Master 2: ***International Centre for Fundamental Physics***

INTERNSHIP PROPOSAL

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Thesis possibility after internship: YES
Funding: Not yet; If YES, which type of funding:ED Paris-Saclay

Control of ultracold quantum gases with shielded interactions

The research field of cold (T<1K) and ultracold (T<<1mK) molecules is continuously expanding in many directions, involving an increasing number of groups throughout the world. This research field actually has initiated a "revolution in molecular physics" [Grimm2005] similar to the one induced by laser-cooling of atoms and Bose-Einstein Condensation (BEC) in dilute gases of weakly interacting ultracold atoms. Due to their much richer internal structure than atoms, ultracold molecules have opened the way towards fascinating researches and new possibilities for controlling quantum systems. A few examples are: (i) High-resolution molecular spectroscopy; (ii) Precision measurements for testing fundamental theories; (iii) Quantum information devices ; (iv) Elementary chemical reactions and (v) Many-body physics.
A major breakthrough has recently been achieved, as molecules in the lowest vibrational level of their absolute ground state have been formed either by PA and optical pumping [Viteau2008] or by MA followed by Stimulated Rapid Adiabatic Passage (STIRAP) [Danzl2008, Ni2008, Takekoshi 2014, Guo 2016]. While paving the way towards a new kind of ultracold chemistry, collisions, in particular inelastic collisions, in general limit the possibility to use such ultracold molecular samples for other purposes. Soon came the desire of suppressing collisions using electromagnetic fields. The basic idea is to couple the initial molecular state of the colliding atoms to a repulsive excited molecular state using laser light detuned to the blue of a resonant atomic transition, preventing the atoms to come close to each other [Suominen1995].
The goal of this project is to identify repulsive excited channels appropriate for optical shielding and to describe their coupling with the initial state of the colliding atom pair (K and Cs atoms) in the framework of the dressed-state picture where the coupling of the involved molecular states is induced by the blue-detuned laser light with Rabi frequency and treated under the rotating wave approximation. The problem will be treated in the framework of a semiclassical Landau-Zener model whose robustness has been assessed [Suominen1995, Suominen 1996] which would readily provide an indication of the shielding efficiency usable in the experiments. The role of spontaneous emission will also be investigated as it may become a limit of the shielding process due to the very weak relative velocities of the atoms at ultralow temperatures.
Good knowledge of *Atomic and Molecular Physics* is required.
Good programming skills (*e.g.*, Fortran, Mathematica) are desirable.

[Grimm2005] R. Grimm, Nature 435, 1035 (2005)
[Guo 2016] M. Guo, B. Zhu, B. Lu, X. Ye, F. Wang, R. Vexiau, N. Bouloufa-Maafa, G. Quéméner, O. Dulieu and D. Wang, *Physical Review Letters* **116**, 205303(2016)
[Ni2008] K.-K. Ni, et al., Science, 322, 231 (2008)
[Viteau2008] M. Viteau, A. Chotia, M. Allegrini,N. Bouloufa, O. Dulieu, D. Comparat, P. Pillet, Science 321, 232 (2008)
[Suominen1995] K.-A. Suominen, M. J. Holland, K. Burnett, and P. Julienne, Phys. Rev. A 51, 1446 (1995)
[Suominen1996] K.-A. Suominen, et al., Phys. Rev. A 53, 1658 (1996)
[Takekoshi 2014] T. Takekoshi, L. Reichsöllner, A. Schindewolf, J. M. Hutson, C. R. Le Sueur, O. Dulieu, F. Ferlaino, R. Grimm, and H.C. Nägerl, Phys. Rev. Lett. 113, 205301 (2014)

Please, indicate which speciality(ies) seem(s) to be more adapted to the subject:

Condensed Matter Physics: NO Macroscopic Physics and complexity: NO
Quantum Physics: YES Theoretical Physics: YES