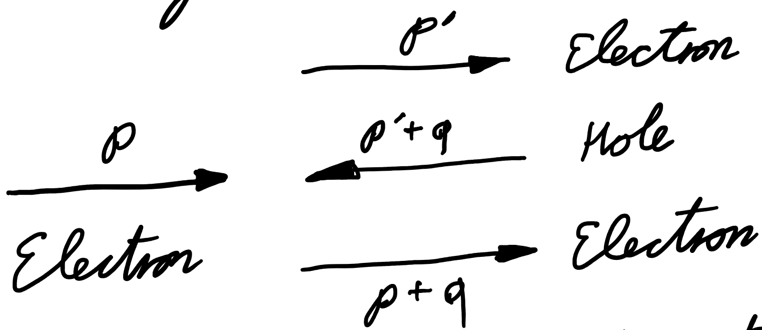
Electron-electron collisions

So far we considered only effectively single-particle processes. But there may be interactions thee as well!



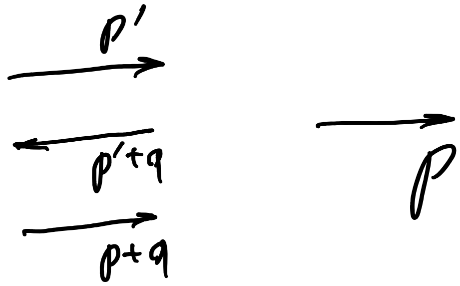
The rate of such transitions

$$\propto f_{p'+q}\,(1-f_{p'})\,(1-f_{p+q})$$

Exact contribution to the collision integral st f:

$$-2\pi \int_{p,q} |U_q|^2\, f_{p'+q}\,(1-f_{p'})(1-f_{p+q})\,\delta(\varepsilon_p+\varepsilon_{p'+q}-\varepsilon_{p'}-\varepsilon_{p+q})$$

$$+\,2\pi \int_{p,q} |U_q|^2\, f_{p'}\, f_{p+q}\,(1-f_{p'+q})\,\delta(\varepsilon_p+\varepsilon_{p'+q}-\varepsilon_{p'}-\varepsilon_{p+q})$$



Assume that quenched disorder is either absent or very weak = strongly correlated systems (high-T_c supercond, heavy fermions, etc.)

Quasiparticle scattering time for e-e interactions

$$\boxed{\frac{1}{\tau_T} = \frac{\pi^3 e}{16 v_F^2 v_F^{\frac{1}{2}} \hbar^3} T^2} \quad (3D)$$

Note: $k_B = 1$
Otherwise, $T \to k_B T$

Reminder: $v_F = \frac{p_F^2}{\pi^2 v_F \hbar^3}$

Inserting it into the formula,

$$\frac{1}{\tau_T} \sim \left(\frac{e^2}{v_F \hbar}\right)^{\frac{1}{2}} \frac{T}{v_F p_F} \frac{T}{\hbar}$$

Usually in a metal $\frac{e^2}{v_F \hbar} \sim 1$

// Actually $\alpha' = \frac{e^2}{\varkappa v_F \hbar}$ „Fine structure constant"

Then $$\frac{1}{\tau_T} \sim \frac{T^2}{\varepsilon_F} \frac{1}{\hbar}$$

– the leading-order combination which follows from dimensions

The number of quasiparticles with which a given quasiparticle may collide is $\propto T$

The number of states into which one may get scattered is also $\propto T$.

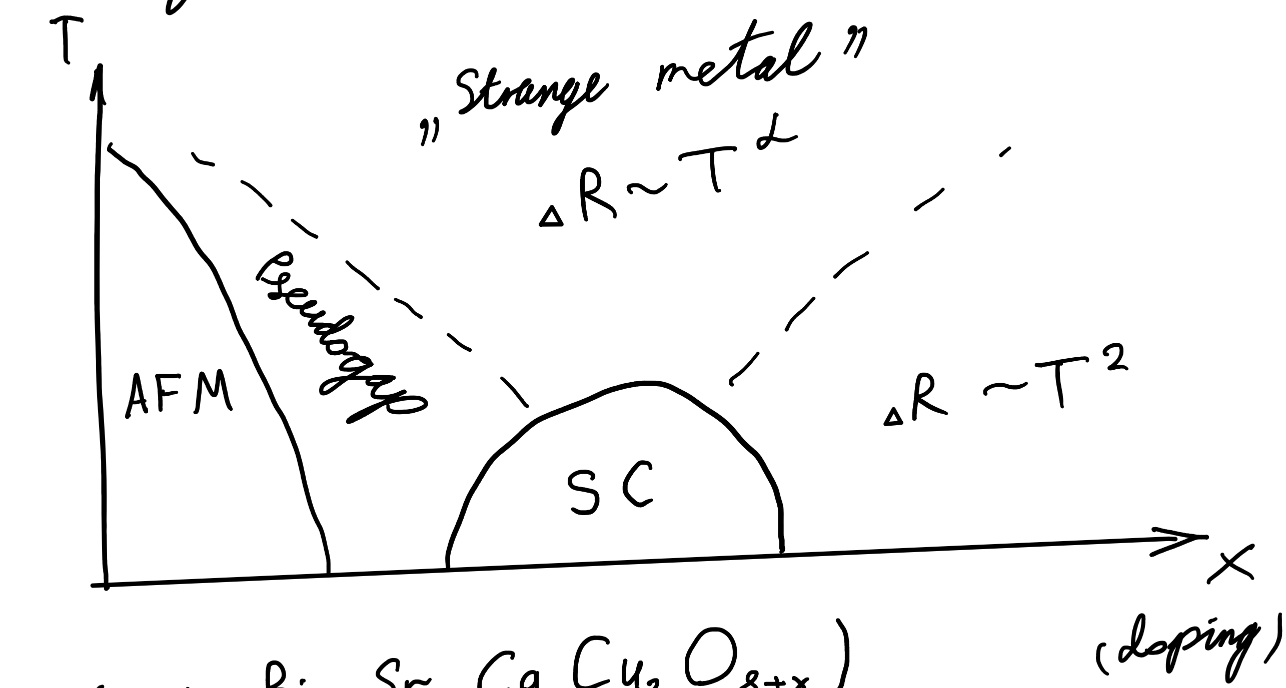
Therefore, $\frac{1}{\tau_T} \propto T^2$

This is often used to identify

This is often used to identify Fermi-liquids!!

In strongly-correlated systems, if there are contributions to resistance $\propto T^2$, then the respective phase is often referred to as Fermi-liquid!!

The typical phase diagram in a strongly cuprate superconductor



(e.g. $Bi_2 Sr_2 Ca Cu_2 O_{8+x}$)

$\Delta R \sim T^2$ applies to strongly correlated systems only!

systems only.

Note: in a system of free particles in the absence of the lattice or quenched disorder there is no resistance.

For particles with quadratic dispersion $\vec{J} = e\frac{\vec{p}}{m}$, and $\vec{p}$ is conserved; therefore $\vec{J}$ is conserved. Umklapp processes are nessesary!

$\vec{p}' \to \vec{p}' + \vec{K}$