Collisions involving cold Rydberg atoms

R.A.D.S. Zanon[1], K.M.F. Magalhães, A.L. de Oliveira[2], and L.G. Marcassa

Instituto de Física de São Carlos, Universidade de São Paulo
Caixa Postal 369, 13560-970, São Carlos-SP, Brazil
Tel 55-16-2712012, Fax 55-16-2713616
E-mail: marcassa@if.sc.usp.br, Website: http://www.if.sc.usp.br/optica
[1]*Universidade do Estado de Santa Catarina,* [2]*Departamento de Física, Universidade Federal de São Carlos and Universidade do Estado de Santa Catarina.*

In the last decades collisions involving Rydberg atoms from an atomic beam have been studied in depth both theoretically and experimentally. The energy transfer collision is a well-known process involving two Rydberg atoms, and it has a unique characteristic, i.e., its cross section can be tuned by a static electric field via the Stark effect. This collisional process has been studied with several alkalis, using thermal atomic beams. This source, however, has some disadvantages as a broad velocity distribution and a short interaction time.

Cold samples of atoms can now be produced very easily with the use of a magneto-optical trap. Several groups have recently observed collisions involving cold Rydberg atoms in a MOT. This achievement has opened up an entirely new field, in which several different experiments can be carried out. This paper reports on a time evolution experiment of energy transfer collisions using cold Rydberg atoms in a MOT. The following collisional process was studied in our experiment:

$$Rb29P_{1/2} + Rb29P_{3/2} \rightarrow \; Rb29S_{1/2} + Rb31S_{1/2}$$

This process presents two resonances between 860 and 940 V/cm (for an electric field of 890 and 903 V/cm). In our experiment we only observed a broad resonance. To simplify the analysis we have restricted the time evolution experiment to an electric field of 897 V/cm where the energy difference (ΔE) between the incoming and the outgoing atoms is 0.02 cm^{-1}. For an electric field of 897 V/cm (ΔE=0.02 cm^{-1}), the $31S_{1/2}$ state population as a function of time, is shown in fig.1. The same experiment was carried out for different values of $\Delta E > 0$ and they each presented the same time evolution. The ion signal is proportional to n^2 (atomic density) indicating a two-body process; but its time behavior is constant (the Rydberg atomic density varied from 107 to 109 atoms/cm^3).

To explain this result, a semi-classical model was developed based on a two-body interaction. In the model, two attractive potential curves are considered, one that connects adiabatically to the $\text{Rb29P}_{1/2}$+$\text{Rb29P}_{3/2}$ state and another that connects to the $\text{Rb29S}_{1/2}$+$\text{Rb31S}_{1/2}$ state. The latter presents lower energy than the former. We consider that these curves cross each other at a very short range. We also assume that at t=0 the laser pulse excites the atoms to the $\text{Rb29P}_{1/2}$+$\text{Rb29P}_{3/2}$ Rydberg potential for all possible internuclear separations (from $R = 0$ to $R \rightarrow \infty$). Once they are at this potential, the colliding atoms will accelerate against each other until they reach short internuclear separation. In this region, the atomic pair may change potential, ending the collision in the $Rb29S_{1/2} + Rb31S_{1/2}$ state, when the $31S_{1/2}$ population is detected. Spontaneous decay is also considered. To calculate the time evolution of the $31S_{1/2}$ state population, we assume the $1/R^3$ potential. The full line in fig.1 is the prediction from the model. In the inset of fig.1 the resonance curve and the theoretical prediction is shown.

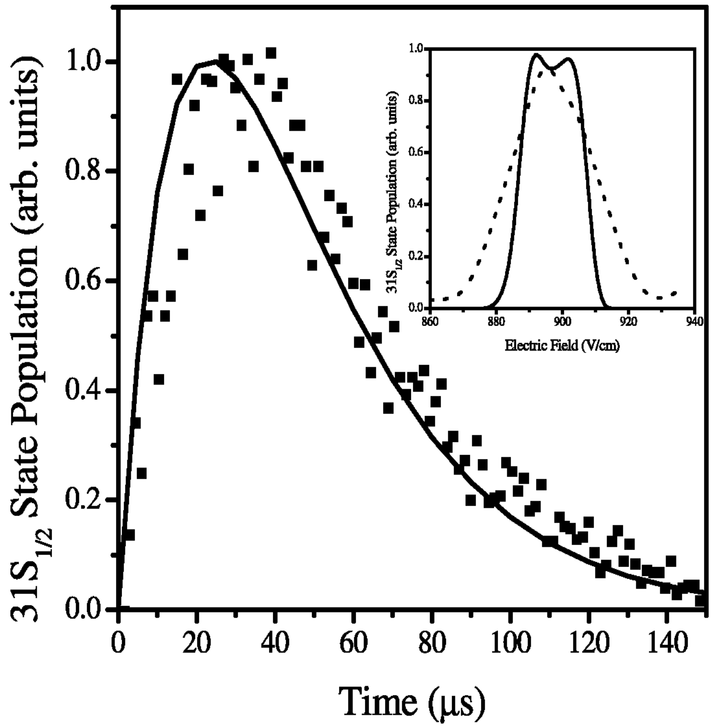

Figure 1: The full line is the prediction from the model. In the inset the resonance curve and the theoretical prediction is shown.

Acknowledgments. The authors want to thank FAPESP and Pronex by the support.