LOCAL AND NONLOCAL PROBABILITIES IN EINSTEIN-PODOLSKY-ROSEN CORRELATIONS

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ABSTRACT

It is shown that the quantum Einstein-Podolsky-Rosen correlations can be described by local and nonlocal probabilities. Nonlocal probabilities are derived from the spectral properties of spin projection operators and local probabilities are derived using spin coherent states. These two types of probabilities are shown to be different, though mathematically equivalent, representations of the same quantum mechanical reality.

1. Introduction

The concept of local realism (LR) is based on the fundamental assumption that physical systems can be described by local objective properties that are independent of observation. LR versus the quantum description has been described best in the framework of spin-1/2 Einstein–Podolsky-Rosen (EPR) correlations.[1]

The spin-1/2 EPR correlations involve the measurements of the spin correlations:

$$P(\vec{a};\vec{b}) = \langle \hat{P}(\vec{a}) \otimes \hat{P}(\vec{b}) \rangle. \tag{1}$$

In this expression $\hat{P}(\vec{a})$ and $\hat{P}(\vec{b})$ are the spin projection operators of the particle $a(b)$ along the polarization direction $\vec{a}(\vec{b})$, and the quantum expectation value is calculated in a singled state of the two spins a and b.

In the framework of LR the spin variables are described by local and deterministic function $\sigma(\vec{a},\lambda_a)$ and $\sigma(\vec{b},\lambda_b)$ with hidden variables λ_a and λ_b. Correlations of local spin realities are obtained using a stochastic model of local hidden variables (LHV). Following the basic ideas of LHV theory the hidden parameters are randomly distributed with a positive and normalized distribution $P(\lambda_a;\lambda_b)$ which depends locally on the hidden-variables. In a LHV approach the spin variables have hidden and unknown orientations which are averaged out during a detection process. Such theories lead to LHV correlation give by the following formula:

$$p(\vec{a};\vec{b}) = \int d\lambda_a \int d\lambda_b P(\lambda_a;\lambda_b) p(\vec{a},\lambda_a) p(\vec{b},\lambda_b). \tag{2}$$

In this formula the action of the polarizer $\vec{a}$ and $\vec{b}$ is described by two local realities:

$$p(\vec{a},\lambda_a) = \frac{1}{2}(1+\sigma(\vec{a},\lambda_a)) \text{ and } p(\vec{b},\lambda_b) = \frac{1}{2}(1+\vec{\sigma}(\vec{b},\lambda_b)). \tag{3}$$