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Phantom relaxation in local many-body Floquet systems

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We would like to understand relaxation towards a long-time steady state under unitary pure-state evolution. Focusing on a bipartite entanglement or out-of-time-ordered correlations, one sometimes finds that relaxation is not a simple exponential with a fixed rate, but that the rate exhibits a jump at an extensive time. Studying some solvable
cases of random circuits one finds that this two-step relaxation can be traced back to interesting non-Hermitian physics. Despite relaxation being described by a gapped Markovian matrix the rate is in the thermodynamic limit not given by the 2nd largest eigenvalue, but rather by a phantom eigenvalue – an "eigenvalue" that is not in the spectrum. Resolution of this puzzle will lead to a pseudospectrum, Jacobi theta
functions, and realization that when dealing with non-Hermitian matrices being exact can actually be wrong, while being slightly wrong is correct.

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