NON-LOCALITY AS A FUNDAMENTAL PRINCIPLE OF REALITY:

BELL'S THEOREM AND SPACE-LIKE INTERCONNECTEDNESS

Elizabeth A. Rauscher, Ph.D.

ABSTRACT: Two very significant principles with vast ramifications discovered in the 20th century are the Heisenberg Uncertainty Principle and the Nonlocality Principles of the Einstein, Podolsky, Rosen (EPR) paradox. These aspects of quantum theory have major physical and philosophical implications. The fundamental bases of nonlocality in quantum theory lie in the EPR paradox, as well as other experiments that demand a nonlocal explanation for the phenomenon they display. The fundamental basis of nonlocality in the universe is fundamental to the properties of consciousness. We examined both micro and macroscopic nonlocality.

KEYWORDS: Quantum Theory; Bell's Theorem; Non-locality; Space

At Lawrence Berkeley National Laboratory (LBNL), where I was a staff member in the 1970's, I started, named and chaired the Fundamental "Fysiks" Group (F"F"G) with George Weissmann, Nick Herbert, Saul Paul Sirag, Henry Stapp, Phillip Eberhard, Jack Sarfatti, Gary Zukav, Fritjof Capra and John Clauser. (I obtained a guest ship for Fritjof Capra at Lawrence Berkeley Theoretical Physics group and Beverly Rubik also joined the group.) (F"F"G, 1974-1979). The purpose of the group was to discuss the fundamental meaning and interpretation of the body of physics and in particular quantum mechanics. I had met John Clauser in 1972 and had seen his experimental test set up of the Bell's theorem, nonlocality experiment on the UC Berkeley campus. I was most impressed and thought the experiment a most vital one. John Clauser joined the F"F"G group as did 40 other physicists. We had weekly meetings and I would choose a speaker and then we would have the most lively and spirited discussions! Some of our activities are written up by David Kaiser (2011) in *How the Hippies Saved Physics* about our explanation of quantum nonlocality, quantum entanglement and Bell's Theorem.

1. EXPERIMENTAL VERIFICATION OF J.S. BELL'S THEOREM

J.S. Bell's (1964) formulated one of the most significant theorems in relation to quantum mechanics. His theory was developed from the A. Einstein, B. Podolsky and N. Rosen (EPR) "completeness" formulation of quantum theory (Einstein, Podolsky and Rosen, 1935). Heisenberg introduced the uncertainty principle in 1927 that states that one of the principal features of quantum mechanics is that not all the classical physical observables of a system can be simultaneously precisely defined. The quantum interpretation is defined by the uncertainty principle which stated that it is not possible to precisely determine the exact position and momentum of a particle at any specific time.

To explain this phenomena, Bohr suggested the Copenhagen Interpretation as an explanation for quantum physics. The quantum interpretation is defined by the uncertainty principle which stated that it is not possible to precisely determine the exact position and momentum of a particle at any specific time. Einstein did not want to rely on probabilities even at the quantum level so Einstein, Podolsky and Rosen came up with a thought experiment, "Does a particle have a position in the moments just before it is measured?" (Einstein, Podolsky and Rosen, 1935). If not, the quantum theory is *incomplete*. The conclusion to the EPR paper stated: "While we have thus shown that the wave function does not provide a complete description of the physical reality, we left open the question of whether or not such a description exists. We believe, however, that such a theory is possible." For the quantum description to be complete, it implies fundamental nonlocality!

Einstein sought to maintain the single state vector approach and seriously questioned the uncertainty principle, and the statistical nature of the quantum theory stating "God does not play dice with the universe." His fundamental vision was to determine the position and momentum of each particle in the universe and develop a unified field theory of the four force fields and explain all of reality! The hitch in this plan was that the position (or location), and momentum cannot be accurately measured nor can the energy and time be scientifically accurately measured, i.e., the Heisenberg uncertainty principle (Rauscher, 1972). The Heisenberg uncertainly relations,

$$\Delta \mathrm{x}\, \Delta p = h \quad \text{and} \quad \Delta E\, \Delta t = h$$

where Δx is the uncertainty in the position of a particle, Δp, or we can consider that the uncertainty in energy, ΔE, and the uncertainty in time, Δt implies restrictions on the absolute knowledge of the universe, that is, it is impossible to know the measurement of position and the momentum of a particle at the same time, or the energy and time measurement to a degree of accuracy which is restricted by the value of Planck's constant *h*.

Einstein continued to seek to define a unique state vector, but was willing to agree that it may not be the state of an individual object, but the statistical group of objects or the ensemble. For example, there should be within quantum physics, for every electron or particle in the universe, an assignable wave function, Ψe. If the completeness principle holds, we can understand that although the preciseness of measurement may be beyond an individual object, it may be sufficient to describe the ensemble.

In the EPR paper (Einstein, Podolsky and Rosen, 1935), the completeness of quantum theory implies nonlocal interactions. The concept of nonlocality, which Einstein called this "spooky action at a distance," is now called quantum entanglement and is basic to the development of quantum computing. Bohm, in order to explain nonlocality (or "spooky action at a distance") in real terms, introduced additional quantum non-observable variables, or "hidden variables," in order to make the EPR quantum hypothesis and Bell's theorem appear local. Experimental demonstrations and mathematics continued to show that locality is incompatible with the statistical predictions of quantum mechanics. (Bohm, 1952, 1977; Bell, 1964, 1987; Freedman and Clauser, 1972; Clauser and Horne, 1974; Amoroso, Kaufman and Rauscher, 2010). This lead to Bell's theorem which states that the quantum-mechanical description of a physical system is incomplete and the state of the system cannot be exactly defined without nonlocal interactions.

J.S. Bell states that "no theory of reality, compatible with quantum theory, can require spatially separate events to be independent." That is confirmed by the measurement of the J. Clauser experiment (Clauser and Horne, 1974), where the polarization of one photon determines the polarization of the other photon at its respective measurement site when the two emitted spin 1 photons are initially correlated. The key was that the spatial orientation of angular momentum states of spin ½ particles such as electrons, showed there are discreet points on the plate which displays the quantized effect. According to Bell (1964): "In a theory in which parameters are added to quantum mechanics to determine the results of individual measurements, without changing the statistical predictions, there must be a mechanism whereby the setting of one measuring device can influence the reading of another instrument, however remote. Moreover, the signal involved must propagate instantaneously, so that such a theory could not be Lorentz invariant." The Lorentz invariant acts as a constraint for $v \leq c$ signaling (Herbert, 1975).

The pragmatic view of Bell's Theorem has recently been expanded by Stapp, who discusses the role of the macroscopic detection apparatus, as well as the possible role of superluminal signals. Stapp has explored both cases for superluminal propagation or subluminal connection issuing from the points in common to the backward light cones coming from the two regions (Stapp, 1976; Stapp, Nadean and Kafatos, 1999). In his examination of the relationship between Lorentz invariance and superluminal signals, G. Feinberg (1967) found that they were not incompatible.

The research into and verification of the physics of nonlocality has been repeatedly verified even over kilometers. The long distance research has continued with more recent long distance measurements by Gisin, *et. al.* (Gisin, *et. al.,* 1998a and 1998b) and Salart, *et. al.* in Geneva (2008). In 2015, three experiments were conducted stretching over several floors of a campus building, using multiple devices sending photons through fiber optics and random number generators to pick one of two polarization settings for each polarization analyzer. Other experiments were set up over entire campuses, with similar conclusions, all with excellent results (Hensen, 2015) revealing a nonlocal affect. Despite the lack of definitive evidence that superluminal signals must be invoked to derive Bell's theorem, this author does believe that Bell's theorem almost certainly involves superluminal signaling which I have formatted in complex Eight Space (Ramon and Rauscher, 1980).

The conclusion from Bell's Theorem's implies remote connectedness in that any hidden variable theory that reproduces all statistical predictions of quantum mechanics must be nonlocal. While, to date, all these formulations involve microscopic properties only, in terms of a microscopic spin correlation function, usually for photons (spin 1) or electrons (spin 1/2), some recent formulations seem to imply possible macroscopic non-quantum remote correlated effects. The key appears to lie in the formulation of the correlation function which represents the interconnectedness of previously correlated events.

I observed the experimental set ups of both Clauser and Aspect and was extremely impressed with the experimental designs and implementations. Even though I am a theoretical physicist by training, I have conducted years of experimental work and always like to see the hands-on work. In the Clauser experiments, the position of the polarizers are set before the photons leave their source to reach the photomultipliers (PMT). Aspect added a "delayed-choice" component to the experiment in which the polarizers are randomly set after the two photons leave the source. The photons' spins remain correlated in both cases. John Clauser described his impressions of these nonlocality experiments to me, stating that quantum experiments have been carried out with photons, electrons, and may be carried out with atoms, and even 60-carbon-atom Bucky balls. He claimed that "it may be impossible to keep anything in a box anymore."

Wheeler took this further in his idea for a "delayed-choice experiment" which I discuss in Rauscher and Amoroso (2011) and Rauscher, Hurtak and Hurtak (2017). It is clear that this principle of nonlocality has profound implications about the nature of a nonlocal universe. The fundamental nature of nonlocality supersedes either microscopic or macroscopic phenomena, of which the quantum domain is a subset expressed in a complex Minkowski eight space. The Bell's theorem correlation of distant events is just one of the interesting forms of the principle of nonlocality.

EPR (Einstein, Podolsky and Rosen, 1935) stated that there could be no action at a distance, but quantum theory seems to require action at a distance. What happens in one part of the Universe can have nonlocal consequences in other parts, regardless of the distance between the points and regardless of the speed of light. Before entering the process, neither photon nor electron "knows" which spin orientation to have. After leaving the source, it appears that each "knows" instantly through nonlocally what state its twin is in and so behaves accordingly. To understand the notion of nonlocality, we must also understand Gisin's experiment where two photons originating from the same source are sent to separate locations some 18km distance apart (Gisin, 2013). In modern quantum physics, entanglement is fundamental. Then it appears that space is no longer basic, at least at the quantum informational level and neither may time. The key is in the measurement which seems to trigger a collapse of the wave function of the system! Wheeler states that "no elementary phenomena is a phenomena until it is recorded and analyzed in the world of quantum theory."

If we consider nonlocality as the basic concept, and consider locality as a special and limiting case, applicable when there is relative functional independence of the various "elements" appearing in our descriptions, this means that our notions of space and time will have to change in a fundamental way" (Rauscher, 1971, Wheeler, 1979a, 1979b; Bohm, Hiley, 1975, 1993). The complex eight-dimensional space is intrinsically a nonlocal spacetime geometry. Locality, in four space, becomes an approximation to exact nonlocality as I have shown in my progress to formulate Bell's Theorem in complex Eight Space (Rauscher, 2017; Ramon and Rauscher, 1980; Rauscher, Hurtak and Hurtak, 2016). This approach may alter the concept we have of space and time.

In *Mind Dynamics in Space and Time* (Rauscher, Hurtak and Hurtak, 2016), we explore some of the physical interpretations of Bell's theorem, together with the ontological and epistemological, philosophical and possible metaphysical implications of the theorem. Experimental verification of nonlocality and hence the completeness of the quantum theory, leads to the conclusion of the fundamental existence of nonlocal interactions, indicating that some super psi wave function (Ψ) that was the origin of quantum entanglement at the big bang, exists. Was it this Ψ function that led to everything remaining correlated throughout cosmic evolution? Stapp, Nadeau, and

Kafatos (1999) acknowledge this current physical theory and nonlocality and stated that "...the universal on a very basic level could be a vast web of particles, which remain in contact with one another over any distance and in no time." In his participation in the F"F"G, Stapp stated that the confirmation of the nonlocality of Bell's Theorem is one of the most fundamental discoveries of the 20th century along with the Heisenberg uncertainty principle (Kaiser, 2011; Rauscher, 2010; Stapp, 1976; Heisenberg, 1938).

2. OTHER NONLOCAL MICRO AND MACRO PHENOMENA

Young's double slit experiment (1804), conceived and conducted before the development of the quantum theory, and Wheeler's (1978a, 1979a, 1979b) delayed-choice experiments elucidate some of the quantum properties of nonlocality as quantum entanglement, as well as some of the issues related to the wave-particle phenomena paradox, potential models and possible nonlocality. Whereas, light and even billiard balls via de Broglie $P = h/\lambda$ exhibit wave and particle like properties, where P is momentum, h is Planck's constant and l is the associated wavelength, the issue of nonlocality is not an issue of locality and nonlocality, but that nonlocality exits and that is it!

Other experiments such as the Aharonov-Bohm experiment can be interpreted as displaying occurrences of nonlocality. The experiment designed by Aharonov and Bohm reveals the physical importance of the scalar part of the electromagnetic potential. In their experiment, a charged particle, such as an electron, that passes close to, but does not encounter, a magnetic or electric field will change its dynamics slightly, in a manner that can be measured. The Aharonov-Bohm effect, thus, describes how the potentials, and not the fields, act directly on the particle charges. It also demonstrates the manner in which the amplitude of the electron's wave function gives the probability of finding the electron at a particular location at a particular time. The Aharonov-Bohm effect (1959) may even show a relation to the theory of everything (TOE), where potentials are extended to "gauge fields" and regarded as a fundamental physical quantity.

Young's double slit experiment of 1803 was designed and conducted to elucidate whether light was a particle or a wave. This was a hot topic of interest in his time and it continues today (Young, 1804). The question was to determine, whether particles, and especially photons (or light particles) have wave-like or particle-like properties. Young demonstrated his double slit experiment which uncovered the wave like nature of light. He hypothesized that light was wave-like in analogy to ripples or waves such as in water when two opposing water waves meet, they would reinforce or destroy each other. His equipment was primitive by modern standards. Using only sunlight diffracted through a small slit as a source of coherent illumination, he projected the light rays from the slit onto another screen containing two slits placed side by side, allowing the light to fall onto an observation screen.

Young experimented with different size slits and also different distances between the holes and the screen. Then when he reduced the size of the slits and brought them closer together, the light went through the slits and created distinct bands of light separated by dark regions in a serial order on the screen. With both slits open, there was an interference pattern, or diffraction pattern demonstrating the wave nature of light. He immediately understood that what he was looking at was light acting like a wave and it was showing what he called "interference fringes" which were the variations of white and dark bands he recorded (Young, 1804).

Young's double slit experiment has also been conducted with electrons. Also, tests were made where one slit is closed and one is open. Today this is done by random number generators. Here the implication of the appearance of the pattern on the screen when both slits are open or when a particle passes through one slit seems to be that the particle or photon "knows" or carries information to the screen that appears to contain information about what would have happened had the particle gone through the other slit concurrently or simultaneously.

A form of nonlocality appears to be required for the so-termed "knowing" that the other slit is open or closed by the single photon or electron. Just as the hidden variable hypothesis of Bohm is an attempt to explain Bell's nonlocality, so a pilot wave or advanced potential hypothesized by Heisenberg was an attempt to find a mechanism for this nonlocality. Young's work was furthered by by Augustine Jean Fresnel, leading to the construction of a mathematical basis of a wave theory of light. Young and Fresnel (Crew, et.al., 2010) both adopted the transverse theory of light, which Maxwell (1873) formulated in detail.

In the photoelectric effect, a photon hits a metal and ejects electrons from the surface that can produce a current flow (often used in automatic door openers). What is the fundamental nature of light? What is light, a particle or a wave? This is the particle-wave paradox. There is actually no paradox in nature. Paradoxes arise from our misunderstanding or ignorance as to the manner in which nature works. Both waves and particles obey quantum nonlocality. To resolve this and other paradoxes may require going beyond our western based logic system or Aristotelian logic of the concept of "either-or". At its most basic nature, light may be neither or both (Zen four-logic) a particle or a wave but display particular attributes depending on what experiment is performed to examine its nature as discussed by Targ and Hurtak in their book (2006) and also Targ, Rauscher and Brown (2003; Targ, 2004).

3. THE VELOCITY PARADOX OF BELL'S THEOREM AND THE YOUNG'S DOUBLE SLIT EXPERIMENT RESOLVED

When we formulate Bell's Theorem and the Young's double slit experiment in complex Eight Space, the velocity resolution is achieved. That is, the nonlocal connection of Bell's Theorem and the paradox at the Young's double slit experiment involve luminal or subluminal signaling in complex Eight Space.

This can be shown in a real time separation from P_1 (photomultiplier 1) at the origin and P_2 (photomultiplier 2) separated by a real part on X_{Re} axis. For these photons to appear contiguous i.e., simultaneously detected for state spin up or down determined at PMP_1 and PMP_2, we require access to $t_{x,Im}$, from P_1 and P_4 along the $t_{x,Im}$ axis. Hence, causality is maintained in the complex Eight Space and nonlocality explained. This is analogous to the nonlocality of remote viewing.

In Rauscher, Hurtak, and Hurtak (2016), we consider the Young's double slit experiment in terms of a hyperdimensional geometry such as complex Eight Space. Consider the case of a photonic source, s, or we can use a source of electrons going through one slit at a time because the source emitter is of such low intensity. Consider the case of the emission of two sequential photons $\gamma_1(t_1)$ and $\gamma_2(t_2)$ respectively where $t_1 \neq t_2$ in the case of a lower intensity source. In complex Eight Space then by having access to dimension x_{Im}, we use the metrical line element in complex Eight Space as

$$s^2 = |X|^2 - c^2 \; |t|^2$$

for $X = X_{Re} + i\, X_{Im}$ and $t = t_{Re} + i\, t_{Im}$.

The key is that it is the square of the variable that occupies the role in Minkowski four space, as well as the complexified Minkowski eight space. The square of the modulus of an imaginary yields a real quantity. Then essentially, t_1 appears for $t_1 = t_2$ so that γ_1 (t_1) and γ_2 (t_2) appear to be emitted simultaneously. We associate γ_1 (t_1) with being located at P_1 and γ_2 (t_2) located at P_3. Now these two photons appear to the contiguous by access to X_{Im} so that at P_4, we have the appearance that $t_1 = t_2$ where the origin is at P_1 (Rauscher, in progress). In complex Eight Space, the frame of reference for $t_{x,Im} \neq 0$ corresponds to real time remote viewing, and for $X_{Im} \neq 0$ corresponds to precognition.

4. WHEELER'S DELAYED-CHOICE GEDANKEN EXPERIMENT

Wave-particle duality is further exemplified in Wheeler's delayed-choice Gedanken Experiment (1978b). Wheeler believed we live in a participatory Universe (which is counter to Bohr's Copenhagen view). He proposed a modification of Young's double slit experiment which he termed the "delayed-choice" experiment. Using a standard configuration of a two-path interferometer, the photon enters the path via beam splitter

1 and is recombined by beam splitter 2. The delayed-choice is introduced by determining when the beam splitter 2 needs to become active. If splitter 2 is used, a "wave" property of interference is detected. If it is not used, the "particle" property is detected. In the "delayed-choice" version, the observer performs a last-minute choice, after the photon has already traversed the first beam splitter, whether to open beam splitter 2 or to close or change its position.

Many variations of the experiment have been performed (e.g., Hensen, 2015, Jacques, 2007). One can also determine "through which slit" each quantum goes. As in Wheeler's description all the features to the right of the photographic plate, including the slicing of the splitter into venetian blind-like slats are fundamental to the "delayed-choice" experiment. Is this the basis for deducing that a photon has "gone through both slits," creating a divided photon? Not possible.

Einstein objected, stating that, deciding which slit the photon went through is a logical inconsistency of the quantum theory. Einstein argued that by measuring the vertical component of the kick that the photon imparts to the photographic plate, would indicate whether it had come from the upper hole, kicking the plate down, or from the lower hole, kicking the plate up.

Bohr responded that two separate experiments, not one had been conducted. Both experiments could not be performed at the same time according to Bohr's complementarity principle (Rauscher, 2010). In the opinion of Rauscher, Hurtak and Hurtak (2017), the "delayed-choice" experiment further exemplifies the property of nonlocality and is becoming more and more an established concept, with the latest experiment in combination with the National Institute of Standards and Technology (NIST) (Takesue, 2015), and more expected to follow.

An obvious experiment is the triple or multiple slit experiment. My idea, as well as others was to add a third slit. Max Born, however, in the 1920's, proposed that only pairs can interfere and that adding one or more slits would not contribute any changes to the two slit interference pattern on the screen. He was right, but there is still no clear reason why quantum interference stops at two slits. Sinha *et. al.* (2010) of the University of Waterloo, Canada recently conducted an experiment using three parallel slits in a stainless steel plate, each 3×10^{-3} cm wide and 3×10^{-2} cm tall (Sinha, *et. al.*, 2010). The results confirmed Born's hypotheses that the three-slit interference pattern is the same as a double slit interference pattern, as there were no new fringes observed (Rauscher and Amoroso, 2009).

We contend, based on Rauscher and Amoroso (2011) and Rauscher, Hurtak, and Hurtak (2016), it is in the Eight Space formulation that we have macro and micro nonlocality and not the four space, although by the principle of Lorentz invariance, the laws of physics are invariant or unchanged by the perspective from where one looks, specifically the frame of observation that one observed from. Perhaps, it is moving from the specific to the whole that demonstrates the unity of observation. Another thought is that of the one big problem in the old debate about free will and determinism. Can we change our future with future information brought into the now present in the twin paradox? Complex Eight Space allows for a macro nonlocality explanation of Bell's theorem and special relativity.

CONCLUSION

Intense debate has revolved around the particle-wave nature of light over the last five centuries, often resulting in the breaking of lifelong friendships. Light appears to be either and both a particle or/and a wave. The debate over the fundamental existence of locality and nonlocality has also been contested. The existence of nonlocality is now no longer in question. In the study of physics, there is a striving toward a more basic knowledge of the nature of reality. Using the precise and logical language of mathematics, physics is assumed to be the most fundamental of all sciences and perhaps the basis for all human knowledge. It is our attempt to understand the natural world that has led to the growth of our current understanding of physics. A succession of inductive and deductive inferences derived from observation and theoretical hypothesis, theory explanation and prediction has led to our accumulated knowledge.

Tecnic Research Laboratory
Apache Junction, AZ 85119
bvr1001@msn.com

REFERENCES:

Aharonov, Y. and D. Bohm 'Significance of Electromagnetic Potential in the Quantum Theory,' *Phys. Rev.* 115, 1959, p. 485.

Amoroso, R.L., L.H. Kaufman, E.A. Rauscher and P. Rowlands "Hidden Parameters Describing Internal Motion Within Extended Particle Elements," pp. 1-27, Eds. R.L. Amoroso, P. Rowlands and S. Jeffers, The Search for Fundamental Theory, *American Institute of Physics*, AIP Conference Proceeding, 1316, Melville, NY, 2010.

Aspect, A., P. Grainger and G. Roger, Experimental tests of Bells inequalities using time-varying analyzers. *Phys. Rev. Lett.*.*49*, 1804 and private communication with A. Aspect, Orsay, France, 1977 and 1992.

Bell, J.S., "On the Einstein Podolsky Rosen paradox," *Physics* 1, 1964, p. 195.

Bell, J.S., *Speakable and Unspeakable in Quantum Mechanics*, Cambridge University Press, 1987.

Bohm, D. *Phys. Rev 85,* 166 and 180 and private communication at LBNL when he spoke to the Fundamental Physics Group also called the Fundamental "Fysiks" Group (1978) and at Birkbeck College, physics department, University of London during my (EAR) teaching summer 1977 and E.A. Rauscher, discussion on the physics of hyperdimensional geometrics. University of London presentation, 1952.

Bohm, D. "Bell's Theorem and Hidden Variables," presentation to the Fundamental Physics Group, LBNL chaired by E.A. Rauscher April 7, 1977.

Bohm, D. and B. Hiley "On the Understanding of Nonlocality as Implied by Quantum Theory," *Found. of Phys.* 5, 1975, p. 93.

Bohm, D. and B. Hiley, *The Undivided Universe* London. Routledge and private communication with D. Bohm and B. Hiley, 1993.

Clauser, J.F. and M.A. Horrne, 'Experimental consequences of objective local theories' *Phys. Rev.* D 10, 15 July 1974, 1974, p. 526.

Crew, H., *et.al., The wave theory of light; memoirs of Huygens, Young and Fresnel.* Nabu Press, 2010.

Einstein, A., B. Podolsky, and N. Rosen, 'Can a quantum mechanical description of physical reality be considered complete?' *Phys. Rev.*, 47, 1935, p. 777.

F"F"G (1973-1979) The Fundamental Physics Group for the Fundamental "Fysiks" Group (F"F"G) named by EAR (1973-1979) also termed the Fundamental Physics Group.

Feinberg, G., *Phys. Rev.* 159, 1967, 1089 and private communications with E. Rauscher and H. Puthoff the University of Columbia (1975).

Freedman, S. and J. Clauser, 'Experimental test of local hidden variable theories,' *Phys. Rev. Lett.*, 28., 1972, pp. 934-941.

Gisin, N., W. Tittel, J. Brendel and H. Zbinden, Violation of Bell inequalities by photons more than 10 km apart. *Phys. Rev. Lett.*, 81, 1998a, p. 3563.

Gisin, N., J. Brendel, W. Tittel and H. Zbinden, 'Quantum correlation over more than 10 km,' *Optics and Photonics News,* 9, 1998b, p. 41.

Gisin, N., "Quantum Nonlocality: How Does Nature Do It?" *Science Magazine*, July 27, 2013, p. 1358.

Heisenberg, W. (1938) *Der Durchgang sehr energiereicher Korpuskeln durch den Atomkern*, *Nuovo Cimento* Vol. 15, 31–34; *Verh. Dtsch. physik. Ges.*, 19, p. 2.

Hensen, B. *et. al.* "Loophole-free Bell inequality violation using electron spins separated by 1.3 kilometres" *Nature*, 526, 29 October 2015, pp. 682–686.

Herbert, N. (1975) "An Elementary Proof of Bell's Theorem on the Incompatibility of Local Hidden Variable theories with Quantum Mechanics," *Am. Jour. Physics* 43, 315 and "Bell's Theorem and Superluminal Signals" presentations to the Fundamental Physics Group of EAR at LBNL (1977).

Jacques, V., et. al. (2007) Experimental realization of Wheeler's delayed-choice Gedanken Experiment (LPQM), Science 315, 5814 (2007) 966, 10.1126/science.1136303.

Kaiser, D. (2011) *How the Hippies Saved Physics*, W.W. Norton.

Maxwell, James Clerk (1873), *A treatise on electricity and magnetism Vol I. and Vol 2.*, Oxford : Clarendon Press.

Ramon, C. and E.A. Rauscher (1980) "Superluminal Transformation in Complex Minkowski Spaces," *Found. of Phys.* 10, 661, demonstrates the compatibility of superluminal signals and multidimensional geometries.

Rauscher, E.A. (1971) A Unifying Theory of Fundamental Processes, LBNL/UCB, UCRL-20808, book.

Rauscher, E.A. (1972) "A Set of Heisenberg Generalized Relations and a New Form of Quantization," *Lett. Al. Nuovo Cimento* 4, p. 747.

Rauscher, E.A (2010) "Quantum Mechanics and the Effect of Intentional Will," Chapter 3, pp. 35-63, *Complement only of mind and body: Realizing the Dream of Descartes, Einstein and Eccles.* ed. R.L. Amoroso, Nova Science Pub.

Rauscher, E.A. (2017) "Formulating Bell's Theorem in Complex Eight Space," in progress.

Rauscher, E.A. and R.L. Amoroso (2009) Relativistic Physics in Complex Minkowski Space, Nonlocality, Ether Model and Quantum Physics, in the *Ether Space-Time and Cosmology* 3, Physical Vacuum, Relativity and Quantum Physics, Ed. M.C. Duffy, Apeiron, Montreal.

Rauscher, E.A. and R.L. Amoroso, (2011) *Orbiting the Moons of Pluto: Solving Einsteins, Maxwells, Schrodingers and Dirac Equations in Complex Space*, London: World Scientific.

Rauscher, E.A. J.J. Hurtak and D.E. Hurtak (2016) *Mind Dynamics in Space and Time.* Los Gatos: Academy For Future Science.

Rauscher, E.A., J.J. Hurtak and D.E. Hurtak (2017) "What is Time? What Time is it?" *Proceedings of the 10th Vigier Conference.*

Rauscher, E.A. and R. Targ (2001) The Speed of Thought: Investigation of a complex Spacetime Metric to Describe Psychic Phenomena, *Jour. Sci. Explorations*, p. 331.

Salart, D., Baas, *et. al.* (2008): "Testing the speed of 'spooky action at a distance'", *Nature,* 454, pp. 861-864.

Sinha, U. (2010) "Ruling out Multi-order Interference in Quantum Mechanics," *Science.* Vol. 329, p.418.

Stapp, H. (1976) presentation on "The Interpretation of Bell's Theorem" presented to the FFG, chaired by E.A. Rauscher at Lawrence Berkeley National Laboratory, LBNL. October 31 and June *2*.

Stapp, H., R. Nadeau and M. Kafatos (1999) *The Nonlocal Universe: The New Physics and Matters of the Mind*, Oxford, UK, Oxford University Press and extensive conversations with Stapp at LBNL (1966-1996).

Targ, R (2004) *Limitless Mind: A Guide to Remote Viewing and transformation of consciousness*. San Francisco: New World Library.

Targ, R. and J.J. Hurtak (2006) *The End of Suffering*. Charlottesville: Hampton Rhodes Press.

Targ, R., E.A. Rauscher, and D. Brown (2003) "The Physics of Zen in Four Logic," Draft.

Takesue, H., et. al., 'Quantum teleportation over 100 km of fiber using highly efficient superconducting nanowire single-photon detectors,' *Optica* Vol. 2, Issue 10, 2015, p. 832.

Wheeler, J.A. (1978a) The "Past" and the "Delayed Choice" double slit experiment, ed. A.R. Marlow, *Mathematical Foundations of Quantum Theory*. New York: Academia Press.

Wheeler, J.A. (1978b) The "Past" and the "delayed choice" Double Slit Experiment, Ed. A.R.M. Marlo, *Mathematical Foundation of Quantum Theory*, Academic Press, NY. Also, private communication University of Texas, Austin, TX, June.

Wheeler, J.A. (1979a) *Beyond the Black Hole, Center for Theoretical Physics.* University of Texas, Austin, Texas.

Wheeler, J.A. (1979b) *Frontiers of time, Center for Theoretical Physics,* University of Texas, Austin, Texas.

Young, T. (1804) Experiments and calculations relative to physical optics. *Philosophical Trans of the Roy. Soc. of London* 94, p. 1-16.