ELECTRICAL CONDUCTANCE OF QUANTUM PLASMAS

VARIOUS TECHNIQUES : Kinetical Equations

Projection Operator Techniques — ZWANZI

Modern Perturbation Theory — (BRUSSE

Correlation Function Methods

Linked Clusters — [ISIHARA, MC FUJITA, KOJIMA, M

Response Theory — KUBO - TOMI

$$0 = \frac{\partial W}{\partial t} + \frac{i}{\hbar}[H, W]$$

Non-Ideality

∞

LRT

(NLRT)

0

BBGKY - HIERARCHY

WAY OF UNIQUE EXPANSION OF

$$\frac{1}{i^2}\langle T(\psi_a \psi_b \psi_b^+ \psi_a^+)\rangle \cong$$

STEPWISE HIGHER-ORD. KIN. EQUS.

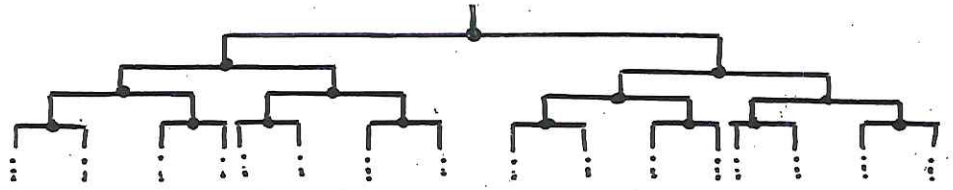
QT - BOLTZ- MANN - EQU.

$\langle \ldots \rangle_{\text{NON-EQUILIBRIUM}}$

$$= \sum_{i=1}^{j-1} G_i + G_c^j \qquad G_i \cong \mathcal{O}\left(\frac{V^{i-1}}{\omega^i}\right)$$

$$G = G_1 \left(1 - \frac{G_1^c}{G_1} \frac{1}{1 + G_1^c / G_1}\right)^{-1}$$

$$G_n^c G_n^{-1} = G_{n+1} G_n^{-1} \left(1 - G_{n+1}^c G_{n+1}^{-1} \left(1 + G_{n+1}^c / G_{n+1}\right)^{-1}\right)^{-1}$$



$$(2^N)$$

KUBO-YAMADA-ZUBAREV-PLAKIDA :

$$\sigma(k,\omega) = i\varepsilon(k,\omega) \sum_{ab} \frac{e_a e_b \hbar^2}{m_a k^2} \int \frac{d\vec{p}}{(2\pi)^3} \vec{k}\left(\vec{p} - \frac{\vec{k}}{2}\right) G_{ret}^{ab}(\vec{p},\vec{k},\omega)$$

$$\varepsilon(k,\omega) = 1 - \sum_{ab} V_{ab}(k) \int \frac{dp_1\, dp_2}{(2\pi)^6} \Pi_{ab}(p_1, p_2 - k, p_1 - k, p_2, \omega)$$

$$\overset{\text{H.T.C.}}{=} 1 + \mathcal{O}(n)$$

more general: $b_\nu = L(G_2^c; V^s; n, T)$

EXAMPLE : RÖPKE & HÖHNE 1981 : IDEAL APPROACH FOR M_ν :

(SIMILAR FRAMEWORK) σ ENHANCES

cf. H. MORI 1959

ZUAREV's statistical operator

$$W_{NEQ.} = Z_{NEQ}^{-1} \cdot \exp - \beta \left[H - \sum_a \mu_a N_a + \sum_\mu b_\mu \bar{M}_\mu \right]$$

$$\frac{d}{dt} \langle M_\mu \rangle_{NEQ.} = 0 \quad , \quad \vec{\nabla} \cdot \vec{j}_M + \frac{\partial M_\mu}{\partial t} = \sigma$$

GRAD-like expansion

LINEAR RESPONSE IN A NON-EQULIBRIUM STATE

[KUBO]

$$J_\nu = \sum_\mu b_\mu \langle j_\nu M_\mu \rangle_{GC} + \int_{-\infty}^{+\infty} \langle\langle j_\nu(t) ; H_F^{(1)}(t') \rangle\rangle_{GC} \, dt'$$

$b_\mu = O(\vec{E})$

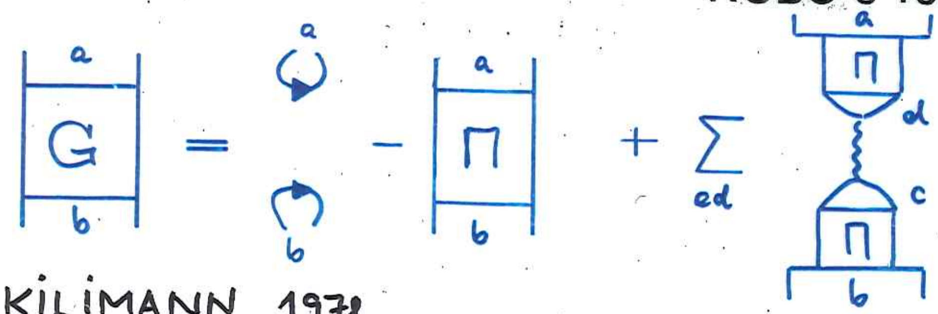
G^{ab}_{caus} , Π^{ab}

$\left(G^{ab}_{ret}(\omega) = G^{ab}_{caus}(\omega + i0) \right)$

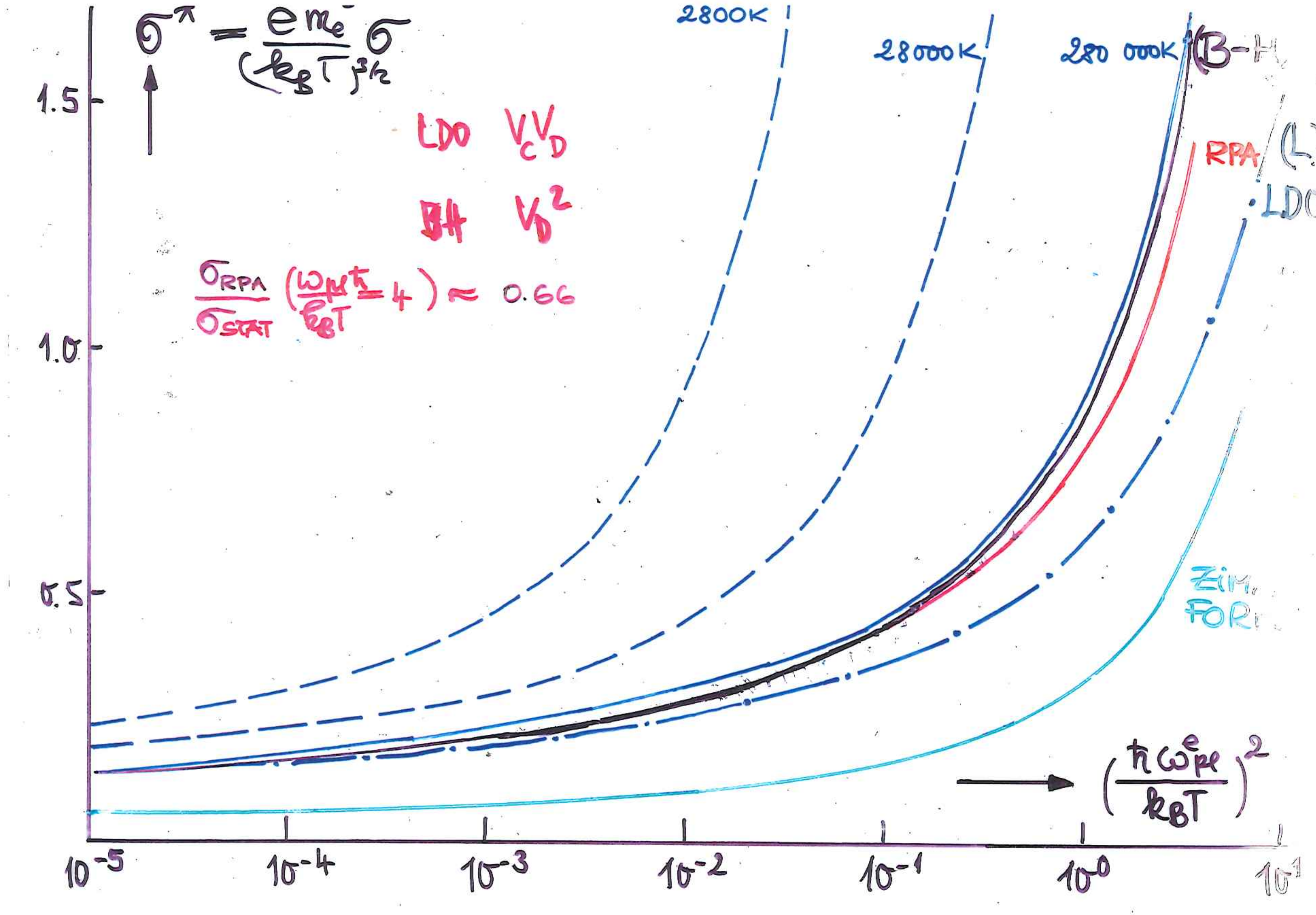
$$\sum_\mu b_\mu \langle j_\nu M_\mu \rangle_{GC} \; : \; E \longrightarrow \begin{cases} \Delta T \\ \Delta n_a \\ \Delta v \end{cases}$$

extremly strong baths : ≈ 0 $\uparrow$

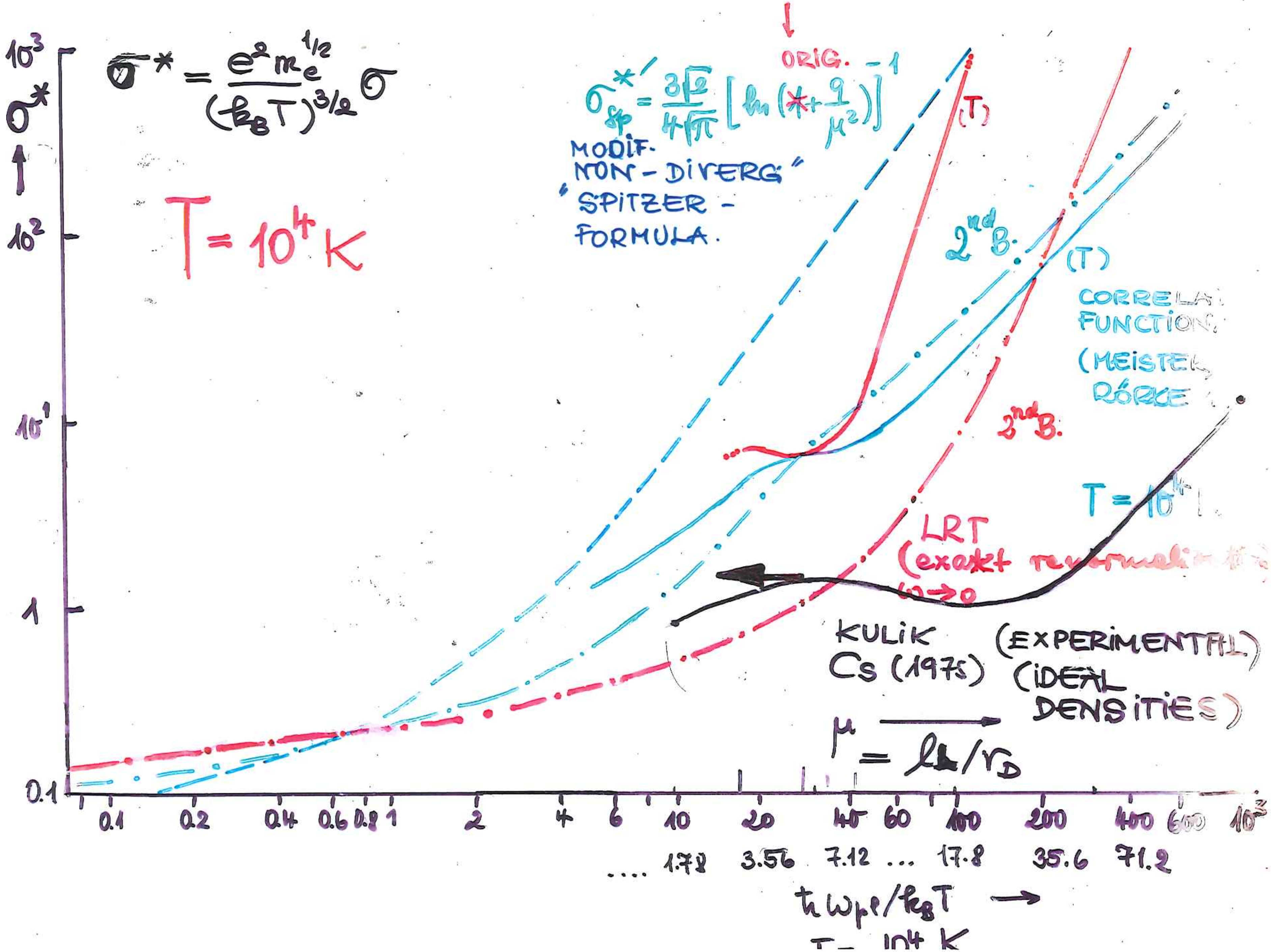
KUBO's formula



e.g. KILIMANN 1978



$\sigma^* = \frac{e m_e}{(k_B T)^{3/2}} \sigma$
LDO $V_C V_D$
BH V_D^2
$\frac{\sigma_{RPA}}{\sigma_{STAT}} \left(\frac{\omega_{pe} \hbar}{k_B T} = 4 \right) \approx 0.66$
2800K
28000K
280 000K
B-H
RPA
(L)
LDO
1.5
1.0
0.5
10^{-5}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
10^{0}
10^{1}
$\left(\frac{\hbar \omega_{pe}^{e}}{k_B T} \right)^2$



$\sigma^* = \frac{e^2 m_e^{1/2}}{(k_B T)^{3/2}} \sigma$
σ^*
$T = 10^4$ K
ORIG.
$\sigma^*_{Sp} = \frac{3\sqrt{2}}{4\sqrt{\pi}} \left[\ln \left(1 + \frac{9}{\mu^2} \right) \right]^{-1}$
MODIF. "NON-DIVERG" SPITZER-FORMULA.
(T)
2^{nd} B.
(T)
CORRELAT. FUNCTIONS (MEISTER, RÖPKE)
2^{nd} B.
$T = 10^4$
LRT (exakt renormalization) $\omega \to 0$
KULIK Cs (1975) (EXPERIMENTAL) (IDEAL DENSITIES)
$\mu = l_k / r_D \longrightarrow$
10^3
10^2
10^1
1
0.1
0.1 0.2 0.4 0.6 0.8 1 2 4 6 10 20 40 60 100 200 400 600 10^3
.... 1.78 3.56 7.12 ... 17.8 35.6 71.2
$\hbar\omega_{pl}/k_B T \longrightarrow$
$T = 10^4$ K