Observation of Spin-Spin Fermion-Mediated Interactions and Nonlinear Spin Dynamics in a BEC

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In a mixture of a condensed Bose gas (BEC) and spin-polarized degenerate Fermi gas (DFG), fermions can mediate collisions between bosons, leading to effective long-range interaction between the bosons, analogous to Ruderman–Kittel–Kasuya–Yosida (RKKY) interaction in solids. Using Ramsey scheme spectroscopy, we measured frequency shifts of the bosons' hyperfine levels due to interactions with fermions. We were able to isolate the frequency shift related to mediated interaction from shifts caused by the direct collision of fermions and bosons. Our measurement showed an increase of spin-spin interaction between bosons by a factor of 1.43 in the presence of the DFG, providing clear evidence of spin-spin fermion mediated interaction. Fermion mediated interactions can potentially give rise to interesting new magnetic phases and extend the Bose-Hubbard model when the atoms are placed in an optical lattice. This interaction can be tuned with a boson-fermion Feshbach resonance.

We also study the evolution of the BEC in a two-state superposition due to inter-state interactions using microwave spectroscopy. These interactions have a non-linear spin component, leading to a shearing effect on the Bloch sphere. We use a population imbalanced dynamic decoupling scheme that accumulates inter-state interactions while cancelling intra-state density shifts and external noise sources. We repeat measurements on both magnetic sensitive and insensitive transitions with similar uncertainties, showing that we successfully decoupled our system from strong magnetic noises. Our scheme can be extended to other systems, such as quantum memories that are inherently imbalanced populations, and used close to a Feshbach resonance, where interactions diverge and strong magnetic noises are ever-present. Our results also allow for a better understanding of interatomic potentials.