Flat Band Phase Transition in GGG

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Gadolinium garnet, $Gd_3Ga_5O_{12}$ (GGG), is a frustrated antiferromagnet with a ground state which does not show long-range order. The interaction between local ($S = 7/2$) moments on the Gd sites is thought to be well described by a nearest neighbour exchange together with the long-range dipole interaction [1].

While the nature of the low temperature zero- and low-field properties of GGG have attracted much interest, its high field properties have not been so closely studied. However this high field phase shows remarkable properties. In particular it has, as lowest lying spin wave excitations, almost dipersionless bands corresponding to excitations localized on 10 site rings (they are completely dispersionless in the limit of no dipole interaction). A magnetic field couples to these spin wave excitations via the Zeeman energy and hence acts like a chemical potential for these (weakly interacting) bosonic excitations. When this chemical potential approaches zero, the exact nature of the ground state is unclear but will be determined by the interplay between the interactions between the excitations and the small dispersion coming from the dipole interaction.

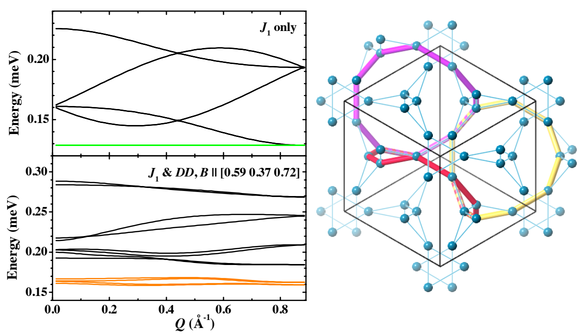

Figure 1: The spin wave dispersion for GGG in the polarised phase (B>1.5T) with only nearest neighbour exchange, J_1, (above left) and including the dipole interaction for a given field direction (below left). The low-lying flat bands are for excitations localised on 10-site Gd rings (right).

The project is to look at the transition from pure ferromagnet at fields above (B$\gtrsim$1.5T) to partly antiferromagnetic phase. The transition can only be controlled by two effects—the effect of the dipole interaction on the spin wave dispersion and the interaction between bosonic spin waves (spin flips can be represented as bosons but with a repulsive interaction). Experiments gives one clear target for theory to explain, namely the appearance of an incommensurate elastic magnetic Bragg peak. The work would start by computing the spin wave energies taking account of the long range dipole terms and the consequent non-conservation of the total spin. There are other garnets, involving for example Al instead of Ga or transition metal ions instead of Gd. A long term aim would be to make progress on the understanding of frustration in garnets and other open magnetic structures.

[1] N. d'Ambrumenil, O. A. Petrenko, H. Mutka, and P. P. Deen. *Phys. Rev. Lett.*, 114:227203, 2015.