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Clocks and superpositions of proper time – Post-Newtonian effects in quantum mechanics IGOR PIKOVSKI, ITAMP / Harvard University, MAGDALENA ZYCH, University of Vienna, FABIO COSTA, University of Queensland, CASLAV BRUKNER, University of Vienna — Phenomena inherent to quantum theory on curved space-time are typically assumed to be only relevant at extreme physical conditions: at high energies and in strong gravitational fields. Here we consider low-energy quantum mechanics in the presence of weak gravitational time dilation and show that the latter leads to novel phenomena that can be probed in experiments. We study a quantum version of the "twin paradox" in which a system is brought in superposition of being at two different gravitational potentials, and show that time dilation induces entanglement between internal degrees of freedom and the center-of-mass of a composite particle. The effect of general relativistic time dilation on a quantum wave function can thus be probed in optical or matter-wave interferometry. In addition, we derive that time dilation causes universal decoherence of all composite quantum systems and thus causes the transition to classicality for microscale systems. Our results show that the interplay between quantum theory and general relativity offers novel phenomena and that such a regime can be accessed with quantum optical experiments.

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