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## The ontological basis of quantum theory, nonlocality and local realism

To cite this article: E A Rauscher *et al* 2019 *J. Phys.: Conf. Ser.* **1251** 012042

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# The ontological basis of quantum theory, nonlocality and local realism

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**Abstract.** In considering models of reality we must consider the fundamental nature of quantum mechanics, which has had great success in describing the spectrum of light from distant stars and galaxies, formulating the properties of the strong, electro-weak or electromagnetic and weak decay forces, and explaining atomic order formulated as the atomic periodic table and atomic spectra. A vast array of technologies has resulted from quantum theory, from semiconductors to NMR machines, nuclear reactors and possibly encryption secured, fast quantum computers. Quantum theory, however, has yet to fully engage with the gravitational force. With the advent of quantum theory, several major issues stand out, leaving us with major philosophical questions on the nature of physics and reality, and our ability to comprehend them. The issues involve the interpretation of quantum measurement, the Heisenberg uncertainty principle on the completeness of quantum theory and nonlocality. The frontiers of science continue to open new concepts based on a multidimensional reality which we use to address these issues, including solving the Schrödinger and Dirac equations in complex Minkowski eight space. We also formulate Bell's theorem and the Young's double slit experiment in Rauscher's complex eight-space. We formulate an interpretation of the quantum that yields locality in a hyper-dimensional complex space and that maintains the completeness of quantum theory and nonlocality in usual four space, with local connectivity and the Lorentz invariant conditions, where subluminal and luminal signaling are maintained. Are we really forced to choose between two alternate views of reality? One view that external reality exists independent of the observer, and the other that the observer somehow is a participator or an integral part of all of nature. Must we choose between these or is there another way out? We find our way out and we satisfy both Bohr (Copenhagen) and Einstein (determinism) in bringing about a practical outcome of the debate. By developing and applying complex eight space, we can accommodate locality or local realism in terms of contiguous event connections in complex eight space. In four space, nonlocality dominates and also can be considered locality in eight space. The determination of the state of a system naturally collapses to its final state where quantum mechanics is functioning completely in four and in eight dimensional spaces.

## 1. Introduction

Volumes have been written about the philosophical implications of the Heisenberg Uncertainty principle. Volumes more will be written about quantum nonlocality. Again, the essential exploration of reality is to understand its deep philosophical implications where the consideration of the paradox gives us a major clue where to look for a resolution. Nature does not admit to a paradox as that would indicate a lack of understanding of nature which can be profound! Its resolution opens us to new knowledge and perhaps a new way of thinking with a new philosophical vision.



What we believe reality to be profoundly affects us and the world, where we refine our views of reality and truth. The philosophical foundations of a belief profoundly affect who we are and how we act in the world. The quantum picture has landed us on a new frontier for over one hundred years! We find new foundations with the resolution of the paradox that arises from the quantum theory and its myriad applications. Quantum technology is the backbone of our current technological age. Technology empowers us but can also enslave us. It is critically important that we understand the philosophical basis of our understandings. We need to understand our role in the world.

The classical mechanical concept of reality is that of objective reality or world view, that there is an “out there,” an external reality that exists in a definite state, independent of us and what we measure. Of course, the quantum theory and linear superposition of a multitude of unmeasured states, limited by the Heisenberg uncertainty principle, leads to new views of reality.

Einstein wanted a deterministic, objective reality, which, in an ultimate sense, is a completely knowable reality. Hence, Einstein’s “God does not play dice with the universe” statement, while Bohr could live with the probabilistic nature as the quantum world and quantum prediction, and the measurement issue with its Heisenberg uncertainty principle. This leads to the famous Bohr-Einstein debates. These debates lead to the Einstein-Podolsky-Rosen Paradox paper of 1935 [1].

We have developed an extension of the Minkowski four spacetime metric by complexing spatial-temporal dimensions to a complex eight space. We summarize the philosophical, advances in physics and technological by this new physics. For example, we resolve the quantum paradox of quantum completeness, nonlocality and local realism. We also shed new light on free will and determinism and have developed new particle technologies that result from the theory [2-4].

We have solved the Schrödinger and Dirac equations in complex Minkowski eight-space [5-7]. We also formulate Bell’s Theorem [8] and the Young’s double slit experiment [9] in our complex eight space. We formulate an interpretation of the quantum that yields locality in a hyper-dimensional complex space while maintaining the completeness of quantum theory and nonlocality in usual four space.

Along with Albert Einstein, physicists have not yet grasped the structure of quantum mechanics in a deep manner, but new experiments and new tools have opened the door to look behind the screen at the true Wizard of Oz and give us a non-philosophical basis for quantum physics. In the past before the Fundamental Fysiks Group and the quantum revolution of the 1970’s, physicists were primarily concerned with the wonderful practical applications of the quantum theory [10,11]. Now, the door is open to a new set of experimental designs whose results will open the door to a better and more fundamental understanding of the physical underpinnings of reality. We discuss in this paper, some of the major tenants of quantum mechanics, its implications for nonlocality and the possible reconciliation of some of the paradoxes of quantum theory.

Neils Bohr and Werner Heisenberg’s position is known as the Copenhagen interpretation of the quantum theory. The Heisenberg interpretation expresses the fact that the observer disturbs the system he or she is measuring. The Copenhagen view led Schrödinger to purpose his cat paradox, which is a statement of a probabilistic prediction of a state of a system in quantum theory that is determined by an experiential observation of that system. Bohr’s Copenhagen interpretation of the collapse of the wave function stems from the lack of ability to definitely describe and determine the associated particle wave function from all the possible states it can be in, until it is measured. The Copenhagen concept is that the state of the wave function defines the definite state of the measured particle. This was confirmed by the double slit experiment in the sense that wave mechanics predicts the outcome of the experiment correctly, where the state “created” by the observer is seen as collapsing the probabilistic possibility to one slit. This is the conundrum which is the loss of objective realism. Einstein and Schrödinger were not willing to accept the Copenhagen complementarity and the Heisenberg principle completely and its interpretations, nor the implications.

The exact outcome of the measurement cannot be definitely mediated by only one possible outcome that is measured. The measurement faithfully records one state at a time out of the possible perturbations of the system after the measurement. In contrast, macrocosmic phenomenon appears not to be governed by the quantum mechanical array of probabilities that decoheres into one observed state. We invoke the concept of what does a wave function really mean. We assume a one to one correspondence between a physical system and the wave function that describes a realistic physical theory. In the modern understanding of quantum mechanics, the wave function,  $\Psi$  is derived from a collection of physical settings. Therefore, quantum theory is not as a theory of individual quantum systems, but of quantum phenomena that interact with each other in a way understood as quantum entanglement.

Quantum entanglement involves two particles which can be two photons, each of which arises from a single source as a connected pair and each of which occupy multiple states at once or they obey linear superposition before a measurement is made. Nonlocal wave functions collapse when either one is measured, “causing” the other particle to instantaneously or superluminally assume a corresponding state. For example, a measurement at A gives spin up and hence the measurement at B gives the corresponding spin down. Einstein’s famous reference to this nonlocal entangled interaction was referred to as “spooky action at a distance.” The extensive Bell’s Theorem tests yield results consistent with nonlocal particle-particle entanglement, which violates Bell’s inequality [8]. This is the case in ordinary four space.

Realism or objective reality assumes that the world and the universe exist “out there” in a definite state independent of the observer and whatever measuring apparatus is used. This is the Newtonian view and the view of most humans. The Copenhagen view is another matter and brings the observer as an active participant into play. There is no objective reality and no potential for an exact deterministic description of reality. The Heisenberg principle, Bell’s Theorem, nonlocality and the probability value of quantum theory lead us on another path. This path is to nonlocality! However, we may be able to reconcile natural local realism in a hyper-dimensional geometry, as well as the apparent nonlocality in the usual four Minkowski space, which appear contiguous in hyper-dimensional complex eight space.

Because event correlation is Lorentz invariant in the complex eight-spaceour formulation of the Schrödinger, Dirac, and other quantum mechanical approaches in complex eight space, allows us to formulate a Lorentz invariance condition and general causality criterion applied to the quantum domain. This approach may allow us to develop a general quantum relativistic theory that may allow us to reconcile the quantum theory with the tensor structure of general relativity to lead to a possible useful unification of these two profoundly successful theories.

This can occur when we incorporate eight-space into our four spacetime as part of the entanglement. Here eight-space corresponds to the Kaluza [12] and Klein [13] formulations of extra dimensions [3], but it goes beyond the Calabi-Yau formulations. This paper will show the mathematical theory behind the wave function and spin determination in four space through not only real numbers, but complex numbers, which provides the needed correlation for understanding the mathematics of our spacetime.

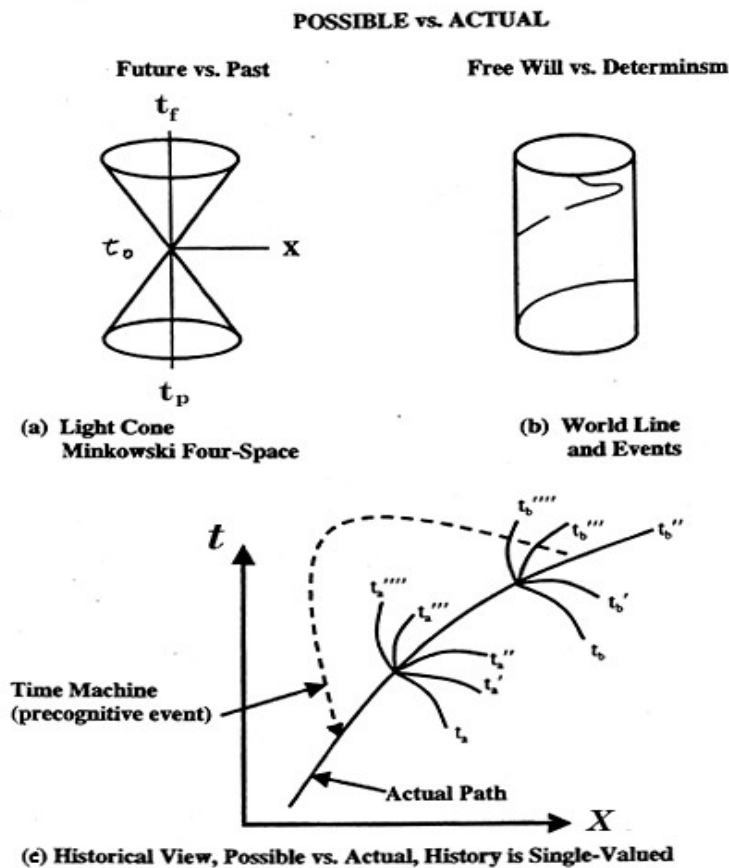
We can consider the Copenhagen view as epistemological. The quantum theory in the past has to be considered in epistemological terms. With our new current approach, we may be able to grasp the fundamental aspects of quantum mechanics on an ontological basis. Essentially the Copenhagen interpretation is probably considered one of epistemology, however, some consider it to be ontological.

## 2. Why the need for higher dimensions?

In order to resolve the fundamental quantum paradoxes, we have developed a multidimensional geometry. We address some of the considerations in resolving quantum paradoxes and issues related to constructing a hyperdimensional geometry [3,4,14].

It appears that a normal macroscopic causality demands that no point in the forward light cone is connected to another point outside the forward light cone, that is, all signals are time-like (see Fig 1a).

Real events involve simultaneity, which is defined by signals that do not exceed the velocity of light,  $v \leq c$  where  $v$  is the velocity of propagation and  $c$  is the velocity of light. Causality conditions for superluminal signals in constructing a Lorentz invariant quantum field theory are given in [3,4]. The relationship of causality and locality conditions are discussed [4]. See Fig 1.



**Figure 1.** Possible versus actual events are displayed. Several types of world lines are depicted in Fig 1a which depicts a world line with a single-valued “now” on the usual light cone, but Fig 1b depicts a multi-valued “present” on a cylinder in ordinary spacetime. In Fig 1c, we depict the multiple futures in which, at each interval of time, multiple possibilities exist.

We present an analogy of the relationship between lower and higher dimensional geometries and signal propagation in the manifold. In a lower dimensional geometry, signaling can be superluminal, whereas in the higher dimensional geometry such signaling may appear subluminal. We associate the surface as a lower dimensional geometry, as a circle, having  $v \geq c$  and a chord can be drawn across the area of a circle in which its area is a higher dimensional space. This space can accommodate  $v \leq c$  signaling. Therefore, two entangled events will appear luminally connected in the higher dimensional geometry.

In a lower dimensional space the velocity of propagation appears superluminal,  $v > c$  and luminal in the hyperdimensional space,  $v \leq c$ . In analogy, the velocity of propagation for Bell’s Theorem and the Young’s double slit experiment in four space is  $v > c$  or instantaneous, but in complex eight-space signaling can be luminal,  $v = c$  as subluminal  $v \leq c$ .

The problem of Closed Time-like Loops, CTL is resolved in the complex eight space. Certain spacetime relationships that involve Closed Time-like Loops (CTL) paradoxes can be resolved utilizing formulations in terms of multidimensional geometries of  $n > 4$ . The issues involved are presented and extensively discussed in [3,4,15]. In the so-called twin paradox, only future time travel is possible in non-inertial frames because time dilation only occurs in the rapidly accelerating frame. This restriction does not apply to complex eight space.

In order to describe processes involving apparent future-to-past light cone connections, one has paradoxes involving CTL, multi-valued 'nows' and 'accelerated times' which involve the paradox of moving more slowly than a rest frame. These paradoxes cannot be resolved in the usual Minkowski four space metric. In  $n > 4$  dimensional spaces we have the possibility of a more definitive formalism and description of quantum nonlocality.

### 3. The mathematical structure and implications of our complex eight-space

The complexification of Minkowski four space,  $M^4$ , gives rise to an eight-dimensional complex Minkowski space,  $M^4 \subset \mathbb{C}^4$  in which we take each of the eight dimensions as an independent orthogonal dimension and in which the real and imaginary components can be considered as two independent four space lightcones,  $(x_{Re}, t_{Re})$  and  $(x_{Im}, t_{Im})$ . Here four space is then a slice through eight space, rather than a subset or subspace formed by a projected geometry distorted by the projection, causing variation in the defined variable length and vector orientation, whereas orthogonal slices maintain uniformity.

We introduce a complex eight-dimensional geometry in which the real components comprise the usual four space of three real space components, a real time component, four imaginary components composed of three imaginary space components, one imaginary time component which comprise the properties of a complex Minkowski space and explore the properties of this geometry in detail. Each of the eight dimensions are orthogonal to each other. The formalism involves defining a complex space  $Z^\mu = x_{Re}^\mu + ix_{Im}^\mu$  where the metric of the space is obtained for the line element  $ds^2 = g_{\mu\nu} dZ^\mu dZ^{*\nu}$  where  $\mu$  and  $\nu$  run 1 to 8. The eight-dimensional space is the least number of dimensions to accommodate nonlocality, Lorentz and anticipatory incursion in complex symmetry, and this eight-space is also Lorentz invariant.

In defining conditions of causality for  $ds^2 = 0$  for the metrical form, we have the usual four space Minkowski metric with signature  $(+++ -)$

$$ds^2 = g_{\mu\nu} dx^\mu dx^\nu \quad (1)$$

Using units  $c = 1$  as  $dx_1 = dx$ ,  $dx_2 = dy$ ,  $dx_3 = dz$  and  $dx_4 = cdt$  where the indices  $\mu$  and  $\nu$  run 1 to 4; which is a 16-element matrix where the trace,  $tr = 2$ .

In complex eight space, we have for our differential line element coordinates labeled  $dZ^\mu = dx_{Re}^\mu + i dx_{Im}^\mu$  (in which  $dZ$  is complex and  $dx_{Re}$  and  $dx_{Im}$  are themselves real), with a complex matrix where  $\eta_{\mu\nu}$  is analogous to  $g_{\mu\nu}$  such that

$$ds^2 = \eta_{\mu\nu} dZ^\mu dZ^{*\nu} \quad (2)$$

so that for example,  $dZ^\mu dZ^{*\mu} = (dX_{Re}^\mu)^2 + (dX_{Im}^\mu)^2$  where  $\eta_{\mu\nu}$  is a 64-element matrix. We can write in general for real and imaginary space and time components:

$$ds^2 = (dx_{Re}^2 + dx_{Im}^2) + (dy_{Re}^2 + dy_{Im}^2) + (dz_{Re}^2 + dz_{Im}^2) - c^2 (dt_{Re}^2 + dt_{Im}^2) \quad (3)$$

Now we have the invariant line elements as

$$s^2 = |x'|^2 - c^2 |t'|^2 = |x'|^2 - |t'|^2 \quad (4)$$

Again, where we chose units where  $c^2 = c = 1$  and

$$x' = x_{Re} + ix_{im} \quad (5)$$

and

$$t' = t_{Re} + it_{im} \quad (6)$$

as our complex dimensional component [2-4,14-17]. We use

$$x'^2 = |x'|^2 = x_{Re}^2 + x_{im}^2 \quad (7)$$

and

$$t'^2 = |t'|^2 = t_{Re}^2 + t_{im}^2 \quad (8)$$

Using the properties that the square of a complex number is given as the modulus

$$|x'| = x'x'^* = (x_{Re} + ix_{im})(x_{Re} - ix_{im}) \quad (9)$$

Where  $x_{Re}$  and  $x_{im}$  are real. The fundamental key to this calculation is that the moduli of complex numbers are real. Causality is defined by remaining on the light cone, in real spacetime, as the product of complex numbers is real. Therefore, we have the eight-spaceline element

$$\begin{aligned} s^2 &= x_{Re}^2 - c^2 t_{Re}^2 + x_{im}^2 - c^2 t_{im}^2 \\ &= x_{Re}^2 - t_{Re}^2 + x_{im}^2 - t_{im}^2 \end{aligned} \quad (10)$$

Causality is further defined by remaining on the light cone, in real spacetime, as

$$s^2 = x_{Re}^2 - c^2 t_{Re}^2 = x_{Re}^2 - t_{Re}^2 \quad (11)$$

Using the condition  $c = 1$ . Then generalized causality in complex spacetime is defined by

$$s^2 = x_{Re}^2 - t_{Re}^2 + x_{im}^2 - t_{im}^2 \quad (12)$$

in the  $x_{Re}, t_{Re}, x_{im}, t_{im}$  generalized light cone eight space.

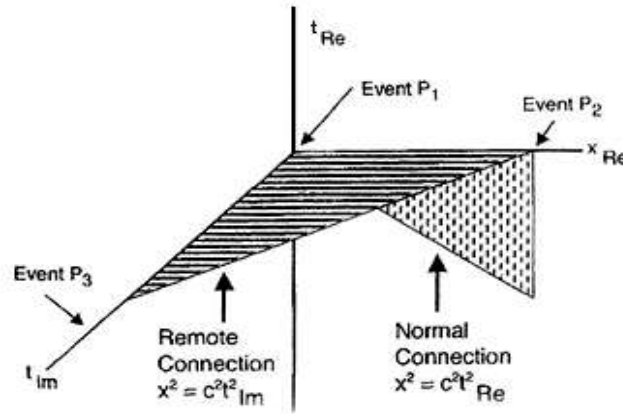
Let us also calculate the interval separation between two events or occurrences  $E_1$  and  $E_2$  with real separation  $\Delta x_{Re} = x_{2Re} - x_{1Re}$  and imaginary separation  $\Delta x_{im} = x_{2im} - x_{1im}$ . Then the distance along the line element is  $\Delta s^2 = \Delta(x_{Re}^2 + x_{im}^2 - t_{Re}^2 - t_{im}^2)$  and it must be true that the line interval is a real separation. Then

$$\begin{aligned} \Delta s^2 &= (x_{2,Re} - x_{1,Re})^2 + (x_{2,im} - x_{1,im})^2 \\ &\quad - (t_{2,Re} - t_{1,Re})^2 - (t_{2,im} - t_{1,im})^2 \end{aligned} \quad (13)$$

$$\begin{aligned} \Delta s^2 &= (x_{2,Re} - x_{1,Re})^2 + (x_{2,im} - x_{1,im})^2 \\ &\quad - (t_{2,Re} - t_{1,Re})^2 - (t_{2,im} - t_{1,im})^2 \end{aligned} \quad (14)$$

Because of the relative signs of the real and imaginary space time components, to achieve the causality connectedness condition between the two events, or  $\Delta s^2$ , we must “mix” space and time. That is, we use the imaginary time component to affect a zero space separation. We identify  $(x_{1,Re}, t_{1,Re})$  with one spacetime event causally correlated with another spacetime event,  $(x_{2,Re}, t_{2,Re})$  [4]. See Fig 2. By introducing the imaginary time component, one can achieve a condition in which the apparent separation in the real physical plane defined by  $x_{Re}, t_{Re}$  is zero, given access to the imaginary time,  $t_{im}$  or the  $x_{Re}, t_{im}$  plane yielding spatial non locality. Again, see Fig 2.

The light cone metric representation may imply superluminal signal propagation between an event A transmitter,  $P_1$  and even in the four real subset space by the event B receiver,  $P_2$  or two simultaneously remotely connected events. Separation will not appear superluminal in the eight-space representation. The causality conditions, which do not contain closed time-like loops, are for the complex eight-space geometry, where four space is a cut through the eight-space [4,14]. Causality conditions in four space have superluminal signals. In the complex eight space, the imaginary time term cancels off the real space separation term, in which nonlocality is formulated as a local separation. The imaginary space term cancels out the real space component to create time contiguity having subluminal signaling.



**Figure 2.** A complex model of remote connectedness where we have the usual physical spatial separation of events on the  $x$  axis in the  $x_{Re}, t_{Re}$  plane as event  $P_1$  to  $P_2$  which appears separated by a zero separation by ‘moving’ to the  $t_{Im}$  axis. The separation of events  $P_1$  and  $P_2$  appear to be contiguous at  $P_3$ .

Here the real physical space separation of the two particles as  $x_{Re,1}$  and  $x_{Re,2}$  can be denoted as

$$\Delta x_{Re} = x_{Re,2} - x_{Re,1} \neq 0 \quad (15)$$

and can either involve a current or real time observation, such that

$$\Delta t_{Re} = t_{Re,2} - t_{Re,1} = 0 \quad (16)$$

or a temporal separation of a retrocausality time interval

$$\Delta t_{Re} = t_{Re,2} - t_{Re,1} \neq 0. \quad (17)$$

By introducing the complex time component  $\Delta t_{Im} \neq 0$ , one can achieve a condition in which the apparent separation in the real physical plane defined by  $x_{Re}, t_{Re}$  is zero, given access to the imaginary space and time in the  $x_{Im}, t_{Im}$  plane. Note that the  $x_{Re}, t_{Re}$  plane defines the usual light cone in four space.

Figure 3a and Fig 3b represent the case where there is a real time element, or  $\Delta t_{Re} = 0$  and  $\Delta x_{Re} \neq 0$  denoted between  $P_1$  to  $P_2$  and  $\Delta t_{Im} \neq 0$  denoted between  $P_1$  to  $P_3$  with the origin at  $P_1$  (Fig 3b). In the simplest causal connection then,  $\Delta x_{Im} = 0$  and

$$\Delta s^2 = 0 = (x_{Re,2} - x_{Re,1})^2 - (t_{Im,2} - t_{Im,1})^2 \quad (18)$$

That is, if we have real spacetime correlated events, then

$$(t_{Re,2} - t_{Re,1}) = 0 \text{ and } (x_{im,2} - x_{im,1}) = 0 \quad (19)$$

where a higher dimensional space is understood by the imaginary temporal component  $t_{im,2} - t_{im,1}$  which “subtracts off” the spatial separation by moving into the imaginary temporal plane. See Fig 3b.

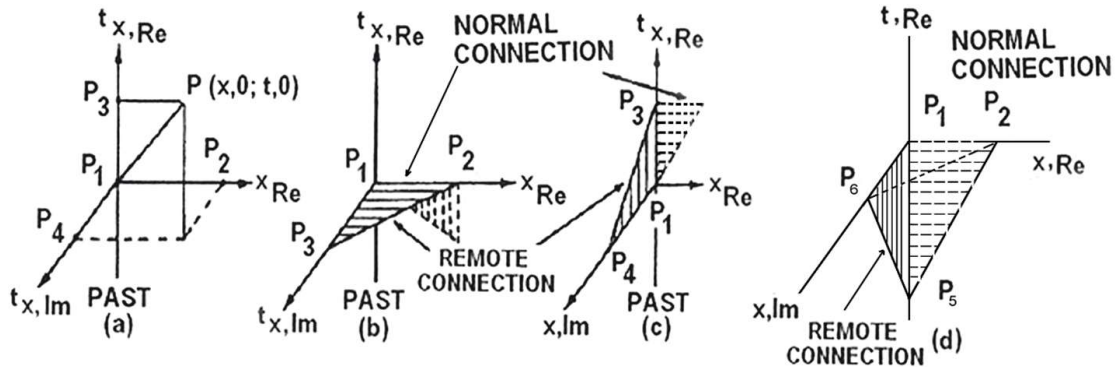
In order to make the apparent separation of events  $t_{Re,1}$  and  $t_{Re,2}$  in time to be zero, for example, for local retrocausality between  $P_1$  and  $P_3$ , then we move into the *im* spatial plane. See Fig 3c. We have

$$\Delta s^2 = 0 = (x_{im,2} - x_{im,1})^2 - (t_{Re,2} - t_{Re,1})^2 \quad (20)$$

$$\text{or } (x_{im,2} - x_{im,1})^2 = (t_{Re,2} - t_{Re,1})^2 \quad (21)$$

$$\text{or } t_{Re,2} - t_{Re,1} = \pm (x_{im,2} - x_{im,1})$$

As stated, this is the simplest case for retrocausality, one in which there is no spatial separation between the Particle A at  $P_1$  on  $x_{Re,1}$  and the retrocausality event and Particle B receiver  $P_3$  on  $x_{Re,2}$  in Fig 3c. In this case, an event at Particle A can acquire information about a “future event” occurring at receiver particle B, separated by a time interval  $t_{Re,2} - t_{Re,1} > 0$  and  $x_{Re,2} - x_{Re,1} = 0$ . We construct the diagram in Fig 3c, such that we define an  $x_{Re}$ ,  $t_{Re}$  plane and a  $x_{Re}$ ,  $t_{im}$  plane. See Fig 3.



**Figure 3.** For events in a complex plane,  $P_1$  is at the origin for Particle A (Bob) (a) event is marked by non-zero spatial and temporal separation from the origin.  $P_1$  and  $P_2$  for Particle B (Alice) are separated in space but synchronous in time. In the case were  $P_1$  (Particle A) and  $P_3$  (Particle B) are separated in time, but there is no spatial separation. Event  $P_3$  is located on the imaginary time axis; (b) Remote and normal connections of events  $P_1$  and  $P_2$  as viewed by an observer at  $P_3$  such that space-like separation,  $x(P_2) - x(P_1)$ , between the events  $P_1$  and  $P_2$  is zero, at  $P_3$  and in (c) Remote and normal connection for zero time-like separation between the events  $P_1$  and  $P_3$  as viewed by an observer at  $P_4$ , such that,  $t(P_3) - t(P_1) = 0$ . Note that Fig 2 is the same as what is depicted in Fig 3b and for Bell’s theorem  $P_1$  corresponds to  $PMP_1$  and  $P_2$  corresponds to  $PMP_2$  which appears contiguous at  $P_3$ . In Fig 3d events  $P_1$  or  $P_2$  are retrocausality at  $P_5$  and specifically connected to  $P_6$  by the dashed line.

Moving beyond spacetime cannot be represented by a simple three coordinate diagram since we will have both the  $\Delta x_{im} \neq 0$  for  $\Delta t_{Re} \neq 0$  and imaginary time component  $\Delta t_{im} \neq 0$  for  $\Delta x_{Re} \neq 0$ . The causality condition in eight-space is then the full eight-space metric,

$$\Delta s^2 = 0 = (x_{Re,2} - x_{Re,1})^2 + (x_{im,2} - x_{im,1})^2 - (t_{Re,2} - t_{Re,1})^2 - (t_{im,2} - t_{im,1})^2 \quad (22)$$

We rewrite the above expression as

$$(x_{Re,2} - x_{Re,1})^2 - (t_{im,2} - t_{im,1})^2 = (t_{Re,2} - t_{Re,1})^2 - (x_{im,2} - x_{im,1})^2 \quad (23)$$

where the left side relates to that of moving beyond space and the right side refers to moving beyond time. The complex time and space in the eight-space representation make it appear in that modality that one can access complex spacetime as though it is not distant and access information about future events as though it were being accessed in current time. In Fig 3, we present some related theoretical models to Rauscher's complex geometry [17].

With the complex time model of remote connectedness, we have the usual physical spatial separation of events on the  $x$  axis in the  $x_{Re}, t_{Re}$  plane which appears separated by a zero separation by 'moving' to the  $x_{im}, t_{im}$  plane. The separation between event  $P_1$  and  $P_2$  appears contiguous or simultaneously nonlocally correlated from the perspective of  $P_3$ . In an  $n > 4$  space or an eight-dimensional space, nonlocal events can be correlated in such a manner that subluminal or luminal signaling can be maintained.

We have solved the Schrödinger equation and Dirac equation in the complex eighth dimensional Minkowski space [4,5,7]. The basic structure of the geometries is based on the construction of complexified dimensions, consisting of orthogonal real and imaginary parts. We examine the implication of a complex eight-space geometry in which we introduce imaginary components for each real spatial dimension,  $X = (x, y, z)$  and temporal dimension,  $t$ . For additional symmetry considerations, we have also introduced a twelve-dimensional space in which we consider a three-component time which is complexified [3].

#### 4. Tachyonic signaling falls out of the complex eight-spaceformation.

Let us examine the way this form of the Lorentz transformation relates to the properties of mass dilation. We will compare this case to the ordinary mass dilation formula and the tachyonic mass formula of Feinberg [18] which nicely results from the complex eight space. In the ordinary  $x_{Re}, t_{Re}$  plane then, we have the usual Einstein mass relationship of

$$m = \frac{m_0}{\sqrt{1 - v_{Re}^2/c^2}} \quad \text{for } v_{Re} \leq c \quad (24)$$

and we can compare this to the tachyonic mass relationship in the  $x_{im}, t_{im}$  plane

$$m = \frac{m_0^*}{\sqrt{1 - v_{Re}^2/c^2}} = \frac{im_0}{\sqrt{1 - v_{Re}^2/c^2}} = \frac{m_0}{\frac{\sqrt{v_{Re}^2}}{c^2} - 1} \quad (25)$$

for  $v_{Re}$  now  $v_{Re} \geq c$  and where  $m^*$  or  $m_{im}$  stands for  $m^* = im$  and we define  $m$  as  $m_{Re}$ ,

$$m = \frac{m_0}{\sqrt{1 + v_{Re}^2/c^2}} \quad (26)$$

For  $m$  real ( $m_{Re}$ ), we examine two cases on  $v$  as  $v < c$  or  $v > c$ , so we let  $v$  be any value  $-\infty < v < \infty$  where the velocity,  $v$ , is taken as real, or  $v_{Re}$  [4,18].

Consider the case of  $v$  as imaginary (or  $v_{im}$ ) and examine the consequences of this assumption. Also, we examine the consequences for both  $v$  and  $m$  imaginary and compare to the above cases. If we choose  $v$  imaginary or  $v^* = iv$  (which we can term  $v_{im}$ ) the  $\frac{v^{*2}}{c^2}$  and  $\sqrt{1 + \frac{v^{*2}}{c^2}}$  becomes  $\sqrt{1 - \frac{v^{*2}}{c^2}}$  or

$$m = \frac{m_0}{\sqrt{1 - \frac{v_{Re}^2}{c^2}}} \quad (27)$$

We get the form of this normal Lorentz transformation if  $v$  is imaginary ( $v^* = v_{im}$ ).

If both  $v$  and  $m$  are imaginary, as  $v^* = iv$  and  $m^* = im$ , then we have

$$m = \frac{m_0^*}{\sqrt{1 + \frac{v^{*2}}{c^2}}} = \frac{im_0}{\sqrt{1 - \frac{v^2}{c^2}}} = \frac{m_0}{\sqrt{\frac{v^2}{c^2}}} - 1 \quad (28)$$

or tachyonic conditions in Table 1, for major contributions of complex eight-space to current physics.

**Table 1. Implications of and Solutions by the Complex Eight-Space**

1. Remote connectedness properties exist between physical events and process in spacetime (such as for the Bell's Theorem experimental test).
2. Anticipatory-like processes are allowed in temporal processes (Young's double slit experiment).
3. Superluminal 'signals' appear to exist in four space and subluminal in complex eight-space [4,19].
4. Tachyonic signaling are predicted in complex eight-space [3,4].
5. Expanded Lorentz invariance conditions for quantum theory to relativity theory [20].
6. Maxwell equations formulated in eight-space yield new solutions that lead to new patent technologies [21-24].
7. A model for unification of electromagnetic and gravitational phenomena [3,4] through the one-to-one mapping of the spinor calculus and twister algebra of the complex space [3].
8. A mechanism of formulating the so-called "collapse of the wave function" in terms of the geometric structure of space and interpretation of the "observer effect".
9. The complex geometric spaces is consistent with the main current body of physics [3,4].
10. Resolution of the Bohr-Einstein debate.

### 5. Bell's theorem, its experimental test, nonlocality, solved in complex eight-space

A most significant theorem about the nature of physical systems is J.S. Bell's formulation of the Einstein, Podolsky and Rosen (EPR) paradox related to the issue of the "completeness" formulation of quantum mechanics. The EPR paper was written in response to Bohr's proposal that the noncommuting operators (Heisenberg uncertainty principle) comprise a complete theory (Copenhagen quantum mechanics view). Einstein, Podolsky and Rosen define a complete theory as one in which every element of the theory corresponds to an element of "reality". Bohm [25] and others introduced additional quantum nonobservable variables or the "hidden variables" in order to make the EPR quantum interpretation consistent with causality and locality [26]. In 1964, Bell quantified the EPR statement and showed mathematically that locality is incompatible with the statistical predictions of quantum mechanics [27,28].

Any theory that generates predictions that is consistent with the quantum theory must necessarily violate the EPR-locality condition. The statement of locality is that a process of measurement performed in one spacetime region cannot perturb anything in a specially separated region. These separated regions do not connect or correlate with each other. Locality is associated with the concept of physical local realism. No EPR local theory can produce certain basic predictions of quantum theory which leads to

the incompleteness of quantum theory. Either quantum theory holds true and locality fails or vice versa. Many experiments have been performed that demonstrate the fundamental nature and completeness of quantum theory and hence violates local causes at least in Minkowski four space.

Assuming the existence of “hidden variables,” Bell determined certain inequalities, which are violated by quantum mechanical calculations of these correlations. These violations have been experimentally shown to be false and that quantum theory has been vindicated and is a complete theory. Not only do these experiments disprove a large set of hidden variable theories but leads us to the spectacular nonlocality implications as our understanding of reality, at least in four space. To quote Bell [26], “if nature behaves in accord with the statistical predictions of quantum mechanics, then there must be a mechanism whereby the setting of one measurement device can influence the reading of another instrument, however remote.” Direct intercommunications between two spatially recorded events occurs when the quantum theory is complete.

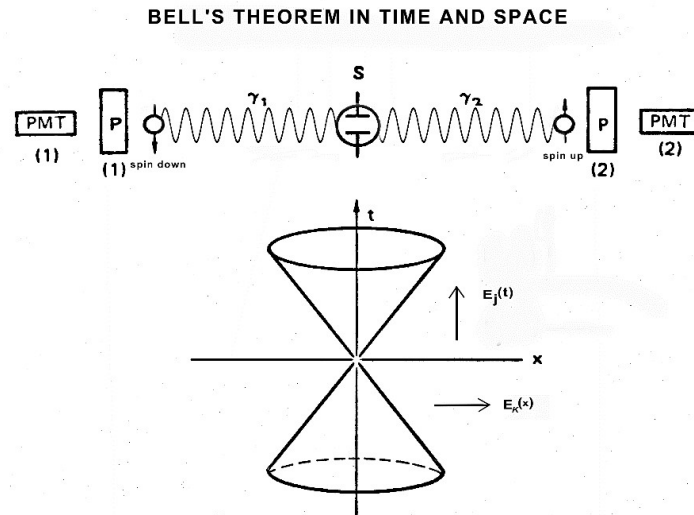
Bell’s Theorem as applicable to the correlations of two particle events is involved with the measurement of the correlated polarization of photons emitted in a two-photon decay from a singlet state source. The Theorem consists of an inequality applicable to the correlations observed in a range of different measurements. From Bell’s Theorem one can derive the corollary that no local model of physical reality can exist unless statistical predictions are in agreement with those of quantum mechanics.

Bell showed that for a simple two particle spin correlation experiment that no local hidden variable theory is constant with quantum mechanical predictions. Stapp also demonstrates that hidden variables occupy no essential role in the proof of Bell’s Theorem [29]. He asserted that no theory which predicts the outcome of individual observation conforming to quantum theory, can be local. To restate, nonlocality is inconsistent with objective realism and is independent of the observer. The locality or separability assumption states that the result of a measurement of one system is unaffected by operations on a distant system with which it may have previously interacted or become correlated or entangled.

The experimentally determined quantum probabilities, however, do not satisfy Bell’s inequalities, a fact confirmed in a number of subsequent experiments [30-35]. In fact, the fit to quantum probabilities indicates the completeness of quantum mechanics. This means that nonlocal effects must necessarily exist. This has led us to hotly debated issues of where we stand on an ontological basis in the micro-domain and possibly in the macro-domain. The confirmation of the violation of Bell’s inequalities produces the strong indication of non-locality, thus expanding on quantum and in some instances, possibly, classical causality in the usual four space. These nonlocal interactions of entangled particle spin mechanisms occur between particles over large distances, over meters or more. This nonlocal correlation is considered to be instantaneous.

Bell discusses a specific experiment, Stern-Gerlach measurements of two spin one-half particles in the singlet spin state moving freely in opposite directions. If the spins are called  $s_1$  and  $s_2$  we can make our component spin measurements remote from each other at position (1) and (2), such that the Stern-Gerlach magnet at (1) does not affect (2) and vice versa in terms of a four-space locality assumption. In terms of spin photons, the particle events can be detected by photomultipliers often passing through polarizers. We discuss the photon experiment arising from  $\text{Ca}^{40}$  singlet state decay moving  $180^\circ$  from each other [14].

Since we can predict, in advance, the result of measuring any chosen component of  $s_2$  at (2) by previously measuring the same component of  $s_1$  at (1), this implies that the result of the second measurement must actually be predetermined [36] by the result at the first (remote) measurement. In Bell’s proof, he introduces a more complete specification of the parameters of a system by introducing parameters which in essence are hidden variables. Bell’s proof is most eloquent and clear. He calculates the conditions on the correlation function for measurements at (1) and (2), as an inequality. See fig 4.



**Figure 4.** Schematic Diagram of the Design of the J. Clauser Bell's Theorem Correlation Function Experiment: The two detectors at position (1) and (2) are Photomultiplier tubes (PMT) and P(1) and P(2) and polarizers for photons  $\gamma_1$  and  $\gamma_2$  produced by the atomic cascade of a Calcium source, S. The detectors of photons at (1) and (2) appear to be outside each other's light cones: events  $E_j(t)$  are purely time-like and events  $E_k(x)$  are purely space-like.

Bell's formulation precise statement made it possible for Clauser and Horne [30] to test the predicted statistical distribution of quantum processes and demonstrate a laboratory instance of quantum connectedness and hence non-locality. Indeed, in Clauser's two photon system, two photodetectors remote from each other are each preceded by independent, randomly-oriented polarizers, and the statistical predictions of quantum mechanics is borne out. In the Clauser-Horne type experiment, a left hand polarizer is arranged in order to pass only a photon of a certain polarity once detected then the experiments immediately "knows" how the other polarizer is set to pass the correct spin orientation of the other photon. The signal involved must propagate instantaneously so that a theory could not be Lorentz invariant. Lorentz invariance in the usual sense, implies  $v \leq c$ . Feinberg [18] discusses the relationship between Lorentz invariance and superluminal signals, two concepts which he found to be compatible. It is not completely clear that superluminal signals must be involved to derive Bell's Theorem, but Rauscher believes that indeed Bell's Theorem implies  $v > c$  in four space and subluminal or luminal, and Lorentz invariant in complex eight-space [4]. Tachyonic signaling naturally falls out of complex eight space. See section 3.

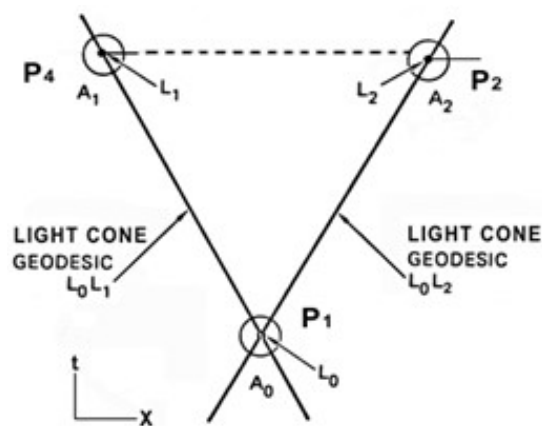
Then the conclusion from Bell's Theorem is that any hidden variable theory that reproduces all statistical predictions of quantum mechanics must be nonlocal (implying remote connectedness). Of course, thus far, all these formulations involve micro-quantum properties only, but some recent formulations seem to apply to long distances macroscopic consequences of Bell's Theorem as well [14]. It is believed that the key lies in the formulation of the correlation function which represents the interconnectedness of previously entangled correlated events. At present, the Bell's Theorem correlation function has been formulated for primarily quantum systems only. Bell's Theorem is formulated in terms of a microscopic spin correlation function, usually for photons (bosons) or electrons (fermions). Clauser derives the correlation function for spin one particles. See Fig 5.

Essentially, we can formulate and maintain local realism and the completeness of quantum mechanics and entanglement (non-spatially separated) in complex eight-space. What appears to be superluminal

nonrelativistic invariant in four space, obeys Lorentz invariant in the hyper-dimensionally complex space [14]. We essentially resolve the Bohr-Einstein debates and the EPR paradox and Bell's inequality that allows locality in a hyper-dimensional space. Here practical realism and nonlocal interactions in ordinary Minkowski space and switching between the real and complex space allows us the completeness of the quantum theory (Bohr) and local realism in complex eight-space (Einstein). There is no need to add back hidden variables and the Everett, Graham-Wheeler spin off "universes" or counterfactual finiteness in the higher dimensional space [37,38].

Stapp [29] discusses the role of the macroscopic detector system in quantum measurement as well as the possible relationship of nonlocal correlations and the need to invoke the concept of superluminal signals in four space. He explores both cases, the existence of superluminal signal propagation or the luminal connections through a prior event depicted as  $P_1$  at  $A_0$  in Fig 5. These events  $A_1$  and  $A_2$  may be luminally retrocausality connected at  $A_0$  in the backwards light cone of the two events,  $A_1$  at  $L_1$  and  $A_2$  at  $L_2$ . If past light cone connections at  $L_0$  are neglected, then a remote connection between  $L_1$  and  $L_2$  would be outside  $L_1$ 's and  $L_2$ 's light cone and a space-like connection would exist, which is represented by a dashed line in Fig 5.

We formulate the two remote connected events of the Bell's Theorem test are denoted by  $A_1$  and  $A_2$  as  $P_4$  or  $P_2$  in Fig 5 here also represented by points  $P_1$  and  $P_3$  in Fig 3b. These two points are contiguous, that is local (obeying local realism) in the complex eight space. By having access to imaginary time,  $t_{x,im}$  at  $P_3$ , we have event correlations as contiguous events at  $P_3$ . In four space  $A_1$  and  $A_2$ , Fig 5 and by  $P_1$  and  $P_2$  in both Figs 3b and 5 are nonlocal. In Fig 5 the two events originate at  $A_0$  and are contiguous at  $P_3$  Fig 3b. The particles remain entangled at  $P_2$  to  $P_4$  in Fig 5. We also represent the nonlocal connection of events,  $A_1$  and  $A_2$  located at  $L_1$  and  $L_2$  in Fig 5 by either their past time retrocausality-like connection at  $P_3$  Fig 3d at  $L_0$  or as a superluminal connection (dashed line) which is space-like. See Figs 1 and 5.



**Figure 5.** The Common Point of Origin of Two Events Connected by a Light Signal. In Fig 5 is also displayed a common point of origin,  $A_0$  connected to two nonlocal events  $A_1$  and  $A_2$ . These events  $A_1$  along world line  $L_0L_2$ , and  $A_2$ , along  $L_0L_2$ , the events  $A_1$  or  $A_2$  are superluminally connected as pointed out by Stapp. The events  $A_1$  and  $A_2$  correspond to  $P_4$  and  $P_2$  of Fig 3b and  $P_1$  to  $A_0$  in that Fig. The measurement at  $P_1$  corresponds to the photomultiplier PMP1 and  $P_2$  corresponds to PMP2. We can access the backward light cone in eight-space where  $P_1$  and  $P_2$  appear contiguous at  $P_3$ , Fig 3b.

Bell's Theorem and the Young's double slit experiment can be formulated in complex eight space. For this procedure, we refer also to Fig 3c and 3d. The velocity resolution is achieved in that the nonlocal

connection of Bell's Theorem and the paradox of the Young's double slit experiment involve luminal or subluminal signaling in complex eight space. See section 5.

For a real time separation from  $P_1$  (photomultiplier detector 1) at the origin and  $P_2$  (photomultiplier detector and 2) is 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  $P_2$  and  $P_4$  along the  $t_{x,im}$  axis (Fig 3b). Hence, causality is maintained in the complex eight-space and nonlocality explained. This represents the nonlocality of remote connection.

The two remote connected events of the Bell's Theorem test are denoted by  $A_1$  and  $A_2$  in Fig 3c are represented by points  $P_1$  and  $P_4$  in Fig 5. These two points are contiguous, that is local (obeying local realism) in the complex eight space, by having access to imaginary time,  $t_{x,im}$ . In four space  $A_1$  and  $A_2$ , in Fig 5 and by  $P_1$  and  $P_2$  in Fig 3b are nonlocally connected. In Fig 5, originating from event at  $A_0$  are  $A_2$  and  $A_3$ . We represent the nonlocal points in Fig 3d where  $A_0$  corresponds to  $P_5$  and  $P_6$  to  $A_1$  and  $P_1$  to  $A_2$  in Fig 3d. This nonlocality can be made local by the introduction of an imaginary component of space,  $x_{im}$ .

We also consider multidimensional geometries in terms of complex Minkowski space which have remote macroscopic connectedness properties [4]. Although these geometries are derived in terms of the causality conditions in relativity, one finds a fundamental relationship to the microscopic interconnectedness of Bell's Theorem which can formulate a connected correlated function in complex Minkowski space.

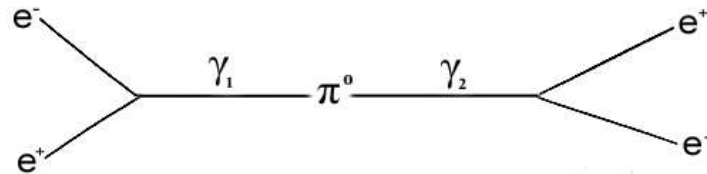
We can write a general mutual correlation function for example for an angle  $\theta$  between crossed polarization vectors for two polarizers,  $P_1$  and  $P_2$  are  $C(\theta) = \frac{1}{2} + \frac{1}{2} \cos 2\theta = \cos^2\theta$  for Clauser's experiment, or for odd integers we can write  $nC(\theta) - C(n\theta) - (n-1) \leq 0$  Bell's inequality. We can write in general  $c(\theta) = \frac{1}{2} + g \cos 2\theta$  where  $g$  is determined by the particular experiment under consideration. The magnitude of correlation function constant,  $g$ , relates to the type of nonlocal correlation experiment. For  $g = \frac{1}{2}$ , we have the Bell's Theorem for photon-photon correlation. For a specific case for  $n = 3$  then Bell's equality is  $3C(\theta) - C(3\theta) - 2 \leq 2$ .

The interpretation of the Clauser experiment and that of others such as Aspect [32] in France, at Orsay must be consistent with the predictions of quantum mechanics which is borne out by experimental tests. Stapp introduced the concept of Counter-factual definiteness (CFD) in the Fundamental Fysiks Group, in which he discussed the effect on the calculation of the probability function in Bell's Theorem [29]. He assigns a physical interpretation to the wave function of a spin which is an alternate to the one measured in the case where there are two possible spin assignments to be measured at event locations (1) and (2). Again, Bell's Theorem states that if the predictions of quantum mechanics are borne out that necessarily all connections are nonlocal. This circumstance holds only if CFD is a valid assumption. If the CFD assumption is relaxed there may be a way out of the finding that all connections are nonlocal and possibly space-like [39]. Clauser's original hypothesis had been that locality held, in a sense similar to Bohm's "hidden variable" interpretation of quantum theory.

"It is clear" as Stapp and others point out, "that Bell's Theorem has deep philosophical implications about the quantum measurement problem" Stapp adds, the test of Bell's Theorem has the most profound implications of the 20<sup>th</sup> Century [29]. Wigner [40], Wheeler [41] and others discuss great concern over the interpretation of the so called "collapse of the wave function" and other ontological hypothesis as the Everett-Graham-Wheeler (EGW) many worlds interpretation. Much work and interpretation can be made on this fascinating topic of the ontological vs. epistemological basis of quantum theory.

Other "Bell's Theorem" like experiments have been suggested by Rauscher, see Fig 6. For example, Rauscher suggests at the comparison of the plane of decay from  $\pi^0$  decay into two photons. Another suggested experiment by Rauscher [10], involves the decay of the prior neutral ( $\pi^0$ ) decay into two

photons and the sequential decay of the two photons (impinging on heavy atoms) producing electron positron pairs. The nonlocality condition implies the connection of the plane of the two (left) and (right) of the electron-positron pairs compared to each other should nonlocally be determined.



**Figure 6.** We can examine the decay of a pion,  $\pi^0 \rightarrow 2\gamma$  and then examine the relative spin orientations of the two gammas by the planes of decay of the  $e^+e^-$  pairs produced in the  $\gamma \rightarrow e^+e^-$  in three dimensions.

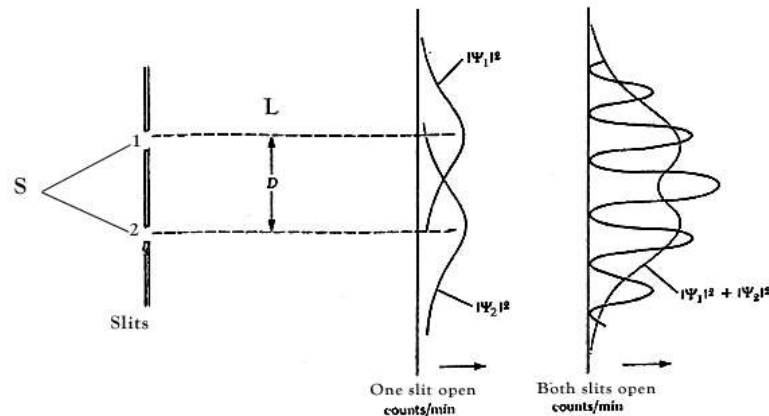
In conclusion, we assume that the particle counter efficiencies to be nearly ideal. The wave function is said to decohere to the specific state measure [6]. The system's evolution before the measurement is unknown, except for probable possibility outcomes linearly superimposed. The exact outcome linearly superimposed state, becomes actualized as a single known final state. Also it has been determined that in Bell's Theorem inequality measurement experiments, the measurement of one nonlocal event can simultaneously determine or deduce the other entangled photon. Since nonlocality exists, this does not violate the Heisenberg uncertainty principle. Since the quantum theory holds that nonlocality is a fundamental property of physical measurement, this leads us to an apparently probabilistic universe.

## 6. Quantum measurement, Young's double slit experiment, delayed choice and four-logic

Young's double slit experiment and the Bell's Theorem test maintain a domain of local realistic theories and causality realistic conditions on the manifold and maintain the Lorentz conditions. We accomplish this resolution by complexity and expand the Minkowski space which forms our complex eight space. Here we can reconcile locality and nonlocality and retain causal conditions and resolve the quantum measurement paradox. Superluminal signaling in the usual four space appears to be subluminal in the complex eight space; we demonstrate that in the complex eight-space we have subluminal and luminal signaling, this space is Lorentz invariant.

The double slit experiment developed and performed by Young was designed to examine the fundamental nature of light, particle or wave [9]. A source of monochromatic light or also particles is allowed to impinge on an opaque sheet or plate having two narrow slots where both can be open or only one can be open. The source is placed equally between both slits. After the light or particle source is emitted it goes through the plate with the slits and on to a screen. The size of the slits is small compared to the distance to the screen.

With both slits open, an interference pattern is formed with dark and light intensity bands. When only one slit is open, then only a central dot and no interference appears on the screen. Even when the source of light is of very low intensity, for example emitting one photon per second, and both slits are open, an interference patterns builds up over time. For the case of low intensity means only one photon at a time though one slit at a time. Even in this case, we have an interference pattern! It is as if a photon "knows" if one or both slits are open ahead of imaging on the screen. This leads to the hypothesis of the concept of advanced potentials by Heisenberg and others. The source appears to be a wave when both slits are open and a particle when only one slit is open. Also, a three open slits experiment yields an interference pattern similar to the double slit experiment. See Fig 7.



**Figure 7.** A Model of the Young Double Slit Experiment, the standard experimental results of a single photon with one slit open of slit 1 or 2 in center of the Fig and when both slits open an interference pattern is displayed at the far right. Note  $D \ll L$ . In the standard interpretation of the Young's double slit experiment slits 1 and 2 are denoted with their corresponding wave function and their probabilities are  $|\Psi_1|^2$  and  $|\Psi_2|^2$ .

The Young's type experiment has been performed with photons, of course, and also electrons and even neutrons and, with design modifications with atoms. Since the wavelength,  $\lambda$  of a wave-particle is inversely proportional to velocity,  $v$  or  $p = mv = \frac{h}{\lambda}$ , or  $v \propto \frac{1}{\lambda}$  for momentum,  $p$  and mass,  $m$ . To have a detectable wavelength, the velocity of the atom or perhaps even a molecule has to move more slowly. An electron wavelength is about  $10^{-13}$  cm but an atom wavelength is about  $10^{-8}$  cm so for an atomic beam to get through an interferometer, it would take  $10^5$  times as long as an electron. It is interesting how the photons or electrons or whatever is used as a source "know" to avoid certain areas on the screen, the dark bands and where to generate light bands based on one or two open slits! We consider this experiment a nonlocal interaction in space and time. The knowledge of photon path before the screen appears to indicate that Young's double slit experiment is truly a nonlocality test. But a measurement of the photons between the double slits and the screens erase the interference pattern.

The two photons passing through the two slits at different delayed time act in such a manner as to reach the screen apparently simultaneously in the complex light space. They are no longer separated and sequential, but act as simultaneous events and hence the buildup of the diffraction pattern can be understood. In the complex eight space, the photons striking the double slit plate are no longer separated in spacetime, where slits 1 and 2 correspond to  $P_1$  and  $P_2$  and connect to  $P_4$  in Fig 3c.

We can identify the two remote slits from each other with  $P_1$  and  $P_2$  in space and also for low intensity in time  $P_1$  to  $P_5$  in Fig 3c and 3d in time. Simultaneity of the photons passing through one or both slits are contiguous at  $P_4$  with access to  $x_{im}$  or  $P_6$  having access to ongoing space contiguous at  $P_6$  in Fig 3d.

We can also compare Fig 3c to Fig 3d for Young's double slit experiment in an analogous manner as we did for Bell's theorem in order to formulate it in complex eight space. We understand the Young's double slit experiment only in terms of a hyperdimensional geometry. 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  $\gamma_2(t_2)$  which appear to be emitted simultaneously. In Fig 3c, we associate  $\gamma_1(t_1)$  with being located at  $P_1$  and  $\gamma_2(t_2)$  located at  $P_3$ . Now these two photons appear to be 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  $P_1$  in Fig 3c. We can identify the two remote slits

from each other with  $P_1$  and  $P_3$  in Fig 3b and 3c in time. Simultaneity of the photons passing through one or two slits are contiguous at  $P_4$  with access to  $t_{x,im}$  or  $P_6$  having access to ongoing time centered at  $P_6$  in Fig 3d. See Section 3.

The properties of linear superposition for the Young's double slit experiment are represented in Fig 3b and 3d. In this case, a source of photons is represented. Experiments of this type have been conducted with electrons and other particles including even neutrons, which all obey the same superposition principle. Also represented in the particle experiment is the de Broglie particle-wave paradox.

We can describe the result of the Young's double slit experiment in terms of the usual four space where in Fig 3b and 3d the photons going through one or both slits at a time is represented by the four space separation  $P_1$  and  $P_2$  in both Figs. If we access the imaginary space, we can locate a point in real time,  $P_5$  where the photons are contiguous or entangled in the past and hence correlated contiguous in eight space. In Fig 3d the path to the contiguity of the two photons separated in space,  $P_1$  to  $P_2$  and time  $P_1$  to  $P_5$  are contiguous through access to imaginary space from  $P_1$  to  $P_6$ . We can represent the non-local connection as  $P_1$  to  $P_2$  in Fig 3b a point,  $P_4$  on an imaginary time axis and in Fig 3c, we can represent the connection of even low intensity photons correlated in time where  $P_1$  and  $P_3$  are contiguous by access to imaginary space,  $P_4$  to  $P_3$ . Hence, the "knowingness" of the photons is represented by their contiguous properties in four space and time in the complex eight-space and nonlocality in four spacetime.

In summary, for the Young double slit experiment for a strong source of light, we relate Fig 7 to Fig 3b. The two slits 1 and 2 in Fig 7 correspond  $P_1$  and  $P_2$  in Fig 3b and are spatially separated, but are contiguous at  $P_3$  so that the two slits or one slit case is known. For a low light source where the photons are going through slit 1 and 1 or 2 separately, these events are retrocausality connected as shown in Fig 3d at  $P_6$  and spatially causality connected at  $P_6$ .

### 6.1 Delayed Choice

We consider another similar experiment to the Young's double slit experiment as Wheeler suggested experiment in 1980 which he termed the delayed choice experiment [42]. This is based on another two particles coherent experiment where a light beam can pass through a beam splitter. The splitter is a semi-mirror (half silvered) that lets some photons through and reflects others. Any photon can then end up in one of two possible paths. Due to quantum superposition, a photon can follow both paths at once. This enables the photon to interface with itself just as any two light beams crossing paths interfere with each other create light and dark bands where these waves add or cancel each other out. This and the Young's double slit experiment gives the same kind of results even when the source of photons is of such low luminosity to only emit one photon at a time with such a time interval so as the photon travels, it goes through the complete system.

The essential feature of Wheeler's Gedanken experiment is that the choice of either one or both slits open is made after the source photon is emitted and after the choice slit opened or closed. This experiment was performed using a laser beam which uses a beam splitter instead of a plate with two slits. A half-silvered mirror reflects half the photons striking it and the other half passes through. On the other side of the beam splitter the two beams are steered both together by mirrors and then guided into a photon detector (a photo multiplier). The two paths of photon interference with each other is detected by the detector. Variations on the delayed choice experiment give the same kind of results.

An expansion on the Young's double slit experiment is the delayed choice experiment. In analogy, the Young's double slit experiment corresponds to Clauser and Horne tests of Bell's theorem [30] and the delayed choice experiment corresponds to Aspect's test of Bell's theorem [33].

### 6.2 Four Logic and Quantum Computing

An example of four logic can be seen by comparing a classical computer to a quantum computer. A

classical computer processes in the form of bits or single units of information that can be represented as 1 or 0. The 1 bit can represent on and the 0 can represent off for a yes or no. This comprises Boolean algebra. Quantum computers rely on quantum bits or qubits. Because quantum superposition can exist as 1 and 0 at the same time comprising a non-Boolean algebra. Because the quantum computers data can exist in multiple states it can perform multiple operations simultaneously instead of one at a time. This may lead to the path of big data or more secure cryptography.

In the Aristotelian or Boolean logic of yes or no or either or algebra. In four logic [43,44] we have also neither and both forming, E or O or N and B. An interesting issue that may involve four logic is the Young's double slit experiment wave particle duality and other conundrums of the quantum theory and the Schrödinger cat paradox.

The particle-wave duality is of interest. Since the formalism of de Broglie particle-wave formulism  $p = \frac{h}{\lambda}$ , for momentum is related to the wavelength,  $\lambda$ . Whether an event displays a wave-like or particle-like nature depends on the experiment one performs such as one or both slits open in the Young's double slit experiment. The essential nature of light or a particle may not be a particle or a wave but manifests as one or the other depending how it is looked at by the experimenter!

## 7. Conclusions

A new view of the role of human consciousness may be emerging in terms of its role in the structure of physical theories, particularly in quantum mechanics. We have developed a complex multi-dimensional complex Minkowski geometry where we describe nonlocal micro and macroscopic connections of events that do not violate causality. There are several motivations for introducing such a model; one of which relates to a possible macroscopic formulation of a Bell's theorem-like nonlocal correlation function that may have macroscopic and astrophysical consequences and fits to some recently observed data reconciling causality problems and superluminal signaling in ordinary four space. The additional imaginary dimensions allow for a description in which they make it possible for apparently remote spacetime events in four space to be contiguous even to the observer in eight space. Thus causality is preserved, yet acquisition of remote information is allowed.

The EPR paper arose out of the famous Bohr-Einstein debates. In this paper, we have resolved their fundamental issue between local realism and quantum non-locality. We now have a new platform in the complex dimensional space, not only to reconcile local reality and the nonlocal quantum mechanics, but may allow us to develop new quantum computing technology. This constraint places a major constraint on quantum computers. We consider quantum computing in our discussion of four logic. In the usual four space, the no-cloning theorem applies.

In the domain of complex eight-space, we can consider the role of nonlocal communication and whether we can develop a meaningful remote communication system. We have conducted some preliminary experiments that indicate it may be possible to transfer information over nonlocal space. The path of information in complex eight-space events can occur instantaneously and hence allow Lorentz invariant subluminal signaling in the higher dimensional space.

The nonlocal connection and cancelations of events in Bell's inequality, Young's double slit experiment, the delayed choice experiment, the Stern-Gerlach experiment and the Aharonov-Bohm experiment, as well as new quantum computer designs and test appear to not be mediated by a force with an equation of motion. Remote long distances correlation experiments have no apparent fall off with distances. Again, the nonlocal quantum correlation implies space-like superluminal signaling between remote correlated events in ordinary four space. As we definitely demonstrate that we have casual conditions that are maintained and Lorentz invariance obeyed and where signaling is subluminal in the complex Minkowski eight space.

It is still believed that meaningful information does not transcend the velocity of light, meaningful information is defined, in general terms, as information that cannot be predicted before a measurement

of either counter is made. Whereas the second photon or particle detected by the second counter is directly predictable once the state of the first counter result is determined.

**Acknowledgments.** Elizabeth A. Rauscher wishes to acknowledge the fruitful discussions with David Bohm and realistic models. She also gives a thank you to the advice and guidance of John A Wheeler and Eugene Wigner. Advice valuable assistance of Geoffrey Chew and Glen T. Seaborg, the latter two at Lawrence Berkeley National Laboratory, is greatly appreciated. A special thank you is given to Russell Targ, for encouragement on the development of the complex eight-space and setting up the meeting with Gerry Feinberg at Columbia University. She also acknowledges the core members of her Fundamental Fysiks Group (1975-1978) at LBNL which grew to include faculty members. She expresses her acknowledgement to Saul Paul Sirag, Nick Herbert, Henry Stapp, Geoffrey Chew, John Clauser, Jack Sarfatti and Philip Eberhard.

All the authors wish to acknowledge Gary Zukov, Fritjof Capra and Fred Alan Wolf for their pioneering efforts in the field of quantum physics and George Weissman for his ongoing encouragement. We wish to also acknowledge Richard Amoroso and Louis Kauffman for their understanding that science is the foundation for understanding the oneness of the universe and The Academy For Future Science (USA) for its support of this work.

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