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A Spin-Based Pathway to Testing the Quantum Nature of Gravity

A key open problem in physics is the correct way to combine gravity (described by general relativity) with everything else (described by quantum mechanics). This problem suggests that one or both of these cherished theories may need fundamental corrections. Most
physicists expect that gravity should be quantum in character, but gravity is fundamentally different to the other forces because it alone is described by spacetime geometry. Experiments are needed to test whether gravity, and hence space-time, is quantum or classical. We propose an experiment to test the quantum nature of gravity by checking whether gravity can entangle two micron-sized crystals. A pathway to this is to create macroscopic quantum superpositions of each crystal first using embedded spins and Stern-Gerlach forces. These crystals could be nanodiamonds containing nitrogen-vacancy (NV) centres. The spins can subsequently be measured to witness the gravitationally generated entanglement. This is based on extensive theoretical feasibility studies and experimental progress in quantum technology. The eventual experiment will require a medium-sized consortium with excellent suppression of decoherence including vibrations and gravitational noise. In this white paper, we review the progress and plans towards realizing this. While implementing these plans, we will further explore the most macroscopic superpositions that are possible, which will test theories that predict a limit to this.

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