TEQ JUNIOR WORKSHOP – November 8, 2018 – TUD, Delft

ALESSIO BELENCHIA (OEAW)

Title: **Quantum Superposition of Massive Objects and the Quantization of Gravity**

In this talk we analyse a gedankenexperiment, previously considered in the literature, which involves quantum superpositions of charged and/or massive bodies. In the electromagnetic case, we show that the quantization of electromagnetic radiation and vacuum fluctuations of the electromagnetic field both are essential for avoiding apparent paradoxes with causality and complementarity. We then analyze the gravitational version of this gedankenexperiment which was not correctly analyzed in the previous literature. We show that the analysis of the gravitational case is in complete parallel with the electromagnetic case provided that gravitational radiation is quantized and that vacuum fluctuations limit the localization of a particle to no better than a Planck length. This provides support for the view that (linearized) gravity should have a quantum field description, a relevant result in view of the growing interest in proposals for table-top experiments probing gravity-induce entanglement.

CAITLIN JONES (UNITS)

Title: **Special Relativity and Spontaneous Collapse Outside the Light Cone**

In this talk, I will discuss the relativistic properties of the distinguishable particle non-interacting relativistic GRW model presented by Tumulka [1]. I will discuss how the relativistic properties of this theory are contingent on the points of collapse being time-like to each other. This implies that models describing indistinguishable or interacting particles require space-like points of collapse, hence it is not possible to extend this model to such cases whilst retaining the desired relativistic and collapse dynamics.

[1] Roderich Tumulka. A relativistic version of the Ghirardi–Rimini–Weber model. Journal of Statistical Physics, 125(4):821–840, 2006.

MASSIMILIANO BAZZI (INFN)

Title: **Low noise DC supply**

In order to achieve a particle trapping in the current set-up, an ultra-low noise DC supply is required.
Noise requirements are so tight that no commercial device is available on market.
At this point a DC Amplifier has been developed and its inner noise kept as low as possible.
Low noise startegies and techiniques will be shown with measurements of the noise level achieved.
Furthermore, some proposals of improvements of the system will be presented.

MARKO TOROŠ (SOTON)

Title: **Detection and control of optically levitated particles**

We discuss detection and control of nanoparticles in levitated optomechanics. Specifically, we consider anisotropic particles trapped by an elliptically polarized focused Gaussian laser beam [1,2]. We obtain the full rotational and translational dynamics, as well as, the measured photo-current in a dyne detection. As an example, we discuss homodyne detection, and how it can be used for

Wigner function reconstruction [3]. In addition, we introduce feedback terms in the dynamics and discuss cooling of the translational motions of the nanoparticle using a Kalman filter [4]. In the second part we discuss how optically levitated systems can be used to test theoretical models. In particular, we consider conventional models (classical and quantum) as well as non-unitary modifications of the quantum dynamics. We present a general method of model selection from the experimentally recorded time-trace data [5], which is an alternative to state-reconstruction based statistical tests.

[1] Toroš, M., Rashid, M. and Ulbricht, H., 2018. Detection of anisotropic particles in levitated optomechanics. arXiv preprint arXiv:1804.01150.
[2] Rashid, M., Toroš, M., Setter, A. and Ulbricht, H., 2018. Precession Motion in Levitated Optomechanics. arXiv preprint arXiv:1805.08042.
[3] Rashid, M., Toroš, M. and Ulbricht, H., 2017. Wigner function reconstruction in levitated optomechanics. Quantum Measurements and Quantum Metrology, 4(1), pp.17-25.
[4] Setter, A., Toroš, M., Ralph, J.F. and Ulbricht, H., 2018. Real-time Kalman filter: Cooling of an optically levitated nanoparticle. Physical Review A, 97(3), p.033822.
[5] Ralph, J.F., Toroš, M., Maskell, S., Jacobs, K., Rashid, M., Setter, A.J. and Ulbricht, H., 2018. Dynamical model selection near the quantum-classical boundary. Physical Review A, 98(1), p.010102.

THOMAS PENNY (UCL)

Title: **Opto-electric feedback cooling in a linear Paul trap**

Cooling of the centre-of-mass motion of charged nanoparticles in a Paul trap is likely to be an important tool for the TEQ programme. In addition, the frequency and mass stability of the trapped nanoparticle will be key for reproducible measurements. In this talk I will report on recent experiments that have realized parametric feedback cooling in a linear Paul trap. I will also present measurements of the frequency and mass stability of the trapped nanoparticle as a function of time. Using parametric feedback cooling we demonstrate centre-of-mass cooling to temperatures just below 1 K. In this scheme we detect the motion in the trap by scattering of laser light and use electrical feedback via the RF and endcap electrodes to damp the motion. The centre-of-mass temperature is currently limited by detection noise and excess micromotion. Our experiments detect a drift in the charge-to-mass ratio of the trapped particle over time. This increases as the pressure decreases and stabilizes over time periods on the order of hours. This process appears to be primarily due to mass loss caused by evaporation of surface contaminants that are introduced during the trap loading process.

JENCE MULDER (TUD)

Title: **The synthesis and optical characterization of photon upconverting particles and their broad variety of possibilities**

The particles that will be studied in the TEQ-project might, amongst others, be photon upconverting alkali-lanthanide-fluoride nanocrystals such as Yb:LiYF4. In this talk, the synthesis and optical characterization of these particles will be briefly discussed. Furthermore, a summary from literature (indicating the broad variety of possibilities in e.g. particle size, shape and composition) will be treated. This, with as main purpose to discuss the main requirements for the particles that are needed by the different groups, to ensure the studied particles will meet all requirements.

MARTA MARIA MARCHESE (QUB)

Title: **Macrorealism in optomechanical system**

This talk will be about the search of violation of macroscopic realism in optomechanical systems. Leggett and Garg derived a set of inequalities (LGI) fulfilled by any classical system which behaves according to our intuition of macroscopic reality [1]. They rely on two postulates: (A1) macroscopic realism per se (A2) non-invasive measurement. If a system violates the inequality, either one of the two assumptions or both will fail and we can no longer interpret the evolution of the system as classical. These inequalities provides a useful tool to investigate the coherence at macroscopic level and to look for quantitative criteria to discern the classical world from the quantum world.
An optical cavity [2] in which one of the two mirror is attached to a spring is an optomechanical system in which the mechanical part and the light field are coupled through the radiation-pressure force. It is possible to create non-classical states of the mirror through a projective measurement on the cavity field[3].
Leggett-Garg inequalities have been tested with a hybrid optomechanical system, in which the cavity field is replaced by a two-level system coupled with a harmonic oscillator, which represent the mirror. We defined a total evolution map, which includes the unitary free evolution due to the Hamiltonian, plus a projective measurement on the two level system to originate non-classicality in the harmonic oscillator state. The computed Leggett-Garg function violates the boundary whithin which the system can be understood as macrorealist, then we can infer that this evolution generates totally non-classical states of the mechanical part.

[1] A. J. Leggett, Anupam Garg, Quantum mechanics versus macroscopic realism: Is the ux there when nobody looks?, Phys. Rev. Lett. 54, 857, (1985).
[2] Markus Aspelmeyer, Tobias J. Kippenberg, Florian Marquardt, Cavity Optomechanics, Rev. Mod. Phys. 86, 1391, (2014).
[3] S. Bose, K. Jacobs, P. L. Knight, Preparation of Nonclassical States in Cavities with a Moving Mirror, Phys.Rev. A 56, 4175-4186, (1997).