[PHYSICS]

The entanglement formula

Group from Rio de Janeiro proposes equation that describes a reduction in the quantum phenomenon due to environmental influence

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On April 20, 2006, a team from the Quantum Optics Group of the Physics Institute of the Federal University of Rio de Janeiro (UFRJ) published an article in the UK journal *Nature* that reported the first direct measuring of one of the weirdest and most fascinating phenomena in the quantum world, the so-called entanglement or interlacing of particles, such as atoms, electrons or photons, the elementary light particles. On April 27, 2007, Brazilian researchers published yet another important paper on this complex field of physics. On the pages of *Science*, an American periodical, they explained how entanglement, an essential property for the development of a quantum computer, can disappear abruptly, suffering a sort of sudden death. Now the same team, comprised of researchers Luiz Davidovich, Paulo Henrique Souto Ribeiro and Steve Walborn, has added a further, major contribution to the question, in an article published on May 14, 2009, on the *Science* website. They formulated and experimentally demonstrated a law that describes the dynamics of entanglement.

In more colloquial language, what the physicists from Rio de Janeiro did was to create a general equation that allows them to estimate, simply and precisely, the loss of entanglement of a two-particle system, when one of the particles is adversely affected by the environment. Factors outside such a system, such as attrition or temperature, may cause entanglement to drop off or even disappear altogether. The new method can do without the reconstruction of the final state of an entangled system, a difficult task that sometimes yields inaccurate results.

“Up until now, there has only been one equation, proposed in a theoretical study published last year in the journal *Nature Physics*, for describing the dynamics of entanglement in a highly particular and idealized case: a system whose initial state was fully known,” explains Davidovich, the study’s main author, who had collaboration from two graduate students, Camille Latune and Osvaldo Jiménez Farías. “Our equation is a generalization of the previous one

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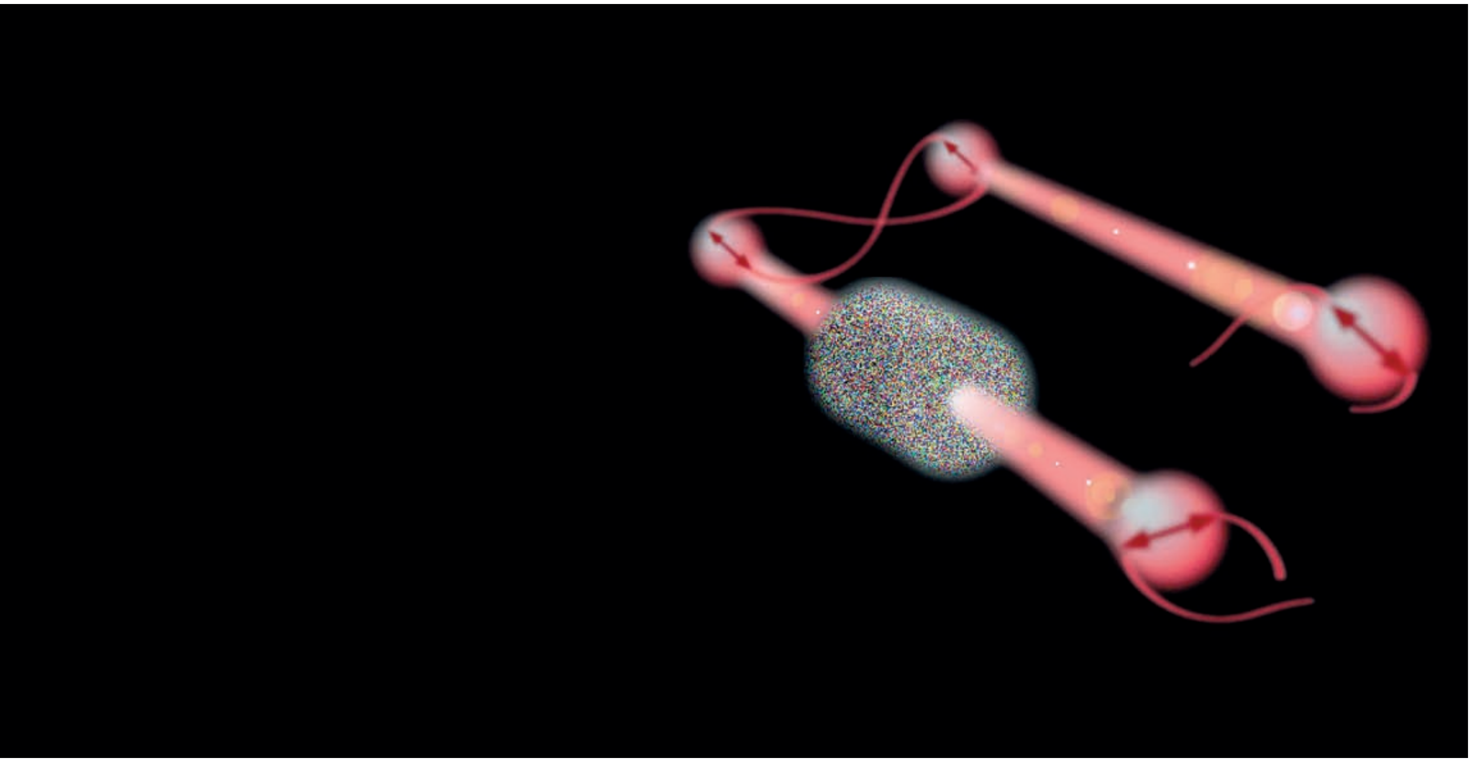

Illustration of photons with entanglement (*full circular lines*) and without entanglement

and also works in situations that are closer to reality, when there is uncertainty about the system's initial state." The environment's influence on one of the entangled system's particles was demonstrated by the Brazilian scientists in an experiment with photons, using a method known among physicists as the "quantum process tomography."

Defined by Albert Einstein as something wrapped up in "phantasmagoric action at a distance," quantum entanglement is a phenomenon that is alien to the world of classic, Newtonian physics in which we live. As if by magic, it causes a set of elementary particles to share certain characteristics even though there is no physical connection between them. The problem is that it is impossible to determine the properties of each one of the entangled particles, but only of the overall system. If, instead of two elementary particles, the reader can imagine a system comprised of two entangled dice, this disconcerting concept from the world of quantum physics becomes easier to understand. Because they have this strong correlation, when they are thrown, the dice always produce the same result: for instance, their sum is ten. The end result of the system is known and easy to measure, but one does not know what combination of numbers (five plus five, seven plus three, eight plus two, etc.) yield this sum. However, as the dice are entangled, when the number of one is determined, the number of the other is automatically discovered.

In the experiment now described in *Science*, Davidovich's team, by shining a laser beam onto a crystal, generated pairs of photons entangled with regard to one of their physical parameters: polarization (the spatial direction – vertical or horizontal – in which its electromagnetic field vibrates). Another parameter of the photons, momentum (connected with their propagation direction, i.e., their trajectory in space) acted as the system's external environment in the experiment. The researchers realized that, when they produced interaction between the photons' momentum and polarization, there was a reduction in the degree of entanglement in the system . They also found that their equation could account for this loss in the entaglement. "We took a small step towards understanding the dynamics of entanglement, which can help to build more stable and robust quantum systems," comments Davidovich, whose team is part of the National Science and Technology Institute for Quantum Information. Storing, transmitting and processing information by exploring the quantum world's peculiar properties is one of the likely bets for IT in the 21st century. But there is still a lot of basic and applied research to be done before an atom- or photon-driven PC can materialize in people's homes. ■

Scientific article

FARÍAS, O. J. *et al.*"Determining the dynamics of entanglement." **Science Express Reports,** published online on May 14, 2009.