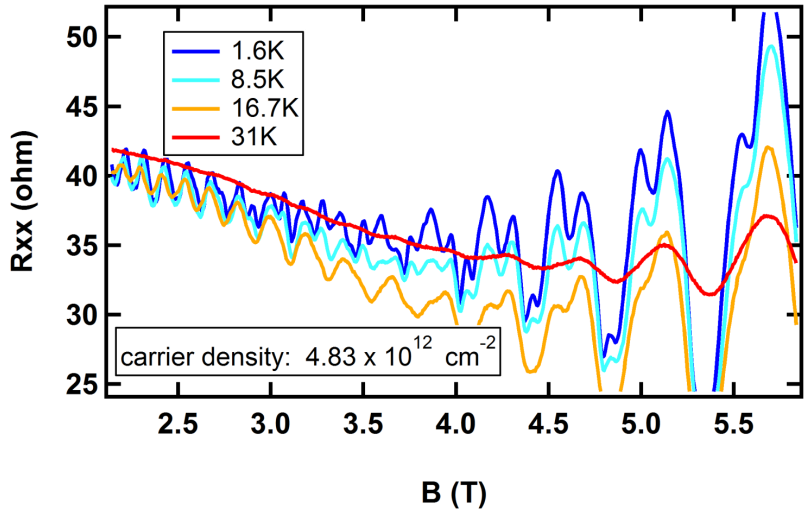
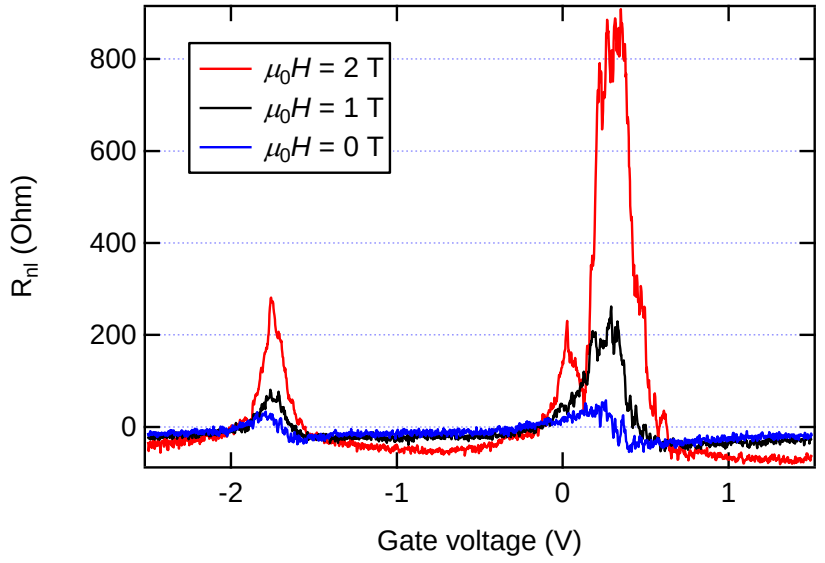
Exploring Proximity-Induced Ferromagnetism in Graphene/$Cr_2Ge_2Te_6$ Heterostructures

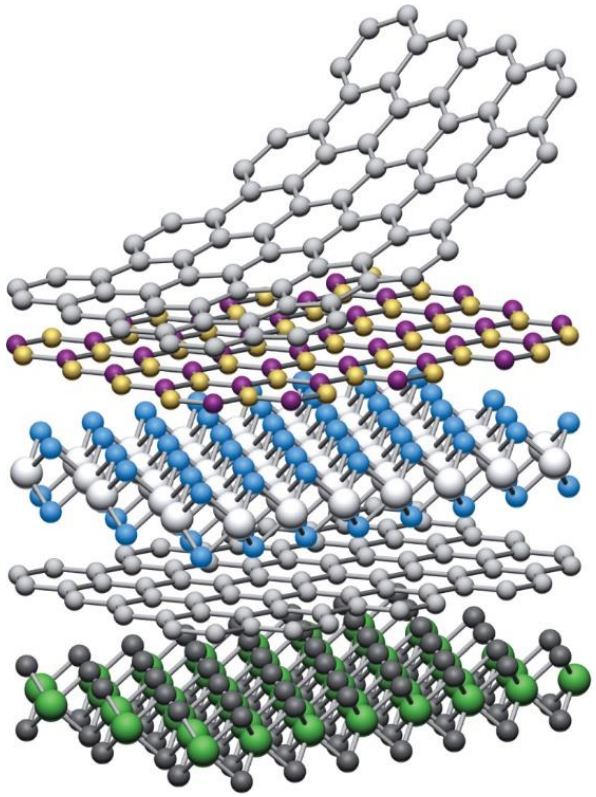
Aaron Sharpe, Wenmin Yang, Menyoung Lee, Kenji Watanabe, Takashi Taniguchi, David Goldhaber-Gordon

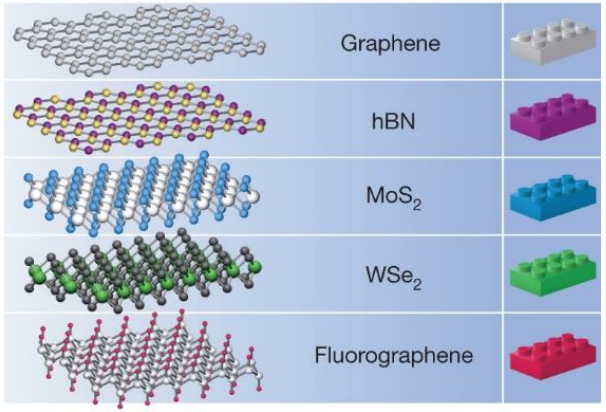


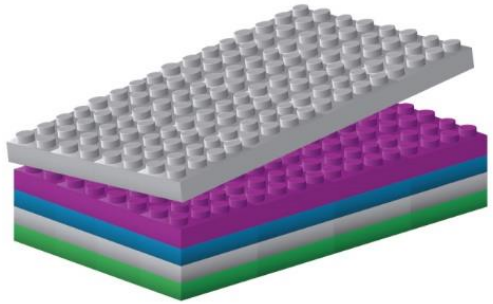
March Meeting 2017



Van der Waals (VdW) Heterostructures

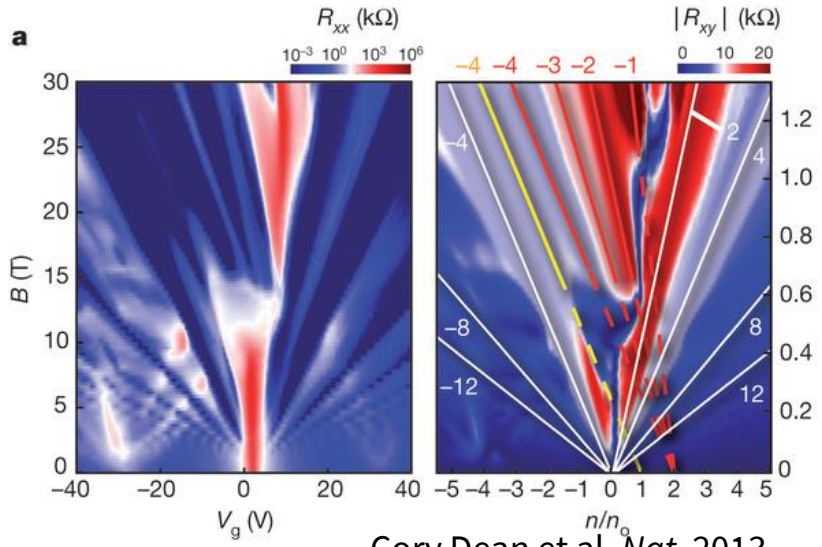






Geim et al, *Nature* (2013)

hBN: Superlattice



Cory Dean et al, *Nat.* 2013

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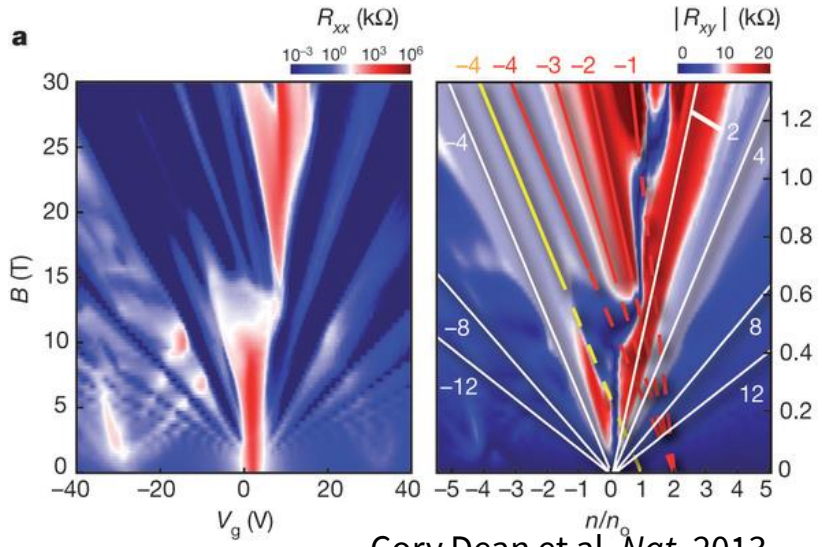
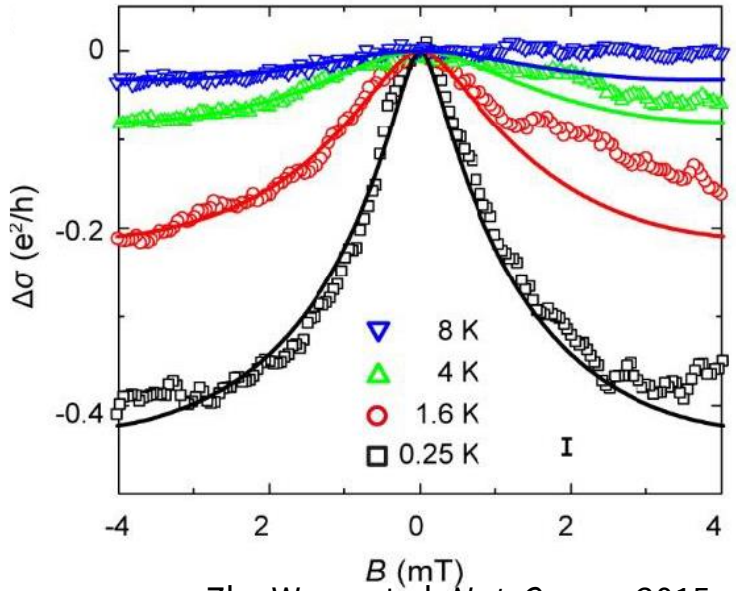


Cory Dean et al, *Nat.* 2013

WS_2: Enhanced spin-orbit



Zhe Wang et al, *Nat. Comm.* 2015

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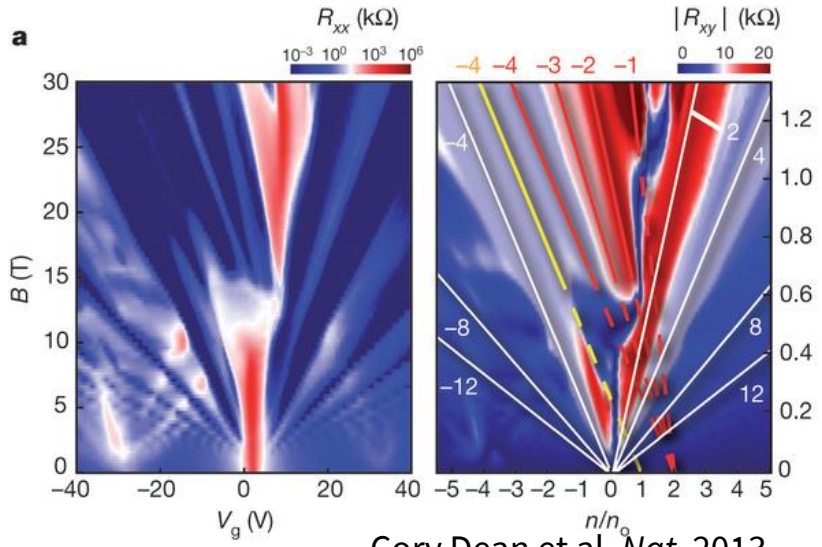
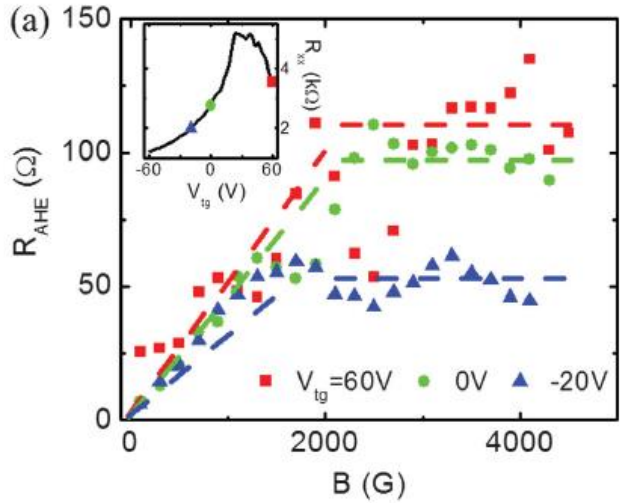


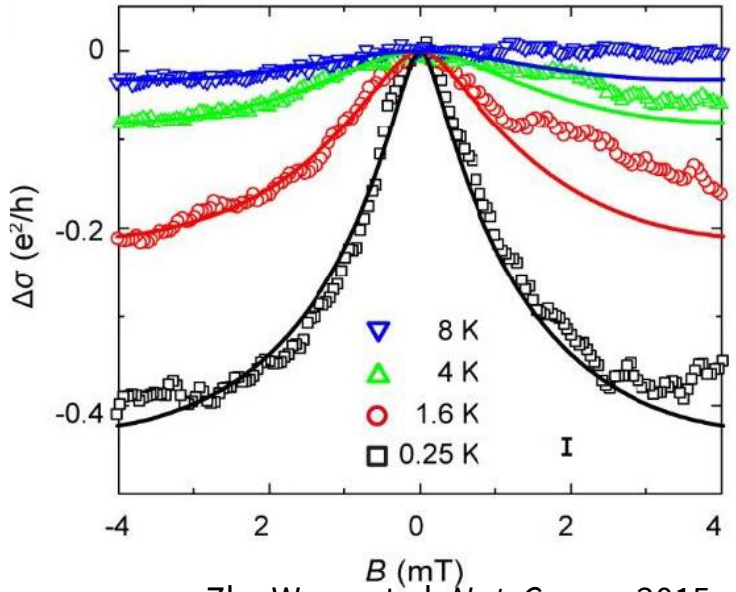
Cory Dean et al, *Nat.* 2013

YIG: Anomalous Hall



Zhiyong Wang et al, *PRL* 2015

WS_2: Enhanced spin-orbit



Zhe Wang et al, *Nat. Comm.* 2015

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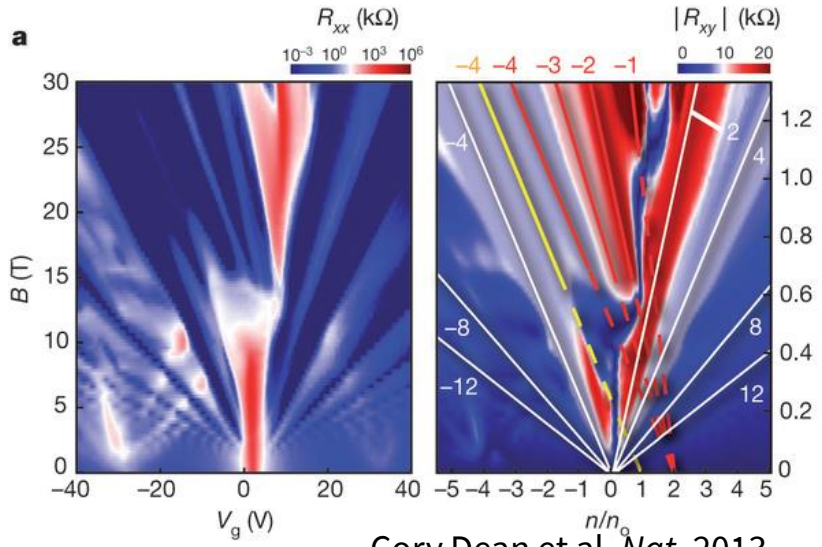

Cory Dean et al, *Nat.* 2013

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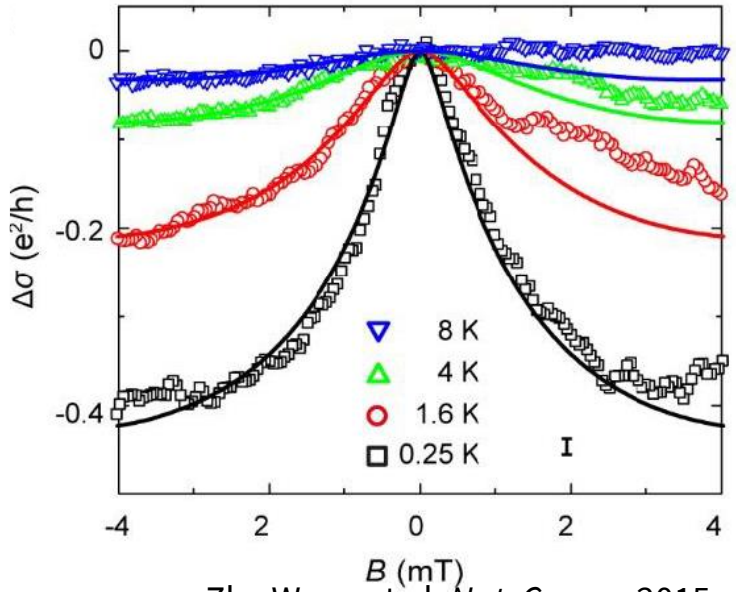

Zhe Wang et al, *Nat. Comm.* 2015

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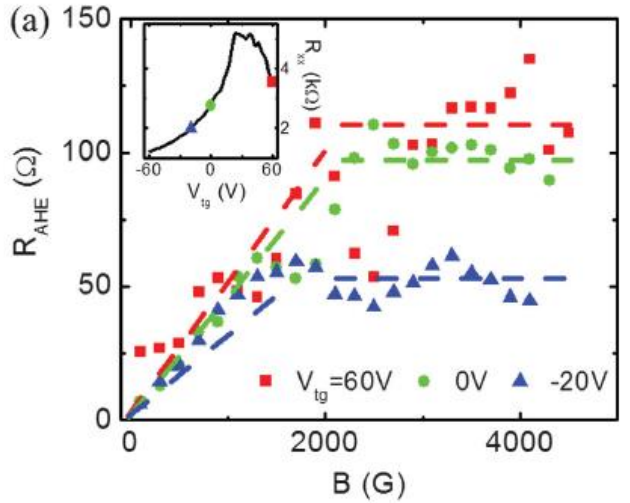
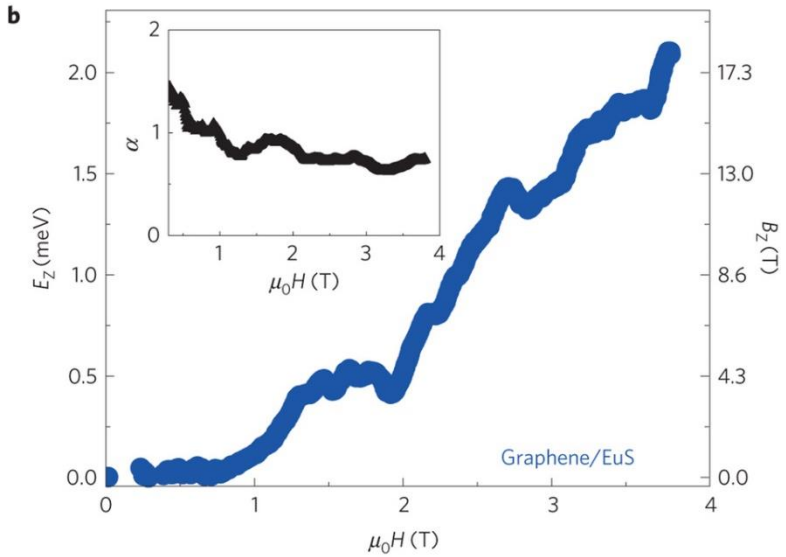


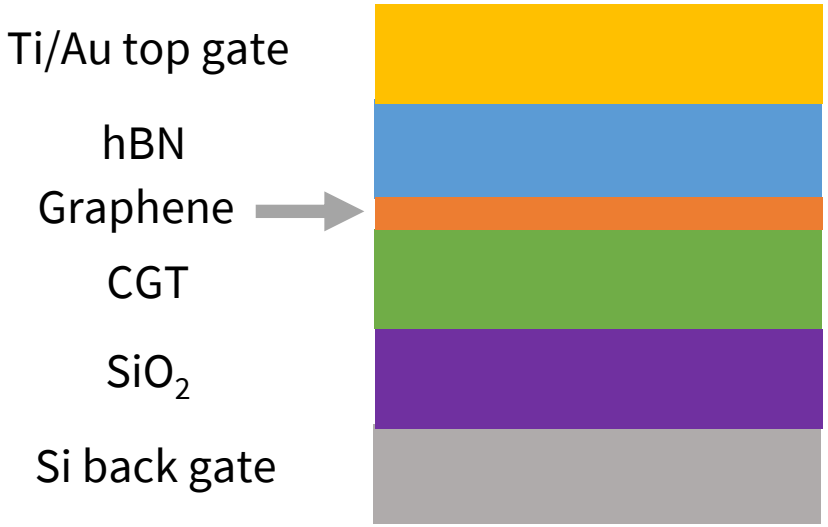
Zhiyong Wang et al, *PRL* 2015

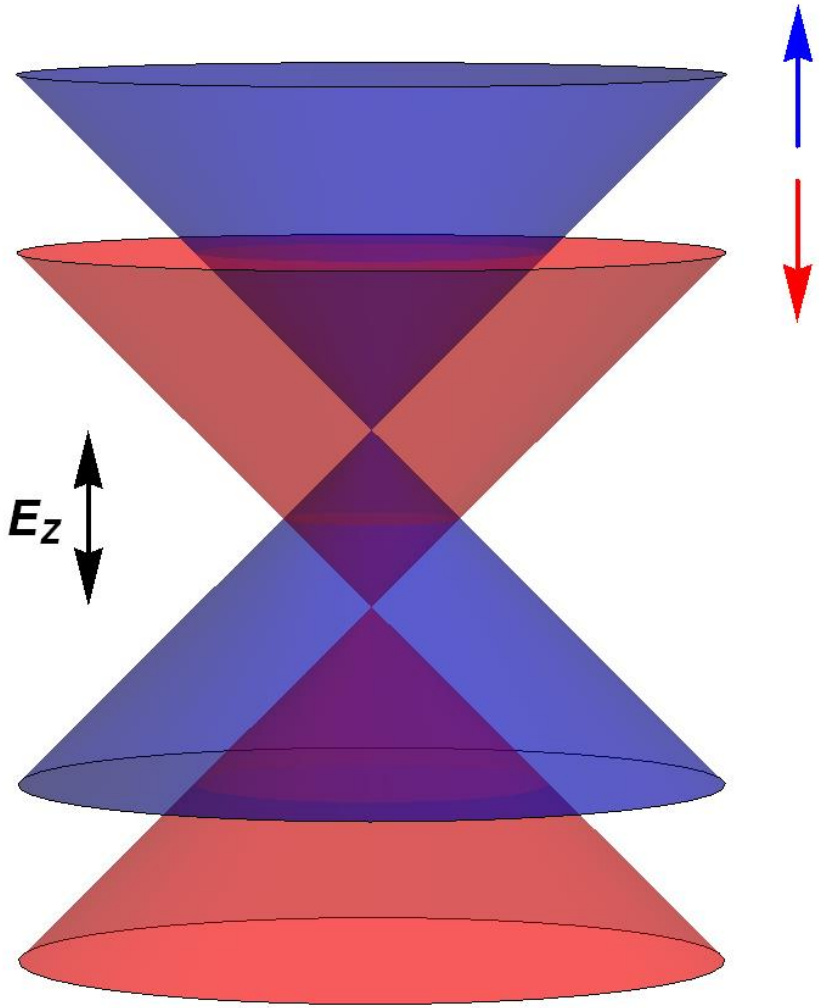
EuS: Zeeman Spin Hall



Peng Wei et al, *Nat. Mat.* 2016

Tunable Ferromagnetism





$Cr_2Ge_2Te_6$ (CGT)

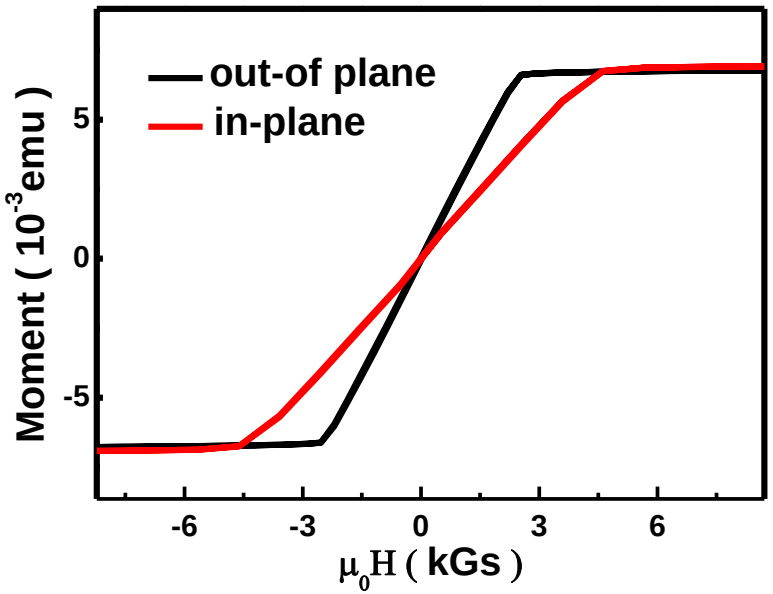
- Cleavable
- Ferromagnetic Insulator $T_C = 61$ K

Alegria et al, *APL* 2014

$Cr_2Ge_2Te_6$ (CGT)

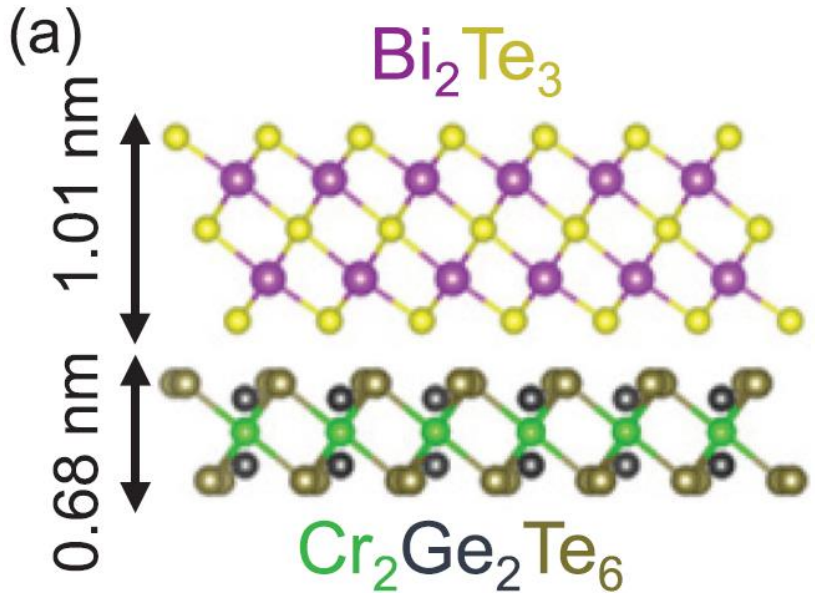
- Cleavable
- Ferromagnetic Insulator $T_C = 61$ K
- Soft Ferromagnet
- Easy axis out of plane

Alegria et al, *APL* 2014

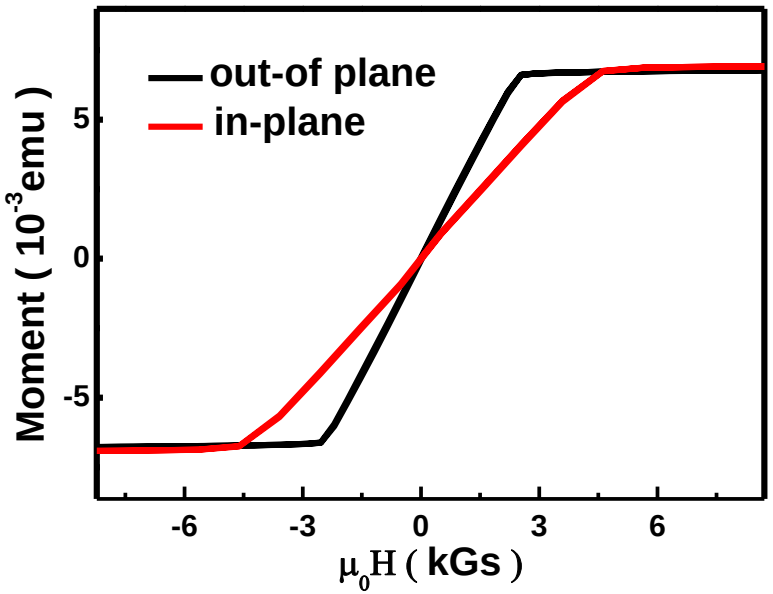


$Cr_2Ge_2Te_6$ (CGT)

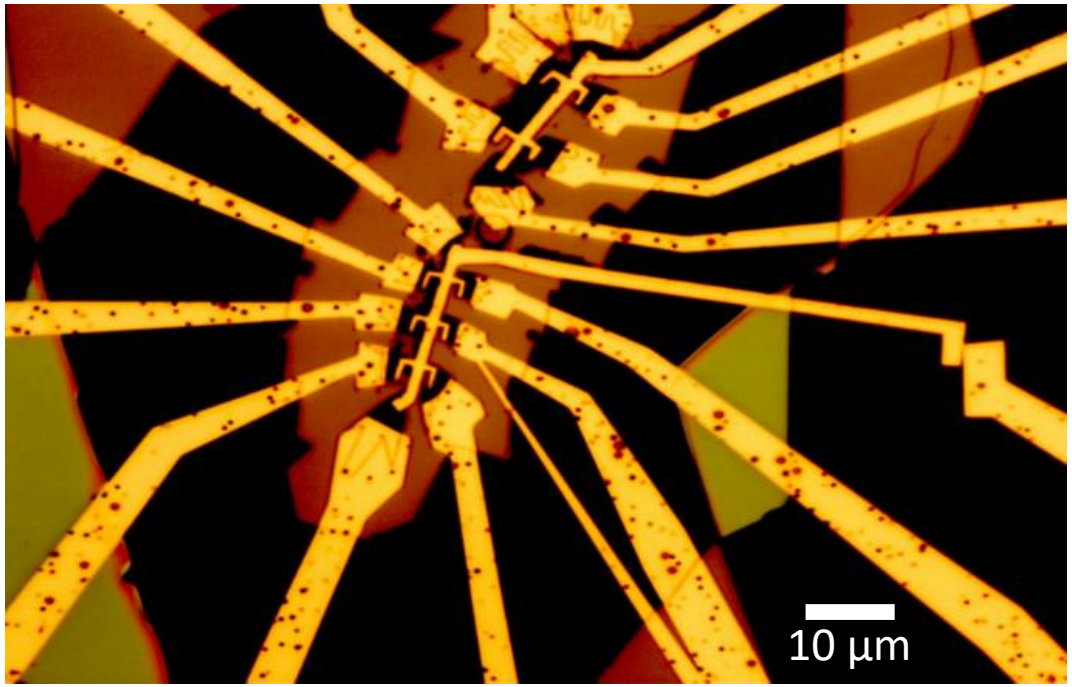
- Cleavable
- Ferromagnetic Insulator $T_C = 61$ K
- Soft Ferromagnet
- Easy axis out of plane
- AHE with Bi_2Te_3

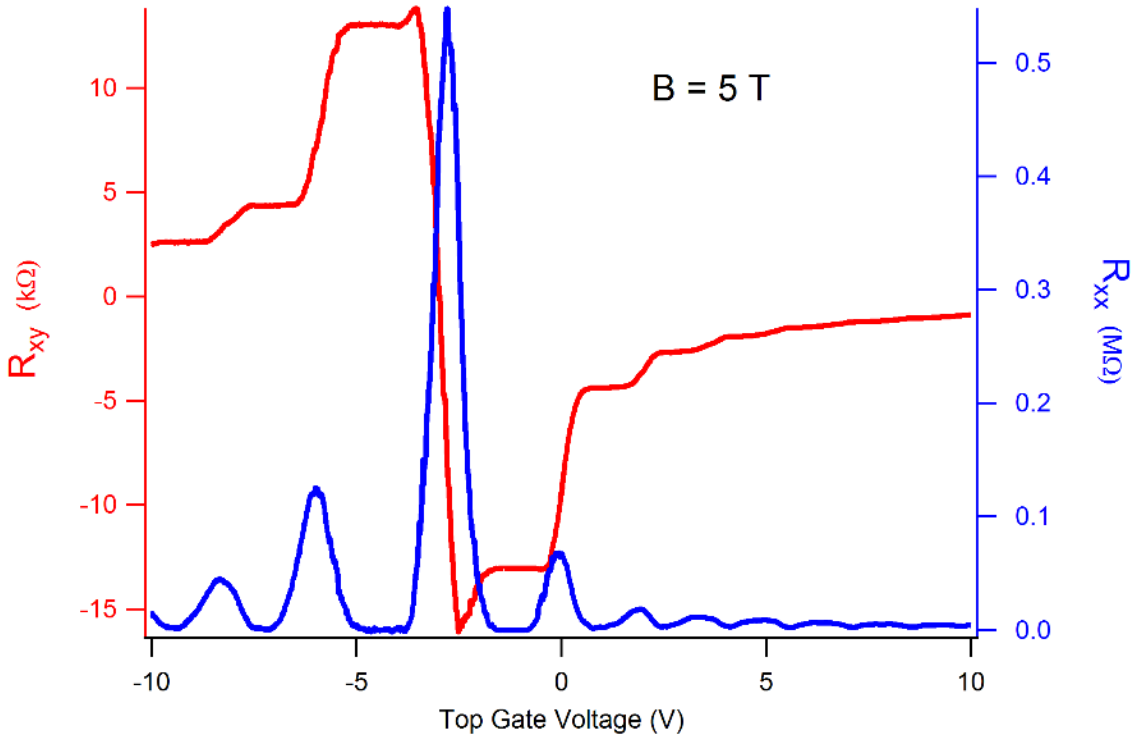


Alegria et al, *APL* 2014

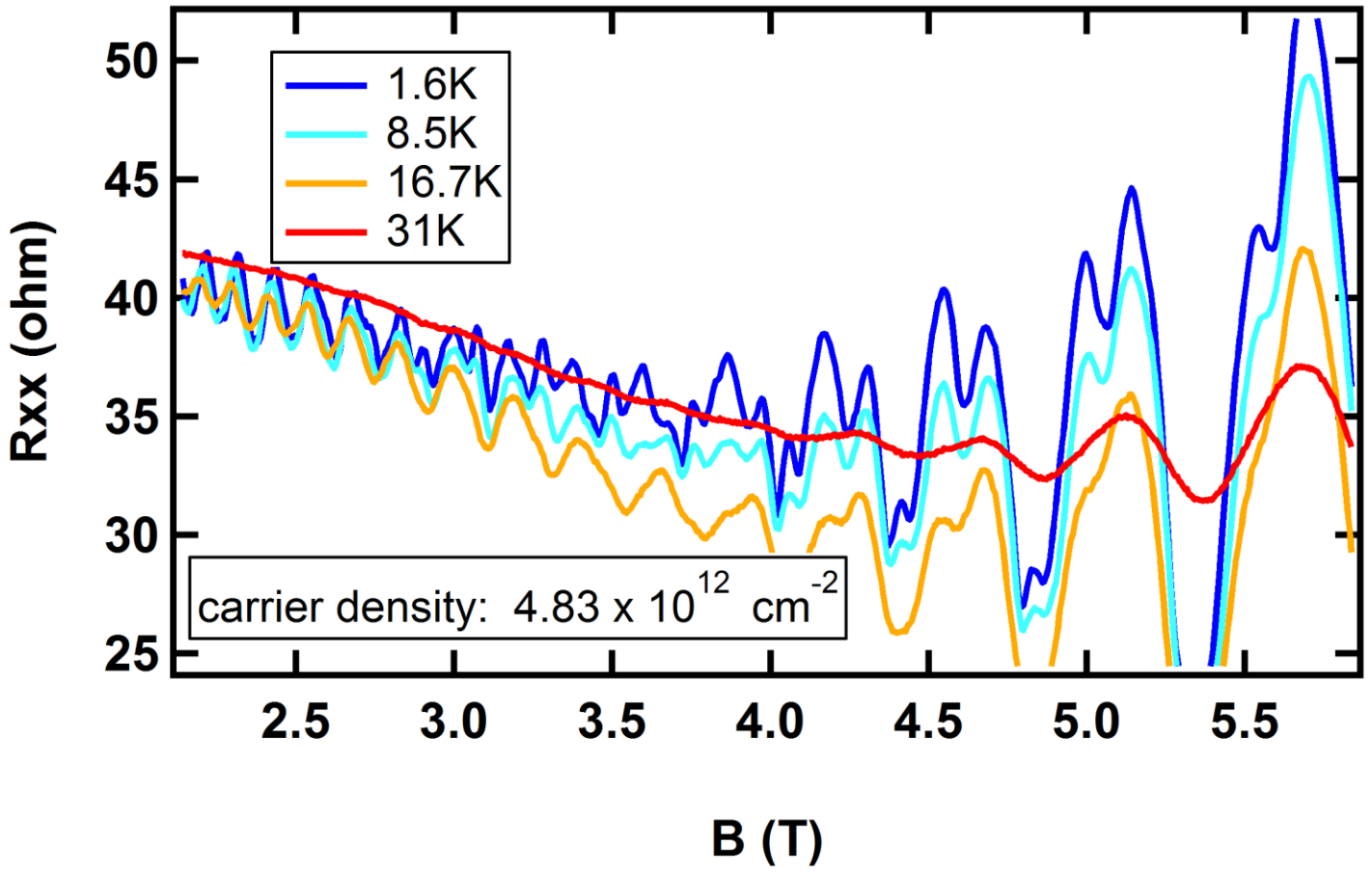


Clean Quantum Hall

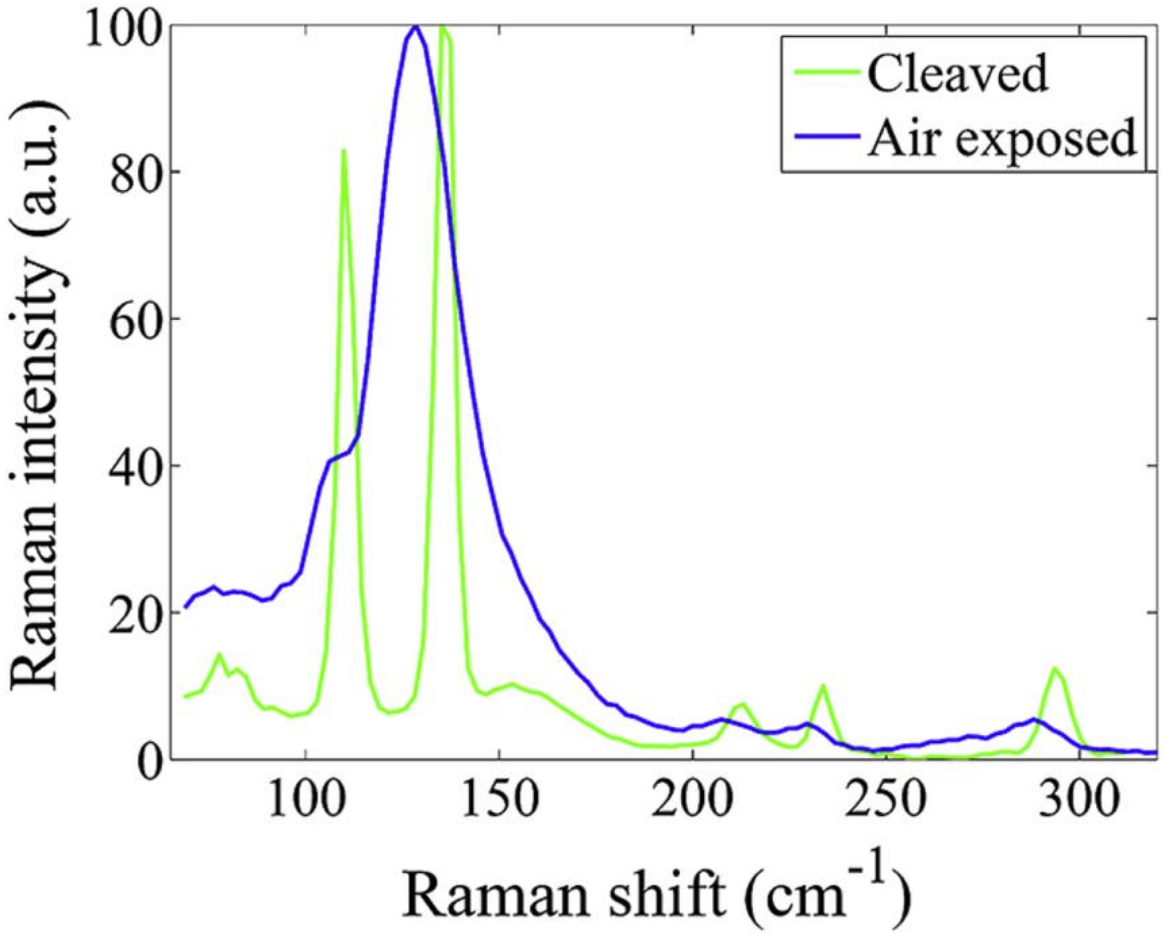




Splitting in Longitudinal Resistance Peaks

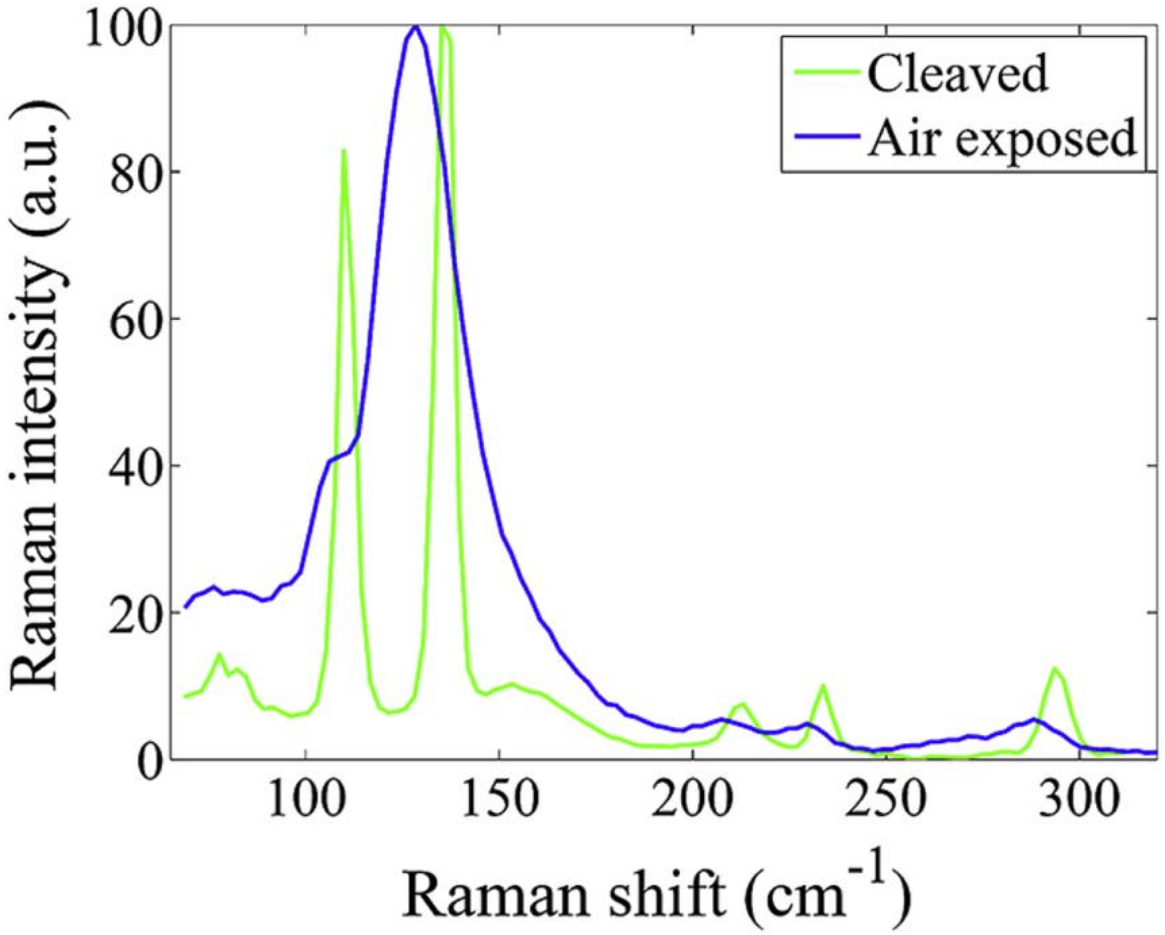


CGT Sensitive to Air

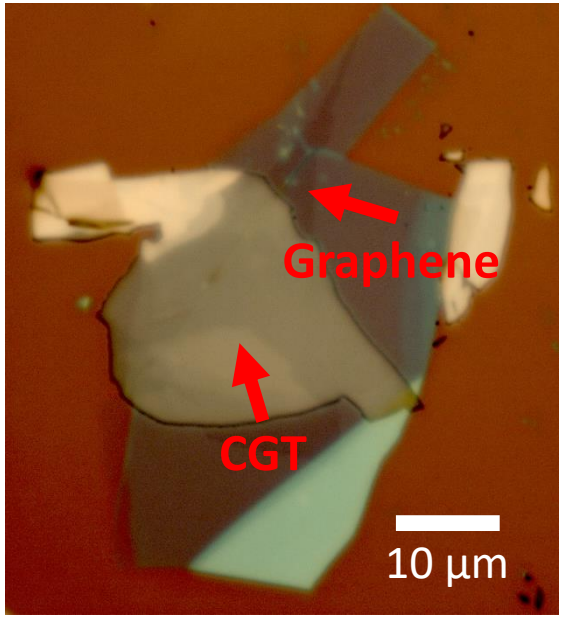


Tian et al, *IOP Science* 2016

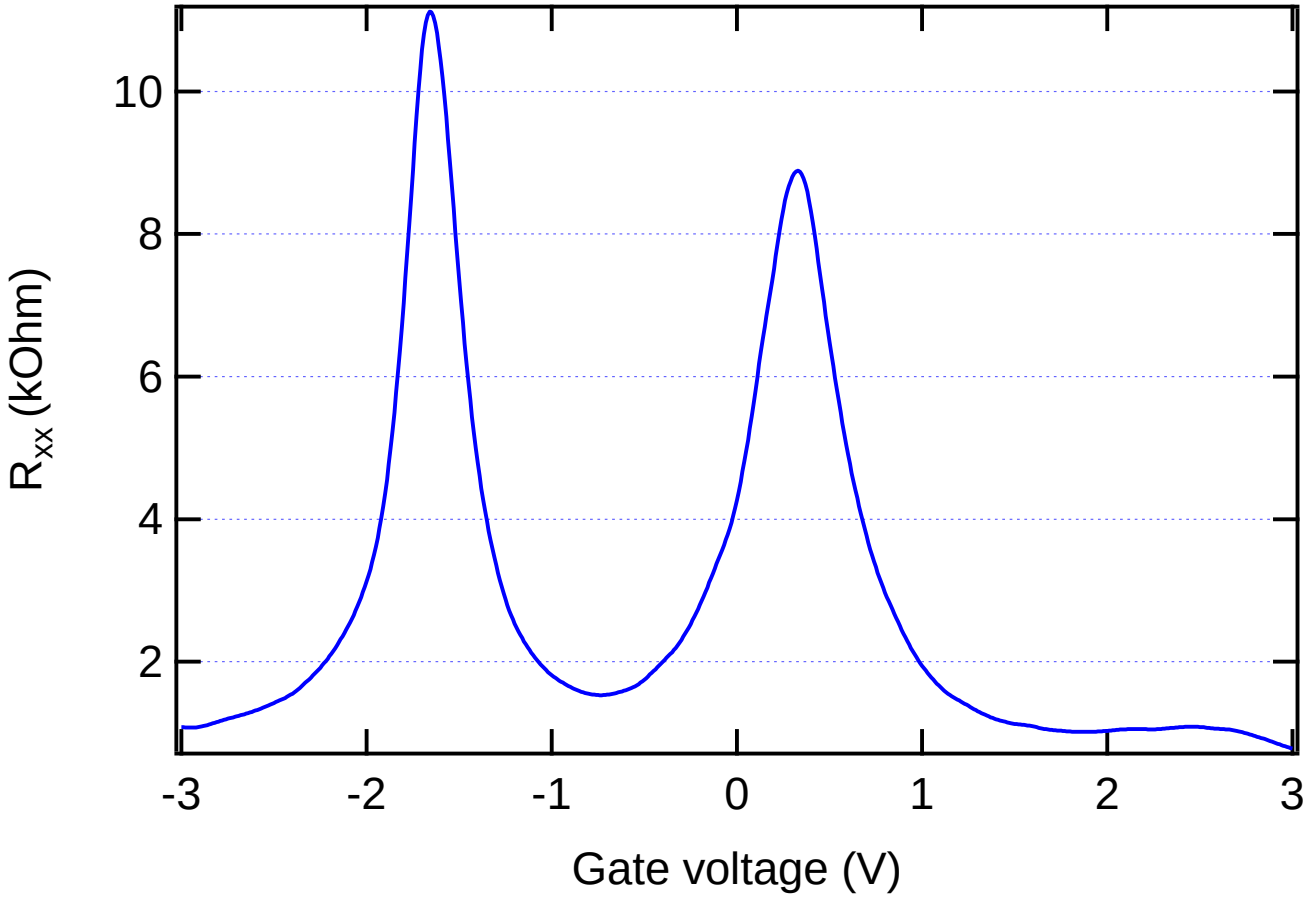
CGT Sensitive to Air

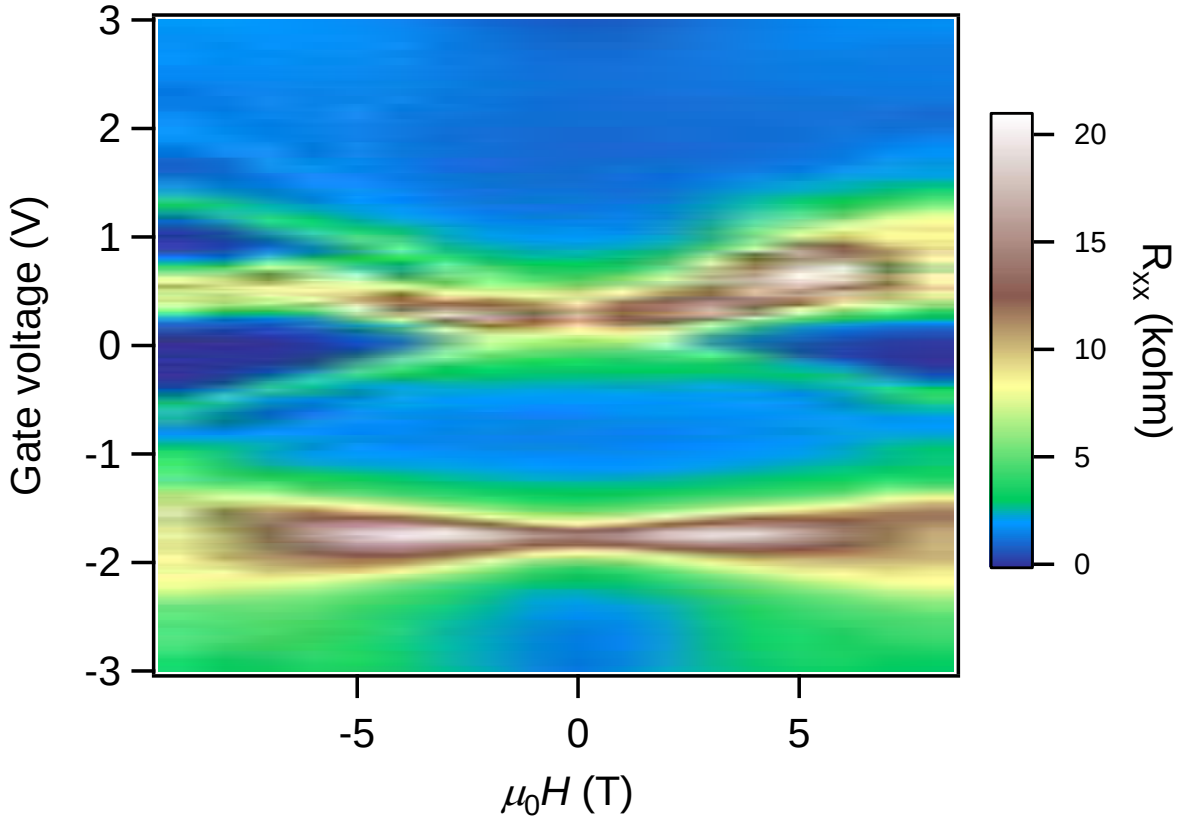


Tian et al, *IOP Science* 2016

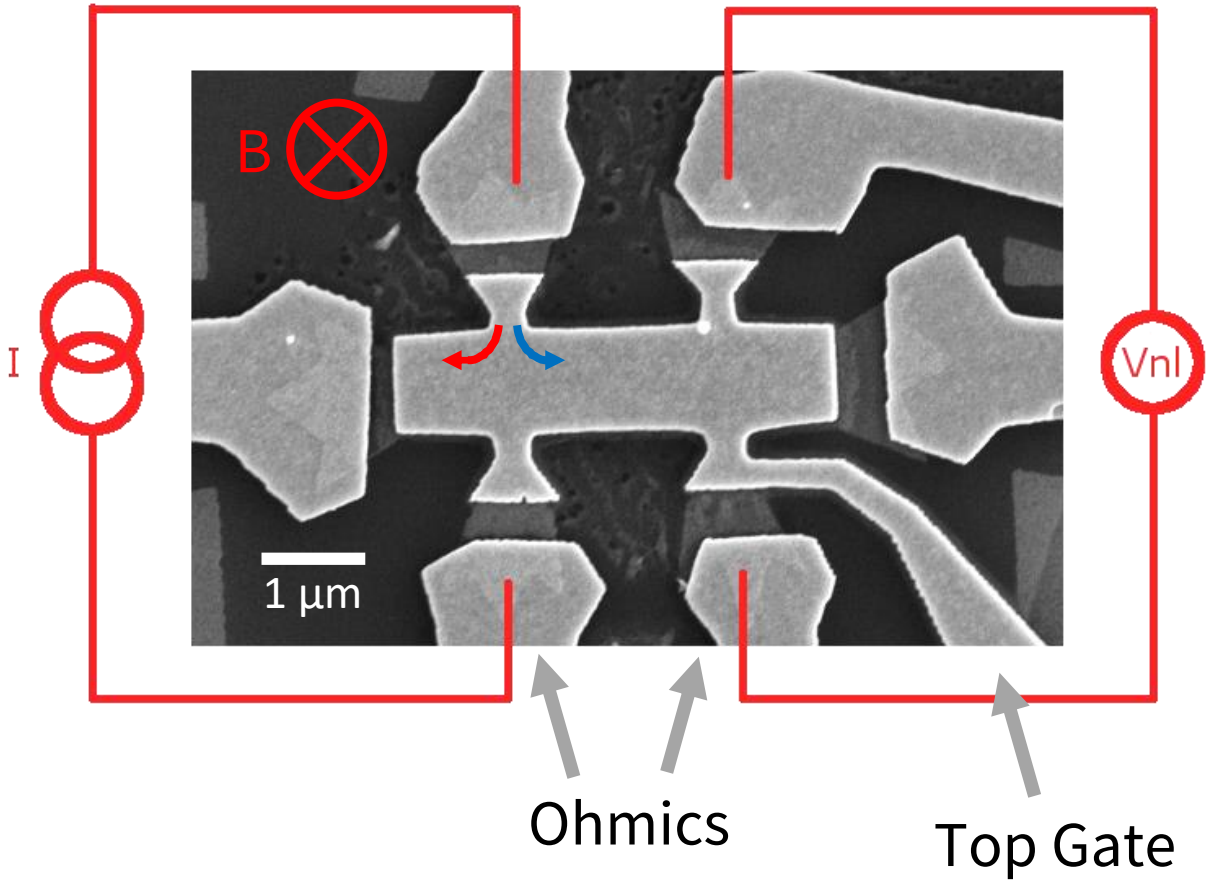


Basic Characterization





Field Dependence of non-local signal



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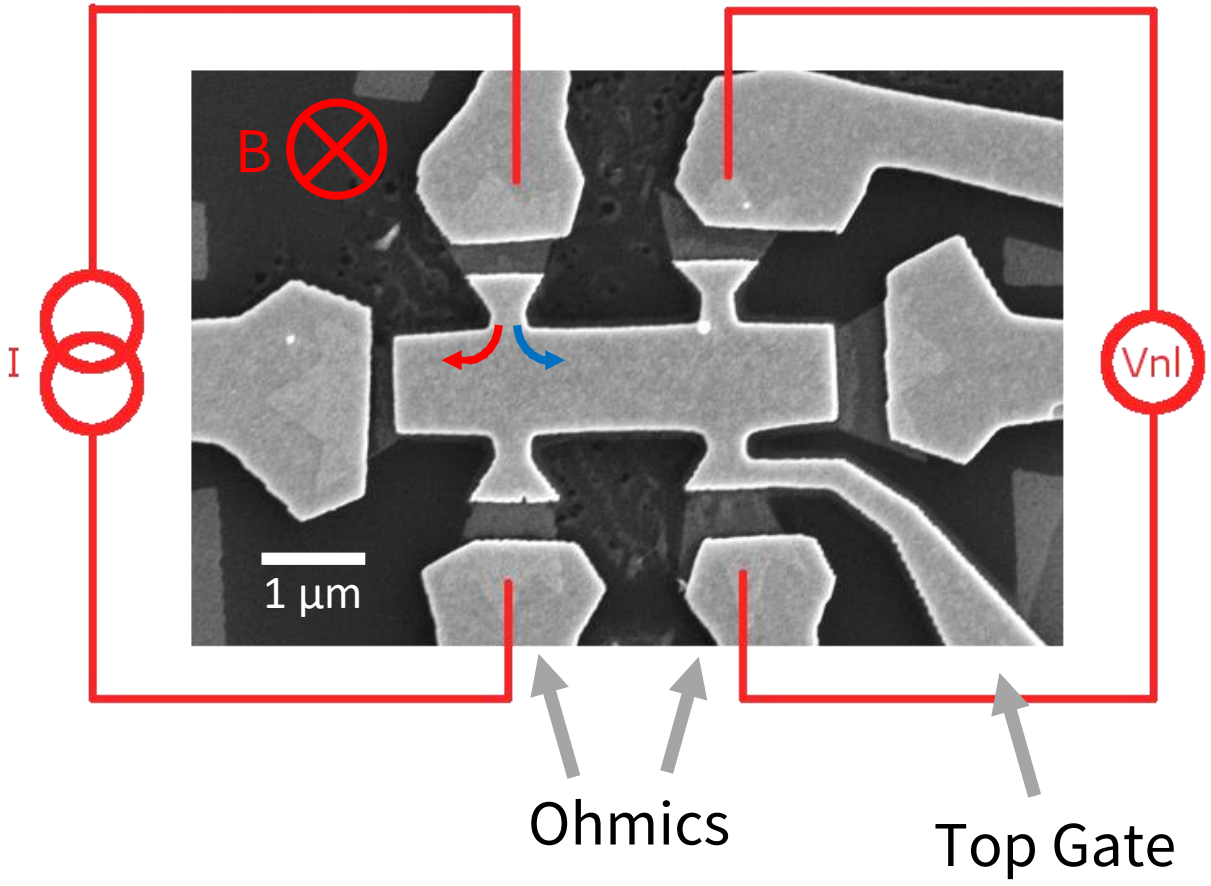

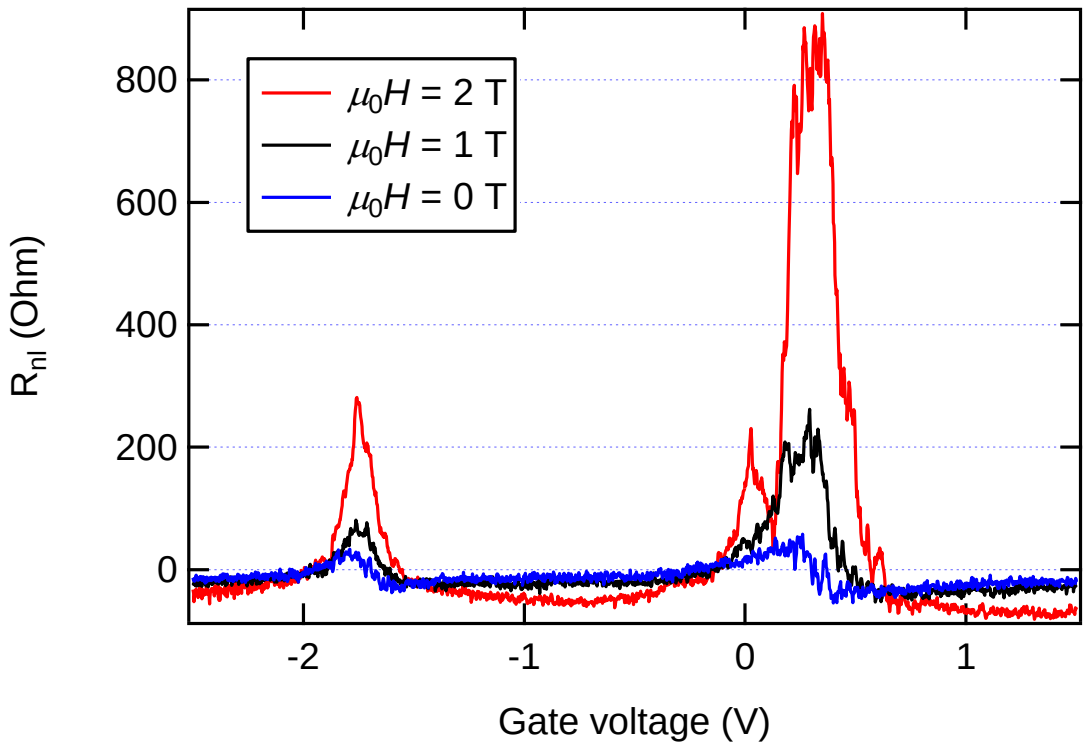

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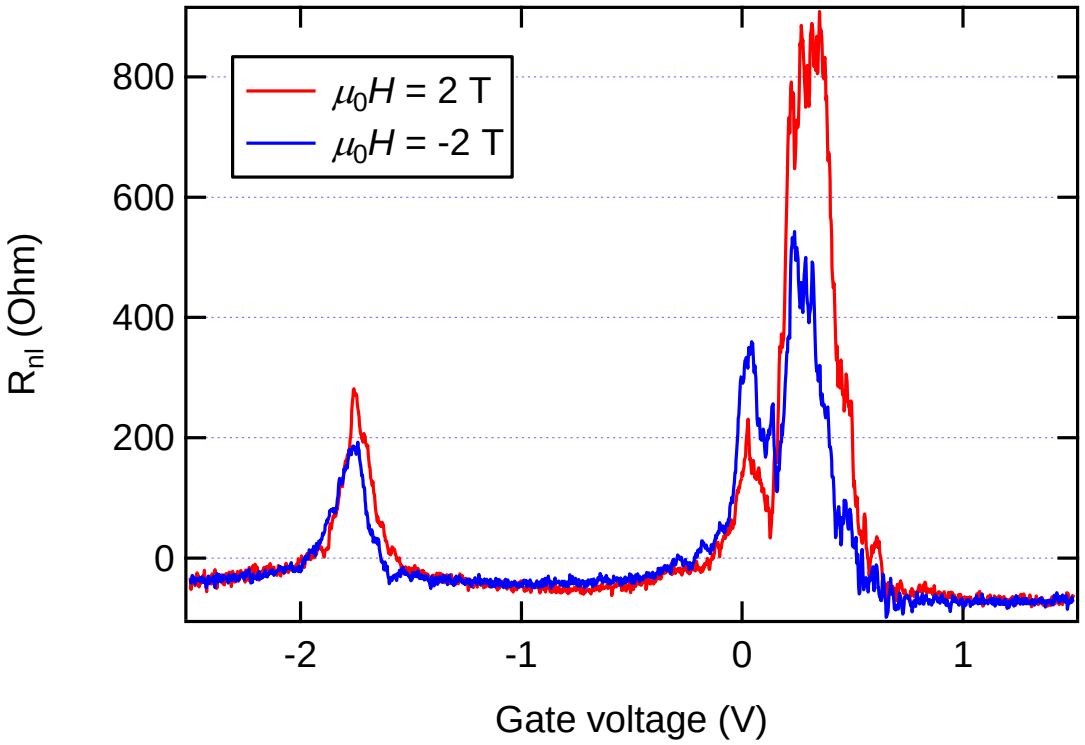
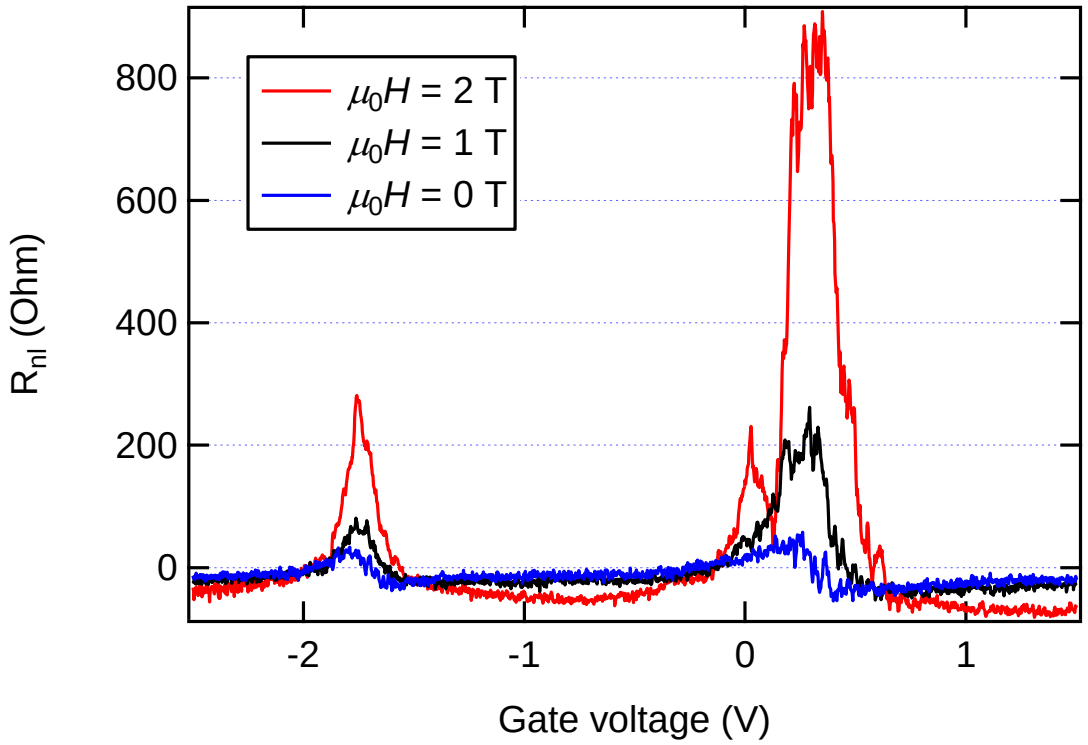
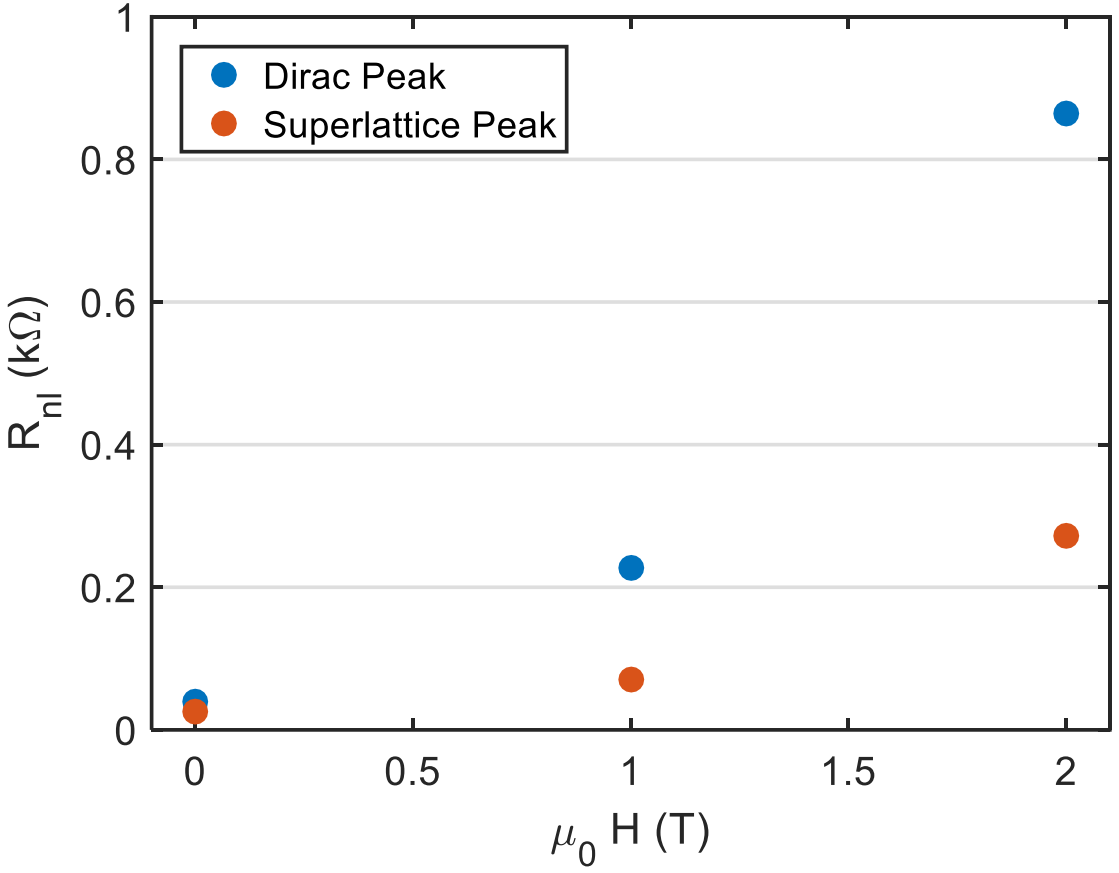
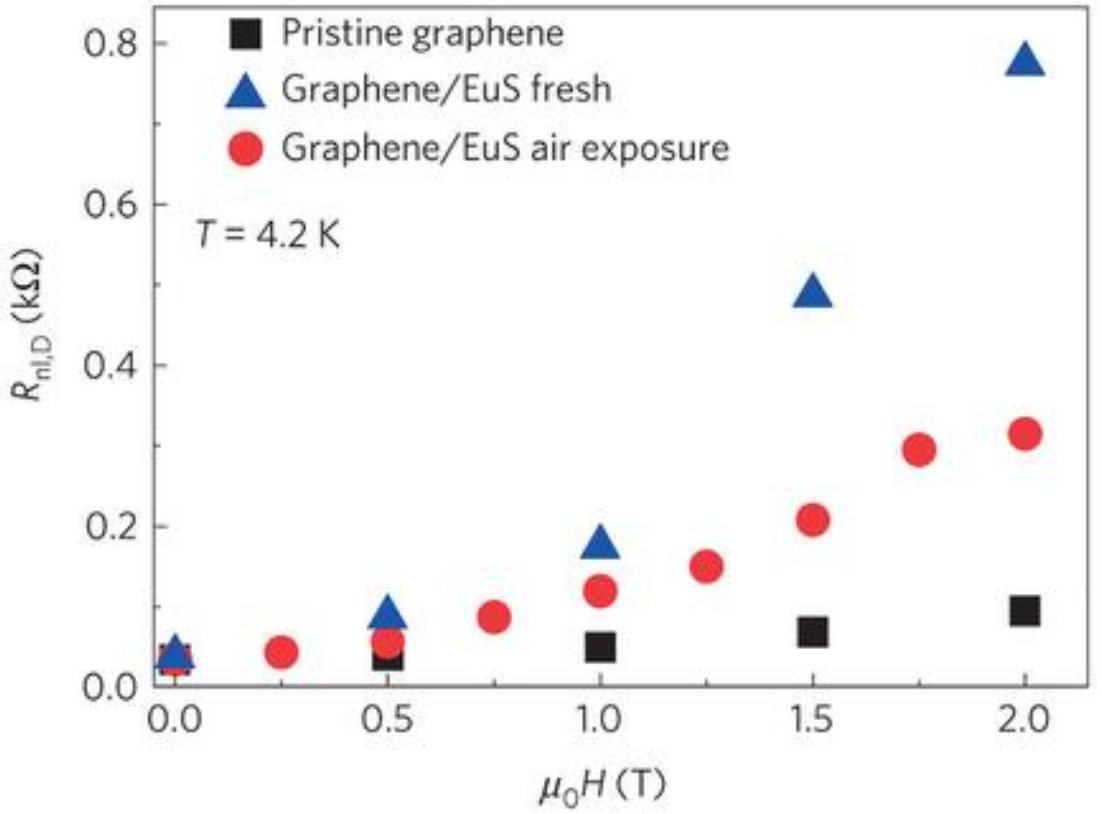




CGT/Graphene



EuS/Graphene



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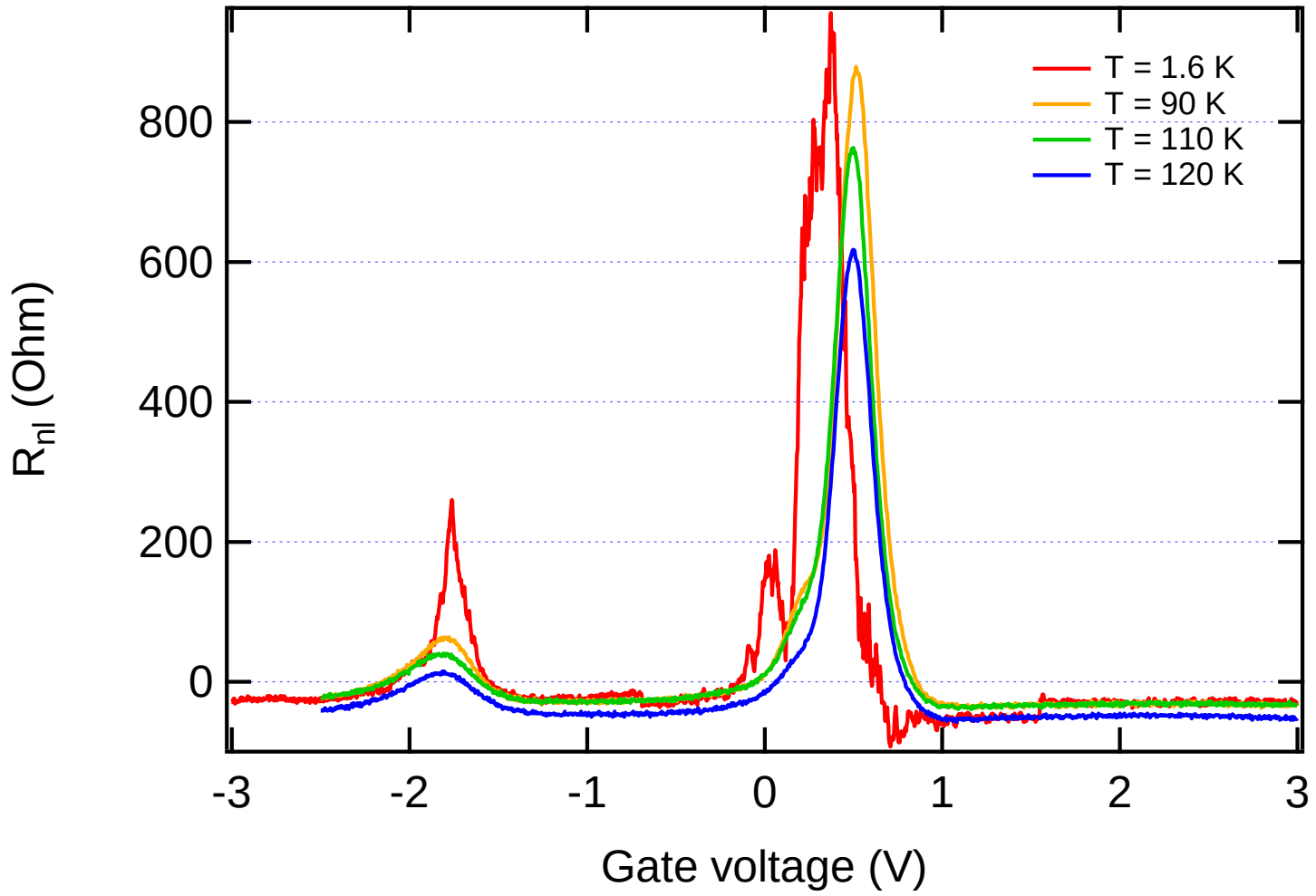
Non-Local Peak Persists to High T



Conclusions

- See signs of ferromagnetism in graphene/CGT heterostructures
  - Splitting of longitudinal resistance peak
  - Substantial Zeeman spin Hall peak
- Potentially enhanced ferromagnetism

Open Questions

- Temperature dependence
- In-plane magnetic field
- Shoulder in Zeeman spin Hall peaks
- Field asymmetry

Contributions

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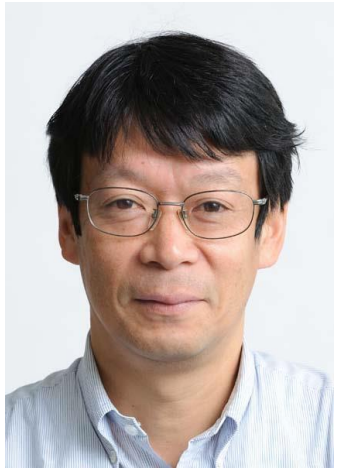
Stanford

Kenji Watanabe
NIMS



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Acknowledgments

Jason Petta and Bob Cava
Princeton