INTERNSHIP PROPOSAL

Laboratory name: Laboratoire de Physique des Solides (LPS)
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Thesis possibility after internship: YES
Funding: NO

Crystalline defects in quantum lattice systems

Symmetry is a fundamental principle of physics: it defines phases of matter, and quite often phase transitions can be understood as the proliferation of defects that break the symmetry [1]. In contemporary condensed matter, a topological theory has been formulated that unifies symmetry, defects, and the underlying quantum phases they define [2].

Crystalline defects in lattice systems – such as dislocations and disclinations – break lattice symmetry of the system (such as translation and rotation). While their presence in classical system has been an old subject of study [3], their effect on quantum systems is much richer, yet far less explored [4].

This M2 internship project is the very first step in completing the topological data of crystalline defects in order to define crystalline quantum phases of matter. The content of this project is purely classical and does not a priori require quantum mechanics: we will start by revisiting the theory of lattice defects in classical media, and examine how the theory applies to crystalline lattice systems. The first goal in this step is to have a complete classification of the types of crystalline defects according to the crystal symmetry they break, and their visualization in various crystals. The second goal is to understand the fusion statistics of crystalline defects, namely what is the outcome of the merging/splitting of two or several defects.

This internship can be extended to a full PhD project in quantum condensed matter physics on the following aspects [5]: 1. To understand the quantum anomaly aspects of how crystalline defects affects quantum degrees of freedom (electric charge, spin, pseudospin etc.) and define phases of matter; 2. To explore the experimental consequences of crystalline defects in quantum spin systems, especially topological ordered phases and quantum spin liquids; 3. To develop algebraic topology tools for calculating the quantum anomaly associated with crystalline defects.

[1] Altland, Alexander, and Ben D. Simons. Condensed matter field theory. Cambridge university press, 2010.

[2] Barkeshli, Maissam, Parsa Bonderson, Meng Cheng, and Zhenghan Wang. "Symmetry fractionalization, defects, and gauging of topological phases." *Physical Review B* 100, no. 11 (2019): 115147.

[3] Kleman, Maurice, and Jacques Friedel. "Disclinations, dislocations, and continuous defects: A reappraisal." *Reviews of Modern Physics* 80, no. 1 (2008): 61-115.

[4] Else, Dominic V., and Ryan Thorngren. "Crystalline topological phases as defect networks." *Physical Review B* 99, no. 11 (2019): 115116.

[5] Liu, Chunxiao, and Weicheng Ye. "Crystallography, group cohomology, and Lieb–Schultz–Mattis constraints." *SciPost Physics* 18, no. 5 (2025): 161.

Condensed Matter Physics: YES	Quantum Physics: YES
Soft Matter and Biological Physics: YES	Theoretical Physics: YES