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An analysis of the validity of local causality at the statistical level in Einstein-Podolsky-Rosen-type situations

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Abstract. We investigate the question of local causality at the statistical level in Einstein-Podolsky-Rosen (EPR) type situations, taking into account the most general class of measurements envisaged in quantum theory. The condition for local causality at the statistical level used in this paper pertains to the invariance of statistics of measurements on one sub-system with respect to the choice and type of measurements on its correlated partner in the EPR-type examples. Our analysis is based on a criterion for measurements performed on one of the EPR sub-systems, which is more general than the criterion used in the earlier treatments. We discuss both non-absorptive measurements (where the system is available for further observation after the measurement is performed) as well as absorptive measurements (where the system is absorbed in the process of a particular outcome being realized). We show that in the case of arbitrary non-absorptive measurements characterized by operation-valued measures, the requirement of local causality at the statistical level is satisfied and in the process we identify the key inputs in such a proof. We also obtain the specific conditions under which an absorptive measurement satisfies local causality at the statistical level.

Keywords. Local causality at statistical level; Einstein-Podolsky-Rosen argument; absorptive measurements.

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1. Introduction

The peculiarities of quantum correlations between spatially separated systems have been discussed eversince the work of Einstein *et al* (EPR) (1935) over fifty years ago. The standard illustration of an EPR type set up is that discussed by Bohm (1951) and involves a spin-zero system decaying into two correlated spin-1/2 particles. A key element in this example and all its variants is the non-separable character of the (non-factorizable) two particle wave function, which is a superposition of products of one particle wave functions. The intriguing feature of an EPR type set up is that the state of any one particle of the pair "collapses" (or changes due to measurement) depending on the measurement performed on its partner and the outcome realized, even though the members of the EPR pair are sufficiently separated so that they are mutually non-interacting (see Selleri (1988) for a recent overview).

There have indeed been several demonstrations that the above non-local feature of the state vector collapse does not lead to any observable violations of local causality at the statistical level (Ghirardi *et al* 1980, 1988; Kraus 1983). It is shown that the density operator characterizing the ensemble of either of the two particles in the EPR type set up, is actually independent of whatever measurement is (or is not) performed