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Gravity may be created by strange flashes in the quantum realm

A model of how wave forms of quantum systems collapse reveals a way they could create gravitational fields, and perhaps even reconcile two pillars of physics

Gravity comes about in a flash
Emma Johnson/Getty

By **Anil Ananthaswamy**

HOW do you reconcile the two pillars of modern physics: quantum theory and gravity? One or both will have to give way. A new approach says gravity could emerge from random fluctuations at the quantum level, making quantum mechanics the more fundamental of the two theories.

Of our two main explanations of reality, quantum theory governs the interactions between the smallest bits of matter. And general relativity deals with gravity and the largest structures in the universe. Ever since Einstein, physicists have been trying to bridge the gap between the two, with little success.

Part of the problem is knowing which strands of each theory are fundamental to our understanding of reality.

One approach towards reconciling gravity with quantum mechanics has been to show that gravity at its most fundamental comes in indivisible parcels called quanta, much like the electromagnetic force comes in quanta called photons. But this road to a theory of quantum gravity has so far proved impassable.

Now Antoine Tilloy at the Max Planck Institute of Quantum Optics in Garching, Germany, has attempted to get at gravity by tweaking standard quantum mechanics.

In quantum theory, the state of a particle is described by its wave function. The wave function lets you calculate, for example, the probability of finding the particle in one place or another on measurement. Before the measurement, it is unclear whether the particle exists and if so, where. Reality, it seems, is created by the act of measurement, which "collapses" the wave function.

But quantum mechanics doesn't really define what a measurement is. For instance, does it need a conscious human? The measurement problem leads to paradoxes like Schrödinger's cat, in which a cat can be simultaneously dead and alive inside a box, until someone opens the box to look.

One solution to such paradoxes is a so-called GRW model that was developed in the late 1980s. It incorporates "flashes", which are spontaneous random collapses of the wave function of quantum systems. The outcome is exactly as if there were measurements being made, but without explicit observers.

Tilloy has modified this model to show how it can lead to a theory of gravity. In his model, when a flash collapses a wave function and causes a particle to be in one place, it creates a gravitational field at that instant in space-time. A massive quantum system with a large number of particles is subject to numerous flashes, and the result is a fluctuating gravitational field.

"A spontaneous collapse in a quantum system creates a gravitational field at that instant in space-time"

It turns out that the average of these fluctuations is a gravitational field that one expects from Newton's theory of gravity (arxiv.org/abs/1709.03809). This approach to unifying gravity with quantum mechanics is called semiclassical: gravity arises from quantum processes but remains a classical force. "There is no real reason to ignore this semiclassical approach, to having gravity being classical at the fundamental level," says Tilloy.

"I like this idea in principle," says Klaus Hornberger at the University of Duisburg-Essen in Germany. But he points out that other problems need to be tackled before this approach can be a serious contender for unifying all the fundamental forces underpinning the laws of physics on scales large and small. For example, Tilloy's model can be used to get gravity as described by Newton's theory, but the maths still has to be worked out to see if it is effective in describing gravity as governed by Einstein's general relativity.

Tilloy agrees. "This is very hard to generalise to relativistic settings," he says. He also cautions that no one knows which of the many tweaks to quantum mechanics is the correct one.

Nonetheless, his model makes predictions that can be tested. For example, it predicts that gravity will behave differently at the scale of atoms from how it does on larger scales. Should those tests find that Tilloy's model reflects reality and gravity does indeed originate from collapsing quantum fluctuations, it would be a big clue that the path to a theory of everything would involve semiclassical gravity.

This article appeared in print under the headline "Quantum collapse spawns gravity?"