Researchers propose a new way to detect the elusive graviton

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(Phys.org) —Among the four fundamental forces of nature, only gravity has not had a basic unit, or quanta, detected. Physicists expect that gravitational force is transmitted by an elementary particle called a graviton, just as the electromagnetic force is carried by the photon.

While there are deep theoretical reasons why gravitons should exist, detecting them may be physically impossible on Earth.

For example, the conventional way of measuring gravitational forces – by bouncing light off a set of mirrors to measure tiny shifts in their separation – would be impossible in the case of gravitons. According to physicist Freeman Dyson, the sensitivity required to detect such a miniscule distance change caused by a graviton requires the mirrors to be so massive and heavy that they'd collapse and form a black hole.

Because of this, some have claimed that measuring a single graviton is hopeless. But what if you used the largest entity you know of – in this case the universe – to search for the telltale effects of gravitons. That is what two physicists are proposing.

In the paper, "Using cosmology to establish the quantization of gravity," published in *Physical Review D* (Feb. 20, 2014), Lawrence Krauss, a cosmologist at Arizona State University, and Frank Wilczek, a Nobel-prize winning physicist with MIT and ASU, have proposed that measuring minute changes in the cosmic background radiation of the universe could be a pathway of detecting the telltale effects of gravitons.

Krauss and Wilczek suggest that the existence of gravitons, and the quantum nature of gravity, could be proved through some yet-to-be-detected feature of the early universe.

"This may provide, if Freeman Dyson is correct about the fact that terrestrial detectors cannot detect gravitons, the only direct empirical verification of the existence of gravitons," Krauss said. "Moreover, what we find most remarkable is that the universe acts like a detector that is precisely the type that is impossible or impractical to build on Earth."

It is generally believed that in the first fraction of a second after the Big Bang, the universe underwent rapid and dramatic growth during a period called "inflation." If gravitons exist, they would be generated as "quantum fluctuations" during inflation.

Ultimately, these would evolve, as the universe expanded, into classically observable gravitational waves, which stretch space-time along one direction while contracting it along the other direction. This would affect how electromagnetic radiation in the cosmic microwave background (CMB) radiation left behind by the Big Bang is produced, causing it to become polarized. Researchers analyzing results from the European Space Agency's Planck satellite are searching for this "imprint" of inflation in the polarization of the CMB.

Krauss said his and Wilczek's paper combines what already is known with some new wrinkles.

"While the realization that gravitational waves are produced by inflation is not new, and the fact that we can calculate their intensity and that this background might be measured in future polarization measurements of the microwave background is not new, an explicit argument that such a measurement will provide, in principle, an unambiguous and direct confirmation that the gravitational field is quantized is new," he said.

"Indeed, it is perhaps the only empirical verification of this very important assumption that we might get in the foreseeable future."

Using a standard analytical tool called dimensional analysis, Wilczek and Krauss show how the generation of gravitational waves during inflation is proportional to the square of Planck's constant, a numerical factor that only arises in quantum theory. That means that the gravitational process that results in the production of these waves is an inherently quantum-mechanical phenomenon.

This implies that finding the fingerprint of gravitational waves in the polarization of CMB will provide evidence that gravitons exist, and it is just a matter of time (and instrument sensitivity) to finding their imprint.

"I'm delighted that dimensional analysis, a simple but profound technique whose virtues I preach to students, supplies clear, clean insight into a subject notorious for its difficulty and obscurity," said Wilczek.

"It is quite possible that the next generation of experiments, in the coming decade or maybe even the Planck satellite, may see this background," Krauss added.

More information: "Using Cosmology to Establish the Quantization of Gravity" Lawrence M. Krauss, Frank Wilczek. *Phys. Rev. D* 89, 047501 (2014) DOI: 10.1103/PhysRevD.89.047501 , arXiv:1309.5343

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