Title: Majorana State Properties in Semiconductor and Oxide Superconducting Quantum Wires

Date: Nov 08, 2013 09:00 AM

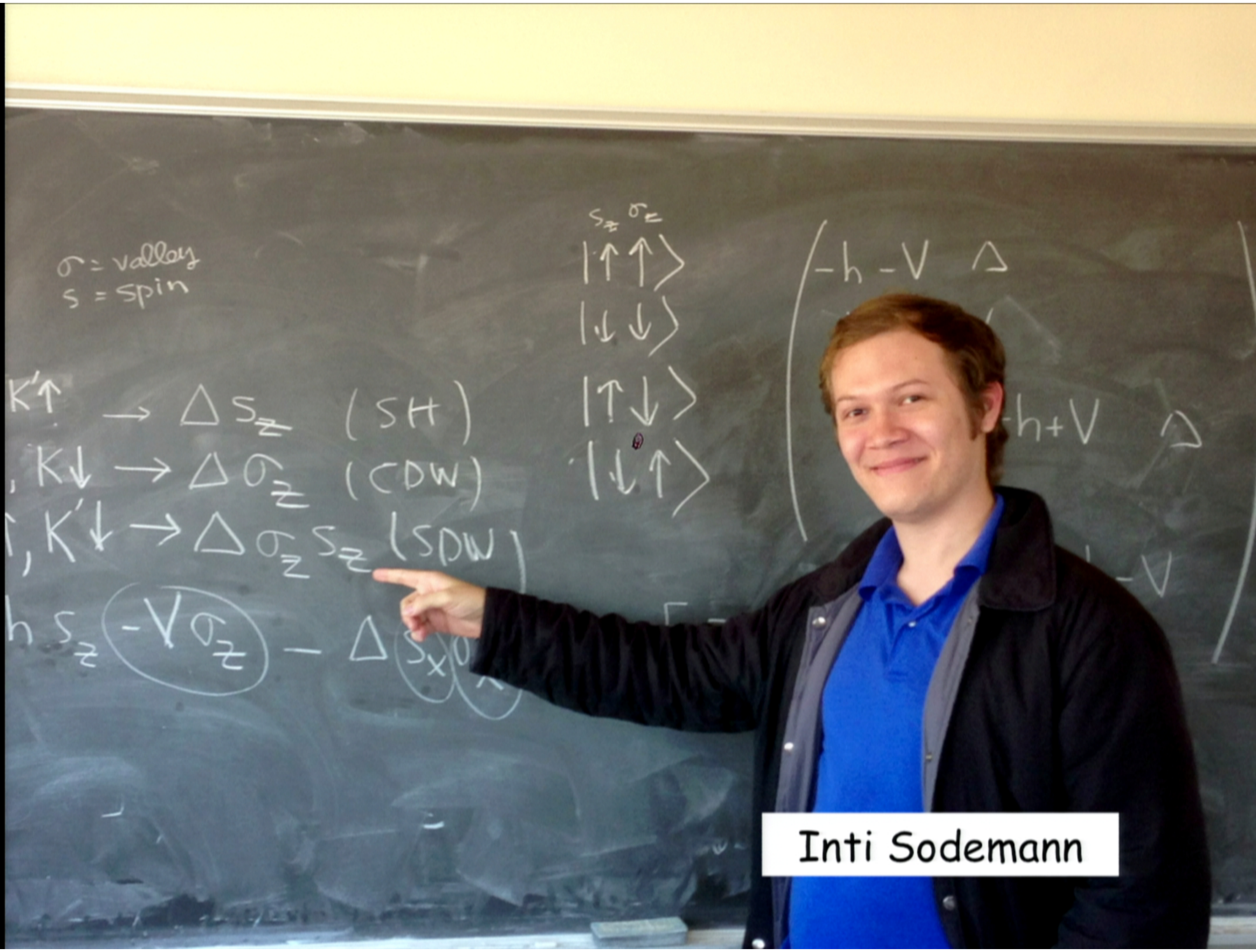
URL: http://pirsa.org/13110076

Abstract: When proximity coupled to s-wave superconductors, quantum wires can support effective p-wave superconductivity under appropriate circumstances. The p-wave state has Majorana states at the wire ends which can store quantum information. I will discuss some properties of Majorana states formed in oxide and semiconductor quantum wires, including superconducting state phase diagrams as a function of spin-orbit coupling strength, Fermi energy, and external magnetic field strength, and Majorana exchange properties.

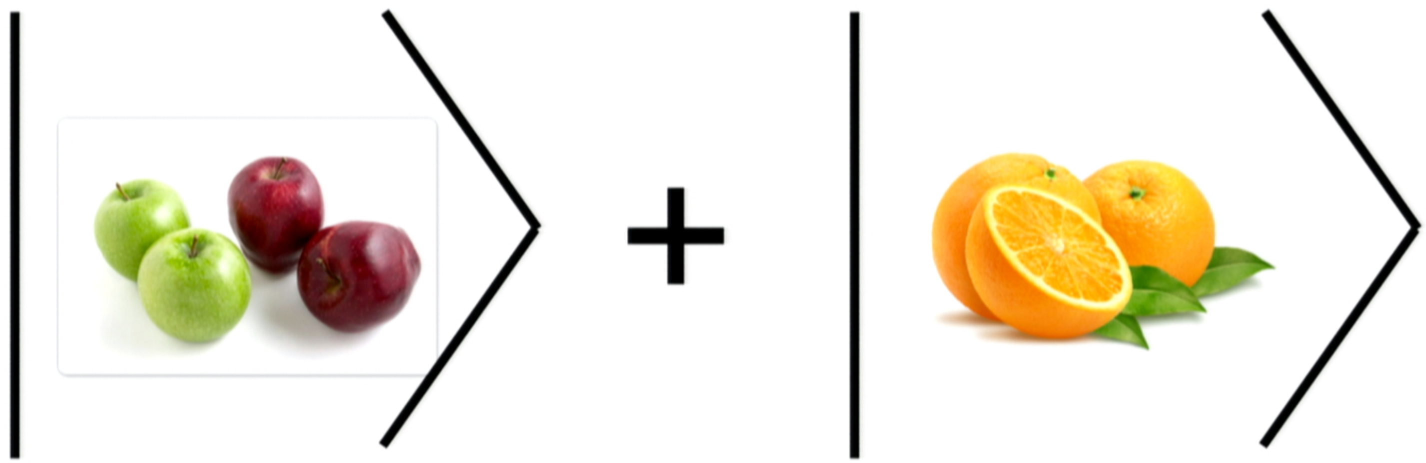
Broken Symmetries

&

The Quantum Hall Effect


σ = valley
s = spin
(SH)
(CDW)
Inti Sodemann

Additional Degrees-of-Freedom



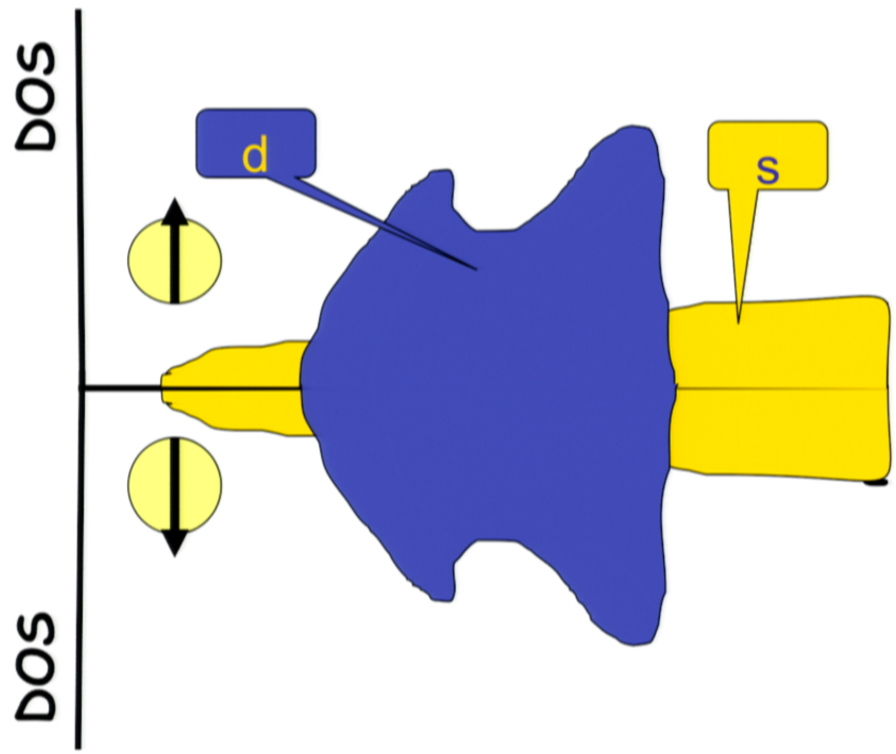
Three Examples

Spin

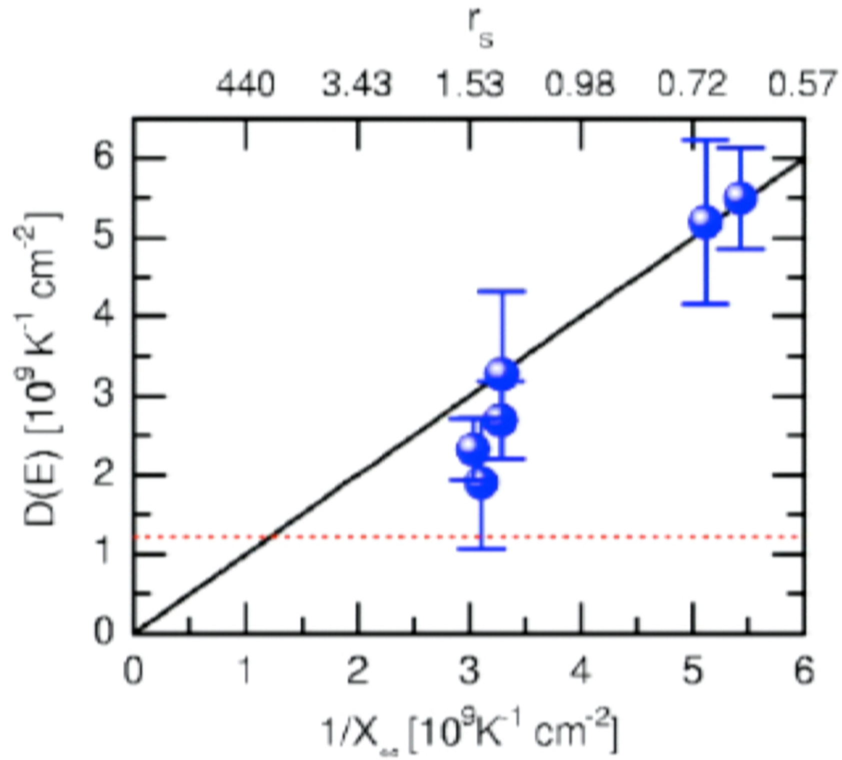
Layer

CR Orbit

Ordered States - Stoner Instability

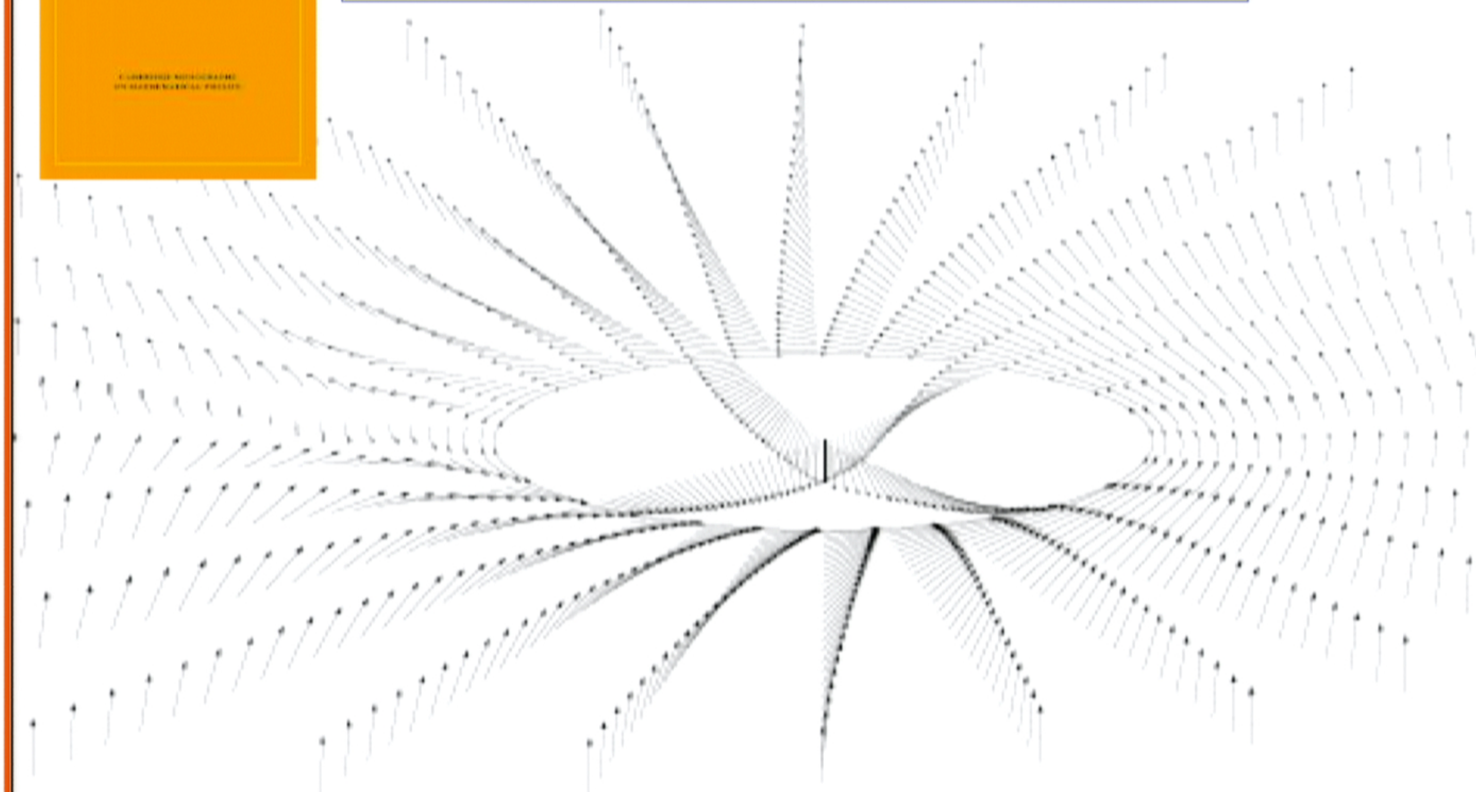


QHF- Stoner-Criterion



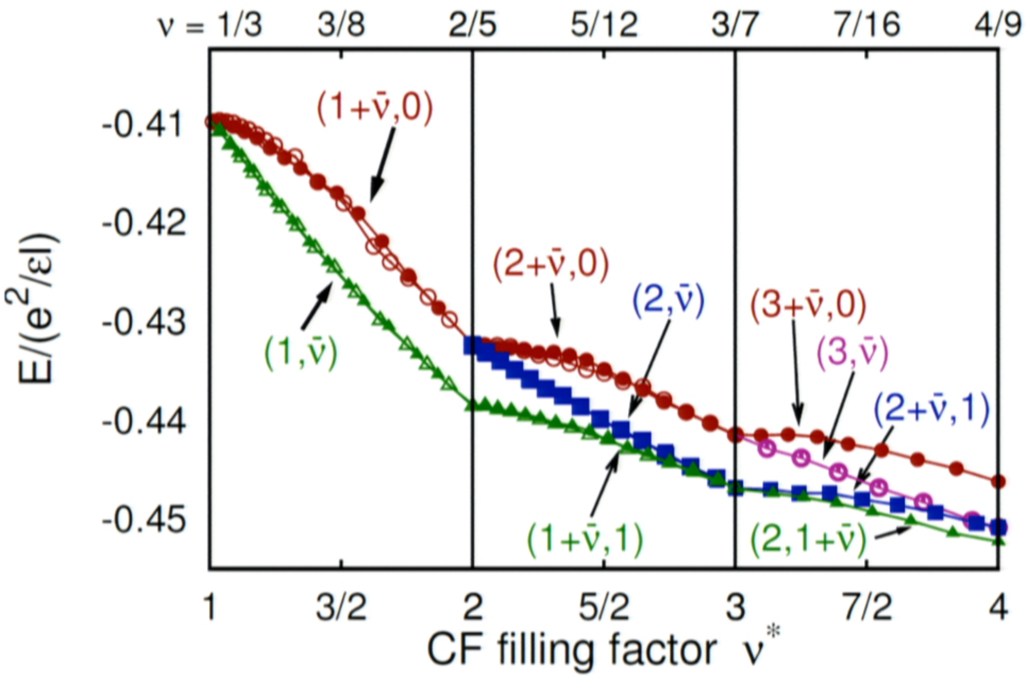
Maude et al. PRB (2005)

Skrymion in 2D O(3) Ferromagnet
Sondhi et al. (1993)



Fractional Filling Factors

Archer & Jain PRL (2013)



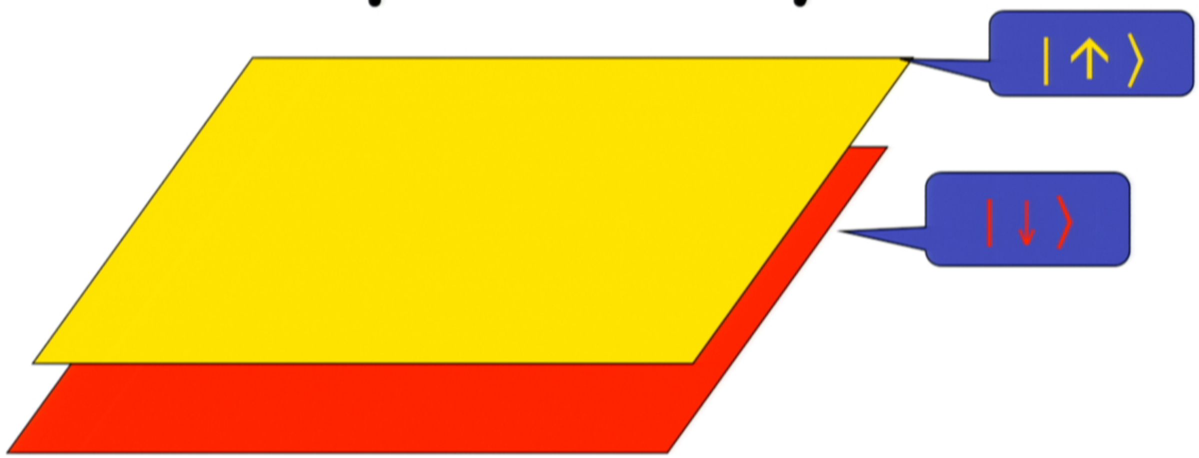
Three Examples

Spin

Layer

CR Orbit

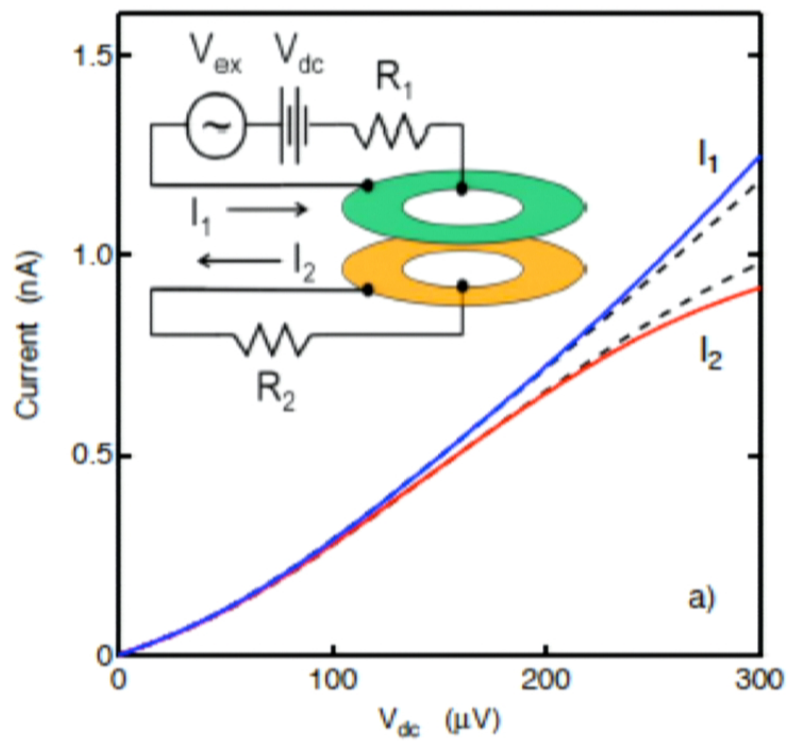
Bilayer Excitonic Superfluidity



Spontaneous Interlayer Phase Coherence =
Excitonic Superfluidity =
Pseudospin Ferromagnetism

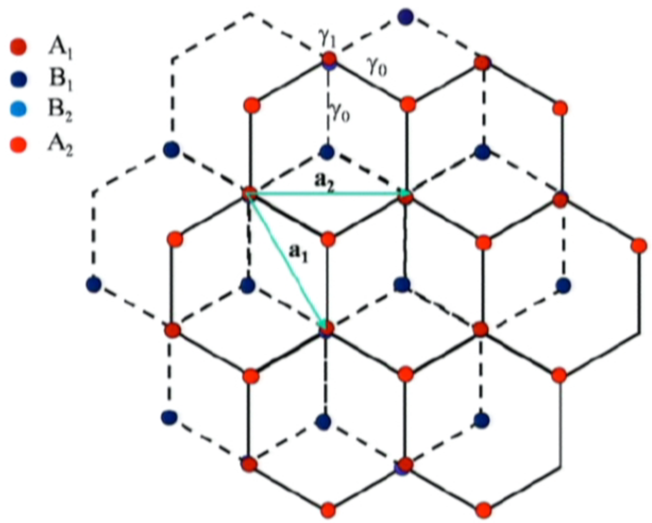
$$|\Psi\rangle_0 = \Pi_i \left(|\uparrow\rangle_i + e^{i\varphi} |\downarrow\rangle_i \right)$$

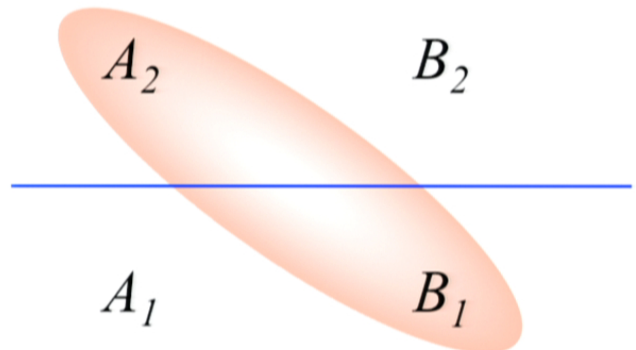
Counterflow Drag



Eisenstein – Nature (2012)

Bilayer AB stacking

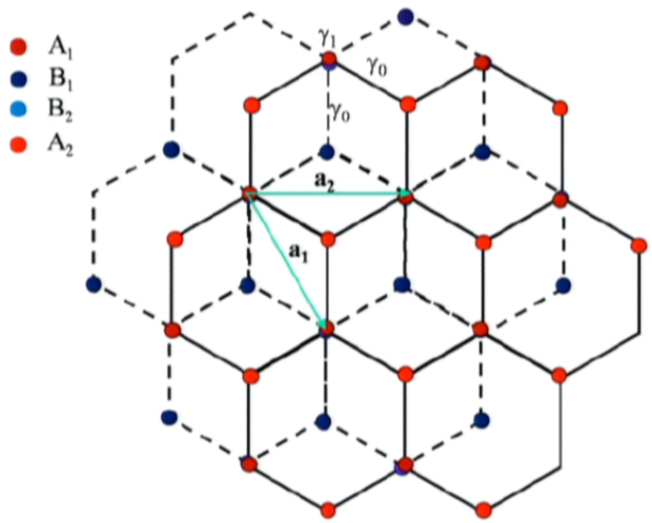


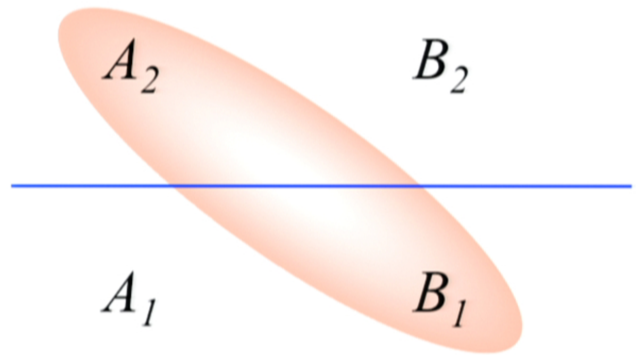


$\pi = \pi_x + i\pi_y$
=perturbation

$$\mathcal{H}_{MD}(\boldsymbol{k}) = -\begin{pmatrix} 0 & v\pi^\dagger \\ v\pi & 0 \end{pmatrix} \begin{matrix} |A\rangle \\ |B\rangle \end{matrix}$$

Bilayer AB stacking





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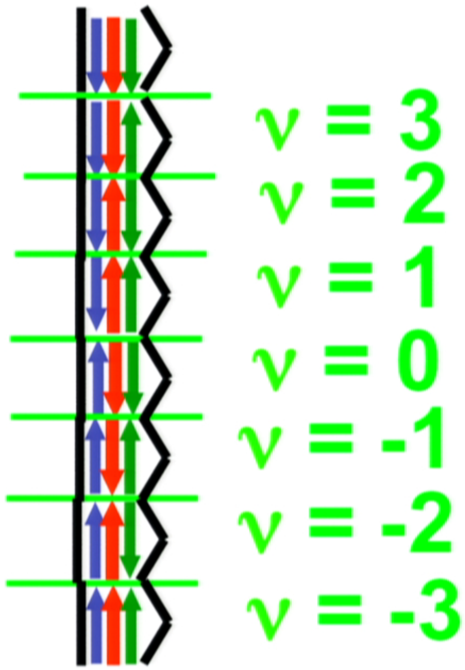
N=8 Quantum Hall Ferromagnets

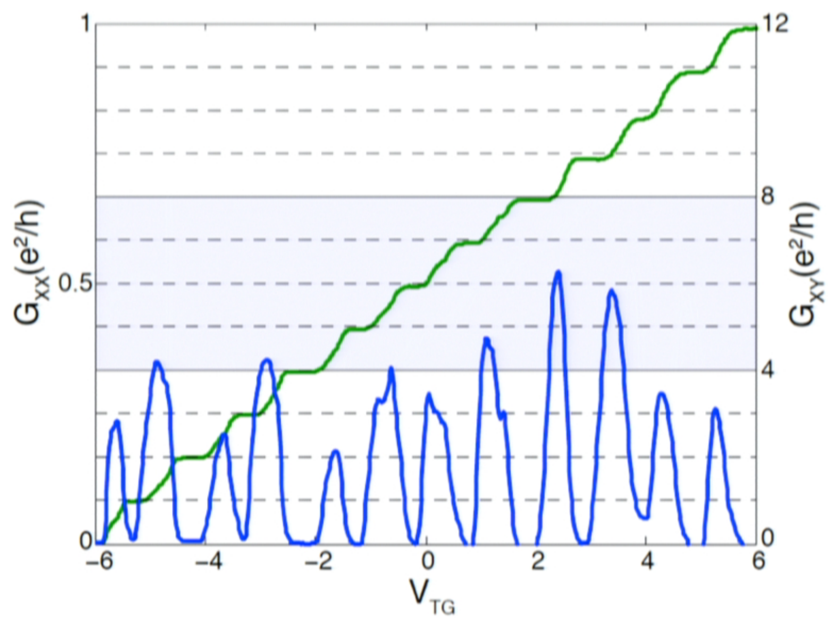
= LL (0,1) = layer = spin

$$\mathcal{H} = -\hbar\omega_c \begin{pmatrix} 0 & a^2 \\ (a^\dagger)^2 & 0 \end{pmatrix} \begin{matrix} |A\rangle \\ |B\rangle \end{matrix}$$

FQHE: Papic and Abanin arXiv:1307.2909

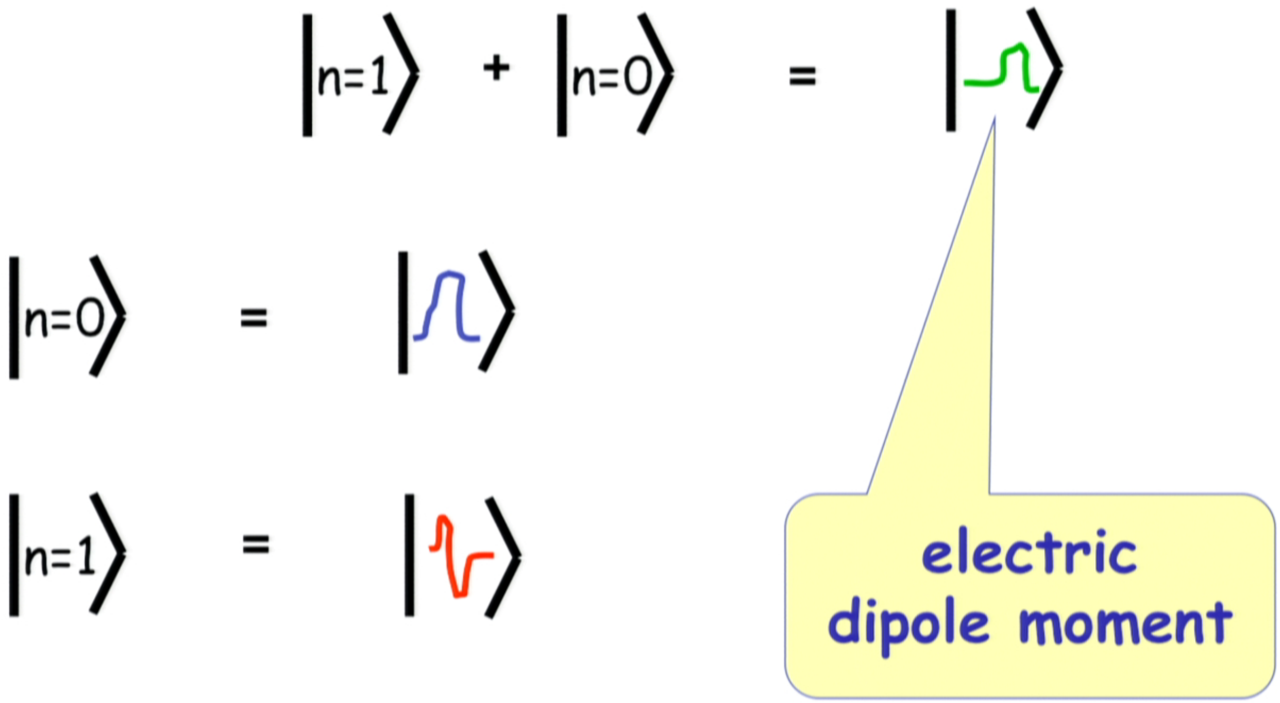
Hunds Rules: Spin then layer then LL



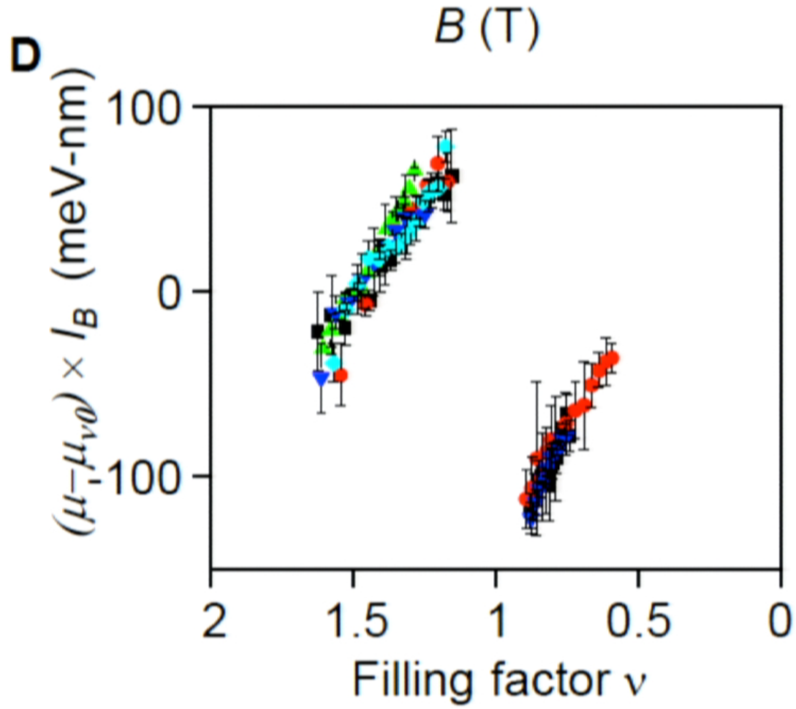


Mayer et al. Nature Physics (2013)

Electronic XY Ferroelectric

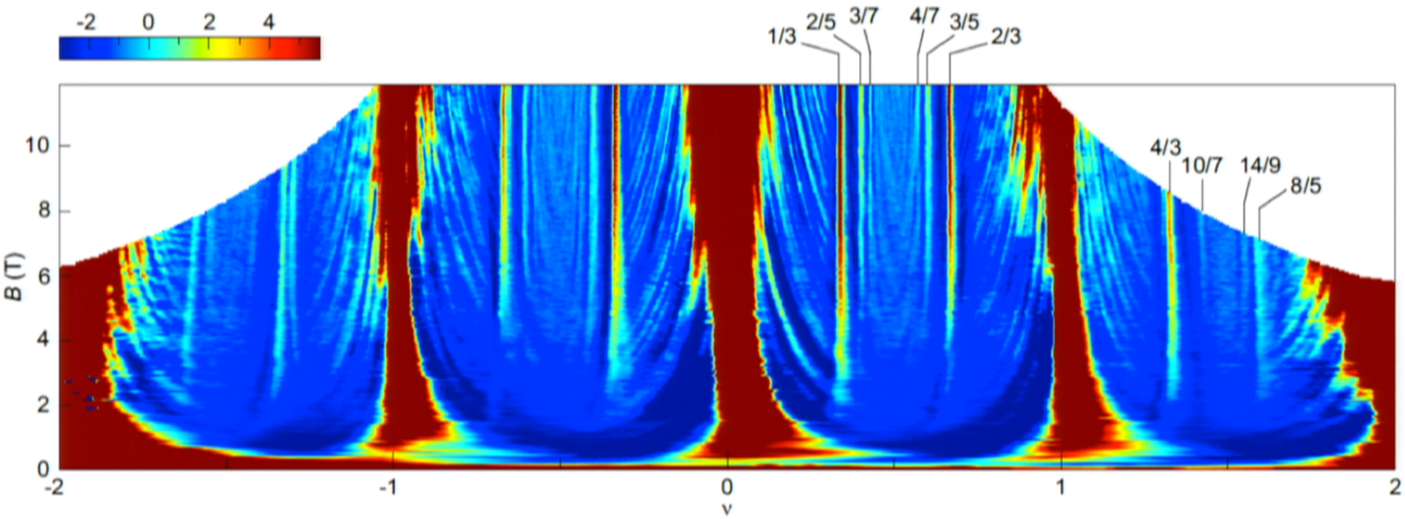


Strong Quantum Hall Effects at Intermediate Integers



Deshpande *et al.* (2012)

Surprising FQHE

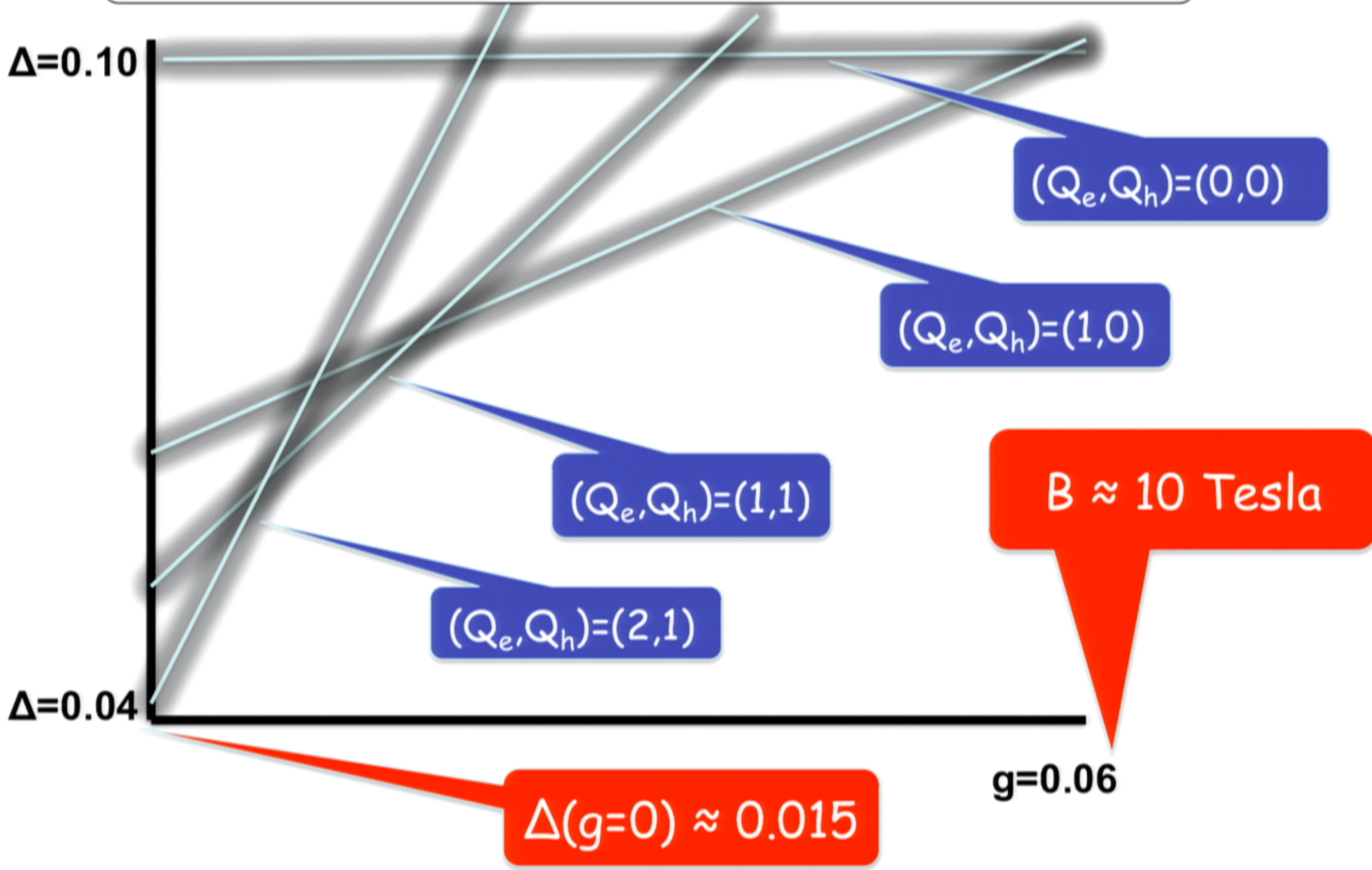


$-2 \leq \nu \leq -1$ $\quad -1 \leq \nu \leq 0$ $\quad 0 \leq \nu \leq 1$ $\quad 1 \leq \nu \leq 2$

Bolotin *et al.*, Du *et al.* Nature (2009)
Feldman *et al.* Science (2012)

Skyrmions at $\nu = 1/3$?

Sondhi et al. PRB '93, Moon et al. PRB '95
Palacios & AHM PRB '98



Simple Rule for New FQHE States

$$|\Psi(N)\rangle \to \prod_{N<i<j\leq N+N_\phi} (z_i - z_j) \; |\Psi(N)\rangle$$

2/3 ➔ 5/3

$$(\nu_1, \ldots, \nu_k) \to (1, \nu_1, \ldots, \nu_k)$$

Sodemann and AHM arXiv:1310.1642

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Simple Rule for New FQHE States

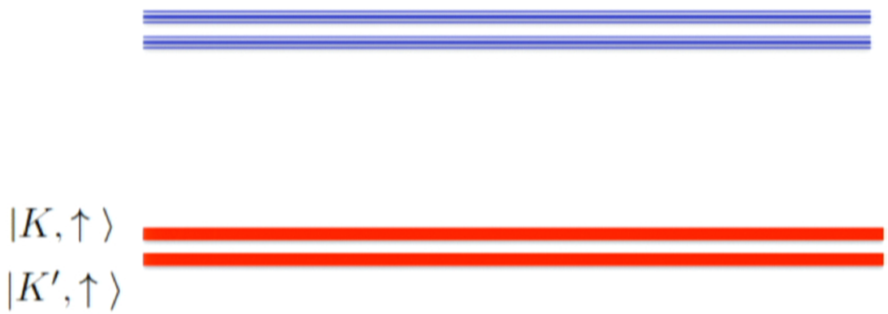
$$|\Psi(N)\rangle \rightarrow \prod_{N<i<j\leq N+N_\phi} (z_i - z_j) \; |\Psi(N)\rangle$$

$$E_{2-\tilde{\nu}} = E_{\tilde{\nu}} + (1-\tilde{\nu})2E_1$$

$$E_{1+\tilde{\nu}} = E_{\tilde{\nu}} + E_1,$$

Sodemann and AHM arXiv:1310.1642

Neutral Graphene in a Magnetic Field

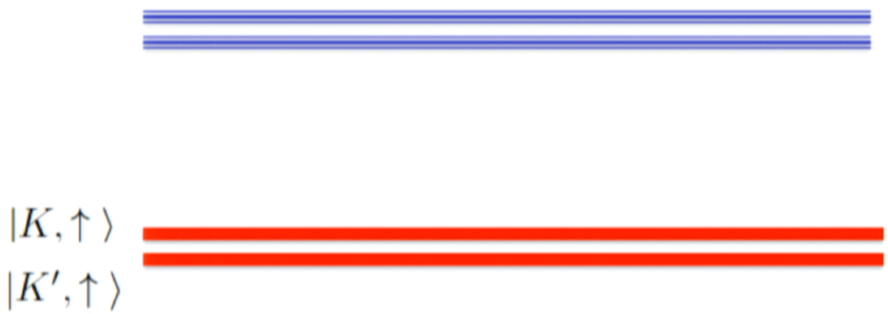


$$\epsilon = \frac{\Delta_z}{2}$$

$$\epsilon = -\sqrt{\frac{\pi}{2}}\frac{e^2}{\epsilon\ell} - \frac{\Delta_z}{2}$$

Spin Hall State

Neutral Graphene in a Magnetic Field



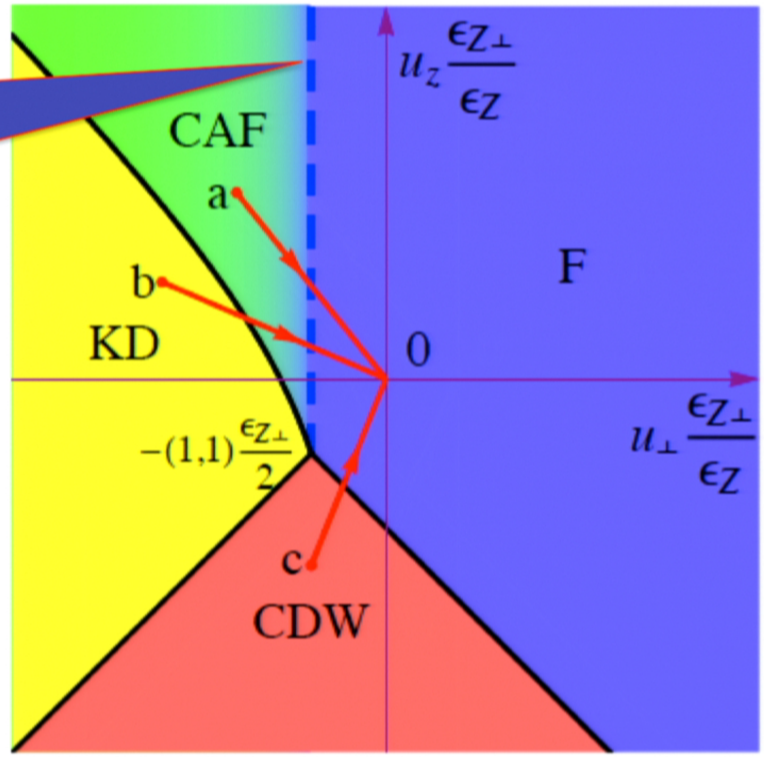
$$\epsilon = \frac{\Delta_z}{2}$$

$$\epsilon = -\sqrt{\frac{\pi}{2}}\,\frac{e^2}{\epsilon \ell} - \frac{\Delta_z}{2}$$

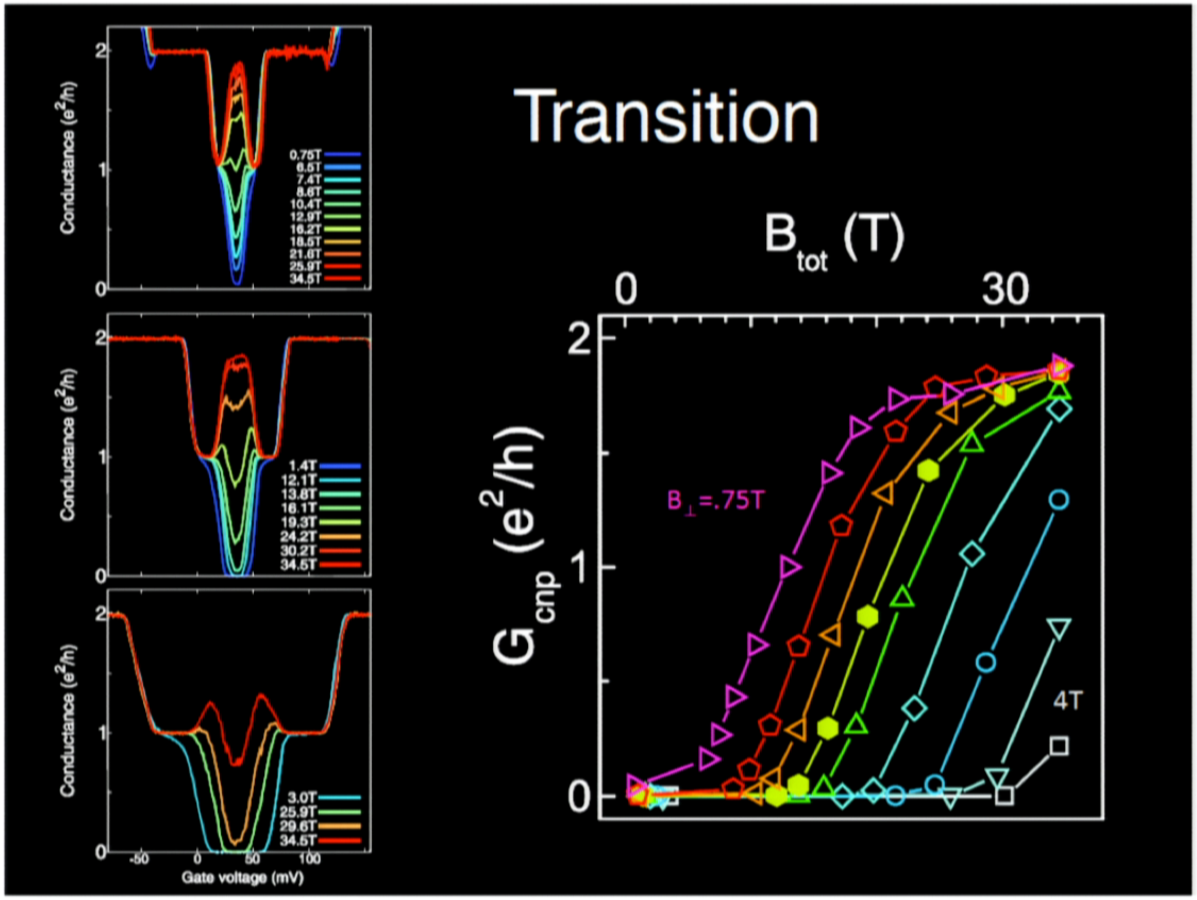
Spin Hall State

Kharitonov Phase Diagram for ν =0

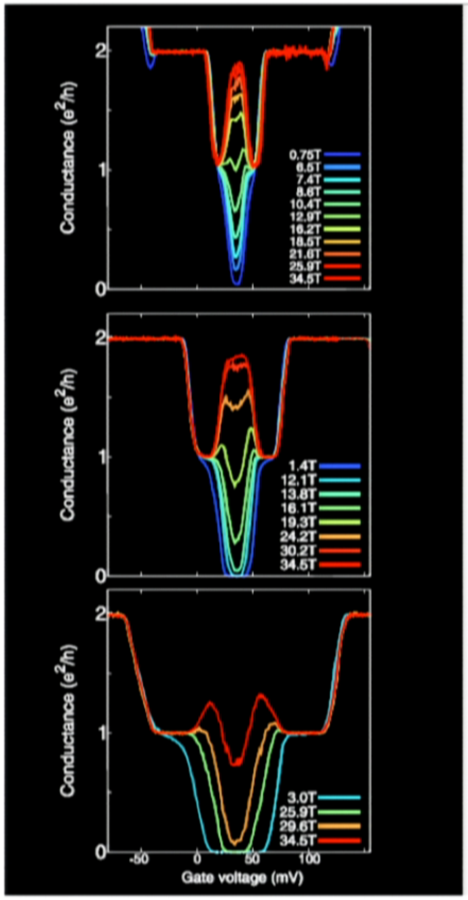
F to CAF Transition at $\varepsilon_z = 2\,U$



Kharitonov – PRB (2012)



Andrea Young, Sanchez-Yamagishi, Hunt et al.
APS March Meeting - 2013



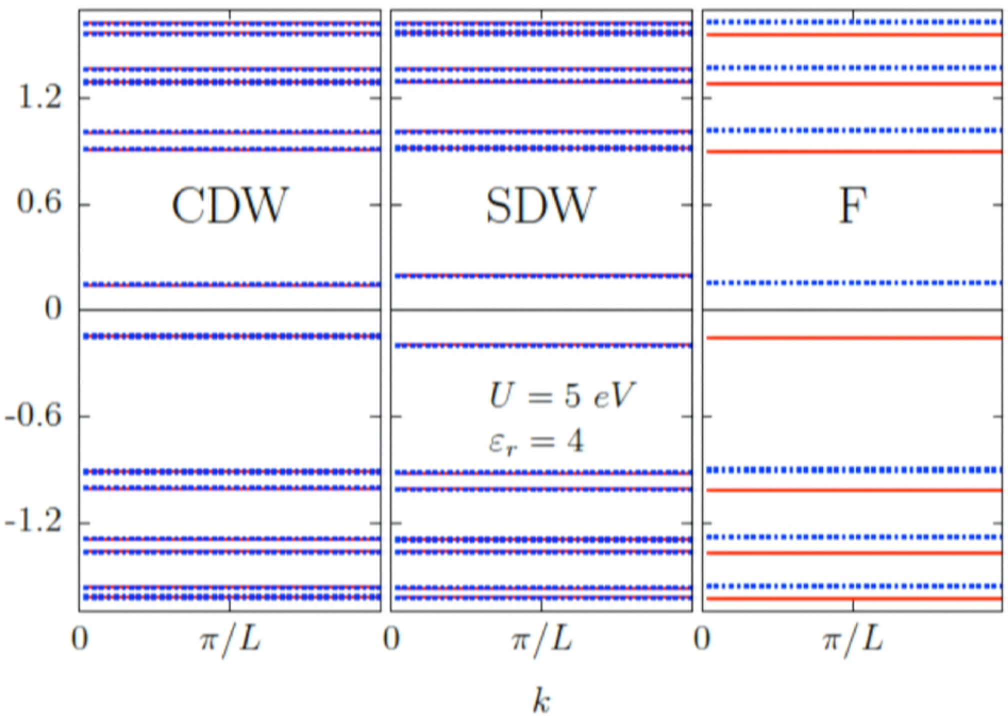
U = - 0.37 meV
at B=.75 Tesla

U= - 0.47 meV
at B=1.4 Tesla

U= - 1.00 meV
at B= 3.0 Tesla

Andrea Young, Sanchez-Yamagishi, Hunt et al.
APS March Meeting - 2013

SU(4) Symmetry Breaking



Jeil Jung & AHM
PRB (2009)