Testing quantum and gravity interplay with composite quantum particles

M. Zych[1]

[1]ARC Centre for Engineered Quantum Systems, University of Queensland, 4072 St Lucia, Brisbane, Australia.

A major goal of modern physics is to understand and test the regime where quantum mechanics and general relativity both play a role. However, new effects of this regime are usually thought to be relevant only at high energies or in strong gravitational fields, beyond the reach of present day experiments. I will discuss a promising route towards testing joint effects of quantum theory and general relativity, focused on low-energy but composite quantum systems. The key insight is that quantized internal energy of particles such as atoms, ions or molecules leads to new phenomena. In particular, coherence of such systems, in the context of matter-wave interference experiments, can be measurably affected by relativity even at low-energies and in weak gravitational fields through time dilation [1-4]. I will explain the resulting new phenomena and prospects for their tests. I will further discuss new insights into the Einstein Equivalence Principle (EEP) stemming from this approach [5]. Most importantly, for composite systems testing validity of the EEP in quantum theory requires measuring more parameters than for classical systems, and to do so one needs conceptually new experiments. I will present the first such test [6] probing quantum aspects of the universality of free fall, and sketch ideas for future experiments [7,8]. I will close with a brief outlook of the relevance of studying quantized mass-energy effects for metrology and quantum information processing.

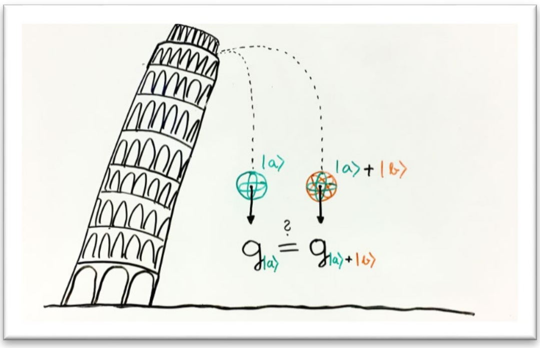

Figure 1. Testing validity of the EEP in quantum theory requires testing equivalence of the internal energy operators. An examples includes testing universality of free-fall for a system in a superposition of different mass-energy eigenstates such as in ref. [6].

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