PhD THESIS DEFENSE: A cold-atom approach to topological quantum matter across the energy scales

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December 11, 2020
10:00 to 13:00
Online (Teams) and ICFO Auditorium

The outstanding progress achieved in the last decades to isolate and manipulate individual quantum systems has revolutionized the way in which quantum many-body phenomena, appearing across Nature's different energy scales, can be investigated. By employing atomic systems such as ultracold atoms in optical lattices, an enormous range of paradigmatic models from condensed-matter and high-energy physics are being currently studied using table-top experiments, turning Feynman's idea of a quantum simulator into a reality.Quantum simulators offer the possibility to gather information about complex quantum systems, which are either not accessible to experiments or whose properties can not be easily derived using standard analytical or numerical approaches. These synthetic quantum systems can be designed precisely such that they are described under the same models as natural systems, and their remarkable control allows to probe the relevant phenomena associated to them. Apart from their quantum simulation capabilities, atomic systems can also be employed to generate quantum matter with novel properties beyond those found in Nature, offering interesting prospects for quantum technological applications. In this thesis, we investigate the possibilities that cold-atom systems present to address, in particular, quantum matter with non-trivial topological properties. Using mixtures of ultracold atoms, we analyze various quantum simulation strategies to access several many-body phenomena for which a satisfactory understanding is still lacking. Moreover, we show how such platforms display strongly-correlated topological effects beyond those found in natural systems. We first focus on models inspired by condensed-matter physics. More precisely, we propose how lattices dynamics, similar to those described by phonons in solid crystals, can be implemented in an otherwise static optical lattice. By coupling the former to quantum matter using a mixture of bosonic atoms, we reproduce typical effects described by electronic systems, such as topological defects or charge fractionalization. We then extend these results and find novel features, from boson fractionalization to intertwined topological phases.We then consider the quantum simulation of high-energy-physics problems. By using Bose-Fermi mixtures, we show how non-perturbative phenomena characteristic of non-abelian gauge theories, such as quark confinement, emerge in simpler models that are within the reach of current technology. Finally, we investigate how the interplay between gauge invariance and strong correlations gives rise to various mechanisms to prepare robust topological order in near-term quantum simulators.In summary, our results show several connections between different areas of theoretical and experimental physics, and indicate how these can be harnessed further to advance our understanding of strongly-correlated quantum matter, as well as to utilize the latter for new technological applications.

Friday December 11, 10:00hr - Auditorium and Teams

Thesis Advisor: Prof Dr Maciej Lewenstein

Thesis Co-advisor: Prof Alejandro Bermudez

Due to recommendations in place to contribute containing the spreading of COVID-19, th defence will be carried out semi presencial with a maximum of 66 Icfonians in t e Auditorium, and partly remotely via MS Teams

If you are interested in attending in person, please address your request to mery.gil@icfo.eu **by Monday November 30.**

Hosted by: Maciej Lewenstein