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L-changing through very-long-range interactions in high-*n*, *n*~300, Rydberg-Rydberg collisions

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Synopsis State-changing in thermal-energy collisions between strontium atoms in high-*n*, *n*~300, n^1F_3 Rydberg states is studied in an atomic beam and analyzed using classical trajectory Monte Carlo simulations. The *L*-changing cross section is large, ~10^{-4} cm^2, much greater than the corresponding "hard-sphere" cross section.

Because of their large dipole moments, Rydberg atoms provide a valuable tool for exploring long-range interactions. Such measurements, however, are complicated by collisions which can lead to rapid state changing (and to ionization). Here we examine collisional state changing in a strontium atom beam by exploiting dipole blockade to create a string of high-*n*, *n*~300, n^1F_3 Rydberg atoms through (pulsed) multiphoton excitation using focused laser beams that define a small excitation volume (~50 μm on a side). Excitation of a Rydberg atom suppresses further excitation until the atom has traveled one blockade radius (~100 μm) in the beam direction. If, once this occurs, excitation of an additional Rydberg atom occurs quickly, a string of Rydberg atoms is created with approximately equal initial separations but a distribution of initial velocities. The state-changing due to their subsequent collisions is monitored by observing the damping of quantum beats induced by sudden application of a "pump" field with rise time $t_R << T_n$, the classical orbital period.[1]

Figure 1 shows the time dependence of the quantum beats seen following application of the pump field. Two very-different beat frequencies are evident and correspond to the electron orbital period (~4 ns) and to Stark precession of the electron orbit in the pump field. Comparison of quantum beat data recorded with less than one Rydberg atom excited per laser pulse (i.e., no collisions expected) and with ~15 Rydberg atoms created per laser pulse shows that collisions lead to a marked reduction in the quantum beat amplitudes. In particular, the fast beats are sensitive to *n*-changing collisions, the slow beats to L-changing processes.

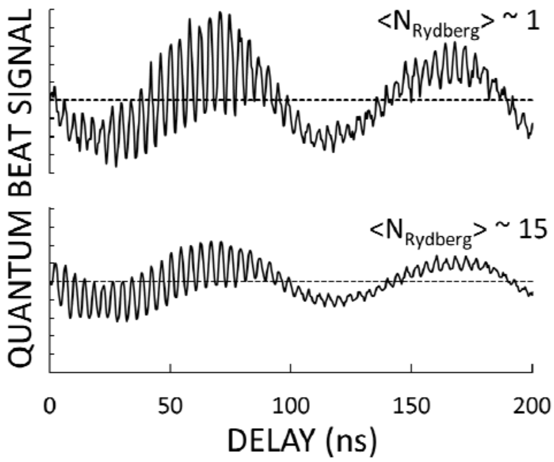

Figure 1. Time dependence of quantum beat signals recorded when creating ~1 and ~15 Rydberg atoms per (~6 μs) laser pulse.

The experimental data are analyzed using classical trajectory Monte Carlo simulations that use an effective four-body Hamiltonian. These simulations show that while collisions lead to only small changes in *n*, they cause dramatic changes in the *L* distributions, which results in a large reduction in the predicted quantum beat amplitudes. Theory and experiment show that, even for impact parameters *b*~50μm, collisions lead to strong *L*-changing. The cross-sections, ~10^{-4} cm^2, are large, much greater than those typically associated with neutral-neutral collisions.

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References

[1] Yoshida S *et al* 2007 *Phys. Rev. A* **75** 013414

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