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Probing many-body dynamics on a Rydberg quantum simulator

MIKHAIL LUKIN, Harvard University

We demonstrate a method for the creation of controlled many-body quantum matter that combines deterministically prepared, reconfigurable arrays of individually trapped cold atoms with strong, coherent interactions enabled by excitation to Rydberg states. Using this approach we realize a programmable Ising-type quantum spin model with tunable interactions and system sizes up to 51 qubits. Within this model, we observe transitions into ordered states that break various discrete symmetries, verify their high-fidelity preparation, and investigate dynamics across the phase transition in large atom arrays. In particular, we observe novel, robust many-body dynamics corresponding to persistent oscillations of the order after a sudden quantum quench. These observations enable new approaches for exploring many-body phenomena and open the door for realizations of novel quantum algorithms.