Control of few body resonant-transfer interactions in a cold Rydberg gas

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Observing the transition between 2-body and many-body physics in complex systems is a challenge as it is difficult to isolate few-body interactions from many-body interactions. Cold Rydberg atoms, which are known for their strong interaction properties [1], constitute in this prospect an interesting system to study many-body physics.

Previously in Laboratoire Aimé Cotton, we have succeeded [2] to isolate a 4-body interaction process appearing as a specific resonance of energy exchange between Rydberg atoms. This process originated from the coincident recombination of two 2-body energy exchange resonances [3] like the one in Eq. (1) called Förster resonance in analogy to FRET in biomolecules. Such a coincidence prevents *a priori* to extend this process to other systems, atoms or molecules. We have thus searched for more general processes.

$$2 \times np_{3/2}m \leftrightarrow ns + (n+1)s \qquad (1)$$

We will present here a new resonant 3-body energy transfer process in cesium Rydberg atoms. This process, presented in Eq. (2), is a revival of the known 2-body resonance in Eq. (1) induced by a much smaller energy exchange of a third atom changing only its magnetic sub-level.

$$3 \times np_{3/2}m \leftrightarrow ns + (n+1)s + np_{3/2}m' \qquad (2)$$

We have found that this exchange process is particularly strong and is present for any starting $p_{3/2}$ state in cesium. For instance Fig. (1) presents these resonances from the $32p_{3/2}m_{1/2}$ state: the 2-body resonance of Eq. (1) is expected at a field of 6.89V/cm and is used as field calibration. The 3-body process of Eq. (2) is then well observed at the expected field of 6.61V/cm with a large transfer to the s states.

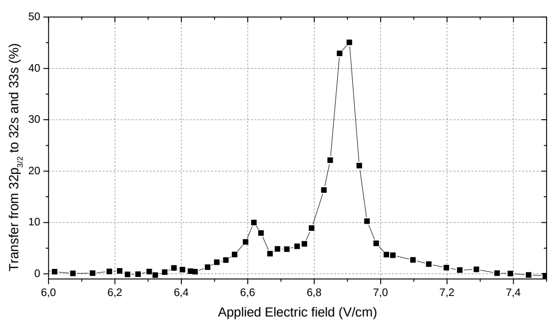

Figure 1: *Resonant exchanges from $32p_{3/2}m_{1/2}$. The 2-body resonance is expected at 6.89V/cm while the 3-body resonance is calculated at 6.61V/cm.*

Our observations are likely to have implications in various domains, from quantum physics to biology and new materials: This new FRET process could be used to design a 3-Qbit quantum gate or to provide an effective Quantum Non Demolition measurement of the entanglement between 2 atoms, measuring the 3^{rd}. FRET is also widely used in biology as an imaging tool [4] which could be extended using additionnal molecules inducing 3-body FRET. Finally, 3-body FRET could help improving new solar cell technology which already tries to mimic light-harvesting.

References

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