From Non-Markovianity to the Quantumness of Gravitational Dynamics

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Non-Markovian dynamics in open quantum systems arise from memory effects due to the coupling between a system and its environment. While such memory effects can often be accounted for by purely classical mechanisms, certain dynamical signatures necessarily require the environment to store and return genuinely quantum information. In these cases, the observed system dynamics alone certifies the quantumness of the environmental degrees of freedom, without any detailed knowledge of their structure. Building on this idea, we construct experimentally accessible witnesses for these signatures, based solely on measurements of the probe system. We then show that this framework enables a one-sided verification of the quantumness of gravitational dynamics, providing an alternative to the standard two-probe proposals based on gravity-induced entanglement.

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