INTERNSHIP PROPOSAL

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Internship location: Jussieu
Thesis possibility after internship: YES
Funding: YES If YES, which type of funding: ANR

Heisenberg spin models on lattices with defects or hyperbolic geometry

The quantum Heisenberg Hamiltonian is a faithful approximation of crystalline compounds or cold atom realizations, hosting fascinating low temperatures phases as topological spin liquids, superfluids or long range ordered phases. High temperature superconductivity is related to the understanding of such models. The general Hamiltonian writes:

$$H = \sum_{(i,j)} J_{ij} \mathbf{S}_i \cdot \mathbf{S}_j,$$

where S_i are spin S = 1/2 operators and i are lattice sites. Analytical approaches fail to solve this problem when frustration is present (competing interactions), but many numerical or semi-analytical methods have been developped. We can cite for example tensor network methods [1] or mean-field theories.

These models have mainly been considered on perfect euclidean 2d or 3d lattices. However, real compounds host defects [3], either from chemistry (substitution of a magnetic atom by a non-magnetic one for example), or structural (dislocations). Besides, hyperbolic lattices[2] are lattices on a curved space and host interesting variations of the phases living in euclidean geometry.

During the internship, we will first study the classical Heisenberg spin model on 2d hyperbolic space, using the specific translational group to generalize the concept of regular magnetic order [4], and look for new classical spin liquids. The way defects such as dislocations affect spin order will be explored. If followed by a PhD, the subject will be extended to treat defects in experimental compounds (Herbertsmithite, averievite), in collaboration with experimentalists from LPS. Various analytical and numerical methods will be used, from classical Monte Carlo simulations to tensor networks calculations.

[1] S. Yang, Z.C. Gu and X.G. Wen, Loop Optimization for Tensor Network Renormalization. Phys. Rev. Lett. 118, 110504 (2017)
[2] R. Mosseri, R. Vogeler and J. Vidal, Aharonov-Bohm cages, flat bands, and gap labeling in hyperbolic tilings Phys. Rev. B. 106, 155120 (2022)
[3] C. Letouzé, P. Viot and L. Messio, Chiral order emergence driven by quenched disorder. arXiv2503.24139 (2025)
[4] L. Messio, C. Lhuillier and G. Misguich, Lattice symmetries and regular magnetic orders in classical frustrated antiferromagnets Phys. Rev. B. 83, 184401 (2011)

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