PhD Opportunity: Topology and strong interactions in non-equilibrium quantum simulators

Advisor: Diego Porras, IFF-CSIC (Madrid, Spain)

Project Summary. Quantum simulators, such as superconducting circuits or trapped ions, enable the creation of new phases of quantum matter. These new phases are important from a fundamental viewpoint, as they challenge our understanding of quantum complex systems. They can also find applications for designing precise sensors and amplifiers. In recent years, our group has developed a novel formalism for describing topological non-equilibrium phases of matter in quantum simulators. However, many questions remain open, like the role of interactions and disorder. This project will develop a theoretical description of complex topological phases based on analytical approaches and numerical algorithms. We will analyse how interactions lead to exotic new topological phases and explore their dynamical and structural properties.

Your role

The ideal candidate will have a solid theoretical background in quantum mechanics, quantum optics, and condensed matter physics. More specifically, you will:

- Modelize quantum simulators based on quantum optical setups using theoretical techniques from quantum open systems (master equations, Floquet theory)

- Analyze quantum phase transitions and topological phases

- Develop numerical algorithms based on phase-space methods (truncated Wigner approximation) or Matrix Product States to describe interacting phases. Numerical experience with Python is useful here.

What we offer

- Funded PhD position within the 4-year research project (“FPI Grant” funded by the National Project PID2024-159152NB-I00)

- A stimulating environment: the QUINFOG group at IFF-CSIC (6 faculty, several postdocs/PhDs)

- Possibilities for international collaborations with theory and experimental groups.

How to apply:

Send an email with a short description of yourself and your motivation, together with a CV to diego.porras@csic.es

The search is restricted to students fulfilling the criteria of the call (European citizens with certification of at least 300 ECTS, or students from outside the European Union with the Spanish equivalent of 300 ECTS).

The call is expected to mirror last year's. Selected candidates will apply to the official opening expected in November, with PhD start around January 2026 (exact dates TBA).

Relevant References:

[1] Emerging Non-Hermitian Topology in a Chiral Driven-Dissipative Bose-Hubbard Model L Rassaert, T Ramos, T Roscilde, D Porras, arXiv:2411.08965 (2024)

[2] Floquet control of interactions and edge states in a programmable quantum simulator, Or Katz, Lei Feng, Diego Porras, Christopher Monroe, Nature Communications **16**, 8815(2025)

[3] Driven-dissipative topological phases in parametric resonator arrays, Á Gómez-León, T Ramos, A González-Tudela, D Porras, Quantum **7**, 1016 (2023)

[4] Topological amplification in photonic lattices, D Porras, S Fernández-Lorenzo, Physical Review Letters **122**, 143901 (2019).