UNIVERSITÄT DUISBURG ESSEN

Offen im Denken

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Levitated nanoparticles as testbeds for fundamental aspects of physics

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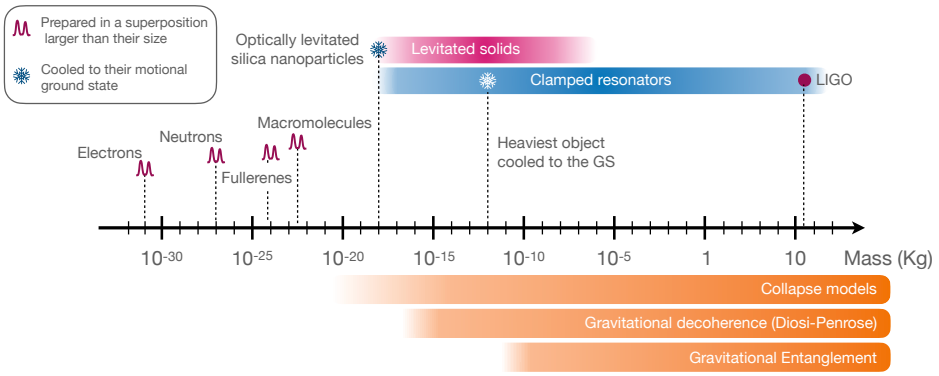

Figure: Mass-spectrum of experiments in the quantum regime

Quantum mechanics has been enormously successful at describing the microscopic world, however, at scales that exceed the mass of a few thousand atoms, it remains largely unexplored. Recent progress in the quantum control of the mechanical degrees of freedom of solids suspended in a vacuum suggests that this situation might be changing in the near to mid-term future. Containing billions of atoms, levitated nanoparticles might be able to perform quantum experiments in an unprecedented mass regime, and thus, interrogate Nature about fundamental aspects of physics for which we do not have an answer, for example, does the linearity of quantum mechanics hold at macroscopic scales? or, can a source of the gravitational field be placed in a spatial superposition? In my talk, I will examine the opportunities and challenges that this nascent quantum platform presents to address these fascinating questions.
First, I will present a collection of proposed experimental techniques that can both extend the coherence times and shorten the duration of experiments aimed at realizing matter-wave interferometry with levitated solids. Secondly, I will discuss the prospects of observing gravitationally mediated entanglement between levitated solids, which has been suggested as a route to explore quantum aspects of gravity with tabletop, quantum-optical experiments. In this regard, I will present a novel experimental protocol for the enhancement of the gravitational interaction between levitated systems.

[1] J. S. Pedernales, G. W. Morley, and M. B. Plenio, *Motional dynamical decoupling for interferometry with macroscopic particles*, Phys. Rev. Lett. 125 (2), 023602 (2020).
[2] F. Cosco, J. S. Pedernales, and M. B. Plenio, *Enhanced force sensitivity and entanglement in periodically driven optomechanics*, Phys. Rev. A 103, 061501 (2021).
[3] J. S. Pedernales, K. Streltsov, and M. B. Plenio, *Enhancing Gravitational Interaction between Quantum Systems by a Massive Mediator*, Phys. Rev. Lett. 128 (11), 110401 (2022).
[4] J. S. Pedernales and M. B. Plenio, *Robust Macroscopic Matter-Wave Interferometry with Solids*, Phys. Rev. A 105, 063313 (2022).