Magnetic-field-tunable density modulations and spin tilting in a layered altermagnet

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In recent years, several groups reported theoretical predictions of collinear antiferromagnets demonstrating time-reversal symmetry breaking phenomena and spin-polarized behaviors, subsequently named altermagnets. Altermagnetism by a net zero magnetization, yet the Kramers degeneracy is lifted by a nonrelativistic, momentum-dependent spin-splitting of the electronic bands. Due to intrinsic time-reversal symmetry breaking predicted to emerge in these systems, altermagnets have been theorized to exhibit numerous exotic phenomena. Atomic-scale spectroscopic insights into altermagnets are highly-desirable, but elusive.

Here we study a new layered triangular lattice altermagnet, Co-intercalated $NbSe_2$ using scanning tunneling microscopy and spectroscopy (STM/S) [1]. Spatial mapping using spectroscopic-imaging STM and spin-polarized STM further reveals emergent tri-directional charge and spin density modulations with a $2a_0$ wavelength on the Se surface (Figure 1). Density functional theory (DFT) simulations suggest that these modulations reflect the underlying Co superstructure. Interestingly, we discover that out-of-plane magnetic field can serve as a knob to tune the amplitudes of the modulations as well as alter the overall electronic density-of-states in a manner that is strongly dependent on the field direction and strength. This can be attributed to the tilting of spins by the external magnetic field, which can have profound implications on the electronic properties of the altermagnet. By providing elusive atomic-scale insights, our work uncovers a magnetic-field tunable band structure in an altermagnet and highlights the crucial need to understand and quantify spin canting in altermagnets.

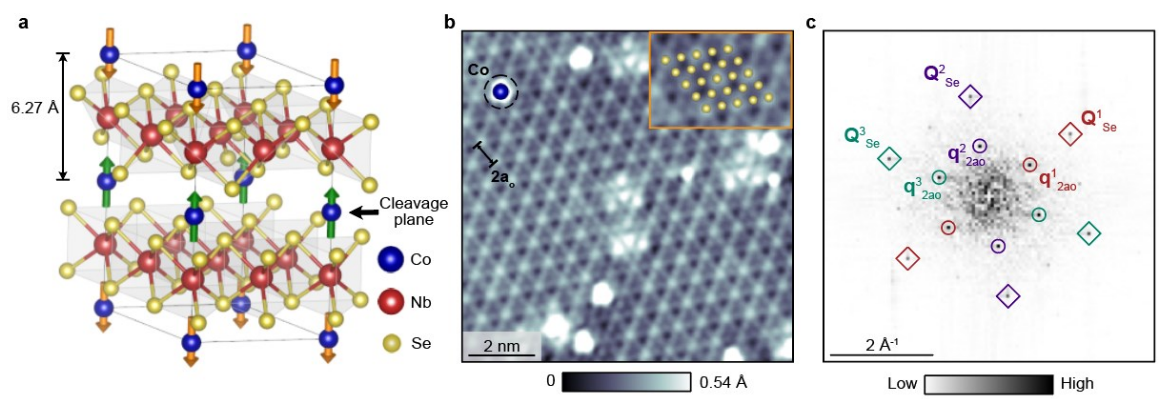

Figure 1. (a) Crystal structure. (b) STM topograph of Se-terminated surface and (c) its Fourier transform showing $2a_0$ x $2a_0$ modulations that can be tuned by magnetic field.

[1] Candelora et al, arXiv:2503.03716 (2025)