From quantum Hall to quantum spin Hall

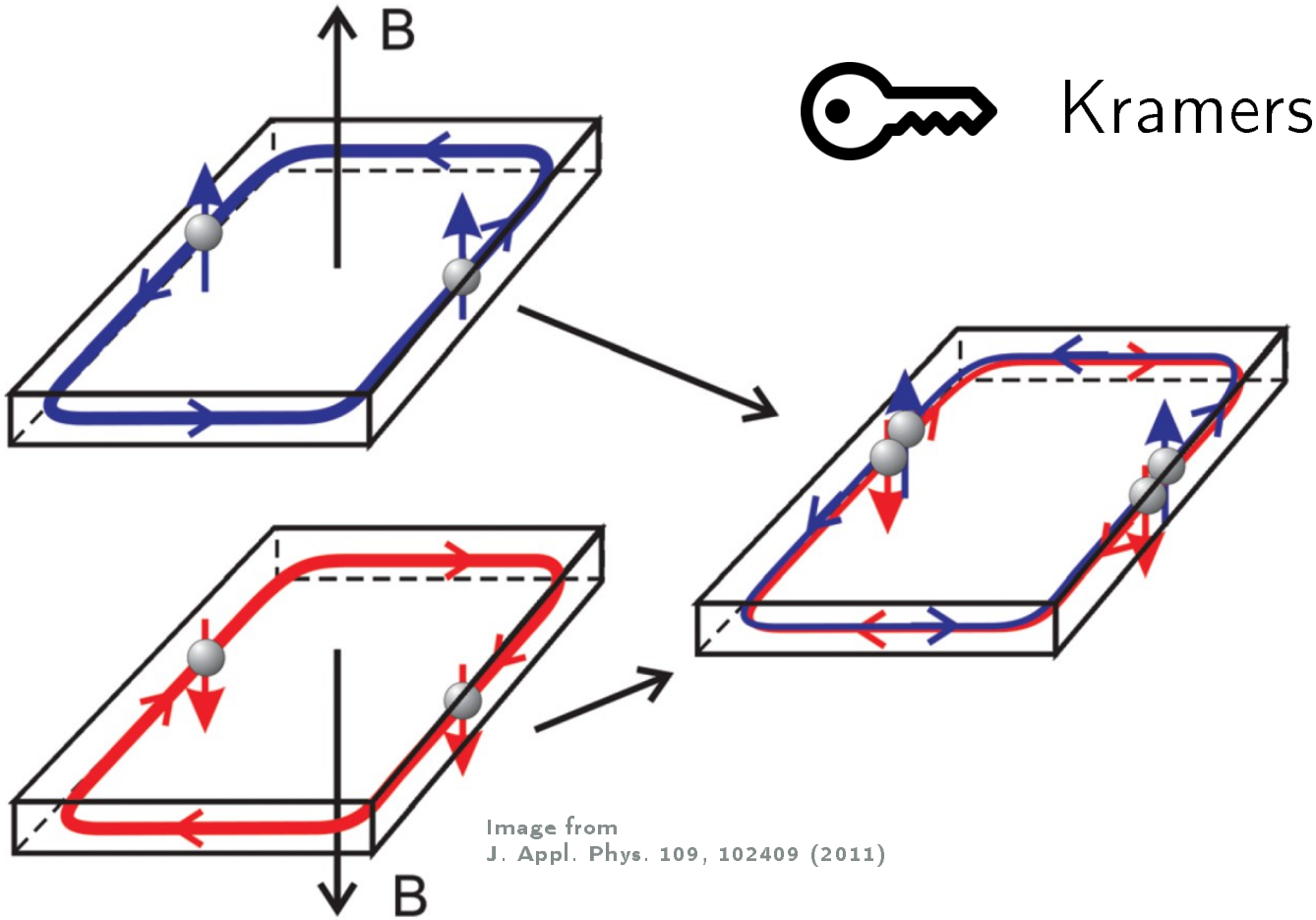
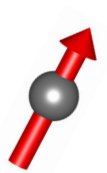


Image from
J. Appl. Phys. 109, 102409 (2011)

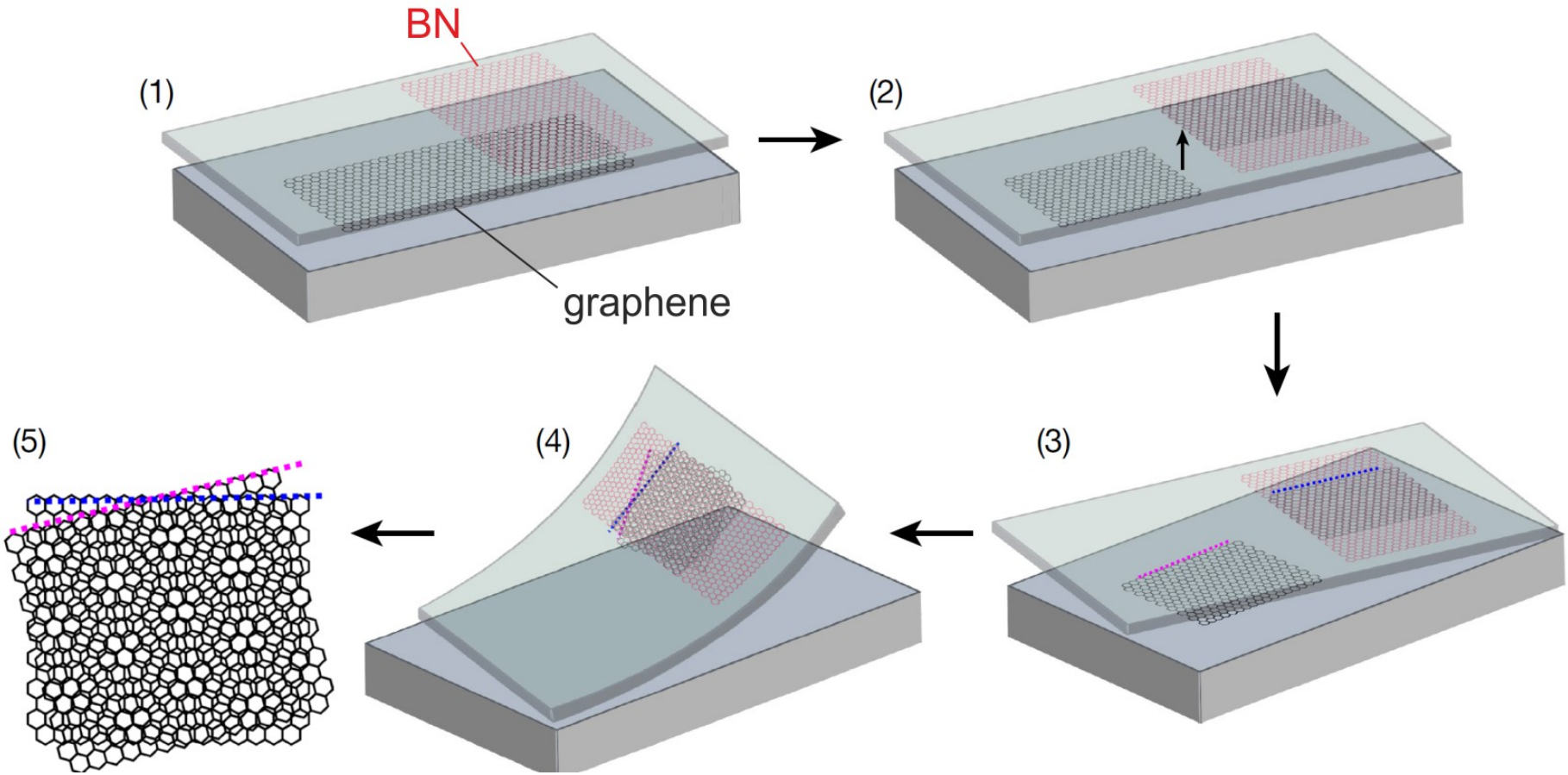
Kramers theorem



by Alexander Tsirlin, Leipzig University

Lecture 9: November 18, 2024

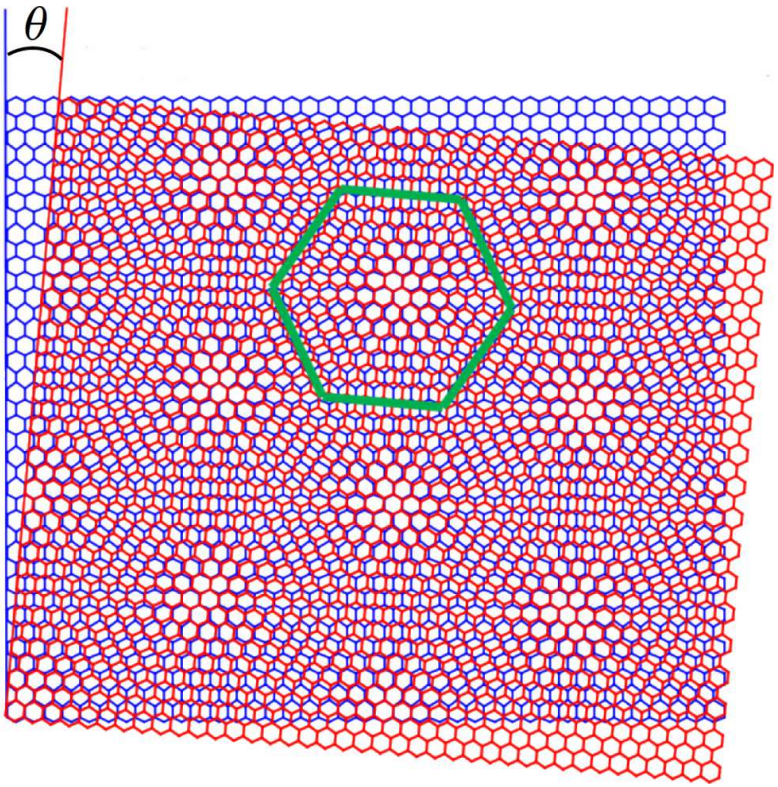
Chern insulator: Fabrication of twisted bilayers



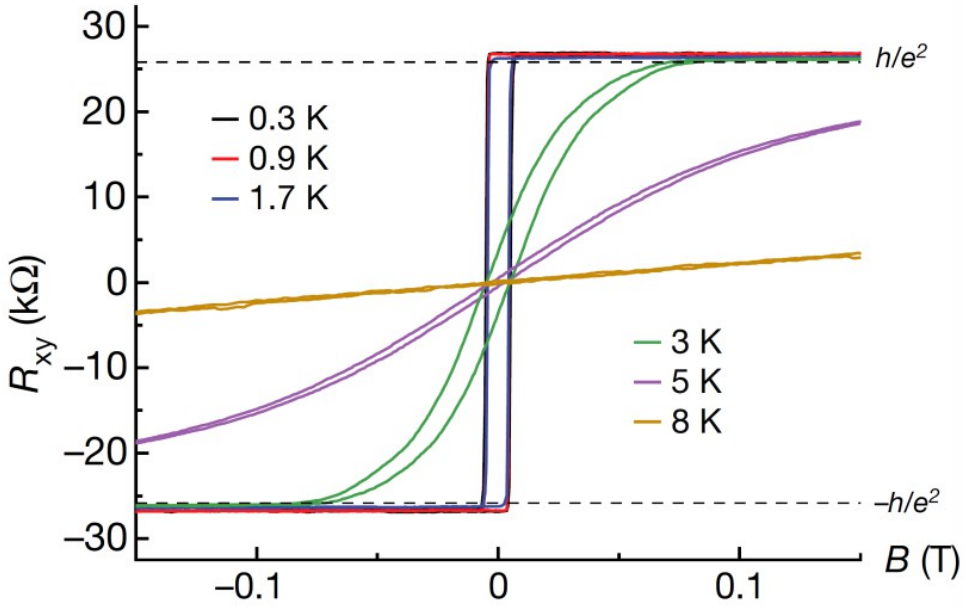
twisted bilayer graphene
on top of a BN flake

Nature 602, 41 (2022)

Chern insulator: moiré superlattices

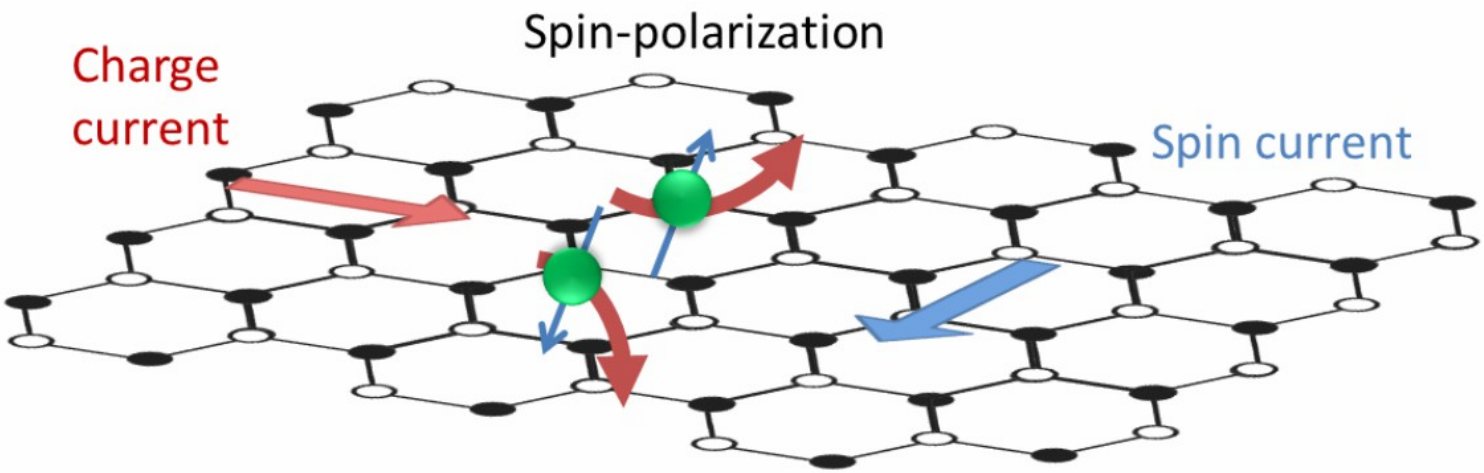


Quantized R_{xy} reached,
but physics may be quite intricate



Nature 602, 41 (2022) and Nature 600, 641 (2021)

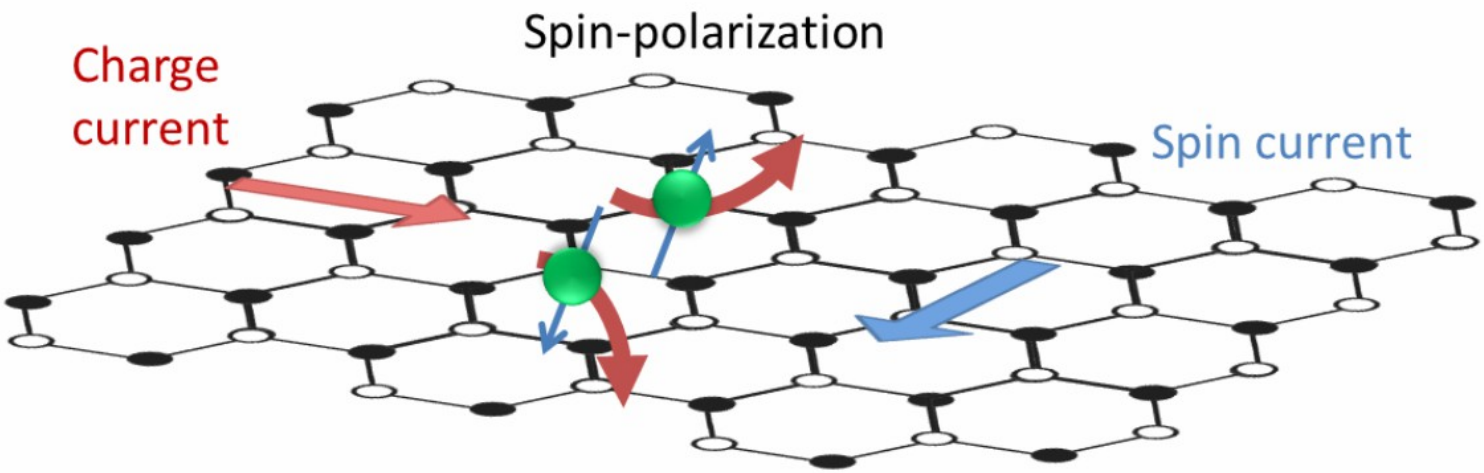
Spin Hall effect



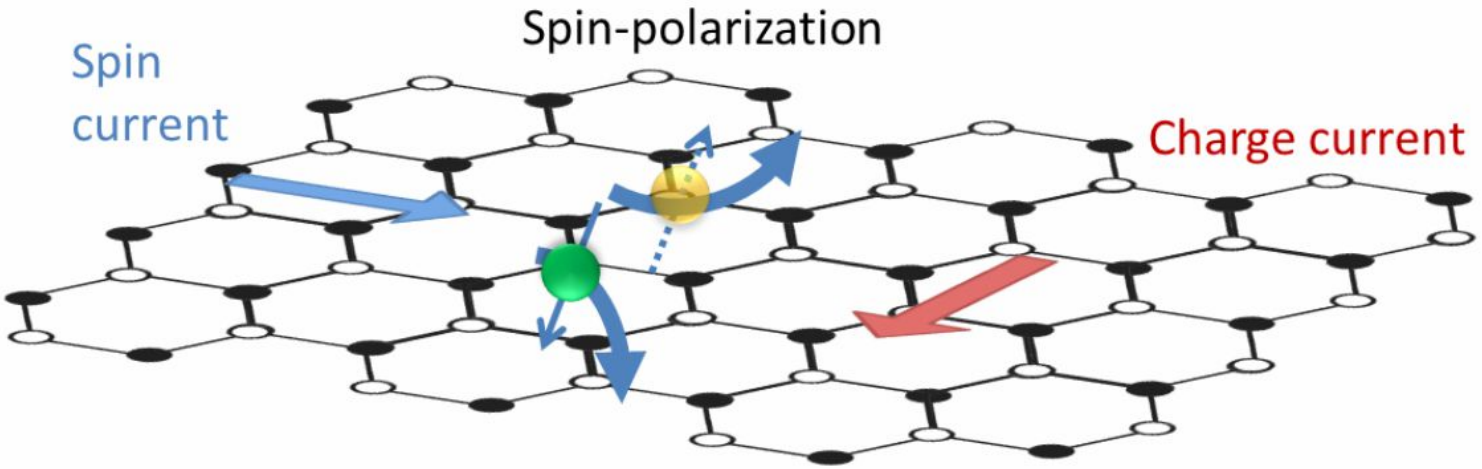
spin Hall

Image credit: Eleanor Holmes (CC-BY-SA)

Spin Hall effect

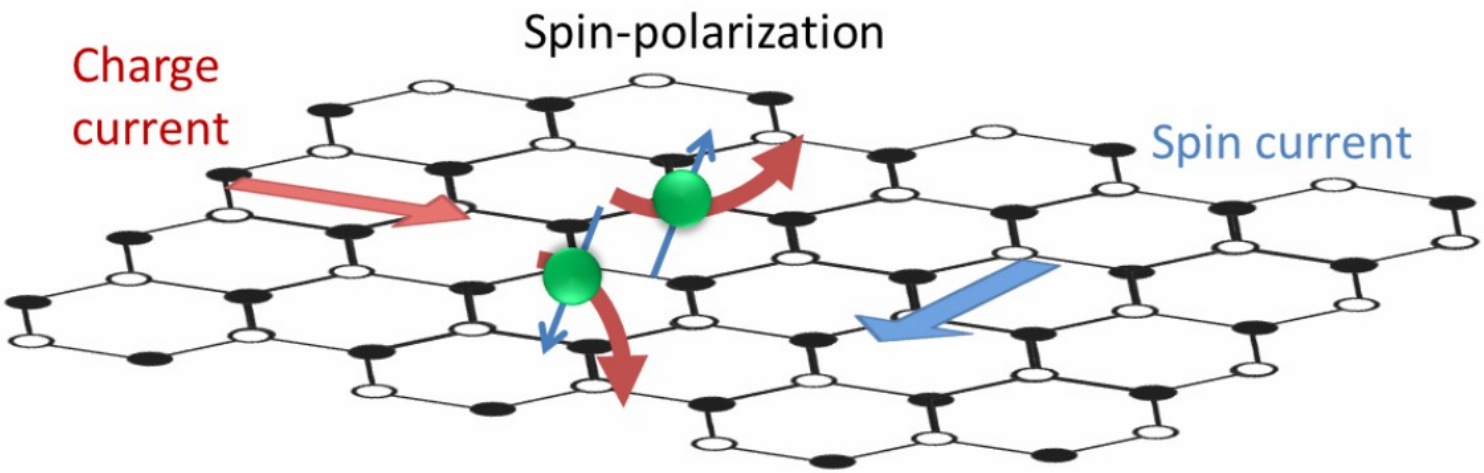


spin Hall



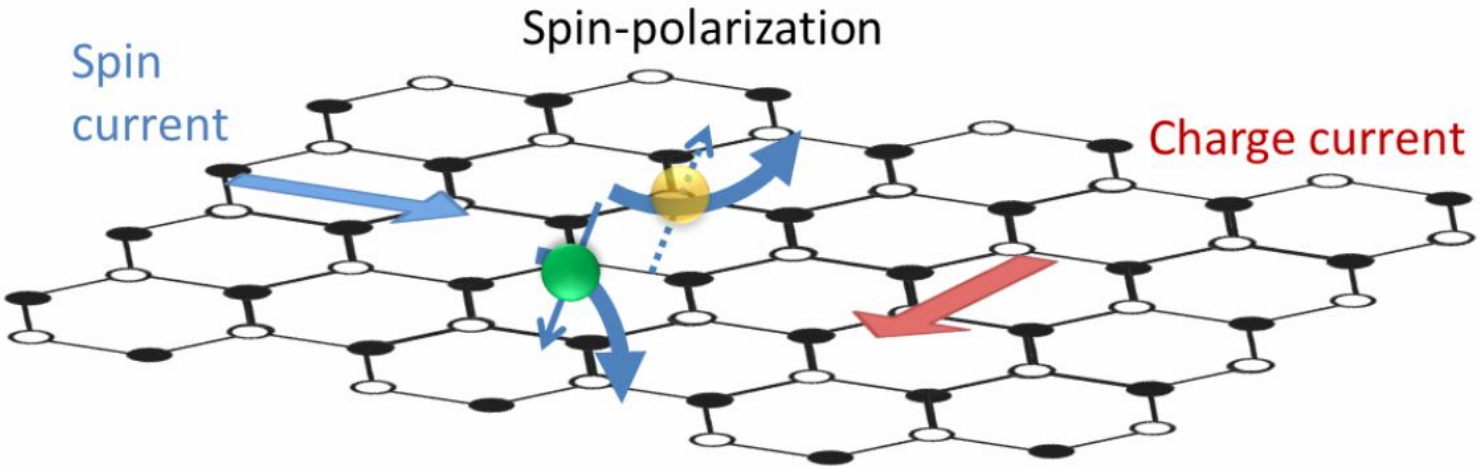
inverse spin Hall

Spin Hall effect



spin Hall

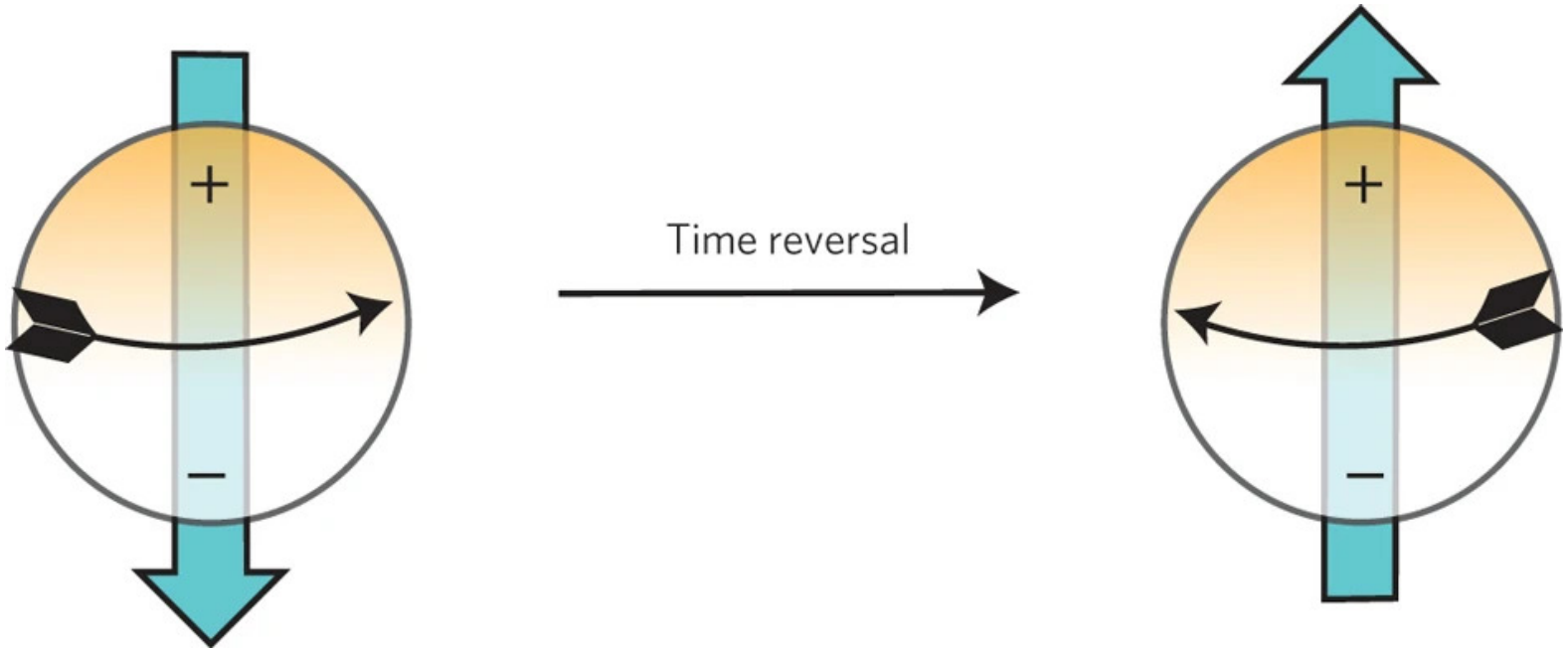
no magnetic field needed!



inverse spin Hall

Image credit: Eleanor Holmes (CC-BY-SA)

Spin vs. time reversal



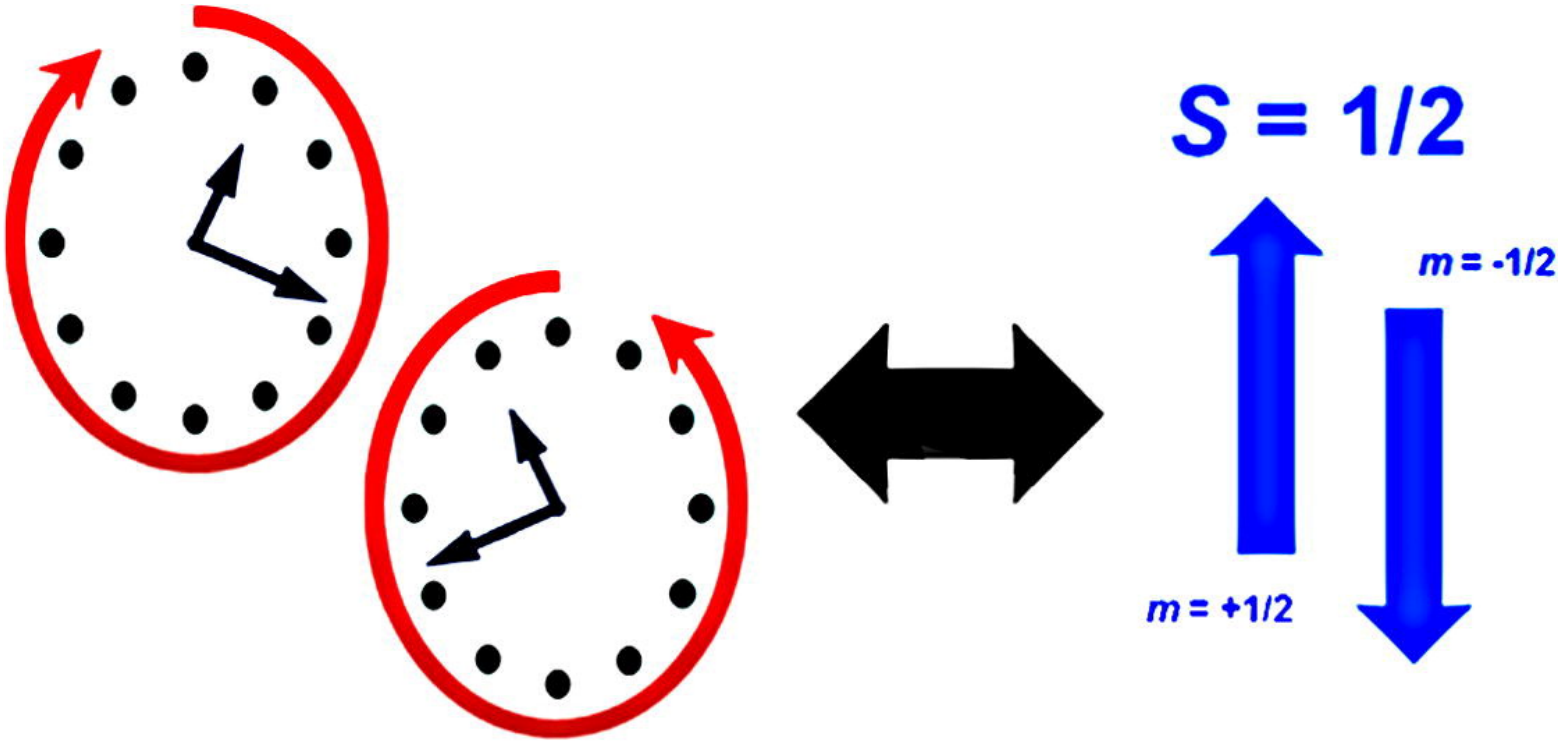
Spins are pseudo-vectors (*axial vectors*):

– no sign change on spatial inversion

– sign change on time reversal

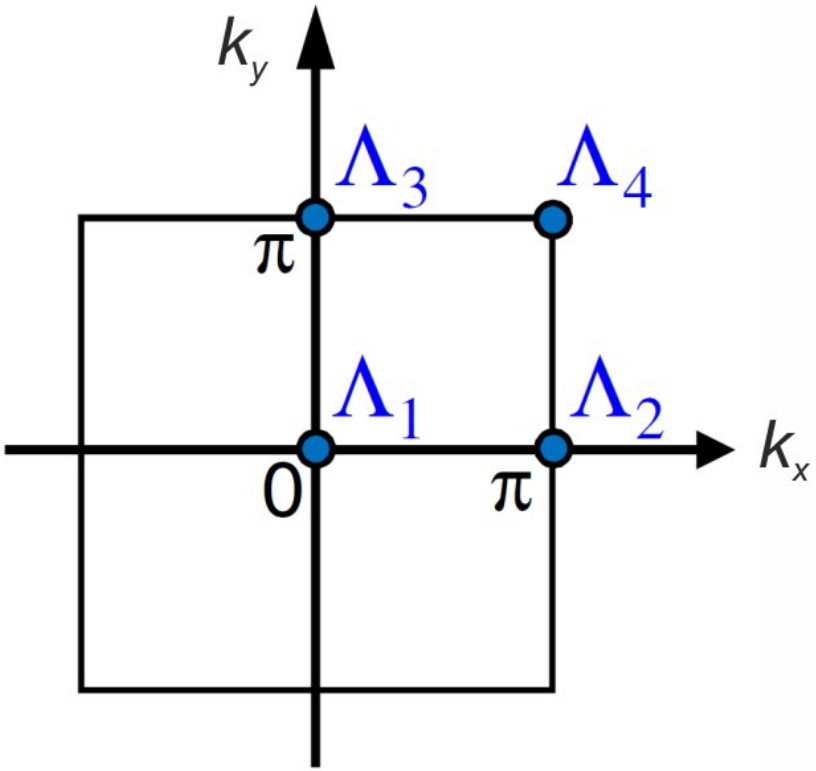
Nature Mater. 9, 649 (2010)

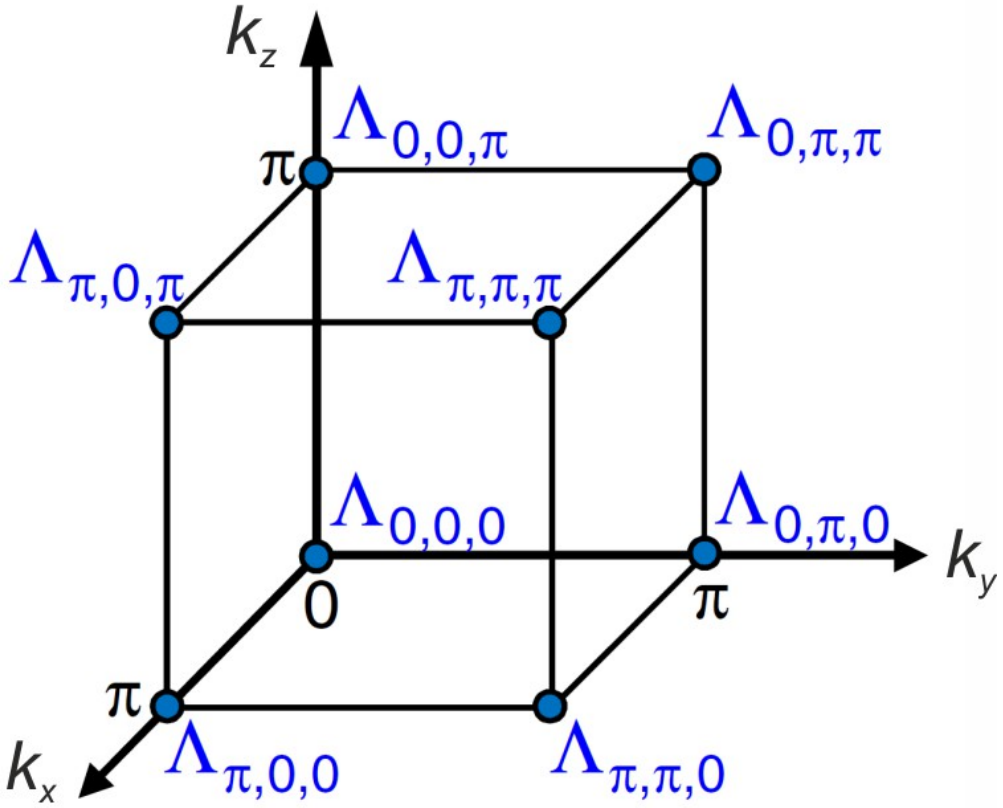
Kramers pair



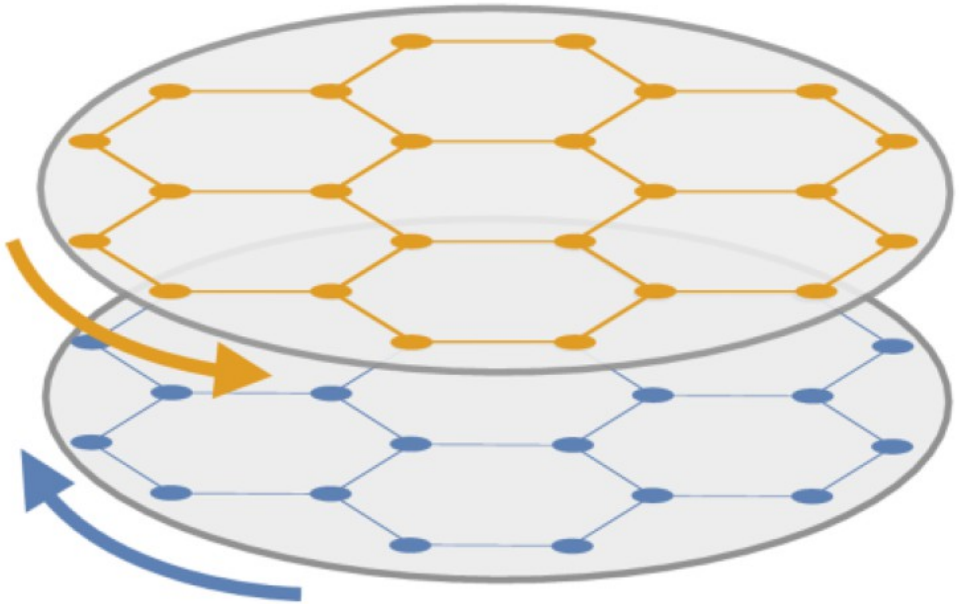
J. Magnet. Res. 255, 1 (2015)

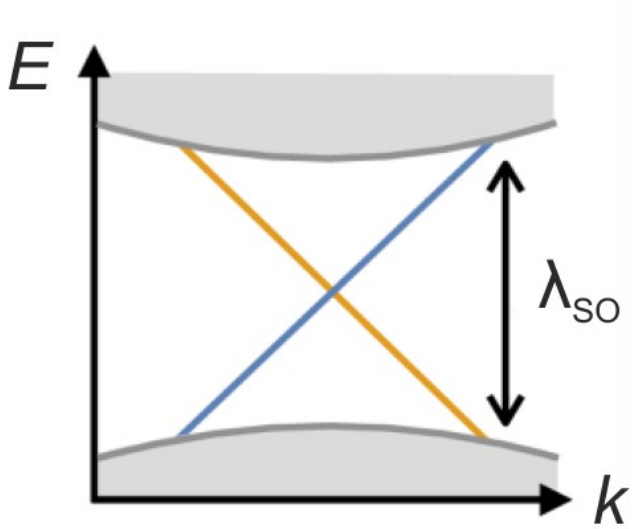
TRIM: time-reversal invariant momenta





J. Phys. Soc. Jpn. 82, 102001 (2013)





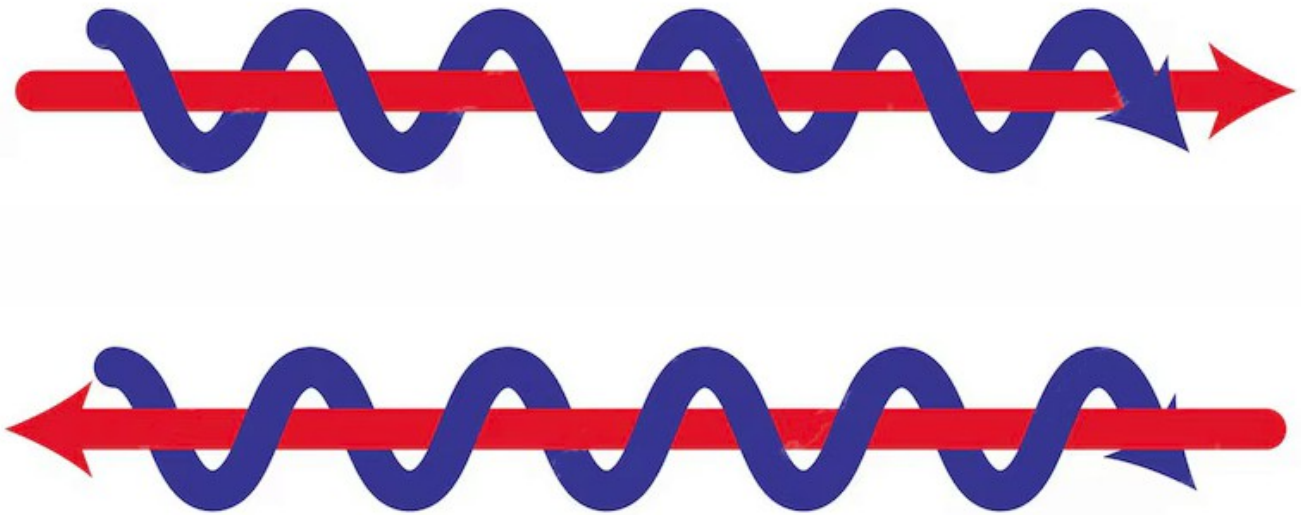
First model of a topological insulator: Kane and Mele (2005)

Topological invariant ($\mathbb{Z}_2$): Fu and Kane (2007)

Extension to 3D: Fu, Kane, and Mele (2007)

Image from Phys. Rev. Research 2, 033071 (2020)

Chiral (helical) modes



Chiral / helical indicates the unique propagation direction

Image credit: Freepik