

Conjectured Breaking of the Superluminal Quantum Correlations By Turbulent Fluctuations of the Zero Point Vacuum Field

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If the observed superluminal quantum correlations are disturbed by turbulent fluctuations of the zero point vacuum energy field, with the turbulent energy spectrum assumed to obey the universal Kolmogoroff law, a length is derived above which the correlations are conjectured to break. A directional dependence of this length would establish a preferred reference system at rest with the zero point energy. Assuming that the degree of turbulence is given by the small anisotropy of the cosmic microwave background radiation, a length of ~ 60 km is derived above which the correlations would break.

1. Introduction

The violation of Bell's inequality in EPR-type two photon quantum correlation experiments, carried out over a distance of about 10 meters, has established the reality of superluminal connections outside the light cone [1]. An escape into the Copenhagen interpretation does not help, with the time sequence of cause and effect in these experiments being reversed by simply making a Lorentz transformation to another reference system. The same problem remains if assuming nonlocal "ghostlike" interactions to explain the quantum correlations. The observed superluminal quantum correlations being in gross violation of Einstein's special relativity postulates, a growing number of physicists have urged a return to the pre-Einstein theory of relativity by Lorentz and Poincaré. Unlike Einstein's theory, it had an aether with objects in absolute motion through this aether subject to true length contractions and time dilations. This older theory had less symmetry than Einstein's special theory of relativity, but it could explain as well all the observed facts, like the outcome of the Michelson-Morley, Trouton-Noble and similar experiments. With a preferred reference system at rest with an aether, it can (unlike Einstein's theory) explain the quantum mechanical correlations by superluminal transmissions passing through this aether, with the time sequence reversal of cause and effect through a Lorentz transformation explained as an optical illusion [2]. With solid bodies held together by electromagnetic forces, Lorentz had shown that the transformations named

after him can be derived from Maxwell's equations, which he assumed to be valid in a reference system at rest with the aether. This dynamic interpretation of Lorentz invariance did not take into account the (repulsive) quantum mechanical forces, expressed through the uncertainty principle or the quantum potential, but the remarkable fact that the quantum mechanical zero point fluctuations obey an ω^3 frequency spectrum, the only one which is Lorentz invariant, makes it possible to incorporate the quantum forces in the dynamic interpretation of Lorentz invariance. In the opinion of Bell [2], the unobservability of the preferred reference system remains uncomfortable, but the difficulty to detect the conjectured aether, and hence the preferred reference system, should come as no surprise if one recognizes the growing evidence indicating that physics seems to have its origin at extremely high energies, like the GUT energy of $\sim 10^{16}$ GeV or the Planck energy of $\sim 10^{19}$ GeV. If the discreteness of an aether establishes itself only at these energies it will be very difficult to ever observe the aether directly, but such detection may still be indirectly possible through the quantum correlations if the aether provides a mechanism for the correlations to break above a certain length. Standard quantum theory (where the quantum correlations propagate with infinite speed) predicts that the correlations are valid for arbitrarily large distances, even though the most recent measurements were done over a length of only ~ 10 km.

It should be emphasized that quantum theory is not the only physical theory having correlations going with infinite speed and over arbitrarily large distances. The same is true for incompressible fluid mechanics, where the cause of the correlations is the assumption of an incompressible fluid, which like a rigid body can transmit a sig-

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nal instantaneously. In reality, though, there is not such a thing as an incompressible fluid, which rather is a mathematical model for a fluid, with the model becoming invalid for velocities approaching the velocities of sound.

2. On the Interpretation of Quantum Mechanics

According to the Copenhagen interpretation, the superluminal wave function collapse associated with the correlations is not real, with the wave function only a measure of our knowledge. And it is argued, as our knowledge can change abruptly through the result of a measurement, so can the wave function [3]. As von Neumann has shown, this interpretation ultimately requires conscious observers, but with conscious observers only present at a few places in the physical universe, not all physicists have accepted this subjective interpretation of reality.

In the past there have been many attempts to obtain a more realistic interpretation of quantum mechanics, beginning with de Broglie's pilot wave theory [4], first rejected but later adopted by Bohm [5]. The theory was criticized by Heisenberg [6] on the grounds that it was physically meaningful only for one particle, while Einstein rejected it as too cheap ("zu billig"). A derivation of the Schrödinger equation was later obtained by Fényes [7] with a stochastic model. It too was rejected by Heisenberg [6] as an example of abstract mathematics not connected to physical reality. Because Bohm required a background medium to generate the stochastic motion of quantum mechanics as a kind of hidden variables, Weizel [8] tried to specify this background medium by assuming the existence of hypothetical particles, called zeron, with the zeron giving rise to a stochastic motion. But it was pointed out again by Heisenberg [6], that Weizel's model would run into difficulties with the 2nd law of thermodynamics through the rise in entropy of the zeron particle fluid. A somewhat different model, proposed by Nelson [9], can be seen (according to Nelson's own opinion) as somewhere in between the models of Fényes and Weizel. All these models assume the existence of a background medium, that is a kind of an aether. A quite different model, proposed by Janossy, suggested that the wave function is real and that its collapse would go with superluminal speed in an aether [10]. The hypothesis that superluminal wave function collapse might be real was also considered by Renninger [11], who had invented the delayed choice experiment (incorrectly credited to Wheeler, who only had rediscovered it

many years later). More realistic models for wave function collapse were proposed by Penrose [12] and the author [13, 14], both of which suggest the involvement of the Planck mass.

Any one of these models must make some ad hoc assumptions, but for an experimental test establishing the reality of an aether as the carrier of superluminal wave function collapse, the test should be based on something which is universal and absolute. There are two "things" in physics which meet this condition: 1) The zero point energy of the vacuum with a spectrum going in proportion to k^3 , and 2) a universal turbulent energy of the universe, with a spectrum going in proportion to $k^{-5/3}$. Then, by making the conjecture that the quantum mechanical correlations break at a wavelength at which the turbulent energy exceeds the zero point energy, an experimental test of wave function collapse would become possible provided this length is within reach.

3. The Breaking of the Quantum Correlations by Turbulent Fluctuations of the Vacuum

Quite independent of any proposed model, the superluminal quantum correlations can be explained making two assumptions:

1. The wave function is real and so is its superluminal collapse.
2. The superluminal collapse of the wave function takes place in a background medium.

Whereas for the evolution in time of the wave function there is a theory called quantum mechanics, no such theory is known for the superluminal collapse. With the assumption of a background medium making possible the superluminal connections, there can be no violation of the law of causality as long as all measurements are referred to the distinguished reference frame at rest with this medium. And as long as the superluminal connections are stochastic, (as suggested by quantum mechanics), no information can be transmitted with superluminal speed.

To obtain a value for the conjectured length above which the correlations might begin to break, it is conjectured that the superluminal correlations are transmitted by the field of the zero point vacuum energy, but that the vacuum is also subject to turbulent fluctuations destroying the correlations above a certain length. This hypothesis implies that the very large density of the zero point vacuum energy gives the vacuum a large stiffness per-

mitting superluminal propagation, but that this stiffness fails over larger distances due to turbulent fluctuations. In this sense, the zero point vacuum energy plays the role of an aether. Unlike the ω^3 frequency spectrum of the zero point energy, the turbulent energy spectrum is not Lorentz invariant.

With the zero point vacuum energy going in proportion to $1/\lambda^4$ where λ is the wave length, and the turbulent energy going in proportion to $\lambda^{2/3}$, there should be a critical wave length above which the turbulent energy exceeds the vacuum energy. This wave length shall now be determined.

The spectrum of the zero point vacuum energy is of the order

$$f(k) = \hbar ck^3 \quad (1)$$

with an energy density up to the wave number k :

$$\varepsilon(k) = \int_0^k f(k) dk = (1/4) \hbar ck^4. \quad (2)$$

With the Planck length r_p and Planck mass m_p , it can be written as

$$\varepsilon(k) = \frac{m_p c^2}{4r_p^3} (kr_p)^4. \quad (3)$$

The universal turbulent energy spectrum is given by the universal Kolmogoroff law

$$F(k) = \text{const} \cdot k^{-5/3}, \quad (4)$$

where the constant has to be determined from the energy of the largest eddies. In the form given by (4), the turbulent energy spectrum is expressed in a reference system at rest with the universe.

From (4) one obtains for the energy density of the turbulent vacuum field

$$E(k) = (1/2) \rho v^2 = \int_0^k F(k) dk = \text{const} \cdot k^{-2/3}. \quad (5)$$

The size of the largest eddies is of the order of the world radius R , where $v \leq c$ and $(1/2)\rho v^2 \rightarrow \kappa \rho c^2$, $\kappa \leq 1$, with ρ set equal the critical mass density of the matter in the universe. The parameter κ is a measure for the degree of turbulence. For $\kappa = 1$, the largest eddies would reach the velocity of light. Putting $k = 1/R$ for the largest eddies, one thus obtains

$$E(k) = \kappa(\rho c^2/R^{2/3})k^{-2/3}. \quad (6)$$

The world radius can be expressed by Hubble's constant H :

$$R = c/H \quad (7)$$

with the critical density given by (G Newton's constant)

$$\rho = \frac{3H^2}{8\pi G} = \frac{3m_p H^2}{8\pi r_p c^2}. \quad (8)$$

One thus finds that

$$E(k) = \frac{3H^{8/3} m_p}{8\pi r_p^{1/3} c^{2/3}} (kr_p)^{-2/3} \kappa. \quad (9)$$

The critical wave number k_0 below which the correlations would break is determined by equating $\varepsilon(k)$ with $E(k)$, with the result that

$$k_0 = (3/2\pi)^{3/14} (Hr_p/c)^{4/7} r_p^{-1} \kappa^{3/14}. \quad (10)$$

With $H = 1.6 \times 10^{-18} \text{ sec}^{-1}$ and $r_p = 1.6 \times 10^{-33} \text{ cm}$, one finds that $k_0 = 5.3 \times 10^{-3} \kappa^{-3/14} \text{ cm}^{-1}$, and that $\lambda = 2\pi/k_0 \approx 12 \kappa^{-3/14} \text{ meter}$.

In the presence of more than one quantum, the length above which the correlations break should become larger, because the energy of all quanta present in an experiment should be added to the vacuum energy. With the energy going in proportion to $(n + 1/2) \hbar ck$, where n is the number of the quanta, $\varepsilon(k)$ would have to be multiplied by $(2n + 1)$, whereby k_0 is reduced (and λ increased) by $(2n + 1)^{3/14} \approx 1.16 n^{3/14}$.

The two photon correlation experiment by Aspect et al. [1] was done over ~ 10 meters, which still would be compatible with the largest possible turbulent energy reached at $\kappa = 1$. However, the most recent experiment by Gisin [15], shows that the correlations hold up to a length of ~ 10 km. Assuming that the degree of turbulence is about equal the spatial temperature variation $\Delta T/T \sim 10^{-5}$ observed in the cosmic microwave background radiation, suggests to put $\kappa \sim \Delta T/T \sim 10^{-5}$, with the result that $k_0 \approx 10^{-6} \text{ cm}^{-1}$ and $\lambda \approx 60 \text{ km}$. This suggests to repeat the experiment done by Gisin over larger distances.

We would like to mention that a possible breakdown of the quantum correlations above a certain distance was first suggested by Janossy and Naray [16] back in 1958, who tried without success to demonstrate such a breakdown with a large Michelson interferometer possessing an arm length of ~ 15 meter.

4. Concluding Remarks

Because the turbulent energy spectrum is not Lorentz invariant, an observed directional dependence of the breakdown length would have to be interpreted as an absolute motion relative to a reference system at rest with the universe. As we had pointed out, the assumption of such a preferred system is necessary to sustain the time

sequence causality of the quantum correlation experiments.

The observation of a length above which the correlations break would open a window to the physics of the Planck scale, which due to the enormity of this energy is closed for particle accelerator technology now and the foreseeable future.

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