NEWS COSMOLOGY

The universe may have a complex geometry — like a doughnut

Scientists previously considered only a small subset of possible topologies

Scientists are considering whether the universe might have a complicated topology, represented by a doughnut shape in this artist's conception.
J. LAW/ESO

By Emily Conover

MAY 13, 2024 AT 9:00 AM

The cosmos may have something in common with a doughnut.

In addition to their fried, sugary goodness, doughnuts are known for their shape, or in mathematical terms, their topology. In a universe with an analogous, complex topology, you could travel across the cosmos and end up back where you started. Such a cosmos hasn't yet been ruled out, physicists report in the April 26 *Physical Review Letters*.

On a shape with boring, or trivial topology, any closed path you draw can be shrunk down to a[illegible]und Earth. If you were to go all the[illegible]op, but you could squish that[illegible] Pole. But the

surface of a doughnut has complex, or nontrivial, topology (*SN: 10/4/16*). A loop that encircles the doughnut's hole, for example, can't be shrunk down, because the hole limits how far you can squish it.

The universe is generally believed to have trivial topology. But that's not known for certain, the researchers argue.

"I find it fascinating ... the possibility that the universe might have nontrivial or different types of topologies, and then especially the fact that we think we might be able to measure it," says cosmologist Dragan Huterer of the University of Michigan in Ann Arbor, who was not involved with the study.

A universe with nontrivial topology might be a bit like Pac-Man. In the classic arcade game, moving all the way to the right edge of the screen puts the character back at the left side. A Pac-Man trek that crosses the screen and returns the character to its starting point likewise can't be shrunk down.

Scientists have already looked for signs of complex topology in the cosmic microwave background, light from when the universe was just 380,000 years old. Because of the way space loops back on itself in a universe with nontrivial topology, scientists might be able to observe the same feature in more than one place. Researchers have searched for identical circles that appear in that light in two different places on the sky. They've also hunted for subtle correlations, or similarities, between different spots, rather than identical matches.

Those searches didn't turn up any evidence for complex topology. But, theoretical physicist Glenn Starkman and colleagues argue, there's still a chance that the universe does have something in common with a doughnut. That's because earlier research considered only a small subset of the possible topologies the universe could have.

That subset inclu ı 3-torus, a cube that loops back c :reen. In such a topology, exiting e opposite side.

Searches for that simple 3-torus have come up empty. But scientists haven't yet searched for some 3-torus variations. For example, the sides of the cube might be twisted relative to one another. In such a universe, exiting the top of the cube would bring you back to the bottom, but rotated by, for example, 180 degrees.

The new study considered a total of 17 possible nontrivial topologies for the cosmos. Most of those topologies, the authors determined, haven't yet been ruled out. The study evaluated the signatures that would appear in the cosmic microwave background for different types of topologies. Future analyses of that ancient light could reveal hints of these complex topologies, the researchers found.

The search is likely to be computationally challenging, probably requiring machine learning techniques to speed up calculations. The researchers also plan to hunt for signs of nontrivial topology in upcoming data from surveys of the distribution of galaxies in the cosmos, for example from the European Space Agency's Euclid space telescope (*SN: 12/20/23*).

There's good motivation to look for nontrivial topology, says Starkman, of Case Western Reserve University in Cleveland. Some features of the cosmic microwave background hint that the universe isn't the same in all directions (*SN: 12/23/08*). That kind of asymmetry could be explained by nontrivial topology. And that asymmetry, Starkman says, is "one of the biggest new mysteries about the universe that hasn't gone away."

CITATIONS

Y. Akrami *et al.* Promise of future searches for cosmic topology. *Physical Review Letters*. Vol. 132, April 26, 2024, 171501. doi: 10.1103/PhysRevLett.132.171501.