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Metric descriptions of gravitation, among them general relativity as today's established theory, are founded on assumptions summarized in the Einstein equivalence principle (EEP). Its violation would hint at unknown physics and could be a leverage for the development of quantum gravity. Atomic clocks are excellent systems to probe aspects of EEP connected to (proper) time and have evolved into a working horse for tests of local position invariance (LPI). Even though the operational definition of time requires localized and idealized clocks, quantum systems like atoms allow for spatial superpositions that are inherently delocalized. While quantum experiments have tested other aspects of EEP, no competitive test of LPI has been performed or proposed allowing for an intrinsic delocalization. We extend the concepts for tests of the universality of clock rates (one facet of LPI) to atom interferometry generating delocalized quantum clocks. The proposed test depends on proper time with a favorable scaling and is, in contrast to fountain clocks, robust against initial conditions and recoil effects. It enables optical frequencies so that the projected sensitivity exceeds the one of state-of-the-art localized clocks. These results extend our notion of time, detached from classical and localized philosophies.

Poster Abstract

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