Experimental report

18/02/2019

Proposal: **4-05-703** **Council:** 4/2018

Title: Changes to the Higgs mode in the quasi 1-D antiferromagnet SrCo2V2O8

Research area: Physics

This proposal is a new proposal

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Samples: SrCo2V2O8

Instrument	Requested days	Allocated days	From	To
THALES	6	4	17/10/2018	24/10/2018

Abstract:

SrCo2V2O8 is an example of a 1-D XXZ Heisenberg antiferromagnet; this maps to the Tomonaga-Luttinger liquid state when paramagnetic. At low temperatures, antiferromagnetic order develops. On applying a field, this can be driven into a longitudinal spin density wave state. At temperatures below 250 mK, on either side of this transition, there is a drop in magnetic Bragg peak intensity that is not due to a spin reorientation or change in domains. We suspec that this is driven by a change in the longitudinal (Higgs) excitation, and request time to measure this excitation in this region.

$SrCo_2V_2O_8$ is an antiferromagnetic (AFM) quasi-one-dimensional Heisenberg-Ising quantum magnet. Upon cooling, it develops Néel order at $T_N = 5.0$ K. At very low temperatures ($T < 1.5$ K), a novel magnetic field induced Néel to spin density wave (SDW) order transition occurs around 3.9 T (B_{c1}), followed by another SDW to emergent AFM order transition around 7.0 T (B_{c2}) [1].

This experiment aimed to hunt for the quasiparticle signature of an unknown `hidden state', which occurs between 2.0 T and 2.5 T. Our earlier (unpublished) elastic neutron diffraction work indicated suppression of the longitudinally ordered magnetic moment in this state. In the experiment, we resolved the shortening of the transverse & longitudinal spinon-pair excitation lifetimes at 2.0 T, as well as the emergence of psinon-antipsinon excitations at 2.5 T, identified by cross-referencing with the work of Wang *et al.* [2]. These observations may account for the `hidden state'. As a result, <u>we have accomplished our goal</u>, although many questions remain to be addressed.

In addition, we found a nonnegligible in-plane moment of the SDW order, and saw that the transverse confined spinon-pair excitations are locked by the psinon-antipsinon pairs at B_{c1}. These new insights indicate the potentially dominant role of the psinon-antipsinon pairs in the formation of the high field phases in $SrCo_2V_2O_8$, rather than the previously believed Tomonaga-Luttinger liquid. We call for further investigations on the psinon-antipsinon excitations in both SDW and emergent AFM states to clarify this issue. Some of our preliminary results are summarized below.

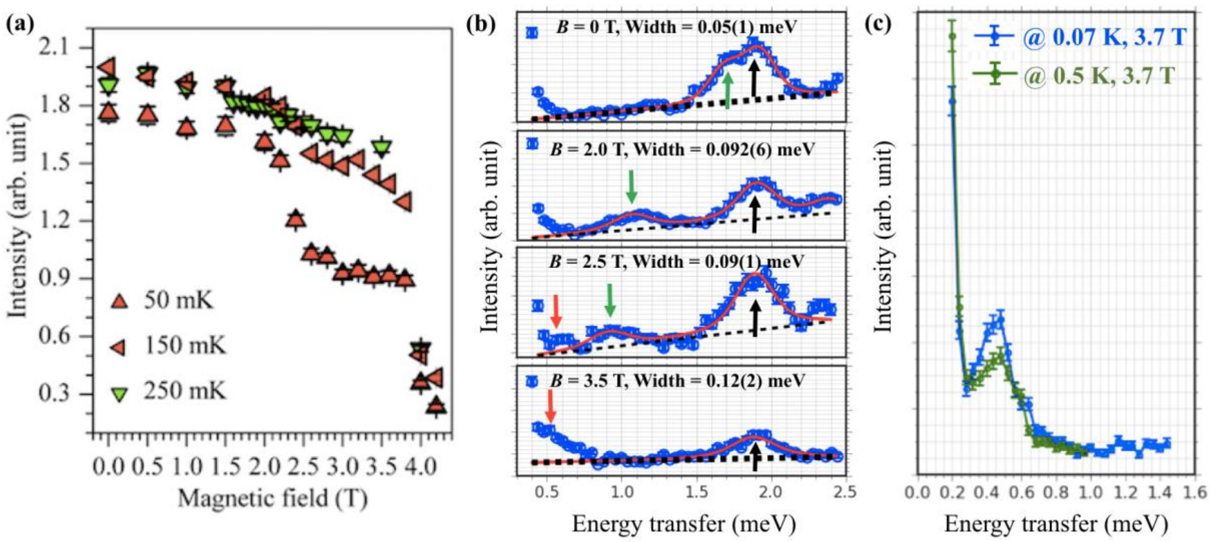

Figure 1: (a) Magnetic field dependences of the AFM reflection (2, 3, 0), measured by elastic neutron diffraction, at different temperatures. In addition to the sharp drop at B_{c1}, which corresponds to the Néel-SDW transition seen in our previous study, another intensity drop is seen between 2.0 T and 2.5 T; we labelled it as a 'hidden' state in our proposal. (b) Inelastic neutron scattering spectra collected on ThALES at 0.05 K (low resolution setup). The confined spinon pair modes are labelled by black and green arrows, as per Ref. [3]. (c) Temperature dependence of the proposed psinon-antipsinon excitations.

In **Fig. 1b**, we see that the transverse branch of the spinon pair excitations Zeeman splits in a magnetic field. The finite linewidth of these modes suddenly broadens at 2.0 T. At 2.5 T, a new mode appears around 0.5 meV. This mode connects linearly with the field dependence observed in the psinon-antipsinon pair excitations from Ref. [2], although they do not report the existence of these excitations in the Neel state, possibly due to the higher measurement temperature. The emergence of the new mode and shorting of the spinon pair life time between 2.0 T and 2.5 T is consistent with the 'hidden' state revealed in by elastic neutron scattering.

In **Fig. 1c**, the temperature dependence of the proposed psinon-antipsinon excitations, indicates that there is still some spectral weight remaining at 0.5 K, although elastic neutron diffraction sees no transition. This means that the psinon-antipsinon pair only affects the static magnetic structure at very low temperatures. Second, ~ 30 % of the spectral weight is lost at 0.5 K. This suggests that this signal is expected to disappear well below T_N = 5.0 K. Based on our observations shown in **Fig. 2a,b**, we propose that the psinon-antipsinon pair only exists at the temperatures where the SDW can be induced.

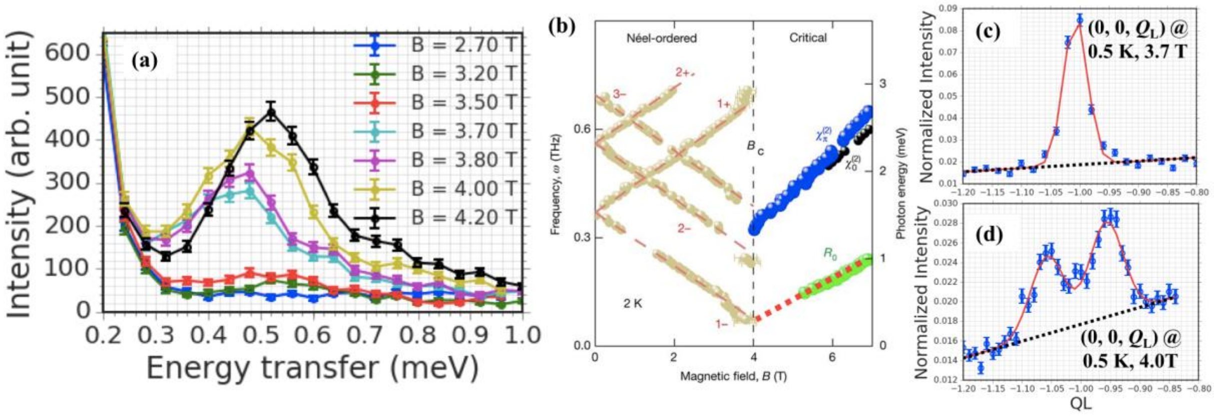

Figure 2: (a) Low-energy magnetic excitation spectra at (2,3,0) collected at 0.05 K (high resolution setup). The psinon-antipsinon energy increases above B_{c1}= 3.9 T, while it stays around 0.45 meV below. This terminating value is also exactly where the transverse spinon pair mode terminates at B_{c1}. This can be seen in panel (b), the Terahertz spectrum collected at 2.0 K in Ref. [2]. The yellow solid points are the transverse spinon pair excitations. The green solid points are the psinon-antipsinon excitations. The red dotted line is a manual extrapolation of the psinon-antipsinon mode down to B_{c1}. We propose that the field-induced SDW is related to the interactions between psinon-antipsinon and spinon pairs. Panels (c) and (d) are the Q_L scans around the (0, 0, 1) elastic peak. The non-vanishing intensities prove that both the Néel and SDW order are not longitudinal in nature.

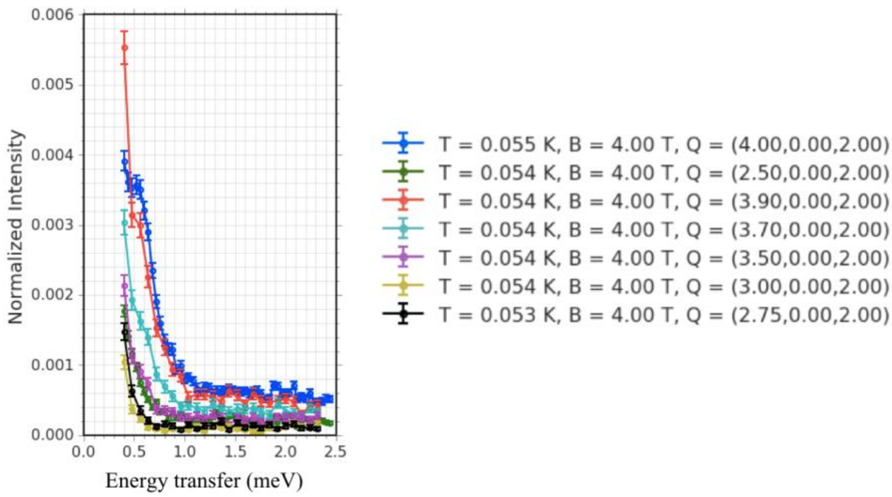

Figure 3: The reciprocal space dependence of the proposed psinon-antipsinon pair excitations.

[1] L. Shen *et al.*, arXiv:cond-mat/1801.10237.
[2] Z. Wang *et al.*, Nature **554**, 219 (2018).
[3] A. K. Bera *et al.*, Physical Review B **96**, 054423 (2017).