WHY THE EPR PARADOX HAS BEEN RESOLVED IN FAVOR OF EINSTEIN

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ABSTRACT

On the practical level the EPR paradox is resolved in favor of Einstein. Quantum systems are usually treated as independent. The usual theory, being valid only for coupled systems, does not say when systems should be treated as independent. On the practical level it is, thus, incomplete or insufficient. If the widely separated correlations reported by Aspect do occur, they may be attributed to extraneous correlations such as in phase or in clumping, which Aspect failed to measure. The Bell theorem sheds no light on the EPR problem; as it is based upon traditional "expectation values" as observables. The traditional theory cannot predict at all the observed interference patterns produced by quantum particles such as phonons and photons. Classical wave theory, predicting interference patterns of quantum particles precisely, supports microphysical reality. Panarella reports that, when light intensity is sufficiently reduced, individual separated photons do not show quantum mechanical or wave behavior. They behave as point billard balls, thus, resolving the EPR paradox in favor of Einstein. Corroborative evidence is provided by Lewis's near-field scanning optical microscope, which also gets rid of wave effects by also limiting the intensity and by using a hole much smaller than a wavelength.

1. ON A PRACTICAL LEVEL THE EPR PARADOX IS RESOLVED IN FAVOR OF EINSTEIN

When quantum mechanical problems are solved at the practical level, a limited system uncoupled from the rest of the universe is always assumed. The hydrogen atom problem is never confused with the simple harmonic oscillator problem or with the helium atom problem or with a Josephson junction. Every system is assumed to exist all by itself independent of every other system in the universe. The great success of such a view in terms of yielding practical answers indicates that quantum systems are, in fact, decoupled from each other in the

A. van der Merwe et al. (eds.), Microphysical Reality and Quantum Formalism, 435–441.

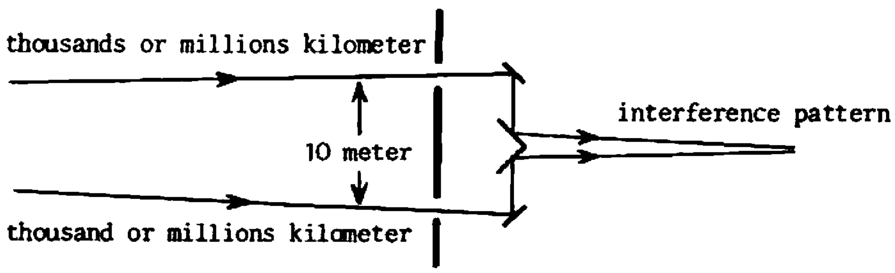
practical sense.

One does not have to assume a grandiose wave function or state function which includes the whole universe in order to get practical answers. Since science is involved with actual experimental results and actual practical predictions of these results, a grandiose wave function or state function which includes the whole universe has to be merely a metaphysical fiction. We all know and readily recognize that on an everyday basis quantum systems are, in fact, decouple from each other. The Einstein, Podolsky, Rosen (EPR) paradox merely points out the fact that the usual traditional quantum theory does not allow in principle for the existence of such uncoupled quantum systems. Although we assume with great success that systems are uncoupled, the usual traditional quantum theory fails to specify precisely how or when we should treat quantum systems as being either coupled or uncoupled. The usual traditional quantum is clearly incomplete or in error. In this practical sense Einstein is right: The traditional quantum theory fails or is incomplete.

2. ASPECT'S EXPERIMENT HAS NOT RESOLVED THE EPR PARADOX

Aspect[1] has not as yet published or supplied sufficient details about his experiments to either permit an adequate analysis of his possible experimental errors or to permit someoneelse to duplicate his experiments. Under the circumstance one may well doubt his reported results.

Even if one were to accept Aspect's reported experimental results as correct, there are alternative explanations which do not support the traditional quantum theory and which can support the Einstein, Podolsky, Rosen view. The simplest explanation of the observed correlations (if they have been observed) is that they result from extraneous correlations neglected by Aspect. The most usual and simplest correlations between photons, which can be observed over very great separation distances, arise from the *phase* between photons. For example, in the Michelson stellar interferometer, where the entrance slits are 10 meters apart, the photons from a distant star passing through the two slits are independent or separted for many hundreds of thousands or millions of kilometers; yet when combined they produce an interference pattern.



The *phase* of the two oppositely directed light or photons in the Aspect experiment was experimentally completely ignored. He apparently assumed that they were incoherent with respect to each other. Even if the polarization or spin is randomized between the two beams, it does not mean that the phase has been randomized. The correlations reported might merely reflect the coherence or matching of phases of the two beams. An adequate experiment should have experimentally determined the coherency of the two beams. Aspect did not do this.

To support the traditional quantum theory, Aspect argued that each photon pair generated in the source was independent of every other photon pair generated in the source with regard to phase and bunching. This assumption violates what we already know today experimentally about sources in general. No matter how complex the mode of generation, photons are observed to be emitted in phase over long periods of time and over macroscopic distances of the source. Sources do not radiate continuously; they emit in uneven bursts or bunches. Every source is observed to lase more or less.(2) For example, a hot gas in a cavity about 10 cm across radiates light that is almost perfectly coherent for over 10^{-9}sec. Photons emitted 180° with respect to each other are also found to be still in phase. From such ordinary observations it may be readily concluded that all of Aspect's photons were in phase with each other over the time interval of 10^{-9} sec that he reports. There have been theories which try to show that Aspect's source was phase incoherent; but these theories start with the unwarranted assumption of initially-independent photons; and they simply ignore the problem of the storage time of any photon in any source. Only experiments, which are easily performed, can resolve the question. If Aspect has observed widely separated correlations, they can be best explained as phase or bunching correlations.

It may also be mentioned that there seems to be a logical inconsistency in the Aspect argument. Photon pairs are supposed to be independent or uncoupled from each other in the small source in order to prove that widely separated photons can be correlated or coupled together. If such widely separated coupling can be accepted, why not accept coupling in the small source to begin with?

3. THE BELL THEOREM SHEDS NO LIGHT ON THE EPR PARADOX

Although one may well wonder about when quantum systems are coupled together and when they are uncoupled, the so-called "Bell theorem" does not help to answer this question. The Bell theorem assumes from the outset that "observables" can be "defined" by "expectation values." However, "observables" can only be demonstrated in the laboratory or defined operationally; they cannot be defined mathematically or theoretically. Apart from a few fortuitous eigenvalues, macroscopically fuzzy "expectation values" bear no relationship at all to actual precise laboratory observations. The Bell theorem is thus merely a variation of the old so-called "von Neumann theorem," which purported to prove that hidden variable theories were impossible. In particular, the argument is that, if you "define" "observables" as fuzzy "expectation values," then you cannot subsequently expect precise predictions. This is obviously true: If one introduces fuzzy ideas by definition at the outset, then one cannot demand precise predictions subsequently.

Wave functions, which are defined mathematically throughout all space, when used to generate a "reality" by integral processes, will then necessarily imply that all systems in the universe must be coupled together. Such an artificial mathematical view will deny the existence of uncoupled quantum systems each with their own individual point properties. Experimental observations fit microphysical reality and not the macroscopic fuzzy traditional quantum theory with its "expectation values" as "observables." The Bell theorem is thus irrelevant.

4. TRADITIONAL QUANTUM THEORY DOES NOT FIT THE EXPERIMENTAL FACTS, MICROPHYSICAL REALITY DOES

To obtain admittance into the physics community, it is customary to incant that current theories in physics fit the experimental facts. This ritual is apparently designed to make it appear that current theories in physics are empirical theories well tested in the laboratory. When difficulties arise - and difficulties always arise - an accepted member of the physics community is suppose to claim that, although the theory fits the facts, it needs to be "reinterpreted." The unfortunate truth is that basic theories in physics seldom fit the experimental facts at all. The usual traditional quantum theory is no exception. It contradicts outrageously almost all of the experimental evidence that we possess. To be explicit, the classical wave theory for the flux of the quantum particles photons and phonons, together with their densities, yields very precise microphysical results in space and time in complete agreement with experimental observation. The usual traditional quantum theory denies all of this experimental evidence. Essentially all of the information that we have about the behavior of quantum particles is provided by classical diffraction and interference accurately predicted by classical wave theory. It would seem that any adequate quantum theory would be able to agree with all of this experimental data; but the usual traditional quantum theory does not agree with any of this classical data.

Although the traditional theory fails in many ways to fit the experimental facts, it will be sufficient here to consider just one point. The traditional theory for a scalar wave associated with slow particles of mass m says the particle density and particle flux are given by

$$\begin{aligned} P &= \Psi^*\Psi, \\ \mathbf{G} &= -(i\hbar/2m)(\Psi^*\nabla\Psi - \Psi\nabla\Psi^*), \end{aligned} \qquad (1)$$

where Ψ is assumed to be complex in general with the imagniary number $i = \sqrt{-1}$. These equations are supported by no experimental evidence whatsoever. These equations have been arbitrarily proposed merely because they happen to satisfy the equation of continuity. By contrast, the results for quantum particles that fit the experimental evidence, as given by classical wave theory for a scalar wave, are

$$P = (\nabla\Psi)^2/2 + (\partial\Psi/\partial t)^2/2u^2,$$
$$\mathbf{G} = -(\partial\Psi/\partial t)\nabla\Psi, \tag{2}$$

where u is the phase velocity and Ψ must be a pure real function of space and time. These Eqs.(2) are unique and supported by a vast amount of observational data involving the diffraction and interference of quantum particles. The second of Eqs.(2), for example, is merely the Poynting's vector when Ψ is appropriately chosen. There is no way at all that one can try to twist Eqs.(1) around to fit the observations as given by Eqs.(2). The traditional quantum theory, as given by Eqs.(1), gives numerical results that have little or no relationship to the observed fluxes and densities of quantum particles.

It should also be mentioned that the particle flux and densities arbitrarily proposed by Madelung, de Broglie, and Bohm also contradict the experimental facts, as they also fail to yield the precisely correct Eqs.(2).

It should be noted that the existence of the imaginary number $i = \sqrt{-1}$ in the usual traditional quantum theory expressions (1) is by itself sufficient to indicate the inability of the traditional theory to fit experimental facts. Does the i mean that the real part or cosine should be used? Does the i mean the imaginary part or sine should be used? Or does the i mean that any value between -1 and +1 is admissible? By contrast, the classical wave theory gives precise unique results; no arbitrariness is involved, as only real functions are admissible.

If one wishes a quantum theory that fits the classical experimental evidence and microphysical reality, then the way to proceed is clear.[3] First, one notes that quantum particle velocities $\mathbf{w}$ are predicted by classical wave theory, in accordance with experimental facts, by

$$\mathbf{w} = \mathbf{G}/P = -\frac{(\partial\Psi/\partial t)\nabla\Psi}{(\nabla\Psi)^2/2 + (\partial\Psi/\partial t)^2/2u^2}. \tag{3}$$

Discrete trajectories which quantum particles follow as a function of time are then given by simply integrating Eqs.(3).[3] The moment for slow particles is given by $m\mathbf{w}$. The kinetic energy is given by $m\mathbf{w}^2/2$. All of the physics for a quantum particle then uniquely follows from Eqs.(3).

It may be noted that this microphysical specification of the behavior of quantum particles, Eqs.(3), is based on differential operations applied to the field variable Ψ. Smeared out fuzzy "expectation values" or integral averages do not occur. Maxwell's theory, the theory of sound, and all classical wave theories specify observables in terms of differential operations on the field. Such differential operations preserve a precise microphysical specification of observables. No fuzzy integral averages occur in classical wave theory. The classical theory of light, the classical theory of sound, and Maxwell's theory are all given by Eqs.(2) and (3). Poynting's vector **G**, in the second of Eqs.(2), involves only differential operations on the field variable. The precise microphysical specification of the behavior of photons does not depend on integral averages as "observables." The traditional quantum theory does not fit the experimental facts at all. It fails miserably. The usual traditional quantum theory cannot yield the observed diffraction and interference behavior of quantum particles.

It is important to note that, once one rejects fuzzy "expectation values" as "observables," then one has to also reject the "Hilbert space approach." the "operator approach," the "matrix mechanics approach," and similar ideas which do not agree with the experimental facts.

5. PANARELLA HAS RESOLVED THE EPR PARADOX IN FAVOR OF EINSTEIN

Panarella[(4)] reports that, when the intensity of a light beam is sufficiently reduced, individual photons no longer produce a single pinhole diffraction pattern. All that remains is the geometrical image of the pinhole with no side bands as observed when wave effects are present. Individual separated photons behave as point billard balls. Thus, truly separated quantum systems, photons in this case, do not show quantum mechanical effects, i.e., wave behavior. Panarella has succeeded where Aspect failed. Panarella has been able to obtain individual separated independent photons. Panarella has resolved the EPR paradox experimentally in favor of Einstein. The experimental procedure that Panarella uses is clear and simple. There is no reason to question his results, in contrast to Aspect's complicated experiment.

Nevertheless, one would like to see Panarella's important results duplicated by someoneelse. Earlier attempts many years ago did not manage to get rid of the diffraction pattern; apparently because higher intensities were involved. To settle the matter a duplication of Panarella's experiment would be most desirable.

Evidence corroborating Panarella's result is provided by Lewis's[(5)] near-field scanning optical microscope. The microscope is capable of discerning objects much smaller than the wavelength of light used. The usual classical resolving power for a microscope is greatly exceeded. Lewis gets rid of the wave effects by using a very small hole less than the wavelength of the light used and very low intensities. Photons behave as individual point billard balls, precisely as in Panarella's experiment. Lewis's results are comparable to an electron microscope using light of ordinary visual wavelength. It is very significant that the illumination must be reduced, otherwise wave effects enter in and smear out the scanning point.

Lewis's results accent the fact that microscopic details can actually be observed which far exceed the limit prescribed by classical wave optics. This fact was already known to electric fish, who find their very small prey using essentially infinitely long wavelengths. The fuzzy traditional quantum theory with its artificial macroscopic "uncertainties," which never fitted the experimental facts anyway, must now be abandoned in the face of Lewis's precise results. Microphysical reality is now experimentally accessible.

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