Experimental report

05/08/2024

Proposal:	**4-05-864**	**Council:**	4/2023
Title:	Quantum dynamics in Pr_2ScNbO_7		
Research area:	Physics		

This proposal is a new proposal

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Samples: Pr_2ScNbO_7

Instrument	Requested days	Allocated days	From	To
ORIENTEXPRESS	1	1	05/09/2023	06/09/2023
IN5	5	4	06/09/2023	11/09/2023

Abstract:

Pr_2ScNbO_7 is a model system in which to study the effects of strain on quantum fluctuations. The variation in charge and ionic radius on the pyrochlore B-site leads to structural distortions that result in quantum spin chains on the Pr sublattice. Our measurements on a powdered sample of Pr_2ScNbO_7 on LET have identified an energy window below 1meV to study the continuum of magnetic excitations from these disordered chains. We now propose to measure the low-energy magnetic excitations from a large single crystal of Pr_2ScNbO_7 on IN5 at dilution temperatures. These wavevector- and energy-resolved measurements will allow us to measure the energy-integrated response S(Q) while eliminating the crystal electric field lines, to determine the spin correlations. The magnetic excitation spectrum S(Q,¿) will be compared with our density-matrix renormalization group calculations.

Experimental procedure

The single crystal of Pr_2ScNbO_7 was aligned with the [1-10] direction vertical on OrientExpress and mounted on an oxygen-free copper holder in a dilution refrigerator on the IN5 spectrometer. Measurements were performed at a base temperature of 50mK, and the background was measured at a temperature of 5K. An incident energy E_i = 3.55meV was chosen since it is below the Bragg cut-off for metals in the beam, it gives a resolution in energy transfer of 0.04meV, and adequate coverage in wave-vector transfer $\boldsymbol{Q}$. The rotation method was employed with a step size of 2° over a range of 120° in order to study $S(\boldsymbol{Q},\omega)$ throughout the (*hhl*) plane.

Results

0D cut

Figure 1(a) presents data acquired at 50mK and 5K, at fixed $\boldsymbol{Q}$ = (002) and (110) as a function of energy transfer. There is excess intensity at low energy transfers at 50mK due to the development of magnetic excitations at low temperature. Figure 1(b) shows the difference between the measurements at 50mK and 5K from the corresponding data sets. The difference data is qualitatively similar to previous measurements on $Pr_2Zr_2O_7$ [1], suggesting there could also be quantum fluctuations in Pr_2ScNbO_7.

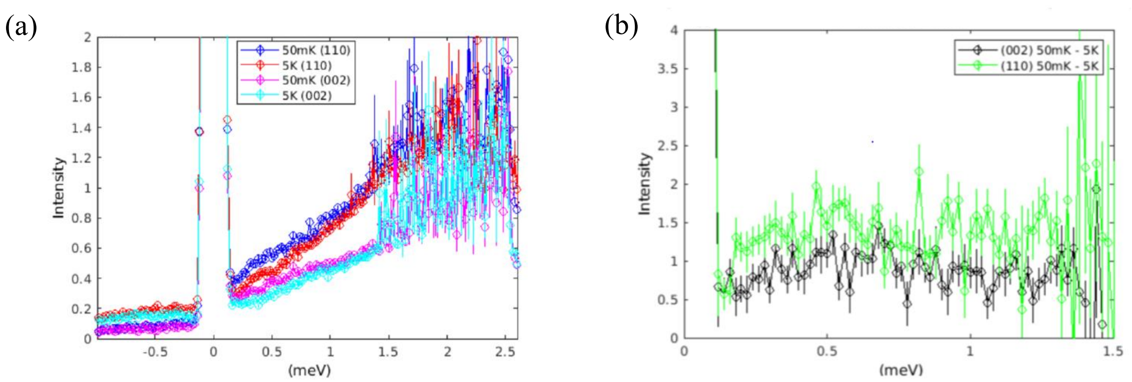

Fig. 1. Cuts showing scans of energy transfer at fixed $\boldsymbol{Q}$ *= (002) and (110) measured at 50mK and 5K. (a) Individual energy scans, and (b) the difference between the scans at 50mK and 5.*

1D cut

Figure 2(a) shows the energy dispersion along the [100] direction measured at 50mK. The dominant feature is the crystal electric field excitation at an energy transfer of ~ 2meV. This feature is not present for $Pr_2Zr_2O_7$, and it makes it challenging to measure the low energy magnetic excitations. Figure 2(b) shows the result of subtracting the corresponding scan measured at 5K. The magnetic scattering comprises an essentially featureless band of scattering up to ~1.3meV.

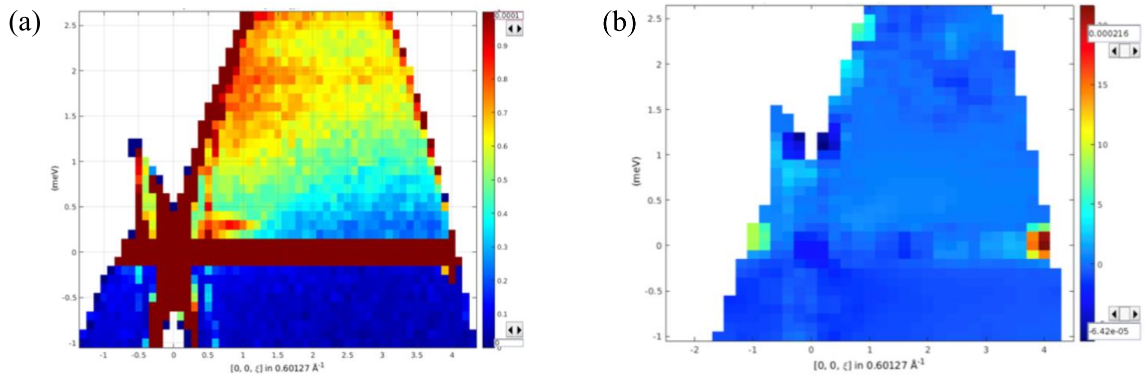

Fig. 2. Cut showing energy dispersion along the [001] direction. (a) The measurement at 50mK, and (b) the difference between the measurements at 50mK and 5K.

2D cut

Figure 3(a) presents $S(\boldsymbol{Q})$ in the (*hhl*) plane, integrated over the range of energy transfer 0.2 - 1.3meV. The scattering is essentially featureless. The weak variation follows that observed for the crystal electric field excitation, which in-turn arises from absorption corrections. Figure 3(b) shows corresponding data for $Pr_2Zr_2O_7$ [1] measured at 100mK and at an energy transfer of 0.25meV, where a characteristic starfish pattern is observed.

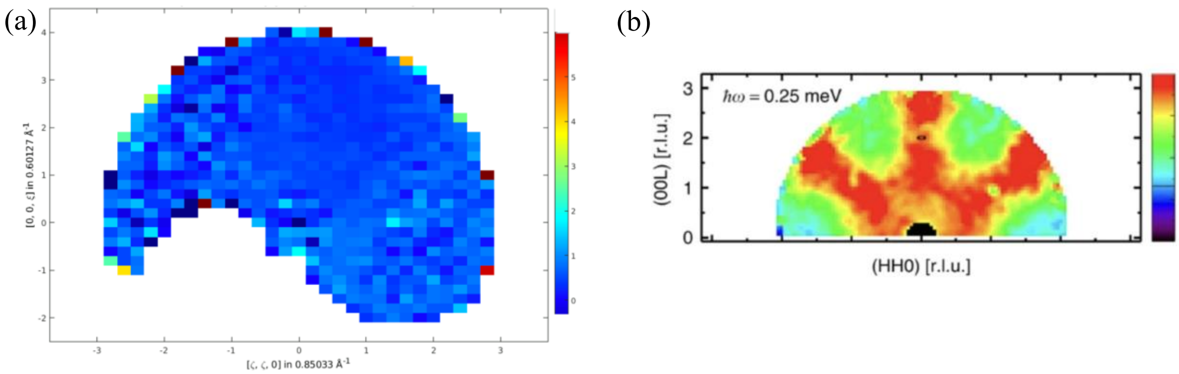

Fig. 3. Map of $S(\boldsymbol{Q})$ in the (hhl) plane for magnetic excitations from the difference between the low and high temperature data (a) for Pr_2ScNbO_7 integrated over energy transfers 0.2 – 1.3meV at 50mK, and (b) for $Pr_2Zr_2O_7$ at 0.25meV at 100mK [1].

Conclusion

The strain distribution in Pr_2ScNbO_7 completely washes out the quantum spin ice correlations.

References

[1] K. Kimura *et al*. *Nat. Commun*. **4**, 1934 (2013).