Incommensurate Transverse Peierls Transition and Chiral Charge Density Wave

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Abstract:

In one-dimensional quantum materials, conducting electrons and the underlying lattices can undergo a spontaneous translational symmetry breaking, known as Peierls transition. For nearly a century, the Peierls transition has been understood within the paradigm of electron-electron interactions mediated by longitudinal acoustic phonons. This classical picture has recently been revised in topological semimetals, where transverse acoustic phonons can couple with conducting p-orbital electrons and give rise to an unconventional Fermi surface instability, dubbed the transverse Peierls transition (TPT). Most interestingly, the TPT induced lattice distortions can further break rotation or mirror/inversion symmetries, leading to nematic or chiral charge density waves (CDWs). In the talk, I present experimental observation of an incommensurate TPT in the tetragonal Dirac semimetal $EuAl_4$. Using inelastic x-ray scattering with meV resolution, we observe the complete softening of a transverse acoustic phonon at the CDW wavevector upon cooling, whereas the longitudinal acoustic phonon is nearly unchanged. Combining with first principles calculations, we show that the incommensurate CDW wavevector matches the calculated charge susceptibility peak and connects the nested Dirac bands with Al 3px and 3py orbitals. Supplemented by second harmonic generation measurements, we show that the CDW induced lattice distortions break all vertical and diagonal mirrors whereas the four-fold rotational symmetry is retained below the CDW transition. Our observations strongly suggest a chiral CDW in EuAl4 and highlight the TPT as a new avenue for chiral quantum states.

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