's now clear that better observations will not solve this mystery on their own.

More information: Massimo Pascale et al, SN H0pe: The First Measurement of H_0 from a Multiply-Imaged Type Ia Supernova, Discovered by JWST, *arXiv* (2024). DOI: 10.48550/arxiv.2403.18902

Provided by Universe Today

In a groundbreaking discovery, the James Webb Space Telescope (JWST) has presented data that directly challenges our current understanding of the universe. For years, cosmologists have pegged the universe's age at approximately 13.8 billion years. Yet, the new JWST findings suggest that this may be a vast underestimation. But how has one telescope managed to disrupt such a long-held belief?

The universe's secrets are vast, but none has been as puzzling as the presence of 'impossible early galaxies'—so named due to their peculiar formation periods.

According to existing models, these galaxies, emerging during the cosmic dawn, roughly 500 to 800 million years post-big bang, shouldn't have evolved disks and bulges so quickly. "It's akin to seeing a toddler with the wisdom of an octogenarian," says a scientist, explaining the paradox.

For years, cosmologists have pegged the universe's age at approximately 13.8 billion years. (CREDIT: CC BY-SA 3.0)© The Brighter Side of News

Yet, there they are: young galaxies appearing as if they've undergone vast periods of evolution. Complicating the picture further, some smaller galaxies seem to have greater mass than their larger counterparts, going against conventional wisdom.

Unlocking the Redshift Puzzle

To understand the age of the universe, one must first grasp the concept of redshift in the light emitted by far-off galaxies. Much like the Doppler effect in sound, wherein noises from an approaching source seem higher-pitched and those from a receding source seem lower-pitched, light too experiences frequency shifts. In this context, a redshift indicates a celestial body moving away from us. The more distant the galaxy, the more pronounced this redshift becomes.

Astronomers found the largest water reservoir in the universe - 140 trillion times more water than on Earth Major discovery about the origins of matter in the universe Dark matter doesn't exist in our universe, study finds

Historically, a hypothesis known as the 'tired light' theory suggested that light loses energy during its long cosmic journeys, leading to the redshift. However, as it failed to explain numerous observations, this theory was largely dismissed.

Expansion: The Key to the Universe's Age

The real game-changer in understanding redshift was the realization of the Doppler effect's role in it. Distinct galaxies moving away from us at velocities directly proportional to their distance hinted at a universe constantly expanding.

This understanding was solidified in 1964, when Arno Penzias and Robert Wilson of Bell Labs stumbled upon the cosmic microwave background radiation—a discovery that further discredited the 'steady-state' model and gave credence to the expanding universe theory.

New research proposes a model that determines the universe’s age to be 26.7 billion years, which accounts for the James Webb Space Telescope’s© The Brighter Side of News

The universe's age largely hinges on its rate of expansion. Data from the 1990s' Hubble Space Telescope launch saw estimates ranging from 7 billion to 20 billion years. It was only later that a consensus was reached, placing the age at 13.8 billion years.

Challenging the Status Quo

While previous studies have attempted to address the enigma of 'impossible galaxies' using the 'tired light' model, they've been largely unsuccessful, often falling short in explaining other cosmic phenomena like supernovae redshifts.

"I attempted to marry the conventional big-bang model with the tired light theory, hoping to account for both supernovae and JWST data. While this expanded our universe's age to 19.3 billion years, it couldn’t entirely account for the JWST data," says Rajendra Gupta from the University of Ottawa.

A galaxy estimated to be as young as 500 million years old, making it one of the youngest galaxies seen. (CREDIT: NASA/ESA Hubble Space Telescope)© The Brighter Side of News

However, combining the tired light theory with an evolving cosmological model based on the evolving coupling constants (proposed by British physicist Paul Dirac in 1937) yielded better results. This new hybrid model both accounted for the JWST's observations and bumped the universe's age to a staggering 26.7 billion years.

Historical Context: A Meeting of Models

The technique of blending models isn't novel. Historically, light was thought to propagate as particles, as suggested by Sir Isaac Newton.

This theory persisted until the 19th century when the wave theory of light emerged, explaining diffraction patterns more effectively. Albert Einstein later revived the particle-like nature of light, revealing that light could demonstrate both particle and wave characteristics.

In another approach, estimating the universe's age involves analyzing the oldest stars in our galaxy’s globular clusters, assuming that all galaxies initiated formation simultaneously. Yet, some stars, like Methuselah, believed to be the galaxy's oldest, defy this with their computed age surpassing the universally accepted 13.8 billion years.

Reimagining the Universe

Although the Hubble Space Telescope had already hinted at the 'impossible early galaxy' conundrum, the JWST's launch in December 2021 fortified these claims.

Many in the astronomy community have tried to stick to the big-bang model, attempting explanations that condense timelines or posit rapid mass accrual in black holes. Yet, the tide seems to be shifting.

As the JWST data continues to challenge the cosmological status quo, the scientific community is leaning towards embracing new physics. While these findings have shaken foundational beliefs, they also promise a future where our understanding of the universe is deeper and more nuanced than ever before.

The early universe was a chaotic place after the Big Bang. It was incredibly hot and dense, far beyond anything we can imagine.

Astronomers are working to understand how galaxies formed and changed over time, and recent observations have made this puzzle even more complex.

Earth-based telescope has discovered a Milky-Way-like galaxy that existed when the Universe was only 700 million years old.

Chile’s Atacama Large Millimeter/submillimeter Array (ALMA) spotted this most distant disc galaxy dubbed REBELS-25.

This discovery questions our current knowledge about how galaxies form.

Until now, astronomers believed that the early universe galaxies were typically chaotic, and clumpy. They lacked the clear spiral or elliptical structures that are common in galaxies today. However, REBELS-25 seems to be surprisingly orderly.

Its structure and rotation are similar to our own Milky Way, which is unexpected for such an early galaxy.

“According to our understanding of galaxy formation, we expect most early galaxies to be small and messy looking,” said Jacqueline Hodge, an astronomer at Leiden University, the Netherlands, and co-author of the study.

Rotating disc galaxy like Milky Way

The light we see from this galaxy left it when the universe was young, only 700 million years old after the Big Bang. This is just 5 percent of the age of the universe now, which is 13.8 billion years old.

Early galaxies were chaotic, but over time, they collided and merged, becoming smoother and more organized. Scientists believe that it takes a long cosmic timescale—billions of years—for a galaxy to become as well-organized as our Milky Way, which has a rotating disk shape with spiral arms. But the discovery of REBELS-25 shows that this might not be true.

Related video: Newly Discovered Galaxy Cluster Is 8.4 Billion Light Years Away And Unexpectedly Calm (Dailymotion)
Astronomers’ observations suggest REBELS-25 to be “the most distant strongly rotating disc galaxy ever discovered.”

“Seeing a galaxy with such similarities to our own Milky Way, that is strongly rotation-dominated, challenges our understanding of how quickly galaxies in the early Universe evolve into the orderly galaxies of today’s cosmos,” said Lucie Rowland, a doctoral student at Leiden University and first author of the study.

ALMA observations

The initial ALMA observations of REBELS-25 suggested rotation, but the data wasn't clear enough to be certain.

To better understand the galaxy's structure and movement, the team conducted additional ALMA observations with higher resolution. The follow-up observations confirmed its unique characteristics.

"ALMA is the only telescope in existence with the sensitivity and resolution to achieve this," said Renske Smit, co-author from Liverpool John Moores University in the UK.

Unexpectedly, the data suggested that REBELS-25 might have more complex features similar to the Milky Way. For instance, the observations suggest the presence of an elongated bar-like structure at its center and possibly even early signs of spiral arms.

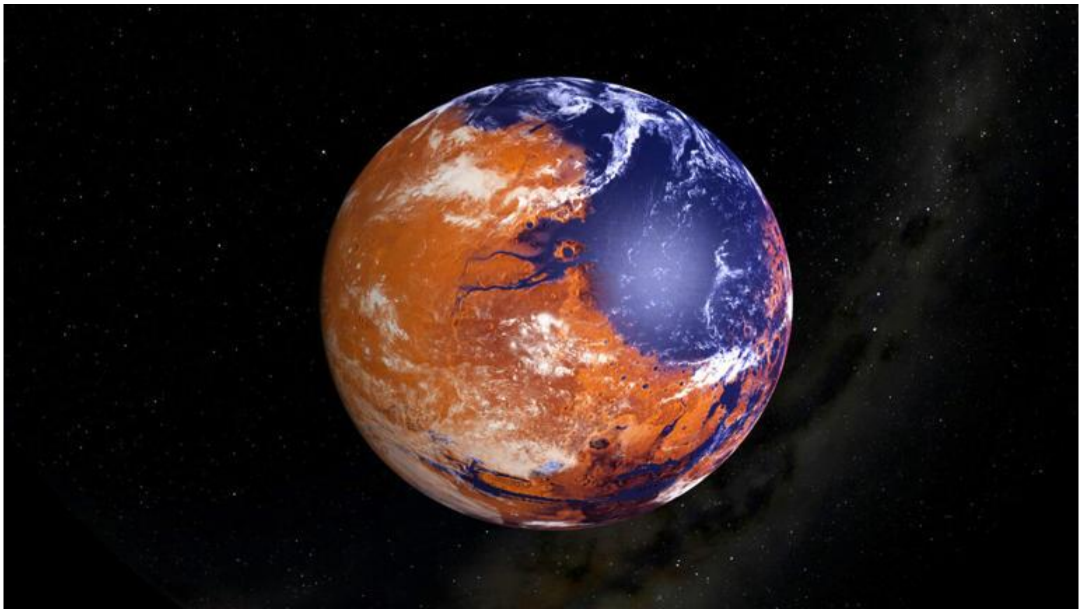
Found mostly in spiral galaxies, the central bar is a long, narrow region of stars that extends from the galaxy's core to its outer disk. However, further observations are required to verify these findings.

"Finding further evidence of more evolved structures would be an exciting discovery, as it would be the most distant galaxy with such structures observed to date," said Rowland in the press release.

Learning more about REBELS-25 and other early spiral galaxies could help astronomers understand how galaxies first formed and how the whole universe changed over time.

Ever since its launch, the far-seeing James Webb Space Telescope (JWST) has been helping in decoding the mysteries of early galaxy formation and evolution. The use of Webb may also help to understand how the early spiral galaxies turned out to be so orderly in such short cosmic timescales.

The findings were published in the journal *Monthly Notices of the Royal Astronomical Society.*


This is an artist's concept of an early Mars with liquid water (blue areas) on its surface. Ancient regions on Mars bear signs of abundant water - such as features resembling valleys and deltas, and minerals that only form in the presence of liquid water. Scientists think that billions of years ago, the atmosphere of Mars was much denser and warm enough to form rivers, lakes, and perhaps even oceans of water. As the planet cooled and lost its global magnetic field, the solar wind and solar storms eroded away to space a significant amount of the planet’s atmosphere, turning Mars into the cold, arid desert we see today. Credit: NASA/MAVEN/The Lunar and Planetary Institute

NASA's Curiosity rover, currently exploring Gale crater on Mars, is providing new details about how the ancient Martian climate went from potentially suitable for life—with evidence for widespread liquid water on the surface—to a surface that is inhospitable to terrestrial life as we know it.

Although the surface of Mars is frigid and hostile to life today, NASA's robotic explorers at Mars are searching for clues as to whether it could have supported life in the distant past. Researchers used instruments on board Curiosity to measure the isotopic composition of carbon-rich minerals (carbonates) found in Gale crater and discovered new insights into how the Red Planet's ancient climate transformed.

"The isotope values of these carbonates point toward extreme amounts of evaporation, suggesting that these carbonates likely formed in a climate that could only support transient liquid water," said David Burtt of NASA's Goddard

Space Flight Center in Greenbelt, Maryland, and lead author of a paper describing this research published in the *Proceedings of the National Academy of Sciences*.

"Our samples are not consistent with an ancient environment with life (biosphere) on the surface of Mars, although this does not rule out the possibility of an underground biosphere or a surface biosphere that began and ended before these carbonates formed."

Isotopes are versions of an element with different masses. As water evaporated, light versions of carbon and oxygen were more likely to escape into the atmosphere, while the heavy versions were left behind more often, accumulating into higher abundances, and in this case, eventually being incorporated into the carbonate rocks.

Scientists are interested in carbonates because of their proven ability to act as climate records. These minerals can retain signatures of the environments in which they formed, including the temperature and acidity of the water, and the composition of the water and the atmosphere.

The paper proposes two formation mechanisms for carbonates found at Gale. In the first scenario, carbonates are formed through a series of wet-dry cycles within Gale crater. In the second, carbonates are formed in very salty water under cold, ice-forming (cryogenic) conditions in Gale crater.

"These formation mechanisms represent two different climate regimes that may present different habitability scenarios," said Jennifer Stern of NASA Goddard, a co-author of the paper. "Wet-dry cycling would indicate alternation between more-habitable and less-habitable environments, while cryogenic temperatures in the mid-latitudes of Mars would indicate a less-habitable environment where most water is locked up in ice and not available for chemistry or biology, and what is there is extremely salty and unpleasant for life."

These climate scenarios for ancient Mars have been proposed before, based on the presence of certain minerals, global-scale modeling, and the identification of rock formations. This result is the first to add isotopic evidence from rock samples in support of the scenarios.

The heavy isotope values in the Martian carbonates are significantly higher than what's seen on Earth for carbonate minerals and are the heaviest carbon and oxygen isotope values recorded for any Mars materials. In fact, according to the team, both the wet-dry and the cold-salty climates are required to form carbonates that are so enriched in heavy carbon and oxygen.

"The fact that these carbon and oxygen isotope values are higher than anything else measured on Earth or Mars points towards a process (or processes) being taken to an extreme," said Burtt.

"While evaporation can cause significant oxygen isotope changes on Earth, the changes measured in this study were two to three times larger. This means two things: 1) there was an extreme degree of evaporation driving these isotope values to be so heavy, and 2) these heavier values were preserved so any processes that would create lighter isotope values must have been significantly smaller in magnitude," he continued.

This discovery was made using the Sample Analysis at Mars (SAM) and Tunable Laser Spectrometer (TLS) instruments aboard the Curiosity rover. SAM heats samples up to nearly 1,652 degrees Fahrenheit (almost 900°C) and then the TLS is used to analyze the gases that are produced during that heating phase.

More information: David G. Burtt et al, Highly enriched carbon and oxygen isotopes in carbonate-derived CO_2 at Gale crater, Mars, *Proceedings of the National Academy of Sciences* (2024). DOI: 10.1073/pnas.2321342121

Provided by NASA

If you want to pinpoint your place in the universe, start with your cosmic address. You live on Earth->Solar System->Milky Way Galaxy->Local Cluster->Virgo Cluster->Virgo Supercluster->Laniakea. Thanks to new deep sky surveys, astronomers now think all those places are part of an even bigger cosmic structure in the "neighborhood" called The Shapley Concentration.

A slice of the Laniakea Supercluster, a local basin of attraction. This structure contains many galaxies and clusters, including our own Milky Way Galaxy. Credit: SDvision interactive visualization software by DP at CEA/Saclay, France

Astronomers refer to the Shapley Concentration as a "basin of attraction." That's a region loaded with mass that acts as an "attractor." It's a region containing many clusters and groups of galaxies and comprises the greatest concentration of matter in the local universe. All those galaxies, plus dark matter, lend their gravitational influence to the Concentration.

Several superclusters were revealed by the 2dF Galaxy Redshift Survey. This contains the structure known as the "Sloan Great Wall." Credit: 2dF Galaxy Redshift Survey

There are many of these basins in the universe, including Laniakea. Astronomers are working to survey them more precisely, which should help provide a more precise map of the largest structures in the universe.

One group, led by astronomer R. Brent Tully of the University of Hawai'i measured the motions of some 56,000 galaxies to understand these basins and their distribution in space. "Our universe is like a giant web, with galaxies lying along filaments and clustering at nodes where gravitational forces pull them together," said Tully.

"Just as water flows within watersheds, galaxies flow within cosmic basins of attraction. The discovery of these larger basins could fundamentally change our understanding of cosmic structure." The paper is published in the journal *Nature Astronomy*.

Cosmic flows and mapping structures

Tully's team is called CosmicFlows and they study the motions through space of those distant galaxies. The team's "redshift" surveys revealed a possible shift in the size and scale of our local galactic basin of attraction. We already know that we "live" in Laniakea, which is about 500 million light-years across. However, the motions of other clusters indicate there's a larger "attractor" directing the cluster flow.

The CosmicFlows data suggest that we could be part of the Shapley Concentration, which could be 10 times the volume of Laniakea. It's about half the volume of the largest structure in space, known as "the Great Wall," which is a string of galaxies stretching across 1.4 billion light-years.

The Shapley Concentration was first observed by astronomer Harlow Shapley in the 1930s as a "cloud" in the constellation Centaurus. This supercluster appears along the direction of motion of the Local Group of galaxies (where we live). Because of that, scientists speculated that it could be influencing our galaxy's peculiar motion.

Interestingly, the Virgo Supercluster (and the Local Group and Milky Way galaxy) appears to be moving toward the Shapley Concentration. The surveys that Tully and others are doing should confirm that motion toward whatever is attracting them.

Exploring ever-larger structures in the universe

Where do these basins of attraction come from? In one sense, they're as old as the universe and its cosmic web of matter that Tully references. The seeds for the web and those basins of attraction were planted some 13.8 billion years ago. After the Big Bang, the infant universe was in a hot dense state. As it expanded and cooled, the density of matter started to fluctuate.

There were tiny differences in those density fluctuations. Think of them as the earliest "seeds" of galaxies, galaxy clusters, and even vaster structures that we see in today's universe.

As astronomers survey the sky, they find evidence for all those different structures. Now, they have to explain them. The idea that the Shapley Concentration is the large basin that our Laniakea belongs to means that current cosmological models don't quite explain its existence.

"This discovery presents a challenge: our cosmic surveys may not yet be large enough to map the full extent of these immense basins," said UH astronomer Ehsan Kourkchi. "We are still gazing through giant eyes, but even these eyes may not be big enough to capture the full picture of our universe."

Measuring the attractors

The main actor in all these galaxies, clusters, and superclusters, is gravity. The more mass, the more gravity influences motions and matter distribution. For these basins of attraction, Tully's research team examined their impact on galaxy motions in the region. The basins exert a sort of "tug of war" on galaxies that lie between them. That influences their motions.

In particular, redshift surveys like Tully's team is doing will map the radial motion (along the line of sight), velocities (how fast they're moving), and other related motions. By mapping the velocities of galaxies throughout our local universe, the team can define the region of space where each supercluster dominates.

Of course, these motions are tricky to define. That's why the team does different types of measurements. They aren't mapping just the luminous material in galaxies. They also have to take into account the inferred existence of dark matter.

There are other complications as well. For example, not all galaxies are the same—that is, they differ in their shapes (morphology) and matter density. Astronomers can get around this by measuring something called "galaxy peculiar velocity." That's the difference between its actual velocity and the expected "Hubble flow" velocity (which reflects gravitational interactions between galaxies).

The results of the Tully team surveys should provide ever more precise 3D maps of these regions of space. That includes their structures as well as their motions and velocities. Those maps, in turn, should give greater insight into the distribution of all matter (including cold dark matter) throughout the universe.

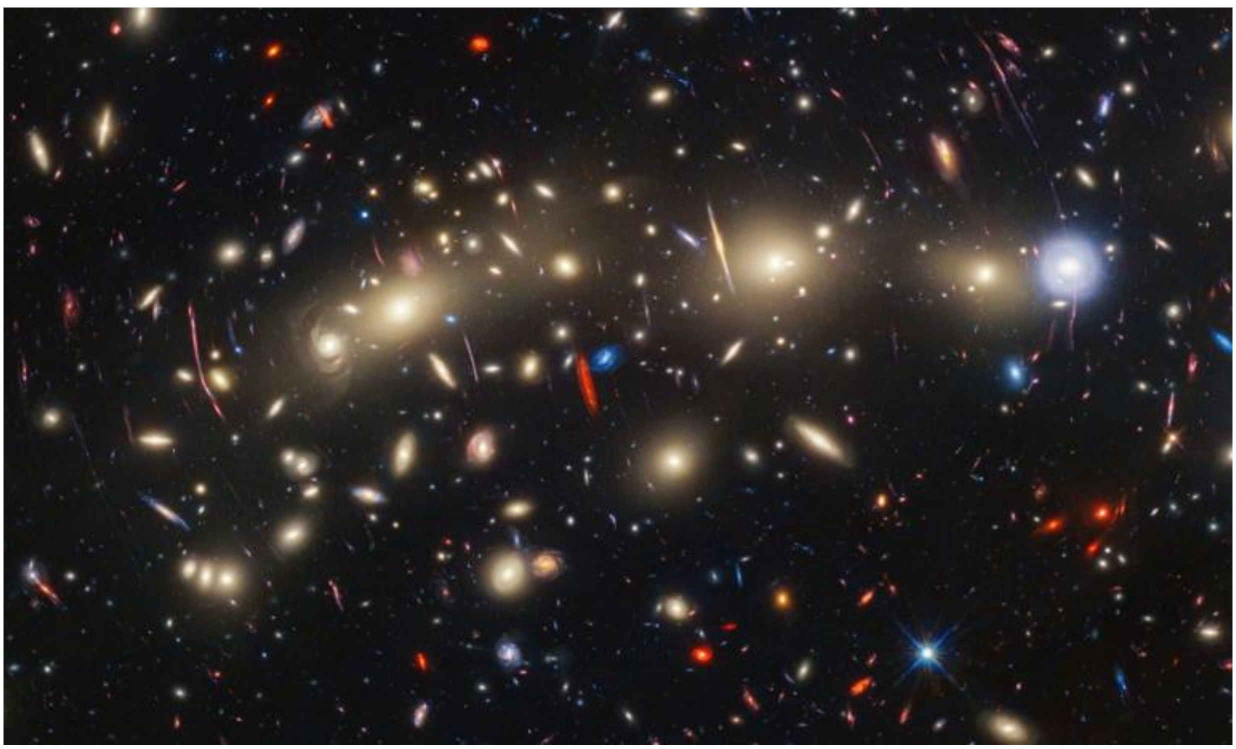
More information: A. Valade et al, Identification of basins of attraction in the local Universe, *Nature Astronomy* (2024). DOI: 10.1038/s41550-024-02370-0

Provided by Universe Today

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.

Related Stories

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.

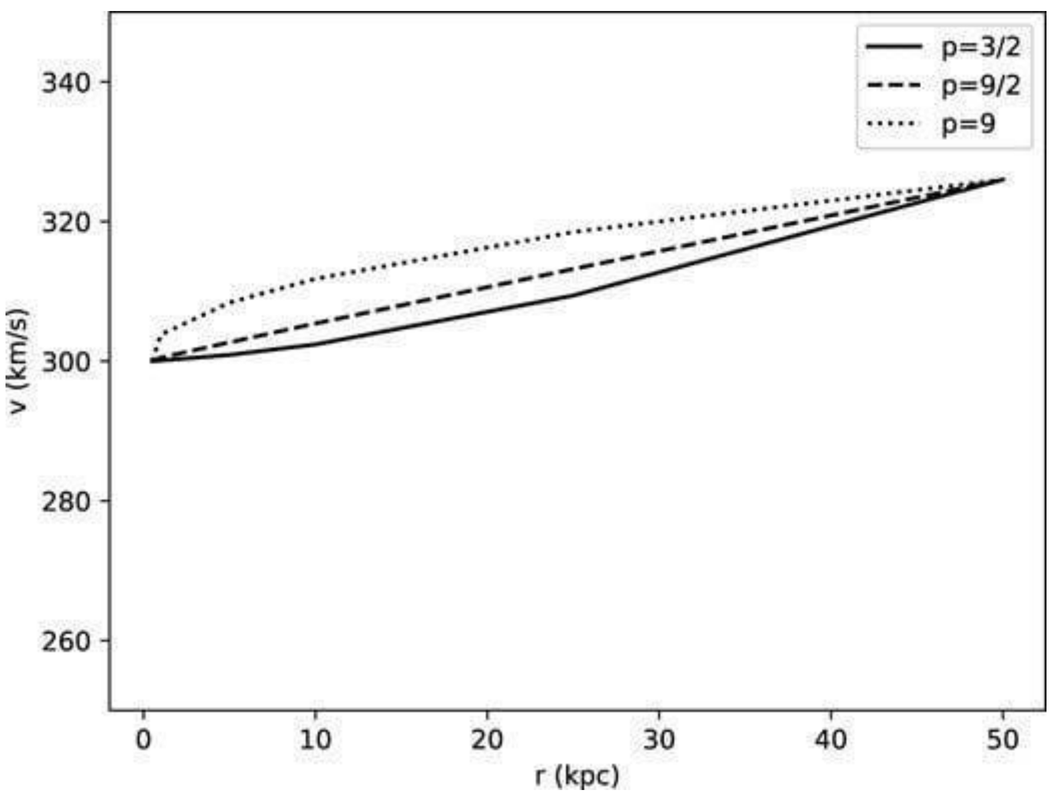
“Gravitational bending of light by a set of concentric singular shells comprising a galaxy or cluster is due to a ray of light being deflected slightly inwards — that is, towards the center of the large-scale structure, or the set of shells — as it passes through one shell,” Lieu notes. “The sum total 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.”

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.

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.

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.

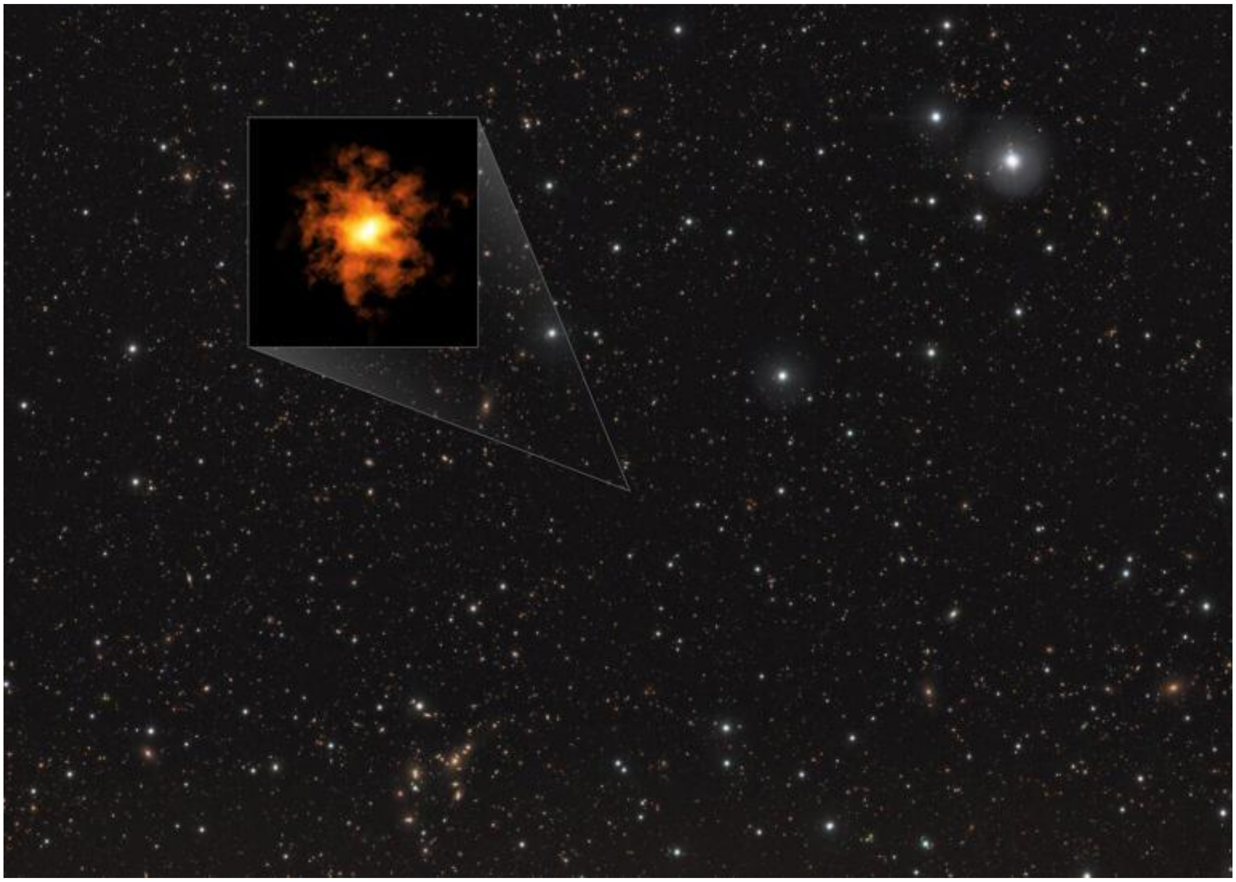
Imagine archaeologists excavating an old cave where they believed they'd see primitive ape-like ancestors and instead found a fossil almost indistinguishable from a modern human.

That might be what astronomers felt when they discovered an evolved galaxy similar to the Milky Way, but lighting up space when the universe was merely 700 million years old. Given that most scientists believe the universe is 13.8 billion today, that period could still be considered the universe's toddler era, shortly after the Big Bang.

Using the Atacama Large Millimeter/submillimeter Array, or ALMA, an observatory in Chile's Atacama Desert, researchers discovered a galaxy that appears to be as orderly as contemporary galaxies. The team named the cosmic wunderkind REBELS-25 and believe it to be the most distant rotating disk galaxy found so far. The findings were published in the *Monthly Notices of the Royal Astronomical Society* on Monday.

"According to our understanding of galaxy formation, we expect most early galaxies to be small and messy looking," said Jacqueline Hodge, a co-author of the paper at Leiden University in the Netherlands, in a statement.

The discovery is not only a record-breaker but another piece of mounting evidence, thanks to the James Webb Space Telescope, that suggests cosmologists need to revise their previous notions about galaxy evolution. Up until recently, theorists have believed a galaxy as elegant as the Milky Way — having a rotating disk and spiral arms, for example — would require billions of years of evolution.


Astronomers found a rotating disk galaxy, dubbed REBELS-25, only 700 million years after the Big Bang.

Just how similar REBELS-25, short for ALMA's Reionization Era Bright Emission Line Survey program, is to our home galaxy may become clearer soon. The study found hints of other mature traits, such as a central elongated bar and spiral arms. The research team intends to conduct subsequent studies on the ancient galaxy to confirm those features.

Such structures, if proven, would make REBELS-25 the most distant barred spiral galaxy known. That would beat the record holder, Ceers-2112, discovered just last year with NASA's Webb telescope. The detection placed Ceers-2112 at 2 billion years after the Big Bang.

Astronomers previously thought it took many billions of years for galaxies to become stable enough to develop so-called "bars," ribbons of stars and gas that cut across the core of a galaxy. Bars form in spiral galaxies when the orbits of stars near the galaxy's nucleus become erratic and stretched out. As the stars' orbits get larger, they start to fall in line, so to speak.

Bars grow as their gravity collects more nearby stars. Eventually, a large percentage of the stars within the galaxy's heart get caught up in the bar. When astronomers detect a star bar, they usually interpret it to mean the galaxy has reached a settled phase.

It was not that long ago that NASA proclaimed barred spiral galaxies were "latecomers" to the universe, based on the Cosmic Evolution Survey. The study, led by Kartik Sheth of the Spitzer Science Center at Caltech in Pasadena, looked at more than 2,000 spiral galaxies from a Hubble Space Telescope census.

That sample found far fewer Milky Way-like galaxies 7 billion years ago, when the universe was about half its current age. Only 20 percent of the spiral galaxies in the distant past possessed bars, compared to nearly 70 percent of their more-modern cohort, according to the prior research. Those observations led astronomers to conclude that even massive galaxies closer to the dawn of time would have been more clumpy, with ill-defined structures.

A spiral galaxy usually has a rotating disk with spiral 'arms' that extend from a dense center.

Hubble had limitations, though, observing only as far back as about 8 or 9 billion years ago. With the enhanced sensitivity of the Webb telescope, detecting light that has stretched into the infrared by the universe's expansion, researchers have since seen bar development even longer ago.

A team, led by Durham University in the United Kingdom, used Webb data to study bar formation in galaxies as they would have looked 8 to 11.5 billion years ago. Of 368 disk galaxies sampled, those scientists saw two times more with bars than Hubble, according to their paper published in April.

Lucie Rowland, lead author of the REBELS-25 paper, said this ancient galaxy, which doesn't fit the profile of an early galaxy, is living up to its name.

"Seeing a galaxy with such similarities to our own Milky Way, that is strongly rotation-dominated, challenges our understanding of how quickly galaxies in the early Universe evolve into the orderly galaxies of today's cosmos," she said.

The map was made after monitoring the galaxy for 13 years (Picture: Vista)

Astronomers have published a gigantic map of the Milky Way, unveiling discoveries that have changed their view of the galaxy 'forever'.

The infrared map contains more than 1.5 billion objects, including newborn stars, making it the most detailed one ever made.

Using the European Southern Observatory's (ESO) Visible and Infrared Survey Telescope for Astronomy (Vista) telescope, the scientists monitored the central regions of the Milky Way for more than 13 years.

Dante Minniti, an astrophysicist at Universidad Andres Bello in Chile who led the overall project, said: 'We made so many discoveries, we have changed the view of our galaxy forever.'

The data covers an area of the sky equivalent to 8,600 full moons, and contains about 10 times more objects than a previous map released by the same team back in 2012.

Observing infrared light also enables the telescope to spot very cold objects, which glow at these wavelengths, such as brown dwarfs – failed stars that do not have sustained nuclear fusion, or free-floating planets that do not orbit a star.

The Milky Way is filled with colours and formations of stars (Picture: PA)

The huge infrared map comes in at 500 terabytes of data, making it the largest observational project ever carried out with an ESO telescope.

Infrared light is invisible to the human eye, but it is emitted by all objects based on their temperature.

The telescope can detect and translate this energy into a visual image, creating the pictures that we see.

The map is made up of 200,000 images taken by Vista, which is located at the ESO’s Paranal Observatory in Chile.

Vista’s infrared camera can peer through the dust and gas that is spread throughout our galaxy, and is therefore able to see the radiation from the Milky Way’s most hidden places.

The astronomers started in 2010 and ended in the first half of 2023, spanning a total of 420 nights.

By observing each patch of the sky many times, the team was able to determine the locations of these objects, and also track how they move and whether their brightness changes.

Dr Oscar Gonzalez, senior project scientist at the UK Astronomy Technology Centre (UK ATC) and co-author on the new Astronomy and Astrophysics paper, said: ‘The completion of the largest infrared map of the Milky Way is a remarkable achievement for the astronomy community.

‘The data has provided unprecedented insights into the structure and composition of the Milky Way and will continue to open new avenues for future research that will enhance our understanding of the universe for years to come.’

When wading into the murky realm of theoretical physics, one of the more difficult concepts for scientists to explain is that of dark matter. It’s the invisible form of matter constantly eluding scientific hard proof, whose existence is suggested only by the circumstantial evidence we can measure around it. It doesn't interact with light — it's literally "dark."

As mysterious as dark matter may seem, however, most scientific theories assume its ingredients are pretty basic — just one weird, lightweight particle found all over the universe, that hardly ever touches other kinds of matter. But all that may now be up for debate.

A recent study published on the arXiv preprint database has thrown dark matter's theoretical simplicity out the window by researchers who may have actually figured out how to generate massive dark matter particles. Those particles, they propose, aren't lightweight at all and could come in all kinds of "species" — with their own "dark matter periodic table" of invisible elements, originally formed soon after the Big Bang after getting trapped in black holes. They dub this process "recycling."

As exciting as the researcher's proposed theory may be, however, the problem of actually detecting these particles remains the most pressing question and may still be a hurdle for cosmologists. The key to that detection may lay in understanding how dark matter was historically formed.

"The formation history of dark matter itself is more complex. This is the challenge for astronomers like myself," said cosmology professor Henk Hoekstra, of Leiden University. "Many different ideas for dark matter result in practically indistinguishable features and only direct detection experiments may be able to tell the difference. This paper now suggests that the formation process may be even more complex, which in turn may broaden the possibilities for detection."

The new theory's change in mass also ties dark matter to black hole formation more intimately, from previous assumptions that all dark matter particles are lightweight (known as WIMPs or weakly interacting massive particles) to the possibility that some might be ultraheavy. It's currently understood more widely that when fundamental forces of nature began to splinter off from each other during the Big Bang — creating gravity, electromagnetism, strong nuclear force and weak nuclear force — that splintering was not straightforward, but included some transitional states.

As LiveScience's Paul Sutter explains concisely, the underlying physics change at each one of these transitional phases then pockets of the universe would then exist where some older physics were in still in effect even though the rest of the universe around them had changed — like how bubbles in boiling water are trapped pockets of transitional air.

The researchers suggest that it was in these pockets of transitional physics that the once-lightweight dark matter particles could have gotten trapped, until they became so ultraheavy that they collapsed into black holes before evaporating through radiation.

While the idea of these heavier particles might seem to suggest they'd be easier to find for scientists, that may not actually be the case, and a bigger particle might not necessarily help observation efforts either. The University of British Columbia's Ludovic Van Waerbeke pointed out that this difference could potentially even cancel out new possibilities of detection.

"The model proposed in this paper assumes the existence of very massive dark matter particles. They are indeed very numerous, but because of their mass is greater than WIMPs' mass, their number density is also very low — much lower than WIMPs' number density, so they would escape direct detection as well," Van Waerbeke told Salon.

The problem of actually detecting dark matter particles, however, isn't something that every new model of dark matter looks to solve. This type of approach — known generally as an ad-hoc approach to scientific theory — may have its limitations, but it has also been foundational to exploring the basic assumption in the field to date.

"It is not a criticism. It is a general feature of dark matter models beyond WIMPs," Van Waerbeke said. "They postulate some 'dark sector' based on hypothetical dark matter physics, but it does not have any direct observational motivation."

Underneath the new theory's assumptions, however, is an even bigger question that could play a role in the quest to prove the existence of dark matter: If there really are a bunch of new particle types, does that also mean there could be a whole host of currently undetected laws of physics, operating silently this whole time? If so, it could form a periodic table, much like our own, that atlas of all known matter that includes everything from hydrogen to oganesson.

"It is hard to tell since the paper does not explore the astrophysical consequences of the model," Van Waerbeke said. "What comes to mind is the possible observational signature of the continuous injection of photons across the universe's history."

In other words, the question of "whether it could affect the physics of the cosmic microwave background or later, during the formation of the first stars — the so-called cosmic dawn," Van Waerbeke said.

And that history, as Hoekstra explained, could become more complicated to understand through the lens of the new theory. Still, there would likely be limits to the theory's implications on the laws of physics as we understand them.

"The process that is described acts only in the very early universe, so it does not change anything today," Hoekstra said. "Still, yet-unseen physics does operate under our noses, because dark matter flies through our bodies all the time."

We don't see a lot of aliens when we look up. But why? - Image credit: Vadim Sadovski/Shutterstock.com© IFL Science

A new study has proposed the latest in a long line of bleak solutions to why we haven't yet found signs of intelligent life out there in the universe.

The universe is a big place. With 200 billion trillion (ish) stars in the universe and 13.7 billion years that have elapsed since it all began, you might be wondering where all the alien civilizations are at. This is the basic question behind the Fermi paradox, the tension between our suspicions of the potential for life in the universe (given planets found in habitable zones, etc) and the fact that we have only found one planet with an intelligent (ish) species inhabiting it.

All sorts of solutions have been proposed for the Fermi Paradox, from the simple – life could be rare, and the differences in time and space too far to communicate – to aliens keeping us isolated in a sort of galactic zoo. Several claim that aliens simply wipe out other species rather than compete with them for resources and so everybody else tries to stay quiet, while other, equally bleak scenarios suggest that aliens don't need much help wiping themselves out, thank you very much.

The new paper is in the latter camp, suggesting that alien civilizations meet their ends long before they have a chance to get chatty with fellow intelligent life. According to the preprint paper, which has yet to be peer-reviewed, intelligent civilizations likely meet their end due to climate change on whatever planet they inhabit, on astronomically very short timetables.

In this universe we obey the laws of thermodynamics. Everything moves towards disorder, and no matter how efficient we try to make power generation, we will always produce waste heat. Technological civilizations will likely always encounter the problems humanity faces at the moment; a planet that is increasingly uninhabitable to it, and whatever creatures it shares the planet with.

"Our analysis suggests that, if the energy growth rate is of order 1 percent per year, the maximal lifetime of such putative technospheres is ephemeral compared to stellar evolution," the team writes in their paper. "The upper bound on the lifetime of technospheres is relatively insensitive to stellar spectral type, and is merely hundreds of years in duration."

If civilizations last just a thousand years at most, and are relatively rare, detecting their presence would be unlikely, and would offer a partial solution to the Fermi Paradox. According to the team, "we have not encountered technological species because they are rare at any given moment in time".

This isn't to say that we couldn't pick up signals from such civilizations, but it might mean that by the time we receive them they are likely dead, or long dead.

Detecting alien life, they suggest, may come from seeing the lasting damage a civilization did to their planet before they promptly destroyed themselves.

Before you add "alien ghosts" to your lists of things to worry about, the authors do suggest other possible trajectories for advanced civilizations. The team briefly considers options available to advanced and ever-expanding civilizations to combat this excess heat generation, such as altering the atmosphere with aerosols, altering their star, or nudging their planet into a preferable orbit. However, they suggest that civilizations can drastically increase their longevity by learning to live within their means, and reducing their energy consumption.

"If a species has opted for equilibrium, has learned to live in harmony with its surroundings, that species and its descendants could survive maybe up to a billion years," astrophysicist Manasvi Lingam, and co-author of the study, told Live Science.

Maybe we should try that, instead of becoming a space ghost for some similarly doomed intelligent alien species to detect.

Galaxies Are Bigger Than We Thought

Galaxies—those dazzling collections of stars, planets, and cosmic dust—are vast, much more immense than we could have ever imagined. As our technology advances and our knowledge of the universe deepens, we're discovering just how colossal these stellar systems truly are.

The Milky Way Is Over 200,000 Light-Years Across

New research has revealed that galaxies, including the Milky Way, are much larger than we thought—over 200,000 light-years across! Advanced imaging techniques have uncovered massive gas halos extending beyond visible spirals. This discovery reshapes our understanding of galactic size and complexity, suggesting a more complex cosmic network.

The Milky Way's Mass Is About 1.5 Trillion Solar Masses

Recent estimates reveal that the Milky Way's mass, including dark matter, is about 1.5 trillion solar masses. Though many remain undiscovered, this vast galaxy contains 200 billion stars and potentially over 100 billion planets. Updated data suggests galaxies weigh up to twice as much as earlier estimates due to hidden dark matter and unseen stars.

Galaxies Are Composed of About 90% Dark Matter

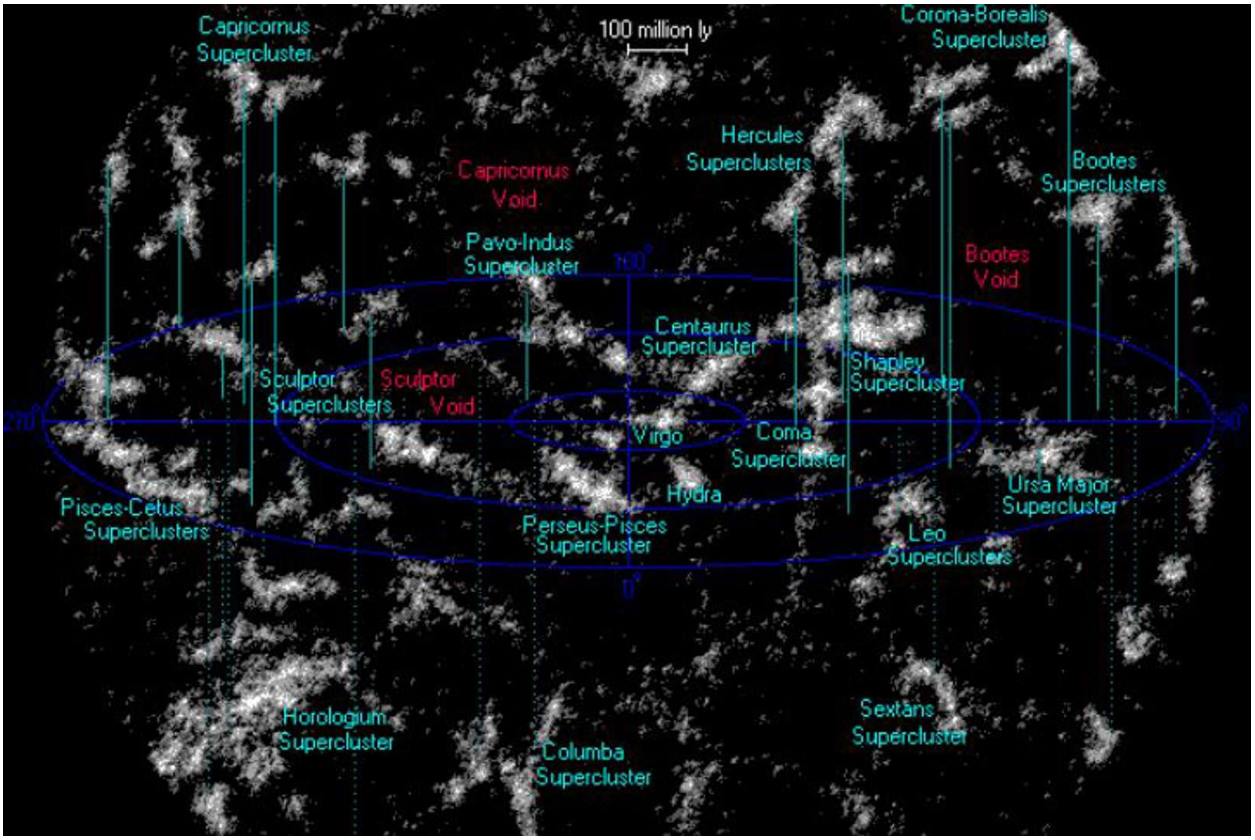
Galaxies are far more than their visible stars and gas. Composed of about 90% dark matter, these invisible halos extend far beyond what we see, making galaxies up to ten times larger. This dark matter is important in that it influences star orbits and stretches galactic influence across vast distances.

The Local Group Contains Over 50 Galaxies

The Local Group, which includes the Milky Way, is larger and more populated than once believed. Spanning about 10 million light-years, this cluster features three major galaxies: the Milky Way, the larger Andromeda, and the smaller Triangulum, along with around 50 dwarf galaxies.

Galaxy Mergers Create Mega-Galaxies

Galaxy mergers are surprisingly common, and when they happen, the resulting galaxies are much larger than either of the originals. The Milky Way itself is on a collision course with the Andromeda Galaxy, and the outcome will be a mega-galaxy beyond anything we've ever witnessed.



Galaxies Have Extensive Stellar Streams

Recent studies show that galaxies, including the Milky Way, have extensive stellar streams—long, diffuse structures from merging galaxies. These streams extend far beyond the visible boundaries of a galaxy, like the Sagittarius Stream, which extends over 100,000 light-years.

The Milky Way's Outer Boundaries Are Expanding

The Milky Way's outer reaches are bursting with discoveries! Recent discoveries of distant stars, gas clouds, and extended halos have pushed the galaxy's boundaries further. Advanced telescopes and surveys reveal new star clusters and streams, showing a more intricate and crowded cosmic structure.

Ultra-Diffuse Galaxies Have Sizes Comparable to the Milky Way

Ultra-diffuse galaxies (UDGs) are vast but faint, with sizes comparable to the Milky Way yet containing only about 1% of its stars. Located 115 million light-years away, UGC 9050-Dw1, linked to the spiral galaxy UGC 9050, features a tail-like structure and signs of recent star formation to reveal the intriguing complexity of these colossal yet sparse galaxies.

Supermassive Black Holes Stretch Galactic Structures

Supermassive black holes, hidden at galaxy centers, exert gravitational forces that stretch entire galactic structures. Though invisible, their influence on nearby stars reveals their massive scale. While our galaxy's central black hole is four million times the sun's mass, the largest can reach up to 100 billion solar masses.

Galaxies Are Moving Further Apart as the Universe Expands

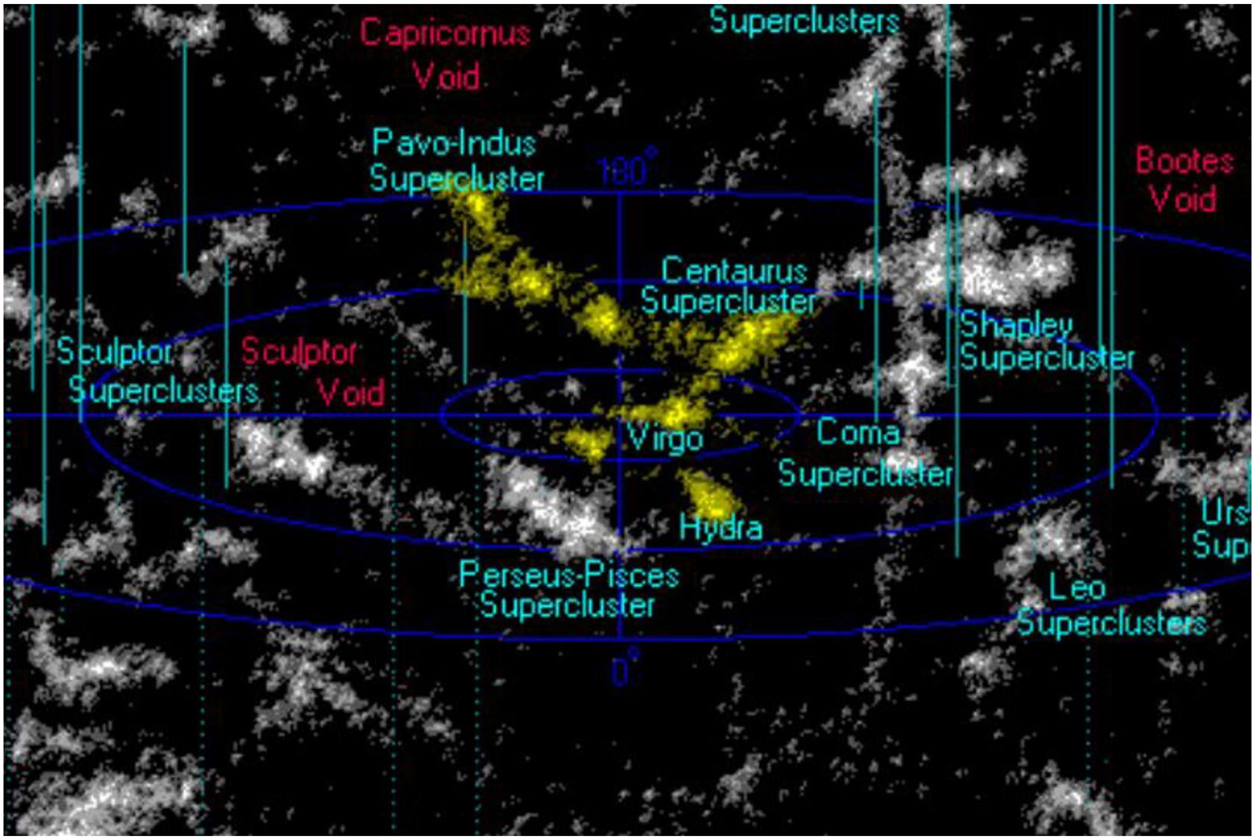
As the universe expands, galaxies drift farther apart, enlarging the space they occupy. This separation, driven by dark energy, accelerates the universe's growth. The Hubble constant measures this rate, while observations of the cosmic microwave background confirm the expansion. Over time, distant galaxies will become too far to observe.

Andromeda Spans About 260,000 Light-Years

Andromeda, our neighboring galaxy, is not just large—it's immense. Spanning about 260,000 light-years and possibly twice the size of the Milky Way, it dominates the Local Group. Estimates suggest it may be 5 to 10 billion years old, with its current form emerging from the merger of two smaller galaxies about 2 to 3 billion years ago.

Galaxies Are Connected by a Cosmic Web

Galaxies are intricately connected within a vast cosmic web, linked by enormous dark matter and gas filaments. These filaments stretch across billions of light-years, forming a network that includes galaxy clusters, superclusters, and immense voids. Dark matter, which cannot be seen directly, plays a key role in shaping this web.



The Virgo Supercluster Spans 110 Million Light-Years

Our Milky Way resides in the Virgo Supercluster, a colossal structure 110 million light-years across. This supercluster, containing the Virgo Cluster and the Local Group, is 7,000 times larger than our local cluster. New discoveries show that Virgo is part of Laniakea, an even grander cosmic web linking multiple superclusters.

Dwarf Galaxies Contribute to Galactic Evolution

Though small, dwarf galaxies are key players in galactic evolution. These tiny galaxies often merge with larger ones, contributing critical dark matter and material that drives growth. They also influence star formation and galactic dynamics, which makes them essential to understanding how galaxies form and evolve.

Dark Energy Fuels the Rapid Acceleration of the Universe's Expansion

The universe is not just expanding—it's accelerating! As galaxies move away from each other, dark energy continues to fuel this rapid growth. Over billions of years, distant galaxies may drift beyond our view, leaving us in cosmic isolation. Could this expansion ever stop or reverse? Only time will tell!

The universe had a secret life before the Big Bang, new study hints© ESA

The Big Bang may not have been the beginning of the universe, according to a theory of cosmology that suggests the universe can “bounce” between phases of contraction and expansion. If that theory is true, then it could have profound implications about the nature of the cosmos, including two of its most mysterious components: black holes and dark matter.

With this in mind, a recent study suggests that dark matter could be composed of black holes formed during a transition from the universe's last contraction to the current expansion phase, which occurred before the Big Bang. If this hypothesis holds, the gravitational waves generated during the black hole formation process might be detectable by future gravitational wave observatories, providing a way to confirm this dark matter generation scenario.

Observations of stellar movements in galaxies and the cosmic microwave background — an afterglow of the Big Bang — indicate that about 80% of all matter in the universe is dark matter, a substance that doesn't reflect, absorb or emit light. Despite its abundance, scientists have not yet identified what dark matter is made of.

In the new study, researchers explored a scenario where dark matter consists of primordial black holes formed from density fluctuations that occurred during the universe's last contraction phase, not long before the period of expansion that we observe now. They published their findings in June in the Journal of Cosmology and Astroparticle Physics.

The bouncing cosmos

The traditional cosmological view of the universe suggests that it started from a singularity, followed by a short period of extremely rapid expansion, called inflation. However, the authors behind the new study analyzed a more exotic theory, known as non-singular matter bouncing cosmology, which posits that the universe first underwent a contraction phase. This phase ended with a rebound due to the increasing density of matter, leading to the Big Bang and the accelerated expansion we observe today.

Related: The universe could stop expanding 'remarkably soon', study suggests

In this bouncing cosmology, the universe contracted to a size about 50 orders of magnitude smaller than it is today. After the rebound, photons and other particles were born, marking the Big Bang. Near the rebound, the matter density was so high that small black holes formed from quantum fluctuations in the matter’s density, making them viable candidates for dark matter.

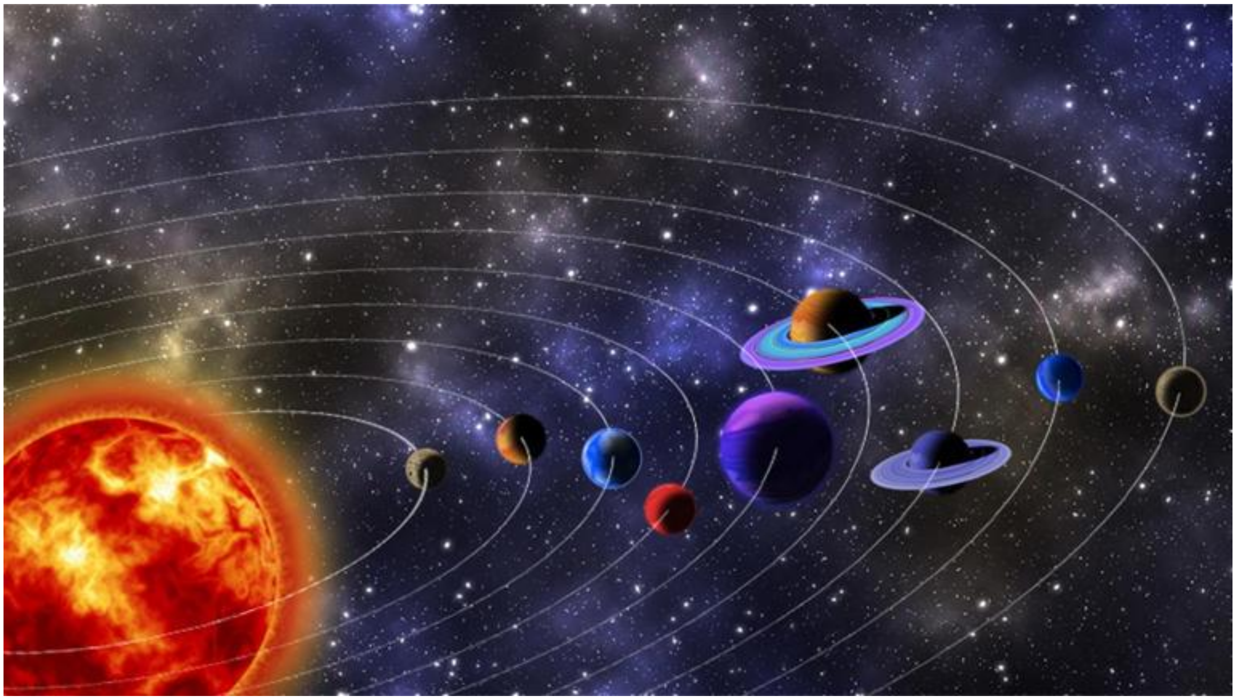
"Small primordial black holes can be produced during the very early stages of the universe, and if they are not too small, their decay due to Hawking radiation [a hypothetical phenomenon of black holes emitting particles due to quantum effects] will not be efficient enough to get rid of them, so they would still be around now," Patrick Peter, director of research at the French National Centre for Scientific Research (CNRS), who was not involved in the study, told Live Science in an email. "Weighing more or less the mass of an asteroid, they could contribute to dark matter, or even solve this issue altogether."

The scientists' calculations show that this universe mode's properties, such as the curvature of space and the microwave background, match current observations, supporting their hypothesis.

To further test their predictions, the researchers hope to make use of next-generation gravitational wave observatories.The scientists calculated the properties of the gravitational waves produced during black hole formation in their model and found that they could be detected by upcoming gravitational observatories like the Laser Interferometer Space Antenna (LISA) and the Einstein Telescope. These detections could confirm whether primordial black holes are indeed dark matter; however, it could take more than a decade before either facility sees first light.

"This work is important in the sense that it provides a natural way of forming small yet still present black holes forming dark matter in a framework which is not the usual one based on inflation," Peter said. "Other works currently investigate the behavior of such tiny black holes around stars, potentially leading to a way of detecting them in the future."

Why is everything in space always moving?



Why is everything in space always moving?© suman bhaumik via Getty Images

Nothing in our universe stands still: Earth orbits the sun, the sun circles the galaxy, and even galaxies are constantly on the move. So why is everything in space in motion?

It all comes down to how the universe and the objects within it were made, Edward Gomez, an astrophysicist and the education director at Las Cumbres Observatory, told Live Science. Scientists think the universe began with the Big Bang, a superfast expansion from an infinitely dense single point that eventually led to the formation of everything we see today.

"From the very beginning of the universe, it started expanding outwards because the force of the Big Bang caused everything to move apart," Gomez said.

"It's sort of the imprint of the beginning," said Carol Christian, an astrophysicist and outreach project scientist for the Hubble Space Telescope at the Space

Telescope Science Institute in Baltimore. "The beginning was movement, and so movement has been built into the universe from the very beginning."

Related: Does the universe rotate?

So one reason everything in space is in motion is because the universe is expanding. But that expansion has effects only on very large scales. "We only see it really happening on things that are very far apart or far away, because it's not necessarily that these objects are moving through space," Gomez said. "It's that the space in between objects is getting bigger."

On smaller scales, though, rotation is the movement that rules objects in space. "This spinning thing is kind of endemic in the universe, too," Christian told Live Science. "There isn't anything that doesn't rotate."

That's due to angular momentum: When two objects in space move close together, their mutual gravity pulls them toward each other, and if they don't collide or fly in different directions, they tend to orbit each other. This phenomenon affects everything, from the smallest mineral grains to the largest galaxies.

"The solar system was made like a pizza is made ... If you're making an Italian pizza, you throw the pizza dough up, and as you spin it, it flattens out into a disc," Gomez said. "And that's fundamentally how our solar system is made: This thing called angular momentum, that spinning effect stretches things out into a disc."

That's why the planets in the solar system orbit the sun: The solar system began as a spinning mass of gas and dust that eventually coalesced into a star and planets. Along the way, angular momentum ensured it never stopped spinning.

But a galaxy's spinning effect happens differently than you'd expect from just the stuff we can see.

"It spins as if it were like a pizza base, as if it was solid instead of being made up of individual components, stars," Gomez said. "It should be that the [stars] further out should be going slower than the ones in the center. But actually, you don't see that ... and that's one of the first indicators that the universe had something crazy that you can't see that we now call dark matter."

Dark matter doesn't interact with light, so we can't see it with telescopes. However, it does have mass and interacts with other objects that have mass through gravitational effects. Dark matter also experiences angular momentum. It's another reason everything in space is moving.

In the end, motion is a fundamental ingredient in the universe. It "shows that the universe is alive — not in a sense of being conscious, but you know, things are happening — chemical reactions, physical reactions are happening, and that requires energy," Gomez said. "And the most basic form of energy is motion."

The idea that the universe is expanding was first proposed by Edwin Hubble in the late 1920s and has been repeatedly backed up by empirical observations over the past century. Despite this, an alternative notion known as the Tired Light theory won't seem to fully go away, with some scientists clinging on to the idea that the cosmos isn't enlarging after all.

In the red corner: The Big Bang

Both scenarios hinge on the fact that more distant galaxies appear redder than those closer to Earth – a phenomenon known as redshift. This happens because the wavelength of light increases as objects move away from each other, thus shifting it towards the red end of the spectrum.

Because all galaxies are redshifted, it follows that they are all moving away from us. It was Hubble who observed that the redshift of a celestial object is always proportional to its distance from Earth, which means that the further away a galaxy is, the faster it is accelerating.

These findings support an expanding universe, and inspired Belgian physicist Georges Lemaître to propose the idea of the Big Bang in 1931. According to current estimates, this cosmogonic explosion occurred around 13.8 billion years ago, and set the universe on its path of relentless growth.

In the... other red corner: Tired Light

The red light emitted by distant galaxies also caught the attention of a contemporary of Hubble named Fritz Zwicky, who put forward an alternative explanation for this maroon mystery. According to Zwicky, the redshift seen from Earth occurs because photons lose energy as they travel across vast distances, thus decreasing in frequency and obtaining a rouge tint.

This so-called Tired Light theory states that more distant objects appear more red because the light they emit has had further to travel and therefore lost more oomph. The hypothesis therefore disputes the idea that more remote galaxies are traveling faster than nearby ones, and has been used to support a static universe rather than an expanding one.

And the winner is...

If this were a fight, the Big Bang would win by knockout in round one. For one thing, no empirical observations have ever shown photons losing energy as they travel through space, and when asked about the Tired Light theory in 1931, Albert Einstein remarked that “no man can get a picture of how this happens.”

More recently, the discovery of the energetic remnants of the Big Bang – known as the cosmic microwave background – along with observations of light fluctuations coming from supernovae have pretty much settled the debate in Hubble’s favor.

And yet, despite having been thoroughly dismissed for decades, Tired Light is currently attempting to get up off the canvas. Staggering to its feet, the theory has gained a small amount of renewed attention thanks to the JWST's observations of the earliest galaxies in the universe.

Noting that these galaxies are more complex and developed than one would expect of structures that formed so soon after the Big Bang, some commentators have attempted to revive the static universe framework. However, Tired Light is simply too full of holes to provide an alternative framework, and there is likely to be another explanation for the state of these early galaxies that doesn't require us to abandon the laws of cosmology.

- The universe is permeated by a field known as the Higgs field, which gives everything its mass.
- But the Higgs field isn't entirely stable, and if it were to "bubble," it would change reality to such a degree that everything in that "bubble" would cease to exist.
- A team of scientists has now argued that the existence of primordial black holes should have triggered the "bubbling" of the Higgs field to such a degree that nothing should have ever been able to form.

The earliest days of the universe are shrouded in mystery. After all, it's not like we can just pop back in time and check it out for ourselves. Instead, we're restricted to piecing together our cosmos's earliest history from hints, echoes, and faded waves propagating out into the infinite.

As a result, the models we create of these earliest times are often called into question by new math or physical observations that challenge the pieces we've put in place so far. And recently, a team of physicists did just that. According to their new study—now accepted for publication in the journal *Physical Letters B*—if many of our current models are correct, we wouldn't exist at all. Nothing would. As things stand now, the whole universe should have annihilated itself.

But, obviously, the universe has *not* annihilated itself. After all, we're here to ask all these probing questions. So, what gives?

It all comes down to two objects: primordial black holes and the Higgs boson particle.

The 2012 discovery of the Higgs boson is widely considered one of the great triumphs of modern physics. This is largely because it confirmed the existence of the Higgs field—a field much like electricity or magnetism that literally gives objects their mass. It's complicated quantum mechanics, but it all boils down to this: if there's no Higgs field, nothing exists at all.

All this to say that the Higgs field is incredibly important, and it's incredibly important *as it is*. Because here's a fun fact that isn't existentially terrifying at all—theoretically, the Higgs field could change.

"The Higgs field isn't likely to be in the lowest possible energy state it could be in," Lucien Heurtier, one of the researchers on the new study, said in an article for *The Conversation*. "That means it could theoretically change its state, dropping to a lower energy state in a certain location. If that happened, however, it would alter the laws of physics dramatically."

Basically, Heurtier explained that if the Higgs field were to drop to a lower energy state, it would cause the formation of little "bubbles" of space that were subject to entirely different rules of physics than the universe as we know it.

"In such a bubble," he wrote, "the mass of electrons would suddenly change, and so would its interactions with other particles. Protons and neutrons—which make up the atomic nucleus and are made of quarks—would suddenly dislocate. Essentially, anybody experiencing such a change would likely no longer be able to report it."

Luckily, that's not going to happen any time soon—no need to panic. But the idea introduces a problem. In many of our existing models of the early universe, that actually should have happened already.

And that's because of object two: the primordial black hole. Primordial black holes are hypothetical objects much like the black holes we see today, but orders of magnitude smaller in mass—they could be as small as a gram. According to many current models, they formed in the second right after the Big Bang, during an era known as inflation. Regions of the universe were so dense at that time that they would have been able to collapse in on themselves and form these teeny tiny black holes without the aid of a supernova. Just… shwoomp! Right into a black hole.

Now, these things—if they ever existed—were short-lived. They would have burned hot and evaporated away pretty dang quickly. But according to Heurtier and his team, they would have been around long enough to have an incredibly powerful impact on the Higgs field.

Those bubbles that we mentioned earlier? The universe-shattering ones? Yeah, primordial black holes should have caused them to appear all over the place.

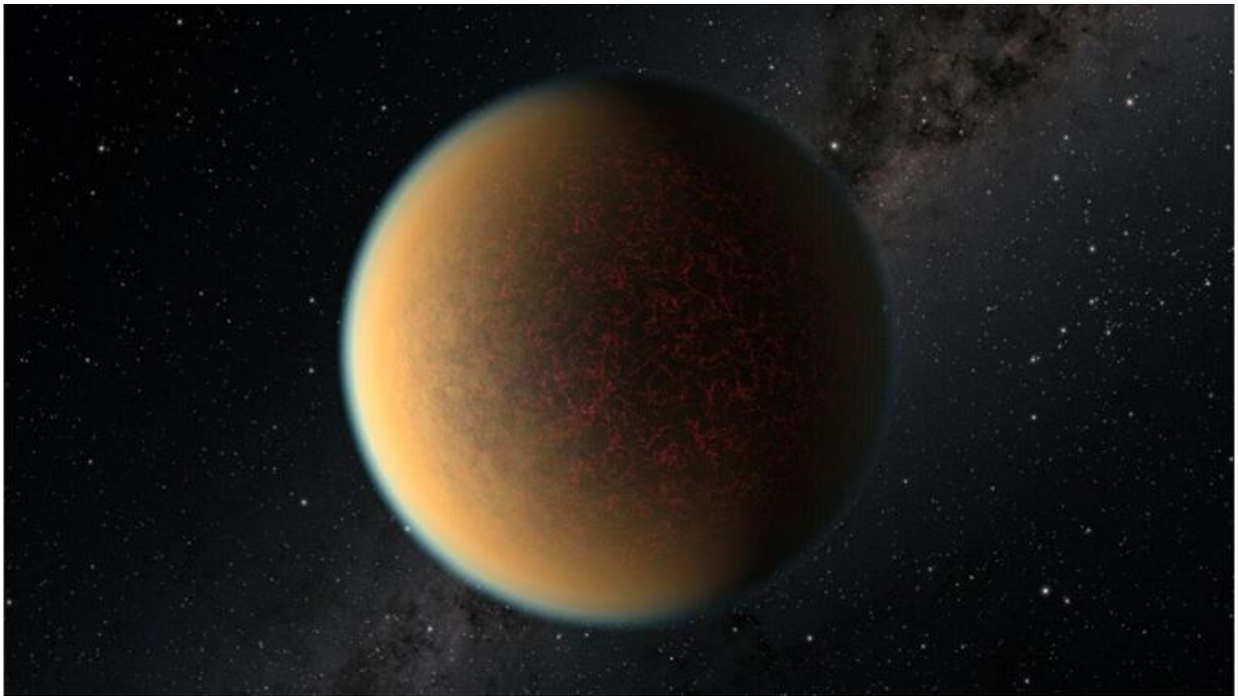
The research team asserts that if primordial black holes existed during this early period of inflation as many current models suggest, the field would have been bubbling away like a shaken can of soda. So much so, in fact, that nothing should have ever been able to form in the first place.

But we exist, as does everything around us. So, where does that leave us?

Heurtier and his team propose two responses to this news. The first is that our models are wrong, and that we should discard the idea of primordial black holes altogether. After all, we know for sure that the Higgs field exists, so if there's a problem, it must lie in the primordial black holes.

Right? Well, not *definitely*. The other scenario posed by the group is that we are missing serious physics—namely, that there is something big that we don't understand about the way the Higgs field works. That's often an option in particularly high-level physics—maybe there's just some law or behavior or force or particle we don't know about yet that will crack the whole thing wide open.

Certainly, this will not be the last team to investigate the theoretical interactions between the Higgs field and primordial black holes. Maybe this new understanding will stand, and maybe it won't. But that's the best part of science—you can, and should, question everything. Who knows what mysteries you'll unlock?



University of Chicago astronomers have tested a simpler, and more accurate way to determine whether or not exoplanets have atmospheres, a leap in learning more about the potential habitability of far-away planets. Above, an artist’s rendering of what terrestrial exoplanet GJ 1132 b may look like. Credit: NASA, ESA, Robert L. Hurt (IPAC)

It is a major goal of astronomical research to find planets other than Earth that might be suitable for sustaining life. There are a number of factors which many scientists agree are essential to a planet being habitable, but an important one is whether or not a planet has an atmosphere.

Scientists have found other rocky, Earth-like exoplanets, but none that we can definitively say have atmospheres. Finding these planets will reveal insights into how such atmospheres are formed and retained, so that we can better predict which planets could be habitable.

A study conducted by University of Chicago Ph.D. student Qiao Xue with Prof. Jacob Bean's group has demonstrated a new way to determine if faraway exoplanets have an atmosphere—and showed that it was simpler and more efficient than previous methods.

The new technique, when applied to more planets, has the potential to help us learn more about patterns in atmosphere formation. The paper is published in *The Astrophysical Journal Letters*.

"When we look at a large enough data set, as we will this year with the James Webb Space Telescope, we are hoping to find trends to help us understand more about atmosphere formation—and what makes planets habitable," said Xue.

The search for atmospheres

As scientists try to understand the conditions on other faraway planets, they would like to know whether or not a planet has an atmosphere—a gaseous layer that insulates the planet and regulates its temperature. On Earth, for example, our atmosphere redistributes the sun's heat around the planet, keeping it a temperate place for life.

Scientists cannot, however, directly image rocky, Earth-like planets close to their stars. Instead, they must piece together different clues, such as the fluctuations in light as the planet moves around its host star.

In the study, the scientists used a method that was proposed in 2019 by a collaboration including Bean and Megan Mansfield (Ph.D.'21, now with the University of Arizona) to look for atmospheres. The approach uses the difference in temperature between an exoplanet measured at its hottest and the calculated temperature of how hot it could theoretically be.

Since atmospheres disperse heat around the entire surface area of planets, they reduce the temperature of the hottest side of the planet (which faces the star directly). The scientists hypothesized that if an exoplanet's actual temperature is not as hot as it could theoretically be, then we can presume it has an atmosphere performing this function.

The trouble was, however, that we have lacked instruments precise enough to provide accurate enough readings for these temperatures. The James Webb Space Telescope has changed that—offering an increased capacity to see in the infrared, which allows for scientists to record the temperatures of the planets by measuring the intensity of energy they emit.

When exoplanets cross in front of their suns, they obscure some of the star's light, leading to a slight decrease in the star's measured brightness. When the planet appears almost behind the star relative to our viewing devices, we can capture the maximum brightness of the system—that is, the unobscured star combined with the comparatively minimal light emitted from the planet.

When the planet crosses behind the star relative to our view, we can record the light emitted by the star on its own. By subtracting this measurement of light from the measurement of the light of the star combined with the light of the planet, the brightness—and thus the temperature—of the planet on its own can be deduced.

In this way, Xue concluded that the first planet to which she applied the new method, planet GJ1132 b, does not have an atmosphere—the measured temperature of the planet is too close to the calculated maximum temperature to be suggestive of any temperature-regulating component of the planet. "It is therefore not a suitable candidate for life," she said.

The new method is not the only way to determine whether an exoplanet has an atmosphere or not, but it is a simpler as well as more reliable way of searching for distant planets with atmospheres. Xue explained that it is less susceptible to false negatives and positives than the other technique.

"This other technique, which measures light filtering through the planet's atmosphere, is more challenging because it can be confounded by activity on the star and the presence of clouds," said Bean.

If scientists can understand what gives rise to atmospheres on planets, it will be easier to rule out uninhabitable planets in the quest for exoplanets that sustain life.

"This study was exciting because I finally got a chance to work with rocky planets, which are the dream subject of every exoplanet scientist because they have so much potential for life," Xue said. "Now I'm so excited to see what comes next."

More information: Qiao Xue et al, JWST Thermal Emission of the Terrestrial Exoplanet GJ 1132b, *The Astrophysical Journal Letters* (2024). DOI: 10.3847/2041-8213/ad72e9

Provided by University of Chicago

Using Europe's Gaia space telescope, astronomers have identified 55 runaway stars being ejected at high speeds from a densely packed young cluster in the Large Magellanic Cloud (LMC), a satellite galaxy of our own Milky Way. This is the first time so many stars have been seen escaping from a single star cluster.

The star cluster R136, located around 158,000 light-years away, is home to hundreds of thousands of stars and sits in a massive region of intense star formation in the LMC. It's home to some of the biggest stars ever seen by astronomers, some with 300 times the mass of the sun.

The runaway stars were ejected in two bursts over the last two million years. Some of them are racing away from their homes at over 62,000 mph (100,000 kph) — about 80 times as fast as the speed of sound on Earth. The runaways massive enough to die in supernovas, leaving behind black holes or neutron stars, will behave like cosmic missiles, exploding up to 1,000 light-years from their origin point.

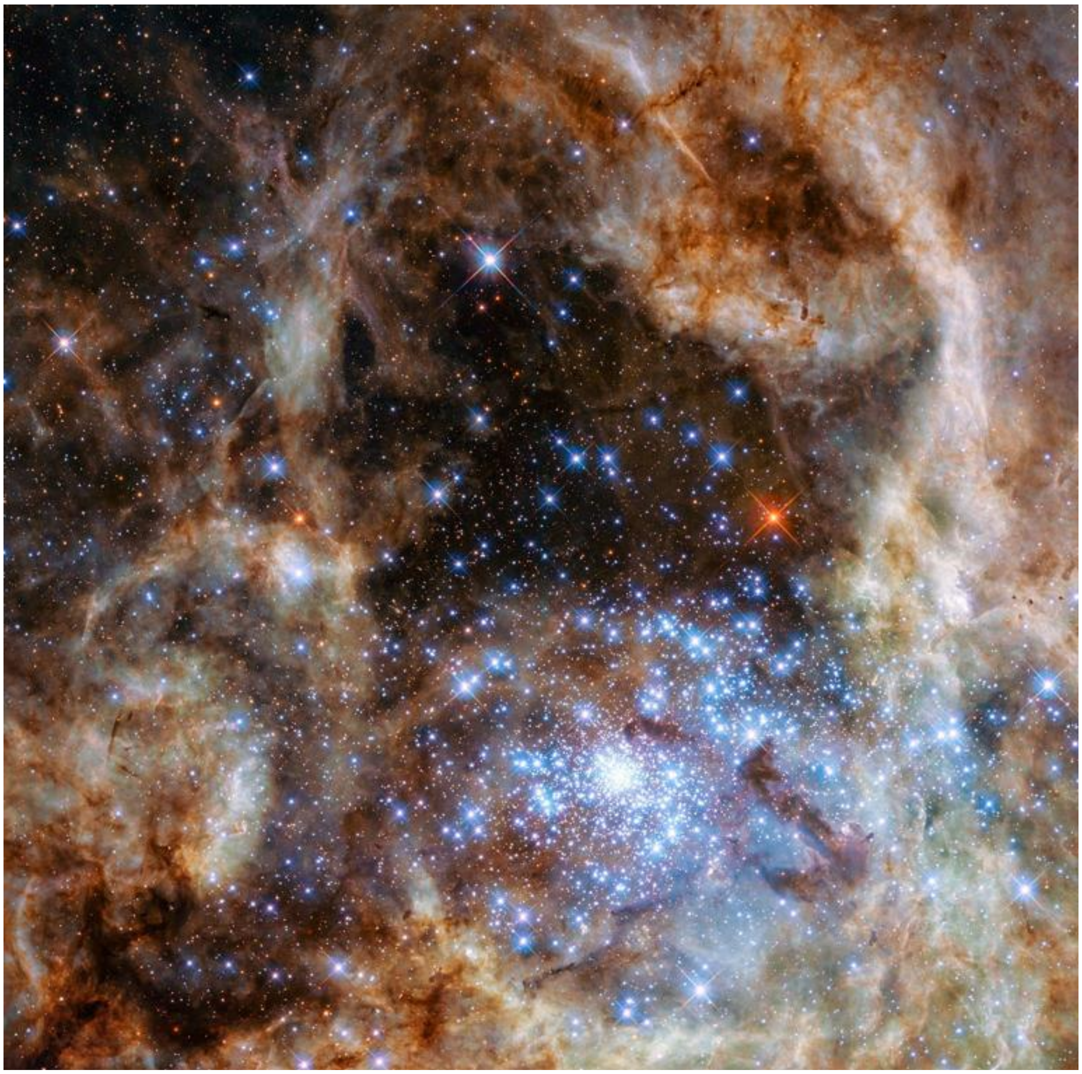
The discovery was made by a team of astronomers led by University of Amsterdam researcher Mitchel Stoop using Gaia, which precisely monitors the positions of billions of stars. The findings increase the number of known runaway stars by a factor of 10.

Related: Runaway 'failed star' races through the cosmos at 1.2 million mph

Scientists think that stars are exiled from young star clusters like R136 — which is estimated to be less than 2 million years old (that may seem ancient, but compare it to our 4.6 *billion*-year-old solar system) — when crowded stellar newborns cross paths and cause orbits to be gravitationally disrupted. What surprised the team, however, was the revelation that more than one major escape event had happened in R136, and the second one happened quite recently (in cosmic terms, at least).

"The first episode was 1.8 million years ago, when the cluster formed, and fits with the ejection of stars during the formation of the cluster," Stoop said in a statement. "The second episode was only 200,000 years ago and had very different characteristics.

"For example, the runaway stars of this second episode move more slowly and are not shot away in random directions as in the first episode, but in a preferred direction."



The young and dense star cluster R136 seen at the lower right of an image of the LMC captured by the Hubble Space Telescope. (Image credit: NASA, ESA, P Crowther (University of Sheffield))

It is thought that these two episodes have resulted in R136 launching away as many as a third of its most massive stars in the last few million years.

"We think that the second episode of shooting away stars was due to the interaction of R136 with another nearby cluster that was only discovered in 2012," team member and University of Amsterdam researcher Alex de Koter said in the statement. "The second episode may foretell that the two clusters will mix and merge in the near future."

Massive stars like those ejected by this young star cluster can be millions of times brighter than the sun, emitting much of their energy as intense ultraviolet light. But this power comes at a cost: Massive stars like these burn through their fuel for nuclear fusion rapidly.

That means that, whereas our sun will live for around 10 billion years, the lives of massive stars will come to an end after just millions of years. The sun will end its life in a whimper, fading away as a cooling stellar remnant called a white dwarf, but these massive stars go out with a bang, erupting in supernova explosions.

Prima donna stellar cluster is losing its star power

R136 isn't just special because of its vast population of massive stars; it is the "prima donna" cluster of the largest star-birthing region of space located with five million light-years of Earth.

"Now that we have discovered that a third of the massive stars are ejected from their birth regions early in their lives, and that they exert their influence beyond those regions, the impact of massive stars on the structure and evolution of galaxies is probably much larger than previously thought," team member and University of Amsterdam researcher Lex Kaper said in the same statement. "It is even possible that runaway stars formed in the early universe made an important contribution to the so-called re-ionization of the universe caused by ultraviolet light."

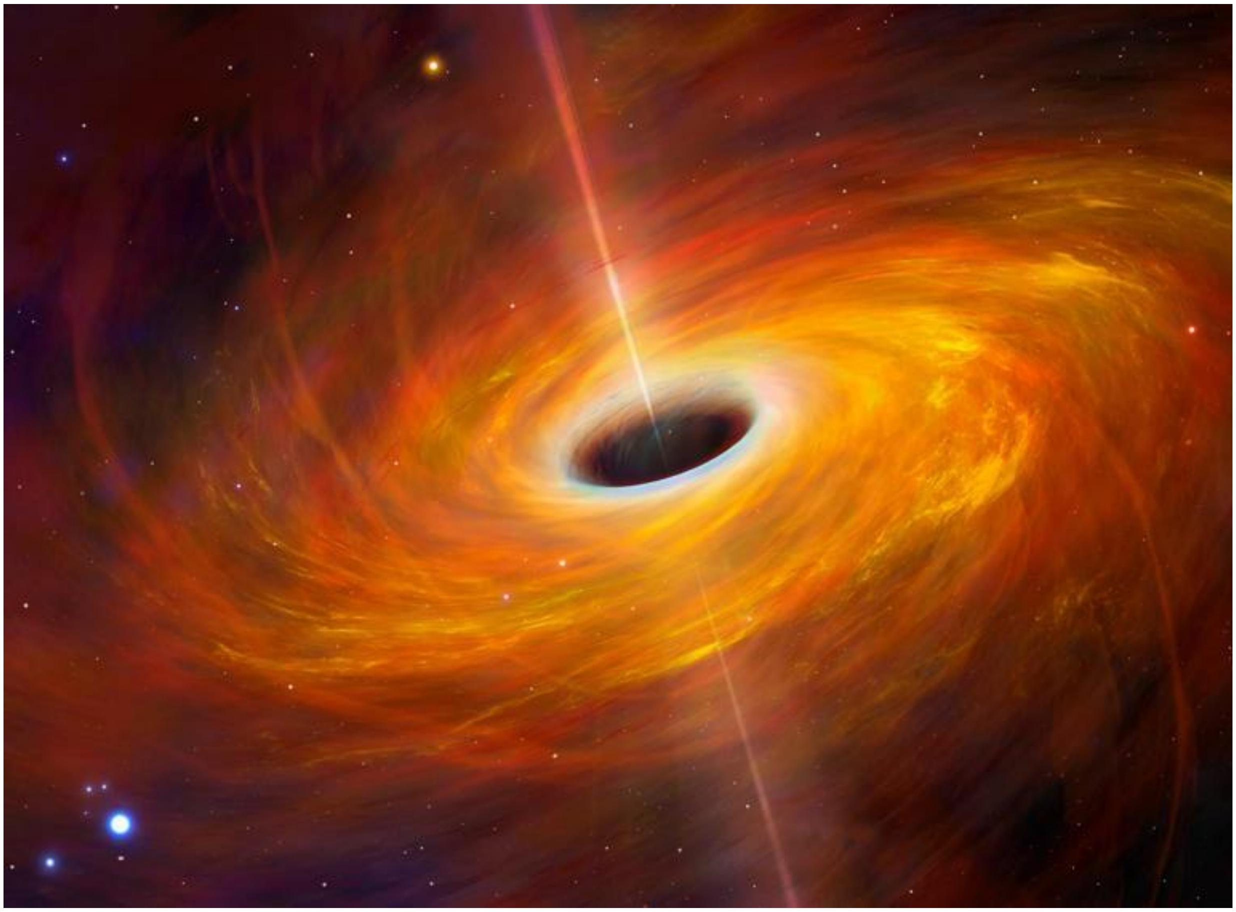
The re-ionization of the universe refers to a vital phase in cosmic evolution that occurred when the now 13.8-billion-year-old universe was an infant, around one billion years old. At this time, light from early stars created bubbles of ionized gas in interstellar material. These ionized bubbles grew in lockstep with early galaxies, reionizing all hydrogen by separating electrons from hydrogen nuclei. This marked the transition from the Cosmic Dawn period to a "mature" cosmic stage that allowed for the evolution of "normal" galaxies.


Another star birthing region of the LMC not quite as profilic as the home of R136, as seen by the JWST. (Image credit: ESA/Webb, NASA & CSA, O. Nayak, M. Meixner)© Provided by Space

The main aim of the team's research was to test the capabilities of Gaia, a European Space Agency mission that's tasked with collecting data to build a 3D map of the Milky Way. The LMC provides a good test because it is much farther away than the stars Gaia usually studies within our home galaxy.

"R136 has only just formed, 1.8 million years ago, and so the runaway stars could not yet be so far away that it becomes impossible to identify them," De Koter concluded. "If you can find a lot of those stars, you can make reliable statistical statements. This worked out beyond expectations, and we are tremendously pleased with the results. Discovering something new is always a thrill for a scientist."

The team's research was published Oct. 9 in the journal Nature.



Nothing can escape the gravitational pull of a black hole, not even light.© MARK GARLICK (Science Photo Libra/Getty)

The universe, as we know it from our limited and biased vision, is dying. The "whole" is expanding, with the distances between galaxies increasing at an accelerating pace, and, as if that weren't enough, galaxies are no longer forming as many stars as before. But why has this rate of star formation slowed down? It's not due to a lack of fuel for creating new galaxies; only about 10% of the gas present in the cosmos has been converted into stars. The mass in the form of planets is even less, a thousand times smaller, indicating that there is ample material available to form new worlds. Yet something is inhibiting the gas — both between galaxies and within them — from generating new suns and planets (and potentially more life?) at the rate it once did.

The most likely culprit behind this phenomenon that is killing our universe is the action of supermassive black holes, which are believed to reside at the centers of all galaxies. This theory is not immediately intuitive, as these cosmic giants — despite having millions or even billions of times the mass of our Sun — are relatively small in size compared to a galaxy.

For instance, the supermassive black hole at the center of the Milky Way is smaller than the orbit of Venus. If these supermassive black holes are indeed responsible for the widespread galacticide in the universe, we are talking about something quite small on a galactic scale, and even more so on a cosmic scale, exerting influence over areas billions of times larger — namely, the galaxies themselves — thus altering the fabric of the entire universe. It's as if an atom could stop a person from growing, the size ratio is similar, and end an entire species and, by extension all life.

There is evidence, gathered over decades, that the energy that can be produced around supermassive black holes is immense. A black hole exerts such a profound influence on space-time that it twists everything around it, causing even time to warp and potentially come to a standstill. It is often stated that not even light can escape its gravitational pull, although this perspective is somewhat outdated and has been superseded by the principles of general relativity. Nevertheless, it effectively illustrates the idea that even something as formidable as a photon cannot escape the space-time well created by a black hole.

When an object, whether a cloud of interstellar gas or a star, passes near a black hole — yet remains far enough away to avoid being consumed — it forms a disk around the dark entity. As this matter spirals inwards, it experiences immense tidal forces, often described with the analogy that a person would be stretched into a spaghetti-like strand if they ventured too close to a black hole. During this process, the material is heated to such extreme temperatures that it can emit light with a luminosity that matches or even surpasses that of the entire galaxy hosting the supermassive black hole. Despite the galaxy potentially containing billions of times more mass, the radiant energy from the disk can overshadow the galaxy itself.

In instances where the material surrounding a black hole — known as an accretion disk — becomes super bright, the galaxy is classified as having an active galactic nucleus (AGN). In the case of quasars — the most extreme type of AGN — we only see that disk of material around the black hole: its brightness completely eclipses that of the host galaxy.

AGNi can also exhibit a phenomenon that releases vast amounts of energy, not only in the form of light but also by expelling material at speeds close to the speed of light. This ejected material originates not from "inside" the black hole, which is unable to release anything, but rather from just beyond the "point of no return," known as the event horizon. The ejected material manifests as jets, which can extend to distances equivalent to tens or even hundreds of times the size of a galaxy like the Milky Way.

One example is Porphyrion, whose discovery came to light only a few weeks ago. The ejection of material can also occur because the vicinity of the black hole is so extraordinarily bright that the emitted light itself exerts pressure on the surrounding gas. The fact that light can push objects — much like wind fills a sail — is truly extraordinary!

Although AGNi certainly release vast amounts of energy and have been shown to expel significant quantities of very hot gas from the vicinity of the black hole at supergalactic distances, there is currently no direct evidence to suggest that they can influence the gas throughout an entire galaxy, let alone the cold gas necessary for star formation, which fills the space between stars within a galaxy and is situated far from the supermassive black hole.

Astrophysicists know what to examine to help validate this theory, but conducting such experiments is not so easy. You must identify suitable galaxies where galactic decline is either imminent or has recently occurred. Like detectives, we must gather information on the health status of numerous galaxies and select the most promising candidates for further data collection.

However, choosing the right galaxy for study is not enough; a powerful telescope, such as the James Webb Space Telescope (JWST), is also essential. The search for more direct evidence that supermassive black holes are contributing to the decline of our universe is one of the scientific objectives of the JWST, developed collaboratively by NASA, ESA, and the CSA (the American, European, and Canadian space agencies).

Spain has been actively involved in the James Webb mission through researchers from the Astrobiology Center (CAB), which is part of the National Institute for Aerospace Technology (INTA) and the Spanish National Research Council (CSIC). A team from CAB, in direct collaboration with the University of Cambridge, has recently published an article reporting the first detection of cold gas being expelled from a dying galaxy in the young universe. This galaxy, dubbed “Pablo’s Galaxy,” was the subject of a *Nature* press release. I presented and defended the findings for an international team that gathered data with JWST to select it, and then some funny colleague named it (behind my back, I must say).

The galaxy, which for the sake of modesty we will refer to as GS10578, is surprisingly massive — comparable in size to the Milky Way — and formed rapidly in the young universe when it was only 15% of its current age. In GS10578, we have found direct evidence of the galacto-homicidal effects of supermassive black holes. The black hole within this galaxy is still active, and we have measured how it is expelling significant quantities of cold gas. Although we cannot directly observe this gas, we detect its presence because it “clouds” the galaxy, lying in the same line of sight and absorbing some of the photons emitted by the stars of GS10578.

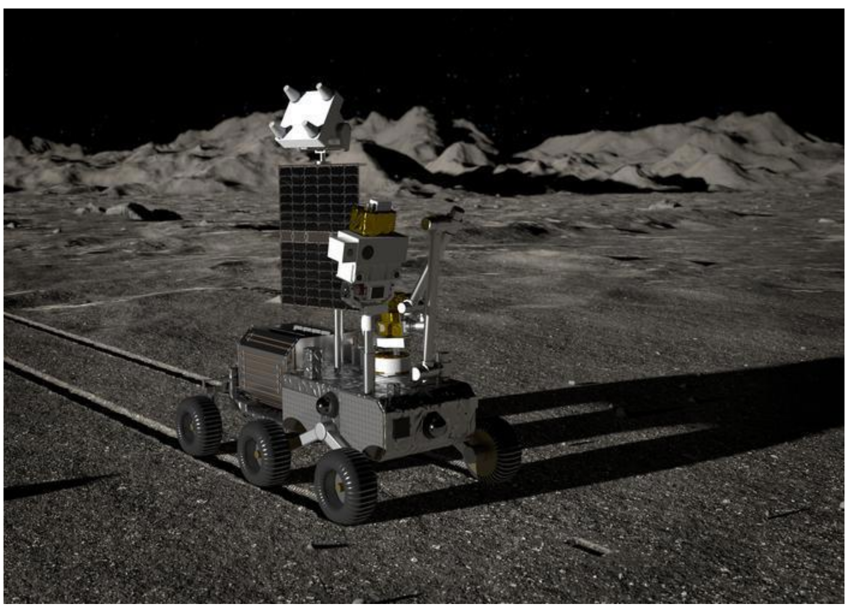
We will continue to search for more evidence of the process through which AGNi siphon material from their host galaxies, leading them to starve — much like the fate of the dying GS10578, and ultimately, all galaxies, including our Milky Way, which are all destined to fade away. The universe will be left devoid of shining stars, transforming into something that may seem hostile to us. This future scenario may not feel as much like our universe anymore, highlighting just how insignificant and limited our existence truly is. It serves as a reminder of the smallness of not only our lives but also the material that composes the Earth, the Sun, and all the other planets and stars that exist in the cosmos.

Energy is a precious commodity in space exploration. Perpetual Atomics, a spin-off from the University of Leicester, is developing nuclear technology for space missions.

The recently launched spin-out company specializes in developing radioisotope power systems to provide a reliable and long-lasting energy source for deep space exploration.

Moreover, it aims to offer energy solutions that can withstand the extreme conditions of outer space.

“The cutting-edge technology that the team at Perpetual Atomics is developing could not only harness nuclear power to sustain exploration of space for longer periods of time but allow us to venture further into space than ever before, enabling more science and bringing more benefits back to Earth,” said Julie Black, Director of Missions and Capabilities at the UK Space Agency.



Depiction of lunar rover powered by an Radioisotope Thermoelectric Generator. University of Leicester/Space Park Leicester

Growing interest in nuclear power

Nuclear power is hailed as the essential ingredient for expanding humanity's reach beyond Earth, whether for the Moon or the distant Red Plant.

Interestingly, nuclear energy has already proven its worth. The Voyager probes, now billions of miles from Earth, have demonstrated the endurance of nuclear power as they journey through interstellar space.

The probes use Radioisotope Thermoelectric Generators (RTGs) that convert the heat generated by the radioactive decay of plutonium-238 into electricity.

Designed in the 1960s, the Voyager probes were groundbreaking for their time. Today's improved understanding of space technology and nuclear power could lead to even more ambitious explorations.

NASA is considering nuclear power for its lunar base camp, which is expected to be operational by the decade's end. Nuclear reactors could provide both electricity and heat.

Furthermore, nuclear engines could be the future of spacecraft propulsion. NASA and DARPA plan to launch a nuclear-propelled spacecraft within the next few years. Meanwhile, the European Space Agency is also exploring the use of nuclear engines for space exploration through various studies.

This is not it. Interestingly, the nuclear system could make the journey to Mars much easier. Current space missions are constrained by time windows and complex trajectories to conserve fuel.

On the other hand, nuclear propulsion would offer more flexibility in planning missions to Mars and other distant destinations.

With this spin-off launch, Perpetual Atomics is well-positioned to take advantage of the increasing interest in nuclear energy.

Long-lasting power source

Building upon two decades of research by the University of Leicester's Space Nuclear Power group, Perpetual Atomics will advance the development of radioisotope power systems.

These systems convert the heat released from radioactive decay into electricity or thermal energy, which can be used to power spacecraft components.

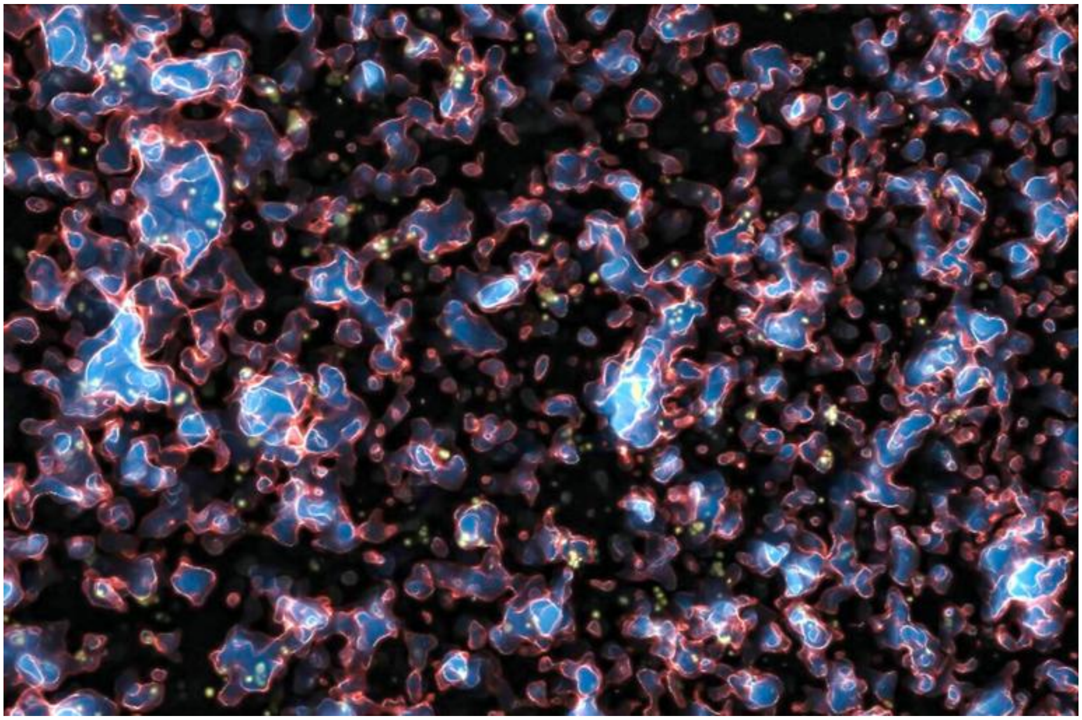
The Radioisotope Heater Units (RHUs) and Radioisotope Thermoelectric Generators (RTGs) will provide sustained power for lunar base camps, rovers, and spacecraft.

Their nuclear systems depend on Americium-241 (an isotope of americium), which has a long half-life. This means it decays slowly and provides a steady source of heat and electricity for many years.

As per the press release, the start-up's development of radioisotope thermoelectric generators has been supported by ESA and the UK Space Agency.

Perpetual Atomics aims to work with partners from around the globe to increase the adoption of radioisotope power technology in space missions.

"The spin-out launch will seize an opportunity that is already pushing new frontiers for the space industry globally, and we are excited to see it do the same for humanity's exploration beyond our world," said Professor Sarah Davies, Pro Vice-Chancellor and Head of the College of Science and Engineering at the University of Leicester.



Simulation of galaxies ionizing hydrogen gas (bright areas) during the epoch of Reionization. Credit: M. Alvarez, R. Kaehler, and T. Abel / European Southern Observatory (ESO).

Reionization is a critical period when the first stars and galaxies changed the physical structure of their surroundings, and eventually the entire universe. Established theories state that this epoch ended around 1 billion years after the Big Bang. However, if calculating this milestone using observations from the James Webb Space Telescope (JWST), reionization would have ended at least 350 million years earlier than expected. That's according to a new paper published in *Monthly Notices of the Royal Astronomical Society: Letters*.

Throughout its history, the universe has undergone several major changes. For the first 380,000 years after the Big Bang, it was a hot, dense plasma of protons and electrons. Eventually, things cooled enough for those protons and electrons to combine and form neutral hydrogen atoms. Then, around 100 million years after the Big Bang, the first stars and galaxies began to form, ushering in the epoch of reionization.

Those first stars were enormous and hot—some predicted to be 30 to 300 times as massive as our sun—and they emitted a lot of energy in the form of extreme ultraviolet light. This energy was so intense that when it struck nearby hydrogen atoms, it split them into protons and electrons in a process called ionization. After hundreds of millions of years, when almost all hydrogen in the universe became ionized, the epoch of reionization ended.

Considering roughly 75% of all matter is hydrogen, this represents an immense transformation. "This is the last major change to happen," explained Julian Muñoz, assistant professor of astronomy at The University of Texas at Austin and lead author on the paper. "You went from neutral and cold and boring to ionized and hot. And this isn't something that only happened to one or two galaxies. It happened to the whole universe."

"The process heated and ionized gas in the universe, which regulated how fast galaxies grew and evolved," added John Chisholm, assistant professor of astronomy at UT Austin and a co-author on the paper. "These early stars established the overall structure of galaxies in the universe."

Because astronomers are unable to observe the reionization process directly, they must use models to predict when it ended. These models are based on indirect evidence, including measurements of how much light has reached us from the afterglow of the Big Bang, called the Cosmic Microwave Background.

Other evidence is an early abundance of the wavelength associated with energy changes in hydrogen, called the Lyman-alpha Forest. Both of these help astronomers calculate how much hydrogen was transformed during reionization, and by extension how much energy was needed to do that.

"It's an accounting game," said Muñoz. "We know that all hydrogen was neutral before reionization. From there, you need enough extreme ultraviolet to split each atom. So, at the end of the day, you can do the math to figure out when reionization ended."

Now, the James Webb Space Telescope is challenging established models. With it, astronomers can peer further into the cosmos than ever before, deep into this critical epoch. This is leading to many unexpected observations in the early universe—one of which is a greater abundance of extreme ultraviolet-emitting galaxies than expected. "JWST has revealed that bright galaxies are enough to ionize the universe by themselves," said Chisholm. "This is counter to what many people anticipated."

So, with these new observations, the accounting is now off. "If you were to trust James Webb blindly, it would tell you that reionization ended 550 million to 650 million years after the Big Bang, instead of current estimates of 1 billion years," explained Muñoz. "If this were true, the Cosmic Microwave Background would look different, and the Lyman-alpha Forest would look different. So, there's a tension."

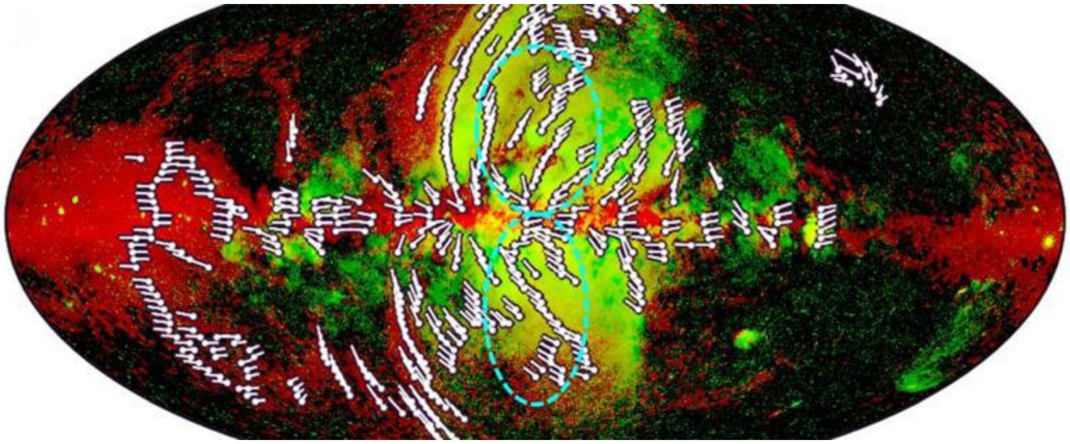
In other words, it's unlikely that reionization happened hundreds of millions of years earlier than predicted. So, what's going on? One explanation could be that established models are missing some key information. For example, sometimes ionized protons and electrons would come back together to re-form neutral hydrogen atoms. This process is called recombination. If it happened more often than current models assume, that could increase how much extreme ultraviolet light was needed to ionize the entire universe.

"We need more detailed and deeper observations of galaxies, and a better understanding of the recombination process," said Munoz. "Resolving this tension on reionization is a key step to finally understanding this pivotal period. I am excited to see what the coming years hold."

Additional study authors are Jordan Mirocha at NASA's Jet Propulsion Laboratory and the California Institute of Technology; Steven Furlanetto at the University of California, Los Angeles; and Charlotte Mason at the University of Copenhagen.

More information: Julian B Muñoz et al, Reionization after JWST: a photon budget crisis?, *Monthly Notices of the Royal Astronomical Society: Letters* (2024). DOI: 10.1093/mnrasl/slae086

Provided by University of Texas at Austin



Giant Magnetic Halo Discovered Wrapped Around The Milky Way

Our little piece of the Universe is contained within a vast shell of dark matter.

Though the space between the few isolated stars scattered throughout this largely invisible sphere seems empty, there's a lot going on out there in the wilds of the Milky Way.

By studying hot gas glowing in circumgalactic space, astrophysicists have found evidence of enormous magnetic fields that wind through and around our galaxy's dark matter 'halo'.

"This work provides the first detailed measurements of the magnetic fields in the Milky Way's X-ray emitting halo and uncovers new connections between star-forming activities and galactic outflows," explains astrophysicist He-Shou Zhang of the National Institute for Astrophysics (INAF) in Italy.

"Our findings show that the magnetic ridges we observed are not just coincidental structures but are closely related to the star-forming regions in our galaxy."

The study was performed on the X-ray light emitted by two huge structures that extend above and below the plane of the Milky Way. Discovered in 2020, these 'eROSITA bubbles' extend more than 45,000 light-years either side of the galactic center. They're powered by huge outflows of gas and plasma; shocks in this medium cause the bubbles to glow brightly in the X-ray range.

When the bubbles were discovered, scientists thought there were two main contenders for a source.

One was activity from the supermassive black hole at the center of the Milky Way. If it went through a period of jet activity, the heat and energy created could have blown the bubbles.

The second explanation was starburst activity. The galaxy is pretty quiet now, but it could have undergone a period of intense star formation. That, too, could have produced enough heat and energy to create the eROSITA bubbles expanding into the galactic halo.

Zhang and his colleagues thought that any magnetic fields, if they were present, may have some answers.

Light, when it travels through a magnetic field, becomes oriented according to the direction of the magnetic field in what's referred to as polarization. We can examine the light collected by our telescopes to see not just evidence of its polarization, but the direction of the magnetic field that produced it.

When the researchers studied the polarization of the broad spectrum of light emitted by the eROSITA bubbles, they found huge, long filaments of magnetization. If we could see these filaments with our eyes, they would stretch across the sky up to 150 times longer than the width of a full Moon, the researchers say.

And the filaments suggest that the origin of the eROSITA bubbles was star formation. At a distance between around 10,000 and 16,000 light-years from the galactic center, a ring of star formation could have produced the heat and winds that caused hot gas and plasma to billow out into the galactic halo over a distance of tens of thousands of light-years and counting.

"It is now well known that a small fraction of 'active' galaxies can generate outflows of matter fueled by accretion onto supermassive black holes or by intense star formation events, which profoundly affect their host galaxy. Such outflows are thought to be fundamental elements in regulating the growth of galaxies and the black holes at their centers," explains astrophysicist Gabriele Ponti of INAF.

"What I find fascinating in this case is to note that even the Milky Way, a quiescent galaxy like many others, can expel powerful outflows, and in particular that the star formation ring at the end of the rotational center contributes significantly to the galactic outflow. Perhaps the Milky Way is revealing to us a phenomenon common in galaxies similar to ours, thus helping us to shed light on the growth and evolution of these objects."

It is not a certainty, of course; it's going to take a lot more analysis to make a solid determination on the source of the bubbles. The team's findings are consistent with recent simulations, but more detailed ones will be needed to determine whether star formation can produce the kinds of outflows we observe in the eROSITA bubbles.

But the magnetic fields represent a significant piece of the puzzle.

"The study opens new frontiers in our understanding of the galactic halo," Zhang says, "and will contribute to deepening our knowledge of the complex and dynamic star-forming ecosystem of the Milky Way."

The research has been published in *Nature Astronomy*.

Astronomers have made a groundbreaking observation using the NASA/ESA James Webb Space Telescope (JWST), uncovering a galaxy from just 700 million years after the Big Bang that demonstrates an ‘inside-out’ growth pattern.

This early universe galaxy, though one hundred times smaller than the Milky Way, shows surprising maturity. Its outskirts have a densely packed core of stars and active star formation.

This phenomenon marks the earliest recorded example of inside-out galactic growth, a discovery made possible only through Webb’s unprecedented capabilities.

Like a bustling city with a dense urban center and sprawling suburbs, this galaxy is compact at its core, where most of its stars are tightly clustered, while newer stars are forming at an accelerated rate in the outer regions.

City of stars?

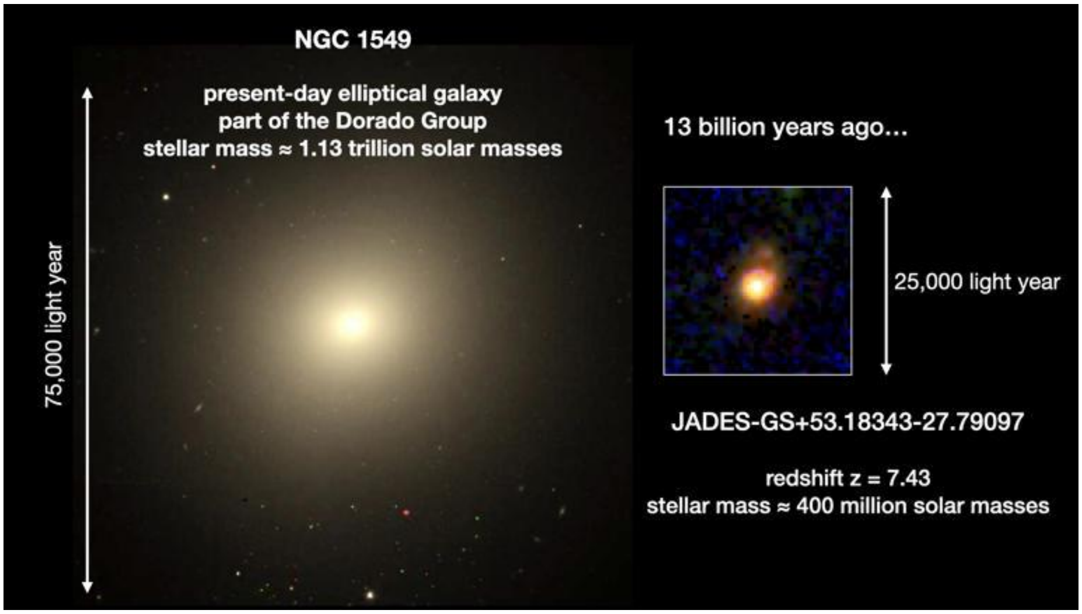
This process of star formation in the outer reaches signals that the galaxy is expanding. The findings, part of the JWST Advanced Extragalactic Survey (JADES), provide fresh insights into how galaxies grew and evolved in the universe's infancy, allowing astronomers to explore new dimensions of cosmic history.

While this observation provides a snapshot of a single moment in time, researchers, led by a team from the University of Cambridge, believe that studying similar galaxies could reveal how these celestial structures evolved from simple gas clouds into the intricate galaxies we observe today.

"The question of how galaxies evolve over cosmic time is an important one in astrophysics," said co-lead author Sandro Tacchella from Cambridge's Cavendish Laboratory. "We've had lots of excellent data for the last ten million years and for galaxies in our corner of the universe, but now with Webb, we can get observational data from billions of years back in time, probing the first billion years of cosmic history, which opens up all kinds of new questions."

Dr. Tacchella likened the growth of galaxies to a spinning figure skater: as gas is pulled inward from great distances, the galaxy spins faster, often leading to the formation of spiral or disc shapes.

This galaxy, though young, has a highly dense core reminiscent of present-day massive elliptical galaxies, which typically contain 1,000 times more stars. Interestingly, most of the star formation is not happening in the core but rather in the outskirts, where a clump of stars is rapidly forming. The growth pattern observed here had been previously predicted by theoretical models, but this is the first time scientists have been able to witness it directly.



Astronomers have used the NASA/ESA James Webb Space Telescope (JWST) to observe the 'inside-out' growth of a galaxy in the early universe, only 700 million years after the Big Bang. (JADES collaboration)

Double the mass in 10 million years

Using JWST's advanced technology, the researchers analyzed the light emitted by the galaxy at different wavelengths to estimate the ages of the stars, their masses, and the rate of star formation. Due to the compactness of the galaxy, the images had to be carefully modeled to account for potential distortions caused by the instrument.

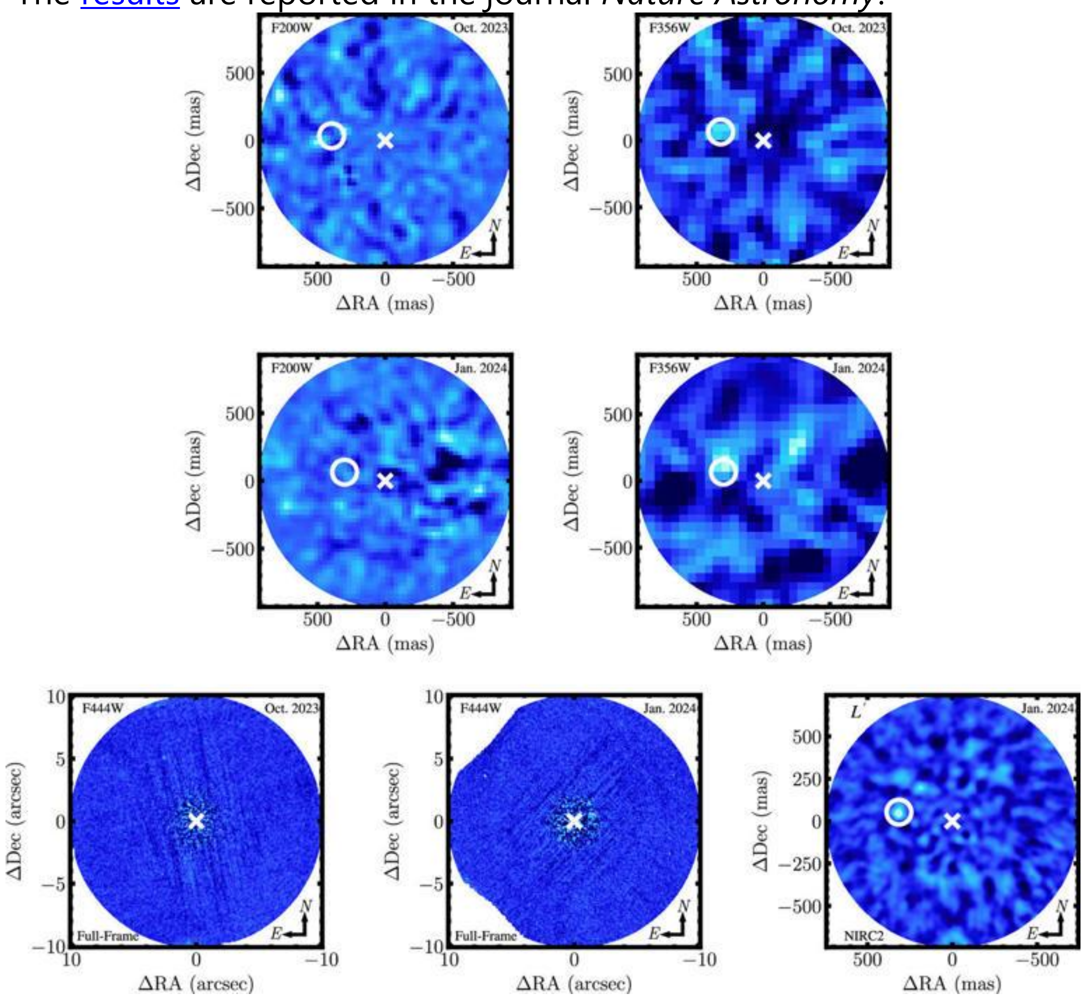
By incorporating models of stellar populations, gas emission, and dust absorption, they discovered that the older stars are concentrated in the core, while the surrounding disc is actively forming new stars. Remarkably, this galaxy doubles its stellar mass in the outskirts approximately every 10 million years—a rate that vastly outpaces that of the Milky Way, which takes 10 billion years to achieve the same mass doubling.

The dense core and rapid star formation suggest that this galaxy is rich in the gas necessary to fuel its growth. This could indicate that conditions in the early universe were markedly different from what we see today, providing ample resources for such rapid star formation.

Despite the significance of this discovery, Tacchella [stressed] the need for further study: “Of course, this is only one galaxy, so we need to know what other galaxies at the time were doing. Were all galaxies like this one? We’re now analyzing similar data from other [galaxies]. By looking at different galaxies across cosmic time, we may be able to reconstruct the growth cycle and demonstrate how galaxies grow to their eventual size today.”

This discovery marks a significant step forward in our understanding of how galaxies formed and evolved in the early universe. As more data from [JWST] becomes available, astronomers hope to continue unraveling the mysteries of galactic growth and the forces that shaped the universe’s earliest stars and structures.

The [results] are reported in the journal *Nature Astronomy*.



Top and middle: F200W (left) and F356W (right) imaging of AF Lep. AF Lep b is not robustly recovered (>5σ) in either filter or epoch. Each image is convolved with a Gaussian filter with a standard deviation of 1 pixel. The circles denote the expected position of AF Lep b at each epoch. The misalignment between the coronagraphic mask and the host star for each data set is incorporated into this prediction. Bottom: the left and middle panels show full-frame F444W imaging of AF Lep for each sequence. No significant point sources are seen at wider separations in this imaging. The artifact to the northeast of the star in the 2023 October imaging is a cosmic-ray artifact that does not appear in the 2024 January imaging. The right panel shows our new Keck/NIRC2 L′ imaging of AF Lep b. To smooth over pixel-to-pixel noise, the image is convolved with a Gaussian filter with a standard deviation of 1.5 pixels. The circle highlights the expected position of the planet. AF Lep b is recovered at an S/N of 6.6σ. Credit: The Astrophysical Journal Letters (2024). DOI: 10.3847/2041-8213/ad736a

Planet AF Lep b is a world of firsts. In 2023, it was the lowest-mass planet outside our solar system to be directly observed and have its mass measured using astrometry. This is a technique that charts the subtle movements of a host star over many years to gain insights about orbiting companions, including planets.

Now, AF Lep b is the lowest-mass planet with the smallest angular separation—that is, how close it is to its host star as seen from Earth—that has been directly observed by the James Webb Space Telescope (JWST). Results were published recently in *The Astrophysical Journal Letters*.

At 23 million years old, AF Lep b is a relatively young gas giant. (For comparison, Jupiter is 4.6 billion years old.) This makes it bright, and therefore, a great candidate to observe. However, the team that wished to learn more about the planet—led by graduate students Kyle Franson at The University of Texas at Austin and William Balmer at Johns Hopkins University—had to race against the clock to capture it. That's because it's moving closer to its host star in its orbit. The closer it gets, the harder it will be to observe.

"AF Lep b is right at the inner edge of being detectable. Even though it is extraordinarily sensitive, JWST is smaller than our largest telescopes on the ground," Franson explained. "And we're observing at longer wavelengths, which has the effect of making objects look fuzzier. It becomes difficult to separate one source out from the other source when they appear so close together."

What's more, JWST uses a coronagraph to observe planets near their stars. This is a tool that blocks the light of the star so nearby objects can be seen. At the angular separation of AF Lep b from its star, the coronagraph blocks out over 90% of the planet's light. As the planet nears its star, more and more of its light will be blocked.

"The conventional wisdom has been that JWST is more sensitive to lower-mass planets on wide orbits than ground-based facilities, but before it launched, it wasn't clear if it would be competitive at small separations," said Brendan Bowler, an astronomer at UT and co-author of the study. "We really are pushing the instrumentation to its limits here."

AF Lep b takes about 25 years to orbit its star. Though in theory, astronomers could capture an image of it on the other side of the star when it will be visible again, it could be more than a decade before that's a possibility.

To ensure they didn't miss this opportunity, the team applied for—and received— Director's Discretionary Time. This is time on the telescope that's held in reserve for critical, time-sensitive observations. It's competitive for proposals to receive observing time on JWST, and even more so under this special designation.

"This is the first Director's Discretionary Time program led by graduate students," said Bowler. "And it's one of only a few within the field of exoplanets."

"It's quite something that two graduate students are able to harness all these incredible technological innovations," added Laurent Pueyo, an astronomer at the Space Telescope Science Institute and co-author of the paper.

The team was eager to learn more about AF Lep b's atmosphere, as it's uncommon to directly observe planets of a similar mass to the gas giants in our own solar system. Based on their observations, it has a very active atmosphere, with convection currents mixing elements between its lower and upper levels.

"We observed much more carbon monoxide than we initially expected," explained Balmer. "The only way to get gas of that type into the planet's upper atmosphere is with strong updrafts."

While learning more about AF Lep b is exciting, the ability to make these observations at all is particularly noteworthy.

"In the big picture, these data were taken in JWST's second year of operations. There's a lot more to come," said Bowler. "It's not just about the planets that we know about now. It's also about the planets that we soon discover. This is foreshadowing some of the exciting work that we will see in the coming years."

More information: Kyle Franson et al, JWST/NIRCam 4–5 µm Imaging of the Giant Planet AF Lep b, *The Astrophysical Journal Letters* (2024). DOI: 10.3847/2041-8213/ad736a

Provided by University of Texas at Austin

Uncommonly common

Our Sun is but one of an estimated 100 to 400 billion other stars in our galaxy. Scientists have so far identified more than 2,500 stars with planets in orbit, but surprisingly, very few appear to be quite like ours. One study estimates only 15 per cent of stars in the entire universe have solar systems even roughly like ours.

Jekyll and Hyde

As the biggest kids in the yard, Jupiter and Saturn have taken a lot of hits. It was widely believed the massive gas giants served as guardians by pulling in many of the comets and asteroids that might otherwise smash into the inner planets, but new research shows they can be bullies too, as their gravity can also slingshot deadly pebbles our way. Either way—whether by providing periods of stability or by sending vital organic ingredients our way—scientists believe they were instrumental in helping life to take hold on Earth.

Diamond rain

The extreme environments of other planets can twist what we know here on Earth on its head. In the crushing gravity of Jupiter and Saturn's atmospheres, scientists have speculated diamond icebergs may be floating around in helium oceans, turning to liquid diamond rain further down as temperatures and pressures rise. Colder Neptune and Uranus could harbour entire oceans of diamond.

Grandest canyon

Mars may be slightly smaller than Earth, but its tourist attractions put Earth's to shame. A massive gash across the red planet's face—the Valles Marineris—runs four times longer and deeper than the Grand Canyon and 20 times wider. Its tallest peak, the Olympus Mons volcano, is the largest in the solar system and three times taller than Mount Everest, looming 25 kilometres (16 miles) above the Martian surface.

The end of the Sun

Even stars must die, and ours is no exception. Our middle-aged Sun shines by consuming 600 million tons of its own hydrogen every second, but in about five billion years it will run out. At that point, our star will swell 200 times its current size into a red giant (engulfing the Earth), fade briefly into a planetary nebula and eventually end up as a white dwarf. Sadly, our planet's shelf life is much shorter: we have about a billion years before increasing solar radiation makes life on Earth impossible.

Space weather

In 1859, the most powerful solar storm in modern history wreaked havoc with telegraph wires and produced aurora as far south as Hawaii. That same storm today would cripple modern society by disrupting power grids and satellites; one scientist describes it as "one of the most important threats the nation faces, bar none." With no accurate forecasts yet available to sufficiently prepare us, experts estimate a similar event could cause up to US$2 trillion in damages in the first year alone and require years of recovery.

Relative scale

Diagrams of the solar system show the planets fanning outward from the Sun at varying sizes, with distinguishing characteristics like Saturn's rings or Mars' ruddy hue. But in fact, the solar system is so big the Earth wouldn't even merit a pixel on a computer screen. For perspective, if Earth were the size of a grape, the Sun would be a block away and hide most of a Smart Car. Jupiter would be a grapefruit four blocks away and the nearest star would be *tens of thousands* of kilometres away.

Rare earths

NASA triggered something of a space gold rush after it identified a metallic asteroid in the asteroid belt worth quintillions of dollars in nickel and iron. The space mining bubble quickly deflated as commercial ventures struggled to find funding to launch their ambitious off-world schemes, but some believe it's only a matter of time. For the moment, there is still valuable knowledge to be mined and NASA's upcoming Psyche mission will more closely examine the asteroid, which scientists believe may actually be the remnant core of a small planet.

Van Allen Belts

The earth is surrounded by two doughnut-shaped rings of charged particles known as the Van Allen Belts. They are so radioactive that scientists thought they'd detected a Soviet nuclear test with their measurements. The radiation is a known danger to astronauts and instruments in their vicinity, but the belts also shield the Earth from many high-energy particles.

Ice volcanoes

Volcanoes are some of the hottest features on Earth but in some corners of the solar system their eruptions are ice-cold. Cryovolcanoes, as they are known, have been discovered on several moons around Neptune, Jupiter, Saturn and Uranus, spewing out cryomagma made of methane, carbon dioxide, water and ammonia.

Oort Cloud

The most remote members of our solar system make up a shell of icy objects—some as large as mountains—known as the Oort Cloud. Believed to be the source of most of the long-period comets (those that take more than 200 years to orbit the Sun), the Oort Cloud is so far away that our most distant probes, Voyager 1 and Voyager 2, will have to travel more than 30,000 years to get to the other side.

Seeding life

The basic ingredients for life have been detected throughout our solar system—even in other star systems—bolstering the case for the theory that life on Earth was seeded by ingredients deposited by comets and meteorites. The theory of panspermia goes a step further to suggest life itself originated elsewhere before crash-landing on Earth. MIT's Search for Extra-Terrestrial Genomes is building instruments capable of detecting "alien" life in places like Mars and the moons of Europa and Enceladus.

Saturn's hexagon

Storms on Earth are generally quite curvy but Saturn has a storm that forms a neat hexagon. The towering polar vortex has raged for decades—perhaps even centuries—and changes from blue to gold through the planet's long seasons. While it may seem odd, scientists say geometric storms are not unusual, it's just that conditions on Earth prevent those shapes from forming. Not to be outdone, Jupiter was spotted with elaborately patterned cyclones resembling mandalas at its poles in 2018.

Planet Nine

After Pluto got demoted as a planet, it seemed our solar system was destined for just eight planets until evidence of a mysterious ninth planet was discovered. Though we haven't observed it directly, astronomers have detected the influence of a large body 10 times the size of Earth and so far away that it takes 20,000 years to orbit the Sun. If its existence can be confirmed, it will serve as a sharp reminder we still have much to discover in our own backyard.

Interstellar headwinds

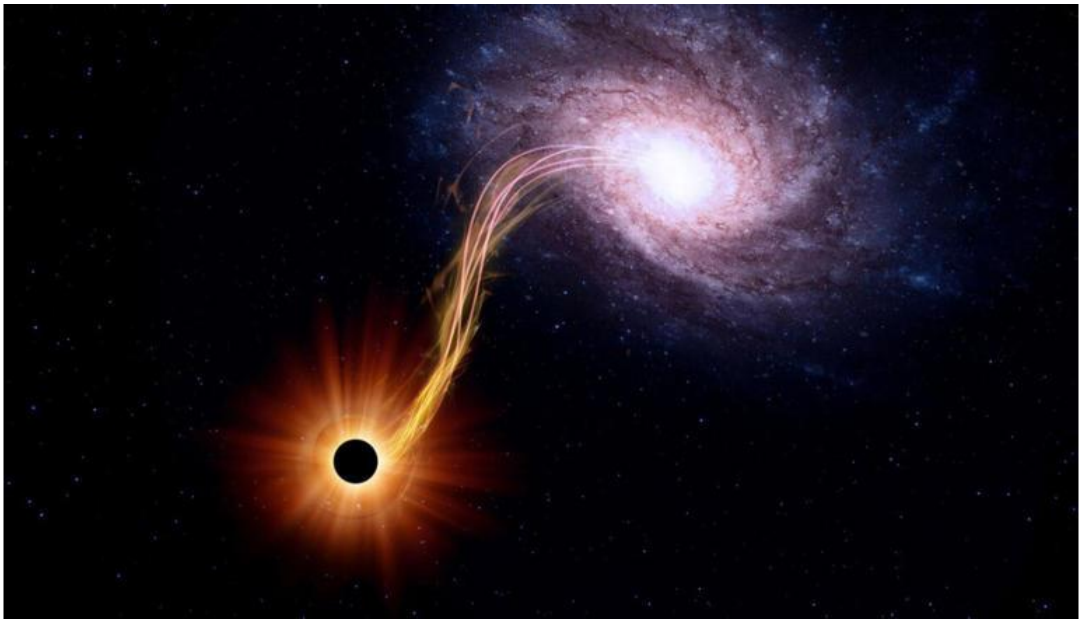
Our solar system fights strong headwinds in its journey through the galaxy. As charged particles streaming from the Sun push up against an interstellar wind of charged particles from space, they wrap back around to envelop our solar system in a shielding wall of plasma called the heliosphere. Our first interstellar probes, Voyager 1 and Voyager 2, revealed that the boundary where the two winds are in equilibrium—the heliopause—resembles the bullet-shaped bow shock of a ship plowing through the ocean.

Lunar genesis

The prevalent theory about the origin of the Earth's moon was that a Mars-sized body named Theia collided with Gaia—our early Earth—throwing debris into space that coalesced into our present-day Moon. A newer theory, however, proposes that the collision vaporized both bodies to produce a new type of structure dubbed "synestia" and that the Moon and Earth both formed from this debris, which would explain why they are so chemically similar.

The long year

Our solar system is located in the Orion arm, one of the Milky Way's two minor spiral arms. It moves through the galaxy at a modest 828,000 km/h (515,000 mph), locked in a stately, 230-million-year-orbit around the supermassive black hole at the heart of the galaxy. While most of the stars in the galaxy lie on a plane, our solar system's orbit is somewhat tilted, moving us back and forth across the spiral arm as we complete our galactic year.



Credit: Pixabay/CC0 Public Domain

Supermassive black holes are some of the most impressive (and scary) objects in the universe—with masses around 1 billion times more than that of the sun. And we know they've been around for a long time.

In fact, astronomers have detected the extremely luminous compact sources that are located at the centers of galaxies, known as quasars (rapidly growing supermassive black holes), when the universe was less than 1 billion years old.

Now our new study, published in *The Astrophysical Journal Letters*, has used observations from the Hubble Space Telescope to show that there were many more (much less luminous) black holes in the early universe than previous estimates had suggested. Excitingly, this can help us understand how they formed—and why many of them appear to be more massive than expected.

Black holes grow by swallowing up material that surrounds them, in a process known as accretion. This produces tremendous amounts of radiation. The pressure from this radiation places a fundamental limit on how quickly black holes can grow.

Scientists were therefore faced with a challenge in explaining these early, massive quasars: without much cosmic time in which to feed, they must have either grown quicker than physically possible, or been born surprisingly massive.

Light vs. heavy seeds

But how do black holes form at all? Several possibilities exist. The first is that so-called primordial black holes have been in existence since shortly after the big bang. While plausible for black holes with low masses, massive black holes cannot have formed in significant numbers according to the standard model of cosmology.

Black holes definitely can form (now verified by gravitational wave astronomy) in the final stages of the short lives of some normal massive stars. Such black holes could in principle grow quickly if formed in extremely dense star clusters where stars and black holes may merge. It is these "stellar mass seeds" of black holes that would need to grow up too fast.

The alternative is that they could form from "heavy seeds," with masses around 1,000 times greater than known massive stars. One such mechanism is a "direct collapse," in which early structures of the unknown, invisible substance known as dark matter confined gas clouds, while background radiation prevented them from forming stars. Instead, they collapsed into black holes.

The trouble is that only a minority of dark matter halos grow large enough to form such seeds. So this only works as an explanation if the early black holes are rare enough.

Too many black holes

For years, we have had a good picture of how many galaxies existed in the first billion years of cosmic time. But finding black holes in these environments was extremely challenging (only luminous quasars could be proven).

Although black holes grow by swallowing surrounding material, this does not happen at a constant rate—they break their feeding into "meals," which makes their brightness vary over time. We monitored some of the earliest galaxies for changes in brightness over a 15 year period, and used this to make a new census of how many black holes are out there.

It turns out that there are several times as many black holes residing in ordinary early galaxies than we originally thought.

Other recent, pioneering work with the James Webb Space Telescope (JSTW) has begun to reach similar conclusions. In total we have more black holes than can form by direct collapse.

There is another, more exotic, way of forming black holes that could produce seeds that are both massive and abundant. Stars form by gravitational contraction of gas clouds: if significant numbers of dark matter particles can be captured during the contraction phase, then the internal structure could be entirely modified—and nuclear ignition prevented.

Growth could therefore continue for many times longer than the typical lifetime of an ordinary star, allowing them to become much more massive. However, like ordinary stars and direct collapse objects, nothing is ultimately able to withstand the overpowering force of gravity. This means these "dark stars" should also eventually collapse to form massive black holes.

We now believe that processes similar to this should have taken place to form the large numbers of black holes we observe in the infant universe.

Future plans

Studies of early black hole formation have undergone a transformation in the last two years, but in a sense this field is only just beginning.

New observatories in space, such as the Euclid mission or the Nancy Grace Roman Space Telescope, will fill in our census of fainter quasars at early times. The NewAthena mission and the Square Kilometer Array, in Australia and South

Africa, will unlock our understanding of many of the processes surrounding black holes at early times.

But it is really the JWST that we must watch in the immediate term. With its sensitivity for imaging and monitoring and spectroscopic capabilities to see very faint black hole activity, we expect the next five years to really nail down black hole numbers as the first galaxies were forming.

We may even catch black hole formation in the act, by witnessing the explosions associated with the collapse of the first pristine stars. Models say this is possible, but it will demand a coordinated and dedicated effort by astronomers.

Haven-2 would serve as a specialized lab in low-Earth orbit, where visitors can conduct microgravity research.© Photographer: NASA/Getty Images

(Bloomberg) -- Vast Space, the aerospace startup founded by former crypto tycoon Jed McCaleb, revealed its plans for a successor to the International Space Station, joining Jeff Bezos' Blue Origin and others hoping to commercialize Earth orbit.

Haven-2 would serve as a specialized lab in low-Earth orbit, where visitors can conduct microgravity research. It's also meant to serve as a destination for NASA's international partners to send their astronauts.

Haot declined to give an exact cost for Haven-2 but said that by the time the company flies the first crews to Haven-1, it expects to have invested as much as

$1 billion. Vast will also be holding a fundraising round between the end of 2024 and the end of 2025 for the development of Haven-2, allowing the company to rely on external investors as well as McCaleb, its primary financier.

Scientists Are Getting Closer to Finding Evidence of the Fifth Force

- Some physicists believe that a fifth fundamental force could be the cause of some observational anomalies.
- A new study is investigating ways to closely examine the trajectories of well-documented asteroids to hopefully detect anomalies that could provide evidence of such a force.
- Although the study shows no fifth force anomaly present in the asteroid Bennu, future explorations of the asteroid Apophis could provide an even better chance to find this elusive force—if it exists at all.

According to the current Standard Model, four fundamental forces underpin all known physics: electromagnetism, gravity, and the strong and weak nuclear forces. However, since the mid-1980s, physicists have wondered if a fifth fundamental force could exist, which would help to explain some observational anomalies. And since then, many studies have boldly claimed discovery of this elusive force.

In 1986, for example, scientists at MIT thought that antigravity could maybe could be a fifth force, and in 2000, another group named the force "quintessence" as a way to explain dark energy. In 2015, a study by the Hungarian Academy of Sciences discovered a particle 30 times heavier than an electron that could form the basis of a fifth force, and the U.S.-based Fermilab stated boldly that they were on the cusp of discovering this mysterious force just last year.

And, of course, there's a strong contingent of physicists who think a fifth force doesn't exist at all.

One proposed way of examining if such a force could exist is by closely monitoring asteroid trajectories, and few near-Earth asteroids are as well observed as Bennu. A new study by an international team of scientists analyzes Bennu to try and placing constraints on a possible fifth fundamental force in the search of ultralight dark matter.

Bennu, one of the most dangerous near-Earth objects, has been meticulously tracked by optical and radar astrometric data since it was discovered in 1999. As the destination for the OSIRIS-REx asteroid retrieval mission, additional X-band radiometric and optical navigation tracking data added even more trajectory precision. The idea is that any deviation in the expected trajectory of the asteroid could be the result of an unknown fifth force at work. The results of the study were published in the journal *Nature Communications Physics*.

“Interpreting the data we see from tracking Bennu has the potential to add to our understanding of the theoretical underpinnings of the universe, potentially revamping our understanding of the Standard Model of physics, gravity and dark matter,” Yu-Dai Tsai, the lead author on the paper, said in a press statement. “The trajectories of objects often feature anomalies that can be useful in discovering new physics.”

The trajectories of heavenly objects have yielded incredible discoveries before. Neptune, for example, was first “discovered” not through a telescope, but by the meticulous calculations of Uranus’ orbit and discovery of gravitational anomalies therein. However, such a technique isn’t foolproof, as some scientists *also* believed that a planet named Vulcan existed between the Sun and Mercury. This, obviously, turned out to be false.

“These results highlight the potential for asteroid tracking as a valuable tool in the search for ultralight bosons, dark matter, and several well-motivated extensions of the Standard Model,” Sunny Vagnozzi, assistant professor at the University of Trento in Italy and study co-author, said in a press statement.

While this study didn’t find “evidence in the data for the presence of a fifth force affecting the motion of Bennu,” the ORSIRIS-REx’s sequel, OSIRIS-APEX, could provide even more data as the mission zooms onward toward the asteroid Apophis. Because this asteroid will zoom by Earth in 2029, a detailed study of its trajectory will deliver even further restrictions on the fifth force than what Bennu could provide.

So, while the ongoing exploration of the fifth force continues in accelerator labs around the world, some scientists are turning toward space to answer the deepest mysteries of physics.

Measuring the atmospheres of other worlds to see if there are enough nutrients for life

Life on Earth depends on six critical elements: carbon, hydrogen, nitrogen, oxygen, phosphorous, and sulfur. These elements are referred to as CHNOPS, and along with several trace micronutrients and liquid water, they're what life needs.

Scientists are getting a handle on detecting exoplanets that might be warm enough to have liquid water on their surfaces, habitability's most basic signal. But now, they're looking to up their game by finding CHNOPS in exoplanet atmospheres.

We're only at the beginning of understanding how exoplanets could support life. To grow our understanding, we need to understand the availability of CHNOPS in planetary atmospheres.

A new paper posted to the *arXiv* preprint server examines the issue. It's titled "Habitability constraints by nutrient availability in atmospheres of rocky exoplanets." The lead author is Oliver Herbort from the Department of Astrophysics at the University of Vienna and an ARIEL post-doctoral fellow. The paper has been accepted by the *International Journal of Astrobiology*.

At our current technological level, we're just beginning to examine exoplanet atmospheres. The JWST is our main tool for the task, and it's good at it. But the JWST is busy with other tasks. In 2029, the ESA will launch ARIEL, the Atmospheric Remote-sensing Infrared Exoplanet Large survey. ARIEL will be solely focused on exoplanet atmospheres.

In anticipation of that telescope's mission, Herbort and his co-researchers are preparing for the results and what they mean for habitability. "The detailed understanding of the planets itself becomes important for interpreting observations, especially for the detection of biosignatures," they write. In particular, they're scrutinizing the idea of aerial biospheres. "We aim to understand the presence of these nutrients within atmospheres that show the presence of water cloud condensates, potentially allowing the existence of aerial biospheres."

Our sister planet Venus has an unsurvivable surface. The extreme heat and pressure make the planet's surface uninhabitable by any measure we can determine. But some scientists have proposed that life could exist in Venus' atmosphere, based largely on the detection of phosphine, a possible indicator of life. This is an example of what an aerial biosphere might look like.

"This concept of aerial biospheres enlarges the possibilities of potential habitability from the presence of liquid water on the surface to all planets with liquid water clouds," the authors explain.

The authors examined the idea of aerial biospheres and how the detection of CHNOPS plays into them. They introduced the concept of nutrient availability levels in exoplanet atmospheres. In their framework, the presence of water is required regardless of other nutrient availability. "We considered any atmosphere without water condensates as uninhabitable," they write, a nod to water's primacy. The researchers assigned different levels of habitability based on the presence and amounts of the CHNOPS nutrients.

To explore their framework of nutrient availability, the researchers turned to simulations. The simulated atmospheres held different levels of nutrients, and the researchers applied their concept of nutrient availability. Their results aim to understand not habitability but the chemical potential for habitability. A planet's atmosphere can be altered drastically by life, and this research aims to understand the atmospheric potential for life.

"Our approach does not directly aim for the understanding of biosignatures and atmospheres of planets, which are inhabited, but for the conditions in which pre-biotic chemistry can occur," they write. In their work, the minimum atmospheric concentration for a nutrient to be available is 10^9, or one ppb (part per billion.)

"We find that for most atmospheres at (p gas, T gas) points, where liquid water is stable, CNS-bearing molecules are present at concentrations above 10^9," they write. They also found that carbon is generally present in every simulated atmosphere and that sulfur availability increases with surface temperature. With lower surface temperatures, nitrogen (N_2, NH_3) is present in increasing amounts. But with higher surface temperatures, nitrogen can become depleted.

Phosphorus is a different matter. "The limiting element of the CHNOPS elements is phosphorus, which is mostly bound in the planetary crust," they write. The authors point out that, at past times in Earth's atmosphere, phosphorus scarcity limited the biosphere.

An aerial biosphere is an interesting idea. But it's not the main thrust of scientists' efforts to detect exoplanet atmospheres. Surface life is their holy grail. It should be no surprise that it still comes down to liquid water, all things considered. "Similar to previous work, our models suggest that the limiting factor for habitability at the surface of a planet is the presence of liquid water," the authors write. In their work, when surface water was available, CNS was available in the lower atmosphere near the surface.

But surface water plays several roles in atmospheric chemistry. It can bond with some nutrients in some circumstances, making them unavailable, and in other circumstances, it can make them available.

"If water is available at the surface, the elements not present in the gas phase are stored in the crust condensates," the authors write. Chemical weathering can then make them available as nutrients. "This provides a pathway to overcome the lack of atmospheric phosphorus and metals, which are used in enzymes that drive many biological processes."

This complicates matters on worlds covered by oceans. Pre-biotic molecules might not be available if there's no opportunity for water and rock to interact with the atmosphere. "If indeed it can be shown that life can form in a water ocean without any exposed land, this constraint becomes weaker, and the potential for the surface habitability becomes mainly a question of water stability," the authors write.

Some of the models are surprising because of atmospheric liquid water. "Many of the models show the presence of a liquid water zone in the atmospheres, which is detached from the surface. These regions could be of interest for the formation of life in forms of aerial biospheres," Herbort and his colleagues write.

If there's one thing that research like this shows, planetary atmospheres are extraordinarily complex and can change dramatically over time, sometimes because of life itself. This research makes some sense in trying to understand it all. Emphasizing the complexity is the fact that the researchers didn't include stellar radiation in their work. Including that would've made the effort unwieldy.

The habitability issue is complicated, confounded by our lack of answers to foundational questions. Does a planet's crust have to be in contact with water and the atmosphere for the CHNOPS nutrients to be available? Earth has a temporary aerial biosphere. Can aerial biospheres be an important part of exoplanet habitability?

But beyond all the simulations and models, as powerful as they are, what scientists need most is more data. When ARIEL launches, scientists will have much more data to work with. Research like this will help scientists understand what ARIEL finds.

More information: Oliver Herbort et al, Habitability constraints by nutrient availability in atmospheres of rocky exoplanets, *arXiv* (2024). arxiv.org/abs/2404.04029

Provided by Universe Today

This Early Galaxy Grew Inside Out And Upends What We Know About Star Formation

Sci-fi tends to paint the edge of our galaxy as a desolate backwater, but in one early galaxy, the galactic rim is the bright, bustling center of activity, and the core is the aging backwater.

The James Webb Space Telescope (JWST) recently spotted a tiny galaxy in the early universe, more than 12 billion light years away, whose core was full of older, slowly fading stars; all the hot new star formation was happening out on the edges of the galaxy, not in the core, like a cosmic version of suburban sprawl and slowly-dying downtowns. The inside-out growth of this ancient galaxy could teach us something about the history of our own Milky Way and how it compares to the rest of the universe.

The Outskirts of the Galaxy Are Where the Action Is

We tend to picture the universe's earliest galaxies as vaguely round, reddish blobs of light, without much structure. But using JWST, Tacchella and his colleagues recently found one galaxy that, less than a billion years after the Big Bang, had already started evolving into something more complex.

"The question of how galaxies evolve over time is an important one in astrophysics," says Tacchella in a recent statement. "By looking at different galaxies across cosmic time, we may be able to reconstruct the growth cycle and demonstrate how galaxies grow to their eventual size today." That's been one of JWST's main science goals.

Like modern elliptical galaxies, this ancient one has a core densely packed with stars, which thin out toward the edges of the galaxy. JWST's instruments measured the spectra of light shining from different areas of the galaxy, and Tacchella and his colleagues used that data to calculate the age and mass of the stars. It turns out that the dense galactic core is populated mostly by older, slowly fading stars, while most of the bustling new stellar neighborhoods are on the outskirts of the galaxy. And those booming galactic suburbs are growing fast enough to double the galaxy's mass every 10 billion years.

(For comparison, our Milky Way is still growing, but much more slowly; we double our mass only every 10 billion years. The galaxy in Tacchella and his colleagues recent study is only one hundred thousandth the mass of our Milky Way, but it may eventually catch up.)

Galaxies in the more recent, nearby universe grow in a very similar way; as a galaxy grows, it's gravity pulls in intergalactic gas from farther and farther away, and stars often form near the edges of galaxies where more of that gas is spiraling inward. Simulations predicted that ancient galaxies should have grown in the same way, but astronomers had never seen it happen. Instead, astronomers have only ever witnessed these early galaxies growing by colliding with each other in the crowded space of the early universe, violently merging into larger galaxies. But mergers don't seem to happen often enough to account for how the little red blobs of light in the very early universe grew into today's huge, complex spirals and disks of stars.

"Galaxy-galaxy mergers lead to the formation of a lot of new stars, and are therefore extremely bright and "easy" to find," Tacchella tells *Inverse*. "However, we think that these mergers are rare, and most galaxies grow by accreting fresh gas. However, we do not know this for sure, particularly [in the universe] at these early times."

To understand more about how galaxies in the early universe grew and evolved into the ones we see today, Tacchella and his colleagues will need to watch the process happening in more than just one early galaxy. The team of astrophysicists is already analyzing data from several other galaxies, comparing the amount of new star formation that is in their cores and at their edges.

It's possible that after a certain point in their lives, all galaxies tend to have aging, rundown cores and bright, fast-growing outskirts. But it's also possible that galaxies alternate between forming new stars in their cores and in their outskirts — maybe depending on the supermassive black hole at the center of the galaxy or the amount of intergalactic gas available nearby.

"The problem is that we cannot observe this specific galaxy as it changes with cosmic time (we would have to wait millions of years!) so we have to study many systems and look for patterns," says Tacchella.

Milky Way's Ancient Stellar Disk Unveils the Galaxy's Unexpectedly Early Origins

Astronomers have identified the oldest stellar disk in the **Milky Way**, a discovery that reshapes our understanding of the galaxy's formation. This early disk, known as **PanGu**, is over **13 billion years old** and represents the original structure from which the Milky Way grew. The finding challenges long-held theories about how and when our galaxy came together and provides new insight into the early development of spiral galaxies.

A Journey Back to the Galaxy's Beginnings

Researchers from the **Chinese Academy of Sciences** and the **University of Toronto** focused on tracking the oldest stars in the Milky Way to uncover its earliest structures. The team used advanced techniques to study the movement of high-α stars, a class of stars enriched in alpha elements, which tend to form early in a galaxy's history. They discovered that a population of stars more than **13 billion years old** formed a disk-like structure, which they named **PanGu**, after the Chinese god of creation.

This stellar disk dates back to a period shortly after the **Big Bang**, about **13.4 billion years ago**, when the first stars began to form. Prior to this discovery, astronomers believed the Milky Way started forming in a more structured way around **12.5 billion years ago**, but the PanGu disk shows that the galaxy had already taken shape earlier than expected. The stars in this ancient disk have a combined mass of around **3.7 billion solar masses**, a significant portion of the early Milky Way.

A Smooth Growth Compared to Other Galaxies

One of the most surprising findings from this study is the steady, uninterrupted growth of the **PanGu disk**. While many galaxies of comparable size formed through violent mergers and chaotic events, the Milky Way's early history appears more stable. Over time, the PanGu disk flattened into the shape typical of spiral galaxies, but its initial form was almost as tall as it was wide, indicating a less violent formation process.

By the time the Milky Way reached its peak of star formation **11 billion years ago**, it was producing stars at a rate of about **11 solar masses per year**. This relatively smooth development sets the Milky Way apart from other spiral galaxies, which often experienced multiple disruptions during their formation.

The PanGu disk now accounts for only **0.2%** of the Milky Way's current mass, as much of the galaxy's material has been acquired through mergers with smaller galaxies over billions of years.

Challenging Traditional Models of Galaxy Formation

The discovery of the PanGu disk not only sheds light on the Milky Way's history but also challenges traditional models of galaxy formation. Previously, astronomers believed that large galaxies like the Milky Way developed through a series of chaotic mergers, leading to irregular growth and frequent restructuring. However, the existence of the **PanGu disk** suggests that the Milky Way followed a more orderly and continuous growth path.

This finding adds complexity to our understanding of how galaxies form and evolve. Simulations of galaxy formation suggest that most galaxies like the **Milky Way** experienced significant disruption early in their histories, but the PanGu disk indicates that such disruption was less severe for our galaxy.

Future Investigations

The discovery of the Milky Way's ancient stellar disk opens new avenues for research into the early development of galaxies. As astronomers continue to study the stars within the **PanGu disk**, they hope to learn more about the conditions that allowed the Milky Way to grow in such a stable manner compared to other galaxies. These findings will also help scientists refine models of galaxy evolution, providing a clearer picture of the processes that shaped the universe after the **Big Bang**.

As the study suggests, the Milky Way's star formation peaked around **11 billion years ago**, and understanding how this disk evolved during and after that period could provide critical insights into the development of other spiral galaxies.

Astronomers’ discovery of distant Milky Way-like galaxy challenges our theories of how cosmos evolved

Researchers have discovered a distant disc galaxy that has surprisingly similar characteristics to our own Milky Way, and it could change our understanding of how galaxies form.

The galaxy, which has been named REBELS-25, is far more orderly than the existing science suggests it should be for its age, according to research led by astronomers from Leiden University in the Netherlands.

REBELS-25 is much younger than our galaxy, but it already shares its rotation and structure, rather than appearing clumpy and chaotic like other early galaxies, the researchers said in a statement published October 7.

“According to our understanding of galaxy formation, we expect most early galaxies to be small and messy looking,” Jacqueline Hodge, an astronomer at Leiden University and co-author of the study, said in the statement.

Early galaxies tend to join together and develop smoother shapes incredibly slowly, with our Milky Way taking billions of years to develop tidy structures, the researchers said.

The light reaching Earth from REBELS-25 was emitted just 700 million years after the universe was formed 13.8 billion years ago, a surprisingly short amount of time for it to have become so orderly, they said.

“Seeing a galaxy with such similarities to our own Milky Way, that is strongly rotation-dominated, challenges our understanding of how quickly galaxies in the early Universe evolve into the orderly galaxies of today’s cosmos,” Lucie Rowland, a doctoral student at Leiden University and first author of the study, said in the statement.

The rotation and structure of the galaxy were observed using the Atacama Large Millimeter/submillimeter Array (ALMA) telescope in northern Chile.

The team also found data that hinted at even more developed features, such as spiral arms, and they plan to carry out more observations to confirm whether they in fact exist.

"Finding further evidence of more evolved structures would be an exciting discovery, as it would be the most distant galaxy with such structures observed to date," Rowland said.

Andrew Blain, a professor of astrophysics at the University of Leicester, who was not involved in the paper, said REBELS-25 is "a bit unusual," but "it's not a revolution."

Blain highlighted the role of ALMA in finding a real example of a kind of galaxy that had previously only been produced in simulations.

"Without ALMA there's been no ability to identify an example – both because individual examples would have been too faint to detect in a reasonable time, and a large enough sample of candidates could not be searched," he told CNN. "ALMA also reveals details finer than earlier telescopes."

Blain said more research is needed before scientists change their understanding of galaxy formation.

"A question would be are they very rare, or does every galaxy go through a phase like this," he said. "If they're common, then models will have to be tweaked."

Dave Clements, a reader in astrophysics at Imperial College London, who was not involved in the paper, said it "is quite a surprise" to find a galaxy like REBELS-25.

"The universe back then is thought to be a lot more chaotic, with galaxy interactions and mergers expected to disrupt the relatively fragile structure of a disk. And yet that's what REBELS-25 looks like," he told CNN.

"Is it just a very unusual galaxy, that's led an unexpectedly quiet life up to when we see it, or are these observations telling us that the early stages of galaxy formation don't work the way we think? At this point we don't know."

The research, which is available as a preprint (a scientific paper that has not gone through the peer-review process), has been accepted for publication in the journal Monthly Notices of the Royal Astronomical Society.

Researchers claim to have found the oldest stellar disk in the Milky Way galaxy

A team of astronomers and astrophysicists at the Chinese Academy of Sciences and the University of Toronto has found what they believe is the oldest stellar disk in the Milky Way galaxy. In their study, reported in the journal *Nature Astronomy*, the group used high-α stars with substantial orbital angular momentum to conduct age determinations across a wide range of stars in the galaxy.

Prior research has shown that the Milky Way started its life as a single entity. Over time, it has drawn in multiple other galaxies, making it much bigger—remnants of such galaxies have been found throughout the Milky Way. Such additions have made it difficult for astronomers to determine the original structure of the Milky Way.

In this new effort, the research team claims that by dating a large number of stars in different parts of the galaxy, they were able to narrow their focus to a particular group that they believe represents the original galaxy disk. The team named the disk PanGu.

By dating the stars in the galaxy, the researchers also found evidence that they have a combined mass of approximately 3.7 billion times that of the sun. These findings challenge prior theories because the first stars likely came to exist approximately 400 billion years after the Big Bang, which translates to 13.4 billion years ago; they could not have belonged to structured galaxies until approximately 12.5 billion years ago.

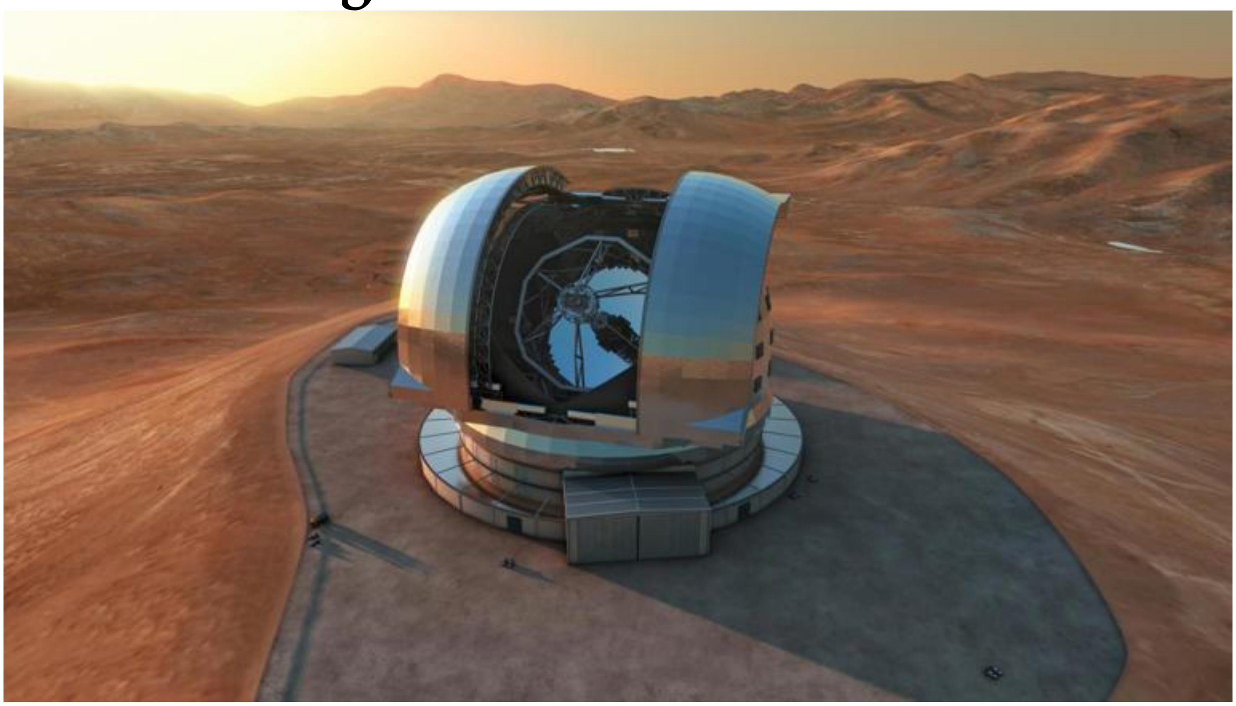
This suggests the Milky Way would not have had time to gain such mass. But the research team is insistent, suggesting further that a steady rate of star production could have resulted in the mass they calculated—the rest of the stars in the early Milky Way would have expired as supernovas.

That, the team claims, leaves the current disk with 2.2 billion solar masses—a figure that represents just 0.2% of the current mass of the galaxy, demonstrating just how much of the Milky Way is made up of material from other galaxies.

The team also suggests their evidence shows that the Milky Way reached its maximum size approximately 11 billion years ago.

More information: Maosheng Xiang et al, The formation and survival of the Milky Way's oldest stellar disk, *Nature Astronomy* (2024). DOI: 10.1038/s41550-024-02382-w

A new generation of telescopes will probe the 'unknown unknowns' that could transform our knowledge of the universe



Artist's impression of the European Extremely Large Telescope (E-ELT) in its enclosure on Cerro Armazones, a 3060-metre mountaintop in Chile's Atacama Desert. The 39-metre E-ELT will be the largest optical/infrared telescope in the world — the world's biggest eye on the sky. Operations are planned to start early in the next decade, and the E-ELT will tackle some of the biggest scientific challenges of our time. The design for the E-ELT shown here is preliminary. Credit: ESO/L. Calçada

In recent decades, we've learned huge amounts about the universe and its history. The rapidly developing technology of telescopes—both on Earth and in space—has been a key part of this process, and those that are due to start operating over the next two decades should push the boundaries of our understanding of cosmology much further.

All observatories have a list of science objectives before they switch on, but it is their unexpected discoveries that can have the biggest impact. Many surprise advances in cosmology were driven by new technology, and the next telescopes have powerful capabilities.

Still, there are gaps, such as a lack of upcoming space telescopes for ultraviolet and visible light astronomy. Politics and national interests have slowed scientific progress. Financial belts are tightening at even the most famous observatories.

The biggest new telescopes are being built in the mountains of Chile. The Extremely Large Telescope (ELT) will house a mirror the size of four tennis courts, under a huge dome in the Atacama desert.

Reflecting telescopes like ELT work by using a primary mirror to collect light from the night sky, then reflecting it off other mirrors to a camera. Larger mirrors collect more light and see fainter objects.

Another ground-based telescope under construction in Chile is the Vera C. Rubin telescope. Rubin's camera is the largest ever built: the size of a small car and weighing about three tons. Its 3,200 megapixels will photograph the whole sky every three days to spot moving objects. Over the course of 10 years, these photographs will be combined to form a massive time-lapse video of the universe.

Astronomy used to be a physically demanding job, requiring travel to remote telescopes in dark sites–-but many astronomers began working from home long before COVID. In the late 20th century, major ground observatories started to put in place technology to allow astronomers to control telescopes for observations at night, even when they were not there in person. Remote observing is now commonplace, carried out via the internet.

Expect the unexpected

The view of any telescope on the ground is limited, though, even if it's on top of a mountain. Launching telescopes into space can get around these limitations.

The Hubble Space Telescope's operational history began when the space shuttle lifted it above the atmosphere on April 25, 1990. Hubble got the full 1960s sci-fi treatment: a rocket to launch it, gyroscopes to point it, and electronic cameras instead of photographic film. But one plan fell through: for Hubble to host a commuting astronaut-astronomer, working decidedly away from home.

Hubble was designed to take a census of the Milky Way and its neighboring galaxies. Its successor, the James Webb Space Telescope, would study even more distant galaxies.

Both telescopes have revolutionized our understanding of the universe, but in ways nobody foresaw. Hubble's original plans mention none of the discoveries now seen as its greatest hits: plumes of water erupting from Jupiter's moon Europa, the vortex around black holes, invisible dark matter that holds the universe together, and the dark energy that is pulling it apart.

Webb, launched on December 25 2021, now spends a third of its time looking at planets around other stars that weren't even known about when it was designed.

The stated goal of an expensive telescope is usually just a sales pitch to space agencies, governments and (shhh...) taxpayers. The Webb telescope should achieve its original science goals, but astronomers have always known that seeing further, finer or in more colors can achieve so much more. The unexpected discoveries by telescopes are often more significant than the science objectives stated at the outset.

Taking the long view

For scientists, it's a relief that telescopes go beyond their brief, because Hubble and Webb both took more than 25 years from napkin to launch. In that time, new scientific questions arise.

Building a large space telescope typically takes about two decades. The Chandra and XMM-Newton space telescopes took 23 years and 15 years to build, respectively. They were designed to observe X-rays coming from hot gas around black holes and galaxy clusters, and were launched very close together in 1999.

They were followed by Japan's Hitomi X-ray satellite, which took 18 years to build, and the German eRosita instrument on Russia's Spektr-RG space observatory, which took 20 years.

Similar timescales apply to the European Space Agency's Hipparcos and Gaia space telescopes, which have mapped all the stars in the Milky Way. The Cobe and Planck missions to study the microwave-light afterglow of the Big Bang also took two decades. Precise dates depend on how you count, and a few exceptions have been "faster, better, cheaper," but national space agencies are generally risk-averse and slow when developing these projects.

The latest space telescopes are therefore millennials. They were designed at a time when astronomers had measured the universe's newborn expansion following the Big Bang, and also its old-age, accelerating expansion. Their main goal now is to fill the gap –- because, surprisingly, interpolations from early times to late times don't meet in the middle.

The measured rates for the expansion of the universe are inconsistent, as are results for the clumpiness of matter in the cosmos. Both measurements create challenges for our theories of how the universe evolved.

Observing the middle age of the universe requires telescopes operating at long wavelengths, because light from distant galaxies is stretched by the time it reaches us. So, Webb has infrared zoom cameras, while the European Space Agency's Euclid space telescope, launched in 2023, and NASA's Nancy Grace Roman telescope, which is set to launch in 2026, both have infrared wide-angle views.

Three buses come along at once

Most stars shine in ultraviolet and infrared colors that are blocked by the Earth's atmosphere, as well as the colors our eyes evolved to see.

Extra colors are useful. For example, we can weigh stars on the other side of our galaxy because massive stars are bright in infrared, while smaller ones are faint—and they stay that way throughout their lifetimes. However, we know where stars are being born because only young stars emit ultraviolet light.

In addition, independent measurements of the same thing are vital for rigorous science. Infrared telescopes, for example, can work together and have already made surprising discoveries. But it's not great for diversity that the Webb, Euclid and Roman space telescopes all see infrared colors.

Hubble's visible light camera has just been switched off due to budget cuts. NASA will not swing back to ultraviolet wavelengths until the 2030s, with the Ultraviolet Explorer and Habitable Worlds Observatory.

Earthly politics gets in the way, too. Data from China's Hubble-class space telescope, Xuntian, is unlikely to be shared internationally. And in protest at Russia's invasion of Ukraine, in February 2022 Germany switched off its eRosita X-ray instrument that had been operating perfectly, in collaboration with Russia, a million miles from Earth.

Cheap commercial launches may save the day. Euclid was to have lifted off on a Russian Soyuz rocket from a European Space Agency spaceport in French Guiana. When Russia ended operations there in tit-for-tat reprisals, Euclid's launch was successfully switched at the last minute to a SpaceX Falcon 9 rocket.

If large telescopes can also be folded inside shoebox-size "cubesat" satellites, the lower cost would make it viable for them to fail. Tolerating risk creates a virtuous circle that makes missions even cheaper.

Telescopes are also being tried in innovative locations such as giant helium balloons and airplanes. One day, they might also be deployed on the moon, where the environment is advantageous for certain types of astronomy.

But perhaps the most unusual telescope technology, which may bring the most unexpected discoveries, is gravitational wave detectors. Gravitational waves are not part of the electromagnetic spectrum, so we can't see them. They are distortions, or "ripples," in spacetime caused by some of the most violent and energetic processes in the universe. These might include a collision between two neutron stars (dense objects formed when massive stars run out of fuel), or a neutron star merging with a black hole.

If telescopes are our eyes, gravitational wave detectors are our ears. But again, current gravitational wave detectors on Earth are mere dry runs for the ones astronomers will ultimately deploy in space.

Asked what the next generation of observatories will discover, I have no idea. And that's a good thing. The best science experiments shouldn't just tell us about the things we expect to find, but also about the unknown unknowns.

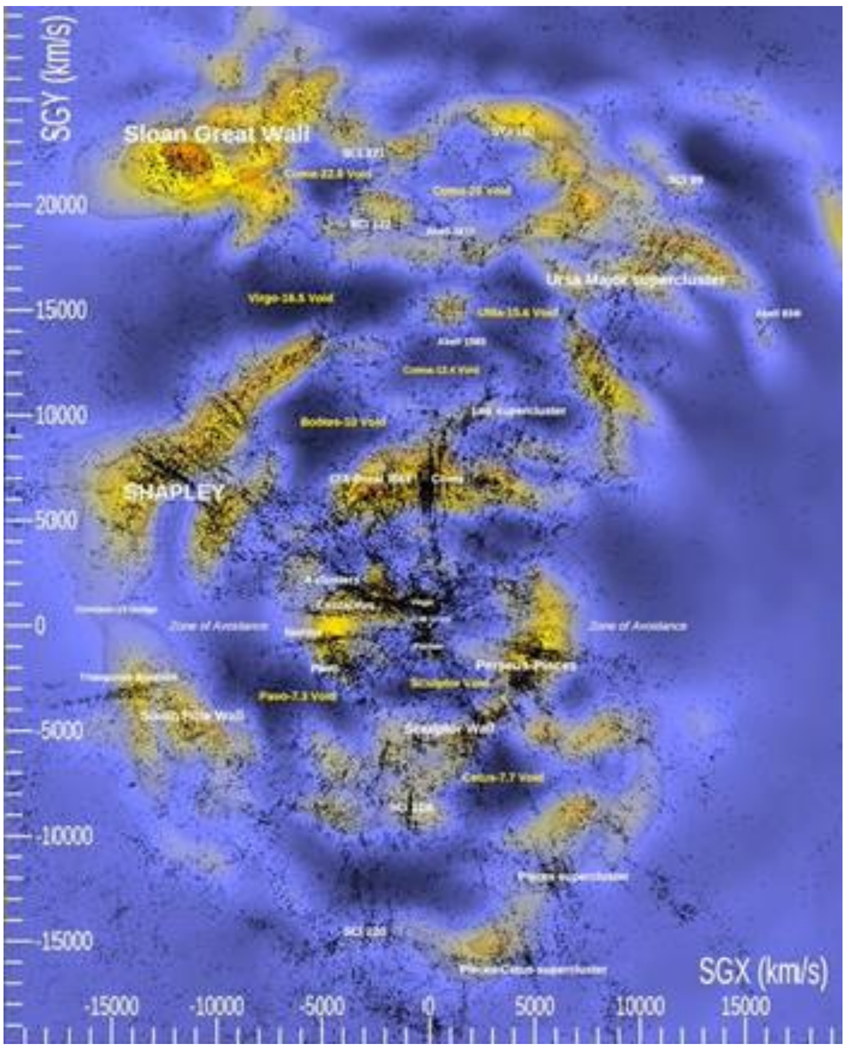
The Milky Way could be part of a much larger 'cosmic neighborhood' than we realized, challenging our understanding of the universe

The region of the universe we live in may be significantly bigger than we thought. A new study reveals that the intergalactic supercluster holding the Milky Way may be part of an even bigger "basin of attraction" that's up to 10 times larger than the one we currently call home.

The universe is full of basins of attraction (BOAs) — regions within which everything is being pulled inward by the gravity of a massive object. BOAs can stack inside one another like nesting dolls. For example, the moon circles Earth, which in turn orbits the sun along with the rest of the solar system, which is itself spiraling around the supermassive black hole at the heart of our galaxy.

But the story doesn't end there. The next layer of the BOA doll is the Local Group, which includes the Milky Way, the Andromeda Galaxy and the Triangulum Galaxy, along with their smaller satellite galaxies such as the Large and Small Magellanic Clouds. After that, the next layers are the Virgo Cluster, which holds around 2,000 galaxies, and the larger Virgo Supercluster. The final known layer is Laniākea (meaning "immense heaven" in the Hawaiian language) — a supercluster first discovered in 2014, which holds around 100,000 galaxies and spans roughly 500 million light-years across.

But in the new study, published Sept. 27 in the journal Nature Astronomy, researchers analyzed the relative movements of more than 56,000 galaxies to create a 3D "probabilistic" map of all the BOAs surrounding the Milky Way. This revealed that there is a decent chance our home galaxy is part of an even larger BOA — the Shapley Concentration — that has a volume up to 10 times greater than Laniākea. (Scientists already knew the Shapley Concentration existed but did not previously believe it impacted the Milky Way.)

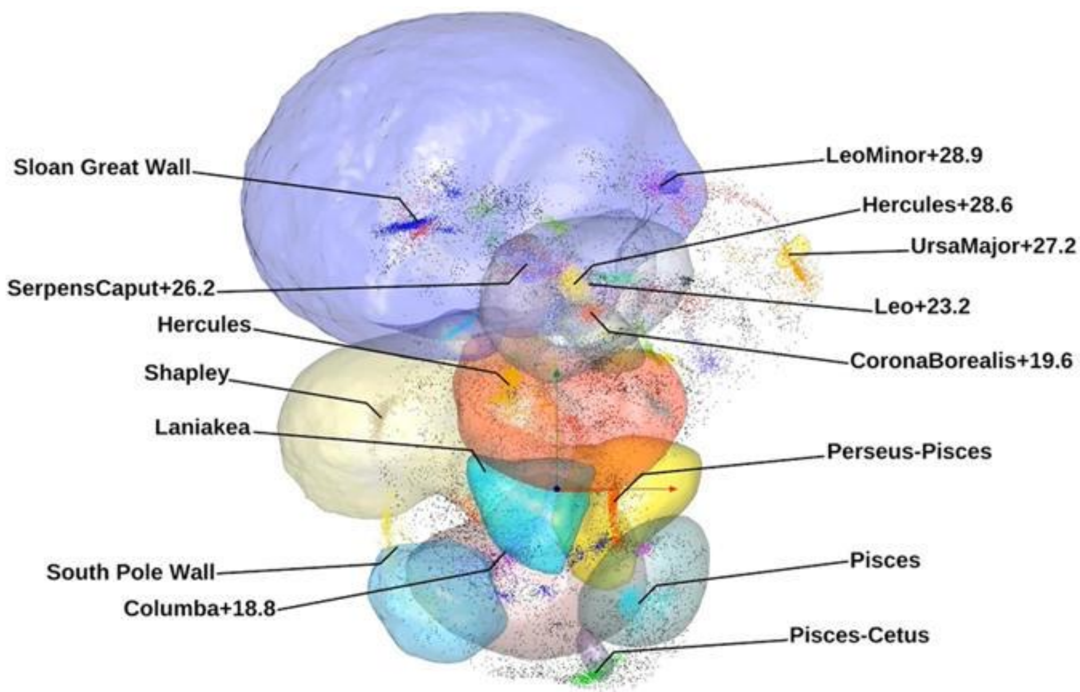


The new map helps us better define our place in the cosmos. (This image is a 2D version of the map.) (Image credit: Valade et al. 2024)

"It is perhaps unsurprising that the further into the cosmos we look, we find that our home supercluster is more connected and more extensive than we thought," study co-author Noam Libeskind, a cosmologist at the Leibniz Institute for Astrophysics Potsdam in Germany, said in a statement. "Discovering that there is a good chance that we are part of a much larger structure is exciting."

At the moment, the researchers — most of whom were involved in the discovery of Laniākea — believe there is a 60% chance that the Milky Way resides in the Shapley Concentration. The uncertainty is largely caused by high error rates in measuring the speeds of distant galaxies, as well as the presence of dark matter between galaxies, which can exert massive gravitational effects across large regions of space without being visible.

If true, the new findings could also mean that the Milky Way is not part of Laniākea and that the heavenly supercluster might not even exist. Instead, it could just be an outer section of the Shapley Concentration, the researchers wrote in the statement.



At least 15 different basins of attraction (BOAs) are highlighted in the new map. (Image credit: Valade et al. 2024)

The map shows dozens of objects spread out across billions of light-years around the Shapley Concentration, such as the South Pole Wall, the Boötes Void and the

Perseus-Pisces Supercluster. The largest BOA on the map is the Sloan Great Wall, which stretches around 1.4 billion light-years across.

While the new map helps us to better pinpoint our place in the wider universe, it also raises the possibility that we could be missing even more information, the researchers wrote.

"This discovery presents a challenge: our cosmic surveys may not yet be large enough to map the full extent of these immense basins," study co-author Ehsan Kourkchi, an astronomer at the University of Hawai'i, said in another statement. "We are still gazing through giant eyes, but even these eyes may not be big enough to capture the full picture of our universe."

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.

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.

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.

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.

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.

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.

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

The universe is awash in islands of matter — some 100 billion galaxies make up the basic building blocks of the cosmos.

At 11 million light-years away, IC 342 is a close galaxy. It's also a member of a loose group along with several others. IC 342 has a low surface brightness and lies in Camelopardalis, near the plane of the Milky Way in our sky. So it's a little difficult for amateur astronomers to spot, despite its elegant form. (Credit: Tony Hallas)

On the evening of Oct. 4, 1923, near Los Angeles, a young astronomer got into his car and began a motorized trek up to Mount Wilson. There, he arrived at the observatory that housed the 100-inch Hooker Telescope, at the time the largest telescope in the world.

Edwin Hubble was a fourth-year astronomer at Mount Wilson; he enjoyed using the Hooker Telescope because he was interested in, among other things, studying spiral "nebulae." These mysterious gas clouds were scattered across the sky, and no one understood their nature. In the early days of the 1920s, Hubble had assigned himself the task of figuring them out.

He pointed the great telescope toward his favorite object: the nebula in Andromeda, M31. This spiral-shaped cloud is faintly visible to the naked eye under a clear, moonless sky. He then captured its image on a photographic plate. Hubble was excited by the result. On it, he found a suspected nova, an exploding star. The next night, he photographed M31 again, hoping to catch the nova and record it under better atmospheric stability. The second plate did indeed record the nova, but little did he know, he also had captured a plate that would become legendary in the history of science.

Astronomer Edwin Hubble made an exposure of the "Andromeda Nebula" with the Hooker Telescope at Mount Wilson Observatory near Los Angeles on Oct. 5, 1923. He was initially excited, believing he had recorded a nova, an exploding star. He marked the star, which lies between two tick marks he drew at the top right on the plate, with the letter N. The star turned out to be a Cepheid variable, and Hubble used it to prove that the distance to the Andromeda Galaxy was far greater than astronomers thought. (Credit: Courtesy of the Carnegie Observatories/Cindy Hunt)

His observing time over, he returned to his office to analyze the catch. Suddenly, Hubble made an astonishing realization: The nova was not a nova at all, but a particular type of star that changed its brightness, a Cepheid variable. Checking earlier plates, he was able to confirm that, and he realized that the star's faintness had incredible implications.

The star, and the nebula that encompassed it, must lie at a distance of a million light-years — three times larger than anyone at the time believed the size of the whole universe to be. Today, thanks to improved measurements, astronomers know the object is 2.5 million light-years away.

Aided in part by earlier work done by Vesto M. Slipher and by his own colleague, Milton Humason, Hubble had at once discovered that the universe was far larger than anyone had believed, and that spiral nebulae like Andromeda were actually distant galaxies. They were whole systems of stars and gas, separated from our own Milky Way by a long hike.

At Arizona's Lowell Observatory, as early as 1912, Slipher had recorded the apparent velocities of spiral nebulae and, with the work now done by Hubble, it was clear the universe was expanding — the galaxies were flying apart from one another over time. The universe was not only far larger than anyone had previously believed, but it was growing as time went on.

NGC 4565 in Coma Berenices is the brightest and most prominent galaxy in our sky that is oriented perfectly edge-on to our line of sight. We see its disk as a thin, silvery needle. Some 57 million light-years off, it lies in the Virgo Cluster and has a prominent central bulge, suggesting it may be a barred spiral. (Credit: Adam Block)

By 1929, astronomers had put a cosmic picture of the past together. If you traced the histories of many of the galaxies backward in time, it meant that the cosmos began with a small, infinitely dense point at its origin. This research was an extension of work originally done by Belgian astronomer Georges Lemaître. Astronomers understood this cosmic point of origin, later called the Big Bang, as the start of the universe, and, they calculated, it must have occurred billions of years ago. The Big Bang had commenced the expansion that was driving all the galaxies away from each other as time rolls on. The whole universe seemed to be flying apart.

In the 1930s, Hubble began to study and classify galaxies into their various so-called morphological types, the array of structures astronomers saw in photographs. He eventually assembled the types of galaxies he observed into a tuning fork-shaped diagram. It contained spiral galaxies, barred spiral galaxies — spirals containing a linear "bar" of material passing through their centers — lenticular (lens-shaped) galaxies, and elliptical galaxies. He also identified irregular galaxies, clouds of stars and gas that lacked an organized shape. Later on, astronomers would identify peculiar galaxies, systems that appeared to be wracked with explosive or disruptive events. They also identified a class of galaxies called dwarf spheroidals, which seemed to be numerous in the local universe.

By the 1950s, French astronomer Gérard de Vaucouleurs of the University of Texas had expanded Hubble's classification scheme into a more complex system that took into account many observed properties of galaxies. De Vaucouleurs produced a pseudo-three-dimensional plot showing the galaxies' relationships, nicknamed the "Cosmic Lemon" due to its shape. De Vaucouleurs included details on bars in galaxies, descriptions of rings of matter visible in them, and an evaluation of how loosely or tightly the spiral arms of a galaxy were wound. He also included evaluative details about the nature of irregular and peculiar galaxies.

The last generation of extragalactic astronomy has moved into far more sophisticated analyses than cataloging. By using the Hubble Space Telescope, astronomers have estimated that some 100 billion galaxies must exist in the cosmos. And the number may be much greater than that. Probably some 2 trillion galaxies existed in the early universe, but it seems clear that galaxies near each other are drawn together by gravity and combine over cosmic time. Despite the universal expansion, then, normal galaxies like the Milky Way are probably made of dozens or more protogalaxies that merged into larger systems. You can see these primitive blobs of matter, bluish protogalaxies, in the early universe within the Hubble Ultra Deep Field pictures.

Our Own Galaxy

Perseus A, also called NGC 1275, is an eruptive galaxy at the core of the Perseus Cluster, which is made up of some 1,000 galaxies about 240 million light-years away. The dominant member of the Perseus Cluster, Perseus A is a Seyfert galaxy with an active nucleus, powered by a 340-million-solar-mass black hole in its core. (Credit: Hubble Legacy Archive, ESA, and NASA)

As astronomers have studied greater numbers of galaxies over the past few decades, they've discovered many things, but one that is impossible to ignore is that the universe is incredibly large. If you look at a galaxy in your telescope's eyepiece tonight, the photons striking your eye have been traveling at the fastest speed there is — 186,000 miles per second (300,000 kilometers per second). Nonetheless, they have taken 2.5 million years at that velocity to reach us from the Andromeda Galaxy. And that object is nearly on our cosmic doorstep. Of course, the knowledge of our own galaxy, in a primitive sense, goes back to antiquity. The name Milky Way comes from the Latin via lactea, which derives from the original idea, the Greek term, galaxías kýklos, "milky circle." The band of Milky Way visible in our sky, most prominently in the summer and winter evenings, is the unresolved light from billions of stars lying along the plane of our galaxy.

But only in the past few decades have we come to understand that the Milky Way is one of the 100 billion galaxies in the universe, and that its disk stretches some 100,000 light-years across. It contains some 400 billion stars, although we don't know exactly how many because dwarf stars are faint and difficult to see over long distances. For decades, astronomers believed the Milky Way was a simple spiral galaxy. But studies in this century have shown the Milky Way is a barred spiral, and that our sun and solar system lie some 26,000 light-years from the center, in one of the galaxy's arms.

The Milky Way consists of a bright disk, a slowly spinning platter of stars and gas that contains most of the stars we see. Our sun orbits the center of the galaxy once every 220 million years, meaning that we've rotated around the galactic center about 20 times since the formation of the solar system. Far away, in the center of the galaxy, lies a supermassive black hole containing around 4.3 million times more mass than the sun. In recent times, astronomers have discovered that supermassive black holes in the centers of galaxies are the norm. Nearly all galaxies, except for dwarfs, have them.

The galaxy's disk is encapsulated by a halo of a small number of stars, along with huge spheres of ancient stars called globular star clusters, and a big envelope of dark matter. Astronomers don't yet know what dark matter consists of, but they know it is there because of the gravitational influence it has on the visible matter they can observe.

The Local Group

The weirdly distorted elliptical galaxy NGC 474 in Pisces lies at a distance of 100 million light-years. The neighboring spiral galaxy NGC 470 lies just above it. Multiple shells and tidal tails surround NGC 474, caused by interactions with its neighbors and by density waves that propagate through the medium. This mammoth object stretches 250,000 light-years across — two and a half times the diameter of the Milky Way. (Credit: P-A. DUC (CEA, CFHT), ATLAS 3D Collaboration)

The Milky Way is hardly alone in the cosmos. It belongs to a group of at least 54 objects called the Local Group of galaxies, a name Hubble gave to this local cloud of objects as he mapped the nearby cosmos. The primary members of the Local Group are the Milky Way, the Andromeda Galaxy, and the Pinwheel Galaxy (M33). But each of these big three spirals has a cloud of attendant galaxies, too. The Milky Way's satellites include the Large and Small Magellanic Clouds, visible to the naked eye in the Southern Hemisphere, and many dwarf galaxies. The diameter of the Local Group is about 10 million light-years, some 100 times the diameter of the Milky Way.

And moving outward into the deeper universe, we encounter more examples of those 100 billion galaxies. These majestic islands of stars and gas exist in groups, like our Local Group, but also in larger assemblages called clusters and very large ones called superclusters. Despite the overall expansion of the universe, meaning that most galaxies are moving away from each other as the cosmos grows, gravity keeps smaller numbers of galaxies bound to each other on their journeys. Our Local Group, for example, is a member of the so-called Virgo Cluster of galaxies, named so because its richly populated center lies in the constellation Virgo in our sky.

The Virgo Cluster contains at least 1,500 galaxies and is centered some 54 million light-years from Earth. You can see some of the brightest galaxies near the core of the Virgo Cluster in amateur telescopes, in an array called Markarian's Chain. This line of galaxies contains supermassive elliptical galaxies such as M84 and M86, and a variety of spiral galaxies, too. For backyard astronomers, this playground of galaxy types is one of the really entrancing areas of the sky, and it is best visible on springtime evenings under clear, moonless conditions.

Most of the Virgo Cluster galaxies contain supermassive black holes in their centers. M87 is quite an example. Whereas the Milky Way's central black hole weighs in at 4.3 million solar masses, the colossal black hole inside M87 contains an estimated mass of 5 billion to 7 billion suns, some 1,000 times more massive than ours. M87 is one of the largest galaxies in our part of the universe — it is a so-called cD galaxy, short for centrally dominant — and it has "eaten" many of the smaller galaxies that once surrounded it. That's what massive galaxies do — they consume their neighborhood partners.

Superclusters

One of the greatest edge-on galaxies in the sky, and the one most people say looks like a flying saucer, is the Sombrero Galaxy (M104) in Virgo. It consists of a great rotating disk with a prominent dust lane edging it, consumed by a glowing halo of gas and stars. It lies 43 million light-years away and is about half the size of the Milky Way, sporting a diameter of 49,000 light-years. (Credit: NASA and the Hubble Heritage Team (AURA/STScI))

A cluster containing 1,500 galaxies is one thing, but much larger assemblages of galaxies also exist. The Virgo Cluster itself is a member of the so-called Virgo Supercluster, which holds thousands of galaxies on a scale an order of magnitude larger yet. The Virgo Supercluster holds our Milky Way, the Local Group, the Virgo Cluster, and altogether some 100 galaxy groups and clusters. This amazingly large framework stretches some 110 million light-years across, and is one of about 10 million superclusters that make up the entire cosmos.

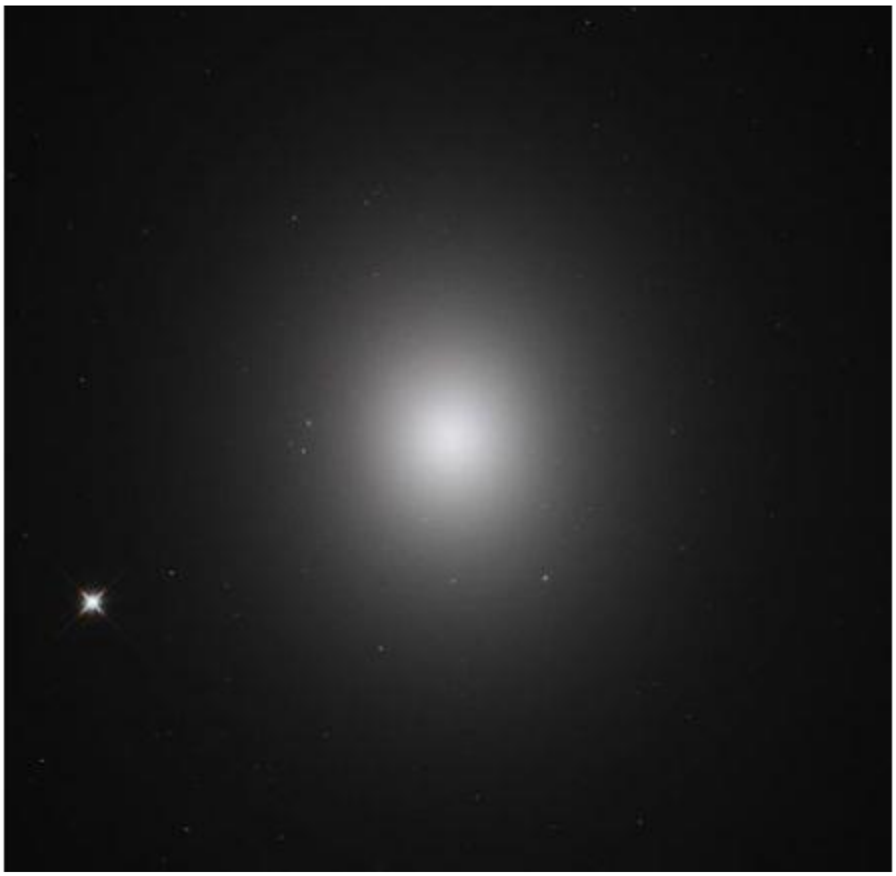
Despite the huge number of galaxies existing in the Virgo Supercluster, astronomers now know that most of the space in this volume is essentially empty. The diameters of these great voids range from dozens to hundreds of millions of light-years. Filamentary chains of galaxies wind their way around the dark, empty spaces. On large scales, galaxies in clusters and superclusters are like soap bubbles, with galaxies coating the surfaces and voids lying in between.

The Whirlpool Galaxy in Canes Venatici, another galaxy near the Big Dipper, is also known as M51 and is a top telescope target. An interacting pair of galaxies, the Whirlpool is being passed by a little interloper, NGC 5195, which is drawing material off one of the larger galaxy's spiral arms. The pair lies 23 million light-years away, and M51's disk stretches across 60,000 light-years. (Credit: Tony Hallas)

By the end of the 1980s, astronomers had identified the Great Wall, a sheet of galaxies measuring 500 million light-years across. More recently, the Sloan Digital Sky Survey uncovered the Sloan Great Wall, an assemblage of galaxies at least twice the size of the Great Wall, which covers a long dimension of some 1.4 billion light-years.

As astronomers discovered more and more distant galaxies, they found that some large mass seemed to be tugging on the local universe, pulling us in the direction of the southern constellations Triangulum Australe and Norma. Called the Great Attractor, this anomaly, some 200 million light-years away, puzzled astronomers. They eventually discovered that an even larger mass in that direction was pulling us. This mammoth structure, called the Shapley Supercluster, is 650 million light-years away and contains the greatest concentration of galaxies in our local part of the cosmos.

The Big Picture



Elliptical galaxies like M49 in Virgo are huge spheres of stars that float in an ellipsoidal cloud. Although their diameters are often similar to large spiral galaxies, they can hold vastly more mass because they are shaped like a football rather than a disk. This galaxy lies some 56 million light-years away and is one of the more massive galaxies in the Virgo Cluster. (Credit: NASA/ESA/STScI)

Additional surprising discoveries have occurred, too. In 2014, astronomers identified a new supercluster based on the relative motions of galaxies analyzed in a more sophisticated way than ever before. University of Hawai‘i astronomers concluded that the Laniakea Supercluster exists, and named it after the Hawaiian word for “immense heaven.”

Laniakea, which is also sometimes called the Local Supercluster, contains some 100,000 galaxies, including the Local Group and the Milky Way. This massive cluster and all its members are traveling together through space, but not all of the galaxies within it are gravitationally bound. Some will splinter apart from the rest of the cluster as time rolls on.

The Laniakea Supercluster has four major components — the Virgo Supercluster, the Hydra-Centaurus Supercluster, the Pavo-Indus Supercluster, and the Southern Supercluster.

Altogether, Laniakea contains around 500 galaxy clusters and groups. And surrounding Laniakea in the local universe are other galaxy superclusters — the Shapley Supercluster, the Hercules Supercluster, the Coma Supercluster, and the Perseus-Pisces Supercluster. Each of these structures holds hundreds of galaxy clusters and are linked by the fabriclike web of cosmic structure.

Beginning in the 1980s, astronomers found evidence of structures even larger than superclusters. At first, objects now called Large Quasar Groups (LQG) baffled astronomers.

In 1982, Scottish astronomer Adrian Webster found what would become known as the Webster Large Quasar Group, a collection of five quasars, or actively feeding black holes, stretching over 330 million light-years. Now, nearly two dozen LQGs are known. A structure known as the Huge LQG contains 73 quasars over a diameter of some 4 billion light-years. This massive structure, dismissed by some astronomers, may hold the title as the largest collection of related matter in the cosmos.

Truly, the universe is so big that it's hard to comprehend. On one hand, the enormity of the universe makes us feel small. Our brief lives happen so quickly, and we wink out, mostly unaware of the incredibly large cosmos around us. But the fact that we are sentient, that we can ponder the stars and galaxies far away from us, makes life in the universe a truly amazing thing. And we're just starting to get to know the immense world of galaxies.

David J. Eicher *is the editor of* Astronomy*. His 2020 book,* Galaxies: Inside the Universe's Star Cities*, is available from* ***My Science Shop.***

Spiral Arms in Space Explain How Star Systems Form

Learn how astrophysicists observed protostars and discovered the complexities of star birth.

(Credit: ALMA (ESO/NAOJ/NRAO)

Unlike our solitary Sun, most stars form in binary or multiple-star systems. However, astrophysicists haven't learned a lot about how these complex stellar systems are born because they lack high-resolution observations to distinguish between different theories of formation.

But international researchers have now gained some insight with the Atacama Large Millimeter/submillimeter Array (ALMA) in Northern Chile. Their study of IRAS 04239+2436, a triple system of protostars about 460 light-years from Earth surrounded by striking structures of gas called streamers, is reported in a recent study published in ***The Astrophysical Journal***. The observations capture a critical moment in the formation process of a multiple star system.

“This is the first time that the origin of protostars and the streamers have been simultaneously and comprehensively clarified. The powerful synergy between ALMA’s observations and advanced simulations reveals the hidden mysteries of star formation,” said astrophysicist Tomoaki Matsumoto of Hosei University, a collaborator on the study, in a statement.

How Star Systems Form

When stars form, gravity pulls in gas that eventually coalesces in a process known as accretion, forming a disk and a growing protostar at its center. This process forms streams of infalling gas, called streamers, that act as conveyor belts, transporting material inward. Before, it was unclear how these streamers form.

With the ALMA radio telescope, the team studied IRAS 04239+2436 by observing radio waves from sulfur monoxide molecules, which glow when gas in the system is being violently shocked. Through observing these molecules, they discovered three spiral arms and were able to trace their outlines around the system’s three protostars. By analyzing the motion of the gas, they found that these arms were streamers, feeding the young stars the material they needed for growth.

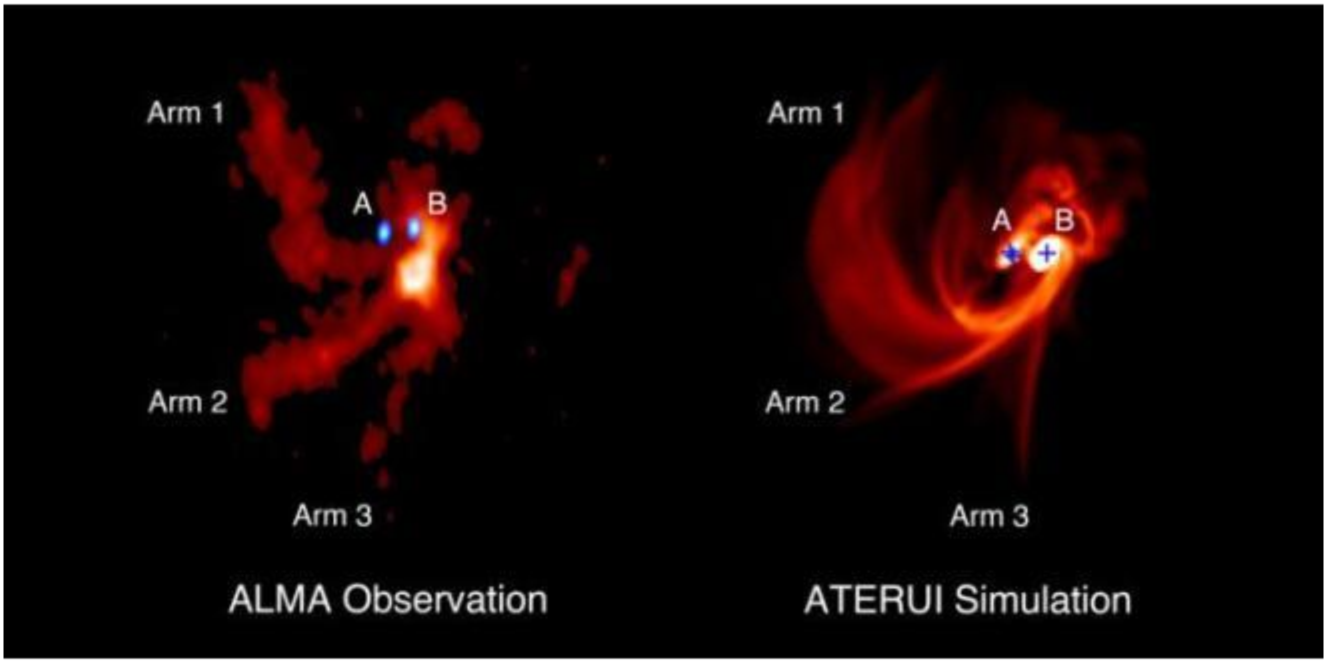
“My first impression was that the structures were dancing together, spinning around the central protostellar system, although we later found that the spiral arms are channels of material feeding the baby stars,” **said** lead author Jeong-Eun Lee, an astrophysicist at Seoul National University.

These arms feed the triplet stars like a cosmic river flowing towards them, extending up to 400 astronomical units (AU; 1 astronomical unit is equal to the average Earth-Sun distance of 93 million miles).

Triple Spiral Arms

To understand how these spiral streamers formed, the team turned to simulations on supercomputers ATERUI and ATERUI II programmed by Matsumoto. Using the simulations, Matsumoto and his team analyzed the gas's motion and found that in the gas cloud where the protostars formed, the gas moving around the triplet stars creates shock waves. These waves take on the form of spiral arms.

"We found that the spiral arms exhibit gas flows toward the triple protostars; they are streamers supplying gas to the protostars," said Matsumoto in a statement. "The velocity of the gas derived from the simulations and the observations matches well, indicating that the numerical simulation can indeed explain the origin of the streamers."



(Credit:ALMA (ESO/NAOJ/NRAO), J.-E. Lee et al.)

Protostar Formation Process

In some existing theories of multiple-star formation, protostars form either out of a turbulent gas cloud or result from an accretion disk fragmenting into multiple protostars. This work gives researchers a new, hybrid scenario that combines those hypotheses. In this scenario, seeds of protostars form as fragments of the disk, and the surrounding turbulent gas cloud sculpts the spiral arms and causes them to reach out widely.

The team also suggests that the study demonstrates why planet formation is difficult in multiple-star systems. When planets form, they are born out of the disks of gas and dust surrounding protostars in calm environments. The chaotic turbulence seen in multi-star systems — especially one as compact as this one — causes the protostars to strip each other's disks. This leads researchers to suspect that IRAS 04239+2436 is not much of a planet nursery.

"One of the big questions in star and planet formation is: How much of the chemical inventory from that early molecular cloud is inherited and forms the base components of the solar system? What we're looking at is the start and the end, and they're showing the same thing. That's pretty strong evidence that this material from the early molecular cloud finds its way into the ice, dust, and rocky bodies that make up our solar system," says Brett McGuire, an assistant professor of chemistry at MIT.

Due to its symmetry, pyrene itself is invisible to the radio astronomy techniques that have been used to detect about 95% of molecules in space. Instead, the researchers detected an isomer of cyanopyrene, a version of pyrene that has reacted with cyanide to break its symmetry. The molecule was detected in a distant cloud known as TMC-1, using the 100-meter Green Bank Telescope (GBT), a radio telescope at the Green Bank Observatory in West Virginia.

After Decades of Searching, Are Physicists Closing In on Dark Matter?

The universe is made up of much more than meets the eye. While telescopes reveal countless galaxies, each containing billions of stars, physicists and astronomers believe that visible matter is just the tip of the iceberg, so to speak, and that some kind of unseen dark matter must be out there as well, accounting for some 85 percent of the mass of the universe. No one knows what dark matter is made of, but scientists are confident it's something that doesn't interact with electromagnetic radiation, such as light—or else we'd be able to see it. But decades of searching have failed to yield any direct detections of this dark matter, leaving researchers wondering if they need to broaden their search strategies, or perhaps even rethink how gravity works.

The case for the existence of dark matter goes back to the 1930s, when astronomers analyzed the rates at which galaxies rotate and found there isn't enough visible matter to account for the observed spin-rates. These so-called rotation curves, which plot the speed at which stars are moving as a function of their distance from a galaxy's center, couldn't be accounted for based on the amount of stars, gas and dust that's visible within each galaxy.

Since then, further evidence has come from examining clusters of galaxies. The shape of a cluster can be distorted because of the gravitational influence of unseen matter between Earth and the cluster. This effect, known as "gravitational lensing," lends further support to the notion of dark matter. Occasionally, galaxy clusters are observed slamming into each other; careful observations of the dynamics of the collision can reveal the presence of unseen matter accompanying both members of the pair. This effect can be seen most dramatically in the so-called Bullet Cluster, a pair of colliding galaxy clusters located some 3.7 billion light-years from our Milky Way, which appears to show the result of a cluster-on-cluster collision. Computer simulations of the collision suggest dark matter drove the process just as much as regular matter. Yet another line of evidence comes from observations of the cosmic microwave background, the radiation left over from the very early universe, which can be studied with radio telescopes. This radiation, which spans the entire sky, shows "hot" and "cold" spots—areas of more intense and less intense radiation—which are difficult to explain without invoking the idea of dark matter.

As compelling as these observations have been, they are all indirect; researchers would still like to snag dark matter particles directly.

For the last few decades, the leading theory has been that dark matter is made up of "weakly interacting massive particles," or WIMPs—elementary particles thought to have been created some 14 billion years ago at the time of the Big Bang. Today these particles would be scattered about the universe, but because they interact only weakly with ordinary matter, they're incredibly hard to detect. And while many sophisticated experiments have been searching for WIMPs, no definitive trace has turned up—leading some scientists to wonder if dark matter may be made of something else altogether.

"I think WIMPs are falling out of favor," says Sean Tulin, a theoretical physicist at York University in Toronto. While the search for these elusive particles continues, he says many of his colleagues "are very happy to explore other alternatives."

Scientists are now turning to a wider array of search strategies—and a longer list of potential dark matter candidates—in an effort to crack the almost century-old mystery.

While no laboratory dark matter searches have yet succeeded, physicists have managed to restrict the range of masses that a particle of dark matter might have. In August, researchers at the LUX-ZEPLIN experiment, located at the Sanford Underground Research Facility in South Dakota, announced that they had ruled out WIMPs with masses greater than about ten times that of a proton. The results are about five times more sensitive than any previous WIMP search.

The LUX-ZEPLIN result "is a beautiful, technical tour de force," says Tracy Slatyer, a theoretical physicist at the Massachusetts Institute of Technology. "It's remarkable that they were able to push the limit down this far."

While the LUX-ZEPLIN result rules out heavy WIMPs, it is still possible that lighter WIMPs could be out there. And while more sensitive experiments will continue to search for lightweight WIMPs, they will inevitably come up against a natural limit:

Eventually, such experiments would be so sensitive that they'd detect neutrinos, nearly massless subatomic particles created in the core of the sun and in other high-energy astrophysical environments. Researchers refer to this limit as the "neutrino floor."

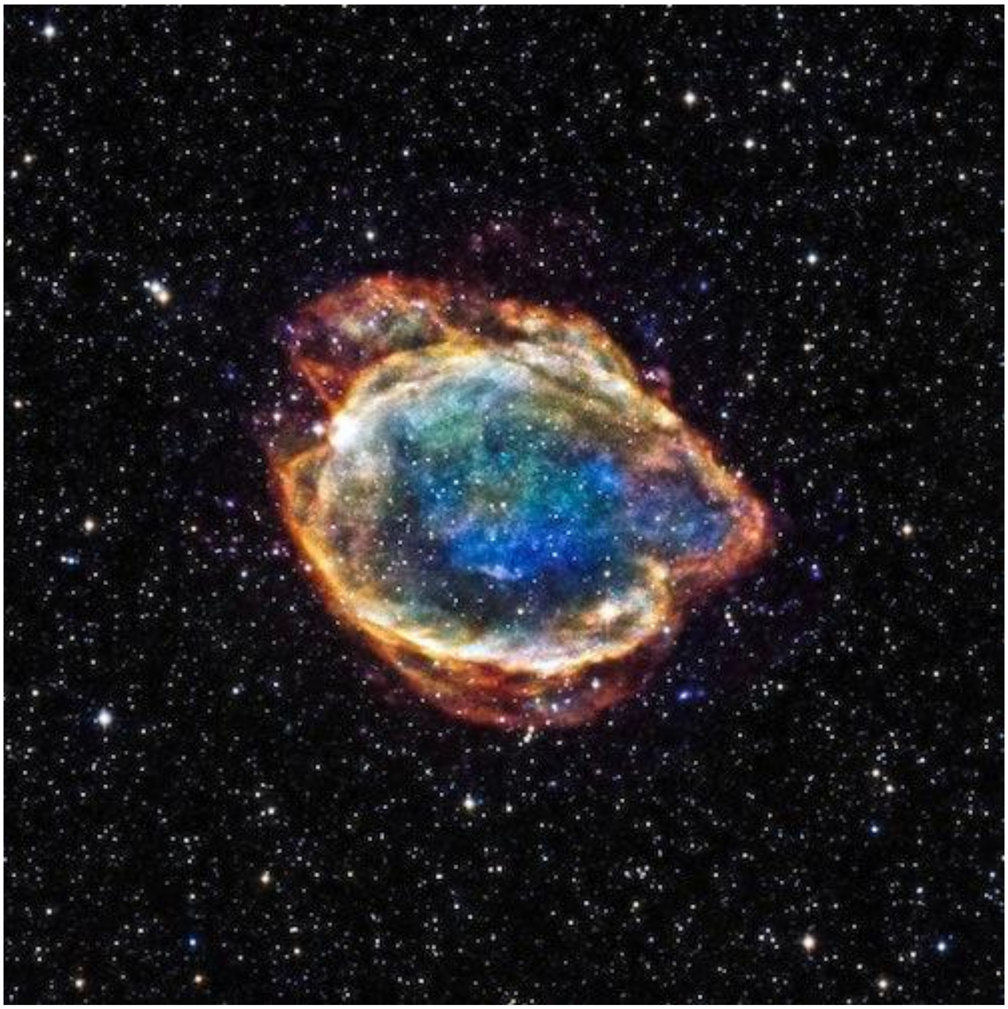
"Eventually we'll be at the point where the background [signal] from neutrinos actually swamps the signal from the dark matter," says Miriam Diamond, an experimental physicist at the University of Toronto. When physicists get to that stage, any dark matter particles that might be detected will be lost in a sea of neutrino detections.

As researchers get ever closer to this neutrino floor, they're naturally thinking about other dark matter candidates besides WIMPs.

"There was a point where people were pretty sure it [the dark matter particle] was the WIMP, and that was a nice story," says Slatyer. "But I don't think anyone believes anymore that it absolutely has to be the WIMP."

Many other potential dark matter candidates have been put forward, from exotic particles known as axions to primordial black holes, to a hypothetical new kind of neutrino known as a sterile neutrino. Dark matter may also be made up of more than one kind of particle, with theorists suggesting the existence of an entire "dark sector," consisting of multiple kinds of dark matter particles.

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



— NASA / CXC / U.Texas, CC BY© Provided by Inverse

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.

A Study Suggests Black Holes Can Create Space Lasers—Just Like Einstein Thought

A new paper theorizes that in rare cases, gravitational waves could propagate across the universe like a laser.© Cinefootage Visuals - Getty Images

- Gravitational waves are known disturbances in the fabric of space-time caused a variety of sources, including supermassive black holes, stellar-mass black holes, neutron stars, pulsars, supernova, and various mergers of these celestial objects.

- A new paper theorizes that gravitational waves could possibly propagate across the universe in the form of a "gravitational laser."
- However, this theory relies on a boson known as the axion, which is one of the leading and *very* hypothetical candidates that could explain dark matter.

If the abundant discoveries of Albert Einstein somehow formed a superhero cinematic universe, then "gravitational lasers" would be the ultimate team-up blockbuster.

In 1916, Einstein theorized the existence of gravitational waves as part of this General Theory of Relativity (though at the time he doubted we'd ever be able to detect them). But only a year later, the former patent clerk *also* revealed his quantum theory of radiation. in which he detailed the idea of "stimulated emission of radiation"—the "ser" in laser.

Now, a new paper published on the preprint archive arXiv theorizes that it's possible gravitational waves could propagate across the universe as a laser. Few sentences get more Einstein than that.

"Stimulated radiation and gravitational waves (GW) are two of the most important predictions made by Albert Einstein," University of Chinese Academy of Sciences and study author Jing Liu wrote in the paper. "We demonstrate that stimulated GW radiation can occur within gravitational atoms, which consist of Kerr black holes and the surrounding boson clouds formed through superradiance."

Ok, let's take a step back. Gravitational waves are literally ripples in the fabric of spacetime. The ones we can detect are formed from the most massive celestial objects and collisions in the universe—things like pulsars, supernovas, merging supermassive black holes, and colliding neutron stars. Since Einstein's conception of this phenomenon, these space-time disturbances have been described as waves, as they literally ripple outward and across the universe. Eventually, some made their way to Earth and were *faintly* detected (for the first time) in 2016 by the Laser Interferometer Gravitational-Wave Observatory (LIGO).

This new paper suggests that gravitational waves can *also* travel much like a laser, but this theory relies on one major *missing* piece of the Standard Model of

Physics: axions. This hypothetical, weakly interacting boson is one of the leading candidates for explaining dark matter, and because they are so light—again, hypothetically—they have quantum properties. As a result of its wave/particle properties, axions wouldn't fall into a rotating (Kerr) black hole, but would instead exist around it "the way electrons exist near the nucleus of an atom," as LiveScience describes it.

This interaction, known as superradiance, would allow axions and gravitational wave emissions to create coordinated excitations until the black hole essentially behaves like a laser, sending "gravitational lasers" (as the paper describes them) throughout the universe.

Because black holes would send these beams in completely random directions, the chance of Earth detecting one is slim to none—but that may not always be the case. Last month, the European Space Agency (in partnership with NASA) gave the go-ahead for a space-based gravitational wave detector named LISA, which will capture much lower frequencies than LIGO and open up gravitational wave detection to a whole new spectrum of possible cosmic sources.

After all, Einstein didn't think we'd ever detect gravitational waves in the first place—who knows what else is out there waiting to be discovered.

Einstein's theory of relativity: A deep dive into modern physics – part I

Physics is a continually advancing field, with new discoveries occurring daily.

Newton's theory of gravity and Galileo's description of planetary motion are key components of classical physics.

Isaac Newton, Gottfried Leibniz, and Galileo Galilei established the foundations of classical mechanics. Two centuries later, James Clerk Maxwell formulated a theory of electromagnetism, explaining the behavior of electricity and magnetism.

These theories are considered classical, indicating they do not account for phenomena under extreme conditions, such as at the quantum level or on the scale of galaxies and the universe.

Enter modern physics. A branch of physics that involves more radical thinking to explain things at microscopic and macroscopic levels. This way of approaching physical theories started in the late 19th century with pioneers like Albert Einstein, Paul Dirac, and Neils Bohr.

Modern physics stands on two pillars: Einstein's theory of relativity and the Standard Model of particle physics. The theory of relativity encompasses the gravitational force, one of the four fundamental forces in the Universe.

Conversely, the Standard Model encompasses the other three forces—nuclear weak and strong and electromagnetic forces.

In this two-part article, we break down these pillars of modern physics and gain a deeper understanding of why they are so integral in science today.

In part one, we will focus on the theories of relativity.

Shortcomings of classical physics

While classical physics successfully explains many day-to-day phenomena—before the development of modern physics—there were several instances where it failed.

One of them was the motion of Mercury around the Sun. Astronomers had observed a shift (or precession) in Mercury's orbit around the Sun over time. Newton's gravitation could not explain this observed shift.

Classical physics also couldn't explain why the speed of light was always constant.

At that time, the prevailing belief was that the universe was filled with ether, a substance through which light waves propagated. This was based on the understanding that waves could only travel through a medium.

Two scientists (Albert A. Michelson and Edward W. Morley) undertook the Michelson-Morley experiment in 1887 to put this hypothesis to the test. Their experiment showed that the speed of light remained constant, contrary to what would happen if the Earth moved through ether.

Einstein's propositions

Einstein's motivation to understand the nature of light began when he was just 16 years old. His theory of special relativity stemmed from his desire to understand the nature of light and what would happen to objects moving near or at the speed of light. This led him to develop the photoelectric effect, which won him the Nobel Prize.

Special relativity

In 1905, Einstein published the first of his many papers addressing the shortcomings of classical physics about light and spacetime. This was his theory of special relativity.

Einstein introduced two main postulates in his special relativity theory.

1. The first postulate is about the laws of physics in inertial frames of reference. According to Einstein, the laws of physics do not change, no matter which inertial frame you are in. Galileo Galilei originally presented this postulate.

   An object in an inertial frame remains in motion or at rest until an external force acts upon it.

2. The second postulate concerns the speed of light. Einstein showed that the speed of light is the same in a vacuum, despite the motion of the light itself or the observer. This value (c) is equal to 299,792,458 meters per second.

   These postulates have several implications for observed phenomena.

Time dilation

One of the most fascinating implications of these postulates is that time passes more slowly for objects traveling near the speed of light than when the object would be at rest.

Several experiments involving muons (a type of subatomic particle) and high-precision atomic clocks have confirmed this.

In other words, a person traveling in a spaceship near the speed of light would age slower than if they were on Earth.

Relativity of simultaneity

According to Einstein's theory, simultaneous events in one reference frame may not be simultaneous in another, which is in motion relative to the first.

For example, a person standing on a train platform might see two lightning strikes simultaneously, but a passenger on a moving train might see one strike before the other.

This is because it takes time for the light to travel. So when the train is in motion, the light will have to cover that extra distance to reach the passenger on the train.

Mass-energy equivalence

E = mc2 is possibly the most famous equation in physics and probably the work Einstein is best known for.

According to this equation, mass and energy are interchangeable, meaning they are different forms of the same thing. However, the conversion factor is the square of the speed of light, which is a huge number.

This means that it is very hard to change one to another. According to PBS Nova, if one atom in a paper clip were converted to pure energy, we would have the same amount of energy that 18 kilotons of TNT would produce!

This equation is how atomic bombs and nuclear fission reactors work.

Minkowski's contributions

In 1908, before Einstein published his work on general relativity, mathematician Hermann Minkowski introduced the concept of four-dimensional space, called Minkowski spacetime.

This four-dimensional space consists of the three spatial dimensions that we are familiar with and added time to it.

Minkowski's work gave us a geometric understanding of why different observers can disagree on the simultaneity of events, and how time can appear dilated depending on relative velocities.

It also laid down the mathematical foundation upon which Einstein built his theory of general relativity.

General relativity

In 1915, Einstein published his paper on general relativity, a theory of gravitation. While Newton's gravity explained everyday phenomena, it did not explain the nature of gravity itself.

$$F=G\ \underline{m\wedge m2}$$

$$g$$

Newton's law of gravitational describing the gravitational forces between two objects. Credit: marekuliasz/iStock .© Provided by Interesting Engineering

Einstein knew that his theory of special relativity was partial. It couldn't be applied to accelerating (or non-inertial) objects or gravity.

Equivalence principle

This led Einstein to formulate the Equivalence Principle, a cornerstone of general relativity. According to the equivalence principle, the effects of gravity are *indistinguishable* from the effects of acceleration for an observer in a small region of spacetime.

So, if you were in a closed room on Earth, the force you would feel would be the same if the room were accelerating upwards in space at 9.8 meters per second squared.

This led Einstein to explore the idea that gravity may not be a force in the traditional sense of pulling or pushing of objects and might be a manifestation of spacetime.

Curved spacetime

From 1912 to 1915, Einstein worked on his theory of gravity, collaborating with mathematician Marcel Grossman. In 1915, he published four papers on general relativity.

The central idea of his work was that mass and energy cause spacetime, which can be thought of as a fabric, to curve or bend.

To illustrate this, let's look at an example. Consider a heavy item (such as a bowling ball) resting on a trampoline. It results in the surface bending. Now, if we were to drop some lighter objects, like marbles, they would move toward the bowling ball as they followed the curves on the trampoline surface.

Einstein formulated *The Field Equations* to mathematically describe the relation between curvature of spacetime and mass and energy.

Geodesics

Einstein also introduced the concept of geodesics in his theory of general relativity.

A geodesic is the path along which an object moves in curved spacetime, and this is the shortest path in curved spacetime. These paths appear curved when seen in our three-dimensional space. This is equivalent to a straight line being the shortest distance between two points on a flat surface.

For example, the paths taken by planets around the Sun follow geodesics and appear as elliptical orbits.

From black hole to GPS

Einstein's special and general relativity theories have been repeatedly tested and consistently proven right.

Mercury's orbit

Einstein published a paper in which he used his theory of general relativity to correctly predict that Mercury's orbit precesses by 43 arcseconds per century.

Arcseconds are a measure of angle used in astronomy, with 60 arcseconds in one arc minute and 60 arcminutes in one degree. This means that Mercury's orbit shifts by 43 arcseconds every century, as observed from Earth, due to gravitational forces.

Black holes

Black holes are regions of spacetime where the gravitational force is so strong that not even light can escape. Einstein's theory of general relativity allowed for the existence of black holes.

A few months after Einstein published his work, physicist Karl Schwarzschild found a solution to Einstein's field equations that described what we now call a black hole.

However, the term "black hole" was not only coined in 1967 by astronomer John Wheeler.

Independent researchers made the first confirmed observations of a black hole in 1971, and it was named Cygnus X-1.

Gravitational waves

Einstein's theory of general relativity also predicted gravitational waves, which are ripples caused by spacetimes. According to this, massive accelerating objects (like black holes or neutron stars) disrupt spacetime, causing ripples to spread in all directions at the speed of light.

These ripples carry information about their origins and were first observed in 2015 by the LIGO observatory in the US. The observatory used laser interferometers to detect the ripples in spacetime caused by the collision of two massive black holes.

GPS

The global positioning system (or GPS) is a system of satellites in orbit around the Earth that provide precise time and location information.

The technology works by constantly transmitting time and position signals from satellites, forming the basis of many modern technologies, such as navigation systems and emergency response services.

Einstein's theories of relativity are crucial to its functioning due to time dilation effects, which would cause the satellite clocks to go out of sync and run at rates different from the clocks on Earth.

If it weren't for Einstein's theories of relativity, GPS systems would not work.

Conclusion

There we have it, folks! Einstein's theories of relativity have revolutionized our understanding of spacetime and gravity, paving the way for discoveries and technology.

Despite its overall success, the theory has some limitations under extreme conditions. For example, Einstein's field equations break down at singularities, regions in spacetime where the gravitational force is infinite, such as at the center of black holes and the Big Bang.

Additionally, they still need to fully integrate with the Standard Model, leaving the quest for a Unified Theory of Everything open.

Theory of everything: How a fear of failure is hampering physicists' quest for the ultimate answer

It has been over a century since the boom period of physics exploded with Albert Einstein, Max Planck and others, sending us spinning into a new world of chaos from our previously ordered universe. This brilliant generation of physicists ultimately peeled back the layers of the universe, as well as of the atom, to reveal a world stranger than fiction.

Ever since those earliest days of quantum mechanics, the theory ruling the microworld of atoms and particles, the holy grail of physics has been finding a theory of everything—uniting quantum mechanics with Einstein's theory of general relativity, which applies to the universe on large scales.

But we still don't have a tried and tested theory of everything. And I believe a fear of failure is a big part of the problem.

Creating a theory of everything isn't exactly easy. It involves producing one framework uniting the fundamental forces of our universe, while accounting for all the underlying constants and quantities as well as every subatomic particle. The prize for whoever answers this ultimate question is eternal glory in the annals of humankind.

There was great hunger to solve it in Einstein's generation. In fact, Einstein worked on a theory of everything on his very deathbed—work that he was ultimately ridiculed for. Einstein's contribution to physics was so great he still remains a superstar. But physicists Arthur Eddington, Hermann Weyl and mathematician David Hilbert were not so fortunate, with some facing much worse consequences.

Take Eddington, for example, perhaps the greatest scientist you have never heard of. The Cambridge astronomer and physicist proved Einstein correct in his work analyzing a 1919 eclipse—launching Einstein to superstardom. Eddington also wrote the first English books on relativity before doing the same on Georges Lemaître's Big Bang theory.

He also wrote a book on quantum physics, and became the greatest popular writer on science in the 1920s and 1930s, alongside his groundbreaking work on stellar physics (the physics of stars). Yet he is obscure today due to his intense pursuit of a fundamental theory.

Published posthumously, his attempt was immediately banished for its incredible failure. Mocked as numerology (the belief in a mystical relationship between a number and events), his strange interest in the power of certain numbers was made fun of by other scientists. And, as many notable astrophysicists have pointed out, it has produced no value since its publication.

Eddington's stunning final failure served as a powerful warning of the price that comes with missing the mark. The final decade of his life spent pursuing a theory of everything ended in severe damage to his legacy.

A new generation

The generation of the physicist Richard Feynman (1918–88), following that of Einstein and Eddington, lost interest in a theory of everything. Feynman and his peers found their own glory in new subatomic discoveries and theories, and applications of physics to chemistry and biology, leading to several Nobel prizes. The ridicule endured by those who tried and failed before them may have been one of the reasons.

This inordinate cost for failure ultimately rose alongside the glory of interwar physics. In a period of unparalleled success, failure was more unforgiving. This was hardly an incentive for young and brilliant modern minds seeking to apply themselves to the largest question.

Even today, attempts at theories of everything get mocked. String theory, for example, is such an attempt, and has been scorned by Nobel laureate Roger Penrose as not being "real science."

He is not alone. Physicist Stephen Hawking believed a version of string theory called M-theory was our best option for a theory of everything. But the theory has struggled in producing predictions that can be tested by experiments.

A young scientist today may wonder, if Einstein, Eddington and Hawking could not solve the problem, then who will? And indeed, many are doubtful that it can be achieved. Is it even necessary as, pragmatically, we can do without one?

It is no wonder, then, that many physicists prefer to avoid the term "theory of everything" these days, opting instead for less grandiose alternatives such as "quantum gravity."

Funding and career progression

Alongside the heavy price of failure, other problems are lurking. A brilliant young mind could be staring at a career dead end in seeking out a theory of everything. What academic progression can one expect at the start of their career if this is desired? Who will give significant funding to young, unproven researchers pursuing a seemingly impossible goal in the short term?

It is likely that a theory of everything will ultimately require massive collaboration to be solved. Ironically, this may be a job for the older physicists, despite the warnings of Eddington and others. Francis Crick dedicated his attention to trying to solve the problem of consciousness in his later years, albeit without success.

We need collaboration. But we may be looking at the prospect of a theory of everything only coming from those who have accomplished so much they can afford the potential embarrassment and will be given the benefit of the doubt. This hardly stirs the enthusiasm of the vibrant, young minds that may otherwise tackle the problem.

In trying to solve the ultimate problem, we may have inadvertently created a monster. Our academic framework for research progression is not conducive to it, and history has presented an unkind picture of what happens to those who try.

And yet, our greatest progress has always come from those willing to take risks.

Scientists finally discover what's inside a black hole

What lies at the center of a black hole? A team of scientists led by Enrico Rinaldi, an American physicist at the University of Michigan, has utilized quantum computing and computer learning to decipher the mathematical description of the quantum state of the matrix model, shedding light on what may lie inside a black hole.

The study was based on the holographic principle, which postulates that the two fundamental theories of particles and gravity are equivalent to one another. However, the challenge lies in the fact that these ideas are constructed in different dimensions.

Black hole theories

Two theories offer explanations for different dimensions, with only one distinction between them. Gravity exists in three dimensions within a black hole's geometry, whereas particle physics resides on its surface in two dimensions, similar to a flat disk

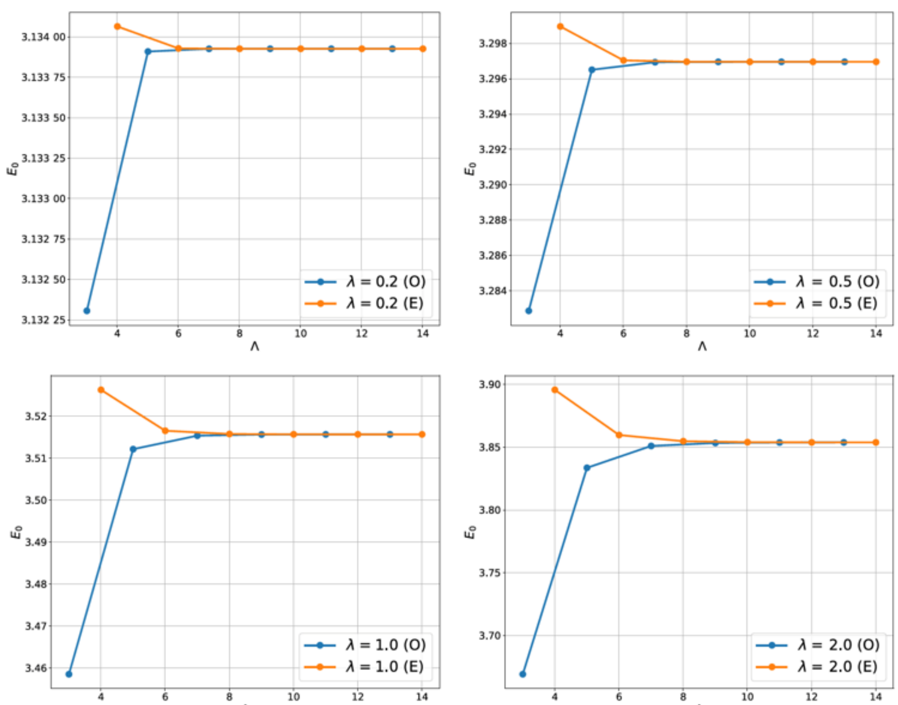
A black hole's massive mass distorts space-time, creating its gravity that operates in three dimensions. This gravity links mathematically to the particles gyrating above the black hole in two dimensions. Therefore, while a black hole occupies According to some scientists, our entire universe could be a holographic depiction of particles, which might provide a consistent quantum explanation of gravity. Enrico Rinaldi explains that in Einstein's General Relativity theory, there are no particles, only space-time, while in the Standard Model of particle physics, there are no gravitational forces, only particles. Bridging these two theories has been a persistent challenge in physics for decades.

A recent study by Rinaldi and his colleagues, published in the journal PRX Quantum, explores the use of quantum computing and deep learning to investigate holographic duality. Their research focuses on determining the lowest energy state of quantum matrix models, which are mathematical problems that can help probe the nature of this duality.

The use of quantum matrix models represents the particle theory. According to holographic duality, the mathematical events that occur in a system representing particle theory can also impact a system representing gravity. Thus, by solving a quantum matrix model, one could gain insights into gravity-related phenomena.

Rinaldi and his colleagues have utilized two matrix models, which are relatively uncomplicated to solve through conventional means but possess all of the attributes of more complex matrix models employed to describe [black holes](#) using holographic duality.

"We hope that by understanding the properties of this particle theory through the numerical experiments, we understand something about gravity," adds Rinaldi. "Unfortunately it's still not easy to solve the particle theories. And that's where the computers can help us.



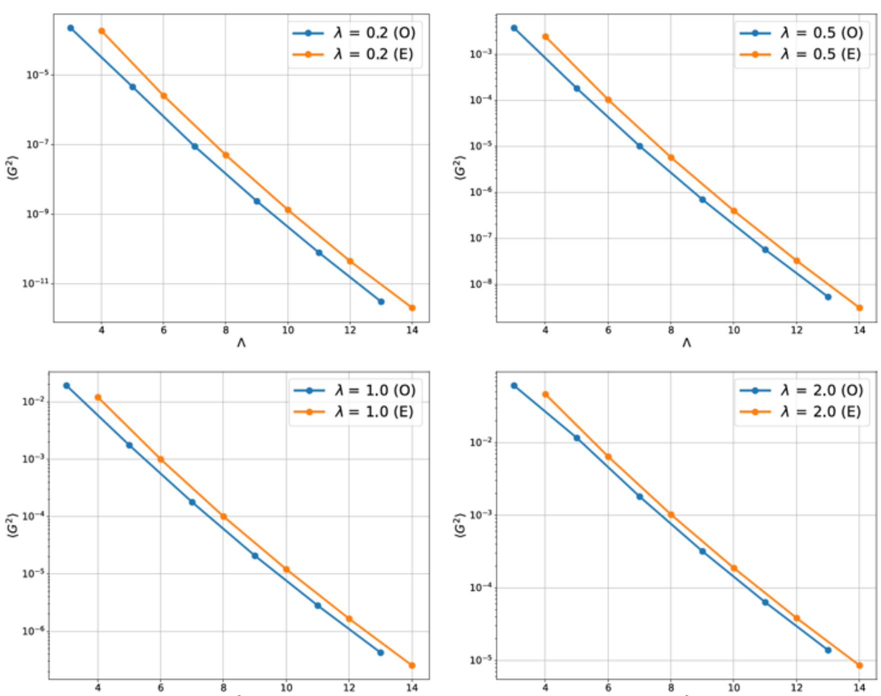
The ground-state energy E0 as a function of the cutoff for various couplings λ = g2 N = 0.2, 0.5, 1.0, and 2.0 for the SU(2) bosonic model. Even (E) and odd (O) values of are plotted with different colors. The other parameters are m2 = 1andc = 0. (CREDIT: PRX Quantum)© The Brighter Side of News

In string theory, objects are represented by numerical matrix models, where one-dimensional strings correspond to particles in particle theory. The focus of researchers is to determine the specific arrangement of particles in the ground state, the lowest energy state of the system, by solving these matrix models. Unless something is added to the system that causes it to be perturbed, it remains unchanged in its natural state.

“It’s really important to understand what this ground state looks like, because then you can create things from it,” Rinaldi says. “So for a material, knowing the ground state is like knowing, for example, if it’s a conductor, or if it’s a super conductor, or if it’s really strong, or if it’s weak. But finding this ground state among all the possible states is quite a difficult task. That’s why we are using these numerical methods.”

According to Rinaldi, the numbers in matrix models can be thought of as grains of sand. When the sand is level, it corresponds to the ground state of the model. But if there are ripples in the sand, you need to find a way to smooth them out. To tackle this problem, the researchers resorted to quantum circuits.

These circuits are depicted as wires, and each wire is associated with a qubit, a quantum information bit. Gates, which are quantum operations that dictate how information flows through the wires, are placed on top of the wires.



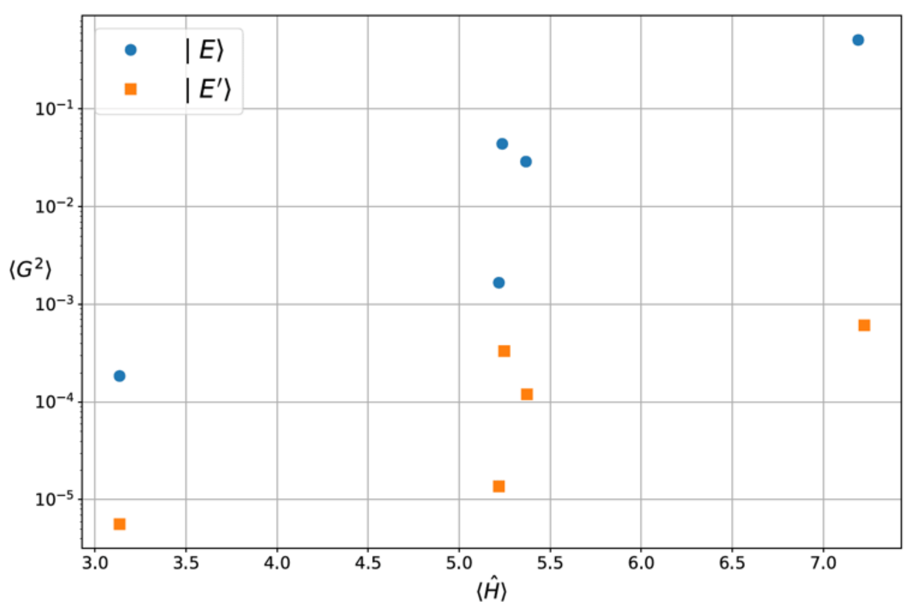
The violation of the singlet constraint αE0| ˆ G2 α|E0 as a function of the cutoff for various couplings λ = g2 N = 0.2, 0.5, 1.0, and 2.0 for the SU(2) bosonic model. Even (E) and odd (O) values of are plotted with different colors in logarithmic scale. The other parameters are m2 = 1andc = 0. (CREDIT: PRX Quantum)© The Brighter Side of News

“You can read them as music, going from left to right,” the author adds. “If you read it as music, you’re basically transforming the qubits from the beginning into something new each step. But you don’t know which operations you should do as you go along, which notes to play. The shaking process will tweak all these gates to make them take the correct form such that at the end of the entire process, you reach the ground state. So you have all this music, and if you play it right, at the end, you have the ground state.”

Rinaldi and colleagues established the mathematical representation of the quantum state of their matrix model, which they referred to as the quantum wave function. Subsequently, they employed a unique neural network to determine the ground state of the matrix, which is the state with the lowest energy level.

To achieve this, the neural network's parameters underwent an iterative optimization process, aimed at leveling all the grains in the bucket of sand, until the matrix's ground state was found.

The researchers were successful in determining the ground state of the two matrix models using both methods. However, the quantum circuits were constrained by the limited number of qubits available in current quantum hardware. With only a few dozen qubits at their disposal, increasing the complexity of the circuit would become prohibitively expensive, much like adding too many notes to a sheet of music would make it more difficult to play accurately.



We take the five eigenstates of ˆ H (|Ej) with the smallest values of αEj| ˆ G2 α|Ej and the five lowest eigen states for ˆ H (|Ej with j = 0,...,4) and we plot them as a function of their energy ˆ H for c = =4, m2 =1, λ =g2 N =0.2 in the SU(2) bosonic model. We can see the deformation does not affect the low-lying modes; it just removes the non singlet modes. (CREDIT: PRX Quantum)© The Brighter Side of News

“Other methods people typically use can find the energy of the ground state but not the entire structure of the wave function,” Rinaldi said. “We have shown how to get the full information about the ground state using these new emerging technologies, quantum computers and deep learning."

“Because these matrices are one possible representation for a special type of black hole, if we know how the matrices are arranged and what their properties are, we can know, for example, what a black hole looks like on the inside. What is on the event horizon for a black hole? Where does it come from? Answering these questions would be a step towards realizing a quantum theory of gravity.”

According to Rinaldi, the findings serve as a crucial milestone for forthcoming research on quantum and machine learning algorithms. These algorithms can be applied by scholars to investigate quantum gravity through the concept of holographic duality.

In the next phase, Rinaldi, together with Nori and Hanada, is examining how these algorithms' outcomes can expand to more extensive matrices and how immune they are to the influence of "noisy" effects, which can lead to inaccuracies.

The solar system's movement is a combination of two main motions: orbiting the center of the Milky Way and moving within the galaxy.

1. Orbit around the Galactic Center:
 - The sun and its planets orbit around the center of the Milky Way in a vast, disk-shaped region. This orbit takes an immense amount of time, roughly around 225-250 million years to complete one full rotation, known as a galactic year.
 - The gravitational force of the massive black hole, Sagittarius A*, at the center of the Milky Way, plays a significant role in keeping the solar system in its orbit.

2. Motion within the Milky Way:

 - The Milky Way itself is a barred spiral galaxy, and our solar system is situated in one of its spiral arms, known as the Orion Arm or Local Spur.
 - The entire galaxy is rotating, and as a result, our solar system is moving through space along with it. This rotational motion contributes to the overall path of the solar system.

3. Velocity and Speed:
 - The solar system travels at an average speed of about 828,000 kilometers per hour (514,000 miles per hour) in its orbit around the galactic center.
 - The specific path is not a perfect circle; it has some elliptical characteristics, and the solar system bobs up and down as it orbits, a motion known as vertical oscillation.

In essence, the solar system's movement is a dynamic interplay of gravitational forces, rotations, and orbits within the vast cosmic dance of the Milky Way galaxy.

Earth Receives a Laser Communication Sent from Nearly Half a Billion Kilometers Away

The recent success of NASA's laser communication test represents a paradigm shift in space technology. Traditionally, space missions have relied on radio frequencies for communication. However, laser-based systems offer a **data transmission capacity up to 100 times greater** than conventional methods.

This advancement is not just about speed; it's about expanding our capabilities in space exploration. With improved data transfer rates, future missions could :

- Send high-resolution images and videos back to Earth more quickly
- Enable real-time communication with spacecraft and rovers
- Facilitate more complex scientific experiments in deep space

- Support potential human missions to Mars and beyond

The implications of this breakthrough are far-reaching, potentially transforming our understanding of the cosmos. Just as the Hubble Space Telescope captured breathtaking views of distant galaxies, future space telescopes equipped with laser communication could transmit even more detailed observations, expanding our knowledge of the universe.

Psyche mission : pushing the boundaries of space communication

At the heart of this achievement is NASA's Psyche spacecraft, equipped with a state-of-the-art laser transceiver designed for long-distance communication. The mission, originally intended to study a metal-rich asteroid, has become a testbed for this revolutionary technology.

The success of the laser communication test was made possible by two ground stations :

- The Palomar Observatory, serving as the receiving station
- The Table Mountain facility, which emits signals to the spacecraft

Both stations are equipped with powerful 7-kilowatt lasers, demonstrating the precision and efficiency required for deep space laser communication.

The Psyche mission has consistently pushed the boundaries of what's possible in space communication :

Implications for future interplanetary missions

The successful laser communication test at 310 million miles (approximately 499 million kilometers) opens up new possibilities for space exploration.
This **unprecedented achievement** in data transmission over vast cosmic

distances could significantly enhance our ability to conduct complex scientific missions in the solar system and beyond.

With this technology, future Mars missions could benefit from :

- Enhanced real-time communication with rovers and potential human explorers
- Faster transmission of large data sets, including high-resolution imagery and scientific measurements
- Improved coordination between multiple spacecraft and ground control

Moreover, this breakthrough could facilitate more ambitious missions to the outer planets and their moons. Imagine receiving detailed images of Europa's subsurface oceans or real-time data from a probe diving into Saturn's rings. The potential for scientific discovery is immense.

A new era of space exploration unfolds

As we stand on the brink of this new era in space communication, the possibilities seem limitless. The success of NASA's laser communication test not only demonstrates technological prowess but also ignites the imagination of scientists, engineers, and space enthusiasts worldwide.

This achievement is more than just a technical milestone; it's a **gateway to deeper understanding** of our solar system and the universe beyond. As we continue to push the boundaries of what's possible in space exploration, we move closer to unraveling the mysteries of the cosmos and perhaps even finding answers to some of humanity's most profound questions.

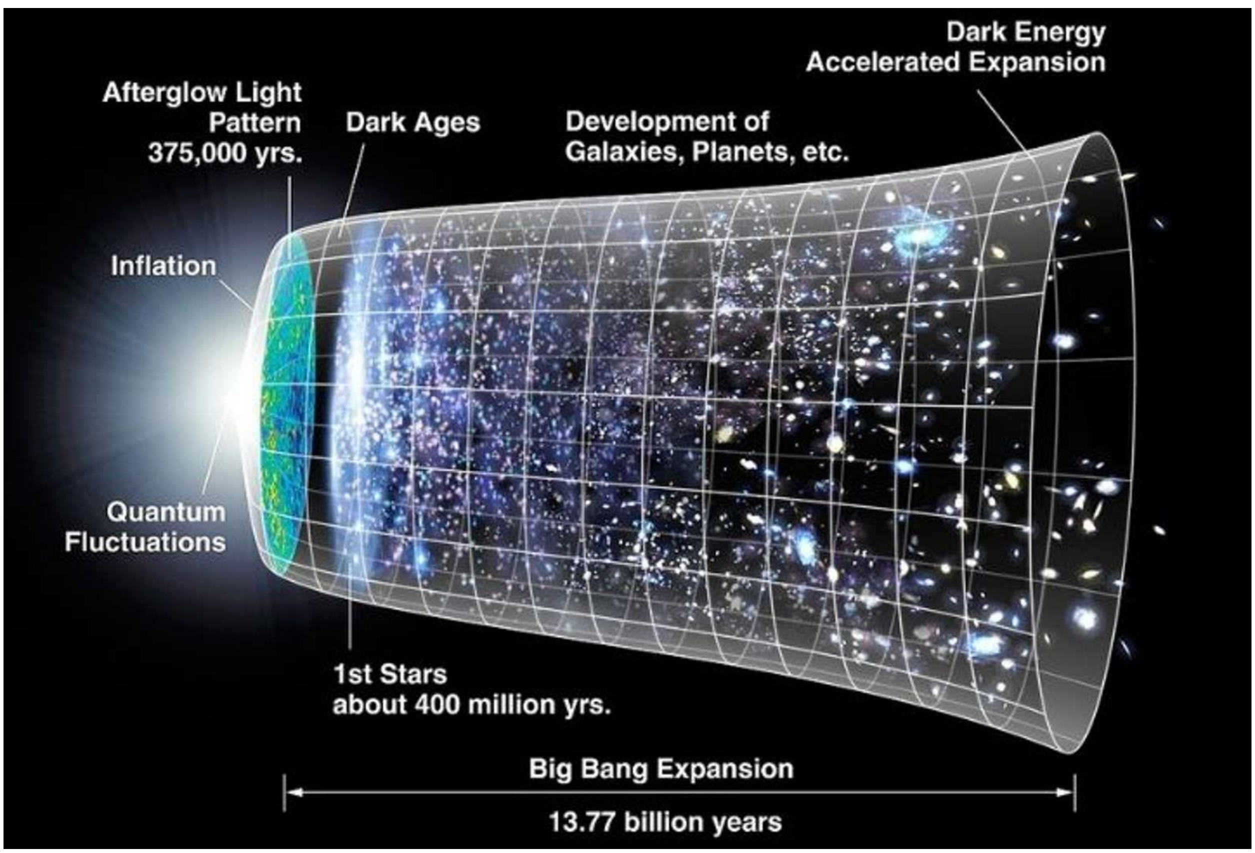
With each successful test and mission, we're not just reaching farther into space; we're expanding the horizons of human knowledge and capability. The future of space exploration looks brighter than ever, illuminated by the precise beams of laser communication stretching across the vast expanse of our solar system.

BIG BANG ORIGINS

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.

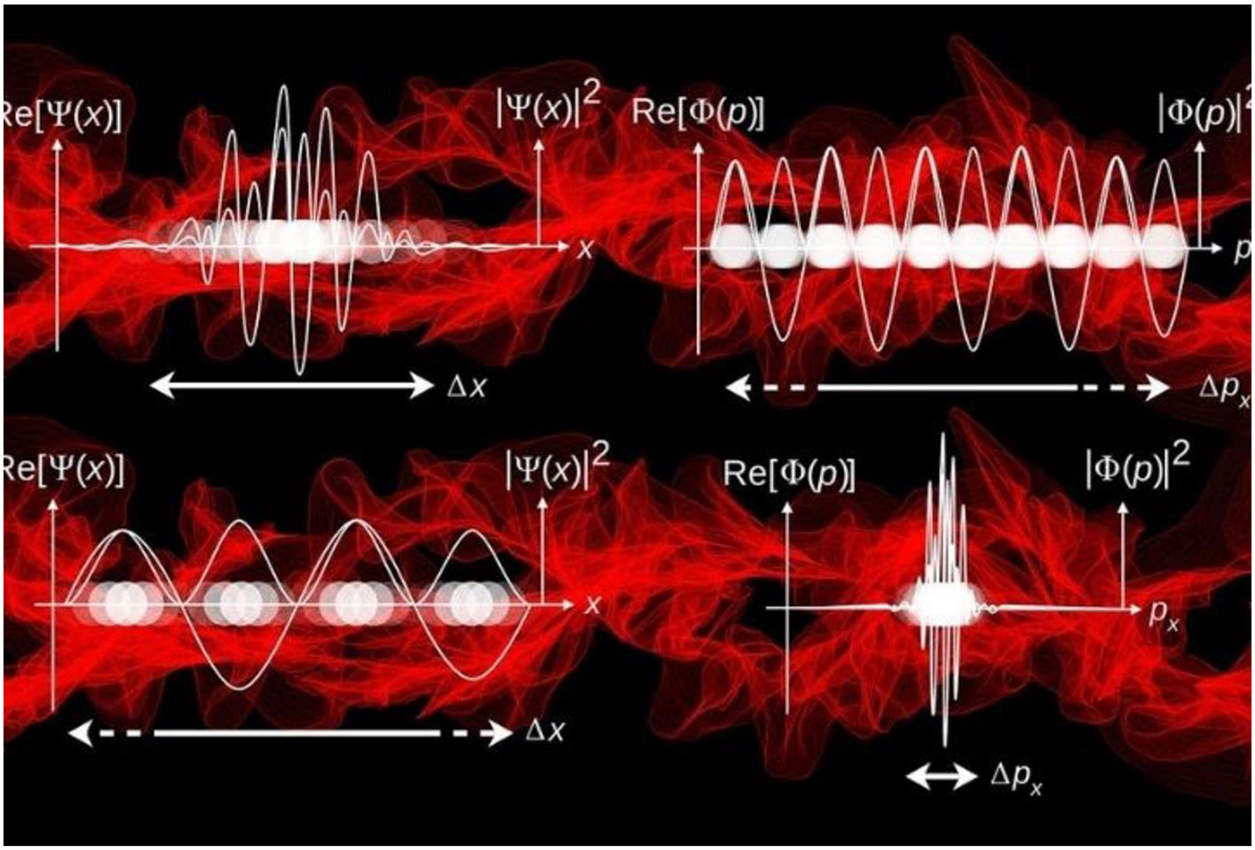
The Big Bang Puzzle

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.



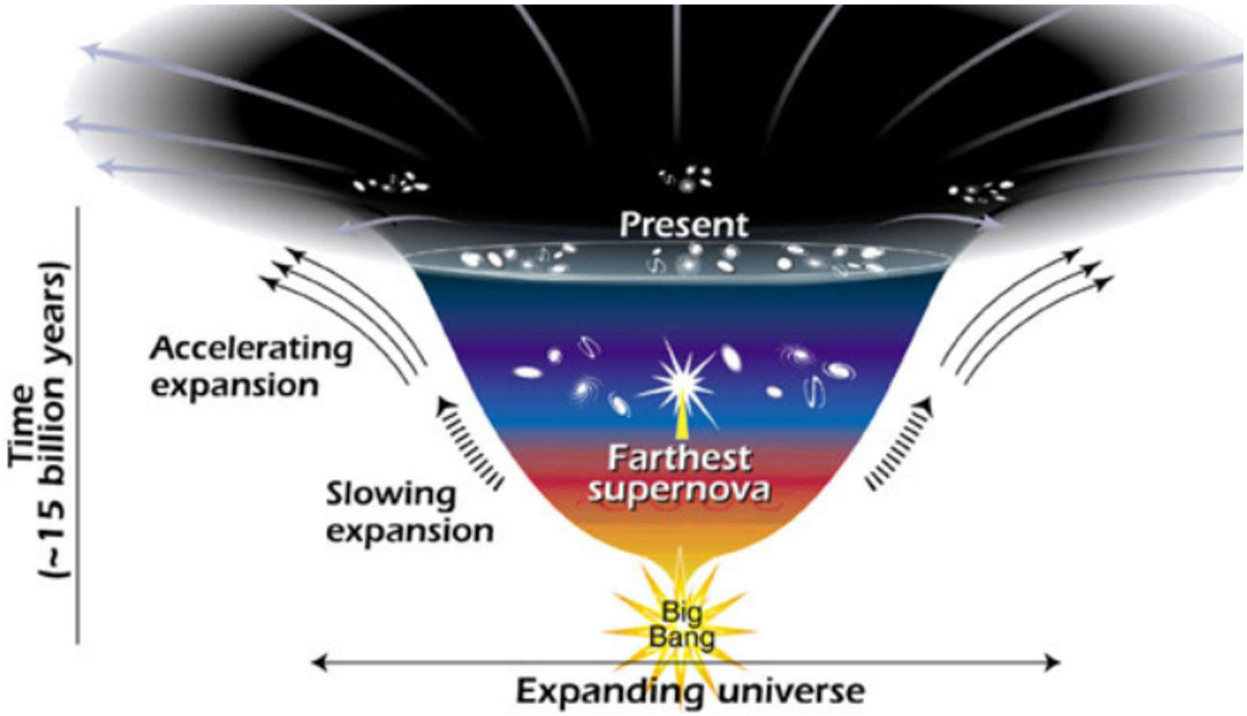
Quantum Fluctuations

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.



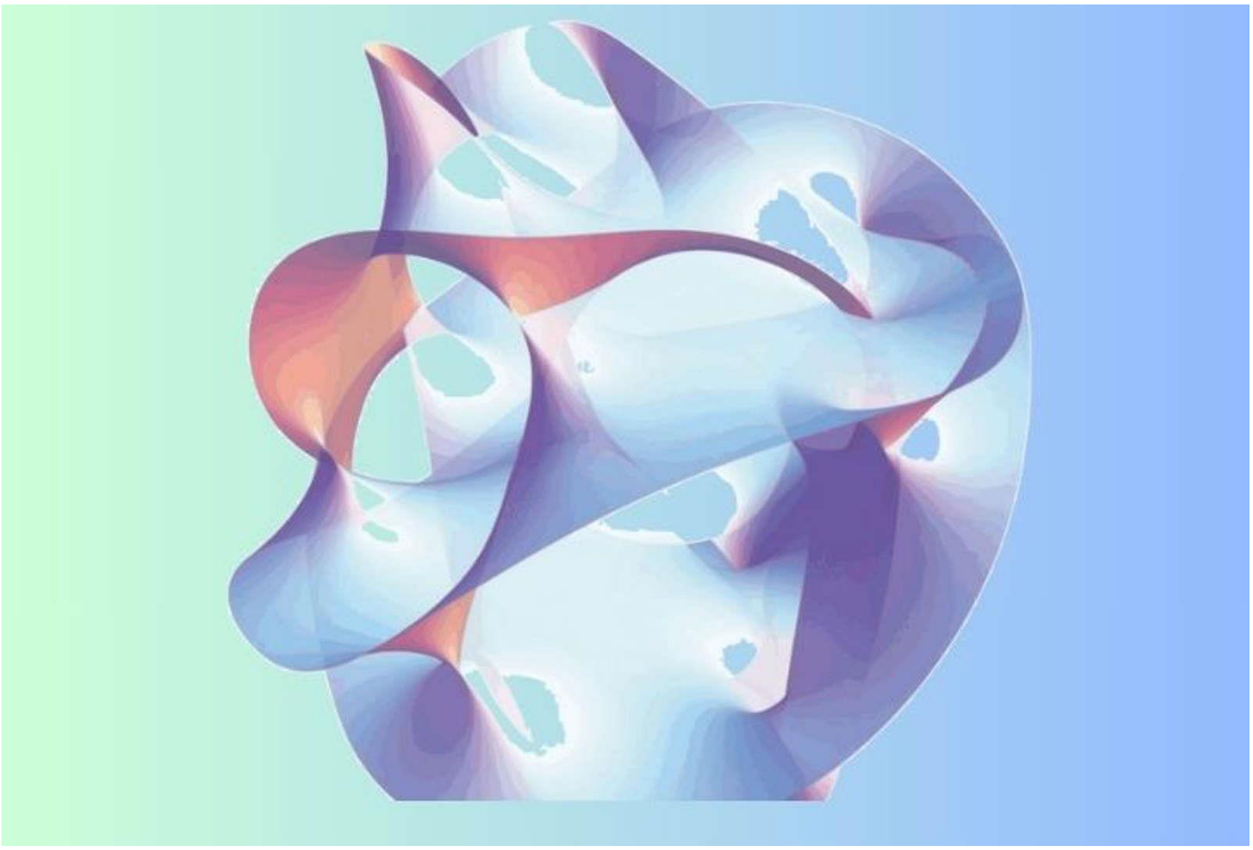
The Role of Dark Energy

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.



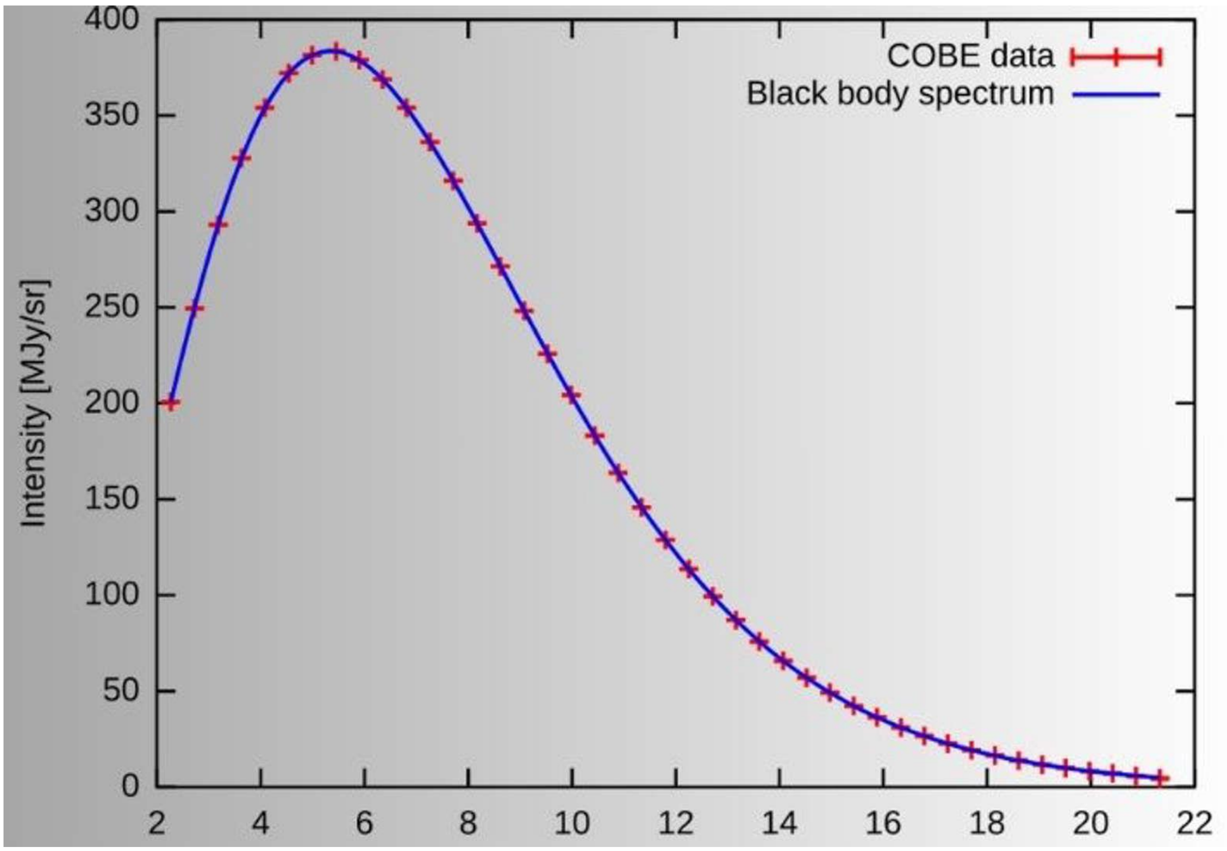
String Theory Insights

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© B. P. Abbott et al /Wikipedia

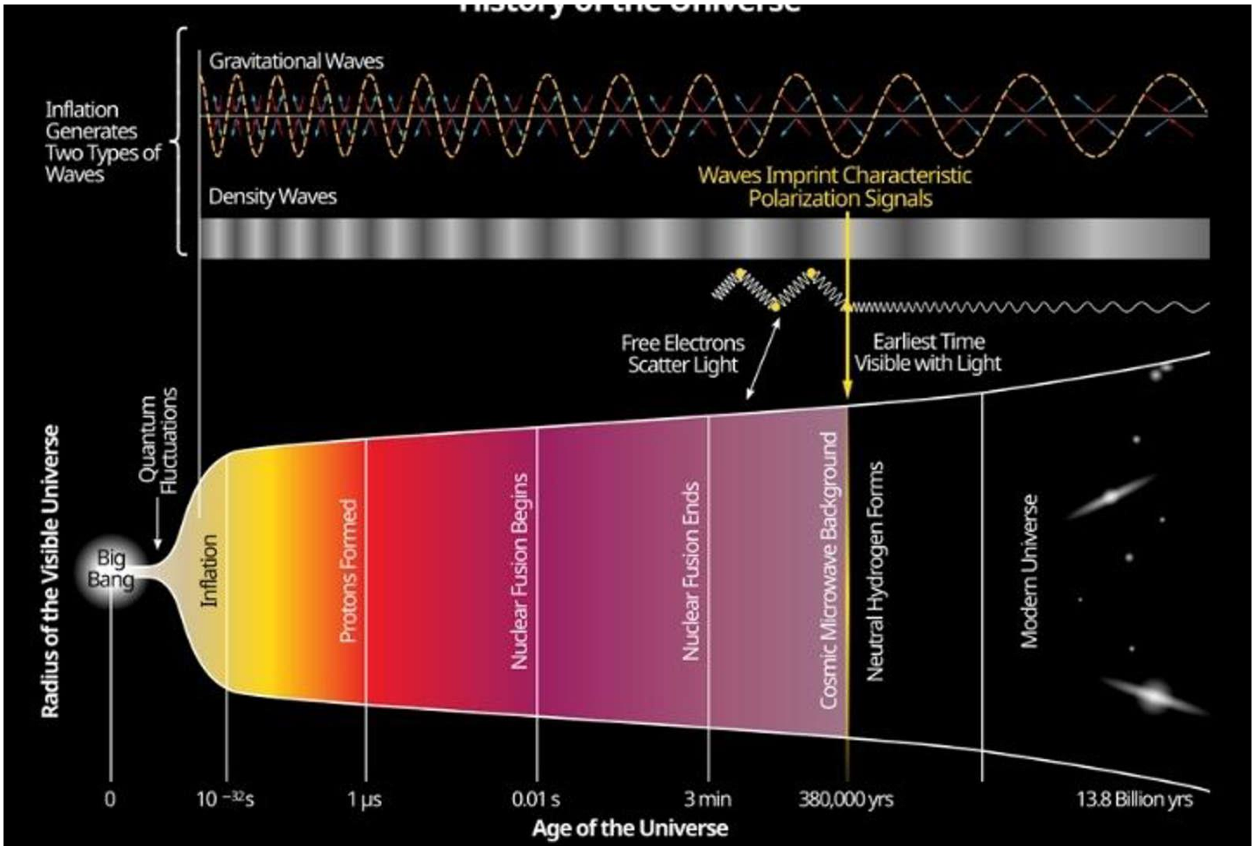
Gravitational waves, tiny ripples in space-time, could carry whispers from before the Big Bang. Scientists are working hard to develop more sensitive detectors, hoping to catch these faint signals. If successful, we might finally "listen in" to the universe's first moments and get hold of the mysteries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

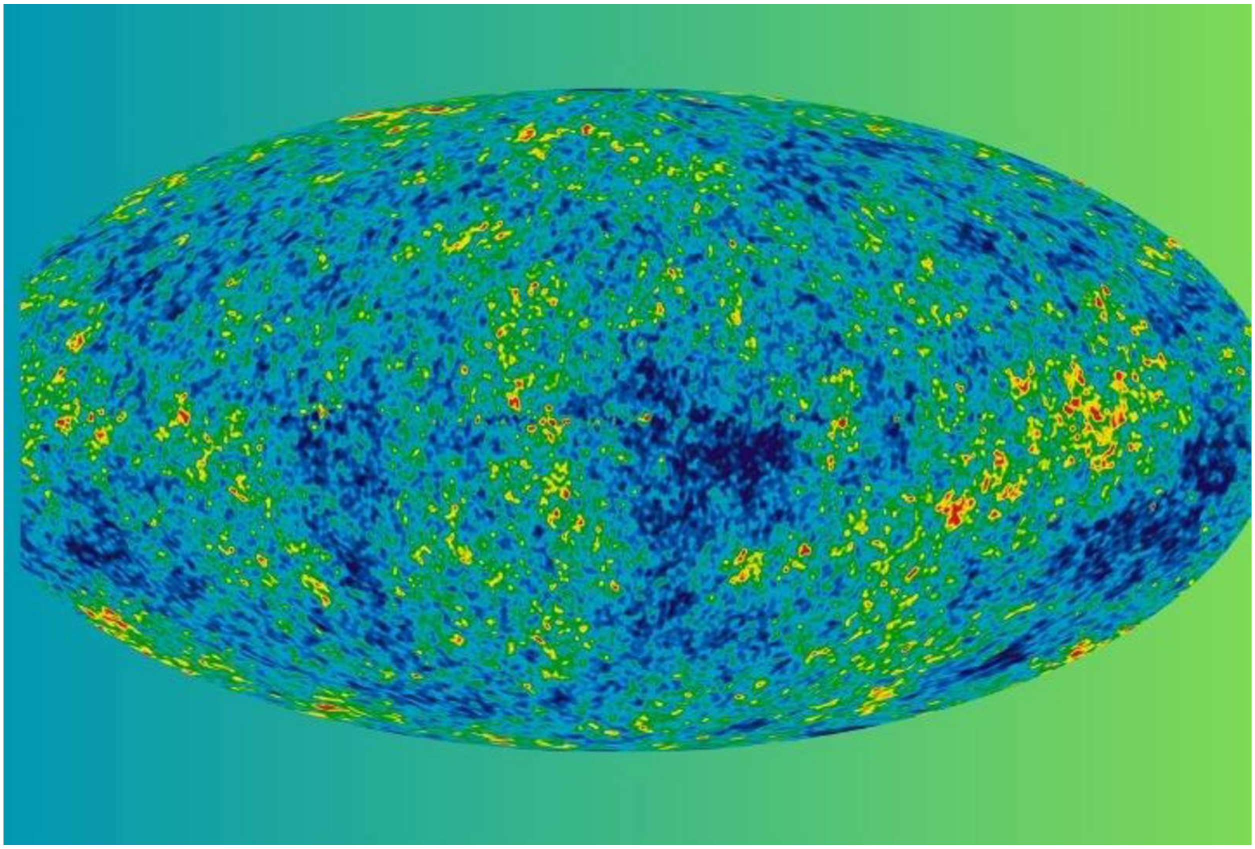
Quantum Gravity

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.

A Recycled Universe Could Explain Why Everything Is So Flat, Physicists Suggest

A new model suggests that the universe did not undergo a Big Bang followed by inflation, as the prevailing model suggests, but a cycle of "bounces". Though so very far from anything approaching confirmed, the authors believe it could help solve a few cosmic mysteries, including dark matter and the "flatness problem".

You may have noticed, but there are a few problems in cosmology and physics that scientists are attempting to get their heads around. One such problem, along with dark matter and dark energy, is that the universe looks sort of flat. First, what do we mean by flat?

"The density of the universe also determines its geometry. If the density of the universe exceeds the critical density, then the geometry of space is closed and positively curved like the surface of a sphere," NASA explains. "This implies that initially parallel photon paths converge slowly, eventually cross, and return back to their starting point (if the universe lasts long enough). If the density of the universe is less than the critical density, then the geometry of space is open (infinite), and negatively curved like the surface of a saddle. If the density of the universe exactly equals the critical density, then the geometry of the universe is flat like a sheet of paper, and infinite in extent."

In a flat universe, parallel lines stay parallel. And it is this type of universe which we appear to be living in. However much simpler this makes studying the universe, it comes with its own problems. The shape of the universe depends upon the average density of matter within it.

"If the density of matter is less than the so-called critical density, the universe is open and infinite. If the density is greater than the critical density the universe is closed and finite," NASA explains. "If the density just equals the critical density, the universe is flat, but still presumably infinite."

In the current age of the universe, the density appears to be very close to the "critical density", which makes it very close to being flat. This was a bit of a problem for Big Bang models of the universe when the flatness problem was first identified, as a hot, dense Big Bang would be above that critical density, and so why did it produce the flat universe that we see today?

While inflationary models can explain this by having the inflation occur very very quickly, some scientists are still looking at other options. While Nobel Prize-winning physicist Roger Penrose suggests conformal cyclic cosmology (far from an accepted idea, but interesting nonetheless), another idea is that the universe goes through cycles of "bounces".

Like string theory or MOND, there are a number of different versions of this. In a new paper, a team looked at "non-singular bouncing cosmology" in which the universe bounces between a hot dense state and the sort of universe we see around us today.

"This cosmological scenario is free of the initial singularity problem present in inflationary cosmology, solving as well the flatness and horizon problems of the standard HBB [Hot Big Bang] theory," the team claims in their paper, "and giving rise to scale-invariant curvature power spectra on large scales, hence being compatible with [Cosmic Microwave Background] observations."

The team looked at how primordial black holes (PBHs) would fit in such a model.

"Interestingly, PBHs can serve as a novel portal in order to probe alternative cosmological and gravitational scenarios," the team explained.

"We found a novel natural model-independent mechanism for PBH formation during the HBB radiation-dominated era, within the context of non-singular matter bouncing cosmologies. In particular, the enhancement of super-horizon curvature perturbations, during a matter contracting phase in combination with a short transitory period from the matter contracting to the HBB expanding Universe, can lead to enhanced curvature perturbations on small scales during the HBB phase, collapsing to form PBHs."

The team suggests that in this model, an array of sizes of black holes would form, rather than just the stellar mass and supermassive black hole mass objects which we have confirmed with observations.

"Interestingly, the primordial black hole masses that we find can lie within the observationally unconstrained asteroid-mass window, potentially explaining the totality of dark matter."

Primordial black holes have been suggested as a potential explanation for dark matter before, but in this model, they would be the remnant of a time before the Big Bang (or bounce), caused by tiny disturbances during this phase of the universe.

While interesting, and we should be open to alternative models, it is far from "problem solved" and the inflationary model remains our best explanation of what we see so far. But the team does give potential ways to look for evidence one way or the other.

"Remarkably, the enhanced curvature perturbations, collapsing to primordial black holes, can induce as well a stochastic gravitational-wave background, being potentially detectable by future experiments, in particular by SKA, PTAs, LISA and ET, hence serving as a new portal to probe the bouncing nature of the initial conditions prevailing in the early Universe."

The study is published in the Journal of Cosmology and Astroparticle Physics.

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

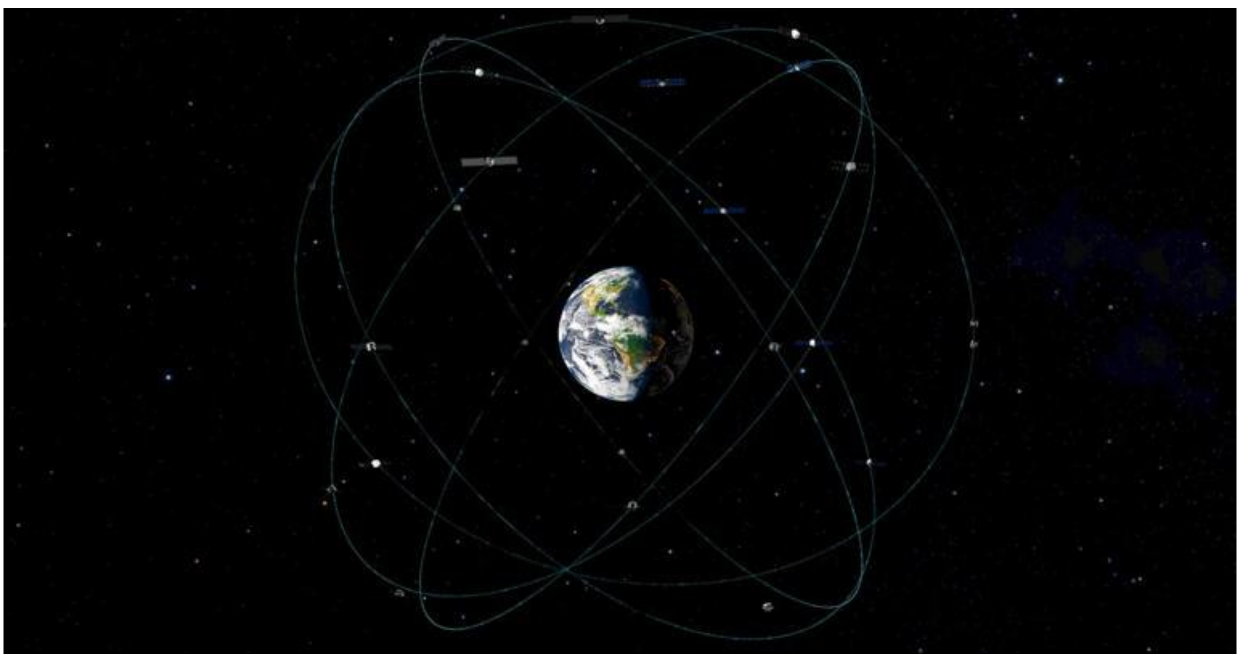
The cluster of galaxies located by the Stockholm team, led by Angela Adamo, has been nicknamed the Cosmic Gems due to their bright, shining appearance. The incredibly luminous structures are said to be magnified and distorted by their crescent-shaped arc, which amplifies the blinding light as the stars 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.

Losing GPS could cost billions, so the Space Force is having companies like Astranis build a backup network

- An outage or loss of GPS satellites is estimated to cost the U.S. military and economy upward of $1 billion a day.
- Pentagon leaders believe that estimate is conservative, leading the U.S. Space Force to kick off a new roughly $2 billion satellite program to build a backup GPS.
- For startup Astranis, one of the four companies selected for R-GPS, the program marks an expansion beyond satellite internet, as it announced its new line of Nexus satellites.



For startup Astranis, which launched its first "MicroGEO" spacecraft last year, the R-GPS program marks an expansion beyond satellite internet into the market for positioning, navigation and timing, or PNT, services.

"We've started to see a huge push towards proliferation in higher orbits by the U.S. national security community," Astranis CEO John Gedmark told CNBC. "Now the Department of Defense has recognized all of the fantastic things that we can do in high orbits with a next-generation small satellite approach."

As it expands as a company, Astranis is announcing its new Nexus product line of PNT satellites, its answer for the R-GPS program. Gedmark noted they use the same type of spacecraft as the company's broadband satellites.

Analysis-Global push for cooperation as space traffic crowds Earth orbit

FILE PHOTO: A satellite model is placed on a picture of Earth in this illustration taken November 25, 2024. REUTERS/Dado Ruvic/Illustration/ File Photo© Thomson Reuters

By Nivedita Bhattacharjee

BENGALURU (Reuters) - The rapid increase in satellites and space junk will make low Earth orbit unusable unless companies and countries cooperate and share the data needed to manage that most accessible region of space, experts and industry insiders said.

A United Nations panel on space traffic coordination in late October determined that urgent action was necessary and called for a comprehensive shared database of orbital objects as well as an international framework to track and manage them.

More than 14,000 satellites including some 3,500 inactive surround the globe in low Earth orbit, showed data from U.S.-based Slingshot Aerospace. Alongside those are about 120 million pieces of debris from launches, collisions and wear-and-tear of which only a few thousand are large enough to track.

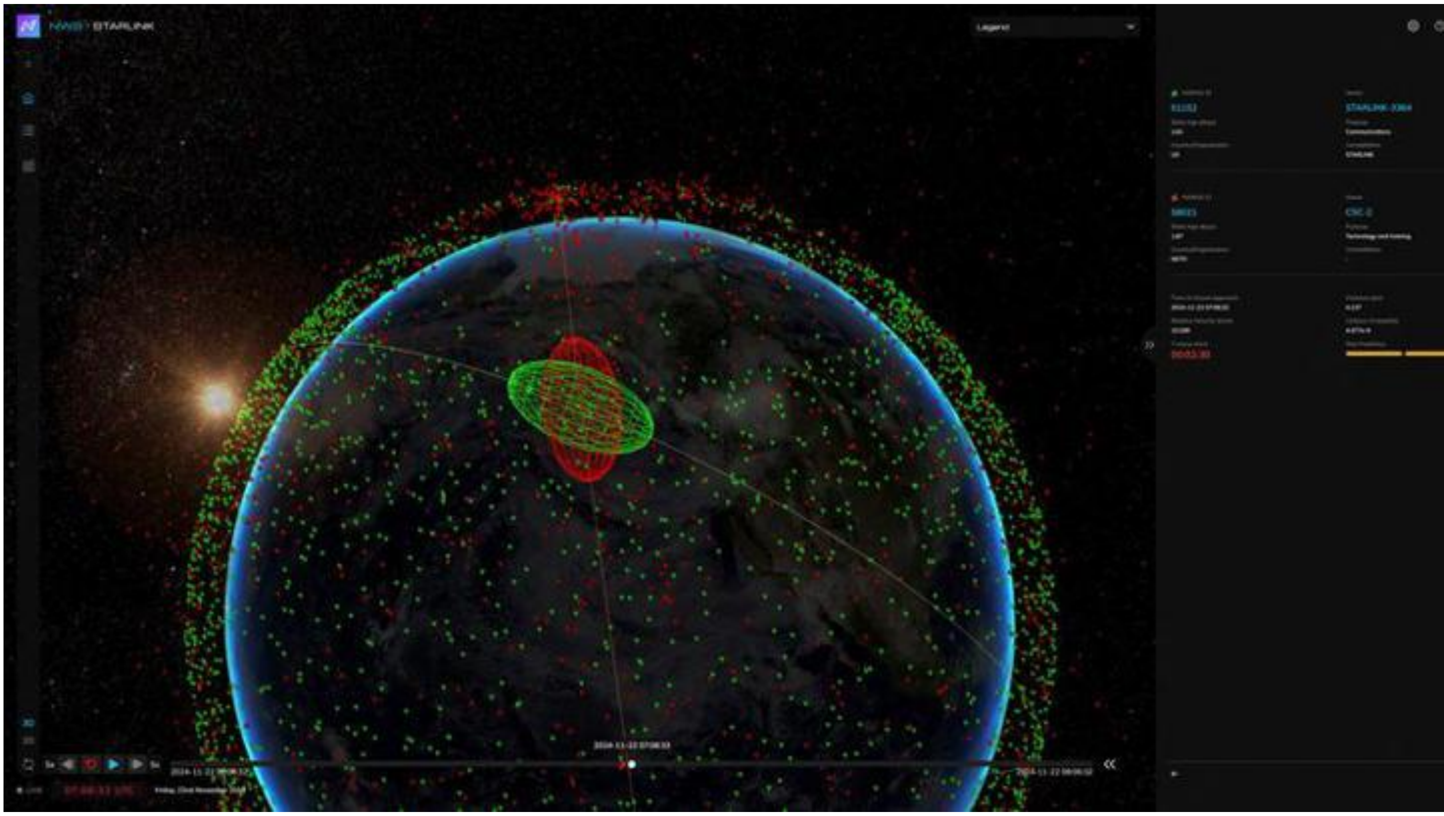
"There's no time to lose on space traffic coordination. With so many objects being launched into space, we have to do everything we can to ensure space safety, and that means facilitating the sharing of information between operators, be they public or private, in order to avoid collisions," said panel co-chair Aarti Holla-Maini, director of the United Nations Office for Outer Space Affairs.

Low Earth orbit must remain safe to prevent costly disruption to the technology behind global communication, navigation and scientific exploration, she said.

Yet there is no centralised system that all space-faring nations can leverage and even persuading them to use such a system has many obstacles. Whereas some countries are willing to share data, others fear compromising security, particularly as satellites are often dual-use and include defence purposes. Moreover, enterprises are keen to guard commercial secrets.

In the meantime, the mess multiplies. A Chinese rocket stage exploded in August, adding thousands of fragments of debris to low Earth orbit. In June, a defunct Russian satellite exploded, scattering thousands of shards which forced astronauts on the International Space Station to take shelter for an hour.

Low Earth orbit is the region most congested with human-made objects as it offers a balance between cost and proximity, making it a prime target for the rapidly growing commercial space sector. It has also seen a 17% rise in close approaches per satellite over the past year, Slingshot data showed.



FILE PHOTO: An image of active and defunct satellites in low Earth Orbit is seen on a Digantara terminal in Bengaluru, India, November 22, 2024. Digantara Handout/via REUTERS/ FIle Photo© Thomson Reuters

Projections point to tens of thousands more satellites entering orbit in the coming years. The potential financial risk of collisions is likely to be $556 million over five years, based on a modelled scenario with a 3.13% annual collision probability and $111 million in yearly damages, said Montreal-based NorthStar Earth & Space.

"We are at a critical point with respect to putting regulations and structure in space to monitor and manage the growing congestion. With Starlink launching thousands of satellites per year, China and others preparing to follow, we will soon push the bearing capacity of prime orbits," said NorthStar CEO Stewart Bain.

RISKY BUSINESS

Low Earth orbit is densely packed, with bands such as the one for satellite internet service Starlink from commercial space company SpaceX - at an altitude of 540–570 km (336-354 miles). As of Nov. 27, Starlink had 6,764 satellites in orbit, Jonathan's Space Report showed.

SpaceX data showed Starlink satellites performed nearly 50,000 collision-avoidance manoeuvres in the first half of 2024, about double the previous six months.

SpaceX did not respond to a Reuters request for comment.

The European Space Agency, which has fewer spacecraft than SpaceX, said in 2021 its manoeuvres have increased to three or four times per craft versus a historical average of one.

The 800–900 km band contains fewer satellites but has 3,114 objects - including operational and non-operational payloads, rocket bodies and fragments - which make up 20% of the total mass of objects in low Earth orbit, posing significant collision risk, LeoLabs data showed.

Expired satellites add to the clutter as they stay in orbit until they fall into - and burn up in - Earth's atmosphere years later or are flown to a "graveyard orbit" some 36,000 km away.

Russia drew global criticism in November 2021 when it test fired a missile at a defunct satellite in orbit, creating thousands of fragments of debris. Russia invaded Ukraine three months after the test.

"The potential for conflicts between states has been on a steep rise in the recent past. If these extend to space it could complicate the outer space environment. We urgently need common global rules for coordination," said Anirudh Sharma, CEO of Bengaluru-based Digantara, which specialises in space situational awareness.

FINAL FRONTIER

The U.N.'s Holla-Maini, whose office serves as secretariat for the Committee on the Peaceful Uses of Outer Space, said the October panel aimed to bring together public- and private-sector experts to outline steps needed to start work on coordination. It will present its findings at a committee meeting next year.

Global cooperation is essential to developing enforceable rules akin to those used by the International Civil Aviation Organization for air traffic, industry experts told Reuters.

Such effort would involve the use of existing tools, such as databases, telescopes, radars and other sensors to track objects while improving coverage, early detection and data precision.

Yet geopolitical tension and reluctance to share data with nations deemed unfriendly as well as commercial concerns over protecting proprietary information and competitive advantages remain significant barriers.

That leaves operators of orbital equipment relying on informal or semi-formal methods of avoiding collisions, such as drawing on data from the U.S. Space Force or groups like the Space Data Association. However, this can involve issues such as accountability and inconsistent data standards.

"The top challenges are speed - as consensus-building takes time - and trust," Holla-Maini said. "Some countries simply can't communicate with others, but the U.N. can facilitate this process. Speed is our biggest enemy, but there's no alternative. It must be done."

(Reporting by Nivedita Bhattacharjee in Bengaluru; Editing by Gerry Doyle and Christopher Cushing)