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**Title**: Concomitant Entanglement and Control Criticality Driven by Collective Measurements

**Abstract**: Adaptive quantum circuits—where a quantum many-body state is controlled using measurements and conditional unitary operations—are a powerful paradigm for state preparation and quantum error-correction tasks. They can support two types of nonequilibrium quantum phase transitions: measurement-induced transitions between volume- and area-law-entangled steady states and control-induced transitions where the system falls into an absorbing state or, more generally, an orbit visiting several absorbing states. Within this context, nonlocal conditional operations can alter the critical properties of the two transitions and the topology of the phase diagram. Here, we consider the scenario where the measurements are nonlocal, in order to engineer efficient control onto dynamical trajectories. Motivated by Rydberg-atom arrays, we consider a locally constrained model with global sublattice magnetization measurements and local correction operations to steer the system’s dynamics onto a many-body orbit with finite recurrence time. The model has a well-defined classical limit, which we leverage to aid our analysis of the control transition. As a function of the density of local correction operations, we find control and entanglement transitions with continuously varying critical exponents. For sufficiently high densities of local correction operations, we find that both transitions acquire a dynamical critical exponent 𝑧 <1, reminiscent of criticality in long-range power-law interacting systems. At low correction densities, we find that the criticality reverts to a short-range nature with 𝑧 ≳1. In the long-range regime, the control and entanglement transitions are indistinguishable to within the resolution of our finite-size numerics, while in the short-range regime we find evidence that the transitions become distinct. We conjecture that the effective long-range criticality mediated by collective measurements is essential in driving the two transitions together.

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