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Prediction, Retrodiction, and Smoothing for a Continuously Monitored Superconducting qubit

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The quantum state of a superconducting transmon qubit inside a three-dimensional cavity is monitored by reflection of a microwave field on the cavity. Measurement outcomes at different times are correlated, and knowledge of later measurement outcomes can be used to provide statistical information about earlier probe results. For a driven, damped and continuously monitored quantum system, the information inferred from measurement data yields a quantum trajectory given by the matrix ρ_t, which is conditioned on probe results until t. Further probing after the time t can be incorporated into an auxiliary matrix E_t. We show that the combination of ρ_t and E_t makes nontrivially different and more precise predictions for the outcomes of measurements in the past. Our experiments verify the predictions of both projective and weak value (weak) measurements conditioned on full measurement records.