Title: Holographic insights into quantum critical transport: from branes to Bose-Hubbard

Date: May 08, 2013 11:45 AM

URL: http://pirsa.org/13050037

Abstract: We discuss the general features of charge transport of quantum critical points described by CFTs in 2+1D. Our main tool is the AdS/CFT correspondence, but we will make connections to standard field theory results and to recent quantum Monte Carlo data. We emphasize the importance of poles and zeros of the response functions. In the holographic setting, these are the discrete quasinormal modes of a black hole/brane; they map to the excitations of the CFT. We further describe the role of particle-vortex or S-duality on the conductivity, which is argued to obey two powerful sum rules.
References (with S. Sachdev): arXiv:1210.4166 (PRB 12); arXiv:1302.0847 (PRB 13)

★Use AdS/**CFT** & other tools to gain insight into **finite-*T*** correlators of CFTs in 2+1D

QCPs with Lorentz invariance, $z = 1$ (often a CFT)

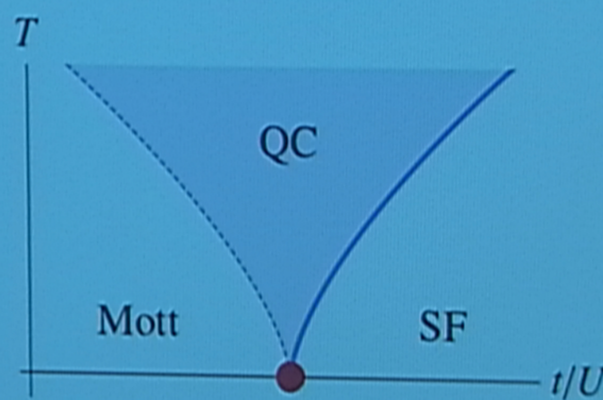
- Dynamics of systems w/out quasiparticles...

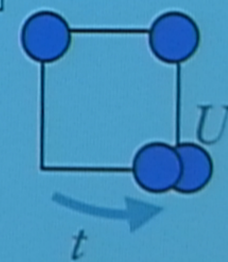

AdS/
CFT
pert.
QFT

Bose-Hubbard in 2+1

$$\boxed{H = -t\sum_{\langle i,j\rangle} b_i^\dagger b_j + U\sum_i n_i(n_i-1) - \mu\sum_i n_i}$$

$\langle n_i \rangle = 1$





QCP = **CFT$_3$**

- SSB of O(2) order parameter

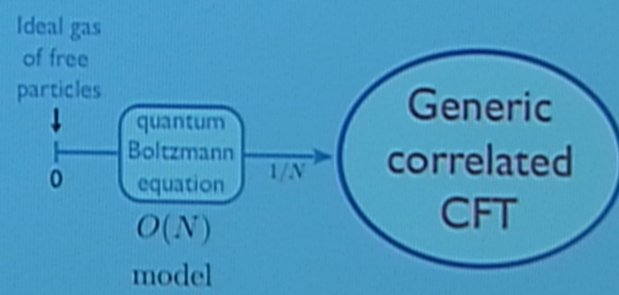
Vector large-N

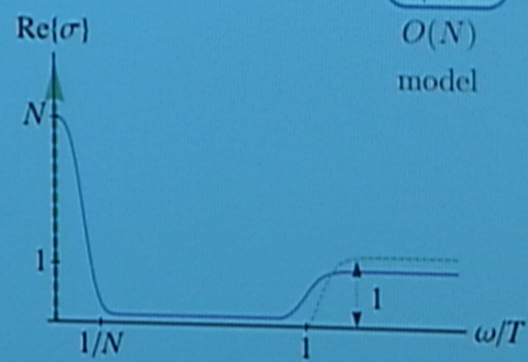
- Finite-T dynamics in QC region = hard problem!
  strongly corr → no sharp qp's → ~~qu Boltzmann~~

- O(2) → O(N) & take $N \gg 1$

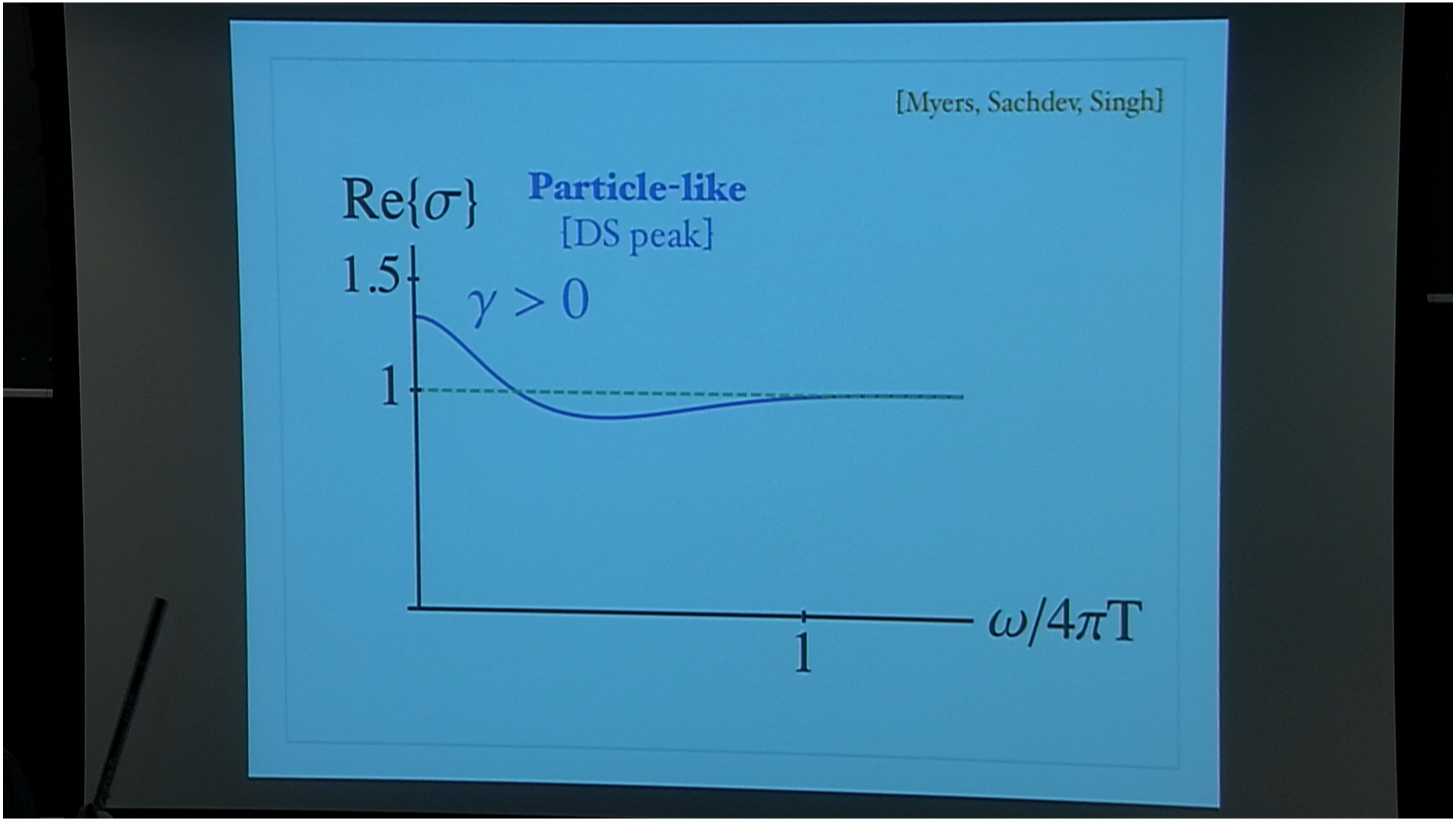
  - N=∞ : **free**

- Conductivity σ(ω/T)





[Damle, Sachdev]



[Myers, Sachdev, Singh]
Re{σ}
Particle-like
[DS peak]
1.5
γ > 0
1
1
ω/4πT

“Particle-vortex” (S) duality

- **CFT**: $\sigma \to 1/\sigma$
- **Gravity**: Electric-Magnetic duality for A_μ

❖ $\gamma = 0$: self-dual!

❖ $\gamma \neq 0$: $\boxed{\text{S-duality} \sim (\text{flip sign of } \gamma)}$

❖ S-duality on QNMs: pole $\leftrightarrow$ zero

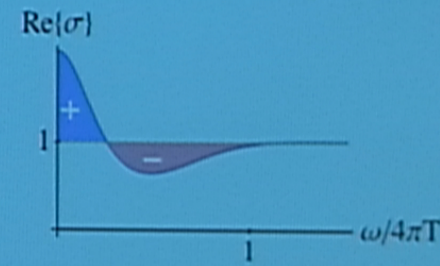
❖ **Particle**-like σ: D-**pole** $(\gamma > 0)$
Vortex-like σ: D-**zero** $(\gamma < 0)$

[Herzog *et al*; Myers, Sachdev & Singh]

Sum-rules

[Gulotta, Herzog & Kaminski;
WWK & Sachdev]

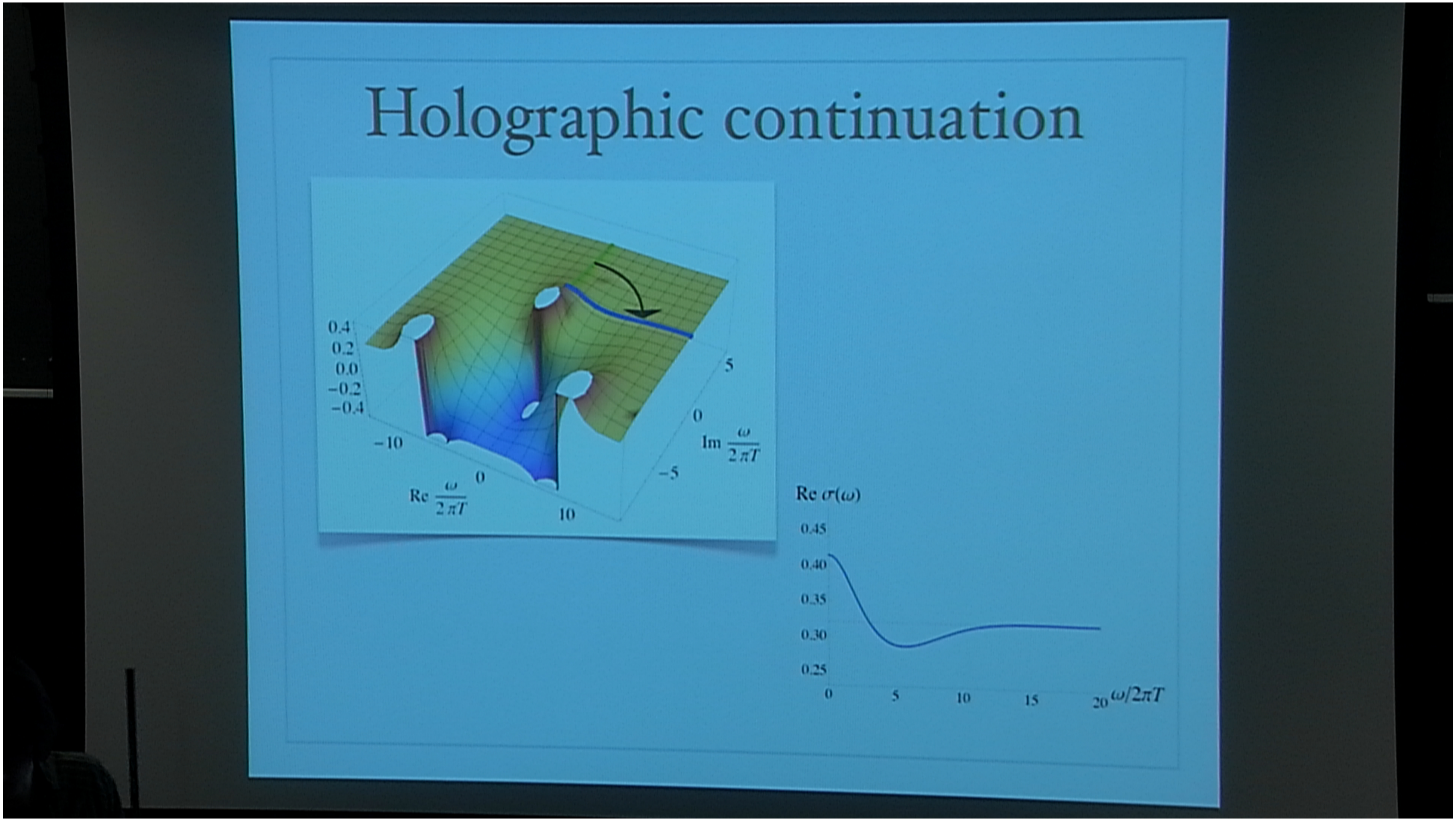
$$\boxed{\int_0^\infty d\omega\,[\mathrm{Re}\,\sigma(\omega/T) - \sigma(\infty)] = 0}$$



Quantum Monte Carlo

WWK, **E. Sorensen** & S. Sachdev, in prep.

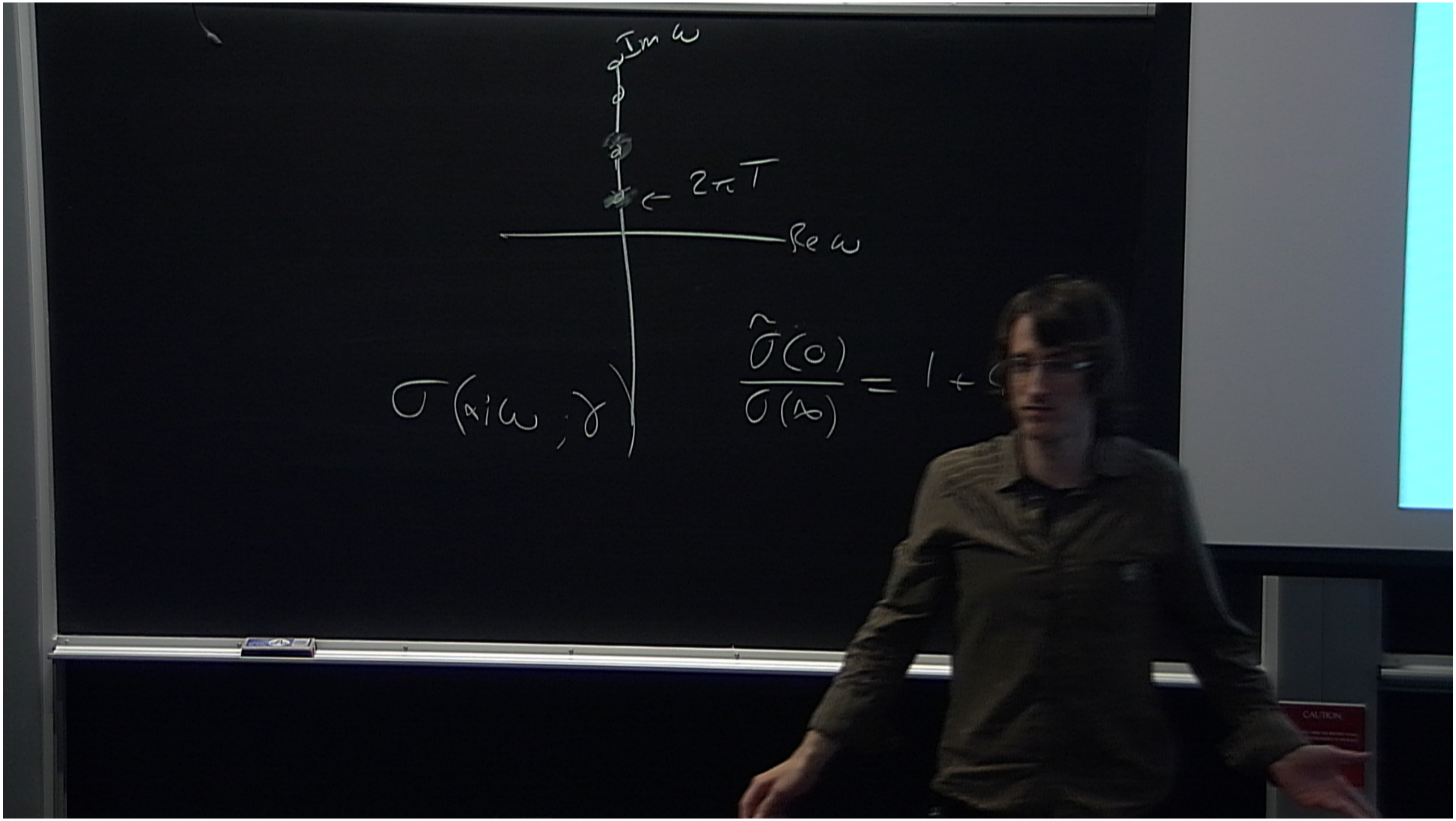
- Use AdS/CFT to analyze high precision numerical data
- QMC simulation of 2+1D quantum rotor model; QCP in same universality as Bose-Hubbard
- Finite-T but **imaginary time**...


Holographic continuation
0.4
0.2
0.0
−0.2
−0.4
−10
0
10
Re $\frac{\omega}{2\pi T}$
5
0
−5
Im $\frac{\omega}{2\pi T}$
Re $\sigma(\omega)$
0.45
0.40
0.35
0.30
0.25
0
5
10
15
20
$\omega/2\pi T$

Conclusions

- Conductivity of CFT in 2+1D: $\sigma(\omega/T)$
- AdS/CFT sheds non-perturbative light on the problem:
  - **Quasi-normal modes**: poles/zero at complex ω
  - Sum rules

★ AdS/CFT is useful to interpret **Quantum Monte Carlo** data => sharp statements about the Bose-Hubbard etc


Im ω
← 2πT
Re ω
σ(xiω; γ)
σ̃(0) / σ(∞) = 1 +