Alice falls into a black hole: Acceleration and quantum entanglement

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Consider that Alice and Bob are two observers at rest separated by a long distance. Each of them has a measuring device that detects, respectively, two different quantum systems. The state of the joint system is said to be maximally entangled if, for many copies of the state, any measurement that Alice makes is completely determined by Bob's and vice versa.

This upcoming publication by I. Fuentes-Schuller and R. B. Mann will appear in Physical Review Letters.

What would happen to their entanglement if Alice fell into a black hole and Bob stayed safely outside? We can model this situation by considering Alice to be stationary and Rob (formerly Bob) to be uniformly accelerated with respect to Alice. We found that although the entanglement between them is reduced due to Rob's acceleration, it remains nonzero as long as Rob's acceleration is not infinite.

It has long been known that an accelerated observer detects a thermal bath of particles whereas an observer at rest sees only a vacuum. Known as the Unruh effect, it is this that causes the degradation in the entanglement measured by Alice and Rob. Our results are a first step in understanding how relativistic effects modify quantum information, and they imply that different observers detect different degrees of entanglement.

This has important consequences in quantum teleportation between relatively accelerated parties, since entanglement is the main resource in this task.

The abstract

Two observers determine the entanglement between two free bosonic modes by each detecting one of the modes and observing the correlations between their measurements. We show that a state which is maximally entangled in an inertial frame becomes less entangled if the observers are relatively accelerated. This phenomenon, which is a consequence of the Unruh effect, shows that entanglement is an observer-dependent quantity in non-inertial frames. In the high acceleration limit, our results can be applied to a non-accelerated observer falling into a black hole while the accelerated one barely escapes. If the observer escapes with infinite acceleration, the state's distillable entanglement vanishes.

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