



INTERNSHIP PROPOSAL

Laboratory name: Laboratoire de Physique et de Modélisation des Milieux Condensés (LPMMC)

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Internship location: LPMMC, Av. des Martyrs, 38000 Grenoble, France

Thesis possibility after internship: YES

Funding: NO (potential fundings EDPHYS Grenoble, QuantAlps, QuantEDU)

Tensor-network methods for tight-binding models on complex lattices

Tight-binding Hamiltonians are simple and versatile models of quantum matter. Beyond regular lattices, tight-binding models defined on complex geometries can show remarkably rich physical behavior. Among these, fractals and quasiperiodic lattices have historically played an important role in theoretical physics. Fractal lattices challenge the usual picture of topological phases, blurring the distinction between bulk and edge[1], while quasiperiodic models show unconventional localization with critical, multifractal eigenstates[2].

Tensor networks[3] have become a powerful tool for simulating quantum many-body systems. Ground states of gapped, local, one-dimensional Hamiltonians can be approximated quasi-exactly at a cost polynomial in the number of degrees of freedom, and hence logarithmic in the Hilbert space dimension. Their use has recently been extended to a wide range of situations, including the representation of tight-binding Hamiltonians [4]. Combined with kernel polynomial methods, this approach gives the spectral functions of non-interacting models at a cost logarithmic in system size, for systems with billions of sites. We recently extended such constructions to a broad class of lattices with hierarchical structure, including fractal and quasiperiodic lattices [5].

The goal of this internship is to extend these approaches to more complex models and to study their properties. Depending on the student's interests, we propose two directions:

- 1) Topological states on fractal lattices. The student will implement topological models in this framework, including magnetic-flux, and then study localization and bulk-edge properties on different fractal lattices.
- 2) Quasiperiodic models in one and two dimensions. Tensor models have shown promising results for large quasiperiodic systems based on Fibonacci chains. The internship will work on more complex two-dimensional substitution tilings. Beyond a direct generalization, we will also explore using categorical symmetries to represent the substitution rules.

Both directions will give the student insight into the physics of these systems and a good understanding of tensor networks and their links with finite automata, which will be useful for all their applications.

[1] Fremling, van Hooft, Smith and Fritz, [Phys. Rev. Res. 2, 013044 \(2020\)](#)

[2] Kohmoto, Sutherland and Tang, [Phys. Rev. B 35, 1020 \(1987\)](#)

[3] Schollwoeck, [Annals of Physics 326, 96 \(2011\)](#)

[4] Antão, Moustaj, Sun, and Lado, [arXiv:2607.00991](#)

[5] Brzezińska, Colbois and Herviou, [arXiv:2609.25276](#)

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

Quantum Physics: YES

Theoretical Physics: YES