

Ferromagnetism near three-quarters filling in twisted bilayer graphene

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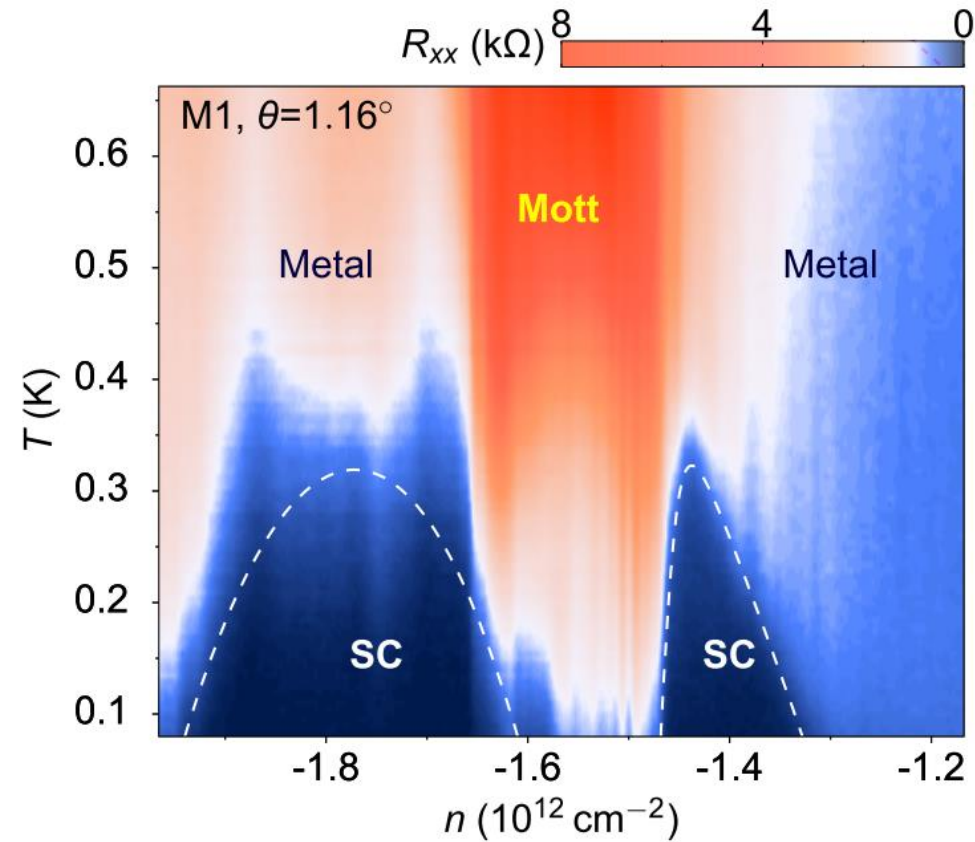
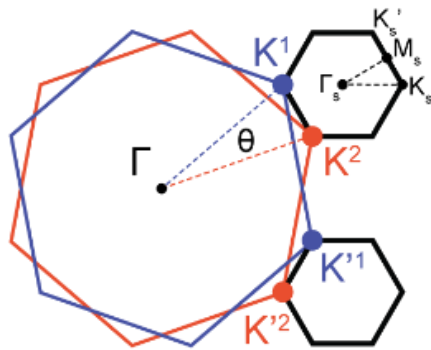
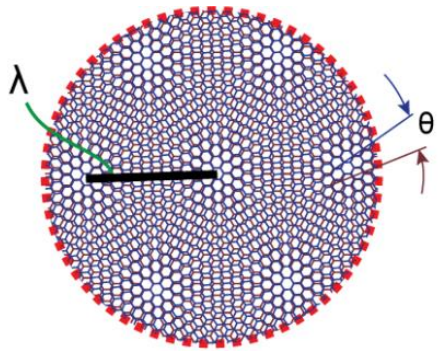
E. Fox, A. Barnard, J. Finney,
K. Watanabe, T. Taniguchi,
M. Kastner, D. Goldhaber-Gordon

arXiv: 1901.03520

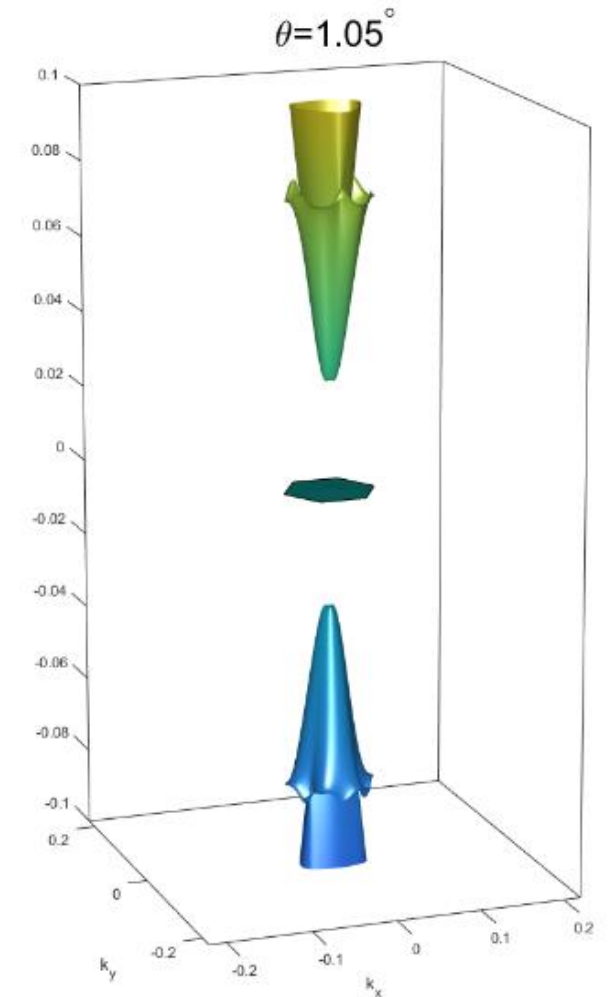


Strong Correlations

Twisted bilayer graphene provides unprecedented control of correlations in 2D electron systems



Cao, *Nature* (2018)



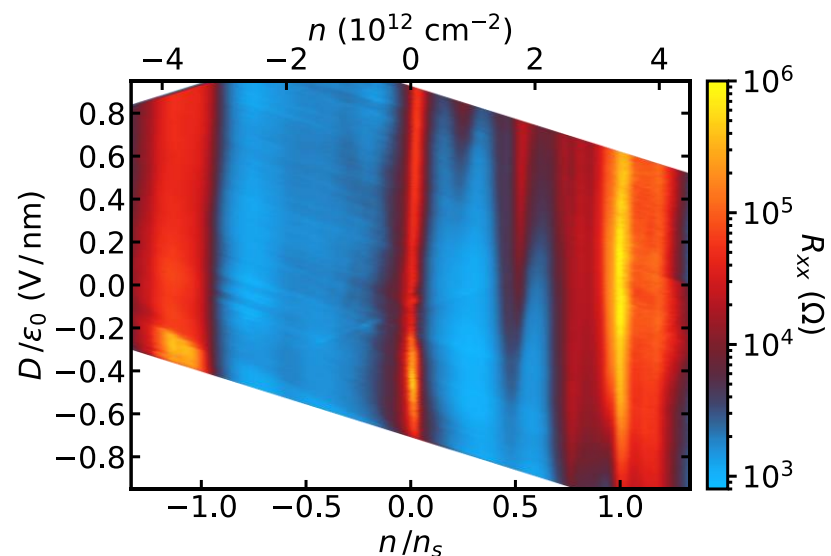
Jarillo-Herrero and Kaxiras groups

Impact of Alignment with hBN

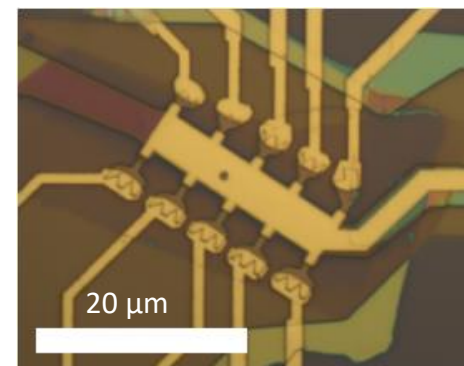
Device 1: aligned hBN



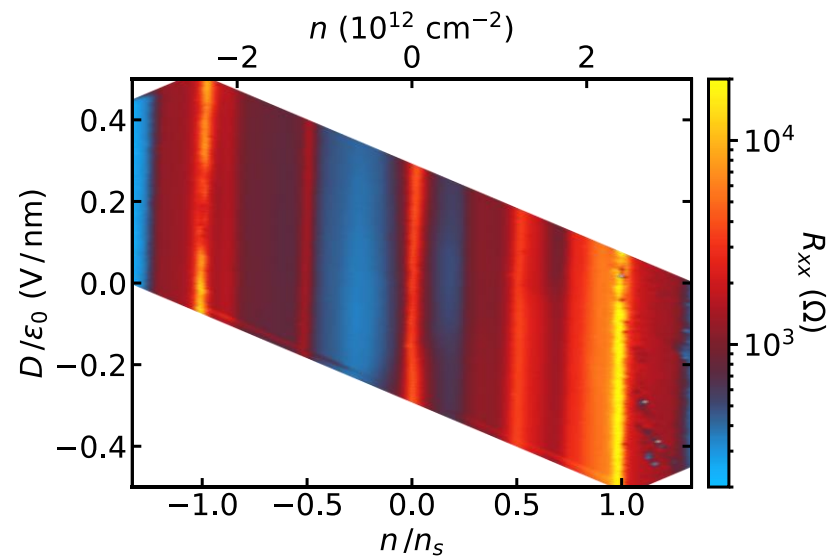
Graphene twist: $1.20 \pm 0.01^\circ$
Twist to one hBN: $0.81^\circ \pm 0.02^\circ$



Device 2: misaligned hBN

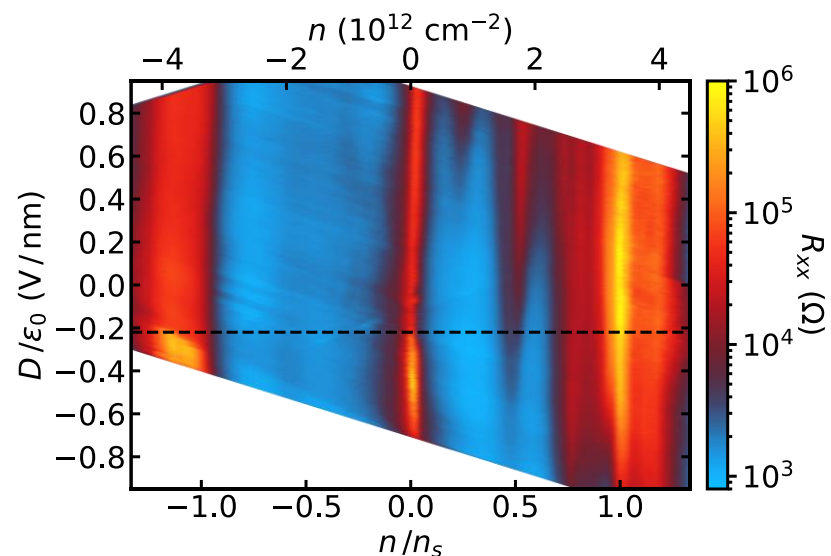
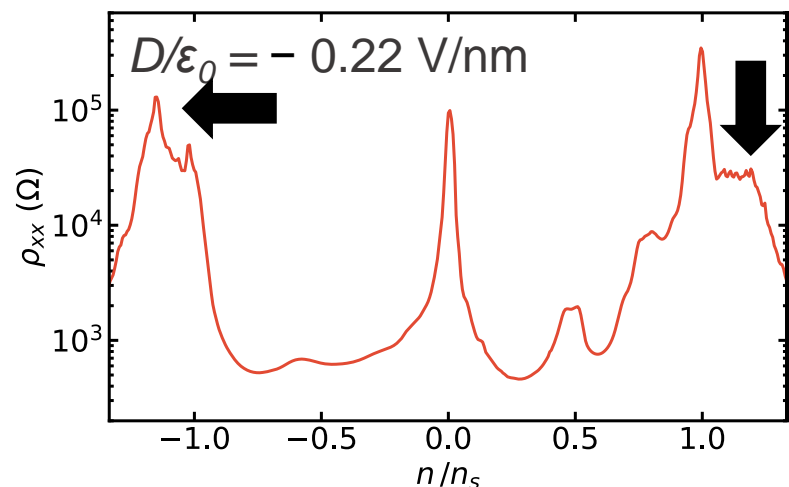


Graphene twist: $1.05 \pm 0.01^\circ$
Twist to hBN: large

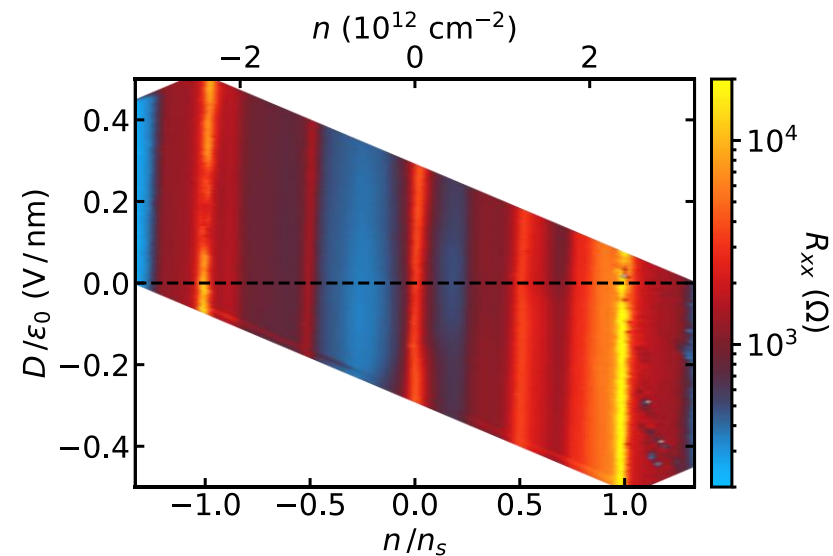
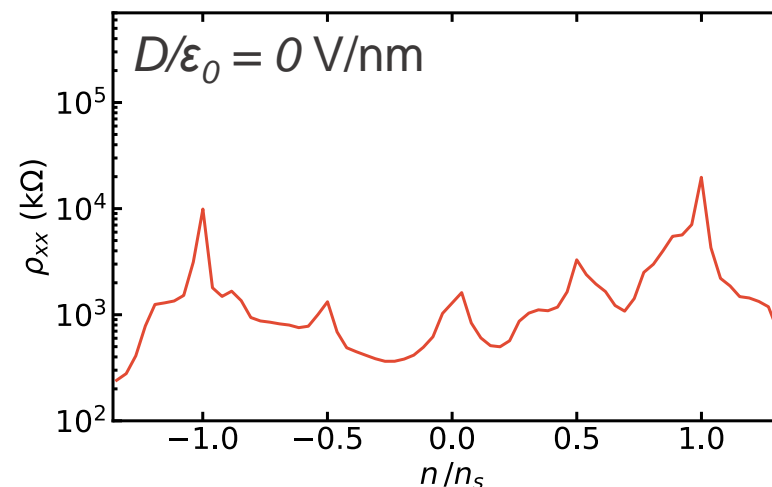


Impact of Alignment with hBN

Device 1: aligned hBN

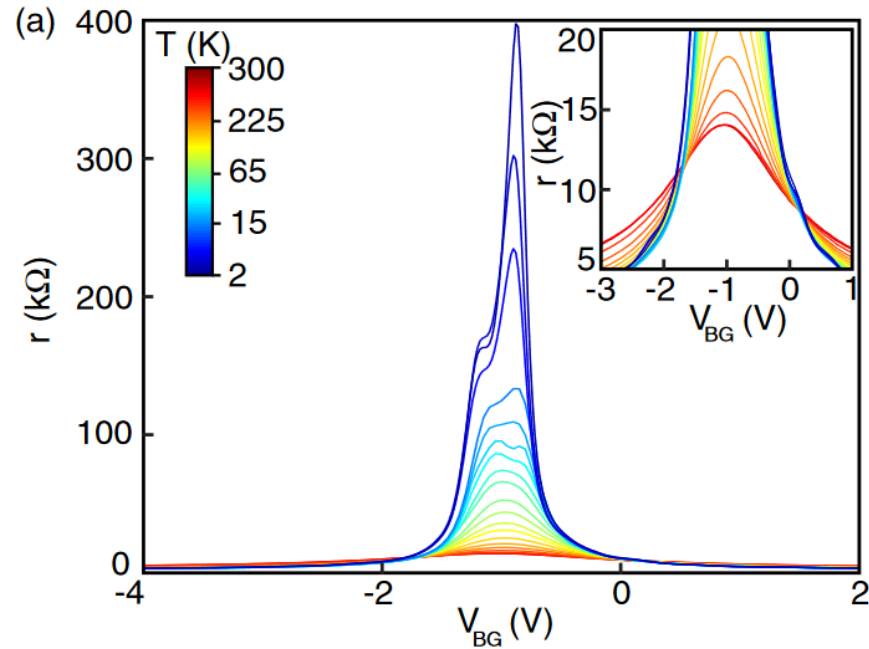


Device 2: misaligned hBN



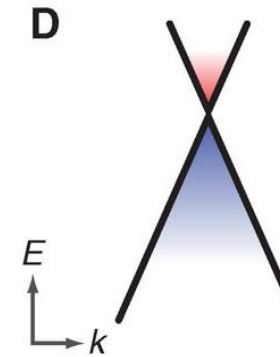
Alignment with hBN

Opens a gap at charge neutrality

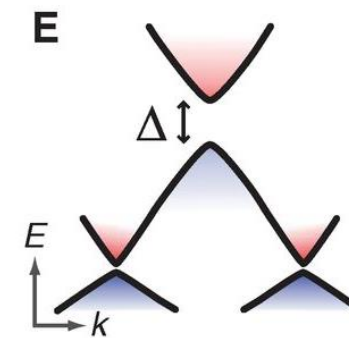


Amet, *PRL* (2013)
Hunt, *Science* (2013)

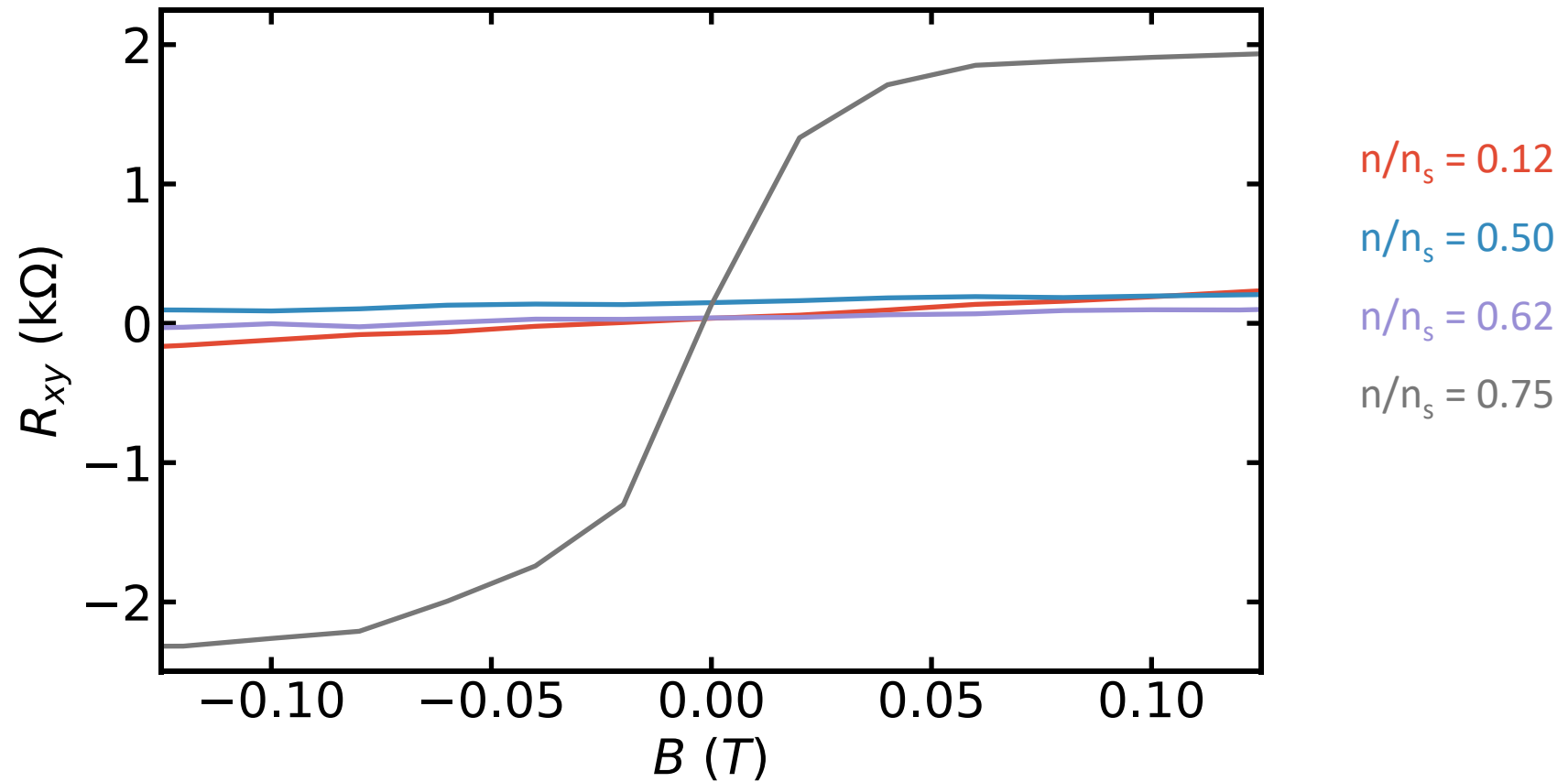
Monolayer graphene



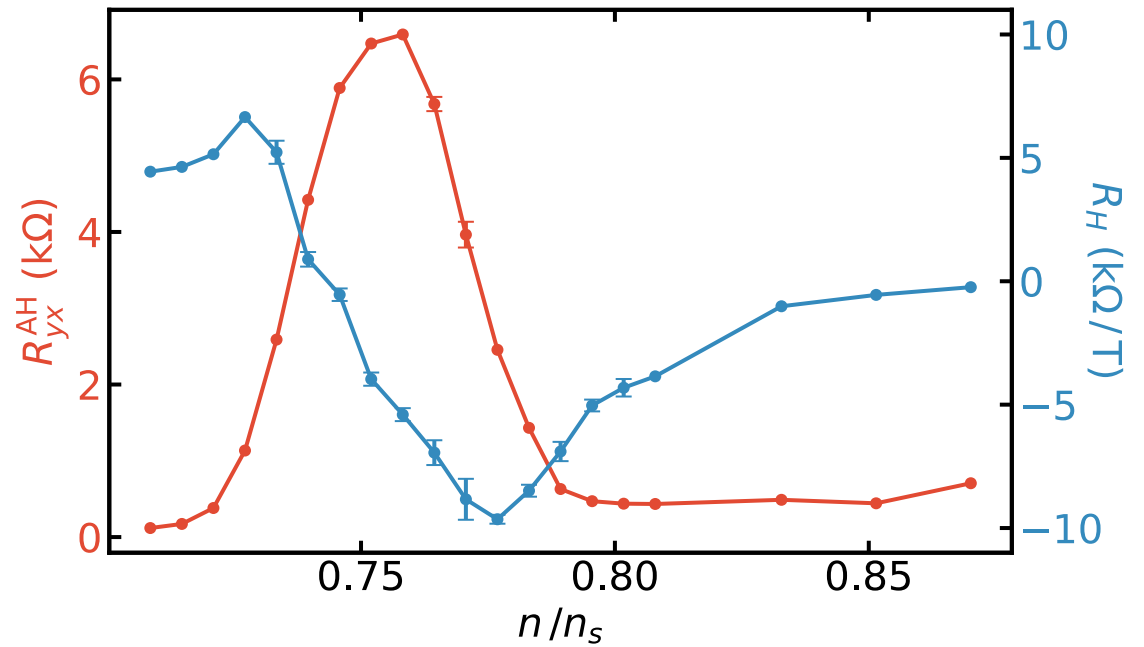
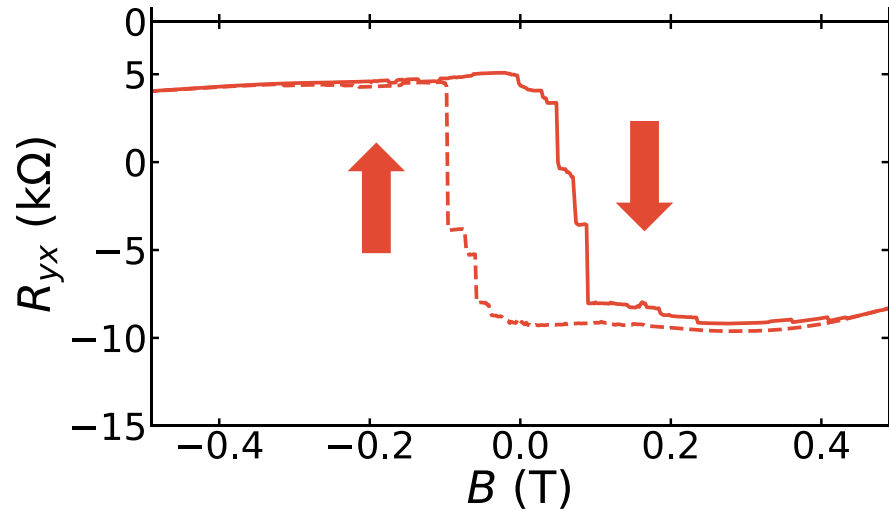
Monolayer graphene + hBN



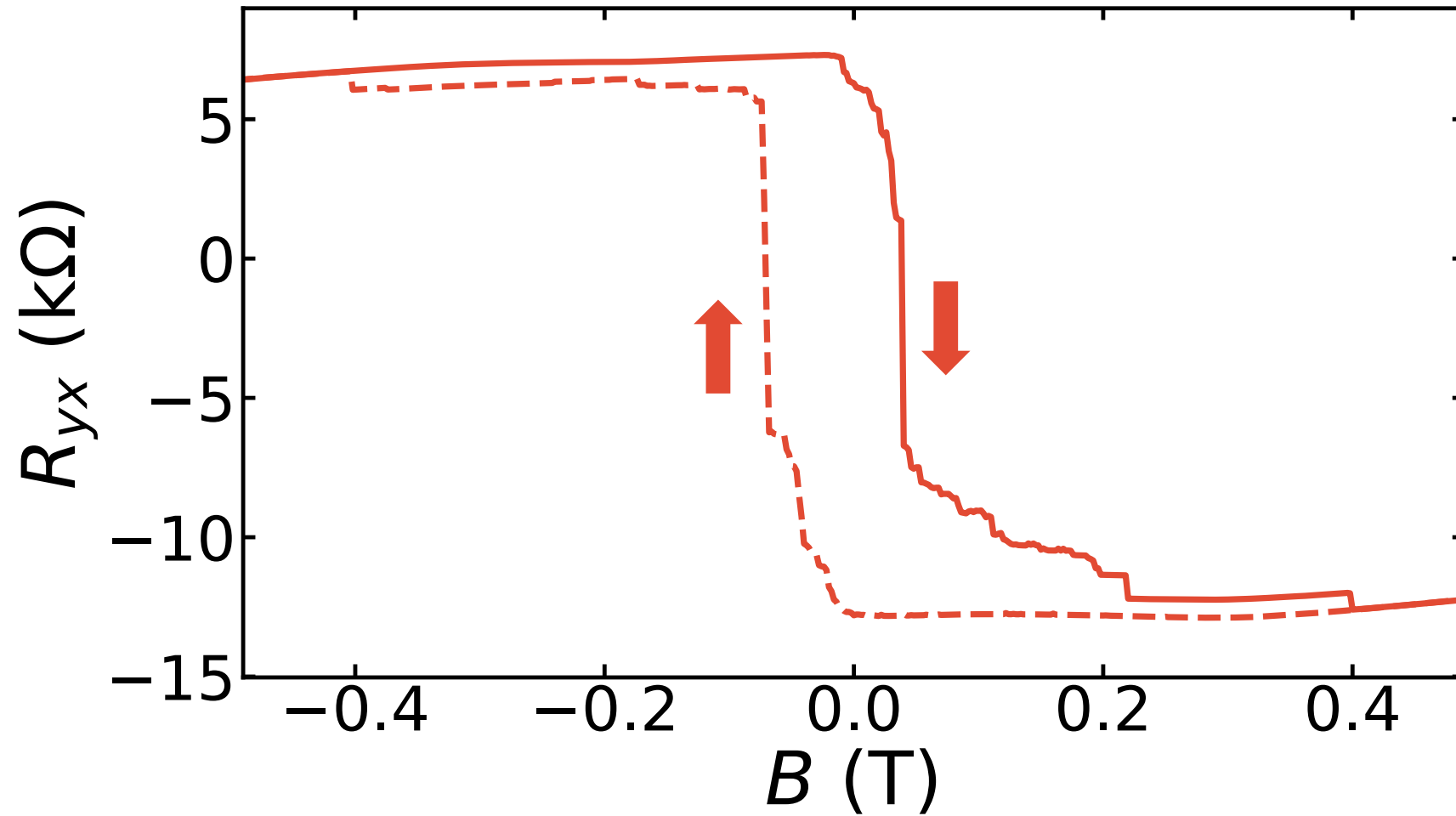
Measuring Hall Slope Density Dependence



Emergent Ferromagnetism at $\frac{3}{4}$ Filling

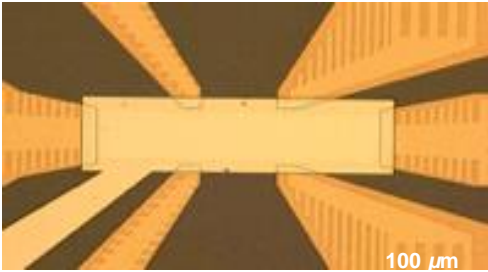


Anomalous Hall Signal Can Be Really Large!



$n/n_s=0.775, T=2.1K$

Comparison: Quantum Anomalous Hall in $(\text{Cr,Bi,Sb})_2\text{Te}_3$



Material & device:

6 QL $\text{Cr}_{0.24}(\text{Bi}_{0.3}\text{Sb}_{0.7})_{1.76}\text{Te}_3$

GaAs substrate

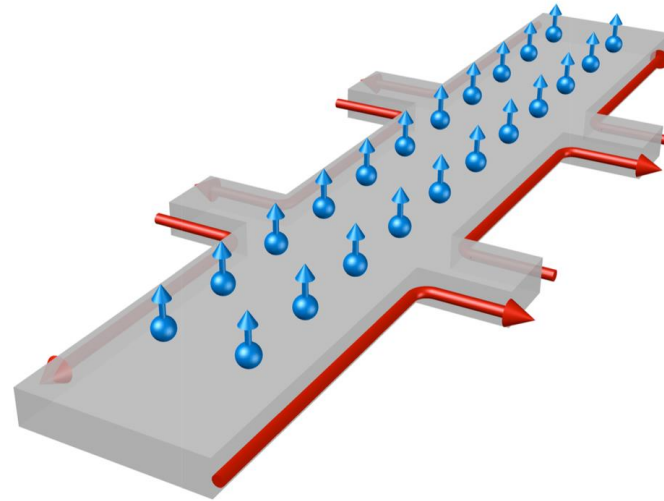
Ti/Au contacts

Top gate

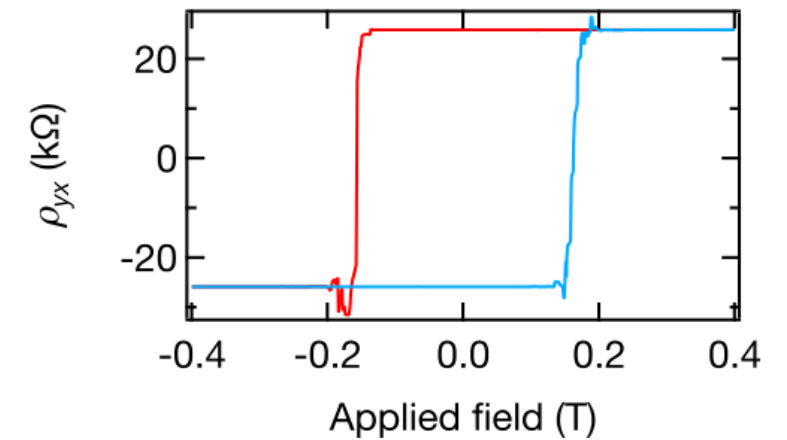
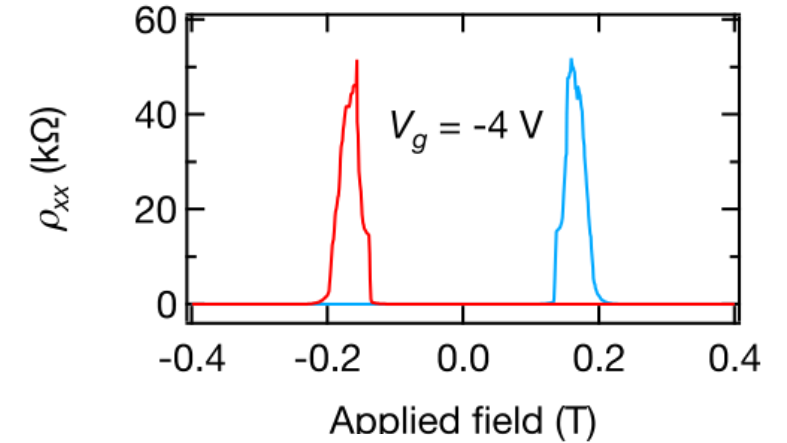
Ideally

$$\rho_{xx} = 0$$

$$\rho_{yx} = h/e^2 \approx 26\text{k}\Omega$$

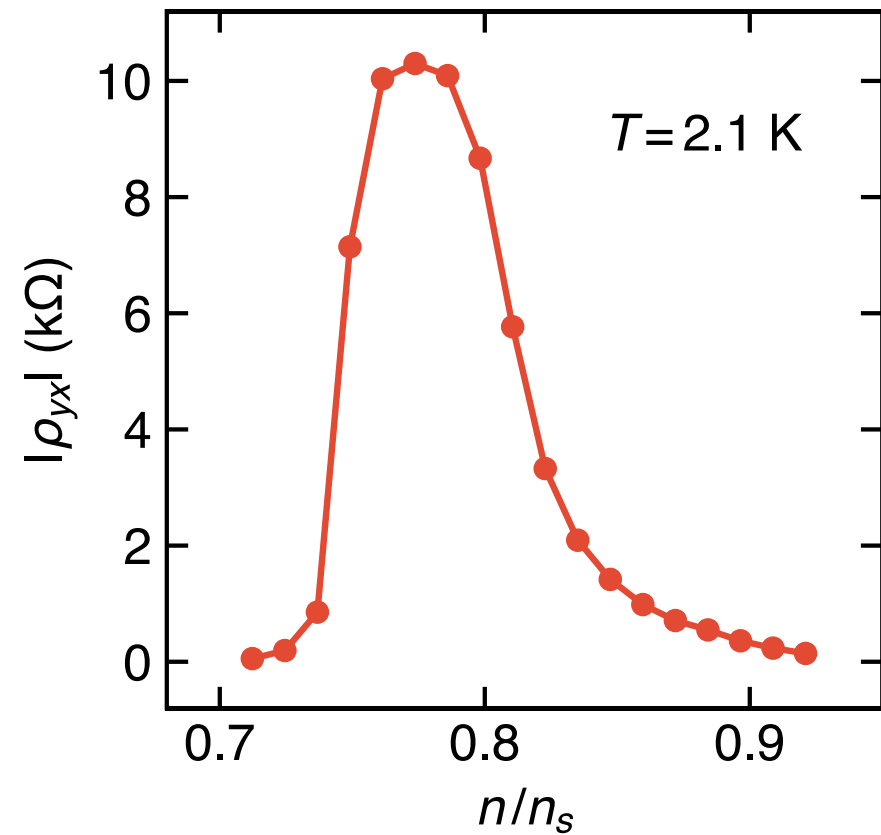
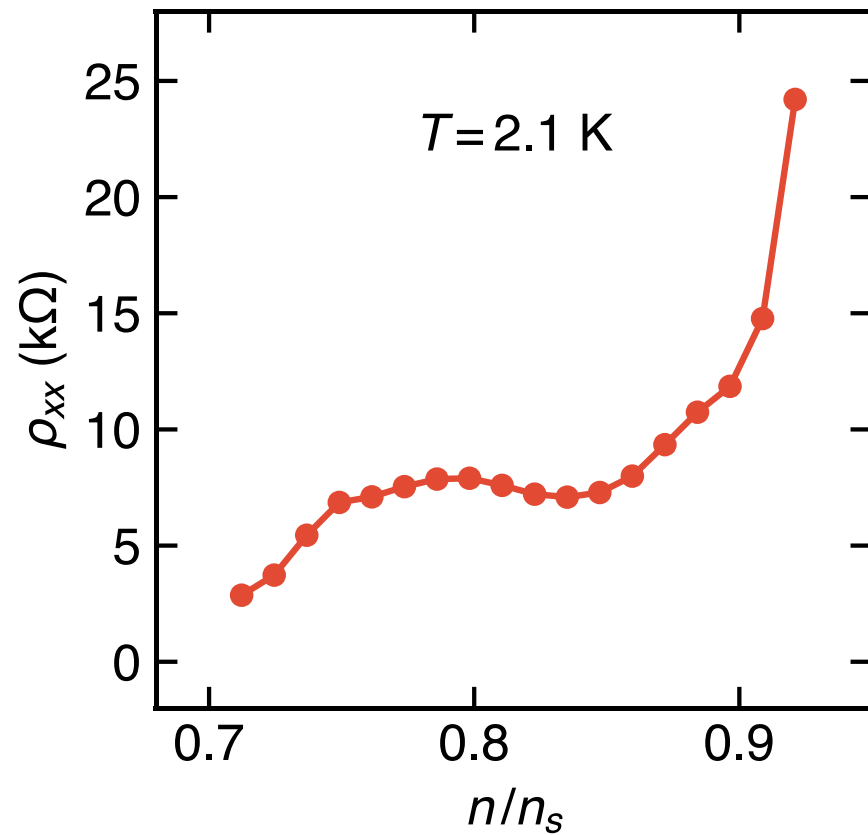


Near optimal gate voltage



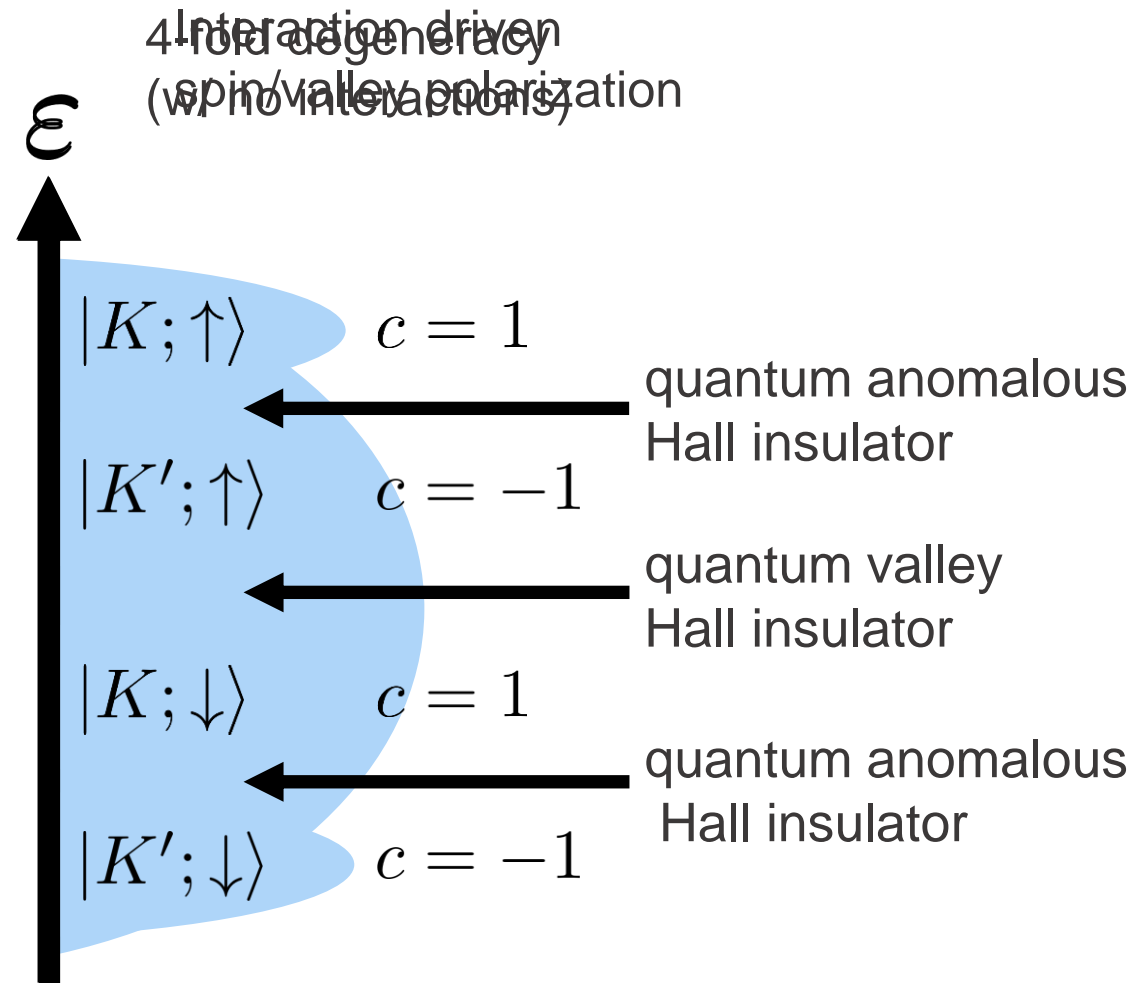
Comparison: Anomalous Hall in TBG

Far from quantization

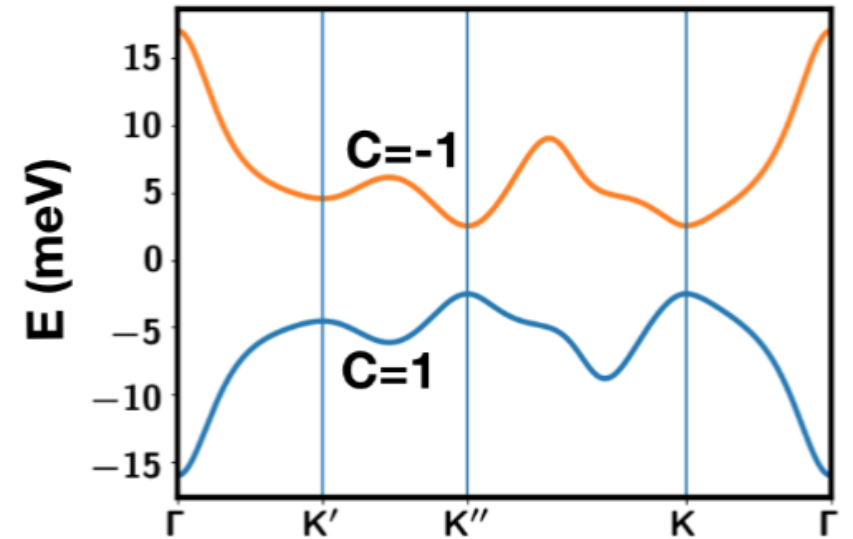


Nature of Emergent Ferromagnetism at $\frac{3}{4}$ Filling?

Simplistic band diagram: what *might* be happening...



Twisted bilayer graphene + hBN

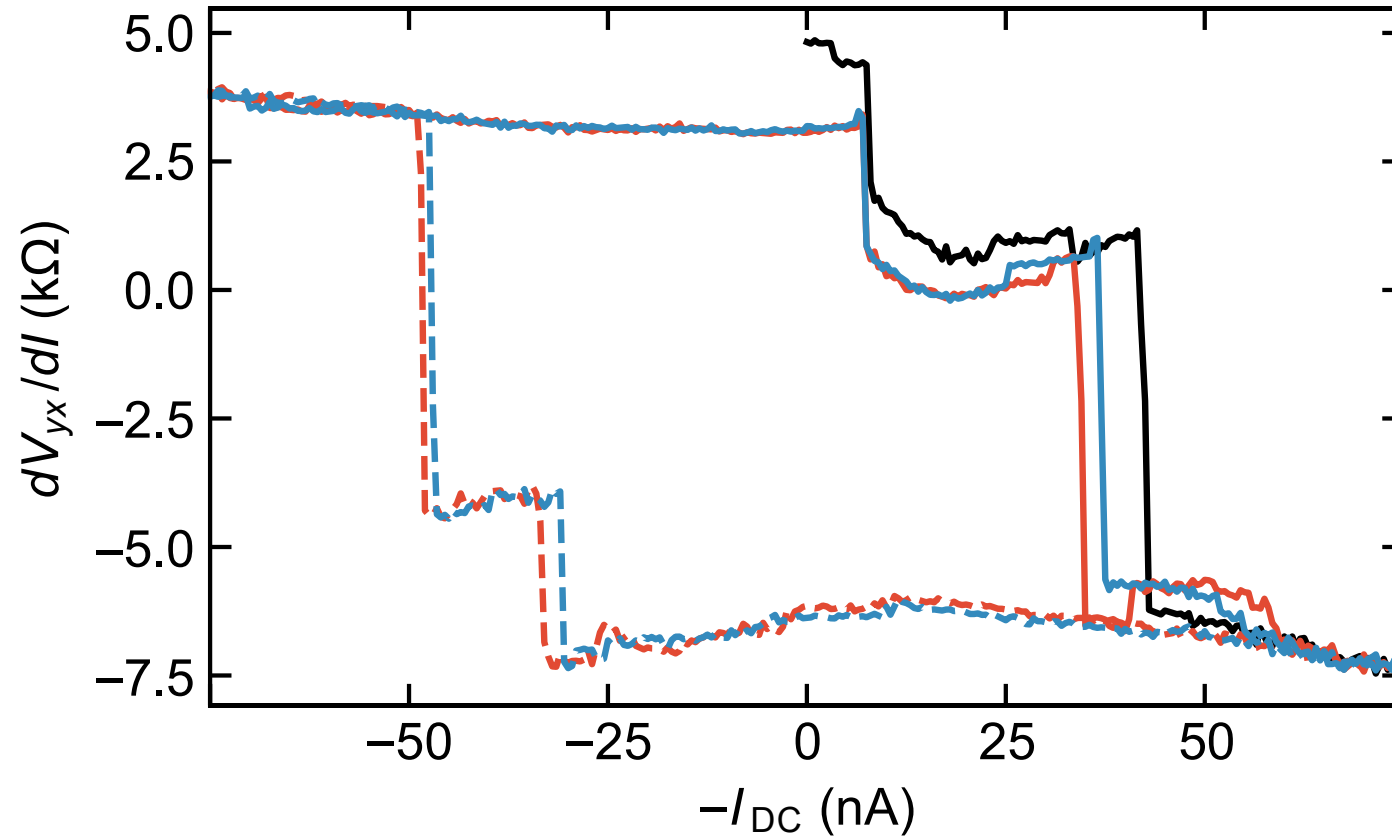


Zhang, [arXiv:1901.08209](https://arxiv.org/abs/1901.08209)
 Bultinck, [arXiv:1901.08110](https://arxiv.org/abs/1901.08110)

Gap may open spontaneously
 Xie, [arXiv:1812.04213](https://arxiv.org/abs/1812.04213)

Repeatable Hysteresis in Current

Another TBG Mystery



Questions?

TBG becomes ferromagnetic near $\frac{3}{4}$ filling up to 5 K!

Alignment to hBN may be crucial

At optimal doping

$$\rho_{xy} = 10.4 \text{ k}\Omega$$

$$\rho_{xy}/\rho_{xx} = 1.4$$

Evidence for edge conduction

Small DC current can flip magnetization

arXiv: 1901.03520

