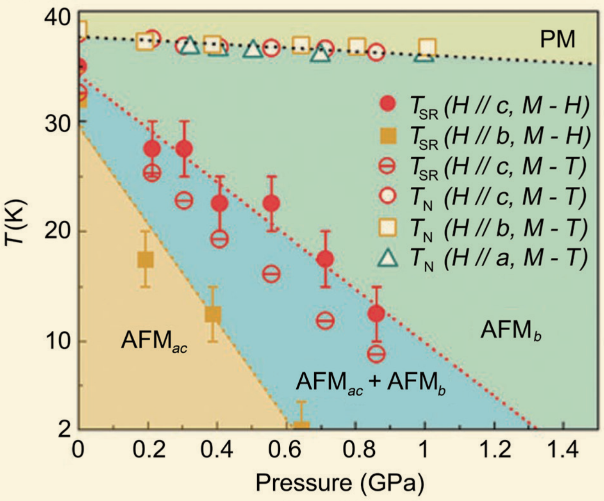

Fig. 2: Temperature-pressure magnetic phase diagram of $CrPS_4$ determined from magnetometry data. The blue region between the AFM$_{ac}$ and AFM$_b$ phases represents the coexistence of both phases (AFM$_{ac}$+ AFM$_b$), reflecting the first-order nature of the magnetic phase transition. [Reproduced from Ref. 2]

in a vdW AFM structure; this experiment may contribute to the understanding and tunability of 2D magnet materials and stimulate future developments in 2D AFM spintronics. (Reported by Chin-Wei Wang)

This report features the work of Wenyun Yang and his collaborators published in Adv. Mater. ***32****, 2001200 (2020) and Adv. Funct. Mater.* ***32****, 2106592 (2022).*

ANSTO ECHIDNA – High-resolution Powder Diffractometer

- NPD
- Materials Science, Condensed-matter Physics

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Field-Induced Magnetic Ordering in a Tetrahedral Sublattice with Strong Magnetic Anisotropy

Neutron powder diffraction is a powerful tool for studying magnetic properties in extreme sample environments.

Geometric frustration in condensed matter systems is a phenomenon in which competing forces act on atoms reside on a regular lattice. Because of the frustration in the geometry, such a system exhibits degenerate ground states, preventing entrance into the long-range order phase. An example is geometrically frustrated antiferromagnets, where antiferromagnetic couplings with neighboring spins cannot be satisfied simultaneously. Pyrochlore compounds, with corner-sharing tetrahedral sublattices, are the most well-known and studied geometrically frustrated systems and undertake various magnetic phases. On the basis of degenerate ground states, a perturbation, such as a dipolar interaction, stabilizes spin ice behavior in $Ho_2Ti_2O_7$ and $Dy_2Ti_2O_7$. Likewise, the conduction electron-mediated coupling, namely the Ruderman–Kittel–Kasuya–Yosida (RKKY) interaction, can serve as perturbation, causing novel magnetic phases in intermetallic compounds composed of geometrically frustrated sublattices. $Ho_5Co_6Sn_{18}$ is one example. Chin-Wei Wang (NSRRC) and co-workers reported comprehensive neutron scattering results for this compound.

Two distinct crystallographic Ho sites, Ho(1) and Ho(2), exist in $Ho_5Co_6Sn_{18}$. Both sublattices contain tetrahedral arrangements and can be magnetically frustrated. Each Ho(1) atom has 12 adjacent Ho(1) atoms, forming edge-sharing tetrahedrons. Conversely, the Ho(2)$_4$ tetrahedra are somewhat isolated; Ho(2)$_4$ units are separated by Ho(1) atoms and together form a rock salt structure. No significantmagnetic order exists in their magnetometry, while their heat capacity exhibit a peak at ~3.4 K, that is closed to the superconducting gap of tin metal. The temperature dependent magnetic peak intensity is measured on **SIKA,** that indicates the 3.4 K peak in heat capacity is associated to the long-range magnetic order. The data for neutron powder diffraction (NPD) performed at 1.5 K on **ECHIDNA** indicate a ferromagnetic structure on the Ho(1) sublattice and no ordered moment on the Ho(2) sublattice. A further investigation at the ultralow temperature of 60 mK demonstrated the magnetic order of Ho(2) spins; the Ho(2) spins on a Ho(2)$_4$ tetrahedron were (Mx, My, 0), (–Mx, –My, 0), (My, –Mx, 0), and (–My, Mx, 0). A 2-in-2-out configuration that is analogous to the magnetic ordered phases in pyrochlore compounds.

At 60 mK, an overall noncollinear spin structure was realized. Ho(1) spins ordered ferromagnetically along the *c*-axis, and Ho(2) spins were located in the *ab* plane. The strong magnetic anisotropy indicated by the nonsaturated character of M(H) suggests the necessity for further investigation into the magnetic field effect of **WOMBAT**.[1] **Figure 2** shows the effect of the magnetic field on the magnetic structure at 2 K. The magnetic space group was not altered by a magnetic field of up to 90 kOe. The order moment of Ho(1) increased linearly to the magnetic field, whereas the fluctuating Ho(2) moment was induced substantially. As shown in **Fig. 2(b)**, not only was the ferromagnetic *c*-component induced, but the antiferromagnetic in-plane component also increased. Thus, Ho(2) maintained an angle of approximately 54° to the *ab* plane between 10 and 90 kOe. This can be attributed to the balance between the in-plane magnetic anisotropy of Ho(2) and the external field, which reduced spin fluctuation rather than deflecting from the easy plane.

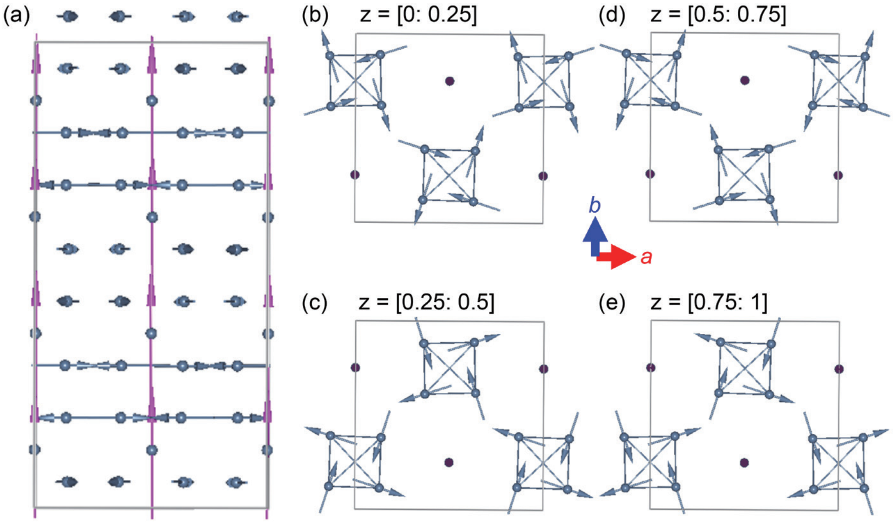

Fig. 1: (a) Magnetic structure at 60 mK shows the Ho(1) spin pointing along the *c*-axis and the Ho(2) spins located in the *ab* plane. Panels (b)–(e) show the magnetic structure viewed along the *c*-axis sliced into four layers: (b) z = [0: 0.25], (c) z = [0.25: 0.5], (d) z = [0.5: 0.75], and (e) z = [0.75: 1]. [Reproduced from Ref. 1]

In summary, the ferromagnetic coupling, $J_{Ho(1)-Ho(1)}$, was strong, and long-range magnetic order developed on the Ho(1) sublattice, causing Ho(2) to be released. The magnetic properties of the Ho(2) sublattice were affected by both the antiferromagnetic $J_{Ho(2)-Ho(2)}$ couplings and in-plane magnetic anisotropy. The high penetration of neutron beams enables the investigation of magnetic properties at an ultralow temperature and with a strong magnetic field. These experiments were undertaken at the neutron facility of Australian Centre for Neutron Scattering at Australia's Nuclear Science and Technology Organisation (ACNS, ANSTO), and are available to Taiwanese researchers. (Reported by Chin-Wei Wang)

This report features the work of Chin-Wei Wang and his collaborators published in Phys. Rev. B ***105****, 104429 (2022).*

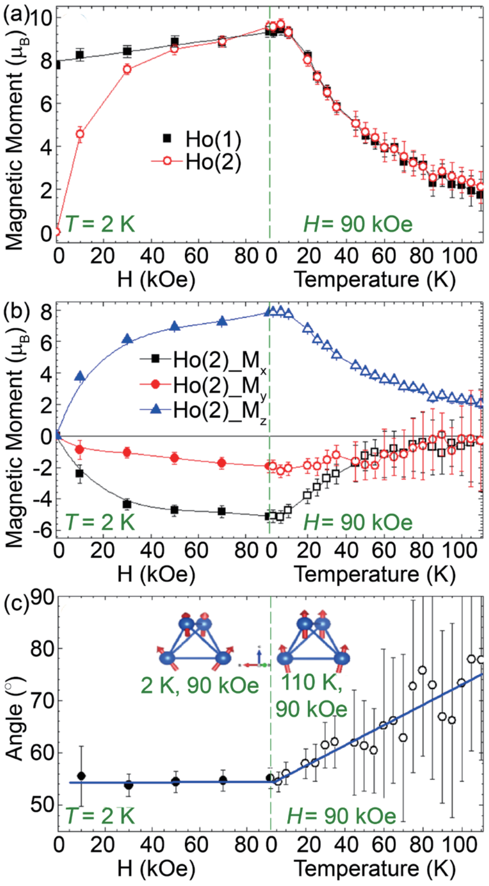

Fig. 2: Refined magnetic moments from the NPD patterns collected under various fields and temperatures. (a) Modulus of the magnetic moments of Ho(1) and Ho(2). (b) M_x, M_y, and M_z components of Ho(2). (c) Angle between Ho(2) and the *ab* plane. [Reproduced from Ref. 1]

ANSTO WOMBAT – High-intensity Powder Diffractometer
ANSTO ECHIDNA – High-resolution Powder Diffractometer
ANSTO SIKA – Cold Neutron Triple-axis Spectrometer

- NPD, Inelastic Neutron Scattering
- Condensed-matter Physics, Materials Science

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