

# TIFR Annual Report 2003-04

## 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  $B_+ = \frac{1}{2} \left( \bigotimes_{k=1}^N \sigma_+^{(k)} + \bigotimes_{k=1}^N \sigma_-^{(k)} \right)$ ,  $B_- = \frac{1}{2i} \left( \bigotimes_{k=1}^N \sigma_+^{(k)} - \bigotimes_{k=1}^N \sigma_-^{(k)} \right)$ . It was proved that quantum correlations in arbitrary separable states must obey  $|\text{Tr } \rho B_{\pm}| \leq 1$ , and  $|\text{Tr } \rho B_+| + |\text{Tr } \rho B_-| \leq \sqrt{2}$ , for every  $N$ -partite separable density operator  $\rho$ . These separability inequalities are stronger than local reality inequalities by a factor  $2^{(N-1)/2}$ . Their experimental violations by entangled states are expected to be signatures of non-separability useful for quantum information processing, in particular, quantum cryptography. [S. M. Roy]