Scanning Gate Microscopy of the QSH edge states

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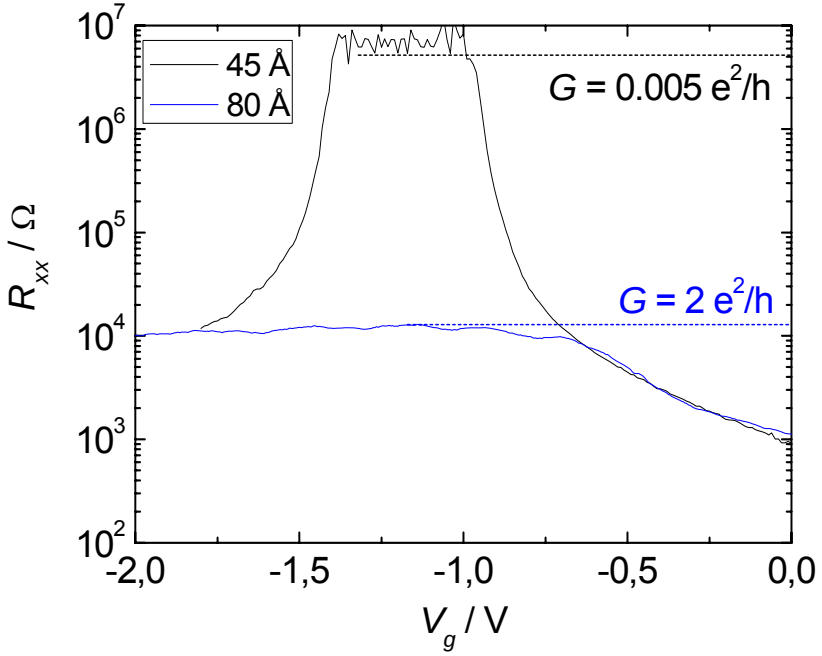
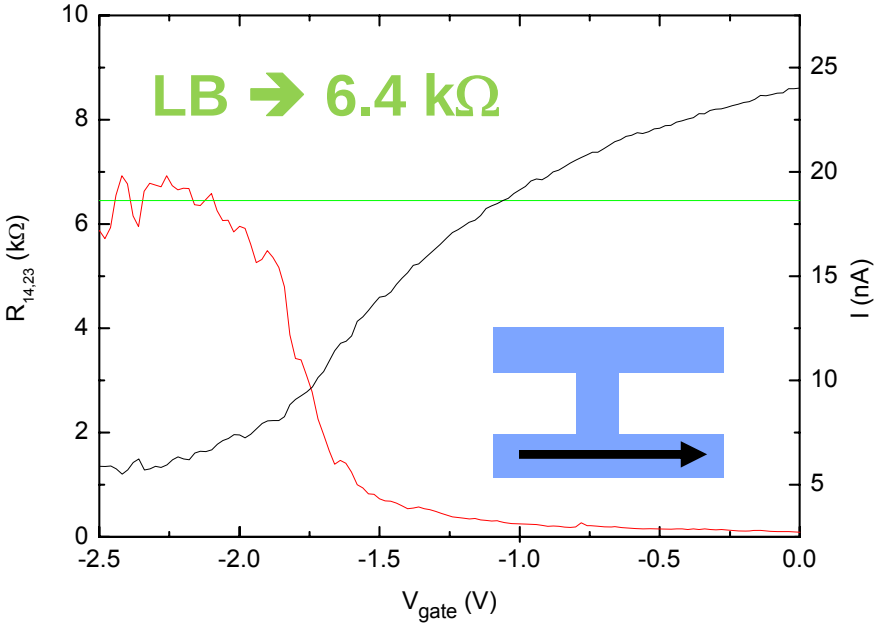
Present experimental results

Demonstration of QSHE in HgTe quantum wells



M. König et al., Science 318, 766 (2007)

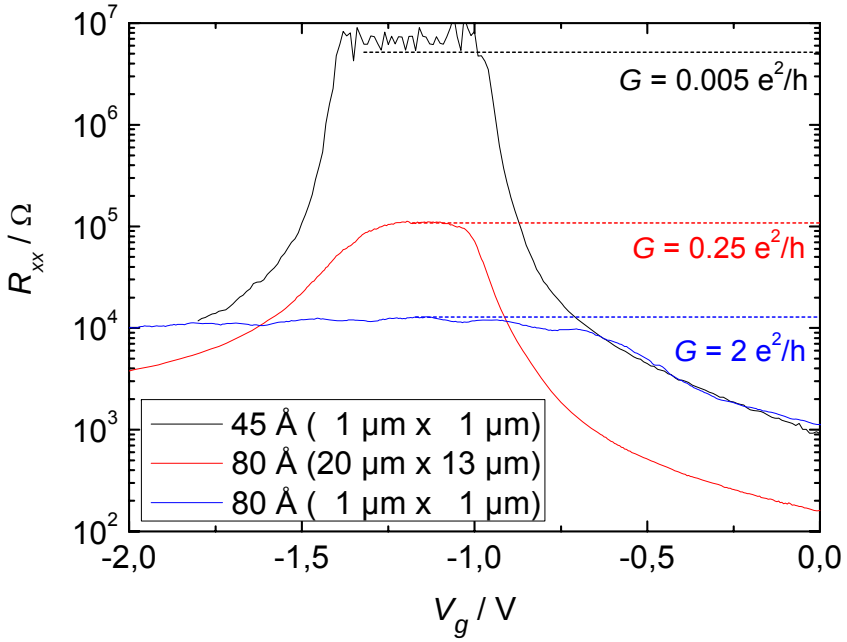
Transport based on edge states



Present experimental results (2)

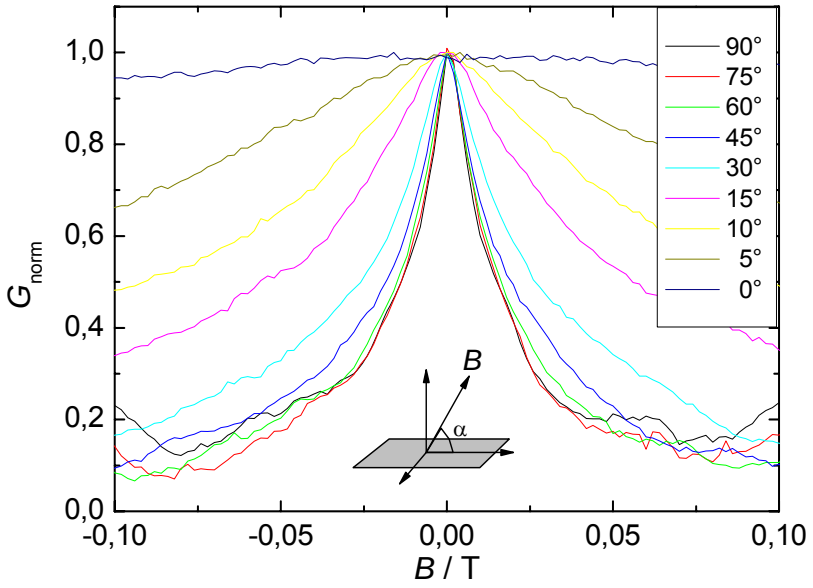
Conductance is suppressed by

inelastic scattering



mean free path ~ 1 µm

magnetic field



field strength ~ 10 mT

Open questions

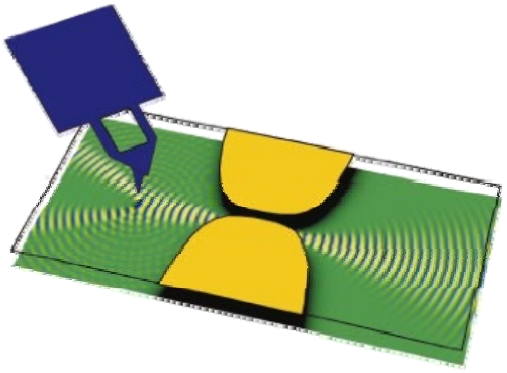
Edge states:

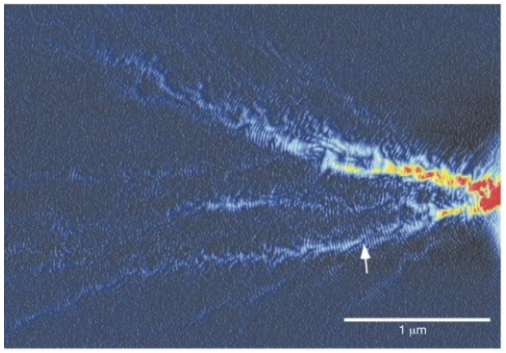
- spatial arrangement
- width
  (Zhou *et al.*, PRL (2008))

Stability of QSH state:

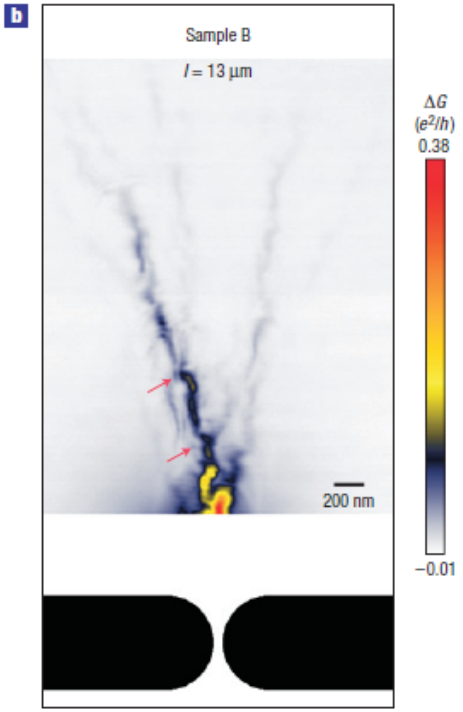
- Scattering due to potential fluctuations
- Breaking time reversal symmetry in B-field

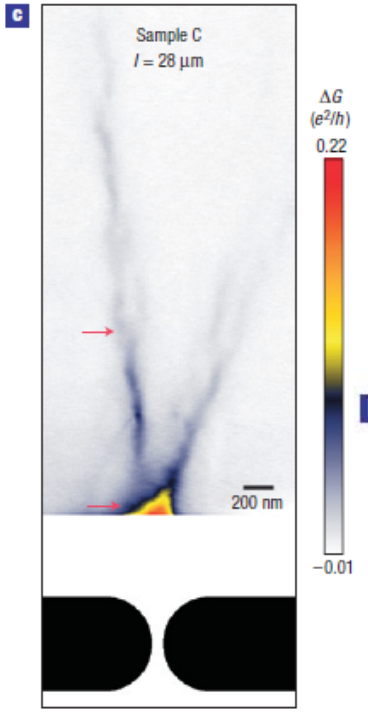
Scanning Gate Microscopy

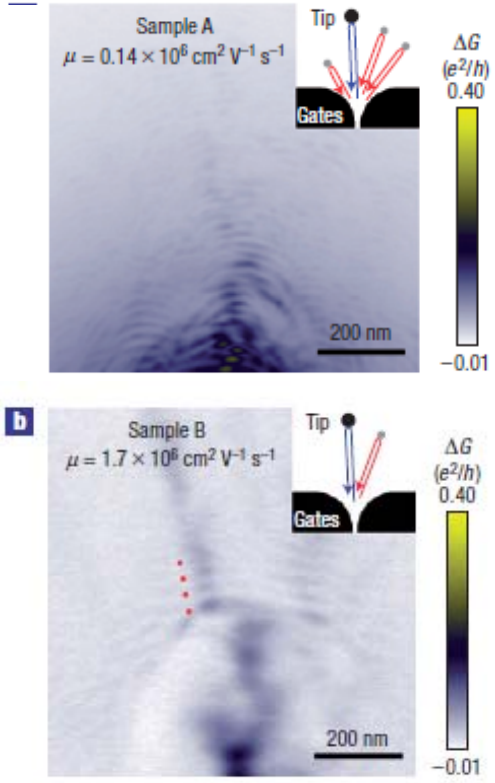




M.A. Topinka *et al.*,
Nature 410, 183 (2001)



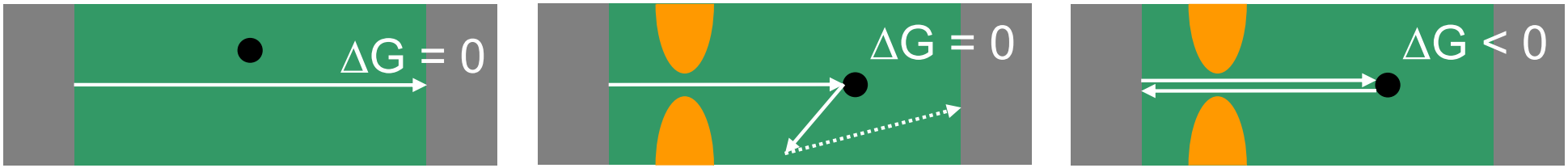


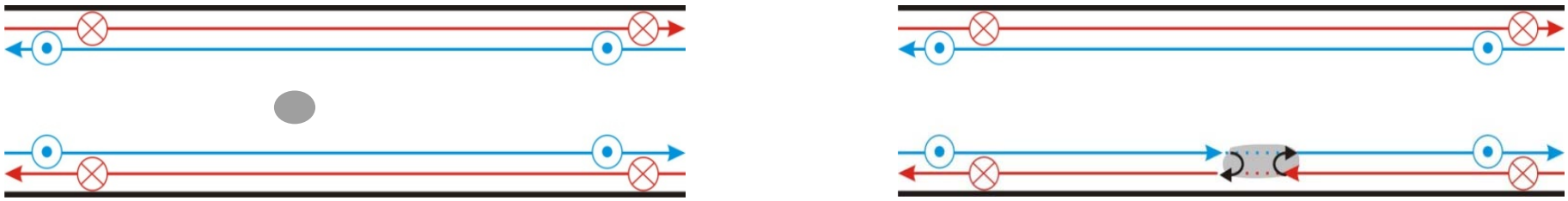


M. Jura *et al.*, Nature Physics 3, 841 (2007)

Basic SGM principles

- tip potential induces perturbation
  → leads to backscattering
- decrease of conductance can be detected





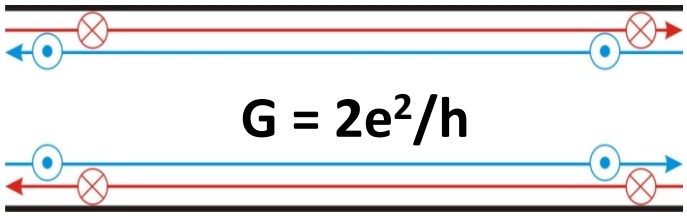
Application to QSH states

- tip acts like local top gate
  - potential fluctuation within the QSH regime
  - Fermi level locally in conduction (valence) band
- potential fluctuation can cause backscattering
- backscattering decreases conductance
  (only scattering into counter-propagating state)

Tip-induced scattering

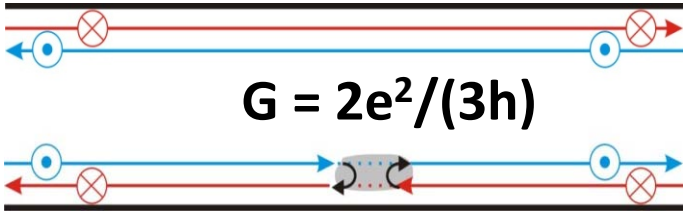
Scattering mechanisms:

- 2D reservoirs
- Kondo impurities



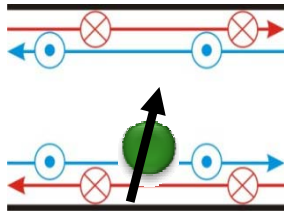
2D reservoirs

- scattering sets in at critical V_{tip}
- G saturates at predictable value



Kondo-like impurities

- scattering depends on occupation of impurity
- transition to 2D island for large impurity



Spatial mapping

AFM as complementary technique

- low-T AFM: in-situ comparison of transport results to spatial properties
- room-T AFM: high resolution of edge profile

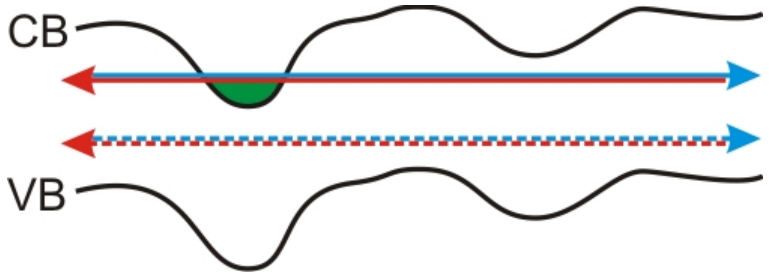
details of scattering might affect results

- Kondo: range of interaction?
- 2D island: size critical → lower spatial resolution

spatial extension of edge states

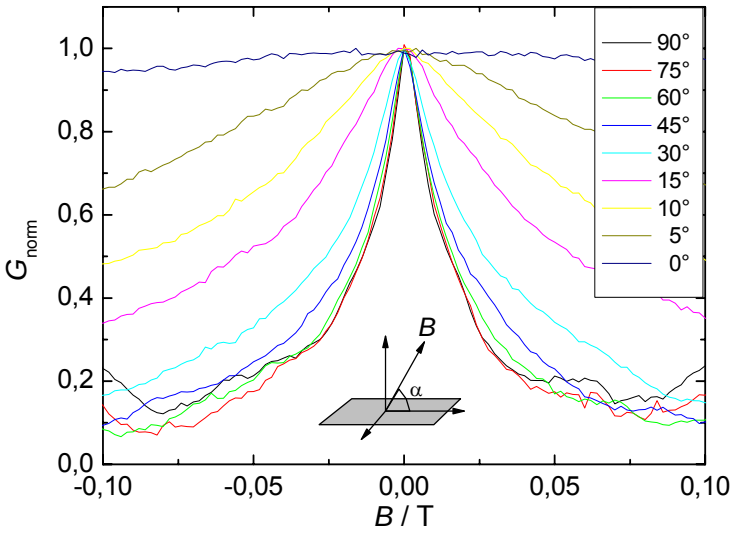
Detailed study of scattering

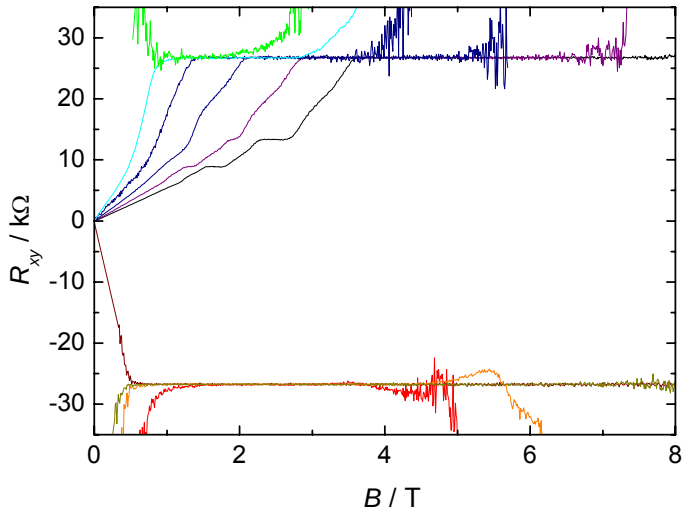
- sensitivity to potential fluctuations
- dominant mechanism?

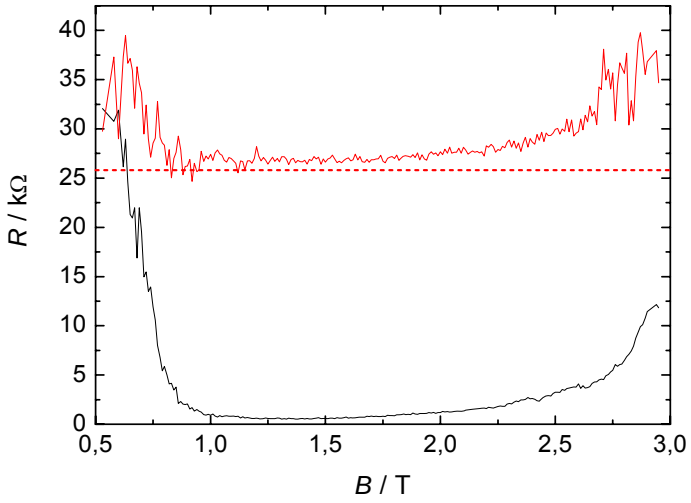


- compensate intrinsic fluctuations
  - for larger samples: $G_0 < 2\ e^2/h$
  - remove single perturbation by suitable tip potential

QSH states in magnetic field







- low B:
  no full suppression of G
- high B:
  reentrant QH state

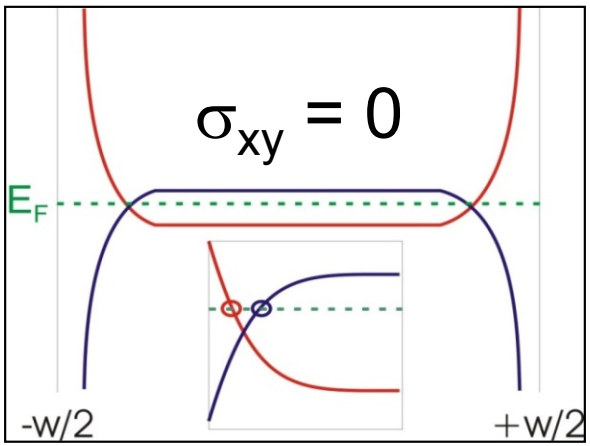
Tracking the states in high B-field

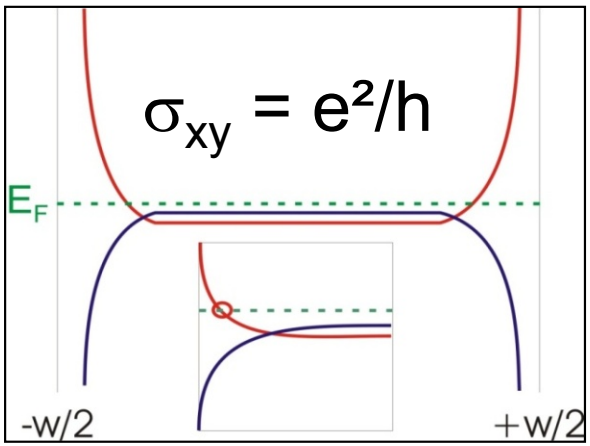
different scattering mechanisms (B vs. V_{tip})

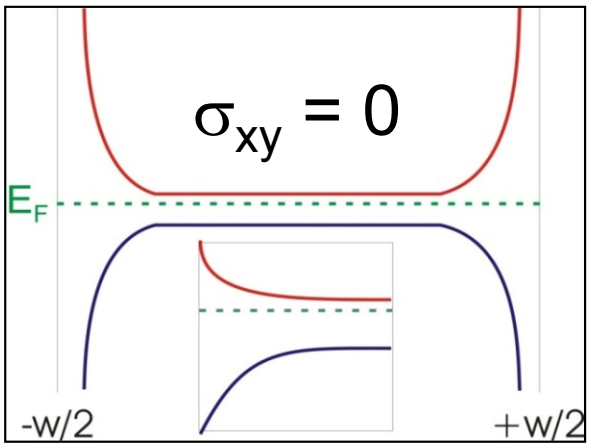
→ tip perturbation leads to further decrease of conductance

change in sensitivity to tip perturbation?

clear connection of QSHE and re-entrant QHE







Magnetic perturbation

- commercial MFM tips: several 10 mT
- homogeneous perpendicular field: significant suppression for B = 10 mT
- effect of local field comparable?
- spatial variation of B-field effect?
  - dependence on intrinsic potential fluctuations
  - increased sensitivity
- combination of magnetic and electric perturbation

Summary

Scanning Gate Microscopy useful for more detailed characterization of QSH states

- spatial mapping
- scattering mechanisms
  - 2D islands
  - Kondo impurities
  - breaking time reversal symmetry
- behavior in high magnetic fields