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THEORETICAL PHYSICS

Foundations of Quantum Theory

Multipartite Separability Inequalities Exponentially Stronger Than Local Reality Inequalities

It was shown that separability of N -qubit quantum states implies new inequalities on Bell correlations which are exponentially stronger than local reality inequalities. Consider a composite system which breaks up into N qubits. The k th component is measured with apparatus specified by a set of parameters a_k to determine the value of a variable $A^{(k)}(a_k)$ which by its very definition must lie between -1 and +1. In quantum theory each $A^{(k)}(a_k)$ becomes a self-adjoint operator. Let $A^{(k)}(a_k)$ be $\sigma_x^{(k)}$ or $\sigma_y^{(k)}$, the Pauli spin operators for the k th qubit. Define $\sigma_{\pm}^{(k)} = \sigma_x^{(k)} \pm i\sigma_y^{(k)}$, and the Bell operators $B_+ = \frac{1}{2} \left(\otimes_{k=1}^N \sigma_+^{(k)} + \otimes_{k=1}^N \sigma_-^{(k)} \right)$, $B_- = \frac{1}{2i} \left(\otimes_{k=1}^N \sigma_+^{(k)} - \otimes_{k=1}^N \sigma_-^{(k)} \right)$. It was proved that quantum correlations in arbitrary separable states must obey $|\text{Tr } \rho B_{\pm}| \leq 1$, and $|\text{Tr } \rho B_+| + |\text{Tr } \rho B_-| \leq \sqrt{2}$, for every N -partite separable density operator ρ . These separability inequalities are stronger than local reality inequalities by a factor $2^{(N-1)/2}$. We expect their experimental violations by entangled states to be signatures of non-separability useful for quantum information processing, in particular, quantum cryptography.