Competing orders in a frustrated Heisenberg model on decorated square lattice

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We have investigated the classical ground states in two dimensional decorated square lattice (which is a square-octagonal dual lattice, structurally equivalent to CaV_4O_9 and can be realized in a two dimensional cut in a hollandite lattice) analytically, followed by a confirmation by a classical monte carlo study where we obtained the phase diagram considering three different types of Heisenberg couplings J_1, J_2 and J_3. We have obtained three different phases in the frustrated regime. First one is uncorrelated AFM chain phase with infinitely degenerate ground state where there is no long range order. In this phase we have investigated the role of thermal and quantum fluctuations in fixing the degeneracy. Without considering the role of fluctuations, noncollinear ground states can exist in this phase. But the consideration of the fluctuation terms in the free energy favours for collinear spin orientation in this phase. But still there is no long range order. However the degeneracy reduced to 2^N where N is total number of vertical and horizontal chains. The other phases are Neel phase and sublattice Neel phase where in the sublattice Neel phase, individual sublattices form the neel order. We have also studied magnon excitation in all the phases. In the Neel phase the excitation spectrum consists of two band crossings which form two non-trivial Dirac nodal loops which remain protected by symmetry. Along with these two nodal loops for every choice of J_2 there will be a value of J_3 for which we can observe an another nodal loop along the zone boundary which is not protected by any symmetry and will be gaped out for other choices of $(J_2/J_1, J_3/J_1)$. Sublattice Neel phase also consists of symmetry protected band crossing at all the high symmetry points. We have also studied the valance bond solid, Plaquette RVB phases using mean field theory. The minimization of ground state energy favours three different regions of parameter space, which we have considered, for three phases (plaquette-RVB, VBS-1 and VBS-2). The triplon excitations consist of gap through out the parameter space which has confirmed stability of these phases.

References:

[1] Atanu Maity, Yasir Iqbal, Saptarshi Mandal, PHYSICAL REVIEW B 102, 224404 (2020)