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**Entanglement and the Jaynes-Cummings model with Rydberg-dressed atoms**[1]

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Controlling quantum entanglement between parts of a many-body system is the key to unlocking the power of quantum information processing for applications such as quantum computation, high-precision sensing, and simulation of many-body physics. Spin degrees of freedom of ultracold neutral atoms in their ground electronic state provide a natural platform given their long coherence times and our ability to control them with magneto-optical fields, but creating strong coherent coupling between spins has been challenging. We demonstrate for the first time a strong and tunable Rydberg-dressed interaction between spins of individually trapped cesium atoms with energy shifts of order 1 MHz in units of Planck's constant[2]. We spectroscopically demonstrate that this system is isomorphic to a Jaynes-Cummings Hamiltonian, and observe the $\sqrt{N}$ nonlinearity of the Jaynes-Cummings ladder with a single symmetric Rydberg excitation. This interaction enables a ground-state *spin-flip blockade*, whereby simultaneous hyperfine spin flips of two atoms are blockaded due to their mutual interaction. We employ this spin-flip blockade to rapidly produce single-step Bell-state entanglement between atoms.

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[2]Y.-Y. Jau, A. M. Hankin, T. Keating, I. H. Deutsch, and G. W. Biedermann, Nature Physics, **12**, 71-74 (2016).