Collective excitation and emission phenomena in a strongly interacting ultracold gas

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Atoms excited to high-lying quantum states, so-called Rydberg atoms, are highly polarizable and, therefore, interact strongly with each other at large distances. One result of these interactions is the Rydberg dipole blockade effect, in which strongly interacting atoms excited by the same driving pulse may prevent other atoms from getting excited. This blockade offers several applications, for example the realization of quantum logic gates [1] and the possibility of creating entangled states with two atoms [2]. A key signature of interactions between Rydberg atoms is the suppression of fluctuations in the number of excitations due to the dipole blockade [3], leading to highly sub-Poissonian statistics with a negative Mandel Q-Parameter (similarly to the photon arrival statistics of squeezed light), with $Q = -1$ in the limit of complete suppression of fluctuations. On the other hand, strong correlations can also result in super-Poissonian counting statistics with $Q>0$. Considering an open quantum system of atoms with a long-range Rydberg interaction, off-resonant laser driving and spontaneous emission, it has been predicted that over time the system occasionally jumps between a state of low Rydberg population and a state of high Rydberg population. These jumps are inherently collective [4,5].

We have studied the dynamics and the full counting statistics of Rydberg excitations of ultracold rubidium atoms in such a regime and found that the salient characteristics of the theoretical models are clearly observable in our experiment.

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