A unified understanding of altermagnets based on C-paired spin-momentum locking

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Since proposal in 2022, altermagnetism has become one of most important topics in spintronics, materials science and condensed matter physics, while there are many controversial conclusions. In this talk, I present a unified understanding of unique novel properties of altermagnets and more general unconventional antiferromagnets (AFMs) based on crystal-symmetry-paired spin-valley/momentum locking (CSVL/CSML), which we proposed in 2021[*Nat. Commun. 12, 2846 (2021)*]. CSML is enabled by the intrinsic crystal symmetries exchanging opposite magnetic sublattices of AFMs (e.g., V_2Se_2O, V_2Te_2O, MnTe and RuO_2) [*Nat. Commun. 12, 2846 (2021)*; *Phys. Rev. X 15, 021083 (2025)*], and exists in all unconventional AFMs with spin-splitting band structures but not limited to altermagnets. CSML enables unique properties and feasible controls of AFMs by manipulating the corresponding crystal symmetry. Typically, one can use a strain field to induce net valley polarization/magnetization and use an electric field to generate a noncollinear spin current even without spin-orbit coupling. All the predictions, in particular the existence of altermagnetism in V_2(Se, Te)$_2$O-family materials, have been confirmed in experiments [*Nat. Phys. 21, 760 (2025)*; *Nat. Phys. 21, 754 (2025)*]. These properties have helped us realize the electric readout and 180^o deterministic switching of the Néel order in our experimental work [*Sci. Adv. 10, eadn0479 (2024)*; *Nature 638, 645 (2025)*], and motivate us to propose a unified theory of all magnetic deterministic switching [*arXiv:2603.29136*].