Experimental report

06/05/2022

Proposal: 5-32-921 **Council:** 10/2020

Title: Exploring Chemical and Magnetic Disorders in the Triangular Antiferromagnet Yb(Mg/Zn)GaO4

Research area: Physics

This proposal is a new proposal

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Samples: YbMgGaO4
YbLiO2

Instrument	Requested days	Allocated days	From	To
D7	7	7	07/06/2021	14/06/2021
D2B	1	1	15/06/2021	16/06/2021

Abstract:

YbMgGaO4 and YbZnGaO4 are triangular based frustrated antiferromagnets. Structural studies show that the non-magnetic ions, Mg/Zn and Ga, are randomly distributed throughout the non-magnetic lattice, which many believe affect the nature of the magnetic ground state. In YbMgGaO4, the ground state is a controversial quantum spin liquid, whereas YbZnGaO4 is characterised as a spin glass. We now ask, how do the average and local structures of YbMgGaO4 and YbZnGaO4 really compare, and how does this affect the nature of the disordered magnetic ground state that is selected in each? To answer this, we propose a comparative study between YbMgGaO4 and YbZnGaO4, in which we seek to explore the nature of their average crystal structures (D2B) as well as the diffuse scattering arising from short-range structural and magnetic correlations (D7) in these materials. From these experiments we stand to gain a unique insight that the role of chemical disorder plays in their magnetic ground state selections.

D7 and D2B experimental summary (5-32-921)

June 2021

Aims

The original aim of this experiment was to measure the local magnetic and nuclear orderings of $YbMgGaO_4$ (MgGa) and $YbZnGaO_4$ (ZnGa). The two compounds have the same chemical structure, $R\bar{3}m$ where Yb^{3+} ions form triangular layers in the ab planes. The non-magnetic ions form double layers of trigonal bipyramids and are completely randomly distributed throughout the layers. However, even though the structures are similar, the magnetic ground states are reported to be different, MgGa takes on a spin liquid state whereas ZnGa is reported to be a spin glass. To understand these claims we wanted to measure both the local and average chemical structures to see the impact on the magnetic ground state. Since the spin glass transition in ZnGa is reported to be 0.1 K, a dilution fridge was required.

Experiment - $YbMgGaO_4$

We began the D7 experiment with the MgGa compound. In Fig. 1 we observed a broad bump in the magnetic diffuse scattering peaking at around $Q = 1.2$ Å^{-1}which remains virtually constant for the 4 lowest temperatures (50 mK to 2.25 K). At 10 K this bump begins to flatten out reflecting the transition into a paramagnetic state. We can model the diffuse feature easily with the `SPINVERT` program and the higher temperature data with an analytical approximation of an Yb^{3+} form factor. The D2B data confirmed the $R\bar{3}m$ structure at base and room temperature, and an equal distribution of Mn^{2+} and Ga^{3+} ions within the non-magnetic sub-lattice.

Unfortunately, we were unable to prepare the ZnGa analogue in sufficient purity before the experiment. A new paper on this compound, published on the archive 2 weeks before our experiment, revealed that specialist equipment were required to make the sample that we did not have access to. Given that we were unable to complete our original experimental aim, and the lack of features in the D7 data, further analysis of these data is low priority for us.

$LiYbO_2$

We substituted the ZnGa analogue for a different material, $LiYbO_2$ which is a frustrated diamond antiferromagnet. This material was previously determined to have an incommensurate helical ground state below 450 mK with propagation vector, $\mathbf{k} = (0.384 \pm 0.384, 0)$. Between 450 mK and 1.13 K there is a partially ordered magnetic phase, which is very similar to the ground state but is considered as a series of magnetic domains with random phasing of the sub-lattices. Between 1.13 K and 2 K there is a region defined by short-range correlations and after 20 K the system is paramagnetic. We became interested in this material due to the partial order and short-range correlation phase, which would be indicative that diffuse scattering will occur but no previous investigations were made into the existence of these features.

A summary of the magnetic contribution to the scattering is shown in Fig. 2. We measured at 50 mK in the ordered phase, 800 mK in the partially ordered phase and 1.5 K in the short-range correlation phase. All

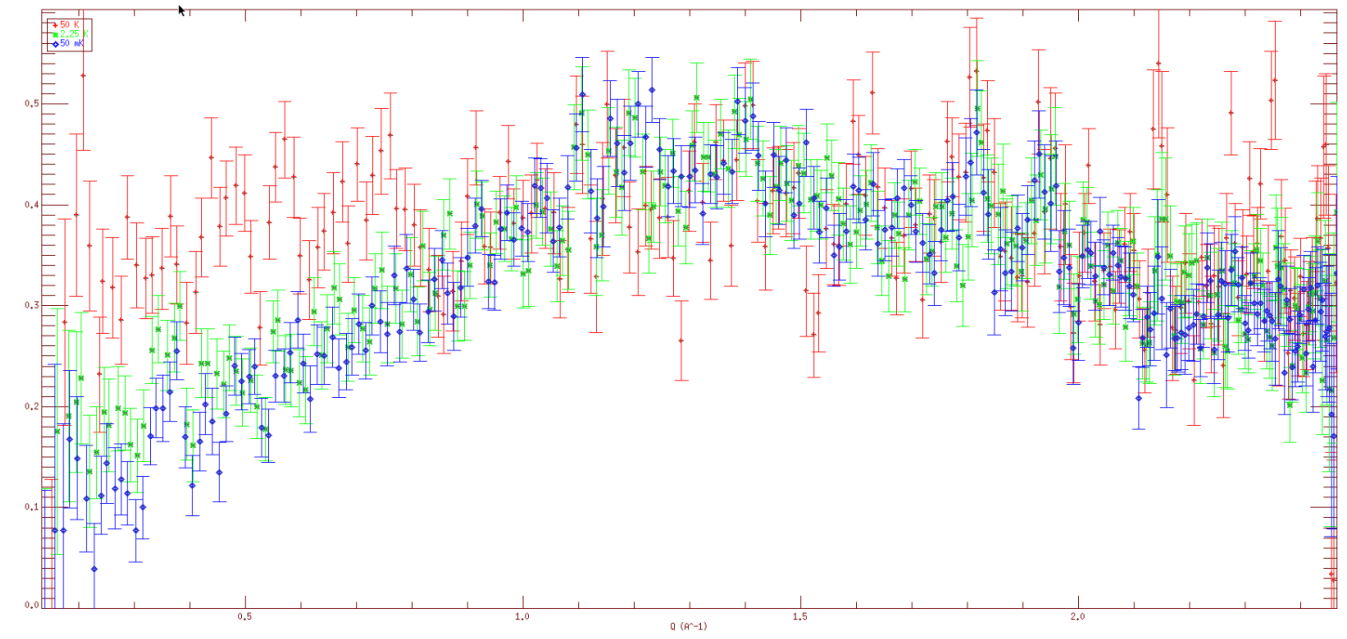

Figure 1: Magnetic component of MgGa measured at 50 mK (dark blue), 2.25 K (green) and 50 K (red). There are very subtle differences between the lowest temperatures at low Q, and a more form factor type shape at 50 K.

three of these lowest temperatures show significant diffuse scattering, and what is particularly interesting is that the size and shape of this scattering has no variation with temperature, indicating a disordered ground state. These correlations persist up to 5 K, before disappearing completely at 25 K, which is in the paramagnetic regime.

We will analyse these data using `SPINVERT`, `Fullprof` and `Mag2Pol`. The combination of short- and long-range scattering makes these data more challenging to analyse. We aim to verify the long-range magnetic states that were previously determined and discuss how the short-range correlations behave as a function of temperature.

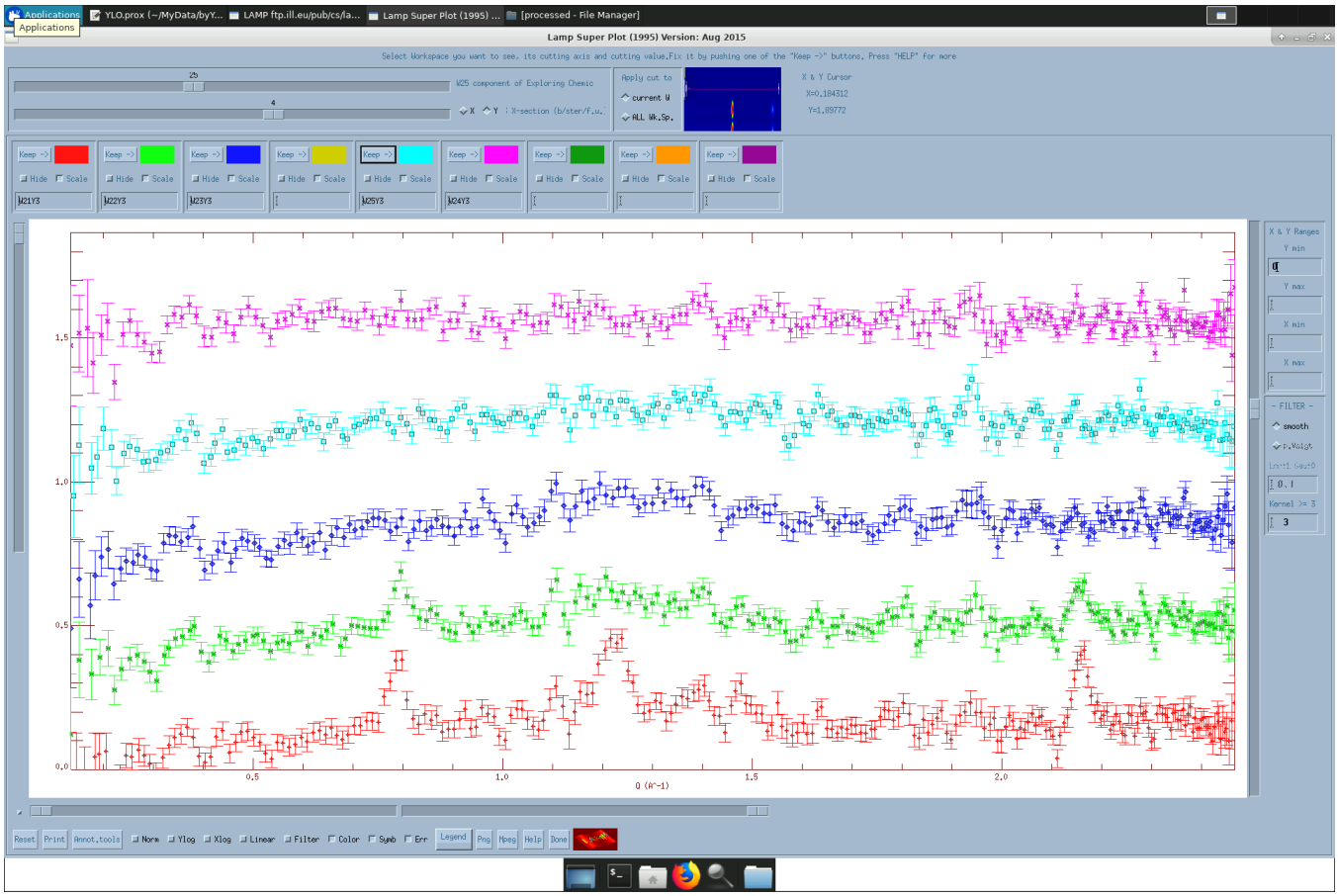

Figure 2: Magnetic component of scattering, 50 mK (red), 800 mK (green), 1.5 K (dark blue), 5 K (cyan) and 25 K (pink).