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Impossible measurements revisited

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It is by now well recognized that the naive application of the projection postulate on composite quantum systems can induce signalling between their constituent components, indicative of a break- down of causality in a relativistic spacetime context. Here we introduce a necessary and sufficient condition for an ideal measurement of an observable to be nonsignalling. As well as being particularly simple, it generalizes previous no-signalling conditions in that it allows for degeneracies and can be applied to all bounded self-adjoint operators. The condition is used to establish that arbitrary sums of local observables will not signal, in accordance with our expectations from relativistic quantum field theory. On the other hand, it is shown that the measurement of the tensor product of commuting local observables, for example bipartite operators of the form $A \otimes B$, can in fact signal, contrary to the widely held belief that such measurements are always locally realizable. The implications for the notion of measurement in relativistic quantum field theory are addressed; it appears that the most straightforward application of the standard quantum formalism generically leads to violations of causality. We conclude that either the class of observables that can be measured should be restricted and/or that the naive translation of the measurement framework of quantum theory, in particular the projection postulate, to quantum field theory should be reevaluated.

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