Counterexamples to Eigenstate Thermalization Hypothesis

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Thermalization of an isolated quantum system to the equilibrium state is one of the most profound problems in theoretical physics. Recently, the eigenstate thermalizaton hypothesis (ETH) [1-5] has been considered to play a key role to understand thermalization, which claims that all energy eigenstates of a given Hamiltonian are thermal (i.e., all macroscopic observables take the same expectation value as corresponding microcanonical ensemble). The ETH guarantees the presence of thermalization. In addition, many numerical simulations [5-7] have shown that systems with (i) shift-invariant, (ii) no local conserved quantity, (iii) far from integrable, and (iv) local interactions, satisfy the ETH and show thermalization, while some non-thermalizing systems including integrable systems and localized systems do not satisfy the ETH. Thus, it is expected that a system with (i)-(iv) satisfy the ETH, and that the ETH is not only a sufficient condition but also a necessary condition for thermalization.
Contrary to such widely-accepted beliefs, in this presentation, we construct counterexamples to the ETH [8,9]. We introduce a general method of embedding, and using this we systematically construct Hamiltonians which satisfy (i)-(iv) but do not satisfy the ETH. The violation of the ETH is proven analytically. In addition, numerical simulations show that the constructed models indeed thermalize after a physically-plausible quench. Our models also show a novel type of prethermalization phenomena, which is triggered by a certain class of initial states. Our findings shed new light on the conventional understanding of thermalization.

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