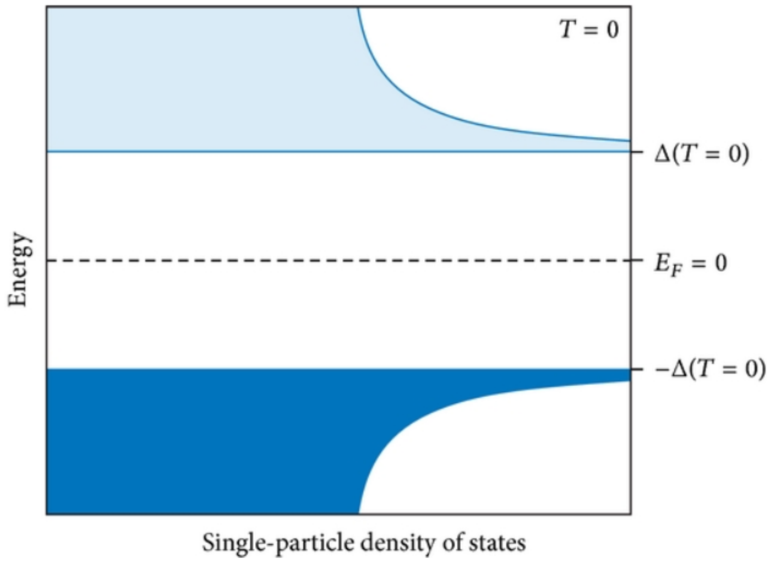
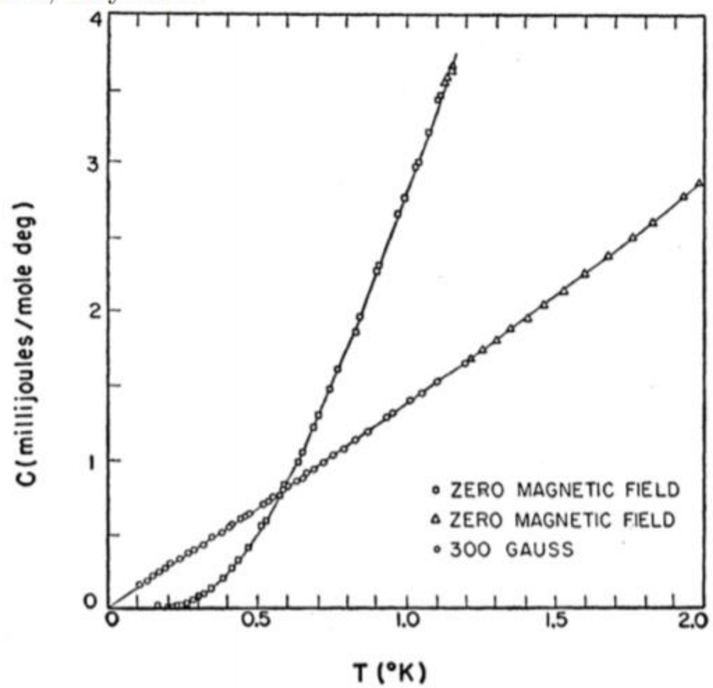
Correlated systems: superconductivity

BCS theory:



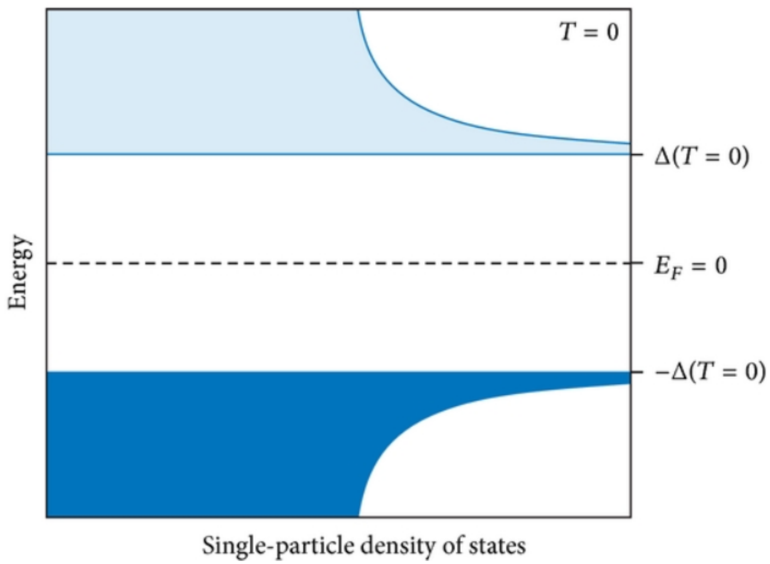
Norman E. Phillips. Heat Capacity of Aluminum between 0.1 K and 4.0 K. *Phys. Rev.*, 114(3):676–685, May 1959.

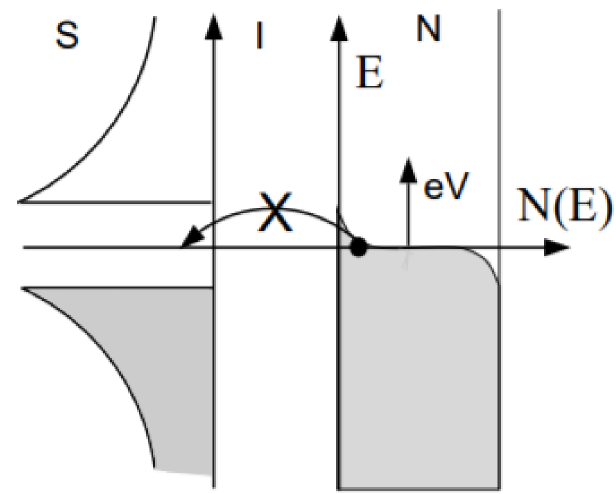


M. Dressel, Advances in Condensed Matter Physics 2013, 104379

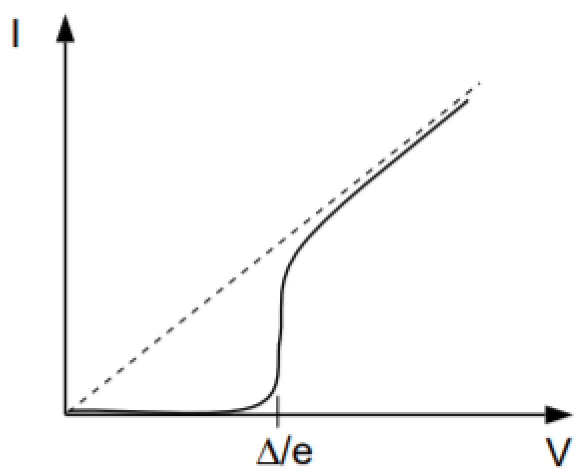
Superconductivity

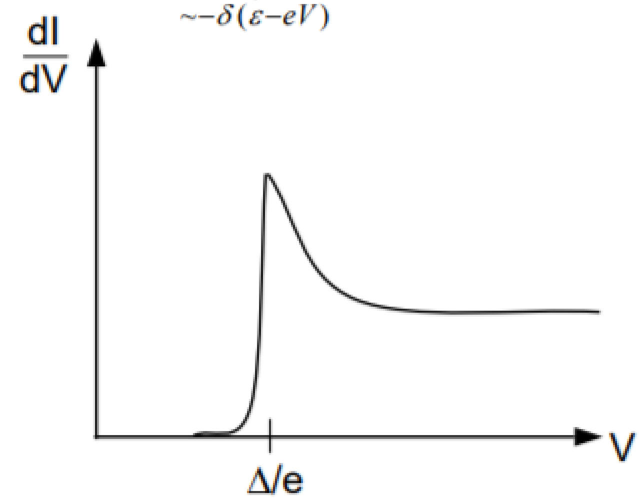
BCS theory:





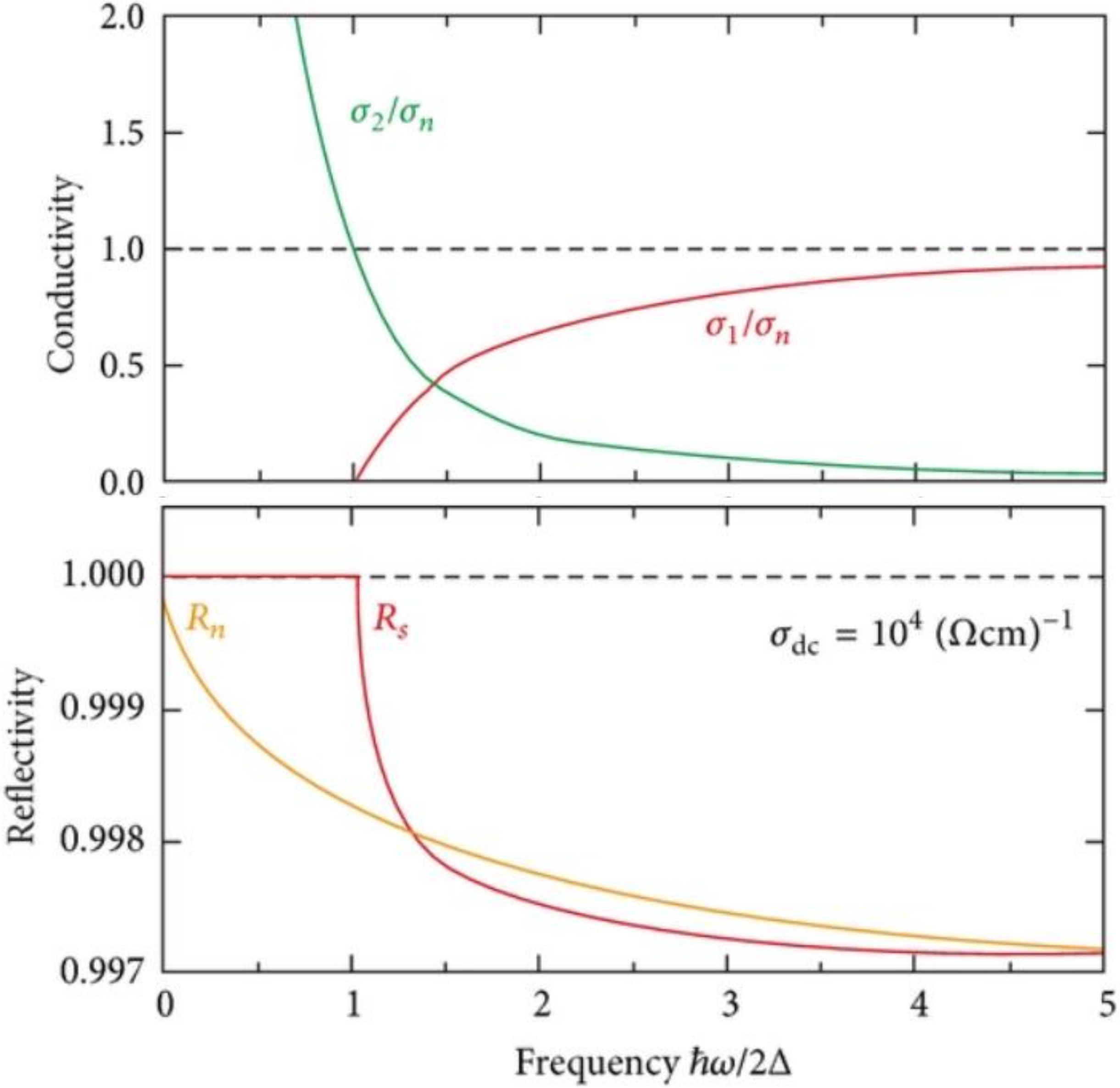
Alkalmazott szilárdtestfizika: $\frac{\mathrm{d}I}{\mathrm{d}V} \sim T \cdot g_{\mathrm{N}}(\varepsilon_{\mathrm{F}}) \int \mathrm{d}\varepsilon \, g_{\mathrm{S}}(\varepsilon) \underbrace{f_{\mathrm{N}}'(\varepsilon - eV)}_{\sim -\delta(\varepsilon - eV)} \sim T \cdot g_{\mathrm{N}}(\varepsilon_{\mathrm{F}}) g_{\mathrm{S}}(\varepsilon - eV)$



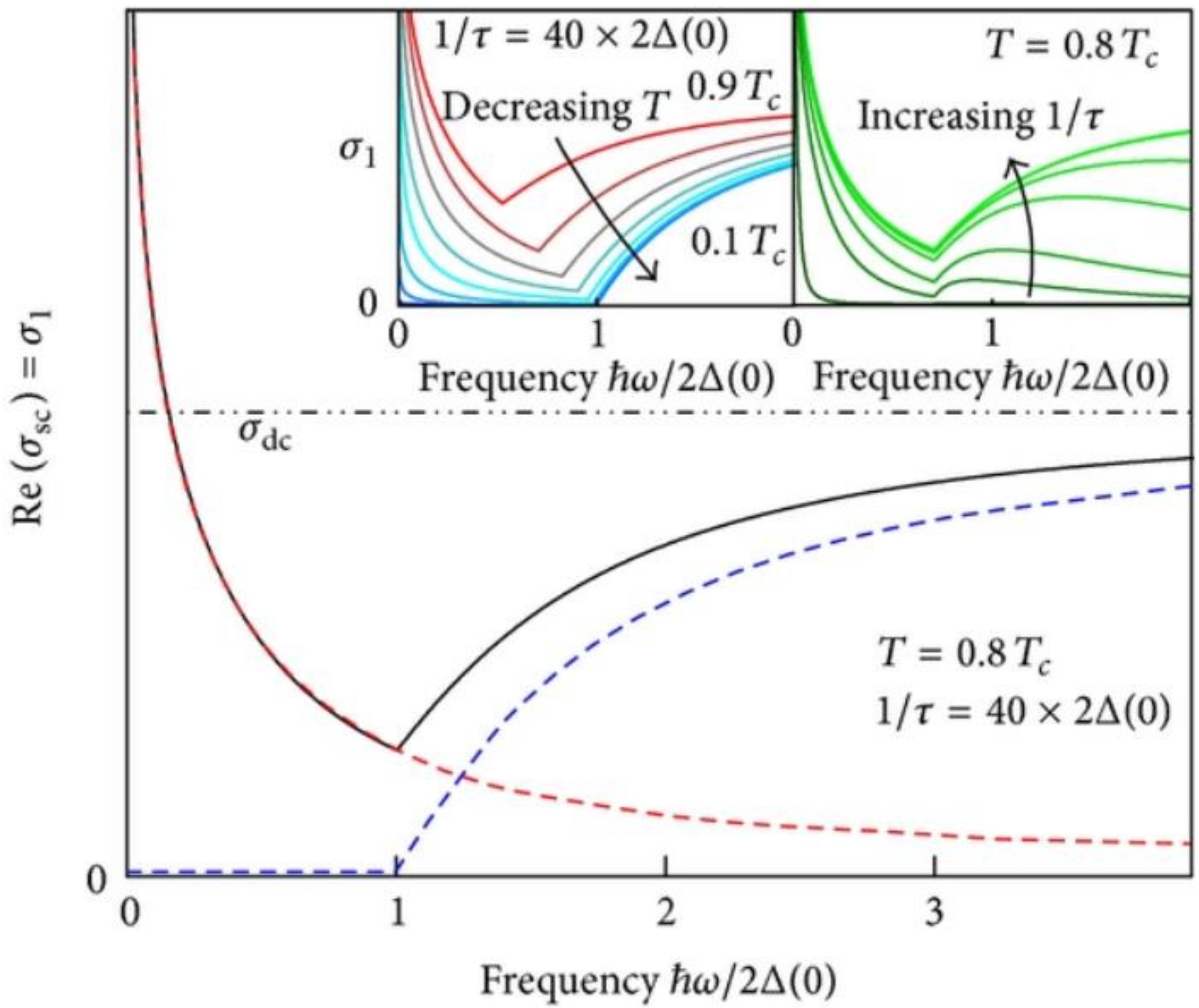


M. Dressel, Advances in Condensed Matter Physics 2013, 104379

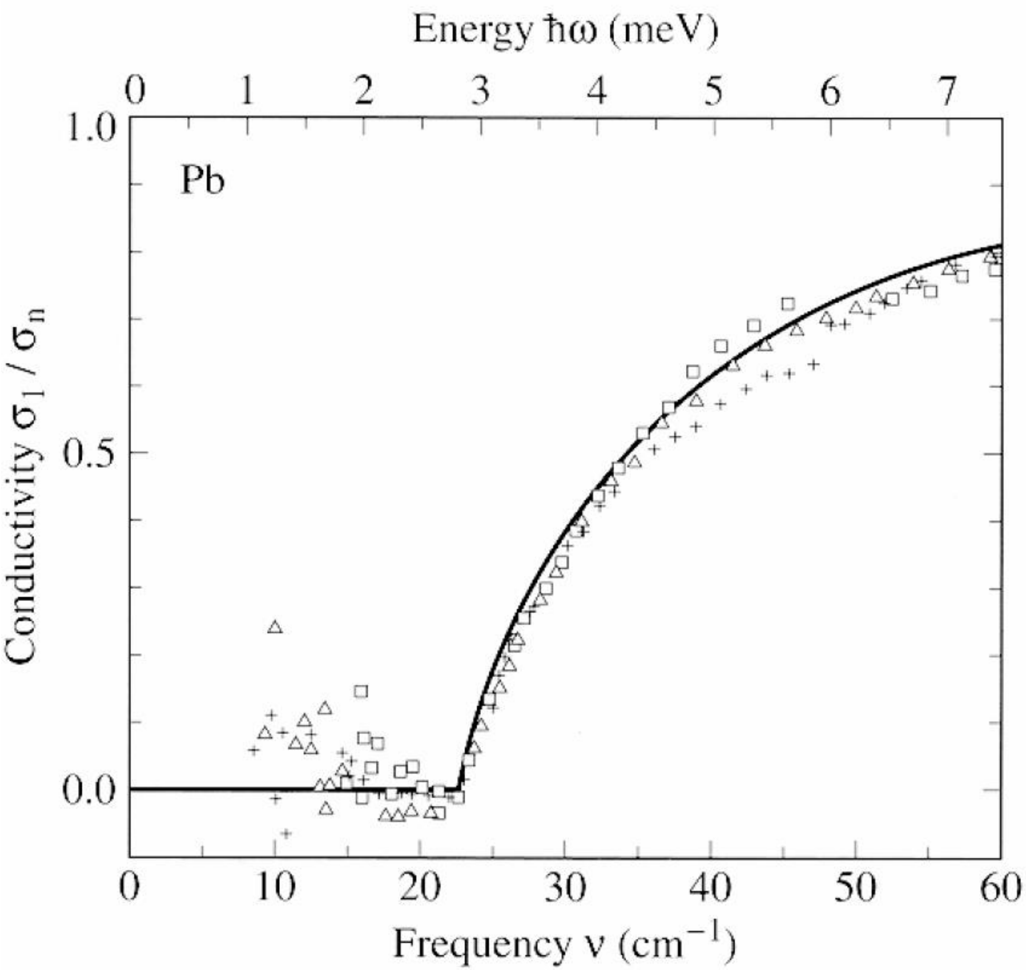
Matrix element: coherence effect



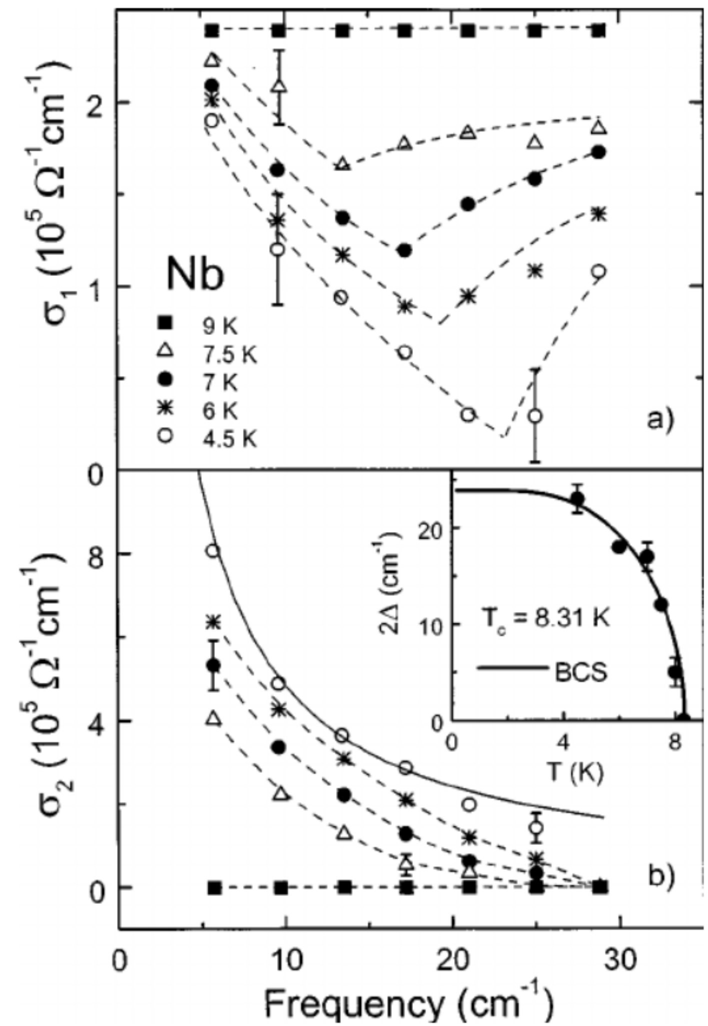
Mattis-Bardeen equation: $$\frac{\sigma_1(\omega,T)}{\sigma_n} = \frac{2}{\hbar\omega}\int_{\Delta}^{\infty}\frac{[f(\mathscr{E})-f(\mathscr{E}+\hbar\omega)]\left(\mathscr{E}^2+\Delta^2+\hbar\omega\mathscr{E}\right)}{(\mathscr{E}^2-\Delta^2)^{1/2}\left[(\mathscr{E}+\hbar\omega)^2-\Delta^2\right]^{1/2}}d\mathscr{E} + \frac{1}{\hbar\omega}\int_{\Delta-\hbar\omega}^{-\Delta}\frac{[1-2f(\mathscr{E}+\hbar\omega)]\left(\mathscr{E}^2+\Delta^2+\hbar\omega\mathscr{E}\right)}{(\mathscr{E}^2-\Delta^2)^{1/2}\left[(\mathscr{E}+\hbar\omega)^2-\Delta^2\right]^{1/2}}d\mathscr{E}$$



Pb at 2K
Phys. Rev. **165** 588 (1968).

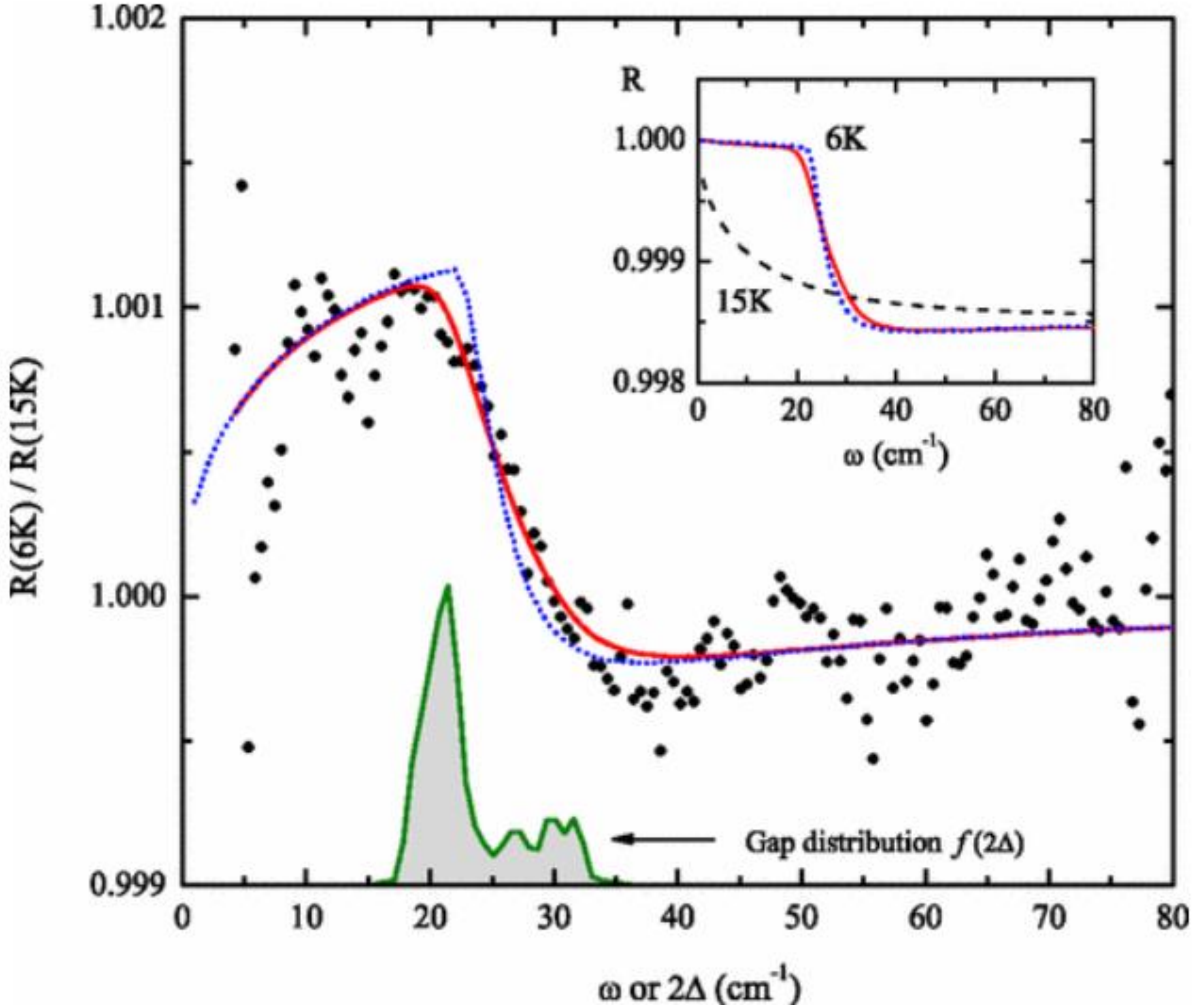


Nb
Phys. Rev. B **57** 14416 (1998).

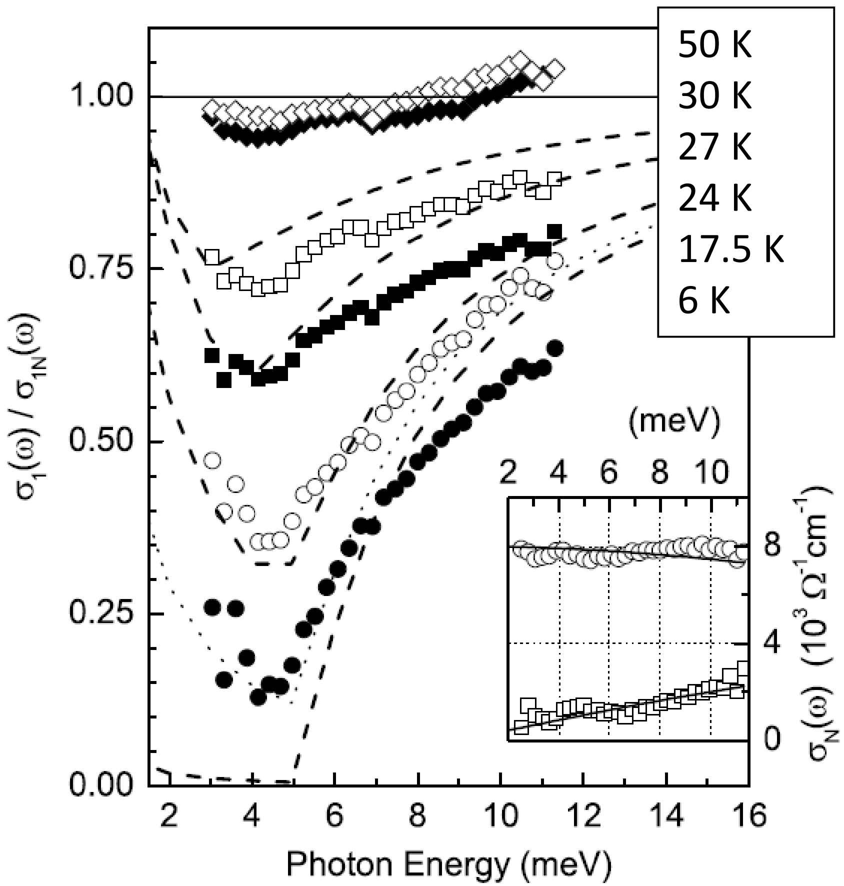


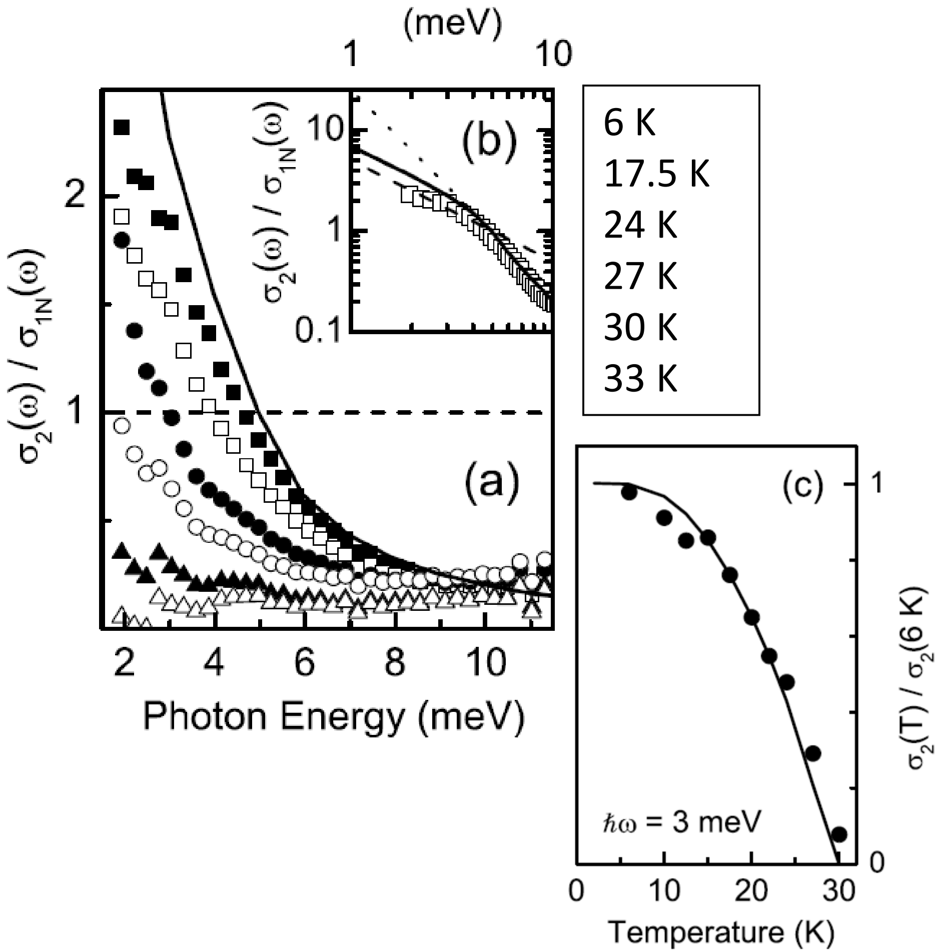
CaC6

Phys. Rev. B **78**, 041404(R) (2008).



MgB2





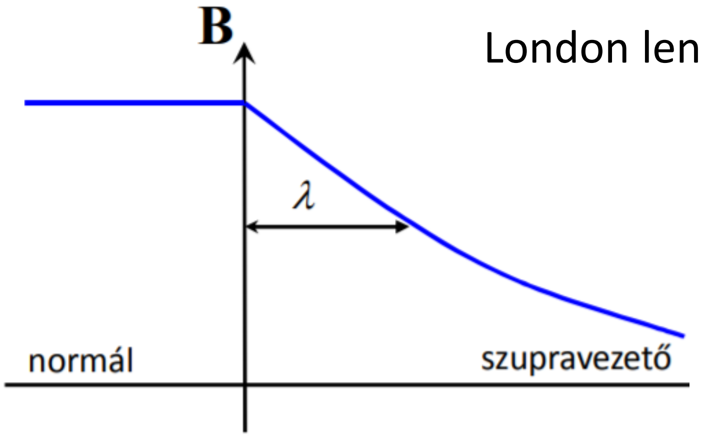
BCS fit: $2\Delta_o$=5 meV

Gyenge csatolás: $2\Delta_o = 3.5 k_B T_C$=9 meV

Gap alatt kvázirészecske gerjesztés

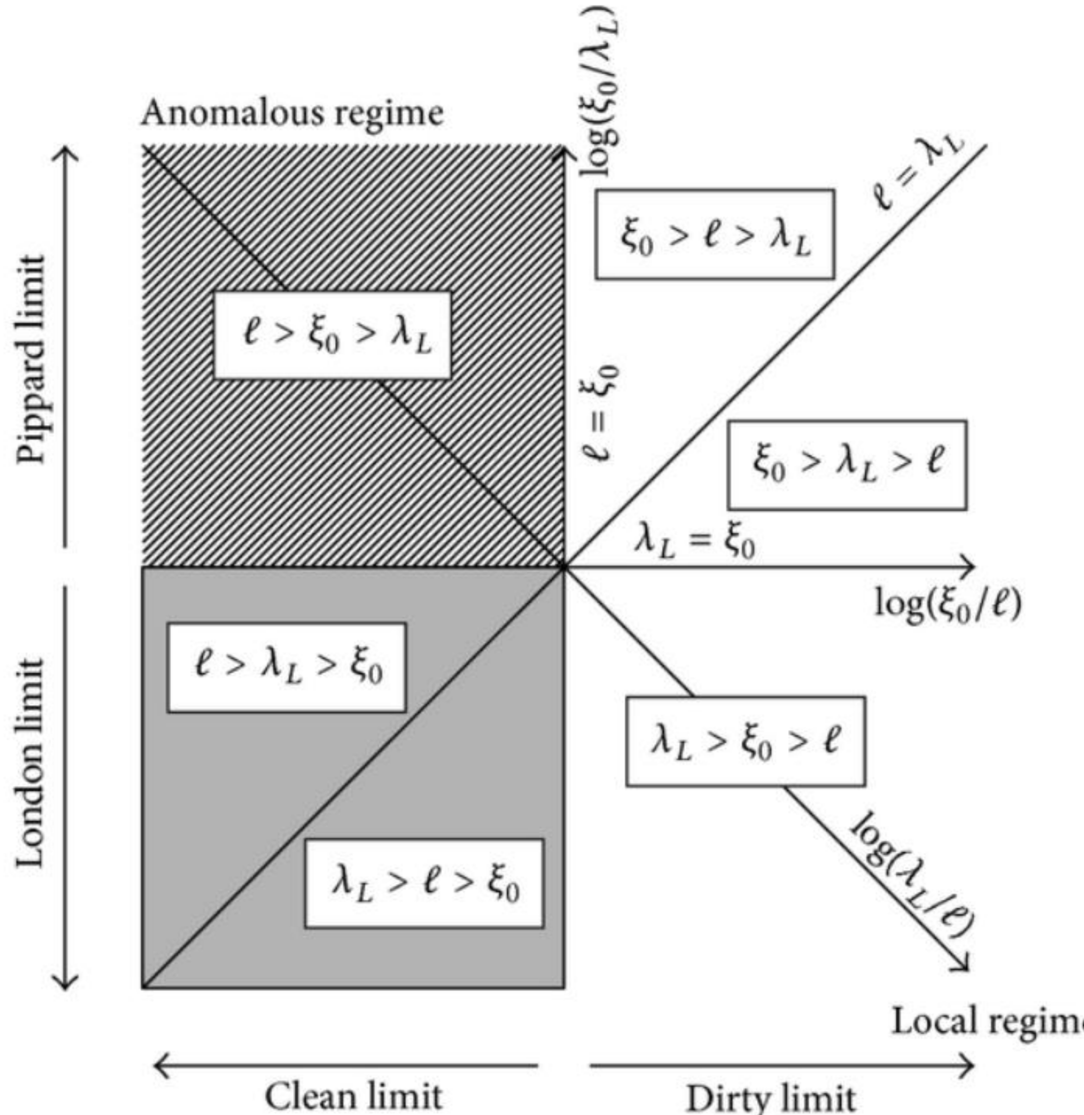
R. A. Kaindl et al., *Phys. Rev. Lett.* **88** 027003 (2002)

Meissner effect:

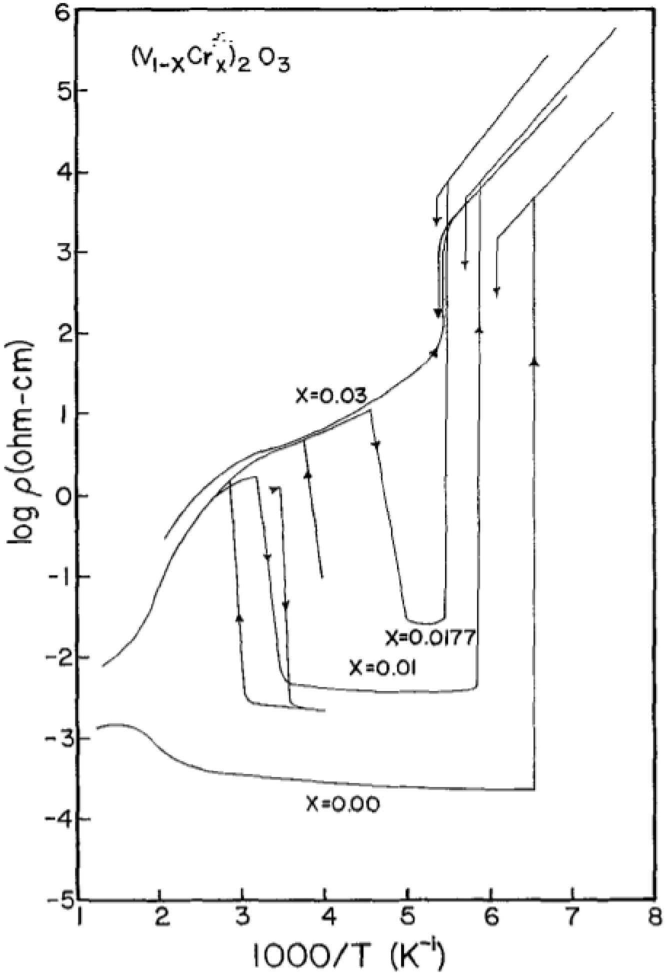


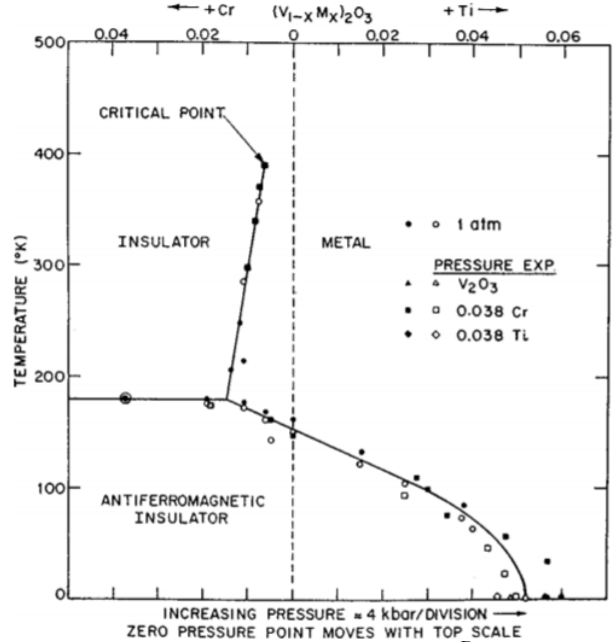
London length:

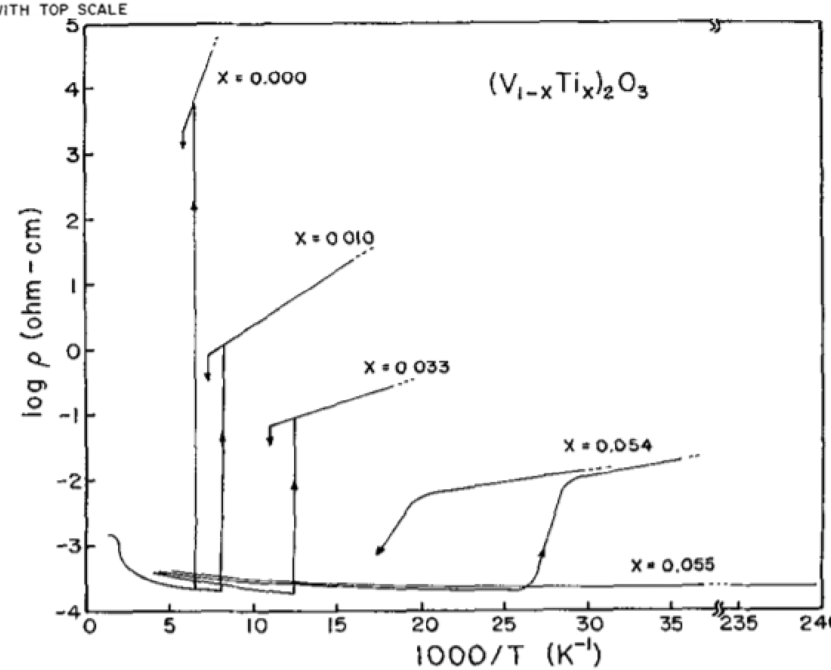
$$\lambda = \sqrt{\frac{m^*}{\mu_0 n_s e^{*2}}}$$



Electron-electron interaction: Mott insulators



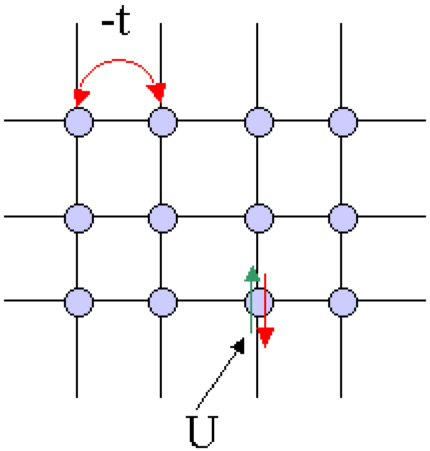




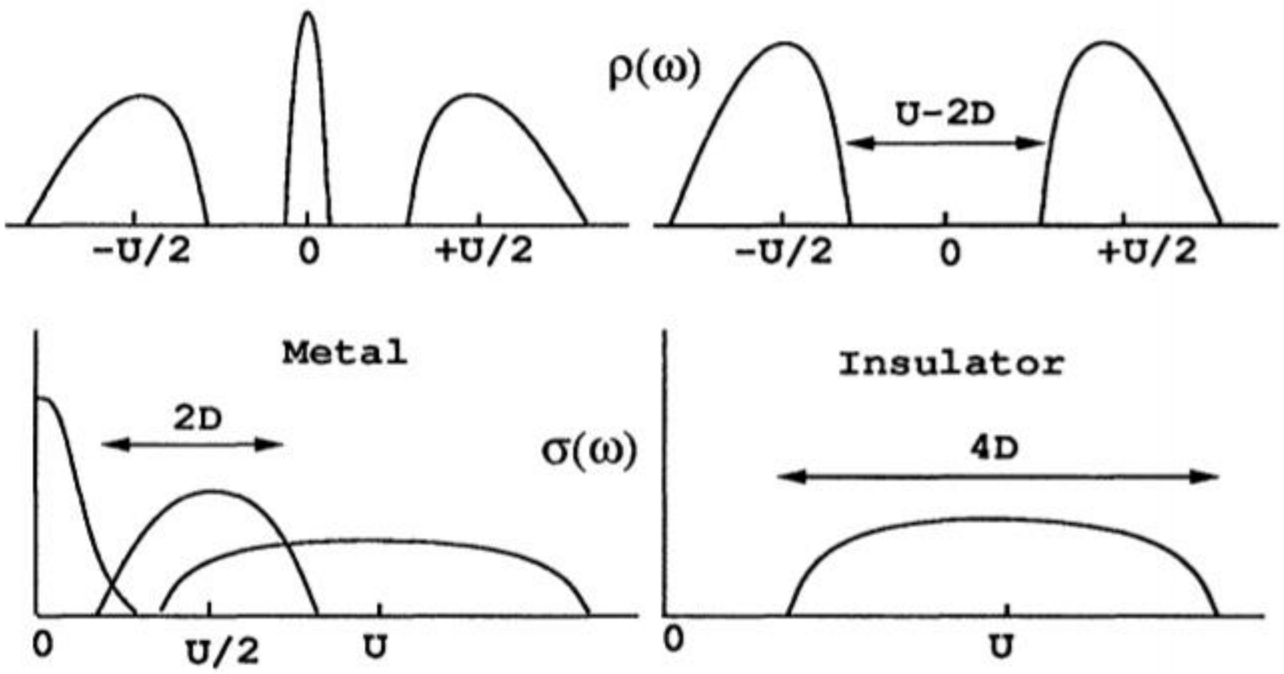
Electron-electron interaction: Mott insulators

Hubbard model:

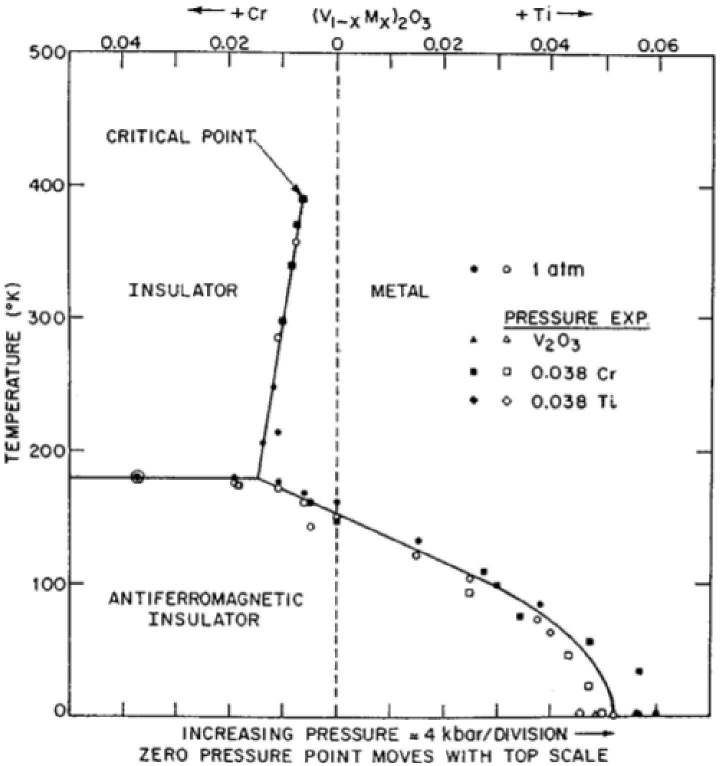
$$\mathcal{H} = \sum_{i,j} t_{i,j}(c^{+}_{i,\sigma}c_{j,\sigma} + c^{+}_{j,\sigma}c_{i,\sigma}) + U\sum_{i} n_{i,\sigma}n_{i,-\sigma}$$

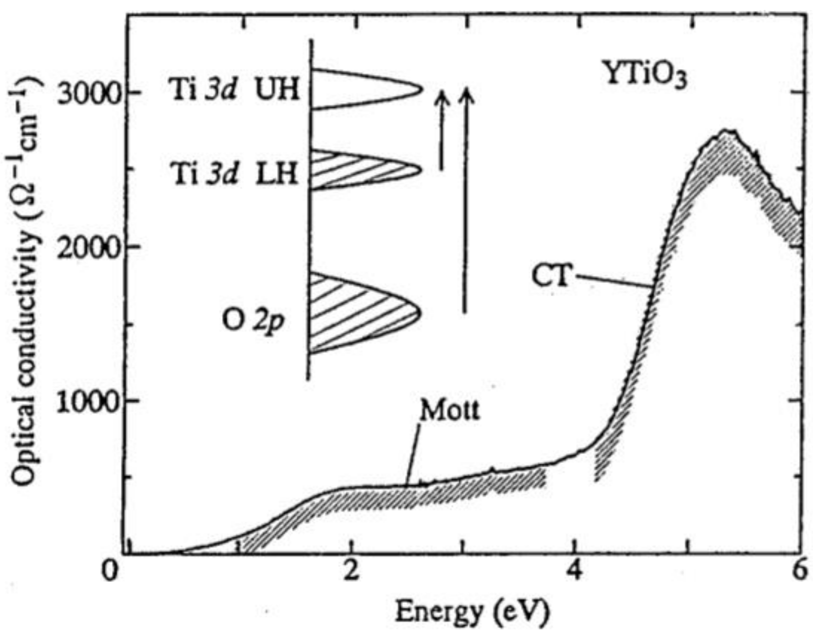


DMFT results:



Phys. Rev. Lett. **75**, 105 (1995).





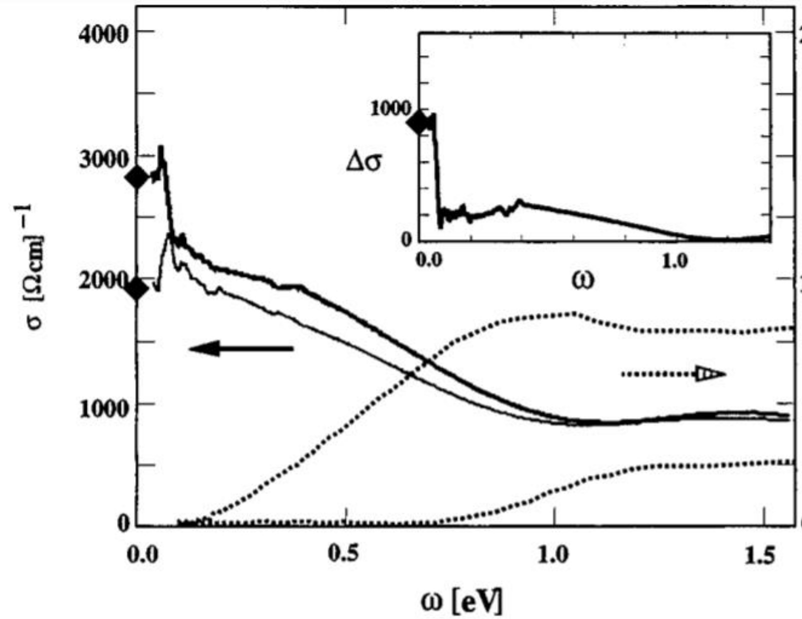
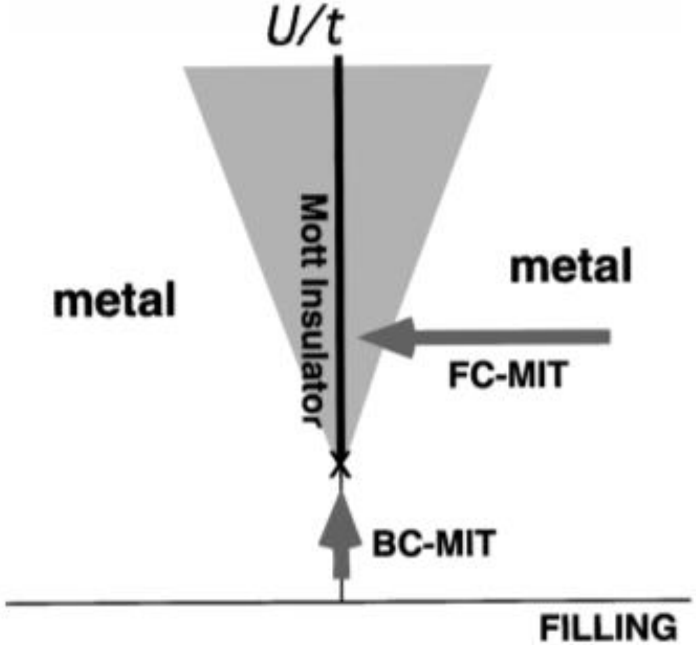
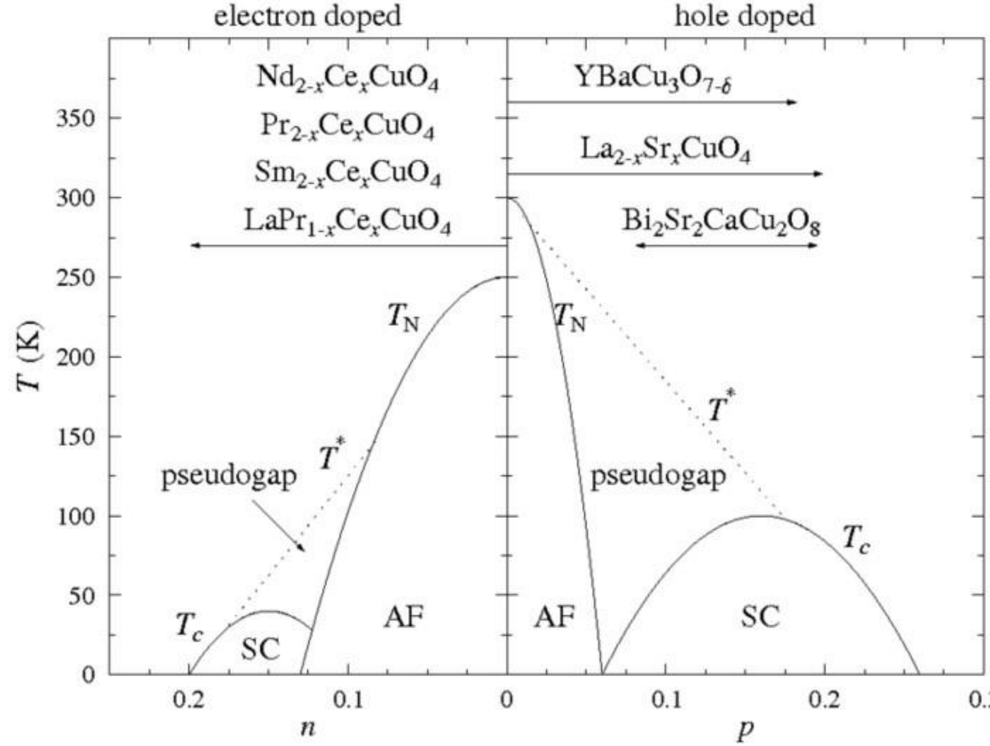
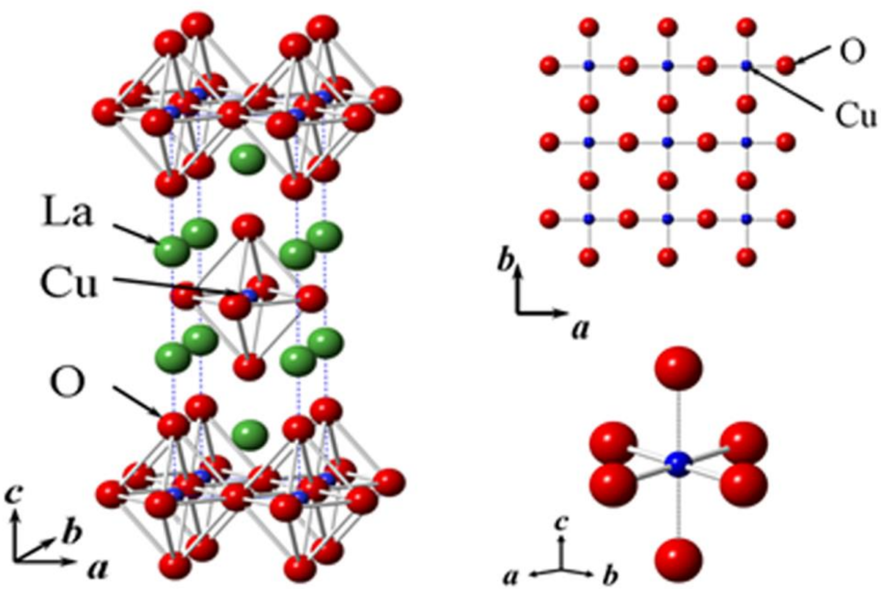
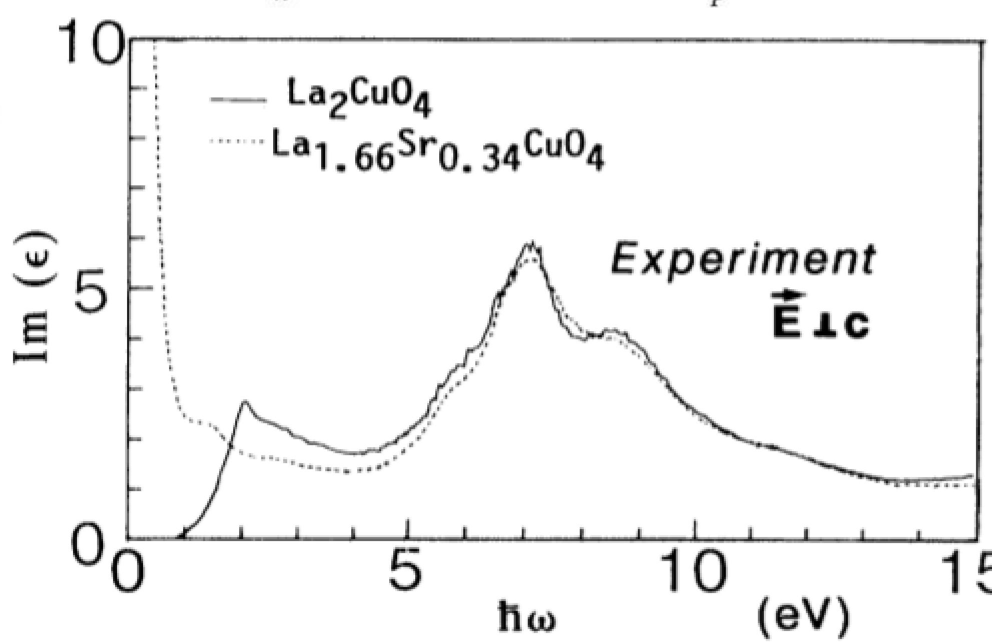


FIG. 75. Optical conductivity spectra of $V_{2-y}O_3$ in the metallic phase (full lines) at T=170 K (upper) and T=300 K (lower). The inset contains the difference of the two spectra $\Delta\sigma(\omega) = \sigma_{170\,K}(\omega) - \sigma_{300\,K}(\omega)$. Diamonds indicate the measured dc conductivity. Dotted lines indicate $\sigma(\omega)$ of insulating phase with y=0.013 at 10 K (upper) and y=0 at 70 K (lower). From Rozemberg *et al.*, 1995.

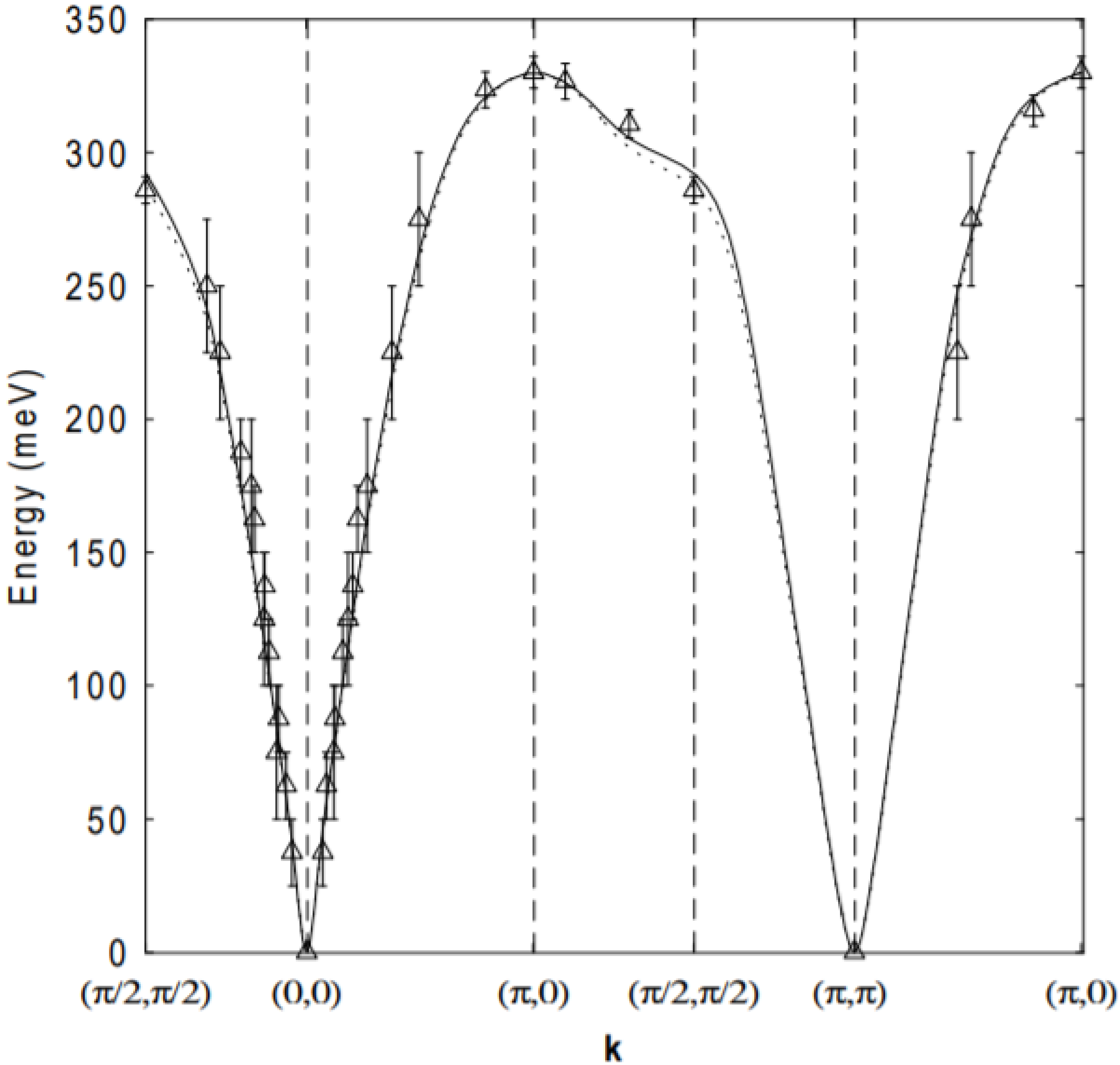

U/t
metal
Mott Insulator
metal
FC-MIT
BC-MIT
FILLING


electron doped
hole doped
$Nd_{2-x}Ce_xCuO_4$
$Pr_{2-x}Ce_xCuO_4$
$Sm_{2-x}Ce_xCuO_4$
$LaPr_{1-x}Ce_xCuO_4$
$YBaCu_3O_{7-\delta}$
$La_{2-x}Sr_xCuO_4$
$Bi_2Sr_2CaCu_2O_8$
T (K)
T_N
T_N
T^*
T^*
pseudogap
pseudogap
T_c
T_c
SC
SC
AF
AF
n
p

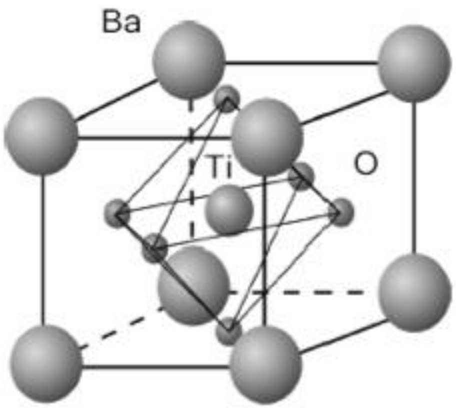

La
Cu
O
O
Cu
c
b
a
b
a
c
a
b

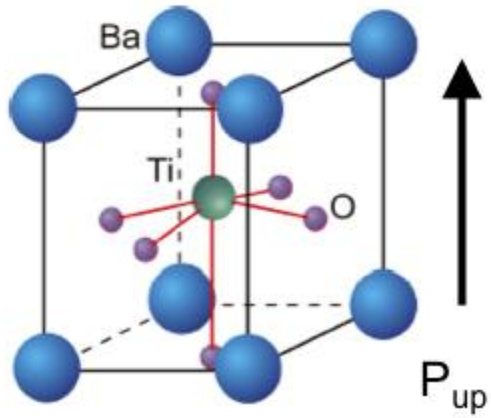

La_2CuO_4
$La_{1.66}Sr_{0.34}CuO_4$
Im (ε)
Experiment
$\vec{E} \perp c$
ħω
(eV)

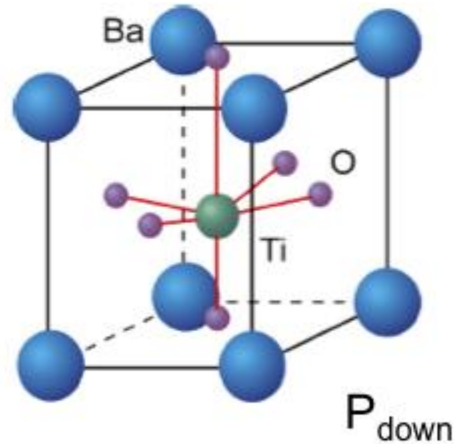
Spin-waves in La_2CuO_4:

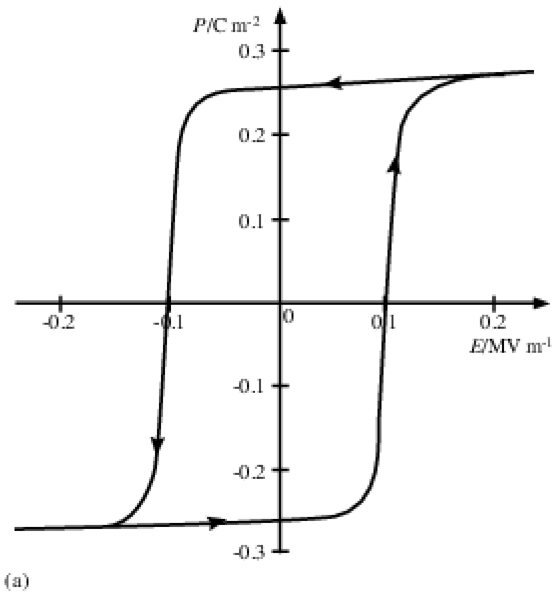


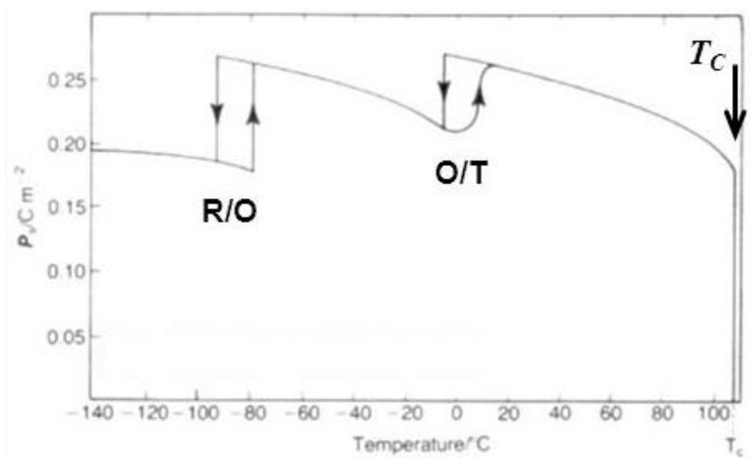
Ferroelectrics

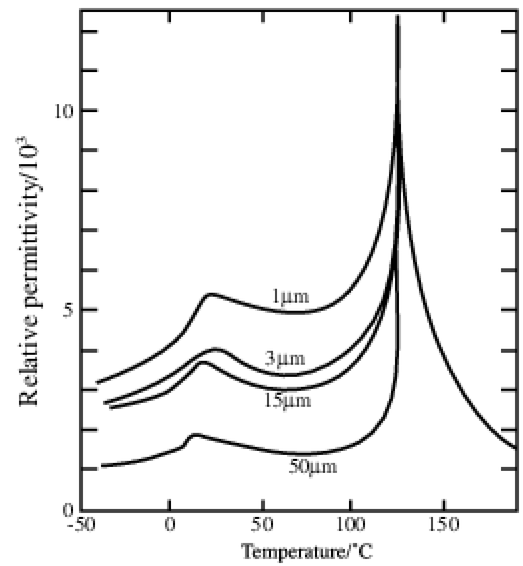








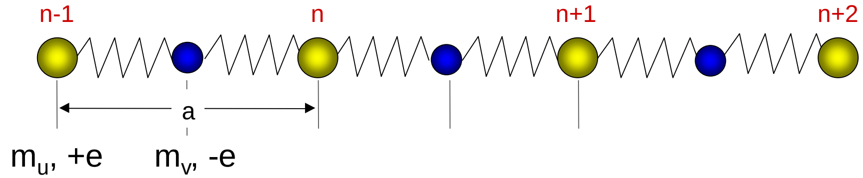




Vibrational spectroscopy

$$m_u \frac{d^2 u_n}{dt^2} = D(v_n + v_{n-1} - 2u_n) - \gamma m_u \frac{du_n}{dt} + eE(t)$$

$$m_v \frac{d^2 v_n}{dt^2} = D(u_n + u_{n-1} - 2v_n) - \gamma m_v \frac{dv_n}{dt} - eE(t)$$



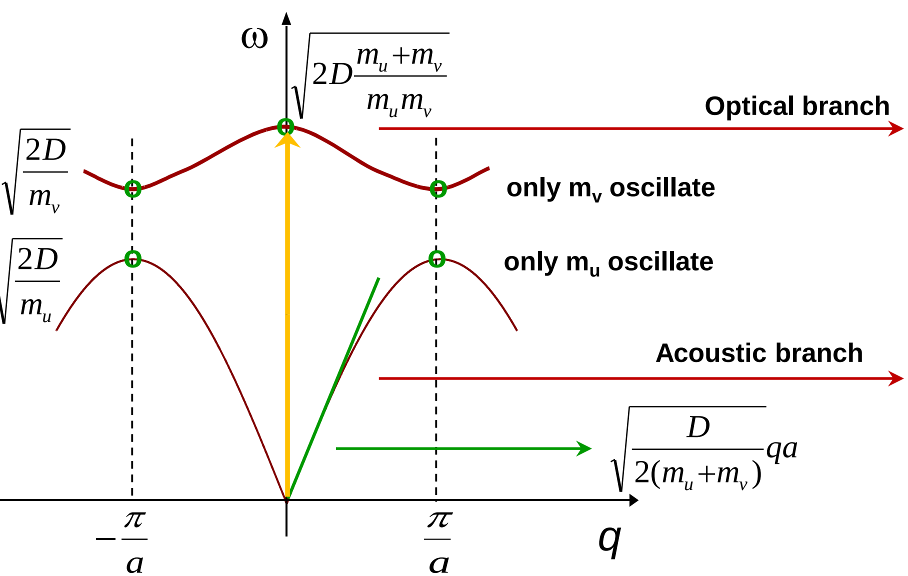
$$\lambda >> a \Rightarrow q << \frac{\pi}{a} \Rightarrow \begin{cases} E(r,t) \approx E_\omega e^{i\omega t} \\ u_n(t) \approx u e^{-i\omega t} \\ v_n(t) \approx v e^{-i\omega t} \end{cases}$$

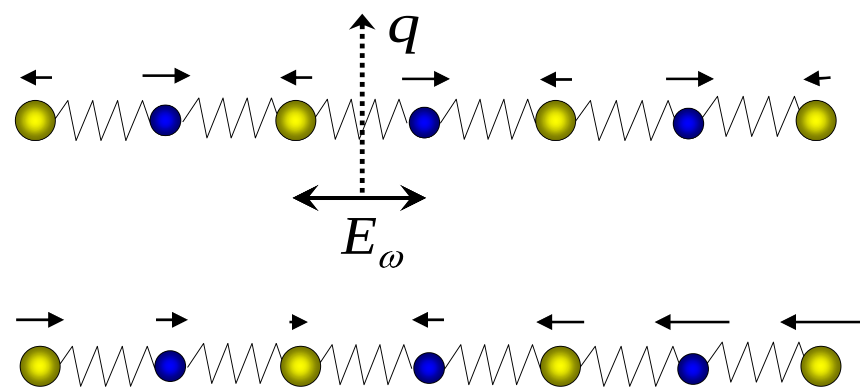
$$\omega_{TO} = \sqrt{2D \frac{m_u + m_v}{m_u m_v}}$$

$$P_\omega = en(u_\omega - v_\omega) = \frac{ne^2}{\mu} \frac{1}{\omega_{TO}^2 - \omega^2 - i\gamma\omega} E_\omega$$

$$\varepsilon(\omega) = 1 + \frac{\Omega_{pl}^2}{\omega_{TO}^2 - \omega^2 - i\gamma\omega}$$

The q=0 case is equivalent to a diatomic molecule, atoms move respect to the center of mass





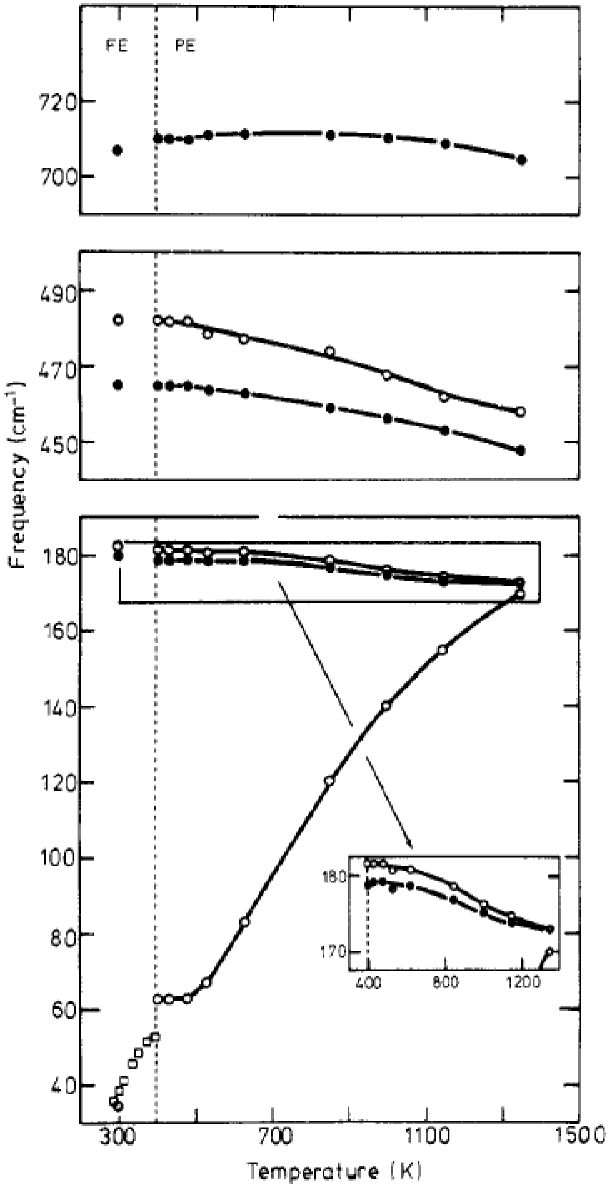


Figure 4. Frequencies of the E modes at room temperature and temperature dependence of the frequencies of F_{1u} modes in the cubic phase for $BaTiO_3$. ○, transverse modes; ●, longitudinal modes. Raman data (□) are taken from Scalabrin *et al* (1977).

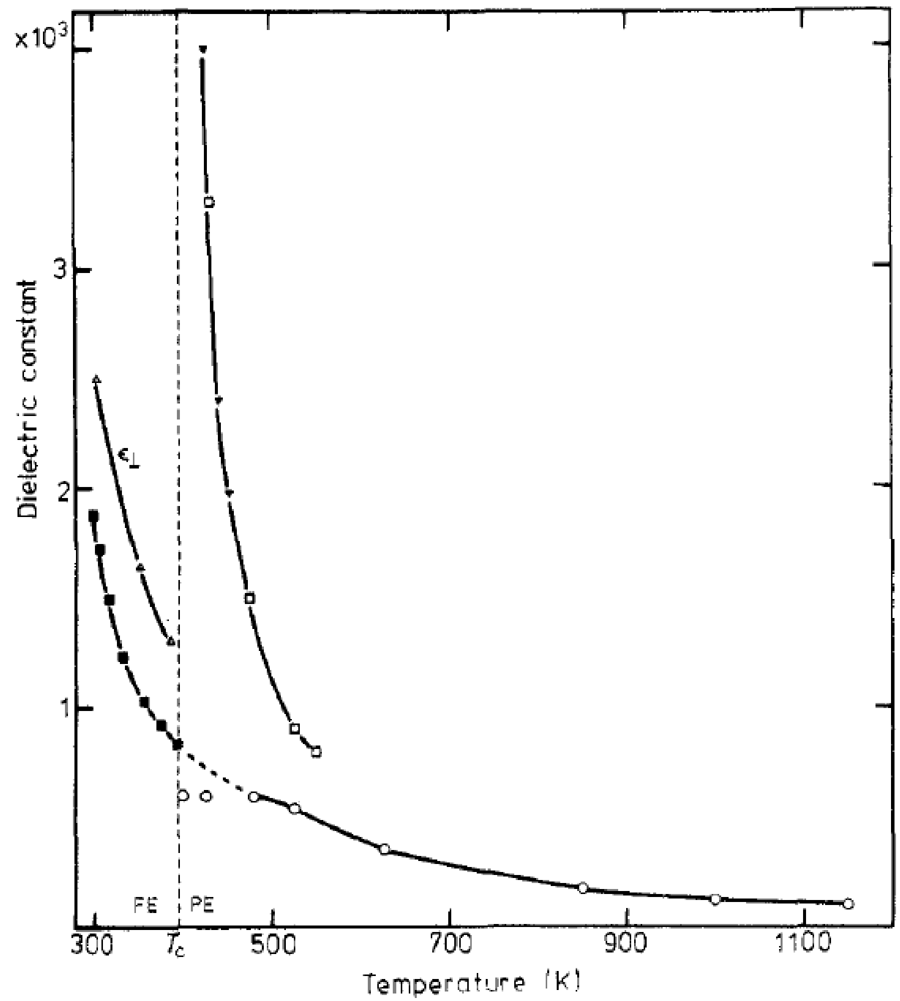
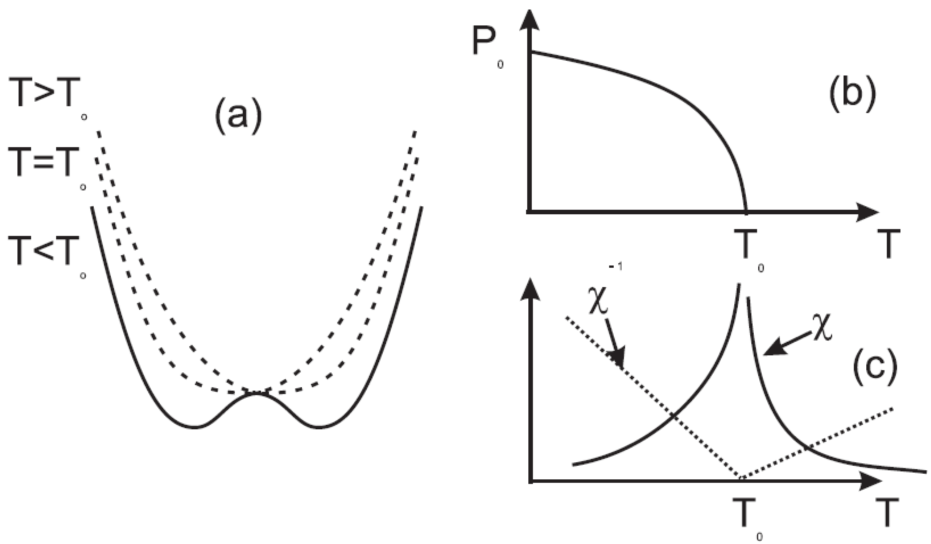
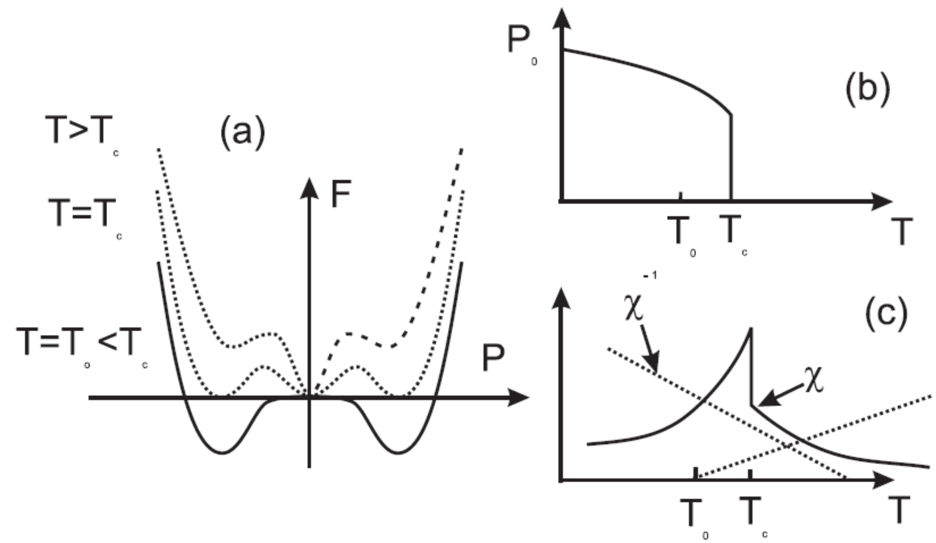


Figure 10. Temperature dependence of the dielectric constant of $BaTiO_3$: ○ present IR study; ■ Raman data of Scalabrin *et al* (1977); direct dielectric measurements ▼ (24 GHz), □ (37 GHz), △ (250 MHz) are those of Benedict and Durand (1958), Poplavko (1966) and Wemple *et al* (1968) respectively.

$$\mathcal{F}_P = \frac{1}{2}aP^2 + \frac{1}{4}bP^4 + \frac{1}{6}cP^6 + ... - EP$$





$$m\frac{\partial^2 u_{opt}}{\partial t^2} = -\frac{\partial \mathcal{F}}{\partial u_{opt}} \propto -a(T)u_{opt}$$

$$\omega(q=0)^2 \propto \frac{1}{\chi}$$