Will we have to rewrite Einstein's theory of general relativity?

November 25 2015, by Robin Tucker

Could the International Space Station be the key to probe the effects of gravity on quantum entanglement? Credit: NASA/wikipedia

Einstein famously laboured hard to create the theory of general relativity, but it is less well known that he also helped to launch quantum mechanics, which he didn't much care for. These two views of the world are the very foundation stones of modern physics – without them we would not have things such as space travel, medical imaging, GPS systems or nuclear energy.

General relativity is unparalleled when it comes to describing the world on a large scale, such as planets and galaxies, while quantum mechanics perfectly describes physics on the smallest scale, such as the atom or even parts of the atom. Uniting the two into a consistent "theory of everything" is the single biggest challenge in physics today – and progress is slow.

The birth of modern physics

Our knowledge of the universe is based on a sequence of "natural laws". With time many laws become morphed into new ones as a result of experimental evidence or changing conceptual prejudices. Einstein's rejection of the concept of universal time was one of the most radical shifts in the history of physics. Its consequences have proved crucial to shaping some of the most profound developments in our understanding of nature.

By fusing the three dimensions of space (height, width and depth) with that of a time direction to construct a "spacetime structure", a new symmetry of nature could be uncovered. When Einstein later added gravitation to his theories, it led to experimentally verifiable predictions as well as the prediction of gravitational waves and black holes, beyond the natural scope of Newton's existing law of gravitation.

But Einstein didn't just work on relativity. A big problem at the time was the fact that Maxwell's laws, describing electromagnetic phenomena, were unable to explain why faint ultraviolet light falling on metallic electrodes could induce sparks more easily than bright red light. Einstein suggested that this could be understood if the energy in the light wave wasn't continuously distributed as a wave but rather as a shower of individual "light bullets" (photons – also known as "light quanta"), each with an energy proportional to the colour (frequency) of the light. Many scientists were sceptical of this groundbreaking thought, as so many experiments had already shown that light was a wave.

One of them was Robert Millikan, who ironically eventually ended up experimentally verifying Einstein's theory. Millikan also discovered that charged particles known as electrons have wave-like properties. Together with Einstein's discovery, this pointed to a duality where both matter and light could be described as a particle or as a wave – an idea which led to the development of quantum mechanics by a number of scientists.

This theory has had wide applicability on the smallest of scales, where gravity can often be neglected as it is so weak compared to the other forces affecting particles. Not only has it led to a consistent description of matter and radiation observed in everyday life, it has also made predictions of new particles and processes that are now observed in high-energy accelerator experiments on Earth or cosmic events in space.

The contenders

To unify the description of matter and radiation quanta with gravitation it became natural to contemplate "gravitational quanta" that carry the force of gravitation. String theory has emerged as a candidate to do this. It states that matter is made up of vibrating extended structures, like tiny strings or membranes, rather than point-like particles. Each type of vibration of these structures corresponds to a particular state of matter.

One type of vibration also corresponds to a gravitational quantum. However, for the resulting quantum description to be consistent it becomes necessary to boost the dimension of spacetime by introducing additional space dimensions that are unobservable to the eye and current technology. To date, there has been no firm experimental confirmation of string theory.

By contrast, in domains where gravitation appears irrelevant, quantum mechanics remains unchallenged, despite describing a very strange world. It states that particles can be in a number of different possible states at once. While the theory can predict a set of probabilities for the particle to be in a particular state, it cannot, in general, predict which probability will actually occur.

In such cases, one must take a large number of observations and then calculate average measurements. Furthermore, such averages depend on what properties are to be measured and when such measurement decisions are made. This peculiar world picture sits uncomfortably alongside Einstein's world view of causal events and frozen histories in spacetime.

What's more, according to quantum mechanics, one particle's state can be correlated with another particle's state, even if it is in a distant location. Einstein didn't like this because it seemed to imply that correlations could occur over events that could not be connected by a beam of light, thereby breaking a rule that says nothing can travel faster than the speed of light. He felt that such "spooky action at a distance" was proof for the incompleteness of the theory, although experimental evidence since points to the contrary.

However, new experiments are underway to see whether gravitational interactions might influence such eerie action in unexpected ways. A research group in Vienna proposes to use the International Space Station to see how gravity might influence this action. A collection of entangled photon pairs will be created on Earth before one member of each pair is sent to the orbiting space station. There, a state known as polarisation will be recorded and compared with the state of its partner on Earth.

It is unclear whether quantum mechanics or general relativity will need either mathematical or conceptual modification in response to future experimental probing. But while the outcome is difficult to predict, Einstein's influence has been and remains pivotal in this quest.

This story is published courtesy of The Conversation *(under Creative Commons-Attribution/No derivatives).*

Source: The Conversation

Citation: Will we have to rewrite Einstein's theory of general relativity? (2015, November 25) retrieved 17 July 2024 from https://phys.org/news/2015-11-rewrite-einstein-theory-relativity.html