

INTERNSHIP PROPOSAL

Laboratory name: Laboratoire de Physique Théorique et Modèles Statistiques (LPTMS)
CNRS identification code: UMR 8626
Internship director's surname: BUCA
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Internship location: LPTMS

Thesis possibility after internship: YES
Funding: YES

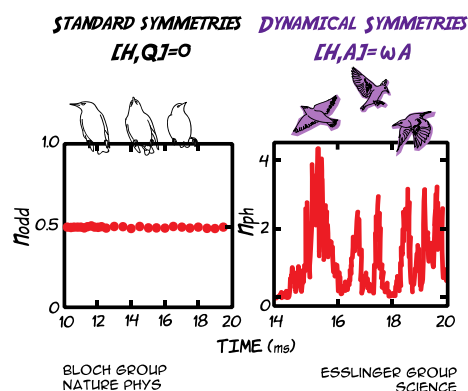
Complex quantum many-body dynamics

One of the central fundamental topics of modern science is the question of emergence of complex dynamics. Complex dynamics means that physical systems of many particles change in time in ways that are difficult to predict from the behaviour of one particle by itself. Existing theory can understand the emergence of complex dynamics from the microscopic quantum laws in only very limited cases. The focus of the project will directly tie into various ongoing research directions in non-equilibrium quantum physics including dissipative [1] and light-induced many-body engineering [2], quantum many-body non-ergodic dynamics (e.g., quantum many-body scars) [3], and quantum information processing [4]. The project is based on unconventional algebraic principles discovered by the principal investigator (PI) called “dynamical symmetries” [5,6], which have potentially broad applications ranging from operator algebras [6], through novel passive quantum error correcting algorithms in realistic quantum computing platforms to computing complex dynamics in driven quantum matter experiments. As a part of the internship the student will have the opportunity to learn and contribute to developing new theoretical approaches to solving wide ranges of quantum many-body physics relevant to condensed matter physics, quantum computing, and quantum science and technology, more broadly. More specifically, we will focus on lattice models, e.g., spin models. For example, one part of the project could be discovering new models that display complex dynamics like a 2D version of the “spin lace model” [7] with quantum many-body scars. A more mathematically oriented student will benefit from studying the stability of the resulting scarred phases using methods similar to the “scarring phase transition” stability analysis (e.g., VI A of [6]). However, these are merely examples and interested and highly motivated candidates should contact the PI to discuss the project details.

The PI is looking for candidates with an interest in fundamental theoretical quantum research and condensed matter. The ideal candidate should have an education background focusing on topics related to non-equilibrium and many-body physics, e.g., open quantum systems, advanced statistical physics, and modern condensed matter theory.

References

1. Stefanini, M., et al. *Is Lindblad for me?* arXiv:2506.22436 (2025).
2. Cavalleri, A., *Photo-induced superconductivity*. Contemporary Physics, **59**(1) (2018).
3. Turner, C.J., et al. Weak ergodicity breaking from quantum many-body scars. Nat. Phys. **14**(7) (2018).
4. Preskill, J., *Quantum computing in the NISQ era and beyond*. Quantum, **2**(79) (2018).
5. Buca, B., et al. *Non-stationary coherent quantum many-body dynamics through dissipation*. Nature communications, **10**(1) (2019).
6. Buca, B., *Unified Theory of Local Quantum Many-Body Dynamics*. Physical Review X, **13**(3) (2023).
7. Buca, B., et al. *Quantum many-body attractors*. arXiv:2008.11166 (2020).



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