

# QUANTUM ENTANGLEMENT AND SIMULTANEITY.

BY PHILIP CREIGHTON.

I think it was J.B.S. Haldane who once observed: "The only thing we can be certain about the future is that there is going to be more and more of it." What sets me in mind of his profound remark is the awareness, for me personally, that I am living in a most extraordinary epoch of human history, fraught with discovery, technological creativity, but also with disturbance and change.

With it comes the prospect of yet another wave of true Renaissance, enlightenment, and the burgeoning of a godlike, yet human, powerfulness which can either transport us into a true Golden Age of human spiritual as well as secular growth, or plunge us into the worst nightmare of depravity and destruction if our social and moral conscience and self-knowledge is not able to match the pace and accomplishments of science and technology.

Forgive me for the dramatic preamble, but it is appropriate, for Act I of the 21st century is already unfolding before our very eyes, and a very remarkable play it promises to be...

For most of the last century it has been believed that the speed of light, and other electromagnetic radiations, is absolute and insurpassable.

Accompanying this belief, amounting almost to a dogma, has come the growth of quantum physics, which reveals the natural world to possess some very quirky properties indeed. Particles and waves become interchangeable, and the concept of locality becomes not absolute but probabilistic.

Just "where" is an electron, or any other particle? A very good question. It appears to be *everywhere*, according to a distributed probability function -that is, until you "look" at it...

Another of the extraordinary properties of particles, as viewed from the point of view of quantum physics, is that their state appears to be a genuine *superimposition*, of alternative, definite, states, a sort of *indeterminate hybrid*, -until an observation of them is made; and observation is *not passive*; it involves *interaction*.

Let us now come to the nub of the present discussion: The consequences of the foregoing when applied to two or more particles interacting or being created together in a single process, as a result of which they have correlated properties which are nevertheless indeterminate until an observation is made. Such experiments are generally referred to as EPR experiments, thanks to those who originally conceived them, namely Einstein, Podolsky and Rosen.

Let us take a definite example: Two photons are generated simultaneously and move away from each other in opposite directions. Because they were created together their properties are the same or

different; in this case they have complementary or opposite polarisations. (This is the angle at which an electromagnetic wave vibrates.)

Two particles related in this way are said to be *entangled*; however, despite this relationship they are also in a indefinite or fuzzy state of superimposition until they are measured or observed.

When one is observed and found to have a given polarisation, say 0°, observation of the other reveals that it has the complementary polarisation of 90°. It appears that the information of the state of one photon is transmitted instantaneously across space to determine the fate of the other. But the actual value of the state is in fact completely random, and so it is *not* possible to use it to send any information, and so this is *not usable as a method of faster-than-light communication*.

Nevertheless, the fact remains that the two photons, even though they may be widely separated, behave as a unified system, connected in a way which has been described a "spooky". Their state of entanglement means that they partake of the same wave function, or probability function, and interacting with, or observing, one particle amounts to observing both -and they do indeed mirror each other's properties.

Recently two groups of researchers have undertaken long-distance experiments in which such entangled photon pairs are sent up to 10 km down separate fibre-optic cables and detected separately. The two sets of results are then compared, and indeed found to be complementary. However, the researchers have to communicate with each other in some independent way to verify this, for the results are in themselves random, and so *faster-than light communication does not seem feasible by this method*.

One group, Nicolas Gisin and colleagues, is based at the University of Geneva in Switzerland. Descriptions of their experiments can be found at <http://www.euroquantum.org/> Another group, led by Peter Zoller at the University of Innsbruck, has performed similar experiments, described at <http://www.aip.org/physnews/graphics/html/teleport.htm> and <http://www.quantum.univie.ac.at/>

It is strangely ironic that, within weeks of these experiments, yet other scientists have managed to slow light down to a speed of about 38 miles per hour. This is done with the help of a remarkable assemblage called an Einstein-Bose condensate. What it is is a group of atoms, typically an alkali metal, cooled to almost absolute zero so that all thermal motion ceases. The group of atoms behaves as if it has coalesced and is described by a single wave-function. For light it acts like a kind of molasses, slowing it down from 186,000 miles per second to 38 miles per hour! See <http://research.spinweb.com/news/articles/> for more. ■

## WEBSITES ON QUANTUM THEORY.

<http://research.spinweb.com/news/articles/quant7.htm> -Theoretical Physics News.  
<http://setis.library.usyd.edu.au/stanford/entries/physics-holism/#Bib> -Holism in Physics.  
<http://www.gsreport.com/articles/art000136.html> -Entanglement Could Have Huge Real-World Impacts.  
<http://www.lanl.gov/worldview/> -Los Alamos National Laboratory, reports on quantum experiments.  
<http://www.nist.gov/> -National Institute of Standards and Technology, reports on quantum experiments.  
<http://www.science-frontiers.com/sf114/sf114p12.htm> -Quantum mechanics is definitely "spooky".  
<http://www.theory.caltech.edu/~alandahl/quic.html> -Theoretical research at CALTECH.  
<http://www.cwi.nl/~wimvdam/quantum.html> -Quintessential Quantum Page, links to all main research.  
<http://www.aip.org/physnews/graphics/html/teleport.htm> -Details of recent experiments at Innsbruck.  
<http://www.research.ibm.com/quantuminfo/> -Quantum Information and Information Physics at IBM.  
<http://www.euroquantum.org/> -Quantum experiments at the University of Vienna.  
<http://www.quantum.univie.ac.at/> -Quantum experiments and the foundation of Physics. Prof. Zeilinger.  
<http://xxx.lanl.gov/> -Print archive containing thousands of papers on Physics and Quantum Physics.

## BIBLIOGRAPHY.

**J. Gribbin:** *In Search of Schrödinger's Cat*, Bantam Books. (A popular treatment of EPR and the paradox of "Schrodinger's cat" that results from the Copenhagen interpretation.)  
**B. d'Espagnat:** *The quantum theory and reality*, Scientific American 241 #5 (November 1979).  
**N. Herbert:** *Quantum Reality, Doubleday*. (A very good popular treatment of EPR and related issues.)