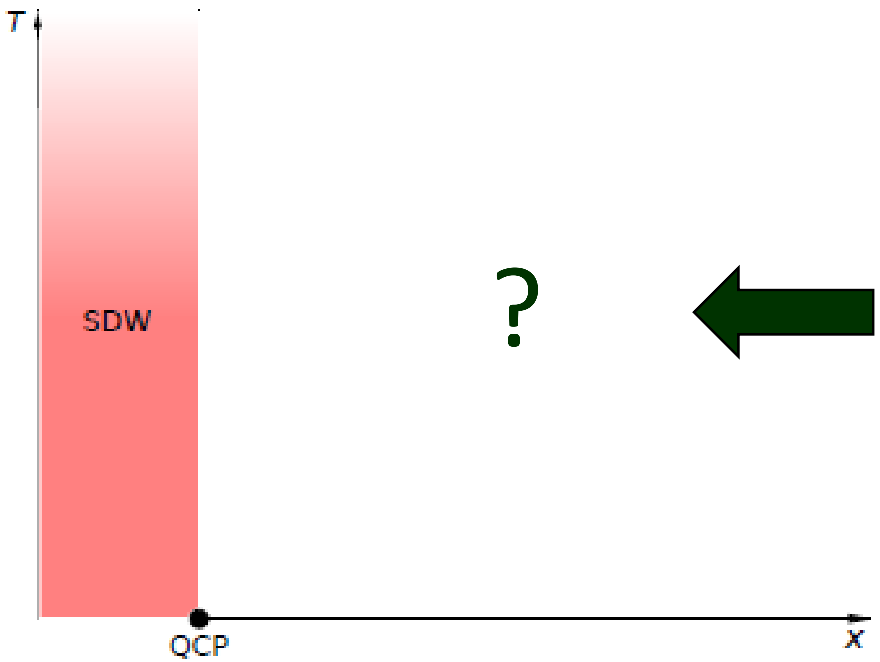
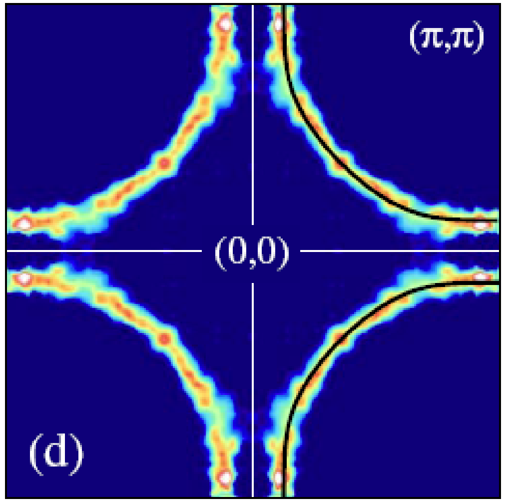
Metallic quantum criticality

2 theory talks: Sung-Sik Lee and Yoni Schattner

1 experimental talk: Ian Hayes (Ba-122)

Two theory talks address a very specific problem:
what happens in a 2D metal near a (π,π) SDW instability.





Fermions interact by exchanging quanta of collective excitations in a spin channel (spin fluctuations)

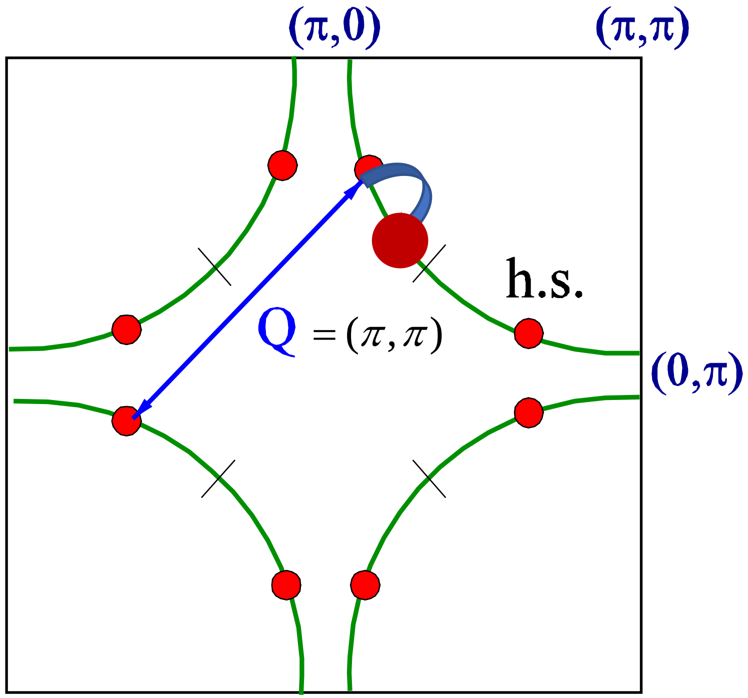
Spin-fermion model

"Canonical" description: Eliashberg-type theory of spin-fermion model in 2D at the onset of magnetic order

1. Critical bosons have dynamical exponent Z_B=2

$$\chi(\mathrm{q},\Omega_m) = \frac{\chi_0}{(\mathrm{q}-\pi)^2 + \gamma|\Omega_m|}$$

2. Fermions show a non-FL behavior at hot spots



Millis, 1993

$$\Sigma(k,\omega_m) \approx \Sigma(\omega_m) \propto \omega_{\mathrm{m}}^{1/2}$$

Fermi liquid with position-dep. Z-factor

$$\Sigma(k,\omega_m) \approx \Sigma(k_{\|},\omega_m) \propto \omega_{\mathrm{m}} / |k_{\|}|$$

Abanov, A.C. Schmalian

S-S Lee talk

Corrections to Eliashberg theory are logarithmically singular

A major repair of the theory is needed at the lowest energies

- …ections contain Log ω
- Correct… velocity contains Log ω
- Corrections to b… agator contain Log ω

At one loop order:
Anomalous dimensions

$$\chi(\mathrm{q},\Omega_m) = \frac{\chi_0}{((\mathrm{q}-\pi)^2 + \gamma|\Omega_m|)^{1-\eta}}$$

… $\omega_m^{(1-\eta)/2}$

A… alian

At two loop order:
bosonic dynamical exponent Zb begins flowing

$$\chi(\mathrm{q},\Omega_m) = \frac{\chi_0}{((\mathrm{q}-\pi)^{2-\delta} + \gamma|\Omega_m|)^{1-\eta}}$$

Metlitski & Sachdev

Various attempts to control the theory: large N expansion, expansion near D=3, etc…

Senthil et al
S-S Lee et al

Yoni Schattner: QMC

What about larger energies: does Eliashberg theory work?
(even non-logarithmical corrections are not parametrically small)

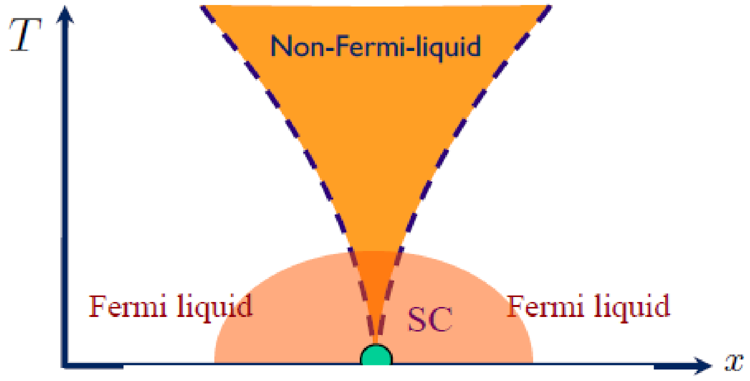
Non FL physics is one aspect of the story
Superconductivity is the other

(π,π) spin fluctuations give rise to an attraction in d-wave channel

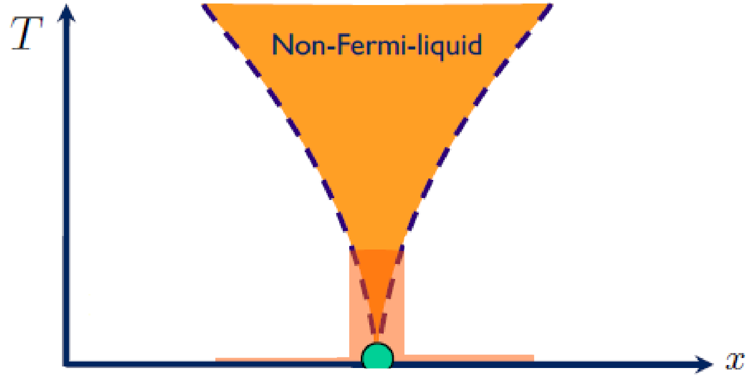
Scalapino, Varma, Pines..

What is the interplay between non-FL behavior and superconductivity

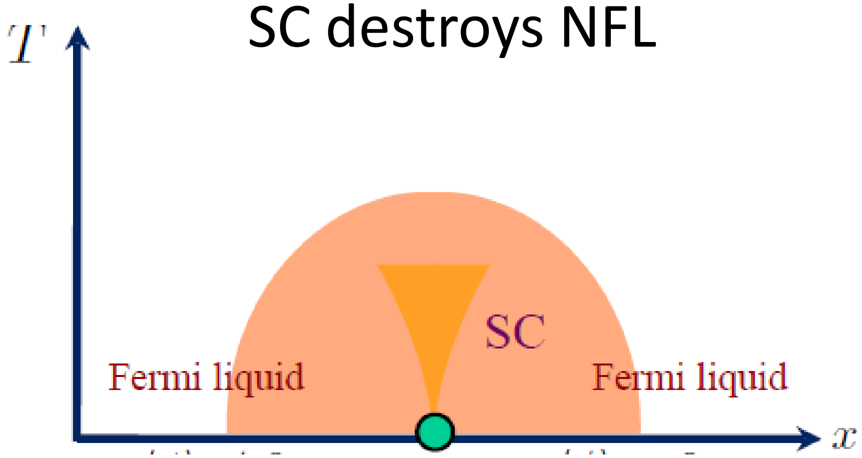
Eliashberg theory



NFL destroys SC



SC destroys NFL



Mross, Metlitski, Sachdev, Senthil

Ian Hayes

Experimental manifestations of AFM criticality in a metal

Thermodynamics

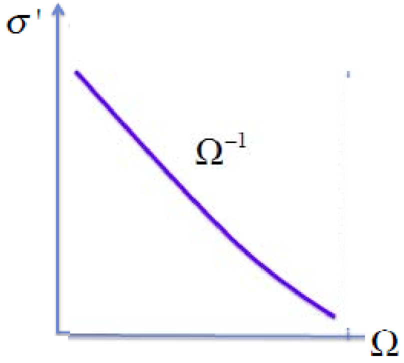
Fermi liquid with position-dep. Z-factor

$$\Sigma(k,\omega_m) \approx \Sigma(k_{||},\omega_m) \propto \omega_m / |k_{||}|$$

$$\Rightarrow \quad C(T) \propto T \,\mathrm{Log}\, T$$

Transport properties

Optical conductivity is singular at a QCP due to composite scattering:



$$\sigma(\Omega) \propto 1/\Omega$$

Hartnoll, Hofman, Metlitsli, Patel, Sachdev, ….
Maslov, Yudson, A.C.

Resistivity:

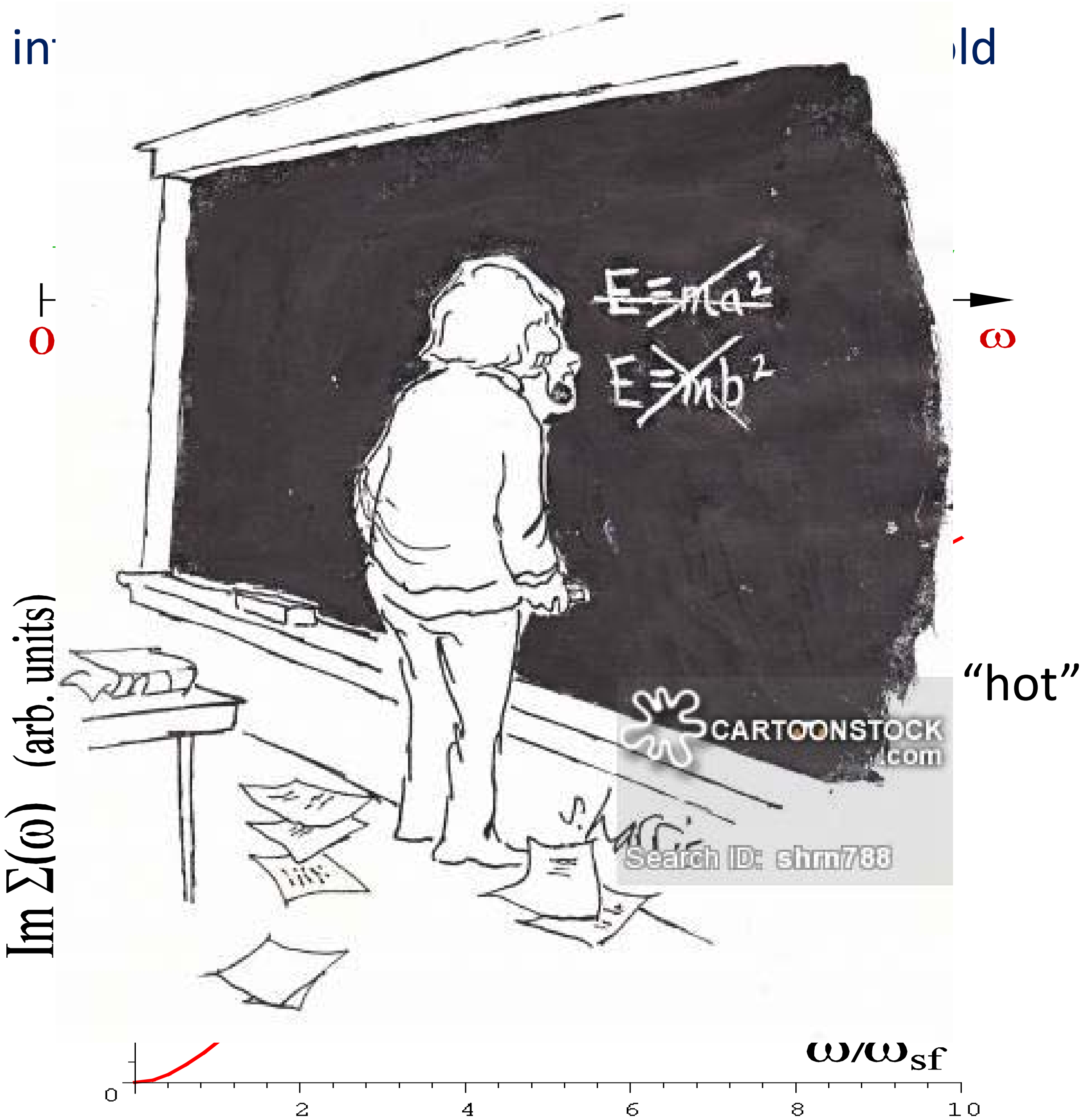
In a dirty system $\rho(T) = \rho_{imp} + AT$ A. Rosch $\rho_{imp} > AT$

In a clean system $\rho(T) \propto T^2$ at the lowest T

Resistivity at the lowest T is determined predominantly by cold fermions with FL spectral properties

At in ... ld

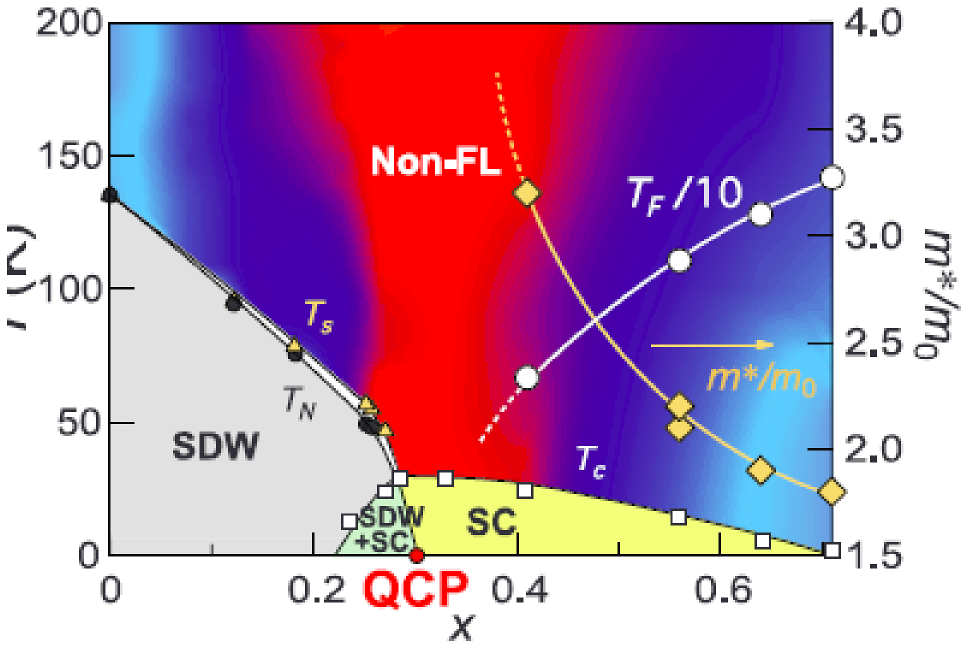
At arbitrary point along the FS



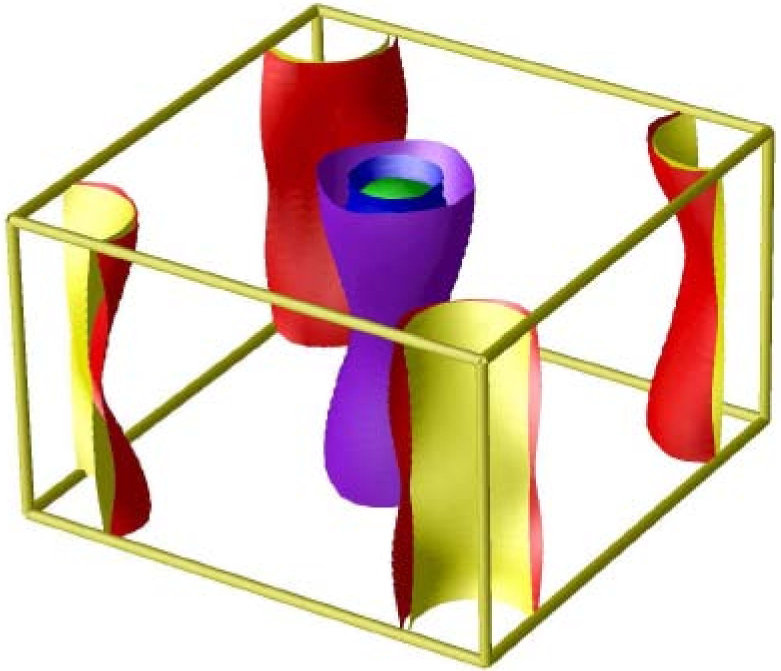
Ian Hayes

Non-FL phenomenology in Ba122

Fe-based superconductor



Hashimoto et al



Mazin & Schmalian

$$\rho(\mathrm{T},\mathrm{H}) \propto \sqrt{\mathrm{T}^2 + (\mu_\mathrm{B}\mathrm{H})^2}$$

Enjoy the talks