PAUL SCHERRER INSTITUT

PSI

CONDENSED MATTER THEORY SEMINAR

Entanglement Complexity and Scrambling via Braiding of Nonabelions

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Thursday, June 7, 2018, 11:00-12:00

WHGA/121 (PSI-West)

Abstract:

Entanglement spectrum (ES) contains more information than the entanglement entropy, a single number. For highly excited states, this can be quantified by the ES statistics, i.e. the distribution of the ratio of adjacent gaps in the ES. I will first present examples in both random unitary circuits and Hamiltonian dynamics, in which the ES signals whether a time-evolved state (even if maximally entangled) can be efficiently disentangled without precise knowledge of the time evolution operator. This allows us to define a notion of entanglement complexity that is not revealed by the entanglement entropy. In the second part, I will discuss how quantum states are scrambled via braiding in systems of non-Abelian anyons through the lens of ES statistics. We define a distance between the entanglement level spacing distribution of a state evolved under random braids and that of a Haar-random state, using the Kullback-Leibler divergence D_{KL}. We study D_{KL} numerically for random braids of Majorana fermions (supplemented with random local four-body interactions) and Fibonacci anyons. For comparison, we also obtain D_{KL} for the Sachdev-Ye-Kitaev model of Majorana fermions with all-to-all interactions, random unitary circuits built out of (a) Hadamard (H), $\pi/8$ (T), and CNOT gates, and (b) random unitary circuits built out of two-qubit Haar-random unitaries. We define as a universal clock the Page limit-normalized entanglement entropy S/S_{max}, which allows us to compare all different models on equal footing. Our results reveal a hierarchy of scrambling among various models — even for the same amount of entanglement entropy — at intermediate times, whereas all models exhibit the same late-time behavior. In particular, we find that braiding of Fibonacci anyons scrambles faster than the universal H+T+CNOT set. Our results promote D_{KL} as a quantifiable metric for scrambling and quantum chaos, which applies to generic quantum systems away from large-N or semiclassical limits.

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