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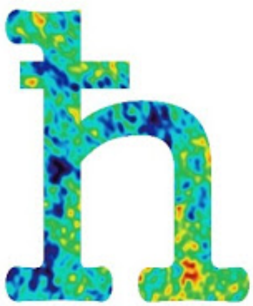
Wednesday, November 27, 2013

Cosmic Bell



On the playground of quantum foundations, Bell's theorem is the fence. This celebrated theorem – loved by some and hated by others – shows that correlations in quantum mechanics can be stronger than in theories with local hidden variables. Such local hidden variables theories are modifications of quantum mechanics which aim to stay close to the classical, realist picture, and promise to make understandable what others have argued cannot be understood. In these substitutes for quantum mechanics, the 'hidden variables' serve to explain the observed randomness of quantum measurement.

Experiments show however that correlations can be stronger than local hidden variables theories allow, as strong as quantum mechanics predicts. This is very clear evidence against local hidden variables, and greatly diminishes the freedom researchers have to play with the foundations of quantum mechanics.

But a fence has holes and Bell's theorem has loopholes. These loopholes stem from assumptions that necessarily enter every mathematical proof. Closing all these loopholes by making sure the assumptions cannot be violated in the experiment is challenging: Quantum entanglement is fragile and noise is omnipresent.

One of these loopholes in Bell's theorem is known as the 'freedom of choice' assumption. It assumes that the settings of the two detectors which are typically used in Bell-type experiments can be chosen 'freely'. If the detector settings cannot be chosen independently, or are both dependent on the same hidden variables, this could mimic the observed correlations.

This loophole can be addressed by using random sources for the detector settings and putting them far away from each other. If the hidden variables are local, any correlations must have been established already when the sources were in causal contact. The farther apart the sources for the detector settings, the earlier the correlations must have been established because they cannot have spread faster than the speed of light. The earlier the correlations must have been established, the less plausible the theory, though how early is 'too early' is subjective. As we discussed earlier, in practice theories don't so much get falsified as that they get

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In a neat recent paper, Jason Gallicchio, Andrew Friedman and David Kaiser studied how to use cosmic sources to set the detector, sources that have been causally disconnected since the big bang (which might or might not have been 'forever'). While this had been suggested before, they did the actual work, thought about the details, the technological limitations, and the experimental problems. In short, they breathed the science into the idea.

> **Testing Bell's Inequality with Cosmic Photons: Closing the Settings-Independence Loophole**
> Jason Gallicchio, Andrew S. Friedman, David I. Kaiser
> arXiv:1310.3288 [quant-ph]

The authors look at two different types of sources: distant quasars on opposite sides of the sky, and patches of the cosmic microwave background (CMB). In both cases, photons from these sources can be used to switch the detectors, for example by using the photon's arrival time or their polarization. The authors come to the conclusion that quasars are preferable because the CMB signal suffers more from noise, especially in Earth-based telescopes. Since this noise could originate in close-by sources, it would spoil the conclusions for the time at which correlations must have been established.

According to the authors, it is possible with presently available technology to perform a Bell-test with such distant sources, thus pushing back the limit on conspiracies that could allow hidden variable theories to deliver quantum mechanical correlations. As always with such tests, it is unlikely that any disagreement with the established theory will be found, but if a disagreement can be found, it would be very exciting indeed.

It remains to be said that closing this loophole does not constrain superdeterministic hidden variables theories, which are just boldly non-local and not even necessarily realist. I like superdeterministic hidden variable theories because they stay as close to quantum mechanics as possible while not buying into fundamental non-determinism. In this case it is the measured particle that cannot be prepared independently of the detector settings, and you already know that I do not believe in free will. This requires some non-locality but not necessarily superluminal signaling. Such superdeterministic theories cannot be tested with Bell's theorem. You can read here about a different test that I proposed for this case.

Posted by Sabine Hossenfelder at 1:35 AM Labels: Astrophysics, Cosmology, Papers, Physics, Quantum foundations

28 comments:

Joy said...

My problem with the whole Bell orthodoxy is the definition of local-

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