Master 2 Internship

Title: Fermi surface and emergence of a quantum order of current loops on a geometrically frustrated lattice

Type: theory

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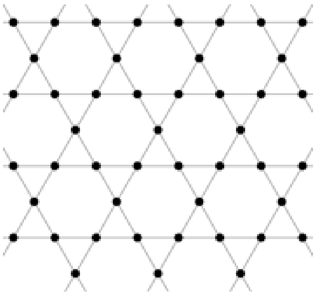
PhD funding (if any): funding application in progress

Key word : theory, quantum materials, electrons

Project:

One of the fundamental problems particularly studied in condensed matter science is the phenomenon of quantum phase transitions, in which the state of a system at zero temperature changes radically under the effect of a physical parameter [1]. The proposed internship is part of our team's international collaboration on studies of quantum phase transitions that can give rise to unusual electronic and magnetic properties in crystalline materials. In general, the Fermi surface plays a key role in explaining the metallic properties of most crystalline systems. Frustration is a phenomenon that arises when, at the microscopic scale, competing interactions clash and do not allow a trivial (generally magnetic) order to be achieved [2]. The interconnection between the roles played by the Fermi surface and those linked to frustration has made it possible to produce real crystalline materials in which a very unusual quantum order appears, characterised microscopically by current loops at the atomic scale.



During this Master 2 internship, the aim will be to study a simple effective theoretical model of the tight-binding type, with one or more electronic bands, with or without spin, on a very special periodic lattice geometry: the Kagomé lattice (see figure). This type of lattice, which is experimentally realised in compounds such as CePdAl, Fe3Sn2 or YCr6Ge6, has the particularity of being geometrically frustrated [2]: this means that constraints linked to the local geometry of the crystal can induce a degeneracy of the fundamental quantum state of the system. We can then expect non-conventional properties to result. For each case, the dispersion will be calculated analytically, and the Fermi surface will be deduced and analysed, highlighting the effect of the various parameters. We will then propose a phenomenological model to describe current loops formed by the quantum state of electrons on this crystalline lattice. This study will enable the student to familiarise himself/herself with the representations of quantum operators in second quantisation, with some general concepts of solid state physics, and finally to use the standard numerical calculation tools needed to visualise a Fermi surface.

This project could be followed up by a thesis (funding application in progress).

[1] S. Sachdev, *Quantum Phase Transitions* (Cambridge University Press, 1999).

[2] *Introduction to Frustrated Magnetism*, edited by C. Lacroix, P. Mendels, and F. Mila (Springer Series in Solid-State Sciences 164, Berlin 2011).