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The Petz (lite) recovery map for scrambling channel

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We study the properties of the Petz recovery map in chaotic systems, such as the Hayden-Preskill setup for evaporating black holes and the SYK model. Since these systems exhibit the phenomenon called scrambling, we expect that the expression of the recovery channel $\mathcal{R}$ gets simplified, given by just the adjoint $\mathcal{N}^\dagger$ of the original channel $\mathcal{N}$ which defines the time evolution of the states in the code subspace embedded into the physical Hilbert space. We check this phenomenon in two examples. The first one is the Hayden-Preskill setup described by Haar random unitaries. We compute the relative entropy $S(\mathcal{R}\left[\mathcal{N}[\rho]\right]||\rho)$ and show that it vanishes when the decoupling is archived. We further show that the simplified recovery map is equivalent to the protocol proposed by Yoshida and Kitaev. The second example is the SYK model where the two dimensional code subspace is defined by an insertion of a fermionic operator, and the system is evolved by the SYK Hamiltonian. We check the recovery phenomenon by relating some matrix elements of an output density matrix $\langle T|\mathcal{R}[\mathcal{N}[\rho]]|T'\rangle$ to R\'enyi-two modular flowed correlators, and show that they coincide with the elements for the input density matrix with small error after twice the scrambling time.

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