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Temporal witnesses of non-classicality and conservation laws

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A general entanglement-based witness of non-classicality has recently been proposed, which can be applied to testing quantum effects in gravity. This witness is based on generating entanglement between two quantum probes via a mediator. We provide a "temporal" variant of this witness, using a single quantum probe to assess the non-classicality of the mediator. Within the formalism of quantum theory, we show that if a system M can induce a coherent dynamical evolution of a quantum system Q, in the presence of a conservation law, then M must be non-classical. We shall explore the possibility of interpreting this temporal witness of non-classicality as the equivalent of generating entanglement in time between the single probe Q before and after the evolution mediated by M, provided that a global quantity is conserved in the evolution. This creates a temporal parallel to the previously proposed entanglement-based witness of non-classicality, offering intriguing perspectives on locality in time and the connections between quantum correlation in space and time. Moreover, this argument supports witnesses of non-classicality relying on a single quantum probe, which can be applied to several open issues, notably in quantum gravity or quantum biology.

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