New era of magnetization: Research sheds light on future applications in spintronics and valleytronics

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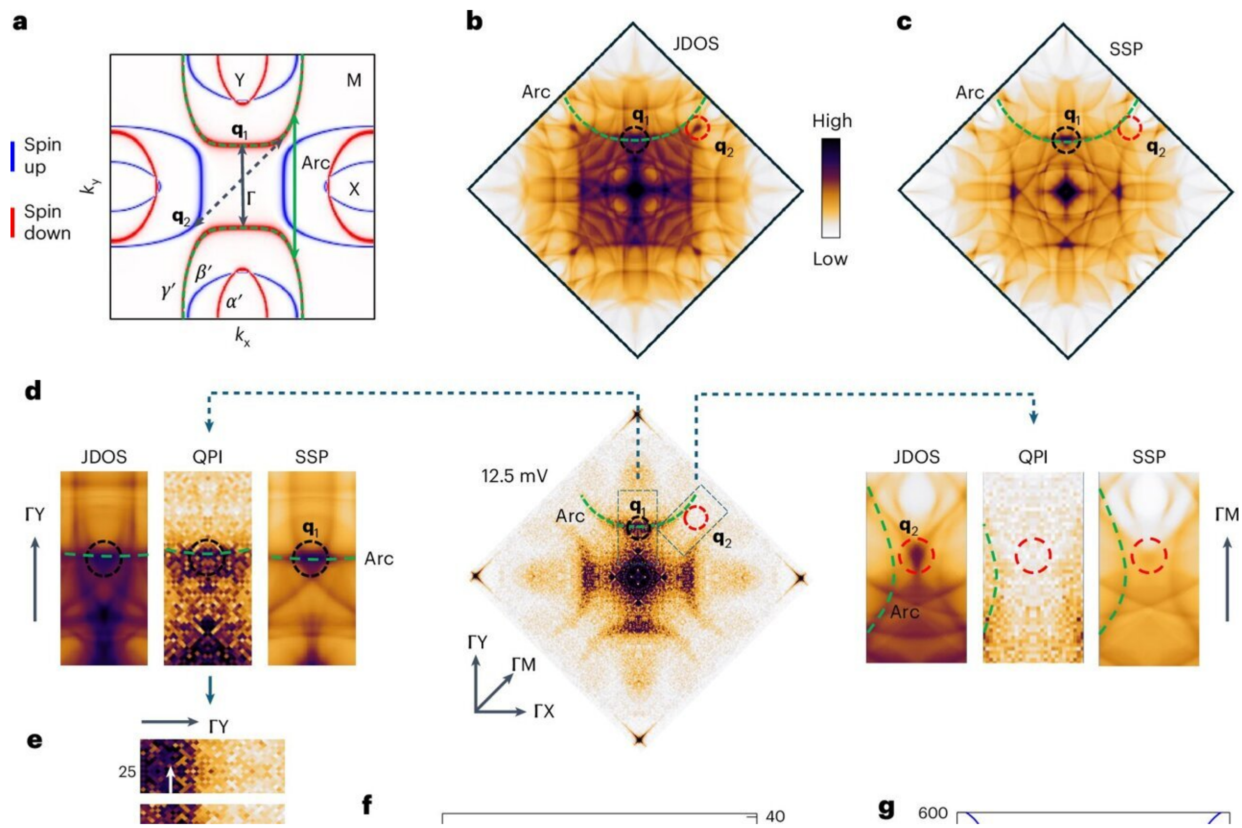

Suppression of intervalley scattering observed in the QPI pattern. Credit: *Nature Physics* (2025). DOI: 10.1038/s41567-025-02864-2

Altermagnets, which exhibit momentum-dependent spin splitting without spin–orbit coupling (SOC) or net magnetization, have recently attracted significant international attention.

A team led by Prof. Liu Junwei from the Department of Physics at the Hong Kong University of Science and Technology (HKUST), along with their experimental collaborators, published their latest research findings in *Nature Physics*, which unveiled the first experimental observation of a two-dimensional layered room-temperature altermagnet, validating the theoretical predictions in *Nature Communications* made by Prof. Liu in 2021.

The realization and control of spin-polarized electronic states in solids are crucial for spintronics for encoding and processing information. Spin polarization is typically generated by coupling an electron's spin to other degrees of freedom, such as orbital or magnetic moments.

This can involve SOC, leading to momentum-dependent spin splitting in non-inversion-symmetric crystals (the Rashba–Dresselhaus effect) or time-reversal symmetry breaking in ferromagnets, resulting in momentum-independent Zeeman-type spin splitting.

In their research studies, Prof. Liu and other researchers proposed a new mechanism for spin splitting in antiferromagnets, where sublattices connected by crystal symmetry allow exchange coupling to produce significant spin splitting with unique C-paired spin-valley locking.

This effect is independent of SOC or net magnetization, combining the stability of antiferromagnetic devices with long spin lifetimes. These unconventional antiferromagnets are termed "altermagnets," and their discovery was recognized as one of *Science*'s top 10 breakthroughs of 2024.

Despite extensive theoretical and experimental efforts to explore unconventional antiferromagnets based on emerging materials like α-MnTe, CrSb, $MnTe_2$, and RuO_2, none meet the symmetry and conductivity requirements for nonrelativistic spin-conserved spin currents due to altermagnetism. The magnetic sublattices of α-MnTe and CrSb possess C_3 symmetry, leading to isotropic conductance and nonpolarized currents.

In $MnTe_2$, spin is not conserved due to its noncoplanar magnetic structure, and its low critical temperature (87 K) limits practical applications. For RuO_2, it remains controversial whether its ground state is antiferromagnetic or nonmagnetic, despite evidence of the anomalous Hall effect and spin splitting. Additionally, these materials are not layered, restricting their potential for exfoliation and integration with other materials to control properties at the microscopic level.

This limitation hinders the exploration of effects in 2D materials, such as topological superconductors via the superconducting proximity effect, tunable electronic properties through gating, and moiré superlattices.

Therefore, exploring layered materials in altermagnets is essential for developing high-density, high-speed, and low-energy-consumption spintronic devices. Prof. Liu's observation of a two-dimensional layered room-temperature altermagnet, sheds new light on this area.

Based on theoretical predictions by Prof. Liu's team for V_2Te_2O and V_2Se_2O in 2021, this work demonstrates the realization of C-paired spin-valley locking (SVL) in a layered, room-temperature antiferromagnet (AFM) compound $Rb_{1-\delta}V_2Te_2O$ using spin and angle-resolved photoemission spectroscopy (Spin-ARPES), scanning tunneling microscopy/spectroscopy (STM/STS), and first-principles calculations.

Key findings include the direct observation of C-paired SVL through Spin-ARPES measurements, which reveal opposite spin polarization signs between adjacent X and Y valleys connected by crystal symmetry C.

Temperature-dependent ARPES measurements show SVL stability up to room temperature, consistent with the AFM phase transition temperature. Additionally, ARPES measurements confirm a strong two-dimensional character with negligible dispersion in the kz direction, while quasi-particle interference patterns from STM maps reveal suppressed inter-valley scattering due to spin selection rules.

Prof. Liu's work demonstrates the first layered room-temperature AFM metal with alternating magnetic sublattices and a new type of spin-splitting effect, providing an ideal platform for further studies and applications in spintronics and valleytronics.

Importantly, all experimental results align well with first-principles calculations, reinforcing confidence in the theoretical work and suggesting potential access to spin-conserved currents and unconventional piezomagnetism.

Similar spin-valley locking has also been observed in K-intercalated V_2Se_2O, further validating Prof. Liu's theoretical predictions in 2021.

More information: Fayuan Zhang et al, Crystal-symmetry-paired spin–valley locking in a layered room-temperature metallic altermagnet candidate, *Nature Physics* (2025). DOI: 10.1038/s41567-025-02864-2

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