Nonlocal Interconnectedness as a Fundamental Principle of Reality

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Two significant principles of the 20th century are the Heisenberg uncertainty principle and the nonlocality principles of the Einstein, Podolsky, Rosen paradox [1]. Both these elements of quantum theory have major physical and philosophical implicatio like Bell's Theorem and Space-Like Interconnect-edness and Other Collective Coherent Phenomena Involve nonlocality. We also present a discussion of the EPR paradox and other experiments that may demand a nonlocal explanation of the phenomenon they display.

The world this appears as a complicated tissue of events in which connections of different kinds alternate or overlap or combine and thereby determine the texture of the whole - W. Heisenberg, 1938.

1. Bell's Theorem and Its Experimental Verification

One of the most significant theorem about the nature of physical systems is J.S. Bell's [2,3] formulation of the Einstein, Podolsky and Rosen (EPR) "completeness" formulation of quantum mecdhanics [1]. The EPR paper was written in response to Bohr's proposal the the noncommuting operators which led to the Heisenberg uncertainty principle. This non-Abelian algebra is said to comprise a complete theory of reality, at least at the quantum domain; this is the Copenhagen view. Einstein abhorded the uncertainty prinfciple stating "God does not play dice with the universe". His vision was to determine the position and momentum of each particle in the universe and a unified field theory of the four force fields and explain all of reality. The hitch in this plan was that neither position-momentum or energy-time could not be exactly localized simultaneously by the Uncertainty Principle, $\Delta \times \Delta p \geq \hbar$ and $\Delta E \Delta t \geq \hbar$ [6]. Heisenberg's principle places restrictions on the absolute knowledge of the universe. The TOE (Theory of Everything) still holds the vision of Einstein's final theory of unification which, in Weinstreg's view is, in a sense, a view of an absolutely complete final theory of everything [7].

Einstien, in his EPR paper defined a complete theory as one in which every element of the theory corresponds to an element of "reality" that is, for example, through the quantum principle, for every election, etc. there is an assignable wave future, Ψe. If the completeness principle holdes, then the principle of nonlocality pervades the quantum world. The concept of nonlocality was not well received by the physics community. Bohm introduced additional quantum non-observable variable or "hidden variables" in order to make the EPR quantum Bell quantified the EPR statement [8, 9] and demonstrated mathematically that locality is incompatible with the statistical predictions of quantum mechanics.

The locality or separability assumption states that the result of a measurement on one system is unaffected by operations on a distant system with which it may have prviously interacted or had become correlated, that is a lack of quantum entanglement. Bell states that "no theory of reality, compatible with quantum theory can require spacially separate events to be independent". That is, the measurement in the Clauser et. al. experiment, of the polarization of one photon determines the polorization of the other photon at its respective measurement site. 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 another one at (2) and vice versa. Since we can predict, in advance, the result of measuring any chosen component of s_2 at (2) by previously measuring the same component spin of s_1 and (1), this implies that the result of the second measurement must actually be predetermined by the result at the first (1) remote from (2) measurement. In Bell's proof, he introduces a more complete specification of the parameters of a system by introducing parameters which in essece 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 [9].

Bell's precise statement in his theorem made it possible for Clauser and Horne [10] to test the predicted statistical distribution of quantum processes and demonstrate a laboratory instance of quantum connectedness or nonlocality. Indeed, in Clauser's two photon system for spin 1 particles, two photodetectors remote from each other are each preceded by independent, randonly-oriented polarizers. The statistical predictions of quantum mechanics is borne out in the measurements made at the two photomultiplyer tubes (PMT); see Fig. 1.

In Bell's words "there must be a mechanism whereby the setting of one measuring device can influence the reading of another instrument, however remote" (they remain quantum mechaincally entangled). Moreover the signal involved must propagate instantaneously so that a theory could not be Lorentz invariant. Lorentz invariance in the usual sense, implies $v \le c$ [11]. Feinberg [12] discusses the relationship between Lorentz invariance and superluminal signals which he found not to be incompatible. It is not clear that superluminal signals must be invoked to derive Bell's theorem [12,14] but we believe that Bell's theorem demands $v > c$ or simultaneity.

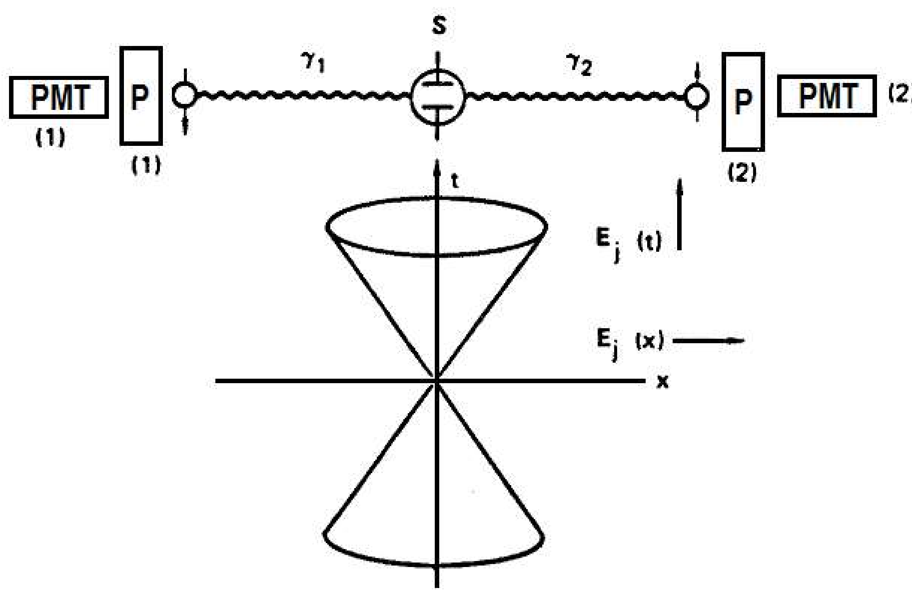

Figure 1 Schematic Diagram of the Design of the Clauser Bell's Theorem Correlation Function Experiment: The two detectors at positions (1) and (2) are Photomultiplier tubes (PMT) and P(1) and P(2) and polarizers for photons, Υ_1 and Υ_2 produced by the laser-stimulated radiative atomic cascade of a Calcium source, *S* that emits entangled photon pairs. The detectors of photon polarization at (1) and (2) appear to be outside each others' light cones; events $E_j(t)$ are purely time-like and events $E_k(x)$ are purely space-like.

Then the conclusion from Bell's theorem is that any hidden variable theory that reproduces all statistical predictions of quantum mechanics must be nonlocal, which implies remote connectedness. Of course, thus far all these formulations involve microproperties only, but recent formulations seem to imply possible macroscopic consequences of Bell's theorem as well. It is believed that the key lies in formulating the correlation function representing the interconnectedness of previously correlated events, see Figure 1.

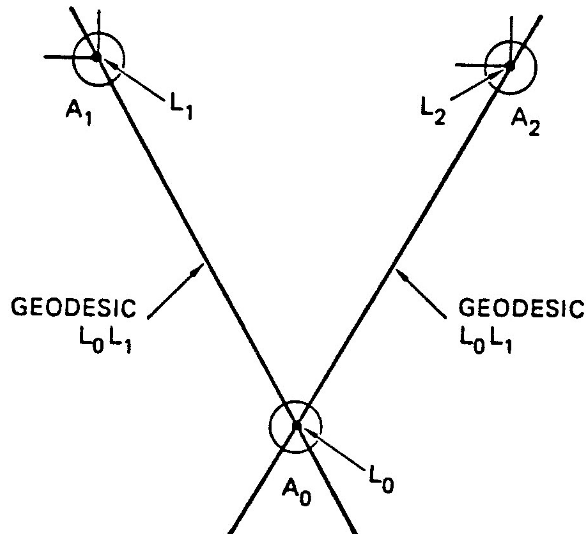

Figure 2. Common Point of Origin of Two Events Connected by a Light Signal: H. Stapp represents the non-local connection of two events E_1 at A_1 and E_2 at A_2 as connected by geodesics to a prior event E_0 at A_0.

Bell's theorem is formulated only in terms of a microscopic spin correlation function, usually for photons (Bosons) or electrons (Fermions). There may be some macroscopic non-quantum remote correlated effects. A number of remote macroscopic effects do occur over kilometer distances for the Bell's theorem experiment discussed in section 2. There exists non-quantum remote correlations. One such example of a Bell's theorem like correlation is the Brown-Twiss effect [15] which involve long distance correlation. Stapp recently has expanded the pragmatic view of Bell's theorem and discusses the role of the macroscopic detection apparatus as well as the possible role of superluminal signals. He explores both cases for superluminal propagation or subluminal connection issuing from the points in common to the backward light cones coming from the two regions. Figure 2

We can write a general correlation function $C(\Theta)$ for example for an angle Θ between polarization vectors in two polarizers as $C(\Theta) = (1/2 + 1/2)\cos 2\Theta = \cos^2 \Theta$ for Clauser's experiment, or for odd integers we can write $nC(\Theta) - C(n\Theta) - (n-1) \leq 0$ which is Bell's inequality, specifically for $n = 3$ then $3C(\Theta) - C(3\Theta) - 2 \leq 0$. We can write in general $C(\Theta) = (1/2) + g\cos 2\Theta$ where g is determined by the particular experiment under consideration. See Figure 3. The magnitude of correlation function constant, g, relates to the type of non-local correlation experiment. For $g = ½$, we have the Bell's theorem photon-photon correlation. For $g \sim 0.25$ is the value of g related to the Furry experiment and $g \sim 0.15$ is the value of g related to the Brown-Twiss experiment. Both of these latter experiments relate to macroscopic correlation. [16,17] For example, the Brown-Twiss effect involves the macroscopic process of the small angle subtended in observing light from distant stars producing parallel rays of light such that their wave fronts are linear which is able to be described as a coherence function or correlation function. Although the photons appear correlated one cannot use the Brown-Twiss effect to demonstrate nonlocality. For $0.361 \leq g \leq 0.5$ (the shadowed region in Figure 3) we have the only region in which one can experimentally demonstrate nonlocality. [17] It is important to note that the macrosystem phenomena of the Brown-Twiss effect and Furry experiment lie outside this region. It may be possible to calculate a macroscopic correlation function in a framework which will allow us to test nonlocality.

2. More Recent Long-Distance Confirmations of Bell's Nonlocality

The physics of nonlocality has been repeatedly verified even over hundrreds of kilometers. This research verifying nonlocality covers the period from 1971 to 1998 when one of us (EAR) met John Clauser at a meeting with David Bohm in the 1970's at Berkeley LBNL, at University of London Birkbeck College meetings, with Alan Aspect at Orsay, France and the more recent long-distance measurements of Gisin, et al in Italy.

In the Clauser experiments the position of the polorizers are set before the photons leave their source to reach the photomultiplyers. Aspect added a delayed chaise component to the experiment in which the polorizers are randomly set after the two photons leave the source. The photon's spin remains correlated in both cases. One of us (EAR) observed both experimental set ups and was extremely impressed with the Clauser and Aspect experimental designs and implimentations. This most exciting research in current quantum physics is the investigation of what Bohm calls quantum-interconnectedness or nonlocal correlations. As we stated, first proposed by Einstein, Podolsky, and Rosen (EPR) in 1935, as evidence of a defect in quantum theory, and later formulated as a mathematical proof by Bell. It has now been repeatedly experimentally demonstrated that two quanta of light emitted from a single source, and traveling at the speed of light, in opposite directions maintain their connection to one another, so that each photon is affected by what happens to its "twin" many kilometers away, (Aspect et al; [18] Bell, [3]; Freedman & Clauser [19]; Gisin et al. [20,21]).

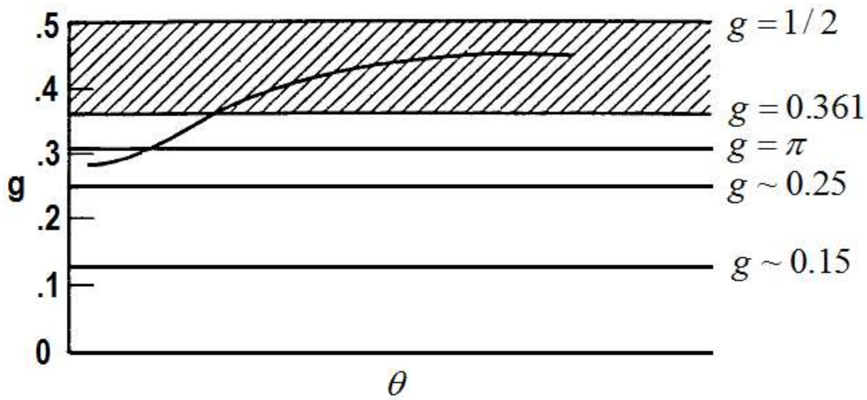

Figure 3. Relationship of the correlation function constant in various nonlocal correlation experiments. the curved line represents a plot of g(Θ) for n odd in the Bell's theorem correlation function C(Θ).

Clauser recently described his impressions of these nonlocality experiments to EAR. He said that quantum experiments have been carried out with photons, electrons, atoms, and even 60-carbon-atom Buckyballs. He said that "it may be impossible to keep anything in a box anymore." Bell emphasizes, "no thoery of reality compatible with quantum theory can require spatially separate events to be independent." This is to say, the measurement of the polarization of one photon determines the polarization of the other photon at their respective measurement sites. This surprising coherence between distant entities is fundamental to the basis of nonlocality which is a property of both space and time. In writing on the philosophical implications of nonlocality, Stapp at LBNL and the Fundamental "Fysiks" Group states that these quantum connections could be the "most profound discovery in all of science" [9,22].

Bohm argues that we greatly misunderstand the illusion of separation in space and time. In his physics book, The Undivided Universe (Bohm and Hiley [23]), he discusses this illusion as he writes about the quantum-interconnectedness of all things. Bohm says "The essential features of the implicate order are, that the whole universe is in some way enfolded in everything, and that each thing is enfolded in the whole." This is the fundamental statement of the metaphor of the holographic ordering of the universe. It says that, like a hologram, each region of spacetime contains information about every other point in spacetime. This model was inspired by the indications of nonlocality in Bell's theorem. Bohm continues:

> …all of this implies a thorough going wholeness, in which mental and physical sides participate very closely in each other. Likewise, intellect, emotion, and the whole state of the body are in a similar flux of fundamental participation. Thus, there is no real division between mind and matter, *psyche* and *soma*. The common term psychosomatic is in this way seen to be misleading, as it suggests the Cartesian notion of two distinct substances in some kind of interaction.

In the holographic universe of Bohm, there is a unity of consciousness, a "greater collective mind," with no boundaries of space or time. Bohm goes on to describe the famous Wheeler delayed choice experiment. He writes that experiments "can be designed to show that, according to quantum theory, the choice to measure one or another of a pair of complementary variables at a given time can apparently affect the physical state of things for considerable periods of time before such a decision is made". Such complementary variables are typically momentum and distance, or phase space variables,or in Wheeler'sexperiment they refer to the dual wave and particle nature of light, as observed in a two slit interference apparatus.[24] We discuss the design of Wheeler's developed chase experiment in Section 3.2. The Bell's theorem correlation of distant events and the principle of nonlocality is one of many forms of nonlocal interaction. See chapter 2. It is clear that this principle of nonlocality has profound inplications about the nature of nonlocality. The fundamental nature of nonlocality supercedes either just microscopic or the macroscopic phenomena and may occupy one point of commonality. The cover space, of which the quantum domain is a subset, is expressed in a complex Minkowski 8D and 12D space. In Section 2 we describe some of the possible implications and interpretations of Bell's theorem and it's verification.

Bohm and Hiley express their assessment of the fundamental nature of reality based upon nonlocality as an acting principle of the universe. They state the following: "Our attitude is that we can sooner or later drop the notion of the quantum potential (as we can drop the scaffolding when a building is ready) and go on to radically new concepts, which incorporate the wholeness of form which we feel to be the essential significance of quantum descriptions. This implies that we have to go deeply into all our basic notions of space, time, and the nature of matter, which are at present inseparably intertwined with the idea of localizability, i.e., that the basic form of existence is that of entities that are located in well-defined regions of space and time. We have instead to start from nonlocality as the basic concept, and to obtain 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" [24]. The complex 8-space, see Chap. 2, is intrinsically a nonlocal spacetime geometry. Locality becomes a condensed approximation to an exact complete nonlocality.

3. Implications of Bell's Nonlocality Theorem

In this section, we explore some of the physical interpretations of Bell's theorem as well as the ontological and epistemological, philosophical and possible metaphysical implications of the theorem. The experimental verification of nonlocality and hence the completeness of the quantum theory leads to the conclusion of the fundamental existence of nonlocal interactions. In this sense is there some super psi wave function, Ψ that was the origin of quantum entanglement at the big bang? Did this Ψ function lead to everything remaining correlated throughout cosmic evolution? In reference [22], Stapp and others discuss current physical theory and nonlocality. He states that "…the universal on a very basic level could be a vast web of particles, which remain in contact with on another over any distance and in no time".

The Fundamental "Fysiks" Group also called the Fundamental Physics Group, was started, organized and chaired by E.A. Rauscher for three years at LBNL [9,25]. Stapp stated in the F"F"G 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. [6,22,26].

4. Conceptual and Philosophical Implications of Bell's Theorem

4.1 BELL'S THEOREM

If the statical predictions of the quantum theory are correct, then principle of local causes is false. A Tacit assumption is that the photon counter efficiencies are not limited, in principle [25].

4.2 PRINCIPLE OF LOCAL CAUSES

What happens in a spacetime region, "A" does not depend on variables subject to the control of an experimenter in distant space-like-separated region, "B". Stapp term sthis contra-factual definiteness and in addition to locality, CFD involves assigning reality to the quantum state wave function, Ψ, whether it is the state measured and observed or not [25]. See Figure 2.1 in Chap. 2.

4.3 SOME POSSIBLE CONCLUSIONS ABOUT BELL'S THEOREM

- Counter efficiencies are limited in principle.
- Statistical prediction of the quantum theory is not always correct.
- Pragmatic Philosophy termed the Copenhagen View of Quantum mechanism should be accepted according to Clauser [27]. We should concern ourselves with relationships between observations and practicality and not with models of external reality.

Arguments For the Copenhagen View

- Limitation on the Mind of Man: Our minds are probably geared to the problem of human survival by forming expectations about future experiences on the basis of past ones. (Pragmatist/Mechanist)
- Utility: To be useful science should concern itself with only experimental consequences.
- Verifiability: We can know the "truth" only through experiments. (Wheeler, "practical ontology" [28].

4.4 CONTRA-FACTUAL DEFINITENESS FAILS

The concept "does not depend on hidden vaiable…" used in theories which involve "contra-factual definiteness," the assumption that what would have happened if the experimenter had done something that he in fact did not do, is assumed to have some definite state which is an unknowable thing. (epistemology) [29]

- Does quantum philosophy rule out contra-factual definiteness? In the double-slit and similar interference experiments "quantum philosophy" Copenhagen View dictates that we not think simultaneously about "what did happen and what would have happened" if some alternative experiment had been performed. However, quantum philosophy denies neither that the experimenter could have conducted another experiment, to quote Bohr: "…our possibilities of handling the measuring instruments allow us to make a choice between the different complementary types of phenomena we want to study" nor that "the other experiment would have had some definite result if it had beeen performed." It denies, rather, the metaphysical interpretation that the particle always goes definitely through one slit or the other. Pragmatic quantum philosophy yields economy that is particles and waves become "unified" …but at a price: no description or reality is then possible from this approach, hence the quantum theory says nothing fundamental about the nature of reality.

- Models of Reality that violate contra-factual definiteness consideration of models of reality incompassing quantum phenomena is contrary to the "wisdom of elders of quantum theory" i.e. the Copenhagen View. [29]

- One possible world: hence no hidden variable as Bohm hypothesized [30]. Ordinarily one thinks that either the experimenter has a choice, or if he/she has no choice i.e. if everything is strictly deterministic then at least one can conceive of a world in which the "other" possible experiments were performed. Bell's theorem then implies that it is not possible to even conceive of these other worlds, if they are required to conform to quantum theory and the results in "A" not "B" do not depend on which experiment is conducted in "B" not "A".

- All possible worlds exist: via Everett-Graham-Wheeler (EGW) [31]. At each experiment Ψ_i, the world breaks into, for example, 16 different worlds, each with an appropriate "weight" (this model is suggested by the Everett-Graham-Wheeler many-world interpretation of quantum theory. Note: Wheeler told this author (EAR) in 1978 that he no longer subscribes to the EGW model.

4.5 POSSIBLE INTERPRETATIONS OF THE WAVE FUNCTION Ψ

- The wave function represents one to one mapping to the real world or to the probabilities of possible states of occurances in the world for the Schrodinger interpretation of quantum mechanics or $\Psi^*\Psi$ or the probability as a fictional mathematical symbol such as in classical statistical or stochastic mechanisms.

- Quasi-Real Potential model of Heisenberg represented the possibilities of what could happen. [26, 32]

4.6 OBJECTIONS TO THE REALITY OF THE QUANTUM THEORY

- Which represents the mathematical properties of probability function.
- The idea that the wave function, Ψ represents reality originates in misinterpretation of Copenhagen claim of completeness.
- There is no fundamental relativistic form Ψ outside of the Dirac equation.
- Chew put forward the concepts approximate completeness and objectivity [33].

4.7 LOCALITY FAILS

- Nonlocal collapse of the (real) or actual wave function.
- Collective coherent nonlinear term in the quantum wave equation [34].
- Psychokinetic Effects and telepathy (Gedunkenbertrangurg) [32].
- Continuous Nonlocal Reality (Problem of time and space ordering and the nature and properties of causality).
- Discrete Nonlocal Reality or the Theory of Events via Stapp, for example [25].
- Bell's theorem and the Clauser, Aspect and Gisin experiment proves locality fails [10,18,21].

4.8 CONCLUDING REMARKS

- The authors hold the concept that the quantum theory holds true and locality fails.
- That the wave function Ψ , in the theory of mathematical representation of physical properties, events and practices is valid.
- That nonlocality is true of the physical world.
- That consciousness is behind and operates throught every physical event and hence one can extrapolate to universal consciousness [35-38].
- The EGW model is only valid in a Wigner-Rauscher nonlinear quantum formalism. In a linear theory, neither the EGW model or Bohm's Hidden Variables can be proved and hence are not practical.
- All measurement observation or interaction proves consciousness exists and the self-referential aspect of consciousness may imply that what is measured is aware of its change of state and is therefore conscious. If a system that is constructed in a suitable manner as to be sensitive to a intention interaction or a remote mentally effected system [6,39,40] is effected by human consciousness is it conscious as remote mentally effected system? Is such a system and perhaps all systems such as a cat, rat, or knat conscious? It appears to be fitting to end this essay on a question. It is less destructive to utilize a rat or knot paradox experiment than a cat paradox experiment? A cat is aware it is alive, a rat also, what about the Ψ_{alive} state for a gnat? Is there a Ψ_{dead} state for a cat, rat or gnat, much less a human?! Certianly, Bell's theorem and its test have lead us into a new age, where before for many centuries of the abhorrence of "action at a distance" has returned to us in a new form, not with Newton's gravity but at a more fundamental level of the quantum domain. [41-43] See Figure 4.

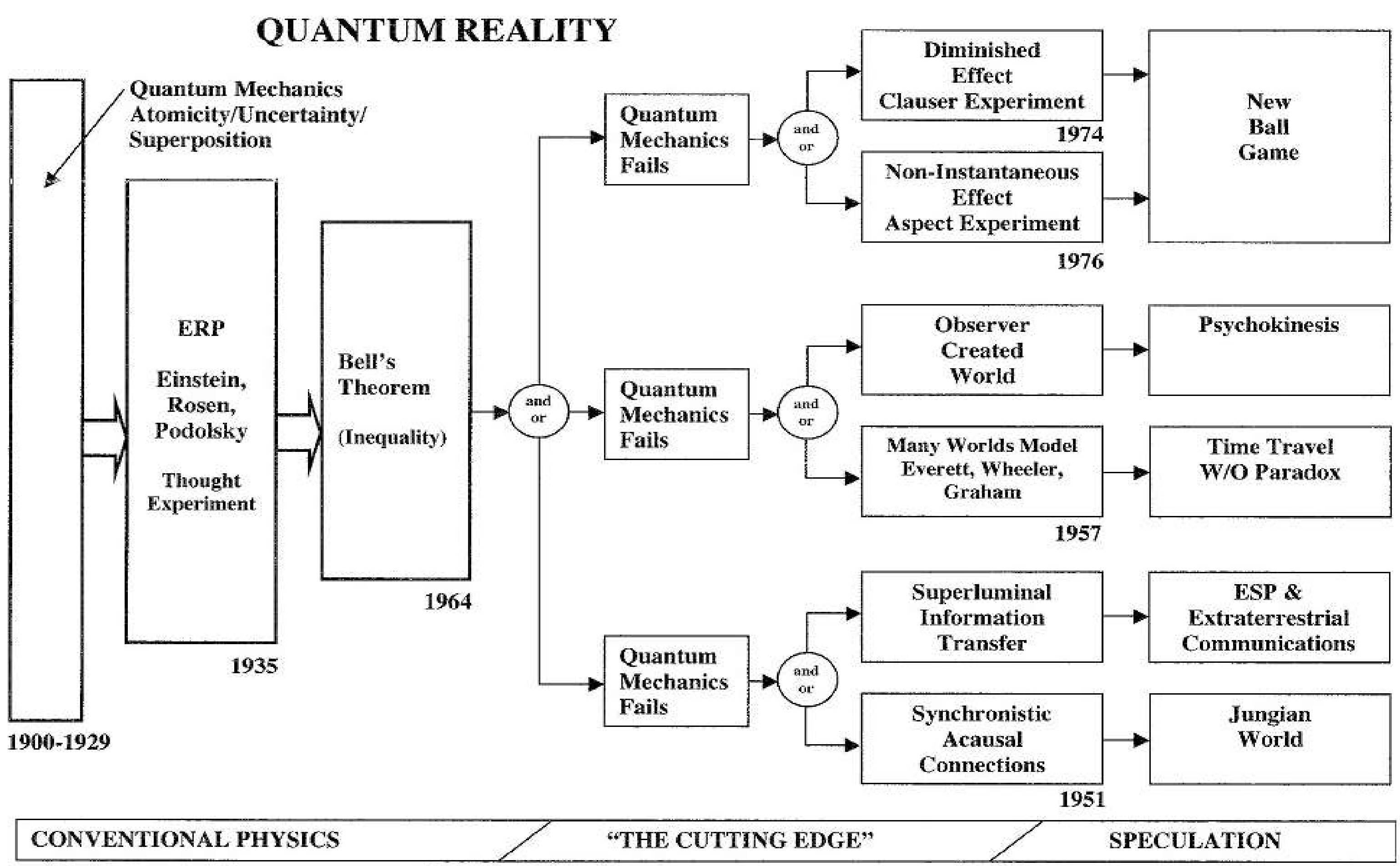

Figure 4.4 Historical development of quantum theory from turn of the last century through second half of that century to it's current status. Collective construct of the members of the Fundamental "Fysiks Group" at LBNL organized by E.A. Rauscher of the Department of Theoretical Physics LBNL.

5. Other Nonlocal Interactive Phenomenon and the Particle-Wave "Paradox" Resolved

In this section, and its subsections, we present a discussion of other theoretical constructs experiments that appear to exhibit nonlocality. The Young double slit experiment [44] and Wheeler's delayed chaise experiments [45-47] not only illucidate some of the quantum properties of nonlocality, even through Young conceived and conducted his experiment before the development of the quantum theory, but some of the issues related to the wave-particle paradox, potential models and possible nonlocality. Whereas, light and even billiard balls via de Broglie waves, $p = \hbar / \lambda$ exhibit wave and particle-like properties. The issue of nonlocality is not an issue of locality and nonlocality but nonlocality exits as a fundamental regime and that is it. The Ahoronov-Bohm experiment is discussed and can be interpreted as displaying the occurrences of nonlocality. Other interesting frame of reference and apparent nonlocality are considered such as Mach's principle.

5.1 YOUNG'S DOUBLE SLIT EXPERIMENT AND ITS EXTENSION, THE WHEELER DELAYED CHOICE EXPERIMENT

The reason Young developed and conducted his research was to resolve whether light was a particle or a wave, a hot discussion of his time and also now [44]. Wheeler expanded this experiment in his delayed choice design, which more closely analogous to Aspect's experimental test of Bell's theorem. Young's double slit experiment of 1803 was designed to elucidate whether light was a particle or a wave. A variety of experiments and theories suggested wave like or particle like properties for light. Sir Issac Newton stuck with the corpuscular-particle theory of light even though he conducted fifteen years of optic experiments involving reflection and refraction. Christiaan Huygens and others thought that light was wave like in nature and showed that light considered as a wave could travel in slight lines and follow the laws of reflection and refraction. He interpreted light to be a longitudinal wave with oscillations taking place along the line of propogation. Thomas Young's double slit experiment, with both slits open, demonstrated the existence of interference patterns of a wave nature of light, whereas, with only one slit open, only a spot of light is observed on the screen. Only light as a wave phenomenon would be consistant with a light source passing through two separate narrow slits that spred out and overlap to form light and dark interference bands at the screen. [44].

In the experimental case in which the beam intensity of photons or electrons is so low as to allow the passage of only one single particle through one slit, a defraction pattern will appear on the screen. If, in another distinct experiment, one slit is covered, no defraction pattern occurs. The Young's double slit experiment is schematically represented in Fig. 5a and 5b. The appearance of the pattern on the screen when both slits are open and when a particle passes through one slit seems to imply that the particle or photon appears to "knew" or carries information to the screen that contained information about what would have happened had the particle gone through the other slit concurrently or simultaneously. The so termed "knowing" the other slit is open or closed by the single photon or electron appears to demand a form of nonlocality. A pilot wave or advanced potential appears to be an attempt to find a mechanism for this nonlocality just as the hidden variable hypothesis of Bohm is an attempt to explain Bell's nonlocality. Augustine Jean Fresnel furthered Young's work, which led to the construction of a mathematical basis of a wave theory of light. Young and Fresnel adopted the transverse theory of light.

Newton's great influence before Young and others, led to many years of the acceptance of the corpuscular nature of light, which he proposed. In fact, many years later, after Young, Huygens, Fresnel, et. al proposed the wave theory of the nature of light, Einstein presented the corpuscular-particle quantum nature of light having an energy $E = h\nu$ where ν is the frequency of the light. In 1905 Einstein published five papers, (his *annum mirabilis*) three of which were of major inportance, one dealt with the photoelectric effect. This effect involves light shown on certain metals was found to stimulate the emission of electrons. Einstein applied Planck quantum, momentum $P = \hbar / \lambda$ where $\hbar$ is Planck's constant and λ is the wave length of light to the photoelectric process.

Experimental work had been conducted earlier in 1902 by Lenard and earlier by Hertz. Experimental determination showed that the intensity of the emitted electrons does not depend on the intensity of light but on its frequency. Higher intensity causes more electrons to be emitted. Einstein's theory predicted the experimental results precisely. So is light a particle or a wave? What is the fundamental nature of light? This history led to the particle wave paradox. However, nature does not admit of a paradox and paradox is caused by our lack of understanding of how nature works. Both waves and particles however, obey quantum nonlocality. This and other paradoxes may require moving beyond Aristotelian logic of an either–or concept. At its most basic nature, light may be neither or both (4-logic) [38] a particle or a wave but display particular attributes depending on what experiment is performed to examine its nature.

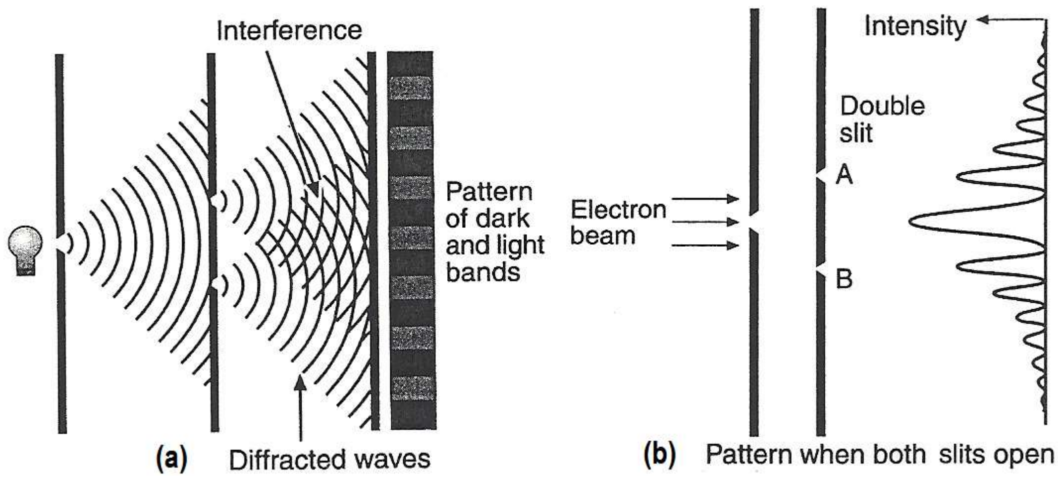

Figure 5 Double-slit experiment 5a) with light. When a beam of pure light passes through the experiment with the two holes open, the diffracted waves interfere to produce a characteristic pattern of light and shaded regions. 5b) with electrons. If one fires an electron beam through the experiment with two holes, one gets an interference pattern, as if the electrons were waves (de Broglie waves). The brightest part of the pattern is midway between the two holes. One does not get the pattern one would expect by adding up the two patterns corresponding to particles going through each of the two holes independently, which would give two bright peaks, one behind each hole for pure particle like properties of the electrons.

Huygens and Young first assumed light was a longitudinal wave. Then the double refraction of calcite or Island spar was carefully observed by Erasmus Barthalin. Objects observed through the crystal are refracted through two different angles. Fresnel's explanation of this phenomena was that one ray could be considered as a wave oscillating in one particular plane, the primary ray, and the other wave, the secondary ray, oscillated in a plane perpendicular to the first plane. These observations led to the transverse mode of light propogation. Young changed his mind and went with the transverse model of light. There is an analogy between the particle wave paradeox and the Hertzian – non-Hertzian wave paradox, that is it depends on what experiment one conducts and the corresponding relevant formalism.

However, the argument continues over the wave-particle paradox. Just as water supported water waves, light in vacuum was considered to be supported by the lumeniferous or light-carrying ether, sometimes spelled aether. If light was longitudinal in oscillatory nature, the aether could be considered a fine gas like substance, but transverse waves can be transmitted through solids and hence because the velocity of light is so great, a very rigid solid at that. Some physicist of this era returned to the particle concept of light.

The aether abandonment came with Michelson's and later the Michelson-Morley experiment that used interfronetry to measure the earth's movement through the aether, conducted with Edward Morley. The concept was that the aether was motionless, comprising an absolute frame of reference, and the earth traveled through it. It was expected from the Michelson-Morley experiment that interference would be observed in right angle light beams measured in parallel and perpendicular to the motion of the earth through the aether. No or few interference fringles were found – no aether? The vote was yes. Einstein's special theory is definably aether free. However, the aether model is not dead, as other aether models have arisen, some primarily mathematical in nature. [50]

5.2 DELAYED CHOICE AS AN EXTENSION OF YOUNG'S DOUBLE SLIT EXPERIMENT

In the Aspect experiments the choice of the position of the two polorizers is made after the photons leave the source; the results of this experimental set up also obey the inequality and nonlocality of Bell's theorem [18]. A modification of Young's [44] double set experiment is proposed by Wheeler [45-47] termed the delayed choice experiment. The double slit experiment did much to clarify certain aspects of the Bohr-Einstein debates on "does a God play dice with the Universe?" [4] That is, in the world of quantum theory, no elementary phenomena is a phenomena until it is recorded (and analyzed). This is the issue proposed by Wheeler who considered the Universe as a participatory Universe (which is counter to Bohr's Copenhagen view). It appears to us that the back cloth of nature is fundamental in science to deducing the nature of reality, not just the process of analysis of experimental data. [49,50]

The double-slit experiment is considered both in the familiar Young's version and in the "delayed-choice" version. [46,47] The familiar experiment includes the source of photons at the bottom left, the entering slit, the first lens, the double slitted metal screen that covers it, and the photographic plate that registers interference fringes. In the delayed choice version, the continuous source of illumination on the bottom left by a source that gives off one photon per timed flash. The photographic plate is replaced to make it like a Venetian blind. We perform a last-minute choice, after the photon has already traversed the double-slitted screen, whether to open this blind or close it. Closed, it registers on a blackened grain of silver halide emulsion the arrival of that photon "through both slits" along both paths. Opened, it allows the light to be focused by the second lens on the two photon counters. Since there is only one photon, only one counter is activated and tells "through which slit the photon has passed through the screen, whether it shall have passed through only one slit or both. All the features of the photographic plate at the right and the slices of that plate are what convert the slats into a venetian blind like structure. See Fig. 6.

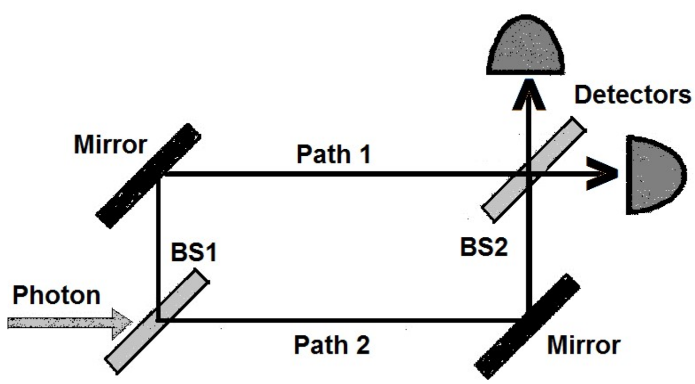

Figure 6 Wheeler's delayed choice experimental set up. Displayed is the photon source, then originally double slited metal screen on a first lens, BS1 to the second lens, BS2 where the photographic plate was made into a Venetion blind-like congiguration which could be open or closed after the photon leaves the source and before it enters the photosensitive detectors.

As in Wheeler's description all the features to the right of the photographic plate, including the slicing of the plate into venetian blind like slats are fundamental to the delayed chaise experiment. A photon enters from the left and is recorded on the photographic plate by the blackening of a grain of silver bromide emulsion or silver halide in general. No matter how great the spacing in time between one photon and the next, the record of arrivals shows the standard two-slit interference pattern, basis for deducing that each photon has "gone through both slits", a divided photon? Not possible. One can also determine "through which slit" each quantum goes, Einstein argued, by measuring the vertical component of the kick that the photon imparts to the photographic plate. If it comes from the upper hole it kicks the plate down and from the lower hole, it kicks the plate up.

Einstein objected, stating that, through which slit did the photon go and through both slits is a logical inconsistency of the quantum theory. Bohr responded that we have conducted two separate experiments, not one. We can fasten the photographic plate to the apparatus so it will not move up and down. Then we can register the interference fringes. Or we can free it to slide up and down in a slot, not shown in figure. We can then measure the vertical kick of the photon. We cannot perform both experiments at the same time according to his complementarity principle. [4] The delayed choice experiment further exemplifies the property of nonlocality.

An obvious experiment is the triple or multiple slit experiment. What does adding another slit do to the interference pattern from the eight possible combinations for the photon to go through of open and closed slits. Max Born, in the 1920's, proposed that only pairs of photons can interfear and that adding one or more slits would not contribute any changes to the two-slit interference pattern on the screen. There is no clear reason why quantum interference stops at two slits.

The test of the three or more slits experiment seemed an obvious one to us. It is only recently that U. Sinha et. al. of the University of Waterloo, Canada conducted experiment using three parallel slits in a stainless-steel plate, each 3 x 10^{-3} cm wide and 3 x 10^{-2} cm tall. [48] Various combinations of the three slits can be open or closed. The results demonstrated that the three-slit interference pattern is the same as from a single or double slit interference pattern, that is no new fringles were observed. [51] More verification is of interest with electrons and other particles from the source. It appears, through that the Born hypothesis holds. Let us now examine some aspects of nonlocality that are macroscopic in nature and may relate to the nonlocal nature of consciousness [14,49-51]

5.3 THE AHARANOV-BOHM EXPERIMENT, FIELDS AND POTENTIALS AS MECHANISMS OF NON-LOCAL INTERACTIONS

Another interesting experiment and theory is the phase shift observed in the coherence of two electron beams in the Aharanov-Bohm effect. Changes in interference patterns are produced outside the actions of the fields of $\underline{E}$ and $\underline{B}$ and are ascribed to the action of the vector and scalor potentials $\underline{A}$ and ϕ. In a sense, the interferometry effect of these two beams, once correlated maintains a specific phase shift through the nonlocal interaction of the fields. The $\underline{E}$ and $\underline{B}$ fields are regarded as pimary because the field energy transfer is expressed in terms of them as the Poynting vector and the momentum transfer or Lorentz forces is also expressed in terms of $\underline{E}$ and $\underline{B}$. The potentials were introduced to obtain the canonical formalism. Ahoranov and Bohm [52] theoretically formulated conditions, using a solenoid for conditions where $\underline{\mathrm{A}}$ and ϕ have physical consequences where both $\underline{E}$ and $\underline{B}$ are zero. A number of experiments have been performed to confirm the existence of this effect such as in [53]. Experimental tests demonstrate that outside radiation fields pure potentials can exist without their associated E and B fields. See Fig. 7.

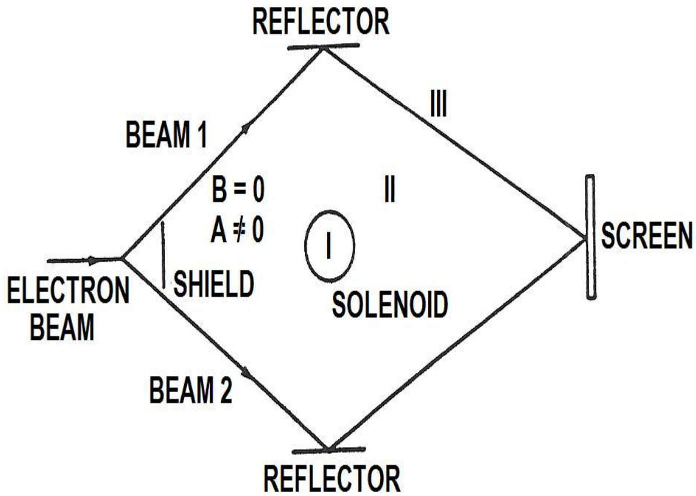

Figure 7. The schematic of the Aharonov-Bohm interferometry experiment with time – independent vector potential.

In the Aharanov-Bohm experiment [52], a coherent beam of electrons is split into two parts by a metal foil and each beam going to opposite sides of a centrally located solenoid. See Fig. 7. The solenoid is shielded by a thin plate. The two electron beams flow very close to the cylindrical solenoid of radius *R* and a length, *l* and *N* the number of windings *N* with a current flow of *i*. The magnetic field inside at the center of the solenoid is $B = \mu_0 (Ni/l)$ and zero at its surface. Dependence on the $\cos\Theta$, where Θ is the angle from the center to the surface of the solenoid. After being reflected, the two electron interferences fringes are measured at the screen. This set up insures that no fields exist outside the region of the solenoid. It was also assumed without $\underline{E}$ and $\underline{B}$ fields, no $\underline{A}$ and ϕ effects would be observed. However, the theoretical approach of Aharanov and Bohm and experimental tests determine a phase shift between the two beams of electrons at the screen demonstrating the effect of $\underline{A}$ and ϕ outside of $\underline{E}$ and $\underline{B}$. The phase shift is given as

$$\Delta\Phi = -\frac{e}{c\hbar}\oint \underline{A}.dx \text{ where } \oint \underline{A}\cdot d\underline{x} = \int H \cdot ds = \phi \qquad (1)$$

or the total magnetic flux inside the circuit. The vector potential cannot be zero outside the solenoid because the total flux through every circuit con-taining the origin is equal to a constant

$$\phi_0 = \int \underline{H}\cdot d\underline{s} = \int \underline{A}\cdot d\underline{x} \text{ for } B = \mu_0 H . \qquad (2)$$

For a singly connected region, $\underline{H} = \nabla\times\underline{A} = 0$ so that solution $\psi = \psi_0 e^{-\Phi/n}$ is the solution when $\underline{A} = 0$ so that $\nabla \Phi/\hbar = (e/c)\underline{A}$. But in the Aharanov-Bohm experiment, we have multiple connected regions outside the solenoid and ψ is no longer a single valued function so that the electron wave function splits into two parts $\psi = \psi_1 + \psi_2$ where ψ_1 represents the beam on one side and ψ_2 the beam on the other side so that the beams stay in a simply connected region so that we can write $\psi_1 = \psi_1^0 \exp -i\Phi_1/\hbar$ and $\psi_2 = \psi_2^0 \exp -i\Phi_2/\hbar$ so that Φ_1 and Φ_2 are equal to $e/c\int A\cdot dx$ along the paths of the first and second beam, respectively. The interference between the two beams depends on the phase difference.

$$(\Phi_1 - \Phi_2)/\hbar = \int \underline{A} \cdot dx = \frac{e}{\hbar c}\phi_0 \qquad (3)$$

Hence, the vector potential influences the electron interference pattern but may also influence their momentum. An experiment involving an array of solenoids is described in [59]. Experimental tests of the Aharanov – Bohm experiments have been performed which display electron interference patterns using various experimental set ups [53].

5.4 SOME TOPICS FOR INTERFERENCE EXPERIMENTS

Figure 8, represents the relationship between the Aharanov-Bohm experiment, the Young's double slit experiment, Bells's theorem set up and a dual laser experiment. In the latter case, we examine dual path interferences between two lasers as correlated coherent source.

- The relation of the remote connectedness properties of Bell's theorem, Young's double slit experiment and laser interferometry from independent beams.
- The relationship between the advanced potential models and complex multidimensional geometries formulation of remote connectedness properties of the manifold.
- Interference effects produced by the superposition of light beams from two independent single-mode lasers for low beam intensities.

The central purpose is the experimental test using the dual laser source system to test the theoretical hypothesis developed in points 1 and 2. Positive results from such an experiment would have strong implication for the nature of the quantum measurement problem.

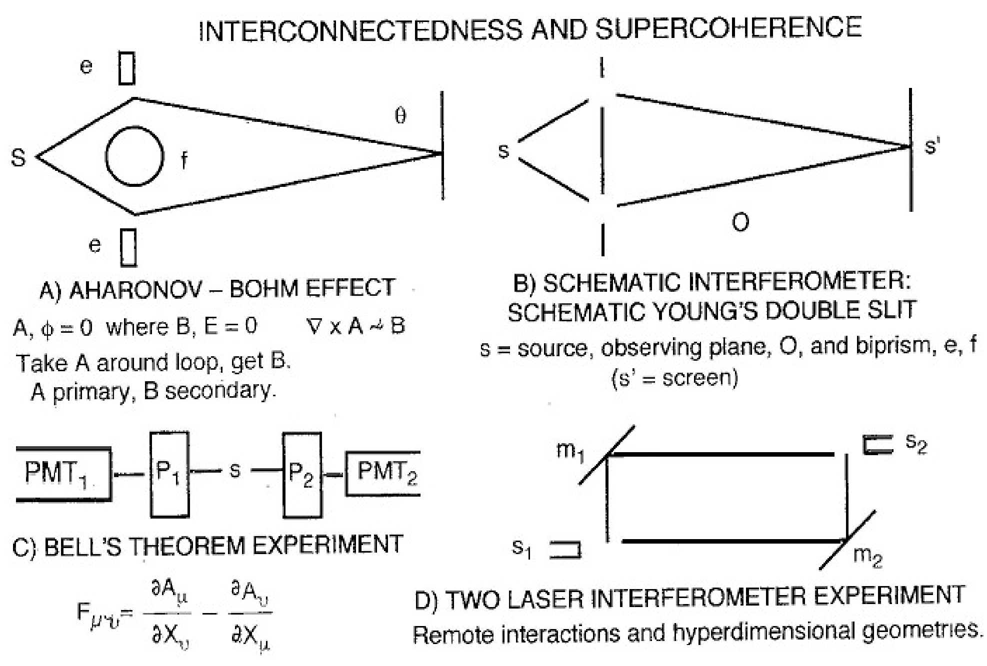

Figure 8 Schematic representations of experiments which involve nonlocal interconnectedness and supercoherence phenomena for four experimental set ups.

5.5 ERNST MACH, FRAMES OF REFERENCE AND NONLOCALITY

Mach's principle states that the inertia of a body is due to the action of forces produced by all other bodies in the Universe. In a basic sense, such a hypothesis appears to imply a nonlocal connection of a remote inertial frame of reference. In a dynamic universe of special relativistic inertial frames and general relativistic non-inertial frames how does Mach's principle apply? Is there a counter part of quantum nonlocality for longer scale correlations or other types of nonlocality even possibly a classical nonlocality? Mach's priniciple appears to imply nonlocal classical connections of remote events. Mach's philosophy influenced Einstein [54]. Mach's principle as we stated, appears to speak of a form of nolocality in that local influences are produced by forces produced from other localities in the universe [55]. Rauscher and others have demonstrated unequivocally that, although Mach's principle relates to an absolute frame of reference in the Universe, it is not inconsistent with the mathematical formulism of relitivity for both inertial and noninertial frames of reference.

For a rotating and at rest bucket of water experiment was conducted by Sir Isaac Newton who hung the bucket of water at the end of a twitsted rope and then let go of the rope. What one observes is that, as the bucket began to spin rapidly, the water's surface remained flat until viscous drag makes the water rolate and its surface became concave. When Newton stopped the bucket suddenly, the water continued to rotate and its surface remained curved until it stopped and the surface returned to being flat. Newton concluded that it was not the rotation of the water relative to the bucket that was important, since this relative rotation was associated with a flat water surface initially and finally with a curved surface, he interpreted that results to imply that one could state that there is rotation in relationship to an absolute space. Does the more massive body effecting a less massive one to a greater extent somehow represent an asymmetry in what is considered an inertial frame of reference? This is an interesting question from the point of view of Newton's law of Universal gravitation

$$F = \frac{4\pi}{G}\frac{m_1 m_2}{r^2}$$

where G is the universal gravitational constant. In this sense, if $m_1 >> m_2$ then does m_1 have more inertial frame effect on m_2 where, for example, m_1 is like mass of the earth and m_2 is the mass of the water in the bucket.

Another experiment that appears to imply an absolute frame of reference for the rotation of the earth, or the fixed star system, is the behavior of the Foucault pendulum. In the mid 1850's, Jean Bernard Foucault conducted pendulum experiments on a pendulum with a heavy bob and long cord or wire. He noted that the pendulum remained in the same plane of oscillation, no matter how the point of attachment was twisted or rotated, that is a large pendulum maintained its plane of oscillation while the earth twisted under it. If the pendulum was at the north pole, the earth will make a complete twist under it in twenty four hours. At the equator there is no twist at all, where the earth's rotation and velocity is the greatest, about one thousand miles per hour. To an observer on the earth's surface, it appears that the pendulum slowly rotates. Also the buldge at the earth's equater is a related phenomenon.

Mach suggests the logical question "How do we measure the inertial mass of a body?" From Newton's second law $m_i = F / a$ that is inertial mass is measured by the ratio of the sum of applied forces to it to the acceleration if produces. But the measurement of absolute acceleration requires the measurement of absolute displacement, whereas what we can really measure is the displacement of that body relative to other bodies. Therefore, according to Mach it is only by virtue of the presence of other bodies that a given body can be said to have inertial mass. Furthermore, Newton's bucket experiment and Foucault's pendulum appear to demonstrate that large masses at great (nonlocal) distances are more important than small masses nearby in defining inertial frames of reference. In what manner does this issue relate to Newton's universal law of gravitation and the universal law of equivalence of gravity?

If can be demonstrated that, although the tenet of special relativity is that there are no preferred reference frames, the structure of the theory may not preclude an absolute reference frame which is constant with Mach's principle. Mach's principle relates to the motion of material particles, separated from the close proximity to other bodies, as relative motion to the center of all other masses in the Universe. [56,57] Mach's explanation is that the difference between a nonrotating bucket of water with a flat, eqipotential surface, and one rotating with a parabolic meniscus is created relative to the fixed stars. The stars were considered fixed at the turn of the last century; this concept changed with the Hubble expansion in 1921 for the analysis of stellar red shift data. The proportionality of rate of expansion of the rate of expansion to distance is Hubble's constant, $H = \dot{R} / R$. This expansion yields multiple frame of reference from which the expansion appears to be the same but it may not preclude another form of so termed fixed frame. The relative frames of the basket and what it is rotating to may represent a large scale, at least earth size, of nonlocal influence. Sciama [58] developed a interesting analogy between gravity and electromagnetism by forming a gravitational analogue of electromagnetic the acceleration dependent inductive force which produces photon emission. His attempt was to reconcile general relativity and Mach's principle including, in the context of this principle, to explain redshift, which is an interesting approach. Rowlands discusses Sciama's approach and make a Machian analogy of the so termed all pervasive Higgs field [55]. In [59] is given a generalized discussion of nonlocality and the complex 8-space.

In [14] we have reinterpreted the meaning of Hubble's expansion law, $H = \dot{R} / R$ to derive the fundamental basis of the continuous-state principle, a key element in developing the Holographic Anthropic Multivers (HAM) cosmological paradigm. HAM cosmology allows an infinitesimal photon mass, m_γ as described by the Proca equation which in a covariant polarized Dirac vacuum leads to the 'tired light' interpretation of cosmological redshift and a Cavity-QED spacetime exiplex model of the Cosmic Microwave Background Radiation (CMBR) as blackbody equilibrium conditions of emission and redshift as absorption. Thus, redshift is virtual, a continuous-state inherent free-fall motion of the M-Theory backcloth illustrated in the HAM mantra 'continuous-state spin-exchange dimensional reduction compactification process' of symmetry breaking in Calabi-Yau mirror symmetry conditions. This, and the 'rest of the story' is a lot to chew on; which is developed to the degree possible in [14] which we will update and refine as we are able.

6 Conclusion

The argument and attempted explanation concerning the particle-wave nature of light during the last five centuries or so has led to intense debate including some broken life long friendships. This also true of the debate over the fundamental existence of locality and nonlocality. The attempt in studying physics is to strive toward a more basic knowledge of the nature of reality. It is assumed that physics is the most fundamental of all sciences and its perhaps the basis for all human knowledge, using the precise and logical language of mathematics. Our current understanding of physics grows out of our attempt to understand the natural world and has been the result of accumulated knowledge by a succession of inductive and deductive inferences derived from observation and theoretical hypothesis and theory explanation and prediction.

The concept of a unified theory of physics or a theory of everything (TOE) assumes there is a point at which the origin of everything is explained and also that the origin of everything can be explained in terms of a single obvious source. It is clear that in every fundamental theory, should one exist, must accommodate the fundamental nature of nonlocality in both micro and macro systems. Therefore, it is imperative that a theoretical framework be constructed to accommodate nonlocality at a very basic level. Such a theory is exemplified by the formulation of the complex Minkowski space which has deeply imbedded in its structure nonlocality in space and time.

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