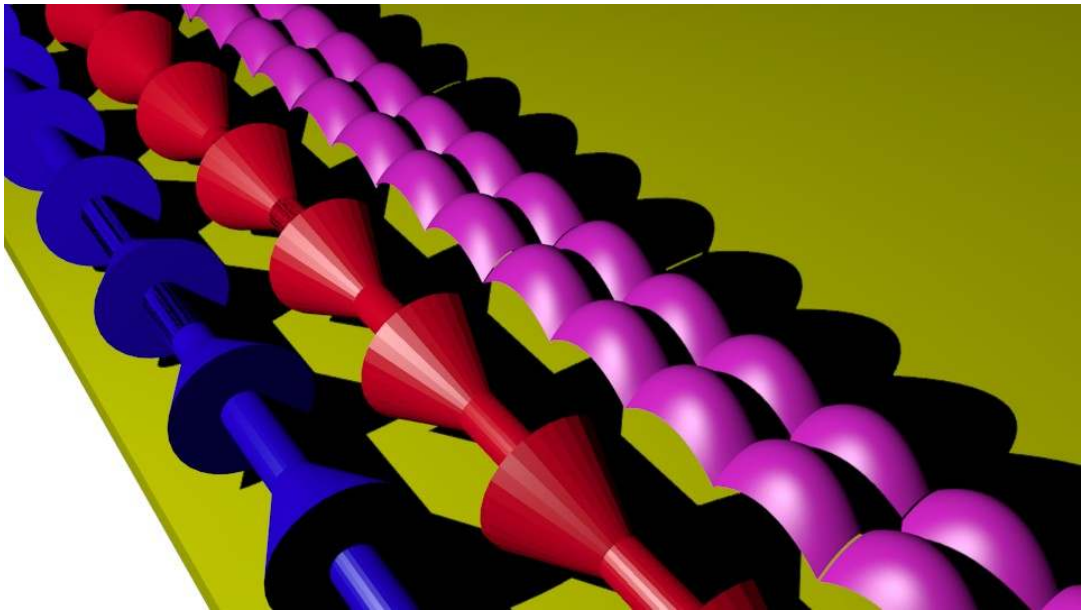
Collective spin excitations in magnetically ordered graphene Quantum Hall insulator

Jose Lado and Joaquin Fernandez-Rossier

International Iberian Nanotechnology Laboratory (INL), Braga, Portugal



Tuesday 3rd March 2015, March Meeting San Antonio

People

Jose Lado

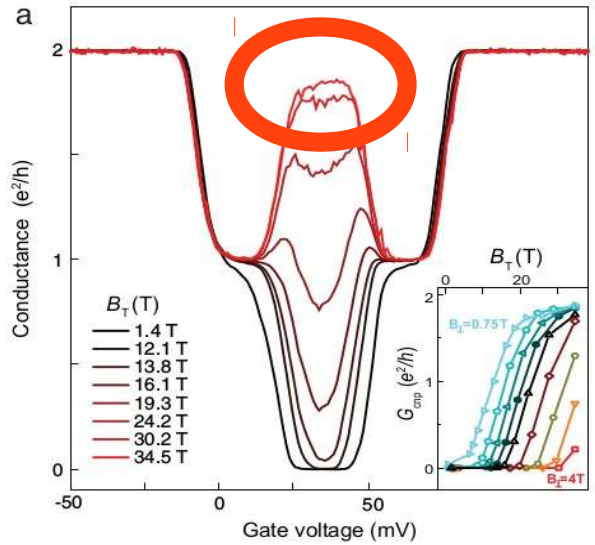
Joaquin Rossier

INL

Overview

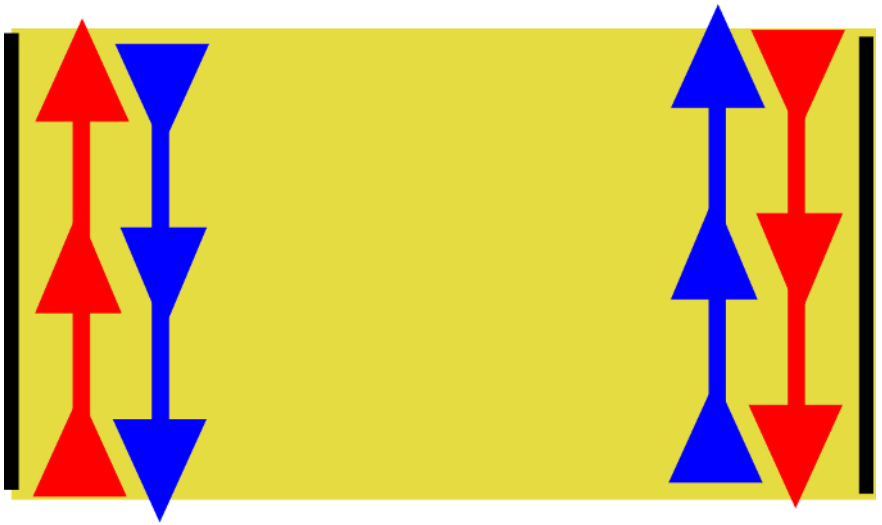
Graphene in Quantum Hall regime and in-plane magnetic field behaves as a Quantum Spin Hall insulator

Quantum conductance



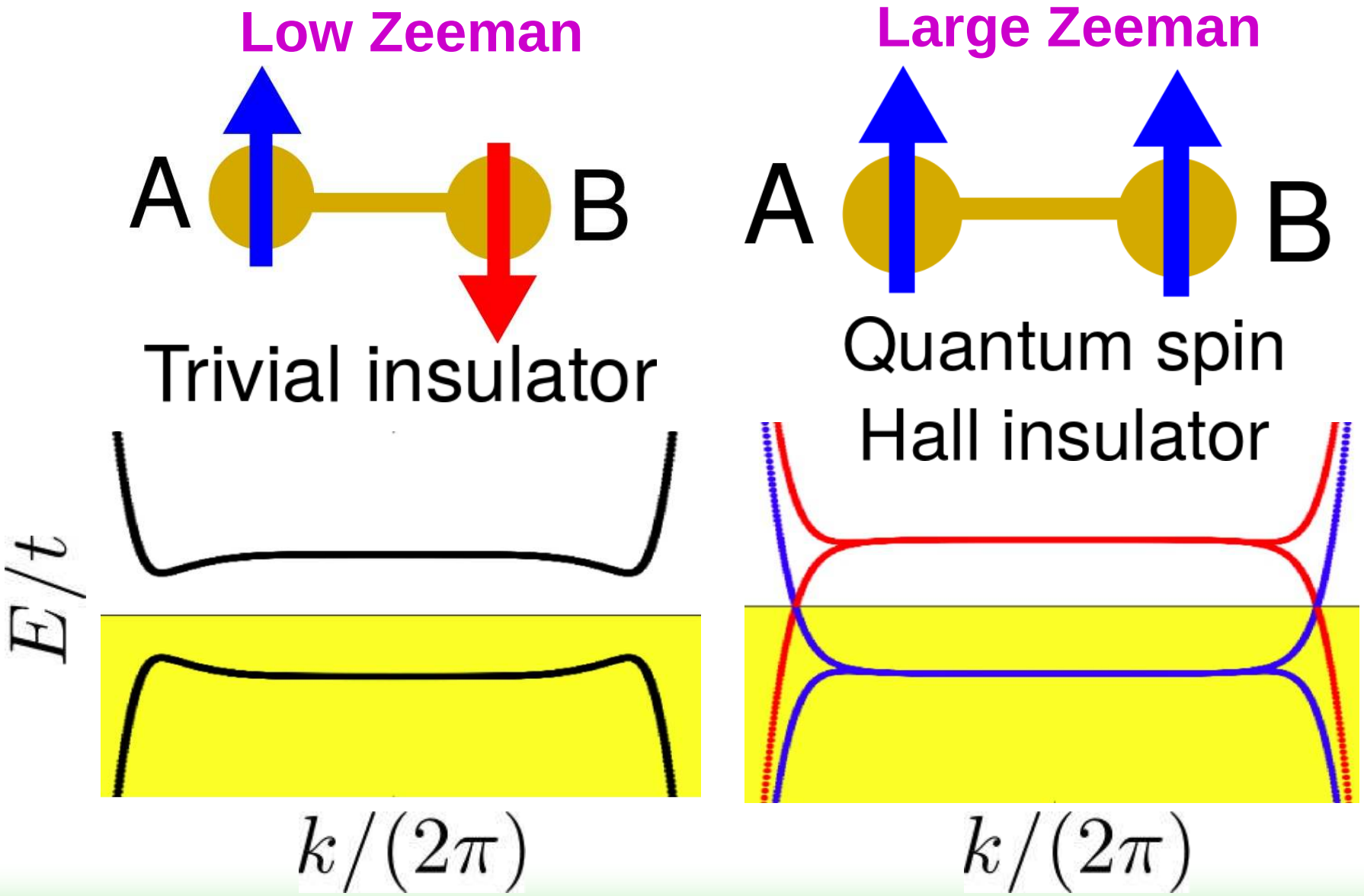
A. F. Young et al, Nature (2014)

Ribbon



<u>Which is the backscattering mechanism???</u>

Two Quantum Hall phases



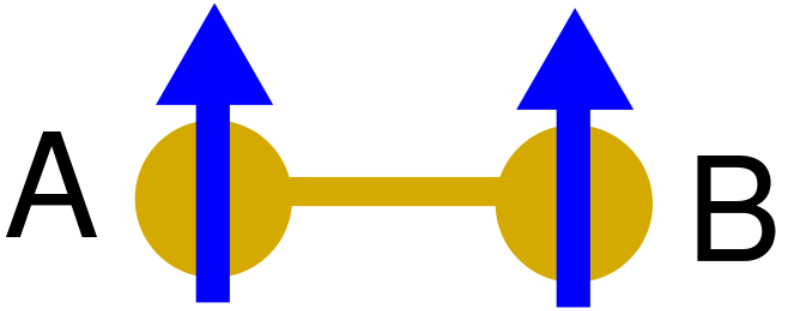
Robustness of QSH

→ Quantum spin Hall without time reversal

→ Protected by spin Chern number

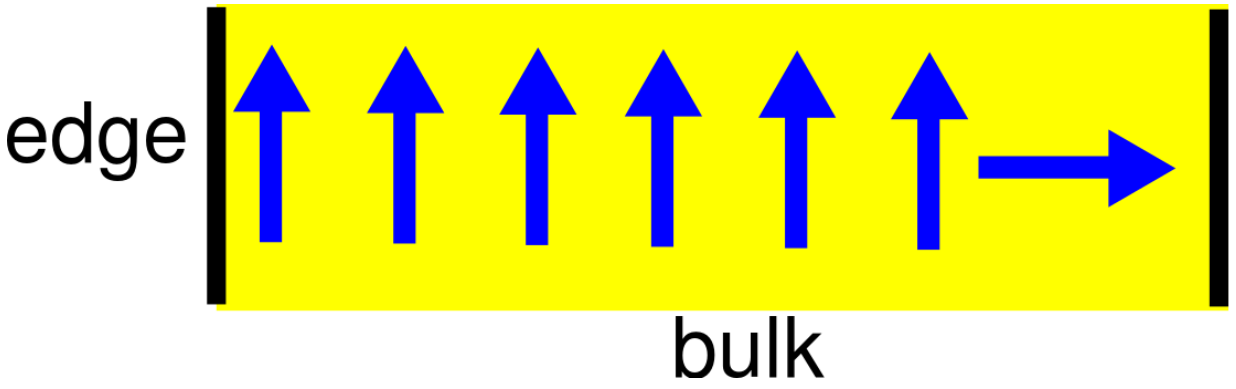
→ **Protected against diagonal Zeeman interactions**

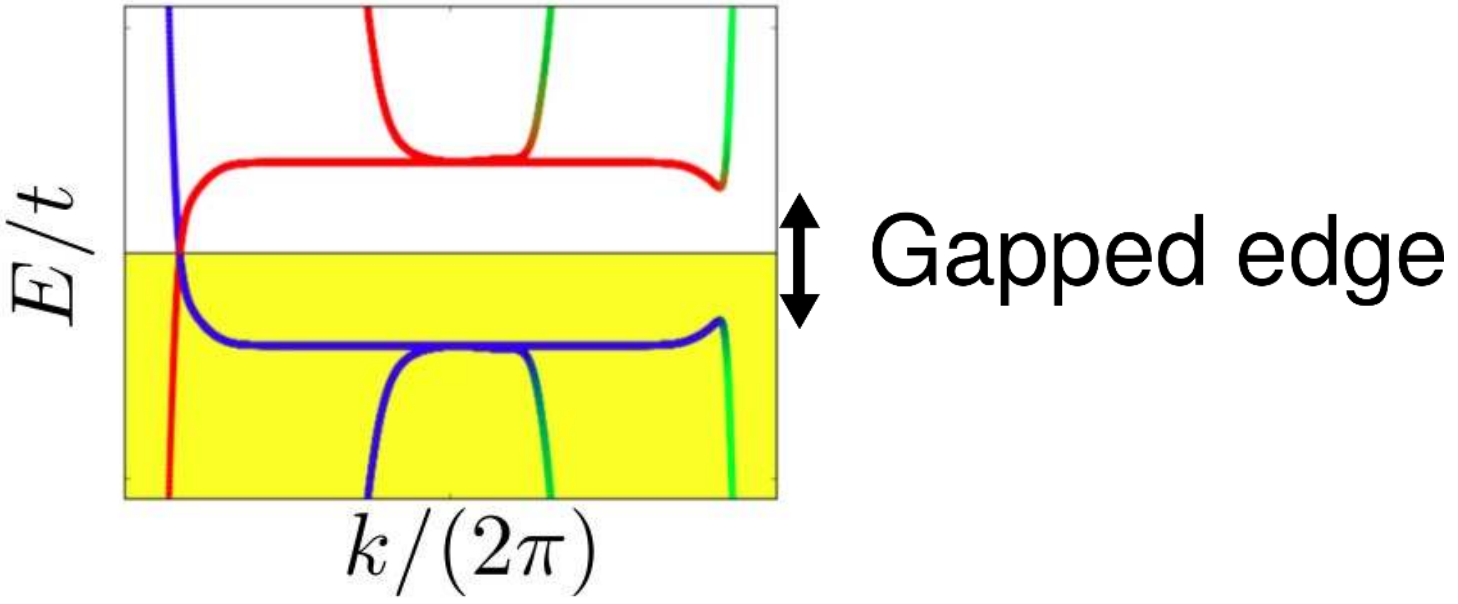
→ **Weak against general spin mixing: spin orbit, canted order**



System is magnetic: do spin waves break the quantum spin Hall?

Naive electron-magnon coupling

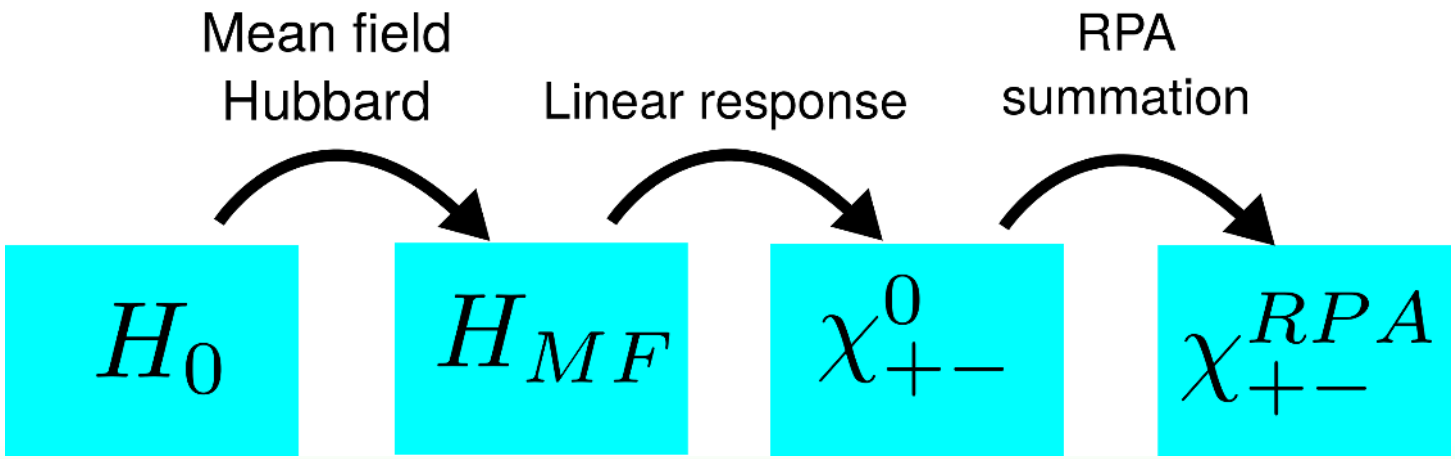




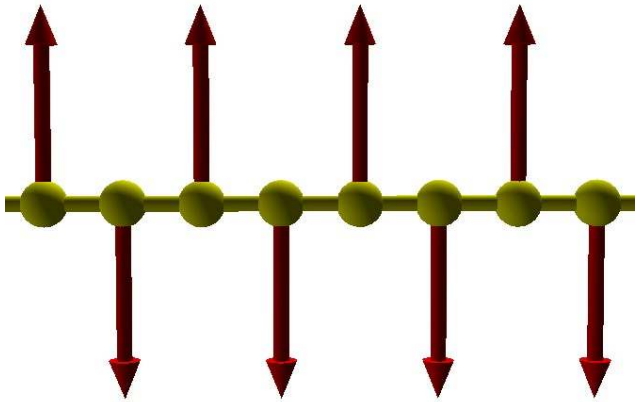
There is chiral state-spin wave coupling!

Method

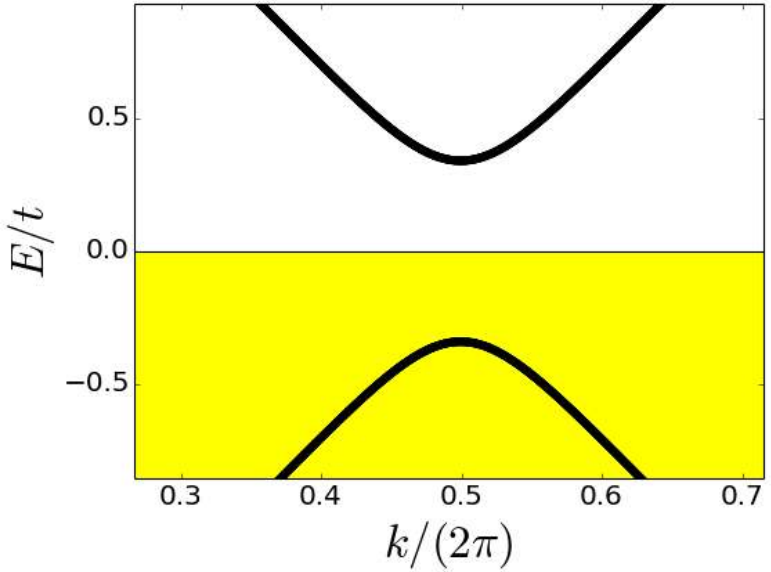
- Formal procedure
  - Tight binding selfconsistent mean field Hubbard model in a ribbon
  - Spin correlation function calculated with linear response
  - Many body summation through RPA



Example: antiferromagnetic chain

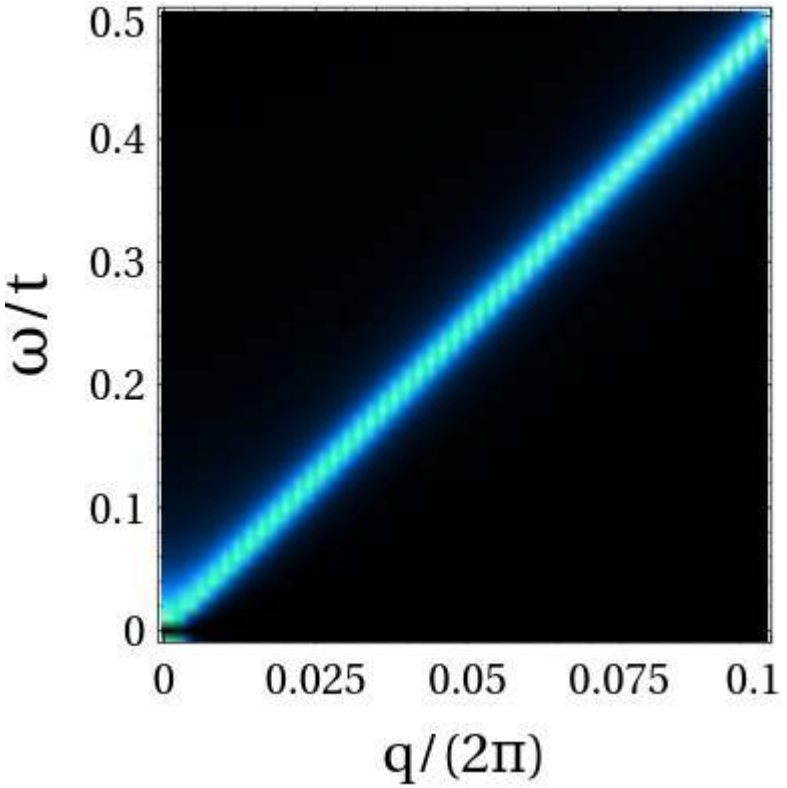


Bandstructure



Gapped quasiparticles

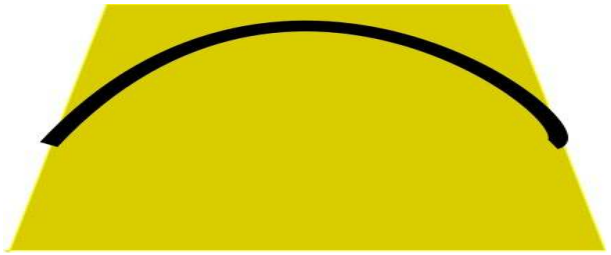
RPA spin response



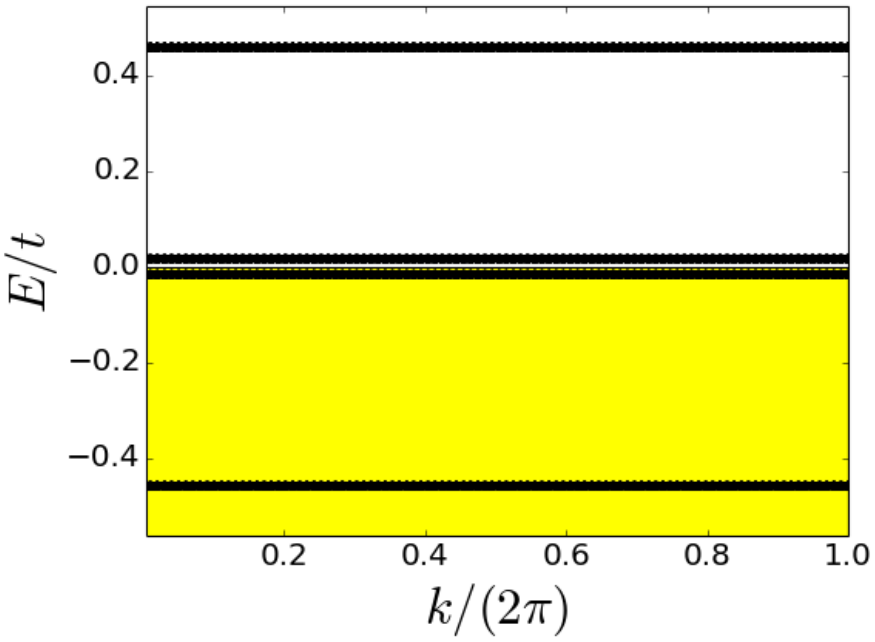
Gapless spin waves

Boundary conditions in Quantum Hall

Periodic conditions

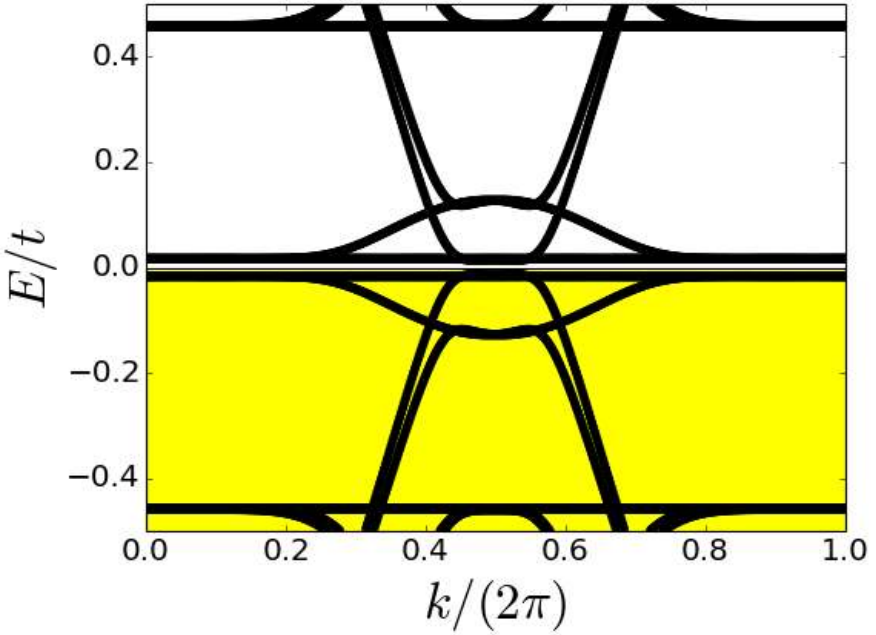


Bandstructure

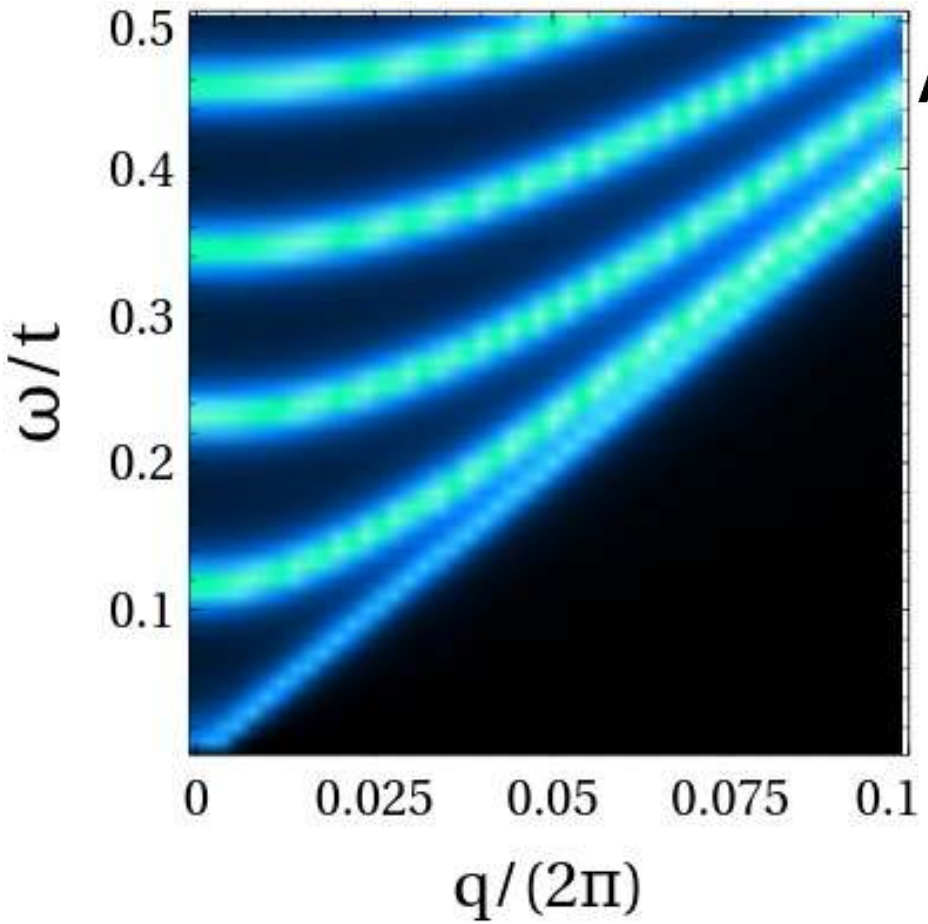


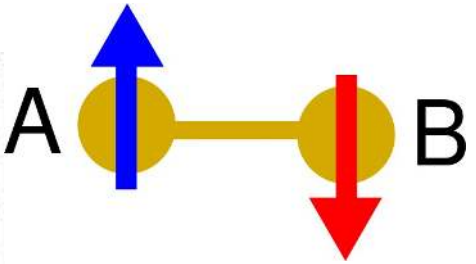
Open conditions

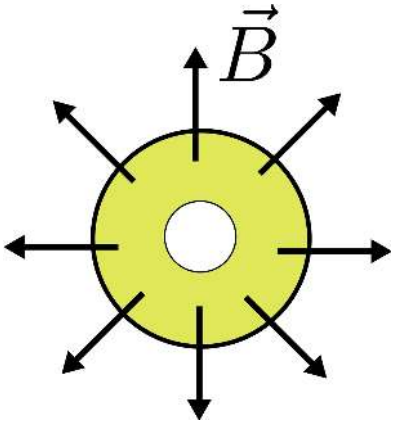
Bandstructure



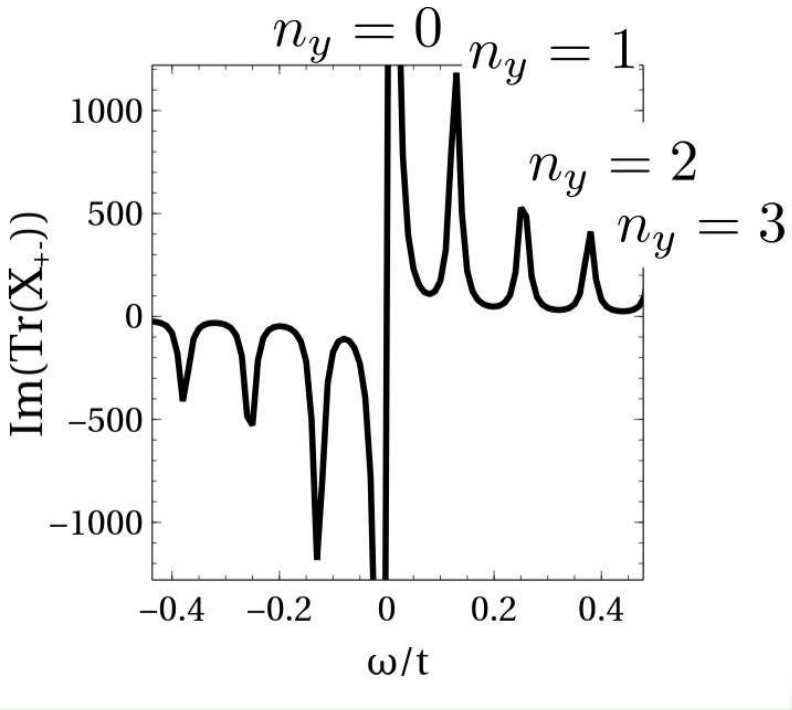
Periodic antiferromagnet QH



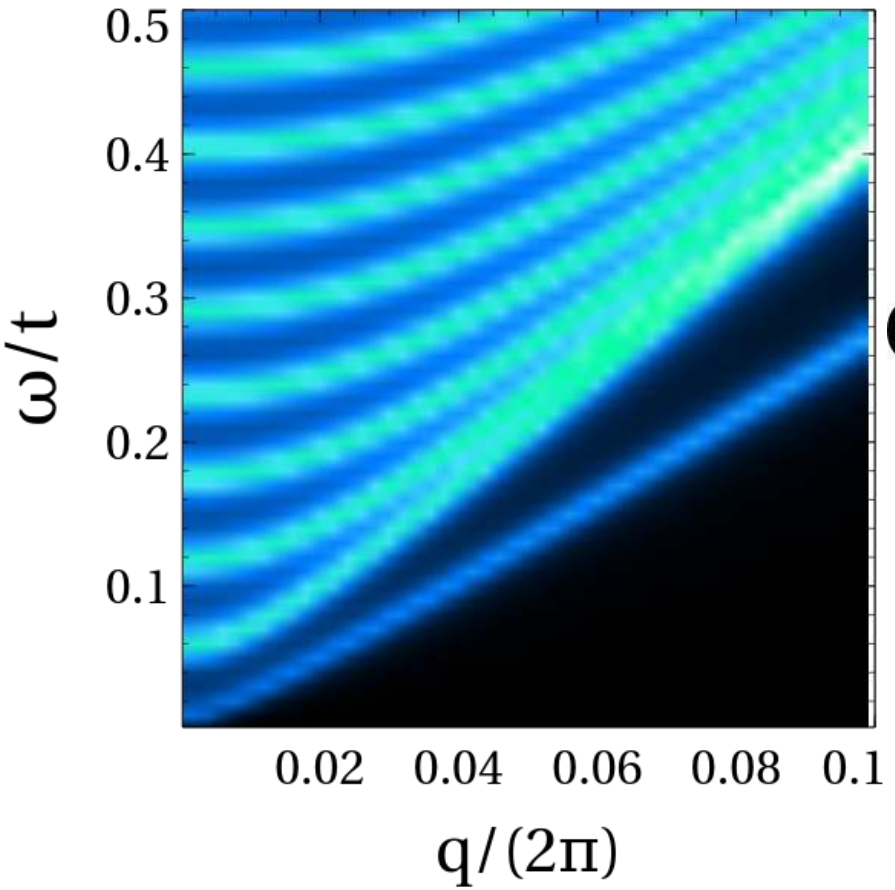




$$\omega = \sqrt{Aq^2 + (2n\pi/W)^2}$$

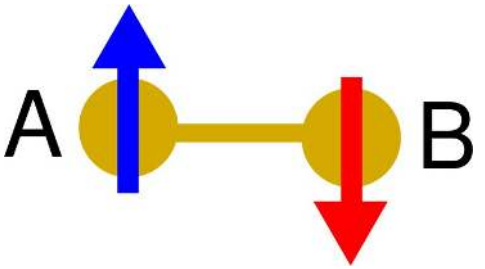


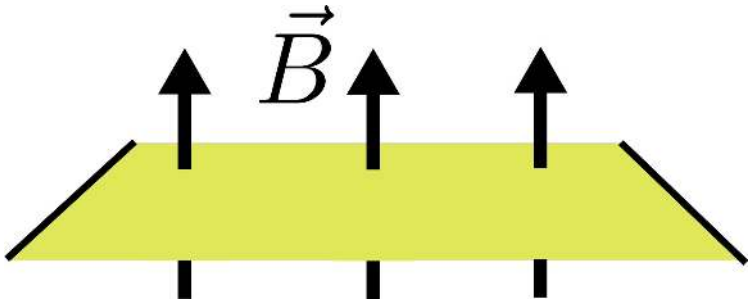
AF bulk and edge spin waves



bulk

edge

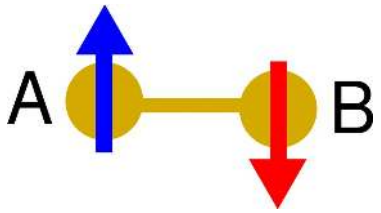




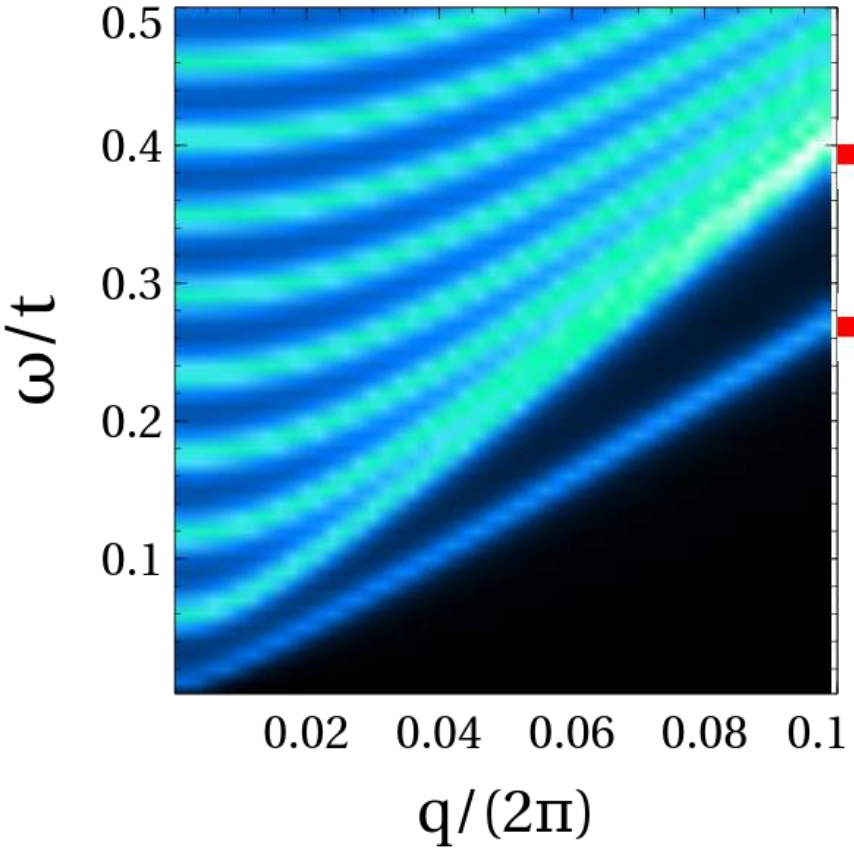
$$\omega = \sqrt{Aq^2 + (2n\pi/W)^2}$$

Edged system develops a spin wave edge branch

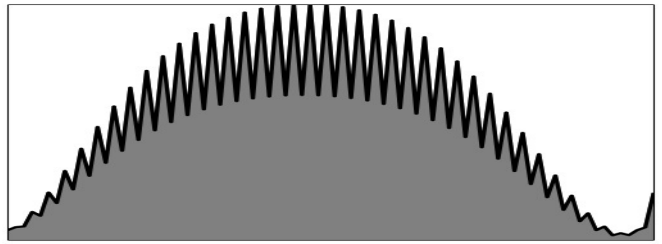
AF edge-bulk decoupling at high q

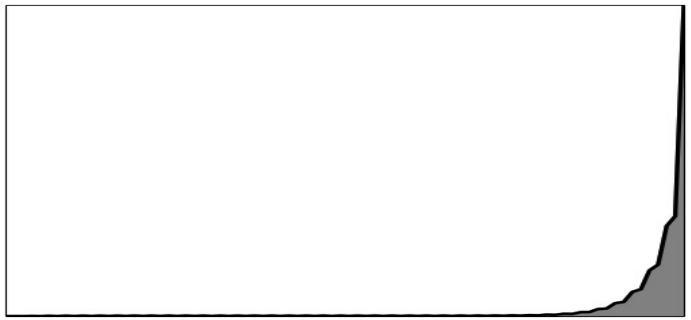


RPA spin response



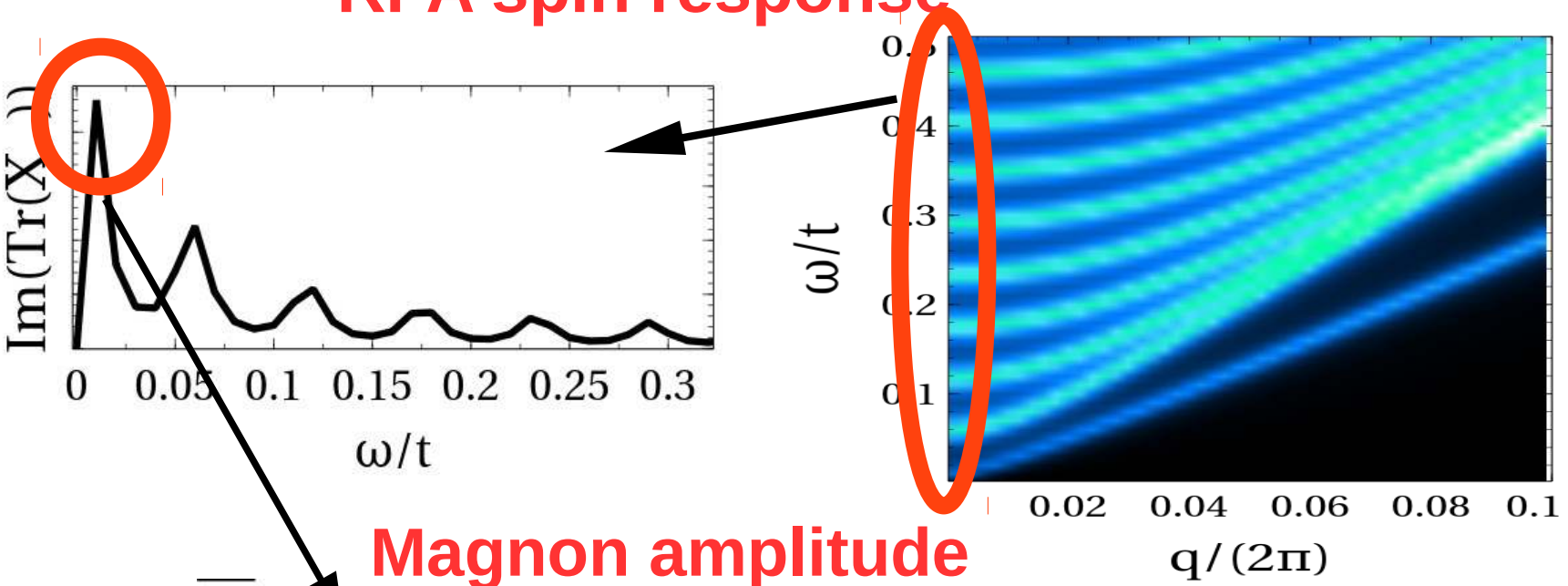
Magnon amplitudes



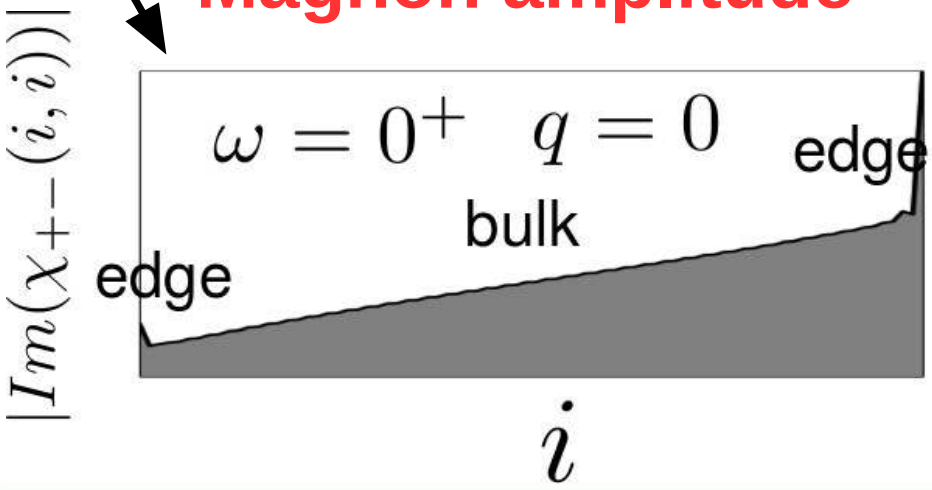


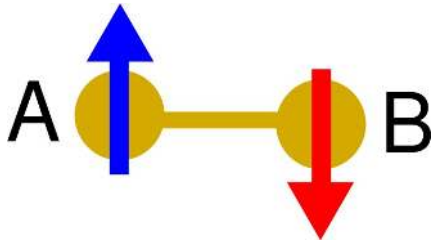
AF edge bulk coupling at low q

RPA spin response



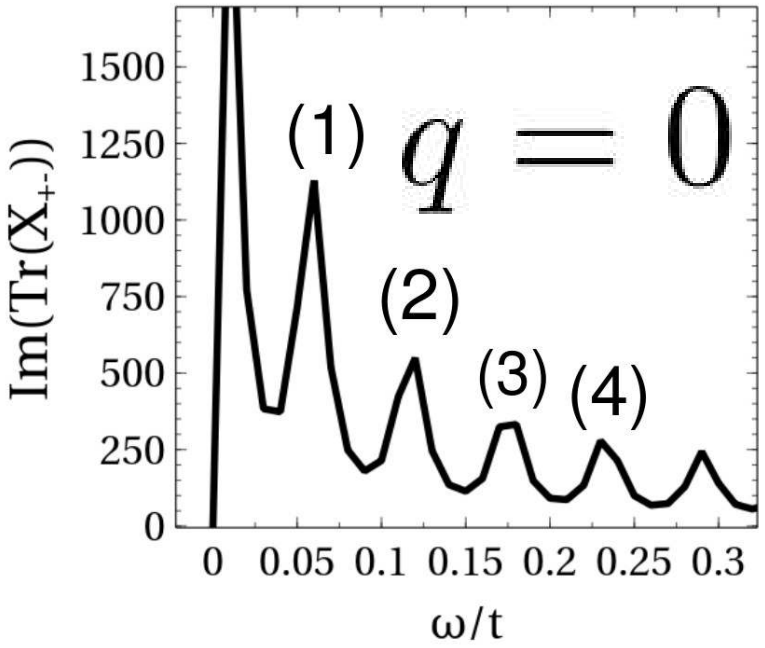
Magnon amplitude

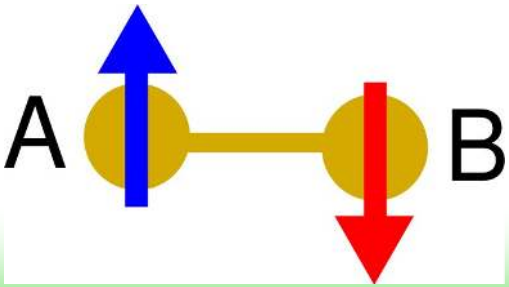




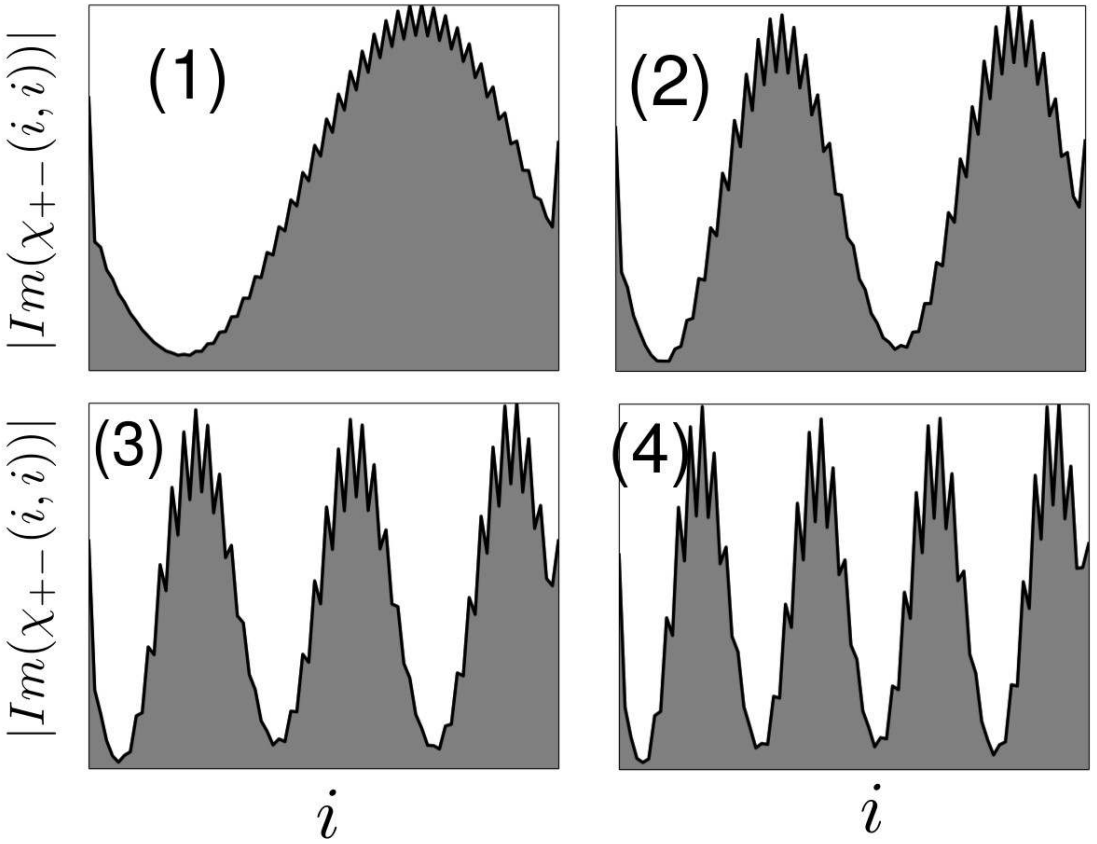
Excited branches at q=0

RPA spin response

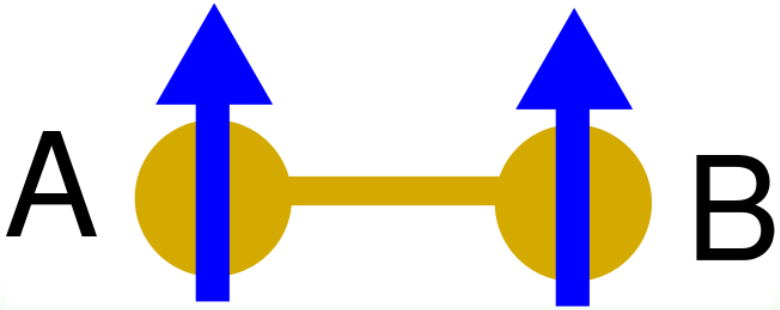


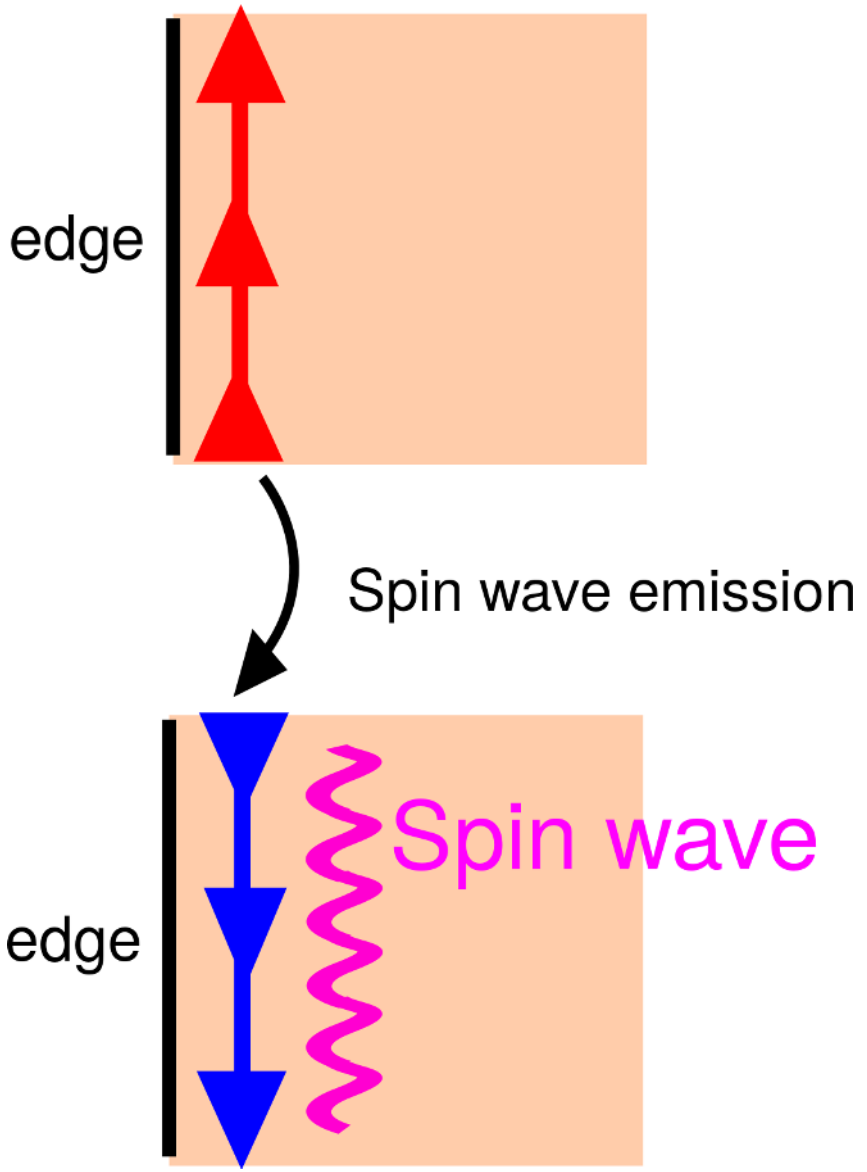


Magnon amplitudes

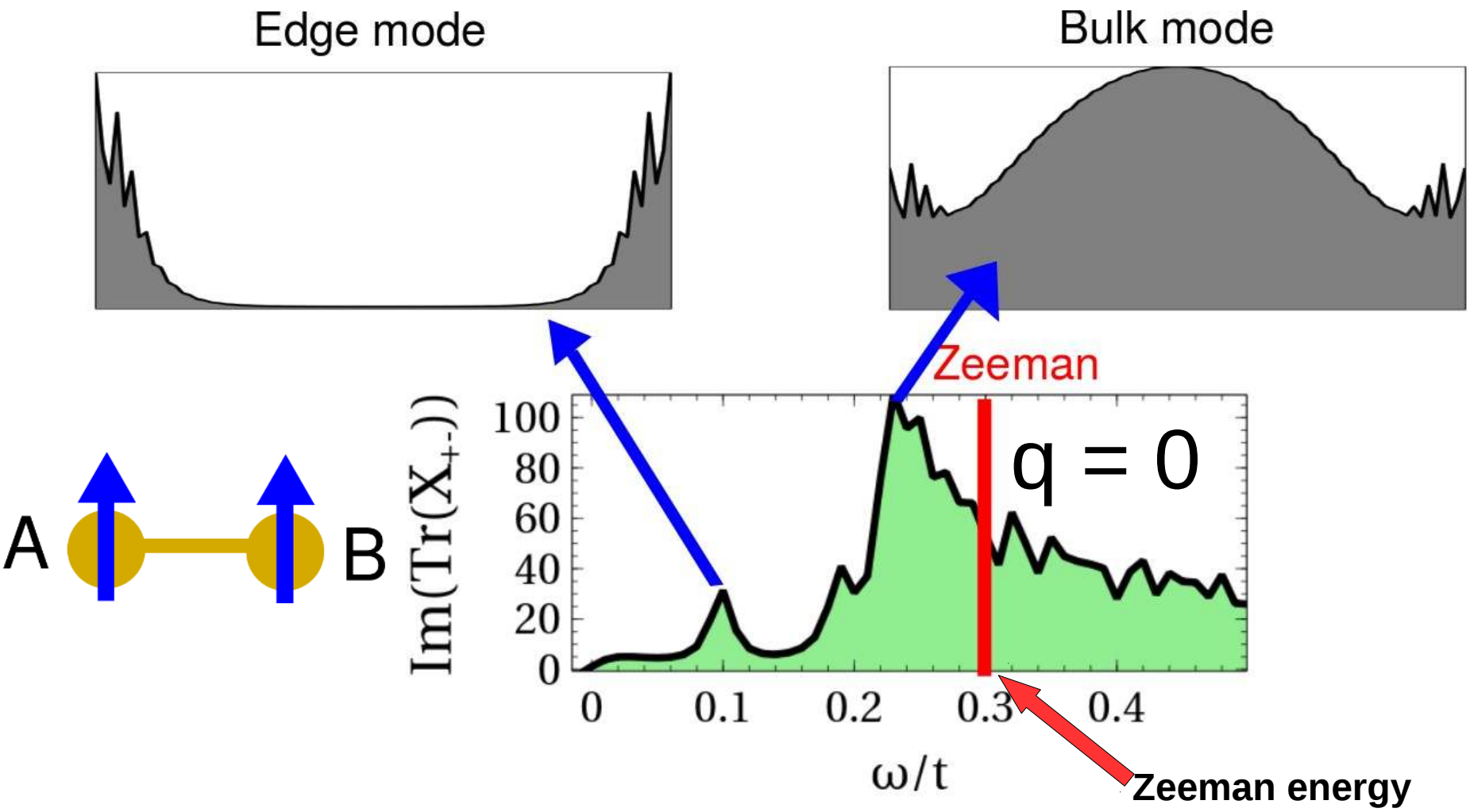


Quantum spin Hall state

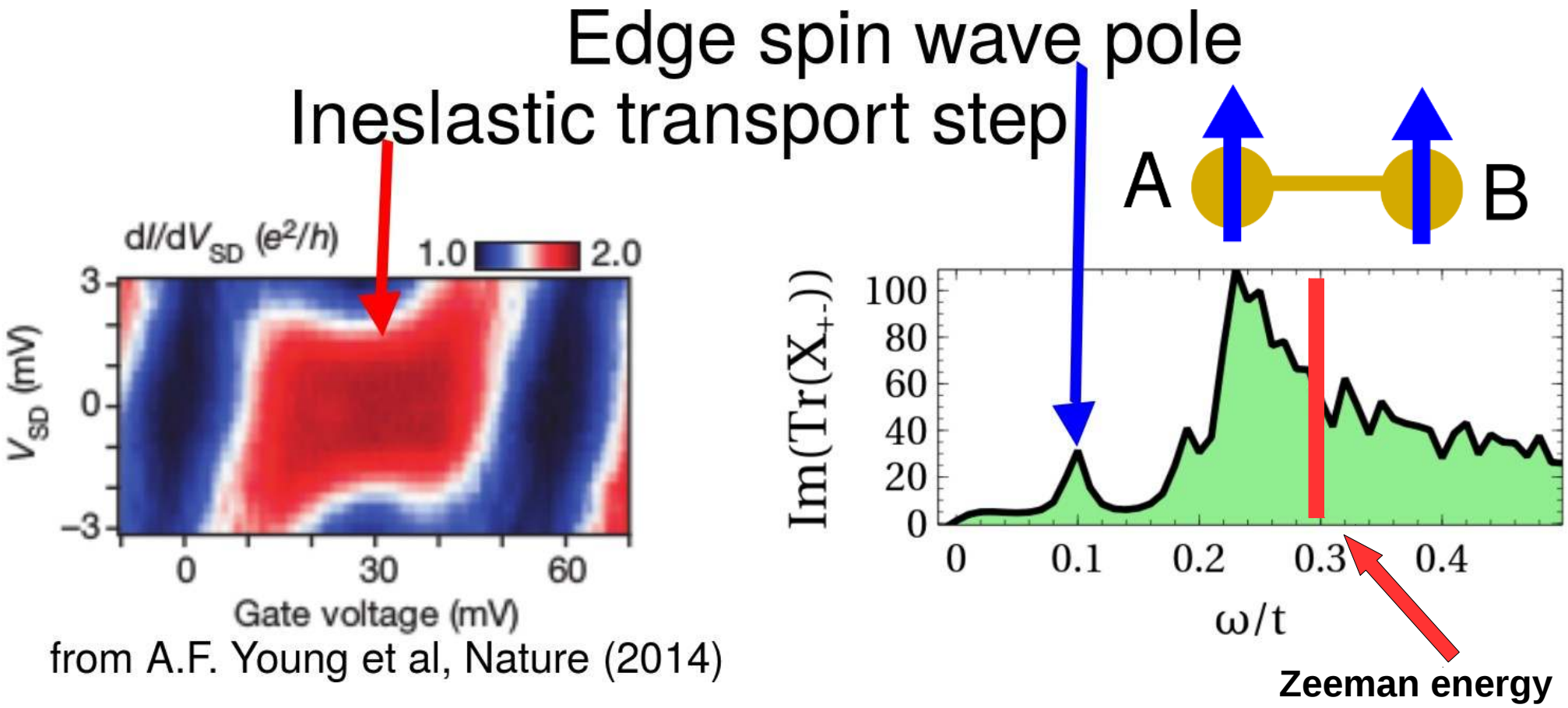




Edge modes in the QSH



Inelastic steps

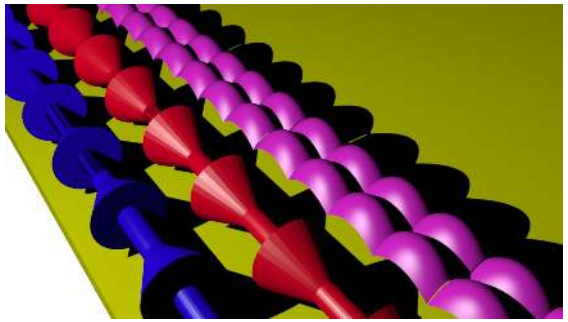


from A.F. Young et al, Nature (2014)

Ineslastic steps below the Zeeman energy

Take home

- Coupling of chiral channels and spin waves opens up a backscattering channel



Thank you!!!

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Spinograph
Spintronics in Graphene