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# Probing Gravitationally Induced Entanglement via Dynamical Superpositions of Quantum Matter

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Gravitationally Induced Entanglement (GIE) between two levitated objects in quantum states can investigates the quantum nature of the gravitational field in a tabletop experiment. To formally treat the entangling dynamics —both unitary and open —between superpositions of quantum states of matter entangled with a qubit, the Gaussian formalism of continuous-variable systems can be extended to include non-Gaussian states. This is achieved by considering a "superposition of phase spaces,"each characterized by an associated covariance matrix and a vector of first moments. Thus, we propose a protocol to exponentially delocalize a cat state of a massive object, which can be successfully recombined to complete an interferometer. When two such interferometers interact via gravity, GIE can be sensed exponentially fast in the expansion time —if gravity is not classical. The introduced formalism allows noise analysis of the protocol.

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