INTERNSHIP PROPOSAL

Laboratory name: Laboratoire MPQ
CNRS identification code: UMR 7162
Internship director'surname: Alexandre LE BOITÉ
e-mail: alexandre.leboite@u-paris.fr Phone number: 01 57 27 62 46
Web page: https://mpq.u-paris.fr/theorie/
Internship location: Laboratoire MPQ

Thesis possibility after internship: YES
Funding: NO If YES, which type of funding:

Theory of finite-component phase transitions in quantum optics

The experimental control of the coherent interaction between light and matter is one of the corner stones of the recent developments in the field of quantum technologies. In this context, cavity quantum electrodynamics has reached an important milestone in the last decade with the achievement of the ultrastrong coupling (USC) regime, where the coupling strength becomes comparable or even larger than the cavity frequency [1]. Furthermore, recently developed quantum simulation techniques made it possible to observe the physics of the ultrastrong-coupling regime even in systems that do not naturally achieve the required interaction strength. These effective implementations of USC can reach extreme regimes of parameters, where phase transitions emerge, even in systems with a finite number of components [2]. These finite-component phase transitions are easier to control than their many-body counterparts and offer an interesting framework for the study of critical phenomena, with possible applications to quantum metrology.

The general motivation behind this project is to explore the rich phenomenology of these finite-component phase-transitions. One first goal will be to understand the effect of photon losses and dissipative processes on the phase transition recently predicted when three non-linear cavities are connected via ultrastrong 3-body interactions [3]. While some features of the transitions have been shown to be robust against dissipation, not much is yet known on the nature of the steady-state in the vicinity of the transition point.

The project involves the implementation of state-of-the-art numerical methods used to simulate open quantum systems, such as quantum-to-classical mappings and the resulting stochastic differential equations (phase-space approach to quantum optics).
The numerical approach will be complemented by analytical calculations to derive in a controlled way the most efficient stochastic differential equations for the dynamics. In particular, implementation of field-theoretical tools recently developed for open quantum systems will be considered.

[1] P. Forn-Díaz, L. Lamata, E. Rico, J. Kono, and E. Solano, Rev. Mod. Phys. **91**, 025005 (2019)
[2] S. Felicetti and A. Le Boité, Phys. Rev. Lett. **124**, 040404 (2020)
[3] F. Minganti, L. Garbe, A. Le Boité and S. Felicetti, Phys. Rev. A **107**, 013715 (2023)

Condensed Matter Physics: YES Soft Matter and Biological Physics: NO
Quantum Physics: YES Theoretical Physics: YES