2D magnetic materials: probing magneto-electronic coupling.

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2D magnets are an exciting area of research for exploring fundamental magnetic phenomena and with the potential for new electronic and optoelectronic functionalities [1]. Following the recent first demonstration of long-range magnetic order in a truly 2D magnet in 2017 [2], there is now a wide class of layered magnetic materials where crystal anisotropy stabilises magnetism in 2D. These crystals can be exfoliated down to monolayers and show strongly layer-dependent phenomena, including layer-dependent magnetic phase transitions. In these thin 2D forms, the magnetic state can be controlled by external control parameters such as electric fields or strain, opening a new toolbox for exploring correlated phenomena in low dimensions. In addition, the 2D magnetic layers can be integrated into van der Waals heterostructures that combine atomically thin layers of different 2D materials into atomically precise stacks, stimulating the design of proximity effects and new spintronic device geometries.

The atomically thin nature of the 2D magnetic materials (2DMMs) brings both challenges and opportunities for their study. Many conventional probes of magnetism require 'bulk' samples (e.g. neutron scattering, ac susceptibility etc.) and hence are precluded by the small sample volume of 2DMMs. However, 2D magnets often display strong magneto-electronic coupling with electronic structure changes driven by and driving magnetic ordering. Associated with this, there are reports of strong coupling between magnetic order and charge transport, magnetic control of interlayer electronic coupling, and strong magnon–exciton coupling to give just a few examples. Hence, transport and optical spectroscopy can give clear signatures of the onset of magnetic ordering, giving convenient tools for studying layer dependent magnetic properties and electron correlation effects. Understanding the magneto-electronic coupling in 2DMMs is thus essential. Allied with the difficulties in predicting electronic structure in these strongly correlated materials, this highlights the importance of experimental studies.

Through this project, we will gain new insight into 2D magnetic materials through direct electronic structure measurements using angle resolved photoemission spectroscopy (ARPES). Our preliminary results have shown strong magneto-electronic coupling, with clear electronic structure changes through a magnetic phase transition. We will probe, in situ and for the first time, the effects of electric field and strain on 2DMMs, using techniques pioneered by our group at the University of Warwick [3]. This will initiate a new field of research in 2D materials.

Applicants with interest in condensed matter Physics and aptitude for experiment and data-analysis are encouraged to apply. In addition to the experimental work at the University of Warwick (sample fabrication and testing, optical spectroscopy measurements etc.), a significant fraction of the results will be acquired at international ARPES facilities such as Diamond Light Source (UK, we have a long-standing collaboration with Dr Cephise Cacho and Dr Matthew Watson of the I05 ARPES beamline) and the ELETTRA synchrotron light source (Italy).

References:

[1] C. Gong and X. Zhang, Science (80-.). **363**, (2019).
[2] N. Samarth, Nature **546**, 216 (2017).
[3] P. V. Nguyen, N. C. Teutsch, N. P. Wilson, J. Kahn, X. Xia, A. J. Graham, V. Kandyba, A. Giampietri, A. Barinov, G. C. Constantinescu, N. Yeung, N. D. M. Hine, X. Xu, D. H. Cobden, and N. R. Wilson, Nature **572**, 220 (2019).