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A Unified Understanding of Novel Responses in Altermagnets Based on C-paired Spin-momentum Locking

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In 2021, we proposed crystal-symmetry-paired spin-momentum/spin-valley locking (CSML/CSVL) in spin-splitting antiferromagnets (named "altermagnets" in 2022) governed by the intrinsic crystal symmetries, predicting several realistic candidate materials, such as V_2Se_2O, V_2Te_2O, MnTe, and RuO_2 [1]. This concept provides a unified framework to understand and predict various novel physical phenomena, including unconventional itinerant piezomagnetism, noncollinear spin currents, and distinctive quasiparticle interference patterns even in the absence of spin-orbit coupling (SOC) [1,2]. Remarkably, all these predictions have been experimentally confirmed recently [3,4]. Moreover, Rb/K-intercalated $V_2(Te,Se)_2O$ has been verified to be a room-temperature layered metallic altermagnet, providing an ideal platform to explore novel phases in two-dimensional (2D) altermagnets [3,4]. Recently, we extended the CSML framework to general cases by incorporating noncollinear antiferromagnetic orders and SOC, thereby establishing a new methodology to study magnetic systems through their momentum-space spin structures [2]. This generalized CSML scheme leads to two qualitatively different spin responses driven by spin tilting or occupation imbalance via breaking symmetries in the little cogroup or coset representatives, respectively. This mechanism directly explains emergent phenomena such as the anomalous Hall effect [5,6] and magneto-optical responses [7] in altermagnets. Ultimately, these advanced responses open clear avenues for spintronic applications [8], enabling electrical readout and deterministic switching of the Néel vector [5,6]. Finally, to address the longstanding scarcity of realistic altermagnetic materials, we predict a series of altermanetic candidates based on the layered altermagnet V_2Se_2O [9] and construct an effective model for this V_2Se_2O family [10].

References:

[1] H.-Y. Ma, M. Hu, N. Li, J. Liu, W. Yao, J.-F. Jia, and J. Liu, Nat. Commun. 12, 2846 (2021).

[2] M. Hu, X. Cheng, Z. Huang, and J. Liu, Phys. Rev. X 15, 021083 (2025).

[3] F. Zhang, X. Cheng, Z. Yin, C. Liu, L. Deng, Y. Qiao, Z. Shi, S. Zhang, J. Lin, Z. Liu, et al., Nat. Phys. 21, 760 (2025).

[4] Z. Wang, S. Yu, X. Cheng, X. Xiao, W. Ma, F. Quan, H. Song, K. Zhang, Y. Zhang, Y. Ma, et al., arXiv:2512.23290 (2025).

[5] L. Han, X. Fu, R. Peng, X. Cheng, J. Dai, L. Liu, Y. Li, Y. Zhang, W. Zhu, H. Bai, Y. Zhou, S. Liang, C. Chen, Q. Wang, X. Chen, L. Yang, Y. Zhang, C. Song, J. Liu, and F. Pan, Sci. Adv. 10, eadn0479 (2024).

[6] Z. Zhou, X. Cheng, M. Hu, R. Chu, H. Bai, L. Han, J. Liu, F. Pan, and C. Song, Nature 638, 645 (2025).

[7] X. Yang, X. Cheng, Z. Deng, Y.-H. Gao, Q.-L. Yang, Z. Chang, P.-T. Yang, H.-M. Feng, X.-Q. Zhang, W. He, et al., Phys. Rev. Lett. 136, 256702 (2026).

[8] C. Song, H. Bai, Z. Zhou, L. Han, H. Reichlova, J. H. Dil, J. Liu, X. Chen, and F. Pan, Nat. Rev. Mater. 10, 473 (2025).

[9] R. Xu, Y. Gao, and J. Liu, Natl. Sci. Rev. 13, nwaf528 (2026).

[10] X. Cheng, Y. Gao, and J. Liu, arXiv:2602.09465 (2026).