INSTITUT NEEL Grenoble

Quantum internship – Academic year 2025-2026

Quantum many-body states induced by kinetic frustration

Level : M1

General Scope : We usually expect that, at zero temperature, magnetic moments arrange in a perfect order forming the unique ground state of the system (up to symmetries). Yet, in classical and quantum magnetic systems, competition between irreconcilable interactions ("frustration") can give rise to vastly different scenarios. Consider a model of antiferromagnetically interacting spins on the kagome lattice (corner-sharing triangles). In the classical (Ising) limit, this model has an exponential number of ground states such that, at zero temperature, some disorder subsists in the orientation of the magnetic moments, forming a complex state, analogous to a liquid. The role of additional non-commuting terms in the Hamiltonian (introducing quantum fluctuations) is generally highly non-trivial: a priori, it favors singlets (entangled pairs of spins) on each bond. However, these singlets cannot be formed on all bond simultaneously. It was proposed by Fazekas and Anderson [1] that the loss in energy may be compensated by a gain in kinetic energy if the spin singlets are allowed to resonate over the lattice, similar to the resonant covalence bonds of aromatic molecules [2]. This *Resonating Valence Bond* state is a quantum superposition of many different singlet configurations over the lattice; but it remains elusive in experiments. A new route to the RVB state was recently proposed through *kinetic* frustration of a hole instead [3].

Research topic and facilities available :

The project will focus on the *counter*-Nagaoka effect in lattices of corner-sharing frustrated clusters. In the Nagaoka effect, ferromagnetism is induced by the hopping of a single hole in a otherwise half-filled Hubbard model with infinite on-site repulsion (« t » model): the hole can gain more kinetic energy if the background is ferromagnetic. In our case,the hole doping instead stabilizes a RVB. The project will start by recovering exact analytical results on small simplices : the triangle [4] and the tetrahedron [3]. We will then proceed on other elementary clusters, either with analytical methods or exact diagonalization. Computations can be performed on the supercomputer at Institut Néel.

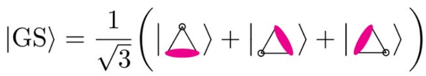

Figure 1 - Counter-Nagaoka effect on a triangle: introducing a hole creates a singlet which resonates with the hole. (reproduced from [4]).

[1] Anderson, Materials Research Bulletin 8, 153 (1973); Fazekas and Anderson, Philosophical Magazine 30, 423 (1974)
[2] Pauling, The Journal of Chemical Physics, (1933)
[3] Glittum et al, Nat. Phys. 21, 1211–1216 (2025)
[4] Kim, Phys. Rev. B 107, L140401 (2023).

Possible collaboration and networking :

The student will join the NEEL theory team with well-established expertise in the field of frustrated magnetism, and will have opportunities to meet experimentalists experts of quantum spin liquids. They will be welcome and encouraged to interact with and learn from these researchers and PhD students. There could be opportunities to interact with researchers internationally.

Required skills :

Solid background in quantum mechanics, statistical mechanics and ideally solid state physics / condensed matter theory. Curiosity towards theory and experiments, open-mindedness, enthusiasm to perform analytical or numerical computations.

Starting date and duration : Up to14 weeks from middle of May 2026 (date to be agreed upon)

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