Observing the Space- and Time-Dependent Growth of Correlations in Dynamically Tuned Synthetic Ising Models with Antiferromagnetic Interactions

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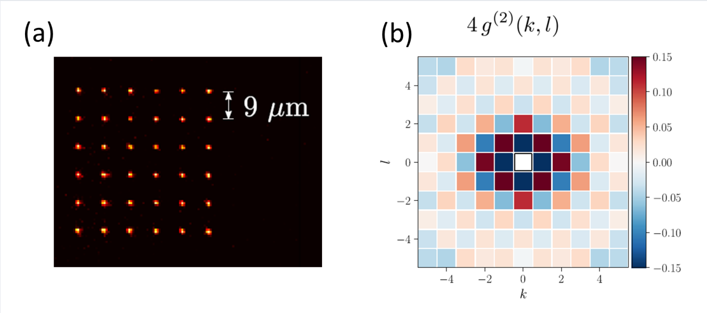
The ability to create and control ensembles of interacting quantum objects, such as atoms and ions, paves the way to quantum simulators, which could solve difficult computational problems that cannot be tackled by simulation on traditional digital computers. For some such tasks, one can vary in time the parameters describing the system and then let the system evolve to a state where the different particles are correlated; that is, the state of one particle depends on that of the others. However, these quantum correlations need time to build up, which places a limit on how fast one can tune the system. Here, we experimentally observe this fundamental limit and develop a theory to explain it, both of which are prerequisites for many applications of quantum simulators.

We arrange up to 36 rubidium atoms in two-dimensional arrays of optical tweezers with tunable geometries. When illuminated by lasers, the atoms are promoted to highly excited states known as Rydberg states, where one electron is excited to high energy. The system can then be described as an ensemble of interacting spins such that, for some range of parameters, any two neighboring spins want to align in opposite directions, giving rise to what is called antiferromagnetic order. When varying the laser parameters, we observe the progressive buildup of these correlations in space and time over a few microseconds, and we are able to model it theoretically, thus understanding the current limits of the platform.

Our results are an important step towards developing more complex quantum simulations of correlated systems.



Quantum simulation of an Ising antiferromagnet using individual Rydberg atoms. *(a): fluorescence image of single atoms, arranged in a 6x6 square array. (b): spin-spin correlation function of the system after a quasi-adiabatic sweep of the system parameters, showing the onset of antiferromagnetic order, albeit with a finite correlation length.*

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