Gravitational decoherence

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abstract We investigate the effect of quantum metric fluctuations on qubits that are gravitationally coupled to a background spacetime. In our first example, we study the propagation of a qubit in flat spacetime whose metric is subject to flat quantum fluctuations with a Gaussian spectrum. We find that these fluctuations cause two changes in the state of the qubit: they lead to a phase drift, as well as the expected exponential suppression (decoherence) of the off-diagonal terms in the density matrix. Secondly, we calculate the decoherence of a qubit in a circular orbit around a Schwarzschild black hole. The no-hair theorems suggest a quantum state for the metric in which the black hole’s mass fluctuates with a thermal spectrum at the Hawking temperature. Again, we find that the orbiting qubit undergoes decoherence and a phase drift that both depend on the temperature of the black hole. Thirdly, we study the interaction of coherent and squeezed gravitational waves with a qubit in uniform motion. Finally, we investigate the decoherence of an accelerating qubit in Minkowski spacetime due to the Unruh effect. In this case decoherence is not due to fluctuations in the metric, but instead is caused by coupling (which we model with a standard Hamiltonian) between the qubit and the thermal cloud of Unruh particles bathing it. When the accelerating qubit is entangled with a stationary partner, the decoherence should induce a corresponding loss in teleportation fidelity.