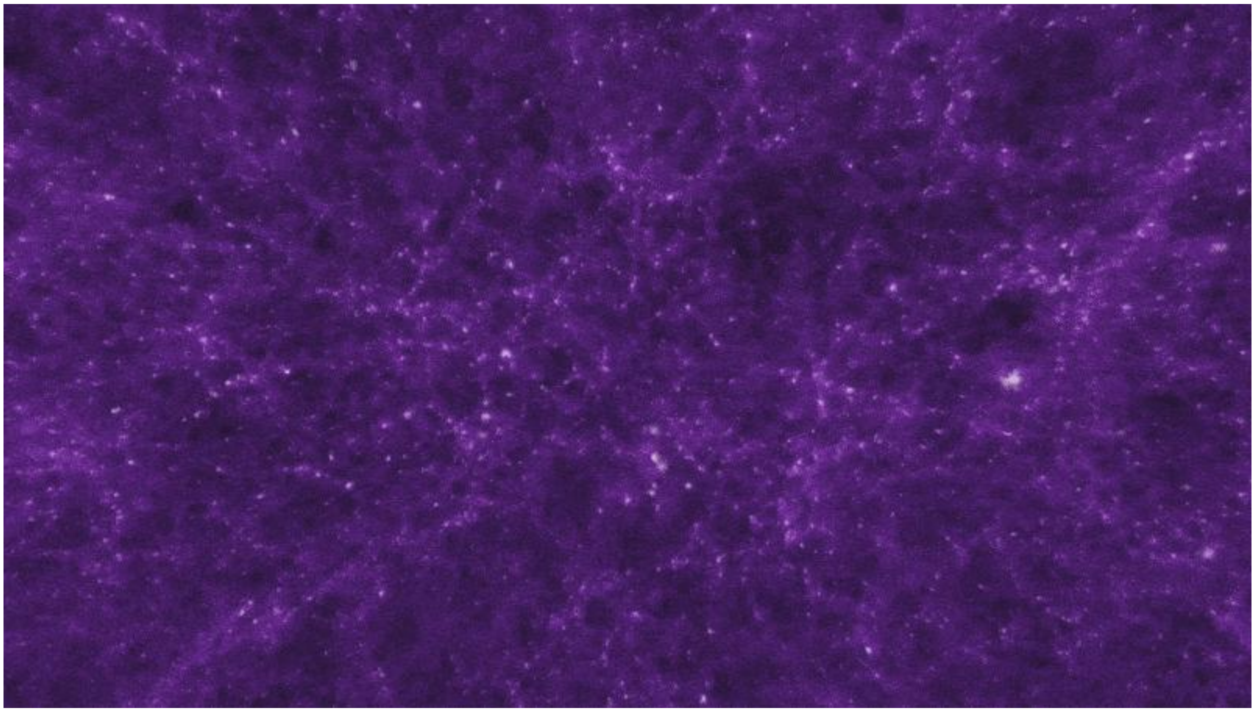

Researchers have only just begun to map out the cosmic web. This animation shows what it might look like if you could move through it faster than light speed. (Image credit: NASA/NCSA University of Illinois Visualization by Frank Summers, Space Telescope Science Institute, Simulation by Martin White and Lars Hernquist, Harvard University)

The universe's first magnetic fields were 'comparable' to the human brain — and still linger within the 'cosmic web'

The universe's first magnetic fields may have been much weaker than we first imagined — and were roughly equivalent to the strength of the magnetic activity within the human brain, according to a new study.

Researchers used hundreds of thousands of computer simulations to examine the remnants of these ancient magnetic fields, which still reside within the "cosmic web" billions of years later.

Magnetism is a natural force generated by the movements of electrical charges and has existed since the early days after the Big Bang, when the infant universe was full of jostling electrically charged particles. Experts have long suspected that the initial magnetic fields created by these particles, known as primordial magnetic fields, were much weaker than those created by complex cosmic objects that exist today, such as stars, black holes and planets.

But in the new study, published Aug. 13 in the journal Physical Review Letters, researchers have revealed that these primordial fields may have been even weaker than they previously imagined. Using exhaustive computer simulations, the team constrained an upper limit on these fields' magnetic strength and found that they likely maxed out at 0.00000000002 gauss, which is billions of times weaker than a standard fridge magnet (~100 gauss).

Such magnetic fields are "comparable to magnetism generated by [the electrical activity of] neurons in the human brain," the researchers wrote in a statement.

Despite their weakness, remnants of these magnetic fields still reside within the intergalactic cosmic web — a mysterious, sprawling structure that permeates the entire known universe — and this was key to uncovering the new findings.

The cosmic web is an expansive network of ghostly filaments that connect all the galaxies in the universe like a giant 3D spider's web. There is still a lot we don't know about the cosmic web, including what it is really made of. However, in recent years, scientists have started to image this gigantic structure properly and have begun to map it out in detail.

One of the biggest mysteries about the cosmic web is why it has its own magnetic fields. This is especially confusing in regions of space in-between galaxies, where the web is isolated within large expanses of nothingness.

"Our hypothesis was that this [magnetism] could be a legacy of events occurring in cosmic epochs during the birth of the universe," study lead author Mak Pavičević, a doctoral candidate at the International School for Advanced Studies (SISSA) in Trieste, Italy, and co-author Matteo Viel, an astrophysicist at SISSA, jointly said in the statement. "This is what we sought to ascertain with our work."

Their team believes that the earliest primordial magnetic fields could have been caught up in the initial inflation of the universe and later become intertwined with the cosmic web as it grew in the expanding spaces between galaxies.

The cosmic web connects all the galaxies in the known universe. But there is still much about this mysterious network that we do not fully understand. (Image credit: Robert Lea (created with Canva))

In the study, the researchers used approximately 250,000 computer simulations, based on observational data of the cosmic web, to reverse engineer this supposed series of events, allowing them to set "strict limits on the intensity of magnetic fields formed in the very early moments of the universe," Pavičević and Viel said.

These findings are still theoretical as there is currently no way of directly observing primordial magnetic fields. However, the researchers claim that the results align with recent findings concerning the cosmic microwave background (CMB), which is the radiation leftover from the Big Bang, although it is unclear which specific findings they are referring to.

The study team also notes that continued observations of the cosmic web with the James Webb Space Telescope (JWST) could allow them to create more powerful simulations to further test their hypothesis in the future.

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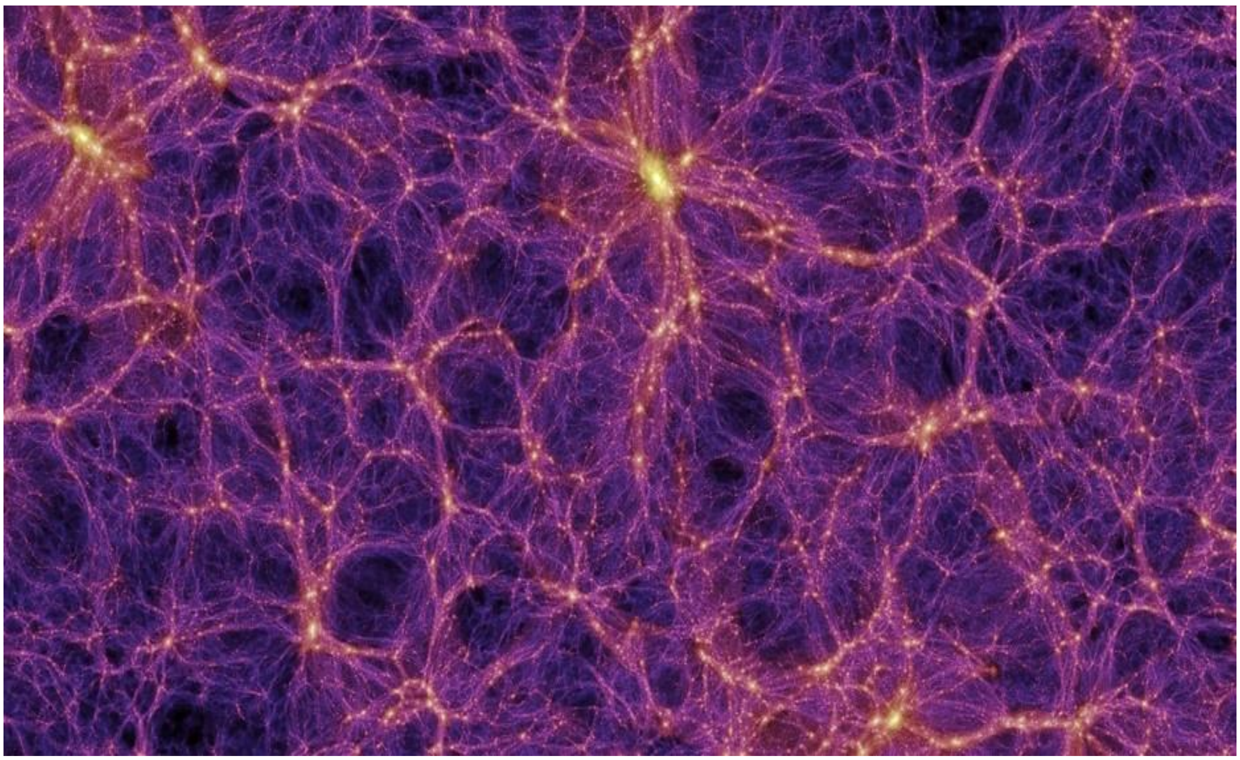
James Webb telescope detects the earliest strand in the 'cosmic web' ever seen

By Joanna Thompson July 6, 2023

Astronomers using the James Webb Space Telescope have discovered a clump of ancient galaxies that may be the oldest strand of the "cosmic web" ever detected.



A model of the cosmic web, showing bright galaxies clustering where tendrils of gas meet. (Image credit: ESA/ Springel et al., Virgo Consortium)

On a clear night, it might look like the stars above are distributed more or less evenly. But that isn't the case — all stars are part of a gigantic cosmic web that links galaxies across the universe like threads of spider's silk, leaving unfathomably large swaths of nothingness in between. Now, in two papers published in The Astrophysical Journal Letters on June 29, scientists detail evidence that this massive cosmic highway stretches back nearly to the dawn of the universe.

Using data from the James Webb Space Telescope, astronomers discovered a massive, gassy tendril composed of 10 closely packed galaxies stretching over 3 million light-years. According to the researchers, this ancient filament of gas and stars may represent the oldest known thread of the cosmic web.

"I was surprised by how long and how narrow this filament is," Xiaohui Fan, an astronomer at the University of Arizona and a member of the research team, said in a statement. "I expected to find something, but I didn't expect such a long, distinctly thin structure."
The newly discovered filament formed when the universe was young — a mere 830 million years after the Big Bang. It is anchored by an extremely bright celestial object with a supermassive black hole known as a quasar at its center.
This bright black hole is the reason scientists discovered the tendril in the first place. Fan and his team are working as part of the ASPIRE (A Spectroscopic Survey of Biased Halos in the Reionization Era) project, which aims to study how the earliest black holes influenced galactic evolution. The quasar detected here was one of 25 early-universe quasars that the project has its sights set on.

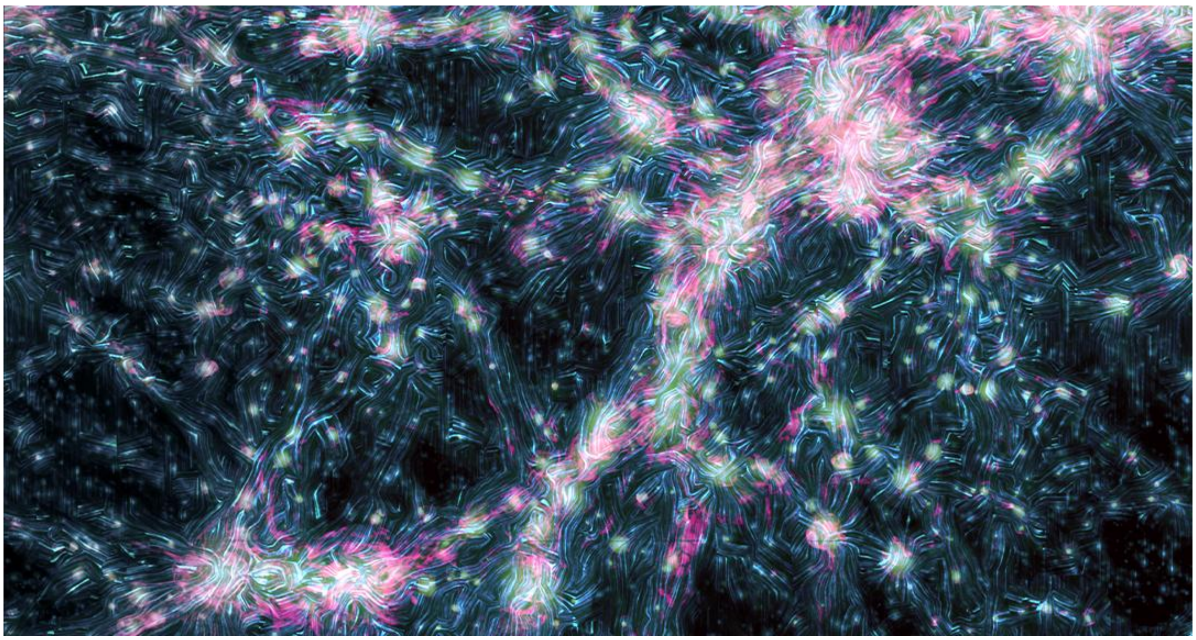
"This is one of the earliest filamentary structures that people have ever found associated with a distant quasar," Feige Wang, an astrophysicist at the University of Arizona and the program's principal investigator, said in the statement.
The researchers hypothesize that black holes helped to form the cosmic web by acting as gravity wells to draw matter together, and occasionally by flinging it far away on "cosmic winds," which whip up around extremely active quasars. Gravity keeps these strands of stars and dust connected, even as the winds pull them across the universe.

The researchers think that eventually, the filament will condense into a cluster of galaxies, similar to the Coma Cluster, which lies approximately 330 million light-years from Earth.

Galaxy-size shock waves found rattling the cosmic web — the largest structure in the universe

By Ben Turner published March 7, 2023

Astronomers have detected enormous shockwaves rattling the cosmic web that connects all galaxies in the universe, offering vital clues on how the largest structures in space were shaped.



A simulation of the cosmic web showing shock waves producing radio waves (pink) as they crash through magnetic fields (blue). (Image credit: F. Vazza/D. Wittor/J. West)

For the first time, astronomers have spotted enormous, galaxy-scale shock waves rattling the "cosmic web" that connects nearly all known galaxies. These cosmic waves could reveal clues about how the largest objects in the universe were sculpted.

The discovery was made by stitching and stacking thousands of radio telescope images together, which revealed the soft "radio glow" produced by shock waves from colliding matter in our universe's biggest structures.

The cosmic web is a gigantic network of crisscrossing celestial superhighways paved with hydrogen gas and dark matter. Galaxies tend to form where multiple strands of the web intersect, often in clusters numbering in the hundreds of thousands. Now a new study, published Feb. 15 in the journal Science, could provide vital clues into the nature of the mysterious magnetic fields that stretch beside these tendrils.

"Magnetic fields pervade the universe — from planets and stars to the largest spaces in-between galaxies," lead author Tessa Vernstrom, an astronomer at the International Centre for Radio Astronomy Research in Crawley, Australia, said in a statement. "However, many aspects of cosmic magnetism are not yet fully understood, especially at the scales seen in the cosmic web."

Taking shape in the chaotic aftermath of the Big Bang, the cosmic web's tendrils formed as clumps of matter from the roiling particle-antiparticle broth of the young universe — whose rapid expansion pushed the filaments outwards to form an interconnected soap-sud structure of thin films surrounding countless, mostly empty voids.

Far from being completely frozen in place, the cosmic web's matter can sometimes violently collide. When matter in the web merges, enormous shock waves send charged particles ricocheting through the web's magnetic fields, causing the particles to emit a faint radio wave glow. These shock waves have been spotted around some of the universe's largest galaxy clusters, but until now they were never observed around the web itself.

"These shock waves give off radio emissions which should result in the cosmic web 'glowing' in the radio spectrum, but it had never really been conclusively detected due to how faint the signals are," Vernstrom said.

To search for the faint signals, the researchers used data from the Global Magneto-Ionic Medium Survey, the Planck Legacy Archive, the Owens Valley Long Wavelength Array and the Murchison Widefield Array to stack radio imaging from 612,025 galaxy cluster pairs, grouped together if they were close enough to be directly connected by cosmic web tendrils. This stacking helped boost the faint radio emissions from the shock waves beyond noisy background effects.

Then, by looking only for polarized radio waves — whose rays vibrate at the same angle as each other and were predicted in simulations to be emitted by the shock waves — the researchers found the signal.

"As very few sources emit polarised radio light, our search was less prone to contamination and we have been able to provide much stronger evidence that we are seeing emissions from the shock waves in the largest structures in the universe, which helps to confirm our models for the growth of this large-scale structure," Vernstrom said.

'A bundle of microscopic tornadoes' may have given the universe its structure

By Andrey Feldman June 19, 2025

When invisible dark matter spins, it may form clumps of "vortexes" that stretch across space, forming the cosmic web that links all galaxies, new research proposes.

The cosmic web, the large-scale structure that links galaxies across the universe, may in part be the result of countless microscopic "vortexes" created by dark matter. (Image credit: Getty Images)

The universe's invisible dark matter might swirl into spinning clumps laced with countless tiny vortices, new theoretical work suggests.

The findings, published May 30 in the journal Physical Review D, offer a fresh perspective on the strange behavior of "ultralight" dark matter — a hypothetical substance made of extremely light elementary particles.

In the new study, physicists explored what happens when a dark matter halo rotates — a natural expectation for real galaxies, which typically spin as they evolve. Based on their theoretical modeling and detailed simulations, the authors found that this exotic material could behave like a superfluid, forming stable, rotating cores threaded with vortex lattices much like those seen in laboratory experiments.

A special kind of dark matter

Unlike the standard view of dark matter as a cloud of heavy, sluggish particles with no internal structure, the new research focuses on dark matter made of particles lighter than a

millionth of an electron's mass. These particles may not float passively in space; if they interact slightly with one another through a repulsive force, they can behave more like a quantum fluid.
That fluid-like behavior allows the formation of "solitons" — compact, coherent structures where gravity's pull inward is balanced by an outward pressure from self-interactions.

"Solitons are classical solutions of the equations of motion," Philippe Brax, a theoretical physicist at Université Paris-Saclay and co-author of the study, told Live Science. "They correspond to hydrostatic equilibria where the attractive gravitational force is balanced by the repulsive particle self-interaction, somewhat like the Sun, which is also in hydrostatic equilibrium."
These solitons could range from the size of stars to entire galaxies, depending on the unknown mass of the dark matter particle. In larger cases, they could help explain why the centers of galaxies appear less densely packed with dark matter than predicted — a long-standing issue in cosmology.

From spinning clouds to vortex lattices

The researchers simulated what happens when clouds of this unusual dark matter rotate. The result was surprising: Instead of spinning smoothly like a hurricane or a solid sphere, the solitons developed an internal lattice of microscopic vortices.

"When the initial conditions are such that the dark matter cloud rotates, the end result is a rotating soliton at the center of the collapsed halo," said study co-author Patrick Valageas, also of the Université Paris-Saclay. "This soliton shows an oblate shape aligned with the initial rotation axis, and displays a solid-body rotation supported by quantized vortices."
These vortices aren't like swirling winds or whirlpools in water. Rather, they resemble the quantized vortex lines that appear in superfluids like liquid helium, where the fluid rotates not as a whole but through an array of discrete spinning threads. At the center of each vortex, the dark matter density drops to zero, and together, the vortices align into a regular, lattice-like pattern.

"Our simulations show that these vortex lines are aligned with the total angular momentum and follow circular orbits inside the soliton," Valageas said. "The rotation is not like a smooth wind but more like a bundle of microscopic tornadoes arranged in a crystal pattern."

One intriguing idea the researchers raised is whether these tiny vortex structures have implications on much larger scales. In particular, they speculated that some vortex lines might extend beyond a single halo, connecting galaxies through the vast filaments of the cosmic web — the gigantic tendrils of dark matter that shape the universe's large-scale structure.
"At this stage, the idea that some of these vortex lines could join different halos through the filaments of the cosmic web is a hypothesis," Brax noted. If true, it could mean that quantum effects in dark matter subtly influence how galaxies align and move within these colossal threads.

Detecting such vortex structures would be challenging. Because dark matter doesn't emit or absorb light, scientists can only infer its presence from its gravitational influence on visible matter like stars and gas.

Still, there may be ways to glimpse their effects. "These vortices are associated with troughs in the dark matter density," Brax said. "As such, they imprint characteristic features in the gravitational potential, which may influence the orbits of stars or gas clouds in galaxies like the Milky Way."
In more speculative scenarios, if dark matter interacts even weakly with ordinary matter or light, the vortices might leave more direct fingerprints — but for now, that remains an open question.

The team plans to investigate whether the predicted vortex lattices can be detected through astronomical observations and whether they truly connect to the cosmic filaments that stretch across space.

For now, these ghostly whirlpools remain invisible — but as theory and technology advance, scientists may find that the cosmos is not just filled with unseen matter but woven with patterns of spinning quantum threads.

Now that the shock waves' existence has been confirmed, they could be used to probe the nature of the enormous magnetic fields that suffuse the web, which play an unknown role in shaping the universe.