by another phonon mode. Meanwhile, the rattling mode does not pass through the LA mode but curves upward, deflected away rather than intersecting, resulting in a well-defined energy gap between the two branches. This mutual repulsion of phonon branches constitutes the avoided-crossing event.

The coupling becomes directly visible in the momentum-resolved neutron intensity. In the constant-Q cuts (**Fig. 1(b)**), instead of a single peak, two clear distinct peaks appear simultaneously at the same momentum transfer; this indicates the presence of two phonon branches in close energy proximity. These peaks remain well-separated rather than merging, showing that the modes do not cross but coexist as two resolvable excitations. The existence of this rattling mode is further verified by Raman spectroscopy, where distinct Stokes and anti-Stokes signals appear at 6.17(2) and −6.26(3) meV at room temperature (**Fig. 1(c)**). These symmetric peaks correspond to a rattling mode of ~6.2 meV (≈50 $\mathrm{cm^{-1}}$) at Γ, confirming the presence of a low-lying mode which participates in the avoided crossing observed in neutron scattering.

Overall, the neutron spectra reveal that acoustic phonons in β-$\mathrm{Zn_4Sb_3}$ are intercepted by a low-energy rattling mode and forced into an avoided-crossing state. Because acoustic branches are the primary heat carriers, their dispersion flattening leads to a pronounced reduction in group velocity, thus directly suppressing heat transport. Simultaneously, hybridization with the rattling mode strengthens anharmonic scattering and accelerates phonon decay. The observed linewidth yields an exceptionally short acoustic phonon lifetime of ~0.86 ps, markedly lower than that of conventional crystalline thermoelectrics, and also restricts lattice thermal transport. The reduction of phonon velocity and the ultrafast decay resulting from avoided crossing provides a microscopic mechanism for the intrinsically ultralow κ_L in β-$\mathrm{Zn_4Sb_3}$. (Reported by Chi-Hung Lee, Tunghai University)

This report features the work of Chi-Hung Lee, Hsin-Jay Wu and their co-workers published in Adv. Sci. ***12****, 2411498 (2025).*

ANSTO SIKA – Cold Neutron Triple-Axis Spectrometer

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

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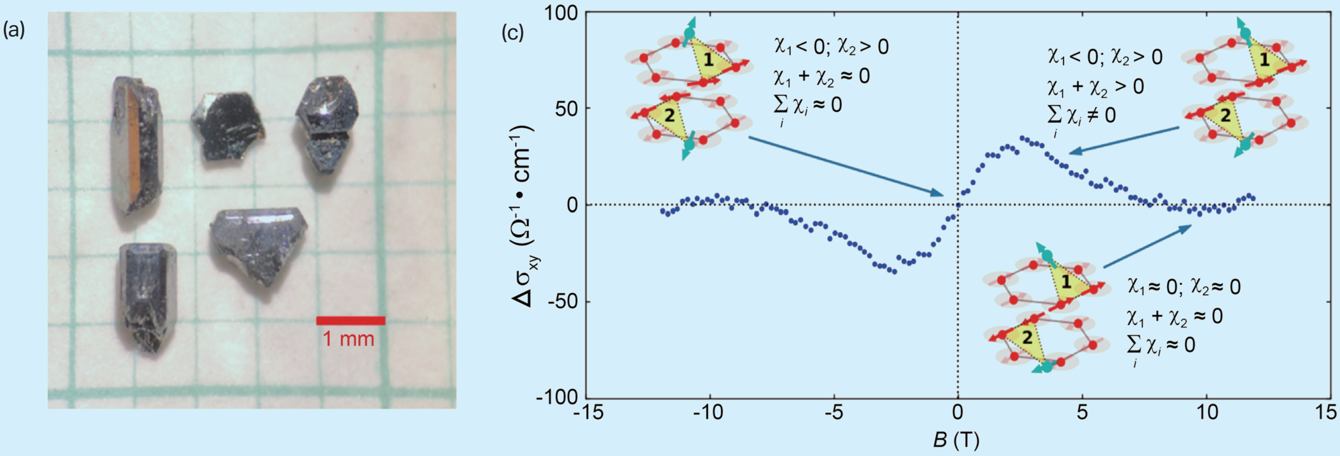
From Motionless to Mad Dance: Neutron Scattering Reveals the Hidden Driver of the Anomalous Hall Effect

Collinear spins with no static chirality still produce a giant anomalous Hall effect—driven purely by wild quantum spin fluctuations, revealed by neutron scattering. A revolutionary new mechanism for future spintronics.

In today's rapidly advancing technological landscape, the materials within our electronic devices are becoming as critical as the devices themselves. As we pursue faster computing, more efficient communication, and highly secure data storage, researchers are increasingly turning to quantum materials—systems in which electrons behave in unexpected ways. Leading this research is Pengcheng Dai's (Rice University, USA) team, whose studies continue to uncover new magnetic and electronic phenomena in complex materials. Their latest investigation of the kagome-lattice magnet $\mathrm{YbFe_6Ge_6}$, shown in **Fig. 1**, marks another significant advance, revealing how subtle quantum effects could one day transform the technologies that shape our lives.

Future electronics aim to control not only electric charge but also electron spin, a field known as spintronics, which promises faster, more efficient, and robust devices. A key phenomenon is the anomalous Hall effect (AHE), where a transverse voltage appears without an external magnetic field.[1]



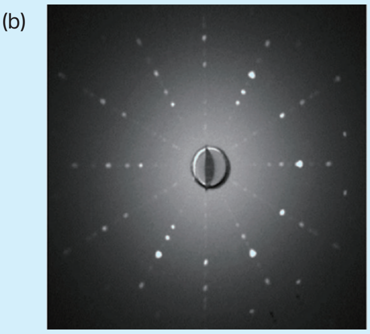


Fig. 1: (a) Typical YbFe$_6$Ge$_6$ single crystals arranged on a millimeter grid. (b) X-ray Laue diffraction pattern measured on the (0, 0, L) surface. (c) Anomalous Hall conductivity $\Delta\sigma_{xy}$ at 10 K. The insets illustrate how the spin arrangements of Yb (cyan) and Fe (red) respond to different magnetic-field strengths, indicated by the blue arrows. The yellow triangles (labeled "1" and "2") mark two representative Yb–Fe spin triads. Light red arrows depict the static magnetic configuration that develop below temperature of spin reorientation, while the light red circles outline the "easy plane" where the Fe spins prefer to align. For clarity, the spin-canting angles are intentionally exaggerated. [Reproduced from Ref. 2]

Dai's team found that in YbFe$_6$Ge$_6$, the AHE arises from dynamic spin fluctuations, not static spin patterns. Below 63 K, iron spins rotate into the kagome plane, triggering the AHE even though the spins remain aligned. Neutron scattering revealed these fluctuations are gapless, allowing brief local chirality that deflects electrons. Above 63 K, the gap suppresses fluctuations and the AHE disappears. This shows that the AHE can be driven by quantum spin motion rather than static magnetism.[2,3]

The neutron scattering experiments were conducted at several leading facilities, but one instrument was especially important: **QUOKKA**, the small-angle neutron scattering (SANS) instrument at the Australian Nuclear Science and Technology Organisation (ANSTO). SANS is highly sensitive to long-wavelength, low-momentum magnetic structures, making it well suited for detecting subtle field-induced features or nanoscale textures that may accompany the AHE.

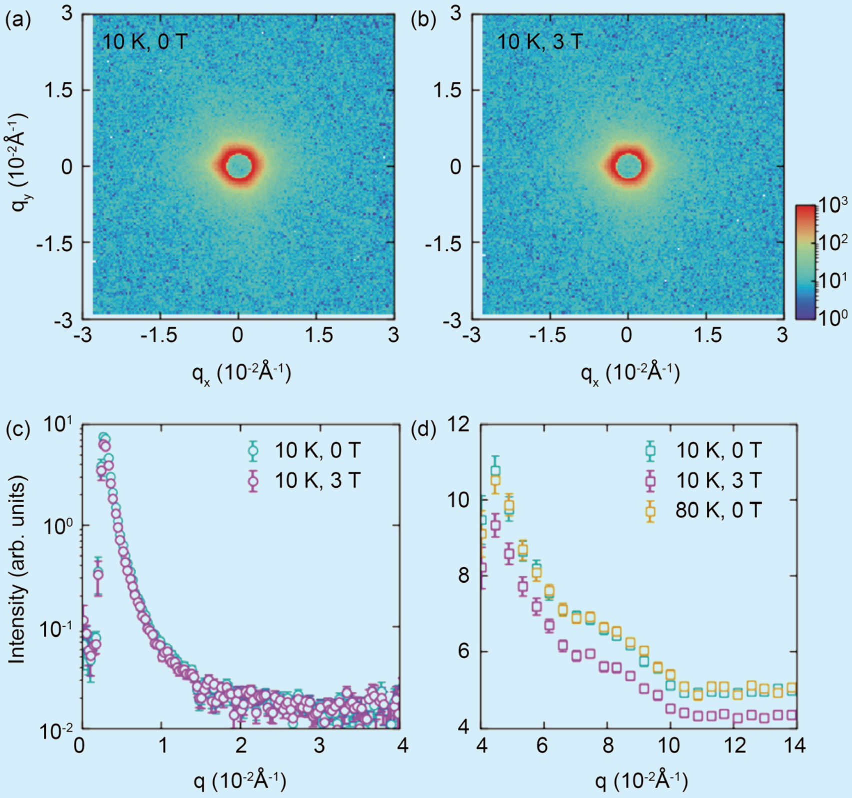


Fig. 2: (a,b) SANS patterns at 10 K, 0 T and 10 K, 3 T measured with the low-q setup. (c,d) Azimuthally averaged SANS intensities as a function of momentum transfer in the low-q and high-q setups, respectively. [Reproduced from Ref. 2]

The team used **QUOKKA** to search for such features when a magnetic field was applied in the material's plane. Importantly, they found no evidence of static magnetic textures, such as skyrmions or other chiral structures.[2] This absence was as significant as a positive detection because it ruled out conventional explanations[4] and strengthened the case that the observed AHE originates from dynamic, rather than static, magnetic behavior.

QUOKKA's ability to reveal what was not there helped clarify what was. By ruling out field-induced static chirality, the SANS measurements supported the team's theory: the AHE arises solely from fluctuating spins interacting with conduction electrons, with ytterbium ions subtly influencing spin orientation and enhancing fluctuations at low temperatures.

In summary, this research demonstrates how complex magnetic materials can exhibit unexpected quantum behaviors that may be useful for future technology. The work led by Dai shows that even materials with simple collinear antiferromagnetic structures can display rich electronic responses when their spins fluctuate appropriately. Neutron scattering, particularly using instruments like **QUOKKA**, was crucial in uncovering the hidden dynamics behind these effects. As scientists seek efficient, low-energy methods to manipulate electron spin, discoveries like this expand the possibilities and open new directions for quantum materials research. (Reported by Chun-Ming Wu)

This report features the work of Pengcheng Dai and his collaborators published in Phys. Rev. Lett. ***134****, 186501(2025).*

ANSTO QUOKKA – Small-angle Neutron Scattering

- SANS
- Condensed-matter Physics

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Ordered Spin Structures of Multiferroic and Skyrmion Compounds

Neutron scattering is a unique probe for spin correlations.

The neutron diffraction technique, developed in the 1930s, has become an indispensable tool for investigating complex behaviors in magnetic, multiferroic, and strongly correlated materials. Due to the neutron's intrinsic spin and charge neutrality, it interacts directly with magnetic moments, enabling precise determination of magnetic ordering, spin textures, and subtle structural distortions that often accompany electronic phase transitions. In multiferroics, where electric and magnetic orders coexist and frequently couple in intricate ways, neutron diffraction reveals the symmetry-breaking mechanisms that link lattice, charge, and spin degrees of freedom. In strongly correlated systems, neutron scattering uncovers collective excitations, long-range correlations, and hidden order parameters that conventional probes cannot detect. By providing sensitivity to both nuclear and magnetic structures, neutron diffraction offers a coherent, microscopic view of how competing interactions shape exotic ground states and emergent phenomena, making it a cornerstone technique in contemporary condensed matter physics.

For researchers in Taiwan, the Australian Centre for Neutron Scattering (ACNS) at Australian Nuclear Science and Technology Organisation (ANSTO) offers a unique opportunity. The Neutron Group of the NSRRC, based at ACNS, can assist Taiwan researchers in various ways. Hung-Duen Yang (National Sun Yat-sen University)