A 600-year-old quantum experiment in the stars

A new experimental Bell test used distant starlight to dictate how entangled photons on Earth were measured. Cathal O'Connell reports.

Two stars in the Milky Way galaxy acted as 'cosmic setting generators' in an experiment of quantum entanglement.
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Physicists have used the light of stars some 600 light-years from Earth to validate a bizarre quantum phenomenon Albert Einstein derided as “spooky action at a distance”.

The work, reported in ***Physical Review Letters <http://journals.aps.org/prl/abstract/10.1103/PhysRevLett.118.060401>*** , confirms that the quantum explanation for "spooky action" is valid, and rules out any influence from other sources – at least over the 600 years it took the starlight to reach us.

It’s the latest in a long series of experiments aiming to prove beyond doubt that our universe is fundamentally weird and not deterministic.

Quantum entanglement is the **mysterious connection between particles <https://cosmosmagazine.com/physics/quantum-physics-terminally-confused>** where one particle seems to influence the other, no matter how far apart they are.

Though entanglement has become the basis of quantum technology, such as the quest to build a **quantum computer <https://cosmosmagazine.com/physics/quantum-computing-for-the-qubit-curious>** , the idea has had a rough ride to acceptance.

Einstein and his crew of quantum sceptics, which included American physicist Boris Podolsky and Israeli physicist Nathan Rosen, thought there must be something else going on – so-called hidden variables, as yet beyond our ken, determining the behaviour of quantum objects.

In the 1960s, the Northern Irish physicist John Bell came up with a way to distinguish between the “spooky action” of quantum theory and the influence of hidden variables.

Say you create two entangled photons shooting off in opposite directions. Now you measure if the light waves are “waving” in an up-down direction or left-right – called polarisation.

On paper, Bell showed that, for entangled particles, the results would be strongly related to one another. A correlation higher than a certain threshold could not be explained by any hidden variable theory.

If right, this idea would mark the death knell for any of the hidden variable ideas favoured by Einstein.

Physicists have been testing Bell’s inequality ever since, although any time it seemed proved, detractors have been able to point out loopholes in the experiments where a hidden variable might creep in.

Results might be explained by particles that communicate faster than the speed of light, for instance, or by a bias in the measuring system.

Then in 2015, after decades of work, several teams independently managed to close these two major loopholes. But one other, called the “freedom-of-choice” loophole, remained.

In Bell experiments, it matters whether you measure the polarisation in either the up-down direction or the left-right direction. Deciding which way to do it must be made individually for each pair of particles. (And one experiment might involve thousands of these individual runs.)

The freedom-of-choice loophole questions whether some unknown effect might be influencing this choice. To close it, **physicists have used a quantum number generator <http://www.pnas.org/content/107/46/19708>** to make the choice and set this far away – 144 kilometres – from the measuring equipment. This ruled out spooky influence in the microseconds it takes light to travel 144 kilometres.

Now, quantum physicists have looked to the stars to be their random number generator. Johannes Handsteiner from the Austrian Academy of Sciences and colleagues used the light from two stars, with the closest 600 light-years away, to determine how their experiment measured photons.

This means that to affect the experiment, any unknown process would have had to have acted 600 years ago, when the light was emitted – a fair stretch of the imagination, even for the most ardent quantum sceptics.

The team proposes the method could be paired with even older light, such as quasars billions of years old, or the cosmic microwave background. Such measurements could "progressively push any viable hidden-variable models further back into deep cosmic history".

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