Experimental Report

05/03/2015

Proposal: **4-01-1366** **Council:** 4/2014

Title: Magnetic excitations in the anisotropic Dirac materials AMnBi2 (A = Ca, Sr)

This proposal is a new proposal

Researh Area: Physics

Main proposer: **PRINCEP Andrew**

Experimental Team: PRINCEP Andrew
RAHN Marein
BOOTHROYD Andrew Timothy

Local Contact: PIOVANO Andrea

Samples: CaMnBi2
SrMnBi2

Instrument	Req. Days	All. Days	From	To
IN8 Flatcone	10	7	29/09/2014	06/10/2014

Abstract:

The electronic dispersion of "Dirac" materials such as graphene and topological insulators is linear, resulting in a variety of peculiar electronic properties. In graphene and known topological insulators this linear dispersion is usually isotropic. Recently the materials SrMnBi2 and CaMnBi2 have been determined to host highly anisotropic 2D Dirac fermions in a square conducting layer of Bi. In addition, the structure contains a separate strongly correlated subsystem in MnBi layers, with our previous neutron diffraction measurements demonstrating a checkerboard antiferromagnetic arrangement in the ab-plane with either a ferromagnetic (Ca) or atiferromagnetic (Sr) coupling along the c-axis. We propose to determine the nature and strength of the magnetic couplings in these materials, specifically the interlayer coupling which is expected to be different in the two systems, and to search for evidence of hybridisation between localised Mn spin-wave modes and Dirac fermions on the Bi layers.

Experimental report 4-01-1366 (instrument IN8)

Magnetic excitations in the anisotropic Dirac materials AMnBi2 (A=Ca, Sr)

Scientific Background

$SrMnBi_2$ and $CaMnBi_2$ are Dirac materials exhibiting magnetic order below 300 K. The understanding of this unusual ground state calls for a thorough characterisation of its electronic and magnetic properties. In our previous elastic study [1], we determined the magnetic order in the two materials and found interesting differences in the magnetic exchange interactions. Our experiment 4-01-1366 complements the elastic data with a full mapping of the magnetic dynamics of both materials.

Aim of the experiment

It was the aim of this experiment to extract quantitative information about the magnetic dispersion in the two Dirac materials $SrMnBi_2$ and $CaMnBi_2$.

Technical

We used the FLATCONE detector on instrument IN8 to efficiently cover large areas of reciprocal space. With the assistance of instrument IN3, we were able to align and mount our samples with great precision, which added to the efficiency of the experiment. Our study comprised four sessions, in which we investigated the magnon dispersion of our two samples in the two relevant crystallographic orientations (i.e., scatteting in the a-c and a-b planes). In each of these four sessions, we were able to obtain reciprocal space maps from 0 to ~60 meV energy transfer, in steps ≤ 2 meV. This fully covered the magnetic spectrum, with a particular attention to resolve the critical parts of the dispersion (onset of the spin gap, merging of branches) in detail. To verify the consistency of our samples with previous magnetisation measurements, we also acquired thermal variations of the magnetic Bragg peaks while cooling to base temperature.

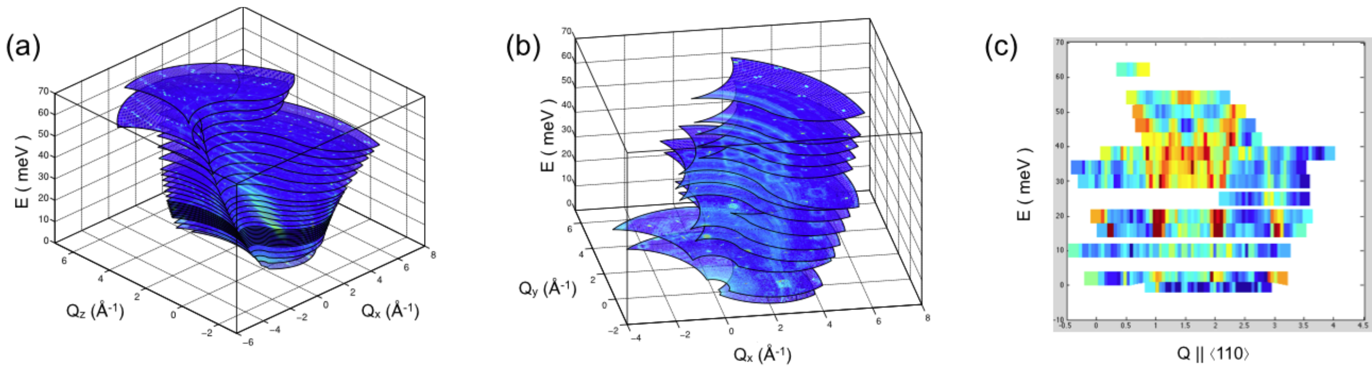

Figure 1. *Illustration of the inelastic neutron scattering datasets obtained for $SrMnBi_2$. Equivalent datasets have also been generated for $CaMnBi_2$. Constant energy-transfer intensity maps of reciprocal space, scattering in the a-c plane* (a)*, in the a-b plane* (b). *From an interpolation of this data we are able to generate slices of the magnetic dispersion along all high-symmetry directions of reciprocal space* (c). *Folding and fitting of this data will yield magnetic exchange and anisotropy parameters with small statistical errors.*

Intrument performance

We experienced no technical difficulties and were extremely satisfied with the assistance and advice given by instrument responsible Dr. Andrea Piovano. The controls of the instrument are very user friendly and additional computational tools provided on the ILL website facilitate the planning of the experiment and add to its efficiency. Moreover, we greatly benefited from a library of MatLab tools for the evaluation of neutron spectroscopy data written by Dr. Paul Steffens (of IN14). This made it straightforward to evaluate acquired data "on-the-fly" and adjust the measurement strategy accordingly.

Key results

The observed magnetic dynamics in $SrMnBi_2$ and $CaMnBi_2$ are qualitative similar. At low energies we observed rods of strong diffuse magnetic scattering along the c-direction. Magnons are being excited above a spin gap of ca. 9 and 7 meV, respectively. The cones of magnetic scattering branching out from these positions are well defined and can be traced to highest energies (ca. 50-60 meV) where they overlap and spread across the Brillouin zone.

Data analysis

The evaluation of our data is in process. We have already verified that our observed data can be modeled by a simple Heisenberg exchange Hamiltonian. Judging from the high resolution of our datasets, we expect to be able to extract the relevant fitting parameters (spin gap and anisotropic exchange constants) with little difficulty. These will likely yield an interesting comparison of the magnetic dynamics of the two materials, complementing our previous elastic study. We plan to submit these results for publication within the year.

Overall evaluation

Instrument IN8 was perfectly suited for the purpose of our experiment, which we would evaluate as highly successful and effective. We would like to acknowledge a sample environment working without technical difficulties, excellent support by the local contact as well as the useful data analysis utilities provided by the ILL.

References

[1] Y. F. Guo *et al.*, *Coupling of magnetic order to planar Bi electrons in the anisotropic Dirac metals AmnBi2 (A =Sr,Ca)* Phys. Rev. B 90, 075120 (2014)