TOPOLOGY AND CORRELATIONS IN SPIN SYSTEMS

TALKS IN THIS SESSION

QUANTUM MAGNETIC MATERIALS

- Yuji Matsuda (Kyoto University, Japan)
  "Majorana Quantization and Half-Integer Thermal Quantum Hall Effect in a Kitaev Spin Liquid"

- Joseph Checkelsky (Massachusetts Institute of Technology, USA)
  "Dirac Electrons in Kagome Lattice Materials"

- Lucile Savary (CNRS / École Normale Supérieure de Lyon, France)
  "Surprising Transport Phenomena in Magnets"

TOPOLOGY IN SPIN SYSTEMS

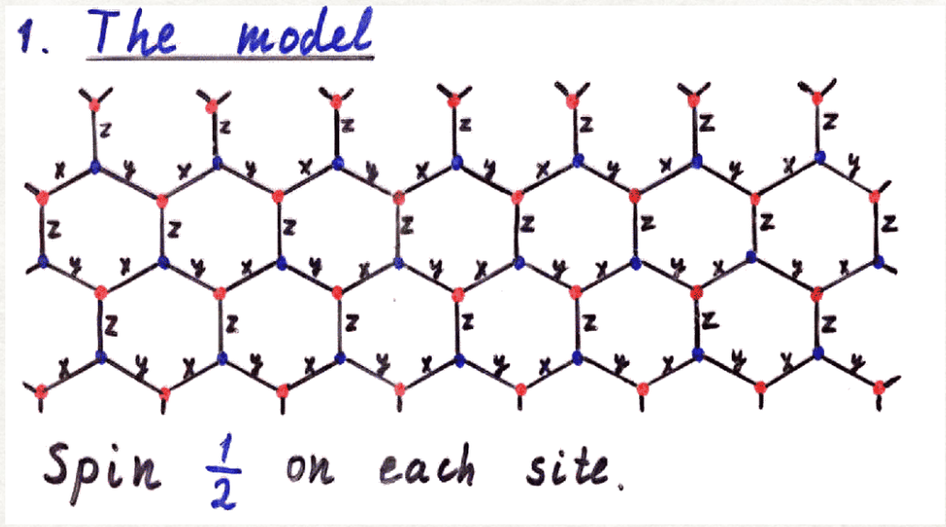
- Previous talks: topology of “free” electron problems
- How do we apply topology to spin systems??
  - Find some emergent fermions 
  - Couple the spins to electrons
  - avoid fermions completely

TOPOLOGY IN SPIN SYSTEMS

- Previous talks: topology of “free” electron problems
- How do we apply topology to spin systems??
  - Find some emergent fermions Matsuda Savary
  - Couple the spins to electrons Checkelsky Savary
  - avoid fermions completely Not today!

KITAEV MODEL

Kitaev's honeycomb model $$H = \sum_{i,\mu} K_\mu \sigma_i^\mu \sigma_{i+\mu}^\mu$$



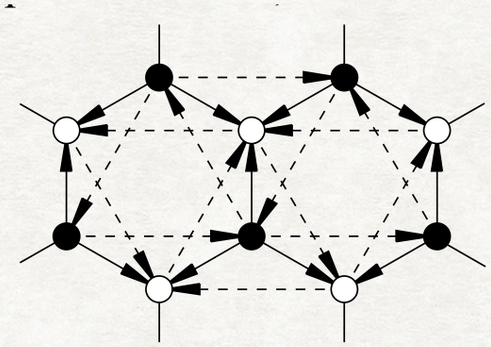
exact parton construction $\sigma_i^\mu = i c_i c_i^\mu \qquad c_i c_i^x c_i^y c_i^z = 1$

effective quadratic Hamiltonian

$$H = \sum_{i,\mu} i K_\mu c_i c_{i+\mu}$$

NON-ABELIAN PHASE

- In an applied magnetic field, the Majoranas acquire a gap
  - BdG Hamiltonian for a topological superconductor

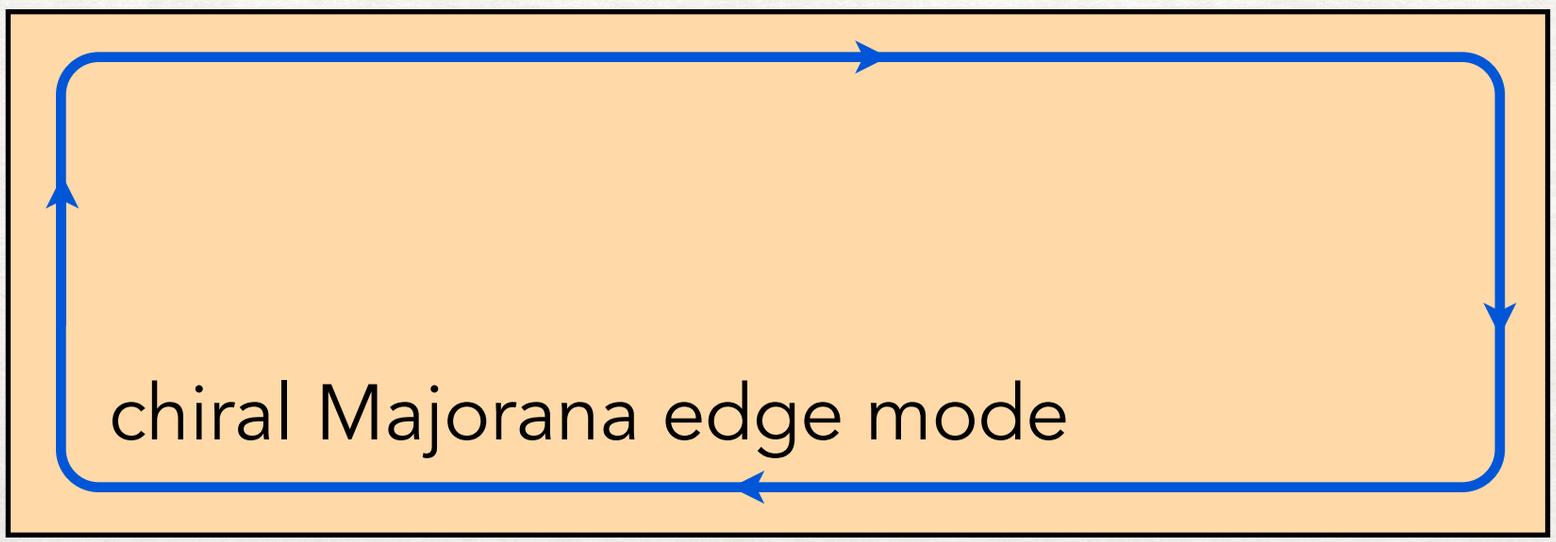


$$H_{\text{eff}} = \frac{\mathrm{i}}{4} \sum_{j,k} A_{jk} c_j c_k,$$

$$A = 2J\,(\longleftarrow) + 2\kappa\,(\leftarrow\!\!\cdots),$$

$$\kappa \sim \frac{h_x h_y h_z}{J^2}.$$

field induces a fermion mass, very similar to the Haldane model (except Majorana)

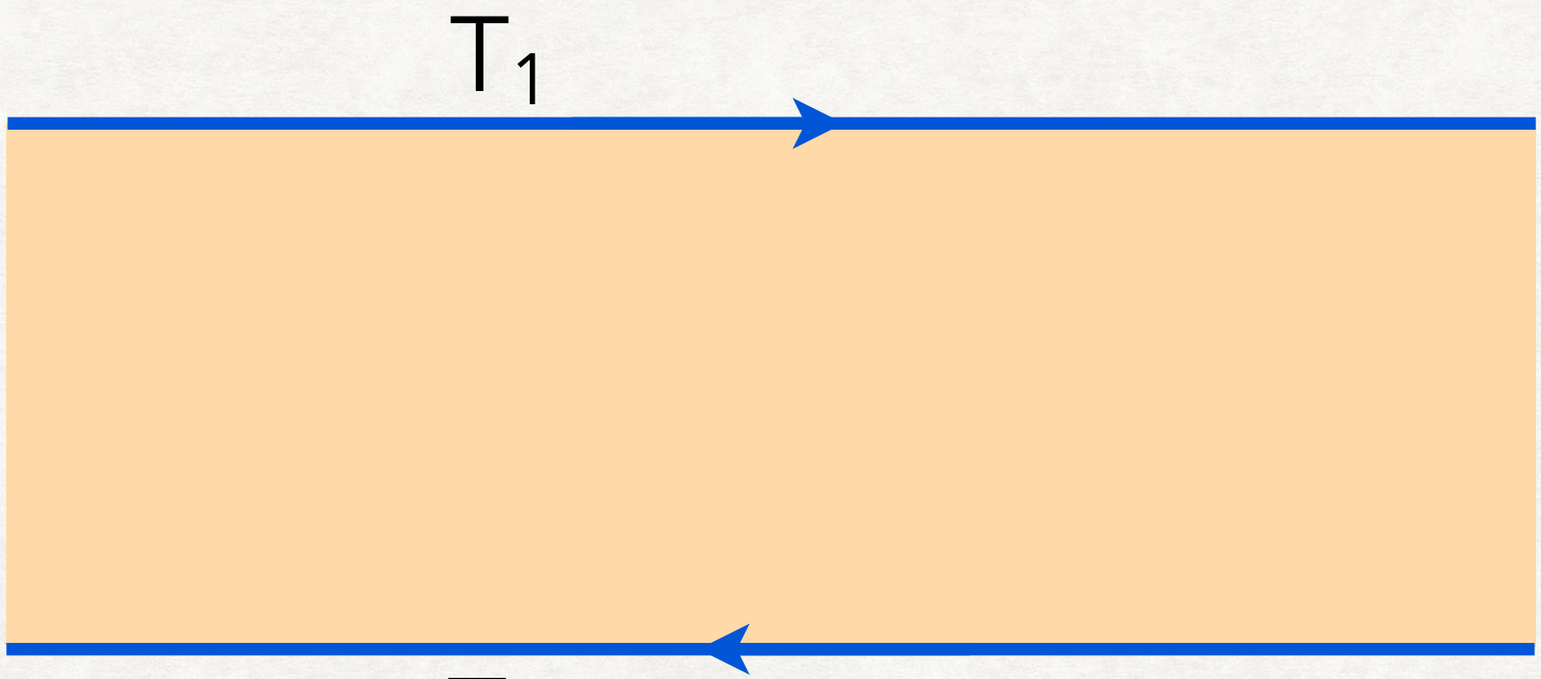


$$H_e = -\frac{iv}{4} \int dx\, \eta \partial_x \eta$$

Like p+ip edge state *except* ***the fermions are not electrons***

THERMAL QUANTUM HALL EFFECT

- Edge state picture



$$I_x = \kappa_H \Delta T_y$$

$$\kappa_H = \frac{\pi c k_B^2 T}{6\hbar}$$

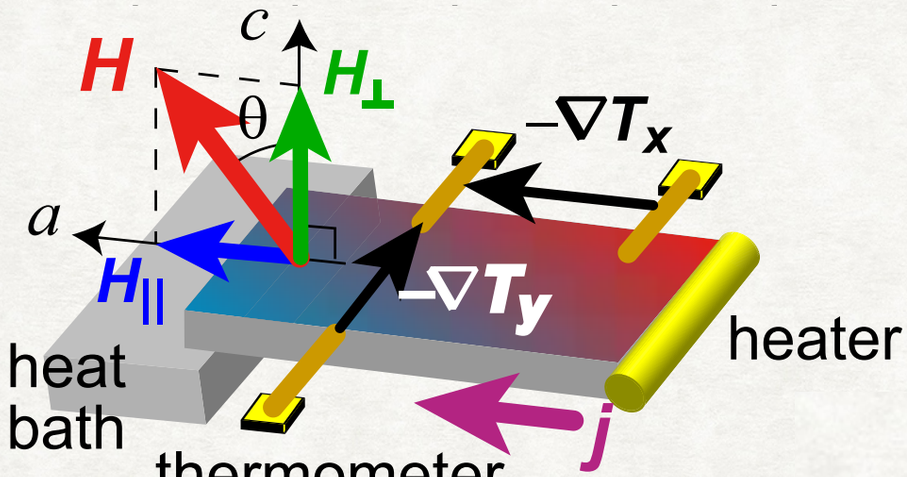
c=1/2

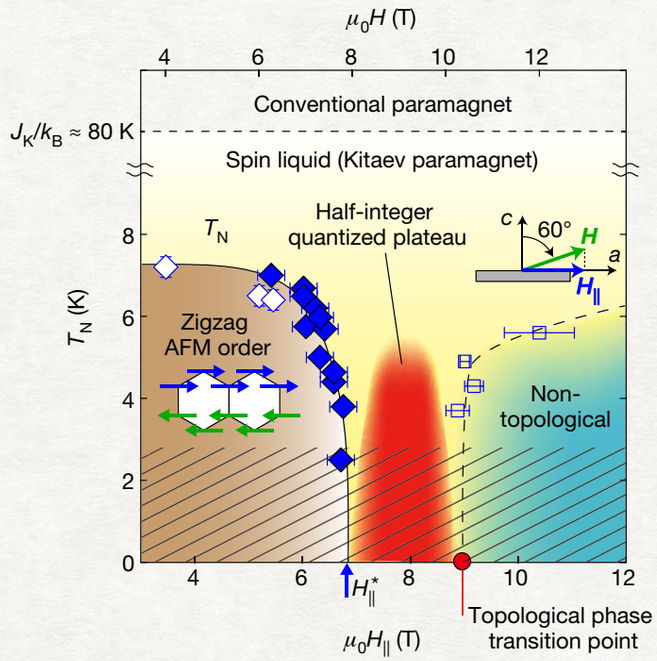
a universal prediction for chiral "Ising anyon" phase: *agnostic to microscopic spin interactions*

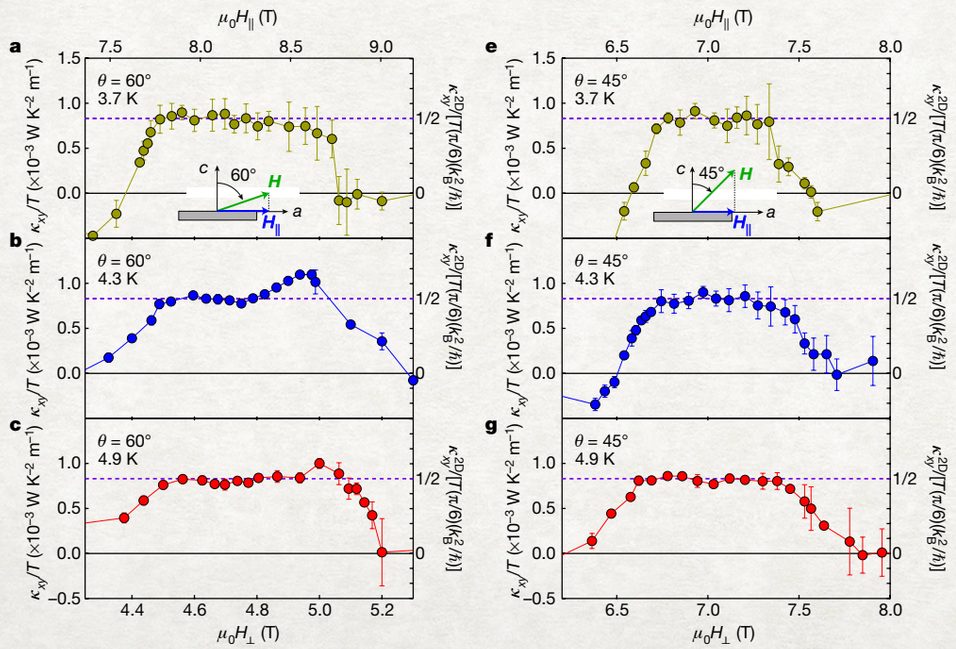
KITAEV SPIN LIQUID

MATSUDA: QUANTIZED THERMAL HALL EFFECT?

- Kasahara *et al*, 2018. α-$RuCl_3$







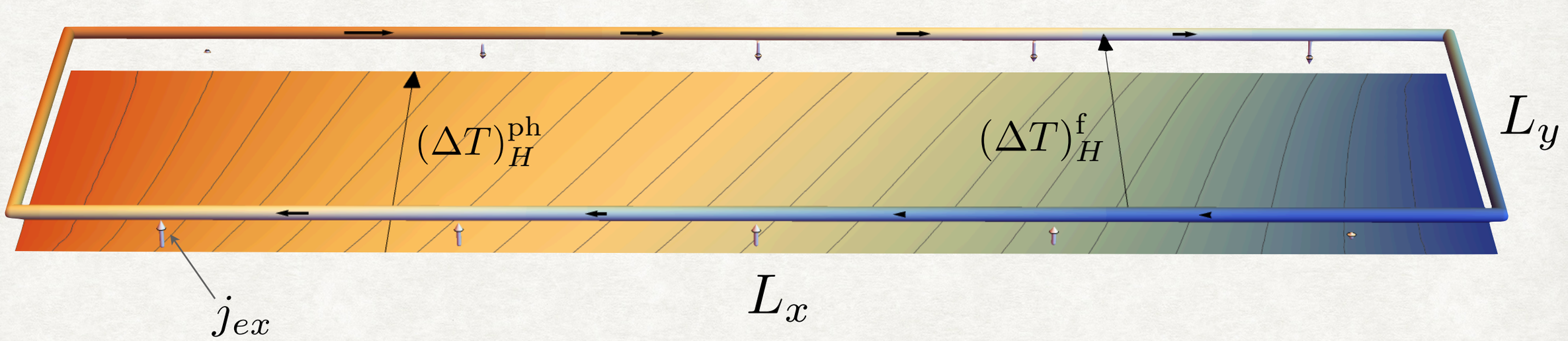
Evidence for an *emergent* chiral Majorana fermion edge mode?

Questions:

- Tiny Hall angle? Savary
- Reproducibility?
- Why should the nonabelian QSL be stabilized?

KITAEV SPIN LIQUID

- Savary: How about that small Hall angle?
  - Difference from electrical transport: phonons+spins both carry heat. May there be a phonon miracle??

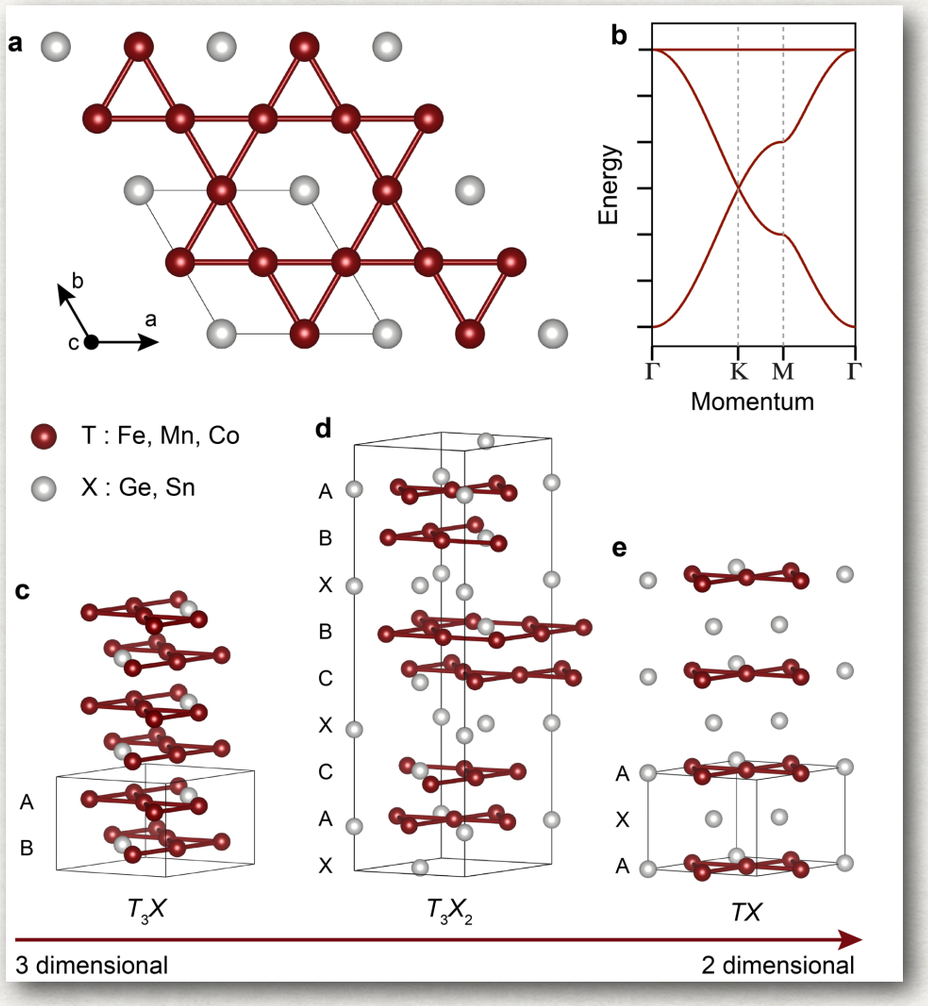


COUPLE SPINS TO ELECTRONS

- Go to war with the fermions you have, not the fermions you might want or wish to have at a later time (Donald Rumsfeld)
- Magnetic Weyls: Pyrochlore iridates, Mn_3Sn, Heuslers, RAlGe,…
- Topological Kondo insulators: SmB_6, YbB_{12}, …
- Magnetically doped topological insulators: Cr-Bi_2Se_3, $MnBi_2Te_4$,…
- Magnetic 2d Dirac fermions? Checkelsky

COUPLE SPINS TO ELECTRONS

- Checkelsky: Fe_xSn_y : Dirac fermions plus spins on a kagome lattice

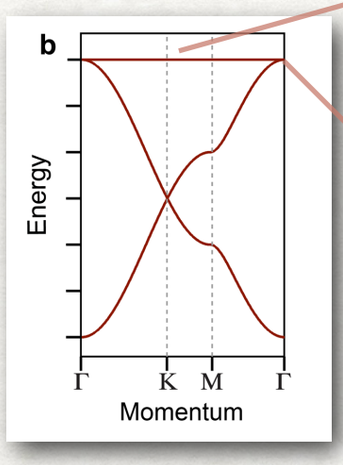


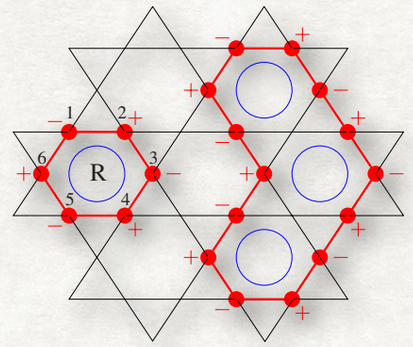
Old times

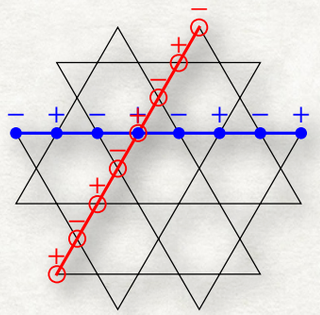
PHYSICAL REVIEW B **78**, 125104 (2008)

Band touching from real-space topology in frustrated hopping models

Doron L. Bergman,[1] Congjun Wu,[2] and Leon Balents[3]



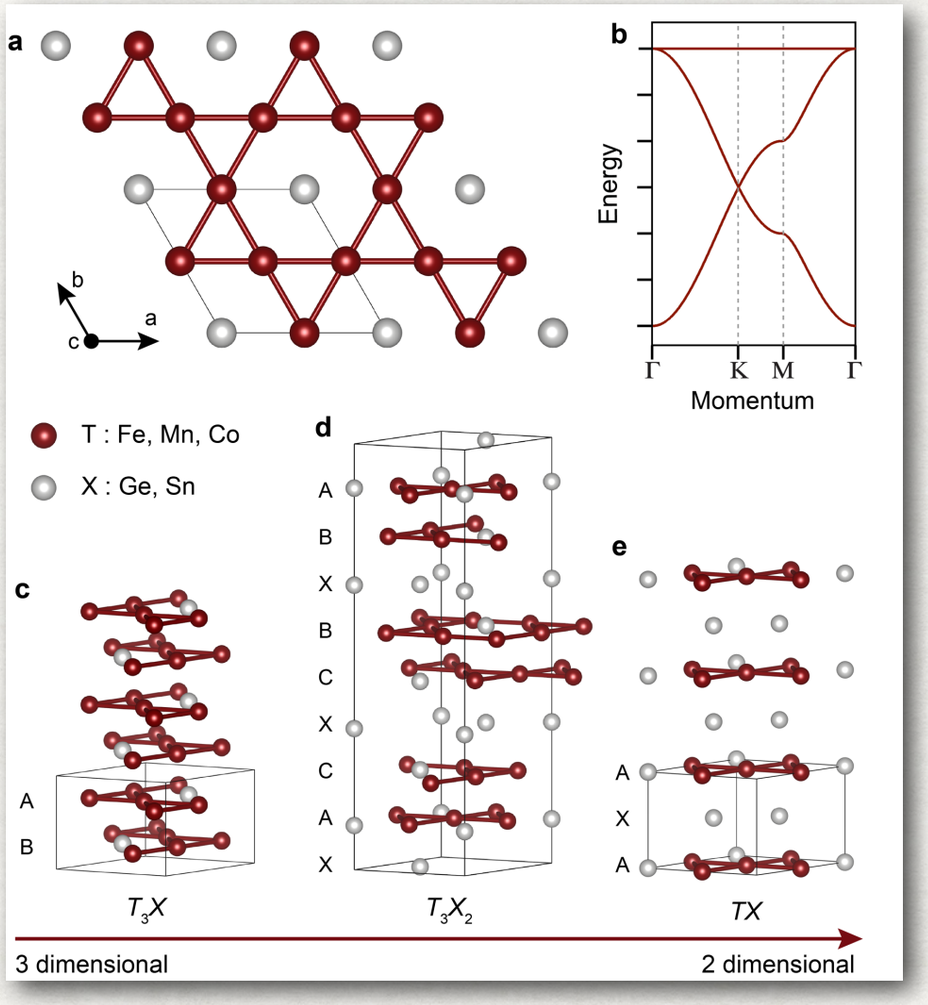


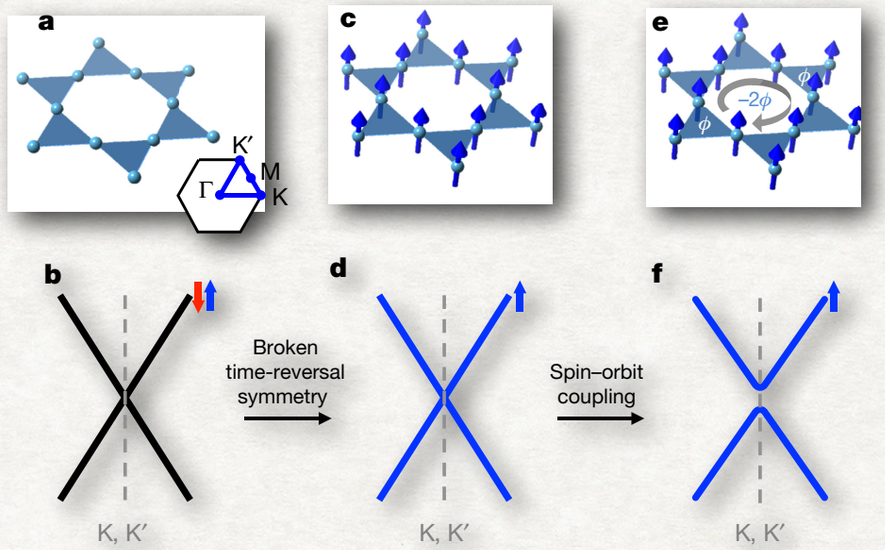


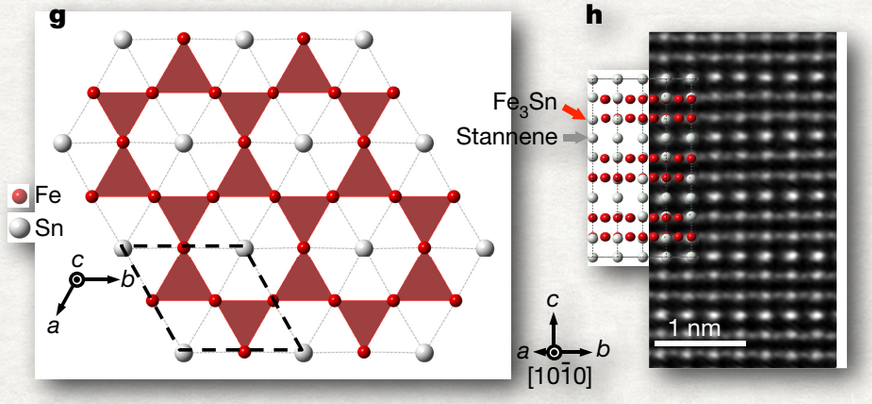
COUPLE SPINS TO ELECTRONS

- Checkelsky: Fe_xSn_y : Dirac fermions plus spins on a kagome lattice

Q: What orbitals? Why is "s"-orbital TB model relevant?

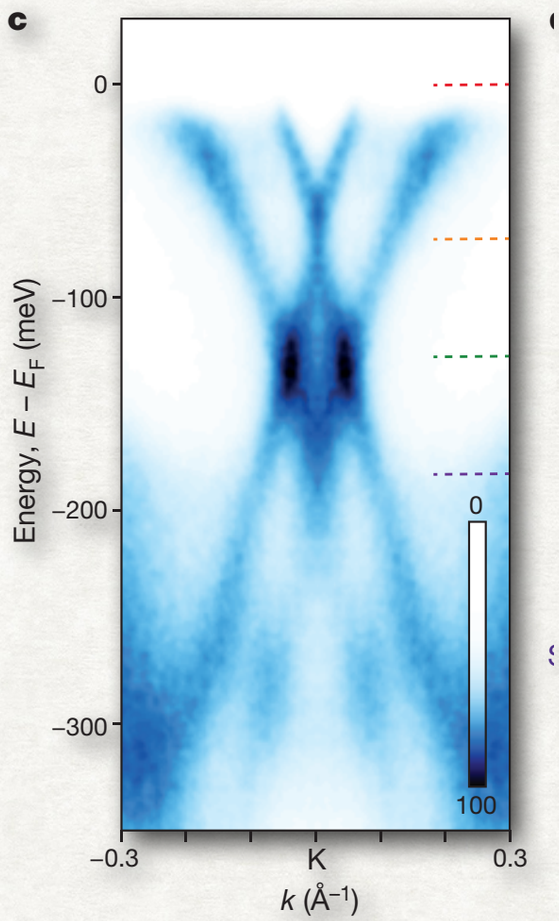


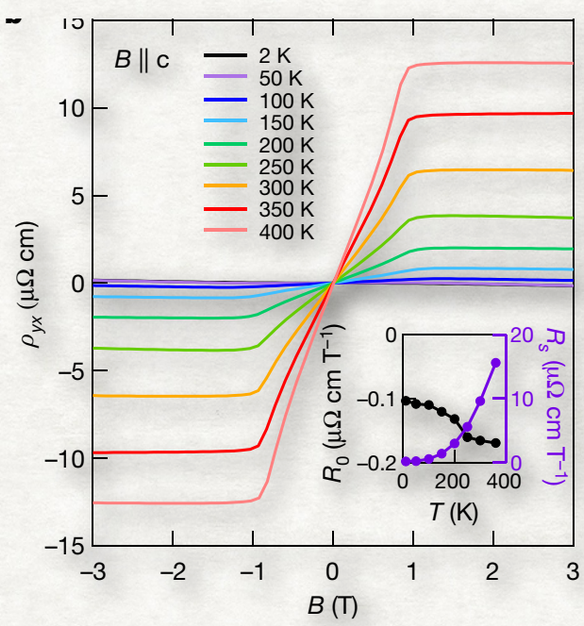




KAGOME DIRAC FERMIONS?

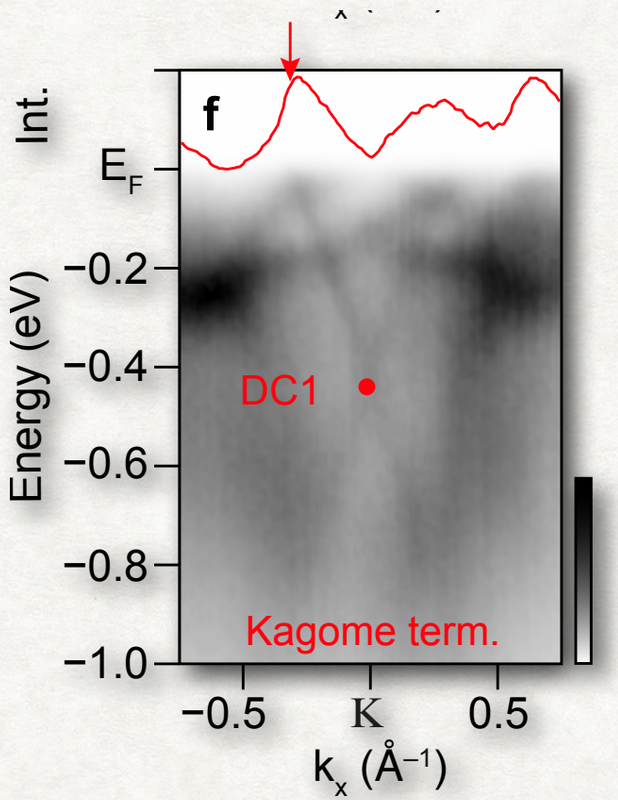
- Fe_3Sn_2 (bilayer)





Q: AHE strongly decreases with lower temperature?

- FeSn (single layer)



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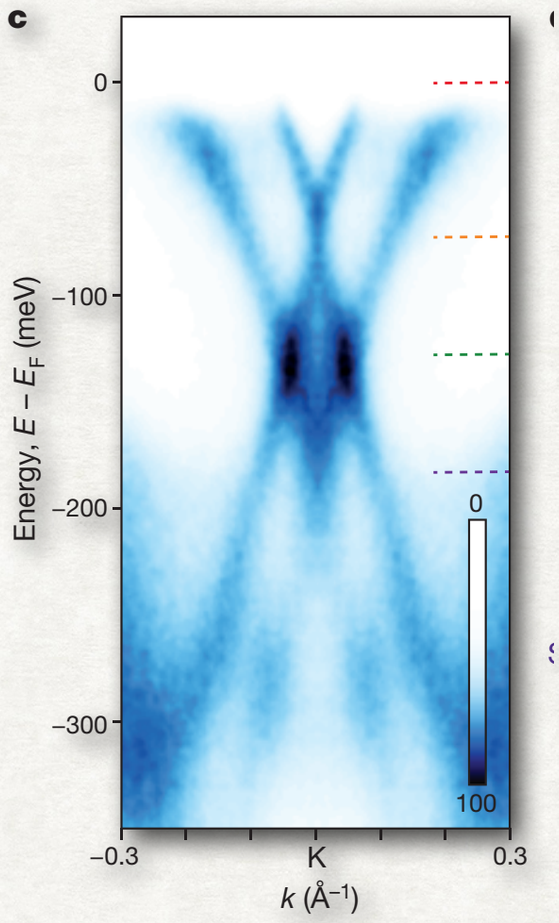

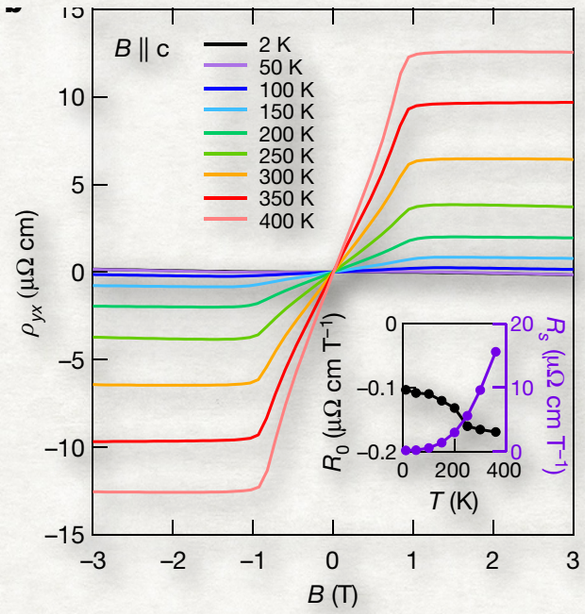

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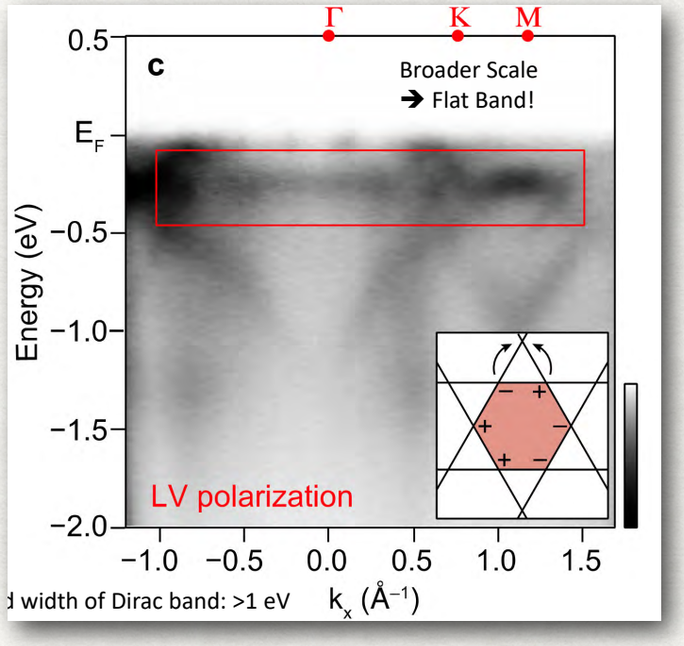
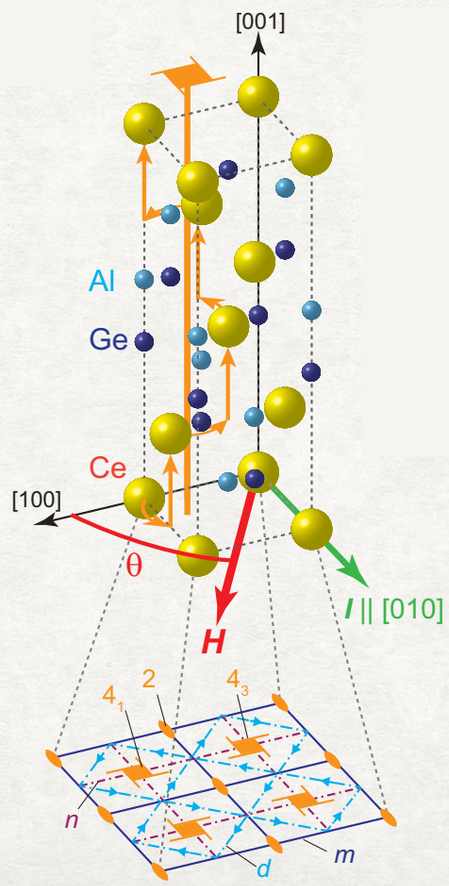


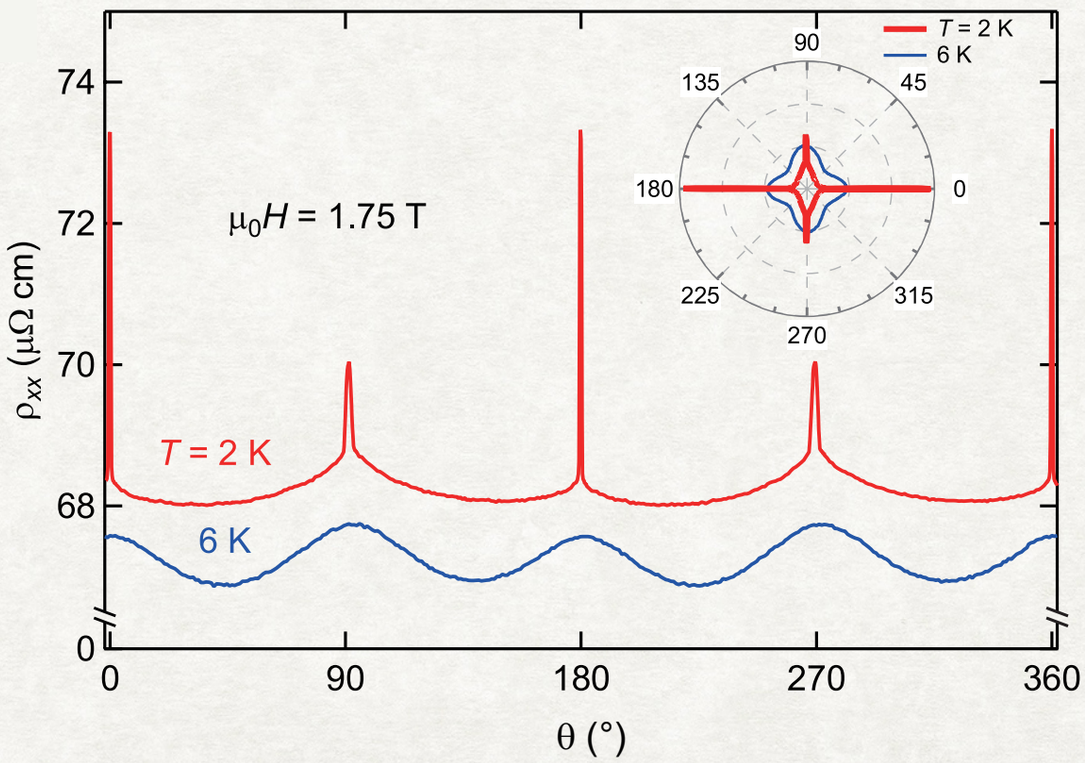
Flat band??!??!

Q: Correlation effects?

SINGULAR ANGULAR MAGNETORESISTANCE

- Savary: surprising transport phenomena in CeAlGe - an antiferromagnetic topological semimetal
  - Let me spoil the surprise





Lucile will explain this!

LET'S GO!!

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