



Plasmons and Optic Phonons in Strontium Titanate

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$$H = \sum_{\mathbf{k}} c_{\mathbf{k}}^{\dagger} (\epsilon_{\mathbf{k}} - \mu) c_{\mathbf{k}} + \Omega \sum_{\mathbf{k}} b_{\mathbf{k}}^{\dagger} b_{\mathbf{k}} + \sum_{\mathbf{k}} g(\mathbf{k}) \rho_{\mathbf{k}} (b_{\mathbf{k}} + b_{-\mathbf{k}}^{\dagger}) + \sum_{\mathbf{k}} V(\mathbf{k}) \rho_{\mathbf{k}} \rho_{-\mathbf{k}}$$

Parameters of the theory:

$$r_s = E_{\text{kin}}/E_{\text{Coul}}$$

$$\Omega/E_F$$

$$\gamma$$

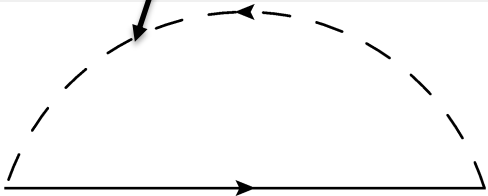
$$g^2(\mathbf{k}) = \frac{\lambda \Omega \gamma}{k^2}$$

$$V_{\text{Coul}}(\mathbf{k}) = \frac{\lambda}{k^2}$$

Rock salt approximation:

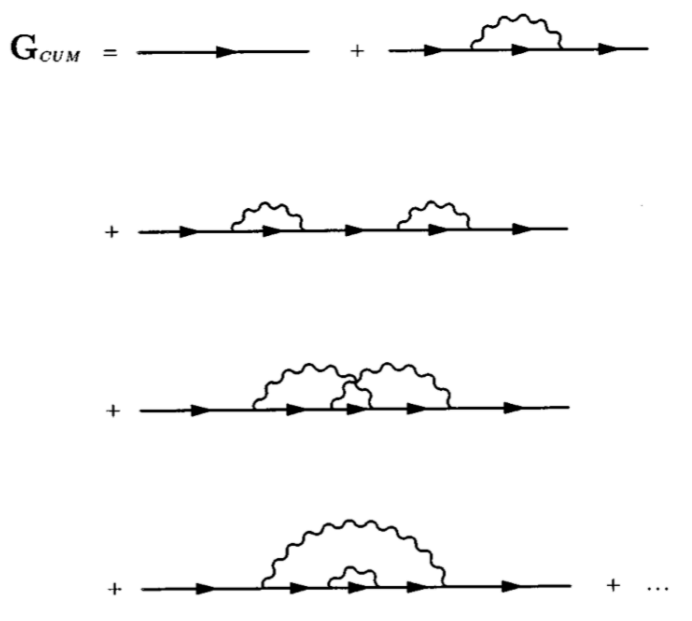
$$\gamma = \frac{1}{2} \left(\frac{1}{\epsilon_{\infty}} - \frac{1}{\epsilon_0} \right)$$

$$V_{\text{eff}}(\omega, \mathbf{k}) = \frac{V_{\text{Coul}} + V_{\text{ph}}}{1 - \Pi_{\text{RPA}}(V_{\text{Coul}} + V_{\text{ph}})}$$

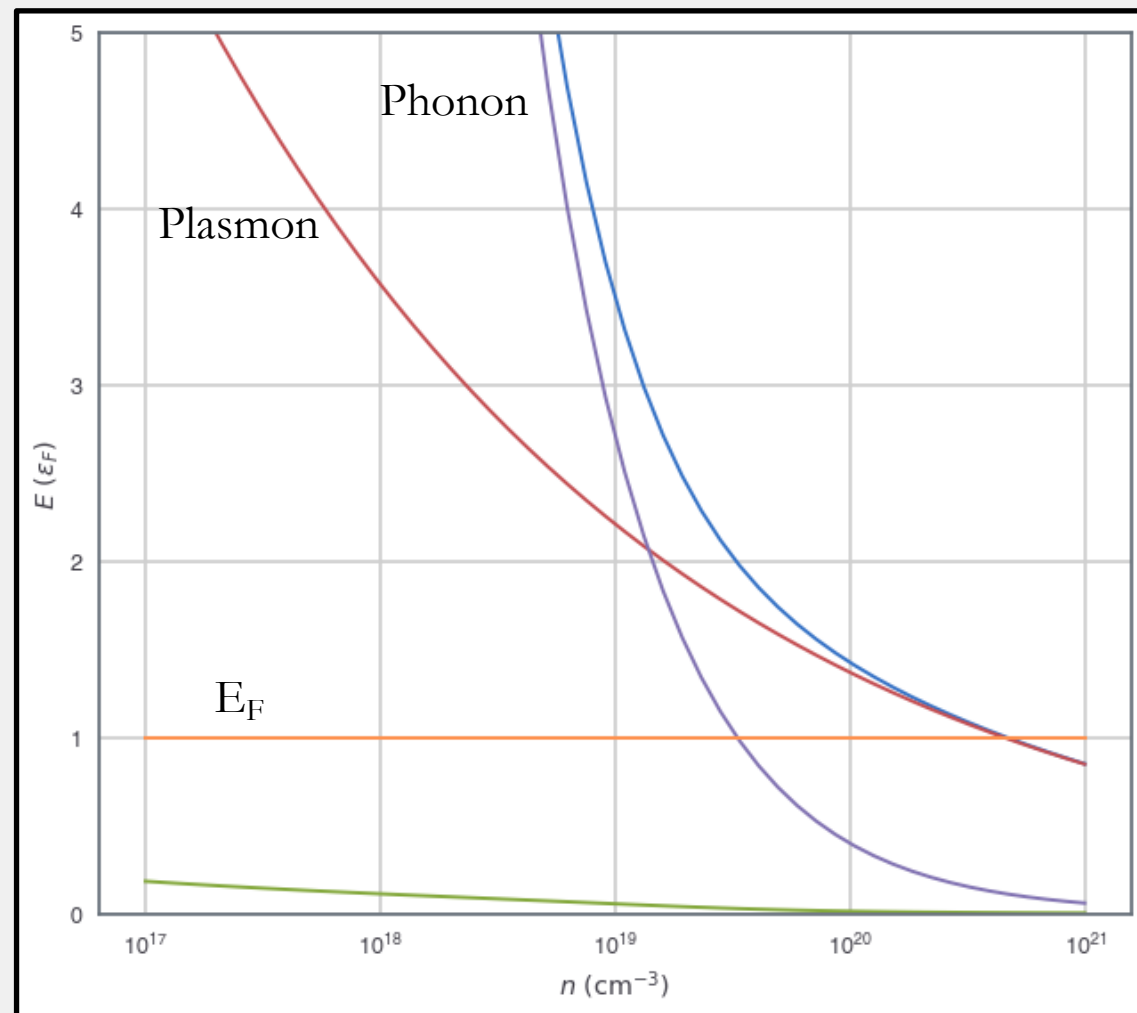
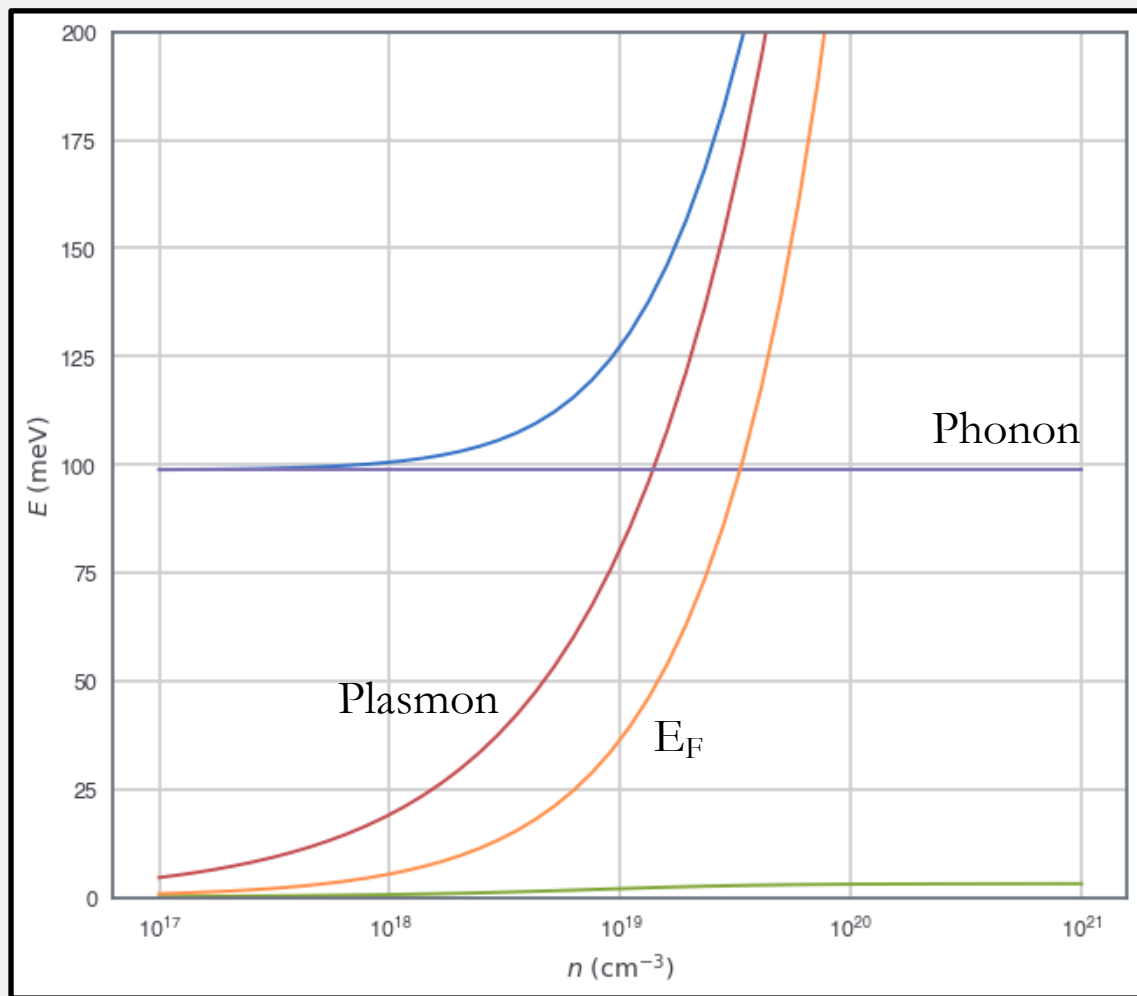
$$\Sigma =$$




Cumulant Expansion
Kas et al PRB **90**, 686 (2014)

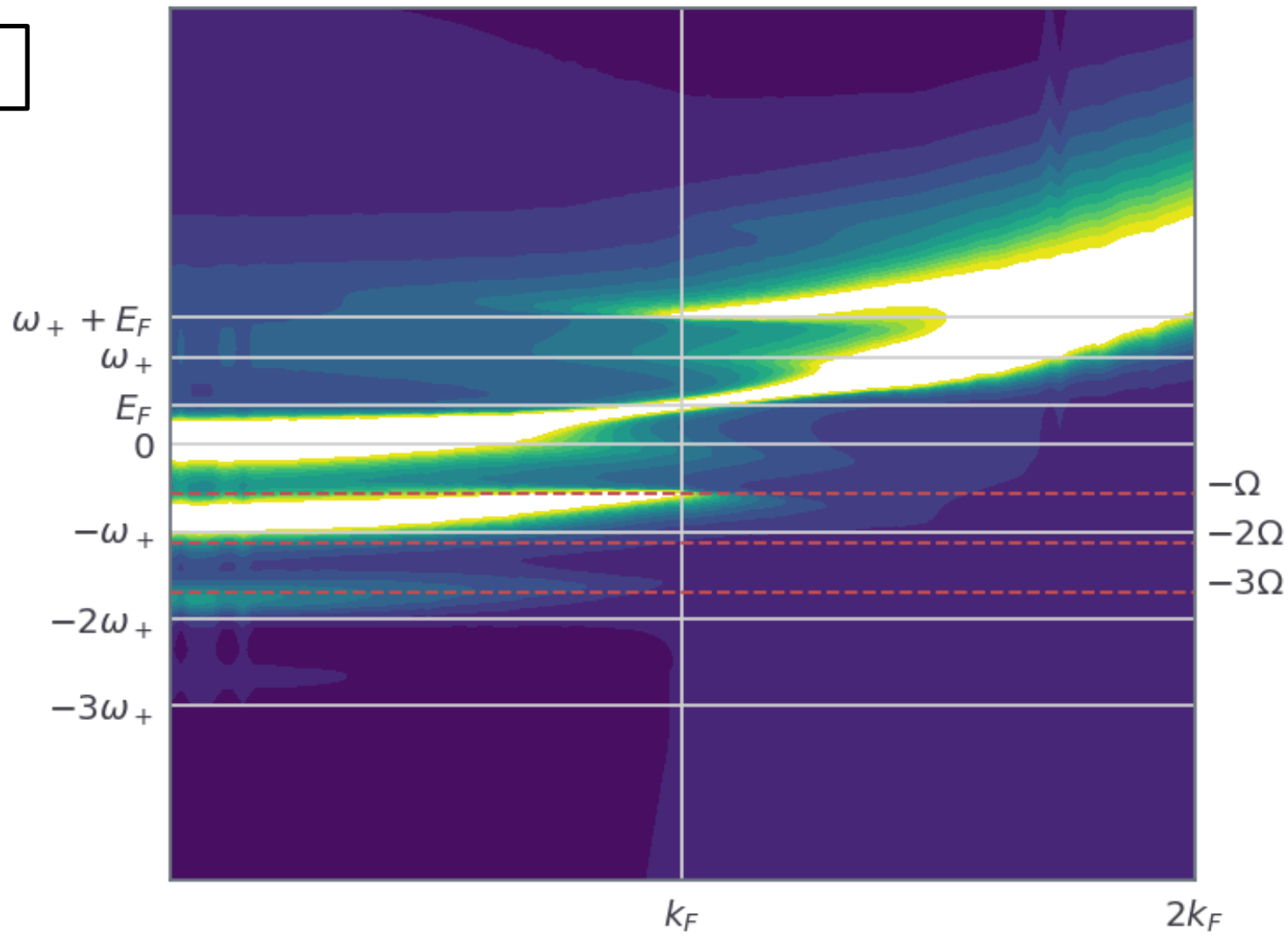
$$\mathbf{G}_{\text{CUM}} =$$


Coupled Modes

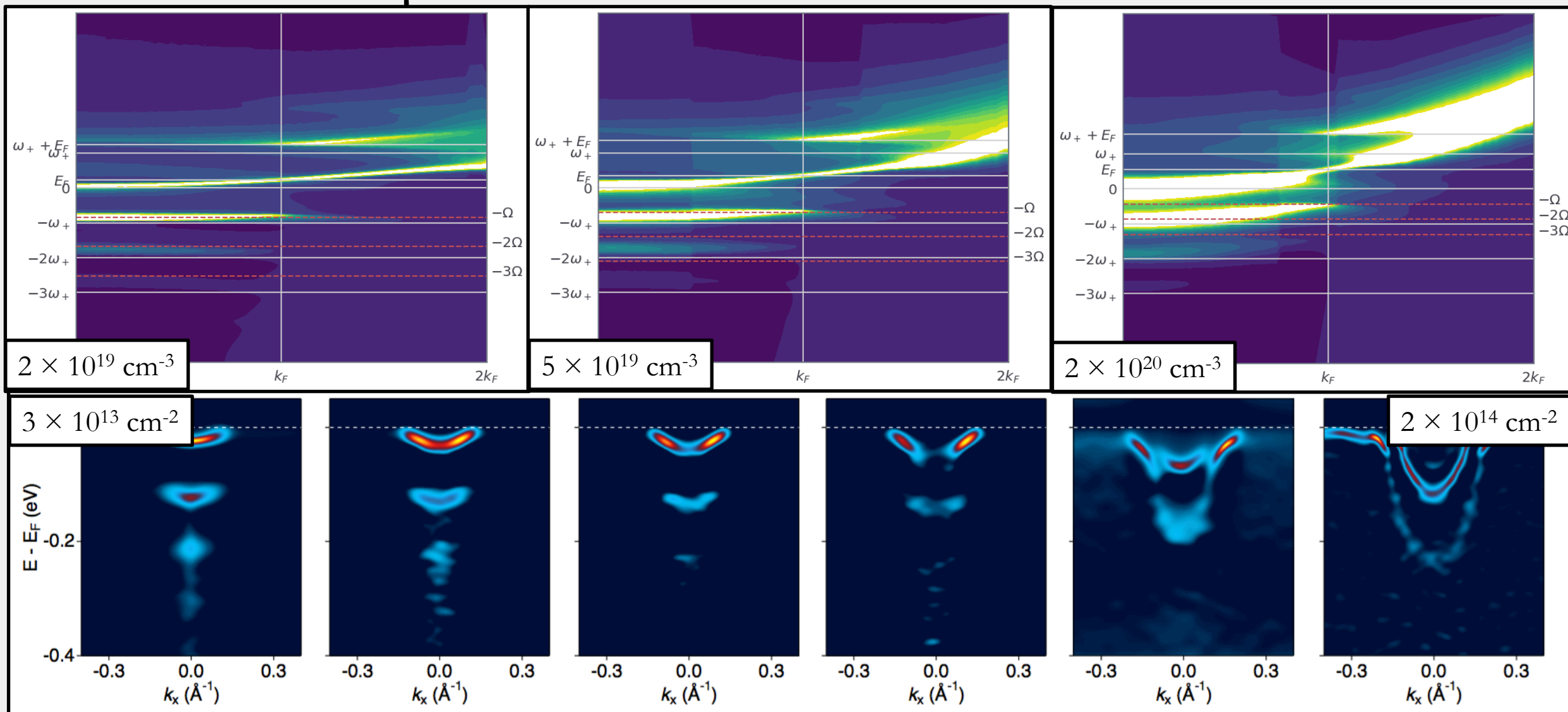


Spectral Functions

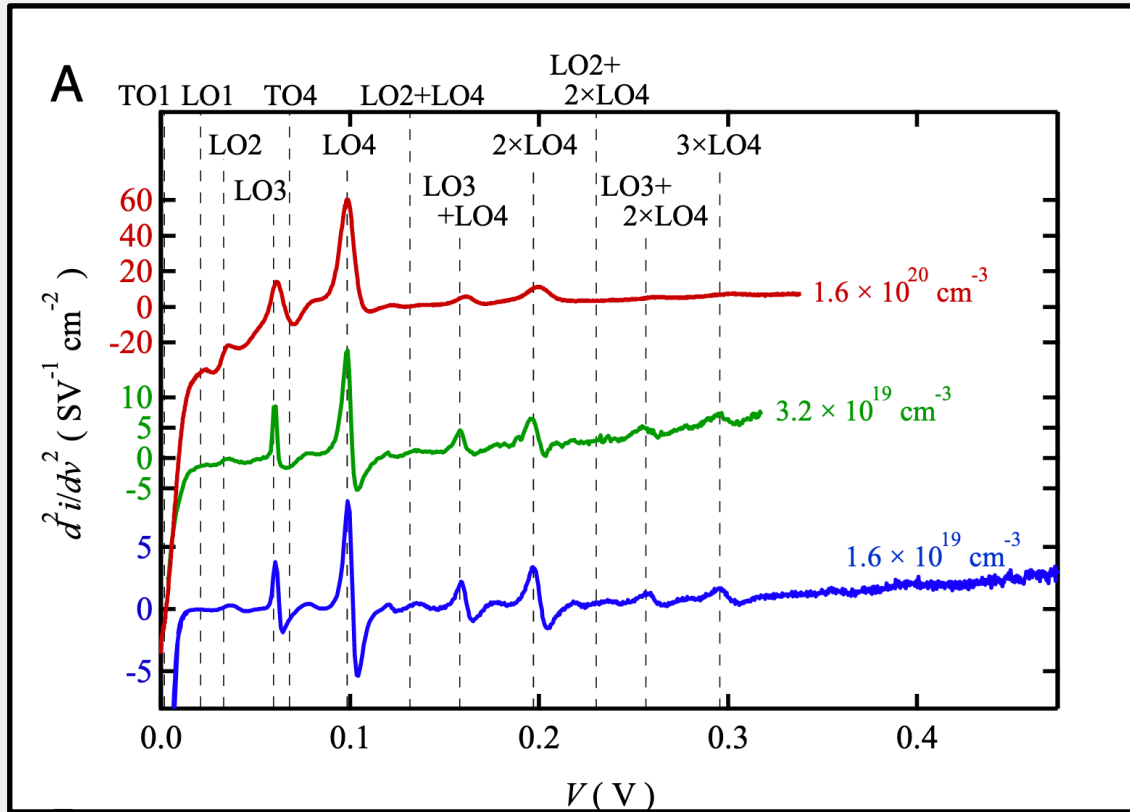
$$n = 1 \times 10^{20} \text{ cm}^{-3}$$



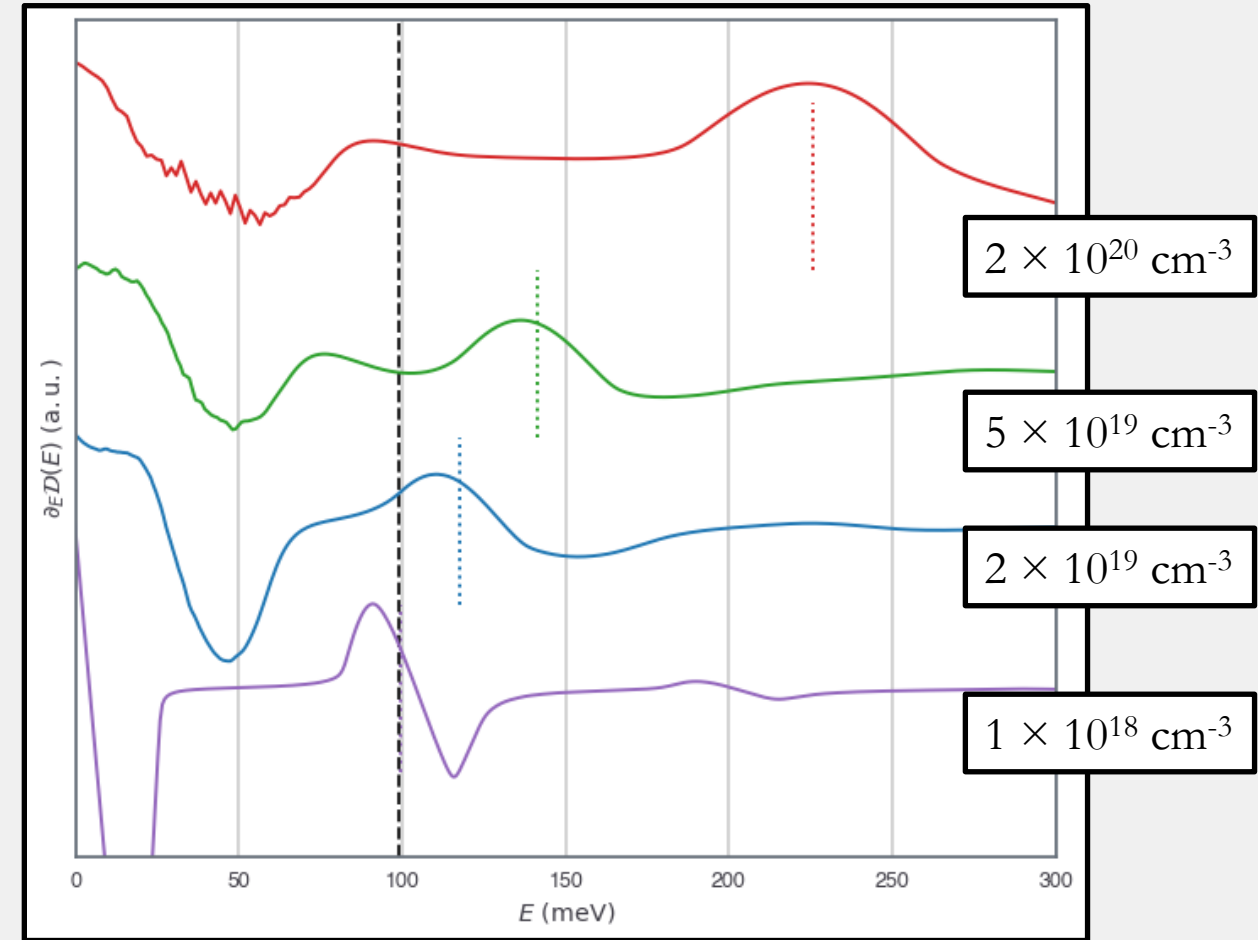
Spectral Functions vs ARPES



∂DoS vs Tunneling

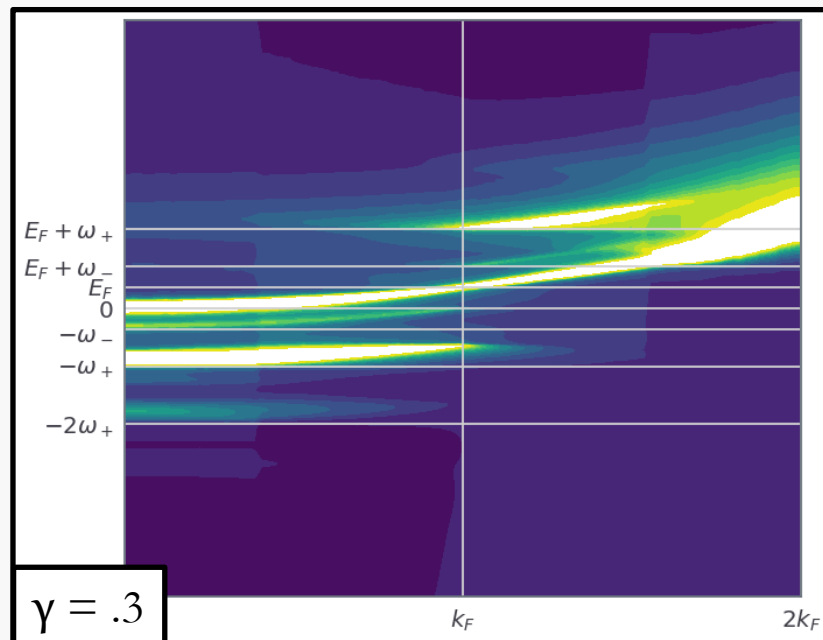
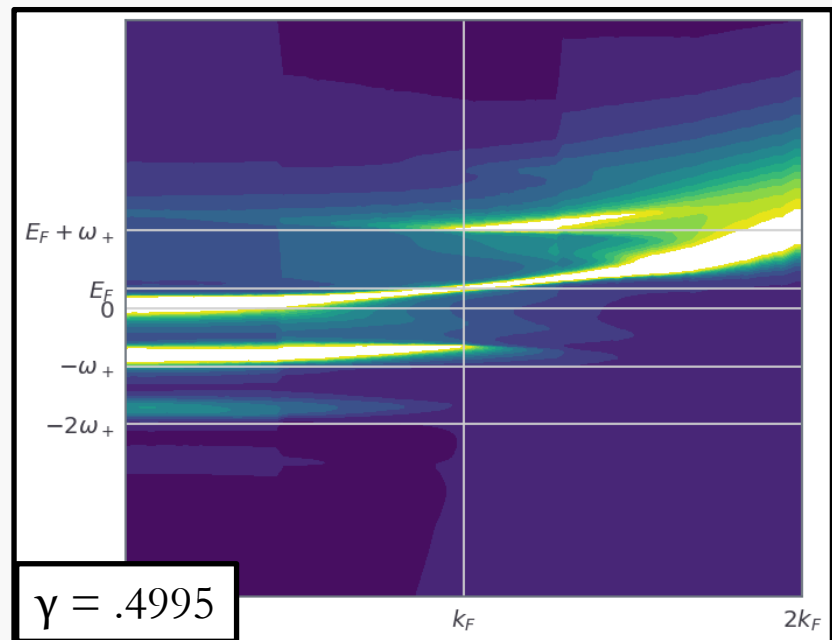


Swartz et al, PNAS (2018)

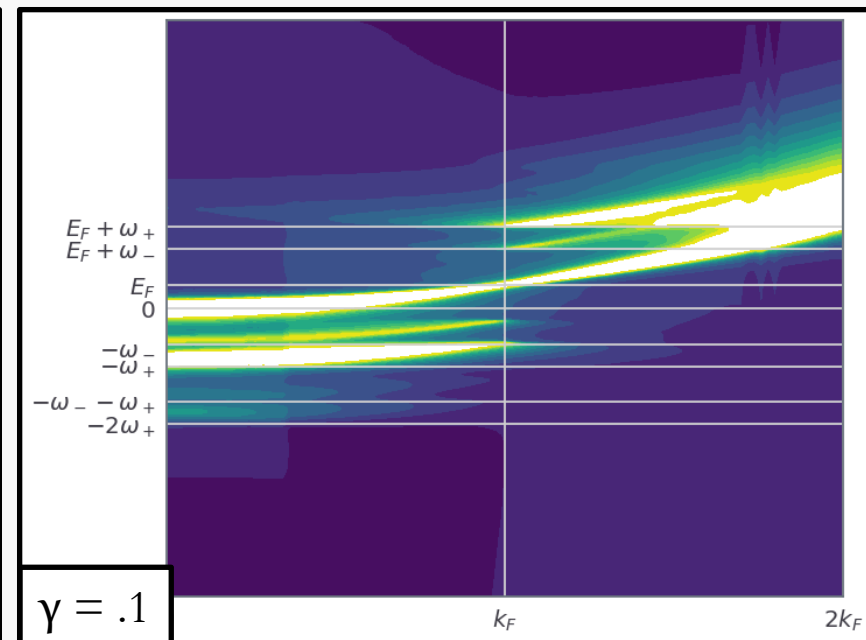


$$n = 5 \times 10^{19} \text{ cm}^{-3}$$

Proximity to the Critical Point



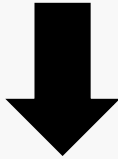
$$(\epsilon_0 \sim 14)$$



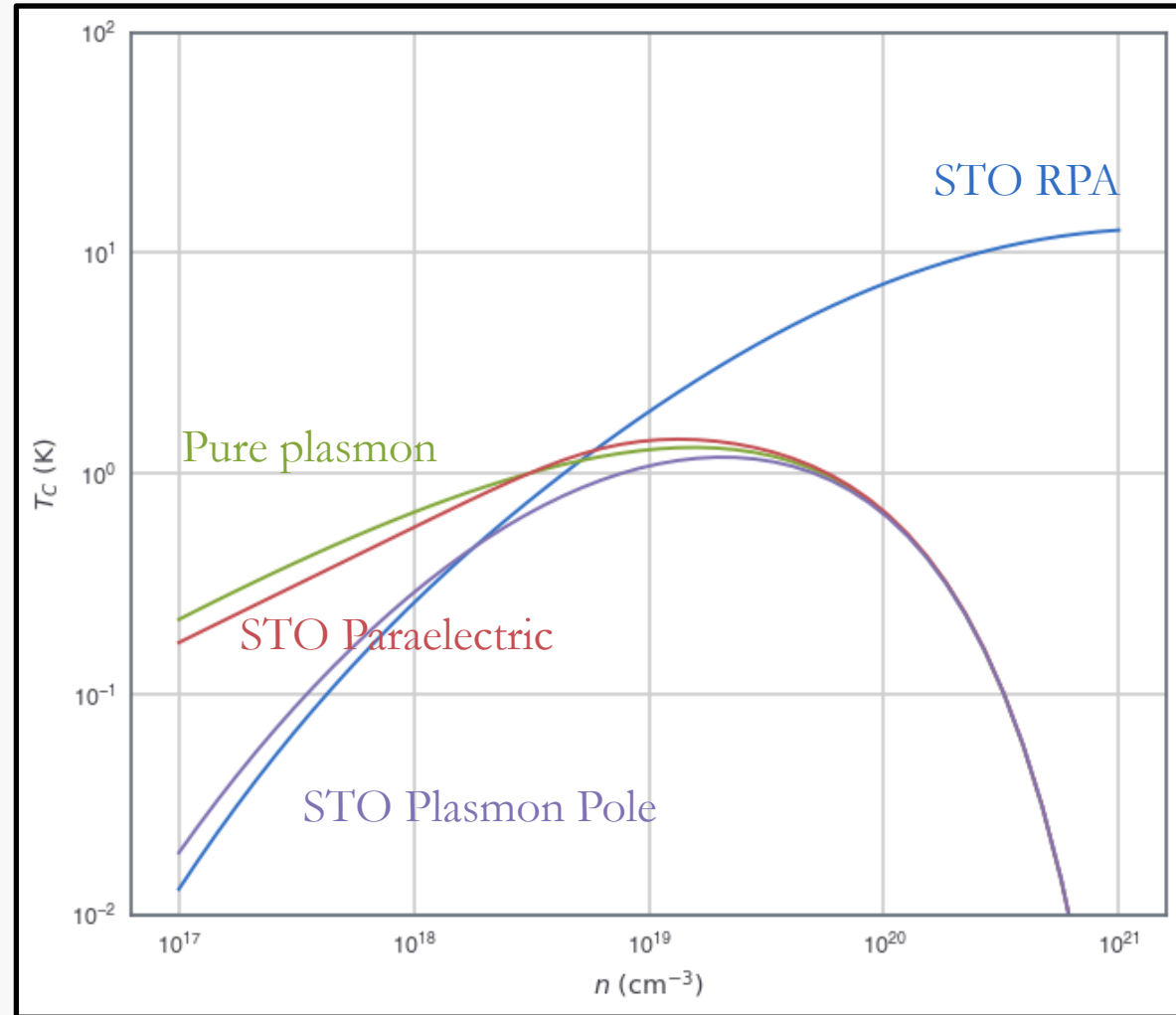
$$(\epsilon_0 \sim 7)$$

A few words on KMK approximations

$$\frac{\Delta}{Z}(\omega, \epsilon) = - \int d\epsilon' N(\epsilon) \int_0^\infty \frac{d\eta}{\pi} \Im F(\eta, \epsilon') \tanh(\beta\eta/2) \times \\ \left(V_0(\epsilon, \epsilon' + \int_0^\infty \frac{d\Omega}{\pi} \Im V(\Omega, \epsilon, \epsilon') \left(\frac{1}{\eta + \Omega + \omega} + \frac{1}{\eta + \Omega - \omega} \right) \right)$$



$$V_0(\xi + \mu, \xi'_\mu) + 2 \int_0^\infty \frac{d\Omega}{\pi} \frac{\Im V(\Omega, \xi + \mu, \xi' + \mu)}{|\xi'| + |\xi| + \Omega}$$



Work in Progress: Corrections to T_C

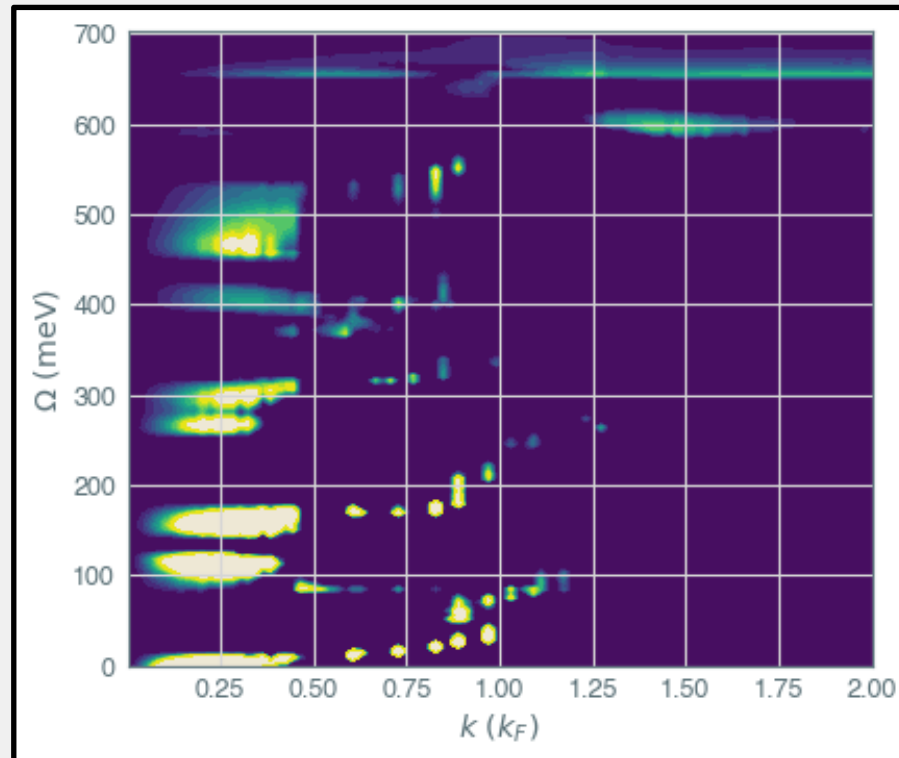
Normal
Self-energy

Anomalous
Self-energy

$$\begin{aligned} S(\mathbf{p}, ip) &= -\int \frac{d^3q}{(2\pi)^3} \frac{1}{\beta} \sum_{iq} V_{\text{eff}}(\mathbf{q}, iq) \mathcal{G}(\mathbf{p} + \mathbf{q}, ip + iq) \\ W(\mathbf{p}, ip) &= -\int \frac{d^3q}{(2\pi)^3} \frac{1}{\beta} \sum_{iq} V_{\text{eff}}(\mathbf{q}, iq) \mathcal{F}(\mathbf{p} + \mathbf{q}, ip + iq) \end{aligned}$$

← Known

$$n = 5 \times 10^{19} \text{ cm}^{-3}$$



Parting Thoughts

- Potential hybrid modes mediating pairing should have dramatic normal-state correlates
- Something funny is going on with the plasmon

