Quantum Violation of an Instrumental Test

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Inferring causal relations from experimental observations is of primal importance in science. Instrumental tests provide an essential tool for that aim, as they allow to estimate causal dependencies even in the presence of unobserved common causes. However, in view of Bell’s theorem, which implies that quantum mechanics is incompatible with our most basic notions of causality, it is of utmost importance to understand if and how paradigmatic causal tools obtained in a classical setting can be carried over to the quantum realm. Here we show that quantum effects imply radically different predictions in the instrumental scenario. Among other results, we show that an instrumental test can be violated by entangled quantum states. Furthermore, we demonstrate such violation using a photonic setup with active feed-forward of information, thus providing an experimental proof of this new form of non-classical behavior. Our findings have fundamental implications in causal inference and may also lead to new applications of quantum technologies.

In this presentation we will discuss how instrumental tests can be used to estimate and quantify causal influences in controlled experiments. Following that we will show how the presence of quantum correlations can lead to an overestimate of such causal relations. Finally we will discuss the implications of these results to the foundations of quantum physics.