Contribution ID: **31** Type: **talk**

Interrelations between local correlations, nonlocal correlations and causality

Monday, 23 September 2019 16:25 (40 minutes)

The set of quantum mechanical nonlocal correlations is unique and intriguing in many ways. Characterizing this set is expected to cast light on the fundamental physical principles governing quantum theory, those from which the mathematical structure of the theory arises. Recently, we have shown ([A. Carmi and E. Cohen, Sci. Adv. eaav8370 (2019)] and followup works) that this set may largely be derived from the requirement that uncertainty relations, broadly understood, are local in the sense of being independent of the choices made by other parties. Relativistic independence, as we have named this condition, treats nonlocal correlations and uncertainty relations on an equal footing. Furthermore, it implies that quantum mechanics can be as nonlocal as it is without violating relativistic causality thanks to the existence of intrinsic uncertainty.
The notion of relativistic independence can be also encoded in a new kind of nonlocal hidden variables we term "pseudolocal". We have shown that different kinds of quantum hidden variables lead to backwards in time signaling if known [A. Carmi, E. Cohen, L. Maccone, and H. Nikolic, arXiv:1903.01349].
In this talk we shall briefly present these previous works and then build upon them to show how this view gives rise to causal structures. We will demonstrate how such a causal structure tightens the bounds on the set of nonlocal correlations in any physical theory as the number of experimenters, measuring devices and incorporated statistical moments increases. Finally, we will connect the failure of counterfactual definiteness with time-irreversibility and discuss a sense in which entanglement gives rise to the arrow of time.

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Session Classification: Teleportation, entanglement and CTCs/OTCs