

Singular corrections to the Fermi liquid theory

Andrey Chubukov

University of Wisconsin

Dmitrii Maslov

University of Florida

APS March Meeting, March 4, 2003

Fermi Liquid

- Self-energy $\Sigma'' \propto (\omega^2 + (\pi T)^2)$

- Resistivity $\rho(T) \propto T^2$

- Uniform susceptibility $\chi(T) = \text{const}$

- Specific heat $C(T) \propto T$

Corrections to the Fermi liquid behavior

Three dimensions

Specific heat

$$\delta C(T) \propto T^3 \log T$$

Uniform susceptibility

$$\delta \chi(T) \propto T^2$$

$$\delta \chi(Q) \propto Q^2 \log Q$$

Carneiro, Pethick

Belitz, Kirkpatrick, Vojta

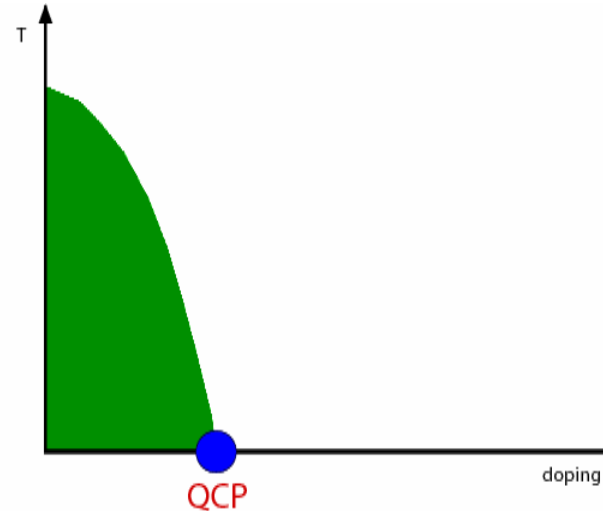
Quantum criticality

- Hertz-Millis-Morya theory
“integrate out fermions”

$$S = \int dQ d\omega [Q^2 + \zeta^{-2} + |\omega|^{2/z}] \eta^2 + b \eta^4 + \dots$$

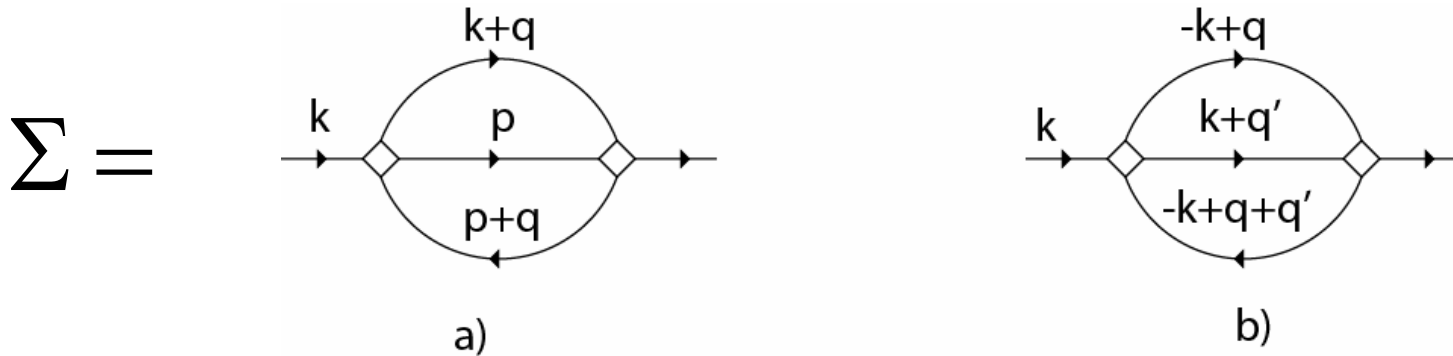
critical dimension $d_{cr} = 4-z$

always assumed

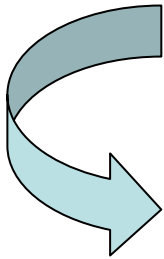


If Q expansion is nonanalytic, the critical theory is different

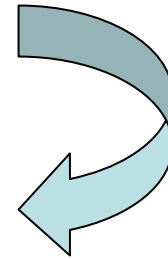
Fermi liquid corrections in 2D



$$\Sigma'' \propto \omega^2 \log \omega, \quad \Sigma' \propto \omega^2 f\left(\frac{\omega}{T}\right)$$



Effective mass



Specific heat

$$m^*(T) = m^*(T=0) \left(1 - 2 \left(\frac{mU}{4\pi} \right)^2 \frac{T}{E_F} \right)$$

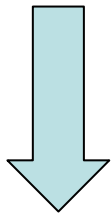
$$\delta C(T) \propto T^2$$

Bedell, Coffey
Millis, Chitov

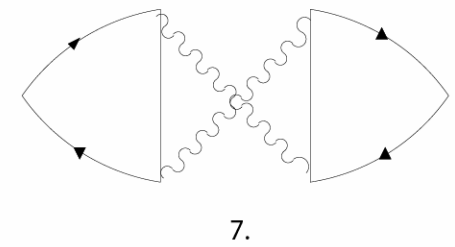
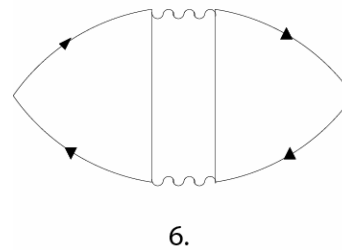
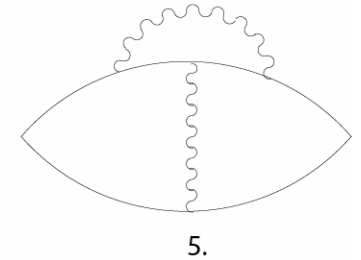
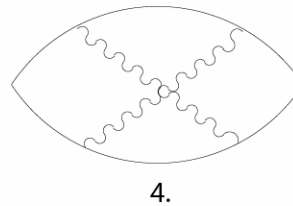
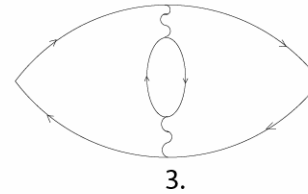
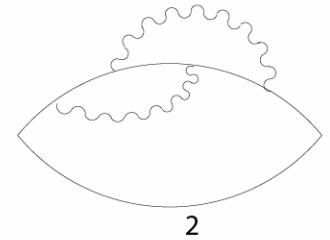
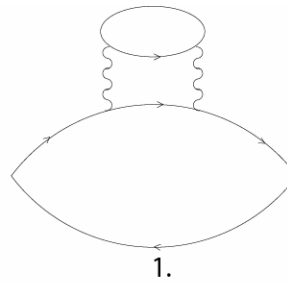
Uniform susceptibility

$$\delta \chi_{\text{spin}} (Q) = \frac{4m}{3\pi^2} \left(\frac{m U}{4\pi} \right)^2 \frac{|Q|}{p_F}$$

$$\delta \chi_{\text{spin}} (T) = \frac{2m}{\pi} \left(\frac{m U}{4\pi} \right)^2 \frac{T}{E_F}$$



linearity in T and in Q



Spicy stuff

- Singular corrections come from the singularities in the dynamical bosonic response functions of a Fermi liquid

$$\chi(q, \omega) = \frac{m}{\pi} \left(1 - \frac{\omega}{\sqrt{\omega^2 - (v_F q)^2}} \right)$$

- For $U = U(q)$, only $U(0)$ and $U(2p_F)$ contribute
- Singular corrections can be equally viewed as coming from $q=0$ or $q=2p_F$ singularities in the particle-hole channel, or $q=0$ singularity in the particle-particle channel

$$\delta\chi \propto U_{2p_F}^2, \quad \delta C(T) \propto (U_{2p_F}^2 + U_0^2 - U_{2p_F} U_0)$$

Conclusions

- Leading corrections to a Fermi liquid are singular and universal

$$\delta C(T) \propto T^2$$

$$\delta \chi_{\text{spin}}(Q) \propto |Q|$$

$$\delta \chi_{\text{spin}}(T) \propto T$$

- Corrections are caused by the Fermi liquid singularities in the response functions