Excitonic Chern insulator and heavy fermion liquid in AB-stacked MoTe2/WSe2 moire bilayers

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Motivation

AB-stacked MoTe2/WSe2 moire bilayers

- Strong Ising-like SOC + AB stacking
  - Opposite spin-valley locking in two layers.
- Moire potential (7% lattice mismatch)
- Wannier orbitals on AB sublattices are layer-polarized.
- Strong interaction in layer B.

Lattice model: Honeycomb, (A) free electron, (B) correlated electron

Experimental evidences on valley-coherent QAH

- Valley coherent QAH
- Partial spin polarization from MCD
- QAH survives 8T (spin-polarized limit)
- Finite charge gap at transition
- QAH onsets as soon as charge transfer into WSe2

Lessons from experiments

- QAH ⇒ hybridization between AB
- Interlayer tunneling? [1]
  - Suppressed by symmetry
  - Favors valley alignment
- Interlayer Hund's* / dipole-dipole?
  - Layer mixing small, negligible
- Interlayer interaction
  - $U_{AB} n_B \sim U_{AB,AA} c_A^+ c_B^+ \sim t_{AB} c_A^+ c_B$ (exciton condensation)

p+ip exciton Chern insulator

- Lattice model: Kane-Mele + U + V
  - $H = -t_A \sum_{\langle \sigma \sigma' \rangle} (c_{\sigma \alpha}^+ c_{\sigma' \lambda} + h.c.)$
  - $+U \sum_{\langle \sigma \sigma' \rangle} n_{\sigma \alpha} n_{\sigma' \lambda} + V \sum_{\langle \sigma \sigma' \rangle} n_{\sigma \alpha}

- Mean-field: Hartree-Fock + Schwinger boson

- ECI with spin polarization (valley anti-aligned on two sub lattices)
- Exciton order $\chi$ and charge gap $\Delta_c$ jumps on the phase boundary.
- Consistent with Schwinger boson mean field theory.
- At low density, trivial EI with 120° order is always favored.
- ECI at finite exciton density.

- Kinetic magnetism
  - Gives a reasonable spin stiffness $J \sim x t_{AB} > T_c$
  - $\phi_A = \phi_B = 0$, $U(2)_A \times U(2)_B$, degeneracy between valley-polarized and spin-polarized states.
  - $\phi_{AB} \rightarrow \phi_{AB} + \frac{2\pi}{3}$ gauged away by local $U(1)_B$, $c_A \rightarrow e^{-i(k_B r_B) / 2} c_A$

- Degeneracy lifted by perturbation in $\phi$ away from the high-symmetry points.

Kondo lattice and heavy fermion liquid

What is the fate at $\nu = 1 + x$?
- Gate-tunable coupling
- Resistance peak
- Enhancement of $m^*$

- $J_K \sim \frac{4 \pi}{3} \ll \pi t_{AB} \ll t_{AB}$ Kondo model not valid in HFL regime.
- Keep charge fluctuations in the Mott layer.

- Kondo physics from a t-J model?
- HFL from slave boson theory (near $D_D + D_A$)
  - $\Delta$ ≪ $t_{AB}$, A Kondo model not valid in HFL regime.
  - $D_D > D_A$, charge transfer to A, orbital-selective Mott ($n_B = 1$), $\chi_{AB} \neq 0$, $\chi_{AB} \neq 0$

- $D_D \rightarrow D_A$, $\chi_{AB} \neq 0$, $\chi_{AB} \neq 0$