

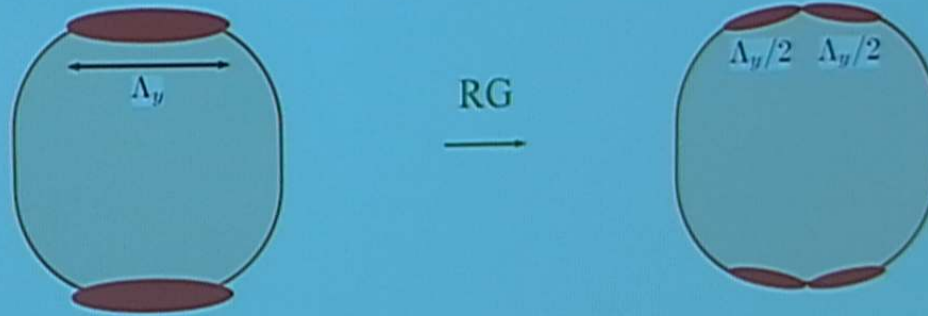
Title: Are non-Fermi-liquids stable to pairing?

Date: Feb 13, 2014 02:00 PM

URL: <http://pirsa.org/14020143>

Abstract: States of matter with a sharp Fermi-surface but no well-defined Landau quasiparticles are expected to arise in a number of physical systems. Examples include i) quantum critical points associated with the onset of order in metals, ii) the spinon Fermi-surface (U(1) spin-liquid) state of a Mott insulator and iii) the Halperin-Lee-Read composite fermion charge liquid state of a half-filled Landau level. In this talk, I will use renormalization group techniques to investigate possible instabilities of such non-Fermi-liquids to pairing. I will show that for a large class of phase transitions in metals, the attractive interaction mediated by order parameter fluctuations always leads to a superconducting instability, which preempts the non-Fermi-liquid effects. On the other hand, the spinon Fermi-surface and the Halperin-Lee-Read states are stable against pairing for a sufficiently weak attractive short-range interaction. However, once the strength of attraction exceeds a critical value, pairing sets in. I will describe the ensuing quantum phase transition between i) the U(1) and the Z_2 spin-liquid states, and ii) the Halperin-Lee-Read and Moore-Read states.

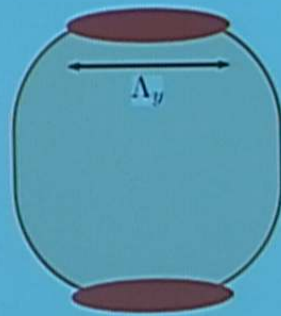
Modification of BCS by gapless boson



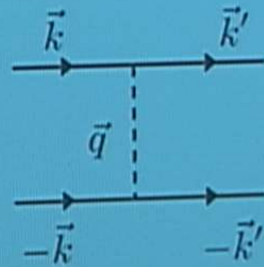
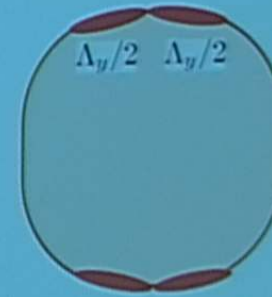
• RG flow: $\frac{dV_m}{d\ell} = -V_m^2$

MM, D. Mross, S. Sachdev, T. Senthil, to appear

Modification of BCS by gapless boson



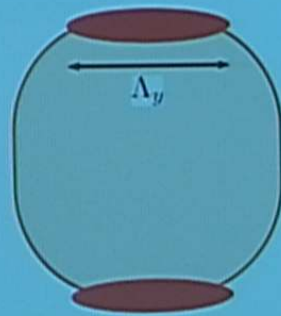
RG
→



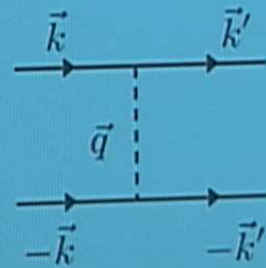
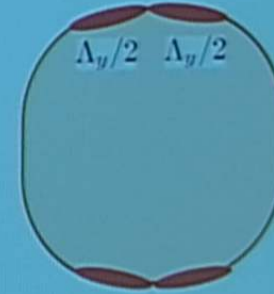
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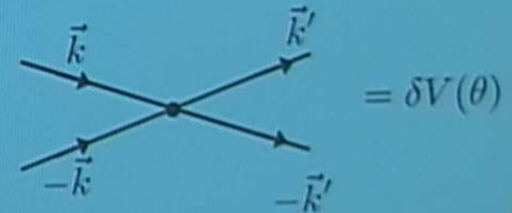
Modification of BCS by gapless boson



RG
→



$\Lambda_y/2 < |\vec{q}| < \Lambda_y$
→



• RG flow: $\frac{dV_m}{d\ell} = -V_m^2$

MM, D. Mross, S. Sachdev, T. Senthil, to appear

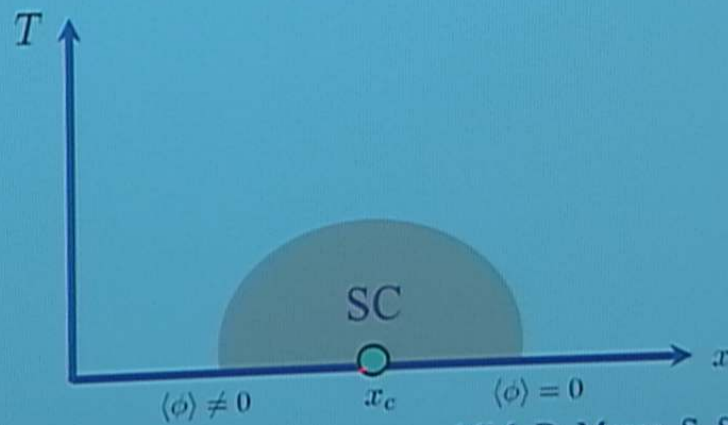
SC instability of Ising-nematic QCP

$$\frac{dV_m}{d\ell} = -\frac{\alpha}{N} - V_m^2$$

↑
order parameter fluctuations

$$\frac{d\alpha}{d\ell} = \frac{\epsilon}{2}\alpha - \frac{\alpha^2}{N}$$

- Always flows to $V = -\infty$



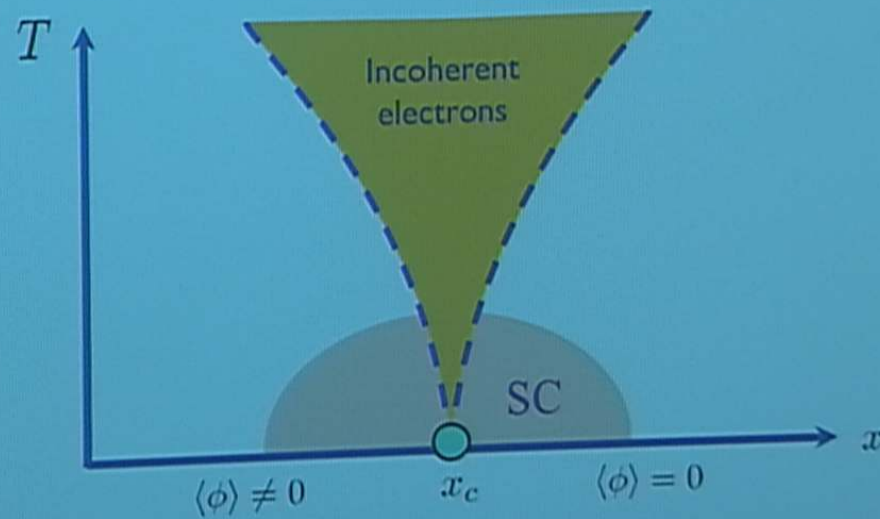
MM, D. Mross, S. Sachdev, T. Senthil, to appear

SC instability of Ising-nematic QCP

- Pairing pre-empts onset of incoherent electron regime

$$\Delta_{\text{SC}} \sim \left(\frac{1}{\epsilon}\right)^{2/\epsilon} E_{\text{incoh}}$$

$$\Delta_{\text{SC}} \gg E_{\text{incoh}}$$



Pairing: spinon Fermi surface

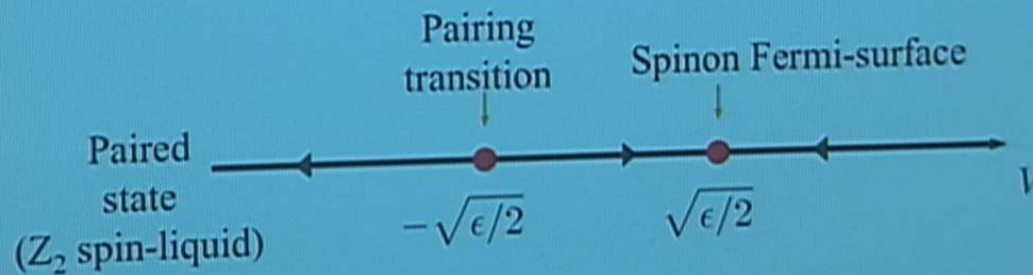
$$\frac{dV_m}{d\ell} = +\frac{\alpha}{N} - V_m^2$$

$$\frac{d\alpha}{d\ell} = \frac{\epsilon}{2}\alpha - \frac{1}{N}\alpha^2$$

$$\alpha \rightarrow \frac{N\epsilon}{2}$$



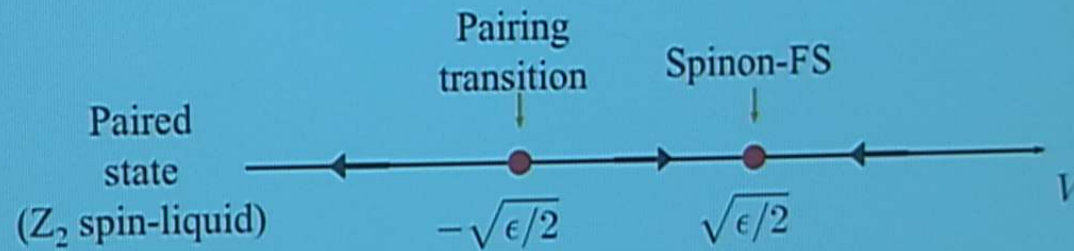
Gauge field fluctuations



- Gap onsets as $\Delta = (V_c - V)^{z\nu}$, $(z\nu)^{-1} = \sqrt{2\epsilon}$

M.M., D. Mross, S. Sachdev, T. Senthil, forthcoming

Open questions



- Properties of the paired state:

- is the “superconductor” type I or type II close to the transition?

Likely type I: $\xi \sim \lambda^2 \gg \lambda$

Important consequences for QHE phenomenology

S. A. Parameswaran, S. A. Kivelson, S. L. Sondhi and B. Z. Spivak (2011)

- how does the vortex mass (vison gap) vanish at the pairing transition?

Conclusion

- Progress (and new challenges) in understanding critical fermi surface states.
- First theory of superconducting instability of a QCP in a 2d metal
 - Pairing glue ✓
 - Quasiparticle destruction
 - Extensions to other types of orders (besides nematic)?
 - Transport ($\rho \sim T$)
- First theory of a transition from a U(1) to a Z_2 spin-liquid
- Non-Fermi-liquids beyond gapless boson + Fermi-surface?

Thank you!