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ICFO
The Institute
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Master in Photonics – “PHOTONICS BCN” Master ERASMUS+ “EuroPhotonics”

MASTER THESIS PROPOSAL

Dates: April 2020 - September 2021

Laboratory: Institute of Cosmos Sciences of the University of Barcelona (ICCUB)

Institution: Universitat de Barcelona

City, Country: Barcelona, Spain

Title of the master thesis: Imbalanced quantum droplets in one-dimensional optical lattices

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Keywords: quantum droplets, bosonic mixtures, optical lattices, tensor networks.

Summary of the subject (maximum 1 page):

Since the theoretical proposal [1] for creating dilute quantum droplets in ultracold atomic systems many experimental groups have been able to produce them using dipolar systems [2,3] or bosonic mixtures [4,5,6]. These droplets exhibit very classical properties like the ones found in water but at the same time its formation resides in the competition between classical and quantum fluctuations [1]. Recently, it has been proposed to study these quantum droplets in one-dimensional optical lattices [7,8]. This provides a very rich scenario where strongly correlated phases can appear and a new phase of paired quantum droplets has been observed [7,8].

In this work a bosonic mixture in a one-dimensional optical lattice will be explored in the imbalanced case. This consists in considering a different number of atoms for each species of the mixture. In this situation all the atoms cannot be paired and this creates a competition between single atoms and pairs. For increasing imbalance new phases are expected.

In this work the student will learn the current techniques used to explore strongly interacting many-body systems in one-dimension. This includes Tensor Networks which are the current state of the art for simulating such systems. Furthermore, other theoretical techniques will be applied.

References:

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- [3] L. Chomaz, S. Baier, D. Petter, M. J. Mark, F. Wächtler, L. Santos, and F. Ferlaino, Phys. Rev. X 6, 041039 (2016).
- [4] C. R. Cabrera, L. Tanzi, J. Sanz, B. Naylor, P. Thomas, P. Cheiney, and L. Tarruell, Science 359, 301 (2018).
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- [7] I. Morera, G. E. Astrakharchik, A. Polls, and B. Juliá-Díaz, Phys. Rev. Research 2, 022008 (2020).
- [8] I. Morera, G. E. Astrakharchik, A. Polls, and B. Juliá-Díaz, arXiv:2007.01786 (2020).

Additional information (if needed):

- * Required skills: Knowledge of many-body physics, computer skills
- * Miscellaneous: