TOWARDS THE FAST SCRAMBLING CONJECTURE

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Many proposed quantum mechanical models of black holes include highly nonlocal interactions. The time required for thermalization to occur in such models should reflect the relaxation times associated with classical black holes in general relativity. Moreover, the time required for a particularly strong form of thermalization to occur, sometimes known as scrambling, determines the time scale on which black holes should start to release information. It has been conjectured that black holes scramble in a time logarithmic in their entropy, and that no system in nature can scramble faster. We address the conjecture from two directions. First, we exhibit examples of systems that do indeed scramble in logarithmic time: Brownian quantum circuits and the antiferromagnetic Ising model on a sparse random graph. Unfortunately, both fail to be truly ideal fast scramblers for reasons we discuss. Second, we use Lieb-Robinson techniques to prove a logarithmic lower bound on the scrambling time of systems with finite norm terms in their Hamiltonian. The bound holds in spite of any nonlocal structure in the Hamiltonian, which might permit every degree of freedom to interact directly with every other one.

Keywords: scrambling, signalling, black holes, thermalization, entanglement, Lieb-Robinson bounds, mean-field approximation

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