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Hardy's paradox and a violation of a state-independent Bell inequality in time ALESSANDRO FEDRIZZI, MARCELO P. ALMEIDA, MATTHEW A. BROOME, ANDREW G. WHITE, Department of Physics and Centre for Quantum Computer Technology, University of Queensland, Brisbane QLD 4072, Australia, MARCO BARBIERI, Groupe d'Optique Quantique, Laboratoire Charles Fabry, Institut d'Optique, CNRS, Universite Paris-Sud, France — Tests such as Bell's inequality and Hardy's paradox highlight the differences between local realistic theories and quantum predictions for measurement probabilities and correlations between distant particles. Transposing these tests to the temporal domain, i.e. making two measurements on the one quantum particle at different times, yield Hardy and Bell tests mathematically identical to their spatial counterparts, but give very different physical results. Here, we use a photonic entangling gate to implement non-destructive temporal measurements on a quantum system. We measure a much stronger form of Hardy's paradox and demonstrate violation of a Bell inequality in time independent of the quantum state, including for fully-mixed states. Our work yields interesting fundamental insights and opens up a path to more efficient quantum information processing protocols based on temporal quantum correlations.

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