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Entanglement dynamics and Page curves in random permutation circuits

The characterization of ensembles of random states over many qubits and their realization by quantum circuits are important tasks in quantum-information theory. In this work, we study ensembles of states generated by quantum circuits that randomly permute the computational basis, thus acting classically on the corresponding states. We focus on the averaged entanglement and present two main results . First, we derive generically tight upper bounds on the entanglement that can be generated applying permutation circuits to arbitrary initial states. Notably, we show that the late-time "entanglement Page curves" are bounded in terms of the initial state participation entropies and its overlap with the "maximally antilocalized" state. Second, starting from simple N-qubit states, we compare the averaged Rényi-2 entropies generated by (i) an infinitely deep random circuit of two-qubit gates and (ii) global random permutations. Interestingly, we show that the two quantities are different for finite N, but the corresponding Page curves coincide in the thermodynamic limit. We also discuss how our conclusions are modified by additional random phases or considering circuits of k-local gates, with $k \geq 3$. Our results, which are based on analytic computations, expand the known phenomenology of random unitary circuits and highlight the implications of classical features on entanglement generation in many-body systems.

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