Experimental report

09/02/2016

Proposal: 4-03-1719 **Council:** 4/2015

Title: Magnetic Excitations in spin 1/2 Ising-like antiferromagnet BaCo2V2O8under a transverse magnetic field.

Research area: Physics

This proposal is a new proposal

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Samples: BaCo2V2O8

Instrument	Requested days	Allocated days	From	To
THALES	0	7	09/11/2015	16/11/2015
IN12	7	0		

Abstract:

We plan to study the magnetic excitation of the quasi-1D Ising antiferromagnet BaCo2V2O8 under a transverse magnetic field (applied perpendicular to the moment direction) on the triple-axis IN12 spectrometer using the 12 T vertical cryomagnet. This remarkable material has already revealed transverse and longitudinal discrete modes resulting from the confinement of spinons in zero magnetic field. We have also studied their evolution under an external magnetic field applied along the moment direction allowing to access a new phase ascribable to the Tomonaga-Luttingher spin liquid physics. The present project aims at unraveling the field-induced behavior of these unconventional excitations, when submitted to an external transverse magnetic field, through the quantum phase transition towards the paramagnetic quantum phase.

Study of the magnetic excitations of $BaCo_2V_2O_8$ in a transverse magnetic field

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The nature of the excitations in spin half antiferromagnets is a topic of considerable current interest in the field of quantum magnetism. The one-dimensional case is especially interesting as quantum fluctuations melt the classical long-range Néel order. The ground state remains disordered, with a spin excitation spectrum consisting in a continuum composed of pairs of $S = 1/2$ excitations called spinons, created or destroyed in pairs, like domain walls in an Ising magnet. Physical realizations of 1D systems, however, eventually order at very low temperature, owing to a small coupling between chains. The metamorphosis of the continuum of spinons that accompany this dimensional cross-over towards a 3D state is an appealing issue.

$BaCo_2V_2O_8$ is a remarkable example of such quasi-one-dimensional Ising-like quantum antiferromagnets. In the Néel zero-field phase, inelastic neutron scattering (INS) measurements performed on IN12 at ILL (Grenoble, France) revealed two interlaced series of discretized longitudinal and transverse excitations, interpreted in terms of bound states of spinons. This original situation occurs due to the moderate Ising anisotropy and the sizable interchain interactions present in this compound [1]. The longitudinal excitations carry a total spin.

$BaCo_2V_2O_8$ has also raised recently much interest for its field-induced behavior, describable in terms of Tomonaga-Luttinger liquid physics (roughly speaking, a 1D gas of interacting spinons) when the field is applied parallel to the Ising axis (longitudinal field) and thus to the ordered moments which also corresponds to the chain direction (c-axis). Some of the authors have recently studied on TASP at PSI (Villigen, Switzerland) the spin dynamics of $BaCo_2V_2O_8$ in a longitudinal magnetic field. This investigation has shown that the longitudinal excitations do not show any field dependence and that there is a Zeeman splitting for the transverse excitations, as expected since the longitudinal excitations carry a total spin $S_z = 0$ while the transverse ones carry $S_z = \pm 1$. A publication is in progress.

The interchain interactions lead to the discretized longitudinal and transverse modes but also to frustration (see Ref. [1]) and the exchange values are still controversial. Besides, it has been shown by macroscopic measurements that in a transverse magnetic field (i.e., perpendicular to the ordered moments), $BaCo_2V_2O_8$ exhibits two phases: a Néel phase up to $H_c = 10$ T and a phase above H_c which should be a spin-liquid phase [2]. Following these two observations, we have investigated the spin dynamics of $BaCo_2V_2O_8$ with a transverse magnetic field in order to get a better understanding of the interchain interactions and also to explore the spin dynamics in the new phase above $H_c = 10$ T.

Firstly we have explored the magnetic-field dependence of the excitations for three different scattering vectors $\boldsymbol{Q}$ corresponding to a minimum of the dispersion curve (see one of those on Fig. 1). We noticed that for the three scattering vectors, what should be a longitudinal mode shows a magnetic field dependence under a transverse field in opposition with the flat dependence seen in a longitudinal field. In addition, the longitudinal mode (excitations parallel to c) starts, unexpectedly, to be visible as soon as from $H \sim 1$ T at $\boldsymbol{Q} = (0, 0, 2)$ (see Fig. 1). These results suggest that the transverse magnetic field tends to hybridize the longitudinal excitations with the transverse ones. Moreover we can also observe a splitting of the two transverse modes by increasing the field but not due to a Zeeman effect and thus non linear in H (because the field is applied perpendicularly to the ordered moments). They show instead a curvature which is not fully understood yet.

Then, we have studied the interchain dispersion (along $a^\star$) both in the Néel phase up to H_c and the phase above in order to get a better understanding of the sizable interchain interactions. The field dependence of the interchain dispersion evidences a sizable increase of the interchain interactions. Finally we have looked at the intrachain dispersion (along $c^\star$) in the phase above H_c, at $H = 12$ T, to compare with the one determined in zero-field. Well defined excitations were observed but their overall dispersion is quite different from that at $H = 0$ and remains to be understood. The analysis of the data is still in progress at the moment.

References

[1] S. Niesen *et al.*, Phys. Rev. B **87**, 224413 (2013).
[2] B. Grenier *et al.*, Phys. Rev. Lett. **114**, 017201 (2015) & Phys. Rev. Lett. **115**, 119902 (2015).

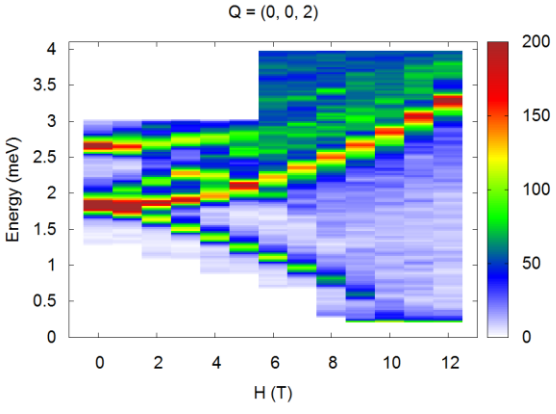

Fig. 1: Field dependence of the magnetic excitations measured at $\boldsymbol{Q} = (0,0,2)$ in a transverse field for $T = 1.8$ K.