Higher-Order Topological Insulators

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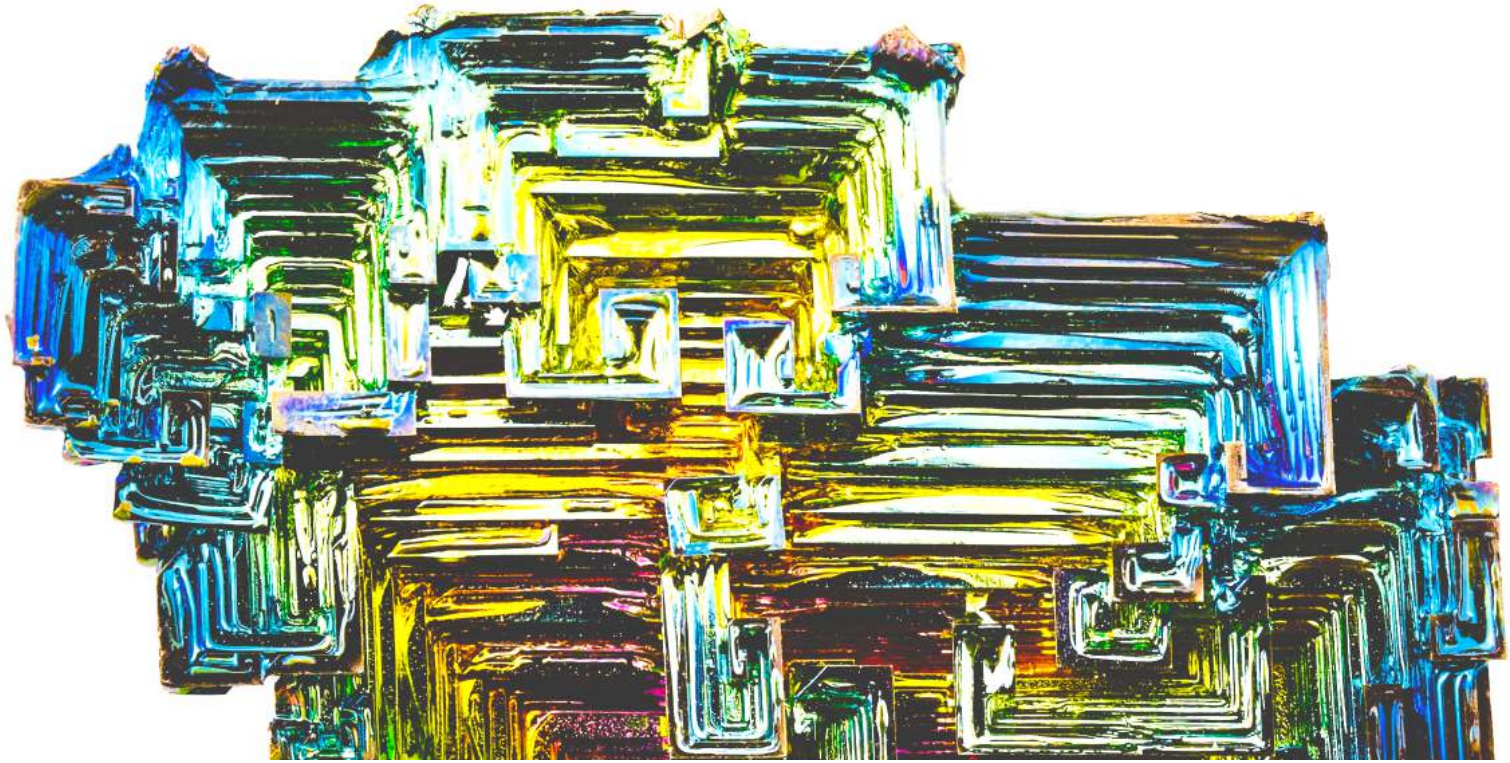
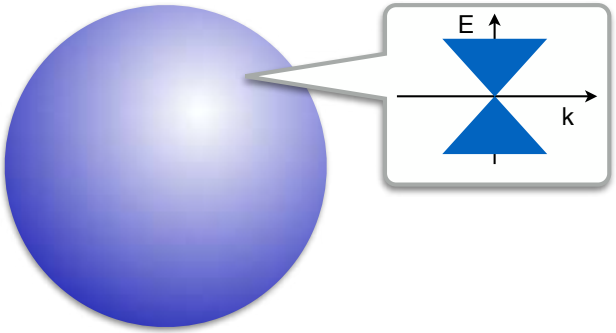
Solid State Seminar 03/10/2018

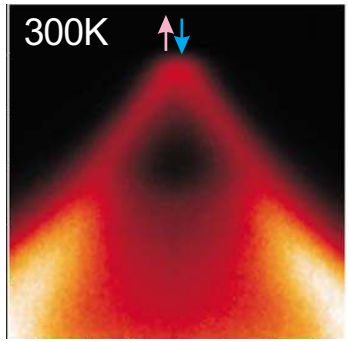


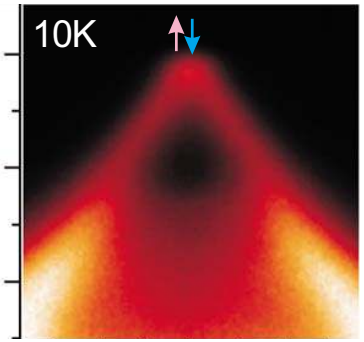
Motivation

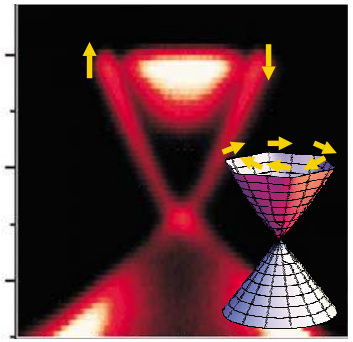
A 3D topological insulator has gapless states on its 2D surfaces

3D TI



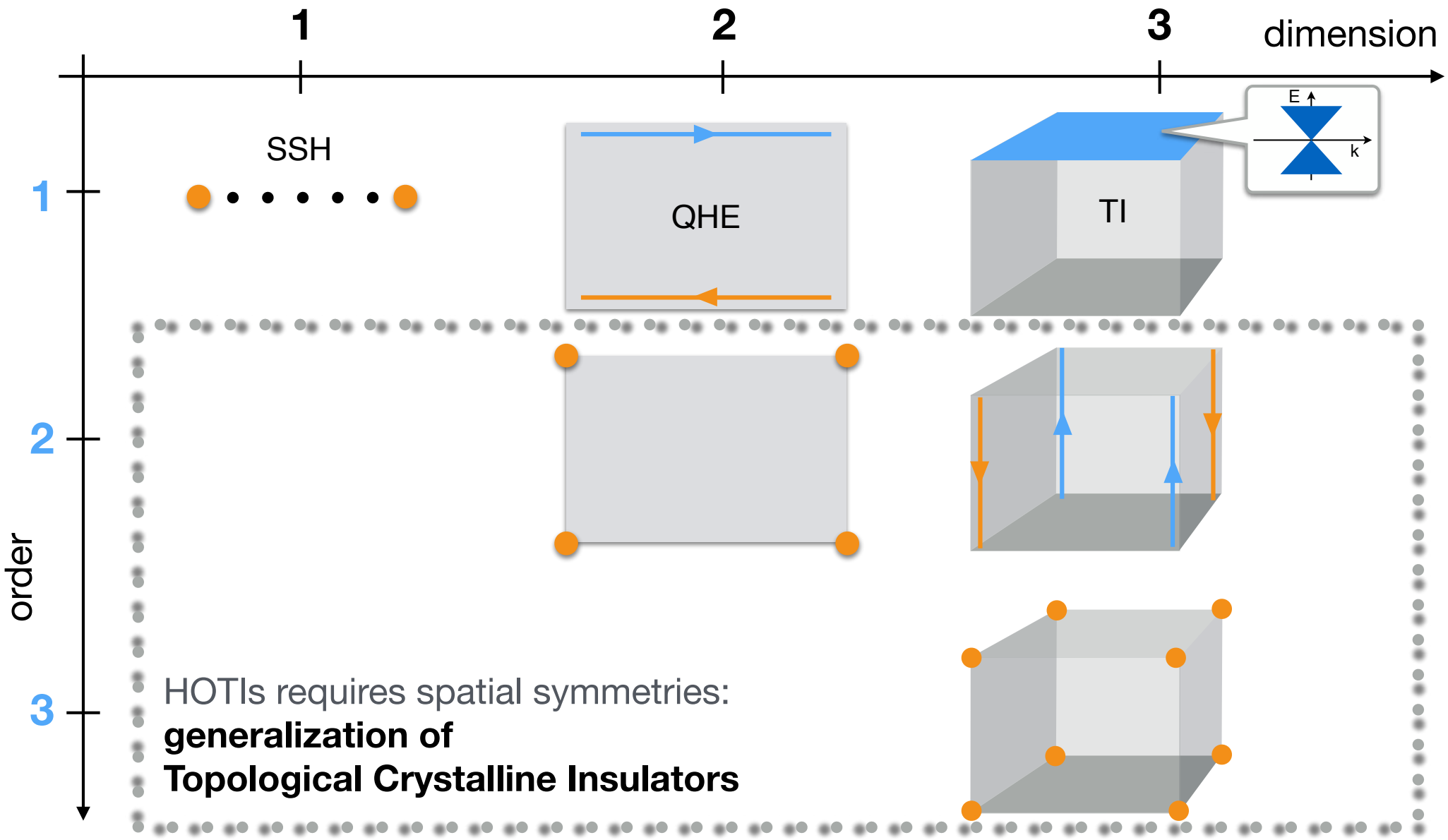






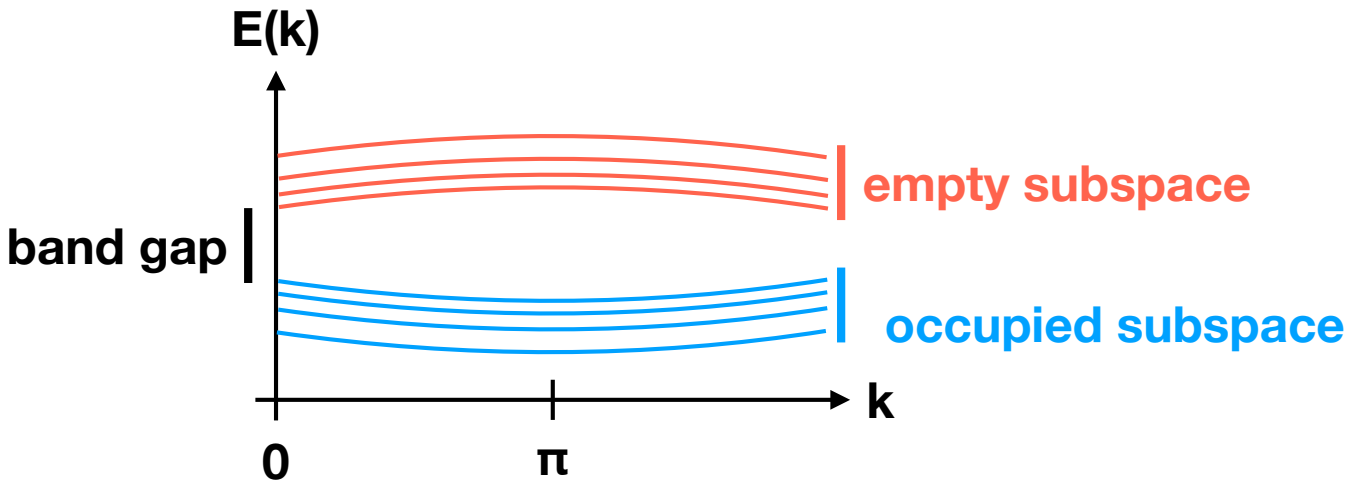
crystals also have 1D edges!

Overview


1
2
3
dimension
order
SSH
QHE
TI
E
k
HOTIs requires spatial symmetries:
generalization of
Topological Crystalline Insulators

Topological Crystalline Insulators

insulating, non-interacting, translationally invariant electron systems are described by a gapped Bloch Hamiltonian H(k)

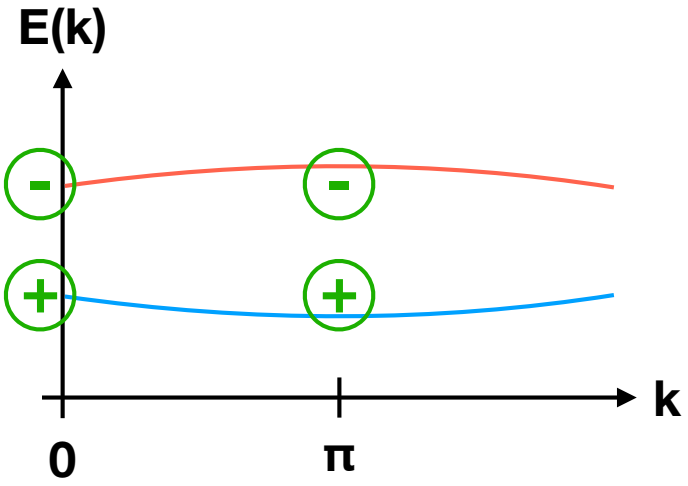


H(k) of a TCI cannot be continuously deformed to that of a trivial insulator without closing the band gap or breaking crystalline symmetries

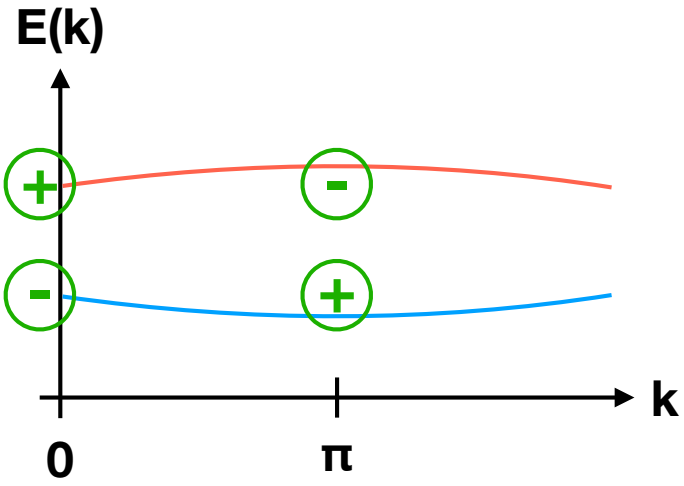
1D Topology from Inversion

$I\,H(k)\,I^{-1} = H(-k)$, $I^2 = 1$, so have eigenvalues ± 1

for a 1D system, have two possibilities:



trivial



topological

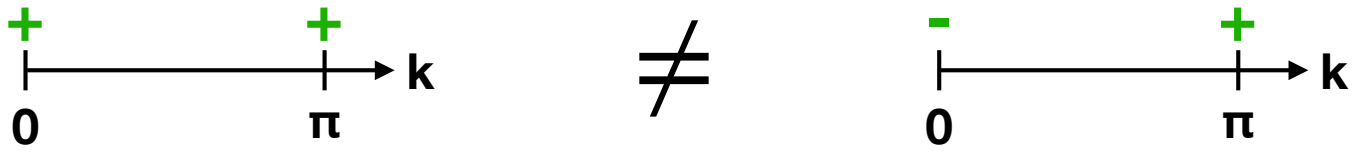
gapped bulk
trivial boundary

gapped bulk
quantized 1/2 end charges

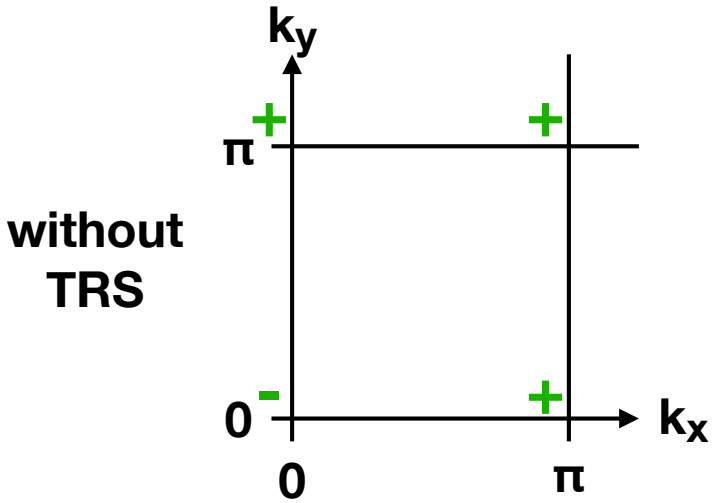
2D Topology from Inversion

forget about energies, they are not topological

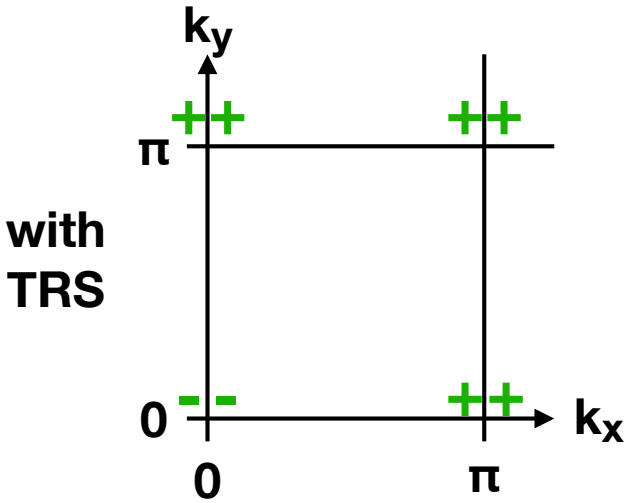
what's important is that



in 2D, famous examples of non-trivial inversion eigenvalues are



Chern insulator
~ integer quantum Hall effect



2D topological insulator
~ quantum spin Hall effect

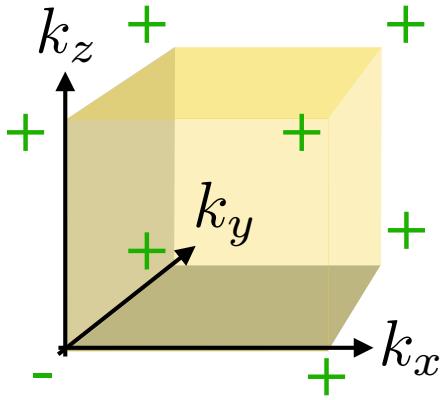
these 2D phases in fact don't even require inversion, but we can use it to diagnose them

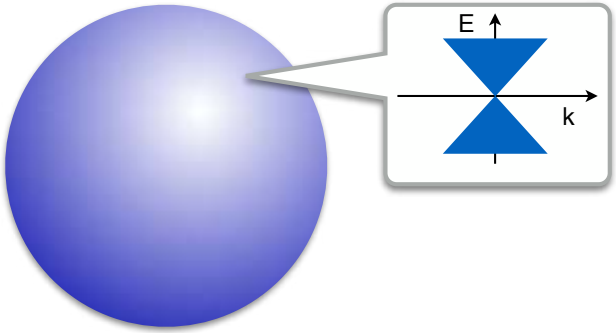
3D Topology from Inversion

from now on, assume TRS:

+ , - now denotes 2 Kramers paired bands with inversion eigenvalues {±1, ±1}

3D TI:





Fu-Kane 3D TI index:

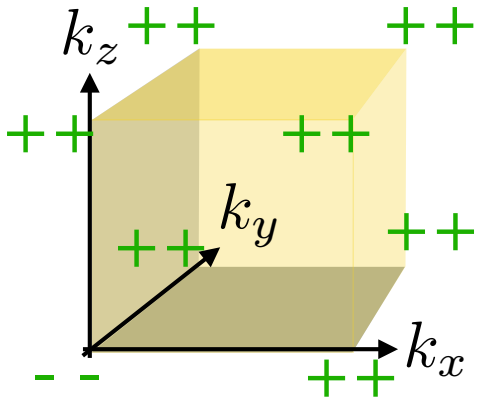
$$\prod_{k \in \mathrm{TRIM}} \xi_k$$

product over inversion eigenvalues per Kramers pair at time-reversal invariant momenta

evaluates to - 1

3D Higher-Order Topology

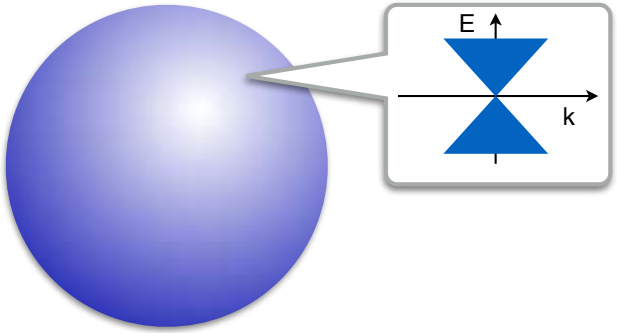
what about



? **Has Fu-Kane index +1.**

= 2 x topological insulator

= 2 x



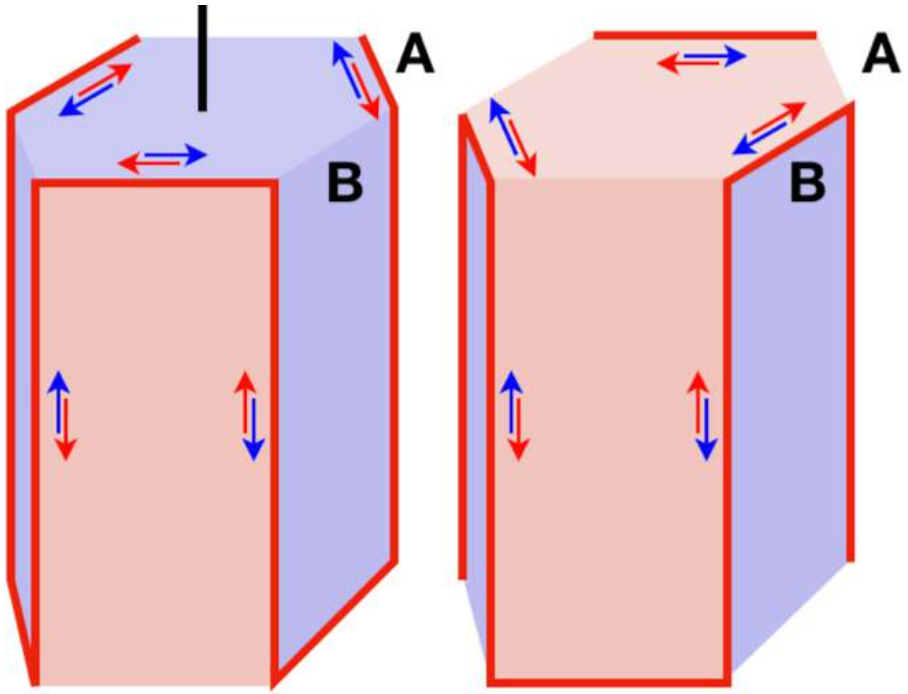
on surface:
Two gappable Dirac cones

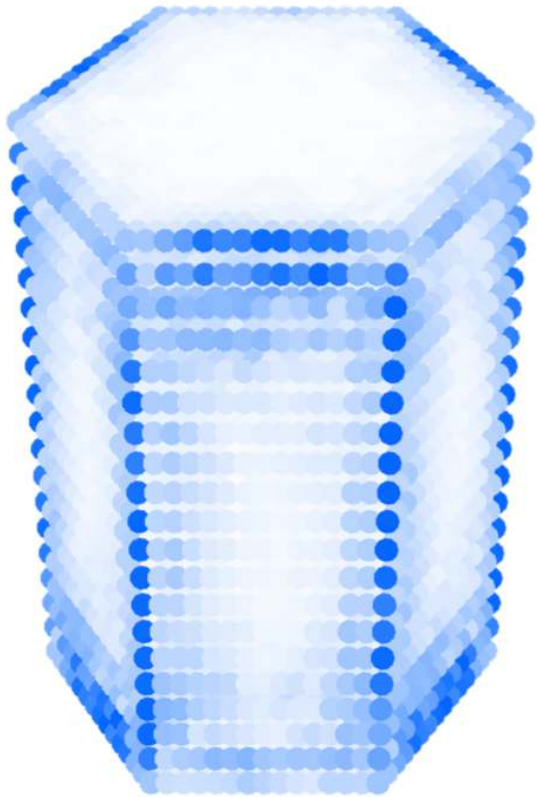
but this configuration of inversion eigenvalues is not quite trivial!

Bulk-boundary correspondence for “double band inversion”

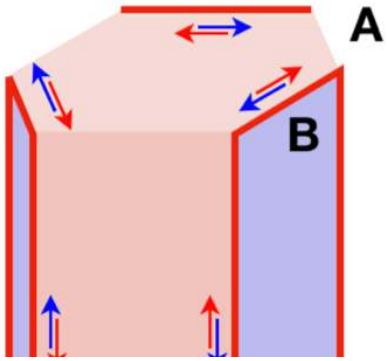
Decoupled subspaces:
Two surface Dirac cones

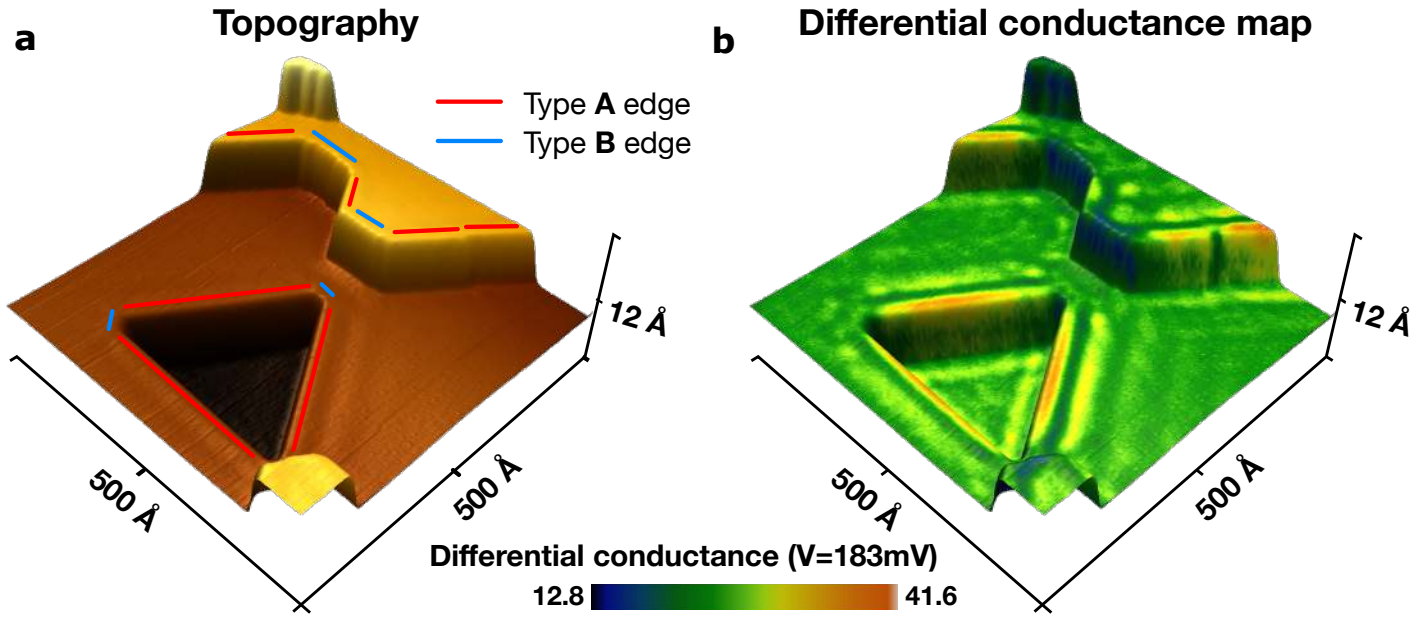
I: m → – m

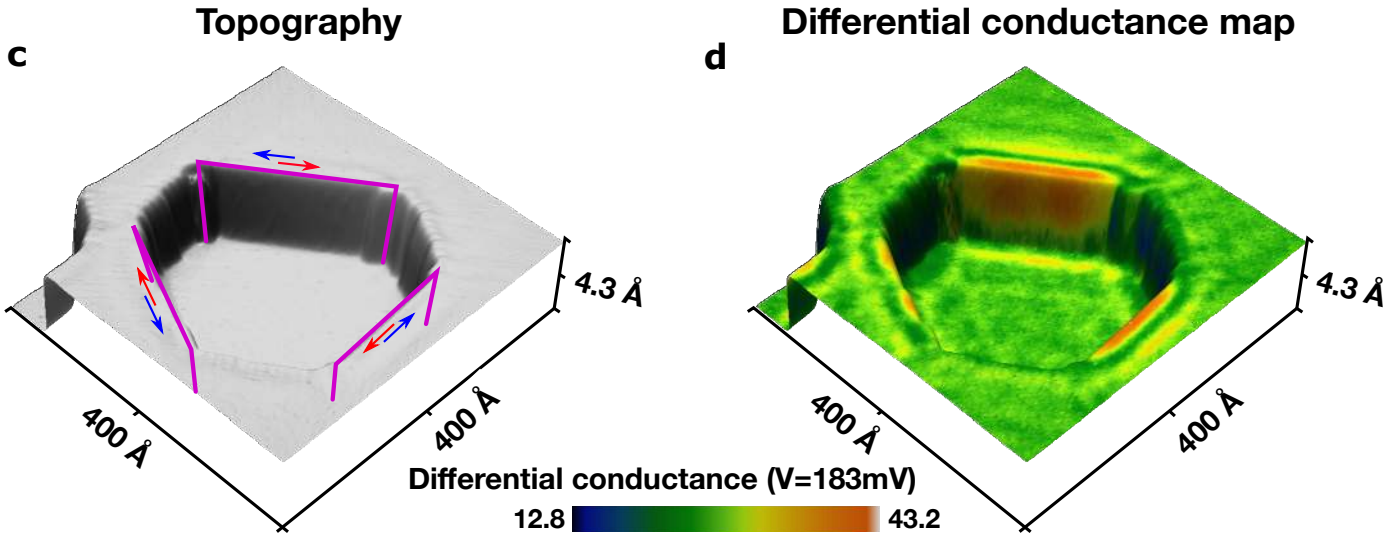




Bismuth Experiment1) **STM**





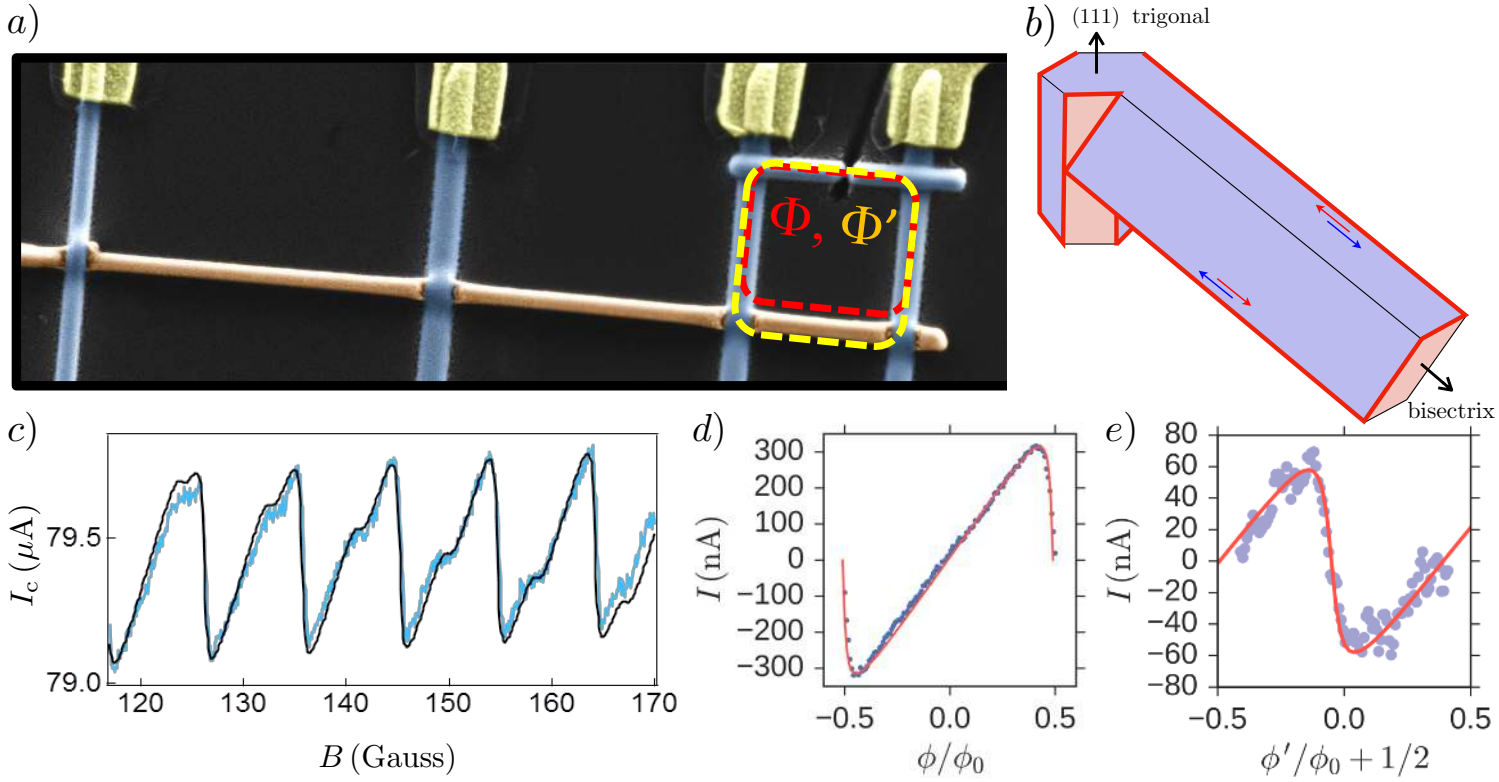


questions:

i) thickness dependence

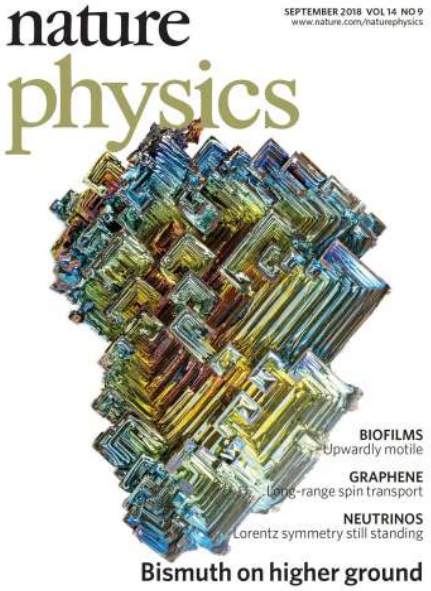
ii) hybridization with lower hinge mode

Bismuth Experiment 2) **Josephson interferometry**



Sawtooth current-phase relation:
Mean free path required way longer than that of Bismuth bulk
—> due to lossless edge states

References



Higher-Order Topological Insulators,

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F. Schindler, Z. J. Wang, M. G. Vergniory, A. M. Cook, A. Murani, S. Sengupta, A. Y. Kasumov, R. Deblock, S. Jeon, I. Drozdov, H. Bouchiat, S. Guéron, A. Yazdani, B. A. Bernevig, T. Neupert

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Thanks to

Theory

M. G. Vergniory,
Z. J. Wang,
S. S. P. Parkin,
B. A. Bernevig,
T. Neupert

Experiment

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