Experimental Report

02/03/2015

Proposal: **4-01-1401** **Council:** 4/2014

Title: Search for spinons in a spin-1 quantum spin liquid

This proposal is a new proposal

Research Area: Physics

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Samples: Ba2.5Sr0.5NiSb2O9

Instrument	Req. Days	All. Days	From	To
IN5	3	3	02/09/2014	05/09/2014

Abstract:

We propose to study the low-energy magnetic excitations of the 6H-B phase of Ba2.5Sr0.5NiSb2O9, a layered triangular spin-1 insulator with a putative spin-liquid state thought to arise from spinons forming a Fermi surface resulting in a linear low-temperature specific heat. The aim is to determine whether the system has a spin-liquid response or not, whether the excitations are gapped or not, and to determine the intrinsic energy scales as well as the exchange interactions (if possible).

Such measurements will provide necessary information on a microscopic level to help distinguish between the large variety of theoretical models that has been advanced within only the last two years to explain the exotic properties of this intriguing system.

Search for spinons in a spin-1 quantum spin liquid

The quantum spin liquid (QSL) is an exotic state of matter that has attracted much attention from condensed matter physicists during the last past years [1]. There are (at least) two open questions that are currently under strong debate. One is whether QSLs are intrinsically gapped (as in dimerized spin systems and spin ladders [2]) or can be gapless (as in the $S = 1/2$ kagomé systems Herbertsmithite [3] and Kapellasite [4]). A second question is whether QSLs could exist for spin values higher than 1/2.

The newly discovered 6-HB phase of $Ba_3NiSb_2O_9$ is of particular interest in both these contexts ($S = 1$) [5]. $Ba_3NiSb_2O_9$ is usually obtained by high-pressure synthesis, which makes it difficult to obtain a sufficient amount of sample for inelastic neutron scattering experiments. We use a different synthesis procedure, by replacing the high pressure by chemical pressure, allowing to make large amounts of $Ba_{2.5}Sr_{0.5}NiSb_2O_9$.

The aim of the experiment was to study the low temperature spin dynamics of a powder sample of $Ba_{2.5}Sr_{0.5}NiSb_2O_9$, in order to determine the energy scale of the magnetic excitations, the presence or not of a gap and, if possible, allow the determination of the magnetic interactions.

Six grams of $Ba_{2.5}Sr_{0.5}NiSb_2O_9$ was put in an annular geometry sample holder made of copper. In order to reach very low temperatures, a dilution insert was used. Measurements were performed on IN5 using four different incident energies in order to cover a sufficient range of the wave vector (Q) – Energy (ω) space and get sufficient energy resolution to determine if the system is gapped.

Most of the first day of the experiment and part of the second day were lost due to cryogenic problems. After having condensed the ^{3}He-^{4}He mixture, the temperature was stuck at 1 K due to a leak on the sample capillary. The dilution insert was thus taken out and opened, the sample capillary was resoldered, and the whole was cooled down again. Low temperatures were reached shortly before midnight. However, the data taken overnight showed a clear roton (and even maxon!) excitation from superfluid ^{4}He (see Fig. 1), due to insufficient pumping of the helium exchange gas. The following day, the mixture was therefore taken out, the inner vacuum can pumped for 2 hours at T=15 K, after which the mixture was condensed again. Stable low temperatures were reached in the late afternoon.

While data taken at small incoming energies, below the aluminium Bragg cut-off, are of good quality, data taken at higher energies are affected by strong spurious scattering from the sample environment. This is illustrated in Fig. 2, which shows spurious features at Q=0.8 Å^{-1} and Q=2.8 Å^{-1}, both near and well beyond the elastic peak.

Despite these problems, successful measurements of $S(Q, \omega)$ were performed for various incoming energies and temperatures. The data, which are of very high quality and show unambiguous spin liquid scattering, are currently being analysed.

In order to verify if the chemical-pressure leads to the same physical properties of the system, we measured the 6-HB phase of $Ba_3NiSb_2O_9$ obtained by high-pressure synthesis. For this, we used a small amount of sample available (~0.7g) and measured $S(Q, \omega)$ at two different incoming energies. Because of the small sample mass, these measurements do not allow an accurate analysis and determination of the physics involved in the system, but confirmed that chemical pressure leads to the same physical properties as high-pressure synthesis.

References

[1] L. Balents Nature 464 (2010) 199.

[2] See, e.g., Ch. Rüegg *et al.*, Phys. Rev. Lett. 95 (2005) 267201 *ibid.* 101 (2008) 247202, and T. Hong *et al.*, Phys. Rev. Lett. 105 (2005) 137207.

[3] T. H. Han *et al.*, Nature, 492 (2012) 406.
[4] B. Fåk *et al.*, Phys. Rev. Lett. , 109 (2012) 037208.
[5] J. G. Cheng *et al.*, Phys. Rev. Lett. , 107 (2011) 197204.

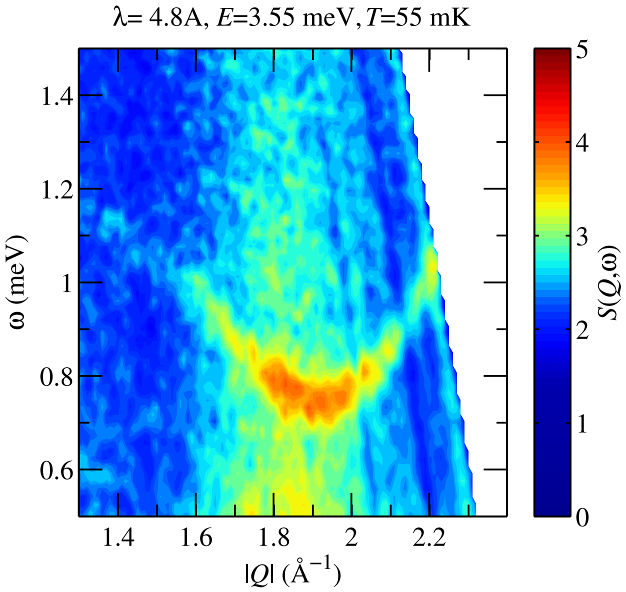

Figure 1 – Focus on Dynamical structure factor $S(Q,\omega)$ measured at $T = 55$ mK with an incoming energy $E_i = 3.55$ meV. The intense excitation spoiling our measurements is attributed to the roton excitation from superfluid ^{4}He, due to insufficient pumping of the helium exchange gas.

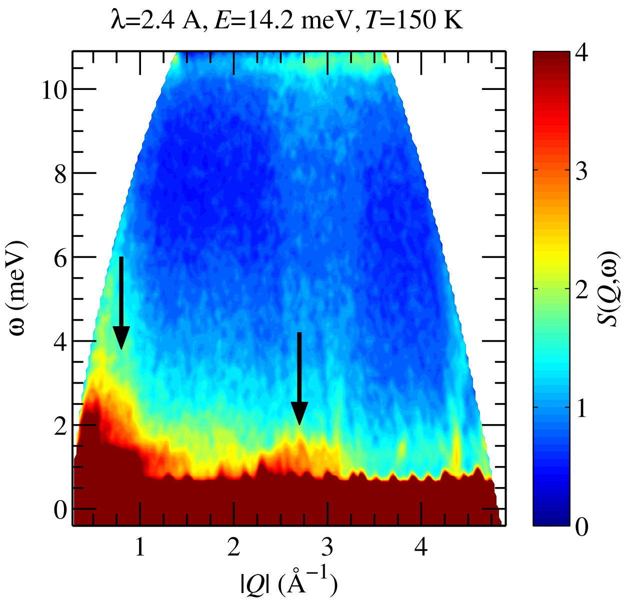

Figure 2 – Dynamical structure factor $S(Q,\omega)$ measured at $T = 150$ K with an incoming energy $E_i = 14.2$ meV. The two black arrows indicate the presence of spurious features at Q=0.8 Å^{-1} and Q=2.8 Å^{-1}.