Einstein, Bell, the Cosmos and You - recent tests of local realism

Prof. Morgan Mitchell

The Institute of Photonic Sciences, Barcelona

Local realism is the principle of locality (no instantaneous action-at-a-distance) joined to realism (the world and its properties exist whether or not we observe them). While it is typical for philosophers to question realism, in physics (as in common sense), realism was implicitly assumed until Niels Bohr and Wehner Heisenberg introduced the anti-realist Copenhagen Interpretation in 1927. Einstein's 1927-1935 arguments in support of local realism showed how Bohr's position describes a radically different understanding of physics and our relation to the physical world. In 1964 John Bell gave local realism a mathematical form, and showed that it was in principle testable. The first such Bell test was reported in 1970, and by now several generations of physicists have grappled with the problem of how to rigorously test a claim at the boundary of physics and philosophy.

After illustrating the nature of Bell tests with historical examples, I will turn to the problem of “loopholes” in Bell tests, a current obsession for the field. I will describe the so-called “loophole-free” tests, which combined high-efficiency detection methods, rigorous statistical analysis, purpose-built physical random number generators, and space-like separation, to simultaneously close the detection efficiency loophole, the locality loophole, the memory loophole, and other named loopholes. A quantum technology spin-off of these tests is the pulsed laser phase diffusion random number generator, which we built and analysed for the three “loophole-free” experiments of 2015. I will then turn my attention to recent tests that address in new ways the “freedom-of-choice” loophole, including steps toward a “cosmic" Bell test using extremely distant sources as randomness generators, and our recent “BIG Bell test" using 13 globally-distributed experiments and 100,000 human beings as randomness generators.