COLD RYDBERG GAS DYNAMICS

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Laser-excited Rydberg gases and plasmas provide a collision-rich environment which has revealed the spontaneous transformation of a cold Rydberg gas to a plasma[1], Rydberg atom formation from three-body recombination in an ultra-cold plasma[2], and $l$-mixing due to interactions between plasma electrons and cold Rydberg atoms[3]. These processes are not independent of one another. A comprehensive description of the evolution of a cold Rydberg gas requires considering them simultaneously. In this poster, we show that in cold Rydberg gases these phenomena occur in a well-defined pattern as a function of experimental parameters (number of atoms, evolution time, initial Rydberg state). Our data also provides strong evidence for inelastic collisions between electrons and Rydberg atoms, predicted to be significant in cold Rydberg gases[4].

Collision-induced dynamics in a cold Rydberg gas is initiated by the generation of free electrons during the first few microseconds after the laser excitation. As they escape, a positive space charge develops which can trap subsequent free electrons. The further development of the cold Rydberg gas is then dominated by collisions between trapped electrons and cold Rydberg atoms and ions.

Fig.1 shows the degree of plasma formation and the distribution of the remaining Rydberg atoms as a function of initial Rydberg atom population for a fixed evolution time of 18 $\mu$s. For small initial atom numbers, a small plasma component develops, which triggers strong elastic $l$-mixing and inelastic $n$-changing collisions. The degree of mixing increases with the plasma size (Fig.1b and c). In addition, we find that a significant fraction of the Rydberg atom population shifts to lower $n$-states than could not be produced by either elastic or inelastic collisions between electrons and Rydberg atoms (Fig.1b-d)[4]. We believe that these low-$n$ states result from dipole assisted auto-ionizing collisions between Rydberg atoms. At our highest atom numbers, the system evolves into a mode of full-scale ionization(Fig.1e). The same stages are observed as a function of evolution time at fixed, initial Rydberg populations.

![Field ionization spectra for initial $n=60$ states. The initial Rydberg atom population, $N_R$, is varied. (a) $N_R$ very low (b) $N_R = 8.4 \times 10^2$, (c) $N_R = 1.1 \times 10^4$, (d) $N_R = 2.2 \times 10^5$, (e) $N_R = 1.0 \times 10^6$.](image)

In the poster, these transformation modes of cold Rydberg gases will be discussed in detail. The utilized setup also allows us to study the effect of thermal background radiation over a range $300 \text{ K} > T_{\text{rad}} > 4 \text{ K}$. Cryogenic temperatures also extend the usable lifetime of Rydberg atoms, especially for high-angular-momentum states, and allow for the possibility of Rydberg atom trapping. Progress in these areas will also be presented.