Quantum Correction to Conductivity Close to Ferromagnetic Quantum Critical Point in 2d

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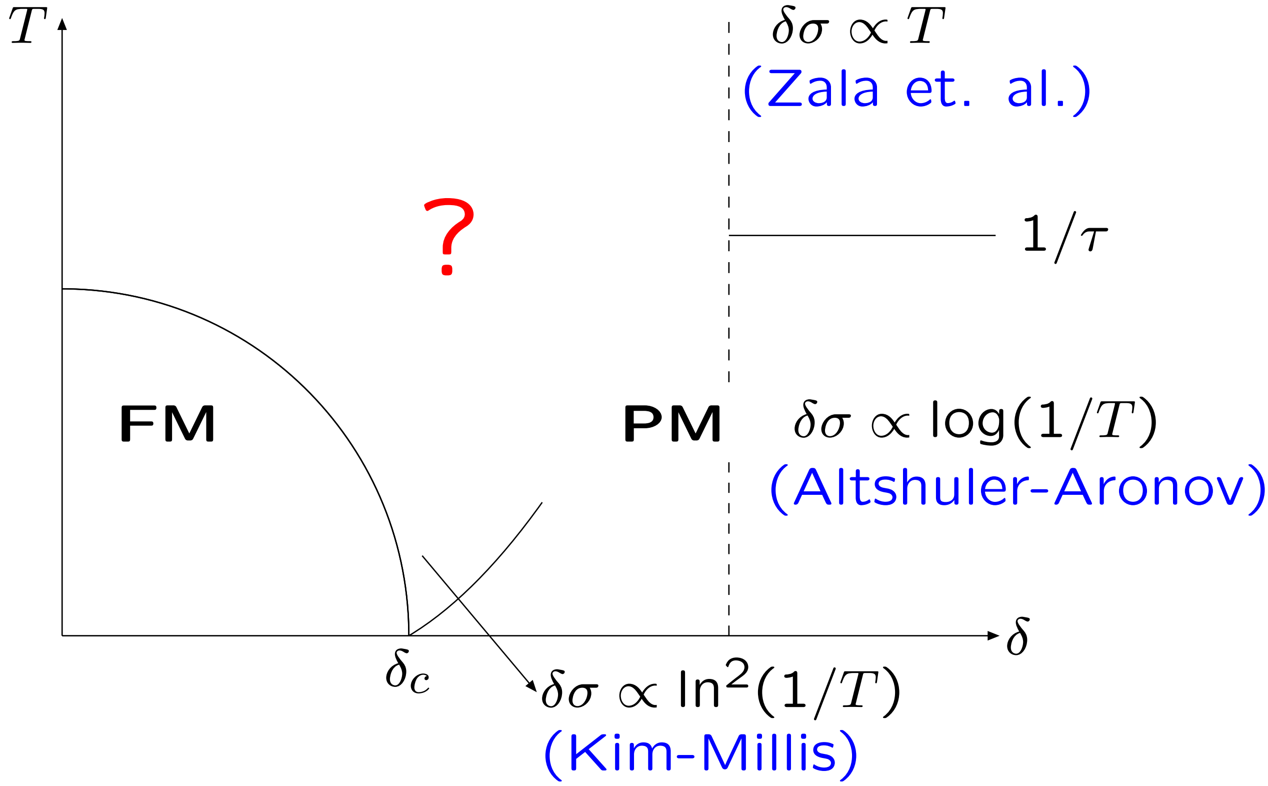
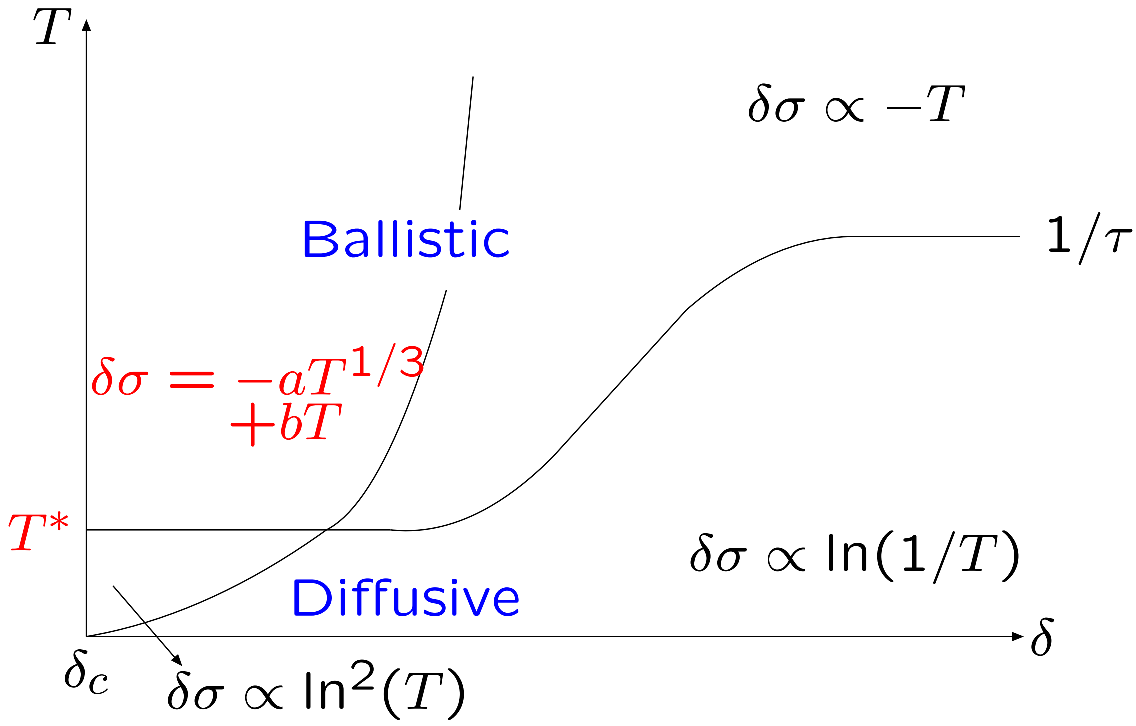
Effect of quantum interference on conductivity



- What is the influence of FM QCP on quantum interference processes?

- which is more important:
  elastic or inelastic scattering?

Main Results



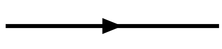
1. near QCP ballistic-diffusive cross-over at
   $T^* \ll 1/\tau$.
   $T^* \approx 1/((E_F\tau)^2\tau)$

2. near QCP, ballistic regime:
   $\delta\sigma = \sigma(T) - \sigma(T=0) = -aT^{1/3}$.

Spin-Fermion Model

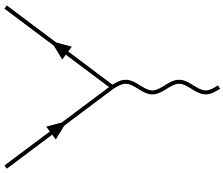
$$
\begin{aligned}
S &= \frac{1}{\beta}\sum_{\omega_n}\int d^2r\,\psi_\alpha^\dagger(\mathbf{r},\omega_\mathbf{n})\left(\mathbf{i}\omega_\mathbf{n}+\frac{\nabla^2}{2m}+\mu\right)\psi_\alpha(\mathbf{r},\omega_\mathbf{n})\\
&+ \frac{1}{\beta\chi_0}\sum_{\Omega_n,\mathbf{q}} D^{-1}(\mathbf{q},\mathbf{\Omega_n})\mathbf{S}(\mathbf{q},\mathbf{\Omega_n})\cdot\mathbf{S}(-\mathbf{q},-\mathbf{\Omega_n})\\
&+ \left(\frac{\alpha}{\chi_0\nu}\right)^{1/2}\int d^2r\int_0^\beta d\tau\,\psi_\alpha^\dagger(\mathbf{r},\tau)\psi_\beta(\mathbf{r},\tau)\left[\mathbf{S}(\mathbf{r},\tau)\cdot\sigma_{\alpha\beta}\right]\\
&+ \int_0^\beta d\tau\int d^2r\,\psi_\alpha^\dagger(\mathbf{r},\tau)\mathbf{V}(\mathbf{r})\psi_\alpha(\mathbf{r},\tau).
\end{aligned}
$$

Spin-Fermion Model

 $= \quad (\epsilon - \epsilon_{\mathbf{k}} \pm i/(2\tau))^{-1}$

 $= \quad D(\mathbf{q}, \mathbf{\Omega})$

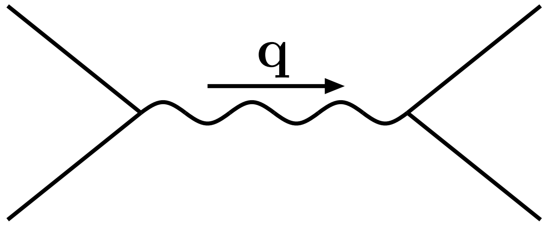
 $= \quad 1/(2\pi\nu\tau)$

 $= \quad \sqrt{\alpha}$

$$D(\mathbf{q}, \mathbf{\Omega_n}) = \left[\delta + \left(\frac{q}{p_F}\right)^{\mathbf{2}} + \frac{\gamma|\Omega_n|}{v_F q}\right]^{-\mathbf{1}} \quad \text{(ballistic)}$$

- α, γ, $1/(E_F\tau)$ are phenomenological parameters.
- theory is controlled for $\gamma \gg \alpha$.

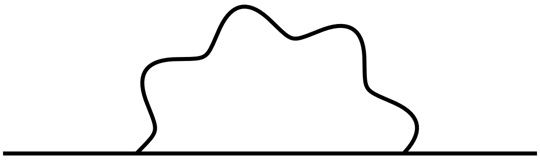
Ballistic-Diffusive Cross-over



- distance traveled by electrons during interaction $\Delta r \approx 1/q$.
- distance traveled between two impurity scattering $v_F \tau$.
- ballistic: $\Delta r \ll v_F \tau$
  single impurity scattering is important.
- in FL, $v_F q \sim T \Rightarrow$
  cross-over temperature is $1/\tau$.
- near QCP, $v_F q \sim (\gamma T)^{1/3} E_F^{2/3} \Rightarrow$
  cross-over is at $T^* = 1/(\gamma \tau^3 E_F^2)$.

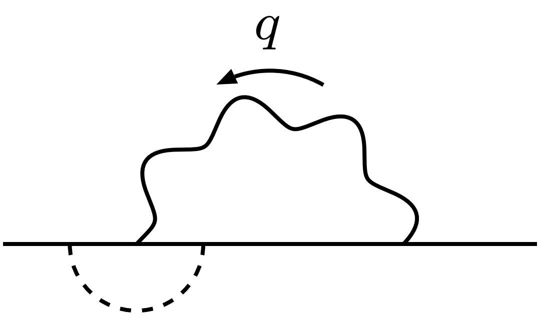
T-dependent Lifetime for Elastic Scattering

FL **QCP**



FL: $\frac{1}{\tau} \propto T^2$

QCP: $\frac{1}{\tau} \propto T^{2/3}$



FL

$$\frac{1}{\tau_{\text{el}}} \propto \left(\frac{1}{v_F q \tau}\right) T^2$$

$$q \propto T$$

$$\frac{1}{\tau_{\text{el}}} \propto T$$

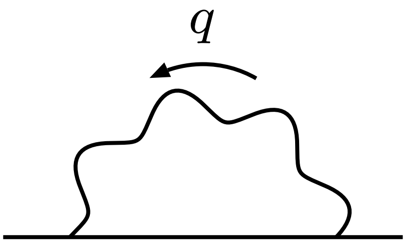
QCP

$$\frac{1}{\tau_{\text{el}}} \propto \left(\frac{1}{v_F q \tau}\right) T^{2/3}$$

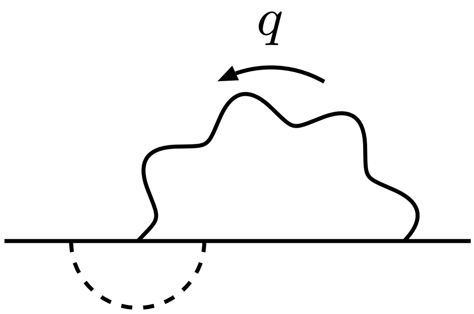
$$q \propto T^{1/3}$$

$$\frac{1}{\tau_{\text{el}}} \propto T^{1/3}$$

Comparing Elastic and Inelastic Lifetimes



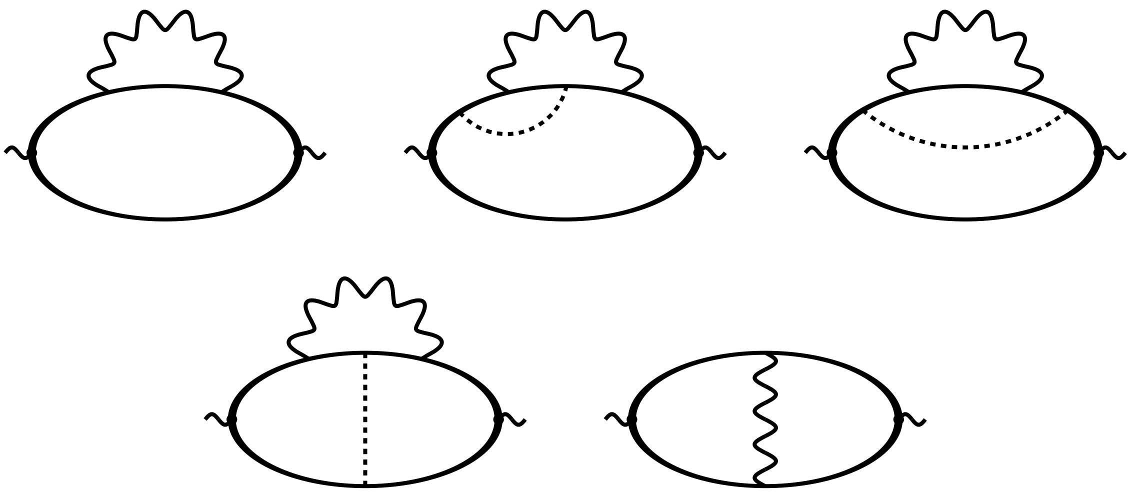
$$\frac{1}{\tau_{\text{in}}} = \underbrace{\underbrace{(1-\cos\theta)}_{(q/p_F)^2}\underbrace{\mathrm{Im}\Sigma_0}_{T^{2/3}}}_{T^{4/3}}$$



$$\frac{1}{\tau_{\text{el}}} = \underbrace{\left(\frac{1}{v_F q \tau}\right)\underbrace{\mathrm{Im}\Sigma_0}_{T^{2/3}}}_{T^{1/3}}$$

- Elastic scattering is important below the temperature $1/(\gamma\tau)$.
- In $Sr_3Ru_2O_7$ this temperature is very low.
- Increasing disorder will raise this temperature.

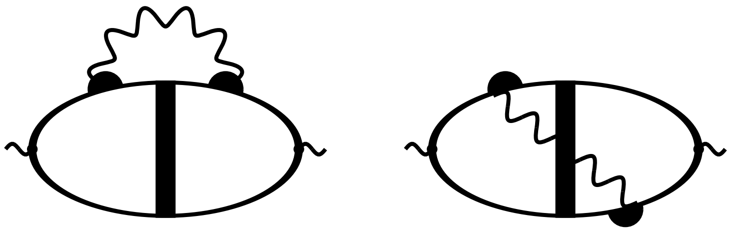
Ballistic Regime



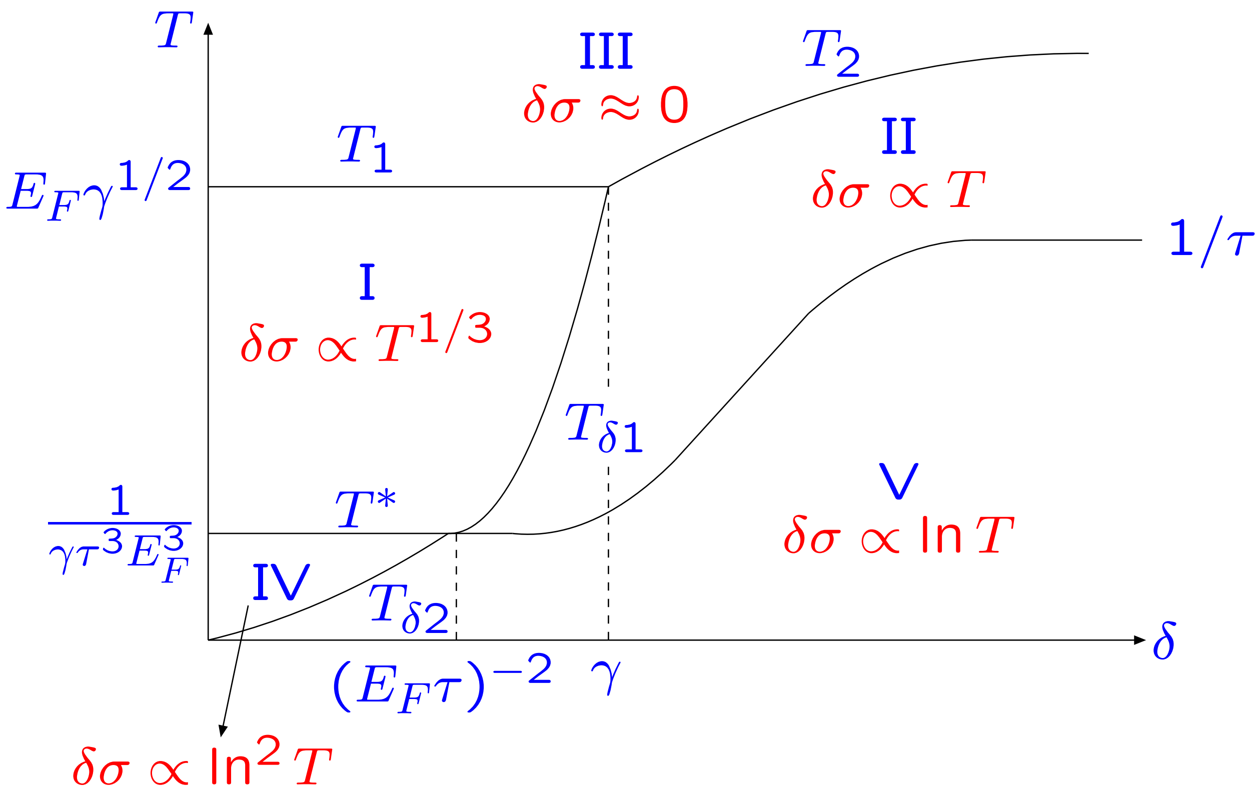
$$\delta\sigma = -(3\pi e^2 v_F^2 \tau\alpha)\int_{-\infty}^{\infty}\frac{d\Omega}{4\pi^2}\left[\frac{\partial}{\partial\Omega}\left(\Omega\coth\frac{\Omega}{2T}\right)\right]$$

$$\times \ \mathrm{Im}\int\frac{d^2q}{(2\pi)^2}D^A(\mathbf{q},\mathbf{\Omega})\mathbf{B}(\mathbf{q},\mathbf{\Omega}).$$

Diffusive Regime



Conclusion


T
T_1
$E_F\gamma^{1/2}$
III
$\delta\sigma \approx 0$
T_2
II
$\delta\sigma \propto T$
$1/\tau$
I
$\delta\sigma \propto T^{1/3}$
$T_{\delta 1}$
$\frac{1}{\gamma\tau^3 E_F^3}$
T^*
V
$\delta\sigma \propto \ln T$
IV
$T_{\delta 2}$
δ
$(E_F\tau)^{-2}$
γ
$\delta\sigma \propto \ln^2 T$