New study suggests researchers can now test the 'theory of everything'

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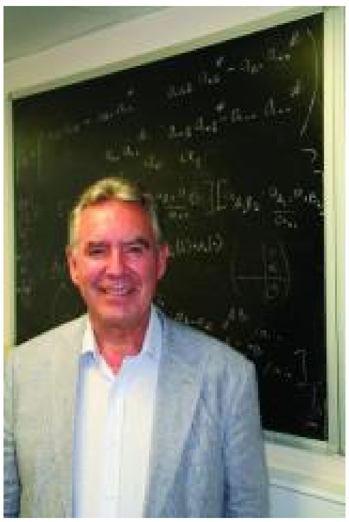

Professor Michael Duff FRS, lead author of the new study. Credit: Imperial College London

(PhysOrg.com) -- Researchers describe how to carry out the first experimental test of string theory in a paper published tomorrow in *Physical Review Letters*.

String theory was originally developed to describe the fundamental particles and forces that make up our universe. The new research, led by a team from Imperial College London, describes the unexpected discovery that string theory also seems to predict the behaviour of entangled quantum particles. As this prediction can be tested in the laboratory, researchers can now test string theory.

Over the last 25 years, string theory has become physicists' favourite contender for the 'theory of everything', reconciling what we know about the incredibly small from particle physics with our understanding of the very large from our studies of cosmology. Using the theory to predict how entangled quantum particles behave provides the first opportunity to test string theory by experiment.

"If experiments prove that our predictions about quantum entanglement are correct, this will demonstrate that string theory 'works' to predict the behaviour of entangled quantum systems," said Professor Mike Duff FRS, lead author of the study from the Department of Theoretical Physics at Imperial College London.

"This will not be proof that string theory is the right 'theory of everything' that is being sought by cosmologists and particle physicists. However, it will be very important to theoreticians because it will demonstrate whether or not string theory works, even if its application is in an unexpected and unrelated area of physics," added Professor Duff.

Professor Duff recalled sitting in a conference in Tasmania where a colleague was presenting the mathematical formulae that describe quantum entanglement: "I suddenly recognised his formulae as similar to some I had developed a few years earlier while using string theory to describe black holes. When I returned to the UK I checked my notebooks and confirmed that the maths from these very different areas was indeed identical."

The discovery that string theory seems to make predictions about quantum entanglement is completely unexpected, but because quantum entanglement can be measured in the lab, it does mean that at last researchers can test predictions based on string theory. There is no obvious connection to explain why a theory that is being developed to describe the fundamental workings of our universe is useful for predicting the behaviour of entangled quantum systems. "This may be telling us something very deep about the world we live in, or it may be no more than a quirky coincidence", concluded Professor Duff. "Either way, it's useful."

String theory

String theory, and its extension M-theory, are mathematical descriptions of the universe. They have been developed, over the last 25 years, by theoreticians seeking to reconcile the theories of general relativity and quantum mechanics. (The former describes the universe at the level of cosmology - the very large, while the latter describes the universe at the level of particle physics - the incredibly small). One of the major bugbears, especially of M-theory, is that it describes billions of different universes and ‘anything’ can be accommodated in one or other of the M-theory universes. Researchers have no way of testing which of the answers that string/M-theory gives us is ‘right’. Indeed, they all may be right and we live in one universe among an infinite number of universes. So far no one has been able to make a prediction, using string theory, that can be tested to see if it is correct or not.

Qubit (quantum bit) entanglement

Under very precisely controlled conditions it is possible to entangle the properties of two quantum particles (two quantum bits, or qubits), for example two photons. If you then measure the state of one of these entangled particles, you immediately affect the state of its partner. And this is true if the particles are close to one another or separated by enormous distance. Hence Einstein’s apposite description of quantum entanglement as ‘spooky action at a distance’. It is possible to entangle more than two qubits, but calculating how the particles are entangled with one another becomes increasingly complex as more particles are included.

Professor Duff and his colleagues realised that the mathematical description of the pattern of entanglement between three qubits resembles the mathematical description, in string theory, of a particular class of black holes. Thus, by combining their knowledge of two of the strangest phenomena in the universe, black holes and quantum entanglement, they realised they could use string theory to produce a prediction that could be tested. Using the string theory mathematics that describes black holes, they predicted the pattern of entanglement that will occur when four qubits are entangled with one another. (The answer to this problem has not been calculated before.) Although it is technically difficult to do, the pattern of entanglement between four entangled qubits could be measured in the laboratory and the accuracy of this prediction tested.

More information: M. J. Duff FRS et al., “Four-qubit entanglement from string theory.” *Physical Review Letters* 2010. prl.aps.org/abstract/PRL/v105/i10/e100507

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