Entanglement and thermodynamics after a quantum quench in integrable systems

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Abstract

Entanglement and entropy are key concepts standing at the foundations of quantum and statistical mechanics, respectively. In the last decade the study of quantum quenches revealed that these two concepts are intricately intertwined. Although the unitary time evolution ensuing from a pure initial state maintains the system globally at zero entropy, at long time after the quench local properties are captured by an appropriate statistical ensemble with non zero thermodynamic entropy, which can be interpreted as the entanglement accumulated during the dynamics. Therefore, understanding the post-quench entanglement evolution unveils how thermodynamics emerges in isolated quantum systems. An exact computation of the entanglement dynamics has been provided only for non-interacting systems, and it was believed to be unfeasible for genuinely interacting models. Conversely, here we show that the standard quasiparticle picture of the entanglement evolution, complemented with integrability-based knowledge of the asymptotic state, leads to a complete analytical understanding of the entanglement dynamics in the space-time scaling limit. Our framework requires only knowledge about the steady state, and the velocities of the low-lying excitations around it. We provide a thorough check of our result focusing on the spin-1/2 Heisenberg XXZ chain, and considering quenches from several initial states. We compare our results with numerical simulations using both tDMRG and iTEBD, finding always perfect agreement.

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