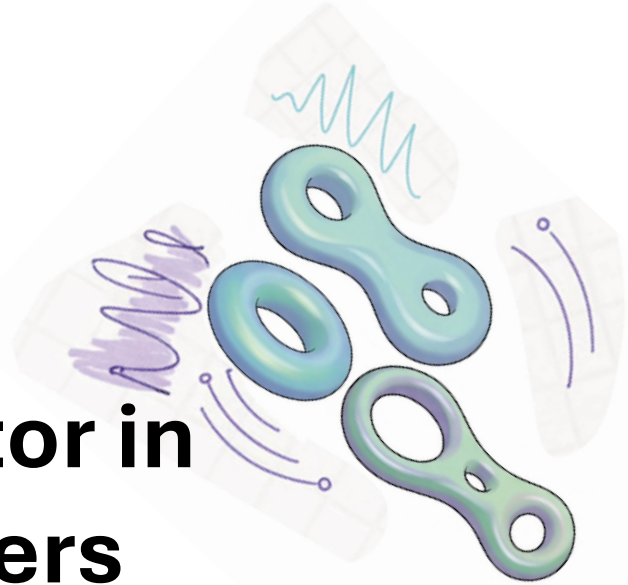
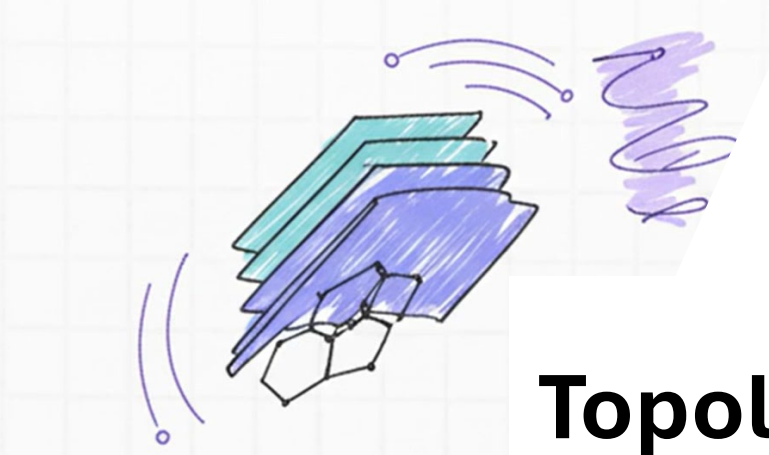


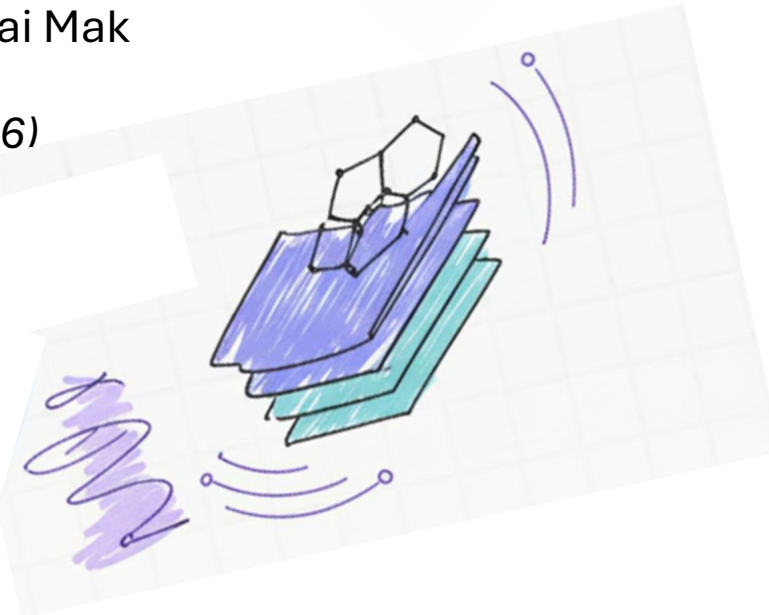
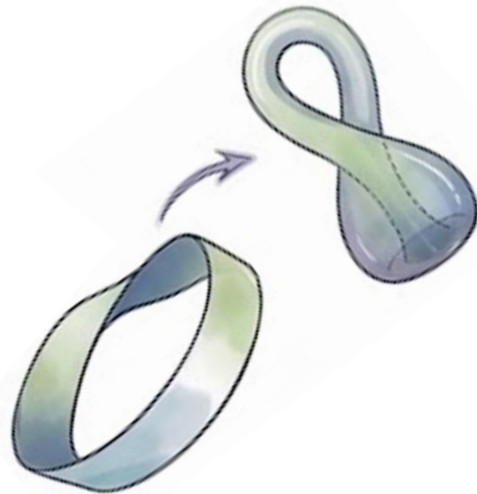


Topological Kondo insulator in $\text{MoTe}_2/\text{WSe}_2$ moiré bilayers

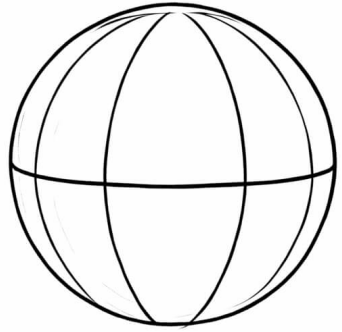
Zhongdong Han, Yiyu Xia, Zhengchao Xia, Wenjin Zhao, Yichi Zhang,
Kenji Watanabe, Takashi Taniguchi, Jie Shan & Kin Fai Mak

Nature Physics volume 22, pages396–401 (2026)

Jibin N Sunil
Journal club /24-09-2026



Introduction to Topology



Gauss-Bonnet Theorem: $\iint_M K dA = 2\pi\chi(M)$

For a Sphere $S^2(R)$: $K = \frac{1}{R^2}$

Euler Characteristic: $\chi(S^2) = 2$



Bánh Mì Khong(Vietnam)

+2



Vada(India)

0



Kringla(Norway)

-2



Pretzel(german)

-4



Churek(Iraq)

-6



Fougasse(France)

-8...

Introduction to Topology: K-space

Chern-Weil Formula: $C = \frac{1}{2\pi} \iint_{\text{BZ}} \Omega(\mathbf{k}) d^2k$

Berry Curvature / Connection: $\Omega(\mathbf{k}) = \nabla_{\mathbf{k}} \times \mathbf{A}(\mathbf{k}), \quad \mathbf{A}(\mathbf{k}) = i\langle u_{\mathbf{k}} | \nabla_{\mathbf{k}} | u_{\mathbf{k}} \rangle$

Topological Invariant: $C \in \mathbb{Z}$ (**Chern Number**)

Example



Berry Curvature (Dirac Cone): $\Omega_z(\mathbf{k}) = \frac{v_F^2 m}{2(v_F^2 k^2 + m^2)^{3/2}}$

Integrated Berry Curvature : $\iint_{\text{BZ}} \Omega_z(\mathbf{k}) dk_x dk_y = 2\pi$

Chern-Weil Formula: $C = \frac{1}{2\pi} \iint \Omega_z(\mathbf{k}) d^2k$

First Chern Number: $C = \frac{1}{2\pi}(\pi) = \frac{1}{2}$

Introduction to Topology: Chern numbers

$$C_{\text{tot}} = C_{\uparrow} + C_{\downarrow}$$

$$\text{TRS} : C_{\text{tot}} = 0$$

$$C_s = \frac{1}{2} (C_{\uparrow} - C_{\downarrow})$$

$$\nu = (C_{\uparrow} - C_{\downarrow}) \pmod{2} \quad \text{or} \quad \nu = C_s \pmod{2}$$

$\nu = 0$ – Trivial topology

$\nu = 1$ – Non-trivial topology

Magnetic field

Strain

Polarized light

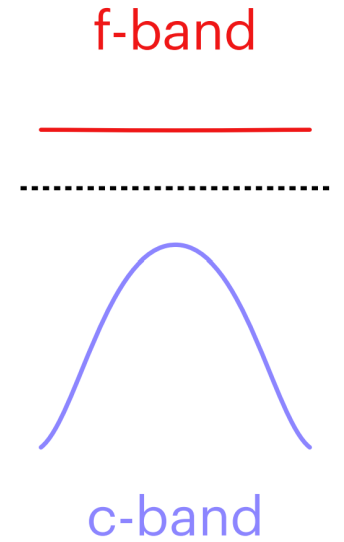
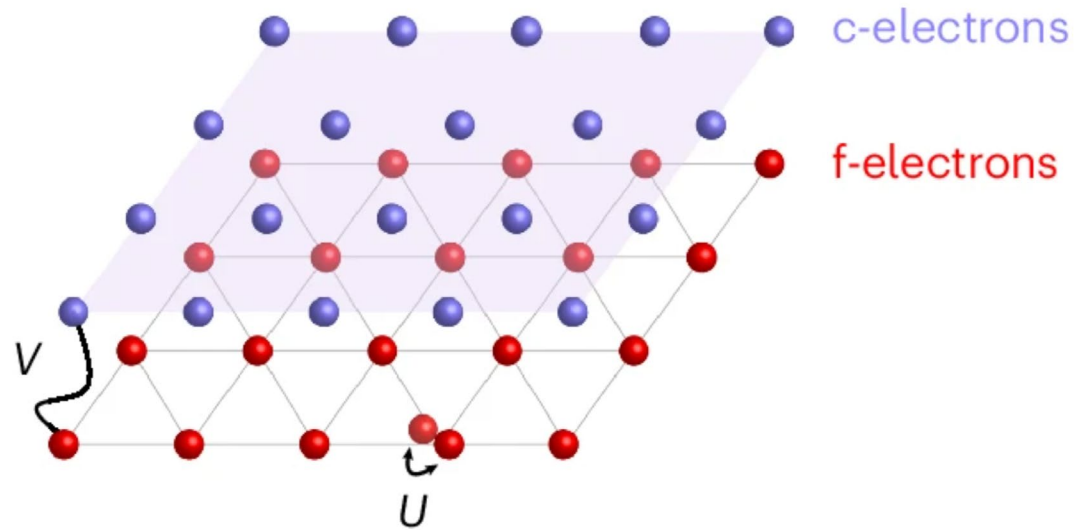
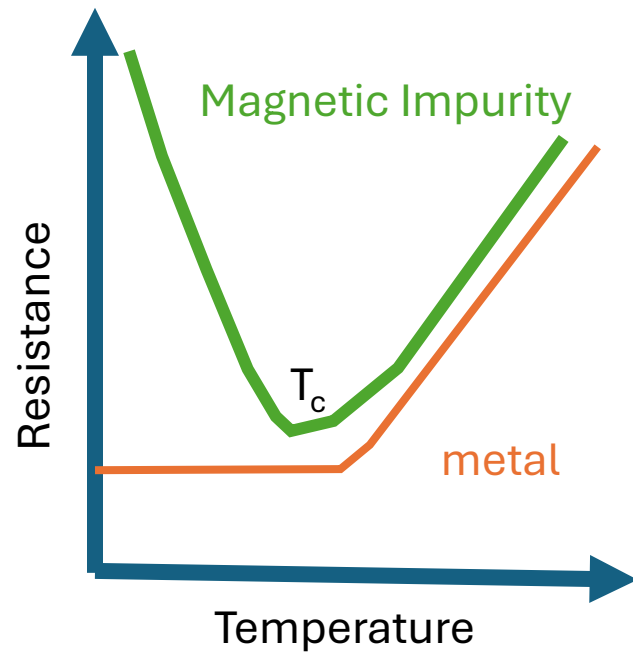
Displacement field

Carrier density

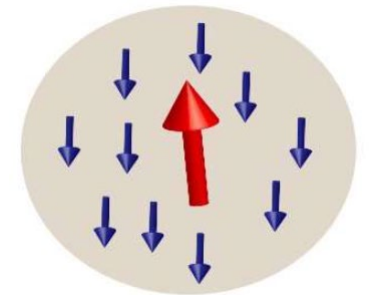
TRS Breaking Knobs

TRS Preserving Knobs

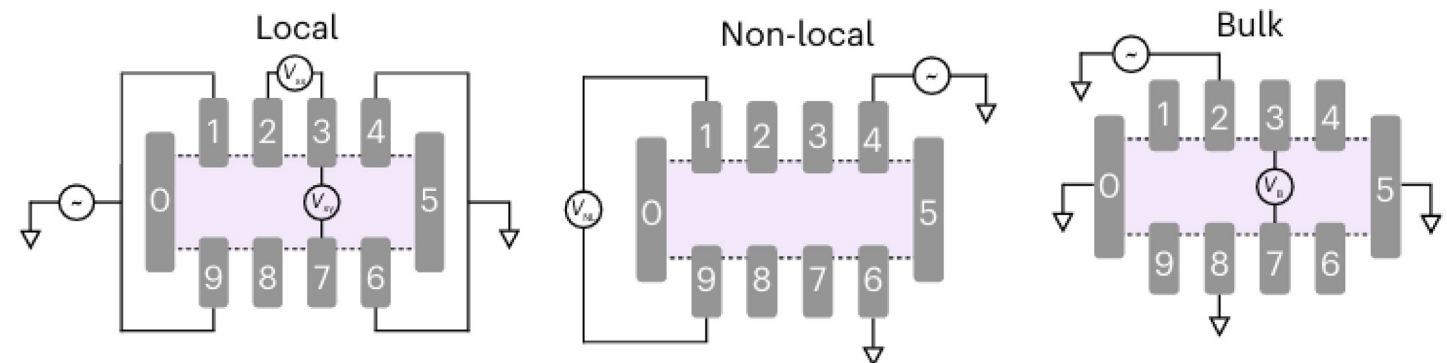
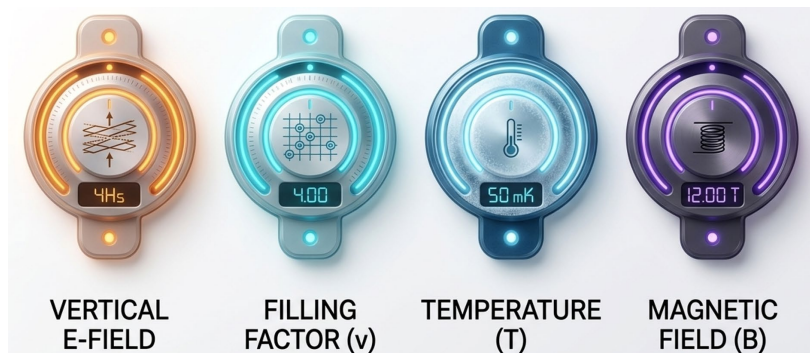
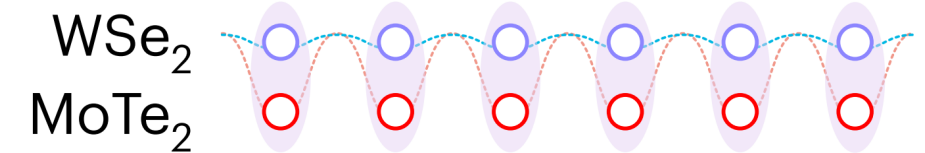
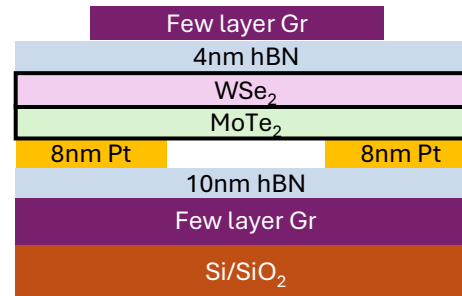
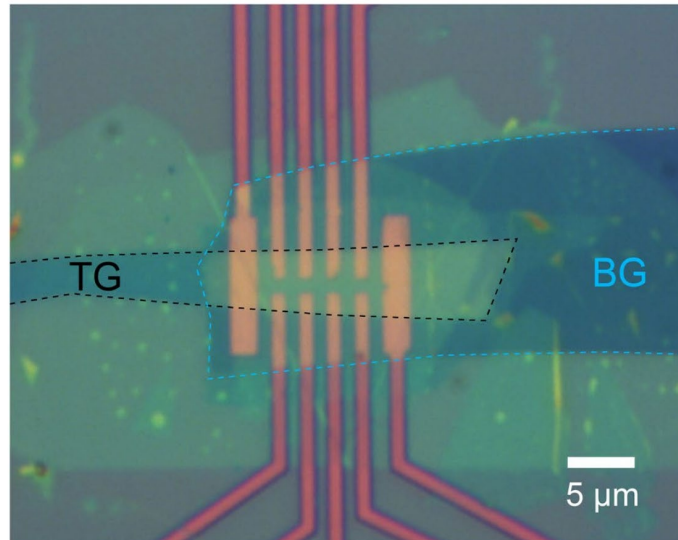
Kondo effect: Anderson lattice model



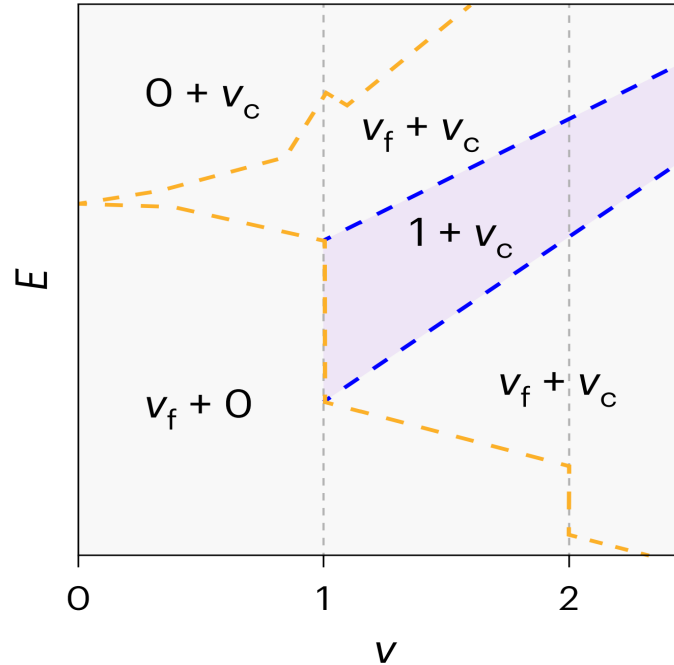
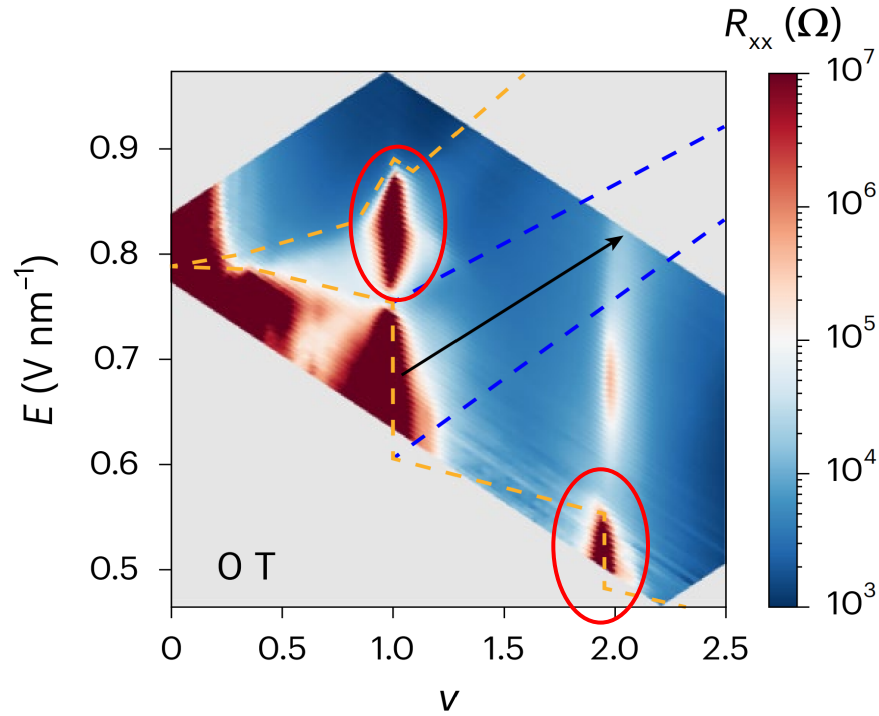
- **Conduction Band (c):** Itinerant, highly mobile c-electrons.
- **Localized f orbitals:** localized states below the Fermi level.
- **Hybridization (V):** Mixing amplitude between c- and f-electrons.
- **On-site Coulomb Interaction (U):** Preventing double occupancy of the f-orbital



Device structure



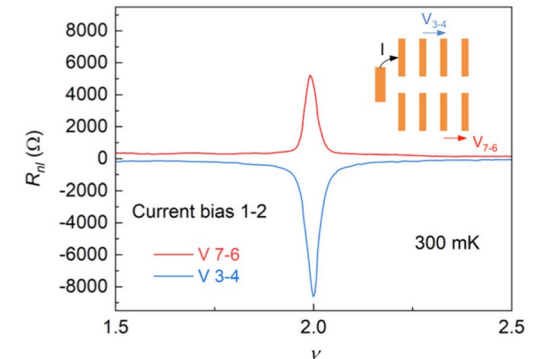
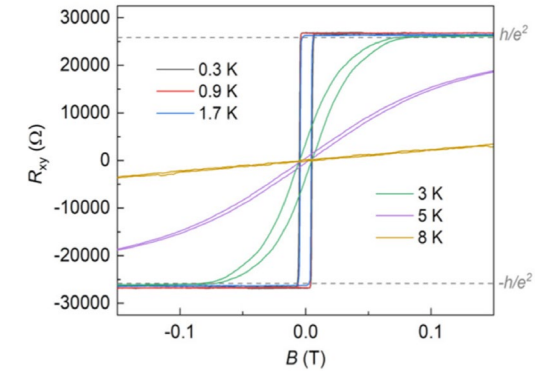
Introduction to Topology: Change C.



- Li et al., *Nature* **600**, 641–646 (2021)
- Zhao et al., *Nature* **616**, 61–65 (2023).
- Zhao et al., *Nat. Phys.* **20**, 275–280 (2024).
- Zhao et al., *Nat. Phys.* **20**, 1772–1777 (2024).
- Han et al., *Nat. Phys.* **22**, 396–401 (2026).

Li et al., *Nature* **600**, 641–646 (2021)

- Quantum anomalous Hall
- Quantum spin Hall insulator

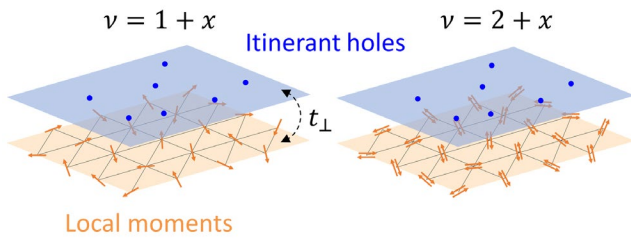
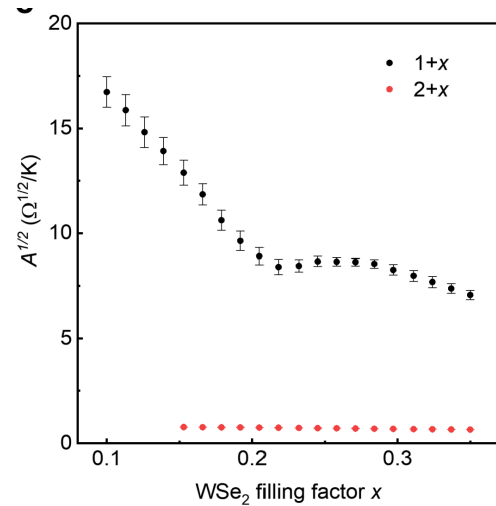


Topological non-trivial hopping

Introduction to Topology: Change C.

Zhao et al., *Nature* **616**, 61–65 (2023).

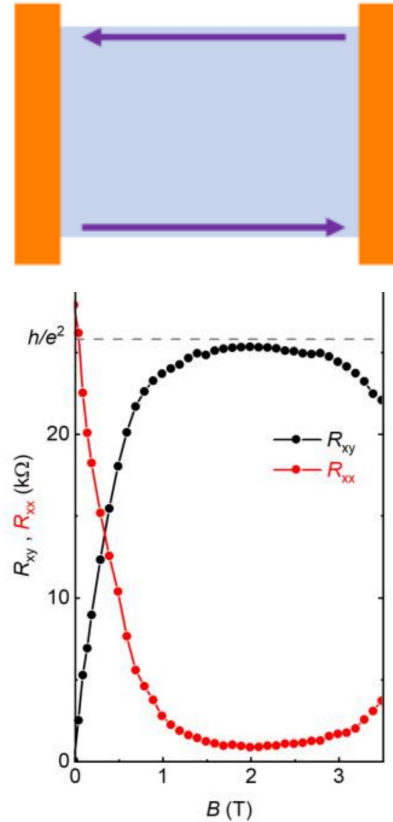
- Mott insulator
- Heavy fermi liquid



Kondo lattice band

Zhao et al., *Nat. Phys.* **20**, 275–280 (2024).

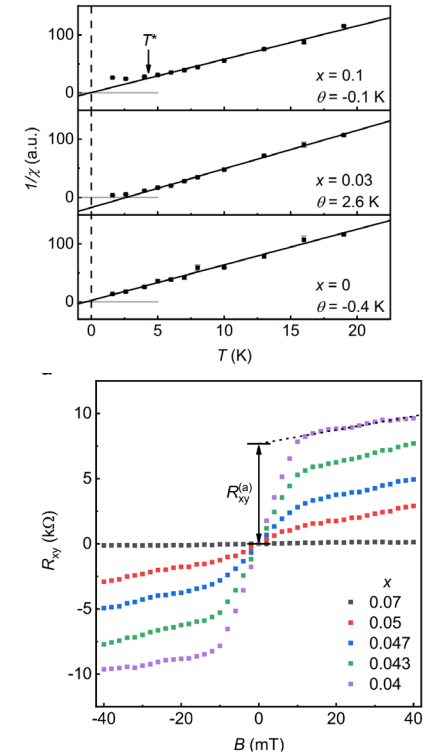
- Chern insulator



Another non-trivial phase

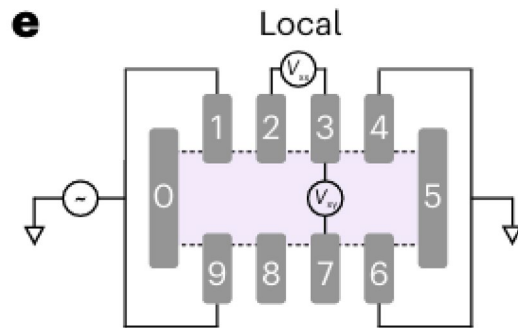
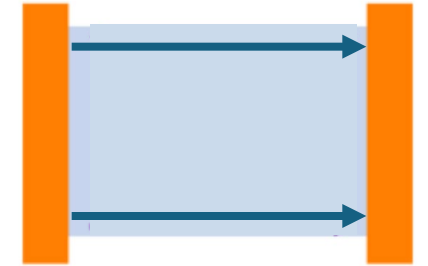
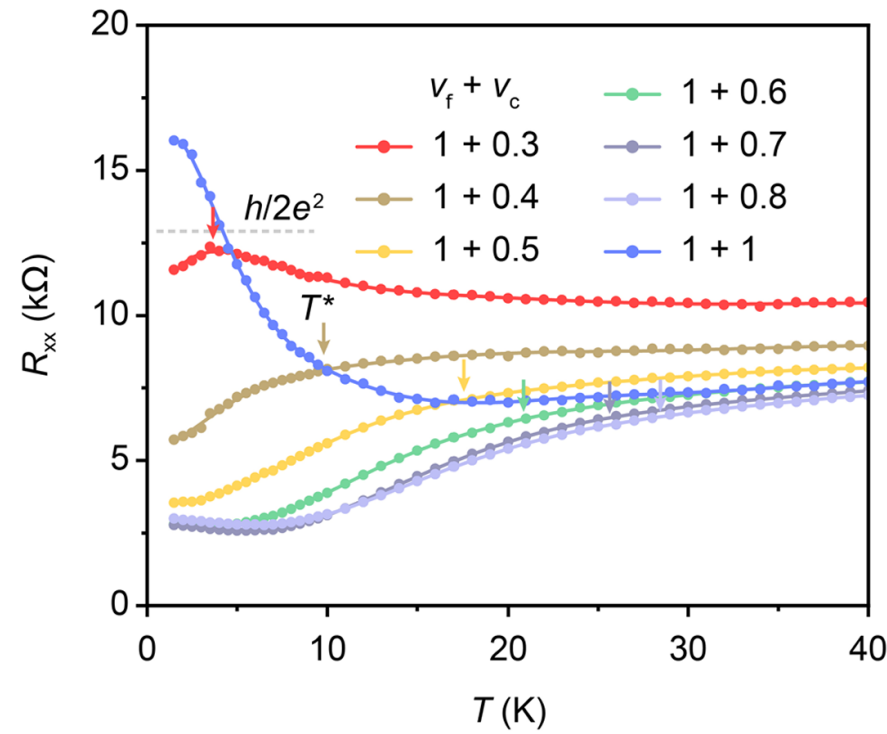
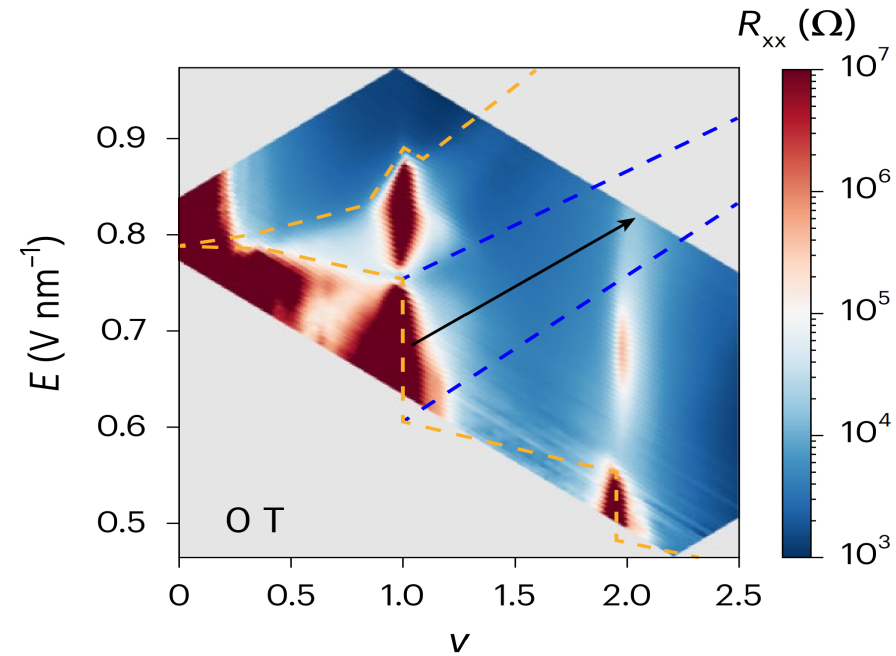
Zhao et al., *Nat. Phys.* **20**, 1772–1777 (2024).

- Ferromagnetism at kondo singlet breaking



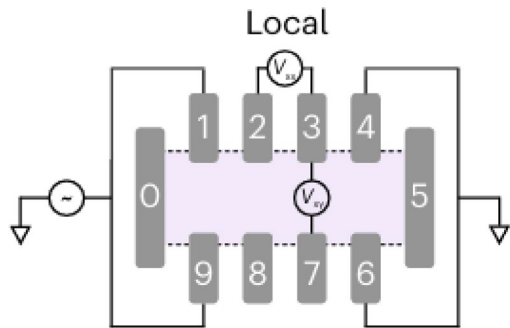
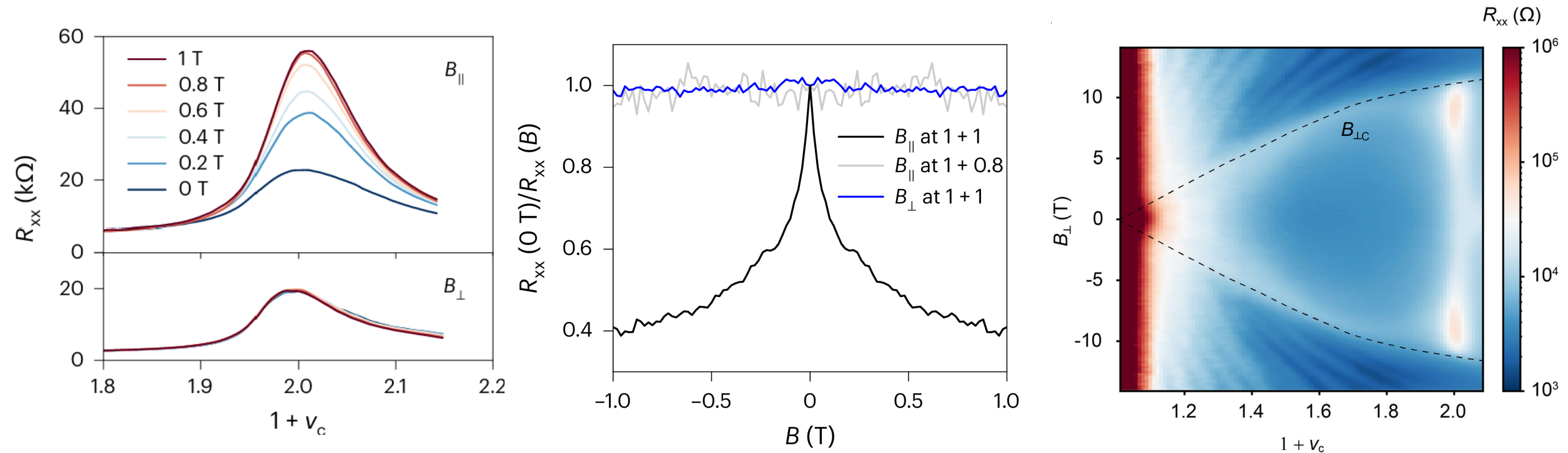
Kondo lattice melting

1. Temperature dependence of Local Resistance

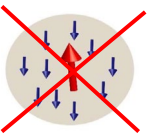


- Increase in resistance below a 30K
- R_{xx} saturates close to – half resistance quanta ($h/2e^2$)

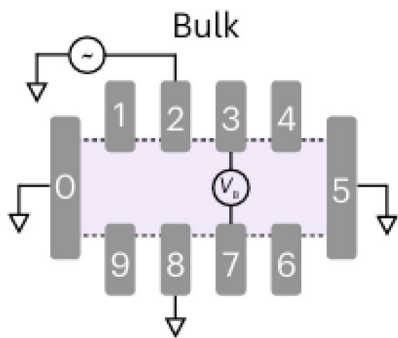
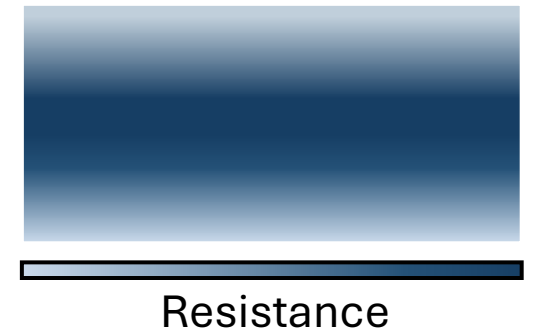
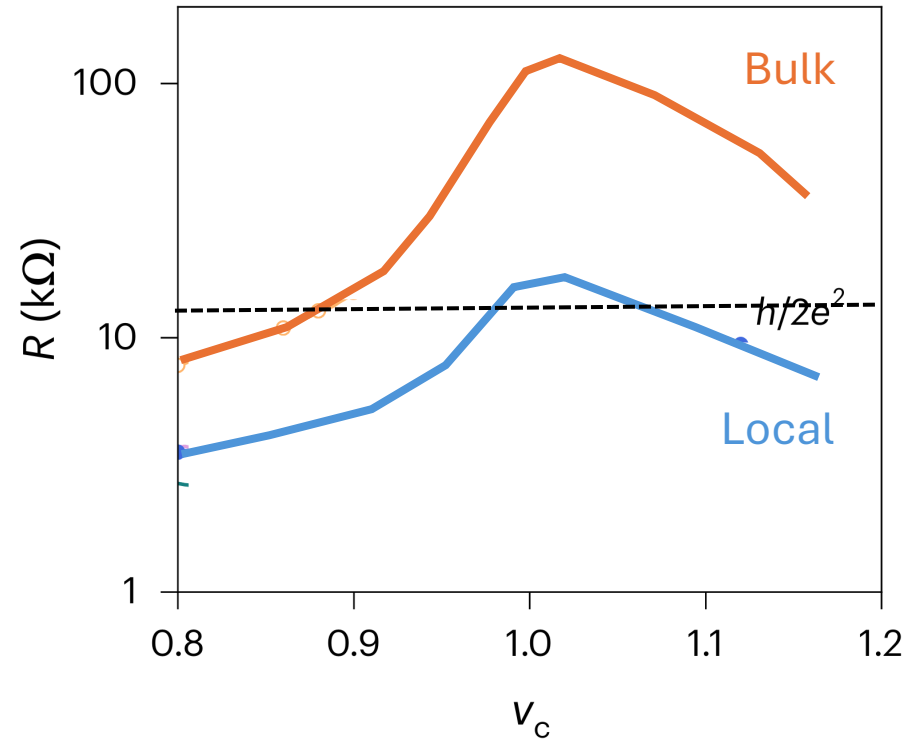
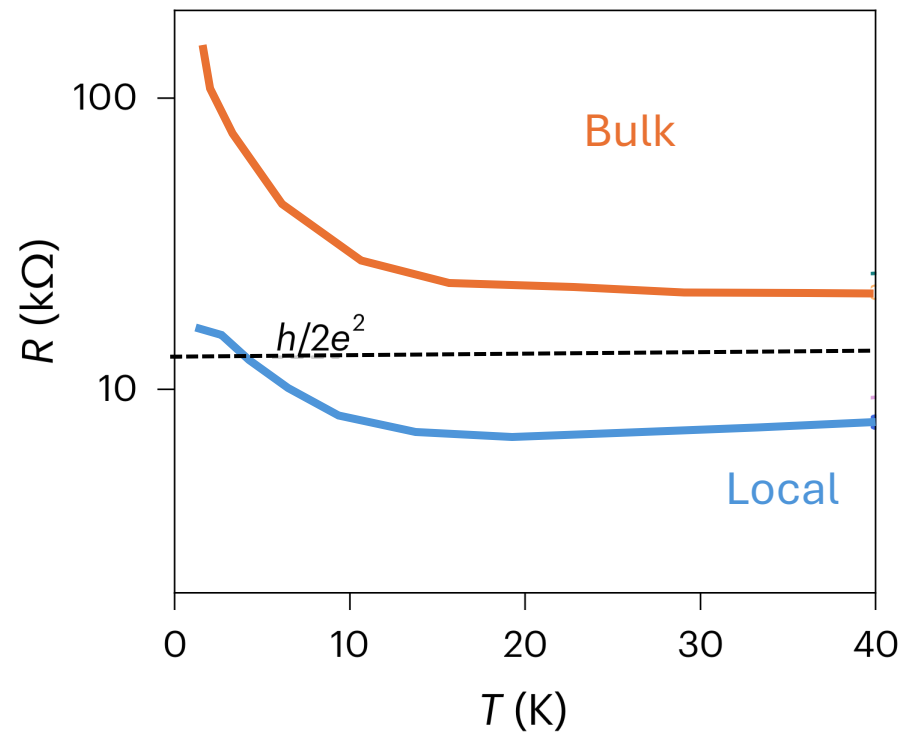
2. Magnetic field dependence of Local Resistance



- In plane magnetic field break TRS and allows scattering
- Conductance at other filling factors doesn't change with B
- SdH oscillations appear above a critical out of plane B

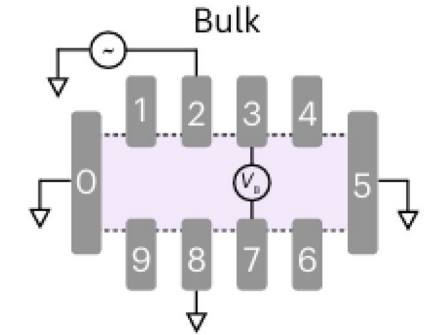
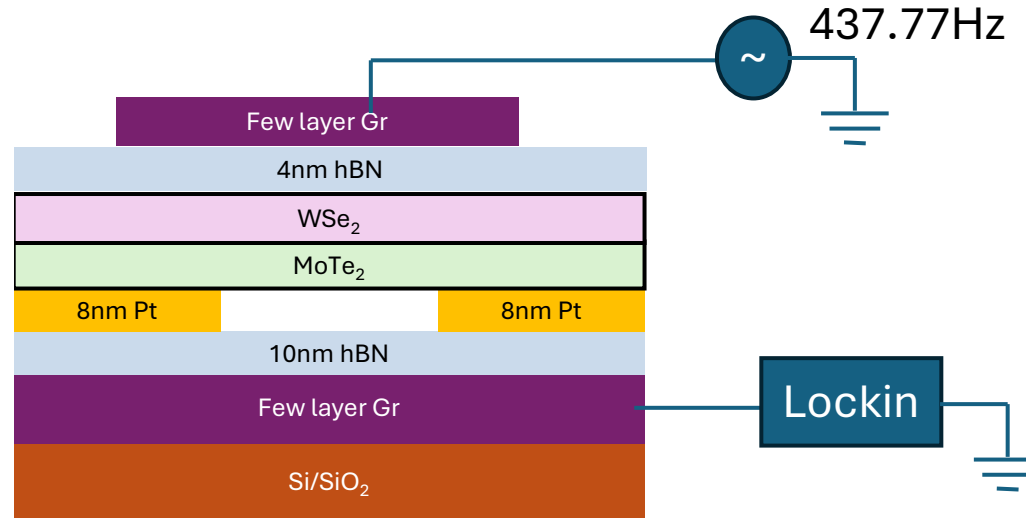
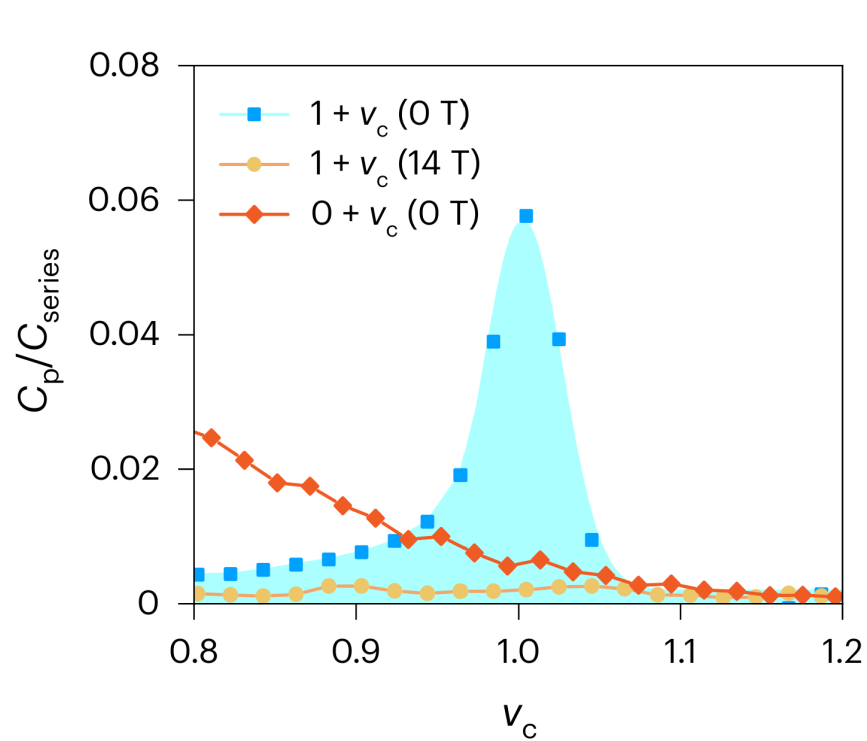


3. Bulk Resistance



- Bulk is resistive compared to the edges
- Bulk Resistance peaks at $1+1$ filling factor

4. Compressibility Measurements



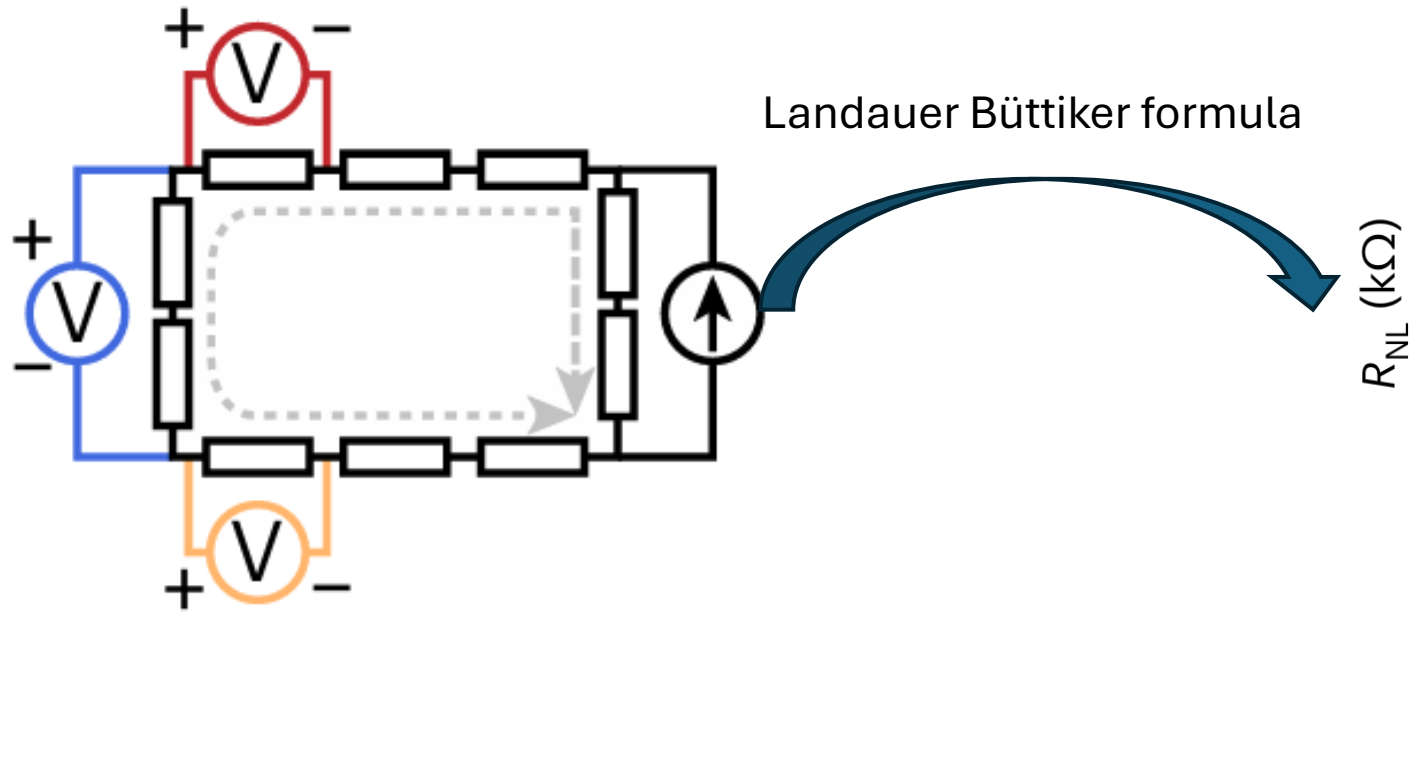
Electronic Compressibility & DOS: $\kappa = \frac{1}{n^2} \frac{dn}{d\mu} = \frac{1}{n^2} D(\mu)$

Metallic / Compressible $\left(\frac{dn}{d\mu} \rightarrow \infty \right)$: $C_q \rightarrow \infty \Rightarrow \frac{C_p}{C_{series}} \rightarrow 0$

Incompressible Gap $\left(\frac{dn}{d\mu} \rightarrow 0 \right)$: $C_q \rightarrow 0 \Rightarrow \frac{C_p}{C_{series}} \rightarrow \text{Peak}$

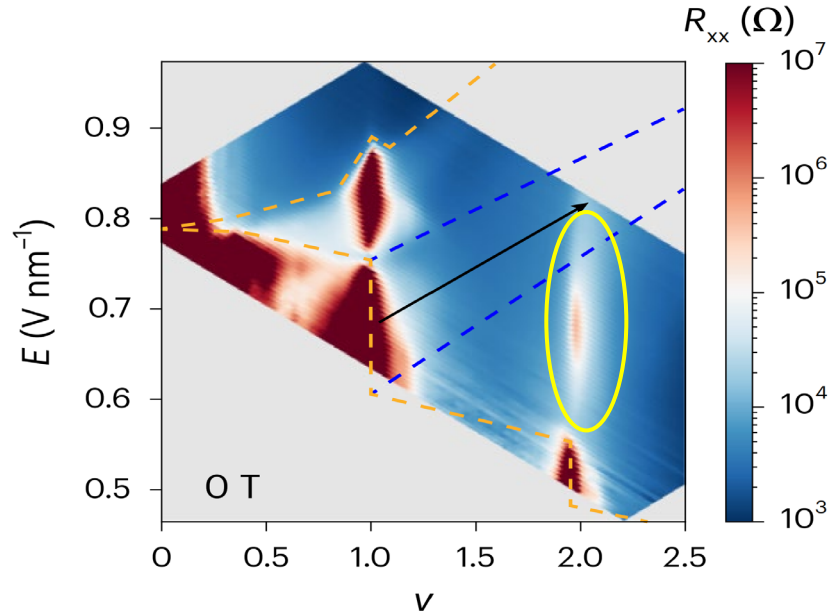
Compressibility measures the DOS of the system
Incompressibility peak disappears after kondo breakdown
Holes in W shows compressible behavior.

5. Non Local Resistance

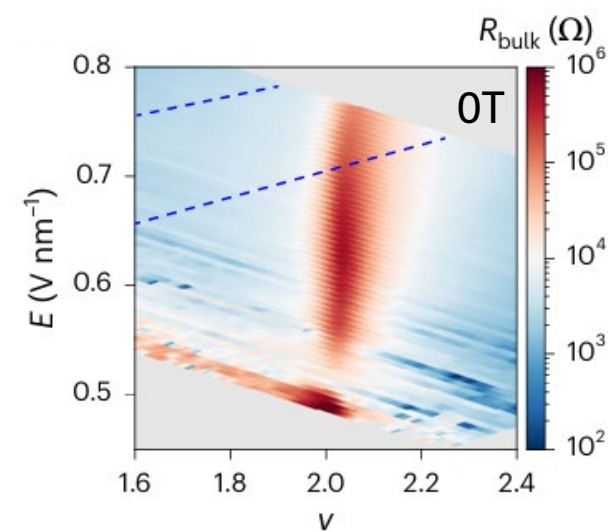
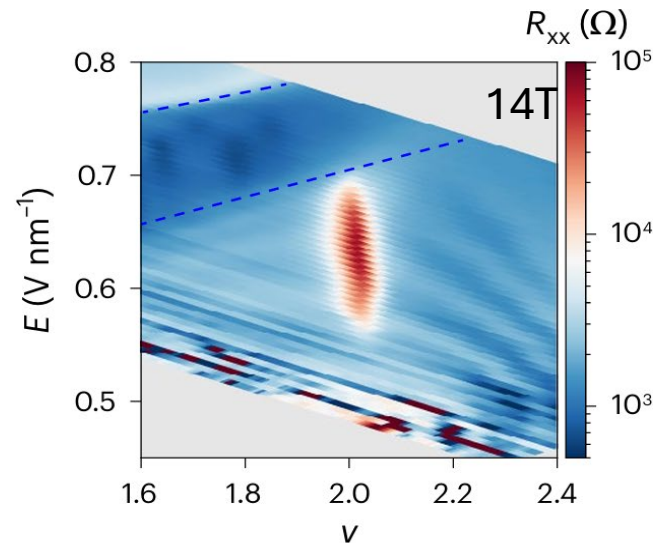
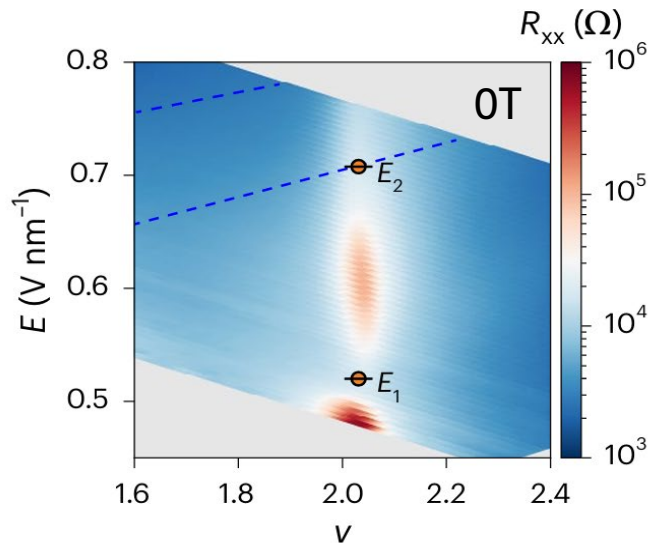


- NL resistance peaks near $\nu_c = 1$
- Supports edge conduction
- $R_{98,46} \approx -R_{12,46}$ highlight edge transport

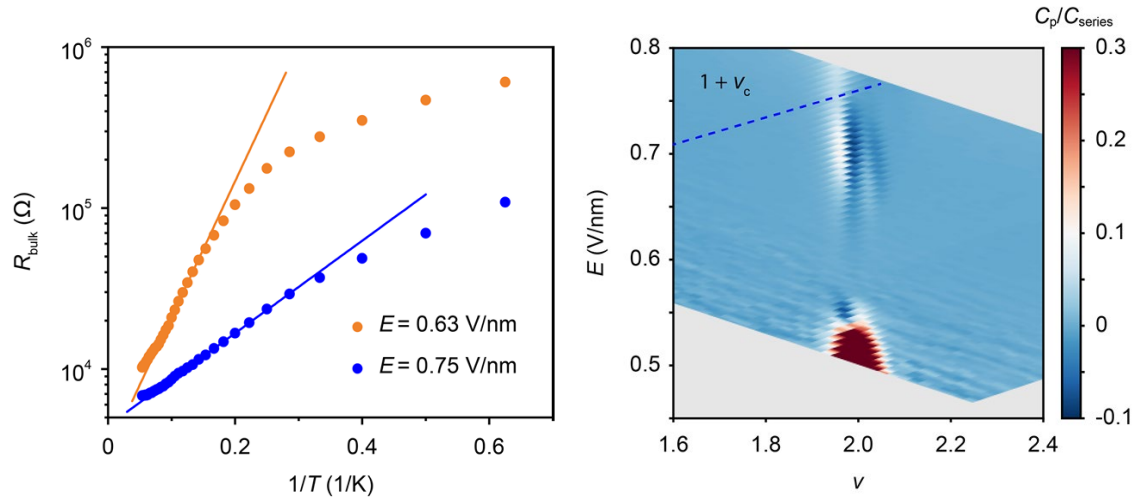
Mixed valence state



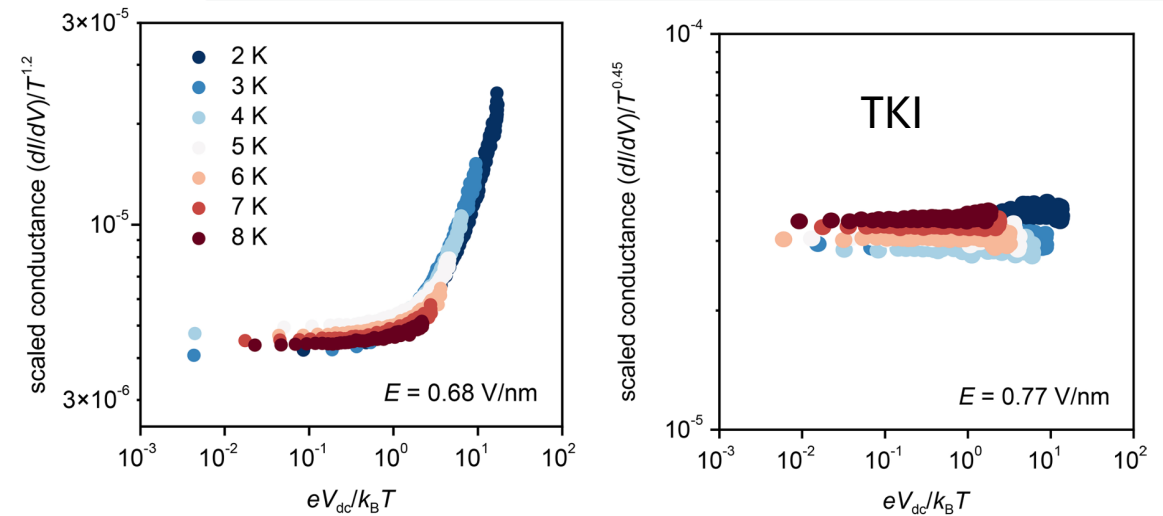
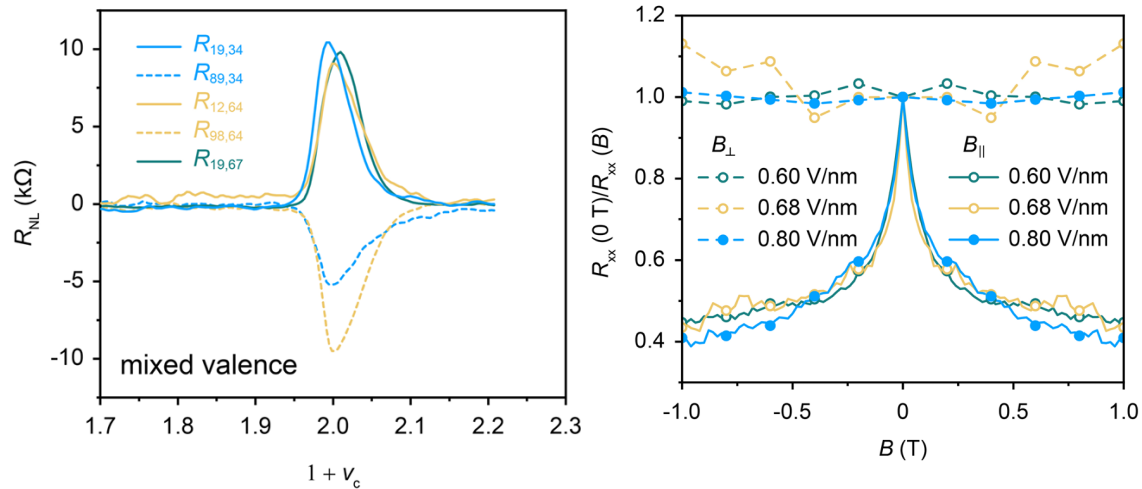
- Comparable Bulk and local resistance
- State is unaffected even at Higher B
- insulating temperature dependence of the resistances
- non-zero incompressibility



Mixed valence state



- Comparable Bulk and local resistance
- State is unaffected even at Higher B
- insulating temperature dependence of the resistances
- non-zero incompressibility
- Non local resistance far exceeds $\frac{h}{e^2}$ with electrode configuration dependence
- Anisotropic magnetoresistance.
- Luttinger liquid behaviour from bias dependence



Conclusion

- Realized Topological kondo insulator in 2d for the first time
- Multi-terminal transport and compressibility measurements confirm an insulating bulk
- Non-local voltage measurements match Landauer–Büttiker circuit predictions
- Spin- S_z Protection & Anisotropy
- Gate-tunable platform to explore heavy-fermion physics, strong correlation, and non-trivial topology in 2D

Thankyou



