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Probing the Quantum Nature of Gravity through Diffusion

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The quest to determine whether gravity is quantum has challenged physicists since the mid-20th century, due to the impracticability of accessing the Planck scale, where potential quantum gravity effects are expected to become relevant. While recent entanglement-based tests have provided a more promising theoretical path forward, the difficulty of preparing and controlling large mass quantum states has hindered practical progress. We present an alternative strategy that shifts the focus from complex quantum state manipulation to the simpler observation of a probe's motion. By proving that a classical and local gravitational field must inherently display randomness to interact consistently with quantum matter, we show that this randomness induces measurable diffusion in a probe's motion, even when the probe is in a classical state. This diffusion serves as a distinctive signature of classical gravity coupling to quantum matter. Our approach leverages existing experimental techniques, requiring only the accurate tracking of a probe's classical center-of-mass motion, and does not need any quantum state preparation, thereby positioning this method as a promising and practical avenue for advancing the investigation into the quantum nature of gravity.

Working Group

WG3 - Low-energy gravitational effects in quantum systems

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