The Bell theorem revisited: geometric phases in gauge theories

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The Bell theorem stands as an insuperable roadblock in the path to a very desired intuitive solution of the EPR paradox and, hence, it lies at the core of the current lack of a clear interpretation of the quantum formalism. The theorem states through an experimentally testable inequality that the predictions of quantum mechanics for the Bell polarization states of two entangled particles cannot be reproduced by any statistical model of hidden variables that shares certain intuitive features. In this paper we show, however, that the proof of the Bell theorem involves a subtle, though crucial, assumption that is not required by fundamental physical principles and, hence, it is not necessarily fulfilled in the experimental setup that tests the inequality. Indeed, this assumption can neither be properly implemented within the standard framework of quantum mechanics. Namely, the proof of the theorem assumes that there exists a preferred absolute frame of reference, supposedly provided by the lab, which enables to compare the orientation of the polarization measurement devices for successive realizations of the experiment and, hence, to define jointly their response functions over the space of hypothetical hidden configurations for all their possible alternative settings. We notice, however, that the preferred frame of reference required by the proof of the Bell theorem cannot exist in models in which the gauge symmetry of the experimental setup under global rigid rotations of the two detectors is spontaneously broken by the hidden configurations of the pair of entangled particles and a non-zero geometric phase appears under some cyclic gauge symmetry transformations. Following this observation, we build an explicitly local model of hidden variables that reproduces the predictions of quantum mechanics for the Bell states.