Exploring Large-Scale Entanglement in Quantum Simulation

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Entanglement is the characteristic feature of quantum many-body systems and unravelling the entanglement structure of complex quantum many-body states represents an outstanding challenge for todays programmable analog quantum simulators. In this talk, I will present novel methods for learning the underlying entanglement structure in experimentally prepared quantum many-body states, based on an efficient parametrization of the reduced density matrix in terms of an Entanglement Hamiltonian (EH). This allows us, for the first time, to reveal fundamental predictions about the EH from conformal field theory (CFT) and relativistic quantum field theory (RQFT) in an experimental setting. I will present results for the tomographic reconstruction of the reduced density matrix up to 20 lattice sites, the transition from area-law to volume-law scaling of the entanglement entropy, and novel insights on the structure of the EH for disjoint subsystems of the lattice. I will conclude with interesting perspectives towards studying theories related to quantum gravity in quantum simulation experiments.