

Internship and thesis proposal – M2 ICFP and M2 PCS

Many-body quantum dynamics in one-dimensional quantum simulators

Laboratory name: Laboratoire de Physique Théorique et Modèles Statistiques (**LPTMS**)

Internship director's name: **MAZZA Leonardo**

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Internship location: LPTMS, Université Paris-Saclay, Bat. 530 "Pascal", Orsay

Condensed Matter Physics: YES

Soft Matter and Biological Physics: NO

Quantum Physics: YES

Theoretical Physics: YES

Ph.D. thesis possibility after internship: YES

Subject of the Stage

Quantum simulators based on arrays of Rydberg atoms have recently emerged as one of the most promising and exciting platforms for the study of many-body quantum dynamics. The studies that have been performed with these setups are at the origin of the notion of quantum many-body scar, which is helping theorists to reshape the understanding of thermalization in many-body quantum systems. Whereas in general an initial state of the chain is expected to thermalize and develop, after a sufficiently long time, a behaviour that resembles that of thermal states and is related to thermodynamics, quantum many-body scars are exceptional in the sense that they do not thermalize. If a state is initialized in a scar, it retains full memory of its initial condition. Surprising long-lived coherent oscillations have been reported in experiments.

A difficulty concerning the scars appearing in the models describing one-dimensional arrays of Rydberg atoms is that they can only be investigated with numerical tools. On the other hand, a lot of models are known which instead support exactly-known quantum many-body scars. These latter models have turned out extremely helpful and taught us a lot about the physics of avoided thermalization. Yet, the precise relation which they have with Rydberg array chains is far from obvious. Should we really trust them?

The goal of this internship is to investigate whether the quantum many-body scars appearing in Rydberg chains can be interpreted as a perturbed form of some unknown exact quantum many-body scars. This internship is a training towards a more ambitious and broad collaborations between the theory group working on many-body quantum systems at LPTMS and the experimentalists working on this subject at Institut d'Optique Graduate School.

Whom are we looking for?

We look for passionate and motivated students with a strong interest in many-body quantum physics. No specific background is necessary: just curiosity and the desire of learning everything that is necessary to know. If you are looking for a Ph.D. in many-body quantum physics, this is your stage! We always support our students in the procedures that are necessary for obtaining a Ph.D. salary from a funding agency.

What will you do?

You will work in close contact with L.Mazza and his research group (notably with the Ph.D. students Alice Marché and Gianluca Morettini), study a part of the existing literature on quantum many-body scars and combine analytical and numerical techniques to study the dynamics of one-dimensional quantum systems with and without quantum many-body scars.

Are we doing this alone?

No, of course. We are currently working on this subject with our colleague M. Fagotti, permanent researcher at LPTMS, and we are developing a collaboration with the experimental research group led by A. Browaeys and T. Lahayé, working at Laboratoire Charles Fabry at Institut d'Optique (IOGS).

Some literature on the subject: [Bernien et al. Nature 551, 579 \(2017\)](#), [Turner et al. Nature Physics 14, 745 \(2018\)](#), [Gotta, Moudgalya, Mazza, Phys Rev Lett 131, 190401 \(2023\)](#), [Morettini, Capizzi, Fagotti, Mazza, arXiv:2502.10387 \(2025\)](#)

Would you like to know more? Just email: leonardo.mazza@universite-paris-saclay.fr