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On the probabilistic description of a multipartite correlation scenario with arbitrary numbers of settings and outcomes per site

Elena R Loubenets

Applied Mathematics Department, Moscow State Institute of Electronics and Mathematics, Moscow 109028, Russia

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Abstract
We consistently formalize the probabilistic description of multipartite joint measurements performed on systems of any nature. This allows us (1) to specify in probabilistic terms the difference between nonsignaling, the Einstein–Podolsky–Rosen (EPR) locality and Bell's locality; (2) to introduce the notion of a local hidden variable (LHV) model for an $S_1 \times \cdots \times S_N$-setting N-partite correlation experiment with outcomes of any spectral type, discrete or continuous, and to prove both general and specifically 'quantum' statements on an LHV simulation in an arbitrary multipartite case; (3) to classify LHV models for a multipartite quantum state, in particular, to show that any N-partite quantum state, pure or mixed, admits an arbitrary $S_1 \times 1 \times \cdots \times 1$-setting LHV description; (4) to evaluate a threshold visibility for an arbitrary bipartite noisy quantum state to admit an $S_1 \times S_2$-setting LHV description under any generalized quantum measurements of two parties.

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1. Introduction

The probabilistic description of quantum measurements performed by several parties has been discussed in the literature ever since the seminal publication [1] of Einstein, Podolsky and Rosen (EPR) in 1935. In that paper, the authors argued that *locality*[1] of measurements performed by different parties on perfectly correlated quantum events implies the 'simultaneous reality—and thus definite values'[2] of physical quantities described by noncommuting quantum observables. This EPR argument, contradicting the quantum formalism [2] and referred to as the EPR paradox, seemed to imply a possibility of a *hidden*

[1] In [1], the Einstein–Podolsky–Rosen locality of parties' measurements is otherwise expressed as 'without in any way disturbing' systems observed by other parties.
[2] See [1], page 778.