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

God does not play dice with the universe. Albert Einstein

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Abstract

This letter attempts to show that the non-classical 5D spacetime geometry-based theory of electromagnetism (http://vixra.org/pdf/1811.0315v2.pdf) is able to preserve both realism and locality for the Bell test thus supporting Einstein's argument in general. In addition, the theory is able to match the quantum-mechanical (QM) predictions for the correlation. With the above-mentioned theory, the Einstein–Podolsky–Rosen (EPR) paradox may be explained with the assumption that real values do exist, however, are inaccessible in principle due to the compactness of the extra spatial dimension.

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, are not accounted for by QM. This explanation is generally referred to as the local hidden-variable theory, and the theory 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 curve (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), any classical field theory would be completely irrelevant. In case the replacement theory uses the QM mathematical descriptions, 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 explains the "hidden" nature of the real values and is able to match 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 is indeed able to match mathematical descriptions of the electromagnetism provided by the QED [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 field 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 the observer. A test particle's (e.g. electron's) 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), and has to use their geometrical projections 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 $\mathbf{R}^3$ x S^1 (the global 4D space topology expected by the theory [4] is S^3 x 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, is unable to calculate real values related to the extradimensional geometry and can only predict corresponding measurable parameters calculated with complex-valued operators as probable values. 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 a theoretical feature related to the measurable, not the real values. Considering the way theory [4] deals with the extradimensional geometrical parameters (i.e. real values), it becomes obvious that the real values are actually not entangled, even though the measurable parameters are. For instance, electron's spin appears to be a theoretical representation of the extradimensional torsion due to the particle's constant rotation along the "hidden" circular extra dimension. As the latter cannot be accessed by the observer, there cannot be any real value in the "visible" 3D space that would correspond to the special (extradimensional) direction. In terms of the theory [4], the real value is not the measurable particle's spin; it is the actual direction of the particle's movement along this special direction. Although the latter does exist at the microscopic scale, there is no rational reason for the electron to have any movement restriction related to this direction. An orbiting electron likely has a non-restricted directional freedom meaning that in the local space modeled by S^4, it can follow any direction, not only the special extradimensional direction. The theory however, cannot operate with the real direction in the 4D space substituting it with the two measurable (and hence variable) values of spin. Notably, the spin is not a real projective value, it is a complex field parameter introduced when the real values are replaced with complex-valued operators [4]. Like any other real value, the real spin-related value is inaccessible in principle, hence, entanglement is simply inapplicable to the real parameters. As the theory [4] purposely "sacrifices" the original background-independence of the 5D spacetime model for the sake of usability, all the theoretical parameters become bound to the observer's coordinate system when the gauge is chosen. As entanglement is a property of the gauged parameters (e.g. spin), it may not be for real, i.e. is not valid at the sub-atomic scale. Simply put, entanglement exists only for the observer in the observer-bound coordinate system, not in reality. Hence, a proper measurement of two distant particles will 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 [4]. 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 thus confirming, in general, Einstein's argument validity [2] by stating that real values do exist, however, are inaccessible in principle due to the compactness of the extra spatial dimension. As the theory [4] predictions for the Bell test match the QM predictions, experimental proof of the Bell's inequalities may not be used as evidence against the non-classical local hidden-variable theory.

References

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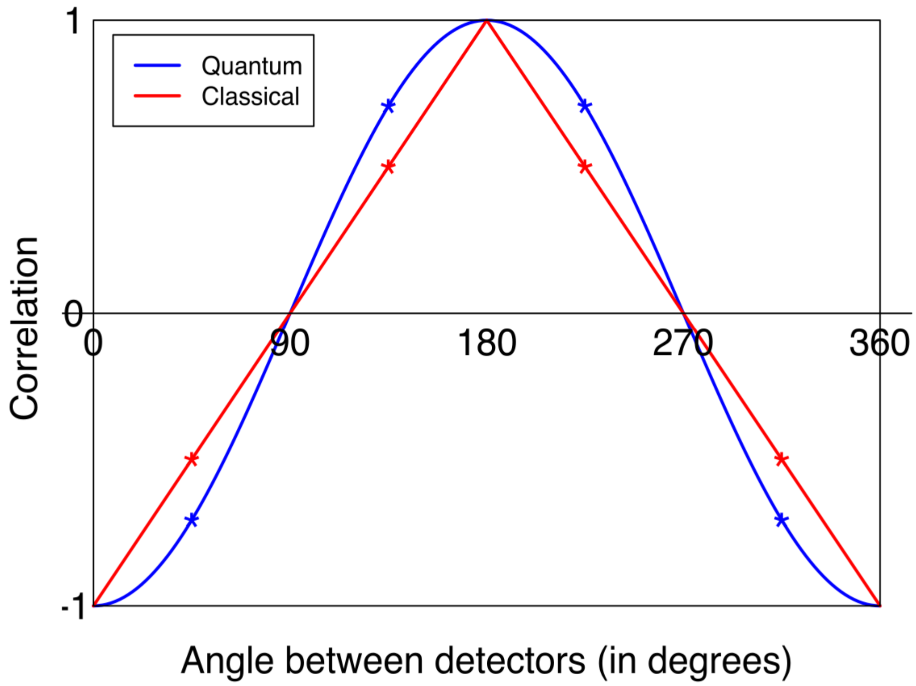

Figure 1. The best possible local hidden-variable classical field theory imitation (red) for the quantum correlation of two spins in the singlet state (blue), insisting on perfect anti-correlation at 0° and perfect correlation at 180°. The angles marked by stars (45°, 135°, 225°, 315°) exhibit maximal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

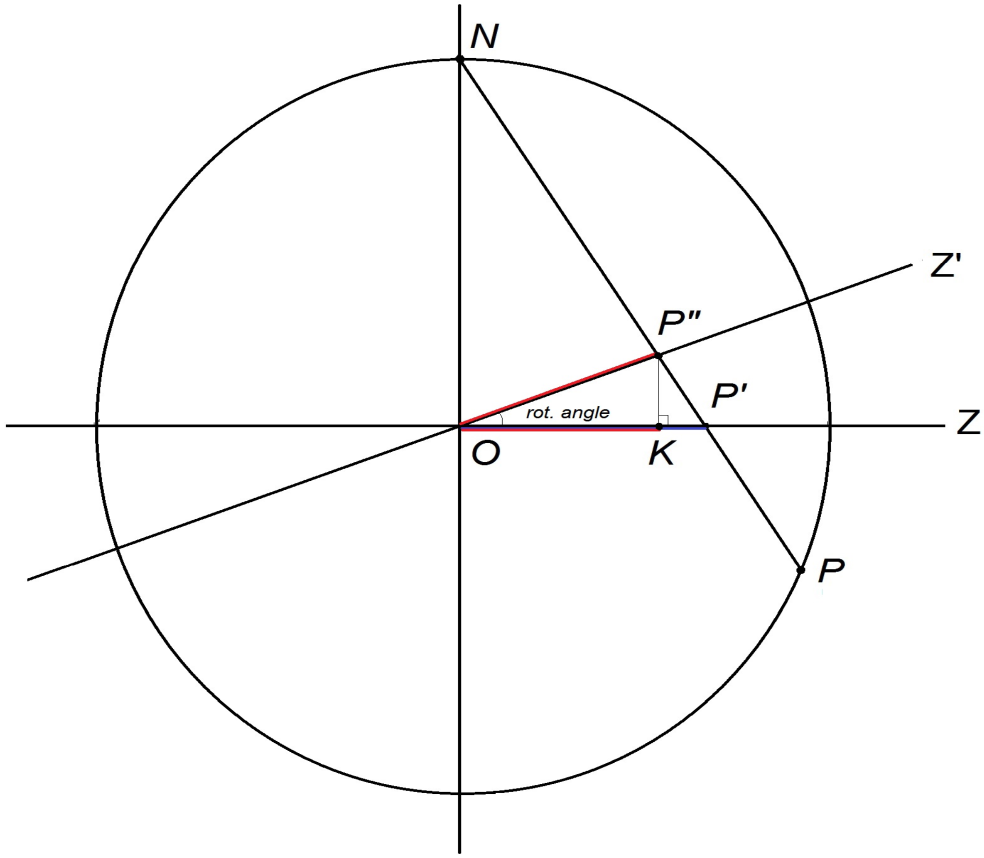

Figure 2. The non-classical local hidden-variable theory predictions for the Bell test match the QM predictions. The 5D spacetime geometry-based theory [4] substitutes the real values with the complex field parameters in $\mathbf{R}^3$. If the real value P is given by a geometrical point on the Riemann 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). 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 another complex projection line (plane Z'). Consequently, point P' transforms into 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. Hence, 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.