

New findings suggest laws of nature 'downright weird,' not as constant as previously thought

April 27 2020, by Lachlan Gilbert



Credit: AI-generated image ([disclaimer](#))

Not only does a universal constant seem annoyingly inconstant at the outer fringes of the cosmos, it occurs in only one direction, which is downright weird.

Those looking forward to a day when science's Grand Unifying Theory of Everything could be worn on a t-shirt may have to wait a little longer as astrophysicists continue to find hints that one of the cosmological constants is not so constant after all.

In a paper published in *Science Advances*, scientists from UNSW Sydney reported that four new measurements of light emitted from a quasar 13 billion light years away reaffirm past studies that found tiny variations in the [fine structure constant](#).

UNSW Science's Professor John Webb says the fine structure constant is a measure of electromagnetism—one of the four [fundamental forces](#) in nature (the others are gravity, weak nuclear force and strong nuclear force).

"The fine structure constant is the quantity that physicists use as a measure of the strength of the electromagnetic force," Professor Webb says.

"It's a dimensionless number and it involves the speed of light, something called Planck's constant and the electron charge, and it's a ratio of those things. And it's the number that physicists use to measure the strength of the electromagnetic force."

The electromagnetic force keeps electrons whizzing around a nucleus in every atom of the [universe](#)—without it, all matter would fly apart. Up until recently, it was believed to be an unchanging force throughout time and space. But over the last two decades, Professor Webb has noticed anomalies in the fine structure constant whereby electromagnetic force measured in one particular direction of the universe seems ever so slightly different.

"We found a hint that that number of the fine structure constant was

different in certain regions of the universe. Not just as a function of time, but actually also in direction in the universe, which is really quite odd if it's correct ... but that's what we found."

Looking for clues

Ever the sceptic, when Professor Webb first came across these early signs of slightly weaker and stronger measurements of the electromagnetic force, he thought it could be a fault of the equipment, or of his calculations or some other error that had led to the unusual readings. It was while looking at some of the most distant quasars—massive celestial bodies emitting exceptionally high energy—at the edges of the universe that these anomalies were first observed using the world's most powerful telescopes.

"The most distant quasars that we know of are about 12 to 13 billion light years from us," Professor Webb says.

"So if you can study the light in detail from distant quasars, you're studying the properties of the universe as it was when it was in its infancy, only a billion years old. The universe then was very, very different. No galaxies existed, the early stars had formed but there was certainly not the same population of stars that we see today. And there were no planets."

He says that in the current study, the team looked at one such quasar that enabled them to probe back to when the universe was only a billion years old which had never been done before. The team made four measurements of the fine constant along the one line of sight to this quasar. Individually, the four measurements didn't provide any conclusive answer as to whether or not there were perceptible changes in the electromagnetic force. However, when combined with lots of other measurements between us and [distant quasars](#) made by other scientists

and unrelated to this study, the differences in the fine structure constant became evident.

A weird universe

"And it seems to be supporting this idea that there could be a directionality in the universe, which is very weird indeed," Professor Webb says.

"So the universe may not be isotropic in its laws of physics—one that is the same, statistically, in all directions. But in fact, there could be some direction or preferred direction in the universe where the laws of physics change, but not in the perpendicular direction. In other words, the universe in some sense, has a dipole structure to it.

"In one particular direction, we can look back 12 billion [light years](#) and measure electromagnetism when the universe was very young. Putting all the data together, electromagnetism seems to gradually increase the further we look, while towards the opposite direction, it gradually decreases. In other directions in the cosmos, the fine structure constant remains just that—constant. These new very distant measurements have pushed our observations further than has ever been reached before."

In other words, in what was thought to be an arbitrarily random spread of galaxies, quasars, black holes, stars, gas clouds and planets—with life flourishing in at least one tiny niche of it—the universe suddenly appears to have the equivalent of a north and a south. Professor Webb is still open to the idea that somehow these measurements made at different stages using different technologies and from different locations on Earth are actually a massive coincidence.

"This is something that is taken very seriously and is regarded, quite correctly with scepticism, even by me, even though I did the first work

on it with my students. But it's something you've got to test because it's possible we do live in a weird universe."

But adding to the side of the argument that says these findings are more than just coincidence, a team in the US working completely independently and unknown to Professor Webb's, made observations about X-rays that seemed to align with the idea that the universe has some sort of directionality.

"I didn't know anything about this paper until it appeared in the literature," he says.

"And they're not testing the laws of physics, they're testing the properties, the X-ray properties of galaxies and clusters of galaxies and cosmological distances from Earth. They also found that the properties of the universe in this sense are not isotropic and there's a preferred direction. And lo and behold, their direction coincides with ours."

Life, the universe and everything

While still wanting to see more rigorous testing of ideas that electromagnetism may fluctuate in certain areas of the universe to give it a form of directionality, Professor Webb says if these findings continue to be confirmed, they may help explain why our universe is the way it is, and why there is life in it at all.

"For a long time, it has been thought that the laws of nature appear perfectly tuned to set the conditions for life to flourish. The strength of the electromagnetic [force](#) is one of those quantities. If it were only a few percent different to the value we measure on Earth, the chemical evolution of the universe would be completely different and life may never have got going. It raises a tantalising question: does this 'Goldilocks' situation, where fundamental physical quantities like the

fine structure constant are 'just right' to favour our existence, apply throughout the entire universe?"

If there is a directionality in the universe, Professor Webb argues, and if electromagnetism is shown to be very slightly different in certain regions of the cosmos, the most fundamental concepts underpinning much of modern physics will need revision.

"Our standard model of cosmology is based on an isotropic universe, one that is the same, statistically, in all directions," he says.

"That standard model itself is built upon Einstein's theory of gravity, which itself explicitly assumes constancy of the laws of Nature. If such fundamental principles turn out to be only good approximations, the doors are open to some very exciting, new ideas in physics."

Professor Webb's team believe this is the first step towards a far larger study exploring many directions in the universe, using data coming from new instruments on the world's largest telescopes. New technologies are now emerging to provide higher quality data, and new artificial intelligence analysis methods will help to automate measurements and carry them out more rapidly and with greater precision.

More information: Michael R. Wilczynska et al. Four direct measurements of the fine-structure constant 13 billion years ago, *Science Advances* (2020). [DOI: 10.1126/sciadv.aay9672](https://doi.org/10.1126/sciadv.aay9672)

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Provided by University of New South Wales

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