Institut de Recherche Interdisciplinaire de Grenoble

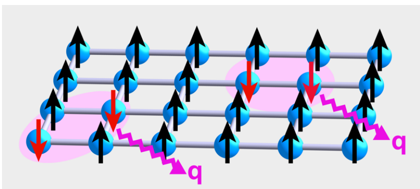
Pheliqs Quantum Physics & Engineering

Master / PhD Thesis Project

Quantum spin nematic and spin liquid states in magnets with competing exchanges

(contact Mike Zhitomirsky)

Geometrically frustrated magnets are at the forefront of fundamental research in modern magnetism. Strong quantum fluctuations in these materials can destroy conventional magnetic ordering and induce exotic quantum states: spin nematics that are only partially ordered and are similar to liquid crystals or completely disordered spin liquids, which may exhibit nontrivial topological properties. In this theoretical project we plan to investigate spin nematic states that result from condensation of bound magnon pairs. Magnon attraction can be induced by competing ferro- anf ferromagnetic interactions or by an easy-axis anisotropy. Recent experiments provide numerous examples for magnetic materials with required properties. In the beginning, we consider a Heisenberg honeycomb-lattice magnet with first-neighbor ferromagnetic J_1 and second-neighbor antiferromagnetic J_2 exchanges. In this case, spin flips (magnons) gain the interaction energy by occupying two adjacent sites. This may lead to formation of bound magnon pairs that are to some extent similar to the Cooper pairs of electrons in superconductors (see figure). The magnon pairs will undergo the Bose condensation transition resulting in the spin-nematic state. The primary task for the Master stage consists in developing an analytic theory for such a transition for non-Bravais honeycomb lattice by generalizing previous theoretical studies for Bravais lattices. Then we apply this approach to a closely related material $BaCdVO(PO4)_2$, which may exhibit a spin nematic phase in high magnetic fields. Another direction to be pursued during the PhD thesis stage is an investigation of the nature of spin liquid state, which appears for J_1 and J_2 fcc antiferromagnet. We plan to develop an approximate theory for an RVB spin liquid state formed by local spin singlets (see figure) starting with the $SU(N)$ generalization of spin operators and performing calculations in the large-N limit. The possible extensions of these studies will include classical Monte Carlo simulations of these models.



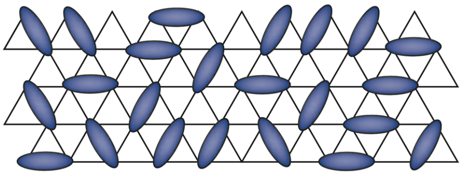


Figure: Cartoons of spin nematic (left) and an RVB spin liquid (right), each oval corresponds to a singlet spin pair.

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