

# ESF SHORT VISIT GRANT (Ref. No. 1778) FINAL REPORT

ESF Programme: **QUEDIS (Physical and Engineering Sciences)**

Visiting Scientist: Dr. Jordi Mur-Petit (CNRS and U. Paris-Sud)

Host: Dr. Muntsa Guilleumas (U. Barcelona)

Project title: Finite temperature dynamics of spin-1 condensates

## PURPOSE OF THE VISIT:

The scope of the visit was to continue an on-going project centered on the dynamics of Bose-Einstein condensates with spin degree of freedom confined in optical traps. In particular, we intended to finish the revision of a submitted paper, and to plan the continuation of the project, by determining the future calculations to be done to complete the study of the dynamics of spin-1 condensates. Discussions with the neighbouring group of Prof. Lewenstein at ICFO where also scheduled.

## DESCRIPTION OF THE WORK CARRIED OUT:

The visit lasted between April 10<sup>th</sup> and 13<sup>th</sup> as scheduled. On Tuesday 10<sup>th</sup>, I could visit Prof. Lewenstein at ICFO, where we discussed on the detection of correlations in cold atomic samples. I am now starting a project on atom number correlations, and the discussion on the projects on fermion counting and atom counting that are developed in Prof. Lewenstein's group where very illuminating. Finally, we also discussed on our project in collaboration with Dr. Guilleumas on spin-1 condensates.

Between Wednesday 11<sup>th</sup> and Friday 13, I visited Dr. Guilleumas at Univesitat de Barcelona. We first discussed the last modifications introduced in our paper [1] by our collaborators Profs. Sanpera and Lewenstein, and the corresponding letter to the Editor. Later, Dr. Guilleumas and her PhD student Mrs. Moreno-Cardoner presented their last numerical results, together with the lines of research that they propose as a continuation of the present work, which they had recently discussed with the experimental group of Prof. Sengstock in Hamburg.

## DESCRIPTION OF THE MAIN RESULTS OBTAINED:

In the discussions with Prof. Lewenstein, we identified the characteristic length scales that are expected to be relevant in the determination of the density-density correlation function for a Bose gas a finite temperature. Above condensation, the ideal gas is characterized by the de Broglie length, which determines the scales over which the function presents the transition from the value  $g=2$  to  $g=1$  (absence of correlations, at long distance) typical of Hanbury Brown-Twiss experiments. For the case of an interacting gas, with short-range repulsion as in alkali gases, one expects the value  $g=0$  at short range. We could argue that the length over which the transition  $g=2$  to  $g=0$  is found at  $Dr_0$  (i.e., the transition between the statistical to the interaction dominated regions occurs) is on a length scale of the order of the scattering length for thermal gases (only two-body physics plays a role), while for a BEC it is the healing length (many-body effects are the most relevant). I plan to address the possibility to

formalize this intuitive picture through the theoretical framework developed in my home group at Laboratoire Aimé Cotton, where a “many-body scattering length” has been introduced that might join this two limits.

In the discussions with the the group at Universitat de Barcelona, we concluded the revision of our paper [1], and decided to continue our work in two parallel lines:

1. Write a forthcoming paper with a deeper discussion of our results on the zero-temperature dynamics of homogeneous spin-1 condensates, clarifying the role of the different possible orbits in phase-space (open vs. closed), and applying this analysis to the understanding of the dynamics in trapped gases.
2. In collaboration with the experimental group at U. Hamburg, study the dynamics of spin-2 systems, both at zero and finite magnetic fields, as the experimental group has found that an external magnetic field can importantly affect this dynamics. Some preliminary numerical results by the group at U. Barcelona show results that qualitatively agree with the experimental outcomes.

#### FUTURE COLLABORATION WITH HOST INSTITUTION:

To fully develop both points 1 and 2 above, it is clear that the collaboration is expected to continue in the future.

#### PROJECTED PUBLICATIONS RESULTING FROM THE GRANT:

Various publications can be foreseen to results from this collaboration:

1. Publication of the already submitted paper [1], where an appropriate acknowledgement to ESF and QUDEDIS has been included.
2. Publication of the extension of [1] as proposed in point 1 above. We expect this work to be in an advance stage by the end of the year.
3. One or more papers could follow the analysis of the spin-2 case, in a longer timescale.

#### OTHER COMMENTS:

The journey Paris-Barcelona was done by car, while the Barcelona-Paris was done by plane. Only the reimbursement of the travel costs for the Barcelona-Paris trip (130 EUR) is demanded (boarding card sent by regular mail together with copy of electronic ticket information).

#### REFERENCES:

[1] M. Moreno-Cardoner, J. Mur-Petit, M. Guilleumas, A. Polls, A. Sanpera, M. Lewenstein, arXiv:cond-mat/0611379 (2006).

Paris, April 17<sup>th</sup>, 2007