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Space

The universe is weirdly lopsided

Two analyses of a million galaxies show that their distribution may not be symmetrical, which may mean our understanding of the cosmos is incorrect, says **Leah Crane**

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The Sculptor galaxy is one of some 2 trillion galaxies in the universe

THE mirror symmetry of the universe may be in trouble. Based on our understanding of the large-scale structure of the cosmos and what we know about how gravity works, if we look at how galaxies are distributed throughout the universe and then compare it with its mirror image, the two should be basically indistinguishable. But two separate analyses of our best map of galaxies have now found that this principle, called parity symmetry or just parity, doesn't seem to hold true.

Each analysis examined galaxies from the Sloan Digital Sky Survey using a technique that takes advantage of the fact that a tetrahedron, or triangular pyramid, is the simplest 3D shape that can be distinguished from its mirror image. The researchers compared all of the possible tetrahedrons that could be made for a given sample of galaxies by placing a galaxy on each vertex.

"It's just like how you can't rotate your right hand and make it impossible to tell the difference from your left hand," says Zachary Slepian at the University of Florida, who performed one analysis along with Jiamin Hou, also at the University of Florida, and Robert Cahn at Lawrence Berkeley National Laboratory in California. "It's the same with these pyramids of galaxies."

To determine whether parity was violated, the researchers assigned a primary vertex for each of the galaxy-assigned tetrahedrons and then split them into two groups: those where, looking down from the primary vertex, the sides increase in length when you move clockwise, and those where they increase in length when you go anticlockwise.

If our universe obeys parity, the two groups of tetrahedrons should be roughly the same size. Neither analysis found that to be the case.

One, by Oliver Philcox at Princeton University, found parity violation at a level of 2.9 sigma, meaning there was only a 0.4 per cent chance that a pattern like this would show up as a statistical fluke due to random noise (arxiv.org/abs/2206.04227). The other, by Slepian and his colleagues, split the galaxies into two groups based on distance. They found even stronger parity violation in both: one at a level of 3.1 sigma and in the other at a level of 7.1 sigma (arxiv.org/abs/2206.03625).

> **"If this is from the early universe, it would mean there's a new interaction between particles"**

"This observation is completely shocking," says Stephon Alexander at Brown University in Rhode Island. "If it was just one group, I might have been more sceptical, but with two groups, it's a lot harder to shake."

"It's potentially making a claim about the physics of the early universe, which is really, really difficult to measure," says David Schlegel at Lawrence Berkeley National Laboratory. The good news is that the analyses are very testable, he says.

The claim about the early universe comes from the fact that the distribution of galaxies takes up so much space that it would be difficult for a force to be so strong that it could affect the symmetry of the entire universe. But just after the big bang, the cosmos was much smaller and everything was closer, so the seeds of asymmetry could have been planted then.

That could upend what we know about the first moments after the big bang and how the universe behaves. "If what we find turns out to be really genuinely from the actual early universe," says Slepian, "it would mean there's a new interaction between particles that previously has not been part of our understanding of physics – basically a new force of nature."

Whatever this exotic new physics is, it could help explain why the universe is made of mostly matter instead of equal parts matter and antimatter. "If we want to generate more matter than antimatter," says Philcox, we "need something to violate parity".

While there are ideas for what might cause this parity violation, including new fields and particles in the early universe, the new analyses don't point to any in particular. Before we can narrow down the hypotheses, the results need to be checked, all the researchers agree. One way to do so is to repeat the analyses on larger maps of the universe that should be released in the next few years. But to be certain, other methods will also have to be used.

"If there is really a parity-breaking mechanism at cosmological scales, it would probably not only pop out in the large-scale structures of galaxies, but maybe also in the cosmic microwave background and even gravitational waves," says Hou. If that happens, the race will be on to find out what strange physics caused it. ■