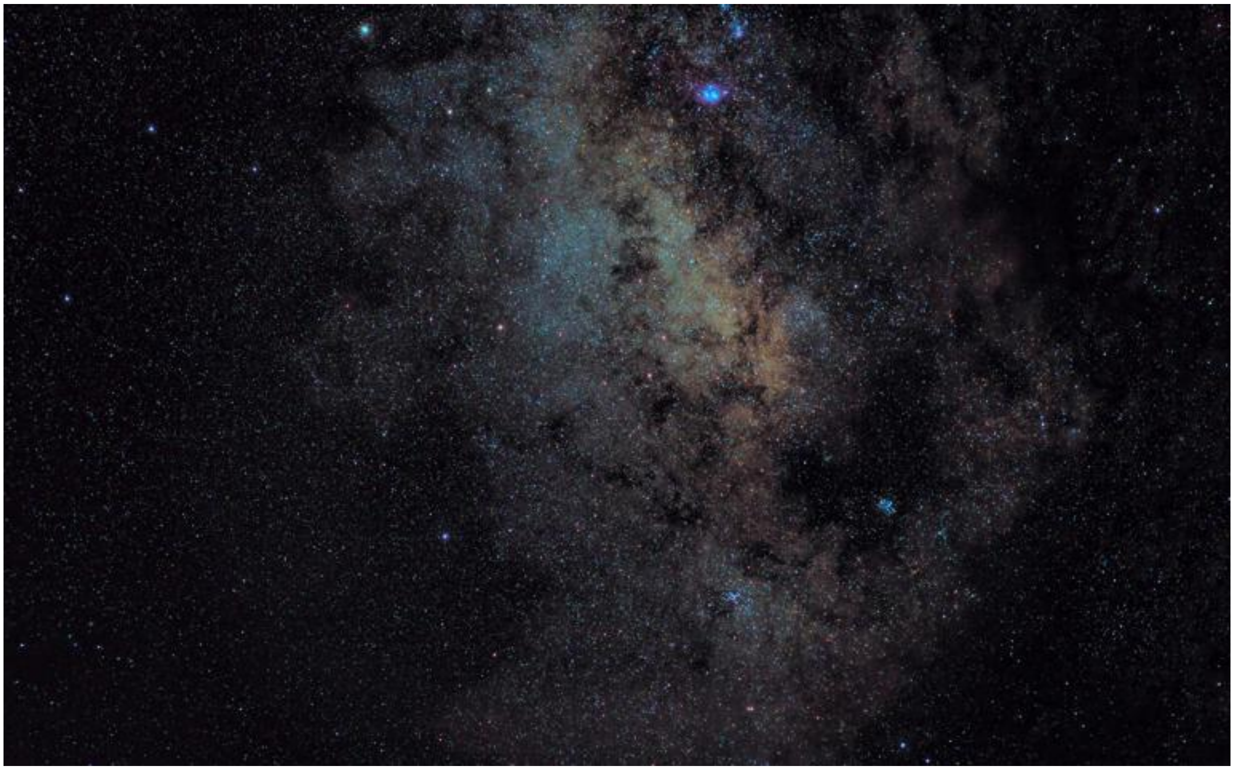
SPACE TECH NEWS



Light from stars travels through space, which is mostly an empty vacuum.© William Attard McCarthy - McCarthy's PhotoWorks/Moment via Getty Images

Curious Kids is a series for children of all ages. If you have a question you'd like an expert to answer, send it to curiouskidsus@theconversation.com.

What is space made of – what does gravity actually bend? – Phil, age 12, Birmingham

What comes to mind when you think of space? Imagine a friend boasting about a spacious building, stadium or museum they recently visited. Do you envision the building as vast and expansive? Is it simply very large, or does it seem empty?

The word spacious does not necessarily mean empty. It simply indicates that there is enough room to move around the objects inside it. Similarly, outer space is not completely empty. It is vast and forever expanding, but there's a lot of stuff in it.

As a kid, I used to wonder about questions like how far away the clouds are, what lies beyond Earth and how vast space is. This curiosity led me to pursue master's and Ph.D. degrees in astronomy. I have been teaching about these very concepts for two decades as a physics instructional professor at the University of Texas, Arlington.

Where does space begin?

Earth is surrounded by different layers of various gases. At sea level, Earth's atmosphere contains about 100 billion molecules per cubic centimeter. As we ascend, the atmosphere becomes thinner and thinner.

At the Kármán line, Earth's atmosphere becomes space.© Mohatatou/Wikimedia Commons

At an altitude of about 50 to 62 miles (80 to 100 km), there isn't enough air for airplanes to fly. This boundary, which separates the Earth's atmosphere from outer space, is called the Kármán line, named after the Hungarian-American engineer and physicist Theodore von Kármán. Everything above the Kármán line is called space.

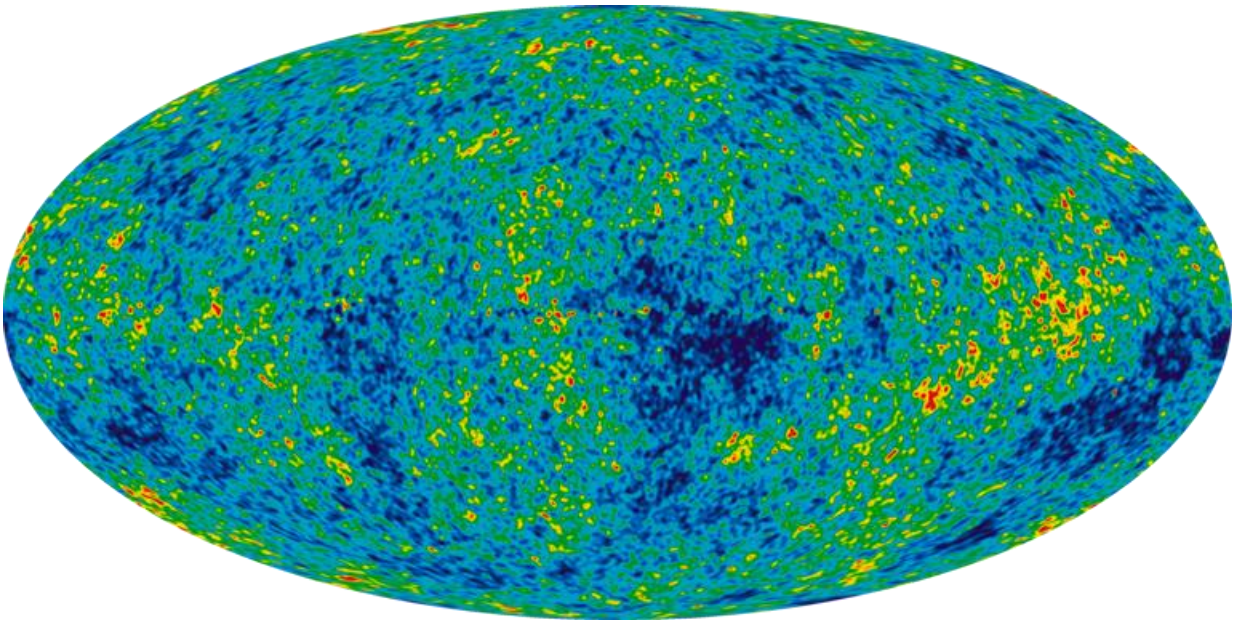
The density of space can vary, but, on average, it is around only 1 atom per cubic centimeter. Just imagine – a dice-sized cube of Earth's atmosphere contains billions of air particles. But in space, the same-sized cube contains only one or two particles.

The interstellar medium and radiation

Space, or outer space, is a vast, near-perfect vacuum largely devoid of matter. This vacuum contains very few particles compared with Earth's atmosphere. However, it's not entirely empty.

Space is dotted with scattered matter called the interstellar medium, which includes hydrogen and helium atoms. These are the most common elements in space, and they exist in both charged and neutral forms. The interstellar medium also contains cosmic dust – tiny particles of various elements, including carbon and silicon, scattered throughout space.

High-energy particles called cosmic rays – which are primarily protons and the nuclei of atoms – travel through space at nearly the speed of light. Cosmic rays come from various stars including our Sun, as well as from supernovae, the material falling into black holes, colliding galaxies and more.



A map of cosmic microwave background radiation from when the universe was only 380,000 years old. The colors are artificial and show tiny temperature variations, which represents heat left over from the origin of the universe.© NASA/WMAP Science Team

Space is filled with various forms of radiation, including cosmic microwave background radiation. This is remnant heat from the origin of the universe. High-energy cosmic events like supernovae and black holes also emit X-rays and gamma rays.

Magnetic fields generated by stars, planets and many other celestial bodies also permeate space. These fields influence the motion of charged particles by attracting or repelling them like magnets.

Dark matter and dark energy

Scientists predict that an as-yet unseen form of matter that does not emit light or energy, called dark matter, makes up a significant portion of the universe's mass. Researchers guess that it exists because they can see its gravitational pull on other visible matter.

Similarly, scientists predict a mysterious form of energy called dark energy is driving the accelerated expansion of the universe. Unlike dark matter, dark energy is not related to matter or gravitational forces, but it's a property of space itself.

Imagine the universe as a balloon. Dark matter is like the balloon's material, affecting its shape, while dark energy is like the air being pumped into it. It doesn't change the balloon's material, but it influences how quickly the balloon expands.

Does space warp? Can gravity bend space?

Space can also warp. Imagine that space is like a big, stretchy trampoline. If you put a heavy ball, like a bowling ball, in the middle of the trampoline, it makes a big dip downward. This dip is similar to how space warps around something big, like a planet or a star. The bigger the ball, the stronger the gravity and the deeper the dip.

If you roll a smaller marble across the trampoline with the bowling ball in the center of it, marbles might start going around the dip made by the bowling ball's gravity. The marble follows the curve of the dip, just like how planets follow the curve of space around the Sun.

Imagine that you shine a flashlight across the trampoline. If the light goes near the dip made by the bowling ball, it might bend a little bit as it travels. This is like how light bends when it passes near a very big object in space, such as a galaxy.

Think of a black hole, which has huge gravity, as an even bigger, deeper dip in the trampoline. If you rolled a marble too close to this super-deep dip, it would fall in and disappear, just like how things can get pulled into a black hole in space and can't escape.

So, space can warp or bend around big things that have lots of gravity, just like a trampoline bends when you put a heavy ball on it.

Space is more than just emptiness. It contains a mix of particles, radiation, magnetic fields and mysterious forms of matter and energy. Imagine space as a

3D playground, inside which objects like stars, planets, nebulas and galaxies exist and together make up our fascinating and complex universe.

Scientists say they can detect the presence of advanced propulsion systems through gravitational waves.© fpm - Getty Images

- If humanity ever wants to escape the solar system, we're going to need a faster-than-light engine. Enter: the warp drive.
- While such a drive pushes the limits of known physics, a new study ponders whether we could detect gravitational waves produced from collapsing warp drives using laser-based detectors, such as LIGO or even the upcoming LISA.
- While purely speculation, this study doesn't continue the conversation about whether gravitational waves could be another tool for our never-ending search for intelligent life beyond Earth.

There's always an enormous elephant in the room when talking about the far future of human space travel. Colonizing other planets is relatively doable with known physics, but if humans have any hope of spreading our wings *beyond* the solar system, space travel gets pretty daunting, pretty quickly. Even traveling at the speed of light—which we can't yet do—means that a trip to Proxima Centauri, the closest star to our Sun, would still take more than four years.

Because of this seemingly insurmountable obstacle, some scientists have relied on exotic ideas like warp drives to cover these fast distances. Instead of going from point A to point B in a straight line, warp drives would bend spacetime itself so that star trekking (see what we did there?) doesn't take whole lifetimes.

While warp drives are a great sci-fi narrative tool, the real-world physics are a bit more complicated. Most of these drives rely on exotic ideas like negative energy or superluminal matter, and while non-profits like Applied Physics are putting up money for research into warp drives based in real physics, these engines remain unattainable—at least to us humans.

A new study published on the preprint server *arXiv* ponders whether it might be possible to detect the presence of warp engines at work among advanced alien civilizations. Scientists from the U.K. and Germany theorized that a warp drive that experiences a containment failure would produce a gravitational wave, otherwise known as a ripple in spacetime.

The paper reads:

> "In this work, we study the signatures arising from a warp drive 'containment failure', assuming a stiff equation of state for the fluid. Our work highlights the importance of exploring strange new spacetimes, to (boldly) simulate what no one has seen before."

First detected by the Laser Interferometer Gravitational-Wave Observatory (LIGO) in 2015, these ripples are usually associated with gigantically violent space phenomenon, such as black hole mergers, supernovae explosions, and neutron star collisions. However, scientists have recently considered whether LIGO, or its space-based big brother, the Laser Interferometer Space Antenna (LISA), could potentially pick up on artificial sources of gravitational waves—a.k.a. *alien tech*.

In late 2022, [a paper published on the arXiv server] analyzed gravitational waves as a means for searching for intelligent life, stating that LIGO "also provides the potential to detect extraterrestrial mega-technology."

The idea of a warp drive is particularly appealing because it's technically describable within general relativity, as the Mexican theoretical physicist Miguel Alcubierre proposed back in 1994. (These theoretical drives are also sometimes called "Alcubierre drives.") This new paper tries to piece together what these grav-wave signatures would look like if some advanced lifeform were able to crack the warp drive conundrum. But just because we know what the signatures *might* look like, actually finding them is a whole other problem.

The paper continues:

> "For a 1km-sized ship, the frequency of the signal is much higher than the range probed by existing detectors, and so

current observations cannot constrain the occurrence of such events. However, the amplitude of the strain signal would be significant for any such event within our galaxy and even beyond, and so within the reach of future detectors targeting higher frequencies."

In other words, it's a long shot—but that's always the case when it comes to faster-than-light ravel.

Scientists Have Determined How to Travel Back in Time With a Ring Wormhole

Scientists believe they have finally calculated a potential method for traveling back in time using a highly theoretical object called a "ring wormhole."

The wormhole would work like a portal, acting as a bridge between two distant points in space. Now, researchers believe these portals could potentially act as time machines and allow humanity to travel back in time.

The Possibility of Time Travel

The idea of traveling back in time has long been a popular fantasy, yet there is little real evidence to suggest that such a feat is possible.

While movies like The Terminator have made time travel popular among the masses, scientists have been hard at work using calculations and equations to determine whether it is possible or if it simply violates the laws of physics.

Researchers Suggest Time Travel is Possible

According to a new paper published by a group of theoretical physicists, the scientists believe they have finally discovered how to time travel. The key to such a phenomenon is ring wormholes.

This particular kind of wormhole was first postulated in 2016 and is comprised of a combination of exotic matter and negative energy. Because of the effect exotic matter has on space-time, physicists theorized it may be able to warp space-time after essentially opening up a portal between two distant regions of the universe.

Stepping Through to Another Universe

Andrei Zelnikov, a researcher from the University of Alberta in Canada, explained the complexity of ring wormholes, explaining, “You could go through and not even notice that you went to another universe.”

Zelnikov and his colleagues have also theorized that these particular wormholes may permit time travel under the correct circumstances.

Time Dilation

According to calculations carried out by Zelnikov and his team, the entrance of a ring wormhole would need to be placed in a higher gravitational field, which essentially means close to a lot of matter.

In turn, the exit would need to experience a lower gravitational field. In this sense, the two sides of the portal would begin to experience time passing at a much different rate. This effect, known as time dilation, was first proposed in Einstein's theory of general relativity.

Traveling Through Time

The researchers then suggested that if you passed through the wormhole and then returned, you would essentially be traveling through time due to the wormhole's effects.

Regarding the theory, researcher Toby Wiseman from the Imperial College London said, “The time machine is a natural consequence of the wormhole existing.”

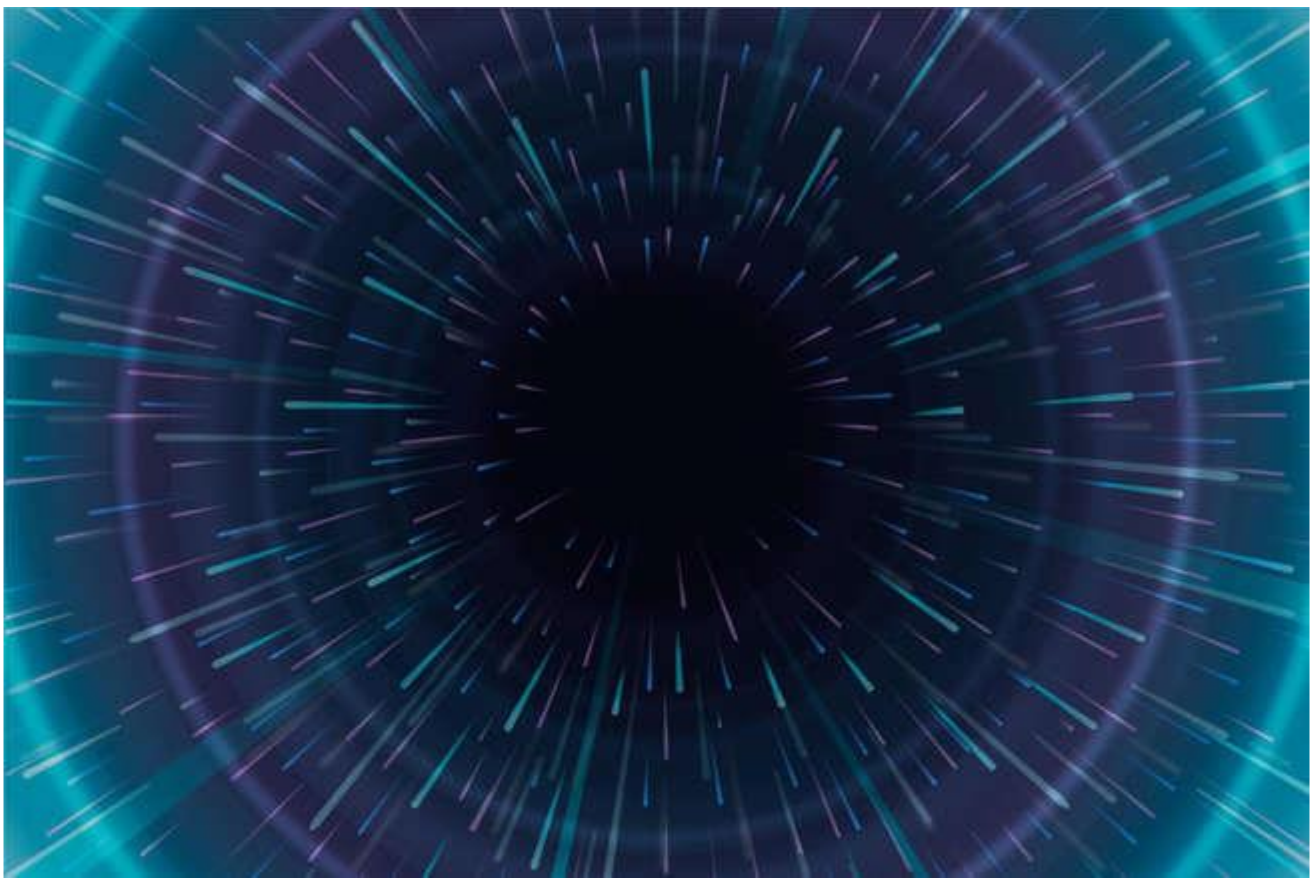
Promising Theory

Wiseman suggests that while the theory is yet to be proven, there's no reason why scientists won’t be able to do so in the future. He admitted the concept is outlandish but certainly possible according to calculations.

“Apart from the crazy matter that makes up the wormhole, there’s nothing too wild being postulated here, and then the consequence is something even more crazy,” said Wiseman.

Scientists Have Determined How to Travel Back in Time With a Ring Wormhole

Story by Ben Campbell



Cambridge Researcher Shares Thoughts on Time Travel

On the other hand, Aron Wall from Cambridge University in the United Kingdom doesn't share the same enthusiasm as Zelnikov. "I doubt there is any way to make such a string with known matter fields, so probably this is not a physically possible situation," he said.

However, the researcher appears open to debate, stating, "We can still ask what would happen."

Quantum Law Prohibits Time Travel

Previous research conducted on the possibility of time travel suggested that quantum effects would immediately destroy any theoretical object that permits us to travel back in time immediately after it forms.

“It may be impossible if you consider quantum effects, but nobody knows how to take into account quantum effects in space-time,” said Zelnikov. “If [ring wormholes] don’t exist, it could be because quantum effects made them blow up.”

Going Forward

As it stands, it's doubtful any scientist will create a machine or portal that will transport humans back to a distant part of the past.

However, Wiseman claims that a ring wormhole is a relatively “very simple construction,” and further studies might help researchers better understand why time travel appears to be impossible.

It seems like everything orbits something in space. Moons orbit planets. Planets orbit stars. Stars orbit the centers of galaxies. But beyond that, things get a little harder to visualize. Do galaxies — and, specifically, the Milky Way — orbit anything?

To answer that, we first need to know how orbits work. Consider two objects orbiting each other. Those two bodies exert a gravitational pull on each other, keeping them bound together. The objects orbit their common center of mass — if you could shrink the system, the center of mass would be the point where you could balance it on your finger. But in the case of the solar system, or Earth and the moon, one of the objects is much larger than the other. The center of mass ends up lying inside the larger body, so the larger object doesn't move much and the smaller object moves on a roughly circular path around the bigger one.

At larger scales, things get a little more complicated. Our galaxy is part of a collection of galaxies called the Local Group, which includes the Milky Way; the Andromeda galaxy; a smaller spiral galaxy called Triangulum; and several dwarf galaxies, including the Large and Small Magellanic Clouds. The Milky Way and Andromeda are the two largest objects in the Local Group. Because their masses are comparable, the center of mass lies between the two galaxies, said Sangmo Tony Sohn, an astronomer at the Space Telescope Science Institute in Maryland. There's nothing significantly larger than either galaxy nearby, so the two end up orbiting each other.

Related: Scientists find galaxy supercluster as massive as 26 quadrillion suns

But the Milky Way's orbit isn't circular or elliptical like the orbits of planets around the sun. "It's going to be weird to say if the Milky Way is orbiting around something, because that kind of implies that there's a bigger object," Sohn told Live Science. "But that's not the concept here."

Instead, both the Milky Way and Andromeda are on mostly radial orbits. "Imagine the gravity of two things pulling on each other, and they're not moving in any way other than the gravitational pull. They will just move directly on the line towards each other. That's a purely radial orbit," said Chris Mihos, an astronomer at Case Western Reserve University in Ohio. The Milky Way's orbit isn't perfectly radial because there's a bit of sideways motion between the two galaxies, Mihos told Live Science.

The Milky Way (seen here) will collide with the Andromeda galaxy in about 4.5 billion years. (Image credit: Kevin Key/Shutterstock)© Provided by Live Science

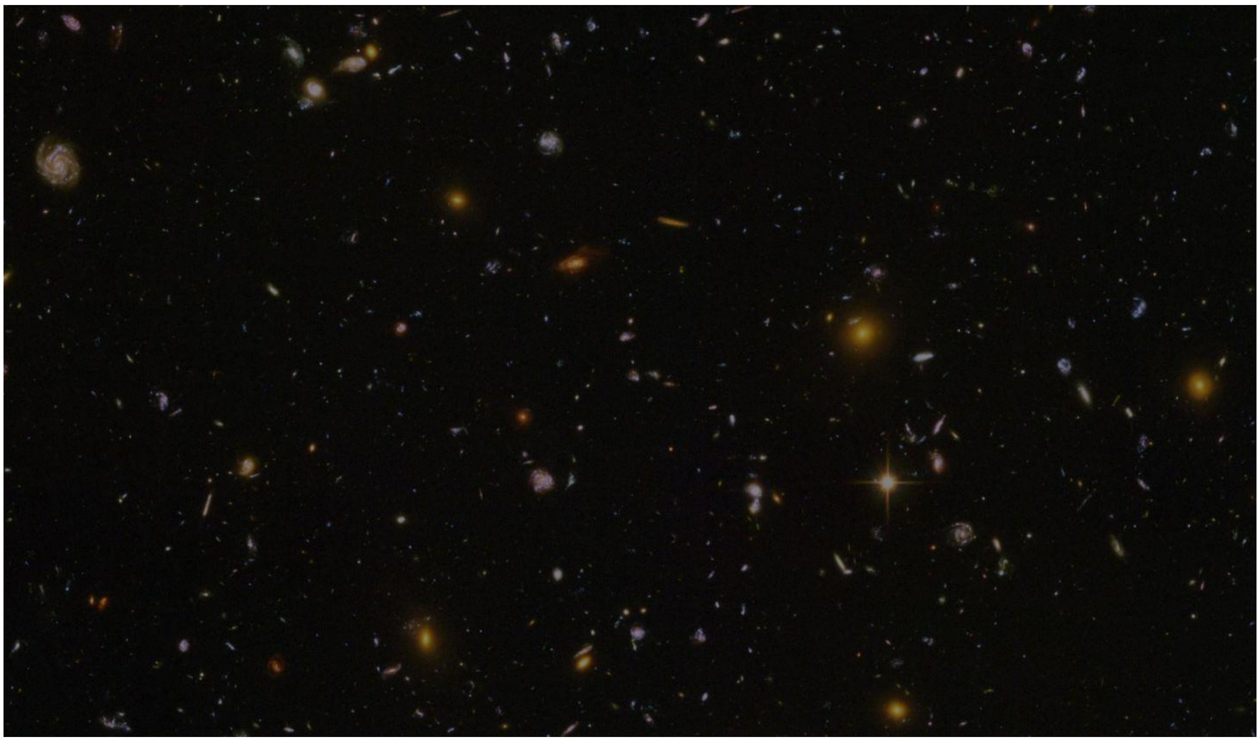
Their mostly radial orbits toward each other mean that the Milky Way and Andromeda will eventually collide, some 4.5 billion years from now. Individual stars likely won't crash into each other because of the huge distances between them, so the galaxies will pass through each other and separate again — but not for long.

"The galaxies [will] then turn around and come back together. And, over the course of hundreds of millions or billions of years, they'll actually merge together into one big galaxy," Mihos said.

The gravitational interactions will likely jostle the stars in both galaxies enough to make the combined galaxy an elliptical galaxy rather than a spiral one like the Milky Way and Andromeda. The merger could also heat the gas along each galaxy's spiral arms enough to form new stars, Sohn said.

Orbits on scales larger than galaxy groups are even less defined, but "we certainly know the Local Group is moving," Mihos said. The Local Group is being pulled toward the Virgo Cluster, which contains several hundred galaxies and lies about 65 million light-years away. But the Local Group will never make it there, Mihos said, because the expansion of the universe is pulling the Milky Way away faster than the gravitational pull of the Virgo Cluster is drawing it in.

There are more than 5,000 worlds beyond our solar system, NASA confirms (AND COUNTING)



March 22, 2022

There are now more than 5,000 confirmed planets beyond our solar system, according to NASA.

The latest addition of 65 exoplanets to the NASA Exoplanet Archive contributed to the scientific milestone marked on Monday. This archive is the home to exoplanet discoveries from peer-reviewed scientific papers that have been confirmed using multiple methods of detecting the planets.

"It's not just a number," said Jessie Christiansen, science lead for the archive and a research scientist with the NASA Exoplanet Science Institute at the California Institute of Technology in

Pasadena, in a statement. “Each one of them is a new world, a brand-new planet. I get excited about every one because we don’t know anything about them.”

A variety of exoplanet types can be seen in this illustration. Scientists discovered the first exoplanets in the 1990s. We’re currently living in a golden age of exoplanet discovery. Although the existence of planets outside of our solar system had been previously proposed and certainly depicted in science fiction, these worlds were only first discovered in the 1990s.

Exoplanets have varied features

The diversity of exoplanets represent populations of planets unlike anything found in our solar system. They include rocky worlds larger than Earth called super-Earths, mini-Neptunes bigger than Earth but smaller than Neptune, and scorching hot Jupiters that dwarf our solar system’s largest planet and closely orbit their host stars. Scientists have also found planets that orbit more than one star and even some around the remnants of dead stars called white dwarfs.

So far, of the confirmed exoplanets, 30% are gas giants, 31% are super-Earths, and 35% are Neptune-like. Just 4% are terrestrial, or rocky planets like Earth or Mars.

Previous exoplanet discoveries have been made thanks to planet-hunting telescopes and satellites like the Spitzer Space Telescope, the Kepler Space Telescope and the Transiting Exoplanet Survey Satellite.

[illegible]

In the new batch of 65 planets, many are super-Earth and sub-Neptune planets, along with some hot Jupiter-size planets. There are also two Earth-size planets, but they're about 620 degrees Fahrenheit (327 degrees Celsius), so more like "hot rocks" than habitable planets, Christiansen said.

She also noted that one is a system with five planets orbiting a small, cool red dwarf star – not unlike the TRAPPIST-1 system, where a similar star hosts seven rocky planets.

Space observatories joining the hunt

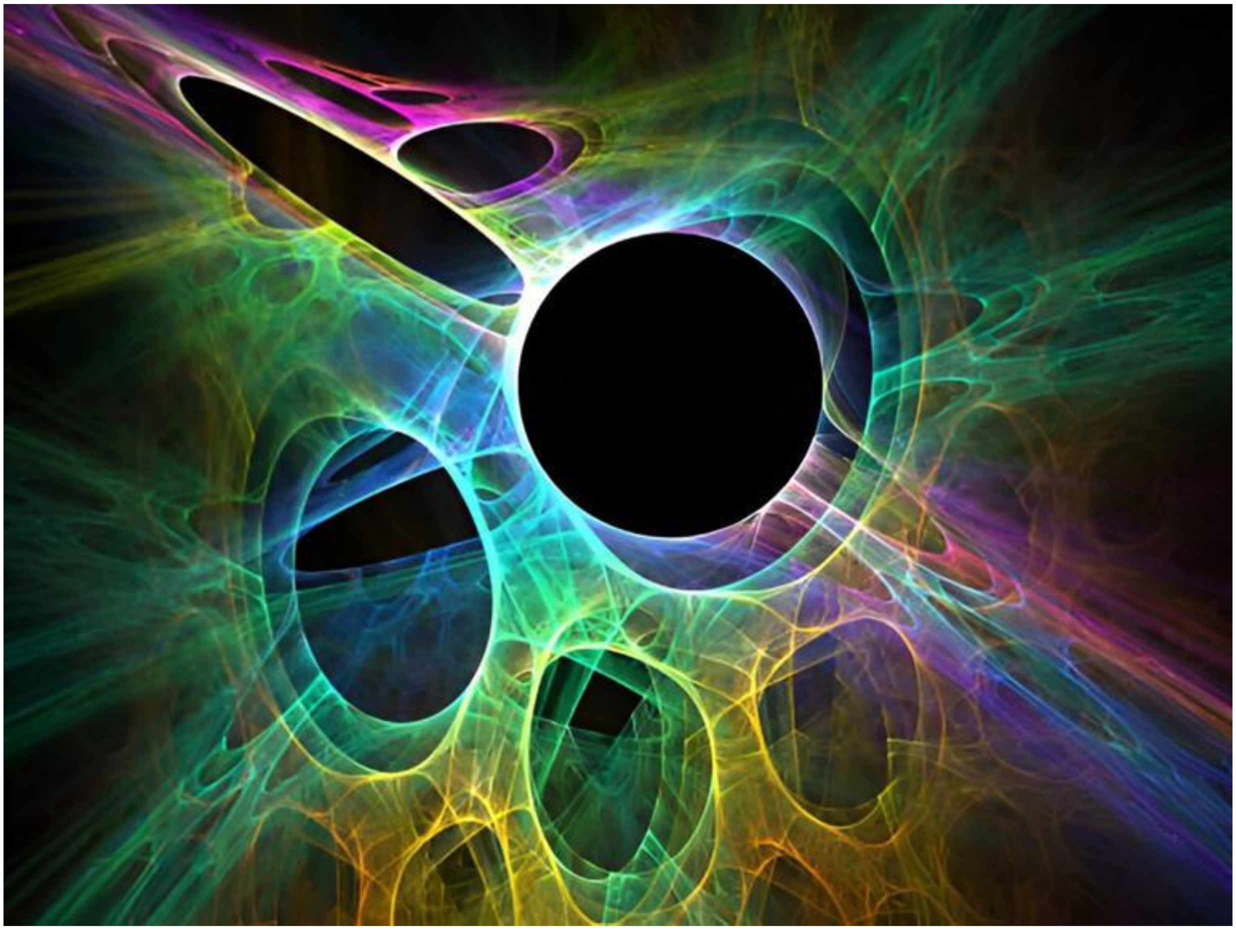
New telescopes will only increase the potential for exoplanet discovery. The James Webb Space Telescope, launched in December, will be able to peer through the atmospheres of exoplanets.

The Webb telescope is poised to study the TRAPPIST system in detail.

The Nancy Grace Roman Space Telescope will launch in 2027 and aid in the search for exoplanets with a variety of techniques. The European Space Agency's ARIEL mission, launching in 2029, will study exoplanet atmospheres.

Although scientists have confirmed more than 5,000 exoplanets, there are likely hundreds of billions of them across the Milky Way galaxy.

"Of the 5,000 exoplanets known, 4,900 are located within a few thousand light-years of us, Christiansen said. "And think about the fact that we're 30,000 light-years from the center of the galaxy; if you extrapolate from the little bubble around us, that means there are many more planets in our galaxy we haven't found yet, as many as 100 to 200 billion. It's mind-blowing."



Superstrings may exist in 11 dimensions at once. Credit: National Institute of Technology Tiruchirappalli© Provided by Phys.org

String theory found its origins in an attempt to understand the nascent experiments revealing the strong nuclear force. Eventually another theory, one based on particles called quarks and force carriers called gluons, would supplant it, but in the deep mathematical bones of the young string theory physicists would find curious structures, half-glimpsed ghosts, that would point to something more. Something deeper.

String theory claims that what we call particles—the point-like entities that wander freely, interact, and bind together to make up the bulk of material existence—are nothing but. Instead, there is but a single kind of fundamental object: the string. These strings, each one existing at the smallest possible limit of existence itself, vibrate. And the way those strings vibrate dictates how they manifest themselves in the larger universe. Like notes on a strummed guitar, a string vibrating with one mode will appear to us as an electron, while another vibrating at a different frequency will appear as a photon, and so on.

String theory is an audacious attempt at a theory of everything. A single mathematical framework that explains the particles that make us who and what we are along with the forces that act as the fundamental messengers among those particles. They are all, every quark in the cosmos and every photon in the field, bits of vibrating strings.

String theory remains the most promising avenue toward a quantum theory of gravity. It can claim this ultimate title because it incorporates all the forces of nature under its banner, potentiality fulfilling the unification dreams of the past half-millennium of physical exploration of the cosmos, and because the theory naturally includes a new particle (or rather, particular vibration of string) that has all the right properties to serve as the quantum force carrier of gravity, the gravitational analog to the photon.

String theory has not been tested, has not been verified, and is not yet even complete. Indeed, despite its enormous promise and potential, the mathematics that underpin the theory are so difficult to solve that nobody has yet come to a solution, let alone a prediction that can be predicted against experiment. It seems that nature is set to tease us again and again. The original attempts to fold gravity into a quantum framework collapse on themselves under the weight of irreducible infinities. And now the most promising solution around those infinities, to replace the point-like particles of old quantum theory with loops of strings, is so unworkable that the infinities sometimes seem preferable.

Despite its shortcomings, theorists have managed to make some headway into the deepening forests of the strings, and in their searching—which sometimes looks more like bold wishes that we hope someday may be proven true—they have struck on something unexpected.

Dimensionality plays a critical role in string theory. The tiny vibrating strings are tasked with the monumental effort of explaining all of creation—every kind of particle to ever have existed, to ever have been discovered, and all the more that we have yet to find. But early on string theorists discovered that the meager three dimensions of space were not enough; confined to our usual and familiar spacetime, strings cannot support enough different kinds of vibrations to explain the full panoply of particles.

And so string theorists came up with an elegant solution. If the universe does not have enough dimensions to give strings the freedom they need to explain all of physics, then we must add most dimensions to the universe. Modern versions of string theory state that we have either ten or eleven spatial dimensions (the difference comes from different formulations of the theory).

To explain why these extra dimensions have escaped our notice thus far in our experiences living in this universe, the dimensions in addition to the familiar three must be curled up on themselves to those same ultra-tiny scales as the strings themselves, shoving them into the hidden corners of perception and experiment. Even our ability to probe the constituents of atoms themselves is far too clumsy to pierce into this string-dominated realm.

We do not need to concern ourselves with the structure or properties of these hidden dimensions, because what matter to us is that string theory, which claims to be a successor in the unbroken chain of unification spanning five hundred years, and claims to one day blossom into a full theory of quantum gravity, admits the possibility, by very nature of mathematical necessity, that our universe has a different number of dimensions than what we may naively assume.

Provided by Universe Today

A new study has found a theory that 'warp drives' could be possible - this method of fast space travel will be known to many sci-fi and *Star Trek* fans.

These super powered space engines can manipulate space time as it compresses what's in front of it and expands it behind.

It creates what's called a 'warp bubble' which is how these spacecrafts in the sci-fi world can travel so quickly, some faster than the speed of light.

This has been looked into because scientists have hinted 'warp drives' may well have been used by aliens as they have left trails through space.

A previous study published in 1994 suggested this could be possible with a substance that may or may not exist but a new study suggests a way to do it without this.

Lead author Jared Fuchs, of the University of Alabama, Huntsville and the research think tank Applied Physics, said: "This study changes the conversation about 'warp drives'. By demonstrating a first-of-its-kind model, we've shown that 'warp drives' might not be relegated to science fiction."

'Warp drives' could mathematically be possible, according to the new study / (coffeekai, iStock)© Provided by Indy 100

According to a statement, the new model uses "a sophisticated blend of traditional and novel gravitational techniques to create a 'warp bubble' that can transport objects at high speeds within the bounds of known physics".

However the proposal says travel faster than the speed of light could not be achieved.

Fuchs and his research team admit this is a single study and even if others could prove the maths behind it, actually building a 'warp drive' is a long, long way off.

"While we're not yet preparing for interstellar voyages, this research heralds a new era of possibilities," Gianni Martire, CEO of Applied Physics, said in the same statement.

"We're continuing to make steady progress as humanity embarks on the Warp Age."

Scientists found an unknown object emitting microwaves near the Milky Way’s center. The object's unique characteristics don't fit known celestial categories.© EzumeImages - Getty Images

- The Atacama Large Millimeter/submillimeter Array (ALMA) interferometer detected a strange object that appears to *only* be emitting microwaves near the Milky Way’s center.
- Now, a new study compares this object to known celestial objects in this chaotic region of deep space. After doing so, the scientists behind the

study discovered that none of the known objects' descriptions fit this new object perfectly.

- While the authors guess the object could be the remnants of stellar merger or an intermediate-mass black hole (IMBH), future studies in millimeter and mid-infrared bands will need to be conducted in order to definitively identify this currently unknown phenomenon.

Space is a big place.

But despite our diminutive size among the hundreds of billions of stars in the Milky Way (which is itself among hundreds of billions of galaxies), scientists have slowly pieced together a long list of all the strange stuff we might encounter throughout the cosmos. However, sometimes humanity's collection of orbital space telescopes, ground-based arrays, and interplanetary spacecraft come across something that's a bit of a head-scratcher.

Meet the latest one—the millimeter ultra-broad-line object, or the MUBLO for short.

Identified in a new paper published last week in the *Astrophysical Journal Letters*, the object in question lies near the center of the Milky Way Galaxy, which the researchers describe as containing "tens of millions of solar masses of gas, a supermassive black hole, a tenth of our Galaxy's ongoing star formation, and an extensive graveyard of stellar remnants."

Although it's a cosmic mess, it's among this interstellar chaos where new celestial objects will be discovered, and the Atacama Large Millimeter/submillimeter Array (ALMA) interferometer is one of the most powerful tools in humanity's star-gazing arsenal. Composed of 66 radio telescopes, this array (as its name suggests) can analyze electromagnetic radiation emanating from space at millimeter and submillimeter wavelengths.

While gazing at our galaxy's center, researchers stumbled upon a compact source subsequently labeled "G0.02467–0.0727," otherwise known as the MUBLO. Made of cold dust and fast-moving gas, the MUBLO also exhibited another strange behavior—it *only* emitted microwave radiation. Adam Ginsburg, the lead author on the paper, and his team went through the long list of celestial explanations and came up short.

“We consider several explanations for the [MUBLO], including protostellar outflow, explosive outflow, a collapsing cloud, an evolved star, a stellar merger, a high-velocity compact cloud, an intermediate-mass black hole, and a background galaxy,” the paper reads. “Most of these conceptual models are either inconsistent with the data or do not fully explain them. The MUBLO is, at present, an observationally unique object.”

According to *Nature*, the gas molecules are also not traveling in a simple ring, which could point to having been blown away by a stellar explosion. But the MUBLO lacks certain chemicals that would be tell-tale signs of such an event.

Among the various celestial phenomena examined in the paper, the authors point out two that *could* explain the MUBLO—a stellar merger or an intermediate-mass black hole (IMHO). However, neither of these hypotheses are perfect. While the stellar merger idea is compelling, the MUBLO has “dust mass is substantially larger, by more than an order of magnitude, than observed toward any other merger remnant.” As for the IMHO suggestion, it “does not explain all of the observed features of the MUBLO.”

To understand this new phenomenon—or, perhaps, a well-disguised known object— uture millimeters and mid-infrared studies will need to analyze the MUBLO and discern previously unseens features that, hopefully, will point toward what it is.

For now, add another galactic mystery to the list.


Scientists created a black hole in a unique lab experiment. Then, it started to glow© Provided by Scoop Upworthy

Scientists created a black hole in a unique lab experiment. Then, it started to glow

Editor's note: This article was originally published on November 17, 2022. It has since been updated.

Black Holes have always captured the interest of scientists and common people alike. While scientists grapple with finding new information about these regions in our universe, we all are forever fascinated by this concept of science. In a revolutionary experiment, scientists have been successfully able to create a replica of the black hole and it can solve several questions about this phenomenon, reports Science Alert.

A team of scientists observed the equivalent of Hawking radiation using a chain of atoms in a single file to recreate the event horizon of a black hole. Hawking radiation describes hypothetical particles created by the boundary of a black hole. This radiation reportedly suggests that the temperatures of black holes are inversely proportional to their mass. In simpler words, the smaller the black hole, the hotter it will glow.

According to scientists, this discovery might aid in resolving the conflict between two currently incompatible frameworks for understanding the universe: The general theory of relativity, which defines gravity's behavior as a continuous field known as spacetime; and quantum mechanics, which uses probability mathematics to describe the behavior of discrete particles.

Mysterious 'tiny red spots' discovered in space© Provided by Earth

NASA's James Webb Space Telescope (JWST) has discovered a cosmic enigma that's shaking up our understanding of the early universe. This finding, called "Tiny Red Spots," is forcing scientists to reconsider their long-held theories about how galaxies form.

Tiny red spots

Researchers at Penn State have discovered three very peculiar objects dating back to around 600-800 million years after the Big Bang. These entities, dubbed "Tiny Red Spots," are a phenomenon unlike any seen before.

"We have confirmed that these appear to be packed with ancient stars - hundreds of millions of years old - in a universe that is only 600-800 million years old. Remarkably, these objects hold the record for the earliest signatures of old starlight," said Bingjie Wang, a postdoctoral scholar at Penn State and lead author on the paper.

"It was totally unexpected to find old stars in a very young universe. The standard models of cosmology and galaxy formation have been incredibly successful, yet, these luminous objects do not quite fit comfortably into those theories."

Rethinking traditional views

These galaxies hold stars that are hundreds of millions of years old, within a universe that is merely 5% of its present age. It's akin to finding a 90-year-old individual in a realm where the eldest person should be 18. This uncovering disrupts our existing models of galaxy creation and development.

"It's very confusing," said Joel Leja, assistant professor of astronomy and astrophysics at Penn State and co-author on both papers.

"You can make this uncomfortably fit in our current model of the universe, but only if we evoke some exotic, insanely rapid formation at the beginning of time. This is, without a doubt, the most peculiar and interesting set of objects I've seen in my career."

Supermassive black holes in tiny red spots

These galaxies also contain supermassive black holes that surpass the anticipated sizes for this cosmic epoch. We're looking at black holes that are 100 to 1,000 times more massive than the one in our Milky Way.

"Normally supermassive black holes are paired with galaxies," Leja said. "They grow up together and go through all their major life experiences together."

"But here, we have a fully formed adult black hole living inside of what should be a baby galaxy. That doesn't really make sense, because these things should grow together, or at least that's what we thought."

Cosmic compactness

These galaxies are incredibly dense, measuring only a few hundred light-years in diameter. For a better grasp, they are roughly 1,000 times smaller than our Milky Way, yet they accommodate about the same number of stars – ranging from 10 billion to 1 trillion.

"These early galaxies would be so dense with stars - stars that must have formed in a way we've never seen, under conditions we would never expect during a period in which we'd never expect to see them," Leja said.

"And for whatever reason, the universe stopped making objects like these after just a couple of billion years. They are unique to the early universe."

Pursuit of solutions

The researchers plan to conduct further observations to collect more data and hopefully shed some light on these Tiny Red Spots.

By focusing the telescope on the entities for extended periods, they aim to obtain more profound spectra, potentially assisting in distinguishing the light sources between stars and conceivable supermassive black holes.

Nevertheless, breakthroughs in science often emerge from unexpected avenues. "There's another way that we could have a breakthrough, and that's just the right idea," Leja said.

"We have all these puzzle pieces and they only fit if we ignore the fact that some of them are breaking. This problem is amenable to a stroke of genius that has so far eluded us, all of our collaborators and the entire scientific community."

Reformulating the laws of the cosmos

This discovery serves as a reminder that the universe is full of surprises, and our knowledge continually evolves.

These ancient, dense galaxies with their aged stars and outsized black holes challenge our established models of galaxy birth and progression. They act as cosmic time capsules, retaining details about the earliest epochs of our universe's narrative.

As we push forward into the cosmos aided by powerful tools like the James Webb Space Telescope, we are destined to uncover more mysteries that expand our horizons of knowledge. The next observation might entirely rewrite the norms of the cosmos.

For now, scientists will continue pondering over these tiny red spots, endeavoring to comprehend their role in the grand cosmic chronicle. And for the rest of us, we can gaze in awe at the marvels of the universe and applaud the devotion of researchers striving to decode its enigmas.

The Concept of Warp Drives

Warp drives may leave telltale signals in the fabric of space-time, a new paper claims. A new paper suggests that we may be able to spot alien spaceships hopping between distant stars using "warp drives" because the sci-fi-inspired technology would give off specific gravitational waves that are unlike anything else we know about. The dream of interstellar travel at faster-than-light speeds, once the exclusive domain of science fiction, is gaining scientific traction. Recent advancements in theoretical physics challenge long-held beliefs about the impossibility of warp-speed travel, sparking renewed excitement and exploration in the scientific community.[1]

The idea of warp drives was first introduced by Mexican physicist Miguel Alcubierre in 1994. He proposed a method to bend the fabric of space-time itself, creating a "warp bubble" that could theoretically allow a spacecraft to travel at effective speeds faster than light without violating Einstein's theory of relativity.

The ship would remain stationary within this bubble while space-time contracts in front of it and expands behind it, propelling the vessel forward.[(ref)]

However, Alcubierre's model required exotic matter with negative energy density—something that has never been observed and remains purely theoretical. This requirement has been a significant barrier to making warp drives a reality.'

New Breakthroughs in Warp Drive Technology

Recent research has provided a glimmer of hope. A team of researchers from Applied Physics, led by Gianni Martire, has proposed a new model that eliminates the need for exotic negative energy. Instead, they suggest using conventional energy sources to create a stable warp bubble, enabling high-speed travel within the bounds of known physics.[ref]

This new approach uses innovative gravitational techniques to manipulate space-time, potentially reducing the energy requirements to a more feasible level.

Dr. Harold White, a physicist at NASA's Johnson Space Center, has also contributed to this research by proposing adjustments to the warp drive design that further reduces energy needs. His team is experimenting with small-scale warp field interferometers to test these concepts in the lab.

Challenges & Future Prospects

While these advancements are promising, there are still significant challenges to overcome. The energy required, though reduced, is still immense, and the practical implementation of a warp drive remains a distant goal. The current models suggest high but subluminal speeds—meaning slightly below the speed of light—are achievable, bringing us closer to interstellar travel than ever before.

Physicist Erik Lentz has also explored ways to bypass the need for negative energy by manipulating space-time differently within the warp bubble. This approach, while still theoretical, offers another potential pathway to achieving warp speeds.

The Road Ahead

As humanity stands on the brink of a new era in space exploration, the prospect of warp drive technology offers tantalizing possibilities. The research is still in its early stages, and much work remains before we can consider practical applications. However, the progress made so far opens up exciting opportunities for future generations of scientists and explorers.

Imagine a future where traveling to another star system is as routine as flying across the globe today. While we're not packing our bags for interstellar voyages just yet, the dream of warp-speed travel is no longer confined to the pages of science fiction.

"Warp drives" used by super-advanced alien civilizations may create specific space-time ripples in their wake that we can spot from Earth, a new paper argues. However, the jury is still out on whether the faster-than-light technology is even possible to create in the first place.
A warp drive is a hypothetical device that enables an object to travel faster than light. In theory, the device creates an invisible sphere around an object, known as a warp bubble, that contracts the space-time in front of it while expanding the space-time behind it. This essentially moves the universe around the object, enabling it to get from point A to B faster than light.
The warp drive concept was first theorized in science fiction books in the 1940s and 1950s but was popularized from the 1960s onwards thanks to the Star Trek franchise.

In 1994, theoretical physicist Miguel Alcubierre proposed the first real-world version of the device, known as an Alcubierre drive. However, while the physics of Alcubierre's concept checks out, it requires the use of large amounts of "negative energy" — energy with a value below zero — which we currently have no idea how to create. This is in addition to other issues, like creating closed space-time loops that violate causality or being able to control a warp bubble once it's formed. However, that doesn't mean we won't eventually figure it all out.
"Some bright soul is going to have a new idea, something quite different from our current understanding of physics," Don Lincoln, a physicist at Fermilab in Illinois, wrote in a 2023 article on the subject. "Then, maybe — just maybe — we will be able to boldly go where no one has gone before."
And while warp drives are a far cry from our current capabilities, that doesn't mean that some super-advanced alien civilization hasn't already come up with the answers.

A depiction of a warp bubble in action from the 2016 film "Star Trek Beyond." (Image credit: Star Trek/Paramount Pictures)

In the new paper, uploaded June 4 to the preprint server arXiv, researchers argued that we could spot warp drives by looking for specific ripples in space-time, known as gravitational waves, given off by warp bubbles. (This paper has not yet been peer-reviewed.)

"Any matter moving around in an irregular way can potentially create gravitational waves," study co-author Katy Clough, a theoretical physicist at Queen Mary University of London, told Live Science in an email. "If you run around in a circle with a friend, you will create gravitational waves too, they are just very small."

Objects traveling at warp speed would not produce any gravitational waves as they zip across the galaxy. However, the creation and subsequent destruction of warp bubbles at the start and end of a journey would produce gravitational waves — especially during the latter phase, which researchers have dubbed a "containment failure."

"The collapse of the warp bubble is quite messy, with the exotic matter that was contained in the wall of the bubble sloshing around and the curvature of space-time that was in the bubble wall also dispersing," Clough said. This would likely create a "strong gravitational wave event," with a specific wavelength, she added.

Astronomers can already spot gravitational waves thanks to state-of-the-art observatories like the Laser Interferometer Gravitational-wave Observatory (LIGO), which is helping scientists tackle some of the biggest questions about phenomena such as wobbling dark matter and black hole collisions. However, warp drives would produce very different gravitational waves to these, which means observatories like LIGO are not fine-tuned to look for them.
To spot warp drives, scientists would have to spend time scouring the cosmos for gravitational waves in different wavelengths without knowing whether there is even anything to find — which could be a massive waste of time and money.

"Whether we see signals is something we can't know until we look," Clough said. "even though I am skeptical about the likelihood of seeing anything, I do think it is sufficiently interesting to be worth a try."

One of the most famous features of the **Star Trek** setting is Warp speed, one of those rare notions that passes over from a single series into pop culture and the public consciousness at large. It may be one of the most well-known aspects of Star Trek overall.

What Is Warp Speed?

The actual name is Time-Warp Factor, shortened to Warp Factor, usually shortened even further down to just Warp. **It is a form of faster-than-light travel**, allowing the interstellar travel that Star Trek is so famous for.

Without travel at the speeds that Warp allows, **travel from one star system to another would take years at a minimum**. It's why other sci-fi shows or movies without Warp show characters needing to be put into stasis during travel, they would otherwise lose years of their life getting from one place to another.

For an example of great sci-fi that uses stasis or cryosleep to keep a ship's crew or passengers alive during long stretches of travel you can look to the likes of **Alien, Lost In Space, or even Star Trek itself**.

Although this would mean you reached a distant destination without aging, **time would still progress while you were asleep**. For you, it would be a short nap, but for everyone else years could have passed by. It's almost a form of time travel, but a major drawback to the method.

Other examples of sci-fi, like Stargate, use the **idea of wormholes for long-distance travel,** a shortcut from one part of space to another. Star Trek also features wormholes, most notably in Deep Space Nine, but Warp is still the most common method used to traverse long distances.

According to Star Trek, it worked by **creating a subspace bubble around the ship, which distorted the spacetime continuum** and moved the ship at extreme velocities that wouldn't otherwise be possible.

In both mathematics and physics, the spacetime continuum is the singular continuum in which three-dimensional space and time co-exist. To break that down, this means **Warp speed is altering the laws of physics to achieve extreme speed.**

Warp technology was the deciding factor in a civilization joining the interstellar community — **without it they wouldn't be able to engage in trade, exploration, or diplomacy to any reasonable standard**. The United Federation of Planets would even specifically avoid pre-Warp civilizations to avoid influencing their development.

A ship losing Warp speed, by damage or malfunction, would often be left close to stranded. **The alternative was Impulse, not dissimilar to conventional propulsion**, reducing a ship's speed dramatically. Ships in this situation would typically need to send out a distress call for help.

Not all of the seemingly scientific language featured in Star Trek really means anything. Some concepts are rooted in real science, but since Star Trek is fiction **the writers are free to invent any technology or concept** that best serves the story.

If you've ever watched a scene where the engineer or scientist has to deliver a string of scientific-sounding words to make the topic sound real, it's usually nonsense. **This spawned the term Treknobabble**, a twist on the word technobabble. LeVar Burton, who played Jordi La Forge, found the best way to deliver these lines was as quickly as possible.

How Fast Is Warp Speed?

Warp speed has different levels, ranging most typically from Warp 1 up to Warp 9. There are increments in between, like Warp 2.5 in between Warp 2 and Warp 3. The series doesn't offer too much explanation about how fast these speeds are, but there is concrete information.

Warp 1 is equivalent to the speed of light, approximately 186,000 miles per second. That's **671 million miles per hour**, which sounds impossibly fast. But even to get from Earth to Alpha Centauri, our nearest neighboring star system, would take over four years at light speed.

Star Trek creator, Gene Roddenberry, initially pictured ships moving at Warp speed as invisible. He believed that since they were moving faster than the speed of light, light wouldn't reach them. **Science doesn't support that idea**, but more importantly, it wouldn't be as visually interesting for viewers.

Warp 2, the next full factor of speed up from Warp 1, is about eight times as fast as Warp 1, which cuts down the time to reach Alpha Centauri to less than a year. Warp 3 is 27 times faster than Warp 1, and it continues to escalate from there. The higher Warp speeds can be **thousands of times faster than the speed of light**.

You can see how speeds at that level make space travel across long distances a matter of days rather than centuries, allowing Star Trek to explore multiple star systems and planets. Otherwise, most of the action would be **constrained to a much smaller section of the galaxy**.

Does Warp Speed Make Distance Meaningless?

It would be easy to think that Warp means travel is a non-factor in Star Trek, but that isn't the case. The universe is so infinitely vast that **travel across long distances, even at top Warp speeds, can take months if not longer**.

The best example of this is Star Trek Voyager, a show that explores the idea of a Starfleet ship stranded in a far-flung and unexplored corner of the universe. They calculate that even if they traveled at top Warp speed, non-stop, **it would still take them around 75 years to get home**.

The Voyager crew managed this journey in just seven years, utilizing advanced technology and **a number of shortcuts**. Their efforts to find a way home caused several advances in interstellar travel, including Warp 10.

What Is Warp 10?

Warp 10 is treated differently depending on which Star Trek series you happen to be watching. **In the original and animated series**, Warp speeds of up to 36 are depicted, but Star Trek would go on to reclassify top speeds.

By the 24th century, **they had classed Warp 10 as the point at which infinite velocity was reached**, causing the ship to exist everywhere in the universe at once. It was also known as the transwarp threshold and considered impossible to reach.

Warp 10 also became **slang for anything that moved extremely fast,** a hyperbolic phrase. In Star Trek Voyager, rumours are described as travelling at Warp 10, while in Deep Space Nine a character's adrenaline is said to be pumping at Warp 10 at one point.

Warp 10 is achieved a few times in Star Trek, most notably in Star Trek Voyager as a possible way to get the crew home faster. It was achieved by fitting a shuttlecraft with a transwarp drive and using a rare form of dilithium.

Although the test flight was successful, it was discovered that **traveling at Warp 10 caused hyper-evolution**, meaning they would undergo millions of years of evolution in a matter of hours. Tom Paris, along with Captain Janeway, underwent this process.

They both evolved into amphibious salamanders, not that it's clear how that is constituted as an evolution. They would have several offspring in this form before the process was successfully reversed. Unsurprisingly, it was decided **Warp 10 wasn't worth the risks**.

Star Trek is no stranger to time travel, showing possible alternatives to faster speeds in the future. Some possible future technologies shown include the quantum slipstream drive or the Sidewarp Factor. Sidewarp, featured in one of the official Star Trek novels, Federation, is described as so fast that regular Warp feels like moving at a crawl in comparison.

The offspring Tom Paris and Captain Janeway have while hyper-evolved are left to fend for themselves on the planet they were born on. Their ultimate **fate is unknown**.

Is Warp Travel Safe?

Warp travel is the primary method of travel for almost all interstellar species in the Star Trek universe, and has no true viable replacement. Given how it's how almost all travel is carried out, the question arises of whether it's safe or not.

In the year 2370, it was discovered that **Warp engines were damaging the fabric of spacetime**, causing subspace rifts. Captain Picard compared it to how walking over a carpet repeatedly will eventually cause enough gradual damage to wear it down.

The temporary solution to this was for Starfleet to impose **a speed limit of Warp 5 outside of emergencies**, to try and reduce the damage caused to subspace. It was believed that lower speeds would cause less damage.

Starfleet imposed this speed limit and communicated the issue to other civilizations, but there was never any guarantee they would be as environmentally conscious. Rival groups like the Cardassians or Romulans **would have huge advantages over Starfleet** by not adhering to the same speed limit.

This speed limit was mentioned only a few further times and then quietly dropped. It's possible that a solution was found to the problem, but the truth is that **the writers for Star Trek just quietly did away with the idea**. Although it was interesting, the issues it caused weren't worth it for the sake of writing interesting stories.

Is Warp Speed Actually Possible?

Every Star Trek fan has wondered at some point or another **whether Warp travel is something we could achieve**, allowing us to travel to the stars at the kind of speeds depicted in the various Star Trek shows and movies.

There **isn't a simple or definitive answer** to this question. We certainly don't have the ability to move at anything even remotely approaching Warp speed yet, many scientists are firm in the idea that nothing with mass could move at the speed of light, let alone faster.

It's important to remember that even in the fictional setting of Star Trek, **faster than light travel isn't possible** most of the time. Warp speed achieves this by creating a shell around a ship, which means that space and time no longer function under their normal rules.

Still, **Warp could be possible** if you listen to some scientists, at least in theory if not in practice. As recently as 2024, applied physics researchers suggested the idea of a "constant-velocity subluminal warp drive" that accords with the principles of relativity.

What that means exactly requires advanced scientific degrees and a lot of time to explain, but it's enough to know that **the idea is still alive**. We can still hope and drama of someday hitting Warp speeds and flying through space faster than light.

After 58 years, ***Star Trek*** reveals why it uses quadrants, despite the universe being infinite. The galaxy is a vast place, much too big for one starship to travel in a lifetime. The sheer size of the galaxy has forced the Federation and **other galactic powers to devise a system of "quadrants" to divide it up, and now *Star Trek: Defiant* #17 reveals how and why it was created.**

Thus, to allow computers to crunch the enormous amounts of data needed to navigate a starship, galactic powers, including the Federation, created a system of quadrants.

Star Trek: Defiant #17 is written by Christopher Cantwell and drawn by Angel Unzueta. Chief O'Brien, now a lecturer at Starfleet Academy, is lecturing on automata theory. O'Brien quizzes the students on the theory's limits, stating that it breaks down when confronted with infinity. The galaxy is large and full of unpredictable elements. Thus, to allow computers to crunch the enormous amounts of data needed to navigate a starship, galactic powers, including the Federation, created a system of quadrants.

Star Trek's Quadrant System's Origins Have Never Been Explained--Until Now

The Star Trek Universe is Vast

The quadrant system is integral to the *Star Trek* universe, but it has not always been used consistently. In early episodes of the classic *Star Trek* series, **the terms "quadrant" and "sector" were used in a seemingly interchangeable fashion.** As *Star Trek* lore solidified, a consistent system was created based on four different quadrants: Alpha, Beta, Delta, and Gamma. Quadrants are massive: in *Star Trek: Voyager's* series premiere, the ship was hurled from the Alpha to the Delta. It was estimated it would take nearly 80 years for *Voyager* to get home–at maximum warp.

A Guide to the Quadrants of the *Star Trek* Universe

Name	Major Power(s)
Alpha	Federation
Beta	Romulans, Klingons
Gamma	The Dominion
Delta	The Borg

As a way to make the vast quadrants even more manageable, the Federation and other galactic powers divided them up into sectors, with Earth at the center of Sector 001. Creating sectors within quadrants allowed starship computers to run their calculations even more efficiently. Not only is it the perfect example of a workaround for the limitations of automata theory, but a testament to the creativity inherent in all species. Critics charge the system is very Earth and human-centric, but the quadrant system is still a useful tool.

Star Trek Producers Should Adopt This Origin for the Quadrant System

The Origin Is Real-World Plausible

The origin of the quadrant system is a neat bit of world-building within the *Star Trek* universe, explaining a key piece of lore. Since this revelation occurred in the comics, it is, per the policy of Paramount, non-canon. However, certain elements from licensed *Star Trek* media, such as novels, have made it into the canon, such as Sulu and Uhura's first names. The origin of the quadrants, as laid out in *Star Trek* are grounded in real-world scientific theory, and future ***Star Trek*** showrunners could easily adapt this theory to the screen.

Creating the Theory

Inspired by the sci-fi technology of his favorite franchises, Mexican physicist Miguel Alcubierre Moya has spent the last few decades investigating the feasibility of a real method for light-speed propulsion.

In his recent paper, which stunned the theoretical physicist community, Moya may have found the quickest way to travel from Point A to Point B.

The Possibility of Warp Speed

Named after the physicist, Alcubierre warp drives hypothetically contracted spacetime in front of the spaceship while expanding the spacetime behind it. By distorting spacetime–the continuum enfolding the three dimensions of space and time–the ship would look like it is moving faster than the speed of light.

Observers inside the craft would feel no acceleration forces as they move through space in the blink of an eye.

The Theory Works With Negative Energy

If Alcubierre warp drive does work, then it could revolutionize space travel, allowing humanity to reach our closest solar system, Alpha Centauri, which is located four light years away, in days or weeks.

In theory, the technology demanded to make warp drive possible would need to take in plenty of negative energy. At least that was the thought until recently.

A Possible Answer to Warp Travel

A team of physicists from the University of Alabama in Huntsville worked with the Advanced Propulsion Laboratory at Applied Physics in New York to develop a new model that could make warp drive possible without negative energy.

In their paper, which was published in the journal Classical and Quantum Gravity, the researchers describe the technique that could create a warp bubble without negative energy.

A New Model of Stable Matter

The researchers believe that a new, advanced blending of traditional and novel gravitational techniques could be used to create a "warp bubble" that could transport objects at high, yet still subluminal, speeds.

The new model uses a stable matter shell combined with a shift vector distribution, which closely approximates the Alcubierre metric proposed in 1994, rather than using negative energy.

The Power of Positive Energy

Positive energy makes all the difference when trying to solve the problem of bending spacetime. Unlike negative energy, positive energy does not violate the laws of physics, and there is an actual way to harness it.

"This work changes the conversation about warp drives," said Jared Fuchs, the principal author of the paper.

Creating the Warp Bubble

A more practical approach involves using conventional positive energy to create the "warp bubble." True to its name, this is a spherical structure that envelops a passenger ship in a shell of ordinary—albeit extremely dense—matter.

The bubble moves the spaceship by harnessing the intense gravity of this shell, all while preventing the passengers from experiencing any sensation of acceleration. "An elevator ride would be more exciting," Gianni Martire, CEO of Applied Physics and co-author of the paper, said.

A Warp Bubble That Adheres to Science

Although nothing can travel faster than the speed of light, according to the gravity-bound principles of Albert Einstein's theory of general relativity, the warp bubble is designed so that observers within the local spacetime environment can experience normal movement in time.

The walls of the bubble are generating the necessary momentum to contain the craft as it moves incredibly fast. "It's the movement of the matter in the walls that actually creates the effect for passengers on the inside," Fuchs explains.

Limitations to the Science

"That's the chief limitation and key challenge we have to overcome—how can we have all this matter in our [bubble], but not at such a scale that we can never even put it together?" Martire says.

The possible answer could be found in matter physics, a branch of physics that deals with the forces between atoms and electrons in matter. But more issues, like current models that will allow a stable warp bubble and constant velocity, are proving difficult to find answers for.

The Beginning of the "Warp Age"

Despite the discovery, Martire believes that humanity is nowhere near prepared for interstellar travel. However, the research does propose an exciting new age of possibilities.

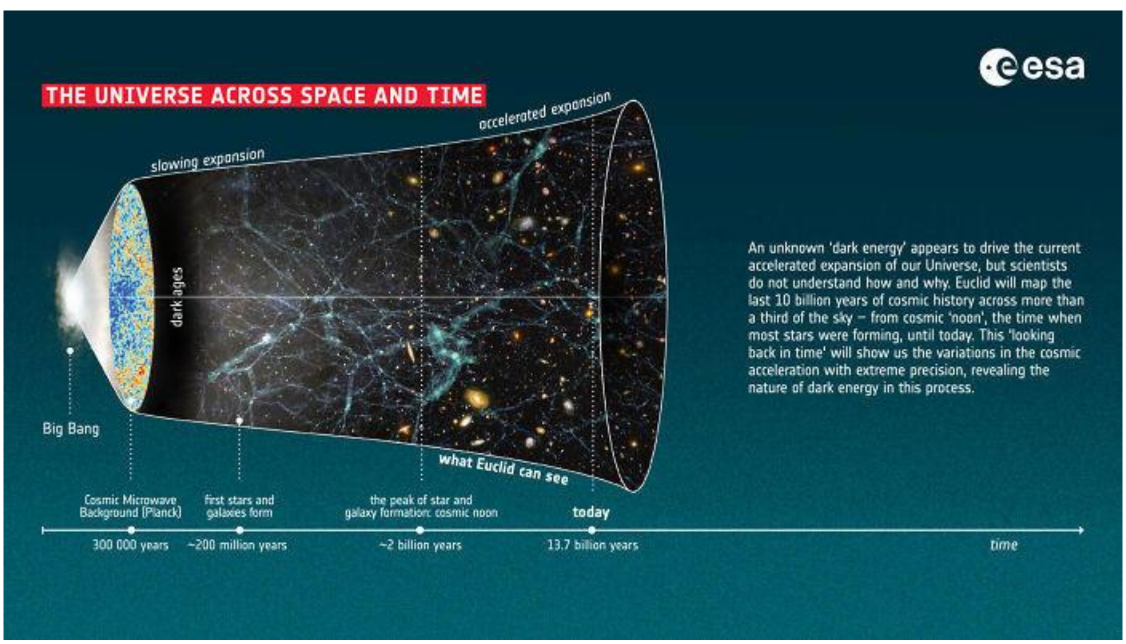
The team believes that this research could act as a stepping stone in a long path toward interstellar flight, marking the beginning of the "Warp Age," according to Martire.

The concept of multiple universes goes back to the 6th century, when pre-Socratic Greek philosopher Anaximander suggested the idea of infinite worlds for the first time.

Yet multiverse ideas gained scientific weight only in the 1980s, together with the inflation theory, which not only explained why the cosmos is so flat and smooth, but also predicted an endless creation of new 'bubble' kinds of universes.

And now, it seems that scientists are finally closer than ever to finding the evidence that could prove the multiverse's existence

.A hundred years on from Edwin Hubble's proof that other galaxies are out there, we might soon find proof of the multiverse's existence



Scientists Are Getting Closer To Finally Proving That The Multiverse Exists© Provided by Bored Panda

Image credits: ESA

The most developed model of a multiverse known to date is cosmological inflation. The theory was first proposed by physicist Alan Guth in the 1980s, who suggested that after the Big Bang, around 13.8 billion years ago, the universe expanded exponentially quickly for a fraction of a second. This process could be compared to a huge microscope that magnified the temporary random change in the amount of energy in a point in space, corresponding to a scale less than 10^{-28}cm, to cosmological distances by leaving marks in the cosmic microwave background and in the distribution of galaxies.

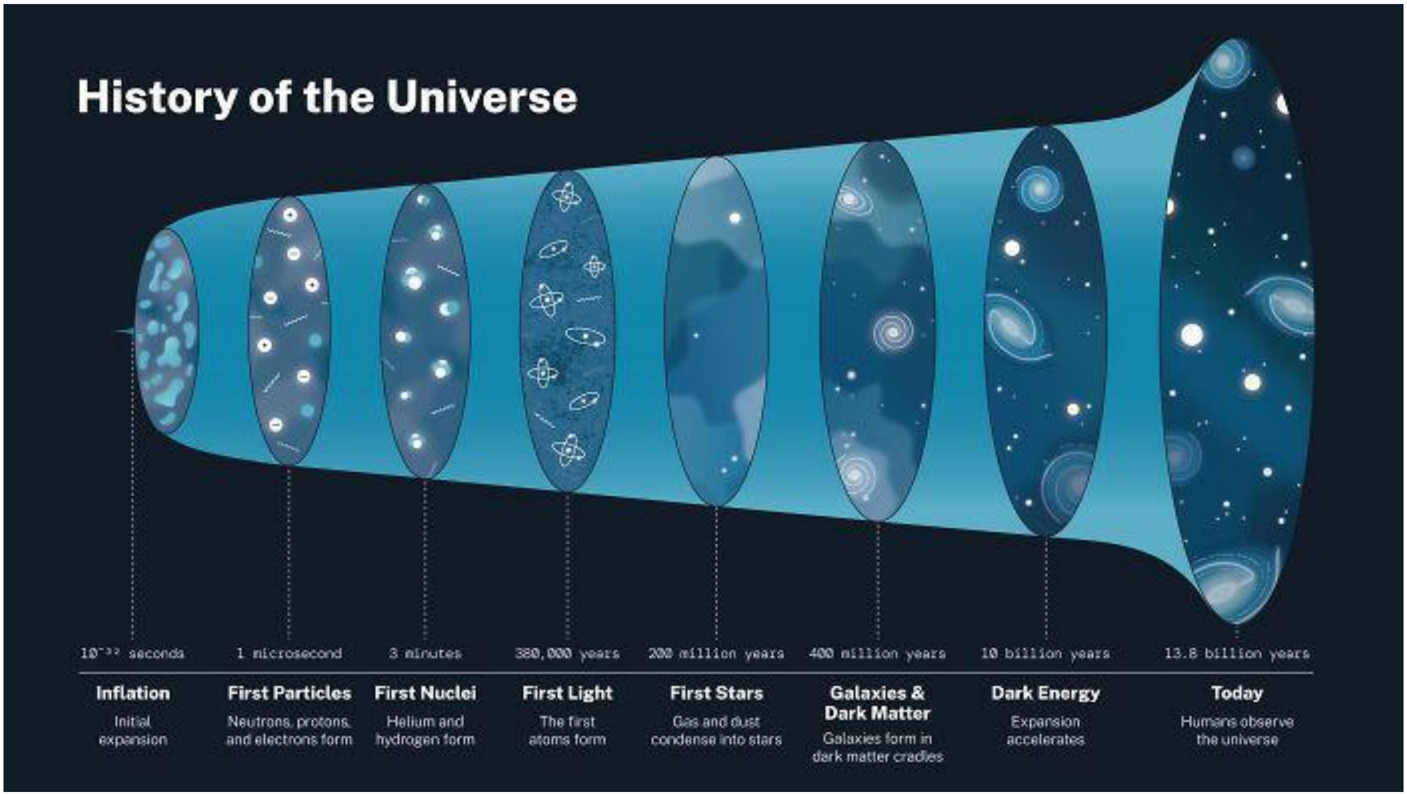
Inflation is also part of the current known model of the universe, called the Lambda Cold Dark Matter (LCDM), in which the shape of the universe's trajectory reminds a funnel which is growing and spreading further out over time.

At the heart of this cosmological inflation there's an idea of 'bubbles' – endless unique universes which were created when some parts of space-time expanded faster than others.

A Russian-American theoretical physicist, Andrei Dmitriyevich Linde, later on noticed that the exponentially rapid expansion of the universe could appear not only in the false vacuum, but also during a slow transition away from the false vacuum. Therefore, in 1983, he suggested another version of inflationary theory – chaotic inflation. The physicist in his study explained the inflation as a natural (and may be even inevitable) consequence of chaotic initial conditions in the early universe.

Yet in 2013, when the European Space Agency announced the map of the cosmic microwave background (CMB) made from the data collected by a satellite called Planck, the inflation theory faced some serious challenges.

While multiverse ideas gained scientific weight in the 1980s with the proposal of inflation, nowadays scientists are looking for alternative ideas



Scientists Are Getting Closer To Finally Proving That The Multiverse Exists© Provided by Bored Panda

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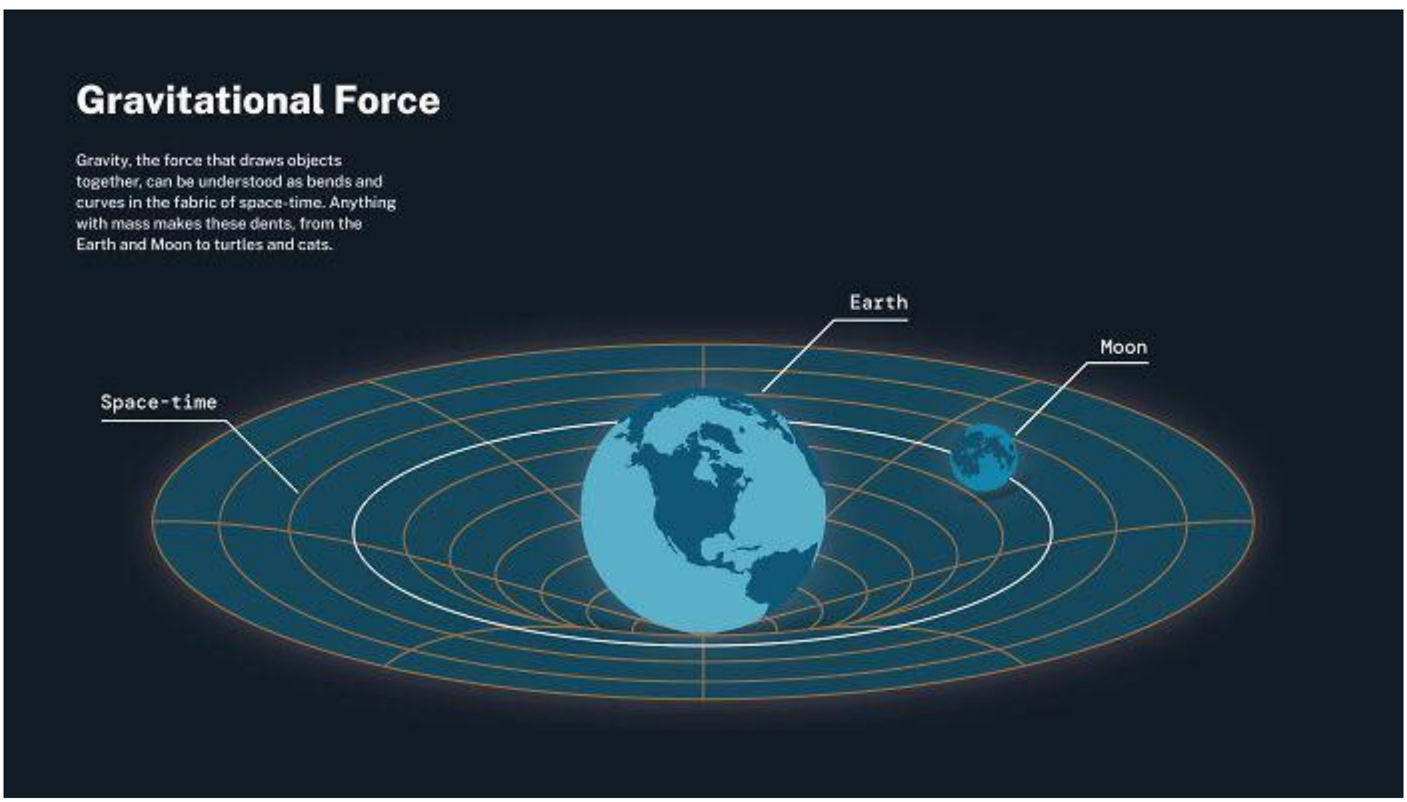


Scientists Are Getting Closer To Finally Proving That The Multiverse Exists© Provided by Bored Panda

Image credits: NASA

Therefore, in recent years, many cosmologists have been searching for the alternatives that could finally reveal the story of our universe's history. One of such could be the cyclic universe theory, which states that the universe forms itself again and again in cycles.

"What I didn't like about inflation was that there are very few genuine predictions – you don't get out much more than you put in. It just struck me that there has to be a better explanation," said Neil Turok, a physicist at the University of Edinburgh, UK.

Scientists who proposed the cyclic model are suggesting that the Big Bang was not the beginning of time. They believe that there was another phase leading up to it, which has multiple cycles of contraction and expansion that repeat indefinitely.

"It allows us to go beyond the Big Bang, but without any kind of magical philosophical issues, because time has always existed in the past," shared Stephon Alexander, a professor of physics at Brown University, and the co-inventor of an inflation model of the universe based on string theory.

As another concept that doesn't invoke cosmic inflation, in 2018, physicist Neil Turok proposed a mirror universe – one that is stretching backwards in time from the Big Bang.

While the inflation theory states that the early universe exploded into an infinite number of different universes, known as the inflationary multiverse, the mirror universe theory is way more economical and predictable.

"It's an approach that was born out of a certain sense of frustration with previous approaches. In my view, they had all become rather complicated and contrived, including my own approaches," Turok explained.

"I think we could be on the verge of the next big revolution in theory. It will be inspired by the data, by the failure of traditional paradigms. It will change our view of the universe," he added.

Turok and his team's prediction is that our universe could have a twin in which time moves backwards.

Scientists Are Getting Closer To Finally Proving That The Multiverse Exists© Provided by Bored Panda

Image credits: Physics

"We know that the early universe was dominated by hot radiation. This means that, if you rewind the clock from there, the size of the universe shrinks to zero in a very simple way. Mathematically, you can follow a straight line which cuts through the Big Bang. This allows us to extrapolate backwards to another 'mirror image' copy of our universe on the other side of the Big Bang," the physicist shared the revolutionary idea.

"The two sides of the universe grow steadily in opposite directions away from the big bang, governed by the known laws of gravity and particle physics. The extreme simplicity of the large-scale universe, which is very smooth and flat, is a direct result of the simplicity of these laws," he added.

Turok's mirror universe theory not only suggests a simpler explanation of the universe's history, but also aims to get some answers about dark matter.

"We realized our idea could solve the puzzle of dark matter, the mysterious substance that holds galaxies together, in terms of particles that we have not directly seen but already have strong evidence for," shared Turok.

"These are called right-handed neutrinos. They have been invoked since the 1970s to explain the tiny masses of left-handed neutrinos, which have been observed. Whereas every other model of dark matter postulates a completely new particle, we don't have to. That came as a huge surprise," he added.

While the mirror universe theory goes further in explaining things inflation can't, all the scientific predictions will be tested in large-scale galaxy surveys such as the Vera C. Rubin Observatory.

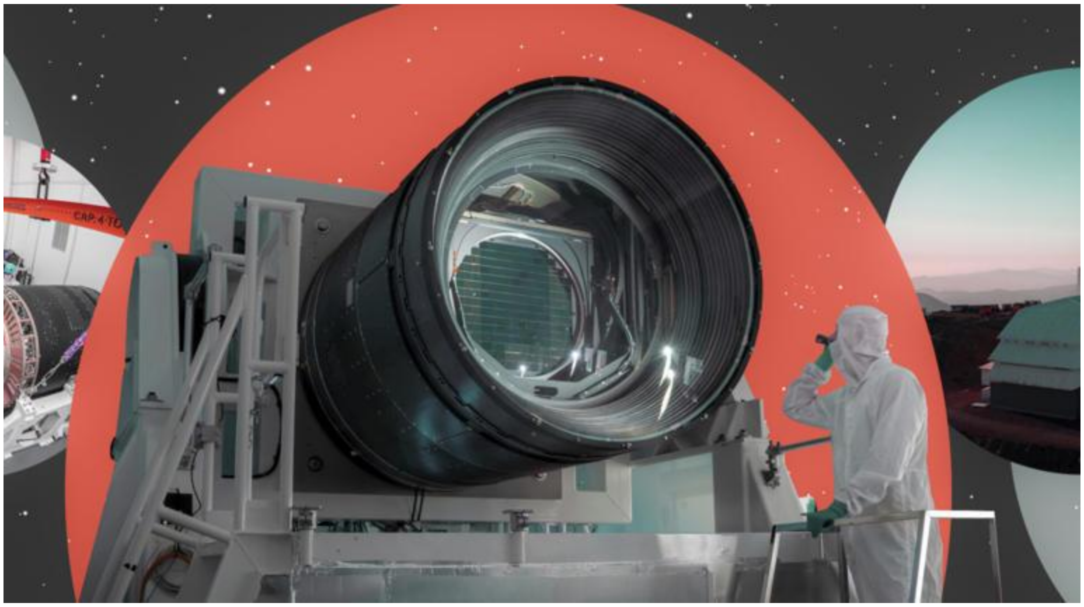
The largest LSST camera ever built for astrophysics, at 3200 megapixels, will soon help unlock the universe's mysteries by taking detailed images of the southern hemisphere sky for 10 years, creating the most comprehensive time-lapse view of our universe we've ever seen.

“Getting the camera to the summit was the last major piece in the puzzle. With all Rubin’s components physically onsite, we’re on the home stretch towards transformative science with the LSST,” excitedly shared Victor Krabbendam, who’s a Project Manager for Rubin Observatory.

Rubin Observatory, with their 3200-megapixel LSST camera, the largest ever built, is on the way to finding evidence of the multiverse’s existence

Scientists Are Getting Closer To Finally Proving That The Multiverse Exists© Provided by Bored Panda

Image credits: VERA C. RUBIN Observatory



Scientists Are Getting Closer To Finally Proving That The Multiverse Exists© Provided by Bored Panda

Image credits: VERA C. RUBIN Observatory

Scientists Are Getting Closer To Finally Proving That The Multiverse Exists© Provided by Bored Panda

Image credits: ESA Hubble

Modern physics, including quantum theory and cosmology, suggest several theories about how our universe may be just one of many. Until today, all of them have still lacked some proof or evidence, yet it seems that very soon, the situation is going to change.

Thanks to Vera C. Rubin Observatory and their largest digital camera ever constructed, we may find out we are living in an entire ocean of other universes.

New Study Proves the Existence of Dark Matter

Have you ever wondered what makes up the majority of the universe?

It's not the stars, planets, or galaxies we see. It's a mysterious substance called dark matter. This invisible matter doesn't interact with light, making it impossible to see.

But, new computer simulations from a team of astronomers, including researchers from the University of California, Irvine, provide strong evidence for dark matter's existence, based on its gravitational effects on the universe around us.

What is Dark Matter?

Dark matter is an invisible substance that doesn't interact with light. We can't see it directly, but we know it exists because of its gravitational effects on visible matter.[ref]

Scientists believe dark matter makes up a significant portion of the universe, especially in the formation and behavior of galaxies. Recent computer simulations have shown proof that dark matter exists, challenging alternative theories that propose modifications to our understanding of gravity.

New Evidence for Dark Matter

Computer simulations by a team of astronomers at UC, Irvine and other institutions support the existence of dark matter.

This new evidence, derived from advanced computer simulations, show that dark matter is needed to explain the way galaxies behave. The results of the simulations match observations of real galaxies.[ref]

Challenging Alternative Theories

The research team utilized cutting-edge simulation techniques to model the behavior of galaxies under the influence of both normal matter and dark matter. The simulations revealed similarities between the observed properties of real galaxies and the predicted behavior of galaxies within a universe dominated by dark matter.

This alignment between simulation and observation strongly suggests that dark matter is not only real but also the dominant force shaping the universe's large-scale structure.(

Unexpected Support

Interestingly, observations used in the study were initially conducted by scientists who didn't believe in dark matter.

These unexpected findings highlight the importance of collaboration and diverse perspectives in scientific research, as even those who disagree can contribute valuable insights that ultimately advance our understanding of the universe.

The Future of Dark Matter Research

Scientists are now working to better understand the properties of dark matter. They hope to use the new findings to distinguish between different types of dark matter.

By developing new techniques and experiments to probe its nature, researchers hope to gain a deeper understanding of the universe's origins, structure, and ultimate fate.

Imagine controlling a drone with your thoughts or "downloading" skills directly into your brain, like Neo learning kung fu through a brain chip in The Matrix. While this may sound like something straight out of a science fiction movie, recent advancements in AI and brain-computer interfaces (BCIs) are rapidly turning these far-fetched ideas into reality.

When looking up into the night sky, you can see millions of stars with the naked eye. When using high-powered telescopes, that number jumps up into the billions.

While most people cannot point out too many specific stars, they know they are always there. Throughout human history, people have even used the consistency of the stars to aid in navigation, planning, and much more.

Of course, today we know that stars do eventually die, often in brilliant explosions known as supernovae. Smaller stars can also simply fade out over time as they exhaust their fuel sources.

Over the past 70 years, however, scientists have documented another phenomenon with stars. They simply disappear without a trace. Astronomers look at the star at one point, then when they return (even just an hour later), and it is gone.

What makes this even more unusual is that the star never returns.

There have been over 800 cases of this documented so far, and they have largely left astronomers baffled.

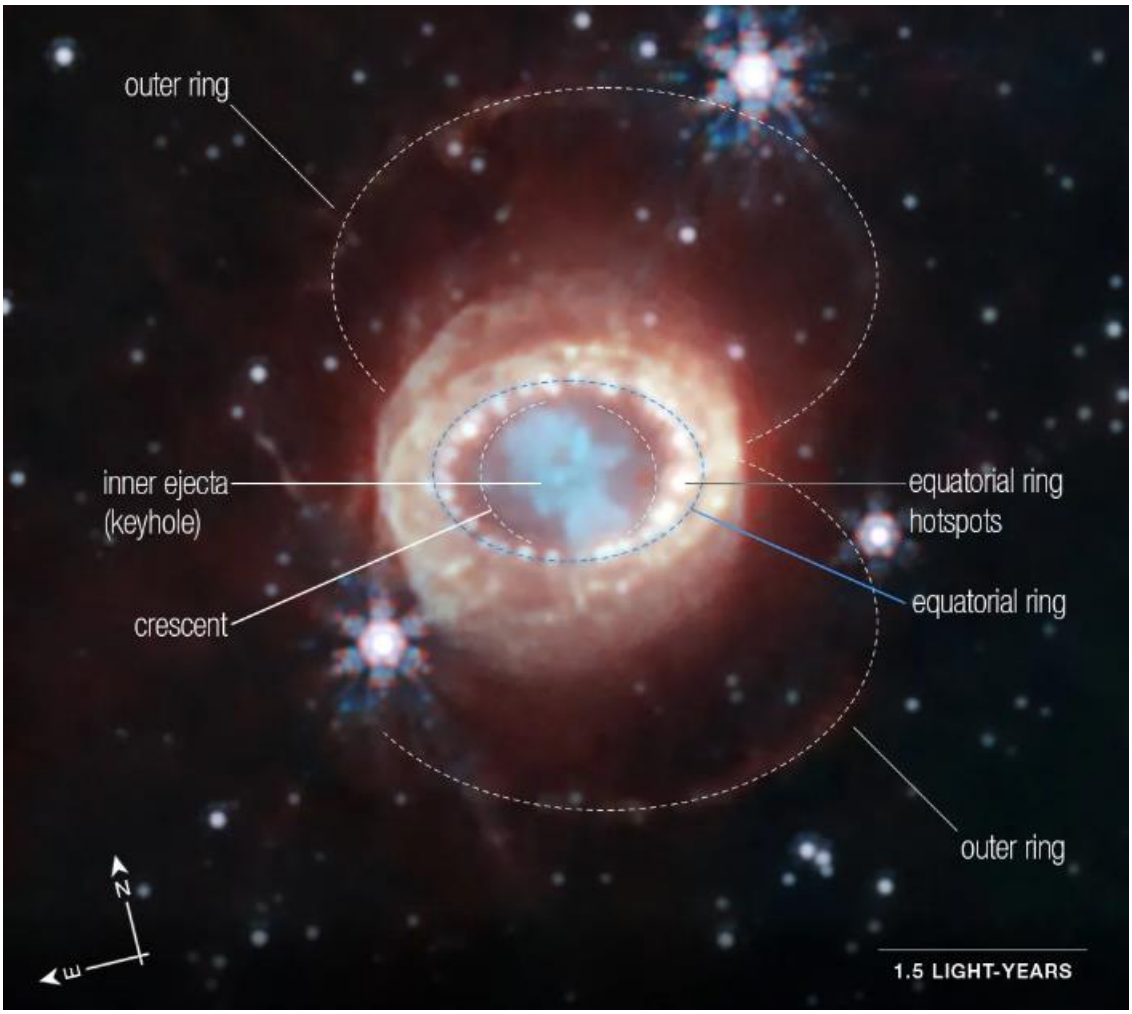
New research from astronomers at the University of Copenhagen, however, has published a paper that may offer an explanation.

The study's co-author, Alejandro Vigna-Gomez said in a statement:

"Were one to stand gazing up at a visible star going through a total collapse, it might, just at the right time, be like watching a star suddenly extinguish and disappear from the heavens. The collapse is so complete that no explosion occurs, nothing escapes and one wouldn't see any bright supernova in the night sky."

This can happen, they theorize, when massive stars collapse under their own gravity and become black holes, or extremely dense neutron star, immediately.

All detectable evidence that this occurred would be captured by the gravity and sucked back in, leaving nothing for us to see. From our perspective, it would look like the star simply disappeared.



Source: NASA/James Webb Space Telescope© Provided by Twisted Sifter

The evidence that they used is from observing a binary star system that is called VFTS 243. In it, a star that is about ten times more massive than our sun is orbiting with a black hole. Vigna-Gomes says of this situation:

“The orbit of the system has barely changed since the collapse of the star into a black hole.”

One obvious problem with this type of theory is that it is difficult to gather any type of hard evidence for it.

All the energy, partials, and even light would be sucked back down into the black hole. in this type of case, scientists can theorize what would happen and compare it to the data that is available.

So far, it seems that things fit well.

Of course, more research is needed before the theory can be widely adopted.

Who knew that stars could disappear?

We Finally Know What Turned on The Lights at The Dawn of Time

We finally know what brought light to the dark and formless void of the early Universe.

According to data from the Hubble and James Webb Space Telescopes, the origins of the free-flying photons in the early cosmic dawn were small dwarf galaxies that flared to life, clearing the fog of murky hydrogen that filled intergalactic space. A new paper about the research was published in February.

"This discovery unveils the crucial role played by ultra-faint galaxies in the early Universe's evolution," said astrophysicist Iryna Chemerynska of the Institut d'Astrophysique de Paris.

"They produce ionizing photons that transform neutral hydrogen into ionized plasma during cosmic reionization. It highlights the importance of understanding low-mass galaxies in shaping the Universe's history."

At the beginning of the Universe, within minutes of the Big Bang, space was filled with a hot, dense fog of ionized plasma. What little light there was wouldn't have penetrated this fog; photons would simply have scattered off the free electrons floating around, effectively making the Universe dark.

As the Universe cooled, after about 300,000 years, protons and electrons began to come together to form neutral hydrogen (and a little bit of helium) gas. Most wavelengths of light could penetrate this neutral medium, but there was very little in the way of light sources to produce it. But from this hydrogen and helium, the first stars were born.

Those first stars delivered radiation that was strong enough to peel electrons away from their nuclei and reionize the gas. By this point, however, the Universe had expanded so much that the gas was diffuse, and could not prevent light from shining out. By about 1 billion years after the Big Bang, the end of the period known as the cosmic dawn, the Universe was entirely reionized. Ta-da! The lights were on.

But because there's so much murk in the cosmic dawn, and because it's so dim and far away across time and space, we've had trouble seeing what's there. Scientists thought that the sources responsible for most of the clearing must have been powerful – huge black holes whose accretion produces blazing light, for example, and large galaxies in the throes of star formation (baby stars produce a lot of UV light).

JWST was designed, in part, to peer into the cosmic dawn and try to see what lurks therein. It's been very successful, revealing all sorts of surprises about this crucial time in the formation of our Universe. Surprisingly, the telescope's observations now suggest that dwarf galaxies are the key player in reionization.

An international team led by astrophysicist Hakim Atek of the Institut d'Astrophysique de Paris turned to JWST data on a galaxy cluster called Abell 2744, backed up by data from Hubble. Abell 2744 is so dense that space-time warps around it, forming a cosmic lens; any distant light traveling to us through that space-time becomes magnified. This allowed the researchers to see tiny dwarf galaxies close to the cosmic dawn.

Then, they used JWST to obtain detailed spectra of these tiny galaxies. Their analysis revealed that, not only are these dwarf galaxies the most abundant galaxy type in the early Universe, they are far brighter than expected. In fact, the team's research shows that dwarf galaxies outnumber large galaxies by 100 to 1, and their collective output is four times the ionizing radiation usually assumed for larger galaxies.

"These cosmic powerhouses collectively emit more than enough energy to get the job done," Atek said. "Despite their tiny size, these low-mass galaxies are prolific producers of energetic radiation, and their abundance during this period is so substantial that their collective influence can transform the entire state of the Universe."

It's the best evidence yet for the force behind reionization, but there's more work to be done. The researchers looked at one small patch of the sky; they need to make sure that their sample isn't just an anomalous cluster of dwarf galaxies, but is a representative sample of the entire population in the cosmic dawn.

They intend to study more cosmic lens regions of the sky to obtain a wider sample of early galactic populations. But just on this one sample, the results are incredibly exciting. Scientists have been chasing answers on reionization for as long we've known about it. We're on the brink of finally blowing away the fog.

"We have now entered uncharted territory with the JWST," said astrophysicist Themiya Nanayakkara of Swinburne University of Technology in Australia.

"This work opens up more exciting questions that we need to answer in our efforts to chart the evolutionary history of our beginnings."

Tachyons are hypothetical particles that travel at speeds greater than the speed of light. These superluminal particles, are the "enfant terrible" of modern physics. Until recently, they were generally regarded as entities that did not fit into the special theory of relativity.

However, a paper just published in *Physical Review D* by physicists from the University of Warsaw and the University of Oxford has shown that many of these prejudices were unfounded. Tachyons are not only not ruled out by the theory, but allow us to understand its causal structure better.

Motion at speeds beyond the speed of light is one of the most controversial issues in physics. Hypothetical particles that could move at superluminal speeds, called tachyons (from the Greek tachýs—fast, quick), are the "enfant terrible" of modern physics. Until recently, they were widely regarded as creations that do not fit into the special theory of relativity.

At least three reasons for the non-existence of tachyons within quantum theory were known so far. The first: the ground state of the tachyon field was supposed to be unstable, which would mean that such superluminal particles would form "avalanches." The second: a change in the inertial observer was supposed to lead to a change in the number of particles observed in his reference system, yet the existence of, say, seven particles cannot depend on who is looking at them. The third reason: the energy of the superluminal particles could take on negative values.

Mixing past and future

To put it simply: in order to calculate the probability of a quantum process involving tachyons, it is necessary to know not only its past initial state but also its future final state. Once this fact was incorporated into the theory, all the difficulties mentioned earlier completely disappeared and tachyon theory became mathematically consistent.

"It's a bit like internet advertising—one simple trick can solve your problems," says Andrzej Dragan, chief inspirer of the whole research endeavor.

"The idea that the future can influence the present instead of the present determining the future is not new in physics. However, until now, this type of view has at best been an unorthodox interpretation of certain quantum phenomena, and this time we were forced to this conclusion by the theory itself. To 'make room' for tachyons we had to expand the state space," concludes Dragan.

The authors also predict that the expansion of the boundary conditions has its consequences: a new kind of quantum entanglement appears in the theory, mixing past and future, which is not present in conventional particle theory. The paper also raises the question of whether tachyons described in this way are purely a 'mathematical possibility' or whether such particles are likely to be observed one day.

According to the authors, tachyons are not only a possibility but are, in fact, an indispensable component of the spontaneous breaking process responsible for the formation of matter. This hypothesis would mean that Higgs field excitations, before the symmetry was spontaneously broken, could travel at superluminal speeds in the vacuum.

More information: Jerzy Paczos et al, Covariant quantum field theory of tachyons, *Physical Review D* (2024). DOI: 10.1103/PhysRevD.110.015006. On *arXiv*: DOI: 10.48550/arxiv.2308.00450

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

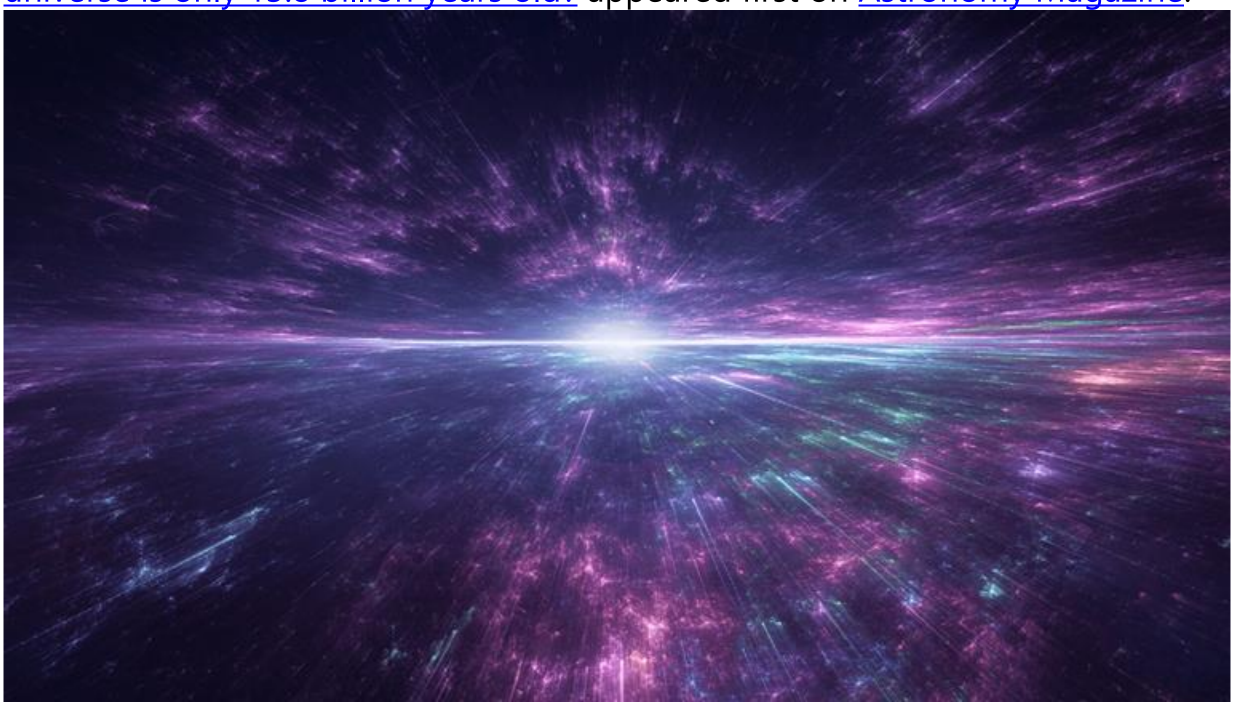
Astronomers widely accept that the universe formed in the Big Bang approximately 13.8 billion years ago. It has been expanding ever since. This expansion explains how a 13.8-billion-year-old universe can be so much larger than 13.8 billion light-years across.

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

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

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

The post How can the visible universe be 46 billion light-years in radius when the universe is only 13.8 billion years old? appeared first on Astronomy Magazine.



How did the universe become so flat? - Image credit: Pixelparticle/Shutterstock.com© IFL Science

The 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.

The colossal asteroid known as "God of Chaos" might be on a collision course with Earth, contradicting earlier data that suggested otherwise.

99942 Apophis, its official name, was discovered in 2004 and was believed in 2017 to have a 2.7% chance of striking Earth in 2029. Further observations ruled out any possibility of an impact in 2029 or 2036.

It was then predicted to make a close approach to Earth on Friday, April 13, 2029, coming no closer than 18,300 miles from our planet.

However, a recent study by Canadian astronomer Paul Wiegert suggests that a "small object" colliding with the asteroid could dramatically alter this trajectory.

He explained scientifically: "The odds of an unseen small asteroid deflecting Apophis enough to direct it into a collision with Earth in 2029 (d 3.4 m, v > 5 102 m s1) are approximately 108."

"Given that only 5% of such impulses are in the correct direction to generate an Earth impact, the overall probability of a small impact directing Apophis into a collision with the Earth is less than one in two billion."

To clarify, according to Google Gemini, the concept specifies that the distance "d" must be at least 3.4 metres or more, and the change in velocity "v" must be greater than 5 102 meters per second for it to alter the asteroid's path.

And the expert added an eerie caution, remarking: "An additional element of the story is that Apophis has been largely unmonitored by telescopes since May 2021 and will remain so through 2027."

"This arises simply because of the relative geometry of Apophis, Earth, and the Sun, which puts the asteroid in the daytime sky for the time span in question."

Some of the most common and unlikely sci-fi tropes could one day be science fact.©Shutterstock

Sci-fi novels and movies are packed with far-out ideas, most often as the springboard for an action-packed adventure rather than a serious attempt to predict future trends in science or technology. Some of the most common tropes, such as accelerating a spacecraft to fantastic speeds in a matter of seconds without crushing the occupants, are just plain impossible according to the laws of physics as we understand them. Yet those same laws appear to permit other far-fetched sci-fi concepts, from wormholes to parallel universes. Here's a rundown of some of the sci-fi ideas that could actually be done — in theory, at least.

The idea of a wormhole —a shortcut through space that allows almost instantaneous travel between distant parts of the universe — sounds like it was created as a fictional story-driver. But under its more formal name of an Einstein-Rosen bridge, the concept has existed as a serious theoretical concept long before sci-fi writers got hold of it. It comes out of Albert Einstein's theory of general relativity, which views gravity as a distortion of space-time caused by massive objects. In collaboration with physicist Nathan Rosen, Einstein theorized in 1935 that points of extremely strong gravity, such as black holes, could be directly connected with each other. And so the idea of wormholes was born.

The forces around a black hole would destroy anyone that came close to it, so the idea of actually traveling through a wormhole wasn't given serious consideration until the 1980s, when astrophysicist Carl Sagan decided he was going to write a sci-fi novel. According to the BBC, Sagan encouraged fellow physicist Kip Thorne to come up with a feasible way to travel interstellar distances in a flash. Thorne duly devised a way — possible in theory, but highly improbable in practice — that humans might achieve interstellar travel by traversing a wormhole unscathed. The result found its way into Sagan's novel "Contact" (Simon and Schuster: 1985) which was subsequently adapted into a film with Jodie Foster in the lead role.

While it's highly unlikely that wormholes will ever become the simple and convenient methods of transportation portrayed in movies, scientists have now come up with a more viable way to construct a wormhole than Thorne's original suggestion. It's also possible that, if wormholes already exist in the universe, they could be located using the new generation of gravitational-wave detectors.

An essential prerequisite for most space-based adventure stories is the ability to get from A to B much faster than we can today. Wormholes aside, there are multiple stumbling blocks to achieving this with a conventional spaceship. There's the enormous amount of fuel required, the crushing effects of acceleration, and the fact that the universe has a strictly imposed speed limit. This is the speed at which light travels — precisely one light-year per year, which in a cosmic context isn't very fast at all. Proxima Centauri, the second-closest star to Earth, is 4.2 light-years from the sun, while the center of the galaxy is a whopping 27,000 light-years away.

Fortunately, there's a loophole in the cosmic speed limit: It only dictates the maximum speed we can travel *through space*. As Einstein explained, space itself can be distorted, so perhaps it's possible to manipulate the space around a ship in such a way as to subvert the speed limit. The spaceship would still travel through the surrounding space at less than the speed of light, but the space itself would be moving faster than that.

This was what the writers of "Star Trek" had in mind when they came up with the concept of a "warp drive" in the 1960s. But to them it was just a plausible-sounding phrase, not real physics. It wasn't until 1994 that theoretician Miguel Alcubierre found a solution to Einstein's equations that produced a real warp drive effect, Live Science's sister site Space.com reported, contracting space in front of a spaceship and expanding it to the rear. To start with, Alcubierre's solution was no less contrived than Thorne's traversable wormhole, but scientists are attempting to refine it in the hope that it might one day be practical.

Even the wildest sci-fi spaceships need some sort of power source, and sci-fi writers seem to have three standard go-tos: some sort of made-up substance, like dilithium crystals; antimatter; or good old-fashioned nuclear fusion. That last one is perhaps the most plausible as a long-term, sustainable source of energy for everything from spaceships to off-world settlements.

Heck, humans already harness nuclear power in portable ships on Earth, under the ocean. But those are fission-based power planets, which derive power from splitting atoms apart. Fusion — in which two small atoms are smooshed together to form a new, larger one — is a whole different animal. Fusion requires much more sophisticated technologies to control and harness the energy produced (we already figured out how to trigger uncontrolled fusion reactions, which is what hydrogen bombs are).

In 2022, scientists with the Department of Energy's National Ignition Facility made a huge advance: For the first time ever, they generated more energy out of a fusion reaction than went into it. That remarkable achievement is only the first step, however. That net-positive energy gain didn't include the power lost to inefficiencies in the lasers themselves or a method to capture that energy and put it to useful work.

Still, scientists and engineers around the globe are hard at work to crack the fusion puzzle, and it may yet become a staple of our future.

Sci-fi writers often introduce artificial gravity as a plot point to save budgets and film their actors on a normal soundstage; otherwise, they would have to use wires or complex visual effects to simulate weightlessness.

But creating gravity at will is easier than you might think. The first trick is to replace acceleration with rotation. If you've ever been in one of those carnival rides that spins really quickly, you've known how strong the centrifugal force can be. So if future Earthlings set up a rotating space habitat and arrange everything so that the outermost edge is "down," then people will feel right at home. Well, almost, because they'd have to deal with the dizziness from the rotation and the counterintuitive motions caused by the Coriolis effect.

The other trick to replicate gravity is to keep moving. Einstein realized that acceleration is the same, regardless of whether that acceleration comes from a massive gravitational object or the push of a rocket, and you can use that to your advantage. If you fire your rocket engines and maintain a constant acceleration of 9.8 meters per second squared, unless you look out the window, you'll have no idea you're in a spaceship. Of course, it will take a lot of fuel to maintain that kind of acceleration, but that's a different problem.

More observations from the James Webb Space Telescope (JWST) continue to challenge the distinct pictures scientists have of planet and star formation. Last year, binary objects not much bigger than Jupiter began to properly challenge the separation between the formation pathways. New research has added more fuel to the fire, having found the lightest free-floating object yet that formed like a star – and it’s only five times the mass of Jupiter.

Planets form bottom-up. They grow from small pebbles in a disk of material around stars. Stars, on the other hand, form top-down. A clump of mostly hydrogen collapses from a larger gas cloud ending in a star or a stellar-like object such as a brown dwarf. However, brown dwarfs did start making astronomers question this separation between the two processes; they are objects just a few tens of times the mass of Jupiter, but definitely from the star-formation side of things.

To investigate how to form a planet, researchers looked at a young star cluster and used JWST to find the faintest objects that formed in a star-like manner. The smallest was just 1,600 times the mass of the Earth (the Sun is 330,000 times more massive than our planet). That's roughly five times that of Jupiter and it still has a disk of debris showing it did indeed form like a star.

"How light an object can form like a star?" Johns Hopkins Provost Ray Jayawardhana, an astrophysicist and senior author of the study, said in a statement. "It turns out the smallest free-floating objects that form like stars overlap in mass with giant exoplanets circling nearby stars."

"Our observations confirm that nature produces planetary mass objects in at least two different ways—from the contraction of a cloud of gas and dust, the way stars form, and in disks of gas and dust around young stars, as Jupiter in our own solar system did," Jayawardhana continued.

The presence of the disk is interesting; it could be possible for these planetary-mass objects to make their own planets from the material forming around them.

"Those tiny objects with masses comparable to giant planets may themselves be able to form their own planets," said co-author Aleks Scholz, an astrophysicist at the University of St Andrews. "This might be a nursery of a miniature planetary system, on a scale much smaller than our solar system."

Peculiar binary systems such as the JuMBOs – Jupiter Mass Binary Objects – were discovered last year: they make the case for the two different pathways to make a Jupiter-sized world. This work found a brown dwarf with a planetary-mass companion, again challenging ideas about their formation.

"It's likely that such a pair formed the way binary star systems do, from a cloud fragmenting as it contracted," said Jayawardhana. "The diversity of systems that nature has produced is remarkable and pushes us to refine our models of star and planet formation."

The team plans to study these objects in more detail, comparing their atmospheres to brown dwarfs and gas giant planets and also looking at the possibility of planets forming in the disk of that one light object.

A paper describing the results is accepted for publication in The Astronomical Journal and available on ArXiv.

New measurements taken with the James Webb Space Telescope (JWST) have deepened the scientific controversy of the Hubble tension — suggesting it may not exist at all.

For years, astronomers have found that the universe appears to be expanding at different speeds depending on where they look — a conundrum they call the Hubble tension. Some of the measurements confirm our best current understanding of the universe, while others threaten to break it.

When JWST came online in 2022, one team of researchers used the space telescope's unprecedented accuracy to confirm the Hubble tension. But according to the new results from a different team of scientists, the Hubble tension may arise from measurement error and not exist after all. Yet even these results are not definitive.

"Our results are consistent with the standard model. But they don't rule out that there's a tension there too," study lead author Wendy Freedman, an astrophysicist at the University of Chicago, told Live Science. "[The experience] is probably the closest thing to a rollercoaster — it's been exciting, but there are these moments when you've got to climb the hill again."

Hubble trouble

Currently, there are two gold-standard methods for figuring out the Hubble constant, a value that describes the expansion rate of the universe. The first involves poring over tiny fluctuations in the cosmic microwave background — an ancient relic of the universe's first light produced just 380,000 years after the Big Bang.

After mapping out this microwave hiss using the European Space Agency's Planck satellite, cosmologists inferred a Hubble constant of roughly 46,200 mph per million light-years, or roughly 67 kilometers per second per megaparsec (km/s/Mpc). This, alongside other measurements of the early universe, aligned with theoretical predictions.

The second method operates at closer distances and in the universe's later life using pulsating stars called Cepheid variables. Cepheid stars are slowly dying, and their outer layers of helium gas grow and shrink as they absorb and release the star's radiation, making them periodically flicker like distant signal lamps.

As Cepheids get brighter, they pulsate more slowly, enabling astronomers to measure the stars' intrinsic brightness. By comparing this brightness to their observed brightness, astronomers can chain Cepheids into a "cosmic distance ladder" to peer ever deeper into the universe's past.

Recently, when Adam Riess, a professor of astronomy at Johns Hopkins University, and his team measured the Hubble constant using the Hubble Space Telescope and JWST, they found a puzzlingly high value of 73.2 km/s/Mpc. Hence the tension, a significant discrepancy between methods measuring the expansion rate in the early universe and those in the more modern one, was born.

But Freedman previously suggested that dust, gas and other stars could be throwing off the brightness measurements of the Cepheids — creating the appearance of a tension where there wasn't one at all.

In the new study, to tease out a possible systematic error in Cepheid crowding, Freedman and her colleagues trained JWST on 11 nearby galaxies containing Type Ia supernovae, measuring their distances and anchoring them to three independent distance ladders with intrinsic brightnesses in similar regions of the sky: the Cepheids; and two other standard candle red giant stars known as "tip-of-the-red-giant-branch" (TRGB) stars and J-region asymptotic giant branch (JAGB) stars.

Their results were puzzling. The TRGB and JAGB stars gave Hubble constant results of 69.85 km/s/Mpc and 67.96 km/s/Mpc, respectively. But the Cepheids returned 72.04 km/s/Mpc, replicating the Hubble tension — albeit less dramatically than the results made by Riess. To Freedman and her colleagues, this is a possible hint that the Cepheid measurements could contain some unknown systematic error.

The end of Hubble tension?

Yet not all scientists agree with the study's conclusions. When asked about the new findings, Riess suggested the mismatched results could be because Freedman and her team's sample was too small.

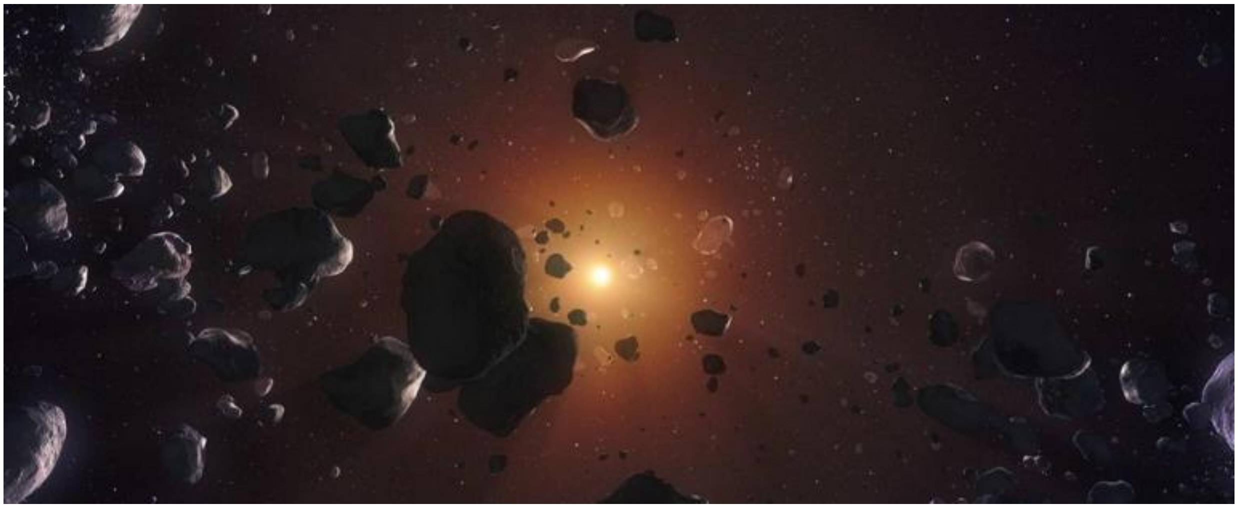
"They get a lower Hubble constant because the sample they selected gives a lower Hubble constant, regardless of whether you measure with JWST or HST [Hubble Space Telescope], or Cepheids, JAGB or TRGB, because the supernovae in the hosts they selected fluctuate that way," Riess told Live Science. "They chose a very small sample ... and they chose these from the tail, not the middle of the distribution."

But Freedman countered this point. Although the sample might be too small to account for the full range of star distances, she said, the results also may mean the measurements of the more distant Cepheid stars contain a "fatal" systematic error — a crowding that is throwing off the calculations of the Cepheid distances.

To make a measurement of Cepheid stars, "you're making a crowding correction, and they're not small corrections," Freedman said. "And if you get that wrong, you get the [star] colors wrong, you get the dust correction wrong, you get the metallicity correction wrong. These effects are covariant, and they could have a much bigger effect [on the final distance measured] than just saying that crowding is not a problem."

Freedman believes the answer is to make even more measurements — potentially some with an additional type of star. She expects this work to be completed in the next two years. Yet whether additional measurements are sufficient will resolve the problem, or add to it, remains controversial.

"We're in the midst of this, and there's more to come," Freedman said. "[JWST] is a marvelous machine, and it's exactly what we need to get at some of these kinds of issues. It's a good time to be working on this."


Hints of a Hidden Structure Detected at The Edge of The Solar System

If you travel far enough away from the Sun, the Solar System becomes a lot more populated.

Out past the orbit of Neptune lies the Kuiper Belt, a vast, ring-shaped field of icy rocks. This is where Pluto resides, and Arrokoth, and countless other small objects in the cold and the dark.

These are known as Kuiper Belt objects or KBOs, and astronomers have just found hints of an unexpected rise in their density, between 70 and 90 astronomical units from the Sun, separated by a large, practically empty gap between it and an inner population of KBOs closer to the Sun.

It seems, almost, like there are two Kuiper Belts, or at least two components – something nobody was expecting to find.

"If this is confirmed, it would be a major discovery," says planetary scientist Fumi Yoshida of the University of Occupational and Environmental Health Sciences and Chiba Institute of Technology in Japan.

"The primordial solar nebula was much larger than previously thought, and this may have implications for studying the planet formation process in our Solar System."

The objects in the Kuiper Belt are thought to represent the most pristine material our Solar System contains.

The belt itself extends from the orbit of Neptune, around 30 astronomical units from the Sun (an astronomical unit is the average distance between Earth and the Sun), out to about 50 astronomical units from the Sun.

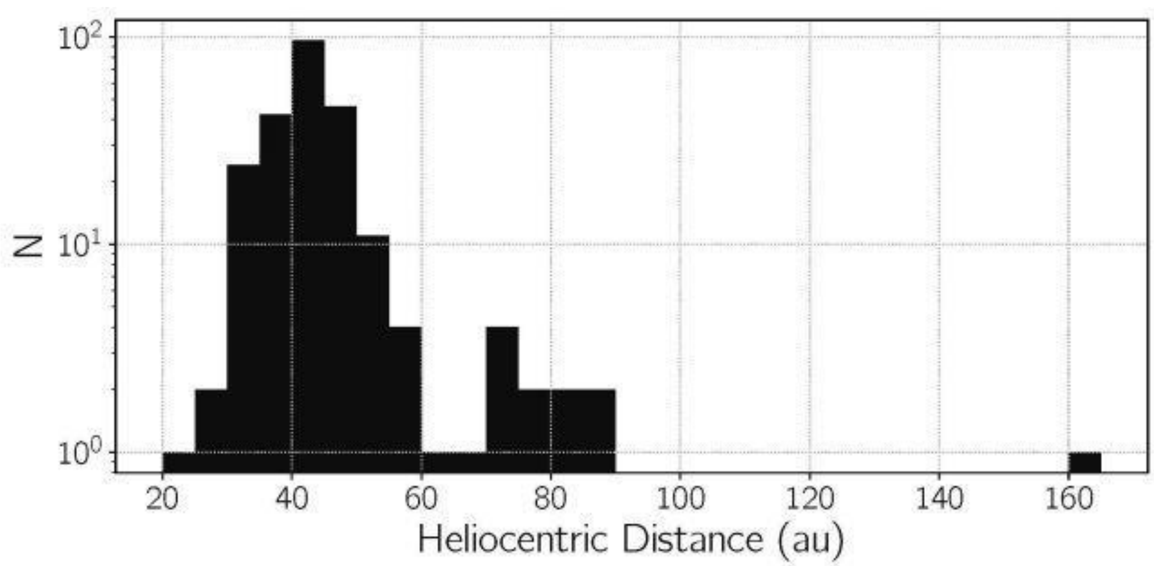
This distance from the Sun means that anything within the Kuiper Belt is only minimally affected by solar radiation, which, in turn, means that KBOs likely remain pretty much unchanged since the Solar System was born, some 4.6 billion years ago.

These objects are ancient remnants of the cloud of material, known as the solar nebula, from which the Sun and planets formed.

The New Horizons spacecraft has been heading out deeper into the Solar System since its flyby of Pluto in 2015; at time of writing, the spacecraft is nearly 60 astronomical units from the Sun and counting.

To support its ongoing exploration of the outer Solar System, astronomers here on Earth have been conducting observations of the Kuiper Belt using the National Astronomical Observatory of Japan's Subaru Telescope in Hawai'i.

To date, the Subaru observations have revealed 263 new KBOs, but a large, international team of astronomers led by Wesley Fraser of the National Research Council of Canada has found that 11 of those objects are much, much farther than we thought the Kuiper Belt ended – out in the region past 70 astronomical units.



Graph showing the distance distribution for Kuiper Belt Objects discovered using the Subaru Telescope's Hyper Suprime Cam. (Wesley Fraser)

From the number of these objects spotted, the researchers were able to extrapolate the density of the outer Kuiper Belt ring. It would be lower than the inner population, but high enough to constitute a new structure.

In the region between 55 and 70 astronomical units, however, next to nothing has been found. This might sound strange, but a gap of this kind is a feature we've seen in other forming planetary systems, and it brings the Solar System more in line with what we've found elsewhere in the galaxy.

"Our Solar System's Kuiper Belt long appeared to be very small in comparison with many other planetary systems, but our results suggest that idea might just have arisen due to an observational bias," Fraser explains.

"So maybe, if this result is confirmed, our Kuiper Belt isn't all that small and unusual after all compared to those around other stars."

A lot of our observations of the Milky Way galaxy suggest that our Solar System is unusual in many ways. Since the Solar System is the only known planetary system to host life, these oddities could be contributing factors to the Solar System's habitability.

But our technology for observing space has limitations that could result in significant observation biases, suggesting peculiarities that don't actually exist. If the new observations of the Kuiper Belt are confirmed, we have just ruled out one of those peculiarities – an unusually small solar nebula.

In order to shed more light on the discovery, observations continue in order to track the orbits of the 11 distant objects.

"This is a groundbreaking discovery revealing something unexpected, new, and exciting in the distant reaches of the Solar System," says New Horizons Principal Investigator Alan Stern of the Southwest Research Institute.

"This discovery probably would not have been possible without the world class capabilities of Subaru observatory."

The research has been accepted into *The Planetary Science Journal* and is available on arXiv.

Following the Space Force's release this spring of its high-level strategy for better harnessing commercial technology, a panel of defense experts is offering a more detailed roadmap for how the Defense Department can better embed off-the-shelf systems and widgets throughout its processes and acquisition plans.

A new report from the Pentagon's Defense Science Board calls on the Space Force to integrate commercial space technology wherever possible - from planning and wargaming exercises to budgets and procurement strategies.

"Commercial firms are driven by the exigencies of the market to deliver new products quickly and cost-effectively, incentivizing innovation and high productivity," the panel said. "The department has much to gain by leveraging those world-leading efficiencies."

The commercial space sector has seen significant growth over the last decade. A 2023 report from consulting firm McKinsey & Company valued the market at $447 billion and projected it would surpass $1 trillion in the 2030s. These companies launch rockets, build satellites and provide key services like Earth observation and ground control.

The Pentagon, and the Space Force in particular, have been making strides to take advantage of that investment. The service has adopted a "buy before you build" approach to space acquisition, meaning that it surveys capabilities already available in industry before pursuing a military-unique system.

Both the Space Force and the Office of the Secretary of Defense released commercial integration strategies in April. The Pentagon's plan called for greater protection for private sector spacecraft targeted by adversaries, while the Space Force identified missions like satellite communications and space domain awareness that are primed for commercial partnerships.

The Defense Science Board review, commissioned in 2022, focuses on the processes that support commercial integration as well as the challenges - including the risks of relying more heavily on non-DOD space systems.

The panel found that while the department appears to recognize the utility of commercial capabilities, its own bureaucracy and culture often gets in the way of adopting them.

"Policy interpretation, security, acquisition practices, funding models, operational employment and military exercises limit the potential reach and application of commercial space," the report states.

To remedy this, the board recommends the department develop what it calls an end-to-end framework to ensure that private sector systems and services are considered an option whenever the Space Force pursues new capabilities.

Practically, that means integrating commercial offerings when defining requirements, empowering program managers to fund technology maturation for dual-use systems and incorporating commercial space capabilities in every tabletop exercise.

The report also proposes putting specific resources toward integrating commercial and DOD operations and sustainment, recommending the Space Force establish a working capital fund to support both. Further, it suggests the service launch a pilot effort to test this concept for wideband military satellite communications, similar to the approach it takes for commercial SATCOM today.

The board also sought to address perceptions within the department about the risk DOD may take on by adopting a more commercial-first posture. The report highlights valid concerns that private sector capabilities are less hardened against cyberattacks or other threats and could make the military more vulnerable.

The study recommends several mitigations. First, the department could make resiliency a requirement in commercial contracts and provide companies with resources to harden their satellites and ground systems.

DOD should also improve the way it shares threat information with industry and find ways to get security clearances for commercial firms, the report says. It points to the Defense Advanced Research Projects Agency's Bridges program, which helps companies in specific technical sectors get cleared for secure briefings.

In another recommendation, the board suggests the Space Force conduct vulnerability assessments of existing commercial providers and use what it learns from that work to inform future requirements and contracts.

"Commercial space systems and architectures are, by their nature, intended for global access and use. While this openness is a necessary component of a world marketplace, it presents distinct risks and challenges, real and perceived," the report states. "Nonetheless, opportunities exist to increase resilience of commercial systems through protection technologies consistent with commercial markets and missions."

It is a well-known fact that Sun is the centre of our solar system and all the planets orbit this yellow star. But that is not the case exactly, the planets and even the Sun are in fact orbiting the centre of mass of the solar system.

As reported by Business Insider, Dr James O'Donoghue, a planetary scientist at the Japanese Aerospace Exploration Agency (JAXA) explains that, "everything orbits the Solar System centre of mass, even the Sun!"

Dr O'Donoghue shared some fascinating animations based on data from NASA JPL Horizons system in a Twitter thread to depict just how the planets and event the Sun orbit the barycentre of our solar system.

In the above animation, the Sun, Jupiter and Saturn are shown orbiting the barycentre of our solar system. The barycentre is the centre of mass of two or more orbiting bodies and is the point in space about which these bodies orbit.

While the Sun is the centre of our solar system, it only makes up about 99.8 per cent of the mass of the entire solar system. So, the Sun's centre is not exactly located on the barycentre of the solar system.

Most of the remaining solar system's mass, consisting of Jupiter followed by Saturn, is able to influence the Sun with its gravitational force.

Dr O'Donoghue explains in another tweet, "The planets do orbit the Sun, of course, we are just being pedantic about the situation. The natural thinking is that we orbit the Sun's centre, but that very rarely happens, i.e. it's very rare for the solar system's centre of mass to align with the Sun's centre."

Like blazing campfires on cold winter nights, galaxies are surrounded by a smoke of gas and dust that blows into the shadows. This thin pall of material is known as the circumgalactic medium, a halo so vast it contains some 70 percent of the galaxy's visible mass.

In spite of its dominating presence across the Universe, little is known about the medium's typical structure, making it difficult to discern where the edge of one cosmic campfire stops and the next begins.

A new investigation of a single galaxy roughly 270 million light years away has revealed interactions between the circumgalactic medium (CGM) and the galaxy's radiant disc that help define a boundary, one that suggests our own galaxy could stretch farther than we imagined.

If so, the implications could very well mean that the Milky Way's long predicted future collision with the Andromeda galaxy may have already commenced – at least in terms of the two circumgalactic mediums beginning to intersect.

Astronomers from Australia and the US used the highly sensitive Keck Cosmic Web Imager to capture a handful of images centered on the relatively tiny spiral galaxy IRAS 08339+6517 (IRAS08 for short).

Most previous studies on the CGM have taken advantage of the illumination delivered by feeding black holes in even more distant background galaxies. Though the bright light can reveal plenty of detail within the medium, its tight beam limits findings to a tiny portion of the halo.

By capturing a far broader sweep of space some 90,000 light years beyond the edges of the galaxy's glowing disc, the team could analyze tell-tale changes in the medium's makeup.

Some of the field's images featured the thread of neutral hydrogen gas connecting IRAS08 with an even smaller neighbor via the cosmic web, so it's little surprise that the team measured plenty of hydrogen drifting about in the vacuum.

What was unexpected was finding hydrogen stripped of its electrons far beyond the cosmic threads of gas mixed with another, far heavier element – oxygen.

"We found it everywhere we looked, which was really exciting and kind of surprising," says lead author Nikole Nielsen, an astrophysicist from Swinburne University in Australia.

Floating about in the intergalactic nothingness, atoms really only have two sources of heating. One is the pale starlight of far-distant galaxies. The other is an occasional run-in with another atom. Both can be calculated to estimate a pattern of ionization expected of a mix of hydrogen and oxygen.

Using the spectral data in the scattering of images, the researchers mapped changes in the density of ionization on a scale of a few thousand light years, identifying a gently fading zone of influence by IRAS08's own starlight.

"In the CGM, the gas is being heated by something other than typical conditions inside galaxies, this likely includes heating from the diffuse emissions from the collective galaxies in the Universe and possibly some contribution is due to shocks," says Nielsen.

"It's this interesting change that is important and provides some answers to the question of where a galaxy ends."

The discovery not only better defines what a galaxy is, but also how the sprawl of smoke and campfires across the Universe combine and evolve over the eons.

Sitting deep within the Milky Way, it's hard to get a good measure on the limits of where our own galactic boundaries peter out. Generalizing the findings, we could imagine the surrounding expanse of gas warmed by our stars may already be mingling with the halo belonging to our nearest neighbor.

"It's highly likely that the CGMs of our own Milky Way and Andromeda are already overlapping and interacting," says Nielsen.

This research was published in *Nature Astronomy*.

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.

Churning nano-wormholes could explain the clash in our cosmological constants.

The wormholes add magnitude to a math parameter called the Gauss-Bonnet term.

Boosting one term in a complex equation helps scientists explain how the results could change.

Scientists in Greece have laid out a mathematical framework to help explain a so-far-unsolved gap in our understanding of how gravity scales up to the full size of our universe.

Specifically, cosmologists can't yet account for how expansion of the universe increased in the "recent cosmological past"—a *very* relative term—because all attempts to quantify the change so far end up clashing with existing mathematical models. The Greek scientists suggest something particularly squiggly: microscopic wormholes, whose nature and density could fill up the missing pieces. These spacetime Orbeez require only a bit of fine-tuning from theories that are already in the zeitgeist.

In the new paper, which appears in the peer-reviewed journal *Physical Review D* from the American Physical Society, the authors explain that the "positive cosmological constant" meant to quantify our expanding universe has, instead, created math issues: "[Q]uantum field theoretical analysis predicts a value up to 120 orders of magnitude larger than the observed one."

An order of magnitude is not simply a 1:1 multiplier, so 120 orders of magnitude is likely far more than 120 times larger. But if your lifetime likelihood of being struck by lightning is about 1 in 15,300, 120 times larger jumps to 1 in 127.

If we want to balance the two possibilities, the scientists explain, we need to add at least one new complicating factor. The two main suggestions for this are, first, a changing cosmological constant explained by the idea of dark energy; or second, to deepen our theory of how gravity behaves on the cosmic scale, from a smooth background to a craggier, fjord-like complexity.

This paper suggests combining both options: What if the solution is a believably craggier background gravity covered with instantons and wormholes, and their more rugged landscape naturally accounts for an amount of dark energy as well?

Let's define some terms. When cosmologists try to model the universe, they break it down using practices like topology and manifold theory. They build in as many variables or ideas as they have at the time, leaving spaces where something is not yet known. And, just like in your high school calculus class, the goal is always to account for everything on both sides of any equal sign or other equivalence in your mathematical model.

The physics of different scales simply don't match easily yet. Concrete observations by Albert Einstein and those before turned into beautiful theories that account for the visible world and parts of outer space; quantum mechanics twists those pieces until they no longer fit together into a completed puzzle. Considering spacetime as a manifold, or a surface that is guided by interlocking math on a grand scale, lets physicists look for the correct new place for a particular piece of the puzzle.

One way spacetime acts up is called quantum foam. On an extraordinarily tiny level, scientists believe, even quantum phenomena break down and create tiny bubbles where principles no longer apply. If someone can be a writer's writer or a comedian's comedian, this is kind of the disruptive quantum mechanics *of* quantum mechanics. And it's in this foam where wormholes could exist in a way that brings cosmic ideas together without breaking any larger rules.

The term "wormhole" may even be misleading, because they can be tunnels, but may also simply be punched holes that cross through higher dimensions behind the scenes. Manifold theory allows scientists to add these dimensions and at least attempt to rationalize them, something difficult to do using a three-dimensional human mind.

Once we allow that there could be wormholes in the foam, the scientists explain in the paper, a number of other relevant math operations and transformations build on that foundation. The solution, "an effective cosmological constant," appears when you apply the Gauss-Bonnet theorem: "[T]he variation of the Gauss-Bonnet term on a manifold that has topology changes due to the formation of wormholes is not zero."

In astrophysics, that's a mic drop.

As for where dark energy comes into this, it's still a part of our working model of the universe, wormholes or not. In this case, the wormholes would directly account for at least some of that dark energy: "[T]he wormhole density in a dynamical spacetime is not expected to be constant, therefore the obtained effective cosmological constant also acquires a dynamical nature, i.e., it corresponds to an effective dark energy sector."

In other words, the churn of the micro wormholes creates a changing constant. And to account for the observed cosmological constant, all we need is "1016 microscopic wormholes," or 10 quadrillion, "per cubic meter per second." That, the scientists conclude, is well within the realm of possibility based on estimates.

Webb Telescope Makes Fascinating Discovery

The galaxies spotted by the JWST contain a mass of stars that could be as much as 100 billion times the mass of the Sun.

To better understand this enormous cluster of stars in the early galaxies, we can compare it to our own galaxy, the Milky Way, which only contains a mass of stars equal to approximately 60 billion suns.

How is This Possible?

The question that continues to perplex astronomers is how such an extensive number of celestial bodies and extensive galaxies existed at such an early period of the universe.

To better understand this, we must explore "redshifting." According to the European Space Agency (ESA), "Redshift is a key concept for astronomers. The term can be understood literally—the wavelength of the light is stretched, so the light is seen as 'shifted' towards the red part of the spectrum."

The Visible Light Spectrum

In simple terms, redshift refers to a particular section of the visible light spectrum.

The shortest wavelength of light is violet, at around 380 nanometers. The longest is red, at around 700 nanometers. Astronomers use the latter to gather valuable data on the age of galaxies.

ESA Defines Redshift

According to the ESA, redshift is used to measure how far a celestial object like a galaxy has moved away from us.

"When an object (e.g. a galaxy) moves away from us, it is 'red-shifted' as the wavelength of light is 'stretched' so the light is seen as 'shifted' towards to red end of the spectrum," according to the ESA.

Redshift and Dating Galaxies

Astronomers can use this redshift to predict the age of galaxies found throughout the universe, as all celestial bodies and objects emit a frequency or hue of color that telescopes can pick up. This red color will differ depending on how young or old the galaxy is, allowing researchers to effectively discern how old galaxies are in the depths of the cosmos.

Redshifting can also be used to instruct researchers on the extreme age of galaxies in the cosmos, as well as to analyze several other factors, including their size. Astronomers can also use redshift to scour the galaxy for massive stars and to give researchers an indication of how far a celestial body is from our own planet.

Galaxies During the Infancy of the Universe Continues to Perplex Astronomers

As galaxies in the cosmos age, they produce more suns, which is generally expected. However, the galaxy spotted by the JWST during the universe's infancy has a mass significantly larger than that of the present-day Milky Way.

Despite their attempts to explain this unusual phenomenon, astronomers and researchers have come up empty-handed, and there is no accepted explanation just yet.

The Universe is 26.7 Billion Years Old, Says Researcher

Physicist Rajendra Gupta from the University of Ottawa in Canada is one researcher who believes he has an answer to the question, suggesting "redshift could be a hybrid phenomenon, rather than purely due to the universe's expansion."

He added, "Our newly-devised model stretches the galaxy formation time by several billion years, making the universe 26.7 billion years old, and not 13.7 as previously estimated," Dr Gupta said.

Why Early Galaxies Appear to Have Larger Masses

The suggestion that the universe is twice as old as originally thought has stirred up considerable controversy in the scientific community.

Such a revelation could undoubtedly explain why early galaxies, which emerged 500 million years after the beginning of the universe, appear with a mass generally associated with billions of years of evolution.

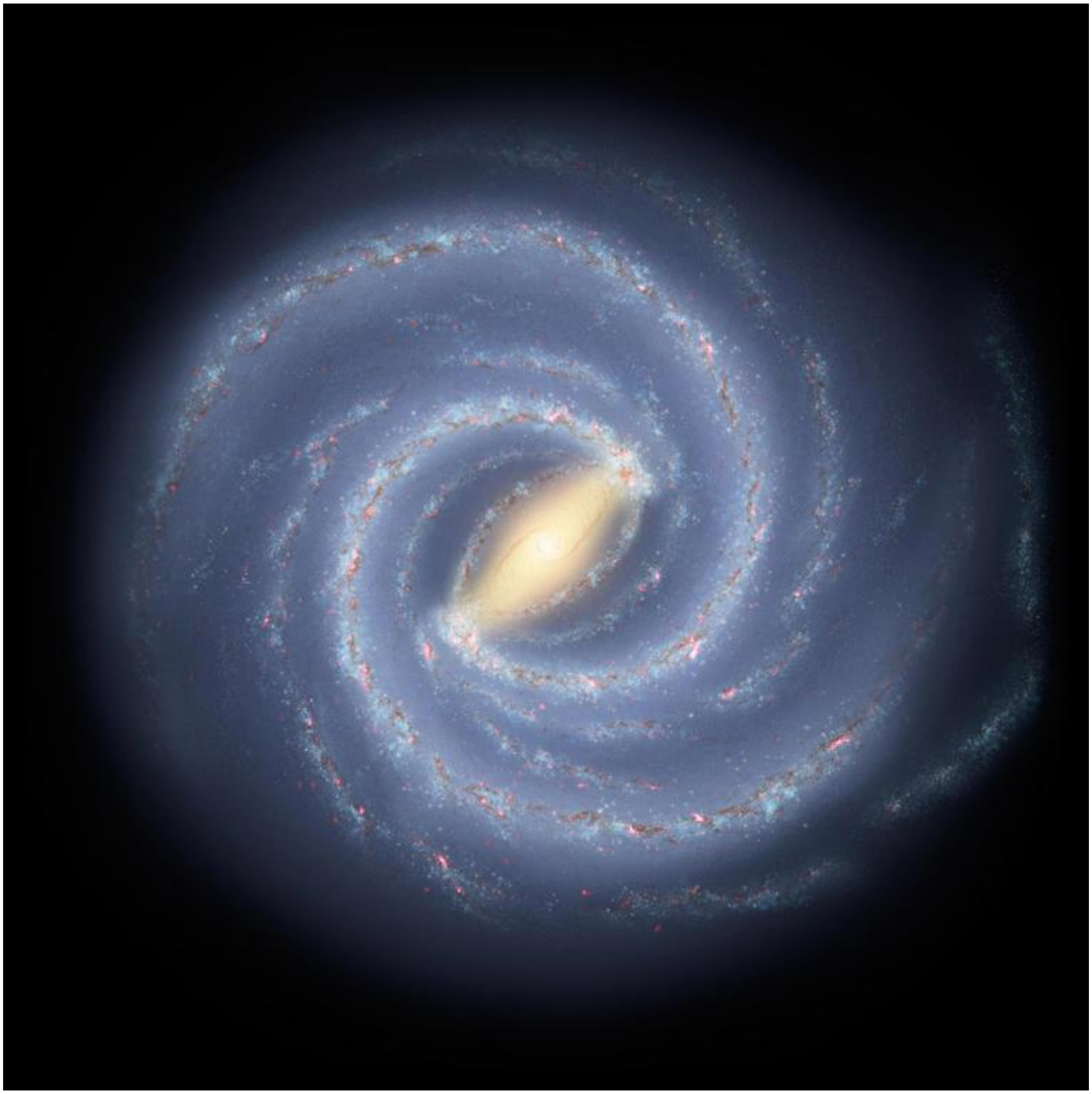


Illustration of what the Milky Way Galaxy may look like to a distant observer. Courtesy of NASA© Courtesy of NASA

- Spiral galaxies like the Milky Way are surprisingly rare in our galactic neighborhood.

- Astronomers have wondered why for years, and now they may have an answer.
- Researchers simulated the evolution of our cosmic neighborhood and discovered a violent past.

The Euclid space telescope's first images show distant, hidden, and irregular galaxies that could help solve 2 of astronomy's grandest mysteries©European Space Agency/Euclid Consortium/NASA; image processing by J.-C. Cuillandre, G. Anselmi

- The Euclid space telescope returned its first photos and they're stunning.
- The five high-res photos show a hidden galaxy, a star cluster, a famous stellar nursery, and more.
- Scientists said they hope to use data from Euclid to better understand dark matter and dark energy.

The Euclid space telescope, which launched in July, has a very important task ahead of it: produce the largest 3D map of the universe to help solve two of astronomy's grandest mysteries: What is dark energy? What is dark matter?

Regular matter, like your body, planets, and stars, only makes up about 5% of the matter in our universe, per NASA. The other 95% is made of dark matter and dark energy.

But scientists don't know what either of these mysterious cosmic entities really are because astronomers can't see them. Astronomers can only observe the effect dark matter and dark energy have on regular matter.

That's where the European Space Agency's Euclid telescope comes in. By taking high-resolution photos, the space telescope will help scientists study both the shapes and motions of billions of galaxies across the universe to better understand the effects of dark matter and dark energy, ESA said in a statement.

On Tuesday, ESA released the first of those high-res photos. "This is an iconic moment," ESA's Director of Science, Carole Mundell, said during an ESA-hosted livestream announcing the photos.

See more

Galaxies come in many shapes and sizes. The Milky Way, for example, is a spiral galaxy because of the way that stars, dust, and gas spiral out from the center of the galaxy.

But spiral galaxies like ours are surprisingly rare in our galactic neighborhood, and for years, astronomers have wondered why since the 1960s.

Now, they may finally have an answer, according to a new study published in the peer-reviewed journal Nature Astronomy earlier this month.

A turbulent past

Using a supercomputer, researchers turned back the clock to approximately 13.8 billion years ago when our galaxy and those around it were just starting to form.

The researchers simulated the evolution of our galactic neighborhood to see what may have happened over billions of years to make spiral galaxies so rare in our corner of the cosmos.

They found evidence of a turbulent past. The simulation showed that galaxies in dense clusters, like the one our Milky Way calls home, experienced frequent collisions and mergers.

When galaxies collide

When galaxies merge, they can form a whole new type of galaxy. For example, when two spiral galaxies collide, it's thought to create what's called an elliptical galaxy.

That's what both observations of our nearby universe and the simulations showed: Our galactic neighborhood has plenty of elliptical galaxies but very few spiral galaxies, suggesting that our Milky Way somehow survived amidst a chaotic scenario of galactic bumper cars over the age of the universe.

"Our simulation reveals the intimate details of the formation of galaxies such as the transformation of spirals into ellipticals through galaxy mergers," said co-author Carlos Frenk with the Institute for Computational Cosmology at Durham University in a statement.

A group of ancient stars have been spotted near our sun, hinting to astronomers that our galaxy is billions of years older than we first thought.

Most of the more than 100 bilion stars in the Milky Way rest on an invisible “halo” that rotates around the supermassive black hole at the center of the galaxy, which scientists previously estimated had formed about 8 to 10 billion years ago. However, new insights into these primordial stars by the European Space Agency’s Gaia spacecraft spacecraft suggest that Planet Earth’s cosmic community could be over 13 billion years old.

Researchers with the Leibniz Institute for Astrophysics Potsdam (AIP) in Germany officially announced their discovery on July 31 following the publication online of their unreviewed report earlier this year.

The whole of our measurable universe is thought to be about 13.8 billion years old, meaning the Milky Way would have formed during the first billion years of existence as we know it, per the study.

“These ancient stars in the disc suggest that the formation of the Milky Way’s thin disc began much earlier than previously believed, by about 4-5 billion years,” said lead study author Samir Nepal in a statement.

Machine learning helped scientists calculate new data into some 800,000 stars in our solar neighborhood, including their surprising metal content.

At the beginning of time, our universe was predominantly composed of hydrogen and helium — and most old stars are a reflection of this environment. However new data revealed that some of the oldest celestial crumbs are more metallic than previously thought possible —- with twice the metal content of much of our relatively young, 4.6-billion-year-old sun.

The Milky Way galaxy was created within the first billion years after the Big Bang, according to the new study. NurPhoto via Getty Images

The discovery of rapid metal enrichment in the early phase of galactic growth has changed how scientists are mapping our galaxy’s history.

“This study also highlights that our galaxy had an intense star formation at early epochs leading to very fast metal enrichment in the inner regions and the formation of the disc,” Nepal said.

NASA’s James Webb Space Telescope (JWST) has unveiled a rare and

striking cosmic phenomenon—a question mark-shaped structure formed by two interacting galaxies. Captured during an observation of the massive galaxy cluster MACS-J0417.5-1154, this discovery offers a deeper understanding of galaxy evolution and the early stages of galactic interactions. The finding is particularly exciting as it demonstrates the immense power of gravitational lensing and Webb’s unparalleled capabilities in observing distant galaxies. Gravitational Lensing: The Key to the Cosmic Question Mark The question mark shape seen in the image is caused by a natural phenomenon known as gravitational lensing, where the immense gravitational force of a massive object, such as a galaxy cluster, warps the fabric of space-time. This bending effect distorts and magnifies the light of more distant galaxies that lie behind the cluster, often creating multiple, smeared images of those galaxies. In this case, a precise alignment between the galaxies, the lens, and the observer resulted in the formation of a cosmic question mark.

"We know of only three or four occurrences of similar gravitational lens configurations in the observable universe, which makes this find exciting," said Guillaume Desprez, an astronomer from Saint Mary's University in Halifax, Nova Scotia, and a member of the team presenting the Webb findings. The rare lensing effect in this case, known as a hyperbolic umbilic gravitational lens, caused the light from two interacting galaxies to appear five times, creating the curve of the question mark. A third, unrelated galaxy happened to be perfectly positioned to form the dot of the question mark. This particular type of gravitational lensing is not only visually stunning but also scientifically valuable, as it allows astronomers to observe galaxies that would otherwise be too distant or faint to study. The power of gravitational lensing effectively acts as a natural telescope, magnifying and revealing details about these galaxies that are billions of light-years away. Interacting Galaxies: A Window Into Early Galaxy Formation The two galaxies responsible for forming the question mark are located billions of light-years away, and their interaction offers crucial insights into the dynamics of galaxy mergers.

Observations from JWST's NIRCam (Near-Infrared Camera) and NIRISS (Near-Infrared Imager and Slitless Spectrograph) show that both galaxies are in the early stages of their collision. As the galaxies' gas and dust collide, regions of intense star formation are triggered. "Both galaxies in the Question Mark Pair show active star formation in several compact regions, likely a result of gas from the two galaxies colliding," explained Vicente Estrada-Carpenter, the lead researcher from Saint Mary's University. This collision-induced star formation is a crucial phase in the galaxies' evolution, as the interaction fuels the creation of new stars. Despite the ongoing collision, neither galaxy's shape has been significantly distorted yet, indicating that this interaction is still in its infancy. This phase of galactic interaction is particularly interesting because it mirrors what astronomers believe the Milky Way might have experienced billions of years ago.

"These galaxies, seen billions of years ago when star formation was at its peak, are similar to the mass that the Milky Way galaxy would have been at that time," noted Marcin Sawicki, another team member involved in the study. This observation provides a rare opportunity to study the processes that shaped galaxies during their formative years, offering a glimpse into how our own galaxy may have evolved. Webb’s Infrared Capabilities: Revealing Hidden Galaxies The JWST’s ability to observe in the infrared spectrum is what enabled this discovery. Previous observations of the MACS-J0417.5-1154 galaxy cluster with the Hubble Space Telescope had revealed some details of the galaxies involved, but much of the light was obscured by cosmic dust. JWST’s infrared instruments, however, were able to penetrate this dust, revealing the red, dusty galaxy that forms the arc of the question mark.

"This is just cool looking. Amazing images like this are why I got into astronomy when I was young," said Sawicki, emphasizing the excitement generated by Webb’s capabilities. The image highlights how Webb’s superior resolution and sensitivity allow astronomers to see objects that were previously hidden from view, shedding new light on the structure and evolution of galaxies in the distant universe. NASA noted in a statement that Webb’s ability to observe in infrared wavelengths allows it to detect the faint light of ancient galaxies that existed during a time when star formation in the universe was beginning to slow down.

The data collected from the NIRCam and NIRISS observations will help astronomers understand the role of dust and gas in galaxy formation and evolution. "Webb’s infrared vision enables us to see galaxies in ways that were impossible before, offering new insights into how galaxies grow and evolve over billions of years," said a NASA spokesperson. The Broader Implications for Understanding Galaxy Evolution This discovery of the cosmic question mark also has broader implications for the study of galaxy evolution. The galaxies observed are from a period when the universe was about 7 billion years old—roughly halfway through its current age—during a time when star formation was beginning to slow. By studying these distant galaxies and their interactions, astronomers can gain a better understanding of how galaxies evolve over time, particularly during periods of intense star formation and mergers.

"Knowing when, where, and how star formation occurs within galaxies is crucial to understanding how galaxies have evolved over the history of the universe," explained Estrada-Carpenter. As galaxies collide and merge, the resulting gravitational forces can reshape their structure, triggering new bursts of star formation and potentially fueling the growth of supermassive black holes at their centers. These types of interactions are believed to play a significant role in the evolution of large galaxies like the Milky Way. The data gathered from this observation will help astronomers refine models of galaxy formation and evolution, offering new insights into the processes that drive the growth of galaxies over cosmic time.

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."

In a continuous pursuit to understand the fundamental laws that govern the universe, researchers have ventured deep into the realms of string theory, loop quantum gravity, and quantum geometry. These advanced theoretical frameworks have revealed an especially compelling concept: the generalized uncertainty principle (GUP).

This principle fundamentally challenges traditional physics by proposing a minimal measurable length, which could profoundly alter our foundational understanding of space and time. It challenges the bedrock of classical mechanics and invites a reevaluation of quantum mechanics and general relativity.

The GUP has catalyzed an impressive range of research efforts, extending from the microscopic domain of atomic physics to the cosmic scales of astrophysics and cosmology. Investigations have explored phenomena such as gravitational bar detectors, condensed matter systems, and the dynamics of quantum optics.

Each study contributes to a broader understanding of the potential implications of the GUP, suggesting it could fundamentally transform our understanding of physics across various scales and systems.

Rethinking the Planck constant

Building upon these insights, our research, published in the *International Journal of Modern Physics D*, introduces a transformative concept: an "effective" Planck constant. This idea challenges the traditional view of the Planck constant as a static, immutable value, proposing instead that it might vary depending on specific experimental or environmental conditions, particularly the momentum or position of the system under observation.

This hypothesis emerges from the GUP, suggesting that the Planck constant is not merely a universal constant but dynamically interacts with the momentum and position of the physical systems being measured.

This new perspective encourages a rethinking of fundamental constants in physics, implying they could be dynamic properties interacting significantly with the physical attributes of systems, such as their mass, size, and quantum state.

A bridge between quantum mechanics and the cosmos

Central to our investigation is a simple yet profound formula: $m\ r\ c = \hbar'$

This formula demonstrates that by inputting the Planck mass and Planck length as the mass and radius, respectively, we derive what we term the "traditional" Planck constant, $\hbar$. This outcome highlights a significant and intrinsic connection between fundamental physical constants and the fabric of the universe.

When this formula is specifically applied to the electron, the results are particularly illuminating: $\hbar'$ equates to the fine structure constant multiplied by $\hbar$, aligning perfectly with established values from quantum mechanics. This precise alignment reinforces the robustness of our formula and its relevance to fundamental particle physics.

For particles like pions, kaons, and gauge bosons, the calculated $\hbar'$ remains comparable in magnitude to $\hbar$, demonstrating the universal applicability of our formula across different scales and particle types.

However, when applied to larger systems, such as chemical elements like helium and oxygen, $\hbar'$ significantly exceeds $\hbar$ by a few orders of magnitude (10 to 10^3), suggesting a scale-dependent variability of the effective Planck constant.

Most importantly, when the formula is applied to the entire universe, it yields a value for $\hbar'$ that offers a potential solution to the cosmological constant problem. This intriguing result suggests a novel approach to resolving one of the most challenging and persistent issues in theoretical physics. By bridging observed discrepancies in vacuum energy densities with empirical observations, the formula provides a reconciled understanding of cosmic phenomena.

Linking to the Bekenstein entropy bound

Furthermore, our research establishes a critical link between the variable Planck constant $\hbar'$ and the Bekenstein entropy bound—a fundamental principle that limits the amount of information that can be contained within a given physical system.

This connection not only supports the theoretical validity of the Bekenstein bound but also significantly enhances our understanding of the role of entropy and information at the quantum level across different scales and systems. This insight suggests a deeper, more nuanced understanding of the relationships between information, entropy, and fundamental constants in the universe.

Conclusion

The implications of our findings are both profound and potentially transformative. By establishing a bridge between quantum mechanics, thermodynamics, and cosmology, our research opens new avenues for a deeper understanding of the universe at its most fundamental level.

This work not only enriches our theoretical insights but also invites the scientific community to reconsider enduring mysteries in physics, such as the nature of dark matter and the cosmological constant problem.

We hope that this research will inspire further exploration and vibrant discussion within the scientific community. By examining the universe through this innovative theoretical lens, we advocate for a more holistic and comprehensive understanding of the fundamental principles that govern everything from the minutest particles to the vast expanses of space.

This journey into the depths of physical laws is far from complete, and we eagerly anticipate the new perspectives and discoveries that it will bring.

This story is part of Science X Dialog, where researchers can report findings from their published research articles. Visit this page for information about Science X Dialog and how to participate.

More information: Ahmed Farag Ali et al, Theoretical and observational implications of Planck's constant as a running fine structure constant, *International Journal of Modern Physics D* (2024). DOI: 10.1142/S0218271824500366. On *arXiv*:

Halos of gas from galaxies is now known to interact with nearby galaxies, like this grouping of five galaxies© NASA, ESA, CSA, STScI, Webb ERO Production Team

"You may think it's a long way down the road to the drug store," wrote Douglas Adams in his Hitchhiker's Guide to the Galaxy, "but that's just peanuts to space."

Space is big. We live on one tiny planet orbiting a star that's tucked away in the far reaches of a galaxy — just one galaxy of around 2 trillion in the known universe. Space is really really big.

Planet Earth is located in one of the spiral arms of the Milky Way (called the Orion Arm) which lies about two-thirds of the way out from the center of the galaxy.

We know how big the Earth is — 12,756 kilometers (7,926 miles) across. And we know how big our sun is too — about 1,391,000 kilometers (864,400 miles) across.

But how big is the Milky Way? Until now, the true size of galaxies has remained a mystery.

Galaxies are much bigger than we thought

A new study, published today in the journal *Nature Astronomy*, has found that galaxies are far bigger than originally thought, perhaps several times bigger.

The spiraled structure of the galaxy we know is only the smaller core of the galaxy. For the Milky Way, this is about 100,000 light-years across.

The starlight from stars nestled in the spiral arms extend to around 7,800 light-years into deep space, which was thought to be where a galaxy ended and deep space began.

The study has revealed that large "halos" of gas extend from the visible spirals of star light far out into deep space.

These gas halos only became visible to astronomers with new imaging techniques. The methods enabled astronomers to detect galaxy gas halos over 100,000 light years into deep space, vastly increasing our estimations of how big galaxies are.

Kissing galaxies

In fact, the halos of gas from galaxies extend so far into deep space that galaxies actually interact with each other.

The findings suggest that our Milky Way is likely interacting with our closest neighbor, Andromeda — around 2.5 million light years away, according to Nikole Nielsen, lead author of the paper, and a researcher with Swinburne University, Australia.

"We're now seeing where the galaxy's influence stops, the transition where it becomes part of more of what's surrounding the galaxy, and, eventually, where it joins the wider cosmic web and other galaxies. These are all usually fuzzy boundaries," said Nielsen in a press statement.

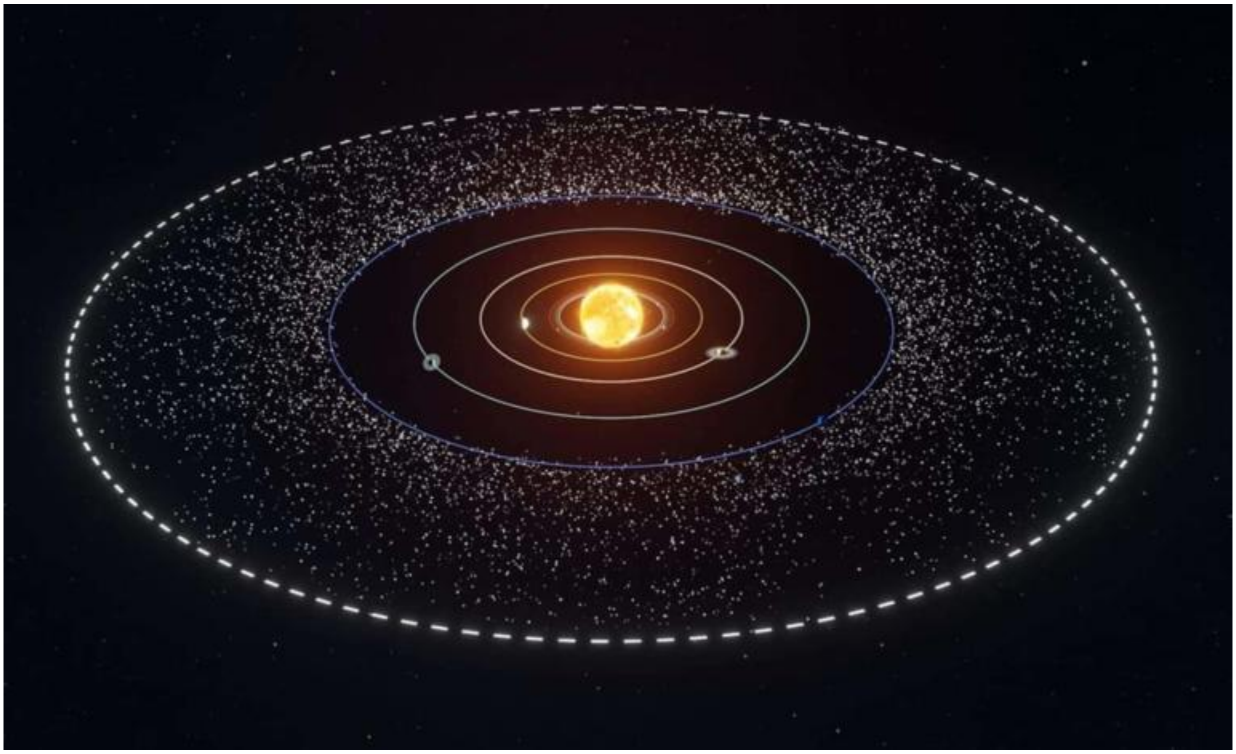
Scientists say the discovery will help to understand one of the biggest questions in astronomy: how do galaxies evolve?

Studying the gas halos from different types of galaxies — ones that form stars, or those that don't form stars any longer — will help to understand how galaxies build mass over time, and what impact galaxies have on each other when they interact.

Edited by: Andreas Illmer

Primary source:

Nielsen, N.M., *et al.* An emission map of the disk–circumgalactic medium transition in starburst IRAS 08339+6517. *Nature Astronomy* (2024). https://doi.org/10.1038/s41550-024-02365-x



Hidden Population of Objects Discovered Beyond Kuiper Belt in the Outer Solar System© Daily Galaxy

Recent discoveries have shown that the outer Solar System is more crowded with celestial bodies than previously believed. Acombination of data from the Subaru Telescope in Hawaii and NASA's New Horizons spacecraft has uncovered a significant number of small, icy objects, known as Kuiper Belt Objects (KBOs), far beyond the known boundaries of the Kuiper Belt.

The research, led by an international team of astronomers, detected 263 new KBOs, including 11 objects situated between 70 and 90 astronomical units (AU) from the Sun—much farther than the traditionally observed range of 30-55 AU. This surprising discovery has forced scientists to reconsider long-held theories about the structure of the outer Solar System and the processes that shaped its formation. Subaru Telescope Uncovers Unexpected Objects Beyond the Kuiper Belt The collaboration between the Subaru Telescope and NASA's New Horizons spacecraft has led to some of the most detailed observations of the outer Solar System to date.

The Subaru Telescope’s Hyper Suprime-Cam (HSC), with its ultra-wide field of view, has proven crucial in surveying distant regions where traditional telescopes have struggled. The telescope’s observations over the past few years revealed a dense population of small objects not previously detected in such numbers, especially in the 70 to 90 AU range. This region lies far beyond Neptune’s orbit and the outer edges of the Kuiper Belt, where only a sparse population of objects had been expected. The team’s discovery of 11 objects in this distant zone was particularly exciting. These KBOs are located beyond what was thought to be the outer boundary of the Kuiper Belt, raising questions about how they formed and why they exist in such an unexpected place.

According to Dr. Fumi Yoshida, one of the lead researchers from Japan’s University of Occupational and Environmental Health Sciences, "If this is confirmed, it would be a major discovery. The primordial solar nebula was much larger than previously thought, and this may have implications for studying the planet formation process in our Solar System." The existence of these objects could suggest that the Solar System's early formation region was far more extensive than previously believed, challenging long-standing models of planetary formation.

A New Understanding of the Outer Solar System’s Structure The discovery of these distant objects, combined with the identification of a "gap" between 55 and 70 AU, suggests a more complex structure in the outer Solar System than earlier models proposed. This gap, where only a few KBOs have been found, is intriguing because such empty regions have been observed in other planetary systems, typically in young, developing systems around distant stars. Gaps like this often indicate regions where planets or other large bodies have cleared out material during their formation, creating divisions between different populations of small objects. This new structure has led scientists to reconsider the uniqueness of our Solar System. Dr. Wesley Fraser, of the National Research Council of Canada, explained that previous studies may have underestimated the complexity of the Kuiper Belt due to observational biases. "Our Solar System’s Kuiper Belt long appeared to be very small in comparison with many other planetary systems," Fraser noted.

"But our results suggest that idea might just have arisen due to an observational bias." The existence of this second group of KBOs at such great distances challenges the assumption that our Solar System's Kuiper Belt is smaller or less dense compared to those observed around other stars. The observations suggest that the early Solar System may have resembled the debris-filled disks seen around young stars today, where gaps and multiple belts of material are common. The presence of these distant objects could offer new insights into how planets and small bodies formed and migrated in the outer reaches of the Solar System. This more complex understanding of the Kuiper Belt brings our Solar System closer in line with other planetary systems, allowing scientists to draw new comparisons between how planets form across the universe.

Implications for Planetary Formation and Solar System Evolution The discovery of these new, distant objects in the outer Solar System has significant implications for our understanding of planetary formation, both within our Solar System and beyond. The existence of a possible second Kuiper Belt raises new questions about how small objects like these form in such distant regions and how they have remained largely unchanged for billions of years. This untouched region of the Solar System could hold critical clues about the primordial solar nebula, the cloud of gas and dust that gave birth to the Sun and planets.

As Dr. Yoshida explained, "The discovery of distant objects and the determination of their orbital distribution are important as a stepping stone to understanding the formation history of the Solar System, comparing it with exoplanetary systems, and understanding universal planet formation." These distant KBOs are relics of the early Solar System and could help scientists understand how the Solar System evolved from a chaotic, debris-filled disk to the more stable structure we see today. Furthermore, these objects are relatively unaffected by solar radiation, meaning they are pristine samples of the material from which the Solar System formed. The implications extend beyond our Solar System, as scientists are now using the findings to compare the formation of the Kuiper Belt with the structures seen in other planetary systems. The discovery of gaps and additional belts in the outer Solar System strengthens the idea that these features are common in planetary systems and may play a crucial role in the formation of planets.

This new understanding could reshape how astronomers search for and study planetary systems around distant stars, offering new insights into how planets form and migrate in their early stages. What’s Next for Outer Solar System Exploration? The detection of these distant Kuiper Belt objects is only the beginning. NASA’s New Horizons spacecraft, which is currently over 60 AU from the Sun, continues to provide valuable data about the outer regions of the Solar System. The spacecraft, which previously conducted flybys of Pluto and the Kuiper Belt object Arrokoth, is now in a position to study these newly discovered KBOs in more detail.

Combined with ongoing observations from the Subaru Telescope, scientists hope to refine their understanding of the orbits and physical characteristics of these distant objects. "This is a groundbreaking discovery revealing something unexpected, new, and exciting in the distant reaches of the Solar System," said Alan Stern, principal investigator of the New Horizons mission. "This discovery probably would not have been possible without the world-class capabilities of the Subaru observatory."

The collaboration between Subaru and New Horizons is expected to continue, with more observations planned to track the newly discovered objects and determine their precise orbits. In the coming years, scientists anticipate that these new discoveries will shed light on the formation of the Solar System and provide fresh insights into how planetary systems evolve over time. The distant reaches of the Solar System, once thought to be sparsely populated, are now proving to be a dynamic and complex region, full of surprises waiting to be uncovered.

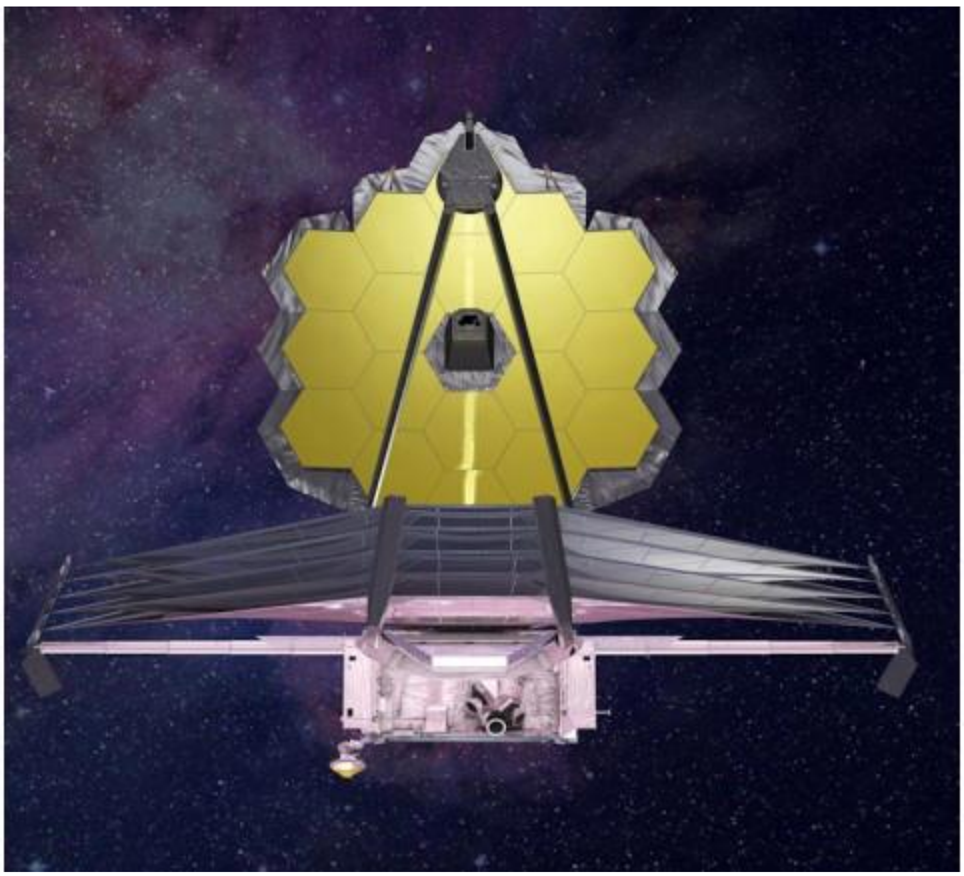
The James Webb Space Telescope, or JWST for short, is one of the most advanced telescopes ever built. Planning for JWST began over 25 years ago, and construction efforts spanned over a decade. It was launched into space on Dec. 25, 2021, and within a month arrived at its final destination: 930,000 miles away from Earth. Its location in space allows it a relatively unobstructed view of the universe.

The telescope design was a global effort, led by NASA, and intended to push the boundaries of astronomical observation with revolutionary engineering. Its mirror is massive– about 21 feet (6.5 meters) in diameter. That's nearly three times the size of the Hubble Space Telescope, which launched in 1990 and is still working today.

It's a telescope's mirror that allows it to collect light. JWST's is so big that it can "see" the faintest and farthest galaxies and stars in the universe. Its state-of-the-art instruments can reveal information about the composition, temperature and motion of these distant cosmic objects.

As an astrophysicist, I'm continually looking back in time to see what stars, galaxies and supermassive black holes looked like when their light began its journey toward Earth, and I'm using that information to better understand their growth and evolution. For me, and for thousands of space scientists, the James Webb Space Telescope is a window to that unknown universe.

Just how far back can JWST peer into the cosmos and into the past? About 13.5 billion years.



Time Travel

A telescope does not show stars, galaxies and exoplanets as they are right now. Instead, astronomers are catching a glimpse of how they were in the past. It takes time for light to travel across space and reach our telescopes. In essence, that means a look into space is also a trip back in time.

Amazing View Of The Southern Ring Nebula Via The James Webb Space Telescope

This is even true for objects that are quite close to us. The light you see from the Sun left it about 8 minutes, 20 seconds earlier. That's how long it takes for the Sun's light to travel to Earth.

You can easily do the math on this. All light – whether sunlight, a flashlight or a light bulb in your house – travels at 186,000 miles (almost 300,000 kilometers) per second. That's just over 11 million miles (about 18 million kilometers) per minute. The Sun is about 93 million miles (150 million kilometers) from Earth. That comes out to about 8 minutes, 20 seconds.

But the farther away something is, the longer its light takes to reach us. That's why the light we see from Proxima Centauri, the closest star to us aside from our Sun, is 4 years old; that is, it's about 25 trillion miles (approximately 40 trillion kilometers) away from Earth, so that light takes just over four years to reach us. Or, as scientists like to say, four light years.

Most recently, JWST observed Earendel, one of the farthest stars ever detected. The light that JWST sees from Earendel is about 12.9 billion years old.

The James Webb Space Telescope is looking much farther back in time than previously possible with other telescopes, such as the Hubble Space Telescope. For example, although Hubble can see objects 60,000 times fainter than the human eye is able, the JWST can see objects almost nine times fainter than even Hubble can.

The James Webb Space Telescope can see back 13.5 billion years – back to when the first stars and galaxies began to form.

The Big Bang

But is it possible to see back to the beginning of time?

The Big Bang is a term used to define the beginning of our universe as we know it. Scientists believe it occurred about 13.8 billion years ago. It is the most widely accepted theory among physicists to explain the history of our universe.

The name is a bit misleading, however, because it suggests that some sort of explosion, like fireworks, created the universe. The Big Bang more closely represents the appearance of rapidly expanding space everywhere in the universe. The environment immediately after the Big Bang was similar to a cosmic fog that covered the universe, making it hard for light to travel beyond it. Eventually, galaxies, stars and planets started to grow.

That's why this era in the universe is called the "cosmic dark ages." As the universe continued to expand, the cosmic fog began to rise, and light was eventually able to travel freely through space. In fact, a few satellites have observed the light left by the Big Bang, about 380,000 years after it occurred. These telescopes were built to detect the splotchy leftover glow from the Big Bang, whose light can be tracked in the microwave band.

However, even 380,000 years after the Big Bang, there were no stars and galaxies. The universe was still a very dark place. The cosmic dark ages wouldn't end until a few hundred million years later, when the first stars and galaxies began to form.

This is a JWST image of NGC 604, a star-forming region about 2.7 million light years from Earth. NASA/ESA/CSA/STScI

The James Webb Space Telescope was not designed to observe as far back as the Big Bang, but instead to see the period when the first objects in the universe began to form and emit light. Before this time period, there is little light for the James Webb Space Telescope to observe, given the conditions of the early universe and the lack of galaxies and stars.

Peering back to the time period close to the Big Bang is not simply a matter of having a larger mirror – astronomers have already done it using other satellites that observe microwave emission from very soon after the Big Bang. So, the James Webb Space Telescope observing the universe a few hundred million years after the Big Bang isn't a limitation of the telescope. Rather, that's actually the telescope's mission. It's a reflection of where in the universe we expect the first light from stars and galaxies to emerge.

By studying ancient galaxies, scientists hope to understand the unique conditions of the early universe and gain insight into the processes that helped them flourish. That includes the evolution of supermassive black holes, the life cycle of stars, and what exoplanets – worlds beyond our solar system– are made of.

Astronomers Discover Hundreds of Asteroid Moons Hiding in Our Solar System

Scientists have found hints there may be two Kuiper Belts, or at least two separate components of the belt, right on the edge of our Solar System.

The Kuiper Belt is a doughnut-shaped region of icy objects beyond the orbit of Neptune which is home to dwarf planet Pluto and is believed to contain a number of comets, asteroids and other small bodies.

These are known as Kuiper Belt objects (KBOs) and astronomers have found hints of an unexpected rise in their density far beyond where the Kuiper Belt is currently known to end, reports Science Alert.

Fumi Yoshida, planetary scientist at the University of Occupational and Environmental Health Sciences and Chiba Institute of Technology in Japan, said: "If this is confirmed, it would be a major discovery.

"The primordial solar nebula was much larger than previously thought and this may have implications for studying the planet formation process in our Solar System."

Scientists have found hints there may be two Kuiper Belts, or at least two separate components of the belt, in our Solar System / (PaulFleet, iStock)

The higher than expected rise in density is between 70 and 90 astronomical units from the Sun; an astronomical unit is a measurement of the average distance between Planet Earth and the Sun.

The Kuiper Belt extends from the orbit of Neptune, which around 30 astronomical units from the Sun, out to around 50.

The New Horizons spacecraft is travelling deeper into the Solar System and is currently around 60 astronomical units from the sun; it flew by Pluto in 2015.

Astronomers have been observing beyond this using the National Astronomical Observatory of Japan's Subaru Telescope in Hawaii.

In the region between 55 and 70 astronomical units, pretty well nothing had been found but 11 KPOs were spotted beyond this which is much further out than where the Kuiper Belt is thought to end.

The orbits of these are continuing to be tracked so astronomers can make further observations.

About **13.8 billion years ago**, the entire contents and energy of the universe were concentrated in a **singularity**—a point of infinite density and temperature. This singularity began to **expand rapidly**, an event we now refer to as the **Big Bang**.
During this explosive birth, the fundamental forces of nature—such as gravity, electromagnetism, the weak force, and the strong force—began to emerge in stages. That's why when the JWST spotted some galaxies that seemed to jump some of those stages it all seems too strange.

Why are these galaxies older than the universe? Did they exist before the Big Bang?

These galaxies were spotted when the universe was a mere **500 to 700 million years old, a** time when it was just **3 percent** of its current age. At that point, the universe was still in its infancy, and most theories predicted the existence of small, young galaxies.

However, these newly identified galaxies are anything but small. Their mass of stars totals several billion times larger than our sun. One of them might even be as massive as **100 billion times** the mass of our sun. To put this in perspective, our own Milky Way galaxy contains a mass of stars equivalent to roughly **60 billion suns**.

To understand this, we have to look at **red-shifting**. The older the body in the universe, the hue of color detected by telescopes changes. The color changes to red, and the difference in the proportion of red indicates whether the **galaxy is older or younger**. The redshift of these galaxies indicates not only their extreme age but also their immense size and the presence of massive stars.

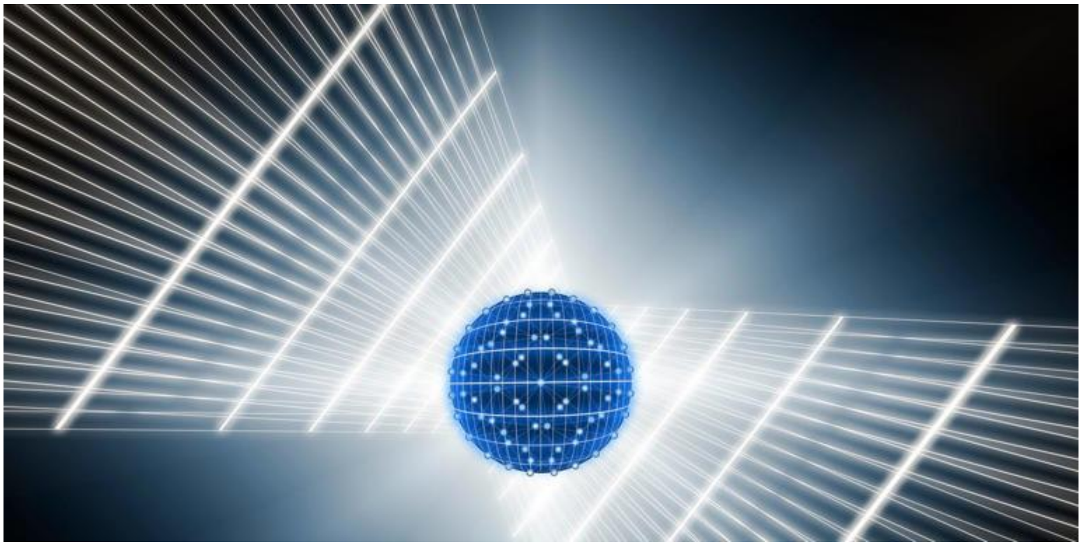
As galaxies age, they produce more suns, and in this case, the total mass is **100 billion** times larger than our galaxy, a phenomenon for which there is currently no clear explanation. This is particularly significant because these galaxies formed without the need for dark matter, an element previously believed to be necessary to hold them together.

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.



Scientists found a math tweak to make tachyons—faster-than-light particles—compatible with general relativity, possibly changing our understanding of physics.© Imagine Photographer - Getty Images

- A straightforward math tweak could bring tachyon fields into line with the rest of physics.
- Tachyons are faster-than-light particles, and tachyon fields are special cases of quantum field.
- The math adjustment enlarges a tiny Hilbert space into a larger one to accommodate variables.

In a fascinating twist of theoretical physics, scientists may have calculated how an elusive particle, the tachyon, could exist without breaking the laws of general relativity.

Theoretical models involving missing pieces and parameters often posit new, exotic particles as a way to close their gaps. But these models are complex, including ranges and likelihoods of other parameters. When a team of scientists can sharpen one of those parameters, the new particle can move closer to or further away from existing and conforming to physics as we know it.

Theoretical physicists live in a world the rest of us can't really understand. They identify phenomena from the far-out cosmos, including things that don't make sense to our Earth-centric mindset, then they flesh out a model using all the things we can roughly calculate. A tachyon is a particle that travels faster than light (superluminal), which is considered impossible. And a tachyon field, therefore, is something that doesn't fit into our current understanding.

Tachyon fields have long been "the *enfant terrible* of physics," these scientists explain, but recent work has continued to move them from outlandish toward, maybe, merely implausible. Now, this team is adding another update to keep moving tachyon fields toward plausibility. Their work appears in the peer-reviewed American Physical Society journal *Physical Review D*.

The key, they explain, is in doubling one of the parameters in today's understanding of tachyon fields. The Hilbert space is a working model used in complex mathematics. When describing quantum fields in general, a Hilbert space model with *just one particle* is enough. In fact, it constrains the math in a way that makes the whole calculation work, because the one particle is never subtracted from or added to. But for tachyon fields, the math is different and must be represented by two intersecting fields instead of one field of just one particle, the scientists say.

That's because Hilbert space that depicts a tachyon field has to have enough room for a tricky mathematical switch. In our understanding of working spacetime, there'a a series of calculations, the Lorentz transformations, that need to be possible in order for a particular idea to be plausible.

Think of it like any other set of qualifications. If you want to apply to be part of a list of squares, you must have exactly four sides of equal length and exactly four right angles. Without those qualifications, you're simply another kind of shape. To be plausible in our world, you must be Lorentz compliant, with the equivalent of four sides and four right angles.

If the tachyon field math is constrained to a Hilbert space of just one side, or input, then the Lorentz transformations don't have room to fully express. That's because in the course of these transformations, the input and output fields can switch and create an outcome that doesn't fit into the Hilbert space anymore. The right space, the scientists explain, must be paired of all inputs and all outputs together. That means they can switch back and forth without moving out of bounds.

It's complicated stuff—but so is cosmology. And despite the heady details, what results is simple: this larger Hilbert space removes the three largest remaining obstacles in our understanding of tachyon fields as part of the same play space as quantum field theory in general.

This, the scientists explain, comes after previous work showing that tachyons are not impossible, but rather more like "disturbances of causality." Other scientists have also shown that the math of superluminal particles may not be impossible after all.

At one time, physicists were sticking their necks out over the idea of quantum mechanics in the broadest sense. Heck, before that, scientists had to risk their livelihoods to suggest that atoms existed at *all*, then that subatomic particles existed. Perhaps in years to come we'll all accept tachyon fields as a building block of our world, with fine-tuned detectors for those as well as dark matter and the other theoretical materials around us. All it takes is a slightly larger working space.

Scientists say microscopic wormholes could explain discrepancies in cosmological constants and affect our understanding of quantum mechanics and dark energy.© sarayut Thaneerat - Getty Images

- Churning nano-wormholes could explain the clash in our cosmological constants.
- The wormholes add magnitude to a math parameter called the Gauss-Bonnet term.
- Boosting one term in a complex equation helps scientists explain how the results could change.

Scientists in Greece have laid out a mathematical framework to help explain a so-far-unsolved gap in our understanding of how gravity scales up to the full size of our universe.

Specifically, cosmologists can't yet account for how expansion of the universe increased in the "recent cosmological past"—a *very* relative term—because all attempts to quantify the change so far end up clashing with existing mathematical models. The Greek scientists suggest something particularly squiggly: microscopic wormholes, whose nature and density could fill up the missing pieces. These spacetime Orbeez require only a bit of fine-tuning from theories that are already in the zeitgeist.

In the new paper, which appears in the peer-reviewed journal *Physical Review D* from the American Physical Society, the authors explain that the "positive cosmological constant" meant to quantify our expanding universe has, instead, created math issues: "[Q]uantum field theoretical analysis predicts a value up to 120 orders of magnitude larger than the observed one."

The 7 Strangest Objects In The Universe

An order of magnitude is not simply a 1:1 multiplier, so 120 orders of magnitude is likely far more than 120 times larger. But if your lifetime likelihood of being struck by lightning is about 1 in 15,300, 120 times larger jumps to 1 in 127.

If we want to balance the two possibilities, the scientists explain, we need to add at least one new complicating factor. The two main suggestions for this are, first, a changing cosmological constant explained by the idea of dark energy; or second, to deepen our theory of how gravity behaves on the cosmic scale, from a smooth background to a craggier, fjord-like complexity.

This paper suggests combining both options: What if the solution is a believably craggier background gravity covered with instantons and wormholes, and their more rugged landscape naturally accounts for an amount of dark energy as well?

Let's define some terms. When cosmologists try to model the universe, they break it down using practices like topology and manifold theory. They build in as many variables or ideas as they have at the time, leaving spaces where something is not yet known. And, just like in your high school calculus class, the goal is always to account for everything on both sides of any equal sign or other equivalence in your mathematical model.

The physics of different scales simply don't match easily yet. Concrete observations by Albert Einstein and those before turned into beautiful theories that account for the visible world and parts of outer space; quantum mechanics twists those pieces until they no longer fit together into a completed puzzle. Considering spacetime as a manifold, or a surface that is guided by interlocking math on a grand scale, lets physicists look for the correct new place for a particular piece of the puzzle.

One way spacetime acts up is called quantum foam. On an extraordinarily tiny level, scientists believe, even quantum phenomena break down and create tiny bubbles where principles no longer apply. If someone can be a writer's writer or a comedian's comedian, this is kind of the disruptive quantum mechanics *of* quantum mechanics. And it's in this foam where wormholes could exist in a way that brings cosmic ideas together without breaking any larger rules.

The term "wormhole" may even be misleading, because they can be tunnels, but may also simply be punched holes that cross through higher dimensions behind the scenes. Manifold theory allows scientists to add these dimensions and at least attempt to rationalize them, something difficult to do using a three-dimensional human mind.

Once we allow that there could be wormholes in the foam, the scientists explain in the paper, a number of other relevant math operations and transformations build on that foundation. The solution, "an effective cosmological constant," appears when you apply the Gauss-Bonnet theorem: "[T]he variation of the Gauss-Bonnet term on a manifold that has topology changes due to the formation of wormholes is not zero."

In astrophysics, that's a mic drop.

As for where dark energy comes into this, it's still a part of our working model of the universe, wormholes or not. In this case, the wormholes would directly account for at least some of that dark energy: "[T]he wormhole density in a dynamical spacetime is not expected to be constant, therefore the obtained effective cosmological constant also acquires a dynamical nature, i.e., it corresponds to an effective dark energy sector."

In other words, the churn of the micro wormholes creates a changing constant. And to account for the observed cosmological constant, all we need is "1016 microscopic wormholes," or 10 quadrillion, "per cubic meter per second." That, the scientists conclude, is well within the realm of possibility based on estimates.

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

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

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

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

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

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

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

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."

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.

Source: Nature

Sometimes, planets go rogue.

Scientists used the powerful James Webb Space Telescope to spot six of these rogue objects, which move through the cosmos untethered from any solar system. They're a little bigger than the gas giant Jupiter, and the discovery suggests these worlds formed similar to the way stars form — rather than how planets are usually created.

Astronomers have waited for years to harness the abilities of the Webb telescope, whose large mirror gathers bounties of distant, faint light, to find such free-floating objects.

"It has been in planning for a decade," Ray Jayawardhana, an astronomer at Johns Hopkins University and senior author of the study, told Mashable.

You can see three of these rogue planets below, circled in green. They're located about 1,000 light-years away in our galaxy, inhabiting the nebula NGC1333, an enormous region of dust and gas where stars form.

"It has been in planning for a decade."

Although it's possible they originally formed as planets around a star, the researchers think they're more likely failed stars — but didn't have nearly the mass needed to ignite a stellar engine like our sun. (Stars form when enormous clouds of gas collapse and heat up, ultimately creating the immense pressure and heat needed for star creation.) The lowest-mass object found, about five times the mass of Jupiter, shows evidence of a dusty disk around it, and space dust often spins around a central object amid star formation. What's more, it's hard to imagine a planet getting ejected from its solar system and maintaining such a disk.

"The objects more likely formed how stars formed," Rayawardhana said.

The research has been accepted for publication in *The Astronomical Journal*, a peer-reviewed science chronicle.

The rogue objects are similar in mass to other large gaseous planets found beyond our solar system, called exoplanets. If they aren't failed stars, these objects would have needed to get thrown out of their solar system, perhaps by a close gravitational interaction with another planet, or a second star (most solar systems have two or more stars).

The investigation of rogue objects continues. The astronomers have been awarded more competitive time with the Webb telescope to peer at such objects with dusty disks. Could they be "mini-planetary" systems like the many curious moons orbiting Saturn and Jupiter? As we know in our own solar system, these planetary systems include intriguing moons, some of which harbor oceans beneath their icy shells.

A bonus sighting: Although not a part of this research endeavor, the Webb image above shows telltale evidence of a newly forming solar system. Look near the bottom right, below the black bar, where you can see two dark cone-like features emanating from a bright central spot. That's Webb, from our perch in the Milky Way galaxy, viewing the dusty disk of the solar system side-on, as we might view the side of a frisbee. The nascent system's dust-filled disk blocks starlight, creating those two dark flares.

The Webb telescope's powerful abilities

The Webb telescope — a scientific collaboration between NASA, ESA, and the Canadian Space Agency — is designed to peer into the deepest cosmos and reveal new insights about the early universe. But it's also peering at intriguing planets in our galaxy, along with the planets and moons in our solar system.

Here's how Webb is achieving unparalleled feats, and likely will for decades to come:

- Giant mirror: Webb's mirror, which captures light, is over 21 feet across. That's over two-and-a-half times larger than the Hubble Space Telescope's mirror. Capturing more light allows Webb to see more distant, ancient objects. As described above, the telescope is peering at stars and galaxies that formed over 13 billion years ago, just a few hundred million years after the Big Bang. "We're going to see the very first stars and galaxies that ever formed," Jean Creighton, an astronomer and the director of the Manfred Olson Planetarium at the University of Wisconsin–Milwaukee, told Mashable in 2021.

- Infrared view: Unlike Hubble, which largely views light that's visible to us, Webb is primarily an infrared telescope, meaning it views light in the infrared spectrum. This allows us to see far more of the universe. Infrared has longer wavelengths than visible light, so the light waves more efficiently slip through cosmic clouds; the light doesn't as often collide with and get scattered by these densely packed particles. Ultimately, Webb's infrared eyesight can penetrate places Hubble can't.

"It lifts the veil," said Creighton.

- Peering into distant exoplanets: The Webb telescope carries specialized equipment called spectrographs that will revolutionize our understanding of these far-off worlds. The instruments can decipher what molecules (such as water, carbon dioxide, and methane) exist in the atmospheres of distant exoplanets — be they gas giants or smaller rocky worlds. Webb looks at exoplanets in the Milky Way galaxy. Who knows what we'll find?

"We might learn things we never thought about," Mercedes López-Morales, an exoplanet researcher and astrophysicist at the Center for Astrophysics-Harvard & Smithsonian, told Mashable in 2021.

Already, astronomers have successfully found intriguing chemical reactions on a planet 700 light-years away, and have started looking at one of the most anticipated places in the cosmos: the rocky, Earth-sized planets of the TRAPPIST solar system.

It was the writer Edgar Allan Poe who first proposed a solution to Olber's paradox: why is the sky dark at night? The reason for the darkness of the night is to be found in the fact that our cosmos has limits, at the very least in time. Since then, astronomers have been searching for another related answer – not *why* it is dark but *how dark* it is, and scientists might just have gotten the best measurement of that yet.

The instrument capable of this feat is on board NASA's New Horizons – the mission that, 9 years ago, flew by Pluto. It is so far from the inner Solar System and its zodiacal dust, that it can get a more precise measurement of the cosmic optical background (COB), the combined light of all the sources of light humans can see in the visible universe.

"If you hold up your hand in deep space, how much light does the universe shine on it?" asked lead author Marc Postman, from the Space Telescope Science Institute in a statement. "We now have a good idea of just how dark space really is. The results show that the great majority of visible light we receive from the universe was generated in galaxies. Importantly, we also found that there is no evidence for significant levels of light produced by sources not presently known to astronomers."

Asteroid collisions and comets have peppered the inner Solar System with dust, and sunlight shining on it has added some celestial light pollution to the measurement of the COB. Different approaches have been used to measure this, but to do so from inside the Solar System is difficult. New Horizons is 7.3 billion kilometers (4.5 billion miles) away from Earth, where dust is not a problem.

"People have tried over and over to measure it directly, but in our part of the solar system, there's just too much sunlight and reflected interplanetary dust that scatters the light around into a hazy fog that obscures the faint light from the distant universe," added co-author Tod Lauer, a New Horizons co-investigator and astronomer from the National Science Foundation NOIRLab. "All attempts to measure the strength of the COB from the inner solar system suffer from large uncertainties."

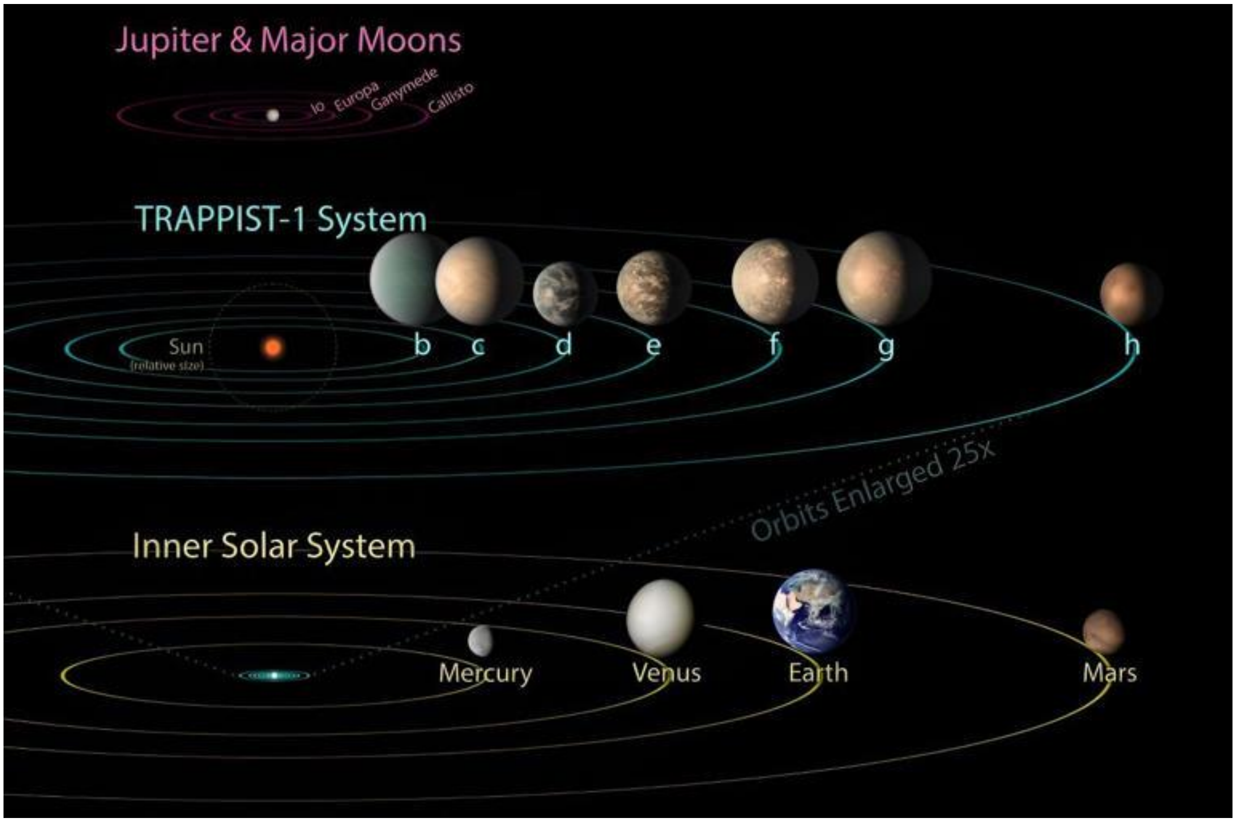
The latest measurements take advantage of new techniques to better estimate the dust not in the Solar System, but in the Milky Way, so that diffuse starlight from our galaxy doesn't erroneously add to the total for the COB. The results tell us where the visible light comes from. There are no sources that are unexpected.

"The simplest interpretation is that the COB is completely due to galaxies," Lauer said. "Looking outside the galaxies, we find darkness there and nothing more."

"This newly published work is an important contribution to fundamental cosmology, and really something that could only be done with a far-away spacecraft like New Horizons," said Alan Stern, principal investigator on New Horizons. "And it shows that our current extended mission is making important scientific contributions far beyond the original intent of this planetary mission designed to make the first close spacecraft explorations of Pluto and Kuiper Belt objects."

This brings into question an important claim from the last decade: how many galaxies are out there in the visible universe? An estimate put the number at 2 trillion, 10 times more than the previous one of 200 billion, but New Horizons data didn't support that. The new work is consistent with the 2021 data and with an even smaller uncertainty.

The study is published in The Astrophysical Journal.



All seven planets discovered in orbit around the red dwarf star TRAPPIST-1 could easily fit inside the orbit of Mercury, the innermost planet of our solar system. In fact, they would have room to spare. TRAPPIST-1 also is only a fraction of the size of our sun; it isn't much larger than Jupiter. So, the TRAPPIST-1 system's proportions look more like Jupiter and its moons than those of our solar system. Credit: NASA/JPL-Caltech/R. Hurt, T. Pyle (IPAC)

Planets are bodies that orbit a star and have sufficient gravitational mass that they form themselves into roughly spherical shapes that, in turn, exert gravitational force on smaller objects around them, such as asteroids and moons.

For most of human history, the only planets our ancestors knew of were those they could see in the night sky. But in the last 30 years, telescopes sensitive enough to infer the presence of exoplanets—planets outside our own solar system—have been developed.

Exoplanets are, of course, much more difficult to directly observe than stars and galaxies. Almost all exoplanet discoveries, particularly starting around 2010, have been based on photometric measurements (the amount of light received) of the exoplanets' host stars, rather than of the planets themselves. This is called the transit method.

Now, with the help of the Spitzer Space Telescope, which made its own first exoplanet detection in 2005; the Kepler/KW Space Telescope, specifically designed to search for exoplanets; and the James Webb Space Telescope, launched in 2021, the transit method and other techniques have confirmed the existence of more than 5,000 exoplanets inhabiting thousands of star systems.

"When we had only our own solar system to analyze, one could just assume that the planets formed in the places where we find them today," says Gabriele Pichierri, postdoctoral scholar research associate in planetary science at Caltech, working in the group of Professor of Planetary Science Konstantin Batygin.

"However, when we discovered even the first exoplanet in 1995, we had to reconsider this assumption. We are developing better models for how planets are formed and how they come to be in the orientations we find them in."

Most exoplanets form out of the disk of gas and dust around newly formed stars and are then expected to migrate inward approaching the inner boundary of this disk. This assembles planetary systems that are much closer to the host star than is the case in our own solar system.

In the absence of other factors, planets will tend to space themselves apart from one another at characteristic distances based on their masses and gravitational forces between the planets and their host star. "This is the standard migration process," Pichierri explains.

"The positions of the planets form resonances between their orbital periods. If you take the orbital period of one planet and then you divide it by the orbital period of its neighboring planet, you get a ratio of simple integers, such as 3:2."

So, for example, if one planet takes two days to orbit around its star, the next planet, farther out, will take three days. If that second planet and a third one farther out are also in a 3:2 resonance, then the third planet's orbital period will be 4.5 days.

The Trappist-1 system, which hosts seven planets and is located about 40 light years from Earth, is a special one for multiple reasons. "The outer planets behave properly, so to speak, with the simpler expected resonances," Pichierri says. "But the inner ones have resonances that are a bit spicier."

The ratio between planet b and c's orbits is 8:5, for example, and that between c and d is 5:3. "This narrow discrepancy in the outcome of Trappist-1's assembly is puzzling and represents a wonderful opportunity to figure out in detail what other processes were at play in its assembly," he says.

"In addition, most planetary systems are thought to have started in these resonant states but have encountered significant instabilities in their lifespan before we observe them today," Pichierri explains. "Most planets go unstable or collide with one another, and everything gets shuffled.

"Our own solar system, for example, was affected by such an instability. But we know of a few systems that have remained stable, that are more or less pristine specimens. They, in effect, exhibit a record of their entire dynamical history that we can then attempt to reconstruct. Trappist-1 is one of these."

The challenge then was to develop a model that could explain the orbits of the Trappist-1 planets and how they reached their current configuration.

The resulting model suggests that the inner four planets initially evolved alone in the expected 3:2 resonance chain. It was only as the disk's inner boundary expanded outward that their orbits relaxed out of the tighter 3:2 chain into the configuration we observe today.

The fourth planet, which originally sat on the inner boundary of the disk, moving farther out along with it, was later pushed back inward when three additional outer planets joined the planetary system at a later stage.

The paper containing this research, titled "Forming the Trappist-1 system in two steps during the recession of the disk inner edge," is published in *Nature Astronomy*.

"By looking at Trappist-1, we have been able to test exciting new hypotheses for the evolution of planetary systems," Pichierri says. "Trappist-1 is very interesting because it is so intricate; it's a long planetary chain. And it's a great exemplar for testing alternative theories about planetary system formation."

More information: Gabriele Pichierri et al, The formation of the TRAPPIST-1 system in two steps during the recession of the disk inner edge, *Nature Astronomy* (2024). DOI: 10.1038/s41550-024-02342-4. On *arXiv* DOI: 10.48550/arxiv.2406.08677

Where does a galaxy end and deep space begin? A recently published study on a gas clouds provides a bit of clarity on this question.

Galaxies aren't isolated entities floating in the void. They're surrounded by an invisible cloud of gas called the circumgalactic medium (CGM), which engulfs the visible galactic disc.

This gaseous halo constitutes about 70% of the galaxy's mass excluding dark matter. Elusive till now, we've only been able to observe it indirectly, through the light absorbed from a background object like a quasar.

Piercing through the cosmic veil

Imagine trying to visualize an entire forest through a narrow beam of light. That's pretty much the challenge scientists faced while studying the gaseous cloud, until now.

However, a cutting-edge study has pierced through this cosmic veil, observing the CGM of a galaxy located a whopping 270 million light years away.

The observed gas cloud extends a colossal 100,000 light years into space, while the starlight from the galaxy's disc, the part we see, extends only 7,800 light years from its center.

Galaxy's gas in action

The lead author of the paper is Associate Professor Nikole M. Nielsen, a researcher with Swinburne University and ASTRO 3D, and an Assistant Professor at the University of Oklahoma.

With an ensemble of researchers from across the globe, they studied the connection between hydrogen and oxygen from the galaxy's center to the far ends of space.

Galaxy's influence

"We found it everywhere we looked, which was really exciting and kind of surprising," says Dr. Nielsen. This observation traces out where the galaxy's influence ceases and where it becomes a part of what's surrounding the galaxy.

It's like encountering a line in the cosmic sand, dividing the interstellar medium of the galaxy from its CGM.

Galaxy's gas cloud conditions

"In the CGM, the gas is being heated by something other than typical conditions inside galaxies, this likely includes heating from the diffuse emissions from the collective galaxies in the Universe and possibly some contribution is due to shocks," says Dr Nielsen.

"It's this interesting change that is important and provides some answers to the question of where a galaxy ends," she says.

The Keck Cosmic Web Imager (KCWI) on the 10-meter Keck telescope in Hawaii made this groundbreaking discovery feasible.

"These one-of-a-kind observations require the very dark sky that is only available at the Keck Observatory on Mauna Kea," said one of the paper's authors, Swinburne's Associate Professor Deanne Fisher.

The KCWI allows scientists to capture thousands of spectra simultaneously, changing how we measure and quantify the diffuse gas around galaxies.

Thanks to this instrument, it's the first time we've managed to take a snapshot of a galaxy's halo. This marks a revolutionary step in our understanding of galaxies.

Piecing together the galactic puzzle

The circumgalactic medium plays a huge role in that cycling of that gas.

According to Dr. Nielsen, being able to understand what the CGM looks like around galaxies of different types -- ones that are star-forming, those that are no longer star-forming, and those that are transitioning between the two -- we can observe differences in this gas.

"This might drive the differences within the galaxies themselves, and changes in this reservoir may actually be driving the changes in the galaxy itself," Dr. Nielsen explained.

How do galaxies evolve? How do they get their gas? Where does that gas go? The study adds another piece in solving the puzzle that is galaxy evolution. The CGM plays a vital role in the cycling of the gas, fueling galaxies' growth over time.

By observing difference in gas around varied types of galaxies -- star-forming, non-star-forming, and transitioning -- it unfolds the granular picture of how galaxies change and interact, and the potential impact they might have on each other.

So, the next time you look up at the sky, try to imagine the cosmic dance unfolding in front of your eyes – galaxies intermingling, evolving, and forming the universe as we know it.

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

When speaking of our universe, it's often said that "matter tells spacetime how to curve, and curved spacetime tells matter how to move." This is the essence of Albert Einstein's famous general theory of relativity, and describes how planets, stars, and galaxies move and influence the space around them. While general relativity captures much of the big in our universe, it's at odds with the small in physics as described by quantum mechanics.

For his Ph.D. research, Sjors Heefer has explored gravity in our universe, with his research having implications for the exciting field of gravitational waves, and perhaps influencing how the big and small of physics can be reconciled in the future.

A little over a hundred years ago, Albert Einstein revolutionized our understanding of gravity with his general theory of relativity.

"According to Einstein's theory, gravity is not a force but emerges due to the geometry of the four-dimensional spacetime continuum, or spacetime for short," says Heefer. "And it's central to the emergence of fascinating phenomena in our universe such as gravitational waves."

Massive objects, such as the sun or galaxies, warp spacetime around them, and other objects then move along the straightest possible paths—otherwise known as geodesics—through this curved spacetime.

Due to the curvature, however, these geodesics are not straight in the usual sense at all. In the case of the planets in the solar system, for instance, they describe elliptical orbits around the sun. In this way, general relativity elegantly explains the movement of the planets as well as numerous other gravitational phenomena, ranging from everyday situations to black holes and the Big Bang. As such, it remains a cornerstone of modern physics.

Clash of the theories

While general relativity describes a host of astrophysical phenomena, it clashes with another fundamental theory of physics—quantum mechanics.

"Quantum mechanics suggests that particles (like electrons or muons) exist in multiple states at the same time until they are measured or observed," says Heefer. "Once measured, they randomly select a state due to a mysterious effect referred to as the 'collapse of the wave function.'"

In quantum mechanics, a wave function is a mathematical expression that describes the position and state of a particle, such as an electron. And the square of the wave function leads to a collection of probabilities of where the particle might be located. The larger the square of the wave function at a particular location, the higher the probability that a particle will be located at that location once it is observed.

"All matter in our universe appears to be subject to the strange probabilistic laws of quantum mechanics," Heefer notes. "And the same is true for all forces of nature—except for gravity. This discrepancy leads to deep philosophical and mathematical paradoxes, and resolving these is one of the primary challenges in fundamental physics today."

Is expansion the solution?

One approach to resolving the clash of general relativity and quantum mechanics is to expand the mathematical framework behind general relativity.

In terms of mathematics, general relativity is based on pseudo-Riemannian geometry, which is a mathematical language capable of describing most of the typical shapes that spacetime can take.

"Recent discoveries indicate, however, that our universe's spacetime might be outside the scope of pseudo-Riemannian geometry and can only be described by Finsler geometry, a more advanced mathematical language," says Heefer.

Field equations

To explore the possibilities of Finsler gravity, Heefer needed to analyze and solve a certain field equation.

Physicists like to describe everything in nature in terms of fields. In physics, a field is simply something that has a value at each point in space and time.

A simple example would be temperature, for instance; at any given point in time, each point in space has a certain temperature associated with it.

A slightly more complex example is that of the electromagnetic field. At any given point in time, the value of the electromagnetic field at a certain point in space tells us the direction and magnitude of the electromagnetic force that a charged particle, like an electron, would experience if it were located at that point.

When it comes to the geometry of spacetime itself, that is also described by a field, namely the gravitational field. The value of this field at a point in spacetime tells us the curvature of spacetime at that point, and it is this curvature that manifests itself as gravity.

Heefer turned to the Christian Pfeifer and Mattias N. R. Wohlfarth's vacuum field equation, which is the equation that governs this gravitational field in empty space. In other words, this equation describes the possible shapes that the geometry of spacetime could take in the absence of matter.

Heefer explains, "To good approximation, this includes all interstellar space between stars and galaxies, as well as the empty space surrounding objects such as the sun and the Earth. By carefully analyzing the field equation, several new types of spacetime geometries have been identified."

Gravitational waves confirmation

One particularly exciting discovery from Heefer's work involves a class of spacetime geometries that represent gravitational waves—ripples in the fabric of spacetime that propagate at the speed of light and can be caused by the collision of neutron stars or black holes, for example.

The first direct detection of gravitational waves on September 14, 2015, marked the dawn of a new era in astronomy, allowing scientists to explore the universe in an entirely new way.

Since then, many observations of gravitational waves have been made. Heefer's research indicates that these are all consistent with the hypothesis that our spacetime has a Finslerian nature.

Scratching the surface

While Heefer's results are promising, they only scratch the surface of the implications of the field equation of Finsler gravity.

"The field is still young and further research in this direction is actively ongoing," says Heefer. "I'm optimistic that our results will prove instrumental in deepening our understanding of gravity and I hope that, eventually, they may even shine light on the reconciliation of gravity with quantum mechanics."

More information: S.J. Heefer, Finsler Geometry, Spacetime & Gravity (2024)

Provided by Eindhoven University of Technology

How were massive galaxies able to exist in the early years of the universe long before scientists say it should have been possible? According to a new study, the answer is incredibly simple: The galaxies weren't as big as we thought.

This finding finally answers a major mystery of astrophysics, which first cropped up thanks to the capabilities of NASA's James Webb Space Telescope. In other words, while the camera may add 10 pounds, the space telescope adds a massive number of stars that defy the laws of physics.

The findings of this study were published in the peer-reviewed academic periodical *The Astronomical Journal*.

Caution: Objects in the James Webb Space Telescope are smaller than they appear

Galaxies are gigantic accumulations of matter, being huge networks of stars, rocks, dust, gas, and more all formed into one enormous structure floating in space.

These galaxies are often ancient, many of them dating back to the earliest years of the universe. Over time, these galaxies grow and evolve, many times merging together and accreting more matter to form truly large galaxies. For example, the Milky Way Galaxy merged with several other galaxies, including the Sausage Galaxy and the still theorized Kraken Galaxy, both of which happened within the last 11 billion years. This made it the massive galaxy it is today, despite it having been formed some 13.6 billion years ago.

An artisitc illustration of a quasar and supermassive black hole from the early universe. (credit: Wikimedia Commons)
Because of this, when NASA was able to look at galaxies just a few hundred million years after the Big Bang thanks to the James Webb Space Telescope, they expected to find small galaxies in the early stages of their life.

However, that's not what they found. Instead, they discovered some truly enormous galaxies, ones that were so big - close in size to the Milky Way as it is now - that they defied all explanation, threatening to upend some of our foundational understandings of the universe.

One of the researchers behind these early studies on these impossible galaxies, Erica Nelson, summed up this puzzling discovery by saying, "It's bananas."

However, a new study by University of Texas at Austin graduate student Katherine Chworowsky may have solved this issue. Simply put, the galaxies in question aren't as big as they seem. They just look that way.

So how is that possible?

Well, the answer lies at the literal heart of these galaxies: The supermassive black holes that reside at their cores.

Supermassive black holes are commonly found at the center of most galaxies. The Milky Way, for instance, is home to Sagittarius A* at our galactic core. These enormous concentrations of gravity are impossibly hungry maws that pull in everything around them, letting nothing escape - not even light.

This last point will be incredibly confusing to the layperson since the study posits that these galaxies seem so huge because of the light emitted by these galactic cores.

But while this seems like a contradiction, it makes sense - it's just as complicated as astrophysics often is.

It must pull it in when supermassive black holes consume matter such as gas. This makes the gas move incredibly fast, with gas particles brushing against one another. This creates friction, and friction creates both heat and light. The more gas that is being consumed at this speed, the more light and heat gets emitted.

There are numerous examples of this happening throughout space. In fact, the brightest objects in existence, quasars, are caused by active supermassive black holes at the center of galaxies consuming so much matter that emits a brightness level unlike anything else.

So how does being brighter lead to scientists thinking galaxies are larger than they actually are?

Stars are also sources of brightness. Often, the brighter a galaxy is, the more stars there must be there. As such, the larger the galaxy, the brighter we often expect it to be. But if the brightness is caused by the supermassive black hole and not the number of stars, then scientists may have misjudged the actual size of the galaxies.

If this is true, then that's one mystery solved. Yes, there are still galaxies from the early years of the universe, but while many are indeed large, they aren't big enough to shatter the standard model of cosmology.

But there is still one lingering problem with all of this. The galaxies may not be impossibly large, but the sheer number of galaxies shouldn't be possible either.

However, this is nowhere near as science-shattering of a problem as the previous one. It simply means that more galaxies formed than we thought possible - and there is a theoretical explanation for this, too: Stars may have formed a lot faster back then. This, too, makes some sense, as the universe would likely have been denser back then before it had billions of years of expansion behind it.

Further research will be needed to confirm these findings as they further add to the growing body of literature, both adding to and challenging our knowledge of the universe.

One of the greatest challenges of modern physics is to find a coherent method for describing phenomena, on the cosmic and microscale. For over a hundred years, to describe reality on a cosmic scale we have been using general relativity theory, which has successfully undergone repeated attempts at falsification.

Albert Einstein curved space-time to describe gravity, and despite still-open questions about dark matter or dark energy, it seems, today, to be the best method of analyzing the past and future of the universe.

To describe phenomena on the scale of atoms, we use the second great theory: quantum mechanics, which differs from general relativity in basically everything. It uses flat space-time and a completely different mathematical apparatus, and most importantly, perceives reality radically differently.

In the quantum description, the phenomena around us are only wavering probabilities of events that we can only measure with limited accuracy.

In an article, published in *Frontiers in Physics*, I managed to demonstrate that there is a method that combines the above descriptions, although it leads to quite a surprising conclusion.

Can curved space-time be straightened?

It turns out that there is a certain mathematical object called the Alena Tensor, which allows the description of physical phenomena in such a way that the curvature of space-time can be smoothly adjusted as if using a slider. In curved space-time, equation naturally transforms into Einstein Field Equations, and in flat space-time it allows the use of classical methods of relativistic physics and, most importantly, it is subject to quantum description.

So far, I have managed to demonstrate that such a space-time slider works for gravity and electromagnetism, and that the Alena Tensor allows to add further fields. It therefore seems possible to reconcile previously contradictory descriptions for other known fields.

A side effect of using the above method is that a certain element of the equation (the field invariant) behaves like a cosmological constant in Einstein Field Equations, which may help explain the nature of dark energy. It also turns out that there must be an additional force in addition to gravity, which could help explain the nature of dark matter.

However, everything that looks beautiful has its price...

What is the universe around us?

The conclusions of the article do not mean the end of work on combining both great theories. The proposed method requires much further research and careful adjustment of field descriptions. There is certainly new hope and a promising new direction for further research, so perhaps we will soon hear about more fields aligned with the space-time slider.

However, there is a certain price associated with using the proposed method, which seems to be the biggest challenge. If the method I have developed turns out to be the right one that we have been looking for 100 years, it will also mean that the entire world around us is just a constantly waving field, and space-time itself is only a way of perceiving this field. This is the most extraordinary conclusion resulting from the equations described by Alena Tensor.

This story is part of Science X Dialog, where researchers can report findings from their published research articles. Visit this page for information about ScienceX Dialog and how to participate.

More information: Piotr Ogonowski, Developed method: interactions and their quantum picture, *Frontiers in Physics* (2023). DOI: 10.3389/fphy.2023.1264925. www.frontiersin.org/articles/1 ... 89/fphy.2023.1264925

Piotr Ogonowski is a researcher, manager and lecturer with over 20 years of experience. He currently works as a lecturer for Kozminski University, Wasaw, Poland.

A mathematical link between two key equations—one that deals with the very big and the other, the very small—has been developed by a young mathematician in China.

The mathematical discipline known as differential geometry is concerned with the geometry of smooth shapes and spaces. With roots going back to antiquity, the field flourished in the early 20th century, enabling Einstein to develop his general theory of relativity and other physicists to develop quantum field theory and the Standard Model of particle physics.

Gao Chen, a 29-year-old mathematician at the University of Science and Technology of China in Hefei, specializes in a branch known as complex differential geometry. Its complexity is not in dealing with complicated structures, but rather because it is based on complex numbers—a system of numbers that extends everyday numbers by including the square root of -1.

This area appeals to Chen because of its connections with other fields. "Complex differential geometry lies at the intersection of analysis, algebra, and mathematical physics," he says. "Many tools can be used to study this area."

Chen has now found a new link between two important equations in the field: the Kähler–Einstein equation, which describes how mass causes curvature in space–time in general relativity, and the Hermitian–Yang–Mills equation, which underpins the Standard Model of particle physics.

Chen was inspired by his Ph.D. supervisor Xiuxiong Chen of New York's Stony Brook University, to take on the problem. "Finding solutions to the Hermitian–Yang–Mills and the Kähler–Einstein equations are considered the most important advances in complex differential geometry in previous decades," says Gao Chen. "My results provide a connection between these two key results."

"The Kähler –Einstein equation describes very large things, as large as the universe, whereas the Hermitian–Yang–Mills equation describes tiny things, as small as quantum phenomena," explains Gao Chen. "I've built a bridge between these two equations." Gao Chen notes that other bridges existed previously, but that he has found a new one.

"This bridge provides a new key, a new tool for theoretical research in this field," Gao Chen adds. His paper describing this bridge was published in the journal *Inventiones mathematicae* in 2021.

In particular, the finding could find use in string theory—the leading contender of theories that researchers are developing in their quest to unite quantum physics and relativity. "The deformed Hermitian–Yang–Mills equation that I studied plays an important role in the study of string theory," notes Gao Chen.

Gao Chen now has his eyes set on other important problems, including one of the seven Millennium Prize Problems. These are considered the most challenging in the field by mathematicians and carry a $1 million prize for a correct solution. "In the future, I hope to tackle a generalization of the Kähler–Einstein equation," he says. "I also hope to work on other Millennium Prize problems, including the Hodge conjecture."

The Universe is big, as Douglas Adams would say.

The most distant light we can see is the cosmic microwave background (CMB), which has taken more than 13 billion years to reach us. This marks the edge of the observable Universe, and while you might think that means the Universe is 26 billion light-years across, thanks to cosmic expansion, it is now closer to 46 billion light-years across. By any measure, this is pretty darn big. But most cosmologists think the Universe is much larger than our observable corner of it. What we can see is a small part of an unimaginably vast, if not infinite, creation. However, a new paper argues that the observable Universe is mostly all there is.

In other words, on a cosmic scale, the Universe is quite small.

There are several reasons why cosmologists think the Universe is large. One is the distribution of galaxy clusters. If the Universe didn't extend beyond what we see, the most distant galaxies would feel a gravitational pull toward our region of the cosmos but not away from us, leading to asymmetrical clustering since galaxies cluster at around the same scale throughout the visible Universe. In other words, the observable Universe is homogenous and isotropic.

The second point is that spacetime is flat. If spacetime weren't flat, our view of distant galaxies would be distorted, making them appear much larger or smaller than they actually are. Distant galaxies do appear slightly larger due to cosmic expansion, but not in a way that implies an overall curvature to spacetime. Based on the limits of our observations, the flatness of the cosmos implies it is at least 400 times larger than the observable Universe.

Then, there is the fact that the cosmic microwave background is almost a perfect blackbody. There are small fluctuations in its temperature, but it is much more uniform than it should be. To account for this, astronomers have proposed a period of tremendous expansion just after the Big Bang, known as early cosmic inflation. We have not observed any direct evidence of it, but the model solves so many cosmological problems that it's widely accepted. If the model is accurate, then the Universe is on the order of 1026 times larger than the observable Universe.

So, given all of this theoretical and observational evidence, how could anyone argue that the Universe is small? It has to do with string theory and the swamplands.

Although string theory is often presented as a physical theory, it's actually a collection of mathematical methods. It can be used in the development of complex physical models, but it can also just be mathematics for its own sake. One of the problems with connecting the mathematics of string theory to physical models is that the effects would only be seen in the most extreme situations, and we don't have enough observational data to rule out various models. However, some string theory models appear much more promising than others. For example, some models are compatible with quantum gravity, and others are not. So often, theorists will define a "swampland" of theories that aren't promising.

When you separate the promising theoretical lands from the swamp, what you are left with are theories where early cosmic inflation isn't an option. Most of the inflationary string theory models are in the swampland. This leads one to ask whether you could construct a model cosmology that matches observation without early inflation, which brings us to this new study.

One way to get around early cosmic inflation is to look at higher-dimensional structures. Classic general relativity relies upon four physical dimensions, three of space and one of time, or 3+1. Mathematically, you could imagine a 3+2 universe or 4+1, where the global structure can be embedded into an effective 3+1 structure. This is a common approach in string theory since it isn't limited to the standard structure of general relativity. The authors demonstrate that under just the right conditions, you could construct a higher-dimensional structure within string theory that matches observation and avoids the swampland. Based on their toy models, the Universe may only be a hundred or a thousand times larger than the observed Universe. It's still big but downright tiny when compared to the early inflation models.

All of this is pretty speculative, but in a way, so is early cosmic inflation. If early cosmic inflation is true, we should be able to observe its effect through gravitational waves in the somewhat near future. If that fails, it might be worth looking more closely at string theory models that keep us out of the theoretical swamp.

Galaxies are beautiful concentrations of stars clustered by gravitational attraction. After studying these galaxies for ages, astronomers have classified galaxies into three major categories: the spirals, the ellipticals, and the irregulars, which do not fit into the other categories.

In an attempt to identify other categories of early galaxies, a NASA research team went on to analyze images from NASA's James Webb Space Telescope, according to a press release published January 17.

For this study, the team focused on a vast field of near-infrared images delivered by Webb, known as the Cosmic Evolution Early Release Science (CEERS) Survey.

The researchers based their focus on the distant galaxies estimated to exist when the universe was 600 million to six billion years old and concluded that galaxies in the early universe are often flat and elongated, like surfboards and pool noodles, and are very rare.

The lead author, Viraj Pandya, a NASA Hubble Fellow at Columbia University in New York, noted that about 50 to 80 percent of the galaxies we studied appear to be flattened in two dimensions. This led the team to believe that these flattened galaxies appearing as surfboards or pool noodles must have been common in the early universe.

As opposed to the distant galaxies, which appeared like surfboards or pool noodles, other galaxies were sphere-shaped and looked like frisbees. Surprisingly, the galaxies that look like pool noodles, which are unpopular nearby, were more common in the early universe, as the sphere-shaped ones were the least frequently identified.

"Identifying additional categories for early galaxies is exciting – there's much more to analyze now. We can now study how galaxies' shapes relate to how they look and better project how they formed in much more detail," stated Kartheik Iyer, a co-author and NASA Hubble Fellow at Columbia University.

What category would the Milky Way Galaxy fall under a billion years ago?

The Milky Way is called a barred spiral galaxy because it looks like a spinning pinwheel when viewed from the top or bottom. However, Webb's images of the early universe have provided new evidence to make one question what category this galaxy would have fallen into a billion years ago.

The study's co-author, Haowen Zhang, a Ph.D. candidate at the University of Arizona in Tucson, asserted that the Milky Way would have most probably appeared as a surfboard at the time. Zhang explained that some theorists rewound the clock to estimate the Milky Way's mass billions of years, correlating with the shape at that time.

The flat and elongated galaxies that have now been established to have been common in the early universe are also smaller than the nearby spirals and ellipticals. Iyer explained that the reason behind this difference in size might be because the galaxies in the early universe, which are the precursors to the bigger ones, had less time to grow at the time.

Webb showed many distant galaxies with similar shapes, all in great detail in its new images. That said, the researchers noted that there are still gaps in their knowledge of these distant galaxies. Hence, they are looking forward to even larger samples from Webb to determine the precise locations of these distant galaxies and study them better.

Time Travel Equation Solved By Astrophysicist

After a lifetime of pursuing the idea, Physics Professor Ronald Mallett at the University of Connecticut has potentially figured out the theoretical aspects of time travel. Professor Mallett believes that black holes, rotating light, and gravitational pulls may hold the key to exploring time, but it's all theoretical for now. There are still a lot of hurdles and limitations to handle before time travel can have real, practical applications.

A Life Spent Thinking About Time Travel

Love and loss pushed Professor Mallett into an obsession with time and space. When he was 10 years old, his father passed away from a heart attack. It was his father who nourished his love of science, but H.G. Wells' book The Time Machine pushed him towards a focus on time travel.

He was hooked from the very first paragraph of the book, "Scientific people know very well that Time is only a kind of Space. And why cannot we move in Time as we move about in the other dimensions of Space?"

That paragraph never left him, and the professor let that time travel question guide him through school and into the Professor Emeritus of Physics position at the University of Connecticut.

Einstein And Black Holes

As he grew up, Professor Mallett spent much of his time on Albert Einstein's theories about black holes. While his interest in time travel only continued to grow, a potential solution never showed itself. At least, not until the professor ended up in a hospital with a heart condition.

There, lying in the hospital bed, inspiration hit him. Black holes and the gravitational fields they created were the answer to time travel. These gravitational fields had the potential to lead to time loops, which then theoretically could allow people and objects to travel back in time.

Black Holes Manipulating Gravity

While this idea offered an ability to manipulate time, the other problem was how to use these time loops for time travel.

Professor Mallett found this time travel solution much easier than the first problem. Strong and continuous beams of light, like a ring of lasers, with a particular rotation could be used to manipulate gravity and mimic the distorting effects of a black hole.

Space-Time

Though the details are rather complicated, the big time travel picture is a lot simpler to grasp. The professor offers a comparison to help people understand. “Let’s say you have a cup of coffee in front of you. Start stirring the coffee with the spoon. It started to spin, right? That’s what a spinning black hole does. In Einstein’s theory, space and time are related to each other. That’s why it’s called space-time. So when the black hole spins, it will actually cause time to shift.”

Much To Figure Out

Professor Mallett may now have a theory on time travel and a machine to use to make it possible, but that doesn’t mean it will be here in the next few decades.

There’s still a lot to figure out to make such travel practical, such as where the insane amount of energy such a machine would require could come from, and how big the machine would need to be.

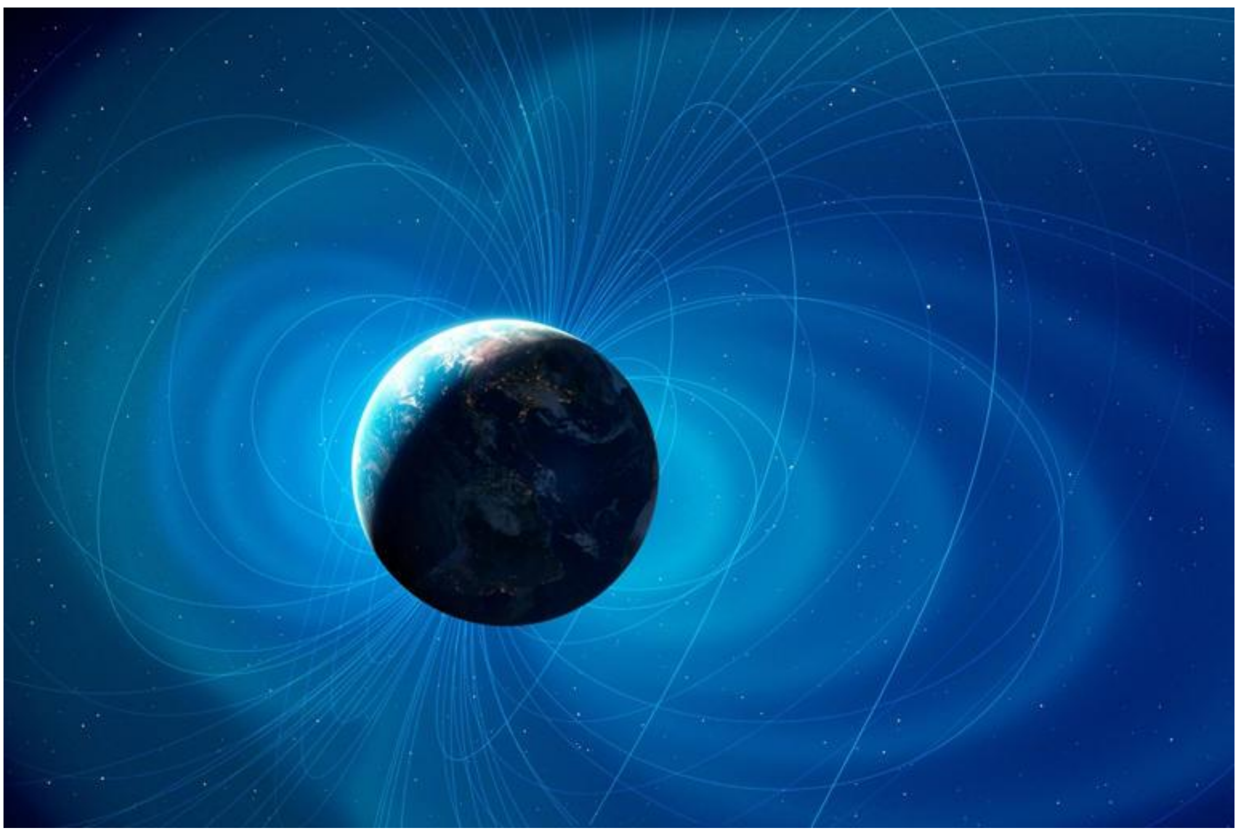
There’s also a major constraint on the machine. According to his theories, time travel would only be possible to the very beginning of when the machine was first built. In this way, it’s more like a one-way message service. You can potentially go forward quite a distance, but going back in time is limited by the machine’s creation.

Theoretical Aspects Of Time Travel

The professor has made a huge leap in figuring out the theoretical aspects of time travel, but there's a lot more to discover and quite a few hurdles and paradoxes to figure out before scientists practically start messing around in time.

Still, the theory is a step in the right direction and does suggest that people can push past what science currently considers possible.

Source: Earth.com



The Endurance rocket was able to discover a force that had been theorized for decades which will help expand our knowledge of the Earth and other planets.

Humans believe they know everything about their surroundings, yet something like the planet Earth on which we live continues to hide a multitude of mysteries that never cease to surprise us. Until now, two energy fields created by the planet itself were known, **but after more than 60 years of searching, a third field, known as ambipolar, has been found** thanks to NASA's Endurance rocket that was launched in May 2022 from Svalbard, an island north of Norway.

The fields created by planet Earth are as follows:

Gravitational field: It is responsible for maintaining our atmosphere and if there were not enough gravity it would go into space.

Magnetic field: The shield that protects planet Earth from the solar wind, the stream of charged particles released by the sun.

Ambipolar field: Counteracts gravity and ejects particles into space. According to scientists, it is as fundamental to the way our planet works as the other two fields.

A historic discovery for science

Space physicist Suzie Imber of the University of Leicester in the UK, co-author of the study on the discovery published in the journal **Nature**, said that **"Svalbard is the only rocket field in the world where you can fly through the polar wind and make the measurements that we needed."** Regarding the discovered field, Glyn Collinson, principal investigator of the mission, confessed that **it was thought that "there must be some invisible force lurking there responsible for this outflow.** But we've never been able to measure this before because we haven't had the technology."

The ambipolar field is **a weak electric field that runs through the entire planet Earth and is as fundamental to its functioning as gravity and the magnetosphere.** An invisible energy field that "lifts the skies up" by shaping the ionosphere. Its discovery raises many questions that can begin to be answered.

"Any planet with an atmosphere should have an ambipolar field," Collinson said. **"Now that we've finally measured it, we can begin learning how it's shaped our planet as well as others over time."**

Why is it called ambipolar?

The field is so called because it works in both directions, with the ions pulling the electrons down as they sink under gravity, and at the same time, the electrons lifting the ions to greater heights as they try to escape into space. The ambipolar field lifts charged particles in our upper atmosphere to heights they would not otherwise reach, **and so may have shaped the evolution of the planet in ways that are still unknown.**

You can best view the Milky Way from places with little or no light pollution. This photo was taken at Royal National Park in Sydney, Australia. Luke Peterson Photography / Getty Images

When you gaze up at the night sky, there's a soft, sweeping band of light that is impossible to miss. This mesmerizing strip, evident near the horizon and arching across the expanse, has been a subject of human fascination for ages. The ancient Greeks named it "galaxies kuklos," or "milk circle," and the Romans dubbed it the "**Milky Way**."

It was in the year 1610 that Galileo Galilei, with the aid of one of the first telescopes, began to decipher this celestial glow. His groundbreaking observations revealed a breathtaking fact: the Milky Way's radiance is a result of billions of dim stars enveloping our cosmic vicinity.

With that pivotal revelation in mind, join us on a journey of discovery as we explore our very own galaxy. We'll explore its size, shape and structure, discuss the movement of its stars and see how it compares to other galaxies.

Exploring the Milky Way From Inside the Galaxy

The Milky Way, our celestial home, has fascinated astronomers for centuries. It is a vast galaxy, a large system that includes stars, gas (predominantly hydrogen), dust and dark matter, all bound together by gravity.

As we navigate through the cosmos, an intriguing enigma emerges: What is the Milky Way truly like? What is it composed of, and what is its shape? These fundamental questions have puzzled astronomers for generations, and finding answers was no easy task.

One significant challenge arises from our unique perspective: We reside inside the Milky Way, which makes it hard to discern its form and contents. Early astronomers faced many limitations due to the technology of their time, including relatively small telescopes with limited range and magnification capabilities, which could only detect visible light.

On top of that, their view of the Milky Way was obstructed because it is shrouded in cosmic dust, akin to peering through a relentless dust storm. They once thought it contained all the stars in the sky.

Thankfully, the 20th century ushered in remarkable advancements in telescope technology, enabling astronomers to pierce through this celestial haze and peer deep into space. These powerful instruments unveiled an astonishing truth: The Milky Way is not a mere collection of stars but a galaxy with a graceful spiral shape. And contrary to popular belief, our solar system does not sit at the center of it.

This newfound knowledge highlights the sheer vastness of the universe, as the Milky Way is just one among countless galaxies that populate the cosmos. Now let's look at some early theories about our humble galaxy.

Early Milky Way Theories

As we mentioned, Galileo discovered that the Milky Way is made of dim stars, which look less bright than other stars, either because they give off less light or because they're far away from us.

So we know the composition of the galaxy, but what about its shape? How can you tell the shape of something if you're inside it? In the late 1700s, astronomer Sir William Herschel addressed this question.

Herschel reasoned that if the Milky Way was a sphere, we should see numerous stars in all directions. So, he and his sister Caroline counted the all stars in more than 600 areas of the sky.

They found that there were more stars in the directions of the band of the Milky Way than above and below. Herschel concluded that the Milky Way was a disk-shaped structure. And because he found about the same numbers of stars in all directions along the disk, he concluded that the sun was near the center of the disk.

Around 1920, a Dutch astronomer named Jacobus Kapteyn measured the apparent distances to nearby and remote stars using the technique of parallax. Because parallax involved measuring the motions of stars, he compared the motions of distant stars with nearby ones.

He concluded that the Milky Way was a disc approximately 20 kiloparsecs, or 65,200 light-years, in diameter (one kiloparsec = about 3,260 light-years). Kapetyn also concluded that the sun was at or near the center of the Milky Way.

But future astronomers would question these ideas, and advanced technology would help them dispute the theories and come up with more accurate measurements.

Measuring Distances to the Stars

If you hold your thumb out at arm's length and alternately open and close each eye, you'll notice your thumb appears to shift against the background. This phenomenon is called a "parallax shift." Astronomers observe a similar effect with stars due to Earth's orbit.

By comparing star positions six months apart, they measure this parallax angle (Θ). Using Θ and Earth's orbit radius (R), they calculate a star's distance (D) as: **D = RCotΘ**. This is effective for stars within 50 parsecs. For farther stars, other methods involving luminosity are used.

Globular Clusters and Spiral Nebulae

Around the time that Kapteyn published his model of the Milky Way, his colleague Harlow Shapely noticed that a type of star cluster called a globular cluster had a unique distribution in the sky.

Although few globular clusters were found within the Milky Way band, there were a lot of them above and below it. Shapely decided to map the distribution of globular clusters and measure their distances using variable star markers within the clusters and the luminosity-distance relationship.

According to his observations, globular clusters were found in a spherical distribution and concentrated near the constellation of Sagittarius. Shapely concluded that the center of the galaxy was near Sagittarius, not the sun, and that the Milky Way was about 100 kiloparsecs in diameter.

Shapely was involved in a great debate about the nature of spiral nebulae (faint patches of light visible in the night sky). He believed that they were "island universes," or galaxies outside the Milky Way. Another astronomer, Heber Curtis, believed that spiral nebulae were part of the Milky Way.

Edwin Hubble's observations of Cepheid variables finally settled the debate — the nebulae were indeed outside the Milky Way.

But questions still remained. What shape was the Milky Way, and what exactly existed inside?

What Shape Is the Milky Way?

Hubble studied galaxies and classified them into various types of elliptical and spiral galaxies. The spiral galaxies were characterized by disk shapes with spiral arms. It stood to reason that because the Milky Way was disk-shaped and spiral galaxies were disk-shaped, the Milky Way was probably a spiral galaxy.

In the 1930s, astronomer R.J. Trumpler realized that the estimates of the size of the Milky Way galaxy by Kapteyn and others were off because the measurements relied on observations in the visible wavelengths.

Trumpler concluded that the vast amounts of dust in the plane of the Milky Way absorbed light in the visible wavelengths and caused faraway stars and clusters to appear dimmer than they actually were. Therefore, to accurately map stars and star clusters within the disk of the Milky Way, astronomers would need a way to peer through the dust.

Enter the Radio Telescope

In the 1950s, the first radio telescopes were invented. Astronomers discovered that hydrogen atoms emitted radiation in the radio wavelengths and that these radio waves could penetrate the dust in the Milky Way.

So, it became possible to map each spiral arm of the Milky Way. The key was marker stars like those used in distance measurements. Astronomers found that class O and B stars would work. These stars had several features:

- **Brightness**: They're highly visible and often found in small groups or associations.
- **Heat**: They emit multiple wavelengths (visible, infrared, radio).
- **Short life**: They live for about 100 million years, so, considering the rate at which stars orbit the galaxy's center, they don't move far from where they were born.

Astronomers could use radio telescopes to accurately map the positions of these O and B stars, and use the Doppler shifts of the radio spectrum to determine their rates of motion. When they did this with many stars, they were able to produce combined radio and optical maps of the Milky Way's spiral arms. Each arm is named for the constellations that exist within it.

Astronomers think that the motion of the material around the galactic center sets up density waves (areas of high and low density), much like you see when you stir cake batter with an electric mixer. These density waves are thought to cause the spiral nature of the galaxy.

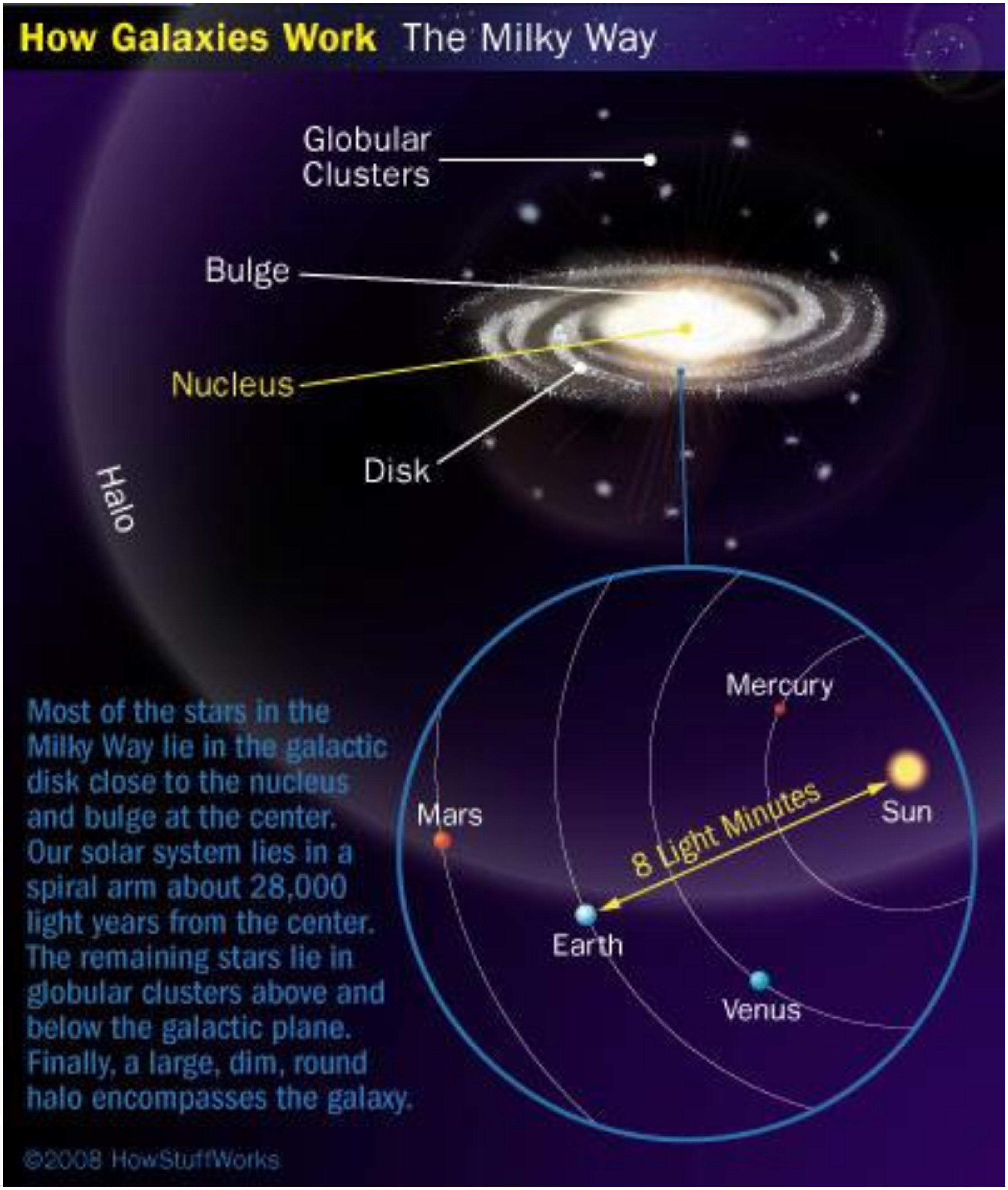
So, by examining the sky in multiple wavelengths (radio, infrared, visible, ultraviolet, X-ray) with various ground- and space-based telescopes, we can get different views of the Milky Way.

The Doppler Effect

Much like the high-pitched sound from a fire-truck siren gets lower as the truck moves away, the movement of stars affects the wavelengths of light that we receive from them. This phenomenon is called the Doppler effect.

We can measure the Doppler effect by measuring lines in a star's spectrum and comparing them to the spectrum of a standard lamp. The amount of the Doppler shift tells us how fast the star is moving relative to us.

In addition, the direction of the Doppler shift can tell us the direction of the star's movement. If the spectrum of a star is shifted to the blue end, it is moving toward us; if the spectrum is shifted to the red end, the star is moving away from us.



The Structure of the Milky Way. 2008 HowStuffWorks

Milky Way Structure

According to Hubble's classification system, the Milky Way is a spiral galaxy, although more recent mapping evidence indicates that it may be a barred spiral galaxy.

The Milky Way has more than hundreds of billions of individual stars. It's approximately 100,000 light-years in diameter, and the sun is located about 28,000 light years from the center. If we look at the structure of the Milky Way as it would appear from the outside, we can see certain parts.

Galactic Disk

The Milky Way's disk consists of both old and young stars, with plentiful gas and dust. Stars in the disk orbit the galactic center in near-circular paths, with slight vertical motion due to gravitational interactions, resembling merry-go-round horses.

The disk has three regions: the nucleus at the center, the bulge around the nucleus extending slightly above and below the disk's plane and the spiral arms radiating outward. Our solar system is located in one of these arms, specifically the Orion Arm. Other arms include the Perseus Arm, Sagittarius Arm and Scutum-Centaurus Arm.

Globular Clusters

Several hundred globular clusters are scattered above and below the plane of the galactic disk, orbiting the galactic center in elliptical paths with randomly scattered directions.

The stars within these clusters are significantly older compared to those in the galactic disk, and the clusters contain little to no gas and dust.

Halo

The halo, a large, dim area surrounding the galaxy, comprises hot gas, dark matter and old stars. Despite the apparent mass in the galaxy's disk and center, rotation curve studies reveal most mass resides in the halo, hinting at dark matter's presence.

The Milky Way's gravity affects two satellite galaxies, the Large and Small Magellanic Clouds, visible from the Southern Hemisphere and orbiting at varying positions around our entire galaxy.

The Large Magellanic Cloud, about 14,000 light-years in diameter and 163,000 light-years away, may lose gas and dust to the Milky Way due to gravitational interactions.

Luminosity-distance Relationship

Astronomers use devices like photometers on telescopes to measure a star's brightness. Knowing a star's brightness and distance allows them to compute its luminosity using the formula: luminosity = brightness x 12.57 x $(\text{distance})^2$.

Luminosity can also indicate a star’s distance from Earth. Stars like RR Lyrae and Cepheid variables, which change brightness predictably, serve as benchmarks.

To determine the luminosities of the globular clusters, Shapely measured the periods of brightness of the RR Lyrae stars in the clusters. Once he knew the luminosities, he could calculate their distances from Earth.

It's complicated, but you can use Newton's version of Kepler's Third Law to figure out how many stars are in the Milky Way. E.L. Wright (UCLA), The COBE Project, DIRBE, NASA

How Many Stars Are in the Milky Way?

We mentioned earlier that astronomers have estimated the number of stars in the Milky Way from measurements of the galaxy's mass. But how do you measure the mass of a galaxy? You obviously can't put it on a scale. Instead, you use its orbital motion.

From Newton's version of Kepler's Third Law of Planetary Motion, the orbital speed of an object in circular orbit and a little algebra, you can derive an equation to calculate the amount of mass (Mr) that lies within any circular orbit with a radius (r):

1. Orbital speed of a circular object **(v) v=2Πa/p**
2. Because it's a circular orbit, **a** becomes radius (**r**) and **M** becomes the mass within that radius (Mr). **Mr rv2/G**

For the Milky Way, the sun lies at a distance of 2.6×10^{20} meters (28,000 light-years) and has an orbital speed of 2.2×10^{5} meters/second (220 km/s), we get that 2×10^{49} kg lies within the sun’s orbit.

Since the sun’s mass is 2×10^{30}, then there must be 10^{11}, or about 100 billion, solar masses (sunlike stars) within its orbit. When we add the portion of the Milky Way that lies outside the sun’s orbit, we get approximately 200 billion stars.

The Keck Telescopes on Mauna Kea (Hawaii), with which the Kuiper Belt was discovered - illustrative photo.© Wikipedia, NASA

Thanks to observations of space using NASA's New Horizons probe, a population of objects in the outer regions of the Solar System has been discovered, reports Cosmos Magazine. Observations indicate that this system was formed from a much larger disk of planetary matter than previously assumed.

The authors of the study, published in the "Planetary Science Journal of the American Astronomical Society," decided to take a closer look at the Kuiper Belt—an area extending beyond Neptune's orbit. It is located at a distance of about 3–5 billion miles from the Sun. At such a great distance, the NASA New Horizons probe, in collaboration with Japan's Subaru telescope, allowed for the discovery of something that scientists had not been able to see before.

Objects far beyond the Kuiper Belt

Both observational instruments discovered objects located beyond the Kuiper Belt—at a distance of 6–8 billion miles from the Sun. Scientists also identified an empty space at a distance of 3–6 billion miles. Only at a greater distance (the aforementioned 6–8 billion miles) were new bodies discovered.

"Our solar system's Kuiper Belt long appeared to be very small in comparison with many other planetary systems, but our results suggest that **idea might just have arisen due to an observational bias**," said the lead author of the study, Wes Fraser, quoted by Cosmos Magazine.

Discovery important for science

So why is the discovery made by scientists, involving the New Horizons probe and the Subaru telescope, so significant for science? Scientists admit that if further research confirms there is an undiscovered population of cosmic objects beyond the Kuiper Belt, **the perception of how the entire Solar System actually formed may change**.

The presence of these bodies could indicate that the nebula from which the Solar System formed was much larger than previously assumed. However, to confirm this thesis, it is necessary to obtain further readings from New Horizons. Scientists continue to research beyond the Kuiper Belt.

"We still have much to learn about what this distant population actually looks like, **but what's fascinating is that there is a new Kuiper Belt population out there at all**," summarizes Fraser. He notes that the disk of planetary matter that led to the formation of planets and other structures in the Solar System 5 billion years ago may be much larger than scientists previously claimed. Until now, however, no one had noticed that there could be additional objects beyond the Kuiper Belt.

What is dark matter?

What is dark matter? Have you ever heard of it before? Over the years scientists have learned a lot about it but there is still much mystery surrounding dark matter.

Dark matter: the invisible majority

Dark matter is like the hidden scaffolding of the universe, unseen but essential, according to astronomists. In a standard theory, the mass-energy content of the universe is just 5% ordinary matter, 27% dark matter and 68% dark energy, according to NASA.

A centuries-old mystery

The concept of dark matter dates back to the 19th century. Lord Kelvin first suggested that a majority of stars may be "dark bodies." Decades later, Dutch astronomer Jacobus Kapteyn and Swiss astrophysicist Fritz Zwicky proposed the idea when they observed that galaxies didn’t have enough visible mass to account for their gravitational effects.

Gravitational fingerprints

Dark matter's presence is felt through its gravitational pull, which is what clues scientists to its existence. Although gravity is relatively a weak force, since there is so much dark matter in the universe, it combines to do some big things... like driving galaxy formation.

Energy dominance

Dark matter even theoretically carries more energy than visible matter. "Five times the amount of energy as the matter," says Randall, underscoring its significant role in the universe's energy balance.

I

t does not interact with light

Unlike ordinary matter, dark matter doesn't interact with light, as far as scientists know. That's why we can't see it. It does not absorb, reflect or emit any light. As Randall put it: "It interacts gravitationally... but it doesn't experience electromagnetism," making it fundamentally different.

Dark halos

Dark matter is thought to form a roughly spherical halo around galaxies. According to the European Organization for Nuclear Research (CERN), this is predicted because galaxies are rotating so quickly that without dark matter, they would have been torn apart long ago. Why? Because the gravity of the "ordinary matter" isn't enough to hold it together. It also explains why galaxies like the Milky Way are shaped like discs.

A vast web-like structure

While we don't know what, scientists have an idea of its structure. "Scientists today think dark matter exists in a vast, web-like structure that winds through the whole universe – a gravitational scaffold that attracts most of the cosmos' normal matter," says NASA.

What is dark matter? The elusive candidates

Weakly Interacting Massive Particles (WIMPs) are a popular dark matter candidate. Despite extensive searches, they remain elusive, but researchers continue to seek these particles. Another particle candidate is the axion.

Primordial black holes?

Primordial black holes (PBHs), possibly formed from density fluctuations shortly after the Big Bang, are a compelling candidate for dark matter. They vary significantly in mass and could mimic dark matter by exerting gravitational forces that affect galaxy formation and movement. Don't confuse these with the black holes formed from the collapse of stars!

Hidden valleys

The "hidden valleys" theory visualizes a parallel world made of dark matter that has little in common with the matter we know. These valleys contain unique particles that don't interact with our familiar matter except through gravity. This theory is intriguing because it proposes entirely new kinds of matter and interactions, potentially solving some dark matter mysteries.

What about dark energy?

According to the CERN, dark energy, which makes up the majority of the universe, appears to be associated with the vacuum in space. It is distributed evenly through space... and time. Said differently, it is not diluted as the energy expands and does not have local gravity effects. NASA adds that it may be responsible for the expanding universe, pushing it apart instead of pulling it back together.

Why do scientists care?

Of course, dark matter sounds cool, but what could cracking its invisible puzzle really solve? According to CERN, "it could help scientists gain a better understanding of the composition of our universe and, in particular, how galaxies hold together."

The cosmic web appears in simulations of the universe using the standard model of cosmology, such as this one. - Image credit: V.Springel, Max-Planck Institut für Astrophysik, Garching bei München© IFL Science

When we look for “the biggest” in the universe, it is important to specify our definition of the object of study. Is it something indivisible and with a neat boundary, like a black hole? Or do we prefer fuzzy edges so we can talk about galaxies? But if we are looking for the BOAT, the biggest of all time (and space), there is only one answer: the cosmic web.

This is how the universe is organized. Galaxies can be found quite isolated, in groups, or in clusters. And no matter their location, they are likely to be involved in a supercluster of galaxies. The superclusters are connected by filaments, sheets, and walls. Between these, there are enormous voids. The "web" in the cosmic web showcases the interconnection between the structures, but the distribution can be visualized as foam: galaxies are in the soapy water, the bubbles are the void.

Larger than you can picture

The structure of the cosmic web itself is not easy to see. The connection between clusters and superclusters of galaxies is made by tenuous gas. Understanding of the large-scale structure of the universe came first from discovering the distribution of galaxies at large scales, and it is a relatively recent discovery. It was only in the 1980s that this picture began to form, and it is much more recently that we have developed instruments sensitive enough to study the filaments directly, or to see several filaments of the cosmic web at once for the first time.

The gas is not the only component of the filaments. The filaments are made of dark matter, a hypothetical form of matter that only interacts with the rest of the universe through gravity. It's called dark but it is actually invisible, since it doesn't interact with light. And while we do not have direct evidence of its existence, it is actually the cosmic web that gives us some important hints.

Simulations of the universe using dark matter and dark energy – a hypothetical form of energy responsible for the accelerated expansion of the universe – create a picture of the universe that is remarkably similar to observations. By using the standard model of cosmology, where dark matter and dark energy are as fundamental as regular matter, light, and gravity, you end up with a cosmic web like that we can measure out there in the universe.

And while we can't see dark matter filaments, researchers are getting pretty clever in finding evidence of their existence. For example, a team used the distortion of light created by massive objects as an indirect way to "see" this dark matter.

Is there an end to greatness?

The cosmic web has its rules. You are not going to find specific structures within it larger than a certain value. If we zoom out from galactic scales, we will find the lumps that make galaxy clusters, a few million light-years across. We zoom out again, and we finds the filaments, the walls, arcs, and bubbles that make up the cosmic web. But what happens if we zoom out again. Well, we reach *the end of greatness*.

This extremely poetic term summarizes a size above which the universe doesn't look lumpy any more and that is at about 300 million light-years. If like some looming deity we could project ourselves to see the universe at that scale, the cosmos would appear to be uniform and isotropic. That means that it would be the same at every point and look the same in every direction. At that scale, voids and filaments don't matter. For a culinary metaphor, it's like the crumb of a cake. You want it delicious and consistent at the level your tastebuds appreciate, but under a microscope, it would not look that regular.

Still, the standard model doesn't preclude structures extending further than 300 million light-years. The theory suggests that up to about 1.2 billion light-years things can exist without being a problem. So imagine the surprise of astronomers finding a few larger structures, namely the Giant Arc and the Big Ring: the first a crescent of galaxies extending for 3.3 billion light-years, and the second a circle of galaxies with a radius of 1.3 billion light-years.

An interesting challenge to square, whether a matter of theory or observations. Still, the universe extends for tens of billions of light-years in every direction, and so does the cosmic web, even if there might be the occasional clump we can't quite explain yet.

- During the 1960s, spacecraft traveling above Earth's poles discovered a stream of particles flowing out of the Earth's poles, and theorized that there must be an unknown field driving these particles into space.
- Now, more than half a century later, NASA has finally recorded this theoretical field and measured a change in electric potential of only 0.55 volts, the correct amount needed to send ions at supersonic speeds.

- Detecting this field is only the beginning of unraveling its mysteries as scientists still aren't certain of what impacts its had on the Earth's atmosphere and its oceans over the planet's 4.6-billion-year-old lifespan.

On May 11, 2022, a rocket soared skyward off the northernmost rocket range in the world in Svalbard, Norway.

More than 50 years before this Arctic launch, U.S. spacecraft flying over the Earth's poles in the 1960s encountered an unexpected stream of particles flowing out of our atmosphere and into space that we now call the "polar wind." Scientists at the time expected some atmospheric particles to be lost to space as unfiltered sunlight essentially evaporates particles, but these particles were cold and showed no signs of being heated. Being more focused on the whole "walking on the moon thing" and having no real way to investigate further, researchers just left if for future generations to figure out.

Back in the 21st century, a NASA rocket named Endurance—a hat tip to the intrepid three-masted barquentine that carried Norwegian explorer Ernest Shackleton toward Antarctica—now screamed toward the skies in search of answers. Reaching a max altitude of 477 miles above the Earth's surface and eventually crashing into the Greenland Sea, the Endurance's 322-mile flight recorded the atmosphere's total electric potential change using an array of instruments and sensors onboard. Thankfully, the Endurance rebuked the fate of its namesake and achieved its mission, recording for the first time the ever-elusive ambipolar electric field.

Two years after this historic flight, NASA has now published its results in a new paper in the journal *Nature*, and there's a very good reason why this important field has remained undetectable until now—it produces only a 0.55-volt electric charge.

"A half a volt is almost nothing," NASA Glyn Collinson, the principal investigator of the Endurance mission, said in a press statement. "It's only about as strong as a watch battery. But that's just the right amount to explain the polar wind."

The scientists of the study compare the importance of this ambipolar electric field to that of Earth's two other natural fields: those of the gravitational and magnetic variety. While the necessity of these two well-known fields is obvious (that is, if you want to live on a habitable planet), the importance and function of the ambipolar electric field is less so.

This field is generated on a subatomic scale around 150 miles above the surface where atoms in the atmosphere begin to break apart into negatively charged electrons and positively charged ions. A field to connect these ions and electrons together forms between them, and the push-pull effect caused by ultra-light electrons and heavier (by comparison) ions counteracts some of the effects of gravity.

This 0.55-volt electric field, while minuscule to us, is an overwhelming amount of energy for subatomic particles and more than enough to send these particles at supersonic speeds, thus forming polar winds. The net effect of this field essentially extends the height of the atmosphere at the poles, causing some of those unexpectedly cold ions to escape into space. It also increases the scale height of the ionosphere by 271 percent, which means the ionosphere remains denser at higher elevations that would be possible without the electric field. Considering the ionosphere is responsible for shielding us surface-dwelling mammals from the cancer-causing effects of solar radiation, the importance of the ambipolar electric field becomes clear.

"It's like this conveyor belt, lifting the atmosphere up into space," Collinson said in a press statement. "Now that we've finally measured it, we can begin learning how it's shaped our planet as well as others over time."

Although scientists have finally detected this field, that's really only the beginning of understanding its impact. It's likely that this field has been present since the Earth's formation, alongside gravity and magnetism, and could've played a key role in the formation of the Earth's atmosphere, especially the ionosphere, and even its oceans. This field also isn't unique to Earth, so any planet in our Solar System and beyond with an atmosphere likely contains its own ambipolar field.

"This field is so fundamental to understanding how the way the planet works," Collison said in a video announcement. "It's been lofting particles to space and stretching up the sky since the beginning. Now that we've finally measured it, we can start asking some of these bigger and exciting questions.

The incredibly insightful animated series Kurzgesagt put together a colorful animation that discusses how the past, the present, and the future can all exist at the same time, as explained by several different theories.

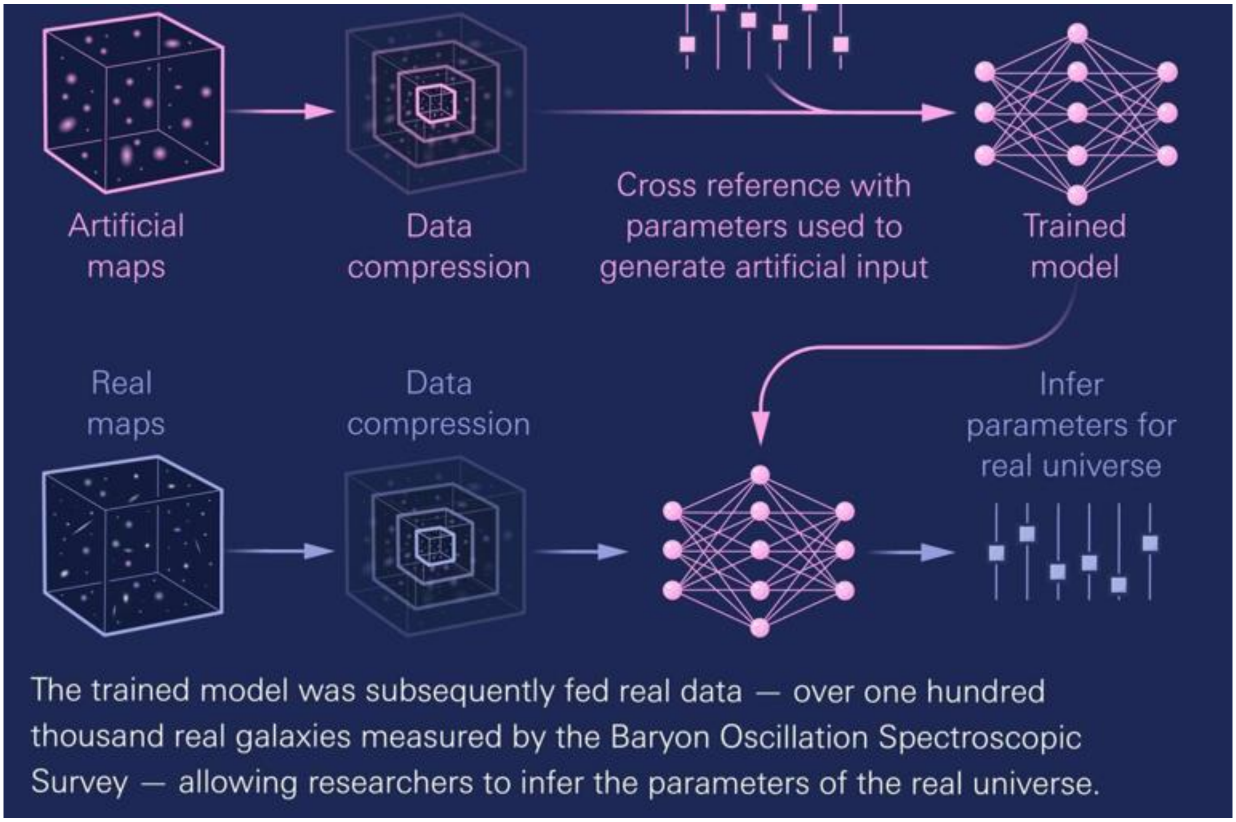
Do your past, present and future all exist right now? Are you watching this video, being born and lying on your deathbed at this very moment? Surprisingly, the answer could be yes. But how can that be? What does that even mean? How does time work?

The "Theory of Relativity" and quantum physics can explain this temporal paradox, as they both see the world as a single space-time continuum, with the "now" being collective.

How can the past and future be real right now? The problem is that according to the Theory of Relativity, they kind of have to be. Heavily simplified, relativity says that time and space are not separated, but one connected spacetime. ...This means time passes differently for different people, depending on how they move through space relative to each other. And this also means that what someone perceives as "now" is a certain cut along the block – a cut that will depend on how fast they are moving.

They remind us that, while scientific, these are just theories. Other theories view the now as belonging to individuals, while others see time as a human construct. But there is no definitive answer.

Some scientists think that the idea of "now" only makes sense near you,but not in the universe as a whole. Others think that time itself doesn't even exist – that the whole concept is an illusion of our humanmind. And others think that time does exist, but that it's not a fundamental feature of the universe – rather, time may be something that emerges from a deeper level of reality. The concept of time is abstract and elusive, possibly beyond complete human comprehension.



An infographic showcasing the methodology behind the Simulation-Based Inference of Galaxies (SimBIG) project. Credit: Lucy Reading-Ikkanda/Simons Foundation

The standard model of the universe relies on just six numbers. Using a new approach powered by artificial intelligence, researchers at the Flatiron Institute and their colleagues extracted information hidden in the distribution of galaxies to estimate the values of five of these so-called cosmological parameters with incredible precision.

The results were a significant improvement over the values produced by previous methods. Compared to conventional techniques using the same galaxy data, the approach yielded less than half the uncertainty for the parameter describing the clumpiness of the universe's matter. The AI-powered method also closely agreed with estimates of the cosmological parameters based on observations of other phenomena, such as the universe's oldest light.

The researchers present their method, the Simulation-Based Inference of Galaxies (or SimBIG), in a series of recent papers, including a new study published August 21 in *Nature Astronomy*.

Generating tighter constraints on the parameters while using the same data will be crucial to studying everything from the composition of dark matter to the nature of the dark energy driving the universe apart, says study co-author Shirley Ho, a group leader at the Flatiron Institute's Center for Computational Astrophysics (CCA) in New York City. That's especially true as new surveys of the cosmos come online over the next few years, she says.

"Each of these surveys costs hundreds of millions to billions of dollars," Ho says. "The main reason these surveys exist is because we want to understand these cosmological parameters better. So if you think about it in a very practical sense, these parameters are worth tens of millions of dollars each. You want the best analysis you can to extract as much knowledge out of these surveys as possible and push the boundaries of our understanding of the universe."

The six cosmological parameters describe the amount of ordinary matter, dark matter and dark energy in the universe and the conditions following the Big Bang, such as the opacity of the newborn universe as it cooled and whether mass in the cosmos is spread out or in big clumps. The parameters "are essentially the 'settings' of the universe that determine how it operates on the largest scales," says Liam Parker, co-author of the study and a research analyst at the CCA.

One of the most important ways cosmologists calculate the parameters is by studying the clustering of the universe's galaxies. Previously, these analyses only looked at the large-scale distribution of galaxies.

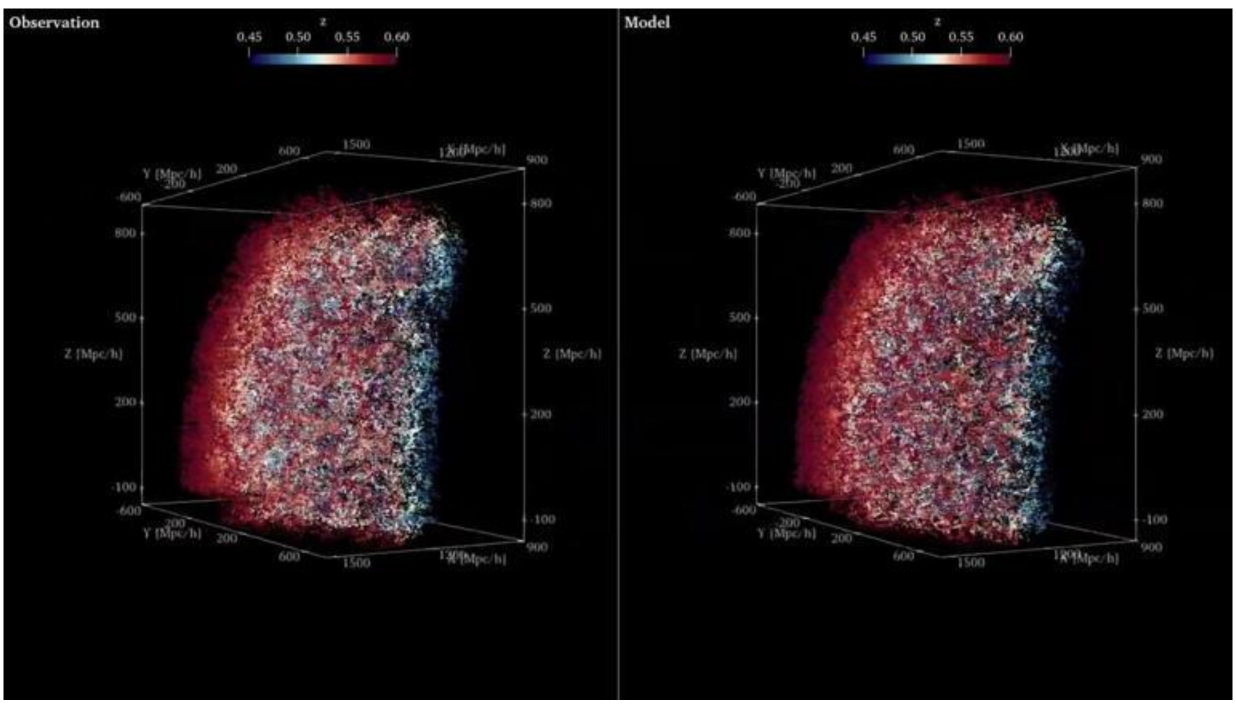
"We haven't been able to go down to small scales," says ChangHoon Hahn, an associate research scholar at Princeton University and lead author of the study. "For a couple of years now, we've known that there's additional information there; we just didn't have a good way of extracting it."

Hahn proposed a way to leverage AI to extract that small-scale information. His plan had two phases. First, he and his colleagues would train an AI model to determine the values of the cosmological parameters based on the appearance of simulated universes. Then they'd show their model actual galaxy distribution observations.

Hahn, Ho, Parker and their colleagues trained their model by showing it 2,000 box-shaped universes from the CCA-developed Quijote simulation suite, with each universe created using different values for the cosmological parameters. The researchers even made the 2,000 universes appear like data generated by galaxy surveys—including flaws from the atmosphere and the telescopes themselves—to give the model realistic practice.

"That's a large number of simulations, but it's a manageable amount," Hahn says. "If you didn't have the machine learning, you'd need hundreds of thousands."

By ingesting the simulations, the model learned over time how the values of the cosmological parameters correlate with small-scale differences in the clustering of galaxies, such as the distance between individual pairs of galaxies. SimBIG also learned how to extract information from the bigger-picture arrangement of the universe's galaxies by looking at three or more galaxies at a time and analyzing the shapes created between them, like long, stretched triangles or squat equilateral triangles.



This snapshot compares the distribution of galaxies in a simulated universe used to train SimBIG (right) to the galaxy distribution seen in the real universe (left). Credit: Bruno Régaldo-Saint Blancard/SimBIG collaboration

With the model trained, the researchers presented it with 109,636 real galaxies measured by the [Baryon Oscillation Spectroscopic Survey](). As they hoped, the model leveraged small-scale and large-scale details in the data to boost the precision of its cosmological parameter estimates. Those estimates were so precise that they were equivalent to a traditional analysis using around four times as many galaxies.

That's important, Ho says, because the universe only has so many galaxies. By getting higher precision with less data, SimBIG can push the limits of what's possible.

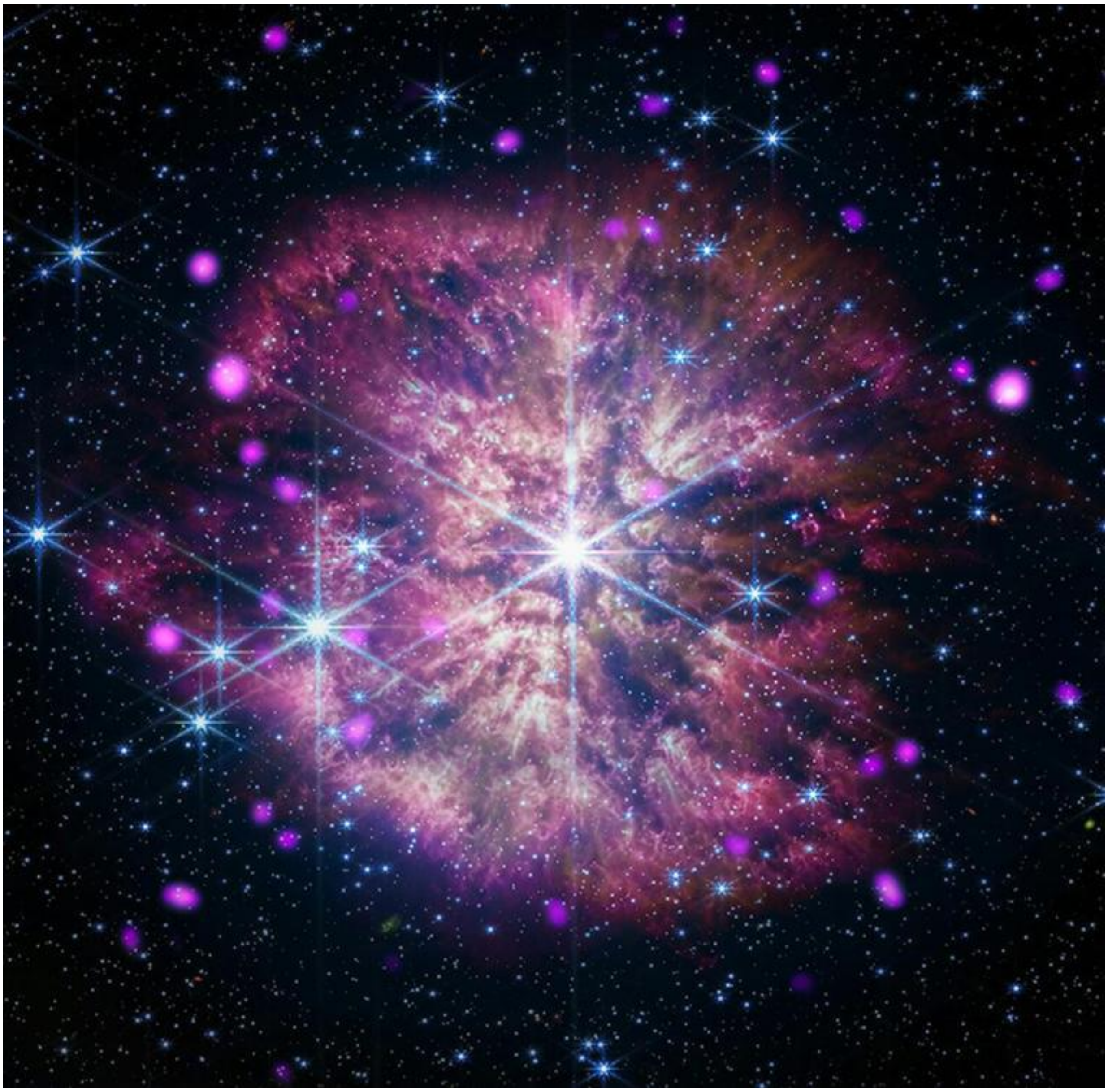
One exciting application of that precision, Hahn says, will be the cosmological crisis known as the Hubble tension. The tension arises from mismatched estimates of the Hubble constant, which describes how quickly everything in the universe is spreading out.

Calculating the Hubble constant requires estimating the universe's size using "cosmic rulers." Estimates based on the distance to exploding stars called supernovae in distant galaxies are around 10 percent higher than those based on the spacing of fluctuations in the universe's oldest light.

New surveys coming online in the next few years will capture more of the universe's history. Pairing data from those surveys with SimBIG will better reveal the extent of the Hubble tension, and whether the mismatch can be resolved or if it necessitates a revised model of the universe, Hahn says. "If we measure the quantities very precisely and can firmly say that there is a tension, that could reveal new physics about dark energy and the expansion of the universe," he says.

Hahn, Ho and Parker worked on the study alongside Michael Eickenberg of the Flatiron Institute's Center for Computational Mathematics (CCM), Pablo Lemos of the CCA, Chirag Modi of the CCA and the CCM, Bruno Régaldo-Saint Blancard of the CCM, Simons Foundation president David Spergel, Jiamin Hou of the University of Florida, Elena Massara of the University of Waterloo, and Azadeh Moradinezhad Dizgah of the University of Geneva.

More information: ChangHoon Hahn et al, Cosmological constraints from non-Gaussian and nonlinear galaxy clustering using the SimBIG inference framework, *Nature Astronomy* (2024). DOI: 10.1038/s41550-024-02344-2


Credit: X-ray: NASA/CXC/SAO; Infrared: (Herschel) ESA/NASA/Caltech, (Spitzer) NASA/JPL/Caltech, (WISE) NASA/JPL/Caltech; Infrared: NASA/ESA/CSA/STScI/Webb ERO Production Team; Image processing: NASA/CXC/SAO/J. Major, CC BY

For the past few years, a series of controversies have rocked the well-established field of cosmology. In a nutshell, the predictions of the standard model of the universe appear to be at odds with some recent observations.

There are heated debates about whether these observations are biased, or whether the cosmological model, which predicts the structure and evolution of the entire universe, may need a rethink. Some even claim that cosmology is in crisis. Right now, we do not know which side will win. But excitingly, we are on the brink of finding that out.

To be fair, controversies are just the normal course of the scientific method. And over many years, the standard cosmological model has had its share of them. This model suggests the universe is made up of 68.3% "dark energy" (an unknown substance that causes the universe's expansion to accelerate), 26.8% dark matter (an unknown form of matter) and 4.9% ordinary atoms, very precisely measured from the cosmic microwave background—the afterglow of radiation from the Big Bang.

It explains very successfully multitudes of data across both large and small scales of the universe. For example, it can explain things like the distribution of galaxies around us and the amount of helium and deuterium made in the universe's first few minutes. Perhaps most importantly, it can also perfectly explain the cosmic microwave background.

This has led to it gaining the reputation as the "concordance model." But a perfect storm of inconsistent measurements—or "tensions" as they're known as in cosmology—are now questioning the validity of this longstanding model.

Uncomfortable tensions

The standard model makes particular assumptions about the nature of dark energy and dark matter. But despite decades of intense observation, we still seem no closer to working out what dark matter and dark energy are made of.

The litmus test is the so-called Hubble tension. This relates to the Hubble constant, which is the rate of expansion of the universe at the present time. When measured in our nearby, local universe, from the distance to pulsating stars in nearby galaxies, called Cepheids, its value is 73 km/s/Mega parsec (Mpc is a unit of measure for distances in intergalactic space). However, when predicted theoretically, the value is 67.4 km/s/Mpc. The difference may not be large (only 8%), but it is statistically significant.

The Hubble tension became known about a decade ago. Back then, it was thought that the observations may have been biased. For example, the Cepheids, although very bright and easy to see, were crowded together with other stars, which could have made them appear even brighter. This could have made the Hubble constant higher by a few percent compared to the model prediction, thus artificially creating a tension.

With the advent of the James Webb Space Telescope (JWST), which can separate the stars individually, it was hoped that we would have an answer to this tension.

Frustratingly, this hasn't yet happened. Astronomers now use two other types of stars besides the Cepheids (known as the Tip of the Red Giant Branch stars (TRGB) and the J-region Asymptotic Giant Branch (JAGB) stars). But while one group has reported values from the JAGB and TRGB stars that are tantalizingly close to the value expected from the cosmological model, another group has claimed that they are still seeing inconsistencies in their observations. Meanwhile, the Cepheids measurements continue to show a Hubble tension.

It's important to note that although these measurements are very precise, they may still be biased by some effects uniquely associated with each type of measurement. This will affect the accuracy of the observations, in a different way for each type of stars. A precise but inaccurate measurement is like trying to have a conversation with a person who is always missing the point. To solve disagreements between conflicting data, we need measurements that are both precise and accurate.

The good news is that the Hubble tension is now a rapidly developing story. Perhaps we will have the answer to it within the next year or so. Improving the accuracy of data, for example by including stars from more far away galaxies, will help sort this out. Similarly, measurements of ripples in spacetime known as gravitational waves will also be able to help us pin down the constant.

This may all vindicate the standard model. Or it may hint that there's something missing from it. Perhaps the nature of dark matter or the way that gravity behaves on specific scales is different to what we believe now. But before discounting the model, one has to marvel at its unmatched precision. It only misses the mark by at most a few percent, while extrapolating over 13 billion years of evolution.

To put it into perspective, even the clockwork motions of planets in the solar system can only be computed reliably for less than 1 billion years, after which they become unpredictable. The standard cosmological model is an extraordinary machine.

The Hubble tension is not the only trouble for cosmology. Another one, known as the "S8 tension," is also causing trouble, albeit not on the same scale. Here the model has a smoothness problem, by predicting that matter in the universe should be more clustered together than we actually observe—by about 10%. There are various ways to measure the "clumpiness" of matter, for example by analyzing the distortions in the light from galaxies, produced by the assumed dark matter intervening along the line of sight.

Currently, there seems to be a consensus in the community that the uncertainties in the observations have to be teased out before ruling out the cosmological model. One possible way to alleviate this tension is to better understand the role of gaseous winds in galaxies, which can push out some of the matter, making it smoother.

Understanding how clumpiness measurements on small scales relate to those on larger scales would help. Observations might also suggest there is a need to change how we model dark matter. For example, if instead of being made entirely of cold, slow moving particles, as the standard model assumes, dark matter could be mixed up with some hot, fast-moving particles. This could slow down the growth of clumpiness at late cosmic times, which would ease the S8 tension.

JWST has highlighted other challenges to the standard model. One of them is that early galaxies appear to be much more massive that expected. Some galaxies may weigh as much as the Milky Way today, even though they formed less than 1 billion years after the Big Bang, suggesting they should be less massive.

However, the implications against the cosmological model are less clear in this case, as there may be other possible explanations for these surprising results. Key to solving this problem is to improve the measurement of stellar masses in galaxies. Rather than measuring them directly, which is not possible, we infer these masses from the light emitted by galaxies.

This step involves some simplifying assumptions, which could translate in overestimating the mass. Recently, it has also been argued that some of the light attributed to stars in these galaxies is generated by powerful black holes. This would imply that these galaxies may not be as massive after all.

Alternative theories

So, where do we stand now? While some tensions may soon be explained by more and better observations, it is not yet clear whether there will be a resolution to all of the challenges battering the cosmological model.

There has been no shortage of theoretical ideas of how to fix the model though—perhaps too many, in the range of a few hundred and counting. That's a perplexing task for any theorist who may wish to explore them all.

The possibilities are many. Perhaps we need to change our assumptions of the nature of dark energy. Perhaps it is a parameter that varies with time, which some recent measurements have suggested. Or maybe we need to add more dark energy to the model to boost the expansion of the universe at early times, or, on the contrary, at late times. Modifying how gravity behaves on large scales of the universe (differently than done in the models called Modified Newtonian Dynamics, or MOND) may also be an option.

So far, however, none of these alternatives can explain the vast array of observations that the standard model can. Even more worrisome, some of them may help with one tension but worsen others.

The door is now open to all sorts of ideas that challenge even the most basic tenets of cosmology. For example, we may need to abandon the assumption that the universe is "homogeneous and isotropic" on very large scales, meaning it looks the same in all directions to all observers and suggesting there are no special points in the universe. Others propose changes to the theory of general relativity.

Some even imagine a trickster universe, which participates with us in the act of observation, or which changes its appearance depending on whether we look at it or not—something we know happens in the quantum world of atoms and particles.

In time, many of these ideas will likely be relegated to the cabinet of curiosities of theorists. But in the meantime, they provide a fertile ground for testing the "new physics."

This is a good thing. The answer to these tensions will no doubt come from more data. In the next few years, a powerful combination of observations from experiments such as JWST, the Dark Energy Spectroscopic Instrument (DESI), the Vera Rubin Observatory and Euclid, among many others, will help us find the long-sought answers.

Tipping point

On one side, more accurate data and a better understanding of the systematic uncertainties in the measurements could return us to the reassuring comfort of the standard model. Out of its past troubles, the model may emerge not only vindicated, but also strengthened, and cosmology will be a science that is both precise and accurate.

But if the balance tips the other way, we will be ushered into uncharted territory, where new physics will have to be discovered. This could lead to a major paradigm shift in cosmology, akin to the discovery of the accelerated expansion of the universe in the late 1990s. But on this path we may have to reckon, once and for all, with the nature of dark energy and dark matter, two of the big unsolved mysteries of the universe.

Planets and stars have magnetic fields primarily due to the movement of electrically charged particles within them, creating what is called a *dynamo effect*. However, not all planets and stars have magnetic fields, or at least not strong ones, and this depends on a few key factors:

1. Composition and Internal Structure: Planets or stars need a conductive core or layer, often metallic, for a magnetic field to form. For example, Earth's magnetic field is generated by its molten iron outer

core. In stars, the plasma (ionized gas) can act as the conductor.

2. Rotational Speed: Faster rotation can enhance the dynamo effect. For example, Jupiter has a stronger magnetic field than Earth due to its faster rotation and larger size.

3. Internal Heat: Internal heat drives convection currents in the conductive material (such as molten metal in a planet or plasma in a star), which is necessary to sustain the movement of charged particles. A planet or star that has cooled significantly may not have the required convective motion, weakening or eliminating its magnetic field.

4. Magnetic Dynamo Process: Not all planets or stars generate strong magnetic fields because the conditions inside them (such as convection currents and rotation) may not be sufficient to drive a dynamo process.

For example, Earth's magnetic field comes from its molten iron core, whereas the Moon, which lacks a similar molten core, has a very weak magnetic field. Similarly, stars like the Sun have magnetic fields due to the movement of plasma in their interiors. However, smaller or older stars may have weaker or diminished fields.

The universe began around 13.8 billion years ago. - Image credit: The Hubble Heritage Team (AURA/STScI/NASA)© IFL Science

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.

Scientists have found hints there may be two Kuiper Belts, or at least two separate components of the belt, right on the edge of our Solar System.

The Kuiper Belt is a doughnut-shaped region of icy objects beyond the orbit of Neptune which is home to dwarf planet Pluto and is believed to contain a number of comets, asteroids and other small bodies.

These are known as Kuiper Belt objects (KBOs) and astronomers have found hints of an unexpected rise in their density far beyond where the Kuiper Belt is currently known to end, reports Science Alert.

Fumi Yoshida, planetary scientist at the University of Occupational and Environmental Health Sciences and Chiba Institute of Technology in Japan, said: "If this is confirmed, it would be a major discovery.

"The primordial solar nebula was much larger than previously thought and this may have implications for studying the planet formation process in our Solar System."

Scientists have found hints there may be two Kuiper Belts, or at least two separate components of the belt, in our Solar System / (PaulFleet, iStock)

The higher than expected rise in density is between 70 and 90 astronomical units from the Sun; an astronomical unit is a measurement of the average distance between Planet Earth and the Sun.

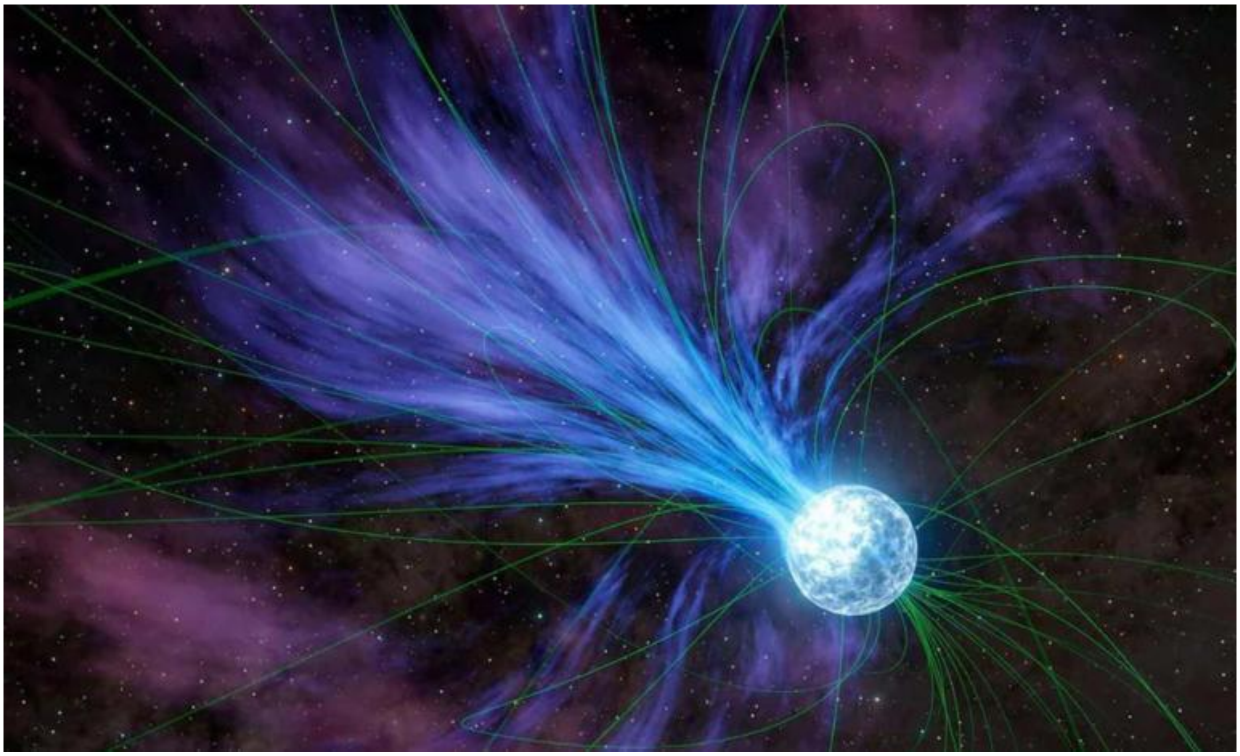
The Kuiper Belt extends from the orbit of Neptune, which around 30 astronomical units from the Sun, out to around 50.

The New Horizons spacecraft is travelling deeper into the Solar System and is currently around 60 astronomical units from the sun; it flew by Pluto in 2015.

Astronomers have been observing beyond this using the National Astronomical Observatory of Japan's Subaru Telescope in Hawaii.

In the region between 55 and 70 astronomical units, pretty well nothing had been found but 11 KPOs were spotted beyond this which is much further out than where the Kuiper Belt is thought to end.

The orbits of these are continuing to be tracked so astronomers can make further observations.



Mysterious 8-Billion-Year-Old Radio Signal Reaches Earth, Offering Clues to the Universe's Hidden Matter© Daily Galaxy

Astronomers have detected a powerful radio signal that has traveled 8 billion years through space before reaching Earth. Known as FRB 20220610A, this signal represents one of the most distant and energetic fast radio bursts (FRBs) ever observed, providing a rare glimpse into the distant past of the universe.

What Are Fast Radio Bursts?

Fast radio bursts (FRBs) are extremely brief, yet highly energetic pulses of radio waves that typically last only a few milliseconds. Despite their fleeting nature, FRBs can release more energy in a fraction of a second than the Sun generates over decades. Since the first FRB was discovered in 2007, astronomers have been captivated by these cosmic phenomena, though much about their origins remains a mystery.

One theory suggests that FRBs may be linked to **magnetars**, which are highly magnetic neutron stars left behind after supernova explosions. These extreme objects could generate the powerful bursts of energy we detect as FRBs. For instance, **FRB 20220610A** emitted an amount of energy comparable to what our Sun produces over **30 years**. However, there are still many unanswered questions about the true causes of these bursts.

To detect **FRB 20220610A**, astronomers used the **Australian Square Kilometre Array Pathfinder (ASKAP)**. "We used ASKAP's radio dishes to skillfully pinpoint where the burst came from," explained **Dr. Stuart Ryder**, one of the leading researchers. The team then employed additional tools, such as the **European Southern Observatory's Very Large Telescope**, to further study the burst's origin. They discovered that the signal had traveled from an ancient galaxy, far older and more distant than any previous FRB source detected.

Mysterious 8-Billion-Year-Old Radio Signal Reaches Earth, Offering Clues to the Universe's Hidden Matter© Daily Galaxy

FRBs as a Tool for Weighing the Universe

While FRBs remain one of the most mysterious phenomena in the cosmos, they hold significant potential for solving some of the universe's deepest mysteries. One of the most intriguing uses of FRBs is their ability to help astronomers resolve the **missing matter problem**. For years, cosmologists have theorized that much of the universe's matter remains undetected, hidden in regions too diffuse and far apart for conventional observation techniques.

According to **Professor Ryan Shannon**, "More than half of the normal matter that should exist today is unaccounted for." This missing matter, referred to as **baryonic matter**, could be spread out in the form of ionized gas in the vast regions between galaxies, making it difficult to detect. **FRBs**, however, offer a unique solution. As these radio waves travel through space, they interact with the ionized material in the near-empty space between galaxies. By studying how FRBs are distorted by this material, astronomers can indirectly measure the amount of matter along the burst's path.

This groundbreaking method was developed by **Jean-Pierre Macquart**, an Australian astronomer, in 2020. Known as the **Macquart relation**, this technique uses FRBs to trace the elusive matter in the universe. As **Dr. Ryder** noted, "This detection confirms the Macquart relation, even for bursts halfway across the universe," proving that FRBs can indeed be used to map out hidden matter on a cosmic scale.

A Glimpse Into the Universe's Distant Past

The detection of **FRB 20220610A** offers scientists a rare opportunity to study the universe as it existed **8 billion years ago**. Because the signal traveled such an immense distance before reaching Earth, it carries information from a time when the universe was much younger. Studying these ancient signals can reveal insights into the processes that shaped galaxies and cosmic structures in the early universe, providing a window into cosmic events that would otherwise be inaccessible.

This particular FRB’s origin in an extremely distant and ancient galaxy adds another layer of fascination to its discovery. Using the **Very Large Telescope**, astronomers confirmed that the galaxy where the burst originated is much older and farther away than any other FRB source ever identified. By analyzing this signal, astronomers can not only study the conditions of this distant galaxy but also gain insights into the **evolution of galaxies** and the **large-scale structure of the universe**.

With such an energetic signal detected at such an immense distance, **FRB 20220610A** challenges existing models of cosmic phenomena, pushing the boundaries of what we know about **energy sources in the universe**. The fact that this FRB traveled so far and still retained enough energy to be detected underscores the power of these cosmic events.

The Future of FRB Research

The detection of **FRB 20220610A** is just the beginning of what is expected to be a growing field of research. Thanks to technological advancements and the development of next-generation radio telescopes, astronomers anticipate discovering thousands more **fast radio bursts** in the coming years. Instruments like the **Square Kilometre Array** (SKA), currently under construction, will significantly increase the number of FRBs detected, allowing scientists to trace these signals back to their source galaxies with greater precision.

As **Professor Ryan Shannon** pointed out, "FRBs are common and hold great promise. We could use them to create a new map of the universe’s structure and answer big questions about cosmology." Each new detection brings researchers closer to understanding the nature of these cosmic events and their potential to unravel some of the universe’s greatest mysteries.

The future of FRB research is bright, and with each discovery, we move closer to a more comprehensive understanding of the cosmos. As more **FRBs** are detected and traced back to their origins, scientists hope to not only solve the **missing**

matter problem but also gain insights into the **formation of galaxies** and the **evolution of the universe**.

A theory known as non-singular matter bouncing cosmology suggests that the universe “bounces” between a hot big bang era and the kind of universe we see today.© Mst Hazera Begum

- Science’s best guess at how the universe came into being includes the Big Bang followed by a moment of *rapid* inflationary expansion.
- However, this theory left a few mysteries and quirks in its wake, including the existence of dark matter and conundrums like “the flatness problem.”
- A fringe theory known as non-singular matter bouncing cosmology claims to answer these issues by suggesting that the universe “bounces” between a hot big bang era and the kind of universe we see today.

Answering the question of how *everything* began was always going to be a difficult one, but humans have made incredible progress—especially considering that, in the cosmological blink of an eye, we’ve gone from writing on cave walls to carrying handheld computers around in our pockets.

The prevailing theory is that the modern universe formed after a cosmological Big Bang, followed by a period of rapid inflation. The expansion of the universe, the cosmic microwave background (CMB), and even the ages of the oldest stars supports this widely accepted theory. However, it’s also left a few nagging mysteries in its wake, and it’s these mysteries—such as dark matter and the “flatness problem,” which involves questions around why the observable universe appears to be flat—that have sent some scientists in search of other possible answers.

In a new paper published in the *Journal of Cosmology and Astroparticle Physics*, an international team of scientists explore the concept of a “non-singular matter bouncing cosmology.” Unlike the current model—which the paper refers to as the Hot Big Bang (HBB)—this proposed theory “bounces” between a hot, dense universe like the one seen during the Big Bang, and the much colder universe. In a way, according to the theory, the observable universe today is recycle from a previous universe.

Although this isn't a new idea, the team explored the concept further by analyzing the existence of primordial black holes (PBH) in this controversial cosmological model.

"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," the authors wrote. "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."

According to *IFLScience*, this effectively suggests that primordial black holes—which are hypothetical and thought to have occurred not long after the Big Bang—could actually be observable remnants formed from disturbances during the chaotic transition phase of the early universe. These black holes have been suggested as a possible explanation for dark matter (though recent studies have shown that they're likely too scarce to explain the mysterious phenomenon), but the researchers are adamant that this cosmological model solves both the flatness problem *and* the need for dark matter at all.

"Interestingly," the paper reads, "the primordial black hole masses that we find can lie within the observationally unconstrained asteroid-mass window, potentially explaining the totality of dark matter."

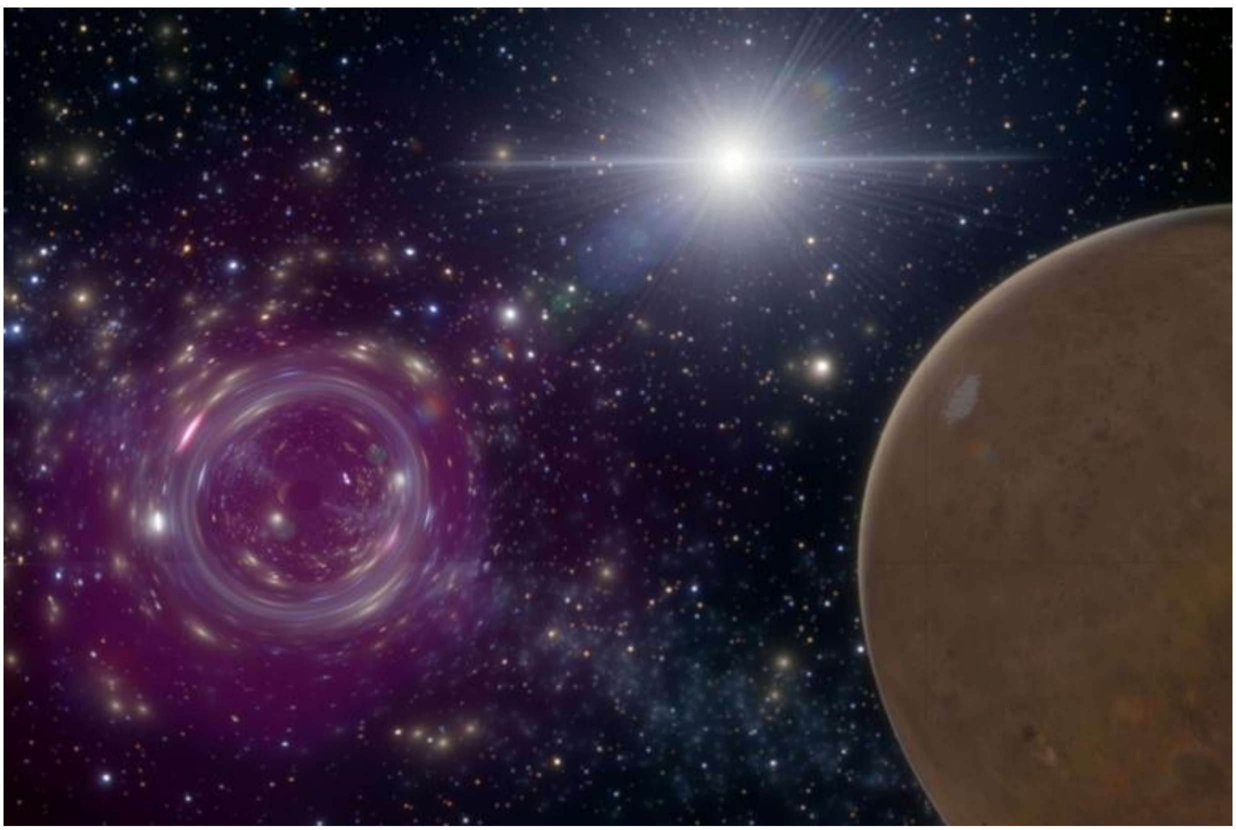
Although an intriguing idea, the Big Bang + Inflation model of the universe is still the modern cave man's best bet at understanding what shaped our universe. But the researchers say it should be possible to figure out if this non-singular matter bouncing cosmology holds any merit as "enhanced curvature perturbations, collapsing to primordial black holes, can induce as well a stochastic gravitational-wave background."

While it's certainly possible that the Laser Interferometer Space Antenna (LISA) mission—which will essentially be a more powerful LIGO, but in *space*—could find something unexpected, this "bouncing" idea has a long way to go to prove itself against a cosmological model that's served us well for decades.

A tiny black hole may pass through our solar system once every ten or so years, researchers have suggested, and this could be detected by watching Mars wobble.

This estimate is based on an idea proposed in the 1970s that the majority of dark matter in the universe is comprised of minuscule black holes.

To determine if this theory is true, researchers are closely watching the orbit of Mars. This is because, according to a new paper due to be [published in the journal *Physical Review D*,] one of these tiny black holes traveling past could cause the red planet to wobble enough that we could spot it from Earth.



An artist's illustration depicts a primordial black hole flying past, and briefly "wobbling" the orbit of Mars, with the sun in the background. MIT scientists say such a wobble could be detectable by today's instruments. Image by Benjamin Lehmann, using SpaceEngine @ Cosmographic Software LLC.© Image by Benjamin Lehmann, using SpaceEngine @ Cosmographic Software LLC.

"Given decades of precision telemetry, scientists know the distance between Earth and Mars to an accuracy of about 10 centimeters [4 inches]," study co-author David Kaiser, professor of physics at MIT, said in a statement. "We're taking advantage of this highly instrumented region of space to try and look for a small effect. If we see it, that would count as a real reason to keep pursuing this delightful idea that all of dark matter consists of black holes that were spawned in less than a second after the Big Bang and have been streaming around the universe for 14 billion years."

Dark matter is a form of matter that does not emit, absorb, or reflect light, making it invisible to telescopes and all other current electromagnetic detection methods. Despite being undetectable by traditional means, dark matter is inferred to exist because of its gravitational effects on visible matter, such as stars and galaxies. Scientists estimate that dark matter makes up about 27 percent of the universe's mass-energy content. This is vastly more than the approximately 5 percent of the universe made up of normal matter, like stars, planets, and all life on Earth.

One way that we know dark matter exists is from the way galaxies rotate: Observations show that galaxies are spinning much faster than can be explained by the mass of visible matter alone, meaning that there must be unseen mass—presumed to be dark matter—present to provide the additional gravitational pull to account for this.

Scientists have been trying for decades to measure the properties of dark matter. In the 1970s, it was suggested that this dark matter could be tied up in teeny primordial black holes that formed during the Big Bang. These black holes could be as wide as a single atom, but weigh as much as a huge asteroid.

In the paper, the researchers estimated that based on the level of dark matter in a given area of space, one of these tiny black holes should zip through our solar system once every decade.

"Primordial black holes do not live in the solar system. Rather, they're streaming through the universe, doing their own thing," paper co-author Sarah Geller, now a postdoc at the University of California at Santa Cruz, said in the statement. "And the probability is, they're going through the inner solar system at some angle once every 10 years or so."

To detect these black holes and prove this theory right, the researchers modeled the orbits of every large body in the solar system, and found that tiny wobbles in the orbit of Mars could indicate one of the asteroid-mass black holes passing through.

"State-of-the-art simulations of the solar system include more than a million objects, each of which has a tiny residual effect," study co-author, Benjamin Lehmann, a researcher at MIT, said in the statement. "But even modeling two dozen objects in a careful simulation, we could see there was a real effect that we could dig into."

These wobbles would only be by around a meter, but this could be detected by equipment here on Earth.

Even if researchers did detect one of these wobbles, much more work would be needed to confirm that it wasn't just caused by an asteroid.

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

If these tiny black holes are indeed real, if one did approach within 3 feet meter of a person, it would push them away by about 20 feet in a single second. Luckily for us, they are incredibly unlikely to come close to a person, according to study lead author and MIT researcher Tung Tran.


Credit: Pixabay/CC0 Public Domain

How much do we really know about what else is out there in the universe?

Let's take an outlandish example. If there were aliens flying around our galaxy with the sort of warp drive technology we often see in sci-fi shows, what would the signal from their ships look like? Perhaps, surprisingly, our research shows we have the tools to answer this question, regardless of whether such things really exist.

Telescopes that use light to probe space can now see almost to the edge of what is observable. Each new frequency we have explored—from gamma rays and X-rays, to infrared and radio—has taught us something new and unexpected.

In 2015, a new kind of telescope, a detector called Ligo, was turned on, not looking for light waves but for gravitational waves, which are invisible "ripples" in space and time. Again nature surprised us with a signal labeled GW150914 from a pair of black holes. Each were about thirty times the mass of our sun, merging together in a violent collision 1.4 billion light years away.

Since then gravitational waves have become an essential new tool for scholars exploring the universe. But we are still at the very beginning of our explorations. What signals might we see in the data, and will they change how we see the physics of the cosmos?

There is, however, a more practical question that often gets overlooked—if something is out there, how would we recognize it?

From sci-fi to serious science

You may have seen warp drives in series like Star Trek. A warp drive is a hypothetical form of technology that compresses the space in front of a starship and expands it behind. While nothing can travel faster than the speed of light, in a warp drive we can cheat by making our distance shorter. So, the time it takes to go from A to B is less than the time light takes on another uncompressed path.

The jump from sci-fi to real science was made by theoretical physicist Miguel Alcubierre in 1994, when he was inspired to model a warp drive using Einstein's equations of general relativity.

General relativity is a relationship between spacetime curvature (gravity) and a distribution of matter or energy (stuff). Typically, we start by knowing the "stuff." For example, we know that we have a blob of matter that represents a planet or star. We then put that stuff into the equations to determine how the spacetime curves. And how it curves tells us the gravity we would measure around the object.

You could say that this is exactly what Isaac Newton's picture of gravity does—giving a relation between an object's mass and the gravitational force it exerts. And you would be right. But the concept of spacetime curvature gives rise to a much richer range of phenomena than a simple force. It allows a kind of repulsive gravity that drives our universe to expand, creates time dilation around massive objects and gravitational waves in spacetime and—in theory at least—it makes warp drives possible.

Alcubierre tackled his problem from the opposite direction to the usual one. He knew what kind of spacetime curvature he wanted. It was one in which an object could surf on a region of warped spacetime. So, he worked backwards to determine the kind of matter configuration you would need to create this. It wasn't a natural solution of the equations, but rather something "made to order." It wasn't exactly what he would have ordered though. He found he needed exotic matter, something with a negative energy density, to warp space in the right way.

Exotic matter solutions are generally viewed with skepticism by physicists, and rightly so. While mathematically, one can describe material with negative energies, almost everything we know appears to have a positive energy. But in quantum physics, we have observed that small, temporary violations of energy positivity can occur, and so, "no negative energy" can't be an absolute, fundamental law.

From warp drives to waves

Given Alcubierre's model of the warp drive spacetime, we can begin to answer our original question—what would a signal from it look like?

One of the cornerstones of modern gravitational wave observations, and one of its greatest achievements, is the ability to accurately predict waveforms from physical scenarios using a tool called "numerical relativity".

This tool is important for two reasons. First, because the data we get from detectors is still very noisy, which means we often have to know roughly what a signal looks like to be able to pull it out of the datastream. And second, even if a signal is so loud that it stands out above the noise, we need a model in order to interpret it. That is, we need to have modeled many different types of event, so we can match the signal to its type; otherwise we might be tempted to dismiss it as noise, or mislabel it as a black hole merger.

One problem with the warp drive spacetime is that it doesn't naturally give gravitational waves unless it starts or stops. Our idea was to study what would happen when a warp drive stopped, particularly in the case of something going wrong. Suppose the warp drive containment field collapsed (a staple storyline in sci-fi); presumably there would be an explosive release of both the exotic matter and gravitational waves. This is something we can, and did, simulate using numerical relativity.

What we found was that the collapse of the warp drive bubble is indeed an extremely violent event. The enormous amount of energy needed to warp spacetime gets released as both gravitational waves and waves of positive and negative matter energy. Unfortunately, it's most likely the end of the line for the ship's crew who would be torn apart by tidal forces.

We knew a gravitational wave signal would be emitted; any movement of matter in a messy way creates such a wave. But we couldn't predict the amplitude and frequency, and how these would depend on the size of the warped region.

We were surprised to find that for a 1km sized ship, the amplitude of the signal would be significant for any such event within our galaxy and even beyond. At a distance of 1 megaparsec (slightly further than the Andromeda galaxy), the signal is similar to our current detector sensitivity. However, the frequency of the waves is about a thousand times higher than the range they are looking at.

We should be honest and say that we can't claim our signal as the definitive warp drive signal. We had to make quite a few specific choices in our model. And our hypothetical aliens may have made different ones. But as a proof of principle, it shows that cases beyond standard astrophysical events can be modeled, and may have distinctive forms and shapes that we can search for in future detectors.

Our work also reminds us that compared to the study of light waves, we are still at the stage of Galileo, taking pictures of the universe in the narrow frequency band of visible light. We have a whole spectrum of gravitational wave frequencies still to explore, which will be sensitive to a range of phenomena happening across space and time.


Photo: AFP (Getty Images)© Photo: AFP (Getty Images)

The first billionaire to conduct a private spacewalk said it wasn't a particularly "peaceful" experience and compared his journey to explorers trying to cross the Atlantic Ocean.

Jared Isaacman, who founded the payments company Shift4 (FOUR), conducted the spacewalk on the recent SpaceX Polaris Dawn mission, which returned from space on Sunday.

"Looking at Earth was obviously very, very special," Isaacman said in a conversation hosted on Twitter Spaces Tuesday. "But when you look off to the side, you look out into the darkness of space, and you see your spaceship there, and how gritty it looks, it gave you this sense of, like 'this isn't going to be easy.'"

Isaacman described outer space as a "hard, very threatening environment."

“It wasn’t [anything] I would describe as peaceful when you’re looking out in the darkness of space,” he continued, “If anything, it was a little bit more of like: ‘If you want to be here, you’re going to have to work for it.’”

Isaacman made the remarks after SpaceX said it plans to have an unmanned mission land on Mars in two years and humans on Mars in four years. The CEO said he imagines looking out into vast expanse of space today feels similar to the explorers five centuries ago on a mission to cross the Atlantic Ocean.

“You shouldn’t interpret that feeling of danger and unwelcomeness as a deterrent, but it’s just more to rise to the challenge, just as explorers had to do throughout human history,” he added.

The Polaris Dawn conducted dozens of science experiments while in space to study the impact on the human body as it tries to better understand how to make the environment livable for humans.

- 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.

Dark the Universe is Beyond Our Solar System (Dailymotion)
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.

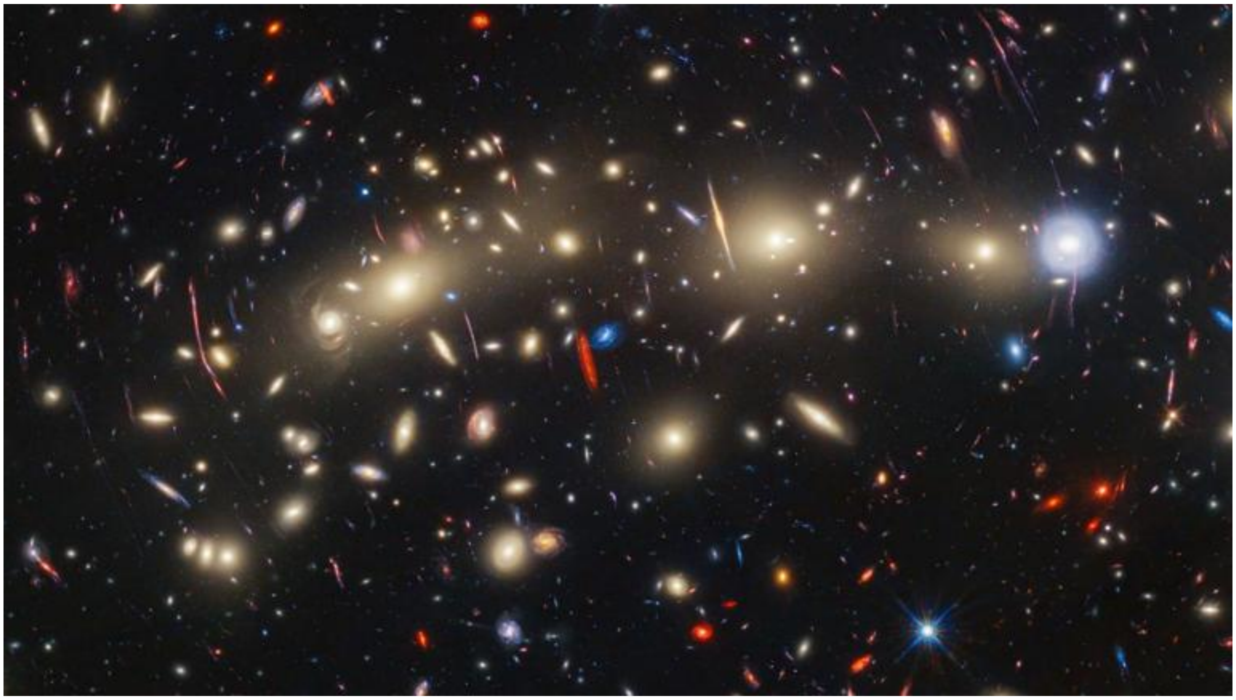
The research team asserts that if primordial black holes existed during this early period of inflation as many current models suggest, the field would have been bubbling away like a shaken can of soda. So much so, in fact, that nothing should have ever been able to form in the first place.

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?



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

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

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

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

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

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

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

Related: Why are galaxies different shapes?

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

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

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

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

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

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

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

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

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

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

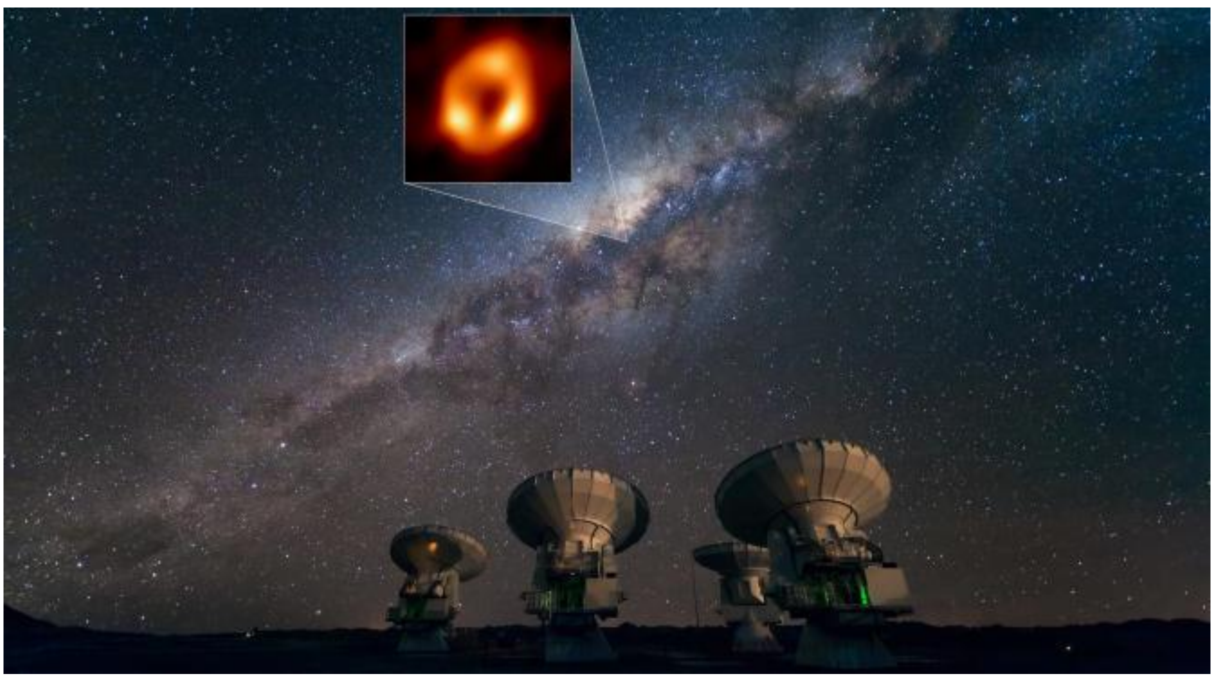
But considering we don't actually know the size of the universe, those estimates are murky. "If it's an infinite universe, you're going to have infinite galaxies," Gay said.

Spiral Galaxy NGC 628© NASA, ESA, CSA, STScI, Janice Lee (STScI), Thomas Williams (Oxford), PHANGS Team

On a clear night with dark skies, you can catch a glimpse of the Milky Way, a luminous arc stretching across the horizon. To the unaided eye, its translucent clouds are simply beautiful splashes in the night, their grandeur inspiring hundreds of creation myths. But a telescope reveals subtle structures within and outside the Milky Way that show how our own galaxy and others formed, explain their evolution through cosmic time, and even hint at their fate.

A galaxy is a massive collection of gas, dust, and huge numbers of stars and their solar systems, all held together by their mutual gravity. Our own galaxy exists within a neighborhood of closely gathered galaxies known as the Local Group. In the vastness of space, galaxies are arranged in filaments, clusters, and sheets, which form superstructures on a still larger scale.

Estimates of the number of galaxies in the universe range from 200 billion to 2 trillion. Dwarf galaxies may contain less than a thousand stars. At the other extreme of mass, supergiant galaxies can encompass a hundred trillion stars in orbit around the galactic center. The Milky Way also has a supermassive black hole at its core: Sagittarius A* (pronounced "A-star").



The Milky Way above the Atacama Large Millimeter/submillimeter Array, at the European Southern Observatory in the Chilean Andes.

The Milky Way above the Atacama Large Millimeter/submillimeter Array, above the European Southern Observatory in the Chilean Andes, a collaborator in the

multi-facility Event Horizon Telescope. Inset: Sagittarius A* as seen through the Event Horizon Telescope. Credit: ESO/José Francisco Salgado, EHT Collaboration
With respect to structure, there are three types of galaxies: spiral, elliptical, and irregular. Scientists also classify galaxies according to the activity at their core, such as a supermassive black hole. Around 10% of known galaxies are active, which means their luminous centers shine hundreds or thousands of times brighter than the combined light of their stars. These active galactic nuclei or *quasars* are what happens when a supermassive black hole devours a large amount of matter. Jets of high-energy photons blast from the quasar's rotational poles, reaching tens or hundreds of light years into intergalactic space.

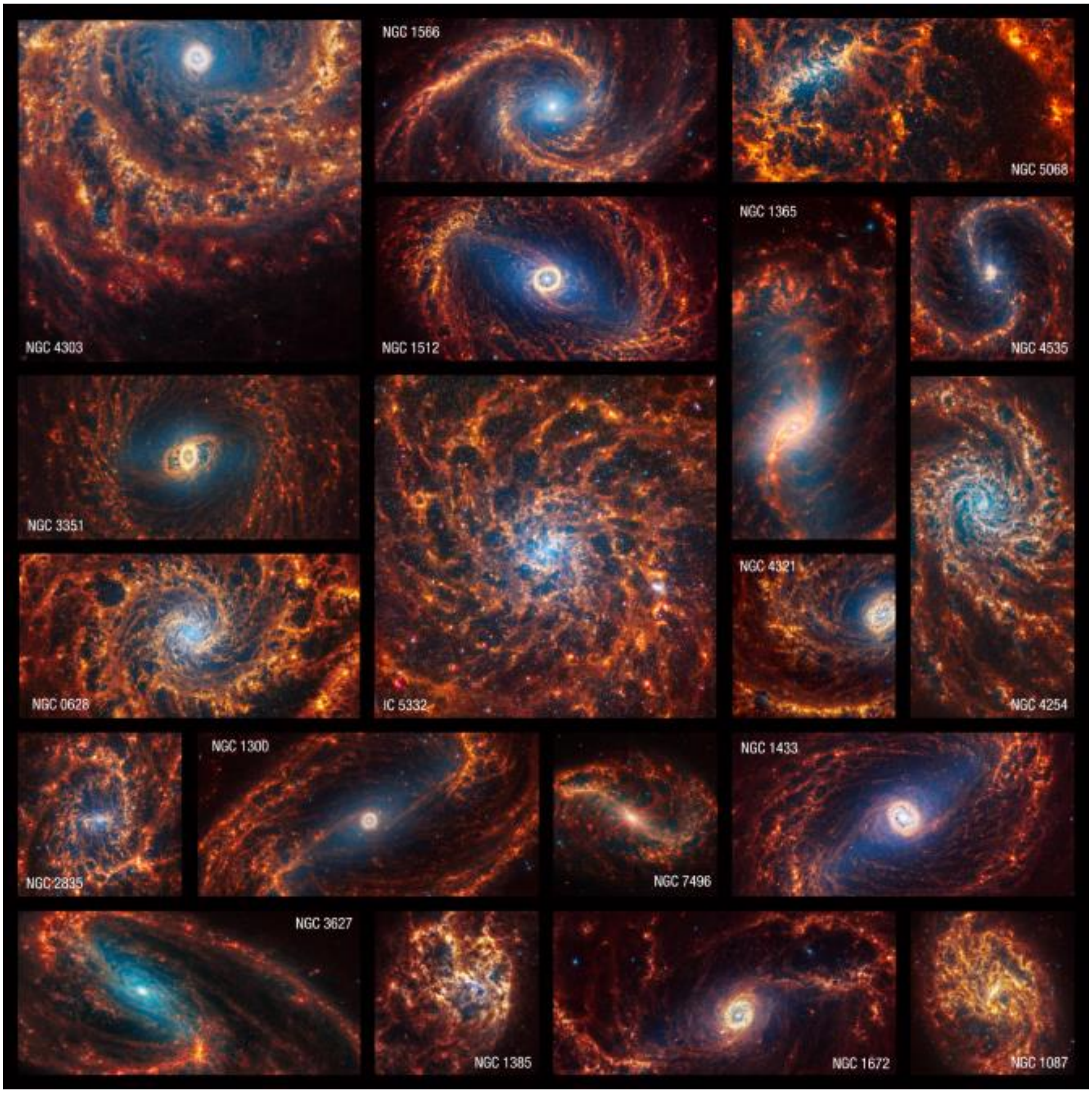
Related video: Astronomers Theorize There’s a Cluster of Black Holes Moving Around Our Galaxy (Amaze Lab)
The Milky Way is not considered an active galaxy—at least, not right now—but according to NASA it likely experienced a "burst of activity" within the past few million years.

Spiral Galaxies

By far the most common type of galaxy, spiral galaxies have a bright, dense core of stars collected in a central globe, from which two or more spiral arms extend in a wide, flat disc. Most have a supermassive black hole at their center. (Sagittarius A* accounts for some 4.3 million solar masses, a measurement that won the 2020 Nobel Prize for Physics.)

Spiral galaxies often have roughly spherical halos, composed of gas, dust, old stars, star clusters, and dark matter—invisible material that does not emit or reflect light but still has a gravitational pull on other matter. Clusters of stars form in stellar nurseries, regions rich in gas and dust found within a spiral galaxy's arms, while older stars can be found throughout the disk and halo.

Spiral galaxies account for the vast majority of galaxies, outnumbering other types by no less than two to one; the Hubble project gives a conservative figure of 60%, while the Sloan Digital Sky Survey's higher-end population estimate identified as many as 77% of all galaxies as spiral galaxies.



19 spiral galaxies as seen through the JWST

Spiral galaxies, as seen by the JWST. Glowing dust appears in shades of red and orange. Older stars are blue. Diffraction spikes indicate that these galaxies may have central active supermassive black holes. Credit: NASA, ESA, CSA, STScI, Janice Lee and Elizabeth Wheatley (STScI), Thomas Williams (Oxford), PHANGS Team

About two-thirds of spiral galaxies are barred spirals, in which the central disk is stretched out into a ribbon. The Milky Way belongs to this class, as well as our nearest galactic neighbor, the Andromeda Galaxy.

Elliptical Galaxies

Older and scarcer than spirals, elliptical galaxies have shapes ranging from long, narrow ovals to spheres. Unlike spirals, elliptical galaxies don't have much ambient gas and dust, and they show little discernible organization or structure. Member stars orbit around the galactic core in random directions, and little of the gas needed to form new stars remains.

Honorable Mention: Globular Clusters

Globular clusters are often mentioned in the same breath as galaxies, so they deserve a nod. A globular cluster can contain anywhere from tens of thousands to "many millions" of member stars, and globular clusters are found within nearly all galaxies. The Milky Way has no fewer than 157, but more globular clusters are thought to exist within the innermost regions of the galaxy which are shrouded in an obscuring veil of gas and dust.

Lenticular Galaxies

Lenticular galaxies are a kind of cross between spirals and ellipticals. They have the central bulge and disk common to spiral galaxies, but lenticular galaxies don't have arms. However, like ellipticals, lenticular galaxies have older stellar populations and not much ongoing star formation.

There are two leading theories about how lenticular galaxies evolved. One suggests these galaxies are late-in-life snapshots of older spirals whose arms have mostly faded or dispersed. The other proposes that they are what remains after the mergers of spiral galaxies, à la the fate that will eventually befall the Milky Way and Andromeda.

Arp 107, a pair of interacting galaxies, shines brightly in high-resolution infrared light. A collision, which occurred hundreds of millions ago, created a tenuous bridge of gas and dust that connects the two galaxies, and started a new wave of star formation.

In September 2024, the James Webb Space Telescope captured this collision in progress between an elliptical galaxy and a special type of spiral galaxy called a Seyfert galaxy, collectively known as Arp 107. Credit: NASA, ESA, CSA, STScI

Irregular Galaxies

A surprising number of galaxies don't quite fit the spiral/elliptical archetypes. These strange and contrarious sky objects may have shapes from teardrops to needles, hooks, and rings. They aren't a special, exotic type of galaxy. Instead, it's thought that many irregular galaxies might be spiral galaxies seen edge-on, distorted by gravitational lensing, or ancient elliptical galaxies disrupted by greater tidal forces.

On a Cosmic Scale

It's easy to feel small, looking up at the Backbone of Night. Our Solar System alone is an easy three light years wide, and it's barely a rounding error in comparison with the galaxy as a whole. The Orion arm of the Milky Way we reside in is a thousand light years thick from bottom to top, and almost a hundred thousand light years wide from edge to edge.

Crop of Webb's First Deep Field (2022)

Webb's First Deep Field (2022) captured a galaxy cluster, SMACS 0723, in truly unprecedented detail. This image contains thousands of galaxies. Credit: NASA, ESA, CSA, and STScI

Galaxies are truly gigantic, but they're dwarfed by the larger-scale structures to which they belong. The Milky Way galaxy, Andromeda, and all our respective satellites form a cluster known as the Local Group. The Local Group and hundreds of others like it form the Virgo Supercluster, which is itself one of four "lobes" of the Laniakea Supercluster: a cosmic structure of mind-boggling size whose common gravitational center is known as the Great Attractor. With its combined mass of 10^{15} M⊙, our Virgo Supercluster is perhaps 0.1% of the total mass of the complex—and yet, the Great Attractor has a gravitational pull that suggests a mass ten times the mass of the entire Virgo Supercluster.

Laniakea and its neighboring superclusters are constituent parts of the Pisces-Cetus Supercluster Complex, a gigantic filament almost a billion light years long. Galactic filaments are the largest known structures in the universe. The largest, known as the Hercules-Corona Borealis Great Wall, is thought to be ten billion light years long.

Looking that far out means looking back in time. The most distant galaxies are often also the oldest, so the light we see today shows us a picture of the galaxy as it existed when the light was emitted, billions of years in the past. The very oldest appear to us today as they did just a few hundred million years after the Big Bang. For example, astronomers used the JWST to identify CEERS J141946.36+525632.8 or "Maisie's Galaxy" formed about 13.2 billion years ago, when the universe was just 390 million years old. Another distant galaxy named GLASS-Z12 has a light travel distance or lookback time of 13.6 billion years, which means it had formed no less than 13.6 billion years ago: well within the cosmic Dark Ages, before reionization of the Universe was complete. But due to the expansion of the universe, its current proper distance is some 33.2 billion light-years.

Redshift

The speed of light is a kind of universal speed limit, and if the universe began 13.8 billion years ago, then you'd think the visible universe could only be 13.8 billion years wide at most. But there's more to the story. Galaxies like GLASS-Z12 can be so far away because the universe itself is expanding. Scientists first discovered this due to a phenomenon called Doppler shifting, or redshift. Light waves from approaching objects are compressed, which makes them seem shorter and thus "bluer" than they are. Objects moving away from an observer will lengthen and shift toward the red instead. The Z12 in GLASS-Z12's name describes its Doppler shift or redshift.

In calculating the size of the visible universe, astronomers including Edwin Hubble and Georges Lemaître discovered that light from distant galaxies was redshifted, with an increase in wavelength corresponding to their distance from Earth. If everything was expanding, though, where had it all started? From that central question arose the idea of the Big Bang. Hubble, meanwhile, lent his name to a mathematical law describing the expansion of the universe—and the space telescope that substantiated his work.

Galaxies near and far are a favorite target for Hubble's spiritual and technological successor, the James Webb Space Telescope, built to investigate (among other things) how galaxies form, grow, merge, and eventually fade. Since its 2021 debut, the JWST has set and broken record after record for the biggest, oldest, and most distant galaxies ever discovered. Another of Webb's key objectives: to check and refine astronomers' models of dark matter and the Hubble constant, both of which are key to the expansion of the universe. Cold dark matter may be invisible by normal methods, but it still has a gravitational pull. Invisible or not, if it's there, the JWST will find it.

Astronomers using the James Webb Space Telescope (JWST) have observed six massive galaxies that seem to defy our understanding of cosmic evolution© Space Telescope Science Institute Office of Public Outreach

About **13.8 billion years ago**, the entire contents and energy of the universe were concentrated in a **singularity**—a point of infinite density and temperature. This singularity began to **expand rapidly**, an event we now refer to as the **Big Bang**.

During this explosive birth, the fundamental forces of nature—such as gravity, electromagnetism, the weak force, and the strong force—began to emerge in stages. That’s why when the JWST spotted some galaxies that seemed to jump some of those stages it all seems too strange.

Why are these galaxies older than the universe? Did they exist before the Big Bang?

These galaxies were spotted when the universe was a mere **500 to 700 million years old, a** time when it was just **3 percent** of its current age. At that point, the universe was still in its infancy, and most theories predicted the existence of small, young galaxies.

However, these newly identified galaxies are anything but small. Their mass of stars totals several billion times larger than our sun. One of them might even be as massive as **100 billion times** the mass of our sun. To put this in perspective, our own Milky Way galaxy contains a mass of stars equivalent to roughly **60 billion suns**.

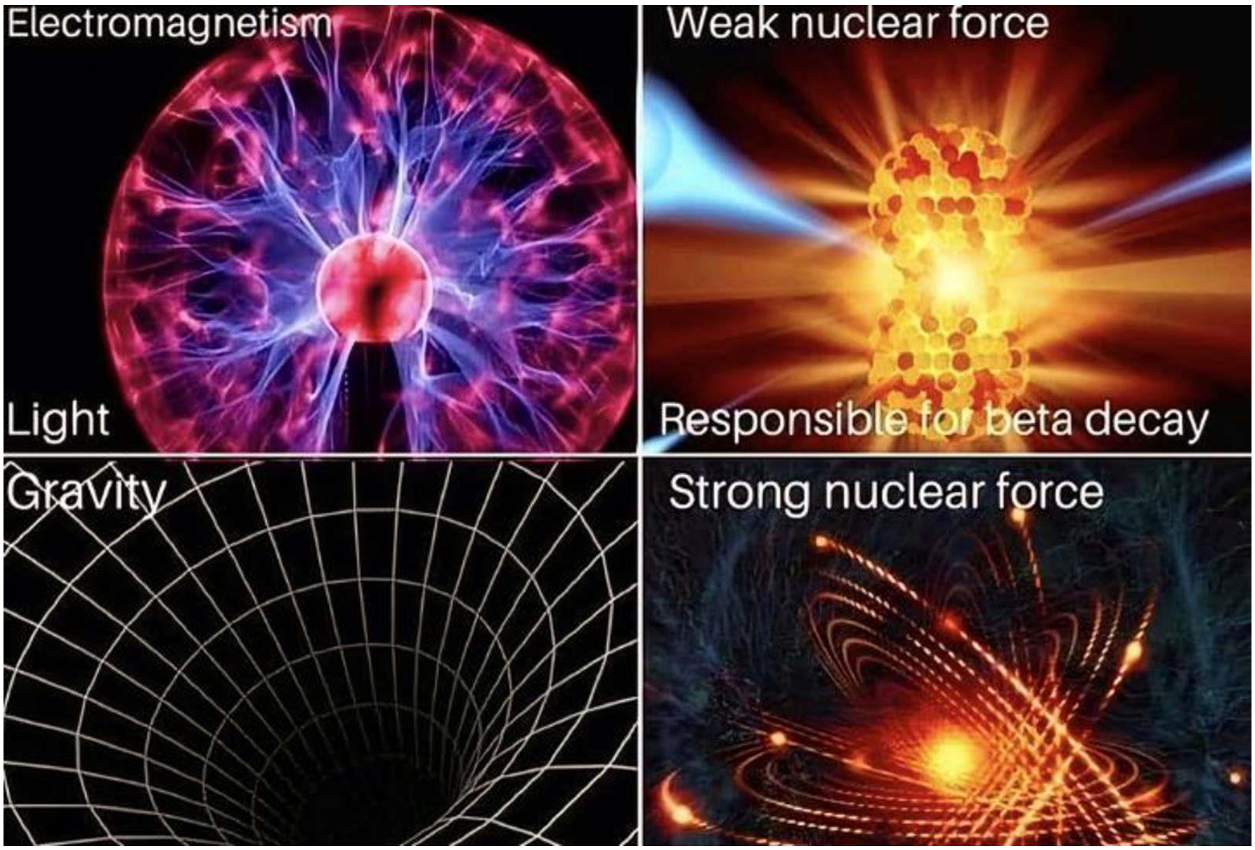
To understand this, we have to look at **red-shifting**. The older the body in the universe, the hue of color detected by telescopes changes. The color changes to red, and the difference in the proportion of red indicates whether the **galaxy is older or younger**. The redshift of these galaxies indicates not only their extreme age but also their immense size and the presence of massive stars.

As galaxies age, they produce more suns, and in this case, the total mass is **100 billion** times larger than our galaxy, a phenomenon for which there is currently no clear explanation. This is particularly significant because these galaxies formed without the need for dark matter, an element previously believed to be necessary to hold them together.

The quest to understand the universe often parallels science and faith in their debate. Yet, what if science holds clues pointing toward a divine creator? Find out the three ways science has hinted at the existence of an intelligent hand behind the creation of the universe.

The Fine-Tuned Universe Discovery

Scientists have made a mind-boggling discovery: the universe is like a finely tuned machine, with all its parts intricately working together to make life possible. This revelation suggests that a creator is intentionally involved in this balance. But that's not all.



The Four Fundamental Forces

There are four main forces in nature: gravity, electromagnetic forces, and two types of nuclear forces. These forces must be balanced, just like ingredients in a perfect recipe. If gravity were even slightly stronger or weaker, the formation of stars like our sun and, consequently, the existence of life would be impossible. This delicate balance further suggests a creator's intentional design of the universe.

Earth's Perfect Positioning

Earth rotates at the right speed to give us day and night, and it's tilted at just the right angle to provide seasons. Astronomers call this the 'Goldilocks zone'—it's just right for liquid water to exist, which is essential for life. It's almost as if someone meticulously adjusted everything to make it perfect for humans to thrive.

The Atmospheric Precision

The atmosphere is another marvel. There is enough oxygen to breathe, but not so much that everything would catch fire easily. And there's plenty of nitrogen to balance things out. Looking at all these factors is like a cosmic miracle, where countless factors have aligned perfectly to allow life to flourish.

Implications Of A Fine-tuned Universe

As a result of the precise balance and calibration of the universe, life points to an external intelligent or creator. However, skeptics propose the alternative multiverse theory, suggesting the universe is only one of many, and we simply exist in one capable of supporting life. The problem with that?

The Problem With The Multiverse Theory

We can't observe other universes, so designing experiments that could definitively prove or disprove the multiverse theory is difficult. The theory also doesn't solve the fine-tuning problem; it merely pushes it back a level and then begs the question: What fine-tuned the multiverse generator itself?

The Redshift and Cosmic Expansion Discovery

This discovery shook up human understanding of the universe in a big way. And it started with one man's mistake. Albert Einstein, arguably the most famous scientist ever, initially thought the universe was static like a frozen snapshot. He even added a constant to his equations to keep it that way. But then along came Georges Lemaître.

An Expanding Universe

Georges was a Belgian priest and astronomer who questioned Einstein's stance. Edwin Hubble backed up his findings with more evidence that distant galaxies were zooming farther away, which caught Einstein's attention.

Einstein's Visit to Hubble

Then, in 1931, Einstein visited Hubble at Mount Wilson Observatory in California. When he saw and reviewed Hubble's data on galaxies' redshifts, he reportedly admitted that sticking to the idea of a static universe was his "biggest blunder."

Implications of a Finite Universe

Hubble's discovery lent strong support to the Big Bang Theory, suggesting a finite beginning to the universe and resonates with the concept of a Creator. If the universe is expanding outwards, it means it started from a point, a "birth moment," which raises all sorts of intriguing questions about what caused it and why it seems so finely tuned for life to exist.

The Information in DNA Discovery

At the heart of molecular biology lies the discovery of DNA, which carries the genetic instructions for all living organisms. The structure of DNA reveals a complexity and information density that is often compared to computer code, leading to discussions about the origins of this information.

The Double Helix

In 1953, two scientists named James Watson and Francis Crick figured out what DNA looks like. It is composed of two long strands of nucleotides twisted around each other. These strands are held together by base pairs to form a code that specifies the amino acid sequences of proteins, the life builders.

Complex Information and Intelligent Design

The complexity and specificity of genetic information in DNA is truly staggering. Unlike random sequences, the genetic code exhibits a high degree of order and functionality, akin to a computer program written by a skilled programmer. This level of complexity attests to the intelligence behind its design.

Complex Information and Intelligent Design

Bill Gates once remarked that DNA is a computer program that is far more advanced than any software. His comparison highlights that DNA's complexity surpasses even the most advanced human-designed systems, suggesting that such complexity might arise from an intelligent source rather than random processes.

Implications Of The Information In The DNA Discovery

DNA's precise coding and functionality are too sophisticated to have arisen purely by chance or through undirected evolutionary processes. The view suggests that the existence of DNA could be evidence of a higher intelligence, creator, and God.

The Cosmic Debate: Divine Design or Random Chance?
Story by Sarah Norman

Limitations

Science, while a powerful tool for understanding the universe, has its limitations, particularly in addressing questions of existence beyond empirical observation. Many argue that phenomena such as consciousness, the origins of the universe, and the intricacies of life suggest the possibility of a higher power or divine intelligence.

Moral and Ethical Laws

Moral and Ethical Laws: Some argue that the presence of moral and ethical laws in human consciousness and societies suggests a divine origin, aligning with the idea of a creator who imbues the universe with purpose and order.

Fine Tuning of the Universe

Fine-Tuning of the Universe: The universe's physical constants and laws are remarkably fine-tuned for the existence of life. Some argue this precision suggests intentional design rather than random chance.

The Big Bang Theory

The Big Bang Theory: The Big Bang theory, which posits that the universe had a beginning, is seen by some as consistent with the idea of a creator initiating the universe.

Cosmic Background Radiation

Cosmic Background Radiation: The uniformity of cosmic background radiation is often interpreted as a remnant of a primordial event, which some believe could be the result of a deliberate act of creation.

The Anthropic Principle

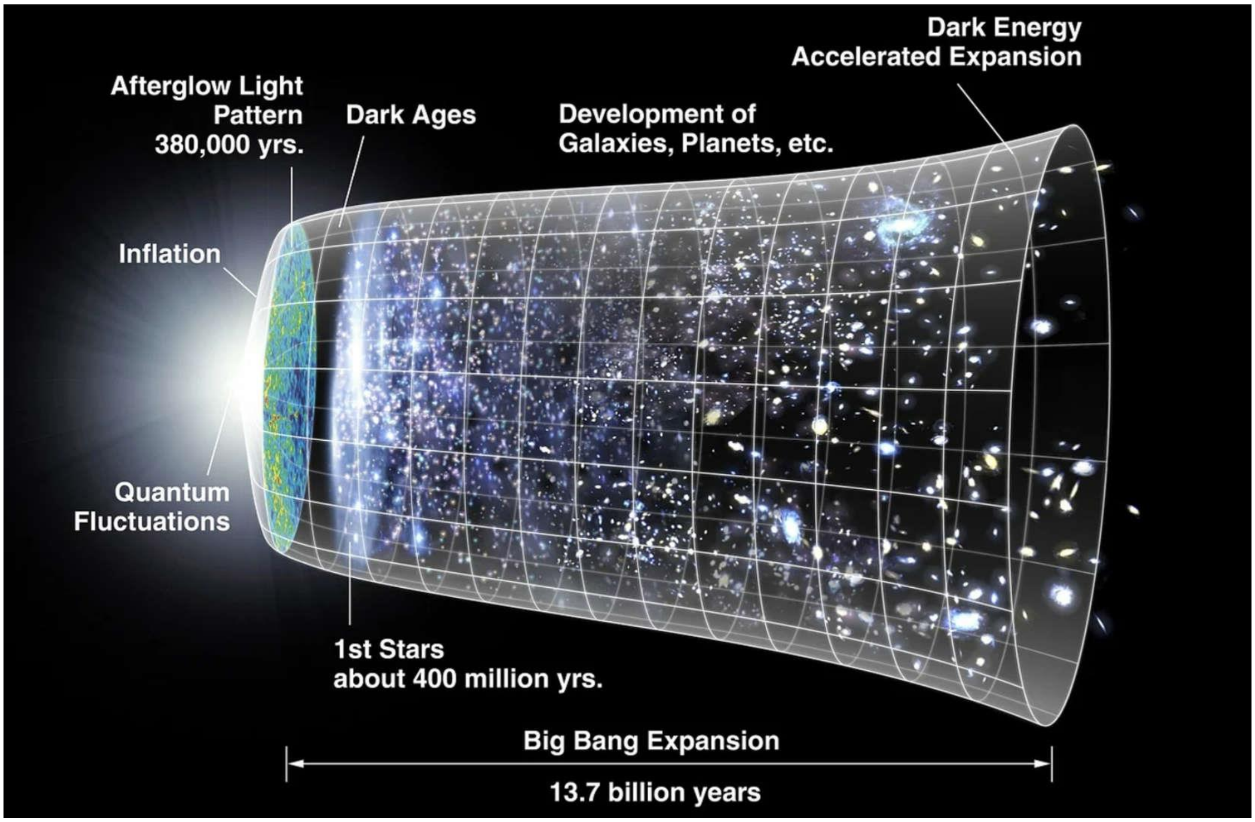
The Anthropic Principle: This principle suggests that the universe's properties are perfectly suited for human life, implying that it might have been designed with purpose.

Order and Complexity

Order and Complexity: The intricate order and complexity observed in natural systems, from galaxies to biological processes, are sometimes cited as evidence of an intelligent designer.

Irreducible Complexity

Irreducible Complexity: Certain biological systems are considered by some to be too complex to have evolved through natural processes alone, suggesting a possible guiding hand.



The Origin of Life

The Origin of Life: The spontaneous emergence of life from non-life remains one of science's biggest mysteries, leading some to argue that a creator might have played a role.

Mathematical Precision

Mathematical Precision: The universe's underlying mathematical framework, which describes everything from subatomic particles to cosmic structures, is viewed by some as indicative of purposeful design.

Quantum Mechanics

Quantum Mechanics: The strange and counterintuitive nature of quantum mechanics is sometimes interpreted as evidence of a creator's involvement in the fundamental aspects of reality.

The Laws of Thermodynamics

The Laws of Thermodynamics: The application of these laws, particularly the law of entropy, raises questions about the universe's origin and complexity, which some argue points to a creator.

Mathematical Laws of the Universe

Mathematical Laws of the Universe: The existence and effectiveness of mathematical laws in explaining natural phenomena are seen by some as evidence of a purposeful design behind the universe.

Planets and stars have magnetic fields primarily due to the movement of electrically charged particles within them, creating what is called a *dynamo effect*. However, not all planets and stars have magnetic fields, or at least not strong ones, and this depends on a few key factors:

1. Composition and Internal Structure: Planets or stars need a conductive core or layer, often metallic, for a magnetic field to form. For example, Earth's magnetic field is generated by its molten iron outer core. In stars, the plasma (ionized gas) can act as the conductor.

2. Rotational Speed: Faster rotation can enhance the dynamo effect. For example, Jupiter has a stronger magnetic field than Earth due to its faster rotation and larger size.

3. Internal Heat: Internal heat drives convection currents in the conductive material (such as molten metal in a planet or plasma in a star), which is necessary to sustain the movement of charged particles. A planet or star that has cooled significantly may not have the required convective motion, weakening or eliminating its magnetic field.

4. Magnetic Dynamo Process: Not all planets or stars generate strong magnetic fields because the conditions inside them (such as convection

currents and rotation) may not be sufficient to drive a dynamo process.

For example, Earth's magnetic field comes from its molten iron core, whereas the Moon, which lacks a similar molten core, has a very weak magnetic field. Similarly, stars like the Sun have magnetic fields due to the movement of plasma in their interiors. However, smaller or older stars may have weaker or diminished fields.

Earth will get a second moon for about two months this year when a small asteroid begins to orbit our planet. The asteroid was discovered in August and is set to become a mini-moon, revolving around Earth in a horseshoe shape from Sept. 29 to Nov. 25.

Researchers at the Asteroid Terrestrial-impact Last Alert System, an asteroid monitoring system funded by NASA, spotted the asteroid using an instrument in Sutherland, South Africa and labeled it 2024 PT5.

Scientists from the Universidad Complutense de Madrid have tracked the asteroid's orbit for 21 days and determined its future path. 2024 PT5 is from the Arjuna asteroid belt, which orbits the sun, according to their study published in Research Notes of the AAs.

But Earth's gravitational pull will draw 2024 PT5 towards it and, much like our moon, it will orbit our planet — but only for 56.6 days.

While other non-Earth objects, or NEOs, have entered Earth's orbit before, some don't complete full revolutions of Earth. Some, however, do and become so-called mini-moons.

Black holes may be behind why the newborn universe appeared to possess more huge galaxies than scientists could explain, a new study finds.

Astronomers made this discovery with the help of NASA's James Webb Space Telescope (JWST), the largest and most powerful off-Earth observatory to date. Launched in December 2021, the $10 billion JWST specializes in detecting infrared light, just like thermal vision goggles.

Scientists are using JWST to investigate the early cosmos. The universe has expanded greatly since it was born about 13.8 billion years ago in the Big Bang, and that means the light from early galaxies appears reddened by the time it reaches Earth, much as how an ambulance siren sounds lower-pitched to people as the vehicle drives away. JWST is designed to help capture light from the earliest galaxies, much of which has shifted into the infrared range.

When astronomers got their first glimpses of galaxies in the early universe from JWST, they were expecting miniature versions of modern galaxies. Instead, they found that some galaxies had grown very large very quickly.

Related: Is the James Webb Space Telescope really 'breaking' cosmology?

This previous research suggested that something might be wrong with scientists' thinking about what the universe is made of and how it has evolved since the Big Bang, known as the standard model of cosmology. All in all, early galaxies seemed to be larger than what the standard model expected by "roughly a factor of two," study co-author Steve Finkelstein, an astrophysicist at the University of Texas at Austin, told Space.com.

Now, Finkelstein and his colleagues find that some of these early galaxies are actually much less massive than they first appeared. They detailed their findings online Aug. 26 in The Astrophysical Journal.

In the new study, the researchers focused on 261 galaxies from about 700 million to 1.5 billion years after the Big Bang. To estimate the mass of galaxies, scientists typically see how much light a galaxy emits and deduce the number of stars it likely possesses to generate all that light. Previously, when it came to early galaxies, NASA's Hubble Space Telescope "was only to glimpse the hottest, most massive stars," Finkelstein said. "JWST observes redder wavelengths, so is sensitive to lower-mass, cooler stars, and so can more accurately measure the total amount of stars in these galaxies."

The scientists discovered that black holes made nine of these early galaxies appear much brighter — and thus bigger — than they really are. Although black holes get their name from how their gravitational pulls are so powerful that not even light can escape, gas falling into black holes can glow brightly from the friction it experiences as it rushes in at high speeds. This extra light can make it appear that galaxies hold more stars than they actually do.

Once the researchers accounted for these black hole-affected galaxies, the standard model could account for the remaining early galaxies.

"So, the bottom line is, there is no crisis in terms of the standard model of cosmology," Finkelstein said in a press release. "Any time you have a theory that has stood the test of time for so long, you have to have overwhelming evidence to really throw it out. And that's simply not the case."

However, "we are still seeing more galaxies than predicted, although none of them are so massive that they 'break' the universe," study lead author Katherine Chworowsky, a graduate student at the University of Texas at Austin, said in the press release.

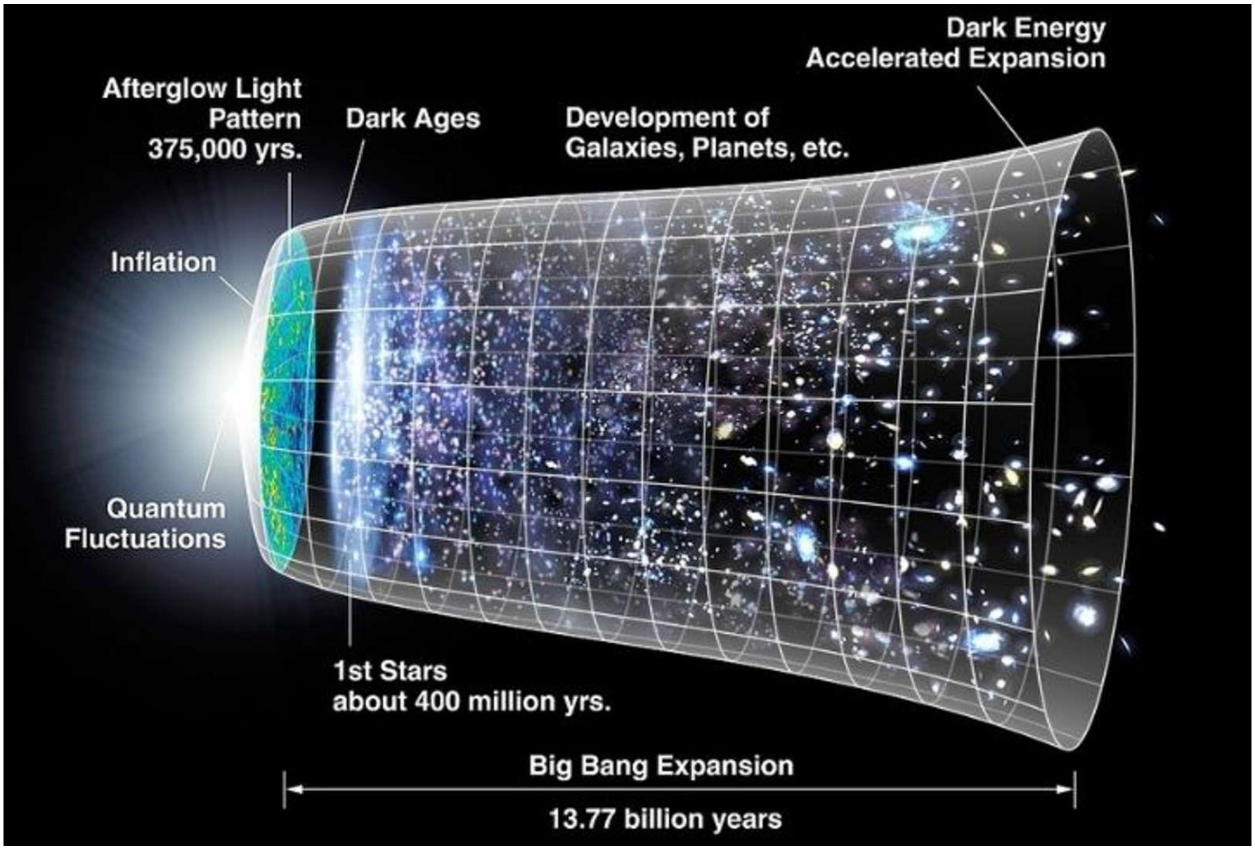
One possible reason that JWST sees about twice as many massive early galaxies as expected from the standard model is that stars formed more quickly in the early universe than they do today. "Maybe in the early universe, galaxies were better at turning gas into stars," Chworowsky said in the press release.

A star is born when a cloud of gas succumbs to its own gravity and collapses. However, as this gas contracts, it heats up because of friction, generating outward pressure. Nowadays, these opposing forces usually make star formation slow. However, since the early universe was denser than it is today, some research suggests it was hard to expel gas during star formation, letting it happen faster.

Now "we would like to understand why we observe what we observe," Finkelstein said. "One way to do this is to study how these galaxies build up their stellar mass." Such data will come in the next few months, "which we should be able to use to better understand how these massive galaxies formed."

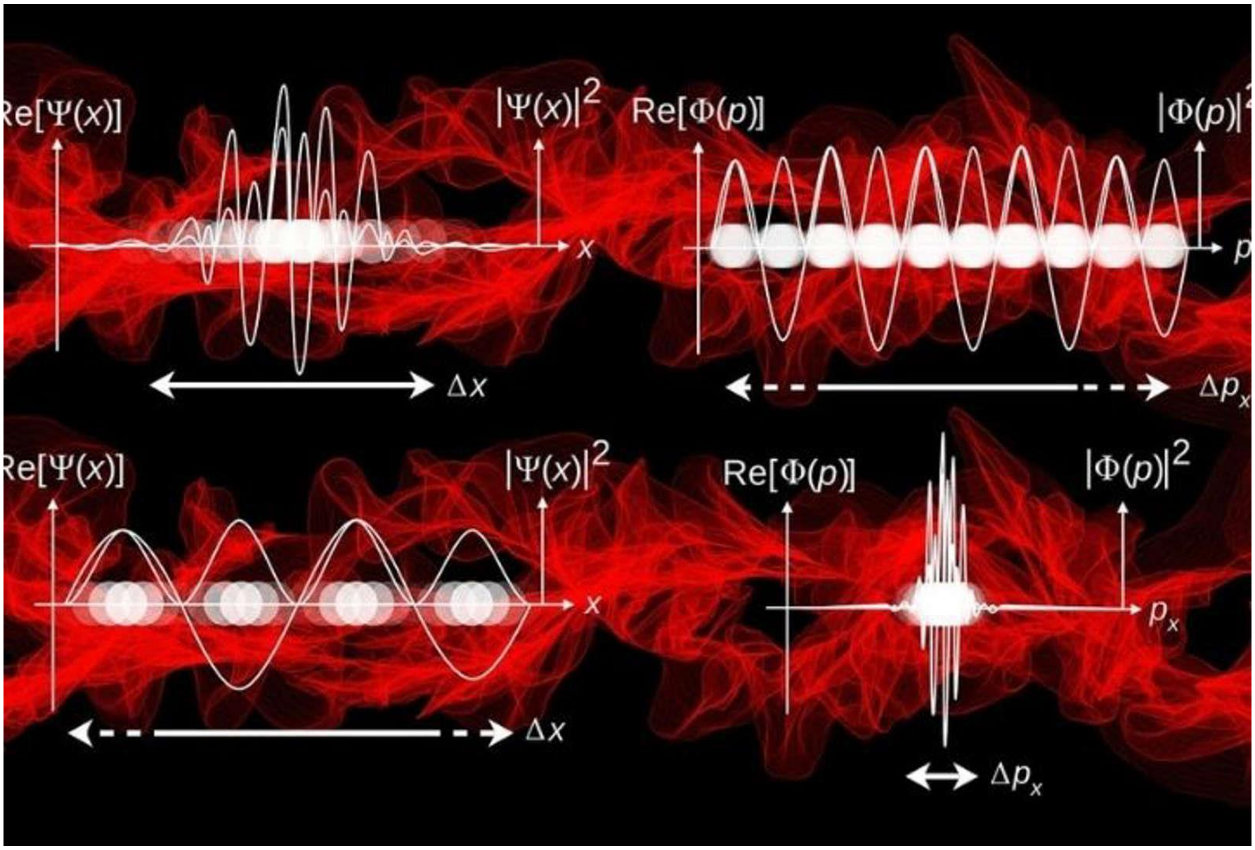
Originally posted on Space.com.

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



The Big Bang Puzzle

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



Quantum Fluctuations

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

The Role of Dark Energy

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

String Theory Insights

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

Cosmic Microwave Background

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

Black Hole Clues

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

Time Before Time

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

Multiverse Theories

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

Advanced Computer Simulations

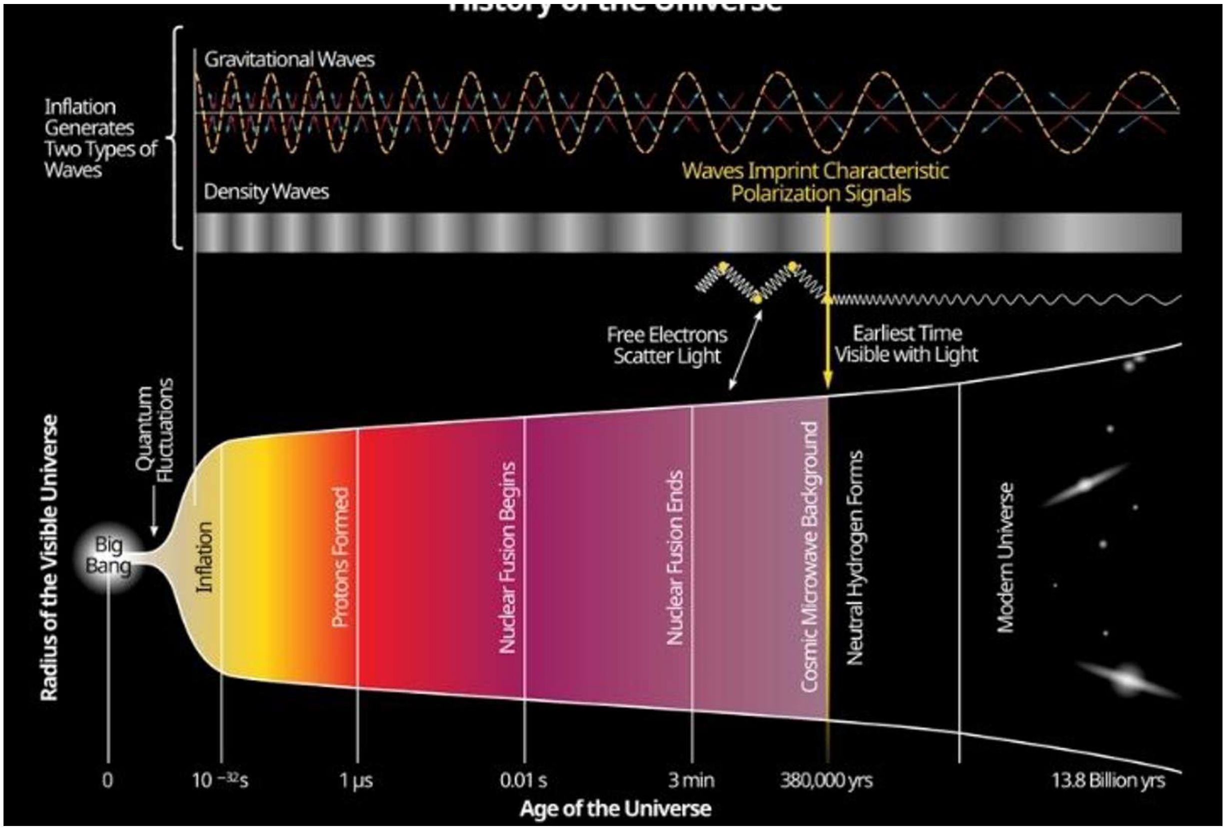
Powerful computers allow scientists to explore pre-Big Bang scenarios and to test various theories about the universe's behavior before its expansion. These models expand our understanding of cosmology by pushing the limits of what we know about the origins and early conditions of the universe.

Gravitational Waves

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

Matter-Antimatter Asymmetry

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



Quantum Gravity

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

Eternal Inflation Theory

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

Philosophical Implications

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

Future Research Directions

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

Astronomers have uncovered something pretty remarkable emerging from the depths of space, after detecting a powerful series of radio waves.

What makes them truly astonishing is that these radio waves have been travelling through space for a total of 8 billion years – and it could help experts to gain a better understanding of one of the great mysteries of the universe.

The signal, known as FRB 20220610A, is made up of dazzling radio wave flashes that last just milliseconds at a time.

It's one of the most distant ever recorded and no-one knows for sure where these bursts of energy come from, or indeed who might be sending them.

The strength of the newly observed signal is truly staggering, with FRB 20220610A emitting the same amount of energy that our sun produces in 30 years in the space of just a few milliseconds.

Experts involved in new research published in the journal Science have speculated that signals such as this one could be linked to the remains of exploded stars, known as magnetars.

These signals could theoretically help astronomers to put together a more comprehensive understanding of the universe, given that the weight of normal matter out there doesn't add up to what experts theorise there should be.

One of the people involved in the research is astronomer Dr. Stuart Ryder from Macquarie University in Australia. He said: "FRBs are common and hold great promise. We could use them to create a new map of the universe's structure and answer big questions about cosmology."

When NASA's Artemis I mission launched on its journey around the moon in 2022, there weren't any astronauts aboard — but there were two torso-shaped dummies, named Helga and Zohar, who were designed to test how much radiation astronauts can expect to be exposed to when they do eventually fly on the Artemis II and III missions.

Now, the German space agency DLR has released the first results from the radiation study, and the good news for future moon explorers is that it looks like the radiation levels are within acceptable limits inside shielded areas of the spacecraft. Radiation is a concern once people travel outside the protective magnetosphere of Earth, and the region of charged particles called the Van Allen belt that help to protect us on the ground from radiation exposure. When traveling beyond low-Earth orbit and out to the moon and beyond, astronauts will be exposed to radiation that can cause cancer, cardiovascular disease, and other health problems.

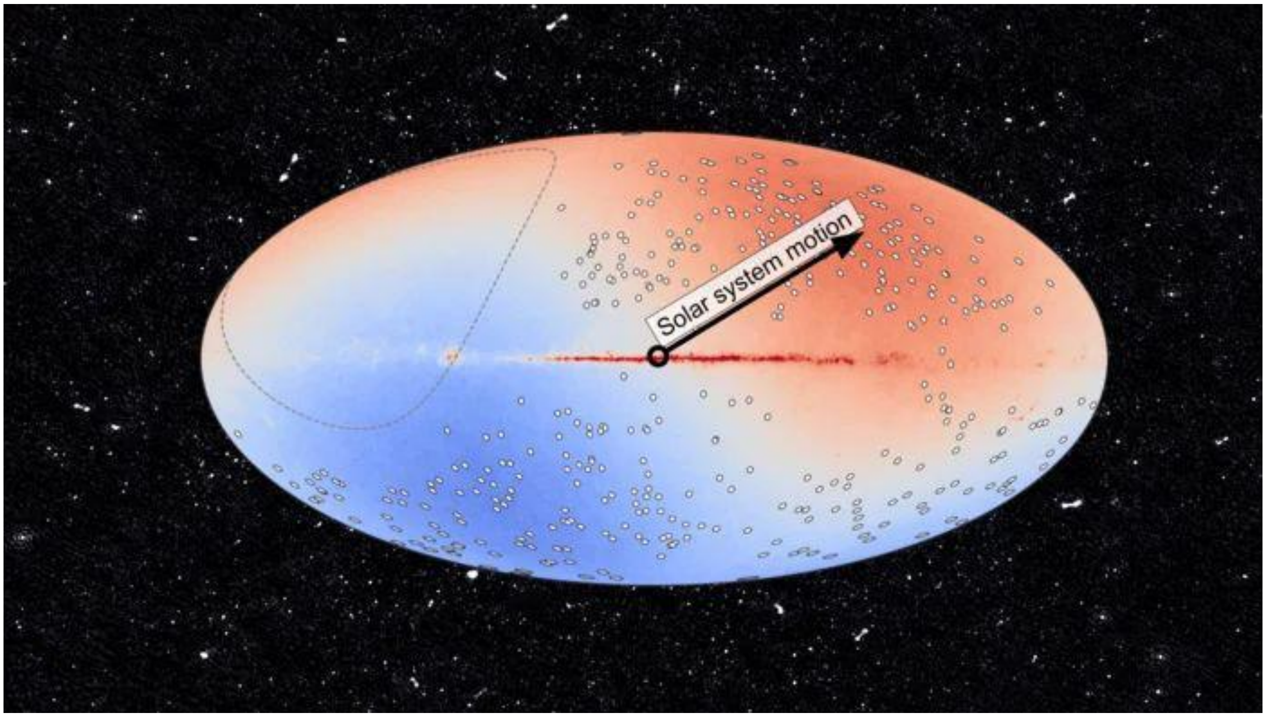
The new study found that the amount of radiation exposure within the Orion capsule varied considerably by location, with shielded areas experiencing four times better protection than unshielded ones. But it's not just the environment inside the capsule that is important. The study also found that the orientation of the spacecraft affected exposure, and that by turning the spacecraft 90 degrees during a flyby of the inner Van Allen belt, the exposure was reduced by 50%.

"This shows us that this flight maneuver can significantly reduce the radiation exposure for the crew. This is also a good sign and confirms the basic suitability of Orion for future spaceflight with astronauts. Our measurement data also provides a solid knowledge base for the design of future missions," said Thomas Berger of the DLR Institute of Aerospace Medicine.

The two dummies were used to simulate the kinds of radiation exposure that might be experienced by the human body, comparing one that was unprotected and one that wore a radiation-protecting vest. The researchers have not yet released the data from that comparison, but they are working on the analysis and should be able to share the results soon.

"With radiation monitors placed throughout the Orion capsule, we are gaining valuable insights into how space radiation interacts with the spacecraft's shielding, the types of radiation that penetrate to reach the human body, and which areas inside Orion offer the most protection. This knowledge is invaluable, as it will allow us to accurately estimate radiation exposure for ESA astronauts before they journey into deep space, ensuring their safety on missions to the Moon and beyond," said Sergi Vaquer Araujo, lead for the Space Medicine Team.

The research is published in the journal Nature.



A map of the sky overlaid on a portion of single MeerKAT pointings containing a few thousand radio sources. In the sky map, circles mark positions of 391 pointings containing a total of 971,980 sources. The arrow shows the direction of the cosmic dipole originally established by measurements of the cosmic microwave background radiation. The dipole effect will make the sources appear more numerous (red portion) in the direction of the motion and less numerous in the opposite direction (blue portion).© MALS Team

When we look out into the universe with our unaided eyes, we are really only seeing a small chunk of what's actually there. That's because there are parts of the electromagnetic spectrum that our visual faculties are not sensitive to.

Radiation is being emitted by all manner of cosmic phenomena across this spectrum, yet we're only able to physically see wavelengths within the visible light range without the help of external tools — but luckily, astronomers have access to telescopes that allow them to observe the universe across this continuum.

The South African MeerKAT radio telescope is one such observatory, allowing astronomers to probe the radio band emissions of stars, blackholes and galaxies in the surrounding universe. Recently, an international team of astronomers from the MeerKAT Absorption Line Survey (MALS) used a vast catalog of radio sources captured by the MeerCAT radio telescope to make a measurement of a phenomenon called the "cosmic radio dipole."

Observing the radio sky can give astronomers insights into the large-scale structure of the universe, as radio emissions from far off galaxies can travel through space on relatively uninterrupted trajectories. The MALS survey has produced an extremely sensitive catalog of close to a million radio sources in the sky because the team pointed the MeerKAT telescope array in 391 directions.

Related: How did the universe's elements form?

"The depth and the expanse of this continuum catalog holds a unique position among modern radio continuum surveys," Neeraj Gupta, an astronomer at the Inter-University Centre for Astronomy and Astrophysics (IUCAA) who leads the MALS project, said in a statement.

The cosmic radio dipole is an effect generated by the motion of the solar system through space as it orbits the center of the Milky Way galaxy, and as the Milky Way gravitationally interacts with other galaxies. The effect makes radio sources appear more numerous in the direction the solar system is traveling in, and less numerous in the opposite direction.

The magnitude of this effect should be directly related to the velocity of the solar system through space — however, the effect has been found to be much higher based on previous measurements of the solar system's motion through space.

This made astronomers question whether the dipole might not just be caused by the motion of the solar system through space, but rather by other radio sources (and therefore more galaxies) in the direction that the solar system is traveling. However, the new dipole measurement based on the MALS survey is aligned with predictions based on current measurements of the solar system's movement through space.

Astronomers think this discrepancy may be related to the design of different surveys, where the MALS survey covered small patches of the sky to a very deep level. By contrast, other radio surveys have measured wider patches of sky but on much shallower scales."Measuring the dipole is an extremely important test of cosmology, and can tell us whether our fundamental assumptions about the structure of the Universe are correct," Jonah Wagenveld, an astronomer at MPIfR and lead author of the paper that reported the findings, said in the statement.

As the new findings reveal, radio astronomy offers scientists novel ways of observing the universe at the largest scales, and therefore, opportunities to test our best cosmological theories against observational data.

A pre-print about these results can be viewed on the paper repository arXiv and a paper has been published in the journal Astronomy & Astrophysics.

Scientists say microscopic wormholes could explain discrepancies in cosmological constants and affect our understanding of quantum mechanics and dark energy.© sarayut Thaneerat - Getty Images

- Churning nano-wormholes could explain the clash in our cosmological constants.
- The wormholes add magnitude to a math parameter called the Gauss-Bonnet term.
- Boosting one term in a complex equation helps scientists explain how the results could change.

Scientists in Greece have laid out a mathematical framework to help explain a so-far-unsolved gap in our understanding of how gravity scales up to the full size of our universe.

Specifically, cosmologists can't yet account for how expansion of the universe increased in the "recent cosmological past"—a *very* relative term—because all attempts to quantify the change so far end up clashing with existing mathematical models. The Greek scientists suggest something particularly squiggly: microscopic wormholes, whose nature and density could fill up the missing pieces. These spacetime Orbeez require only a bit of fine-tuning from theories that are already in the zeitgeist.

In the new paper, which appears in the peer-reviewed journal *Physical Review D* from the American Physical Society, the authors explain that the "positive cosmological constant" meant to quantify our expanding universe has, instead, created math issues: "[Q]uantum field theoretical analysis predicts a value up to 120 orders of magnitude larger than the observed one."

An order of magnitude is not simply a 1:1 multiplier, so 120 orders of magnitude is likely far more than 120 times larger. But if your lifetime likelihood of being struck by lightning is about 1 in 15,300, 120 times larger jumps to 1 in 127.

If we want to balance the two possibilities, the scientists explain, we need to add at least one new complicating factor. The two main suggestions for this are, first, a changing cosmological constant explained by the idea of dark energy; or second, to deepen our theory of how gravity behaves on the cosmic scale, from a smooth background to a craggier, fjord-like complexity.

This paper suggests combining both options: What if the solution is a believably craggier background gravity covered with instantons and wormholes, and their more rugged landscape naturally accounts for an amount of dark energy as well?

Let's define some terms. When cosmologists try to model the universe, they break it down using practices like topology and manifold theory. They build in as many variables or ideas as they have at the time, leaving spaces where something is not yet known. And, just like in your high school calculus class, the goal is always to account for everything on both sides of any equal sign or other equivalence in your mathematical model.

The physics of different scales simply don't match easily yet. Concrete observations by Albert Einstein and those before turned into beautiful theories that account for the visible world and parts of outer space; quantum mechanics twists those pieces until they no longer fit together into a completed puzzle. Considering spacetime as a manifold, or a surface that is guided by interlocking math on a grand scale, lets physicists look for the correct new place for a particular piece of the puzzle.

One way spacetime acts up is called quantum foam. On an extraordinarily tiny level, scientists believe, even quantum phenomena break down and create tiny bubbles where principles no longer apply. If someone can be a writer's writer or a comedian's comedian, this is kind of the disruptive quantum mechanics *of* quantum mechanics. And it's in this foam where wormholes could exist in a way that brings cosmic ideas together without breaking any larger rules.

The term "wormhole" may even be misleading, because they can be tunnels, but may also simply be punched holes that cross through higher dimensions behind the scenes. Manifold theory allows scientists to add these dimensions and at least attempt to rationalize them, something difficult to do using a three-dimensional human mind.

Once we allow that there could be wormholes in the foam, the scientists explain in the paper, a number of other relevant math operations and transformations build on that foundation. The solution, "an effective cosmological constant," appears when you apply the Gauss-Bonnet theorem: "[T]he variation of the Gauss-Bonnet term on a manifold that has topology changes due to the formation of wormholes is not zero."

In astrophysics, that's a mic drop.

As for where dark energy comes into this, it's still a part of our working model of the universe, wormholes or not. In this case, the wormholes would directly account for at least some of that dark energy: "[T]he wormhole density in a dynamical spacetime is not expected to be constant, therefore the obtained effective cosmological constant also acquires a dynamical nature, i.e., it corresponds to an effective dark energy sector."

In other words, the churn of the micro wormholes creates a changing constant. And to account for the observed cosmological constant, all we need is "1016 microscopic wormholes," or 10 quadrillion, "per cubic meter per second." That, the scientists conclude, is well within the realm of possibility based on estimates.

Have you ever wondered how the Sun can burn so brightly in the vast emptiness of space, where there's no oxygen to fuel its flames? It's a question that has puzzled people, leading them online to search for the reason.

Thanks to the wonders of science, we now have the answer. The Sun, it turns out, isn't actually burning at all – it's powered by a fascinating process called nuclear fusion.

People are Asking- How the Sun Burns Without Oxygen in Space© Provided by Viral Chatter

Deep within the Sun's core, where temperatures reach a staggering 27 million degrees Fahrenheit, hydrogen atoms are squeezed together so tightly that they fuse into helium. This fusion reaction releases an enormous amount of energy, which radiates outward from the Sun's core, eventually reaching Earth as the sunlight and warmth we depend on for life.

The Sun's core is like a cosmic pressure cooker, with gravity providing the immense force needed to overcome the natural repulsion between hydrogen atoms. Under these extreme conditions, four hydrogen atoms fuse together to form one helium atom, with a small amount of matter converted directly into energy according to Einstein's famous equation, E=mc2.

The Sun's Layers

The energy generated by fusion in the Sun's core slowly makes its way outward through the dense inner layers (ref). In the radiative zone, energy travels in the form of photons, bouncing around like ping pong balls in the thick solar plasma.

This journey can take over 100,000 years before the photons reach the next layer.

In the convective zone, hot plasma rises to the surface, cools, and sinks back down in massive looping currents, similar to a pot of boiling water. These convection currents are responsible for the granular appearance of the Sun's surface, with each granule about the size of Texas.

Solar Atmospherer

The Sun's visible surface, the photosphere, is just the beginning of its expansive atmosphere. Rising above the photosphere is the chromosphere, a thin, reddish layer that can only be seen during a total solar eclipse. Here, temperatures rise sharply from 10,000°F to nearly 1.8 million°F (ref).

The outermost part of the Sun's atmosphere is the corona, a wispy halo of plasma that extends millions of miles into space. Surprisingly, the corona is much hotter than the surface, reaching temperatures of up to 3.5 million°F.

Scientists are still working to understand the mechanisms that heat the corona to such extreme temperatures.

Solar Wind & Earth's Protection

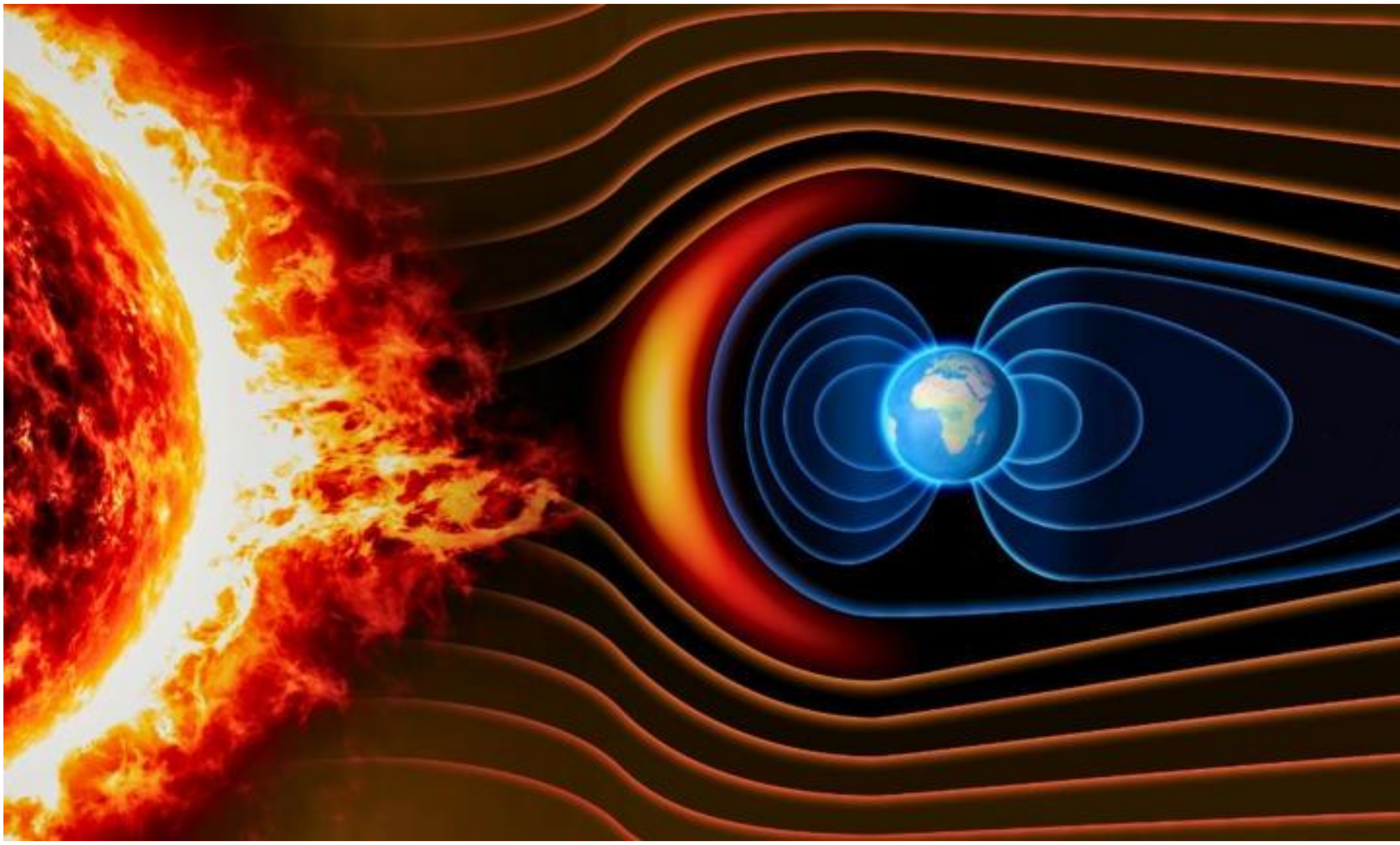


Image Credit: vampy1/DepositPhotos© Provided by Viral Chatter

The Sun’s influence extends far beyond its visible surface. The solar wind, a constant stream of charged particles, flows outward from the corona at speeds of over a million miles per hour.

When these particles encounter Earth’s magnetic field, they can cause spectacular auroras and disrupt satellite communications.

Fortunately, Earth’s magnetic field acts as a protective shield, deflecting most of the solar wind and preventing it from stripping away our atmosphere. Without this invisible barrier, Earth might have suffered the same fate as Mars, losing its air and water to the relentless bombardment of solar particles.

The Future of the Sun

The Sun has been shining for about 4.6 billion years, and it’s expected to continue for another 5 billion years or so. However, it won’t remain the same forever. As the Sun consumes its hydrogen fuel, the core will contract and heat up, causing the outer layers to expand.

In about 1.1 billion years, the Sun will be 10% brighter than it is today, potentially making Earth too hot for life as we know it.

Eventually, the Sun will exhaust its hydrogen supply and begin fusing helium into carbon and oxygen. At this stage, it will expand into a red giant, engulfing Mercury and Venus and possibly even Earth.

But that's a story for the distant future – for now, we can marvel at the Sun's power and appreciate the delicate balance that allows life to thrive on our planet.

The Sun may not be burning in the traditional sense, but the nuclear fusion at its core is a testament to the incredible forces at work in our universe. By understanding the Sun and its processes, we gain a deeper appreciation for the cosmos and our place within it.

Image Credit: Elena11/Shutterstock.© Provided by Viral Chatter

Nearly half a century ago, scientists unveiled a cosmic giant lurking at the center of our Milky Way: a supermassive black hole. This celestial behemoth, located a staggering 25,000 light-years from Earth, tips the scales at 4.6 million times the mass of our Sun [1].

But it's not just its size that's mind-boggling.

Sources

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  nasa.gov/mission_pages/sunearth/science/Sunlayers.html

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If we took a scenic drive through every era of astronomy, we'd start somewhere among ancient humans wondering why there are stationary fireflies stuck in the sky. We'd travel through libraries with scrolls about how those fireflies are, in reality, siblings to our giant yellow sun, and then through rooms with books about how our entire world is somehow orbiting that sun.

Eventually, we'd wind up watching scientists discover the force of gravity being dependent on the fabric of spacetime, obtaining images of iridescent galaxies other than the Milky Way and calculating the strict limits of supermassive black holes.

But just as we begin approaching our exit into the present day, I think we'd start observing something pretty interesting. We'd start to see the growing bond between astronomer and machine enabling us to open cosmic doors more quickly. Aritra Ghosh, a postdoctoral fellow at the University of Washington, is one of those astronomers.

Ghosh recently, for instance, managed to confirm that galaxies in denser regions of the universe can be as much as 25% larger than galaxies with a similar mass and shape in less dense regions. "Size" in this case refers to a galaxy's radius that contains 50% of its total light emission. This is a fine result in itself, but importantly, it's key to highlight how it was achieved: by using machine learning to study more individual galaxies than the human body could possibly analyze in one lifetime. To be precise, there were 2,894,716 galaxies in the dataset.

"Over the last decade, many astronomers, like me, have conducted painstaking studies to develop trust in machine learning, showing that it can replicate traditional techniques," Ghosh told Space.com. "Finally, we can start leveraging these techniques to tease out new scientific results."

This massive galaxy sample set, in fact, came from an even more massive set that Ghosh managed to obtain with the help of machine learning. That original set, achieved with a surveying tool called GaMPEN, encompassed data surrounding 7,805,186 galaxies — the smaller subset for this new study was selected based on where the galaxies are in the sky. In a single millisecond, GaMPEN can determine the structure of a galaxy based on a parameter the user chooses; Ghosh and fellow researchers used a parameter that revealed what fraction of light comes from a galaxy's outer disk when compared to its central bulge.

"I wanted to demonstrate to the broader community how machine learning and large imaging datasets can be combined to make progress on long-standing questions in astrophysics," Ghosh said.

Then, of those nearly 8 million subjects, Ghosh pulled out those in areas where he knew the universe's density via previous calculations. In the work, "dense" environments encapsulated many things, including areas where you'd find superclusters of galaxies. Those are giant conglomerations of many galaxy clusters (one galaxy cluster can contain up to 1,000 individual galaxies!) typically located in the threads of the cosmic web permeating our entire universe. You can think of them as the universe's downtown hotspots.

"Our collaborators in Japan, led by Rhythm Shimakawa, measured environmental densities," Ghosh said. "They used a non-ML computer algorithm to place circles with radii of 30 million light-years in different portions of the sky and count the number of galaxies within each circle — circles in denser regions have a higher-than-average count."

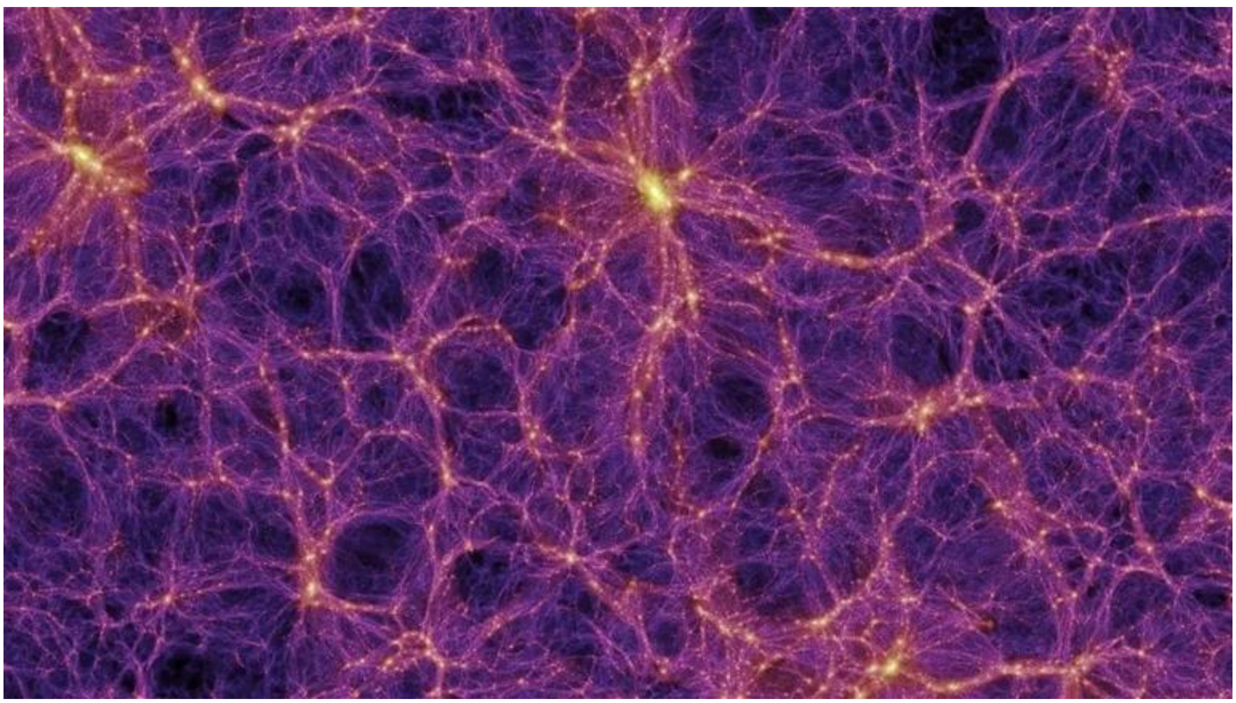
Once the subset was identified, Ghosh and his team began looking at correlations between galactic size and environment.

Because the mass of a galaxy is strongly related to its size and its environment — for instance, more massive galaxies are expected to be larger and live in denser environments — the team compared the sizes of galaxies with the same mass in different environments. "Since massive galaxies are rare," Ghosh explained, "we collaborated with theoretical astrophysicists to develop a new metric for the correlation analysis."

Plus, not only is this the largest catalog ever used for a study about galactic size and environment — and, Ghosh speculates, most likely in the top five for any astrophysical study — but it also sports an error correction mechanism Ghosh says was more or less absent in previous similar studies, thanks in part to the machine learning component.

Speaking of those previous studies, the result that larger galaxies are more into supercluster cities than rural cosmic towns was a bit of a surprise — despite it sounding relatively intuitive. As Ghosh explains, many scientists who have studied the ins and outs of galaxies in clusters believed that strong dynamical forces within those clusters would gradually strip matter away from a galaxy, thus making it smaller in size.

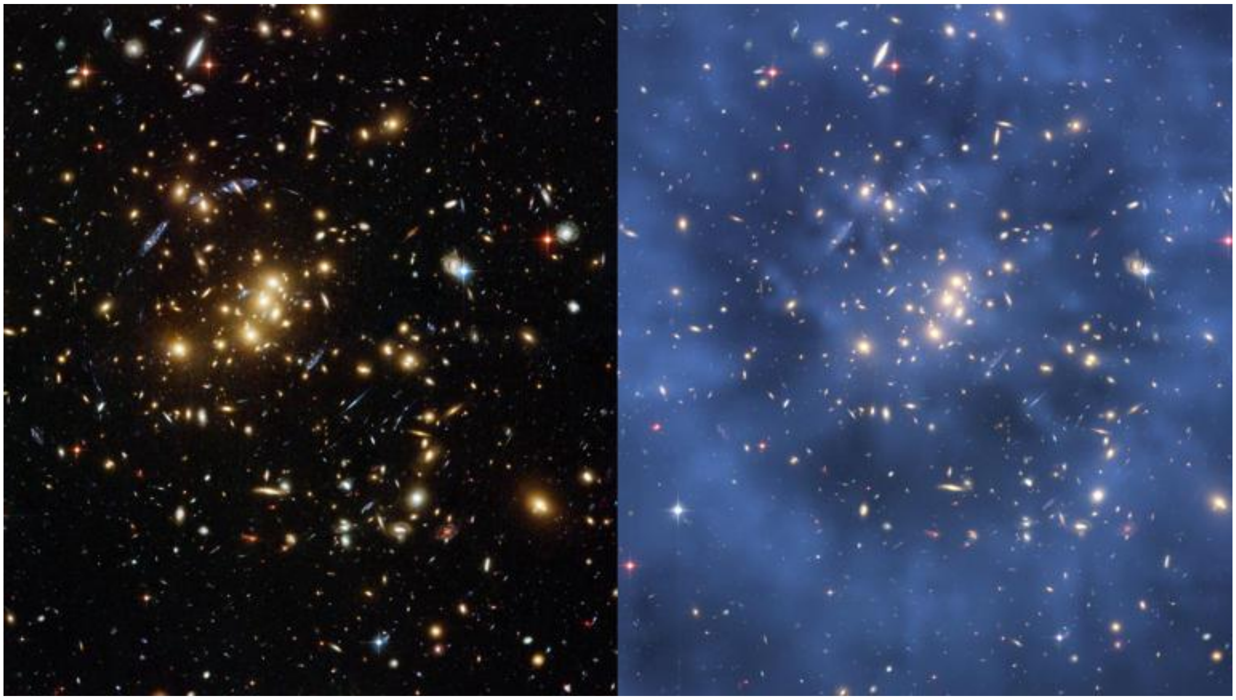
But the team saw larger galaxies in dense, supercluster environments. Weird.



An impression of the cosmic web across the universe that unites galaxies. (Image credit: ESA/ Springel et al., Virgo Consortium)

"We tested our correlation algorithm over smaller subsets first," Ghosh said. "The 'Aha!' moment was when we performed the analysis on the entire sample of 3 million galaxies for the first time, and noticed the strong positive correlation."

As to why this might be? Well, there are some possibilities. One has to do with the kind of "matter" suggested to get stripped off galaxies in dense areas of the universe — normal matter made up of standard protons, neutrons and electrons. This raises the question: What about dark matter? Perhaps this invisible substance has a role to play in keeping galaxies larger. It wouldn't be a terribly far-fetched idea, seeing as scientists have shown that most large galaxies live within a halo of dark matter, including our own Milky Way.



Two views of a galaxy cluster are seen. On the right, areas where dark matter is expected to exist are shaded in blue. (Image credit: NASA, ESA, M.J. Jee and H. Ford (Johns Hopkins University))

"Our work shows that when you average over many, many clusters, dark matter becomes the primary driving force, reversing the trend seen in individual clusters," Ghosh said.

However, it is also possible that galaxies in denser environments happen to be larger when they first form; still further, there's a chance dense environments increase the probability and ease of galactic mergers.

"An interesting follow-up work would be to check how this result changes when you change the radius of the circle within which you are measuring densities," Ghosh said. "What if you use a radius of 1 million light-years instead of 30? This will tell us how physics at different scales of the universe affects galaxies differently."

In the meantime, the team has its eyes set on the upcoming Rubin Observatory, slated to see its first light of the cosmos in early 2025, and the massive datasets it is designed to produce.

"My current fellowship is focused on the Rubin Observatory, Ghosh said, "which will observe 20 billion galaxies over its lifetime."

And, even if Rubin somehow manages to find some extra puzzle pieces under the couch rather than put a few on the table together, there's still a concrete success to Ghosh's study. It's evidence that machines can be trusted with questions about the universe we brought them into.

The study was published on Aug. 14 in The Astrophysical Journal.

An unexpected finding about how our universe formed is again raising the question: do we need new physics? The answer could fundamentally change what physics students are taught in classes around the world. Credit: NASA/JPL-Caltech/SSC

An unexpected finding about how our universe formed is again raising the question: do we need new physics? The answer could fundamentally change what physics students are taught in classes around the world.

A study from SMU and three other universities, available on the *arXiv* preprint server, delved into the possibility of updating fundamental physics concepts.

SMU played a significant part in the analysis, using the university's high-performance computing capabilities to explore different scenarios that could explain the findings.

"The data from what's known as DESI, or Dark Energy Spectroscopic Instrument, combined with what we already had, is the most precise data we've seen so far, and it is hinting at something unlike what we would have expected," explained one of the study's co-authors Joel Meyers, an associate professor of physics at SMU. "Now, we need to get to the bottom of why that is."

Working with Meyers on this analysis were theoretical physicists Nathaniel Craig at UC Santa Barbara and the Kavli Institute for Theoretical Physics, Daniel Green at UC San Diego and Surjeet Rajendran at Johns Hopkins University.

What DESI found...and why it was surprising

DESI is creating the largest, most accurate 3D map of our universe, providing a key measurement that enables cosmologists to calculate what they call the absolute mass scale of neutrinos.

This absolute mass scale was determined based on new measurements from the so-called baryonic acoustic oscillations from DESI, plus information physicists already had from the "afterglow" of the Big Bang—when the universe was created—known as the cosmic microwave background.

Throughout the evolution of the universe, the behavior of neutrinos impacted the growth of large-scale structures, such as clusters of galaxies across vast reaches of space that we see today. Neutrinos are one of the most abundant subatomic particles in the universe, but they're as mysterious as they are ubiquitous. One reason physicists want to know the mass scale of neutrinos is that it can help them get a better understanding of how matter clustered as the universe evolved.

Cosmologists—those who study the origin and development of the universe—have long thought that massive neutrinos kept matter in the universe from clustering as much as it otherwise might have over 13.8 billion years of cosmic evolution.

"But rather than the expected suppression of matter clustering, the data instead favors enhanced matter clustering, meaning matter in the cosmos is more clumped than one would expect," said Meyers, who specializes in theoretical cosmology, including the cosmic microwave background, the early universe and connections to high energy and particle physics.

"Explaining this enhancement may point toward some problem with the measurements, or it could require some new physics not included in the Standard Model of particle physics and cosmology."

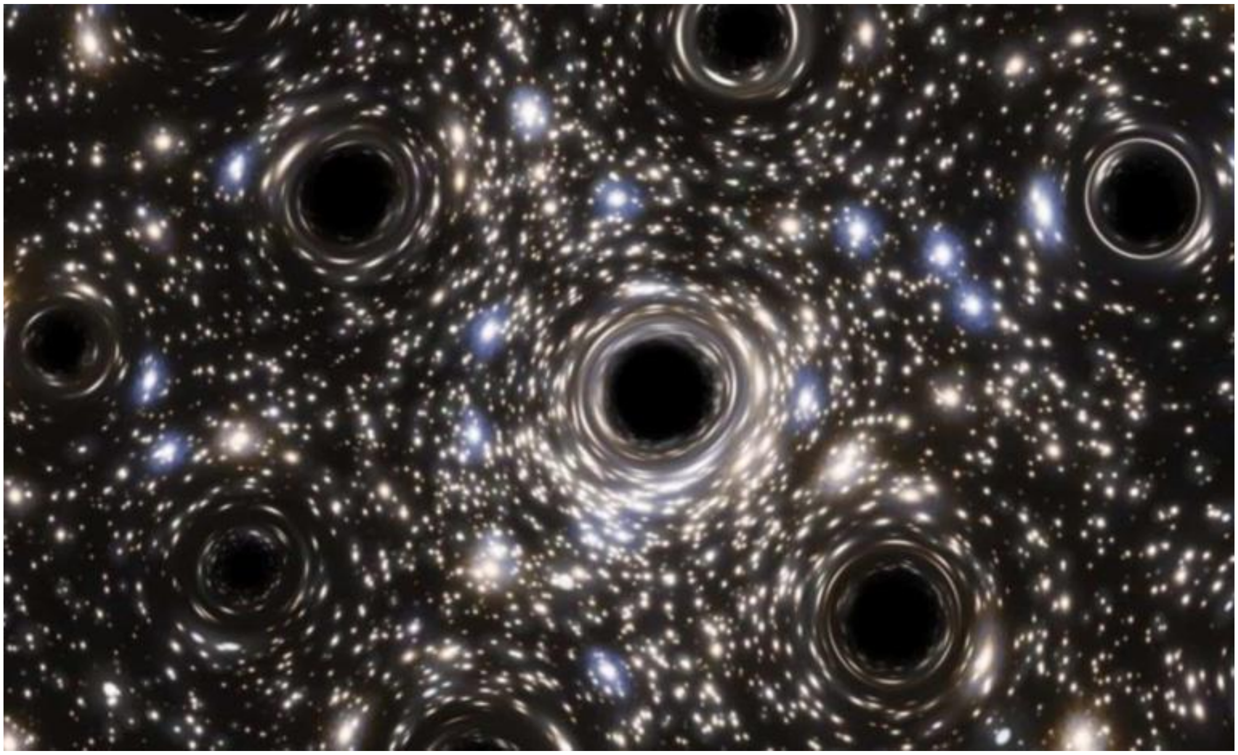
The Standard Model of particle physics—the one that students likely learned in physics class—has long been scientists' best theory to explain how the basic building blocks of matter interact. This finding of neutrinos is the latest measurement, similar to what's referred to as "the Hubble tension," to hint that we might not know our universe as well as we think we do, Meyers said.

In their study, Meyers and his colleagues looked into scenarios where physicists might need to tweak the Standard Model, but not throw it out entirely. They also examined introducing new concepts of physics. And they also explored whether systematic errors of key measures could account for the surprising DESI finding.

It will likely take years to know which of the researchers' theories is correct. But the study gives a blueprint for future research.

More information: Nathaniel Craig et al, No νs is Good News, *arXiv* (2024). DOI: 10.48550/arxiv.2405.00836

Provided by Southern Methodist University



Black Hole Swarm Detected in Ancient Star Cluster in the Milky Way© Daily Galaxy

Astronomers have made a groundbreaking discovery: a swarm of over 100 stellar-mass black holes is traversing through the Milky Way within the star cluster known as Palomar 5.

This extraordinary cluster, located about **80,000 light-years** from Earth, stretches across **30,000 light-years** and contains some of the oldest stars in the galaxy. Researchers believe that the black holes within Palomar 5 have played a critical role in shaping the cluster's distinctive structure, providing new insights into the dynamics of **globular clusters** and the **formation of black holes**.

Palomar 5: A Window Into the Early Universe

Palomar 5 is a type of **globular cluster**, which is a spherical collection of stars tightly bound by gravity. These clusters are often referred to as **"fossils"** of the early universe because they contain ancient stars that formed from the same cloud of gas billions of years ago. Palomar 5 is unique in that it not only has a wide, loose distribution of stars but also a **long tidal stream**—a river of stars that stretches out more than 30,000 light-years from the core of the cluster.

What makes Palomar 5 particularly interesting to astronomers is its relatively low density compared to other globular clusters. Most globular clusters are densely packed with stars, but Palomar 5’s wide and sparse distribution suggested that some force had stripped away much of its stellar material over time. This led scientists to investigate whether**black holes** might be responsible for the loss of stars and the formation of the cluster's tidal stream.

Astrophysicist **Mark Gieles** from the **University of Barcelona** emphasized the significance of Palomar 5 in understanding the formation of tidal streams. **“Palomar 5 is the only case [where a globular cluster and tidal stream coexist], making it a Rosetta Stone for understanding stream formation and that is why we studied it in detail,”** Gieles said, highlighting the importance of the cluster in unraveling the mysteries behind how such streams form.

A Surprising Population of Black Holes

Using detailed **N-body simulations**, the research team recreated the **orbits** and **evolutions** of stars within Palomar 5 to understand how the cluster arrived at its current state. Their simulations included black holes, as evidence suggests that populations of black holes can exist in the **central regions** of globular clusters. Black holes, with their immense gravitational pull, are known to interact with nearby stars, sometimes flinging them out of the cluster and into the surrounding tidal stream.

To their surprise, the researchers found that Palomar 5 likely contains a much larger population of black holes than initially predicted. **"The number of black holes is roughly three times larger than expected from the number of stars in the cluster, and it means that more than 20 percent of the total cluster mass is made up of black holes,"** Gieles explained. These black holes are each estimated to have about **20 times the mass of the Sun**, having formed from the collapse of massive stars in **supernova explosions** billions of years ago.

The simulations suggest that the **gravitational interactions** between these black holes and the surrounding stars have ejected stars from the cluster and into the **tidal stream**, altering the balance between stars and black holes. As stars escaped the cluster more efficiently than black holes, the proportion of black holes increased over time, ultimately resulting in the unusual structure we see today.

The Fate of Palomar 5: A Future Dominated by Black Holes

The research indicates that Palomar 5 is on a path to dissolution. Over the next billion years, the cluster will continue to lose stars until it eventually disintegrates entirely. As this process unfolds, what remains of the cluster will become even more dominated by black holes. **"In around a billion years, the cluster will dissolve completely,"** Gieles said. **"Just before this happens, what remains of the cluster will consist entirely of black holes, orbiting the galactic center."**

This process of **dissolution** is not unique to Palomar 5. The findings suggest that other globular clusters in the Milky Way may follow a similar fate, gradually shedding their stars and becoming dominated by black holes over time. As these clusters dissolve, their black holes will be left behind, contributing to the growing population of **stellar-mass black holes** in the **galactic halo**, the region surrounding the Milky Way's core.

The presence of so many black holes in Palomar 5 also has implications for the study of **binary black hole mergers**. **Fabio Antonini**, an astrophysicist from **Cardiff University**, noted, **"It is believed that a large fraction of binary black hole mergers form in star clusters."** These mergers are responsible for producing detectable **gravitational waves**, and globular clusters like Palomar 5 may serve as breeding grounds for these events. **"A big unknown in this scenario is how many black holes there are in clusters, which is hard to constrain observationally because we can not see black holes,"** Antonini explained. The study of clusters like Palomar 5 may provide new ways to estimate the number of black holes within clusters based on the stars they eject.

Broader Implications for Black Hole Research

The discovery of this **swarm of black holes** in Palomar 5 adds to the growing evidence that **globular clusters** are rich environments for the formation and evolution of black holes. The black holes in these clusters may interact with one another, forming binary systems that could eventually collide and merge, producing powerful bursts of gravitational waves detectable by instruments like **LIGO** and **Virgo**. Moreover, this research offers insights into a previously elusive class of **intermediate-mass black holes**—black holes that are more massive than stellar-mass black holes but less massive than **supermassive black holes**. These intermediate-mass black holes are thought to form in dense environments like globular clusters, and Palomar 5's black hole population could provide new opportunities to study these objects.

In summary, the detection of a **swarm of black holes** within Palomar 5 has provided a deeper understanding of the dynamics of globular clusters and the role of black holes in their evolution. As this cluster continues to evolve, it will offer further opportunities to study the complex interactions between stars and black holes, shedding light on the future of these ancient stellar systems.

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."

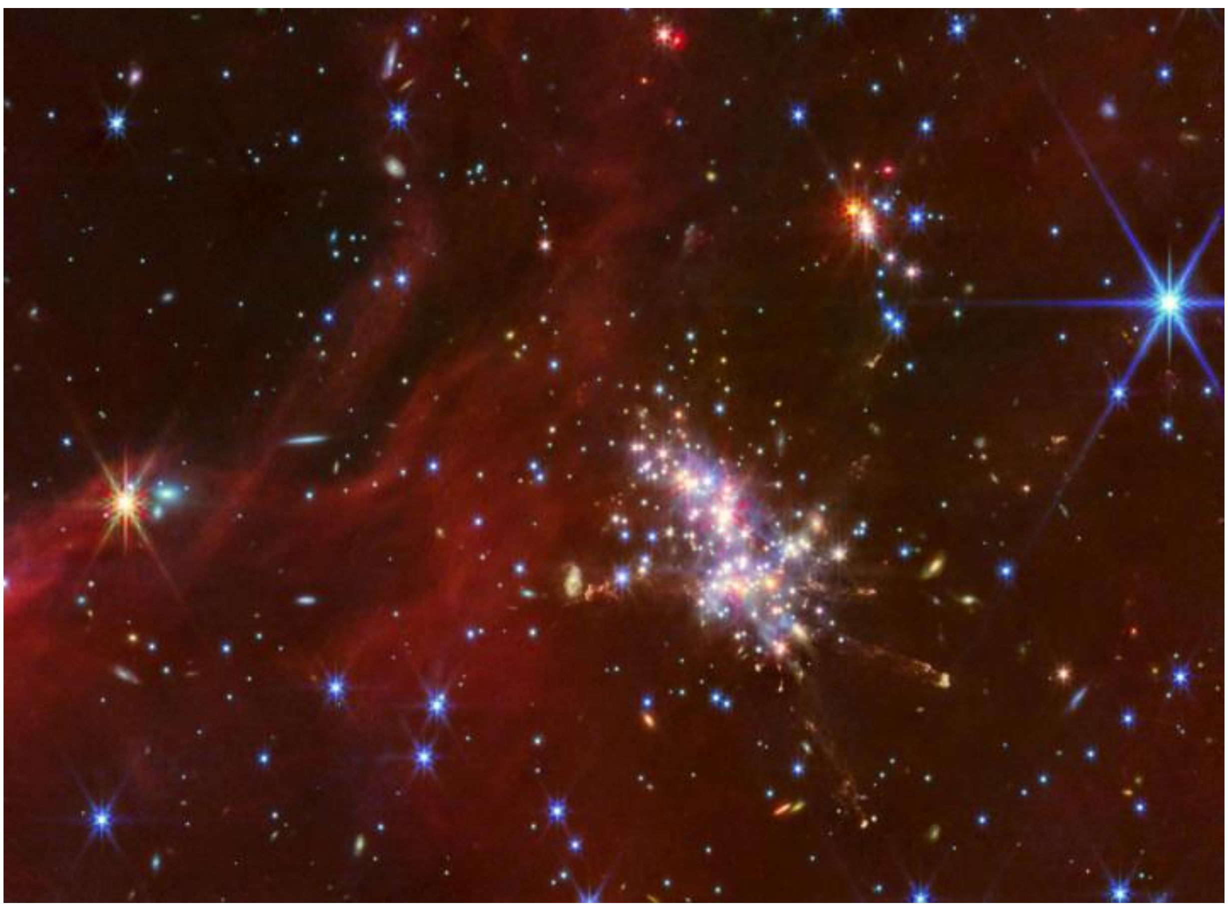
The scientists' calculations show that this universe mode's properties, such as the curvature of space and the microwave background, match current observations, supporting their hypothesis.

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."

A gorgeous new image from the James Webb Space Telescope shows a bustling region of star formation at the distant edge of the Milky Way. Called, dramatically enough, the Extreme Outer Galaxy, this region is located 58,000 light-years away from the center of the galaxy, which is more than twice the distance from the center than Earth is.

Scientists were able to use Webb's NIRCam (Near-Infrared Camera) and MIRI (Mid-Infrared Instrument) instruments to capture the region in sparkling detail, showing molecular clouds called Digel Clouds 1 and 2 containing clumps of hydrogen, which enables the formation of new stars.



The NASA/ESA/CSA James Webb Space Telescope has observed the very outskirts of our Milky Way galaxy. Known as the Extreme Outer Galaxy, this region is located more than 58,000 light-years from the Galactic center. NASA, ESA, CSA, STScI, M. Ressler (NASA-JPL)

"In the past, we knew about these star forming regions but were not able to delve into their properties," said lead researcher Natsuko Izumi of Gifu University in a statement. “The Webb data builds upon what we have incrementally gathered over the years from prior observations with different telescopes and observatories. We can get very powerful and impressive images of these clouds with Webb. In the case of Digel Cloud 2, I did not expect to see such active star formation and spectacular jets.”

Though these clouds are part of the Milky Way, they contain few heavy elements like metals and instead much more hydrogen and helium. That makes them more similar to small dwarf galaxies, or to how the Milky Way may have looked when it was in its early stage of forming. So these regions are great places to study star formation to get clues about how stars formed in the early universe — and their distinctive features, like the jets of material that these young stars throw off at tremendous speeds.

“We know from studying other nearby star-forming regions that as stars form during their early life phase, they start emitting jets of material at their poles,” explained fellow researcher Mike Ressler of NASA’s Jet Propulsion Laboratory. “What was fascinating and astounding to me from the Webb data is that there are multiple jets shooting out in all different directions from this cluster of stars. It’s a little bit like a firecracker, where you see things shooting this way and that.”

The researchers intend to take more data from distant regions of the Milky Way to understand how stars form in these conditions, which are quite different from those elsewhere.

“I’m interested in continuing to study how star formation is occurring in these regions. By combining data from different observatories and telescopes, we can examine each stage in the evolution process,” Izumi said. “We also plan to investigate circumstellar disks within the Extreme Outer Galaxy. We still don’t know why their lifetimes are shorter than in star-forming regions much closer to us. And of course, I’d like to understand the kinematics of the jets we detected in Cloud 2S.”

The research is published in the Astronomical Journal.


What's better than one Kuiper Belt? Two Kuiper Belts!© bymuratdeniz - Getty Images

- New Horizons—the famous NASA spacecraft that flew by Pluto in 2015—is now making new discoveries beyond the Kuiper Belt.
- With help from the Subaru telescope in Hawaii, scientists have discovered what could be a second belt of icy bodies beyond the known Kuiper Belt.
- This possible discovery only highlights how much more there is to learn about our Solar System beyond the reaches of Neptune.

With the James Webb Space Telescope in orbit at Lagrange point 2, roughly 1 million miles from Earth, humanity's view of the universe now extends some 13.5 *billion* years into the past. And while astronomers and cosmologists are eager to study the early days of everything, there's still *a lot* we don't know about our own stellar neighborhood.

We know that the Earth orbits the Sun (thanks for that one, Copernicus), and that our star hosts eight full-fledged planets (sorry about that one, Pluto). But astronomers still only have a fuzzy picture of what lies beyond the reaches of Neptune. In 1951, Dutch-American astronomer Gerard Kuiper hypothesized that a belt of objects must lie beyond the most distant planet, and that prediction proved true in 1992 with the discovery of the Kuiper Belt. Now, mounting evidence suggests that a *second* Kuiper Belt might even lie beyond this first one. A study detailing this discovery, which will be published in the *Planetary Science Journal*, was recently published on the pre-print server arXiv.

"Our Solar System's Kuiper Belt long appeared to be very small in comparison with many other planetary systems," Wes Fraser, the lead author of the study from the National Research Council of Canada, said in a press statement, "but our results suggest that idea might just have arisen due to an observational bias. So maybe, if this result is confirmed, our Kuiper Belt isn't all that small and unusual after all compared to those around other stars."

These results come from a joint effort of the New Horizons probe—which famously flew by Pluto back in 2015—and the 8-meter Subaru telescope Mauna Kea, which sits atop the mountain from which it gets its name and has been searching for potential Kuiper Belt objects (KBOs) for New Horizons to visit. For years, Subaru's search for objects was complicated by being located in front of the dense background of the galaxy's center. But now that it's located in a sparse region of the sky, the telescope's Hyper Suprime-Cam has spotted 239 KBOs in just four years. Of those, about a dozen are *particularly* interesting.

"The most exciting part of the HSC was the discovery of 11 objects at distances beyond the known Kuiper Belt," Fumi Yoshida, a co-author of the study from the Chiba Institute of Technology, said in a press statement. "If this is confirmed, it would be a major discovery."

Their unique nature has to do with their relative distance from both the Sun and the "first" Kuiper Belt, which lies roughly 35 to 55 astronomical units (AU) out from the center of our Solar System (one AU is the average distance from the Earth to the Sun). However, according to *Space.com*, these newly discovered objects lie between 70 and 90 AU from the Sun.

So, why aren't these farflung KBOs considered part of the (much larger than expected) original Kuiper Belt? Well, there appears to be a gap of objects located between 55 AU and 70 AU from the Sun (New Horizons is currently located at around 60 AU from the Sun). That means these 11 objects appear to be forming a defined second ring around the Solar System.

The researchers say they'll continue to track these objects while searching for more like them, and considering that these are clustered in a small part of the sky, there are likely *many* more out there. Upcoming surveys—especially the Legacy Survey of Space and Time (LSST) at the Vera C. Rubin Observatory—will search for unknown KBOs that lie beyond our (current) understanding.

There’s still a lot we don’t know about our Solar System, but much like our broadening view of the universe, some new facts are certainly coming into focus.

Astronomers have discovered seven distant galaxies aligned with a galaxy cluster; together, they form one of the most unique configurations of galaxies ever seen.

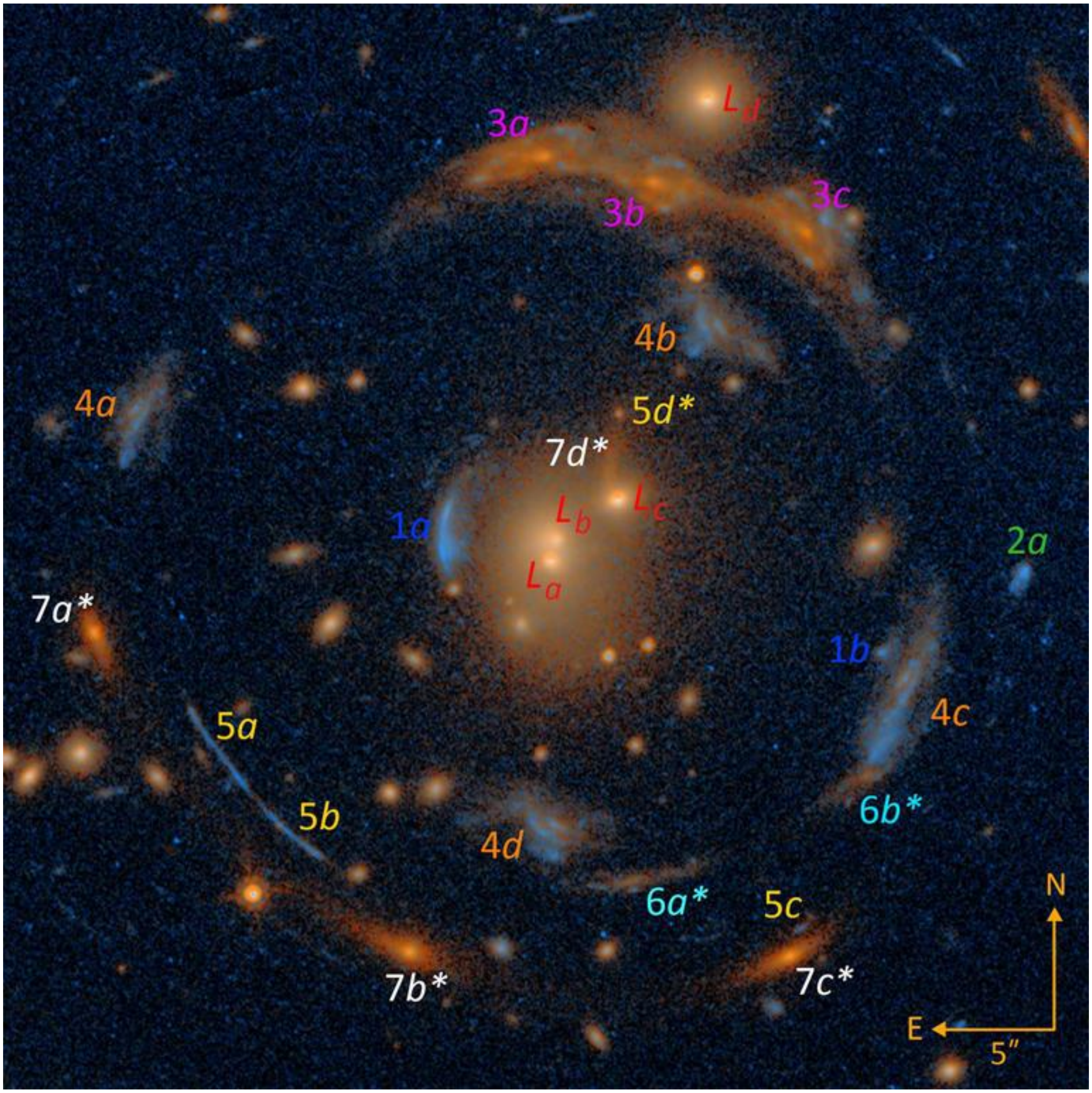
This arrangement of warped and stretched galaxies contains the largest "Einstein cross," in reference to repeated views of the same galaxy in the same image due to consequences of general relativity — namely, gravitational lensing. The newly discovered, strongly lensed galaxies are collectively referred to as the "Carousel Lens." The galaxies appear to be stretched and swirled in the Carousel Lens because of the influence of a so-called "lensing galaxy cluster," which is located closer to Earth at 5 billion light-years away.

Ultimately, this discovery could help solve some of the most pressing mysteries of cosmology. Chief among these mysteries are the natures of dark energy, the invisible force accelerating the expansion of the universe, and dark matter, the invisible stuff that makes up 80% of the matter in the cosmos.

The seven unique galaxies are located at distances ranging from 7.6 billion to 12 billion light-years away from Earth. This is close to the observing limit of the 13.8 billion-year-old cosmos, meaning we couldn't see further that this area even with the most advanced telescopes. That's because because this region of space is accelerating away from us too quickly.

In the Carousel Lens, a number of galaxies also appear in more than one location. Of particular interest to astronomers, dwelling in the Carousel Lens is an Einstein Cross created from four repeated occurrences of galaxy number 4 (4a, 4b, 4c, and 4d in the image below.

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



Hubble image of the carousel lens with the lensing cluster in the center marked by Ls and the lensed galaxies marked 1 to 7. The letters represent the number of times the same galaxy appears thanks to the phenomenon of gravitational lensing. (Image credit: William Sheu (UCLA) using Hubble Space Telescope data.))

These aspects of this galactic arrangement show the intricacies of a mind-blowing physics phenomenon called gravitational lensing, first suggested by Albert Einstein in 1915.

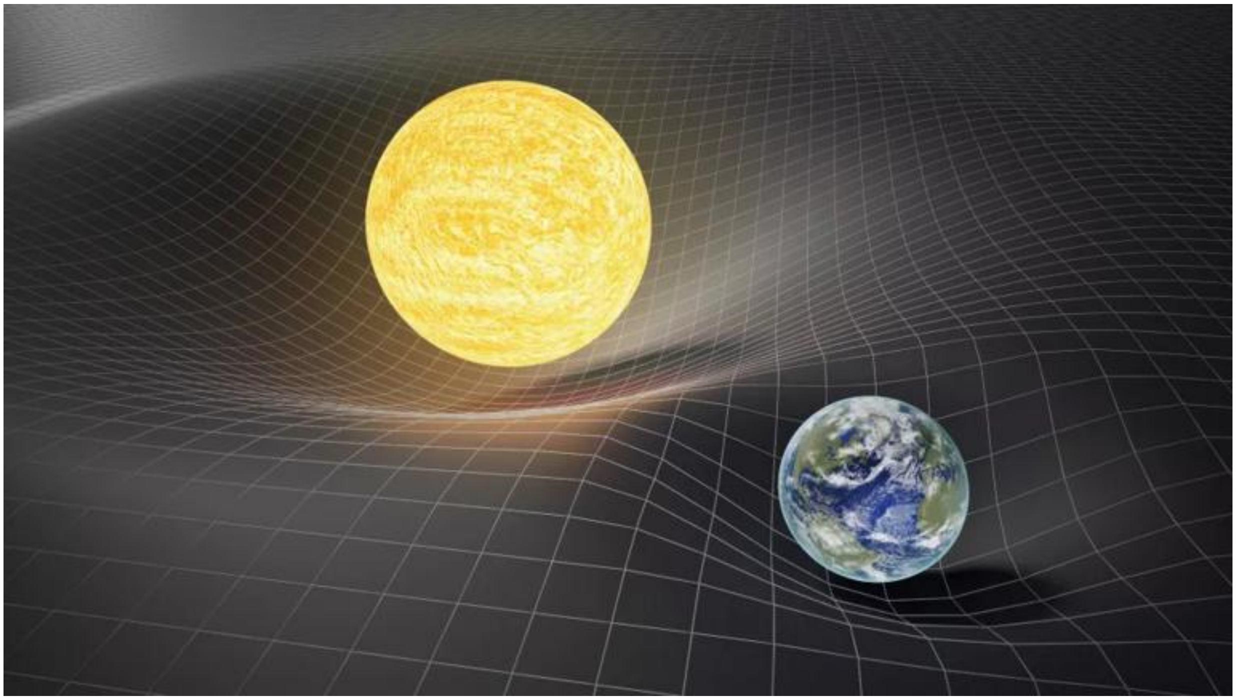
The warped physics of gravitational lensing

Gravitational lensing is a concept that arose from Einstein's most revolutionary theory, general relativity. Also referred to as the "geometric theory of gravity," general relativity superseded Isaac Newton's theory of gravity. It suggests that the presence of mass in the fabric of space and time, united as a 4-dimensional entity called "spacetime," causes that fabric to be "warped."

A commonly used analogy for this is the placement of balls of increasing mass on a stretched rubber sheet. In this 2D analog, a golf ball causes more curvature than a ping-pong ball, a bowling ball creates more curvature than a golf ball, and a cannonball creates quite extreme curvature.

In spacetime, gravity arises from this curvature, so the larger an object's "warp," the larger its gravitational influence. Thus, planets have stronger gravity than moons, stars have stronger gravity than planets, and black holes have stronger gravity than all three.

This doesn't just explain the orbits of bodies around others with greater masses, but it also tells us something really interesting about how light is impacted by a spacetime warp.



3D illustration of the Earth and Sun on distorted spacetime. This shows the gravity and general theory of relativity concept. (Image credit: vchal via Shutterstock)

Though light usually travels in a straight line, the curvature of the very fabric of spacetime changes the definition of what a straight line actually is. To picture that, simply imagine drawing a straight line on a sheet of paper and then picking up that paper and rolling it in different orientations.

This all means that when an object of tremendous mass, like a cluster of galaxies, sits between Earth and a background source of light, it acts as a gravitational lens, shifting that background object's apparent position in the sky. But, light from a single object can take different paths around the lensing body. The closer to the concentration of mass, the more the light will be diverted.

That means light from a single object can arrive at Earth and our telescopes at different times, amplifying the appearance of smearing, for instance. The same object can even appear in multiple places in the same image, with these representations of images appearing in circular arrangements called Einstein Rings. And an Einstein Ring can more specifically be categorized as an Einstein Cross if it fits certain criteria, as we see for the Carousel Lens.

In rare instances, a near-perfect configuration of objects causes a strong gravitational lens, and that is what data from the Dark Energy Spectroscopic

Instrument (DESI) Legacy Imaging Surveys and recent observations from NASA’s Hubble Space Telescope have revealed in the form of the Carousel Lens.

"Our team has been searching for strong lenses and modeling the most valuable systems," said Xiaosheng Huang, a team member and researcher at Berkeley Lab’s Supernova Cosmology Project, said in the statement. "The Carousel Lens is an incredible alignment of seven galaxies in five groupings that line up nearly perfectly behind the foreground cluster lens. As they appear through the lens, the multiple images of each of the background galaxies form approximately concentric circular patterns around the foreground lens, as in a carousel.

"It's an unprecedented discovery, and the computational model generated shows a highly promising prospect for measuring the properties of the cosmos, including those of dark matter and dark energy."

The strength of the Carousel Lens and the model created using the Perlmutter supercomputer at the National Energy Research Scientific Computing Center (NERSC) could help investigate dark energy and dark matter, sometimes collectively referred to as the "dark universe."

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

The team's research is published in The Astrophysical Journal.

Red Era

Earlier this year, astronomers revealed one of the James Webb Space Telescope's most spectacular and intriguing discoveries yet — and that's saying something.

Lying in one of the most ancient regions of the observable universe, they found, were hundreds of galaxies that have come to be known as the "Little Red Dots."

These aren't ordinary galaxies. As Smithsonian Institution astrophysicist Fabio Pacucci explains in an essay for *The Conversation*, these compact red structures, which are only about two percent the size of the Milky Way, puzzle astronomers. The issue is that they can't determine what they are, because observing them through different mediums each points to them being a different kind of object.

Deepening the mystery, the Little Red Dots were only visible for a period of around one billion years, about 600 to 800 million years after the Big Bang. Now, they're nowhere to be found, and determining exactly what they are will be crucial to figuring out where they fit into the evolution of our universe.

Mystery of Interior

There are two leading hypotheses on the Little Red Dots.

One proposes that they're incredibly dense galaxies packed with up to 100 billion stars. That's as many as the Milky Way, despite being just a fraction of the size of our galaxy.

To put that into perspective, Pacucci says this would be like packing the population of China into a huge single room.

"These astrophysical objects may be the densest stellar environments in the entire universe," he wrote (whether that would even be physically possible is unclear.)

The other hypothesis proposes that this ludicrous density can be explained by a supermassive black hole at the center of the Little Red Dots.

Except that observations suggest that these would have to be "overmassive" — or too big for what should be possible based on the scale of the surrounding galaxy, with some being nearly as heavy as them.

Two-Faced

This leads us to one of the Little Red Dots' most puzzling attributes, according to Pacucci: they appear like different objects depending on how you examine them.

A vital indicator of the presence of supermassive black holes are telltale emission lines in light spectra, and when examined this way, the compact galaxies clearly appear to have them — if not be dominated by them.

But if they contain supermassive black holes, the Little Red Dots should also be blasting out x-rays. More recent research, however, has shown that these puzzling galaxies show no sign of such x-rays, favoring the "stars-only" hypothesis. So, black holes or no black holes — which is it?

Pacucci speculates that it's possible that the sheer density of material surrounding the Little Red Dots' black holes are blocking its x-ray emissions, or it could be that they're being emitted in a different spectrum than what we're used to.

In any case, the implications are fascinating. We could be looking at unprecedentedly dense star-filled galaxies, or evidence that "overmassive" black holes may have been the first ones in the universe.


Earth in space© Provided by BGR

Life on Earth. Where did it come from? How long has it existed here? While we're still searching for the answers to one of those questions, scientists think they might have discovered the answer to the other. Most experts believe that the complex life on Earth began around 635 million years ago. However, a new theory is challenging that.

Researchers, including Professor Ernest Chi Fru at Cardiff University, have recently highlighted the new theory after studying unexplained formations found in Franceville, Gabon. Scientists aren't sure if the formations are fossils or not, and it has raised some serious questions about whether or not they could be some of the original signs of life on Earth.

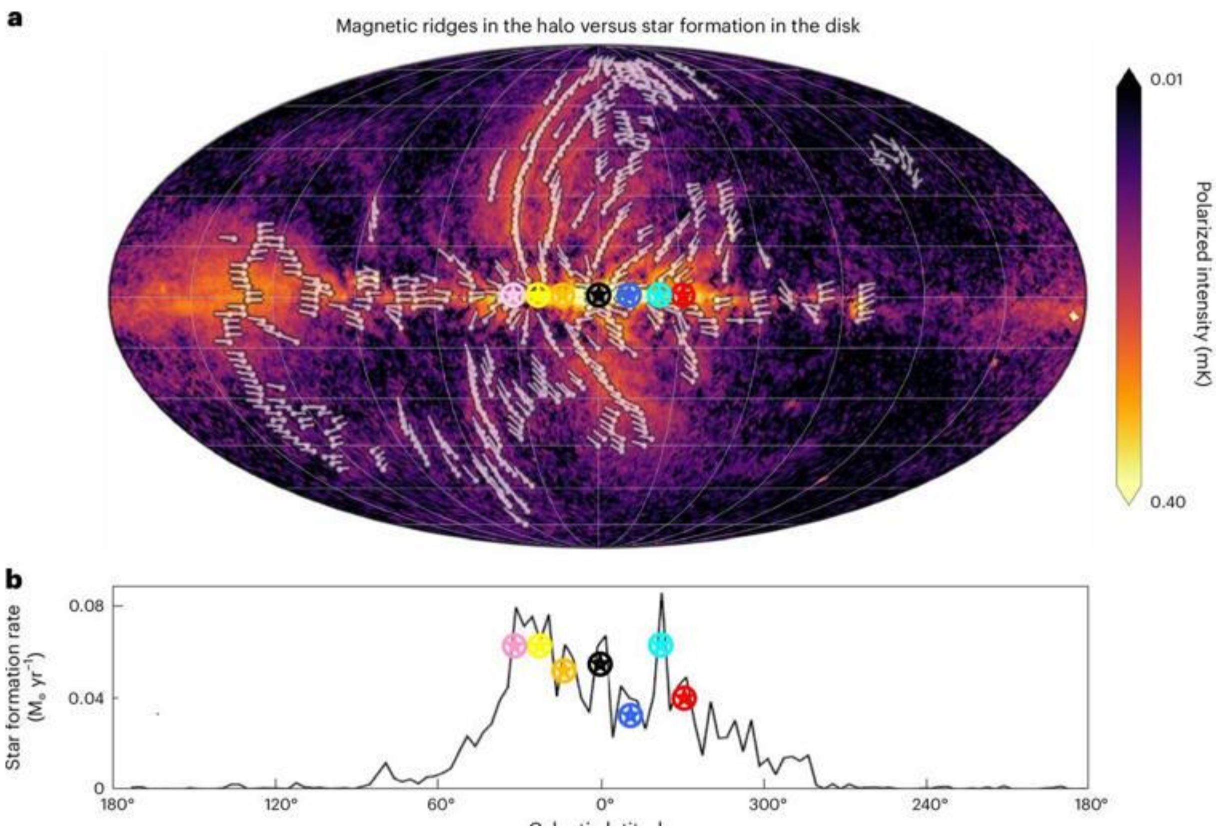
If the formations are fossils, then they appear to date back to around 2.1 million years ago. Roughly 1.5. billion years earlier than scientists believed complex life on Earth could have existed. However, the theory also says that the organisms were still very simple and that they were restricted to an inland sea and didn't spread.

plant growing in soil© Provided by BGR

Of course, eventually, these organisms died out. Leaving an empty place for life as we eventually came to know it to settle in and grow. Of course, proving all of this is an entirely different matter. But, if the researchers can prove that their theory is right, then it will fundamentally change our planet's timeline.

Doing that will give us even more depth in the history of our little blue marble in the great sea of darkness, which is the universe. What's most intriguing about the theory and these formations is that these first possible pieces of complex life on Earth appear to have had circumstances similar to when life bloomed in the Cambrian period, 635 million years ago.

It very well could have stimulated the simpler life forms into becoming more complex and intricate, even if they did eventually die out without spreading very far. However, the findings have not been accepted by all scientists. So, we'll have to wait to see exactly how the researchers proceed with their theory. For now, the theory is published as part of a paper in *Precambrian Research*.



Energy sources of the Galactic outflows. Credit: Nature Astronomy (2024). DOI: 10.1038/s41550-024-02362-0

A new study led by the National Institute for Astrophysics (INAF), and with contributions from Radboud University's Marijke Haverkorn, has unveiled significant insights into the Milky Way: a magnetized galactic halo.

This discovery challenges previous models of our galaxy's structure and evolution. Researchers have identified several magnetized structures extending far above and below the galactic plane (reaching heights of more than 16,000 light-years or 150 quadrillion kilometers), revealing one of the origins of the so-called eROSITA Bubbles, which are large-scale powered by intense outflows of gas and energy that are also being generated by the explosive death of stars in supernovae.

Remarkably, these bubbles—observed by the eROSITA satellite (an X-ray telescope on board the Russian-German space mission Spectr-Roentgen-Gamma

SRG)—stretch across the sky from horizon to horizon, providing the first detailed measurements of the Milky Way's magnetic halo. These results were published today (Sept. 23) in *Nature Astronomy*.

The study discloses that the magnetic fields within these bubbles are highly organized, forming thin filamentary structures. These filaments stretch up to around 150 times the full moon's diameter, showing their immense scale. The filaments are related to the hot winds with a temperature of 3.5 million Kelvin, ejected from the galactic Disk and powered by star-forming regions.

He-Shou Zhang, the first author of the article and a researcher at INAF, highlights that "our results find that intense star formation at the end of the galactic bar contributes significantly to these expansive, multiphase outflows."

Related video: S-Shaped Bend in Milky Way's Galactic Disk Is Actually a Sign of a Galactic Collision (Dailymotion)

He adds, "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. 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."

Galactic bar

The research team used a comprehensive multi-wavelength survey, covering frequencies from radio to gamma-rays, to analyze these structures. This detailed approach allowed them to confirm the extended nature of these magnetic features and their association with galactic feedback processes. Notably, the study represents the first observational evidence linking the Milky Way's star-forming ring at the end of the galactic bar with the formation of large-scale galactic outflows.

"This study marks a significant step forward in our understanding of the Milky Way," Gabriele Ponti from INAF says. "It is well established that a small fraction of 'active' galaxies can launch outflows, powered by accretion onto supermassive black holes or starbursts events, which profoundly impact their host galaxy.

"It is believed that such outflows are fundamental ingredients to regulate the growth of galaxies and the black holes at their centers. What is fascinating to me here is that we see that the Milky Way, a quiescent galaxy like many others, can also eject powerful outflows and, in particular, that the star-forming ring at the end of the galactic bar contributes significantly to the galactic outflow.

"Maybe the Milky Way reveals a phenomenon common in Milky Way-like galaxies, therefore helping us shed light on these objects' growth.

This work was possible using more than 10 different all-sky surveys, covering frequencies from radio waves to gamma rays. He-Shou Zhang concludes, "Our work is a timely result. It is the first comprehensive multi-wavelength study for the eROSITA Bubbles since their discovery in 2020.

"The study opens up new frontiers in our understanding of the galactic halo and will help our knowledge of the Milky Way's complex and impetuous star-forming ecosystem."

More information: He-Shou Zhang et al, A magnetized Galactic halo from inner Galaxy outflows, *Nature Astronomy* (2024). DOI: 10.1038/s41550-024-02362-0

Provided by Radboud University

The universe is expanding at an accelerated rate, however, the nature of this expansion – why it's expanding and why it's doing so at such an accelerated rate – is uncertain. One culprit has been dubbed "dark energy", a hypothetical form of energy that could be seen as anti-gravity. While what dark energy is precisely remains unknown, as a cosmological constant astronomers could roughly agree on its effects to measure the expansion rate of the universe, known as the Hubble constant. But not anymore.

Over the last few months, research has been published and news has followed about new measurements for the expansion rate of the universe. This is a Hot Topic in cosmology. Over the last several years, that earlier agreement has disappeared in the face of a gulf between the value depending on which method you use to measure it. The issue, dubbed the Hubble tension, took center stage, with cosmologists and astrophysicists arguing for one method of measurement – and its resulting number – over the other. But there is no clear winner.

How could it not become a core issue? The standard model of cosmology – the universe started with a Big Bang, inflated exponentially, and has been expanding ever since (made up of regular matter, dark matter, and dark energy in a 5:25:70 proportion) – is possibly at stake. The most advanced observatories humans have ever put into orbit to measure extraordinary phenomena can't agree on a single value for the expansion rate.

One, the Planck Observatory, looked at the cosmic microwave background (CMB). That's the first light ever released in the universe. It is considered the light echo of the Big Bang, emitted once the universe was cool enough for neutral atoms to form, the light no longer shackled to them.

With the data from the CMB, scientists worked out that the universe is expanding at a rate of 67.4 kilometers per second per megaparsec, with 1 megaparsec being 3.26 million light-years. This means that if two galaxies are 1 megaparsec apart, the expansion of the universe would make them look like they are moving away from each other at a speed of 67.4 kilometers (42 miles) per second.

Astronomers approach the measurements of distances in the universe in different ways. One is to use standard candles, objects that have the same intrinsic luminosity so by measuring how dim they appear, we can work out how far away they are. The Hubble Space Telescope has measured several of these standard candles. One in particular, the Cepheid variable star has been particularly useful. That is what astronomers used to work out the expansion rate of the universe. But – it is a different number: 73 kilometers per second per megaparsec.

The uncertainty around each number is small and they do not overlap. It's like there are two expansion rates in the universe, one for the very early universe and one for the last several billion years or so. However, the standard model of cosmology, our current best theory for what the universe is like, says that it should be the same. So either our model is wrong or our measurements are wrong. Thus we have the Hubble Tension.

Multiple observatories have thrown their hat at measuring the expansion rate using standard candles. Even JWST, the most powerful space telescope ever launched into space, was found to be in agreement with Hubble when it comes to Cepheid variables.

A new solution?

Given the inherent uncertainties, the value of the Hubble constant is consistent with that obtained from the cosmic microwave background. But it cannot rule out new physics.

Professor Wendy Freedman

At present, we do not have an answer to what is the correct solution, but back in April, research presented just days apart indicated some exciting new insights. The Dark Energy Spectroscopic Instrument (DESI) released the largest 3D map of the universe, allowing researchers to estimate independently the expansion rate of the cosmos between 8 and 11 billion years ago. Turns out, it agrees with the cosmic microwave background.

Another challenge has recently appeared. A team led by Professor Wendy Freedman of the University of Chicago also used JWST to better estimate the Hubble constant. Their work uses three independent ways to estimate distances in the same galaxies, with different standard candles (including Cepheids variables) measured.

This approach was optimized to make sure that each method for the distance measurements was as accurate as it could be. Professor Freedman and her team found a value for the expansion rate of 69.96 kilometers (43.5 miles) per second per megaparsec. Including its uncertainty, the value is consistent with the cosmic microwave background, but Freedman is not ready to claim that the Hubble tension is now just gone. More observations are still needed, she noted.

"The galaxies that are most distant give a different result than those nearby. The measurements for the more distant galaxies have lower resolution and are less accurate. Thus it remains for JWST to determine if there is a problem with those most distant objects. The more distant objects do not yet have JWST data," Professor Freedman told IFLScience.

Is physics as we know it safe?

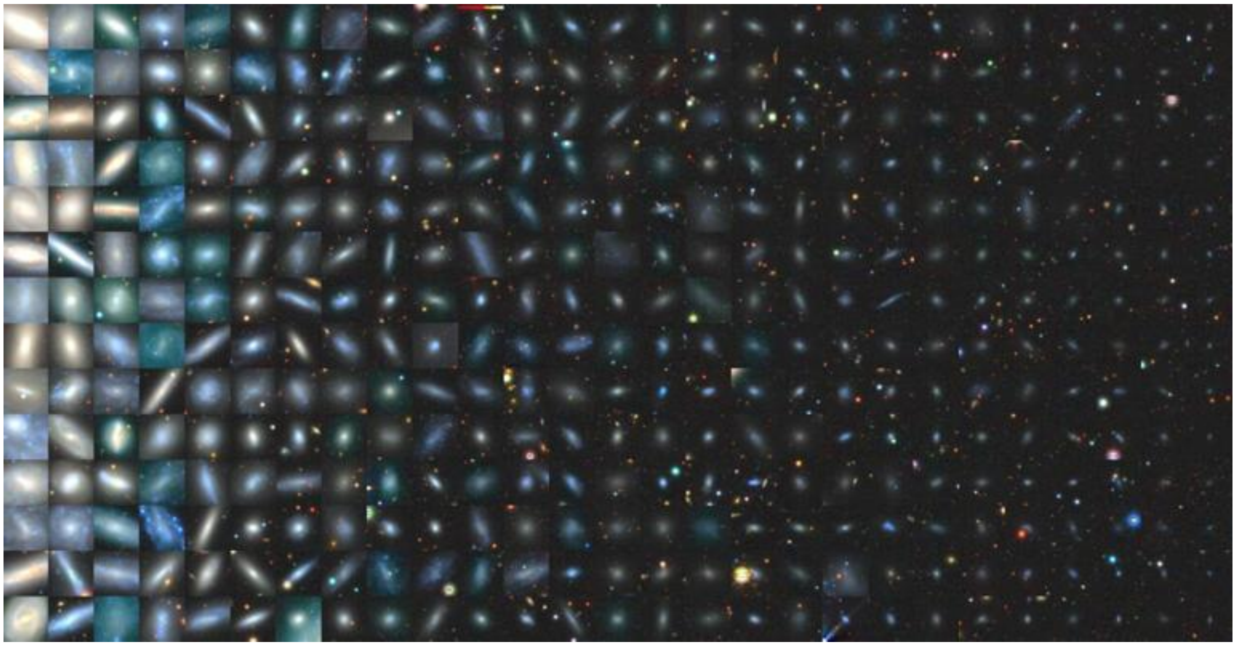
In the uncertainties, new physics might be lurking. A very recent proposal considers a new type of dark energy existing at the dawn of the universe. Unlike the dark energy that continues to exist today (despite the fact we don't know what it is) this version, dubbed "early dark energy", would only stay around for a brief period. Its presence though would fix the Hubble tension.

The presence of this dark energy made the number of early bright galaxies in the simulation increase. A result that kills two birds with one stone. If this is correct though, it will depend on future observations. The Hubble tension might melt away and the paradigm for galaxy evolution might change by other means.

"Given the inherent uncertainties, the value of the Hubble constant is consistent with that obtained from the cosmic microwave background. But it cannot rule out new physics. This work makes clear that more data are needed before additions to the standard cosmological model are required," Professor Freedman told IFLScience.

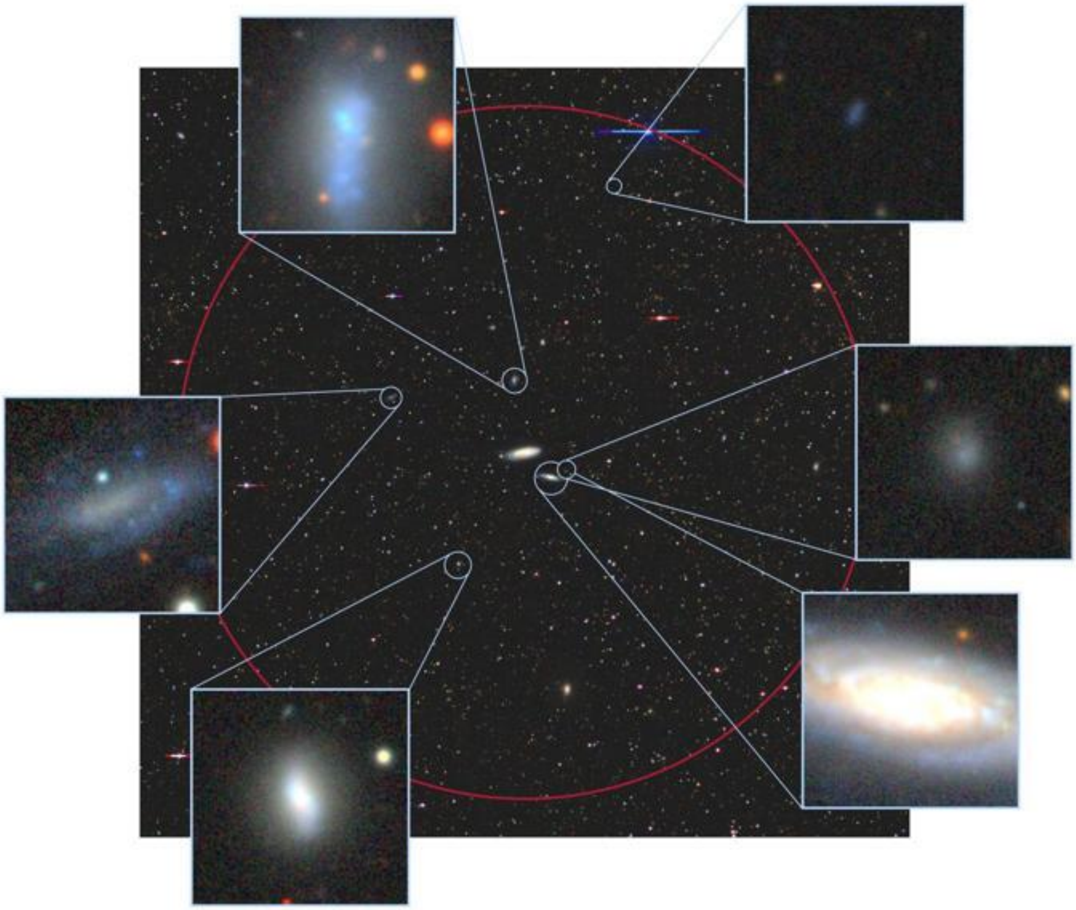
The DESI finding as well as the work from Professor Freedman and her team are an exciting development in the Hubble tension saga. They tease a solution in sight toward a number closer to the CMB-measured one. Still, for now, the uncertainties remain and they will stay there until astronomers can agree on exactly why the tension appeared and where corrections are necessary.

The Hubble tension might indeed die but we will have to wait and see if it is from the bang of destroying our current model of the universe or the whimper of correcting our observations.



A mosaic of the images of 378 satellites across 101 Milky Way-like systems that the SAGA team has surveyed. The satellite images are sorted by their luminosity from left to right. Credit: Yao-Yuan Mao (Utah), with images from the DESI Legacy Surveys Sky Viewer

Is our home galaxy, the Milky Way galaxy, a special place? A team of scientists started a journey to answer this question more than a decade ago. Commenced in 2013, the Satellites Around Galactic Analogs (SAGA) Survey studies galaxy systems like the Milky Way. Now, the SAGA Survey has published three new research articles on the *arXiv* preprint server that provide us with new insights into the uniqueness of our own Milky Way galaxy after completing the census of 101 satellite systems similar to the Milky Way's.



An image of a Milky Way-like galaxy and its system of satellite galaxies. The SAGA survey identified six small satellite galaxies in orbit around this Milky Way analog. Credit: Yasmeen Asali (Yale), with images from the DESI Legacy Surveys Sky Viewer

These "satellites" are smaller galaxies in both mass and size that orbit a larger galaxy, usually called the host galaxy. Just as with smaller satellites that orbit the Earth, these satellite galaxies are captured by the gravitational pull of the massive host galaxy and its surrounding dark matter.

The Milky Way is the host galaxy of several satellite galaxies, of which the two largest are the Large and Small Magellanic Clouds (LMC and SMC). While LMC and SMC are visible to the naked eye from the Southern Hemisphere, there are many other fainter satellite galaxies orbiting around the Milky Way that can only be observed with a large telescope.

The goal of the SAGA Survey is to characterize satellite systems around other host galaxies that have similar stellar masses as the Milky Way. Yao-Yuan Mao, a University of Utah faculty member in the Department of Physics and Astronomy, is co-leading the SAGA Survey with Marla Geha at Yale University and Risa Wechsler at Stanford University.

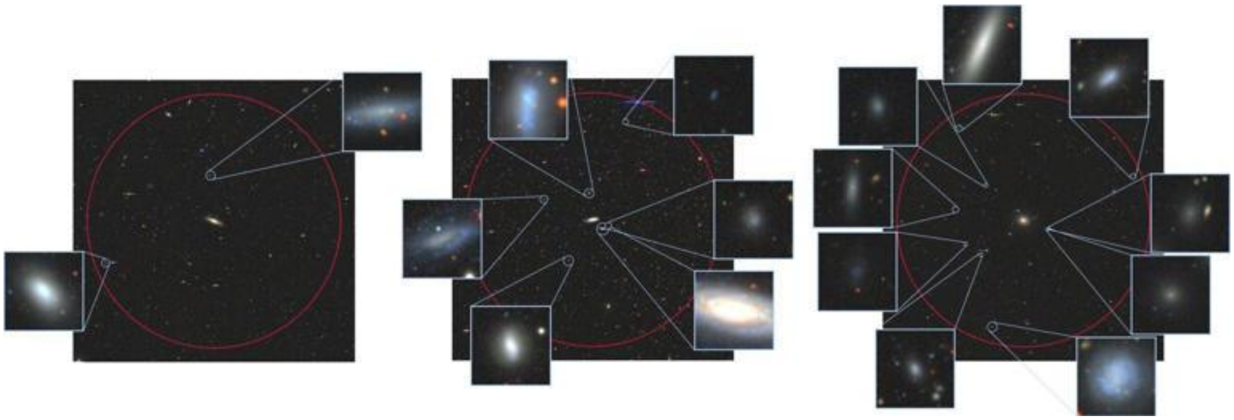


Image of three Milky Way-like galaxies and their systems of satellite galaxies. The SAGA survey identified two, six, and nine small satellite galaxies in these three systems respectively. Credit: Yasmeen Asali (Yale), with images from the DESI Legacy Surveys Sky Viewer

Mao is the lead author of the first article in the series of three that have all been accepted by the *Astrophysical Journal*. This series of articles reports on the SAGA Survey's latest findings and makes the survey data available to other researchers worldwide.

An outlier galaxy?

In the first study led by Mao, the researchers highlighted 378 satellite galaxies identified across 101 Milky Way-mass systems. The number of confirmed satellites per system ranged from zero to 13—compared to four satellites for the Milky Way. While the number of satellite galaxies in the Milky Way system is on par with the other Milky Way-mass systems,

"The Milky Way appears to host fewer satellites if you consider the existence of the LMC," Mao said. The SAGA Survey has found that systems with a massive satellite like the LMC tend to have a higher total number of satellites, and our Milky Way seems to be an outlier in this regard.

An explanation for this apparent difference between the Milky Way and the SAGA systems is the fact that the Milky Way has only acquired the LMC and SMC quite recently, compared with the age of the universe. The SAGA article explains that if the Milky Way is an older, slightly less massive host with the recently added LMC and SMC, one would then expect a lower number of satellites in the Milky Way system, not counting other smaller satellites that LMC/SMC might have brought in.

This result demonstrates the importance of understanding the interaction between the host galaxy and the satellite galaxies, especially when interpreting what we learn from observing the Milky Way.

Ekta Patel, a NASA Hubble Postdoctoral Fellow at the U but not part of the SAGA team, studies the orbital histories of Milky Way satellites. After learning about the SAGA results, Patel said, "Though we cannot yet study the orbital histories of satellites around SAGA hosts, the latest SAGA data release includes a factor of ten more Milky Way-like systems that host an LMC-like companion than previously known. This huge advancement provides more than 30 galaxy ecosystems to compare with our own, and will be especially useful in understanding the impact of a massive satellite analogous to the LMC on the systems they reside in."

Why do galaxies stop forming stars?

The second SAGA study of the series is led by Geha, and it explores whether these satellite galaxies are still forming stars. Understanding the mechanisms that would stop the star formation in these small galaxies is an important question in the field of galaxy evolution.

The researchers found, for example, that satellite galaxies located closer to their host galaxy were more likely to have their star formation "quenched," or suppressed. This suggests that environmental factors help shape the life cycle of small satellite galaxies.

The third new study is led by Yunchong (Richie) Wang, who obtained his doctorate with Wechsler. This study uses the SAGA Survey results to improve existing theoretical models of galaxy formation. Based on the number of quenched satellites in these Milky Way-mass systems, this model predicts quenched galaxies should also exist in more isolated environments—a prediction that should be possible to test in the coming years with other astronomical surveys such as the Dark Energy Spectroscopic Instrument Survey.

Gift to the astronomy community

In addition to these exciting results that will enhance our understanding of galaxy evolution, the SAGA Survey team also brings a gift to the astronomy community. As part of this series of studies, the SAGA Survey team has published new distance measurements, or redshifts, for about 46,000 galaxies.

"Finding these satellite galaxies is like finding needles in a haystack. We had to measure the redshifts for hundreds of galaxies to just identify one satellite galaxy," Mao said. "These new galaxy redshifts will enable the astronomy community to study a wide range of topics beyond the satellite galaxies."

More information: Yao-Yuan Mao et al, The SAGA Survey. III. A Census of 101 Satellite Systems around Milky Way-mass Galaxies, *arXiv* (2024). DOI: 10.48550/arxiv.2404.14498

Marla Geha et al, The SAGA Survey. IV. The Star Formation Properties of 101 Satellite Systems around Milky Way-mass Galaxies, *arXiv* (2024). DOI: 10.48550/arxiv.2404.14499

Yunchong Wang et al, The SAGA Survey. V. Modeling Satellite Systems around Milky Way-mass Galaxies with Updated UniverseMachine, *arXiv* (2024). DOI: 10.48550/arxiv.2404.14500

Recent observations of the outer Solar System using the Subaru Telescope have uncovered objects where none were expected, hinting at the possibility of a larger and more complex structure in our cosmic neighborhood.

This breakthrough could change how we understand the Solar System's formation and history, and it suggests similarities between our Solar System and other planetary systems, which holds important implications for the search for life beyond Earth.

The Subaru Telescope. (CREDIT: CC BY-SA 3.0)© The Brighter Side of News

The Subaru Telescope has been involved in this project in support of NASA’s New Horizons spacecraft. New Horizons, launched in 2006, was the first mission to explore the Kuiper Belt—a vast region beyond Neptune filled with icy bodies. Subaru’s task has been to identify interesting Kuiper Belt Objects (KBOs) for New Horizons to study.

This effort has already led to the discovery of 263 KBOs, with 11 of these objects located beyond the established boundary of the Kuiper Belt.

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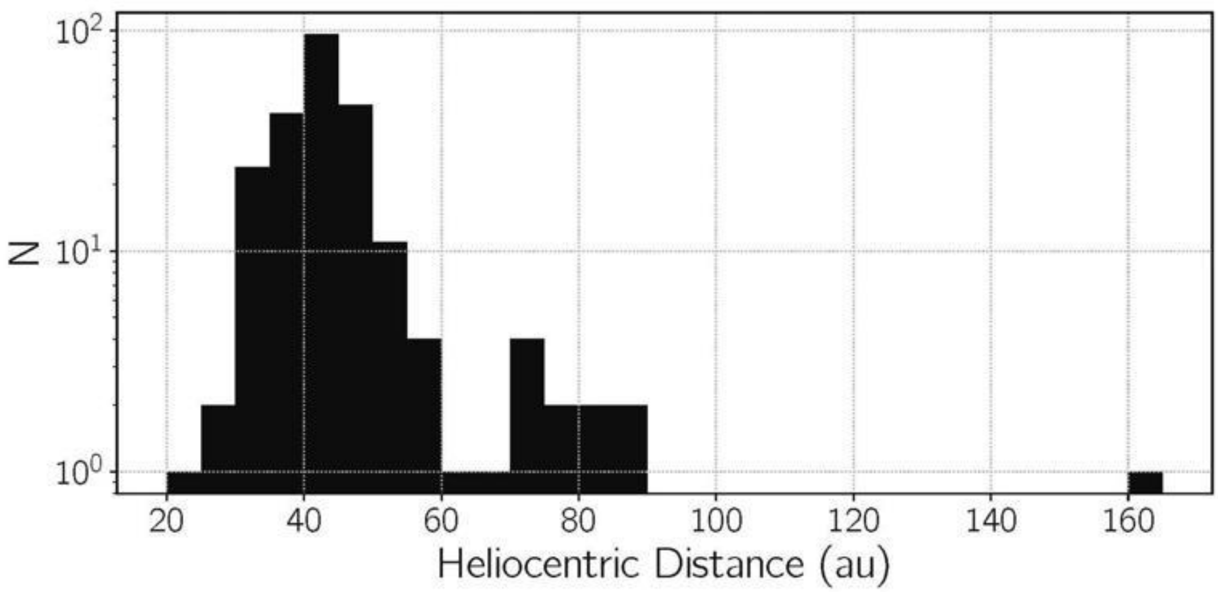
The significance of these 11 newfound objects lies in their location, as they appear to reside in a distinct "ring" beyond the known Kuiper Belt, separated by a "gap" where few objects are found. Such a ring-and-gap structure has been observed in young planetary systems, notably with the ALMA radio telescope in

Chile, but this is the first time such a feature has been suggested in our own Solar System.

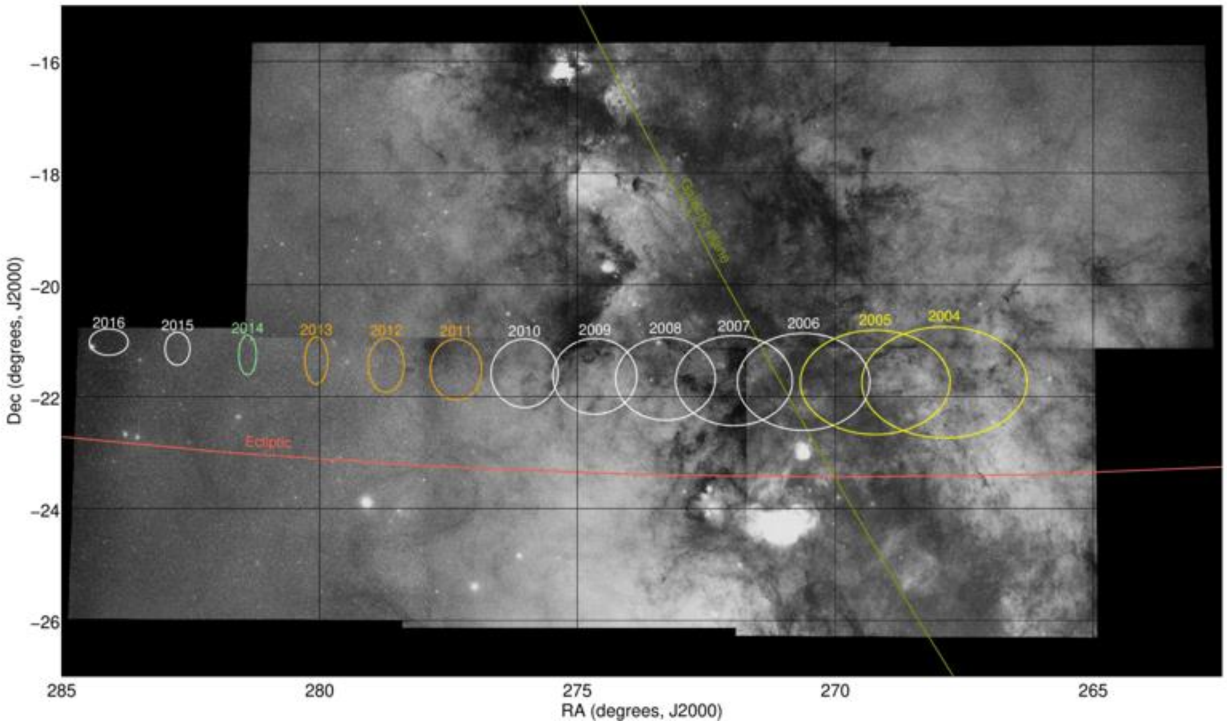
Dr. Fumi Yoshida from the University of Occupational and Environmental Health Sciences and the Planetary Exploration Research Center at Chiba Institute of Technology explained, “If this is confirmed, it would be a major discovery. The primordial solar nebula was much larger than previously thought, and this may have implications for studying the planet formation process in our Solar System."



Distance distribution of Kuiper Belt Objects discovered by HSC on the Subaru Telescope. The horizontal axis represents the distance from the Sun to the objects, measured in astronomical units (au; 1 au is the distance between the Earth and the Sun). The vertical axis represents the number of objects. Notice the drop in the number of objects between approximately 55 au and 70 au. Such a gap had not been reported in other observations. (CREDIT: Wesley Fraser)© The Brighter Side of News

This discovery is a critical piece of evidence in a growing body of research suggesting the presence of objects beyond the known Kuiper Belt. Unlike previous findings, which could be dismissed as outliers or false positives, the high number of objects detected in such a small search area points to the existence of a much larger population of distant bodies.

Dr. Wes Fraser, a co-investigator on the New Horizons science team and the lead author of the study, highlighted the broader implications of the findings. "Our Solar System’s Kuiper Belt long appeared to be very small in comparison with many other planetary systems, but our results suggest that idea might just have arisen due to an observational bias,” he explained. “So maybe, if this result is confirmed, our Kuiper Belt isn't all that small and unusual after all compared to those around other stars."

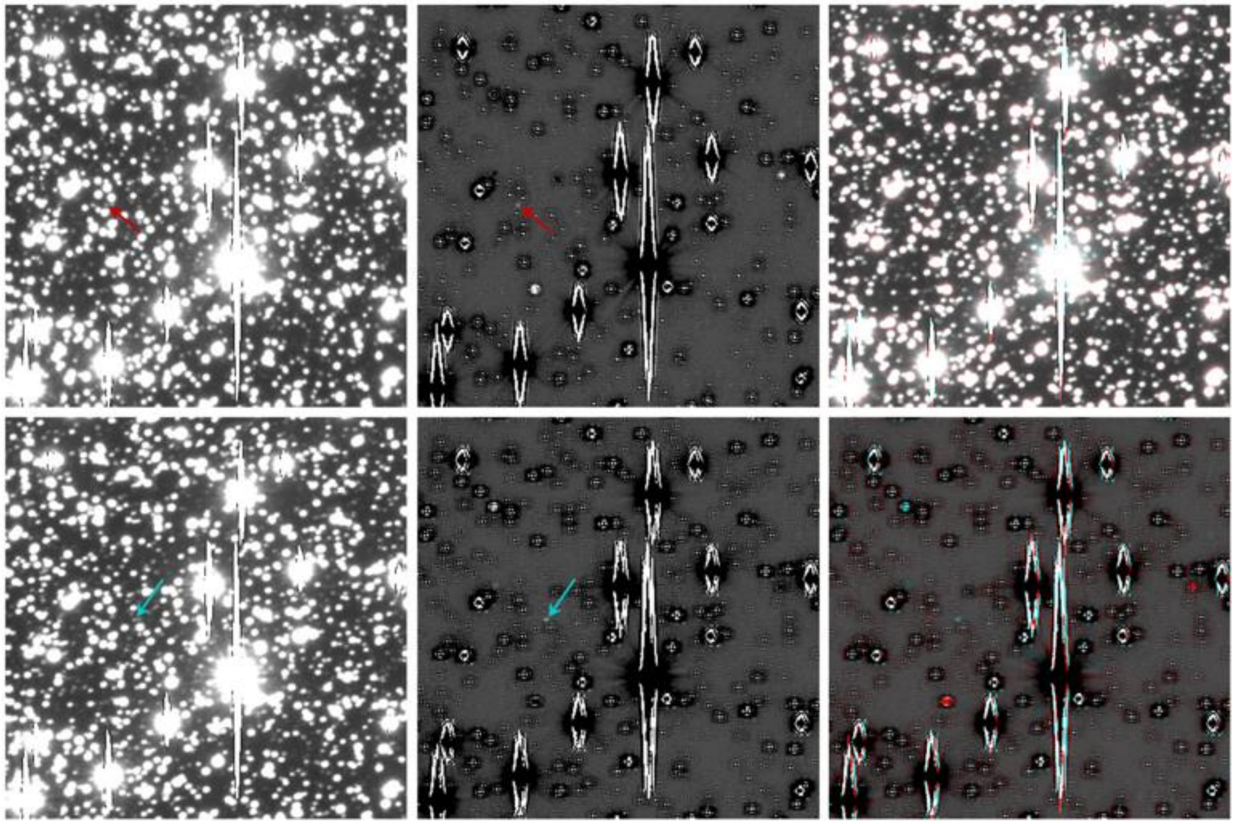


Map showing the search areas on the sky during the timespan of this project. The sky is shown with an overlay of the equatorial sky-plane coordinates. Superimposed are ellipses for the area that includes 67% of the encounterable cold-classical KBO population at opposition for the indicated year. (CREDIT: ARXIV)© The Brighter Side of News

These discoveries extend beyond just the physical structure of the Solar System. In the search for extraterrestrial life, one of the greatest challenges is that we have only one example of a life-bearing planet: Earth. This makes it difficult to discern which factors are necessary for life and which are incidental.

By revealing that the Solar System may not be as unique as once thought, particularly in terms of its formation, the discovery eliminates one more variable that could have been a prerequisite for life.

A larger, less unusual solar nebula increases the chances of finding planetary systems that share the conditions necessary for life. As Dr. Fraser points out, confirming this result could significantly enhance our understanding of which planetary systems may support life, making the search for extraterrestrial life much more focused and hopeful.



Sample SuprimeCam image data from 2011. Two epochs are shown of the discovery images for 2011 HL103. The red arrow (or image) shows the location at the first epoch and the cyan arrow (or image) shows the location at the second epoch. (CREDIT: ARXIV)© The Brighter Side of News

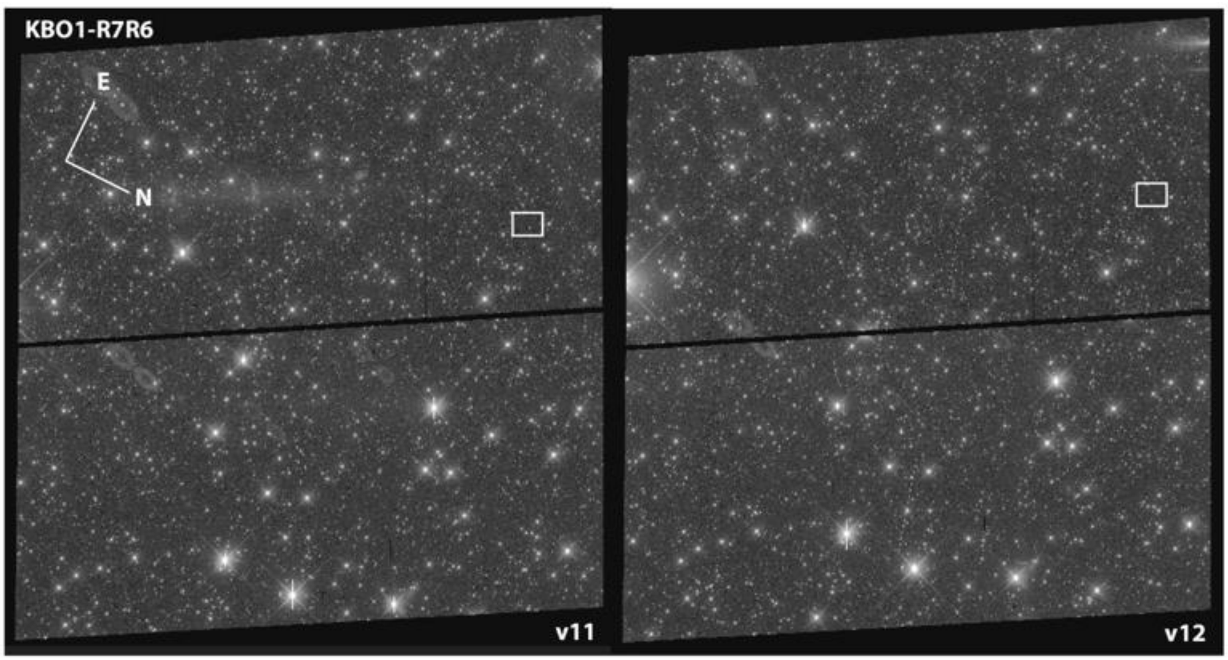
Dr. Alan Stern, the Principal Investigator for New Horizons, emphasized the importance of this discovery. “This is a groundbreaking discovery revealing something unexpected, new, and exciting in the distant reaches of the Solar System; this discovery probably would not have been possible without the world-class capabilities of Subaru Telescope.”

While much remains to be studied about the number and distribution of objects at the far edge of the Solar System, one thing is clear: the Subaru Telescope’s results open up new possibilities in what was once thought to be an empty and uneventful part of space.

Other interesting Kuiper Belt Objects (KBOs) discovered by NASA's new New Horizons spacecraft

NASA's New Horizons mission, famous for its groundbreaking flyby of Pluto in 2015, has since turned its attention to the Kuiper Belt, a region filled with icy bodies and remnants from the solar system’s early days. Here are some of the most interesting Kuiper Belt Objects (KBOs) New Horizons has discovered or studied:

1. Arrokoth (2014 MU69) Closest Flyby: After Pluto, New Horizons performed a historic close encounter with Arrokoth on January 1, 2019. This object, shaped like two flattened spheres stuck together, is the most distant world ever explored. It provided insight into how planetesimals, the building blocks of planets, form. The dual-lobe shape suggests a slow, gentle merger of two smaller objects, offering clues about the early solar system. Significance: Arrokoth's unaltered state and pristine surface provide a window into the conditions of the early solar system, long before planets like Earth fully formed.



Sample image from field KBO1-R7R6 in each of 2 visits separated by 1.05 hours. This field was part of the pilot search and 2014 MU69 is in the top chip on the right side in the area marked by the white box. The visit numbers of HST program 13633 are shown on the lower right hand corner of each image. (CREDIT: ARXIV)© The Brighter Side of News

2. 2014 OS393 and 2014 PN70 Potential Targets: These are two other Kuiper Belt Objects that New Horizons considered as potential targets before choosing Arrokoth. Although the spacecraft didn’t fly by these objects, they were studied using ground-based telescopes, providing additional data about their orbits and physical characteristics. Significance: These observations contribute to a broader understanding of the diversity of KBOs in this distant region. 3. Pluto’s Moons (Nix, Hydra, Charon, Styx, Kerberos) Although Pluto itself is technically a dwarf planet, its status as a Kuiper Belt Object makes its moons important members of

this category. New Horizons captured detailed images of Pluto's large moon Charon and smaller moons Nix and Hydra. Nix, for example, showed surprisingly bright regions, suggesting some internal activity or past collisions. 4. KBO Ring Surveys In its extended mission, New Horizons continues to observe KBOs from afar using its Long Range Reconnaissance Imager (LORRI). These objects provide valuable data about the size distribution, color, and surface properties of KBOs. One of the key findings is that these objects are often covered in methane, ammonia, and other ices. 5. Unseen KBOs In addition to objects it directly targets, New Horizons has revealed previously unseen KBOs using its telescopic instruments. This contributes to cataloging KBO populations and understanding their distribution. Many of these KBOs remain unstudied in detail but will be important for future exploration.

Instead of a desolate void, the region beyond the Kuiper Belt may be teeming with undiscovered objects, waiting to reveal more secrets about the formation and structure of our Solar System.

Researchers at MIT suggest that the microscopic "primordial black holes" could be blasting through our solar system — at a rate of at least once every decade.

These tiny black holes could be extremely dense, they suggest, packing the mass of a sizable asteroid into the space of a single atom, and date back to the very earliest days of the universe, mere moments following the Big Bang.

As detailed in a new paper published in the journal *Physical Review D*, these alleged visitors could shed new light on the nature of dark matter, which is the hypothetical stuff that scientists believe doesn't interact with light or radiation, but is believed to make up 85 percent of the universe.

The scientists suggest these primordial black holes could account for some if not all of the dark matter. To support their theory, the team proposed looking for tiny wobbles in Mars' orbit, which may be caused by repeated flybys of these tiny primordial black holes.

"Given decades of precision telemetry, scientists know the distance between Earth and Mars to an accuracy of about ten centimeters," said author and MIT physics professor David Kaiser in a statement.

"We're taking advantage of this highly instrumented region of space to try and look for a small effect," he added. "If we see it, that would count as a real reason to keep pursuing this delightful idea that all of dark matter consists of black holes that were spawned in less than a second after the Big Bang and have been streaming around the universe for 14 billion years."

Thanks to their immense density, these tiny black holes could exert enough gravitational forces on celestial bodies in our solar system to account for at least a portion of dark matter's observed effect on the motion of stars and galaxies.

After doing some back-of-the-envelope math, lead author and Stanford graduate student Tung Tran concluded that if a primordial black hole would pass by within roughly three feet of a person, they would be pushed around 20 feet away in a matter of a single second.

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

Coauthor and University of California at Santa Cruz postdoc Sarah Geller suggested that while they "do not live in the solar system," they could be ripping through it "at some angle every ten years or so."

Even if such a black hole were to pass within a few hundred million miles of Mars, it could cause the planet's orbit to start wobbling by as much as three feet.

But even if they'd be able to confirm this wobble, the scientists would still have plenty of work to do to confirm the existence of primordial black holes.

"Luckily for us, astronomers have been tracking ordinary space rocks for decades as they have flown through our solar system, so we could calculate typical properties of their trajectories and begin to compare them with the very different types of paths and speeds that primordial black holes should follow," Kaiser said in a statement.

However, spotting them might prove extremely tricky.

"Astronomers are in fact amazingly good at finding even much lighter objects in our solar system, such as small asteroids," Geller told *Space.com*, "whereas direct observation of a small black hole with a telescope would most likely show nothing at all."


Credit: Pixabay/CC0 Public Domain© Provided by Phys.org

Given how unfathomably large the universe is, it is perhaps understandable that we haven't yet cracked all its secrets. But there are actually some pretty basic features, ones we used to think we could explain, that cosmologists are increasingly struggling to make sense of.

Recent measurements of the distribution of matter in the universe (so-called large-scale structure) appear to be in conflict with the predictions of the standard model of cosmology, our best understanding of how the universe works.

The standard model originated some 25 years ago and has successfully reproduced a whole plethora of observations. But some of the latest measurements of large-scale structure, a topic on which I work, indicate that the matter is less clustered (smoother) than it ought to be according to the standard model.

This result has cosmologists scratching their heads looking for explanations. Some solutions are relatively mundane, such as unknown systematic errors in the measurements. But there are more radical solutions. These include rethinking the nature of dark energy (the force causing the universe's expansion to accelerate), invoking a new force of nature or even tweaking Einstein's theory of gravity on the largest of scales.

At present, the data cannot easily distinguish between different competing ideas. But the measurements from forthcoming surveys are poised to take a giant leap forward in precision. We may be on the cusp of finally breaking the standard model of cosmology.

The early universe

To understand the nature of the current tension and its possible solutions, it is important to understand how structure in the universe formed and subsequently evolved. Much of our understanding comes from measurements of the cosmic microwave background (CMB). The CMB is radiation that fills the universe and is a leftover relic from the first few hundred thousand years of cosmic evolution after the Big Bang (for comparison, the universe is estimated to be 13.7 billion years old).

Scientists discovered the CMB by accident in 1964 (garnering them a Nobel prize), but its existence and properties had been predicted years earlier.

In excellent agreement with some of the earliest theoretical work, the observed temperature of the CMB today is an incredibly chilly 3 Kelvin (-270°C). However, at very early times, it was sufficiently hot (millions of degrees) to enable the fusion of all of the light elements in the universe, including helium and lithium, into heavier ones.

The CMB's spectrum (light broken down by wavelength) suggests it must have been in thermal equilibrium with matter in the past—meaning they had the same distribution of energies. Matter and radiation can only reach thermal equilibrium in very dense environments. So measurements of the CMB convincingly demonstrate that the universe was once an extremely hot and dense place, with all the matter and radiation packed into a very small space.

As the universe expanded, it quickly cooled. And as it did so, some of the free electrons that existed at the time were captured by protons, forming atoms of hydrogen. This "era of recombination" happened around 300,000 years after the Big Bang. After this point, the universe was suddenly less dense, so the CMB radiation was "released" to travel without impediment, and it has not significantly interacted with matter since.

As the radiation is very old, when we make measurements of the CMB today, we are learning about the conditions of the early universe. But detailed mapping of the CMB tells us a great deal more than this.

A key insight from CMB maps obtained with the Planck telescope is that the universe was also exceptionally smooth at early times. There was only a 0.001% variation from place to place in the density and temperature of the matter and radiation in the universe. If there had been more extreme variation, that matter and radiation would have been much more clustered.

These variations, or "fluctuations," are of fundamental importance to how structure subsequently evolved in the universe. Without these fluctuations, there would be no galaxies, no stars or planets—and no life. A very interesting question is: Where did these fluctuations come from?

Our current understanding is that they are a result of quantum mechanics, the theory of the microcosmos of atoms and particles. Quantum mechanics shows that empty space has some background energy that allows sudden, local changes, such as particles popping in and out of existence. The quantum nature of matter and energy has been verified to remarkable accuracy in the laboratory.

These fluctuations are thought to have been blown up to large scales in a very rapid period of expansion in the early universe called "inflation," although the detailed mechanism behind inflation is still not fully understood.

Over time, these fluctuations grew and the arrangement of matter and radiation in the universe became more clustered. Regions that were slightly denser had a stronger gravitational pull and so attracted even more matter, which increased the density, which strengthened the gravitational pull, and so on. Regions of slightly lower density lost out, becoming emptier with time—a cosmic case of the rich getting richer and the poor getting poorer.

The fluctuations grew to such an extent over time that galaxies and stars started to form, with galaxies being distributed in and along the familiar filaments and nodes that make up a "cosmic web."

The standard explanation

The rate at which fluctuations grow over time, and how they are clustered in space, depends on several factors: the nature of gravity, the constituent components of matter and energy in the universe, and how these components interact (both with themselves and with each other).

These factors are encapsulated in the standard model of cosmology. The model is based on a solution to Einstein's general theory of relativity (our best understanding of gravity) that assumes the universe is homogeneous and isotropic on large scales—meaning it looks the same in every direction to every observer.

It also assumes that the matter and energy in the universe is composed of normal matter ("baryons"), dark matter consisting of relatively heavy and slow-moving particles ("cold" dark matter) and a constant amount of dark energy (Einstein's cosmological constant, denoted Lambda).

Since its origin approximately 25 years ago, the model has successfully explained a great many observations of the universe on large scales, including the detailed properties of the CMB.

And until very recently, it also provided excellent fits to a variety of measurements of the clustering of large-scale structure at late times. In fact, some measurements of large-scale structure are still very well described by the standard model, and this may provide an important clue as to the origin of the current tension.

Remember that the CMB shows us the clustering of matter (the fluctuations) at early times. So we can use the standard model to evolve that forward in time and predict what it should, theoretically, look like today. If there is a fit between this prediction and observations, that is a very strong indication that the ingredients of the standard model are correct.

The 'S_8' tension

What has changed recently is that our measurements of large-scale structure, particularly at very late times, have significantly improved in their precision. Various surveys such as the Dark Energy Survey and the Kilo Degree Survey have found evidence for inconsistencies between observations and the standard model.

In other words, there is a mismatch between the early time and late time fluctuations: The late-time fluctuations are not as large as expected. Cosmologists refer to this clash as the "S_8 tension," as S_8 is a parameter that we use to characterize the clustering of matter in the late-time universe.

Depending on the particular data set, the chance of the tension being a statistical fluke may be as low as 0.3%. But from a statistical point of view, that is not enough to firmly rule out the standard model.

However, there are strong hints of the tension in a variety of independent observations. And attempts to explain it away due to systematic uncertainties in the measurements or modeling have simply not been successful to date.

For example, it had previously been suggested that perhaps energetic non-gravitational processes, such as winds and jets from supermassive black holes, could inject enough energy to alter the clustering of matter on large scales.

However, we have shown using state-of-the-art cosmological hydrodynamical simulations (called Flamingo) that such effects appear to be too small to explain the tension with the standard model of cosmology.

If the tension is indeed pointing us to a flaw in the standard model, this would imply that something in the basic ingredients of the model is not correct.

This would have huge consequences for fundamental physics. For example, the tension may be indicating that something is wrong about our understanding of gravity, or the nature of the unknown substance called dark matter or dark energy. In the case of dark matter, one possibility is that it interacts with itself via an unknown force (something beyond just gravity).

Alternatively, perhaps dark energy is not constant but evolves with time, as early results from the Dark Energy Survey Instrument (Desi) may indicate. Some scientists are even considering the possibility of a new (fifth) force of nature. This would be a force of similar strength to gravity that operates over very large scales and would act to slow the growth of structure.

But note that any modifications of the standard model would also need to account for the many observations of the universe that the model successfully explains. This is no simple task. And before we jump to grand conclusions, we must be sure that the tension is real and not simply a statistical fluctuation.

The good news is that forthcoming measurements of large-scale structure with Desi, the Rubin Observatory, Euclid, the Simons Observatory and other experiments will be able to confirm with much more precise measurements whether the tension is real.

They will also be able to thoroughly test many of the alternatives to the standard model that have been proposed. It may be that within the next couple of years we will have ruled out the standard model of cosmology and profoundly changed our understanding of how the universe works. Or the model may be vindicated and more reliable than ever. It's an exciting time to be a cosmologist.


dennis_krumm_ – stock.adobe.com – illustrative purposes only

Lately, a surprising discovery about the evolution of our galaxy has been made. A large number of ancient stars were found in an unlikely region of our galaxy, the Milky Way. They formed the thin disk of the Milky Way several billion years earlier than previously believed.

The majority of stars are located in the thin disk of the Milky Way, where our solar system is. These stars follow an organized rotation around the galactic center.

The Sun is nearly five billion years old, making it a middle-aged star. It is also in the thin disk, which was thought to have started forming between eight and 10 billion years ago.

In order to gain a better understanding of how the Milky Way came to be, astronomers must create detailed maps of the galaxy that show the age, makeup, and movements of stars.

It is a challenge to create such maps because they require large datasets of stars with precise ages. So, astronomers often turn to studying old stars to look into the early days of the galaxy.

The old stars formed when only hydrogen, helium, and a bit of lithium were present in the universe. They are "less polluted" by heavier elements such as oxygen, carbon, or iron that were created and distributed by later generations of stars.

A team of astronomers from the Leibniz Institute for Astrophysics Potsdam used a dataset from the European Space Agency's Gaia mission to study stars about 3,200 light-years within the Sun.

They discovered many ancient stars that were over 10 billion years old. Some were over 13 billion years old.

"These ancient stars in the disk suggest that the formation of the Milky Way's thin disk began much earlier than previously believed, by about four to five billion years," said Samir Nepal, the lead author of the study.

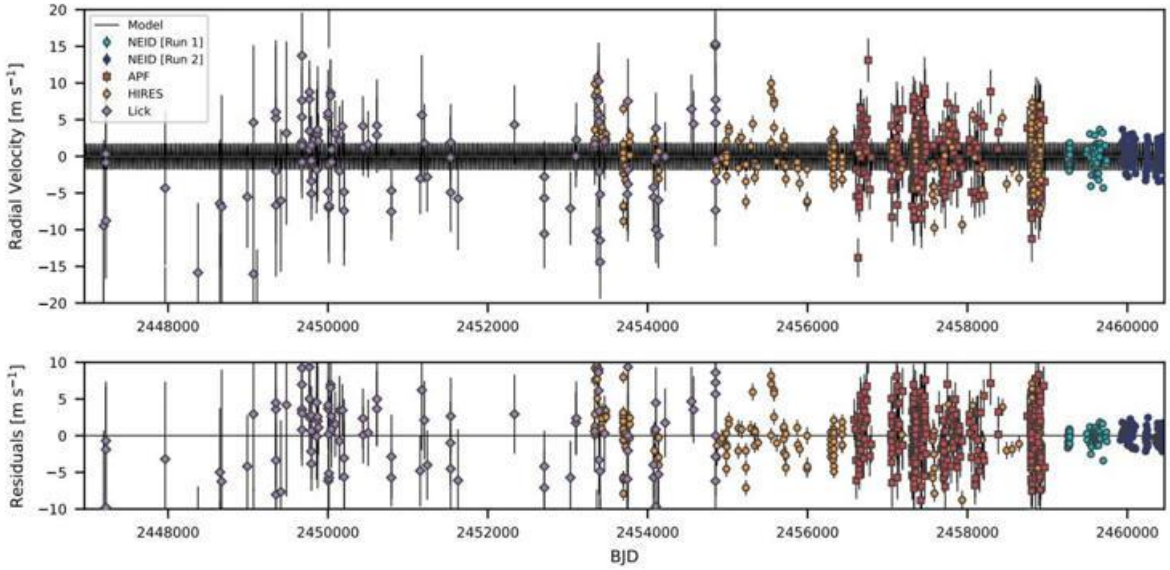
Finding such old stars in the thin disk was unexpected because this region was believed to be the youngest component of the Milky Way.

The results of the study point to two possibilities. For one, it seems that the thin disk of a galaxy can develop quite rapidly, an idea that aligns with observations of ancient galaxies made by the James Webb Space Telescope and the Atacama Large Millimeter Array.

Secondly, the Milky Way must have experienced intense episodes of star formation. Massive stars from these episodes that eventually went supernova gave rise to the heavy metal enrichment seen throughout the disk.

"Our study suggests that the thin disk of the Milky Way may have formed much earlier than we had thought and that its formation is strongly related to the early chemical enrichment of the innermost regions of our galaxy," said co-author Cristina Chiappini.

The paper was published in *Astronomy & Astrophysics*.



Complete radial velocity time series for HD 86728. The NEID data are shown as light (Run 1) and dark (Run 2) blue circles. Credit: Gupta et al., 2024.

An international team of astronomers reports the discovery of a new extrasolar world orbiting a nearby star known as HD 86728. This is the first exoplanet detection made as part of the NEID Earth Twin Survey (NETS). The finding was detailed in a research paper published September 18 on the pre-print server *arXiv*.

NEID is a fiber-fed, environmentally-stabilized optical-near-infrared echelle spectrograph installed on the WIYN1 3.5 m telescope at Kitt Peak National Observatory in Arizona. The NETS survey employs NEID to search for low-mass exoplanets around nearby bright stars.

Now, a team of astronomers led by Arvind F. Gupta of the U.S. National Science Foundation National Optical-Infrared Astronomy Research Laboratory in Tucson, Arizona, has identified the first exoplanet from NETS. The newfound planet orbits HD 86728—a bright star of spectral type G3Va, located some 48.6 light years away.

"In this work, we present the first three years of NETS observations of the HD 86728 system and we confirm the detection of the exoplanet HD 86728 b ... HD

86728 was observed with NEID on 137 separate nights during th e first three years of the NETS program," the researchers wrote in the paper.

According to the study, the newfound exoplanet HD 86728 b orbits its host star on a circular orbit every 31.15 days, at a distance of about 0.19 AU. The projected mass of this planet was estimated to be some 9.16 Earth masses.

The astronomers noted that the vast majority of exoplanets with similar masses and orbital periods to HD 86728 b reside in multi-planet systems. Therefore, if it hosts only HD 86728 b, this planet would be in the small minority (less than 12 percent) with no known siblings. However, further observations are required in order to rule out the presence of additional planets orbiting HD 86728.

When it comes to the host star, HD 86728, it has a radius of approximately 1.24 solar radii, while its mass is comparable to that of the sun. The star has an effective temperature of about 5,610 K and its metallicity is at a level of 0.2 dex.

In concluding remarks, the authors of the paper underlined that the detection of HD 86728 b proves how important extreme precision radial velocity spectrographs are for the search for low-mass alien worlds.

"NEID and other extreme precision spectrographs will continue to chip away at the sensitivity floor for quiet stars, enabling the detection of exoplanets at lower masses and longer periods as we push towards the discovery of Earth analogs with radial velocity measurements," the scientists wrote.

More information: Arvind F. Gupta et al, The NEID Earth Twin Survey. I. Confirmation of a 31-day planet orbiting HD 86728, *arXiv* (2024). DOI: 10.48550/arxiv.2409.12315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Astronomers have made the most detailed infrared map of our galaxy ever made.

The huge map has already helped changed our view of the galaxy in unexpected ways, according to its creators.

In all, it catalogues more than 1.5 billion objects, a vast improvement on previous examples. It includes stars and other objects.

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 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 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 MilkyWay'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."

Credit: Scott Lord from Pexels

The reason we call dark matter dark isn't that it's some shadowy material. It's because dark matter doesn't interact with light. The difference is subtle, but important. Regular matter can be dark because it absorbs light. It's why, for example, we can see the shadow of molecular clouds against the scattered stars of the Milky Way. This is possible because light and matter have a way to connect.

Light is an electromagnetic wave, and atoms contain electrically charged electrons and protons, so matter can emit, absorb and scatter light. Dark matter isn't electrically charged. It has no way to connect with light, and so when light and dark matter meet up they simply pass through each other.

All of our observations suggest that dark matter and light only have gravity in common. When dark matter is clustered around a galaxy, for example, its gravitational tug can deflect light. Because of this we can map the distribution of dark matter in the universe by observing how light is gravitationally lensed around it.

We also know that dark and regular matter interact gravitationally. The tug of dark matter causes galaxies to gather together into superclusters. But an unanswered question is whether dark and regular matter only interact gravitationally. If an atom and dark matter particle intersected, would they really just pass through each other?

Since we haven't directly observed dark matter particles we can only speculate, but most dark matter models argue that gravity is the only common link with light and regular matter. Dark and regular matter clump around each other, but they don't collide and merge like interstellar clouds. But a new study suggests the two do interact, which could reveal subtle aspects of the mysterious stuff.

The study looks at six ultrafaint dwarf galaxies, or UFDs. They are satellite galaxies near the Milky Way that seem to have far fewer stars than their mass would suggest. This is because they are mostly made of dark matter. The findings are published in *The Astrophysical Journal Letters*.

If regular and dark matter only interact gravitationally, then the distribution of stars in these small galaxies should follow a certain pattern. If dark and regular matter interact directly, then this distribution will be skewed.

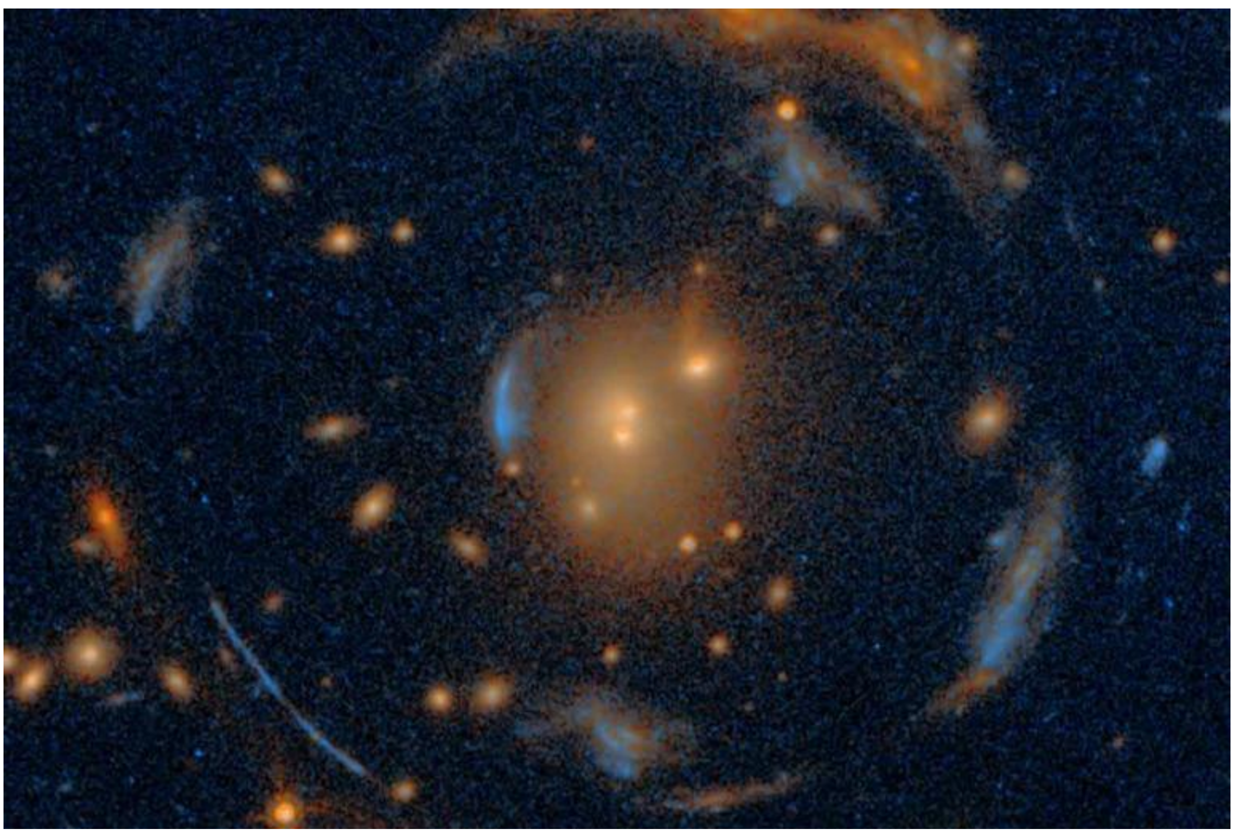
To test this, the team ran computer simulations of both scenarios. They found that in the non-interacting model the distribution of stars should become more dense in the center of the UFDs and more diffuse at the edges. In the interacting model the stellar distribution should be more uniform. When they compared these models with observations of the six galaxies, they found the interacting model was a slightly better fit.

So it seems dark and regular matter interact in ways beyond their gravitational tugs. There isn't enough data to pin down the exact nature of the interaction, but the fact there is any interaction at all is a surprise. It means that our traditional models of dark matter are at least partly wrong.

It may also point the way toward new methods of detecting dark matter directly. In time we may finally solve the mystery of this dark, but not entirely invisible, material.

More information: Jorge Sánchez Almeida et al, The Stellar Distribution in Ultrafaint Dwarf Galaxies Suggests Deviations from the Collisionless Cold Dark Matter Paradigm, *The Astrophysical Journal Letters* (2024). DOI: 10.3847/2041-8213/ad66bc

Provided by Universe Today



Hubble views of the Carousel Lens. - Image credit: William Sheu/UCLA© IFL Science

Astronomers have found an incredible gravitational lens. Thanks to a chance alignment, a foreground cluster of galaxies has magnified the light of not one, but seven background galaxies, creating a gravitational lens that has been described as "most exquisitely aligned". It has been dubbed the Carousel Lens.

Gravitational lenses are created by the gravity of massive objects, usually galaxies or clusters of galaxies. Their density is such that they warp spacetime, creating a lens that can magnify and change the shape of distant objects. In this case, there are four massive galaxies in the foreground that act as a lens, three of them close to each other. They are located about 5 billion light-years from us.

This is literally a one-in-a-billion object in the sky.

Dr David Schlegel

The seven background galaxies are spread out far across the universe, the closest being 7 billion light-years away and the furthest 12 billion light-years away. It was simply chance that placed the lens and those seven galaxies in a single line of sight from our vantage point.

Galaxy number four is particularly interesting. Its location behind the lens is such that it creates an Einstein cross. Four images are clearly visible 90 degrees from each other (with a secret fifth in the middle too dim to see). This is the largest Einstein cross ever seen and it tells us that the distribution of mass in the lens is quite symmetrical.

"This is literally a one-in-a-billion object in the sky. The images that we used for this search contained a billion astrophysical objects, mostly galaxies, and this was a rare alignment of galaxies that we found in those data," co-author Dr David Schlegel, a senior scientist in Berkeley Lab's Physics Division, told IFLScience.

The discovery is part of observations conducted in the context of the Dark Energy Spectroscopic Instrument (DESI) Legacy Imaging Surveys. The team stresses that all the images are publicly available and anyone can see them online. But good luck finding a more striking representative of strong gravitational lenses than the Carousel.

“About 2,000 strong lenses have been found in this set of imaging data, from our team and competing teams. This is visually the most striking, and arguably the most interesting for continued study,” Dr Schlegel explained.

Gravitational lenses are not just pretty – they are also pretty useful. Their formation is predicated on the distribution of dark matter around the galaxies of the lens, a way for astronomers to infer where the invisible dark matter might be. Understanding dark matter and dark energy is critical to discovering if they do indeed exist and exactly what they are.

“Our excitement with this particular object is precisely because it can be used for cosmological studies. What makes a gravitational lens most useful for cosmology is to have multiple lensed galaxies and a simple, symmetric distribution of mass. This satisfies those conditions and then some – lensing seven background galaxies is a record. It’ll be interesting to see if that record is ever broken,” Dr Schlegel told IFLScience.

The study is published in The Astrophysical Journal.

Astronomers have spotted two giant plasma jets streaming from a supermassive black hole in a distant galaxy. At a mind-bending 23 million light-years long, they are the longest plasma jets on record.

140 galaxies long

The statistics are hard to fathom. The jets are blasting out of a black hole that sits 7.4 billion light years away. Each jet covers a distance equivalent to 140 Milky Way galaxies, and they are forcing researchers to rethink what they know about black holes.

Each light year is the equivalent of 5.8 trillion years, meaning these jets are far older than scientists expected. Researchers have named the jets Porphyrion after a giant in Greek mythology. They date to when the universe was 6.3 billion years old, less than half its current age.

Porphyrion's jets are huge streams of charged ions and particles with a power that is equivalent to trillions of suns. The magnetic fields around the black holes are responsible for their incredible speed. Porphyrion is so large and old that astronomers think it, and other jets like it, likely played a role in the formation of the universe.

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

One of 10,000 jet systems discovered

Researchers discovered the jet system during a survey using Europe's Low Frequency Array Radio Telescope (LOFAR). They were amazed to find that it uncovered over 10,000 jet systems. Porphyrion was the largest in the group. Researchers knew that such giant structures existed, but never in this quantity.

"Usually when we get a new observational capability, such as LOFAR's combination of wide field of view and very high sensitivity to extended structures, we find something new. But it was still very exciting to see so many of these objects emerging," says co-author Martin Hardcastle.

Originally, the team was not looking for black hole jets. They were using LOFAR to look at the wispy filaments that crisscross the huge expanses between galaxies. Whilst analyzing the images, Aivin Gast noticed the first pair of jets.

It was quite the catch, Gast wasn't even studying astronomy at the time. His degree was in archaeology and ancient history. He had offered to help friends look through the radio images. It was Gast who suggested the ancient Greek-inspired name.

Once the team saw a few of the jets, they began to actively look for them. They eventually found thousands.

Supermassive black holes sit in the middle of large galaxies. When the black holes are active, their gravitational force heats the surrounding area. The released energy takes the form of jets.

“We are learning that giant jets might be an age-old phenomenon. We now know they have existed for most of the universe’s life. Our LOFAR survey only covered 15% of the sky. Most of these giant jets are likely difficult to spot, so we believe there are many more of these behemoths out there,” lead author Martin Oei told *CNN*.

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

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

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

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

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

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

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

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

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

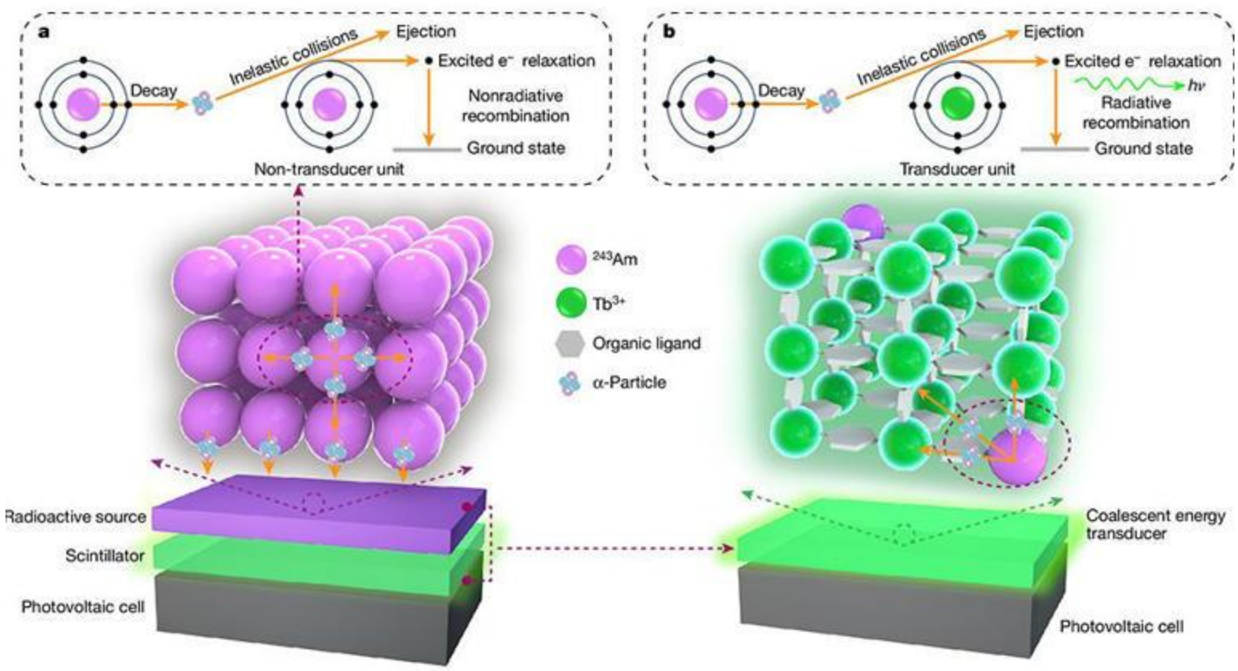
"Our study suggests that the thin disk of the Milky Way may have formed much earlier than we had thought, and that its formation is strongly related to the early chemical enrichment of the innermost regions of our galaxy," explains Cristina Chiappini. "The combination of data from different sources and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

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

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

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

Provided by Leibniz Institute for Astrophysics Potsdam



Chinese scientists use americium to produce ultra-compact nuclear battery that could perhaps one day replace lithium batteries© Nature

Scientists from across several Chinese institutions have unveiled a new ultra-compact nuclear battery that has the potential to replace the existing power sources used in everyday tech.

Powered by Americium, this new battery reportedly achieves an energy conversion efficiency up to 8,000 times greater than previous models, suggesting it could one day serve as a substitute for conventional lithium batteries.

These micronuclear power sources generate electricity by utilizing the radioactive decay of radioisotopes, producing power on a small scale typically measured in nanowatts or microwatts. Unlike chemical batteries, their lifespan depends on the half-life of the radioisotope used. Americium, specifically isotopes 241Am and 243Am, offers operational lifetimes extending over several decades, suggesting it could provide a long-term power solution.

Deep space exploration

Traditional micronuclear batteries have faced challenges with low energy efficiency due to severe self-adsorption during alpha decay. Addressing this issue, the Chinese research team has developed a novel architecture that incorporates 243Am into a luminescent lanthanide coordination polymer.

By combining this new design with a photovoltaic cell to convert autoluminescence into electricity, the radiophotovoltaic micronuclear battery achieves a power conversion efficiency of 0.889%, delivering 139 microwatts per curie. Although the power output remains tiny, the potential for a long-term, maintenance-free energy supply is considerable.

The resilience of this battery is noteworthy, as radioactive decay remains consistent regardless of environmental factors such as temperature or pressure. This stability ensures a reliable power source in challenging conditions.

The technology is still in its early stages and requires further development before widespread adoption is feasible. However, the team suggests initial applications for the americium-based nuclear battery could target small, remote devices, particularly in deep space exploration, where replacing conventional batteries is impractical.

The research findings were published in the journal *Nature*.

A new discovery has solved a black hole mystery that perplexed astronomers for years.

The breakthrough was made by an international team of astrophysicists, led by Queen's University Belfast, using Nasa's Chandra X-ray Observatory and other state-of-the-art telescopes.

A massive black hole has torn apart one star and is now using that stellar wreckage to pummel another star or smaller black hole. The new evidence helps astronomers conclusively link two mysteries where there had previously only been hints of a connection.

In 2019, astronomers witnessed the signal of a star that got too close to a black hole and was destroyed by the black hole's gravitational forces.

Once shredded, the star's remains began circling the black hole in a disc shape in a type of "stellar graveyard".

Over a few years, however, this disc has expanded outwards and is now directly in the path of a star, or possibly a stellar-mass black hole, orbiting the massive black hole at a previously safe distance.

The orbiting star is now repeatedly crashing through the debris disc, about once every 48 hours, as it circles. When it does, the collision causes spectacular light shows and bursts of X-rays that astronomers captured with Chandra.

Lead author Dr Matt Nicholl, of Queen's University Belfast, said: "Imagine a diver repeatedly going into a pool and creating a splash every time she enters the water.

“The star in this comparison is like the diver and the disc is the pool, and each time the star strikes the surface it creates a huge ‘splash’ of gas and X-rays.

“As the star orbits around the black hole, it does this over and over again.”

Scientists have long documented many cases where an object gets too close to a black hole and gets torn apart in a single burst of light. Astronomers call these “tidal disruption events” (TDEs).

In recent years, astronomers have additionally discovered a new class of bright flashes from the centres of galaxies, which are detected only in X-rays and repeat many times.

These events are also connected to supermassive black holes, but astronomers could not explain what caused the semi-regular bursts of X-rays. They dubbed these “quasi-periodic eruptions”, or QPEs.

Co-author Dr Dheeraj Pasham, of the Massachusetts Institute of Technology, said: “There had been feverish speculation that these phenomena were connected, and now we’ve discovered the proof that they are.

“It’s like getting a cosmic two-for-one in terms of solving mysteries.”

The Chandra data was obtained during three different observations, each separated by about four to five hours.

The total exposure of about 14 hours of Chandra time revealed only a weak signal in the first and last chunk, but a very strong signal in the middle observation.

From there, Dr Nicholl and team used Nasa’s Neutron Star Interior Composition Explorer (Nicer) to look frequently for repeated X-ray bursts.

Ultraviolet data from the Hubble space telescope, obtained at the same time as the Chandra observations, allowed the scientists to determine the size of the disc around the supermassive black hole.

They found that the disc had become large enough so that, if any object was orbiting the black hole with a period of about a week or less, it would collide with the disc and cause eruptions.

Co-author Dr Andrew Mummery, of Oxford University, said: “This is a huge breakthrough in our understanding of the origin of these regular eruptions.

“We now realise we need to wait a few years for the eruptions to ‘turn on’ after a star has been torn apart because it takes some time for the disc to spread out far enough to encounter another star.”

This result has implications for searching for more QPEs associated with tidal disruptions.

Finding more of these would allow astronomers to measure the prevalence and distances of objects in close orbits around supermassive black holes.

Some of these may be targets for the planned future gravitational wave observatories.

Nasa’s Marshall Space Flight Centre manages the Chandra programme. The Smithsonian Astrophysical Observatory’s Chandra X-ray Centre controls science operations from Cambridge, Massachusetts, and flight operations from Burlington, Massachuse