Field-Controlled Soliton-Soliton Interactions in the Frustrated Low-Dimensional Quantum Magnet $BiCu_2PO_6$

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Introduction

Quantum magnets that can be described by rather simple and well-defined effective theories, often exhibit rich (*H*, *T*) phase diagrams. Outstanding in this respect are low-dimensional networks of S = 1/2 magnetic moments, where quantum effects are particularly pronounced.

The S = 1/2 zigzag spin-ladder compound $BiCu_2PO_6$ (BCPO) exhibits a variety of field-induced magnetic phases, which strongly depend on the direction of the external magnetic field H with respect to the crystal orientation. Previous nuclear magnetic resonance (NMR) experiments revealed incommensurate magnetic order above a critical field H_{c1} ~ 21 T. The incommensurability is a consequence of frustration. Our data could be explained quantitatively by numerical simulations, which indicated that the magnetic phase above H_{c1} corresponds to a lattice arrangement of field-induced solitons [1]. Upon increasing H, the soliton density increases and theory predicts yet another instability. Indeed, recent bulk measurements revealed such a transition around 36 T [2].

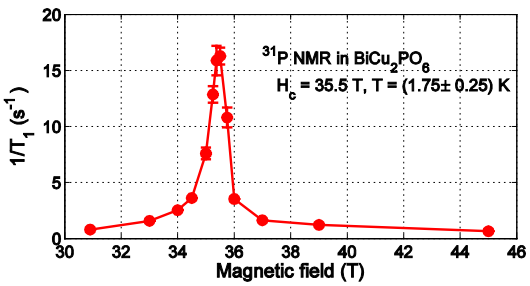

Fig. 1: NMR spin-lattice relaxation rate of ^{31}P in BCPO. The peak corresponds to the phase transition of interest.

Experimental

In order to study the microscopic aspects of the new field-induced phase in BPCO, we performed ^{31}P NMR experiments using the 45 T hybrid magnet at the NHMFL DC field facility. NMR line shapes and relaxation rates T_1^{-1} were measured as function of magnetic field. Sample alignment was found to play a key role in the interpretation of the data and further experiments are planned.

Results and Discussion

The rate $T_1^{-1}(T)$ of the central peak (Fig. 1) exhibits a peak around H_{c2} ~ 35.5 T. This and the emergence of additional peaks in the NMR spectra indicate the presence of a new phase transition, confirming that ^{31}P NMR can be used to track the evolution of the magnetic structure. The asymmetry of the lines is attributed to the aforementioned alignment problems. Based on the available data and the gained familiarity with the equipment at NHMFL, we expect that a future run should provide data of a properly aligned sample, suitable for quantitative comparisons with numerical simulations. As indicated in Fig. 2, T_1^{-1} varies significantly across the resonance signal. This observation, to be addressed in future experiments, may help to understand the magnetic features above H_{c2}.

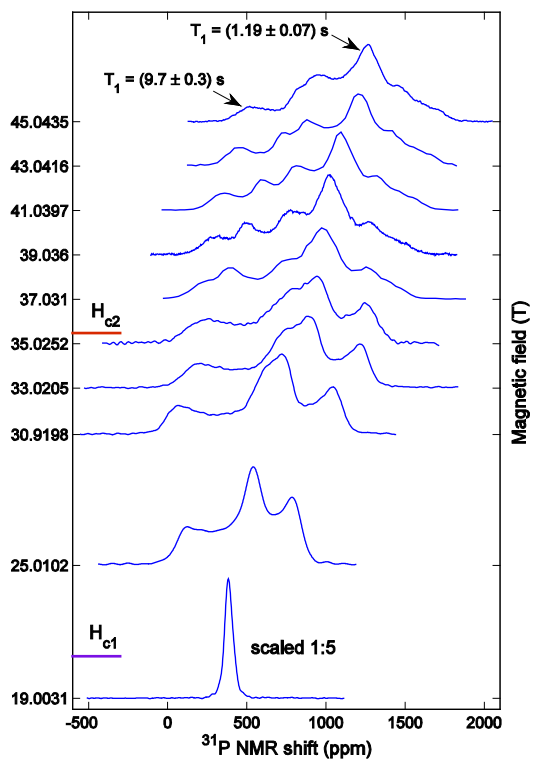

Fig. 2: ^{31}P NMR lineshapes in BCPO measured at T = 1.8 K.

Acknowledgements

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References

[1] Casola, F., et al., Phys. Rev. Lett. **110,** 187201 (2013).
[2] Kohama, Y., *et al.*, Phys. Rev. Lett., **109**, 167204 (2012).