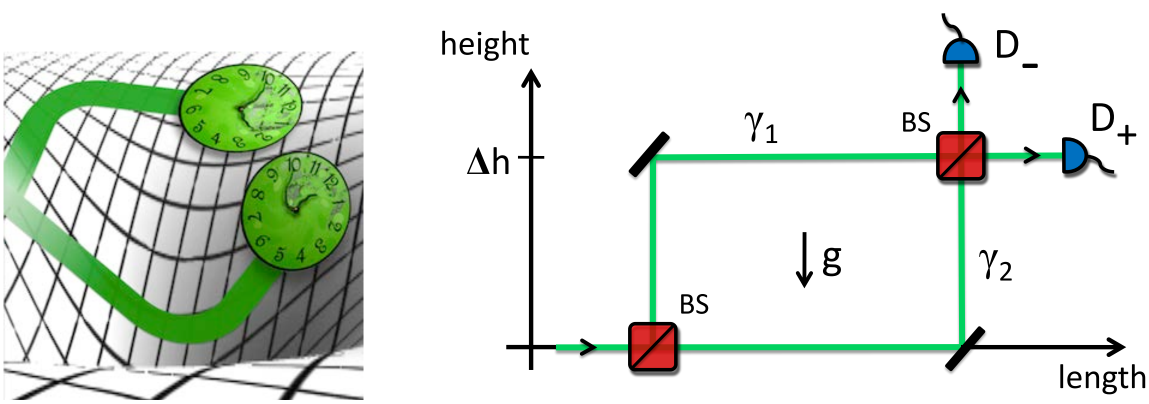
Quantum interferometric visibility as a witness of general relativistic proper time

Magdalena Zych, Fabio Costa, Igor Pikovski, Časlav Brukner

Faculty of Physics, University of Vienna, Austria

Current attempts to probe general relativistic effects in quantum mechanics focus on precision measurements of phase shifts in matter-wave interferometry. Yet, phase shifts can always be explained as arising from the Aharonov-Bohm effect, where a particle in a flat space-time is subject to an effective potential. Additionally, all current experiments with matter-waves probe only the Newtonian limit of gravity. Here we propose a quantum effect that cannot be explained without the general relativistic notion of proper time [1]. We consider interference of a clock - a particle with evolving internal degrees of freedom - that will not only display a phase shift but also reduce the visibility of the interference pattern. According to general relativity, proper time flows at different rates in different regions of space-time. Therefore the visibility will drop to the extent to which the path information becomes available in the clock. Such a gravitationally induced decoherence would provide the first test of the genuine general relativistic notion of proper time in quantum mechanics.



Left: Illustration of a clock in superposition on a curved background space-time. Right: Schematic of a Mach-Zehnder interferometer in the presence of a gravitational acceleration g. A matter-wave with an internal clock is split on a beamsplitter (BS) into a superposition of paths γ_1 and γ_2, which differ in height by Δh. If the clock is precise enough to measure the difference in proper times between the two paths, it will acquire which-way information. The interferometric visibility will therefore be reduced due to the quantum complementarity principle.

[1] M. Zych, F. Costa, I. Pikovski, Č. Brukner. *Nat. Commun.* **2**, doi:10.1038/ncomms1498 (2011).