On the Einstein–Podolsky–Rosen paradox and the Bell's theorem

God does not play dice with the universe.   Albert Einstein

Victor Paromov, PhD
Email: vikus68@yahoo.com
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Abstract

This letter attempts to show that the non-classical 5D spacetime geometry-based theory of particle interactions (http://vixra.org/abs/1806.0181) is able to preserve both realism and locality for the Bell test by explaining the conditional nature of entanglement. In addition, the theory is able to match the quantum-mechanical (QM) predictions for the correlation. Consequently, an explanation of the Einstein–Podolsky–Rosen (EPR) paradox is proposed with the assumption that the real values do exist, however, are inaccessible in principle due to the compactness of the extra spatial dimensions.

The Bell's theorem [1] is generally understood as a strong argument against Einstein's claim that any physical theory must preserve both realism and locality. In the famous EPR paper [2], Einstein and co-authors have made a deep philosophical statement arguing that any material object (e.g. an elementary particle) may only have a pre-existing (real) value for any of its physical characteristics, and any physical interaction is always local (i.e. any effect evolution in the spacetime is always limited to the speed of light). Unfortunately, the quantum-mechanical (QM) descriptions of particles' interactions seem to violate this requirement. Two particles with entangled quantum parameters (e.g. spin) should retain the entanglement even considering the fact that the parameter cannot have a pre-existing measurable value for either particle. Thus, the actual measured value determined experimentally for one particle is actually a variable (i.e. it is not a pre-existing fixed value), and in addition, this measured value always remains entangled with the corresponding parameter of another particle. Thus, a measurement of one particle in one place immediately determines the value that can be measured with another particle in the other place (i.e. the effect seems not local). Thus, both locality and realism become violated. Einstein had suggested only one solution to this paradox arguing that particles must have pre-existing (real) values, which, however, cannot be observed. This point of view is now referred to as the local hidden-variable theory, which is assumed to be a classical field (real field) theory.

This classical interpretation of the local hidden-variable requirement clearly cannot withstand Bell's argument [1]. With the first loophole-free experimental test of the Bell's inequalities [3], it is now a proven fact that no classical field theory would be capable of "saving" local realism for particle interactions. For the Bell test, a classical local hidden-variable theory predicts a linear correlation, whereas the QM approach gives a slightly different prediction (Fig. 1), which indeed have been confirmed in the experiment [3]. However, this does not necessarily mean that the general Einstein's argument is not valid. It is possible that the local hidden-variable theory can be a non-classical field theory with the predictions matching the QM predictions. Indeed, if real values are inaccessible for the observer in principle (see below), the classical field theory cannot be used. In case the replacement theory uses the QM mathematical methods, it would likely provide the same predictions for the Bell test correlation as the QM does. Thus, in case the replacement local hidden-variable theory matches the QM predictions, the general Einstein's argument remains undefeated.

As shown previously, a non-classical field theory solely based on the 5D spacetime geometry does provide mathematical descriptions of the electromagnetism identical to the QED calculations [4]. Like the GR, however, this theory is based purely on the Einsteinian understanding of interaction, with the assumption that particles' movement is governed solely by the geometry of spacetime. The spacetime model assumes that the 4D (Einsteinian) spacetime is extended by a closed microscopic spatial extra dimension (i.e. the original Kaluza hypothesis [5] in the Klein's interpretation [6] and absence of the cylinder condition). It is suggested that geometrical alterations of the microscopic (and hence inaccessible) 5D spacetime govern electromagnetism, whereas alterations of the 4D spacetime govern gravity only. For simplicity reasons, the theory [4] operates not with 5D spacetime parameters, but with 4D space (which is further "divided" into the ordinary 3D space and a compact extra dimension) and absolute time. According to this point of view, the real parameters do exist, however, are inaccessible in principle due to the compactness of the extra spatial dimension. Thus, no theory can operate with the real 5D spacetime (or 4D space) parameters, hence, the "operational" theoretical parameters are never real values being only 4D spacetime (or 3D space) projections of the inaccessible real parameters. Hence, the fact that the measured parameters are always variable is not due to the particles' nature, but to the observational limitations only.

As the closed extra spatial dimension is compact, it cannot be directly accessed by a 4D observer in principle. A test particle (e.g. electron) movement in the 4D space (and absolute time) can be considered as having the two components: 1) "visible" movement in the 3D space, and 2) constant "hidden" spin along the inaccessible round extra spatial dimension. Due to the "hidden" component of the particle movement, the real (pre-existing) values are immeasurable in principle and hence, the theory cannot operate with real values. Thus, the observer can never access the real particle parameters in the 4D space (or 5D spacetime), being left with the corresponding variables, the geometrical projections of the real values in the accessible 3D global space, $\mathbf{R}^3$. This fact explains why in the experiment, particles cannot have any pre-existing value (as predicted by a classical field theory), but always have variable (probable) parameters predicted by the QM descriptions. For instance, let us consider an electron as a 4D space point moving in global space having topology $\mathbf{R}^3 \times S^1$ (the global 4D space topology expected by the theory [4] is $S^3 \times S^1$; however, one can substitute S^3 by $\mathbf{R}^3$ due to the gigantic difference between the sizes of the Universe (S^3) and the hypothetical microscopic extra spatial dimension (S^1)). Assuming this 4D space geometry governs electromagnetism, the electron movement does depend on the extra coordinate in S^1, which, however, is inaccessible in principle. Hence, the theory can operate with 3D geometrical parameters in $\mathbf{R}^3$ only and has to substitute the extra coordinate-dependent values with complex-valued operators. Hence, the theory [4], like QM, being unable to calculate the real values ("hidden variables")can only predict corresponding variable values with certain probabilities.

Thus, the above-mentioned theory [4] actually preserves realism. Real values do exist, however, they always remain "hidden" to the observer due to the compactness of the extra dimension. In addition, the theory [4] preserves locality. Entanglement is actually one of the consequences of the theory's requirement to use a subjective "separation" of the 4D space into a "visible" 3D space and a "hidden" extra dimension. Like the GR, theory [4] originally has no requirement for any special coordinate system. Thus, no special direction corresponding to the extra coordinate may exist at the microscopic scale. Unfortunately, the theory itself [4] is not background-independent due to the necessity to use the observer-bound coordinate system. As entanglement is one of the consequences of this background-dependence, it may not be valid at the sub-atomic scale. Simply put, entanglement exists only for the observer in the observer-bound coordinate system, not in reality. Thus, a proper measurement of two distant particles would require some kind of dynamic correction of the two coordinate systems. With no such correction, no experiment can be considered valid, and no system correction can be accomplished at superluminal speed. Although the first loophole-free experiment [3] does confirm the Bell's inequalities, it did not provide any direct evidence of superluminal "information exchange" between the entangled particles.

Moreover, for the Bell test, the theory [4] indeed predicts the correlation probabilities identical to the QM predictions (Fig. 2). The extradimensional curvature and torsion are assumed to be the origin of particles' motion. Due to the fundamental inaccessibility of the real values of these 5D spacetime parameters, the theory has to operate with the complex field descriptions. Like the QED, the theory [4] can only provide complex-valued field parameters in $\mathbf{R}^3$ given by the Dirac's bispinor field ψ. As the field is a scalar field in $\mathbf{CP}^1$, the field original value is given by a point on the Riemann sphere, which is stereographically projected into a point on a complex plane. The latter gives a complex number, which defines the probability of a certain measurable outcome. Thus, any measurable parameter actually is pre-determined by the stereographic projection of a certain point on the Riemann sphere. In the Bell test, change of the measured parameters (i.e. correlation) depends on the rotation angle of the detector. In terms of the theory [4], this means that the projection plane to be rotated by the angle corresponding to the detector turn. Due to the fact that the measurable value of the field is actually a projective point, the plane rotation changes the predicted values non-linearly, proportional to cosine of the rotation angle (Fig. 2), thus matching the QM predictions.

In conclusion, the non-classical 5D spacetime geometry-based theory [4] appears able to preserve both realism and locality for the Bell test confirming, in general, Einstein's argument validity [2]. As the theory [4] predictions for the Bell test match the QM predictions, no experimental proof of the Bell's inequalities can be considered as evidence against the non-classical local hidden-variable theory.

References

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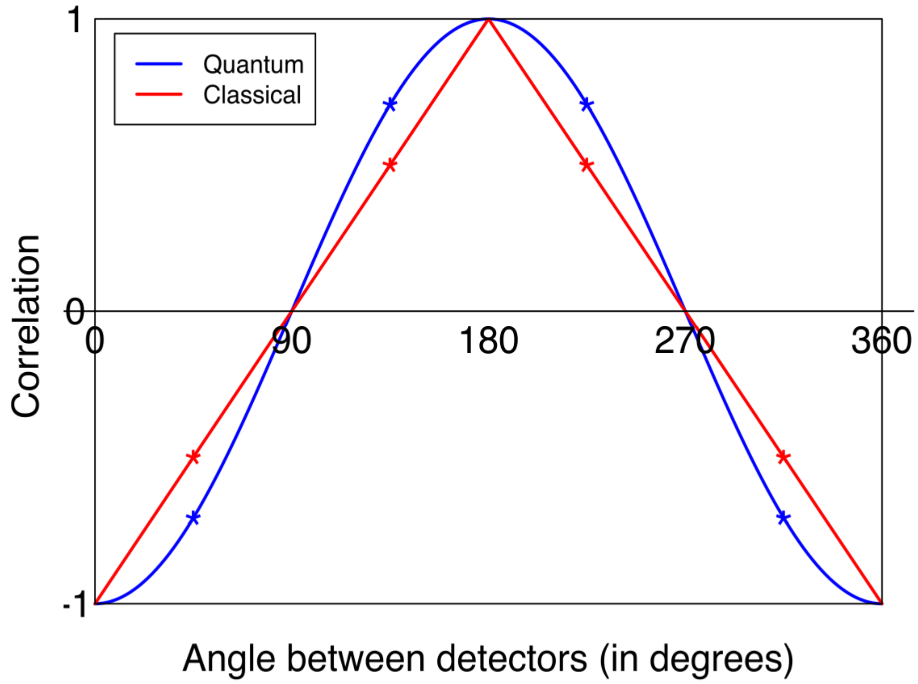

Figure 1. The best possible local hidden-variable classical field theory imitation (red) for the quantum correlation of two spins in the singlet state (blue), insisting on perfect anti-correlation at 0° and perfect correlation at 180°. The angles marked by stars (45°, 135°, 225°, 315°) exhibit maximal difference, and are the values measured in a typical Bell test (https://en.wikipedia.org/wiki/Bell%27s_theorem).

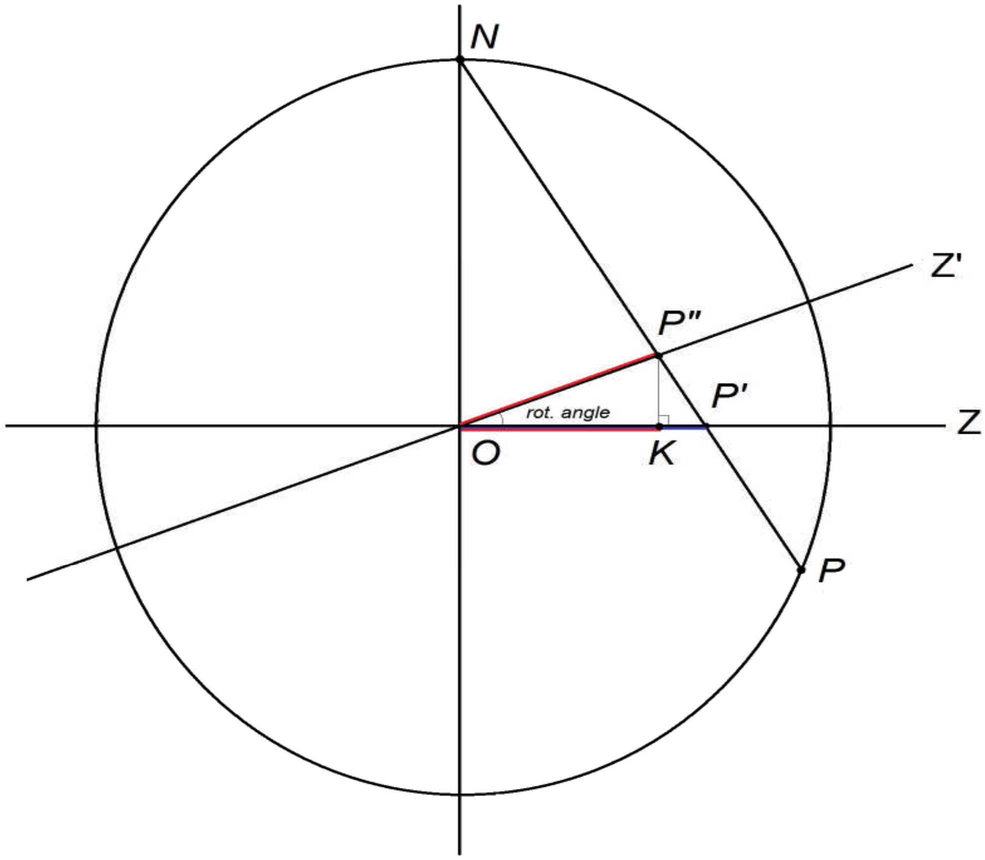

Figure 2. The non-classical local hidden-variable theory predictions for the Bell test match the QM predictions. The 5D spacetime geometry-based theory [4] substitutes the real values with the complex field parameters in $\mathbf{R}^3$. If the real value *P* is given by a geometrical point on the Riemann sphere (shown as a maximal section), when the measured value is defined by the point *P′*, stereographic projection of *P* onto complex line *Z* (geometrical plane shown as a line *Z*). Value *P′* defines the probability of the measurable outcome at the initial detector position. In the Bell test, change of the measured parameters (i.e. correlation) depends on the detector rotation angle. In terms of the theory [4], this means that complex projection line (plane) *Z* to be rotated by the rotation angle (rot. angle) and transformed into complex projection line (plane) *Z′*. Consequently, point *P′* transforms into complex point *P″*. However, all the values must be defined as projections onto *Z*. Hence, point *P″* to be projected into point *K* (changed theoretical value). The value in *K* is equal to the value in *P″* multiplied by cosine of the rotation angle. Thus, the complex line (plane) rotation $Z \rightarrow Z'$ changes the predicted values non-linearly, proportional to cosine of the rotation angle, thus matching the QM predictions.