Calorimetric Determination of Magnetic-Field-Induced Phase Transitions in $Ba_3CoSb_2O_9$

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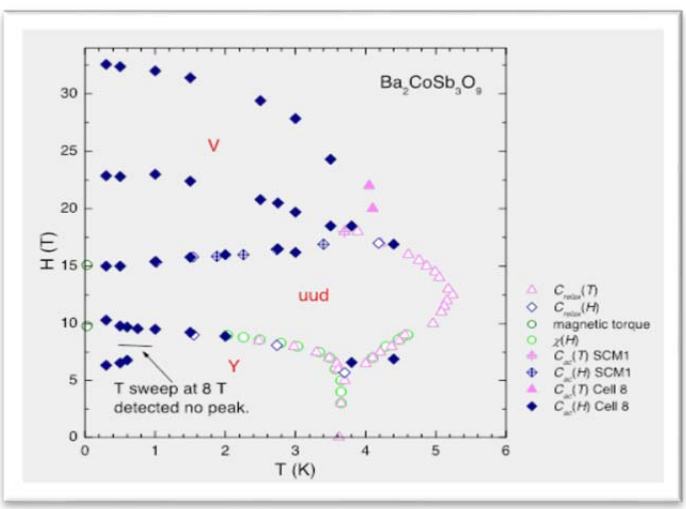
Introduction

In an S = ½ quantum Heisenberg triangular antiferromagnet, magnetic frustration among spins arranged in a triangular lattice leads to a large number of possible spin states sharing the same ground state energy. Quantum fluctuations can remove this accidental degeneracy, and for increasing magnetic fields, three main magnetic phases are expected to occur, each corresponding to a different spin arrangement: a low field 'Y' phase, an elusive intermediate 'up - up - down' phase with a magnetization equal to 1/3 of the saturation magnetization, and a high field 'V' phase [1]. Until recently, however, it has been difficult to find real triangular antiferromagnets that exhibit this expected behavior in field, primarily due to the complicating effects of anisotropic coupling within the XY plane and/or coupling of the spins to the lattice through the Dzyaloshinskii-Moriya interaction.

In earlier work at the NHMFL, we have calorimetrically observed [2] a cascade of spin-states at simple increasing fractions of the saturation magnetization — including the 1/3 up-up-down state — in Cs_2CuBr_4 , the first S = ½ triangular antiferromagnet to exhibit the 1/3 saturation magnetization state. Pulsed field magnetization measurements at 1.3 K reported this year by Suzuki *et al.* [3] reveal the observation of the 1/3 up-up-down spin state in $Ba_3CoSb_2O_9$ — a new spin 1/2 triangular antiferromagnetic material with weak XY (easy-plane) anisotropy and a zero-field ordering temperature of 3.6 K —— and a simple sequence of magnetic states consistent with that originally expected theoretically [1], with the exception of a possible additional transition at approximately 23 T.

Experimental

In work this year (as part of NHMFL proposal P02364), we have measured the heat capacity of $Ba_3CoSb_2O_9$ as a function of temperature, magnetic field, and field, for fields up to the saturation field of H_{sat} =32.5 T and temperatures down to 0.1 K. The measurements were carried out using our custom designed top-loading rotatable miniature calorimeter [4] in a series of two runs at the NHMFL DC field user facility in Tallahassee. The first of these runs made use of the dilution refrigerator/ 18 T superconducting magnet SCM1 in the mK building, while the second made use of the portable dilution refrigerator (PDF) and 35 T resistive magnet in Cell 8. Magnetic field corrections for the resistive thermometers were made as described in Ref. [5].



Results and Discussion

Our preliminary results for a field parallel to the XY plane are summarized in Fig. 1. The presence of a transition at 23 T is confirmed. We observe 5 rather than 3 distinct magnetic phase transitions with increasing field, suggesting that the 'Y' and 'V' phases split into alternating and non-alternating co-planar subphases. We are uncertain, however, precisely where or if the lowest field phase joins the uud boundary, as we were only able to calorimetrically resolve the transition at T ≤ 0.6 K. NMR confirms only one phase below the uud phase at 1.7 K [6].

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References

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