CRC 1227
Designed Quantum States of Matter

Leibniz Universität Hannover

GUEST LECTURE

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Welfengarten 1, 30167 Hannover (building 1101)
Seminar room D326
at the Institute of Quantum Optics
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BEC-based phononic sensors for oscillating gravitational fields of moving masses and light pulses

Bose-Einstein condensates (BECs) are very small and extremely cold systems of a large number of atoms. These properties are famously exploited for high precision measurements of forces using atom interferometry. A further way of utilizing BECs as sensors for forces is to measure the forces' effect on phonons, the collective oscillations of atoms in BECs. A specific example is the measurement of the thermal Casimir- Polder force induced by a material slab [1].
I will explain how BECs could be used to measure gravitational fields on the micrometer scale. Accelerations due to gravitational fields and their gradients give rise to effective external potentials. Moving the source of the gravitational field on resonance with elastic modes of BECs lead to the creation of phonons. For strong enough gravitational fields this effect can, in principle, be detected. For weaker gravitational fields, a squeezed probe state can be prepared and its change due to the interaction with the oscillating gravitational field may be measured.

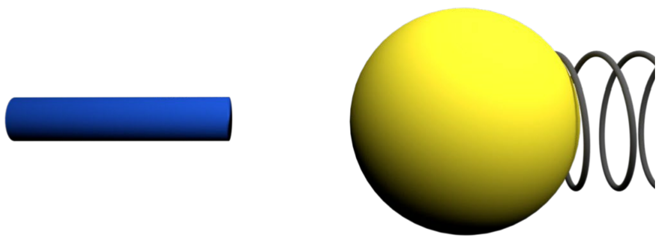

Fig. 1: The gravitational field of a gold sphere oscillating in front of a BEC creates phonons which may be used for sensing the gravitational field.

High precision BEC based gravity sensors may be used for the measurement of gravitational fields due to very small objects, which would offer opportunities for new experiments investigating the interface of quantum mechanics and gravity. Due to the small extension of BECs (of the order of few micro-meters), they can be brought very close to the surface of the source masses, where the gravitational effects are stronger. Researchers around the world are attempting to bring very small massive systems, such as silica-spheres at almost the pico-gram range, into superposition states [3]. The envisioned ability to measure the gravitational field of masses in superposition states may lead to new exciting experiments, for example, about aspects of quantumness of gravity [4]. High precision sensors for oscillating gravitational fields may also be useful in performing searches for fifth forces (e.g. [5]) and measuring the gravitational field of light [6].
I illustrate my experimental proposal with the easily accessible example of the gravitational field of a small oscillating gold sphere in the milligram range. Additionally, I will discuss the gravitational properties of light, and I will give some numbers to illustrate the challenge of its detection.

[1] Obrecht et al. *Measurement of the temperature dependence of the Casimir-Polder force* Phys. Rev. Lett. 98, 063201 (2007)
[2] Rätzel et al. Fuentes *Dynamical response of Bose-Einstein condensates to oscillatinggravitational fields* New J. Phys. 20 (2018) 073044
[3] Kieselet al. *Cavity cooling of an optically levitated submicron particle.* Proceedings of the National Academy of Sciences 110.35 (2013): 14180-14185.
[4] Bose et al. "Spin entanglement witness for quantum gravity." Physical review letters 119.24 (2017): 240401.
[5] Burrage et al. *Radiative screening of fifth forces.* Physical review letters 117.21 (2016):211102.
[6] Rätzel et al. *Gravitational properties of light—the gravitational field of a laser pulse.* New Journal of Physics 18.2 (2016): 023009.

All DQ-mat members and all interested are cordially invited to attend.