Master in Photonics – "PHOTONICS BCN"
Master ERASMUS+ "EuroPhotonics"

MASTER THESIS PROPOSAL

Dates: April 2020 - September 2021

Laboratory: Quantum Tech (ICCUB/UB) + Monte Carlo Group (UPC)
Institution: U. Barcelona and U. Politecnica de Catalunya
City, Country: Barcelona, Spain

Title of the master thesis: A full Monte Carlo study of Quantum Droplets in optical lattices

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Keywords: Quantum droplets, optical lattices, Monte Carlo methods

Summary of the subject (maximum 1 page):

An extension of the quantum droplets in homogeneous geometry originally proposed by Petrov [1] and confirmed experimentally in Refs. [2,3,4,5] to optical lattices has been recently presented in Ref. [6]. In the original proposal, the system consisted of two kinds of bosonic particles which were proven to produce liquids beyond the van der Waals paradigm thanks to the quantum fluctuations present in the system. The predictions were obtained for weakly interacting bosonic particles using the beyond mean-field correction of Lee, Huang and Yang. In our recent extension, we have considered a bosonic mixture but trapped in this case in a one-dimensional optical lattice. Interestingly, we have demonstrated the presence of droplets in this system both in the weakly and strongly interacting regimes, describing in the latter the existence of a dimerized description which captures fairly well the original system [7].

In the current Master Thesis project we will explore the system both in one and three dimensions with the help of quantum Monte Carlo techniques. In this way, we will be able to compare with the Bose-Hubbard predictions valid in deep lattices which will lead to a better understanding of the role played by the optical lattice in the production of strongly correlated phases.

The student will learn Quantum Monte Carlo techniques applied to state of the art physical problems in ultracold atomic gases. First, we will concentrate in the one-dimensional case,

where comparison to our Bose-Hubbard predictions is feasible. Afterwards, we will study the three dimensional case, which is closer to most of the current experimental efforts.

[1] D. S. Petrov, Phys. Rev. Lett. 115, 155302 (2015).
[2] I. Ferrier-Barbut, et al, Phys. Rev. Lett. 116, 215301 (2016).
[3] L. Chomaz, et al, Phys. Rev. X 6, 041039 (2016).
[4] C. R. Cabrera, et al, Science 359, 301 (2018).
[5] G. Semeghini, et al, Phys. Rev. Lett. 120, 235301 (2018).
[6] I. Morera, et al, Phys. Rev. Research 2, 022008 (2020).
[7] I. Morera, et al., arXiv:2007.01786 (2020).

Additional information (if needed):
* Required skills : Computational physics, Quantum physics, Many-body Quantum physics (prefereable)
* Miscellaneous :