

Arrow of Time as an Order Parameter for Measurement-Induced Phase Transitions

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Measurement-induced phase transitions (MIPTs) in monitored quantum systems are typically diagnosed using entanglement-based measures. Here, we develop a complementary thermodynamic perspective based on the arrow of time (AoT), which arises from the intrinsic irreversibility of the quantum measurements driving these transitions. We study the AoT—defined as the logarithmic ratio of forward and backward trajectory probabilities—across a family of models exhibiting MIPTs. We find that, like entanglement entropy, the AoT is a nonlinear functional of the averaged density matrix; however, in contrast to entanglement, it is associated with a local operator. To determine whether the AoT exhibits critical behavior, we formulate and exactly solve a model of a random quantum circuit with non-projective measurements. This allows us to analytically demonstrate that the AoT displays nonanalytic behavior and identify its critical exponent. Our results establish the AoT as a novel diagnostic for phase transitions in monitored quantum systems.

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