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Title: « Bell theorem and its generalization: From foundations to applications »

Abstract:
Quantum theory has several puzzling properties. In particular, it predicts that information carried by quantum objects is incompatible with the use of the logical 'or'. While in our intuition of the world, a cat hidden in a box can be dead or alive, according to quantum mechanics this assertion is not valid anymore. Hence, physicists invented a new concept: a quantum cat can be dead 'and' alive. This new concept is however hard to accept: couldn't we imagine a new theory replacing quantum theory and compatible again with our 'or'? In 1964, Bell proved that, in some sense, this puzzling feature of quantum theory is a necessity: there does not exist any 'reasonable' theory of information (which would replace quantum information theory) compatible with this logical 'or'. Bell's seminal proof is based on quantum correlations, which are obtained when multiple parties perform independent measurements on a shared quantum state, and on very weak assumptions.
I'll first review the Bell theorem. Then, I will discuss some of its foundational main consequences and some of its concrete applications to certification of quantum devices. At last, I will discuss recent generalization of this theorem in the context of causal quantum networks, in which multiple parties perform independent measurements on several, independent quantum states. In particular, I'll show that Real Quantum Theory (the information theory obtained replacing complex by real numbers in standard Quantum Information Theory) can be ruled out by a Bell-like experiment, and discuss applications of Bell ideas to quantum distributed computing.