# Long-range Interactions and Molecular Resonances in Ultracold Rydberg Gases

E. E. Eyler, P.L. Gould, S.M. Farooqi, D. Tong, J. Stanojevic, and R. Côté

*Department of Physics, University of Connecticut, Storrs, CT*

At high principal quantum numbers, interaction forces between Rydberg atoms become extremely large. These interactions can be dominated either by van der Waals interactions or by dipole-dipole interactions, depending on the details of the atomic state distributions, the interatomic distance, and the extent of L degeneracy. Manifestations of these long-range interactions are particularly evident in a cold dense gas. One example is the molecular resonances that result from long-range avoided crossings between interatomic potentials [1,2]. A second is the significant suppression of resonant Rydberg excitation caused by interactions with neighboring atoms [3,4]. We will discuss these phenomena and compare them with theoretical treatments.

The molecular resonances are observed by scanning the frequency of a transform-limited pulsed laser that excites ground-state 85Rb atoms in a MOT. Several spectral features are observed that do not correspond to any atomic resonance. The strongest features occur below each np resonance (n = 50-90) at a frequency corresponding to the average energy of the (n-1)d and ns states. We attribute these to avoided crossings between interatomic potential curves. We will also discuss resonances occurring at the average energy of the (n-1)p and (n+1)p states, a situation for which detailed theoretical analysis is more tractable because fewer potential curves are involved.

The suppression or "blockading" of Rydberg excitation is observed when a laser is tuned to exact resonance with an atomic np state. In experiments on rubidium atoms with $n \approx 70$, we observe a significant density-dependent suppression of atomic excitation. This local excitation blockade is caused by van der Waals shifts from neighboring Rydberg atoms, which detune the atomic resonance outside the laser linewidth if the atoms are sufficiently closely spaced. In this talk we will describe experimental aspects of the work, and in a later talk by Robin Côté, a theoretical analysis will be described together with possible applications to quantum computation.

[1] S.M. Farooqi, D. Tong, S. Khrishnan, J. Stanojevic, Y.P. Zhang, J.R. Ensher, A.S. Estrin, C. Boisseau, R. Côté, E.E. Eyler, and P.L. Gould, "Long-Range Molecular Resonances in a Cold Rydberg Gas", Phys. Rev. Lett. **91**, 183002, 1-4 (2003).

[2] J. Stanojevic, R. Côté, D. Tong, S.M. Farooqi, E.E. Eyler, and P.L. Gould, "Long-Range Rydberg-Rydberg Interactions and Molecular Resonances" , to be published.

[3] D. Tong, S.M. Farooqi, J. Stanojevic, S. Khrishnan, Y.P. Zhang, R. Côté, E.E. Eyler, and P.L. Gould, "Local Blockade of Rydberg Excitation in an Ultracold Gas", Phys. Rev. Lett. **93**, 063001, 1-4 (2004).

[4] K. Singer, M. Reetz-Lamour, T. Amthor, L.G. Marcassa, and M. Weidemüller, "Suppression of Excitation and Spectral Broadening Induced by Interactions in a Cold Gas of Rydberg Atoms", Phys. Rev. Lett. **93**, 163001, 1-4 (2004).