Effect of Disorder on the Magnetic Ground States of the Frustrated Spin-Dimer System $Ba_3(Mn_{1-x}V_x)_2O_8$

A.T. Hristov, M.C. Shapiro, I.R. Fisher (Stanford University, Geballe Laboratory for Advanced Materials); V. Zapf, R. McDonald (NHMFL-LANL)

Introduction

Spin-dimer compounds are a class of materials which consist of pairs of strongly interacting magnetic ions. Antiferromagnetic intradimer exchange leads to a singlet ground state with an energy gap to excited triplets, but application of a magnetic field closes the gap, tuning the system into a state characterized by long range magnetic order at low temperatures. Of particular significance to the current experiments, these materials provide a valuable opportunity to study the effects of disorder on quantum phase transitions.

In the current experiment, we investigate the spin dimer compound Ba3Mn2O8 and its site-diluted analog Ba3(Mn1-xVx)2O8. Ba3Mn2O8 is a spin dimer compound which, in addition to excited triplet states, also features excited quintuplet states (due to the pairs of Mn^{5+} S = 1 ions), leading to a succession of exotic, field-tuned magnetic phases. Initial thermodynamic measurements on the site-diluted compounds revealed a Curie-Weiss enhancement due to broken dimers and a progressive removal of magnetic entropy with decreasing temperature in zero field. There is no indication of an ordered ground state, nor of spin freezing; instead, heat capacity (down to 50 mK) and magnetization (down to 1.8 K) measurements suggested random singlet formation[1].

The goal of the current experiment was, first, to extend the magnetization measurements down to lower temperatures, with the intent of distinguishing the putative random singlet behavior from more conventional spin freezing, and second, to study the high-field regime, with the aim of addressing possible Bose-glass behavior.

Experimental

Magnetization measurements were performed using a Faraday magnetometry technique, wherein the force on a magnetic moment is linearly proportional to an applied field gradient. The force is measured by mounting the sample onto a semiconducting cantilever; lever canting changes the resistance of the base by an amount proportional to the force on the sample. The measured change in resistance is then linearly proportional to the magnetization. These measurements were performed in the 18T superconducting magnet at Los Alamos National Laboratory using a dilution refrigerator and field-gradient coils.

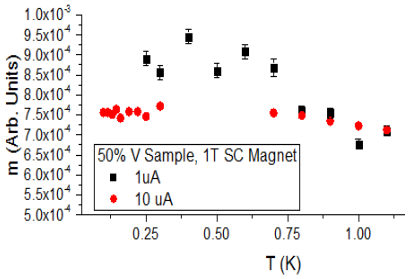

Figure 1: Magnetic moment of the sample, extracted from resistance changes in the cantilevers, measured with two excitation currents. The separation and subsequent plateau below 750mK suggests the onset of self-heating at this temperature.

Preliminary Data

Our measurement faced two major obstacles, which were ultimately surmountable using the LANL 20T magnet and DR system. First, the amplifier available to us could not source a sufficiently large current to the gradient coils to produce a measurable signal. We were therefore left to measurements with a low frequency resistance bridge, which made us susceptible to various noise sources. Consequently, we needed to drive currents larger than 1μA through the cantilevers in order to get a resolvable signal, and this produced self-heating issues (See Figure 1).

Future Directions

To avoid self-heating issues, it has become apparent that the cantilevers need to be immersed in liquid. Incorporating other additional improvements to the experiment developed as a consequence of our experience at LANL, we will perform a second generation of experiments using the DR in SCM1 at the National High Magnetic Field Lab in Tallahassee in the coming year.

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References

[1] Samulon, E.C., *et al*., Phys. Rev. B **84**, 054417 (2011).