AC conductivity of a holographic strange metal

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1507.05633 in collaboration
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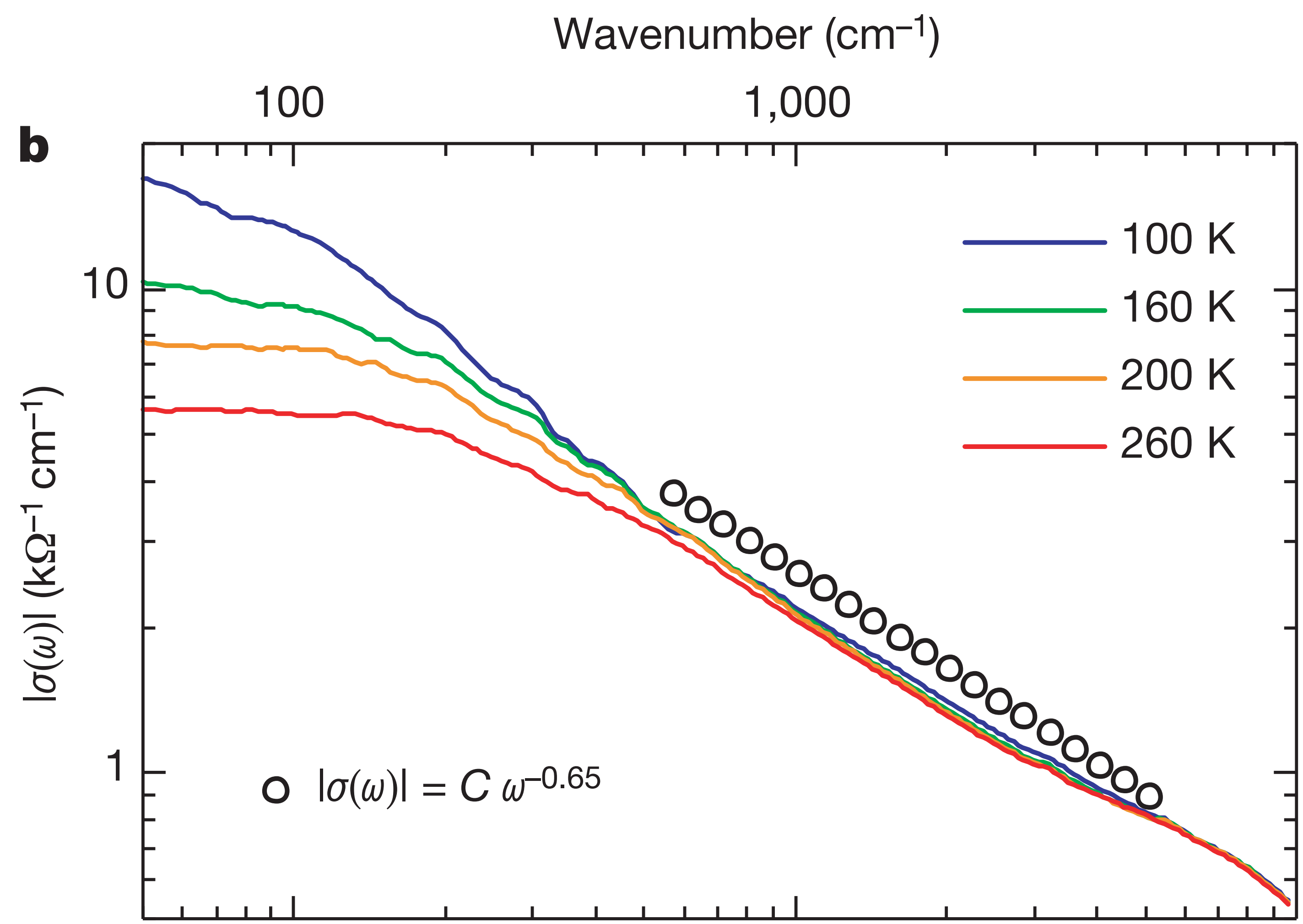
Workshop on Holography and Condensed Matter

motivation

- holography is a good tool for the understanding of new states of matter
- strange metals seem to have a quantum critical point at zero temperature
- the scattering rate is only fixed by the inverse of T
- scaling tails in the frequency dependence



[van der Marel et. al 2003]

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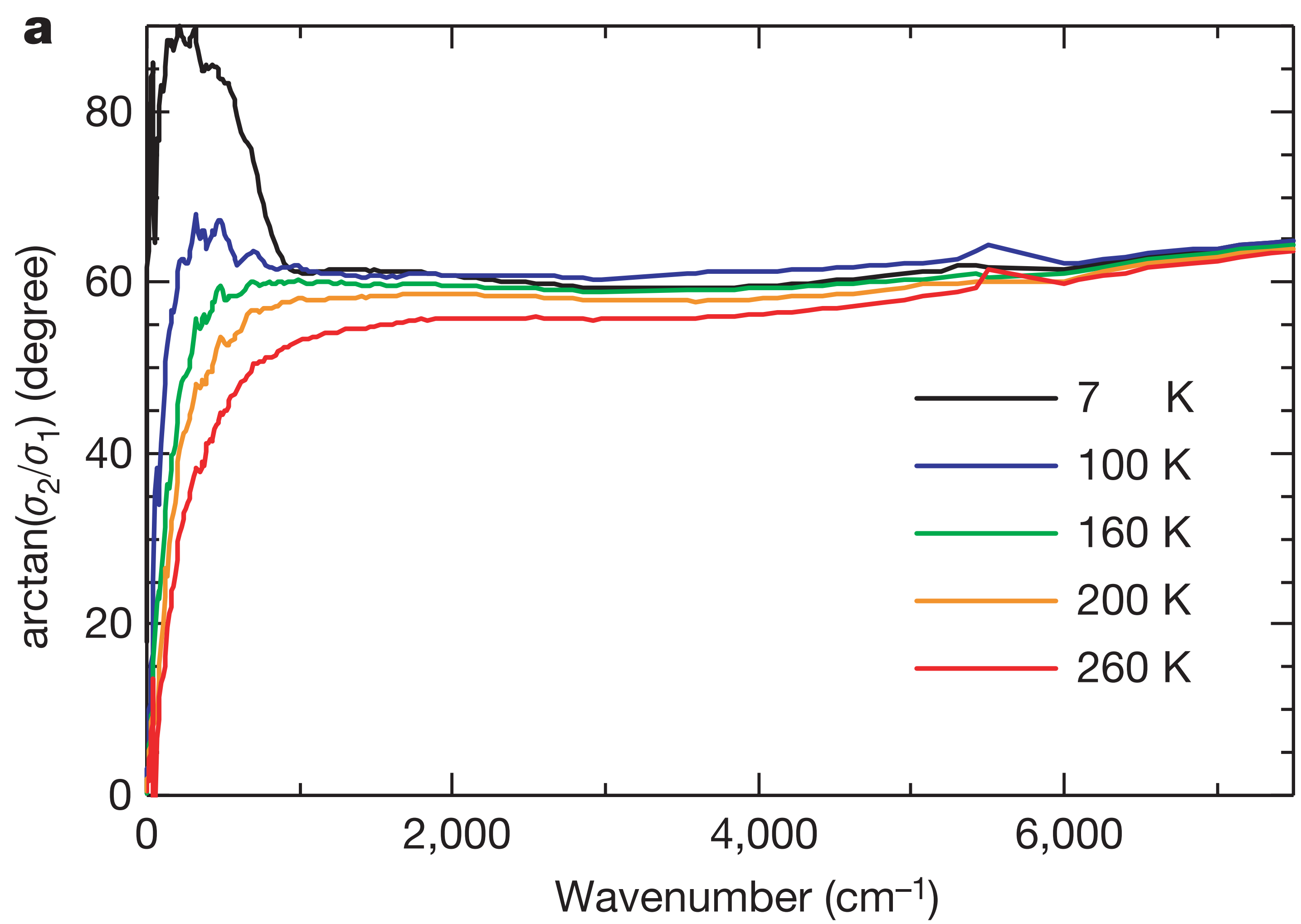


[van der Marel et. al 2003]

outline

- motivation
- a model for non fermi liquids
- results
- more general geometries
- outlooks

DC conductivity

- in translational invariance systems the DC conductivity is infinity

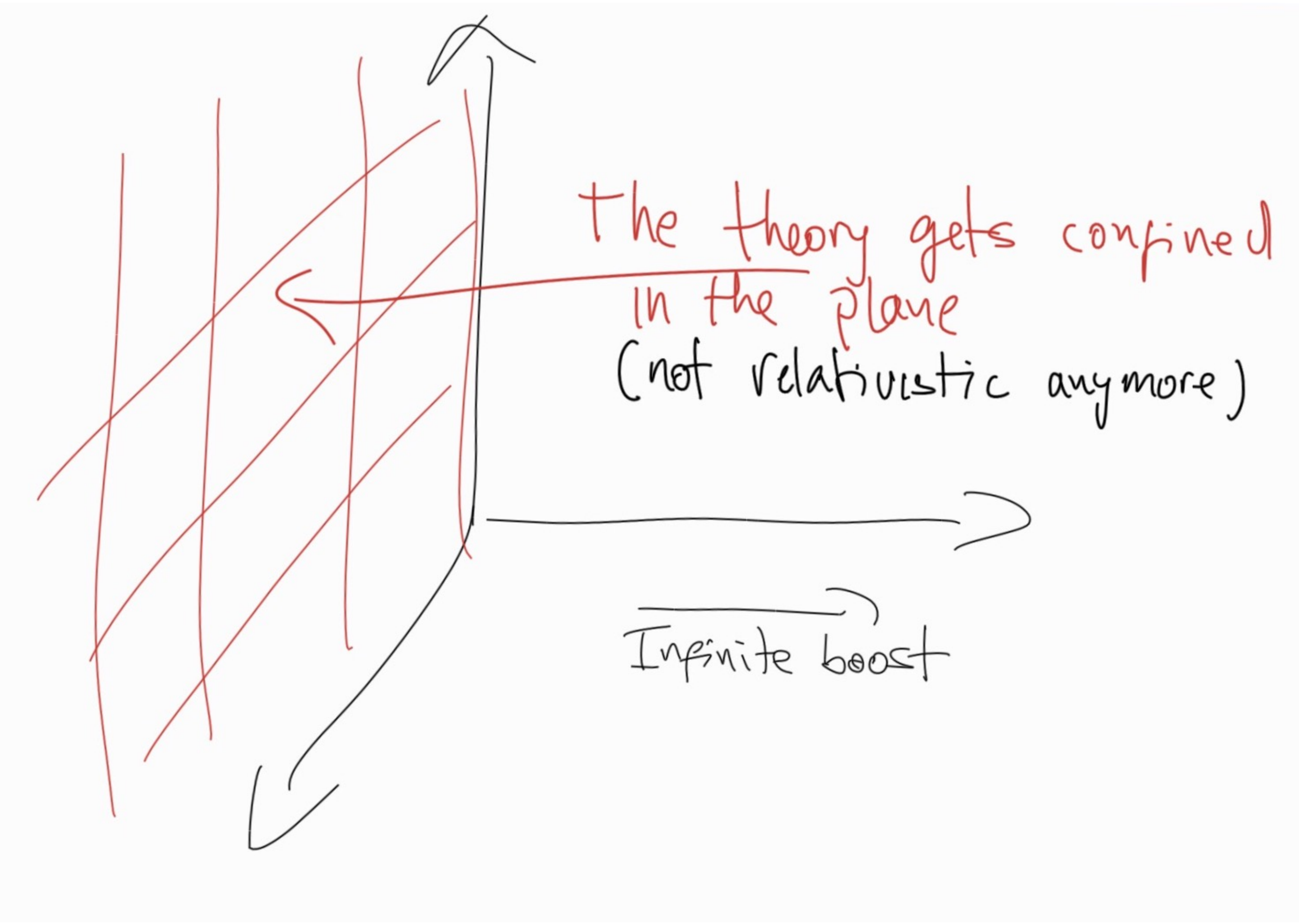
$$\sigma = K \left(\delta(\omega) + \frac{i}{\omega} \right) + \dots$$

- to have a finite DC conductivity translations must be broken

    - in holography it is possible to have also finite conductivities using DBI systems in the probe approximation

the model

(Massless) Fundamental matter in the probe limit on a background of adjoint matter quantized in light cone coordinates.



Breaks relativistic invariance

the model

- AdS-Schwarzschild metric in light-cone coordinates

$$ds^2 = g_{++}(dx^+)^2 + g_{--}(dx^-)^2 + 2g_{+-}dx^+dx_- + \sum g_{yy}(dx^i)^2 + g_{uu}(du)^2$$

- DBI action (probe limit)

$$L \sim \sqrt{-\det{(g+F)}}$$

- Light-cone electric field switched on

$$A = (Ey + h_+(u))dx^+ + (b^2Ey + h_-(u))dx^- + (b^2Ex^- + h_y(u))dy$$

[E. Kiritsis et. al 2012]

DC conductivity

computing DC conductivity using
Karch O'Bannon

$$\sigma^2 = \sigma_0^2(\sigma_{DR}^2 + \sigma_{QC}^2)$$

scaling variables

$$t \sim \frac{T}{E^{1/2}} \qquad J^2 \sim \frac{\rho^2}{E^3}$$

[E. Kiritsis et. al 2012]

DC conductivity

computing DC conductivity using
Karch O'Bannon

$$\sigma^2 = \sigma_0^2(\sigma_{DR}^2 + \sigma_{QC}^2)$$

$$\sigma_{QC}^2 = \frac{t^3}{\sqrt{A(t)}} \qquad \sigma_{DR}^2 = \frac{J^2}{t^2 A(t)}$$

$$A(t) = t^2 + \sqrt{1 + t^4}$$

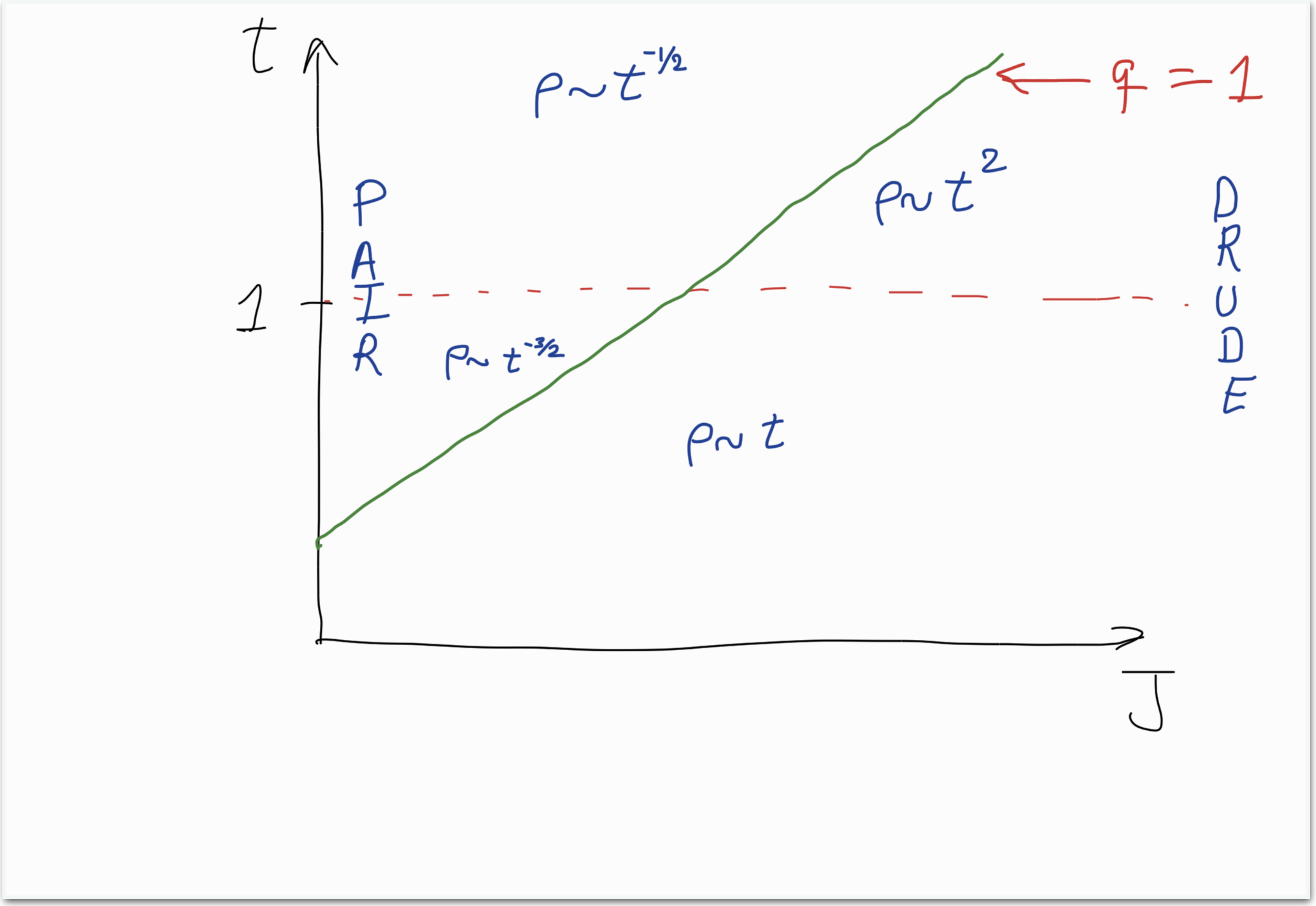
scaling variables

$$t \sim \frac{T}{E^{1/2}} \qquad J^2 \sim \frac{\rho^2}{E^3}$$

[E. Kiritsis et. al 2012]

parameter space

$$q = \frac{\sigma_{DR}^2}{\sigma_{QC}}$$



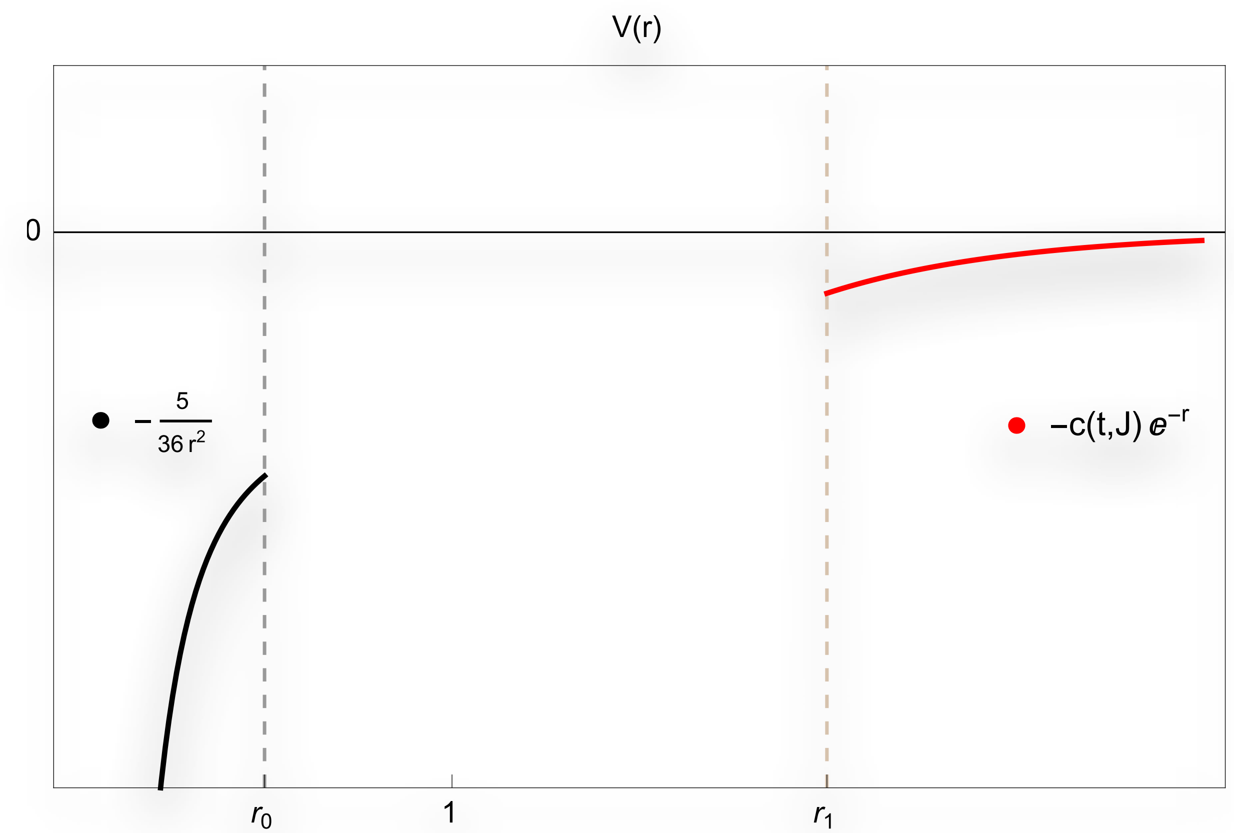
now we switch on fluctuations for the gauge field on top of the previous background configuration results (analytics)

Schrödinger problem & optical conductivity

linearized field equations

$$-\psi'' + \left(V - \omega^2\right)\psi = 0$$

$$\tilde{\sigma} \sim \left(\frac{\omega}{T}\right)^{-1/3} e^{i\pi/6}$$

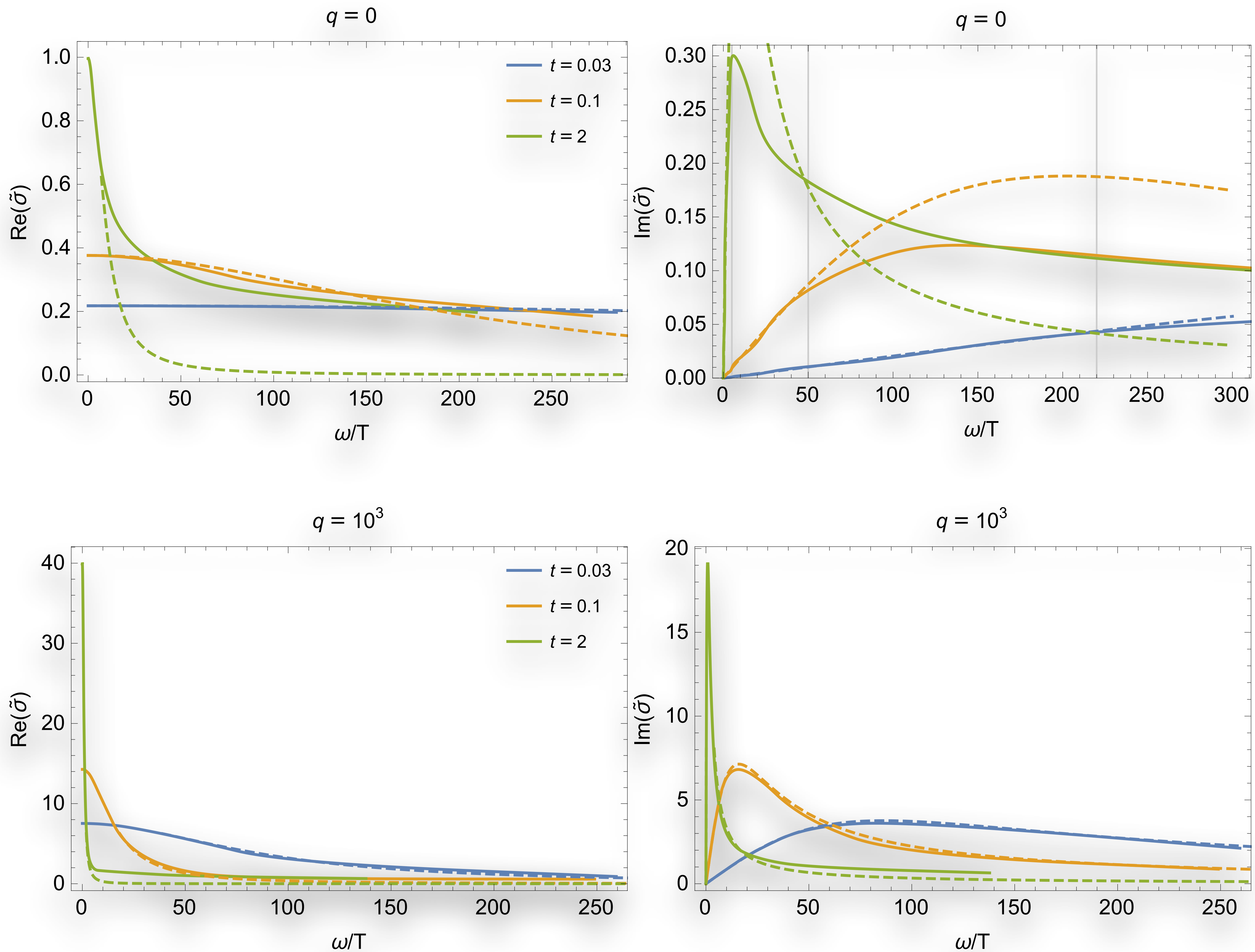


$$\tilde{\sigma} \sim c_1(r_0, T_{eff}) + i c_2(r_0, T_{eff})\omega^{-1}$$

$$r_0\omega \ll 1 \quad , \quad \omega \gg 1$$

results (numerics)

Drude behavior



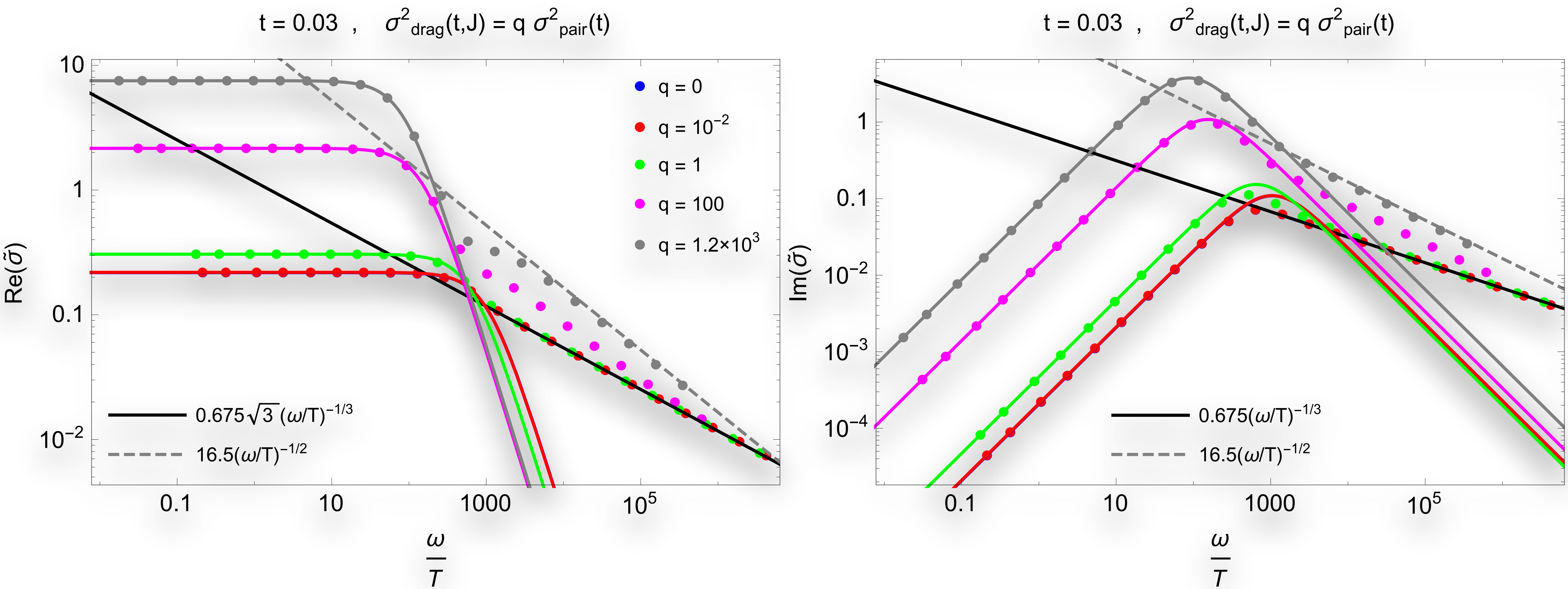
pair creation

$$\sigma = \frac{\sigma_{DC}}{1 - i\tau\omega}$$

drag regime

results (numerics)

full optical conductivity

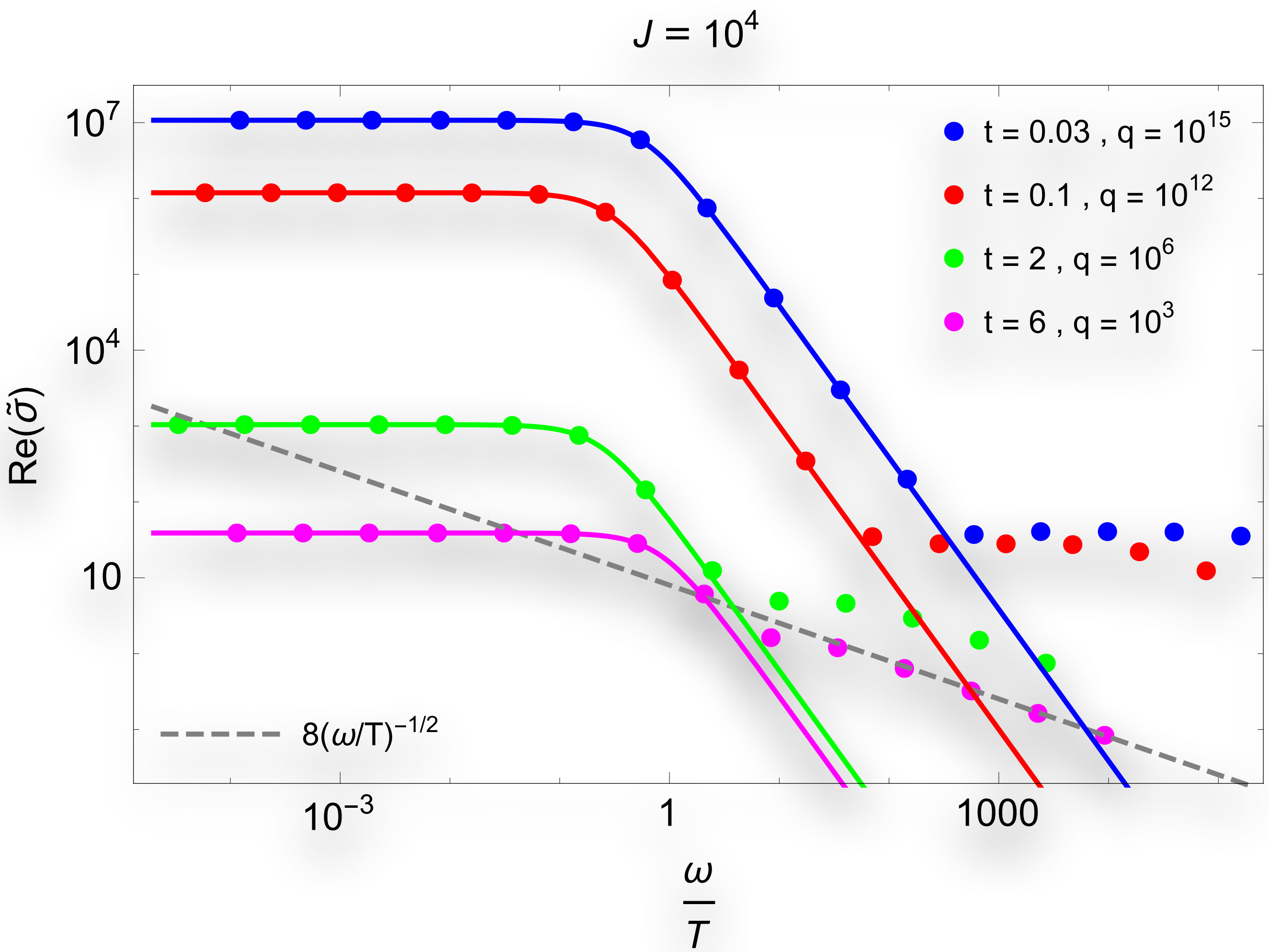


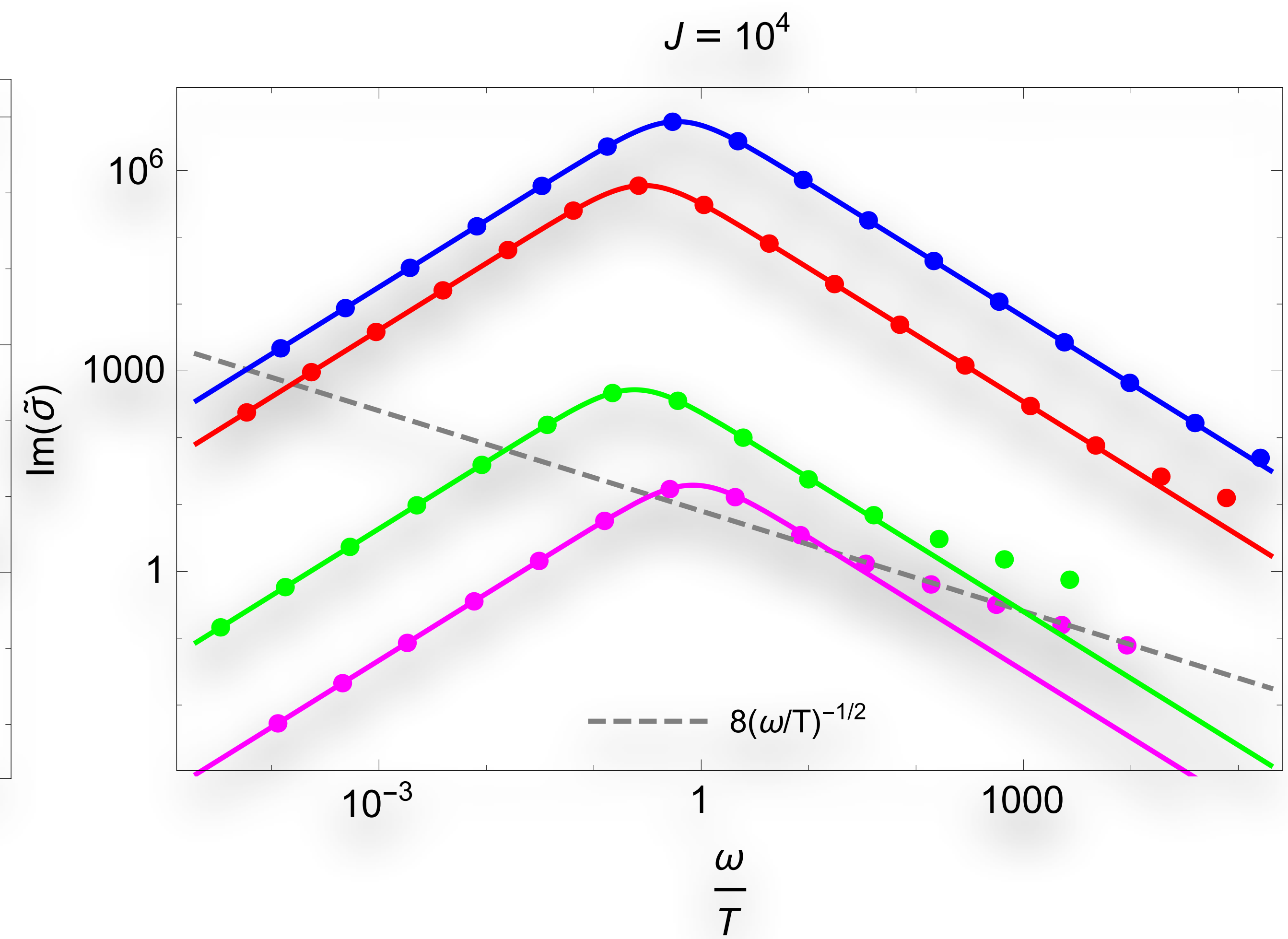
$\rho \sim t^{-3/2}$ blue red

$\rho \sim t$ magenta green

results (numerics)

full optical conductivity





$\rho \sim t$ blue red

$\rho \sim t^2$ magenta green

Summary I

- the DBI model has an UV power law with exponent -1/3
- intermediate regime that can not be seen from analytics arguments
- in absence of charge density no “Drude peak”, only the UV power law appear
- the charged system shows a “Drude peak”

Einstein Maxwell dilaton model

in order to have scaling geometries but violating hyper scaling and with Lifshitz exponent

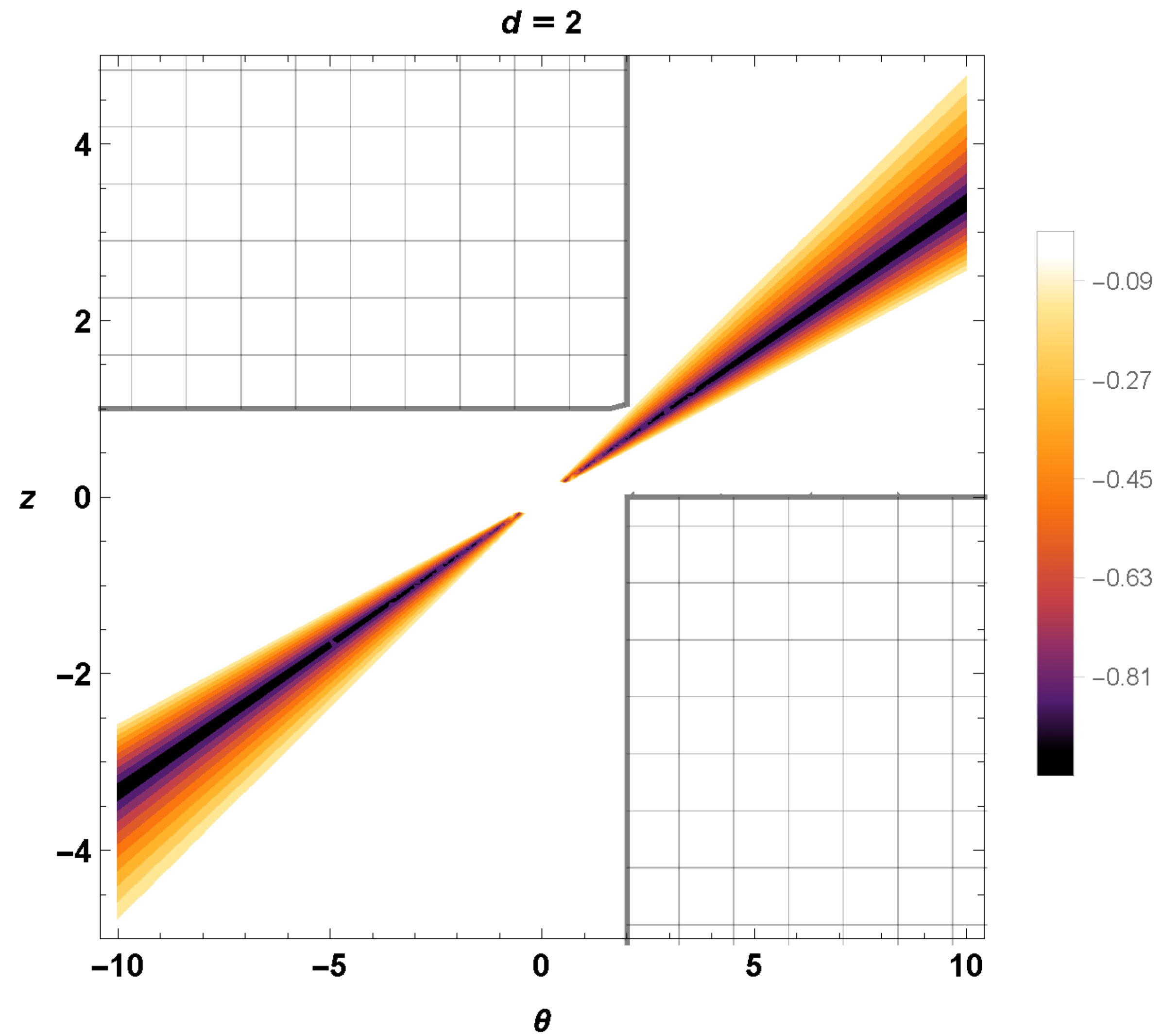
$$S \sim \int \sqrt{-g}\left[R - \frac{1}{2}(\partial\phi)^2 + V(\phi) - \frac{Z_1(\phi)}{4}F_1^2 - \frac{Z_2(\phi)}{4}F_2^2\right]$$

$$ds^2 = r^{\frac{2\theta}{d}}\left[-\frac{dt^2}{r^{2z}} + \frac{dr^2 + dx^2}{r^2}\right]$$

$Z_1 \sim Z_2$ $\qquad$ $Z_2 = 0$ $\qquad$ $Z_2 > Z_1$

conductivity for uncharged gauge field

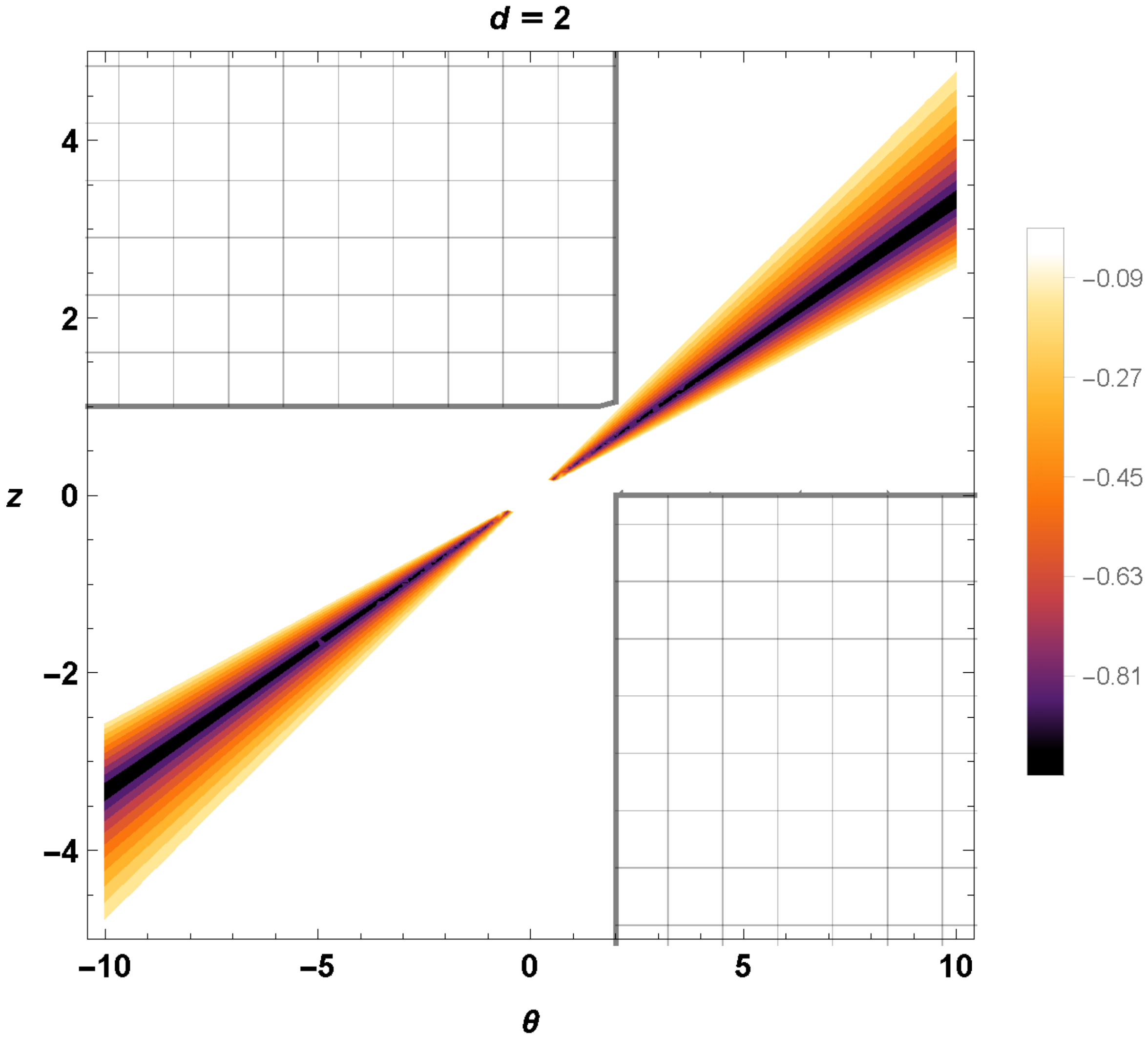
$$Z_2 = 0$$



$$\sigma \sim \omega^m$$

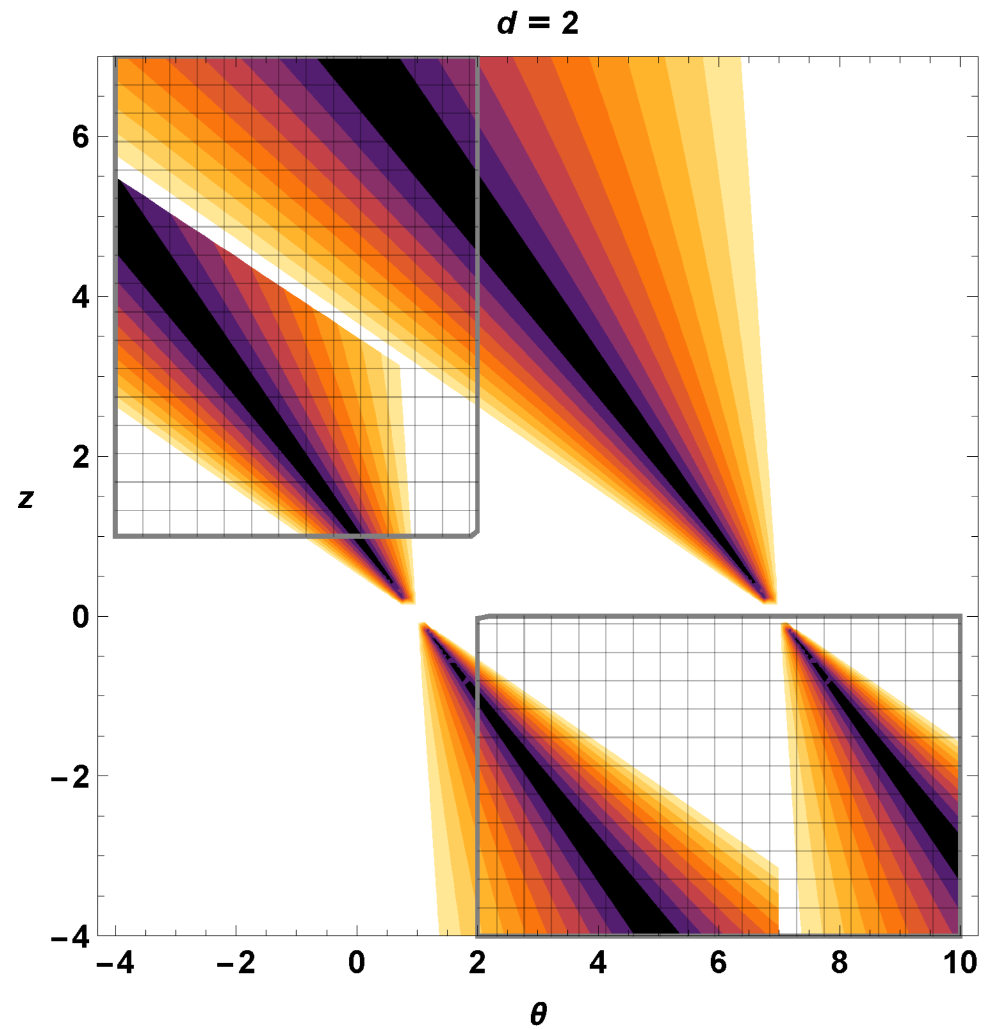
$$m = \left| 3 - \frac{2}{z} + \frac{d-\theta}{z} \right| - 1$$

conductivity for
uncharged gauge field



$$\sigma \sim \omega_1^m$$

conductivity for
charged gauge field



$$\sigma \sim \omega_2^m$$

Summary II

- to have negative exponent in EMD systems it is necessary at least two gauge fields
- full AC conductivity with the full RG flow geometry has to be computed
- are the scaling tales completely determined by the “pair creation” physics in general systems?