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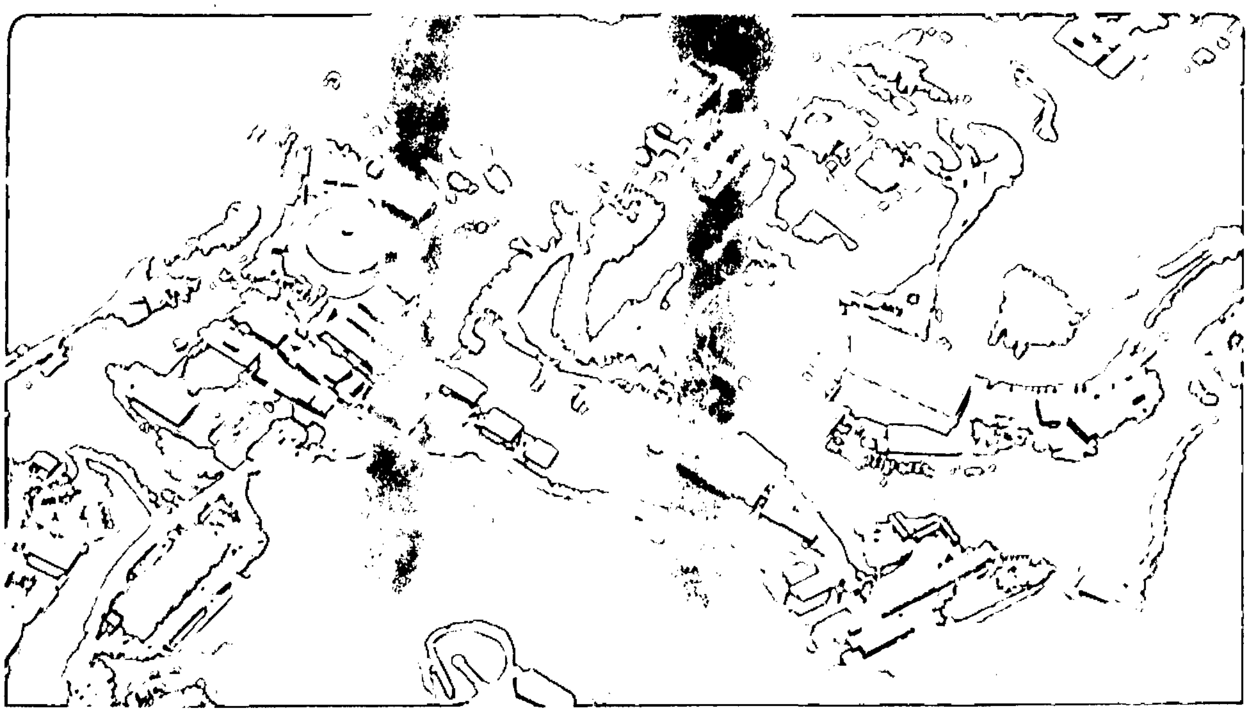

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Abstract

It is pointed out that a recently proposed resolution to the Einstein-Podolsky-Rosen and Bell paradoxes fails to satisfy the required locality conditions.

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Einstein, Podolsky, and Rosen argued in 1935 that if quantum theory is local then it is incomplete.[1,2] Their locality requirement was essentially that the results of experiments in one spacetime region not depend on choices made by experimenters in spacelike-separated regions. Bohr[3] answered EPR in a way that did not directly challenge this locality requirement. However, Bell[4] later showed that this requirement was incompatible with the validity of the statistical predictions of quantum theory. Since the validity of these predictions was assumed by EPR the result of Bell rendered vacuous the EPR argument for incompleteness.

The profound and startling character of Bell's nonlocality result has made it the object of intensive scrutiny from the time of its 1964 publication until now.[5,6] This scrutiny has thus far revealed no escape from Bell's conclusions. Very recently, however, it was claimed in this journal that an escape was possible. In particular, it was claimed that the statistical predictions of quantum theory could be explained without violating locality provided one discards some normal ideas about probabilities.[7]

It would be worth considering unusual ideas about probability if this could save locality. However, the proposed model fails to satisfy the critical locality requirements.

The proposed model is based on the assertion that it is possible to assign a spin value of + 1/2 or - 1/2 to every point on a unit sphere in a way that ensures the following probability result: Let y be any point on the unit sphere, and let $c(y,\theta)$ be the circle on this sphere consisting of the points x on that sphere such that $x \cdot y = \cos\theta$. Then the probability that the spin component along x is + 1/2, if x is confined to $c(y,\theta)$, is $\cos^2 \frac{1}{2} \theta$ or $\sin^2 \frac{1}{2} \theta$

according to whether the component of spin along y is + 1/2 or - 1/2.

This assignment of spin values provides a local classical model for the probability of finding the spin component in a direction x to be (say) + 1/2 subject to the condition that this spin has been determined by a prior direct measurement to have (say) component + 1/2 in the direction y. For if it is supposed that the prior direct measurement of the y component produces an unknown or random rotation about the y axis then for the subsequent measurement of the spin component along any unit vector x satisfying $x \cdot y = \cos\theta$ it will be the average of the original spin function on the circle $c(y,\theta)$ that will be the relevant quantity. Consequently, the spin assignment specified above provides a local classical model for the quantum theoretical probabilities associated with this experiment.

This local model is next applied to the case in which the prior determination of the spin component along the direction y is achieved indirectly by measuring the value of the y component of a far-away particle. The two-particle system was originally prepared in a spin-singlet state, so that the measurement of the y component of spin of the far-away particle determines also the y component of spin of the nearby particle.

In this local model the measurement of the spin of the far-away particle is not supposed to disturb the spin of the nearby particle. Consequently, there is, in the new situation, no physical rationale for averaging over the circle $c(y,\theta)$: in the new situation the natural rule would be to use the value of the spin-component in the direction x specified by the second measurement.

This natural rule leads, however, to mathematical difficulties. Thus it was proposed that the conditional probability [that the

spin component along direction x to be (say) + 1/2, subject to the condition that the spin component along y be (say) + 1/2] be again calculated by averaging over $c(y,\theta)$, even though in this new situation there is no physical justification for this averaging. The model was put forth as a model that admittedly does not conform to normal ideas about how to compute probabilities, but that is nevertheless local and generates the quantum theoretical predictions, and hence is a counter-example to Bell's nonlocality theorem.

However, it was not demonstrated that the proposed model actually satisfies the required locality property that the conditional probabilities generated by the proposed rule be identifiable with the relative frequencies generated by sequences of results that satisfy the locality condition that the results in each region be independent of the choice of experiment performed in the other region.

At first glance it might seem that locality would be guaranteed by the fact that the conditional probability is calculated from a local model. However, the rule for calculating the conditional probability instructs one to perform an average over the circle $c(y,\theta)$, and this circle depends on y, which is determined by the choice of the far-away experiment. Thus the conditional probability is calculated by performing an average over a set that depend on the choice of the far-away experiment. This procedure is not manifestly local, and it is therefore not obvious that the conditional probabilities computed from this procedure will be compatible or identifiable with the relative frequencies obtained from sequences of results that are subject to the locality condition that the results in each region be independent of the choice of experiment performed in the other region. For these latter relative frequencies arise from averages over sequences of results in which the results of the nearby experiments do not depend on the far-away choice of experiment.

To determine whether the proposed model is indeed local, in the required sense, one must determine whether one can identify the conditional probabilities obtained from the model with relative frequencies obtained from sequences of results that satisfy the locality condition that the results in each region be independent of the choice of experiment made in the other region. But the conditional probabilities obtained from the model are the same as those obtained from quantum theory. Consequently, Bell's results immediately establish[6] that the conditional probabilities obtained from the proposed model cannot be compatible with relative frequencies generated by sequences of results that satisfy the above-mentioned locality condition. Thus the unusual treatment of probabilities does not upset Bell's result, which actually applies in a completely standard way. Rather it introduces into an otherwise local model a manifestly nonlocal ingredient. This nonlocal ingredient permits the model to generate the quantum theoretical predictions. The situation is thus in complete accord with Bell's theorem.

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