Speaker: Hendrick Ulbricht
Title: Prospects to use levitated optomechanics to test quantum mechanics and gravity

Abstract: We will discuss ideas to experimentally test collapse models [1] by both matter-wave interferometry [2] and non-interferometric methods [3]. Testing collapse models intrinsically also means to test the quantum superposition principle. Collapse models predict a heating effect, which results in a Brownian-like random motion of any isolated particle in space. We will emphasise levitated optomechanical systems and discuss the possibility to test the heating effect by detecting the motion of the particle in position space [4], as well as in the frequency domain where the collapse heating effect is theoretical treated as noise in a Langevin type approach and predicted to manifest itself as an increase of the area of the related power spectral density [3]. We shall also explain if gravitation decoherence has strong prospects to be tested with levitated optomechanical systems.

We will further discuss some recent ideas to probe the interplay between quantum mechanics and gravitation. One idea is to try to directly test if gravity is quantum or classical, while a second is to test an effect which is predicted for semi-classical gravity (Schrödinger-Newton equation)[5], which would allow to experimentally test whether that semi-classical approach is valid or not.

We shall also give an update on trapping and cooling experiments of levitated optomechanics at Southampton in order to explore the experimental feasibility of tests of quantum mechanics and gravitation. The overarching goal of our attempts is to build a complete toolbox to generate and manipulate Gaussian but also non-Gaussian states, such as a spatial superposition state, of the motion of nano- and micro-particles in order to realise all possible states of the motional dynamics in phase space. This to be done for massive nanoparticles and the systematic investigation of noises will further the prospects for sensing applications of levitated optomechanics too.

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Speaker: Prof. Sougato Bose
Title: The Non-Classicality of Mesoscopic Objects and Applications

Abstract: We show how non-classical states of mechanical objects can be prepared and probed. In particular, we will describe how an ancillary bonafide quantum system can be used to both create and probe the ability of a mesoscopic object to be in a state of superposition of distinct spatial states. In an explicit setting of a levitated nano-object and a Ramsey interferometric scheme, we exemplify how the earth's gravity can be used as an agent to provide the relative phase to detect ultra-small superpositions. How much larger superpositions can be created and probed using a free-flight scheme will be discussed. We will then highlight how other hallmarks of non-classical behaviour such as the violation of Leggett-Garg inequalities can be inferred for trapped mesoscopic objects. I will end the lecture with an open ended discussion on the prospects of such schematics for both gravimetry and probing some feature of quantum gravity.

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Speaker: Prof. G. Massimo Palma
Title: "Collision model of open system dynamics"

Abstract: In collision models of open system dynamics the irreversible dynamics of a quantum system due to its coupling with the environment is described in terms of a sequence of short interactions (collisions) between the quantum system and the environment, assumed to be multipartite. More in detail the environment is assumed to consist of a (usually large) number of subenvironments, or ancillas. The systems interacts with the environment via a sequence of unitary brief collisions with such ancillas. The advantage of such description is that, not only it allows for a mathematically rigorous derivation of a completely positive master equation in Lindblad form, but also for more complex open quantum dynamics, e.g. taking into account either multipartite system or intra ancillary dynamics. In such scenario a rich non markovian dynamics characterizes the system evolution.

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Speaker: Dr. Doug Plato
Title: Testing gravitational effects in low energy quantum systems

Abstract: In recent years, a number of experiments have been proposed which, if successful, should give insight into features at the Planck scale. In this talk I will first give an overview of some of the motivations, from the perspective of semi-classical arguments, to expect new physical effects at the overlap of quantum theory and general relativity. In particular, I will focus on three claims that commonly appear in the literature – 1) the existence of a minimum length scale, 2) a modification of the energy-momentum dispersion relations and 3) that space-time should exhibit a “foamy” structure on small scales (with this latter idea closely connected to the notion of gravitationally induced decoherence). My aim here is to be pedagogical, rather than to appeal to particular QG theories. I will then discuss some of the ways in which ideas from quantum optics are being used to propose novel new experimental tests.

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