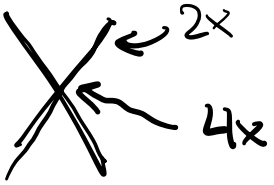
Topological semimetals II: Dirac fermions

last time: Weyl fermions forbidden by TI because $\Omega = 0$

allowed? $H = \begin{bmatrix} vk\cdot\sigma & \\ & -vk\cdot\sigma \end{bmatrix}$ $\quad TI = i\sigma_y\tau_x K$

$E = \pm vk$



basis: $\begin{pmatrix} j_z = 3/2 & P \\ j_z = 1/2 & S \\ j_z = -1/2 & S \\ j_z = -3/2 & P \end{pmatrix}$

not protected!

$H_M = m\tau_x$

to protect Dirac fermion, need rotation

$C_4 = \begin{pmatrix} e^{3\pi i/4} & & & \\ & e^{i\pi/4} & & \\ & & e^{-i\pi/4} & \\ & & & e^{-3\pi i/4} \end{pmatrix}$

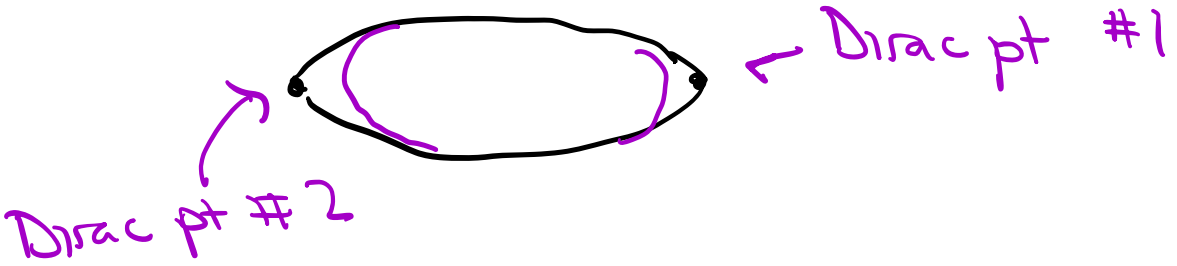
$C_4 H(k_x, k_y, k_z) C_4^{-1} = H(k_y, -k_x, k_z)$

materials: Cd_3As_2 C_4

Na_3Bi C_6

Do Dirac Fermions have Fermi arcs?

~~yes~~? our simple model does



Ref: Kargarian etal PNAS (2016)

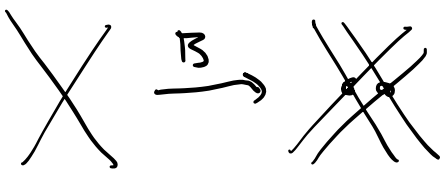
Are Dirac points topological?

NO: Chern #

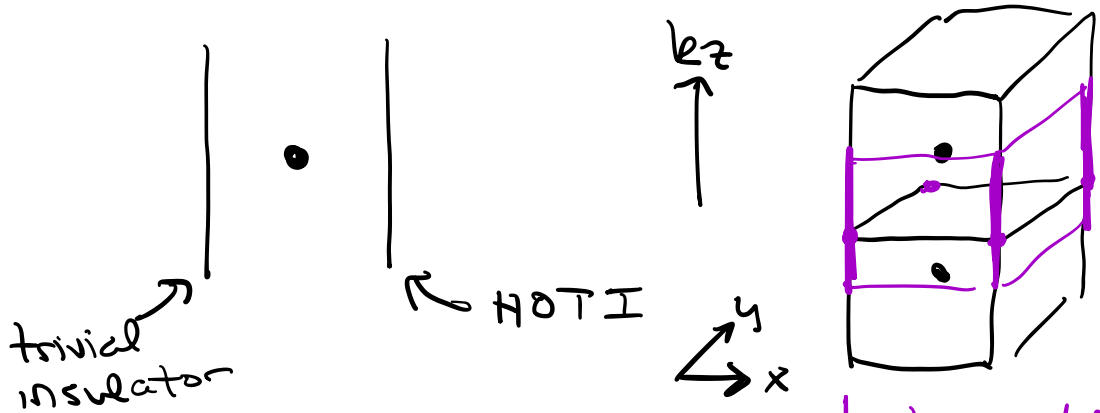
NO: Surface states

YES: transport anomalies

YES: "parent" to Weyl



YES: Dirac pt is critical pt btwn HOTI & trivial

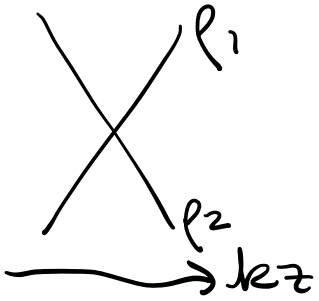


Wieder et al Nat. Comm (2020)
Fang + Cano PRB (2021)

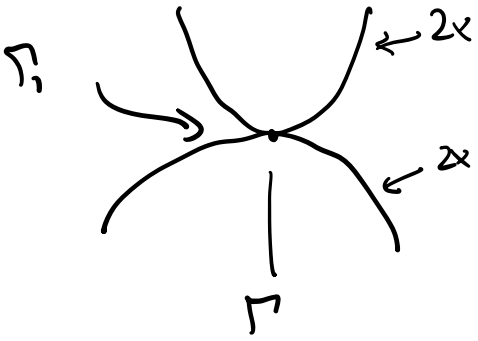
Tyner et al PRR (2023)

Types of symmetry protected band crossings?

high-symmetry line
e.g. Dirac



high symmetry point
e.g. GdPtBi



how to classify band crossings?

① "little group" at k $\quad G_k \equiv \{g \mid gk = k\}$

② find irreps: $d > 1 \Rightarrow$ band touching

Results: 2, 3, 4, 6, 8-dim band touchings in crystals w/ SOC

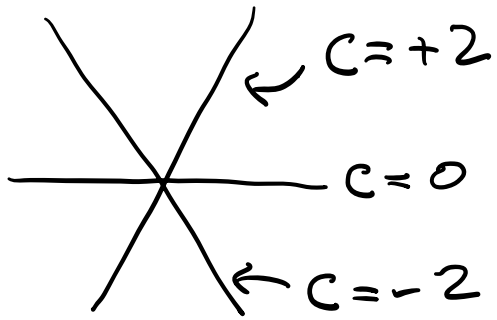
only possible in nonsymmorphic SGs

Ref: Bradlyn et al Science 2016

"spin-1 Weyl"

$H = v\vec{k} \cdot \vec{S}$ ← spin-1 matrices

3-fold crossing

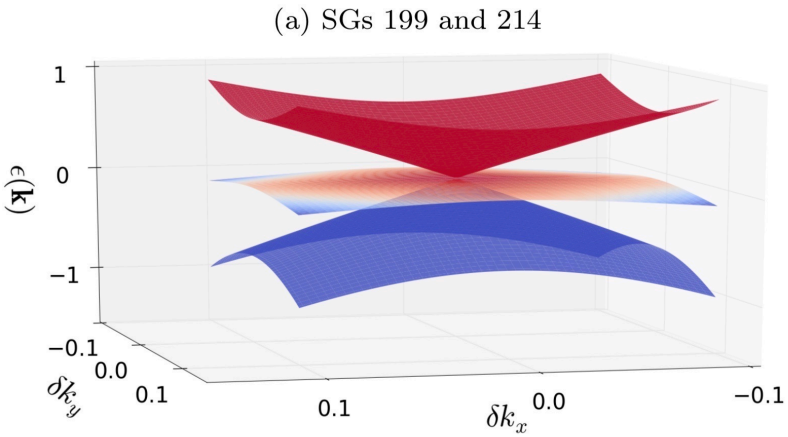


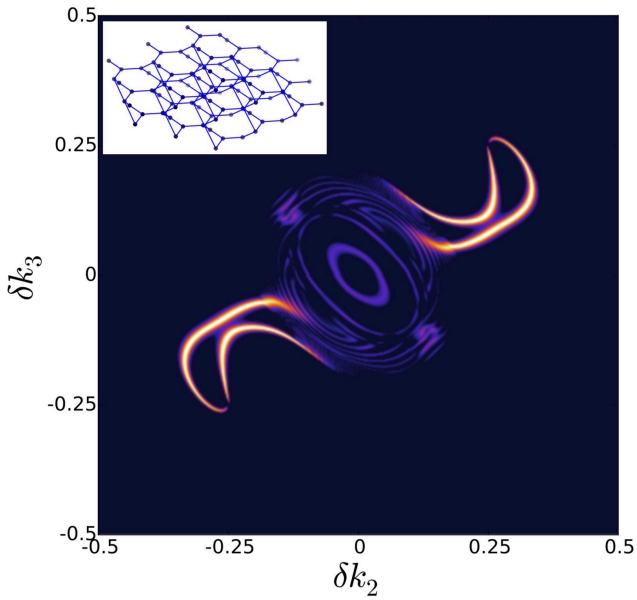
SGs: 199 & 214

$Pd_2Bi_2S_2$ Ag_3Se_2Au

Spin-1 fermions

Bradlyn et al Science 2016





Tang et al PRL 2017