

Description of Additional Supplementary Files

File Name: Supplementary Movie 1

Description: **Photon dynamics in phase space in the DSC regime (degenerate-qubit case) from maximum-likelihood Wigner tomography.** (a) Movie, measured over ~ 40 hours, showing the phase-space evolution of the resonator reduced state for $g^R/\omega_r^R \sim 0.9$ (frames labelled by Trotter step n and simulated time). Plotted tomograms are maximum-likelihood reconstructions of direct Wigner tomography measured data with a systematic phase correction [see Methods]. Clearly observed are the creation of two well-resolved, rotating peaks and their subsequent re-coalescence, which are characteristic signatures of DSC dynamics. The final frame shows the full trajectories determined from 2D double-Gaussian fits to the raw data. Deviation from the ideal circular trajectories (orange curves) arises from photon decay. The measured trajectory shows excellent agreement with a numerical Trotter simulation at $g^R/(2\pi) = 1.79$ MHz which includes resonator $T_{1,r} = 3.5$ μ s (green curves).