AC conductivity of a holographic strange metal

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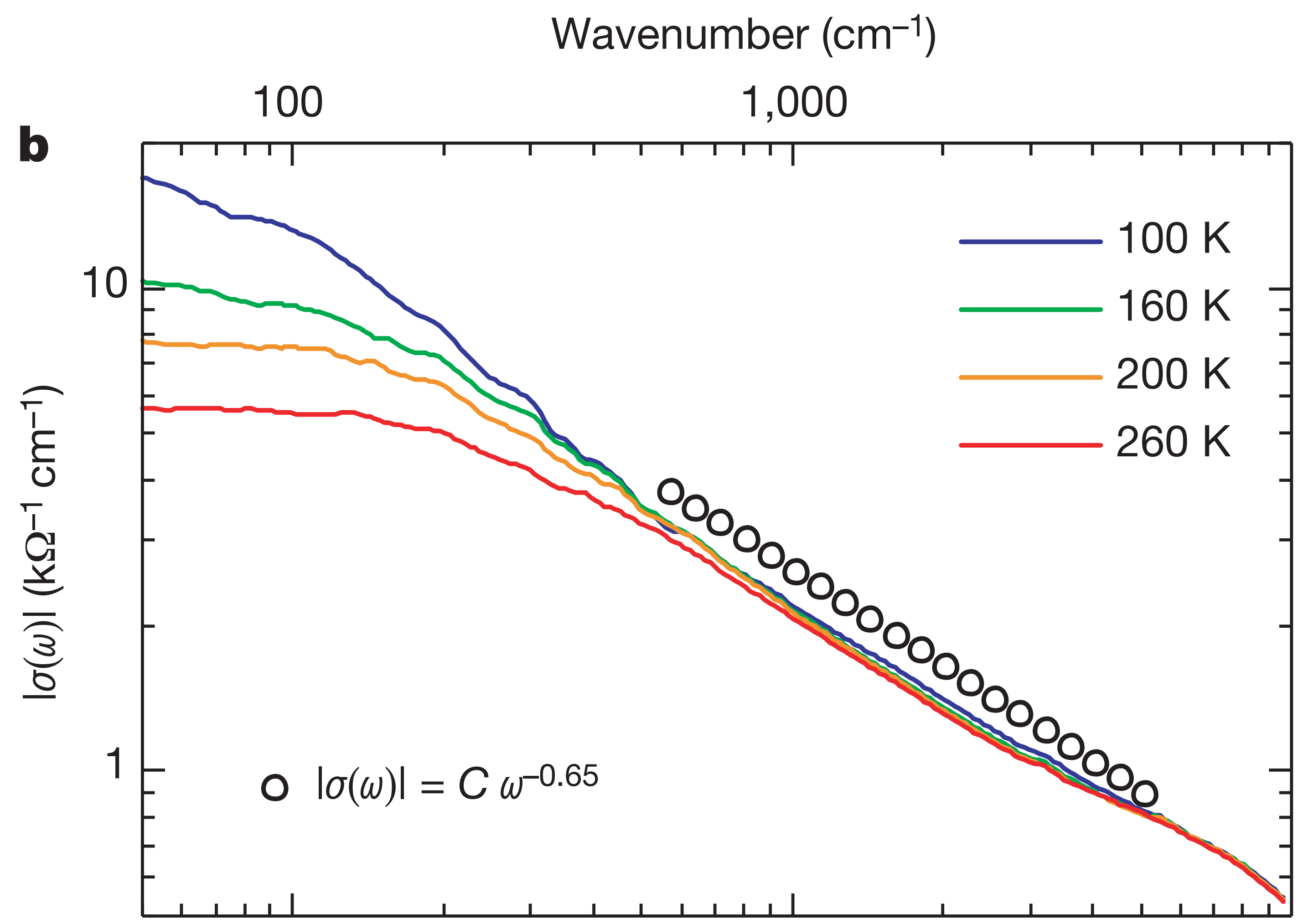
8th regional meeting in string theory

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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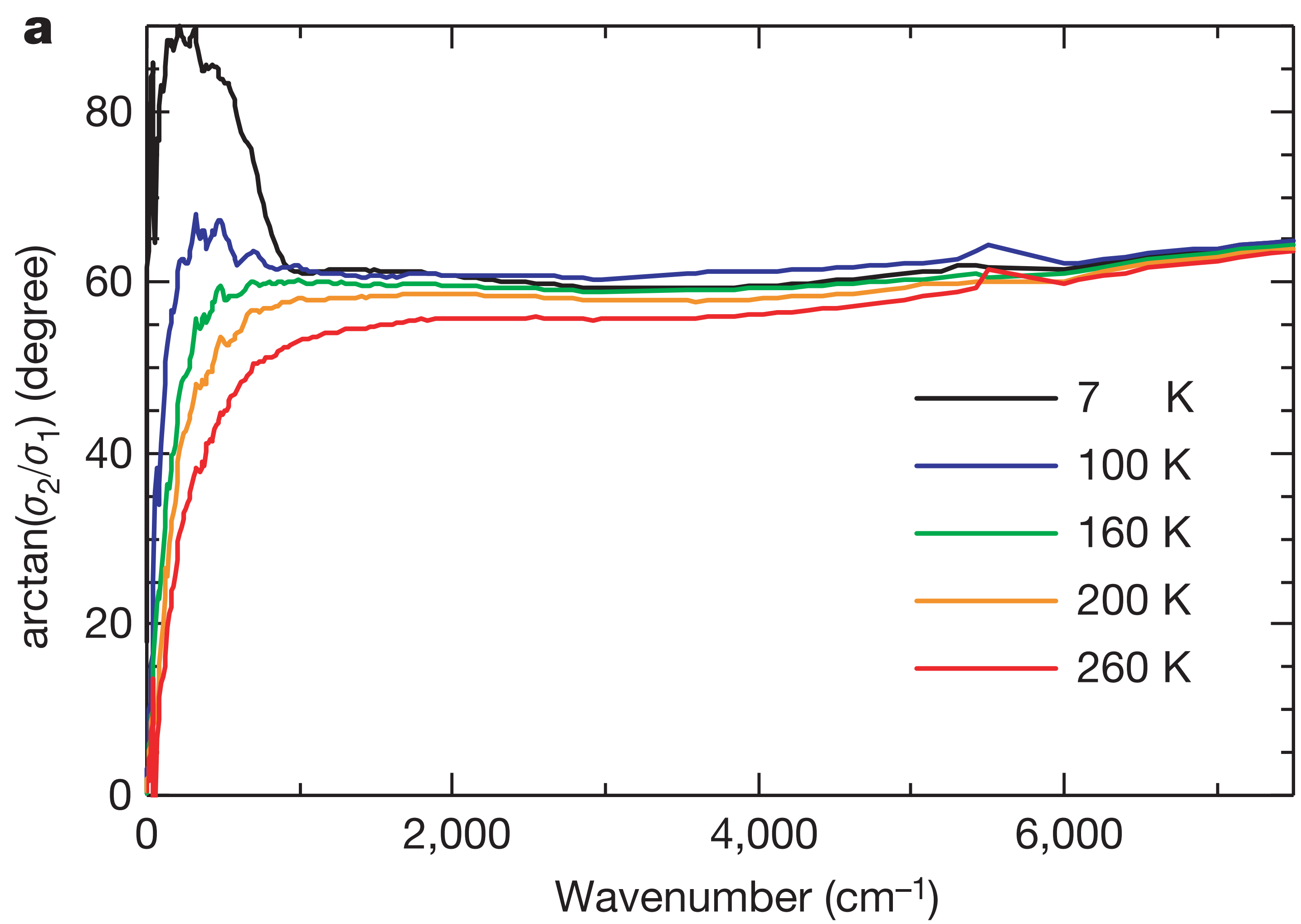


[van der Marel et. al 2003]

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

- 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)

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

- 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

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

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

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

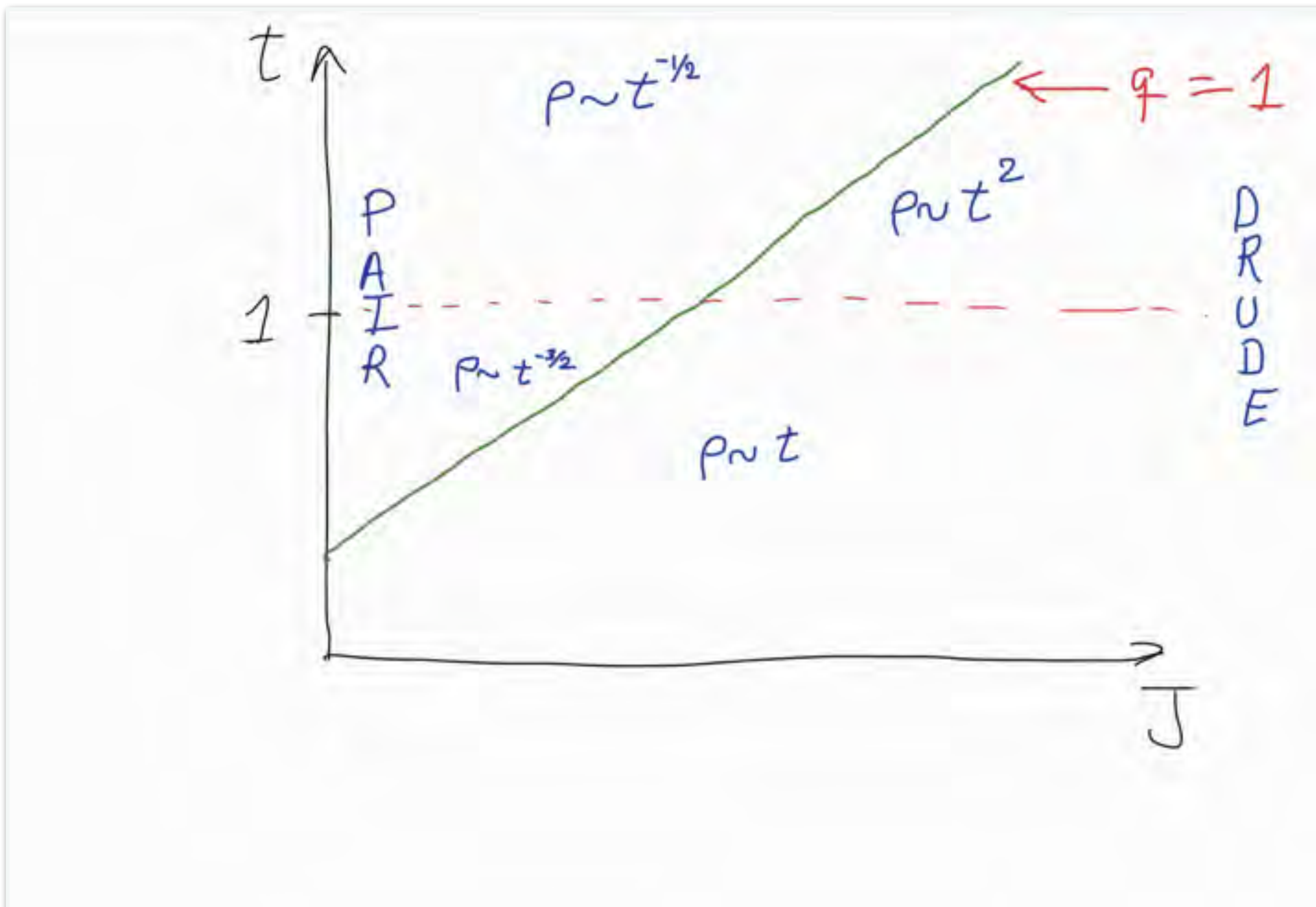
scaling variables

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

[E. Kiritsis et. al 2012]

parameter space

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

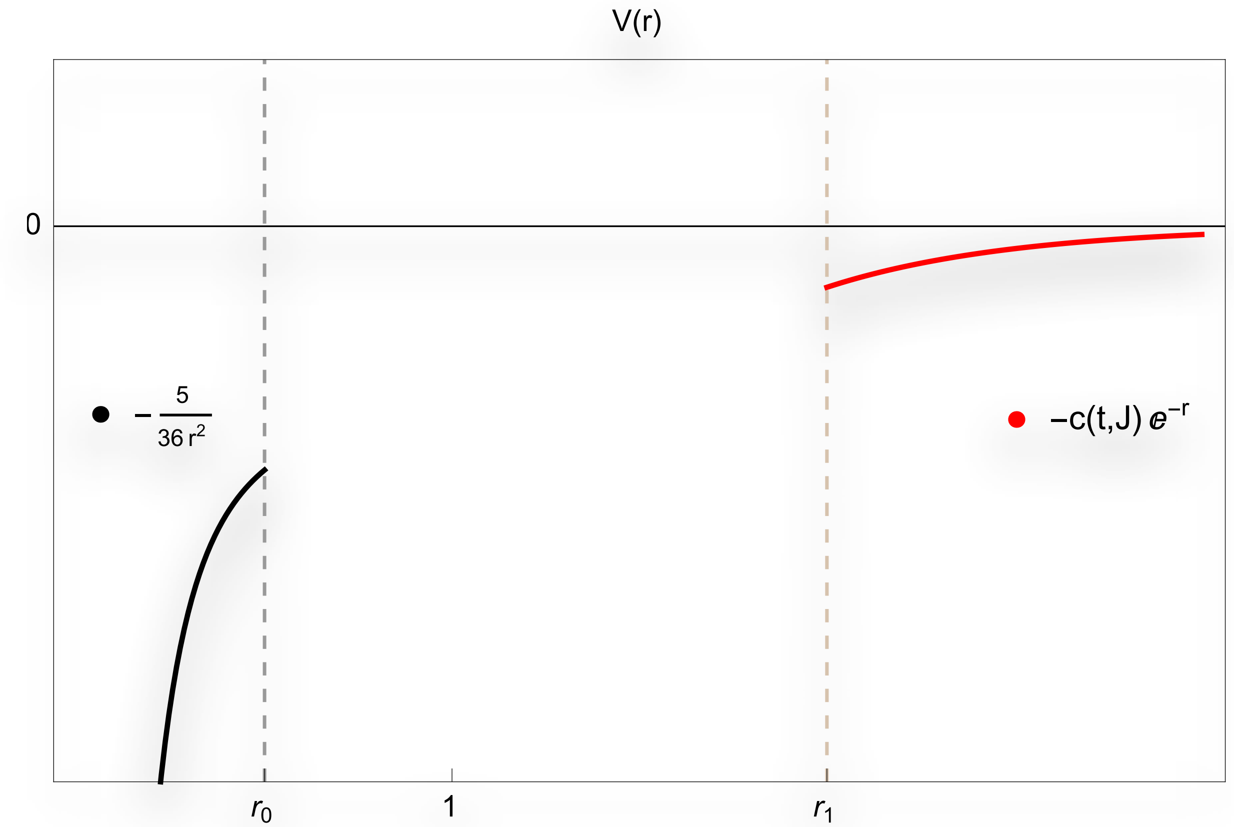


now we switch on fluctuations for the gauge field on top of the previous background configuration results (analytics)

Schrödinger problem & optical conductivity

linearized field equations

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



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

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

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

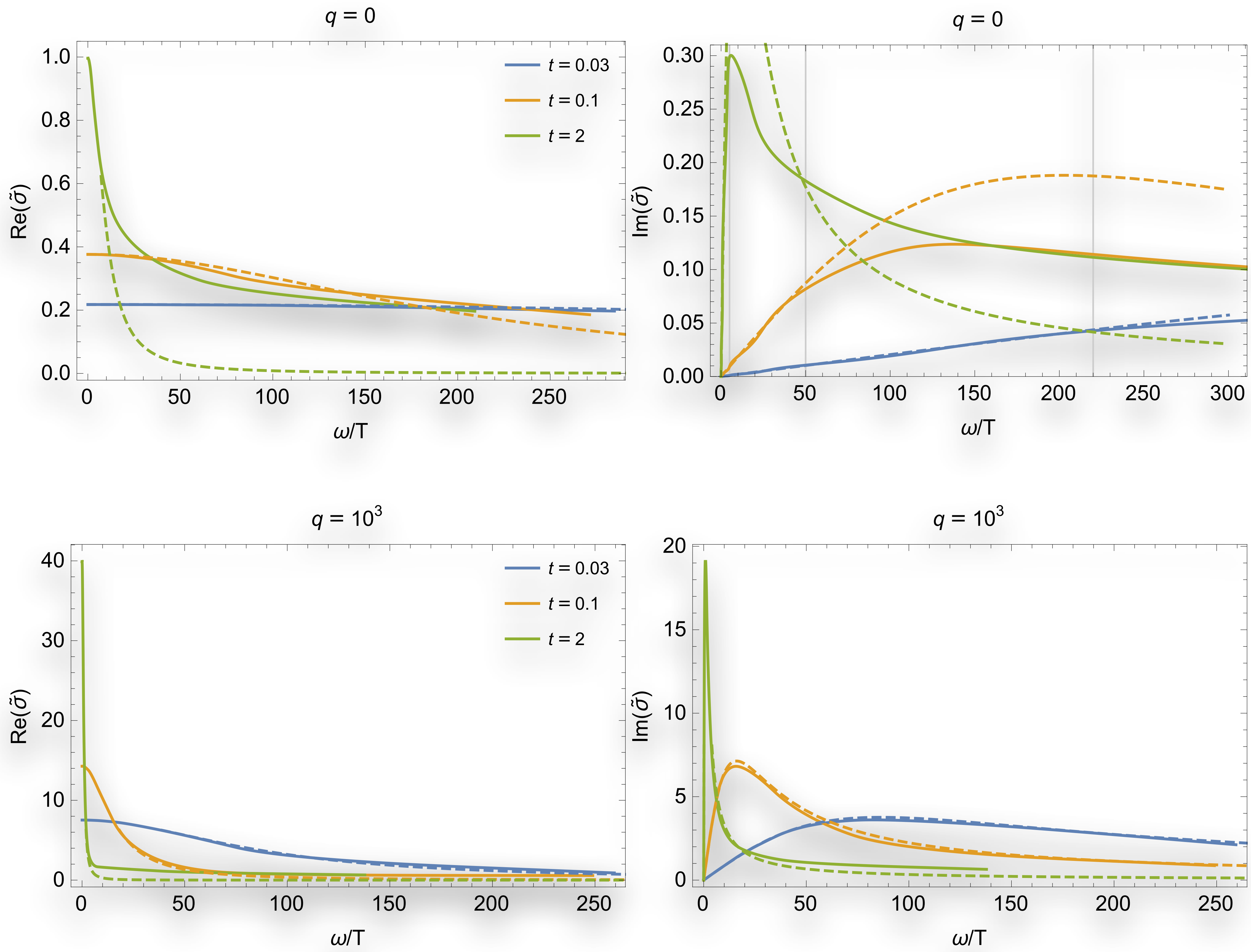
results (numerics)

Drude behavior

pair creation

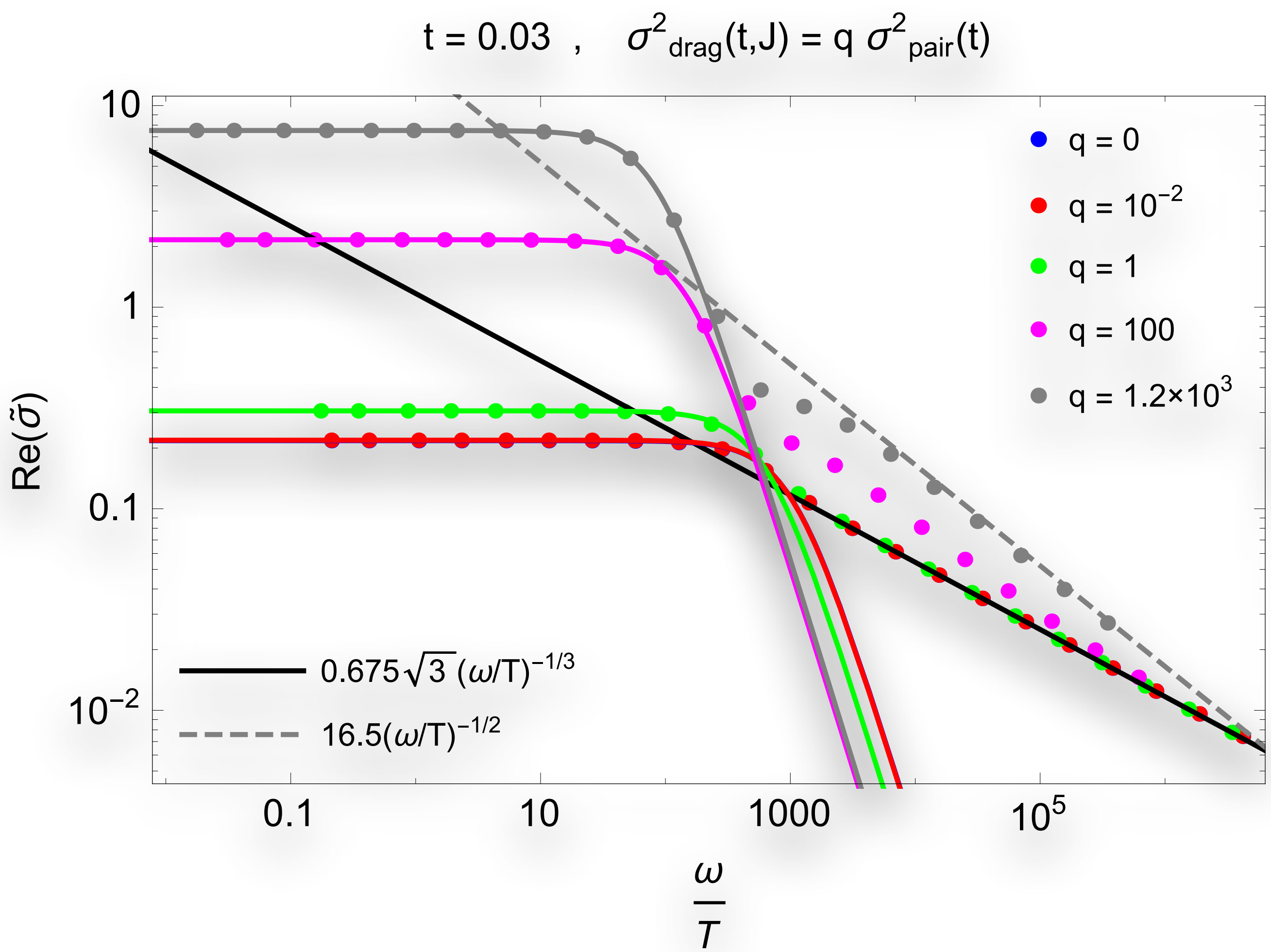
drag regime

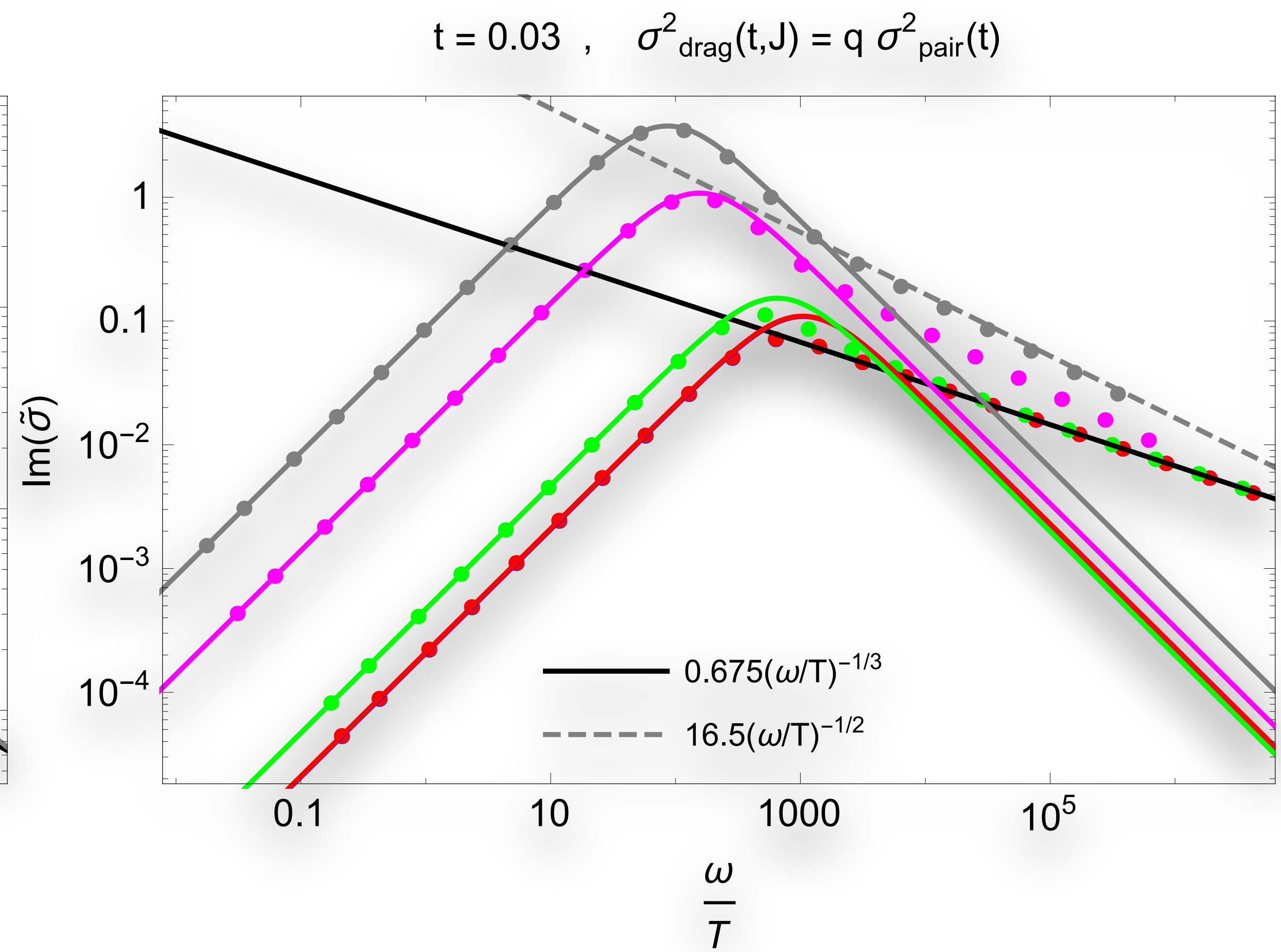
$$\sigma = \frac{\sigma_{DC}}{1 - i\tau\omega}$$



results (numerics)

full optical conductivity



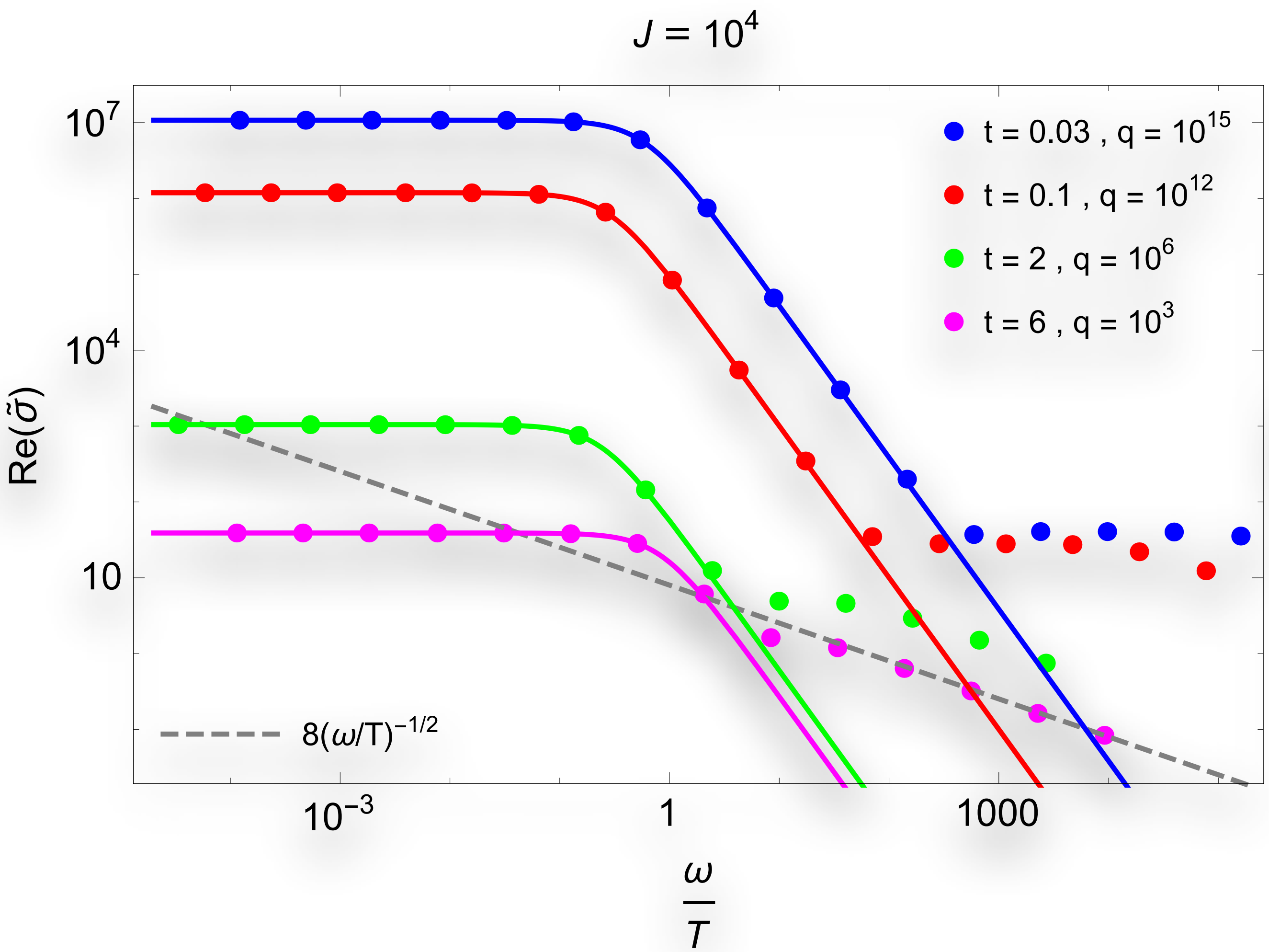


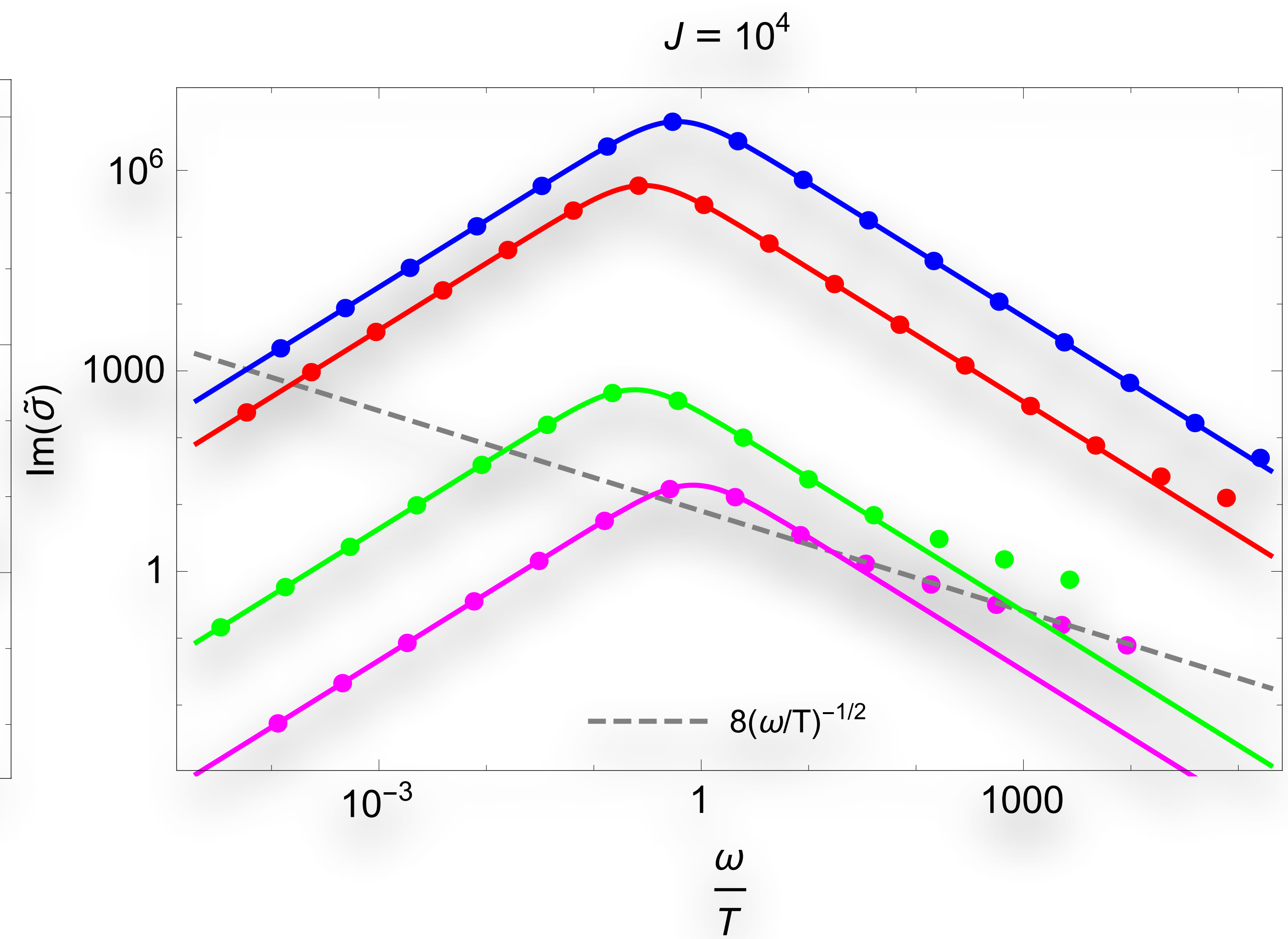
$\rho \sim t^{-3/2}$ blue red

$\rho \sim t$ 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 violting
hyper scaling and with Lifshitz exponent

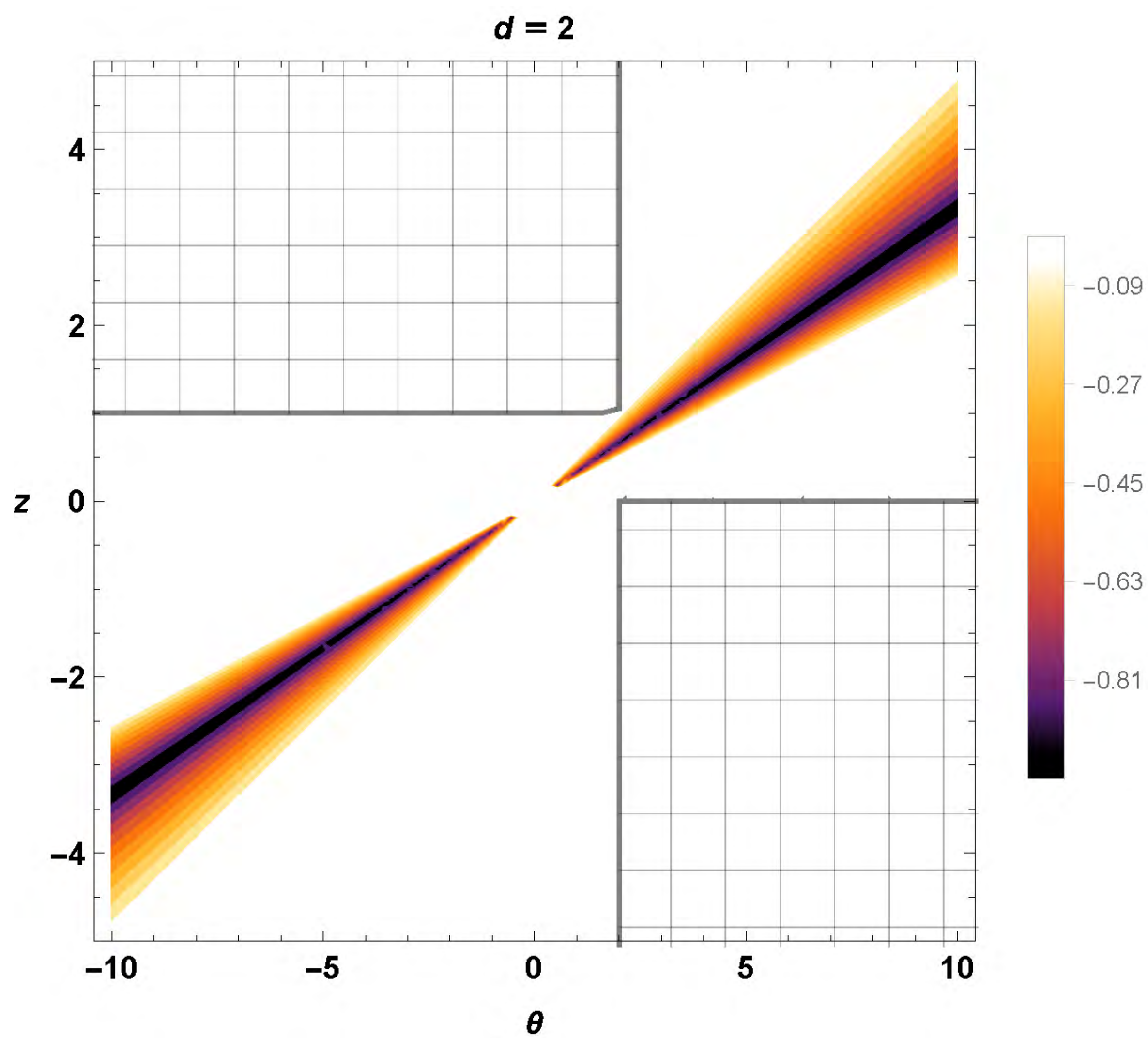
$$S \sim \int \sqrt{-g}\left[R - \frac{1}{2}(\partial\phi)^2 + V(\phi) - \frac{Z_1(\phi)}{4}F_1^2 - \frac{Z_2(\phi)}{4}F_2^2\right]$$

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

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

conductivity for uncharged gauge field

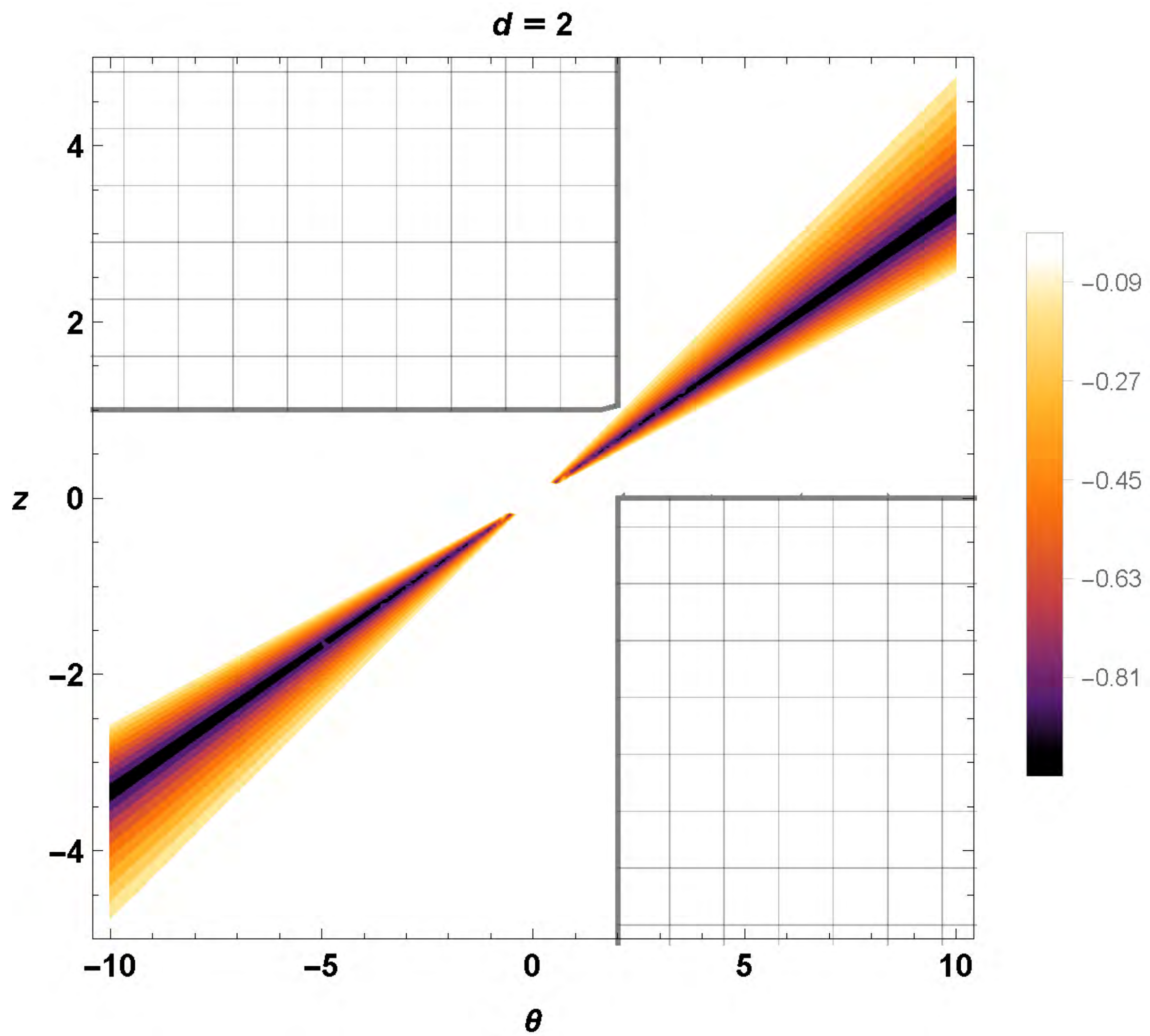
$$Z_2 = 0$$



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

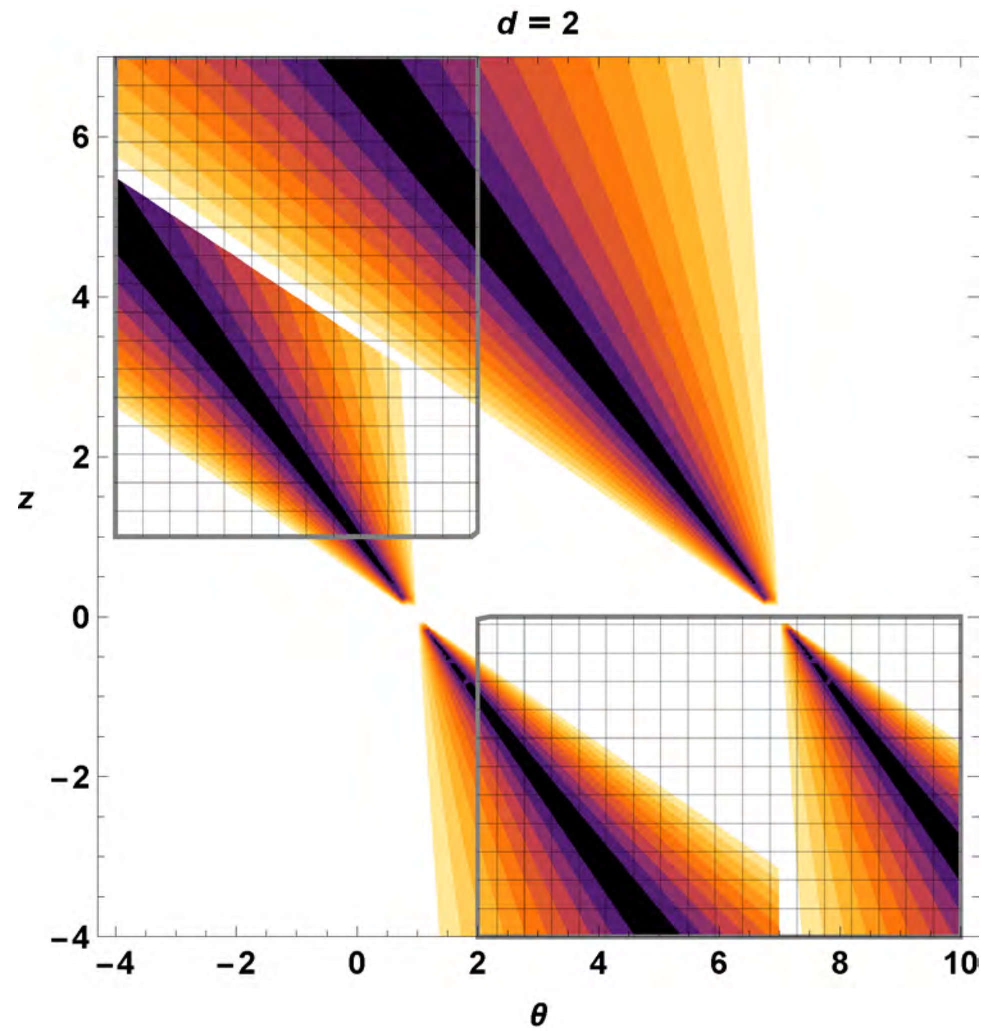
$$m = \left| 3 - \frac{2}{z} + \frac{d-\theta}{z} \right| - 1$$

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?

This research has been co-financed by the European Union (European Social Fund, ESF) and Greek national funds through the Operational Program "Education and Lifelong Learning" of the National Strategic Reference Framework (NSRF), under the grants schemes "Funding of proposals that have received a positive evaluation in the 3rd and 4th Call of ERC Grant Schemes" and the program "Thales"