

Physicists Propose How To Test If The Universe Is Finely Tuned For Life



A new paper has set out ways that we can test the anthropic principle, or whether the universe has been "finely tuned" for life. Surprisingly, it may be possible to have answers to this age-old question in a pretty short timescale.

There is a problem (or not, for fans of being alive) within physics, in that the universe appears finely tuned for life – at least of the kind we find on Earth – to emerge and thrive.

If gravity was substantially weaker than it is (and it's [already pretty weak](#), just ask any magnet), stars and planets would not have formed. If it was just a little weaker, or electromagnetism slightly stronger, stars would be cooler and not explode to produce the heavier elements needed for life to exist. There are countless other examples. Mess around with the values of physics even slightly, and life as we know it in this universe would not exist.

"The cliché that 'life is balanced on a knife-edge' is a staggering understatement," physicist Paul Davies famously [wrote of the problem](#). "No knife in the universe could have an edge that fine."

Naturally, scientists and philosophers have attempted to tackle this problem in different ways. You could argue that the universe is not really fine-tuned for life. Perhaps if the constants had been different, a different sort of life would have emerged (by [different processes](#)) to ask why the universe appears to be so finely tuned for its existence.

One idea is that asking the question "Why is the universe so finely tuned for us?" is a kind of survivor bias, or the observer selection effect, sometimes termed the anthropic principle.

"Suppose the evolution of life and intelligence requires a set of exceedingly unlikely coincidences: planets at just the right distance from an unusually stable star in the galactic life zone, with a stabilizing moon and a comet-deflecting Jovian, just the right chemical diversity, a fantastically unlikely chemical coincidence producing cells, a long list of low-probability evolutionary steps leading up to a generalist species forced by environmental conditions to become a super-generalist intelligent species," [writes](#) Anders Sandberg of the Institute for Futures Studies. "Yet every intelligent species in the universe would have these coincidences under its belt. Conversely, knowing we exist does not tell us whether intelligence is common."

In short, any observer would find themselves in a universe that seems just right for them. If the conditions were not right, they would not be alive. They are alive, so the conditions must have been right for life. Extensions of the idea propose that we are simply in a [multiverse](#) with many possible values for various constants, and are in the part of it in which life is possible.

This is a pretty difficult idea to test, but, according to a new paper, it is possible, and we could have answers surprisingly soon.

The authors focused on dark matter, the mysterious substance that makes up most of the universe's matter, according to the standard dark energy/cold dark matter model of physics. The search for dark matter has, so far, yielded zero particles that fit the required bill. One idea for dark matter was weakly interacting massive particles (WIMPs). This idea was favored because it was predicted by [supersymmetry](#) and was expected to be produced in an abundance that would explain observations at the beginning of the universe. As such, their existence would not require the anthropic principle in order to explain why it (and we) are here.

However, we have not found WIMPs at the predicted energies, and physicists are increasingly turning to axions and "fuzzy axions" as an alternative explanation. [Axions](#) were first proposed to explain charge parity violation (or CP violation) and are predicted to be extremely light.

If they do make up dark matter, they are predicted to have been produced at specific masses during "high-scale inflation" in the early universe. If axion dark matter is found, or signs of it through upcoming observations, we could see it as a test of the anthropic principle.

"The point is, that the presence of high-scale inflation and ultralight axions with masses $m > 10^{-19}$ eV would imply that dark matter 'must' be an axion: for typical initial conditions, we'd end up with way too much dark matter, and we'd desperately need the anthropic principle to constrain it," Nemanja Kaloper, a physicist from the Department of Physics and Astronomy at the University of California, Davis, explained in a [statement](#).

"To find that axion is not dark matter, we'd infer that the initial conditions were not just unlikely (which can be fixed anthropically) but extremely unlikely, which really does not even fall under the domain of anthropic reasoning."

While finding dark matter seems like a long shot – we have been looking for a while, after all – the upcoming Lite Satellite for the Study of B-mode Polarization (LiteBIRD), set for launch by Japan in 2032, could provide evidence for or against the anthropic principle. "It is possible that the LiteBIRD satellite discovers primordial gravity waves close to the current limits, which match high-scale inflation," Kaloper explained. "Most cosmologists would feel this confirms high-scale inflation."

"It is also possible that we discover signs of ultralight axions by surveying supermassive black holes in the universe. The axions affect the spin-to-mass ratio of black holes, and this could be observed," Kaloper continued. "Finally, it is possible that future direct dark matter searches discover that dark matter is predominantly not made up of ultralight axions. In which case, we'd think that the anthropic principle fails."

The study will be published in the Journal of Cosmology and Astroparticle Physics, and a preprint is available on [arXiv](#).