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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 kth 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 kth qubit. Define $\sigma_\pm^{(k)} = \sigma_x^{(k)} \pm i\sigma_y^{(k)}$, and the Bell operators $B_+ = \frac{1}{2}\left(\bigotimes_{k=1}^N \sigma_+^{(k)} + \bigotimes_{k=1}^N \sigma_-^{(k)}\right), B_- = \frac{1}{2i}\left(\bigotimes_{k=1}^N \sigma_+^{(k)} - \bigotimes_{k=1}^N \sigma_-^{(k)}\right)$ It was proved that quantum correlations in arbitrary separable states must obey $|\mathrm{Tr}\ \rho B_\pm| \leq 1$, and $|\mathrm{Tr}\ \rho B_+| + |\mathrm{Tr}\ \rho B_-| \leq \sqrt{2}$, 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.