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DIPARTIMENTO DI SCIENZE MATEMATICHE E INFORMATICHE, SCIENZE FISICHE E SCIENZE DELLA TERRA
Dottorato di Ricerca in Fisica

Appunti di Fisica '26

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Aula Leonardo, Dipartimento di Scienze Matematiche e Informatiche, Scienze Fisiche e Scienze della Terra (MIFT) - Università degli Studi di Messina

Quantum violation of an instrumental test beyond classical causality

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Quantum violations of Bell inequalities, first formulated by John Stewart Bell, show that the physical world cannot simultaneously satisfy several seemingly natural assumptions: freedom in the choice of measurements, locality, the absoluteness of observed events, and classical notions of cause and effect. Bell's theorem and quantum nonlocality therefore reveal a fundamental incompatibility between the predictions of quantum mechanics and any classical local worldview.

Recent research has asked whether this conflict could be avoided by adopting broader notions of causality. In particular, extended Wigner's friend scenarios—motivated by foundational questions about the quantum measurement problem—suggest that quantum correlations can remain incompatible with classical reasoning even under such more general descriptions.

In this talk, I will first introduce quantum nonlocality and the causal framework used to describe it. I will then discuss Wigner's friend scenarios and the conceptual questions they raise. Finally, I will present recent work carried out in collaboration between Griffith University and Sapienza University of Rome. In this work, we study a network called an instrumental test, in which some communication between parties is allowed. We demonstrate, both theoretically and experimentally using quantum photonic systems, that the observed quantum correlations still defy any physical model satisfying freedom of choice, the absoluteness of observed events, and generalized cause-and-effect relations. These results highlight an even stronger departure of quantum physics from classical intuitions and point to new directions in both quantum foundations and quantum technologies.