



ERASMUS MUNDUS



MASTER IN PHOTONICS – PHOTONICS BCN EUROPHOTONICS-POESII MASTER COURSE

PROPOSAL FOR A MASTER THESIS

Dates: April - September 2017

Laboratory : Dpt. Física Quàntica I Astrofísica
Institution: University of Barcelona
City, Country : Barcelona, Spain

Title of the master thesis: Excitations of a 1D Bose-Gas: exact diagonalisation and sumrules study

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Summary of the subject (maximum 1 page) :

Keywords : Bose-Einstein Condensates, sum rules, excitation spectrum

In recent years the striking physics of 1D quantum systems has flourished thanks to the advances in ultracold atomic trapped systems. In particular, ultracold atomic gases have been produced confined in 1D traps in several laboratories around the world [1,2]. This, together with the attainable control on the atom-atom interaction potential enables us to study the transition from non-interacting to the strongly interacting case, going from the BEC to the Tonks-Girardeau regime [3]. In recent works we have studied the appearance of strong correlations on small atomic samples of two different species of atoms [4,5].

In this master thesis our aim is to study a 1D gas of bosons trapped in a harmonic potential and study its excitations. First we will consider the case of two bosons, which solution is already known, and study the sum-rules for the different moments of the dynamic structure function. These sum rules allow us to obtain information about the excitation of the system from matrix elements of the ground state [6].

In a second step we will consider systems of more bosons using an exact diagonalization technique to numerically compute the spectrum of the system and compare it with the predictions of the sum rules.

- [1] B. Paredes et al., *New J. Phys.* 12,093041 (2010).
- [2] T. Kinoshita, T. Wenger, D. S. Weiss, *Nature* 440, 900 (2006).
- [3] F. Deuretzbacher, K. Bongs, K. Sengstock, and D. Pfannkuche, *Phys. Rev. A* 75, 013614 (2007).
- [4] M. A. García-March, B. Juliá-Díaz, G. E. Astrakharchik, J. Boronat, A. Polls, *Phys. Rev. A* 90, 063605 (2014).
- [5] M.A. Garcia March, B. Juliá-Díaz, G. E. Astrakharchik, Th. Busch, J. Boronat, A. Polls, *New J. Phys.* 16 103004 (2014) ; *Physical Review A* 88, 063604 (2013).
- [6] O. Bohigas, A. Lane, and J. Martorell, *Physics Reports*, vol. 51, 267, (1979).

Additional information :

- * Required skills : Good knowledge of fortran of python to perform the numerical simulations
- * Miscellaneous : Knowledge of Many-body quantum mechanics.