Experimental report

05/09/2022

Proposal: 4-01-1607 **Council:** 10/2018

Title: The nature of the anisotropy in MnPS3

Research area: Physics

This proposal is a new proposal

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Samples: MnPS3

Instrument	Requested days	Allocated days	From	To
IN8	3	4	28/06/2019	03/07/2019
IN3	4	4	14/06/2019	18/06/2019

Abstract:

MnPS3 is a quasi-2D collinear antiferromagnet a small magnetic anisotropy. A recent article has suggested that, if the anisotropy contained a Dzyaloshinsky-Moriya component, the k and -k magnons would have different dispersions. This would give the compound a spin-Nernst effect, making it of great interest to the graphene community. We have previously measured the spin waves of MnPS3 on IN3 and seen no such effect, but were limited by small signal and poor resolution. We now propose to perform more precise measurements on IN8 with better resolution to search for any possible differences in the magnons at the corners of the Brillouin zone.

Report for experiment 4-01-1607: The nature of the anisotropy in $MnPS_3$

Experimental team: Andrew Wildes and Ketan Anand

1. *Alignment verification performed on IN3, 13 June 2019*

The IN8 experiment required a measurement of the spin waves along the Brillouin boundary in an *hk*0 plane, following the trajectory shown by the red dashed line in Figure 1. The simplest arrangement would be to align a single crystal of $MnPS_3$ with the *h*0*l* plane as the scattering plane. IN3 was therefore used to verify and prealign the sample.

The sample was the well-characterised and studied single crystal of $MnPS_3$ that had already been the subject of a number of published articles [1 - 4]. This sample is mounted on a pin and aligned with the 0*kl* as the scattering plane. Together with the pin, the total sample length is too great to be able to mount it in the *h*0*l* plane without removing the crystal from the pin and regluing. This operation is to be avoided as sample is very fragile, being a van der Waals compound, and thus at high risk of damage.

Fortunately, the operation was unnecessary. The magnetic Mn^{2+} ions in $MnPS_3$ form an almost perfect honeycomb lattice and the compound orders with a **k** = 0 antiferromagnetic structure below its Néel temperature of 78 K. Figure 1 shows that the Brillouin zones in the *hk*0 plane have 6-fold symmetry. An analogous Brillouin zone boundary to the red dashed line would involve a 30° rotation about the **c*** axis, and the sample-and-pin length was sufficiently short that an adapter could be made that was compatible with a 70 mm bore cryostat.

The sample was attached to this adapter and its alignment was verified, with the 002 and 200 peaks being identified.

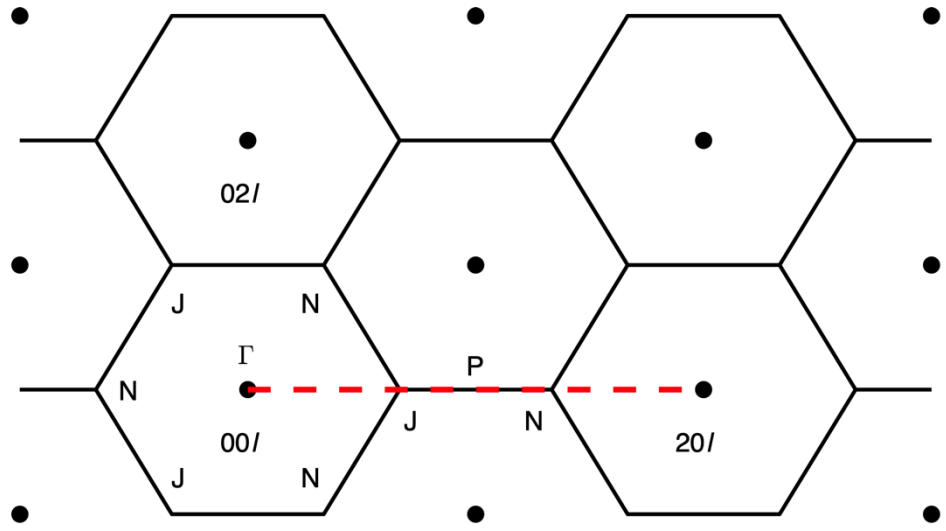

Figure 1: Schematic of the magnetic Brillouin zones for $MnPS_3$ in the *hk*0 plane, showing high-symmetry points. The important scan trajectory for the IN8 experiment is shown as a red dashed line.

2. *IN8 experiment, 28 June – 2 July 2019*

The instrument was configured with the PG002 monochromator and analyser. Collimators with 40′ divergence were used in positions $\alpha_{1..4}$. The sample was aligned and cooled to 1.5 K.

Theory predicts that, in the presence of a Dzyaloshinskii-Moriya interaction, the spin waves at the J and N points in Figure 1 would have significantly different energies. The primary objective of the experiment was to determine the extent of any energy difference. Measurements were therefore made at ±4/3 0 0, corresponding to J and N points at equivalent |**Q**| such that the instrument resolution for the two measurements would be identical. Further measurements were made at ±1 0 0, corresponding to a P point in Figure 1 where theory predicts no difference between the spin waves. The results are shown in Figure 2. There is no significant difference in the spin wave energies between ±**Q** within experimental error. Similar measurements at *l* = ±1 gave the same result.

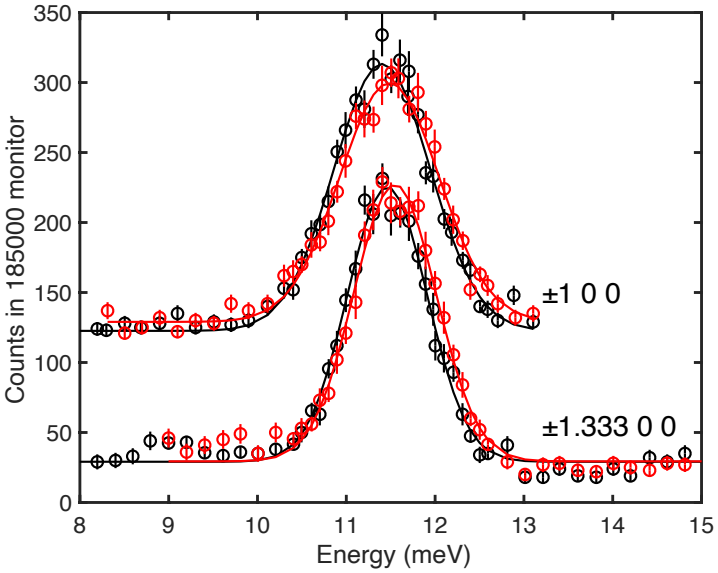

Figure 2: IN8 measurements of the spin waves at J (4/3 0 0) and N (–4/3 0 0) points, and at P points (±1 0 0), for $MnPS_3$.

Subsequent measurements of the spin waves were performed along the *h*01 for $0.5 \leq h \leq 1.5$. The data did not show any significant dispersion along the trajectory. The experiment therefore showed that there is no substantial Dzyaloshinskii-Moriya anisotropy in $MnPS_3$.

Quantitative analysis was possible after experimentally calibrating the instrument resolution by measuring the energy width of the incoherent scattering from $MnPS_3$, and by mapping the reciprocal space around the 200 Bragg peak from the sample.

The data have been published in [5].

References:

[1] A. R. Wildes *et al.*, JPCM **10** (1998) 6417
[2] A. R. Wildes *et al.*, PRB **74** (2006) 094422
[3] E. Ressouche *et al.*, PRB **82** (2010) 100408(R)
[4] T. J. Hicks *et al.*, JMMM **474** (2019) 512
[5] A. R. Wildes *et al.*, PRB **103** (2021) 024424