WS-D2 Orbital Angular Momentum and Spectral Flow in 2D Chiral Superfluids

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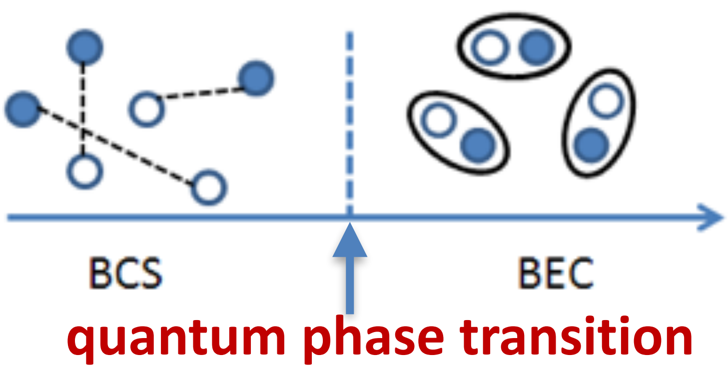
Consider a chiral superfluid (SF) in 2D

Q: What is the total orbital angular momentum(OAM) L of the superfluid consisting of N fermions?

A1: each Cooper pari has angular momentum ν → $L = \nu N/2$

A2: only fermions near Fermi surface are affected → $L = \nu N/2(\frac{\Delta}{E_F})^\gamma$

Which is the correct answer?



- L could be different in weak pairing limit and strong pairing limit!
- Many recent results support $L = N/2$ for $p_x + ip_y$ SF. But why $L = N/2$ holds in BCS?

Ref: arXiv-1409.7459

Topological Quantum Phenomena in Condensed Matter with Broken Symmetries

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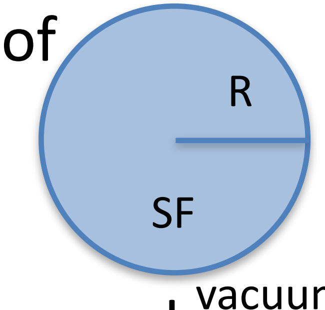
2D chiral SFs confined on a circular disc, in the framework of BdG theory

$$\hat{H} = \int d^2x \psi_\sigma^\dagger [(p_x^2 + p_y^2)/2m_0 + V - \mu]\psi_\sigma + \int d^2x \psi_\uparrow^\dagger \Delta (p_x + ip_y)^\nu \psi_\downarrow^\dagger + (\text{h.c.})$$



We respect Volovik's observation that $\hat{Q} = \hat{L}_z - \nu \hat{N}/2$ is conserved

$Q = 0 \Longleftrightarrow L_z = \nu N/2$ But when do we have $Q = 0$?

We found:

$$Q = \langle GS|\hat{Q}|GS\rangle = -\frac{1}{2}\sum_l (l + \frac{\nu}{2})\eta_l$$

spectral flow: $\eta_l = \sum_m sgnE_m^{(l)}$

The AM of chiral SFs $\hat{\Delta} \sim (\hat{p}_x + i\hat{p}_y)^\nu$ confined on a circular disc:

$\nu = 1 : p_x + ip_y$	$L = N/2$	(BEC+BCS)
$\nu \geq 2$	$L = \nu N/2$	(BEC)
$eg : \nu = 2(d_{x^2-y^2} + id_{xy})$	$L/N \sim O(\Delta_0/\varepsilon_F)$	(BCS)

different with p+ip

WHY??

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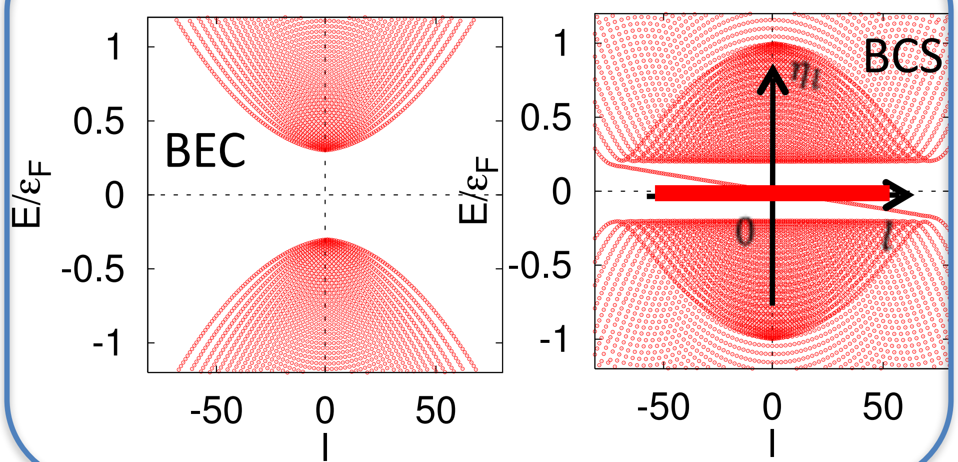
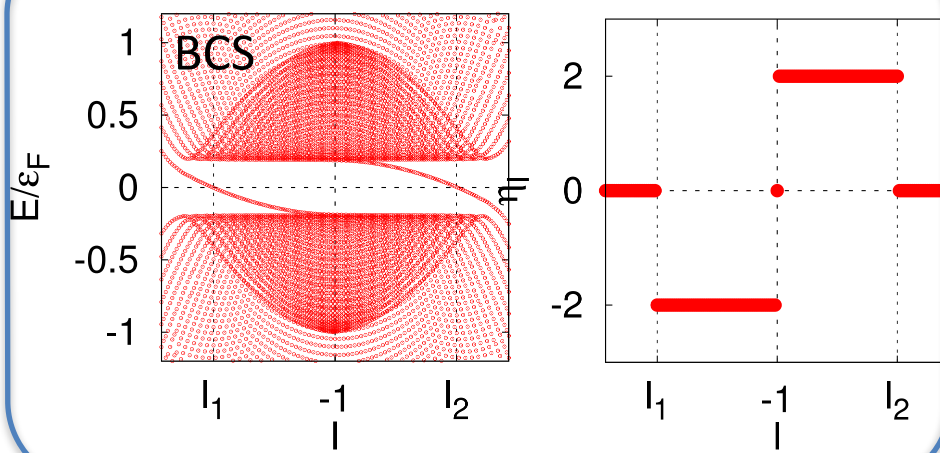
$p_x + ip_y$

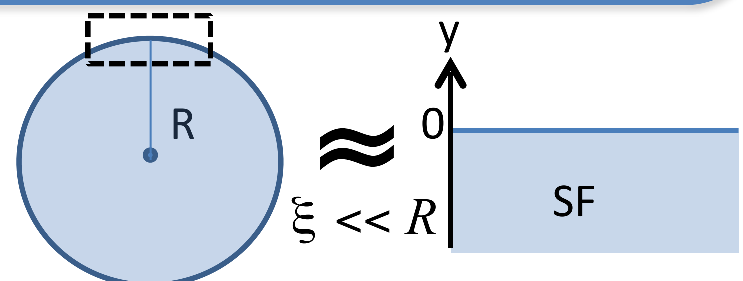


$d_{x^2-y^2} + id_{xy}$



- quasi-classical calculation BCS for

$$Q \simeq -\frac{1}{2}\sum_{j=1}^{\nu} {l_j}^2 = -\frac{1}{2}\sum_{j=1}^{\nu}\left(Rk_{F\parallel}^{(j)}\right)^2 = -\frac{\nu N}{2}$$



- depairing effect of $\nu \geq 2$ SFs at the boundary

$$|\mathrm{GS}\rangle_l = \left(\prod_{j=1}^{n_\uparrow^{(l)}} \tilde{c}^\dagger_{j,l+\nu,\uparrow}\right)\left(\prod_{j=1}^{n_\downarrow^{(l)}} \tilde{c}^\dagger_{j,-l,\downarrow}\right)\exp\left(\sum_{j>n_\uparrow^{(l)}}\sum_{j'>n_\downarrow^{(l)}} \tilde{c}^\dagger_{j,l+\nu,\uparrow}F^{(l)}_{jj'}\tilde{c}^\dagger_{j',-l,\downarrow}\right)|0\rangle$$

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