MAR15-2014-020817

Abstract for an Invited Paper
for the MAR15 Meeting of
the American Physical Society

Understanding Nature from Experimental Observations: A Theory Independent Test for Gravitational Decoherence

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Quantum mechanics and the theory of gravity are presently not compatible. A particular question is whether gravity causes decoherence - an unavoidable source of noise. Several models for gravitational decoherence have been proposed, not all of which can be described quantum mechanically. In parallel, several experiments have been proposed to test some of these models, where the data obtained by such experiments is analyzed assuming quantum mechanics. Since we may need to modify quantum mechanics to account for gravity, however, one may question the validity of using quantum mechanics as a calculational tool to draw conclusions from experiments concerning gravity. Here we use ideas from quantum information to propose an experiment to estimate gravitational decoherence whose conclusions hold even if quantum mechanics would need to be modified. We first establish a general information-theoretic notion of decoherence which reduces to the standard measure within quantum mechanics. Second, drawing on ideas from quantum information, we propose a very general protocol that allows us to estimate decoherence of any physical process for any physical theory satisfying only very mild conditions. Finally, we propose a concrete experiment using optomechanics to estimate gravitational decoherence in any such theoy, including quantum mechanics as a special case. Our work raises the interesting question whether other properties of nature could similarly be established from experimental observations alone - that is, without already having a rather well formed theory of nature like quantum mechanics to make sense of experimental data. We conclude by discussing this possibility.

Joint work with C. Pfister, J. Kaniewski, M. Tomamichel, A. Mantri, R. Schmucker and G. Milburn