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Quantum entanglement near open timelike curves: theory and experimental simulation

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Closed timelike curves are striking predictions of general relativity allowing for time-travel. They are afflicted by notorious causality issues (e.g. grandfather's paradox). Quantum models where a qubit travels back in time solve these problems, at the cost of violating quantum theory's linearity—leading e.g. to universal quantum cloning. Interestingly, linearity is violated even by open timelike curves (OTCs), where the qubit does not interact with its past copy, but is initially entangled with another qubit. Non-linear dynamics is needed to avoid violating entanglement monogamy. Here we propose an alternative approach to OTCs, allowing for monogamy violations. Specifically, we describe the qubit in the OTC via a pseudo-density operator—a unified descriptor of both temporal and spatial correlations. We also simulate the monogamy violation with polarization-entangled photons, providing a pseudo-density operator quantum tomography. Remarkably, our proposal applies to any space-time correlations violating entanglement monogamy, such as those arising in black holes.

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