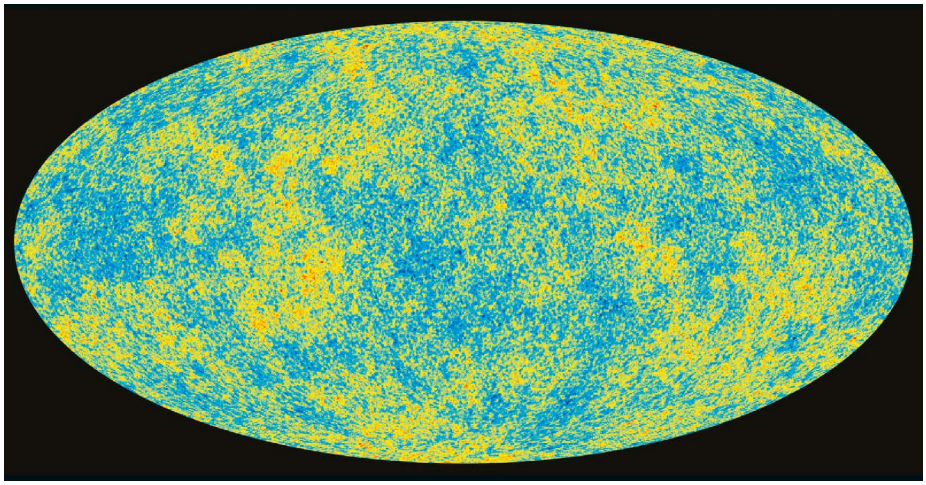

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A map of the Universe's cosmic microwave background radiation.

HINTS OF TWISTED LIGHT OFFER CLUES TO DARK ENERGY'S NATURE

An exotic substance could be accelerating the Universe's expansion — but the evidence is tentative.

By Davide Castelvecchi

Cosmologists say that they have uncovered hints of an intriguing twisting in the way that ancient light moves across the Universe that could offer clues about the nature of dark energy — the mysterious force that seems to be pushing the cosmos to expand ever-faster.

They suggest that the twisting of light — which they identified in data on the cosmic microwave background (CMB) collected by the Planck space telescope — and the acceleration of the Universe could be produced by a cosmic 'quintessence', an exotic substance that pervades the cosmos. Such a discovery would require a major revision of current theories, and physicists warn that the evidence is tentative — it does not meet the '5 sigma' threshold used to determine whether a signal is a discovery.

If dark energy is a quintessence, its push on the expansion could slowly wither or disappear, or could even reverse to become an attractive force, causing the Universe to collapse into a 'big crunch', says Sean Carroll, a theoretical physicist at the California Institute of Technology in Pasadena. "We're back to a situation where we have zero idea about how the Universe is going to end." The work was reported on 23 November (Y. Minami & E. Komatsu *Phys. Rev. Lett.* **125**, 221301; 2020).

The first direct evidence that an unknown force is pushing cosmic expansion to accelerate emerged in 1998, from two separate surveys of supernovae. A host of other studies have since confirmed the presence of this force, dubbed dark energy, but have provided precious little information about its nature. Researchers' first guess — which remains the leading theory — was that dark energy is an intrinsic property of space. This would mean that the amount of dark energy per unit volume of space is fixed as a 'cosmological constant'. But some cosmologists theorized that dark energy is made of something else entirely. They call this a quintessence field, after the fifth element, or aether — the name that ancient Greek philosophers gave to an invisible material that was thought to fill all the empty space in the Universe.

"We're back to a situation where we have zero idea about how the Universe is going to end."

Unlike the cosmological constant, quintessence "is a tangible medium and it has fluctuations of its own", says Robert Caldwell, a cosmologist at Dartmouth College in Hanover, New Hampshire. Quintessence could have properties that are intermediate between those of matter and of a cosmological constant, he adds.

In 1998, Carroll proposed an experimental test for quintessence, based on the prediction that it alters how light propagates in space. A group led by the theoretical physicist Marc Kamionkowski, now at Johns Hopkins University in Baltimore, Maryland, then calculated how this effect could be measured in the CMB, the primordial radiation often described as the afterglow of the Big Bang. The researchers suggested that it would be possible to detect signs of quintessence by looking at maps of polarized light across the CMB. Light is polarized when its electric field 'wiggles' in a particular direction, rather than in a random one. The theory says that quintessence twists the direction in which the polarization points.

Now, cosmologists Yuto Minami at the High Energy Accelerator Research Organization in Tsukuba, Japan, and Eiichiro Komatsu at the Max Planck Institute for Astrophysics in Garching, Germany, have identified that CMB signature in data from the European Space Agency's Planck mission, which concluded in 2013.

Planck's main purpose was to map variations in the CMB's temperature, but it also measured the radiation's polarization. Minami and Komatsu were able to detect signs of quintessence using a technique that they reported last year (Y. Minami *et al. Prog. Theor. Exp. Phys.* **2019**, 083E02; 2019). Their results differ from those of other groups, which have looked at CMB polarization maps — including Planck's — and found no twist, says physicist Suzanne Staggs at Princeton University in New Jersey, whose team measures CMB radiation using the Atacama Cosmology Telescope in Chile.

Big implications

The paper is "quite a nice analysis", but noise in the Planck signals could be a complicating factor, says George Efstathiou, a leading Planck cosmologist at the University of Cambridge, UK. Theoreticians are responding with caution, too. Carroll notes that the result's statistical significance — only 2.5 sigma — is weak, and says that such results often fade away on further scrutiny.

"We'll probably want to be going through all that very carefully before getting too worked up," says Kamionkowski. Other efforts are in the works to map the CMB polarization with greater accuracy, and will put a stringent test on quintessence. If the material is shown to exist, it would have implications for fundamental physics: quintessence is not predicted in the standard model of particle physics.

The existence of quintessence would also have cascading effects on the best estimates of the Universe's features, including its age, which could be a bit younger than the 13.8 billion years cosmologists have calculated on the basis of Planck data. It could also help to explain why CMB data predict that the Universe should be expanding at a slower pace than is currently observed.