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Detecting post-Newtonian classical and quantum gravity via quantum clock interferometry

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Understanding physical phenomena at the intersection of quantum mechanics and general relativity remains one of the major challenges in modern physics. Among various approaches, experimental tests have been proposed to investigate the dynamics of quantum systems in curved spacetime and to examine the quantum nature of gravity in the low-energy regime. However, most previous studies have considered only Newtonian gravity, leaving the post-Newtonian regime largely unexplored. Developing an experimental test to probe how gravitational and quantum mechanical effects interact in this regime would provide valuable insights into the physics bridging quantum mechanics and general relativity. In this study, we propose an experimental test to investigate how post-Newtonian gravity affects quantum systems and to examine its quantum nature. Specifically, we design and analyze two types of experiments: one using a quantum clock interferometry setup to detect the gravitational field generated by a rotating mass, and another leveraging this effect to generate gravity-mediated entanglement. Although the proposed experiments are extremely challenging to implement, they are inherently suited for probing post-Newtonian gravity. This is because, due to the symmetry of the configuration, the setup is insensitive to the Newtonian gravitational contribution while sensitive to the frame-dragging effect. Moreover, assuming the universality of gravitational redshift, our approach may offer a possible way not only to probe the quantum nature of gravity but also to investigate whether spacetime itself exhibits quantum features. The results of this study open up new avenues for investigating physical phenomena in the regime where quantum mechanics and general relativity converge.

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