APS Satellite Meeting, 2022, ICTS Bangalore

Broken-symmetry states at half-integer band fillings in twisted bilayer graphene

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Reference

Bhowmik et al. arXiv:2108.12689, 2021 [Nature Physics, In Press]

Funding

New phenomenology at fractional fillings in zero magnetic field

Fractional Quantum Hall States at Zero Magnetic Field

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Nearly Flatbands with Nontrivial Topology

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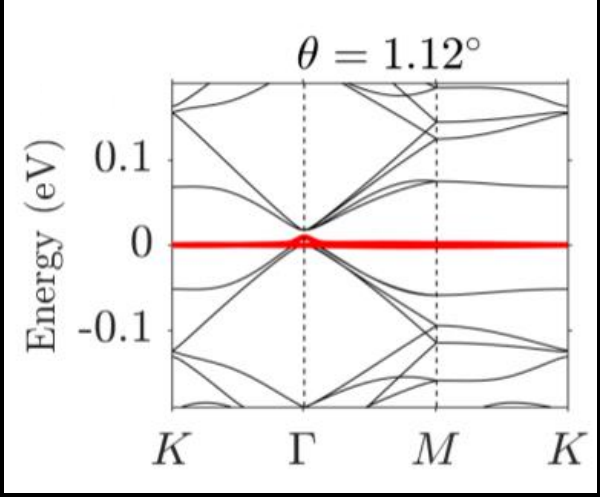
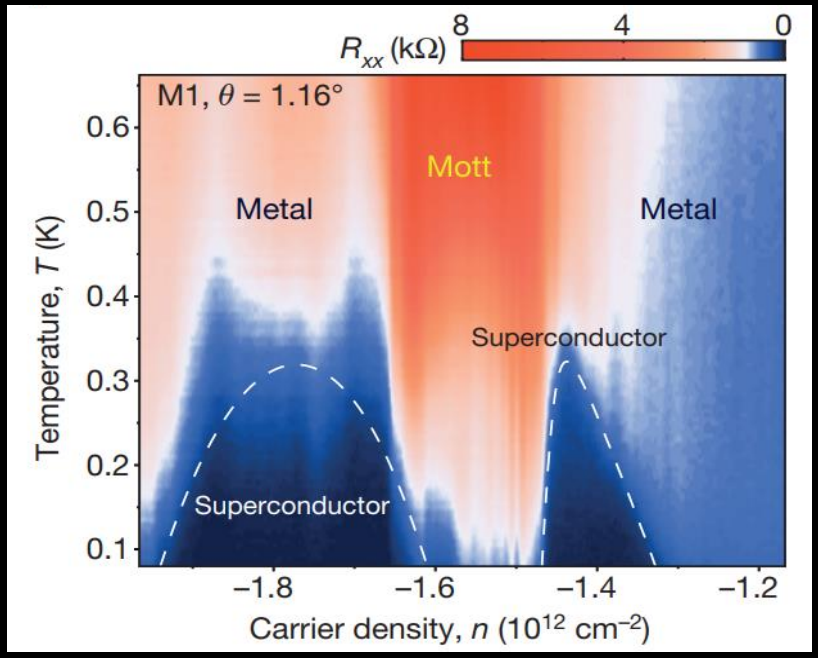


Low-energy ultra flat bands are essential ingredient

Carr et al. PhysRevB.98.085144 (2018)

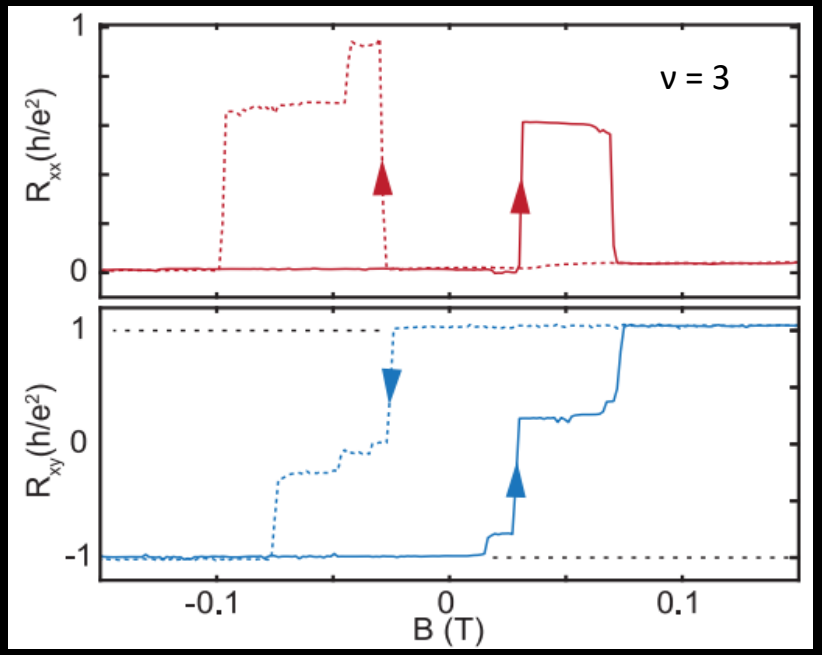
Novel phases within moiré flat bands at zero B-field

Superconductivity



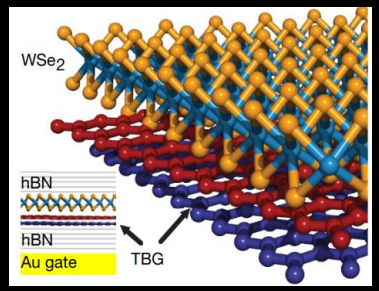
Cao et al. *Nature* 556.7699 (2018): 80-84.

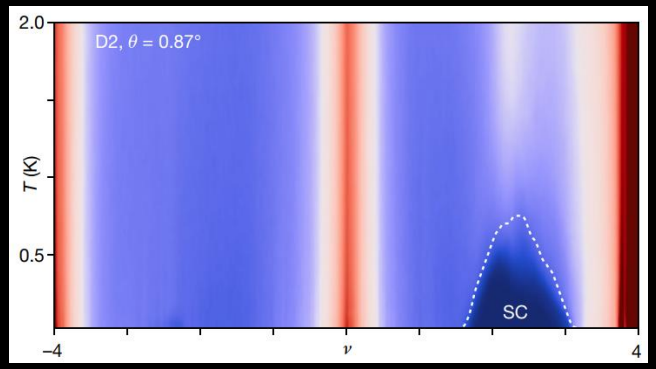
Ferromagnetism



Serlin et al. *Science* 367.6480 (2020): 900-903.

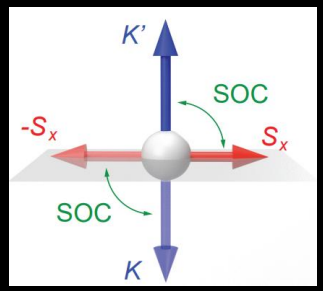
Phases are tunable with dielectric environment

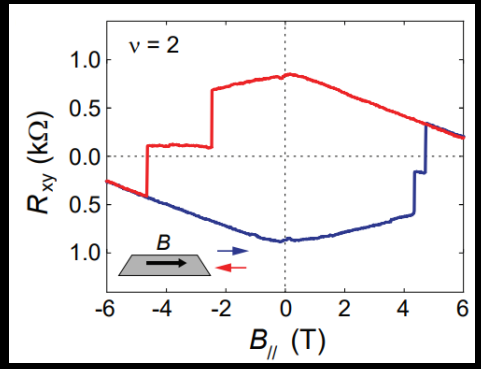




SC at non-magic angles in presence of tungsten diselenide

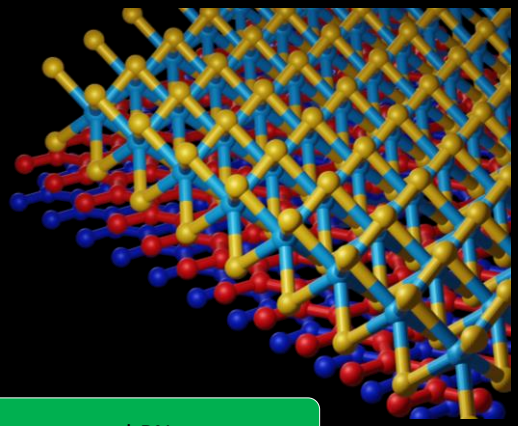
Arora et al. *Nature* 583.7816 (2020): 379-384.

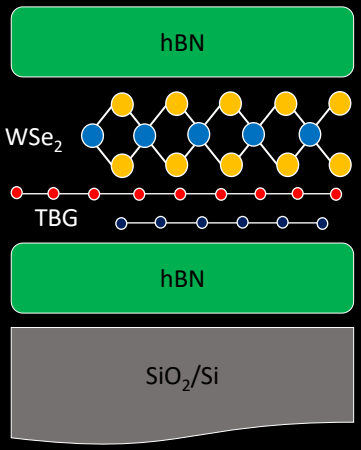




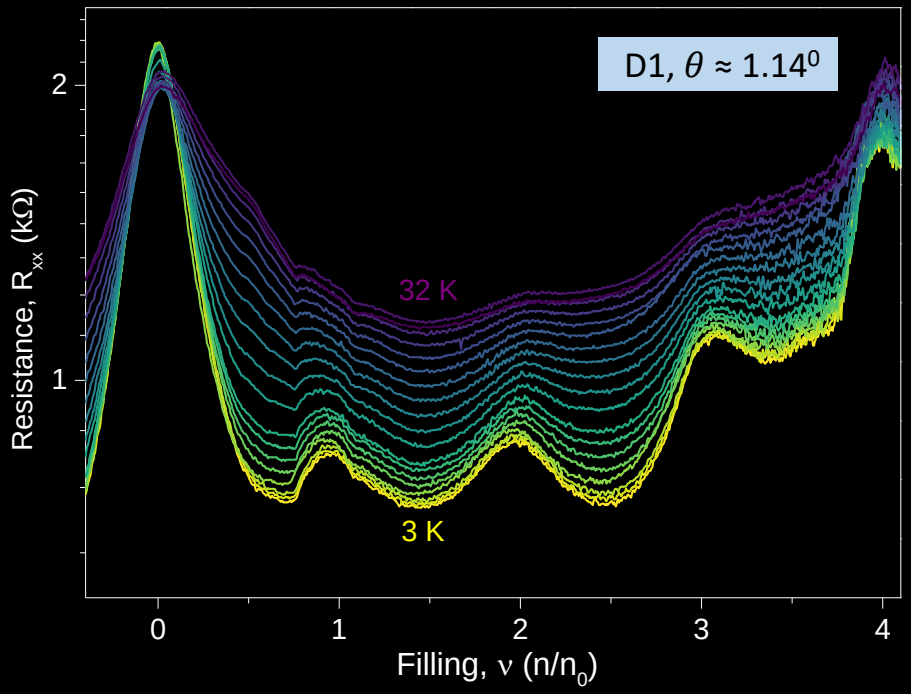
SOC-driven ferromagnetism

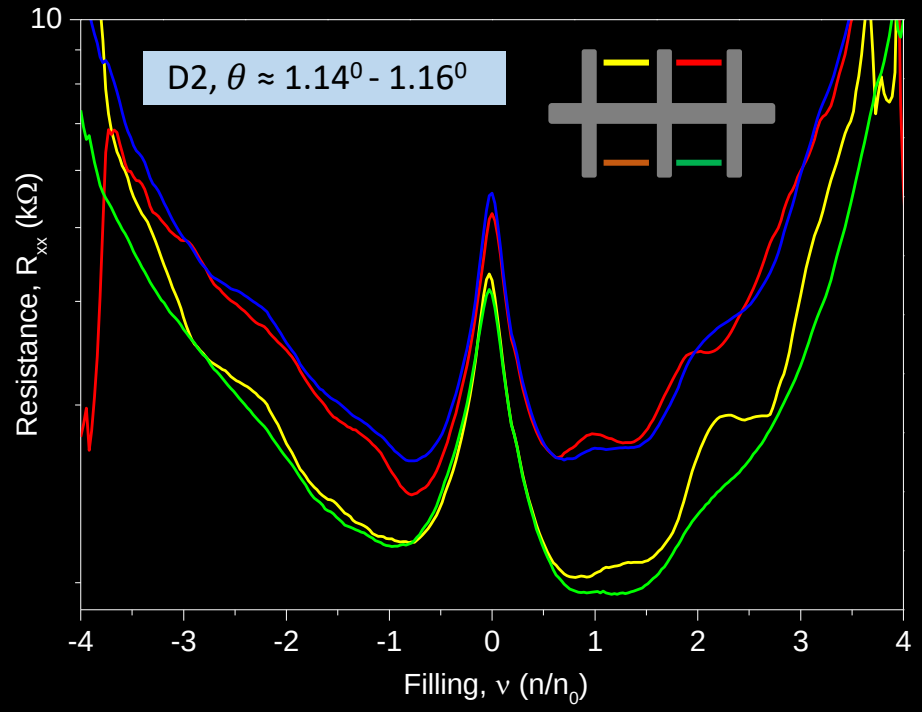
Lin et al. *Science* 375, 437–441 (2022).





Basic electrical characterization of the devices

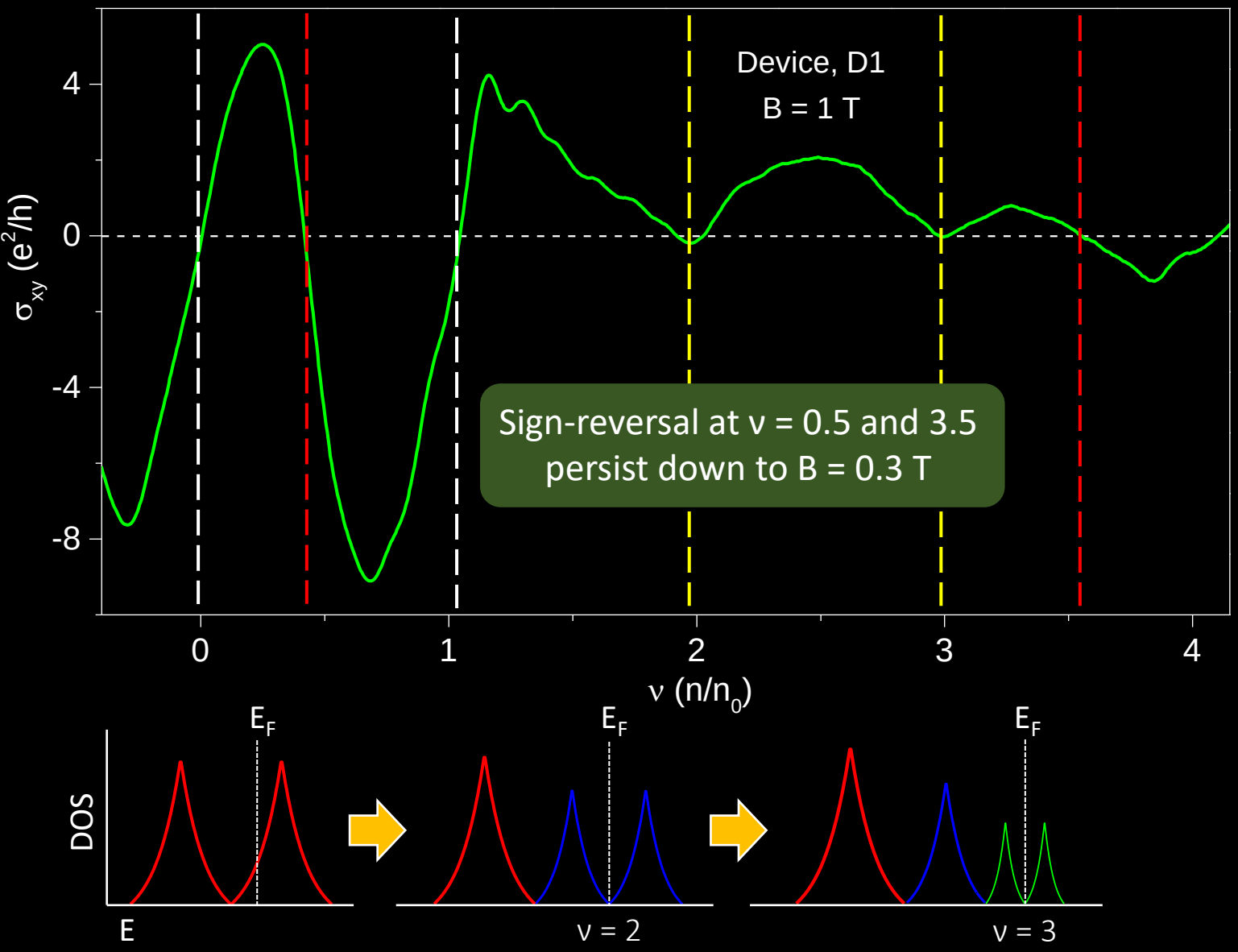




- Peaks in resistance at integer fillings.
- Twist angle homogeneity across various contact configurations.

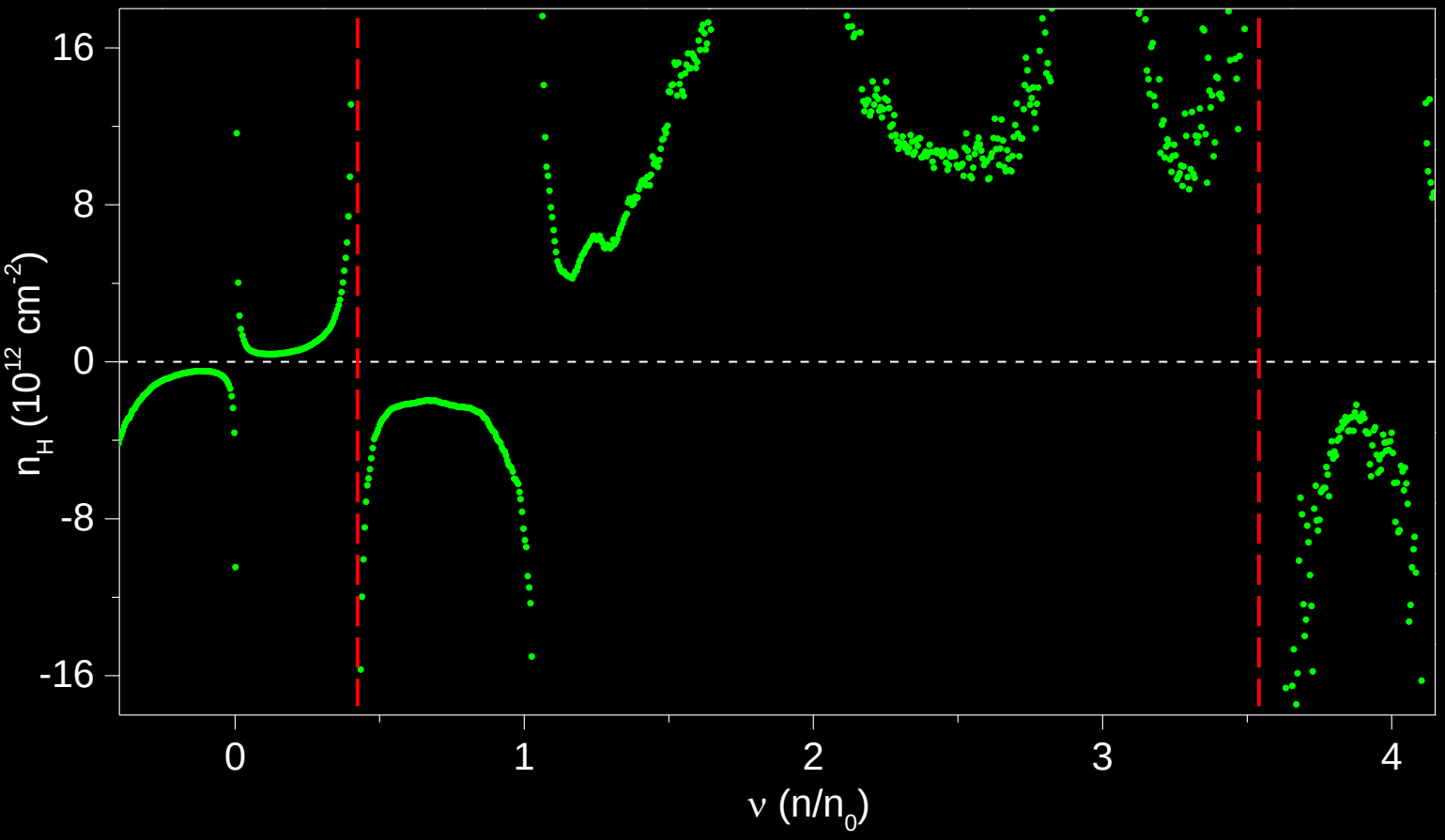
Bhowmik et al. Nature Physics, In Press

States at half-integer band fillings at low B-field



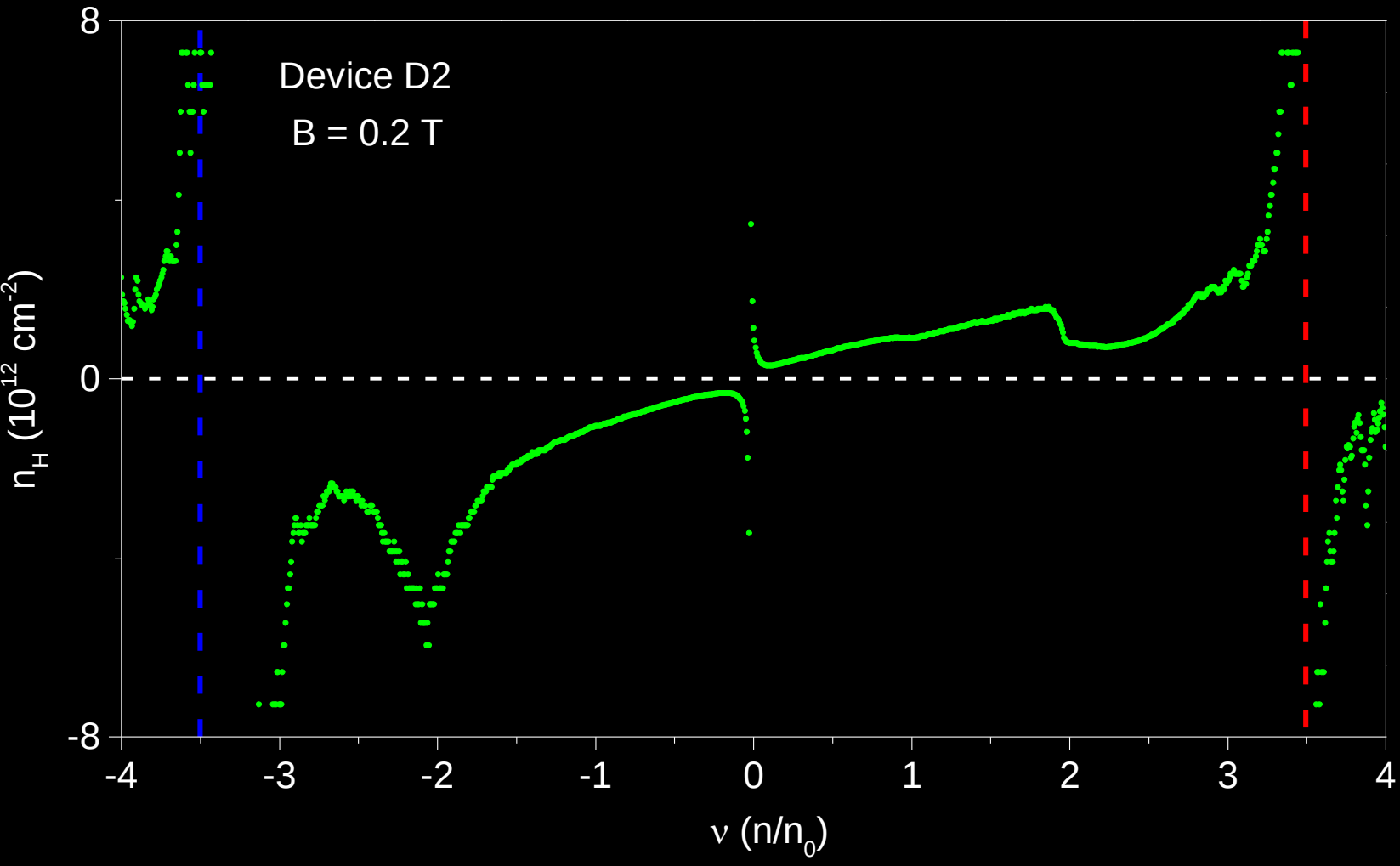
Wu et al. *Nat. Mater*. 20, 488–494 (2021).

States at half-integer band fillings at low B-field

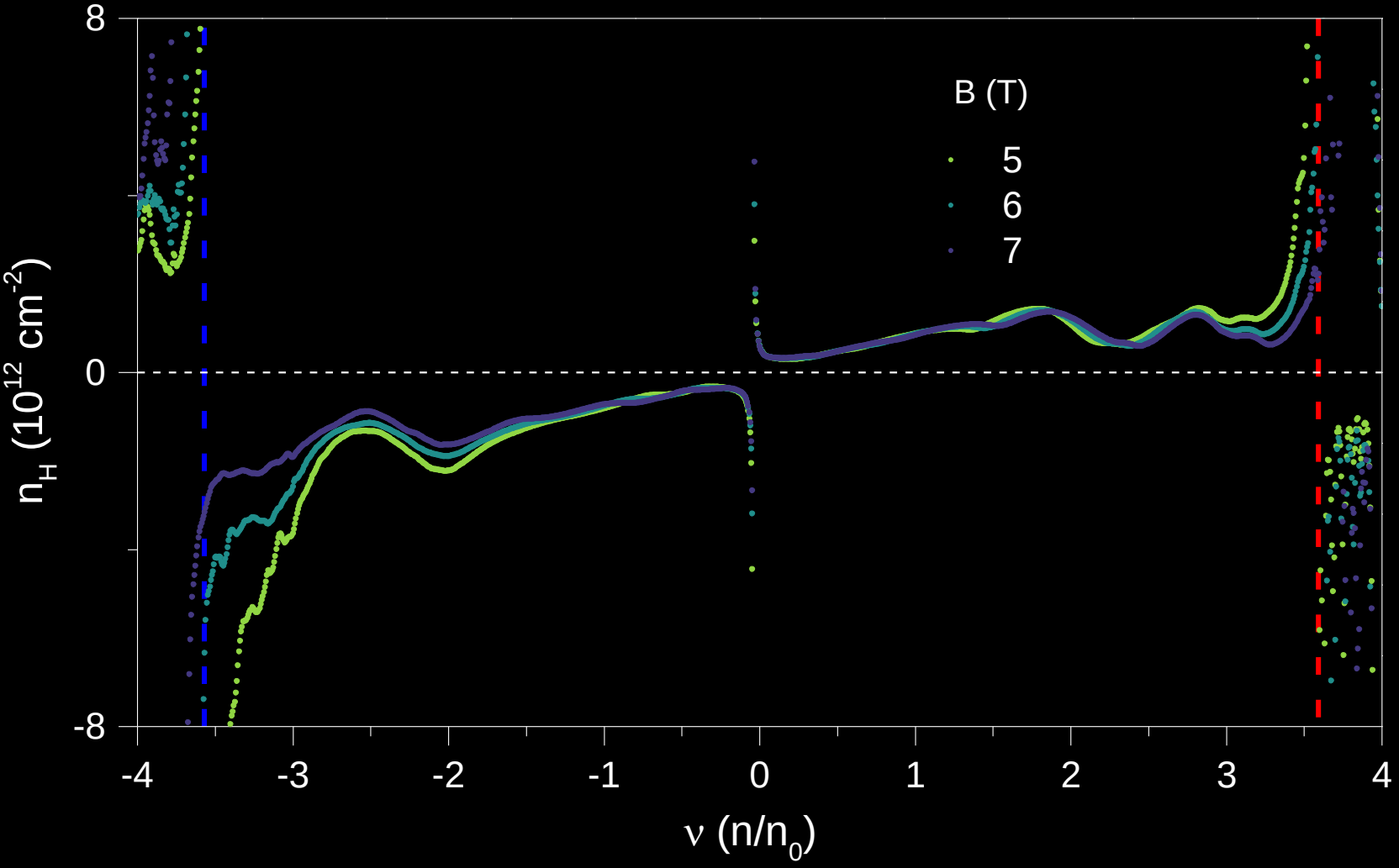


- Sign-reversal at ν = 0.5 and 3.5.
- They persist down to B = 0.3 T.

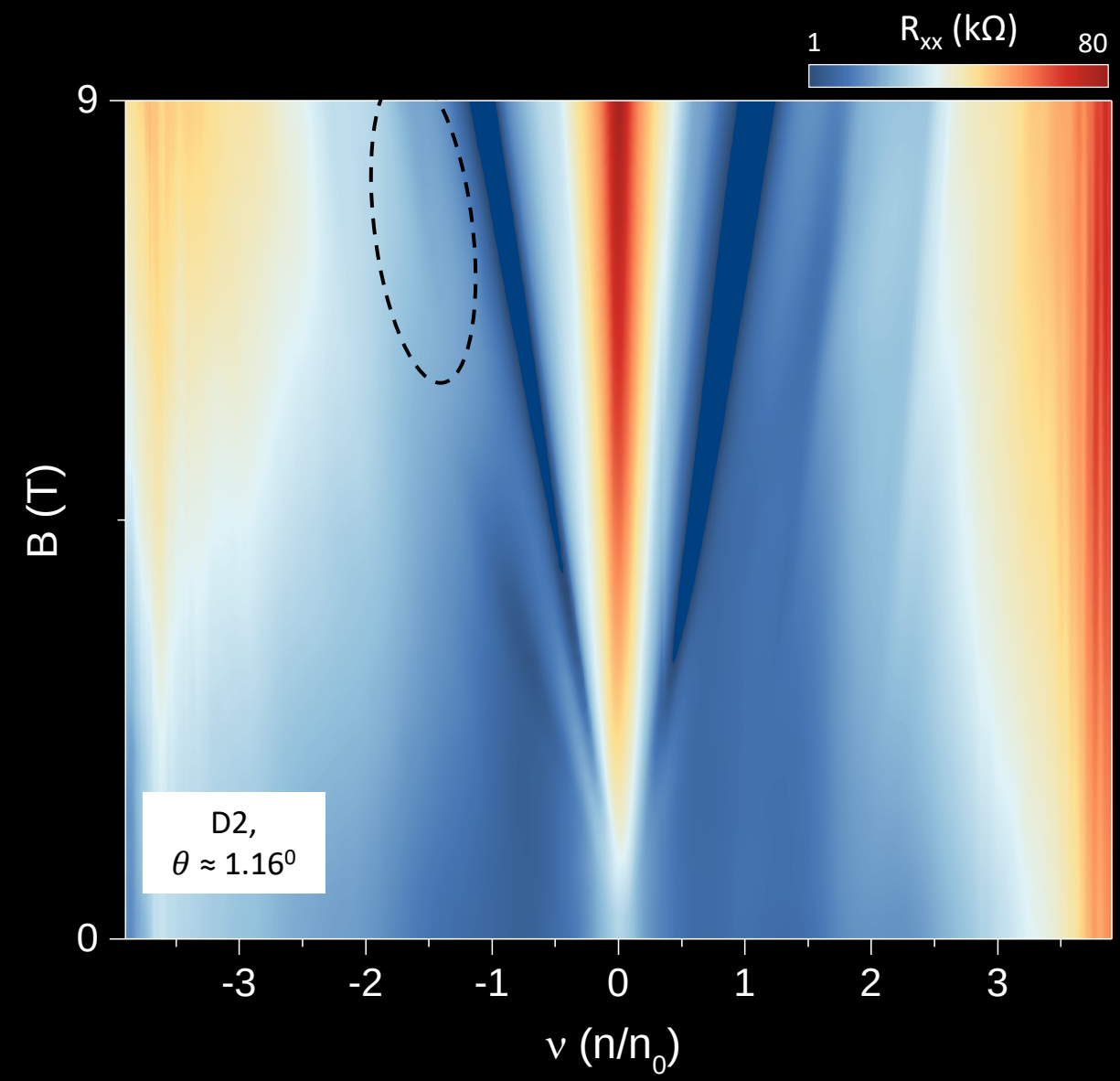
Sign-reversal at ν = +/- 3.5 at low field in device D2



ν = +/- 3.5 persists throughout the entire B-field range

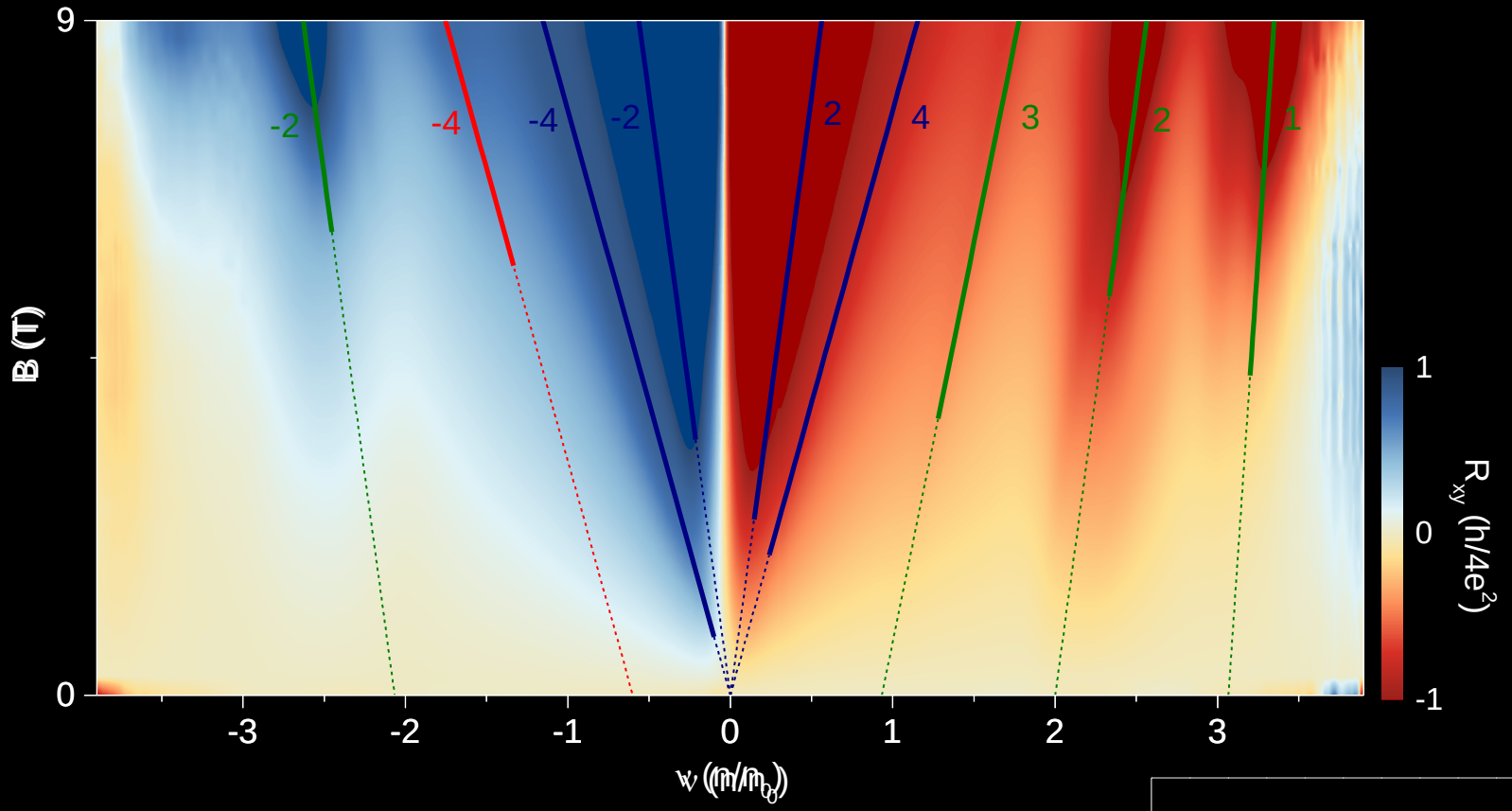


Landau Fan diagram

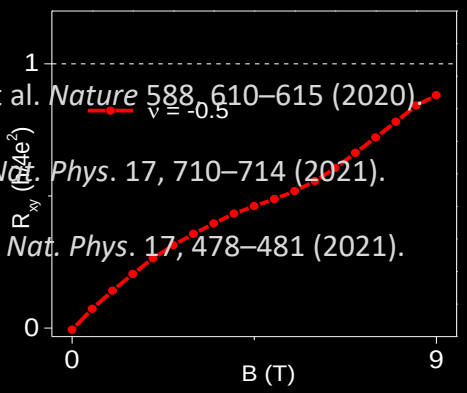


- Linearly dispersing resistance minima from integer fillings.
- A new state appears at ν = -0.5

Correlated Chern Insulators



- Wedge-like resistive features from different fillings are characterized by Chern number C
- Symmetry-broken Chern insulator appears at ν = -0.5

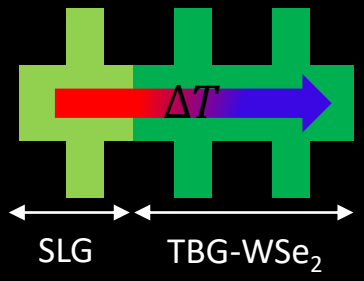


Nuckolls et al. *Nature* 588, 610–615 (2020).

Das et al. *Nat. Phys*. 17, 710–714 (2021).

Saito et al. *Nat. Phys*. 17, 478–481 (2021).

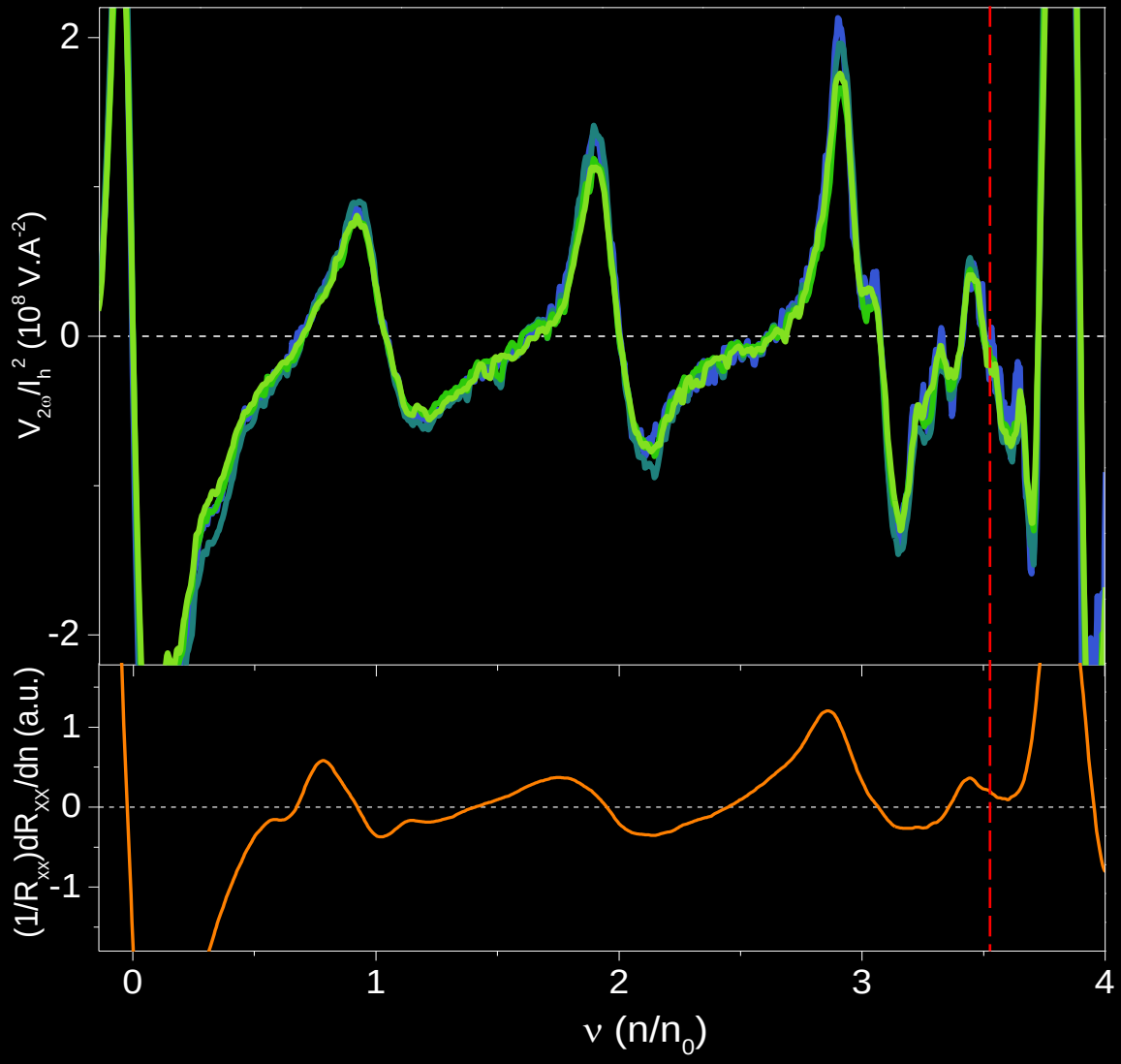
Zero-field thermoelectricity



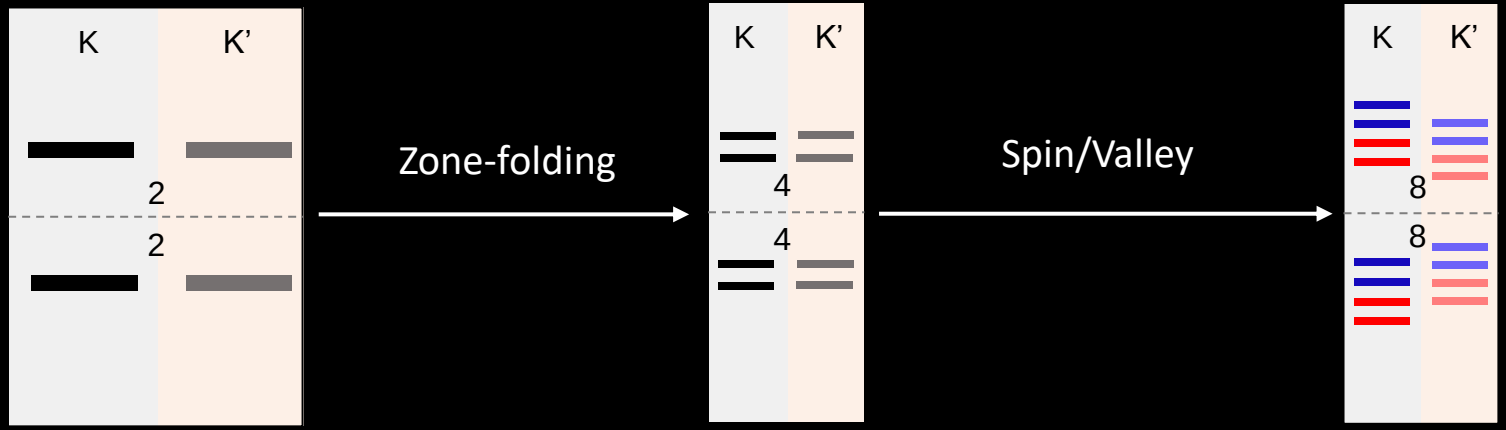
$$S_{Mott} = \frac{\pi^2 k_B T}{3|e|} \frac{1}{R} \frac{dR}{dn} \frac{dn}{dE}$$

- The state at ν = 3.5 appears at B = 0 T.

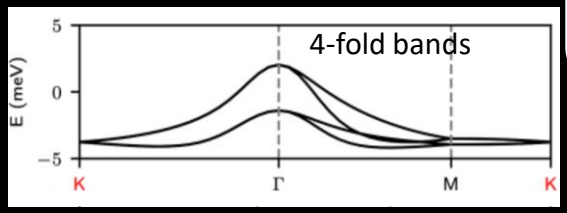
Ghawri, B. et al. (*Nature Communications,* In Press, arXiv:2004.12356)



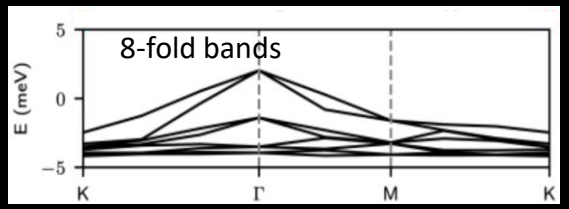
Spin/charge density-driven doubled unit cell



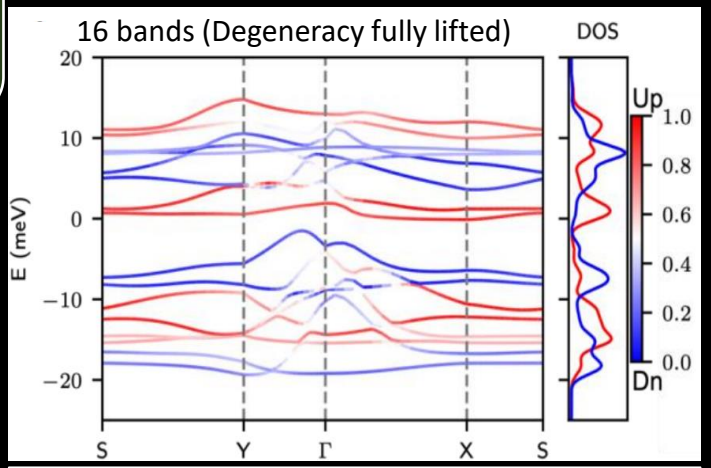
Degeneracy lifting of the folded bands explains the states at ν = 0.5 and 3.5 and a symmetry-broken Chern insulator at ν = -0.5



$H = H_{TBG}$



$H = H_{TBG} + H_{Density\ Wave}$



$H = H_{TBG} + H_{Density\ Wave} + H_{Mass} + H_{Kane\text{-}Mele} + H_{Rashba}$

Theory calculations by Jeil Jung, Nicolas Leconte, S. Appalakondaiah, Dongkyu Lee (University of Seoul)

Summary

- Translational symmetry-broken states appear at half-integer fillings.
- They persist down to zero field which suggests the existence of a spin/charge density wave ground state.
- TMDC dielectrics may be a promising pathway to realize correlated states at fractional fillings.

"Emergence of broken-symmetry states at half-integer band fillings in twisted bilayer graphene" (arXiv:2108.12689, 2021) [Nature Physics, In Press]

Saisab Bhowmik, Bhaskar Ghawri, Nicolas Leconte, S. Appalakondaiah, Mrityunjay Pandey, P. S. Mahapatra, Dongkyu Lee, K. Watanabe, T. Taniguchi, Jeil Jung, Arindam Ghosh and U. Chandni

hBN crystal: Takashi Taniguchi (Research Center for Functional Materials, NIMS, Japan)
Kenji Watanabe (International Center for Materials Nanoarchitectonics, NIMS, Japan)