03/1301 Theoretical study of the interaction of mesoscopic quantum systems with gravity

Type of activity: Fast Study (2 months, 15 KEUR)

Recently there is a growing interest in studying the interaction of quantum fluids with gravitation [1,2]. The expectation expressed in the literature is that the effective gravitational coupling constant of these systems might be modified by quantum effects leading to a different strength of coupling between the quantum system and gravity as that one would expect from classical matter. Also, specific alternative theories of gravity claim to predict fluctuations of the gravitational coupling induced by matter quantum fluctuations [3]. Such modifications of the gravitational interaction could have important technological consequences: even small modifications of gravity could give important impacts to nanotechnology ultimately leading to the advent of “gravity engineering”.[1] Also from the theoretical point of view such modifications would be of utmost interest because they would offer the first possibility to test the framework of semiclassical quantum gravity [4]. Hence the study of gravitating mesoscopic systems should lead to a better understanding of the nature of quantum gravity (cf. also [5]).
Unfortunately, the predictions in the literature are far from being coherent, ranging from a reduced interaction to an extreme enhancement of the interaction. These seemingly unconnected predictions demonstrate the lack of a comprehensive theoretical framework for gravitating mesoscopic systems, which incorporates the various predicted effects. This description should build upon the theory of quantum fields in a gravitational background which already was investigated intensively [4].

The goal of the proposed study is to review the models for the description of mesoscopic quantum systems with the gravitational field, scattered in the literature. A clear account of the present knowledge in this area should be given. The study should include a detailed presentation of the available calculation techniques for the systems under consideration. It should also emphasize open issues and suggest possible further directions of theoretical studies.

References

[1] R. Y. Chiao, W. J. Fitelson and A. D. Speliotopoulos, “Search for quantum transducers between electromagnetic and gravitational radiation: A measurement of an upper limit on the transducer conversion efficiency of yttrium barium copper oxide,”

arXiv:gr-qc/0304026; Raymond Y. Chiao, Walter J. Fitelson, “Time and Matter in the Interaction between Gravity and Quantum Fluids: Are there Macroscopic Quantum Transducers between Gravitational and Electromagnetic waves?” gr-qc/0303089;
R. Y. Chiao, “Conceptual tensions between quantum mechanics and general relativity: Are there experimental consequences?,” arXiv:gr-qc/0211078.

[1] It should be stressed, however, that one should not expect that the effects under discussion lead to new forms of spacecraft propulsion because they will probably only induce small modifications of the gravitational interaction, if at all.

[2] M. Tajmar and C. J. De Matos, “Gravitomagnetic Field of a Rotating Superconductor and of a Rotating Superfluid,” arXiv:gr-qc/0203033.

[3] Ning Wu, “Gravitational Shielding Effects in Gauge Theory of Gravity,” arXiv:hep-th/0307225.

[4] N. D. Birrell and P. C. W. Davies, Quantum Fields in Curved Space (Cambridge University Press, Cambridge, 1982); S. A. Fulling, Aspects of Quantum Field Theory in Curved Spacetime (Cambridge University Press, Cambridge, 2002).

[5] William Marshall, Christoph Simon, Roger Penrose and Dik Bouwmeester, “Towards quantum superpositions of a mirror,” arXiv:quant-ph/0210001