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PRESS RELEASE I PARIS I MAY 9, 2018

WARNING: Embargoed until May 9, 2018, 1300 US Eastern Time / 1800 London time / 1900 Paris time

The Big Bell Test: participatory science puts quantum physics to the test

Quantum chance is intrinsically different than classic chance. That is what the violations of Bell inequalities, a crucial step in understanding quantum mechanics, states. One drawback remains though: until now, testing these inequalities relied on experimental configurations that use parameters set from data generated by quantum systems. Effectively it was testing quantum physics using quantum physics. To overcome this problem, an international collaboration created by The Institute of Photonic Sciences in Barcelona, including twelve laboratories on five continents, including Institut de Physique de Nice (CNRS/Université Nice Sophia Antipolis), conducted a unique participatory science experiment. By gathering about 100,000 people worldwide through a video game, the researchers circumvented the data generation problem and rigorously validated their experimental observations on the violation of Bell inequalities. The results were published in *Nature* on 10 May 2018.

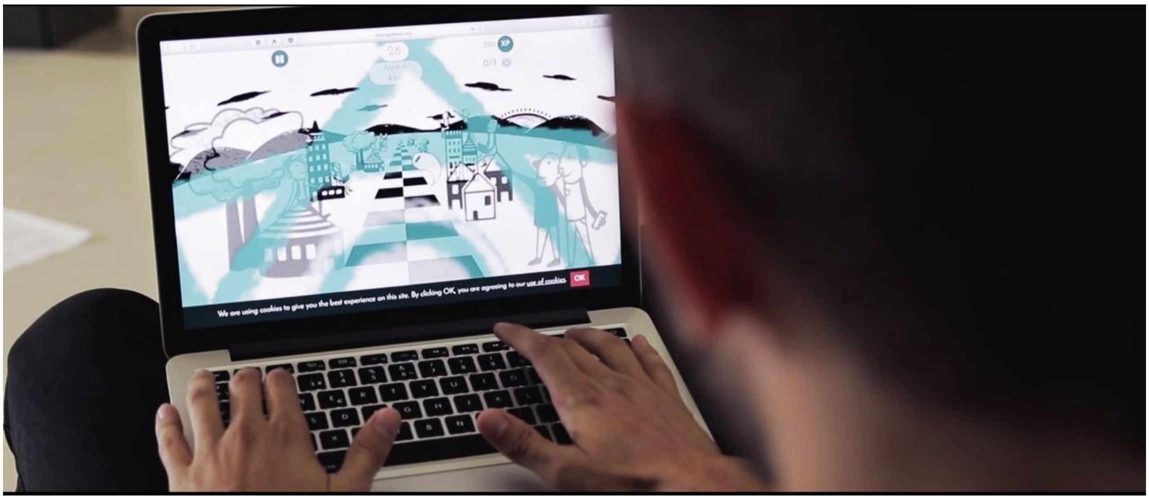
In physics, the principle of local realism states that two distant objects can only have limited correlations: events that one of the two object undergo cannot be correlated to the other beyond a certain degree. During the 20th century, John Stewart Bell formulated this limit between physical objects in mathematical inequalities. However, quantum objects did not follow this rule. In fact, events between quantum particles are correlated, wherever they are in the universe. This observation violates Bell inequalities and therefore the principle of local realism. To explain this phenomenon, conservative physicists in the early 20th century — including Einstein — had made the hypothesis that unknown physical parameters existed, such that the constraint imposed by inequalities would be correct all the same.

Until now, researchers had only managed to demonstrate the violation of Bell inequalities using data generated by quantum systems to set the parameters for their experiments. To test the correlation between intertwined particles, each of them must be observed randomly, without measurements on two particles being related in any way at all. To achieve this, random quantum bit generators[1] gave instructions to observation machines. This meant testing quantum physics using a quantum system. To get out of this paradox, 100,000 people contributed to generate bits randomly by a non-quantum mechanism. The resulting data generated a code that arbitrarily configured measurement instruments for intertwined particles in 13 experiments spread among 12 laboratories and as many countries.

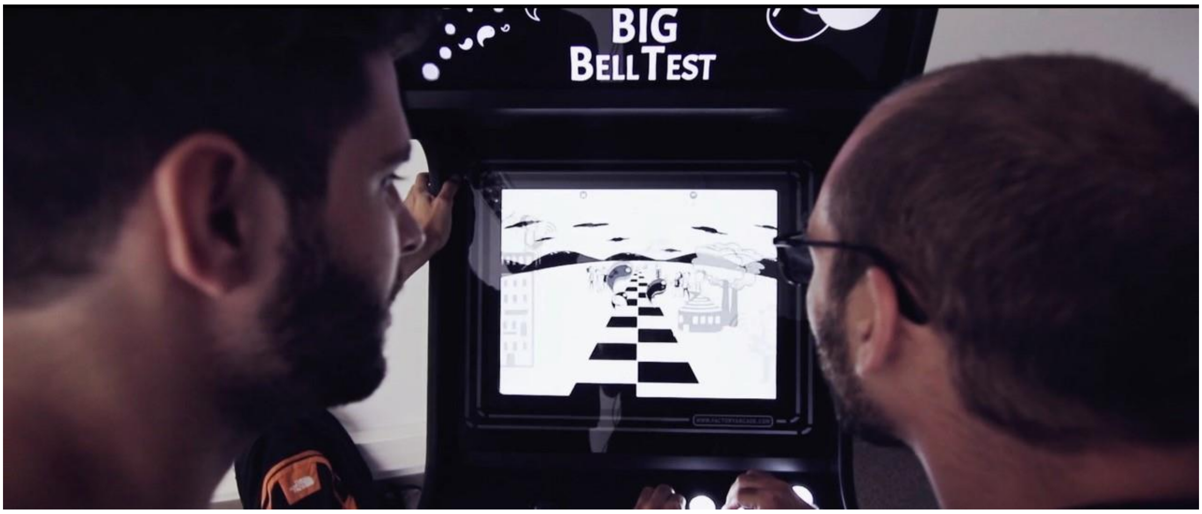
[1] The best physical systems that generate numbers randomly rely on quantum physics. A good generator of this sort is a photon sent onto a semi-reflective mirror. The photon has a 50% chance of passing through, and a 50% chance of being reflected. Depending on whether it goes through or is reflected by the mirror, it will activate a different sensor which will each associated with a bit 1, or a bit 0.

To generate these bits, the cohort of participants was invited to participate in a video game: The Big Bell Quest. To progress in the scenario, players pressed randomly on the keyboard's 1 and 0 keys. These bits were sent directly to the laboratories. On November 30, 2016, the players generated more than 97 million bits that continuously fed the experiments for 12 consecutive hours. As the game progressed, the players were able to discover scientific mediation content such as explanations on Bell inequalities and the way they are tested, accompanied by videos made in the laboratories who were receiving the data.

The results of the experiments confirm the violation of Bell inequalities by a more consistent and rigorous methodology than before. They also open the path to deeper quantum physics applications. The fundamental principles of intrication do play an essential role in the development of quantum cryptography—quantum computing. As for the methodology, it proves that participatory sciences can play a useful role in fundamental physics.



The Big Bell Quest video game © ICFO.



The Big Bell Quest video game © ICFO.

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