

Physikalisches Kolloquium Einladung

Physics Colloquium Invitation

Monday, 26 May 2025

Lecture Hall N24/H13, at 16:15 Coffee and cookies will be served in front of the lecture hall from 16:00

Experiments at the interface of general relativity and quantum mechanics

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The two pillars of modern physics are the theories of General Relativity (GR) and Quantum Mechanics (QM). After decades of theoretical attempts to unify these two pillars under one theoretical framework (often referred to as quantum-gravity), these pillars remain independent. To some this situation is so unnatural, that they claim it actually hints that at least one of the theories is wrong in some fundamental way. As technology in quantum-optics labs improves, new experiments – working at the interface of these two theories – can be realized. Such experiments will hopefully provide new insights that will eventually allow for the sought-after unification to be finally achieved.

In this talk, I will present three experiments conducted at this interface, two already realized and one planned. The first involves clock interferometry, in which a single clock in a spatial superposition experiences two different proper times due to gravitationally induced red shift [1,2]. The second involves the observation of the Einsteinian equivalence principle, measured in the quantum domain [3]. While the first two were realized with atoms, the third involves massive objects, specifically, nano-diamonds [4]. Leaping by ten orders of magnitude in mass relative to the atomic experiments, the third experiment makes use of so-called active mass, where not only the gravitational field of Earth needs to be taken into account.

The experiments are based on Stern-Gerlach interferometry [5]. Time permitting, I will be happy to also address more technical questions. For example, interesting issues concerning decoherence arise [6,7].

[1] Y. Margalit et al., A self-interfering clock as a "which path" witness, Science 349, 1205 (2015).

[2] Zhifan Zhou et al., Quantum complementarity of clocks in the context of general relativity, Classical and quantum gravity 35, 185003 (2018).

[3] Or Dobkowski, Barak Trok, Peter Skakunenko, Yonathan Japha, David Groswasser, Maxim Efremov, Chiara Marletto, Ivette Fuentes, Roger Penrose, Vlatko Vedral, Wolfgang P. Schleich, Ron Folman, [2502.14535] Observation of the quantum equivalence principle for matter-waves, ArXiv: 2502.14535 (2025).

[4] Y. Margalit et al., Realization of a complete Stern-Gerlach interferometer: Towards a test of quantum gravity, Science advances 7, eabg2879 (2021).

[5] O. Amit et al., T³ Stern-Gerlach matter-wave interferometer, Phys. Rev. Lett. 123, 083601 (2019).

[6] Y. Japha and R. Folman, Role of rotations in Stern-Gerlach interferometry with massive objects, Phys. Rev. Lett. 130, 113602 (2023).

[7] C. Henkel and R. Folman, Universal limit on quantum spatial superpositions with massive objects due to phonons, Phys. Rev. A 110, 042221 (2024).

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