

# Real-space evidence for 2D-XY magnetism in atomically thin $\text{Fe}_5\text{GeTe}_2$

Speaker: Ryuji Fujita<sup>1</sup>

<sup>1</sup>WPI Advanced Institute for Materials Research (AIMR), Tohoku University, 2-1-1 Katahira, Aoba-ku, Sendai, 980-8577, Japan  
ryuji.fujita.e1@tohoku.ac.jp

The discovery of two-dimensional (2D) magnetism in  $\text{CrI}_3$  [1] and  $\text{CrGeTe}_3$  [2] has overturned the notion that a continuous symmetry cannot be spontaneously broken in the 2D limit [3]. For  $\text{CrI}_3$  and  $\text{CrGeTe}_3$ , the Hamiltonians can be approximated by the 2D Ising and Heisenberg models, respectively. For the former material, magnetism is stabilized against the gapless magnon dispersion by a robust magnetic anisotropy [1]. However, suitable candidate materials for 2D-XY magnetism remain elusive. A novel magnetic ordering, the vortex-antivortex pair, is predicted to occur in 2D-XY magnets, despite a deceptively simple Hamiltonian  $\mathcal{H} = -\frac{J}{2} \sum_{\langle ij \rangle} \cos(\phi_i - \phi_j)$  [4, 5]. Real-space probes which are directly sensitive to magnetization would be immensely valuable in demonstrating the existence of such ordering.

In this seminar, I will share XMCD-PEEM images of real-space magnetization in  $\text{Fe}_5\text{GeTe}_2$ , a vdW ferromagnet with bulk room-temperature  $T_C$  [6, 7]. Most notably, a renormalization of magnetization by vortex-antivortex pairs, rather than by conventional magnetic domain walls, is observed for 4 ML ( $\approx 3.2$  nm) and 9 nm  $\text{Fe}_5\text{GeTe}_2$ . Temperature-dependent XMCD-PEEM measurements also reveal signs of a Berezinskii-Kosterlitz-Thouless transition in 9 nm  $\text{Fe}_5\text{GeTe}_2$ , which likely originates from the relative lack of anisotropy in this 2D vdW magnet. These results will serve as a basis for the synthesis and characterization of other candidate vdW materials for XY magnetism, and for studying dynamic properties of magnons in 2D vdW magnets.

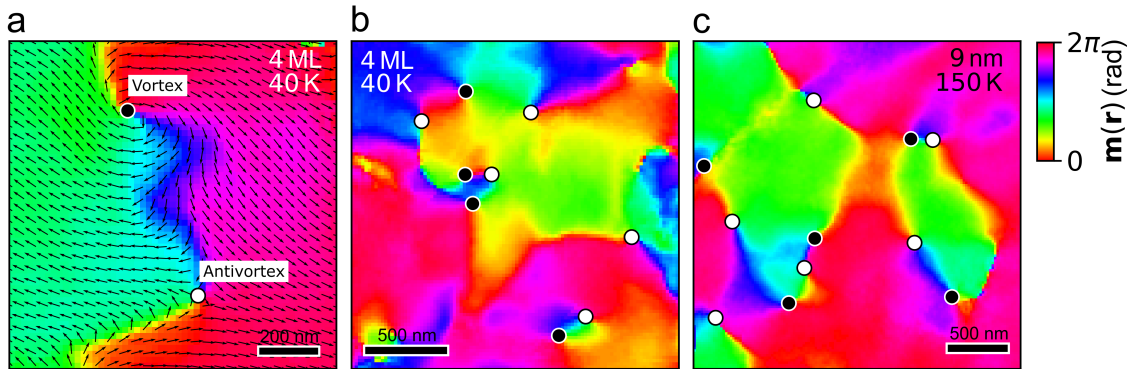


Figure 1: XMCD-PEEM vector maps of magnetization in 4 ML (a, b) and (c) 9 nm  $\text{Fe}_5\text{GeTe}_2$ . These data show magnetic vortex-antivortex pairs, a hallmark of 2D-XY magnetism.

## References

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