Thermalization in a (Holographic) Confining Gauge Theory

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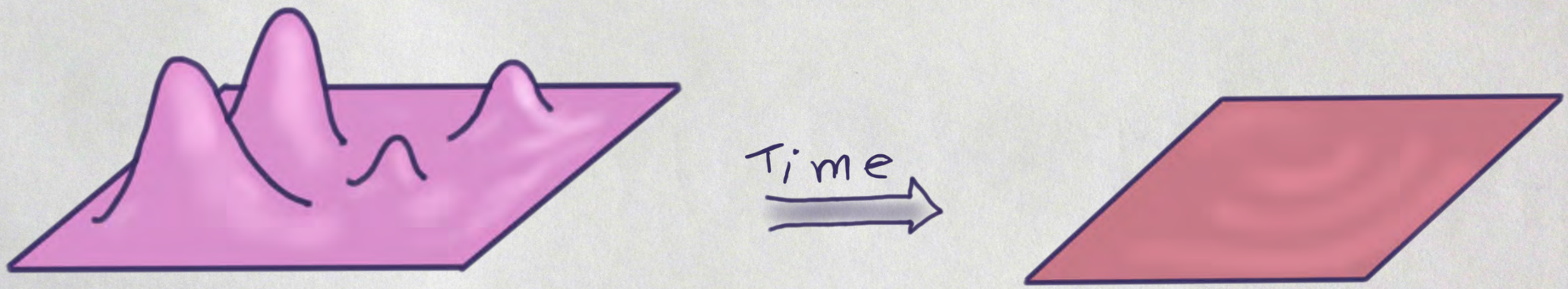
with T. Ishii and E. Kiritsis

[1503.07766]

Thermalization?

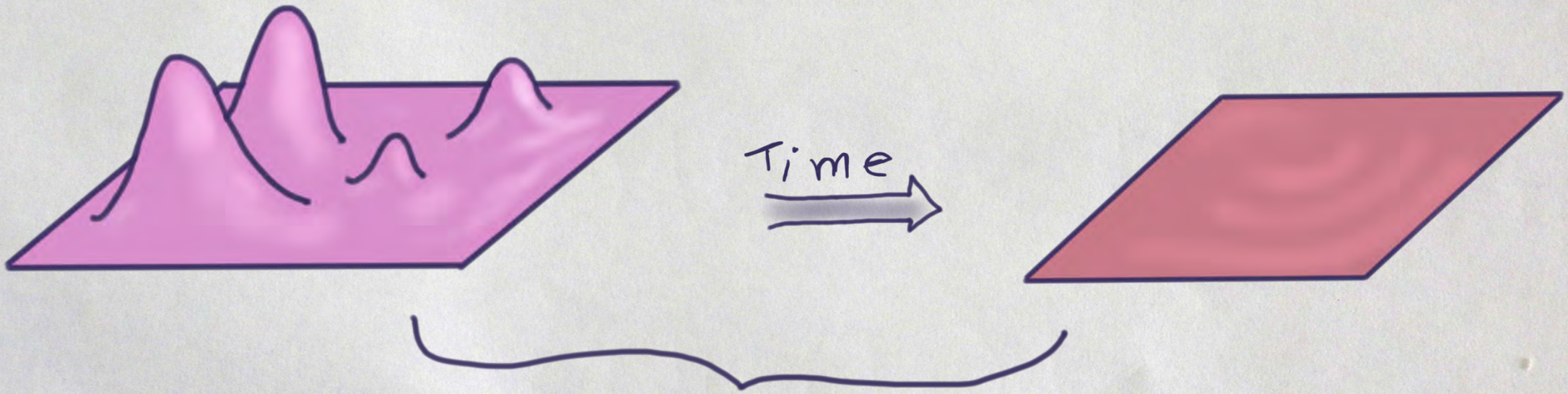
How do strongly coupled field theories equilibrate?



$$\mathcal{L}_{QFT} + f_o(t)\mathcal{O} \Rightarrow \nabla^t \langle T_{tt} \rangle = \dot{f}_o \langle \mathcal{O} \rangle$$

Thermalization?

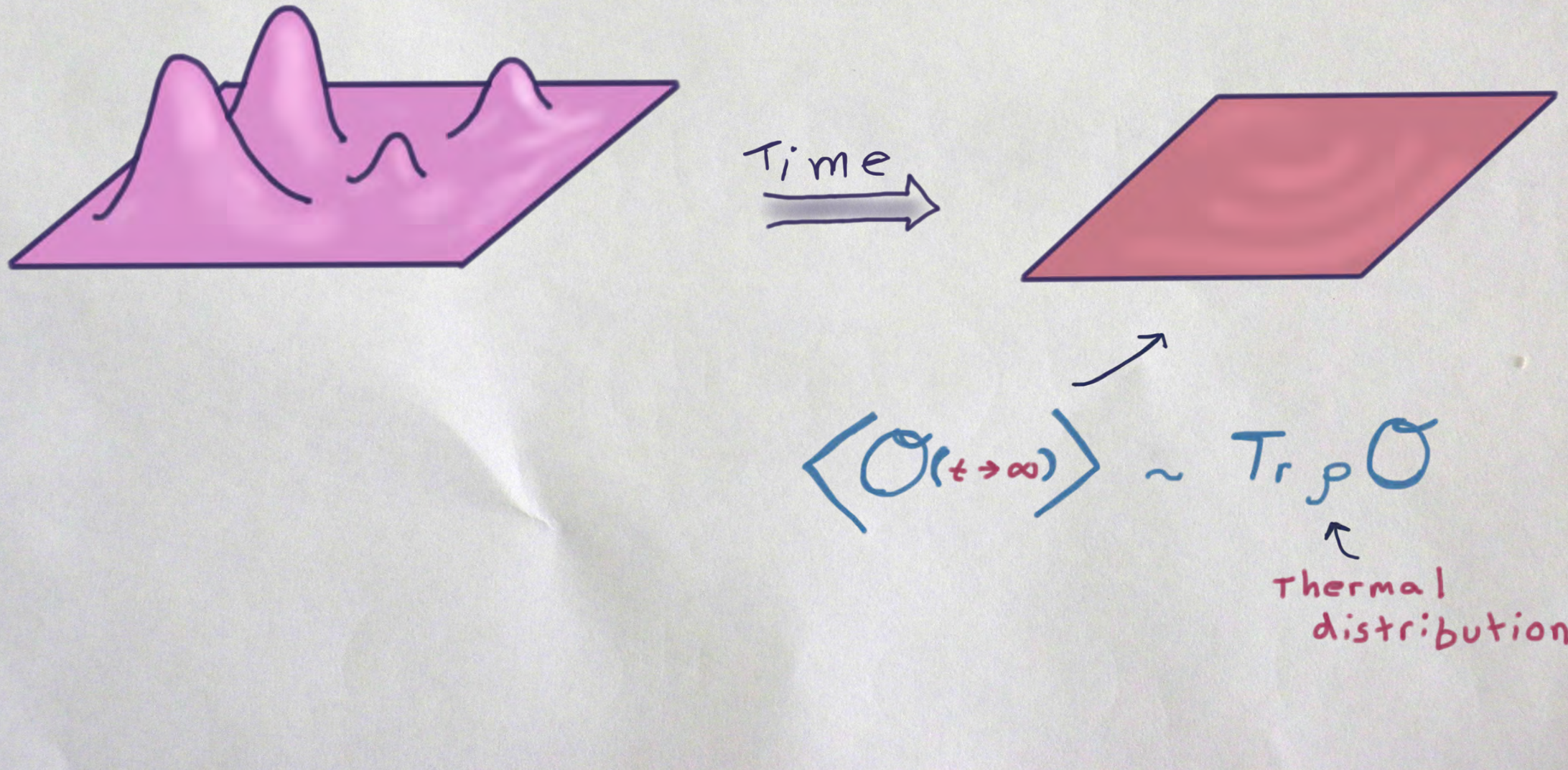
How do strongly coupled field theories equilibrate?



$\langle T_{ij}(t) \rangle$, $\langle \mathcal{O}(t) \rangle$, ...

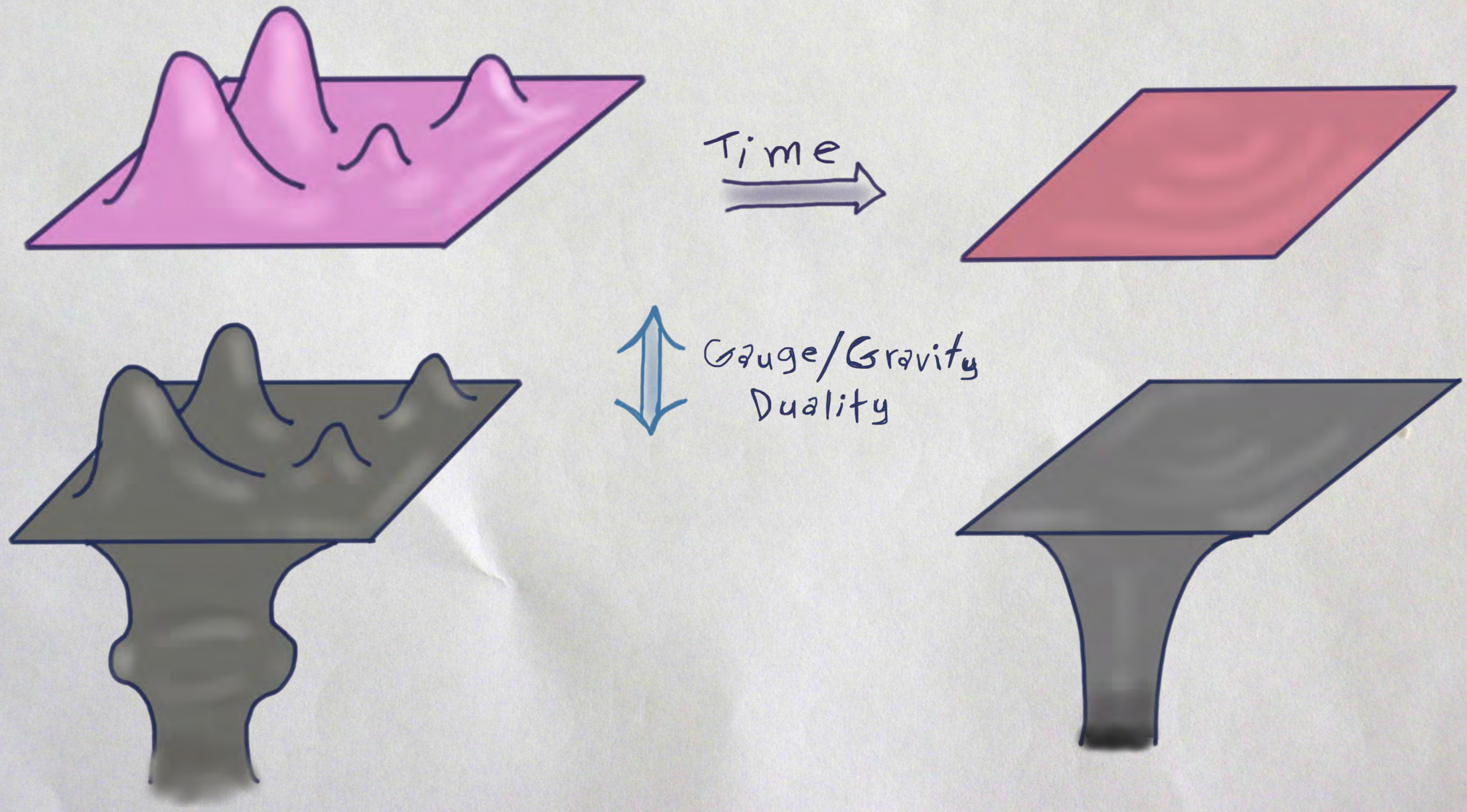
Thermalization?

How do strongly coupled field theories equilibrate?



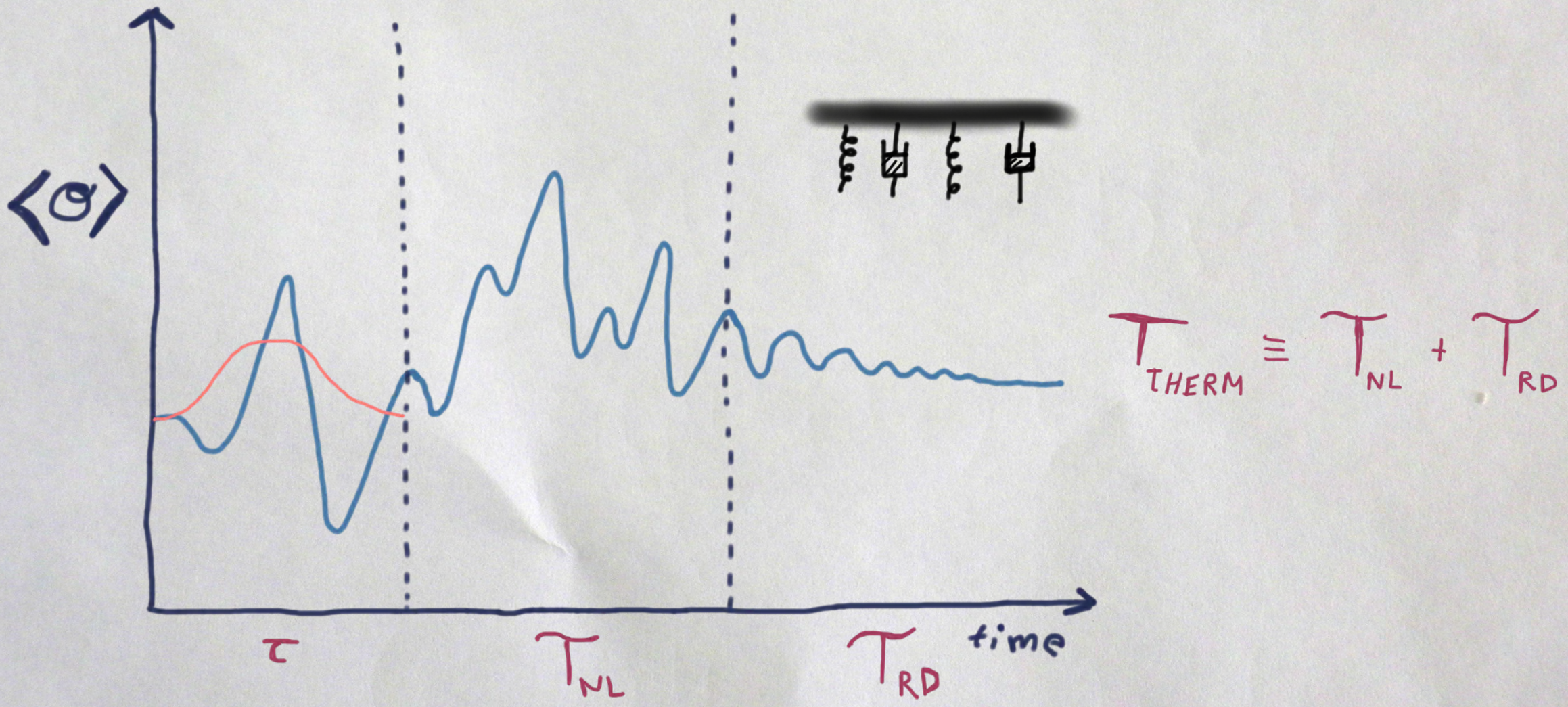
Holographic?

Dynamical properties of strongly interacting matter are difficult to compute



Holographic?

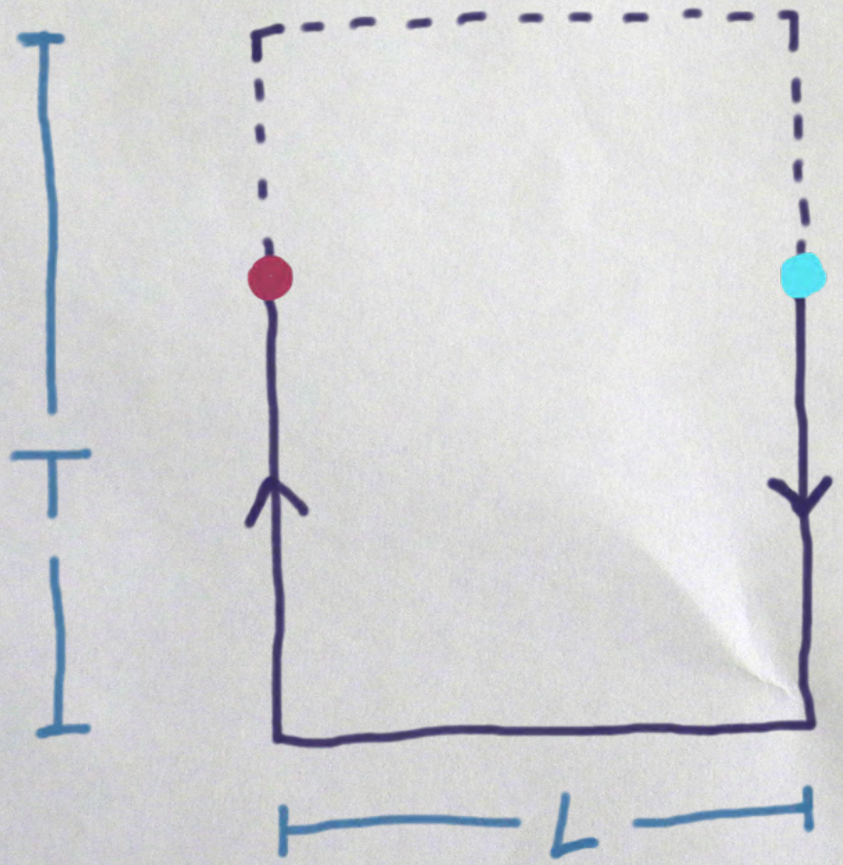
Gravitationally inspired expectations:



Confining?

Gauge Theory

Wilson Loop is Confinement diagnostic



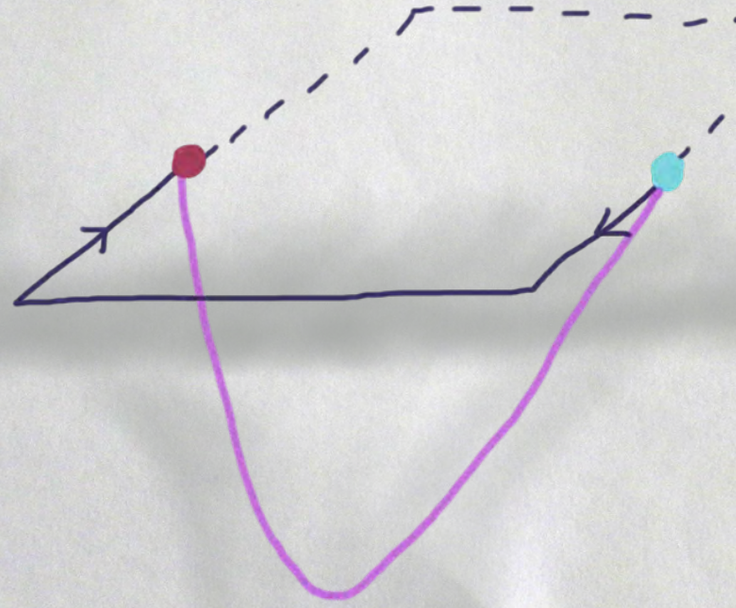
$$\langle W(c) \rangle \sim e^{-T V_{\bar{q}q}}$$

Area Law $\rightarrow$ $V_{\bar{q}q} \sim F_s L$

Confining?

Holography

Wilson Loop is Confinement diagnostic



$$\langle W(c) \rangle \sim e^{-S}$$

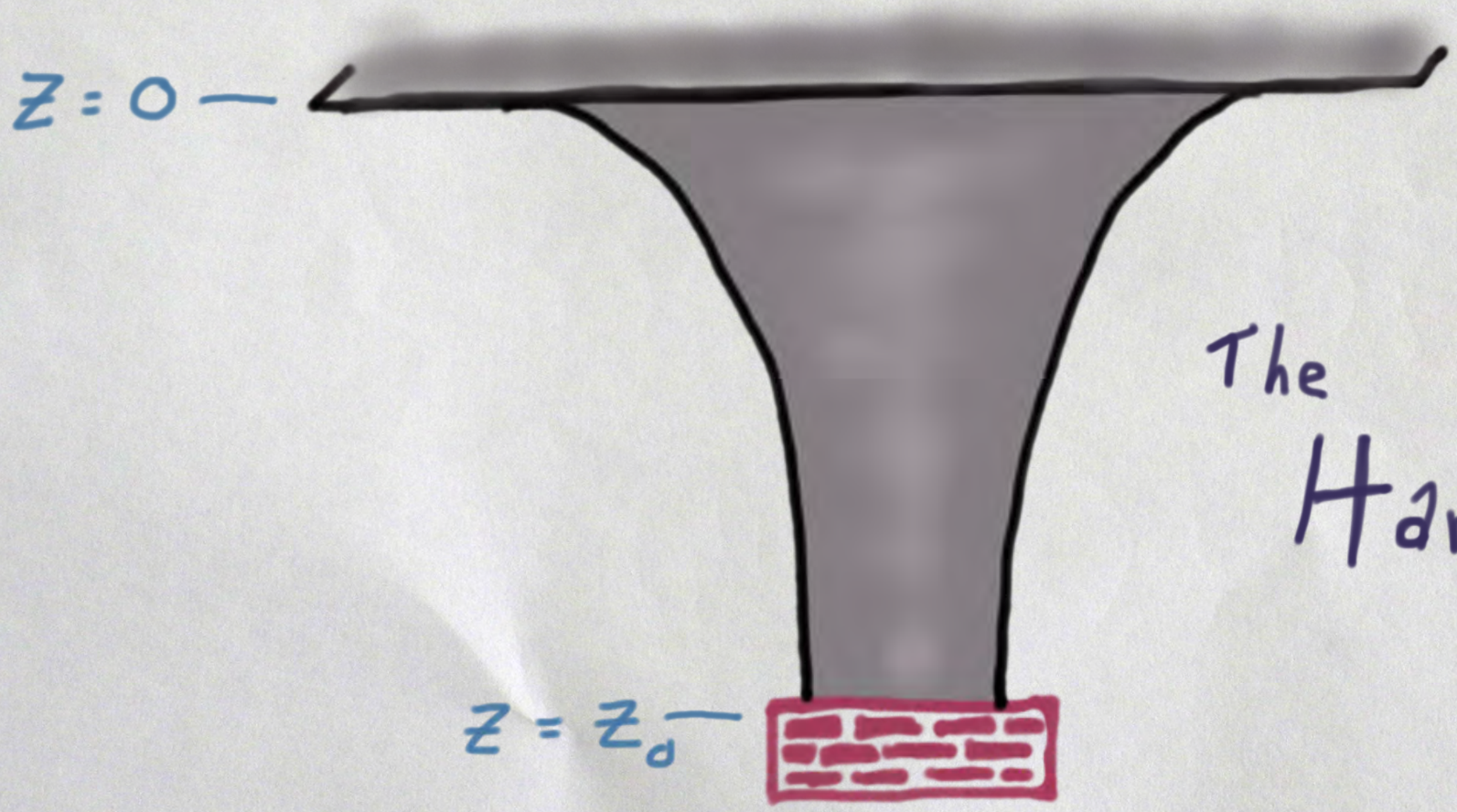
$$S \sim T \cdot \frac{1}{2\pi\alpha'} \cdot e^{2\hat{A}(z_0)} L$$

'cap to gap'

$$ds^2 = e^{2\hat{A}(z)}\left(-dt^2 + d\vec{x}^2 + dz^2\right)$$

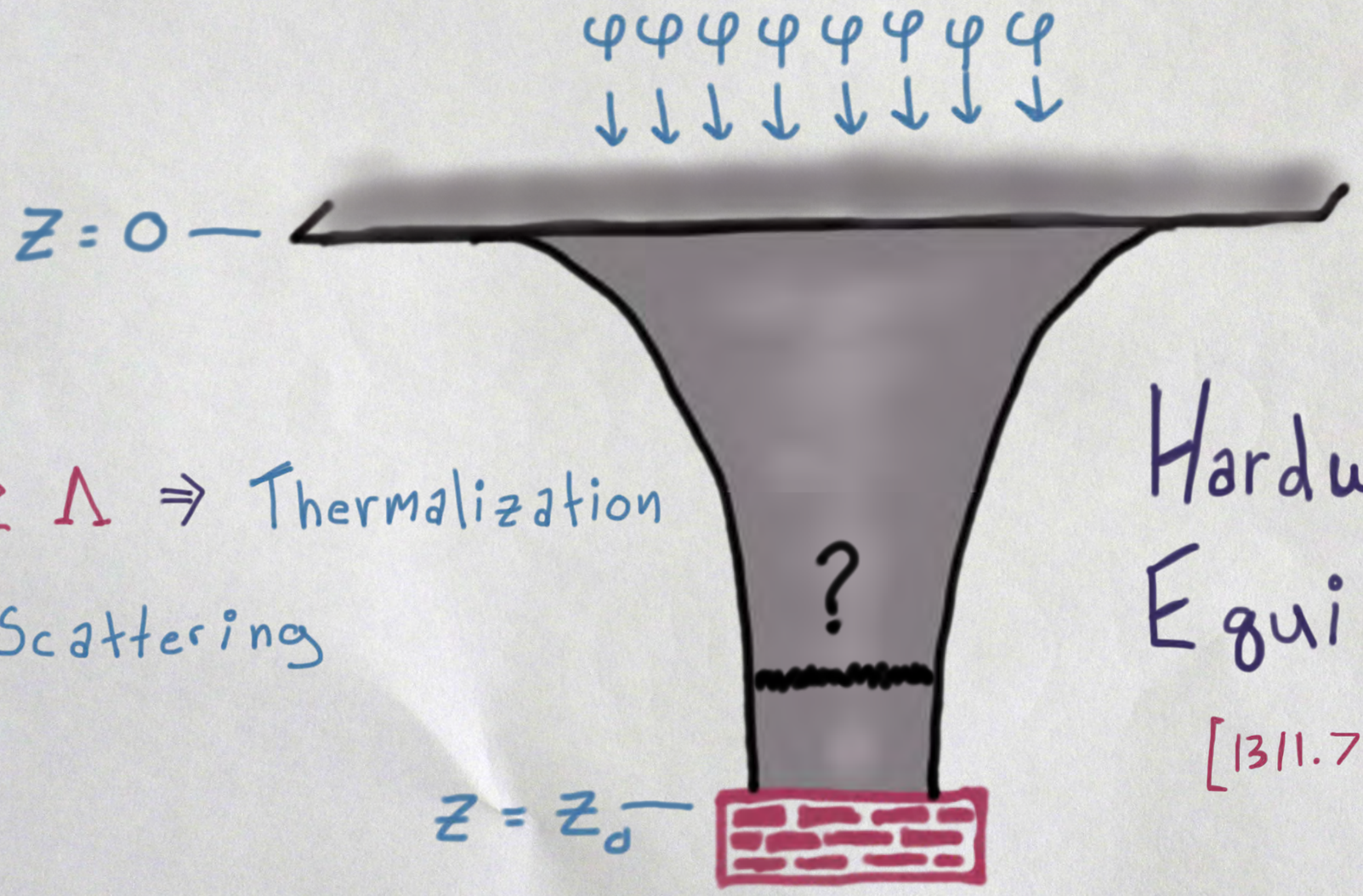
Confining?

mass gap: $\Lambda \sim \frac{1}{z_0}$



The Hardwall

Confining?



If

$T_{BH} \gtrsim \Lambda \Rightarrow$ Thermalization

Else Scattering

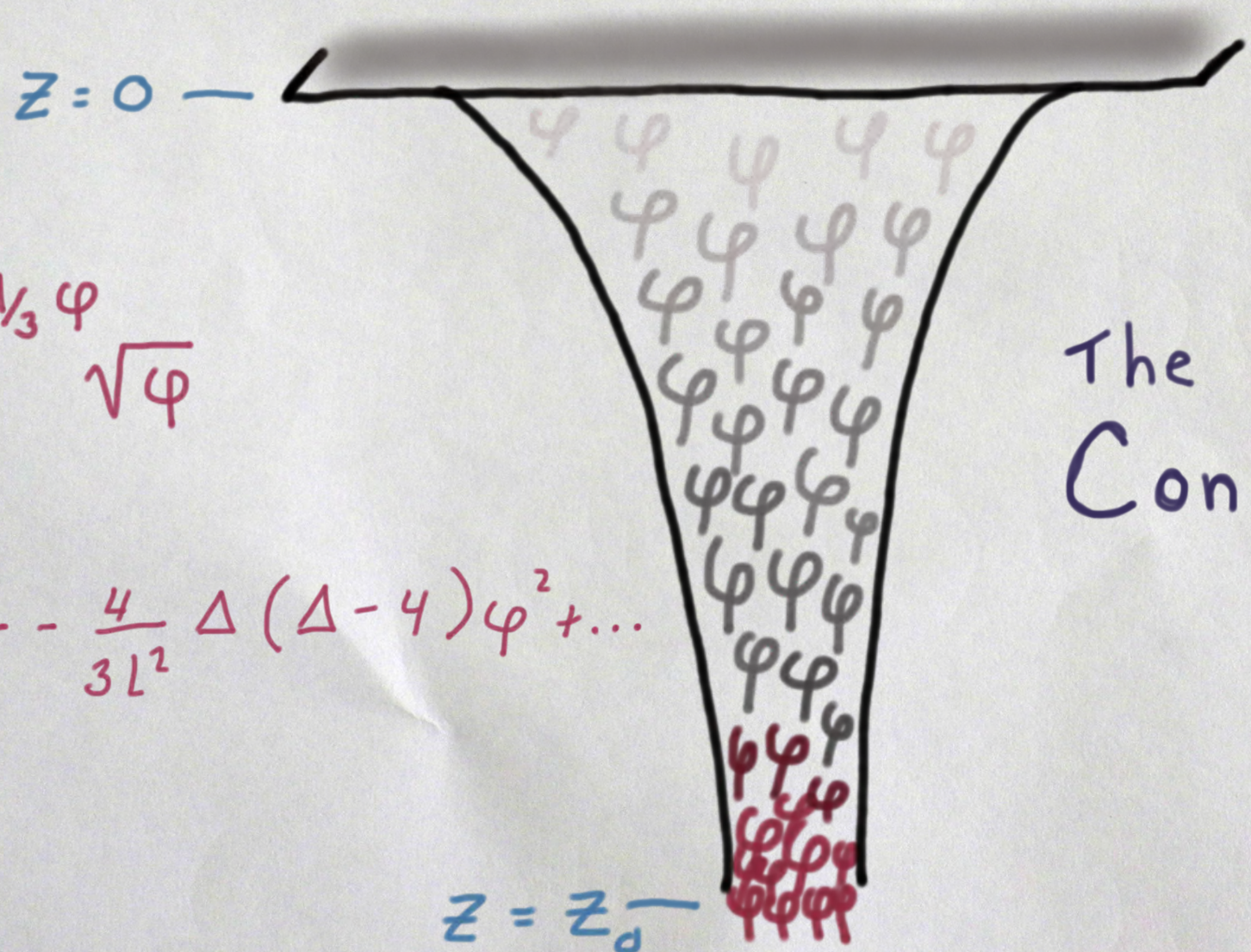
Hardwall

Equilibration

[1311.7650] [1406.1454]

Confining?

$$S = \frac{1}{2\kappa^2}\int d^5x\sqrt{-g}\left[R - \frac{4}{3}(\partial\varphi)^2 + V(\varphi)\right]$$



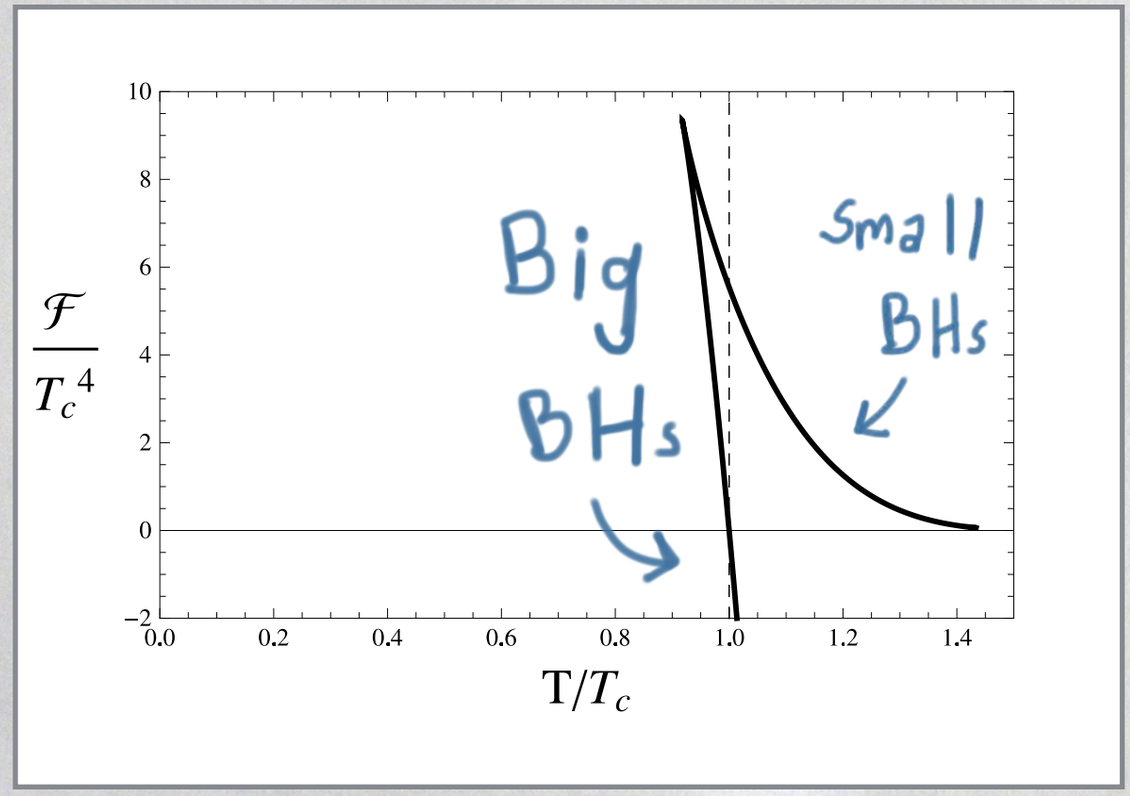
$$V_{IR} \sim e^{4/3\,\varphi}\sqrt{\varphi}$$

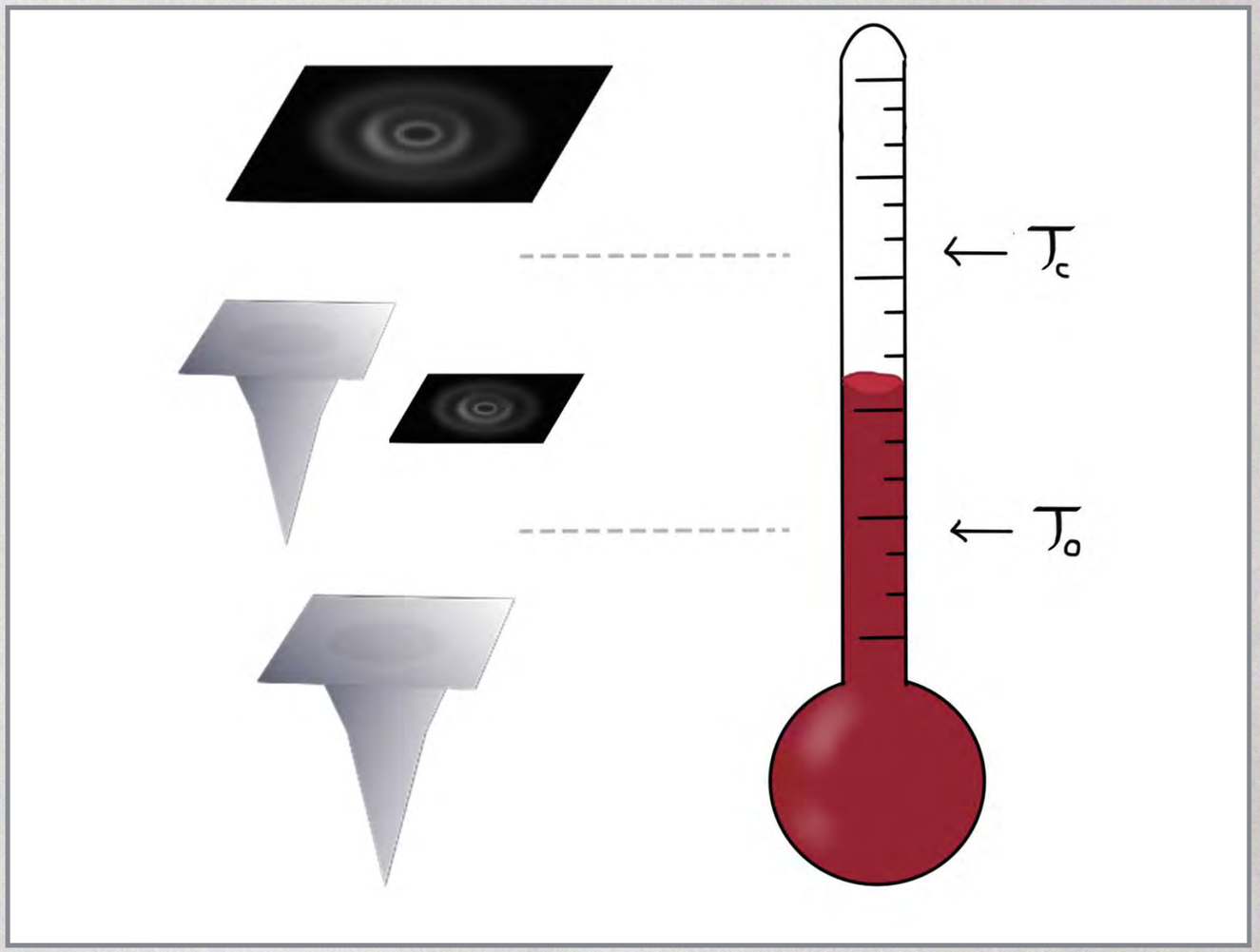
$$V_{UV} \sim \frac{12}{L^2} - \frac{4}{3L^2}\Delta(\Delta-4)\varphi^2 + \dots$$

The Confining E-D

Confining?

static Properties

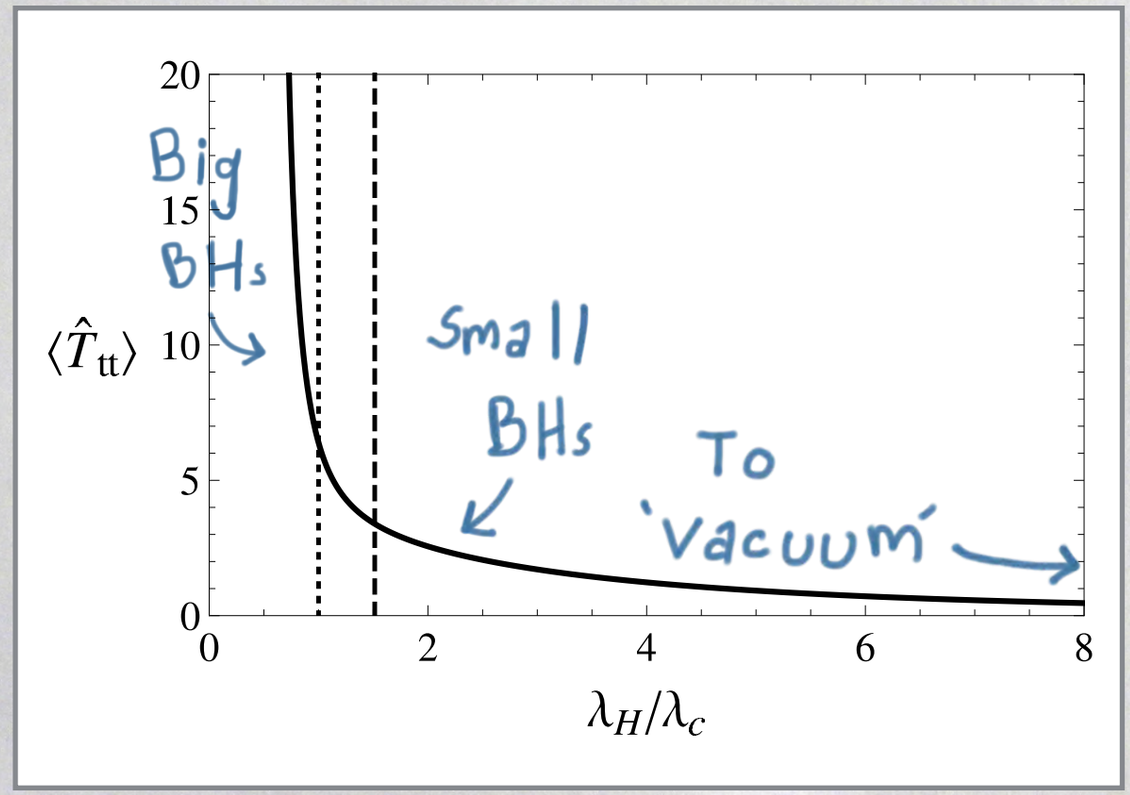


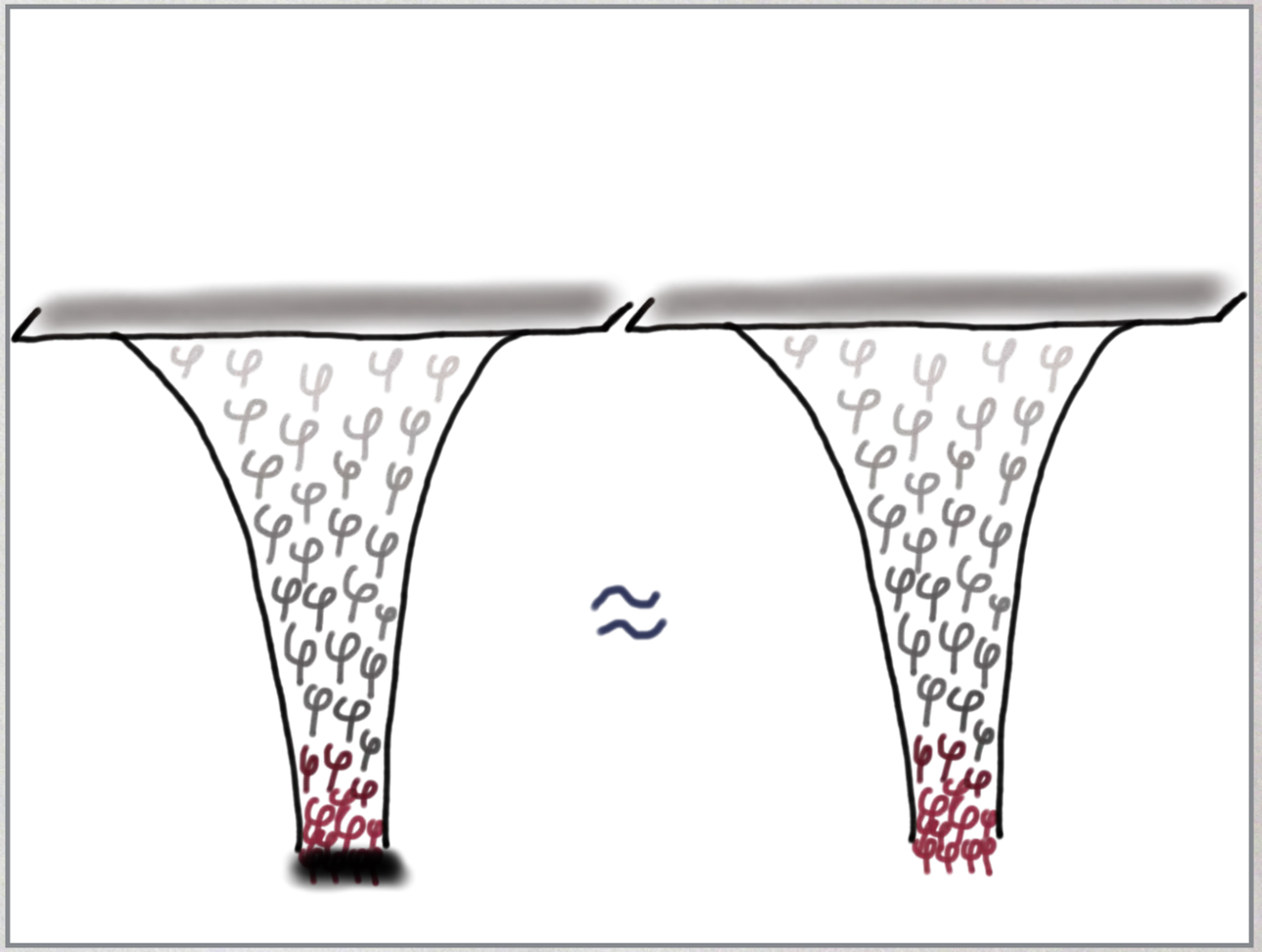


$$C_v = -T\frac{\partial^2 F}{\partial T^2} \Rightarrow$$ Small BHs locally unstable

Confining?

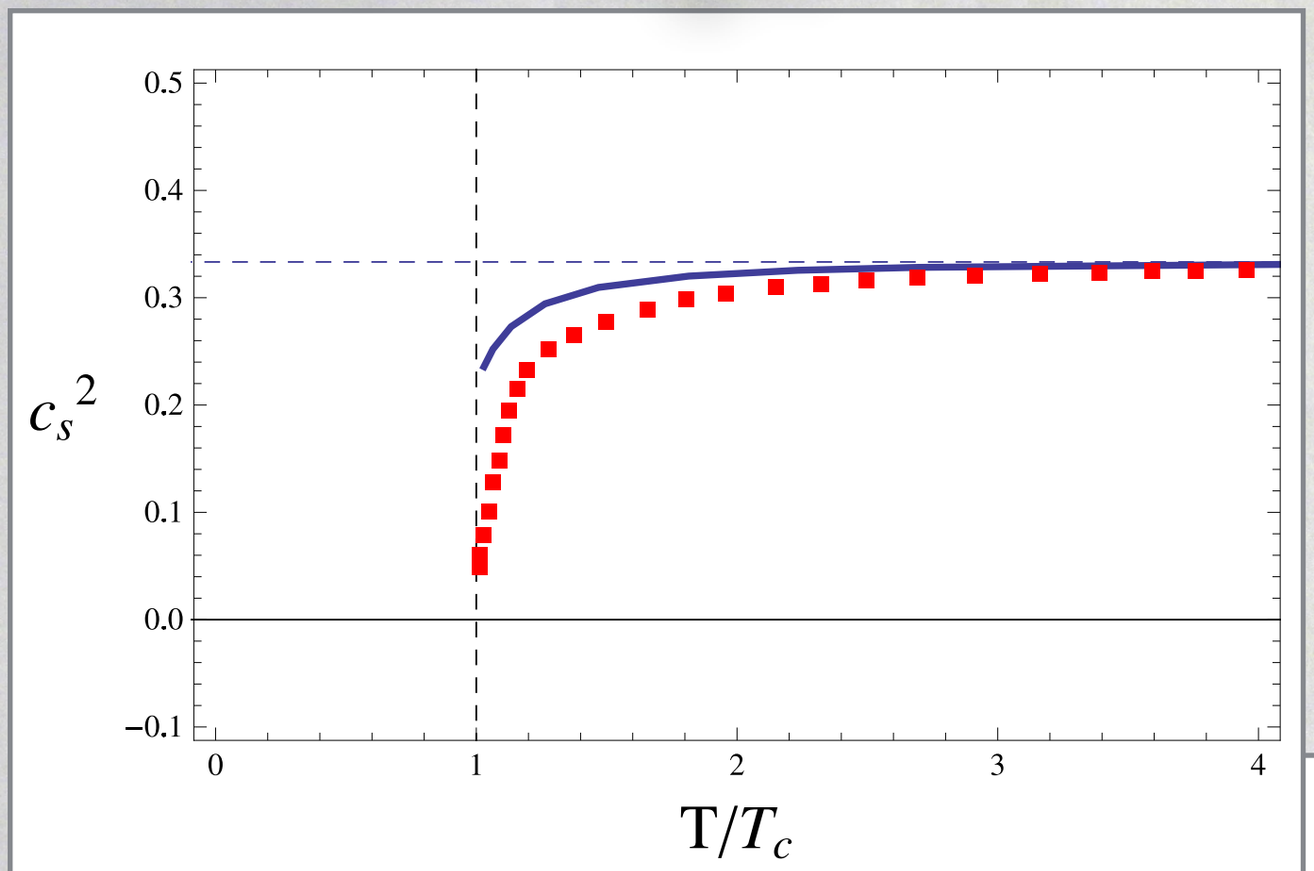
static Properties





Small BHs are asymptotically connected to vacuum solution

Confining?



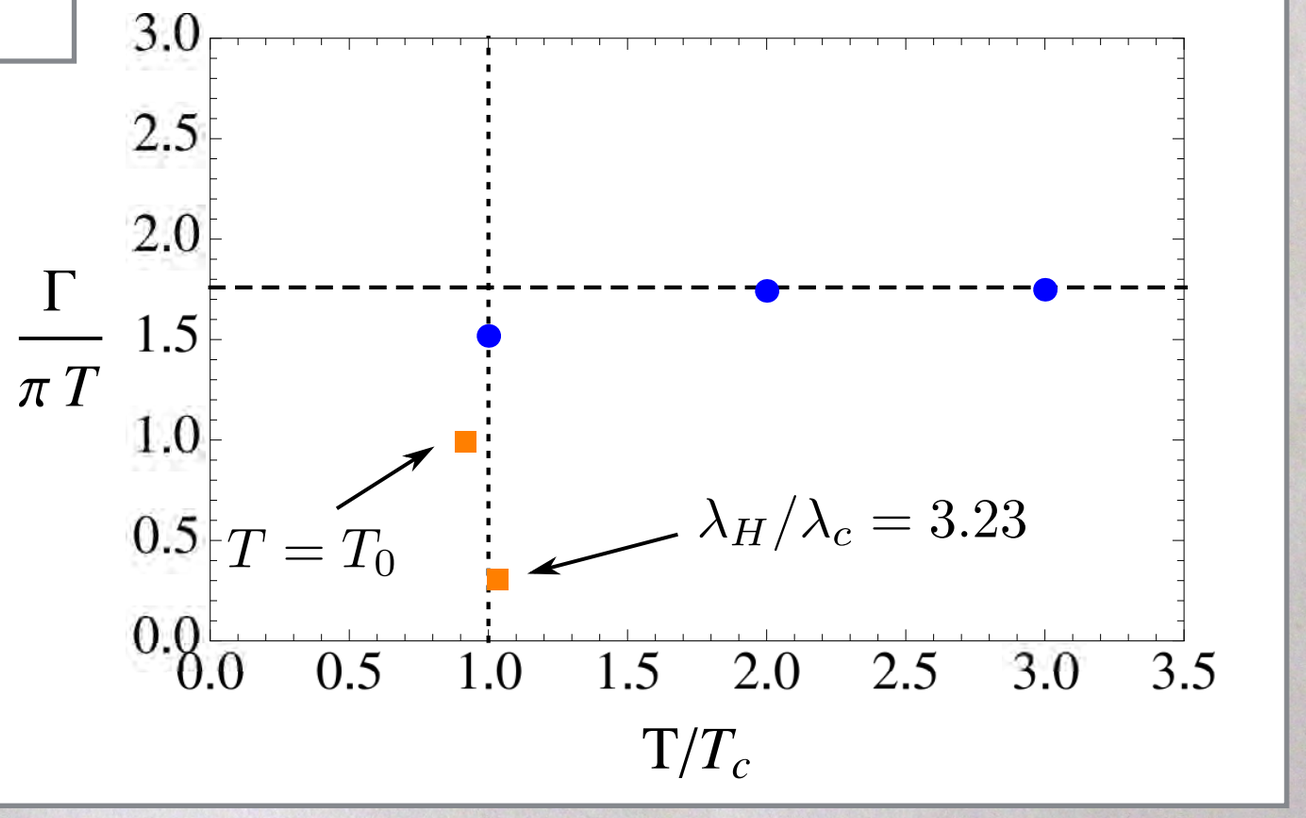
$$V(\varphi) = \frac{12\,(1+a\varphi^2)^{1/4}\cosh\frac{4}{3}\varphi - b\varphi^2}{L^2}$$

Parameters tuned towards "SU(3)-ish" glue

Lowest Lying QNM

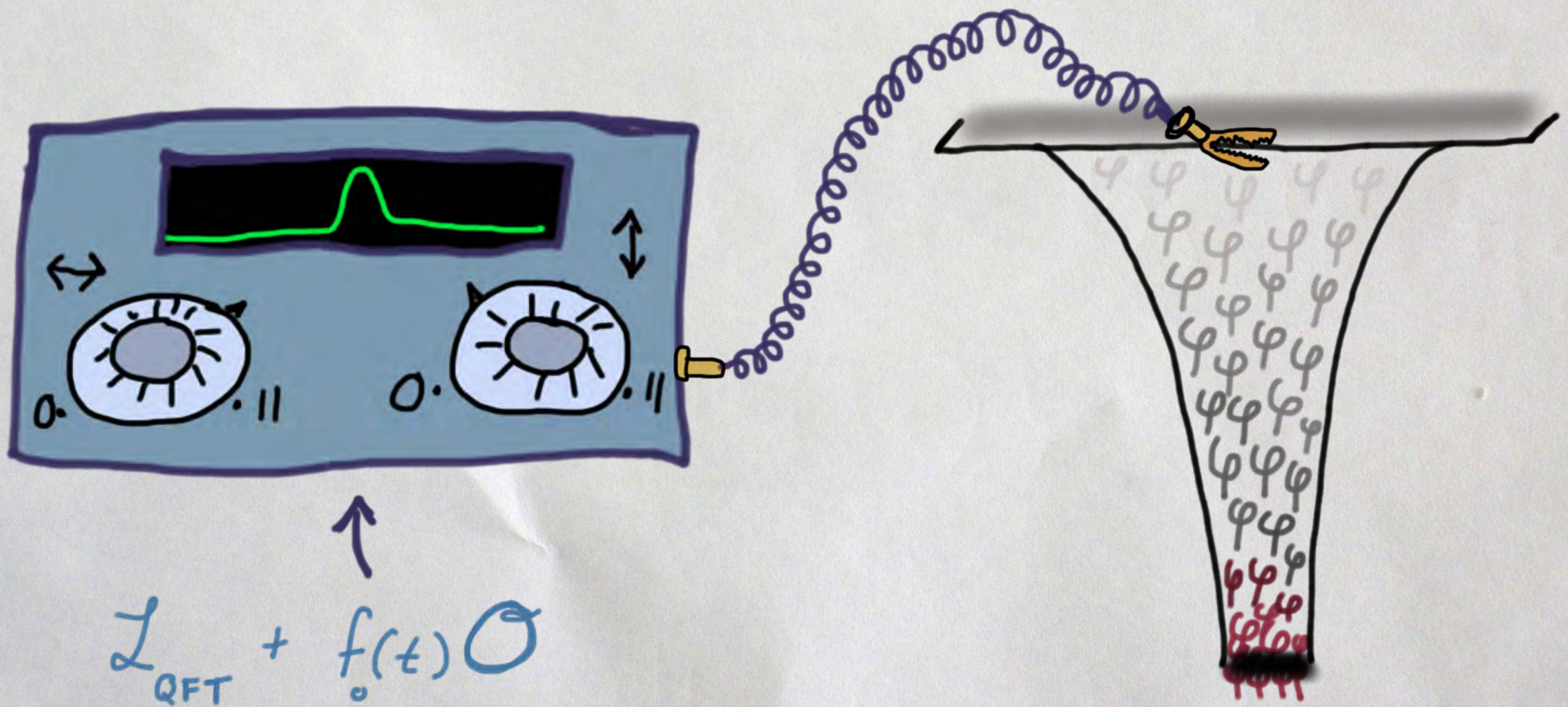
$$\varphi(x) \sim \varphi_s(z) + \delta\varphi(z)\,e^{-i\omega t}$$

$$\omega_{QNM} = \omega^* - i\Gamma$$



Plan of Attack

Heuristically



$$\mathcal{L}_{QFT} + f(t)\mathcal{O}$$

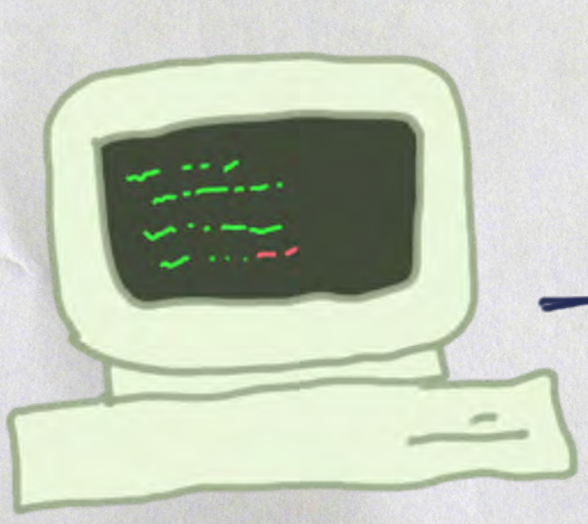
Plan of Attack

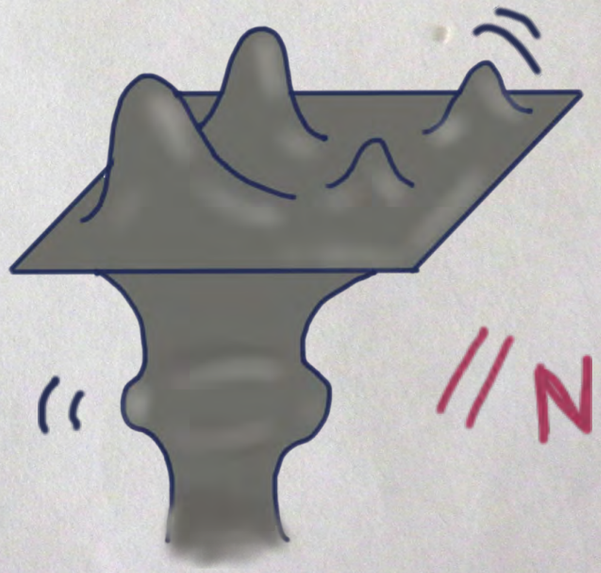
Actually

$$R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} = T_{\mu\nu}$$

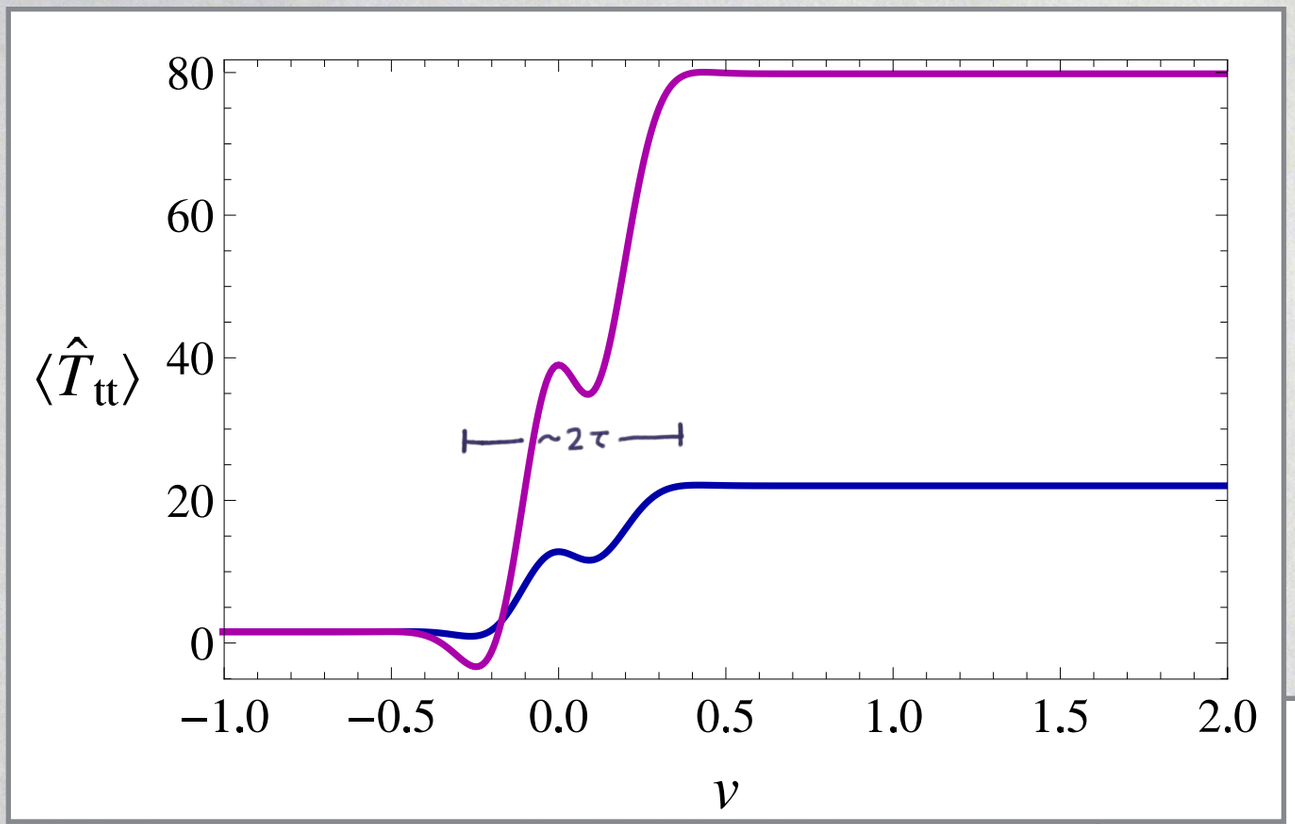
↳ $$ds^2 = -A\,dv^2 - \frac{2}{z^2}\,dv\,dz + \sum^2 d\vec{x}^2$$ (Characteristic formulation)

(Assorted finite difference schemes)





Quench Dynamics

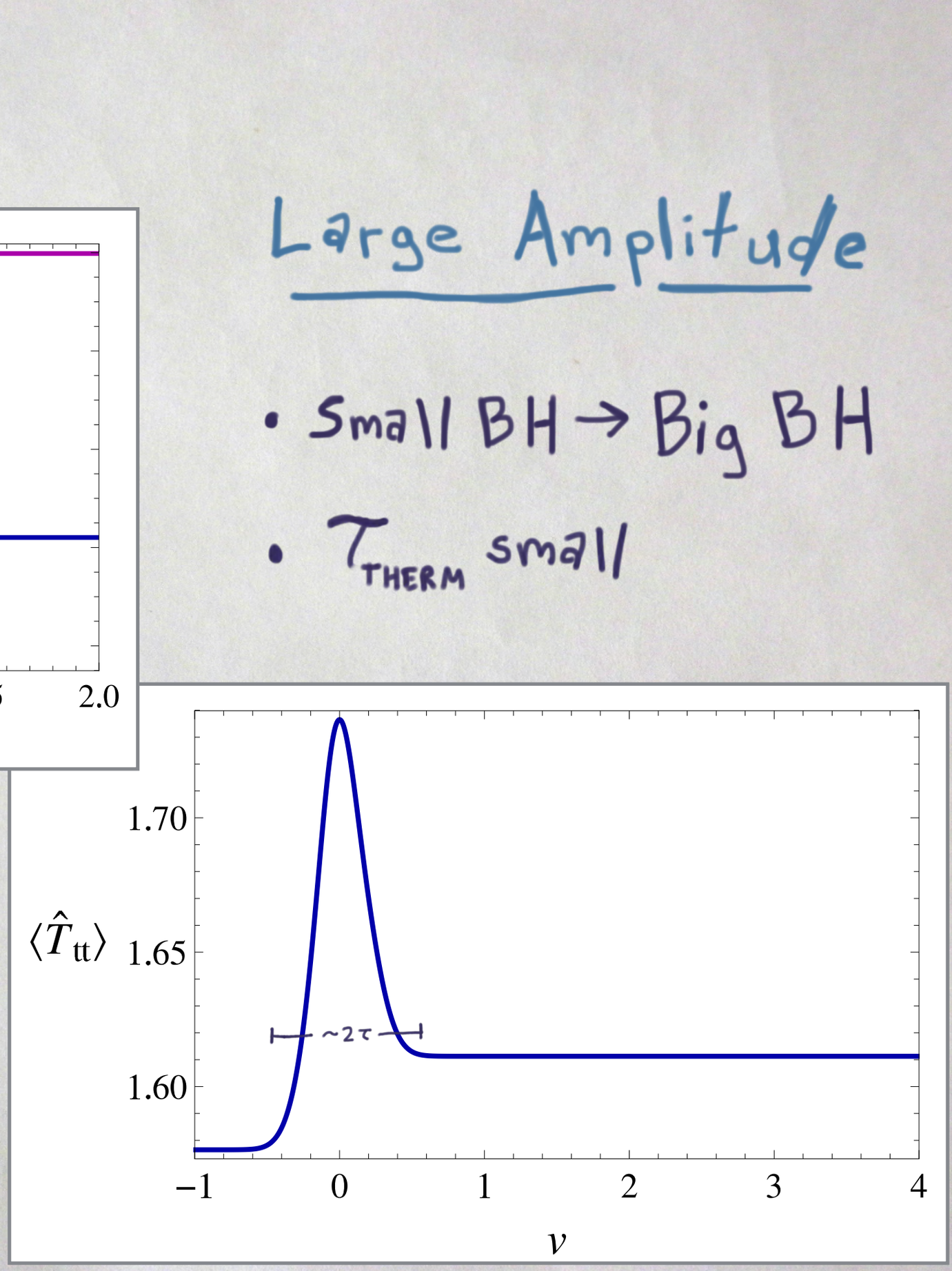


Large Amplitude

- Small BH → Big BH
- T_{THERM} small

Small Amplitude

- Small BH → Small BH
- T_{THERM} large



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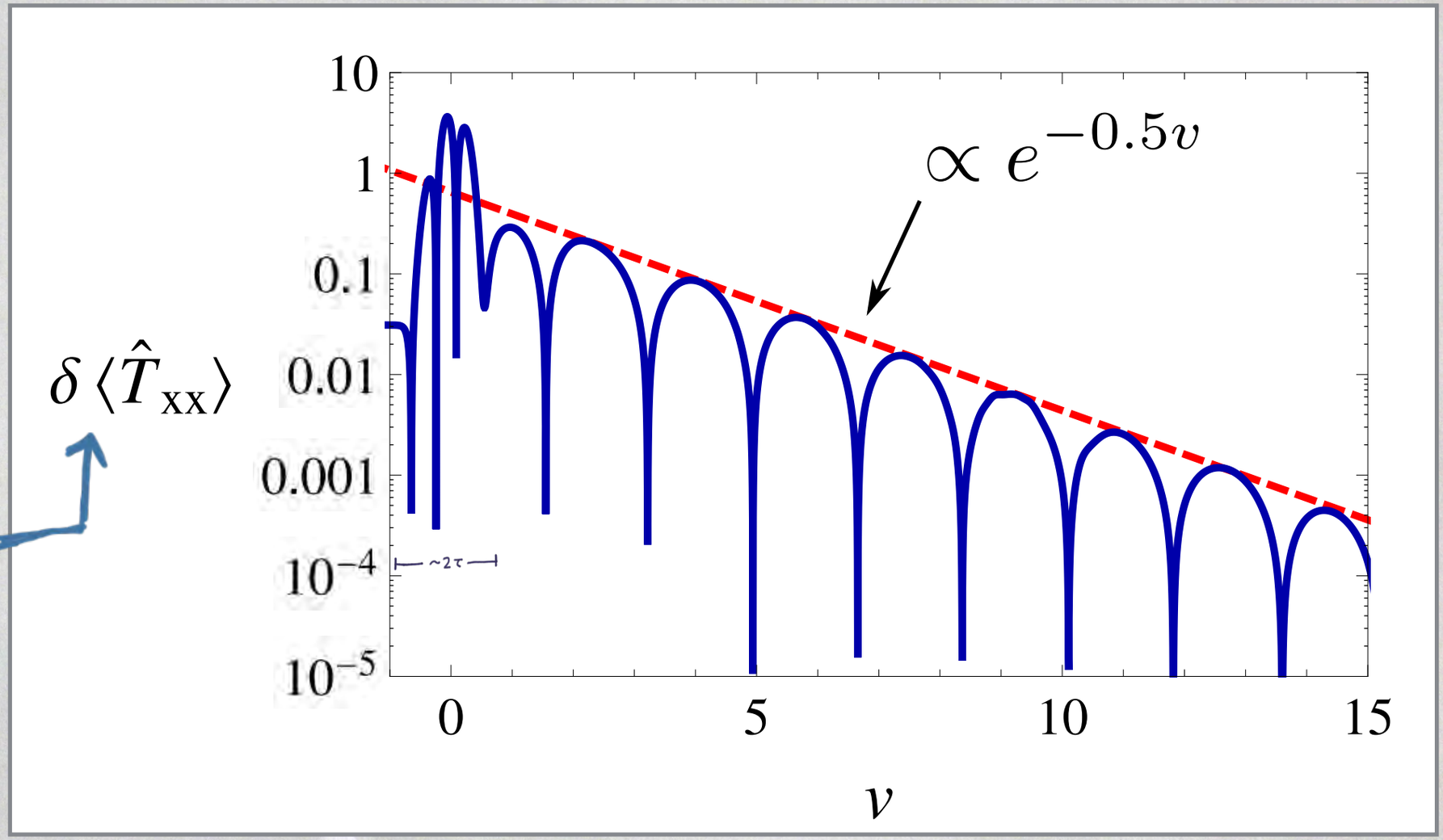
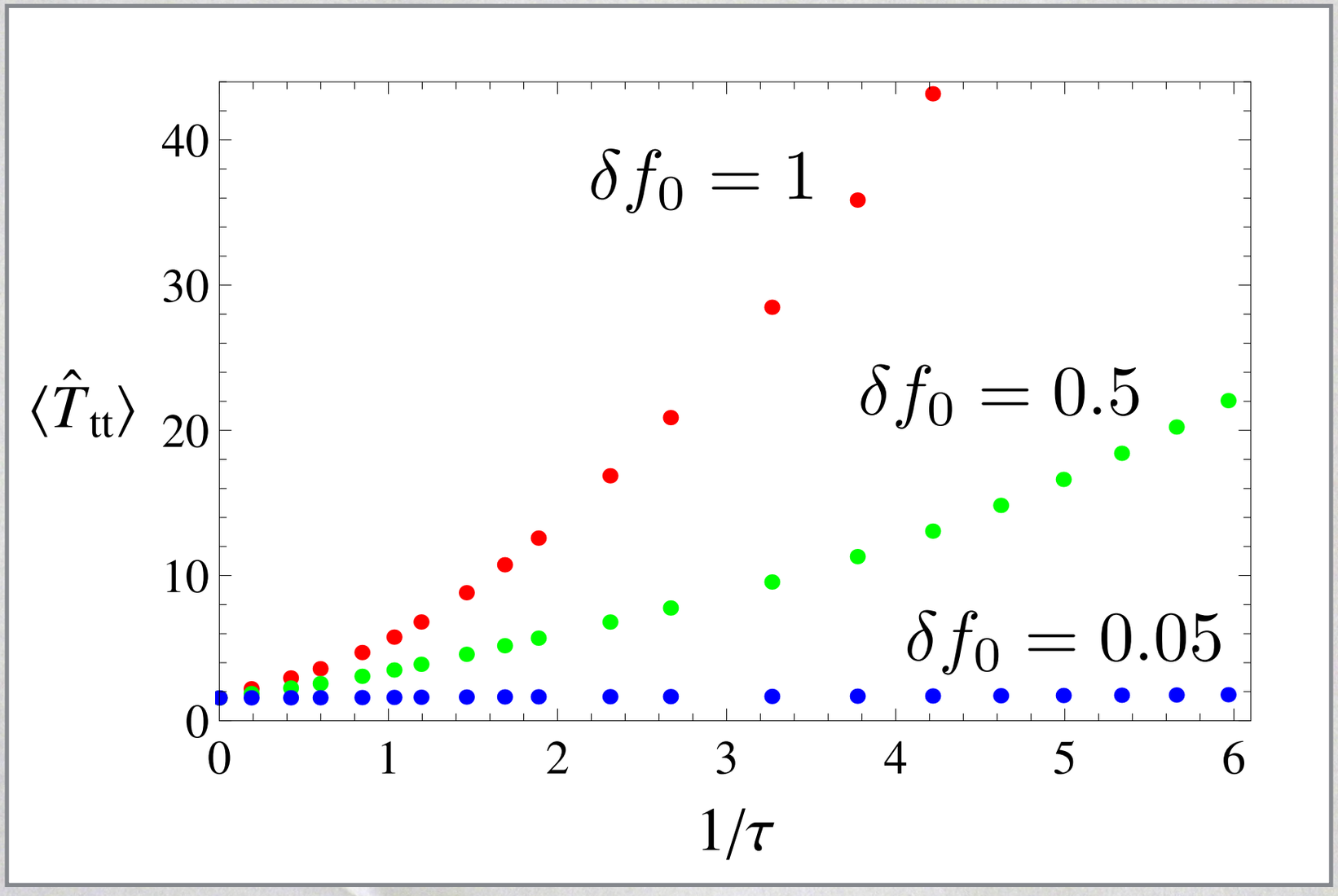


$\langle \hat{T}_{xx}(v) \rangle - \langle \hat{T}_{xx}(\infty) \rangle$

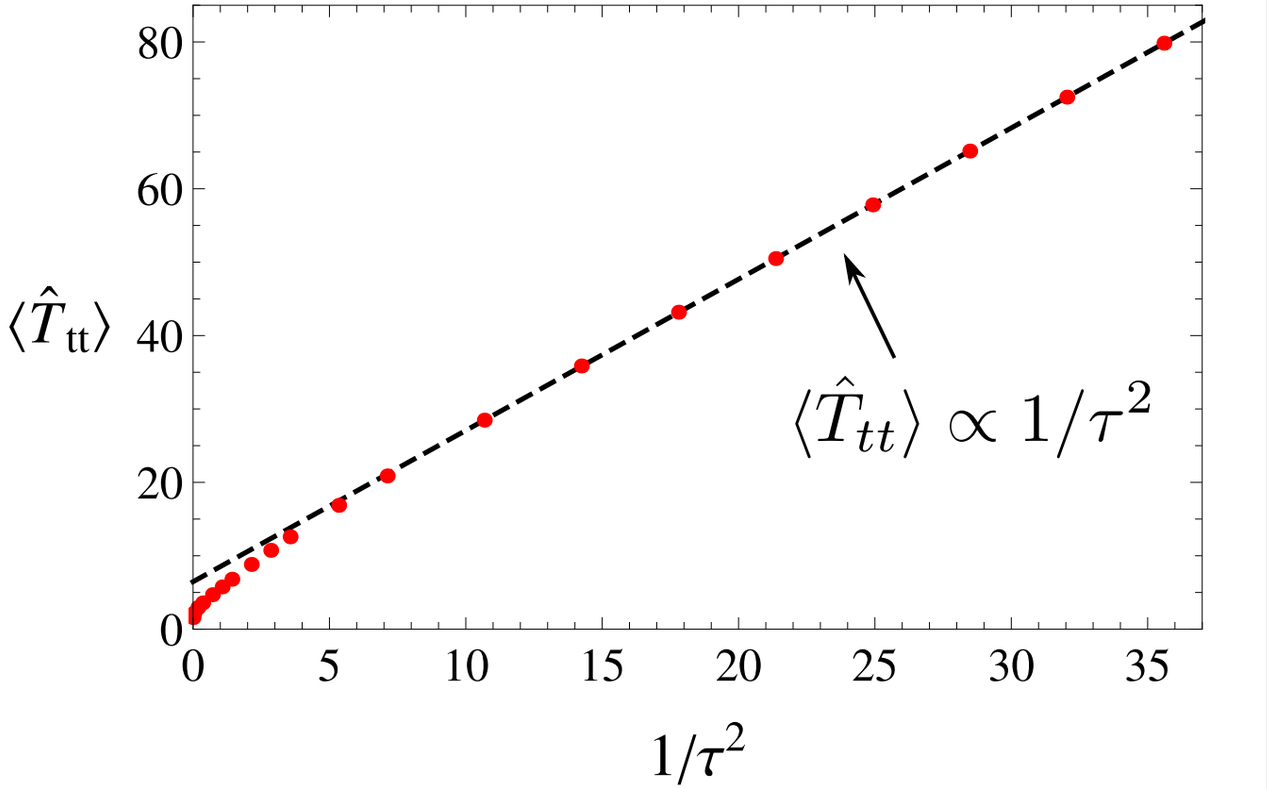
$\tau_{THERM} \sim \frac{1}{\Gamma} \sim 2$

Quench Dynamics



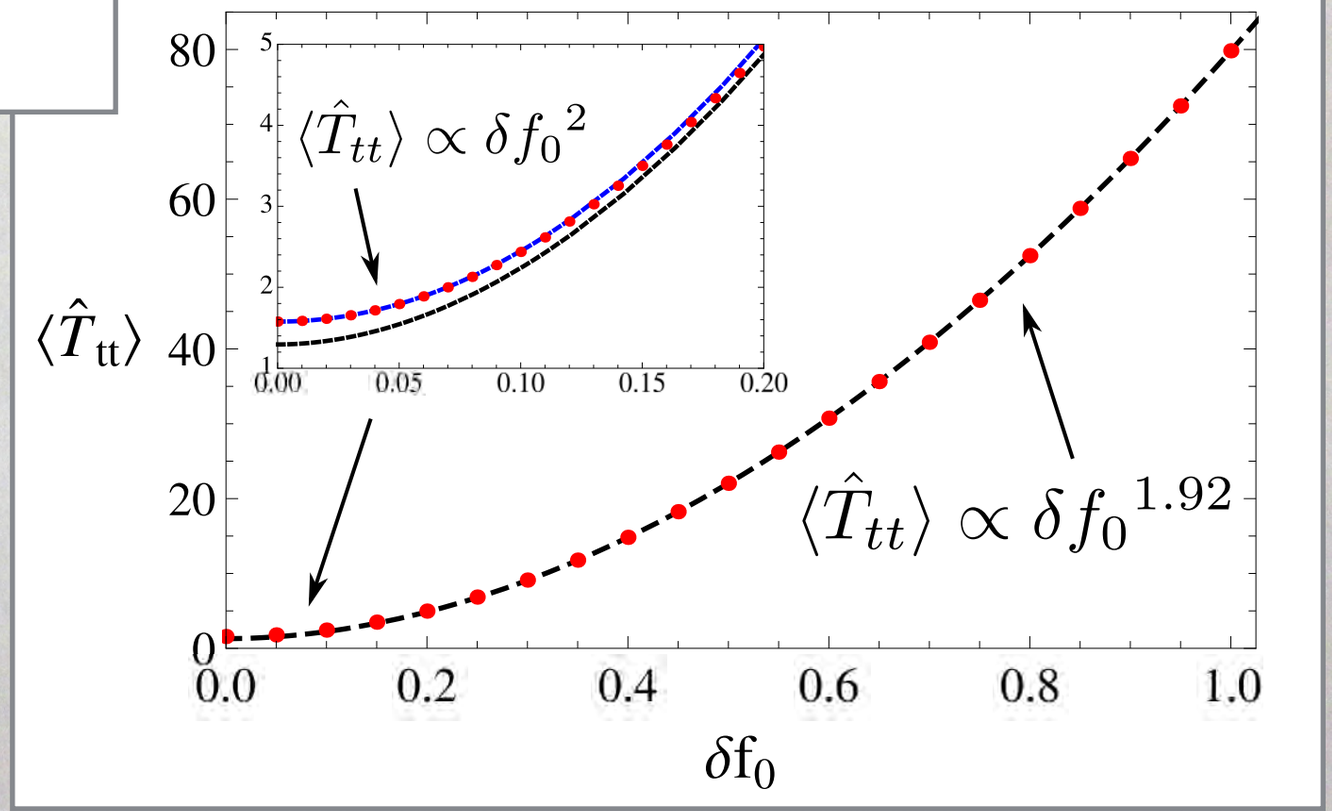
[Data]

Quench Dynamics



Fixed (large) Amplitude

Fixed (small) Duration

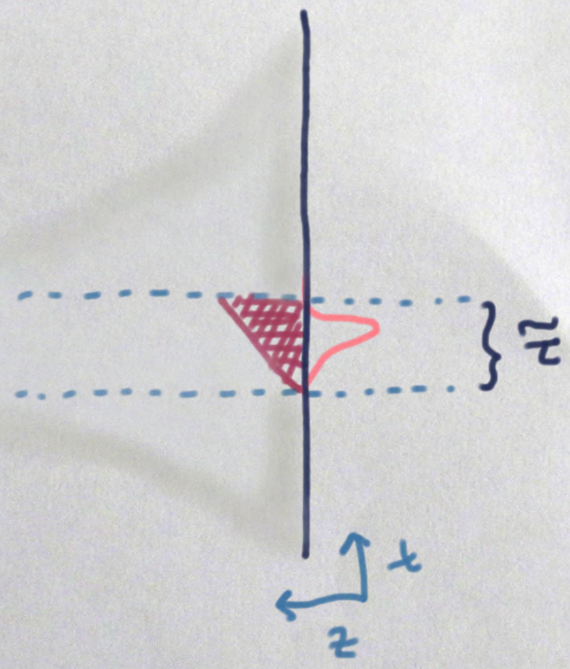


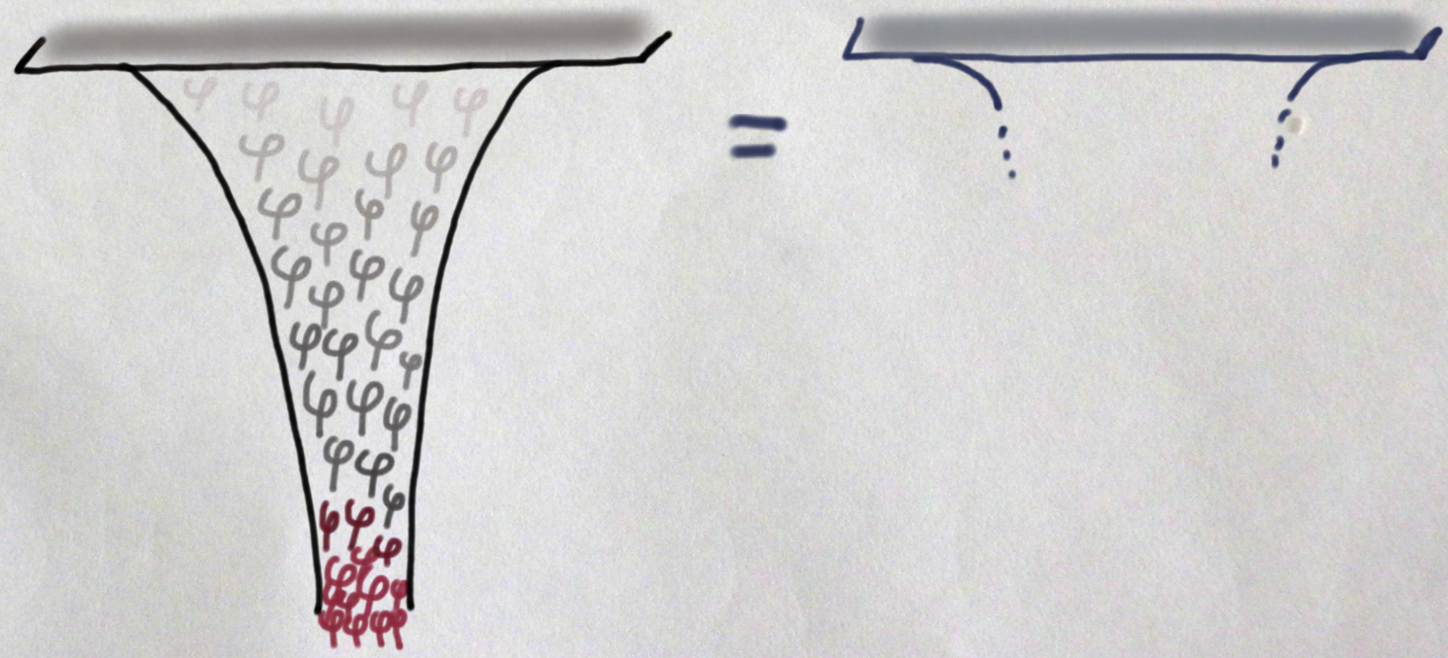
Quench Dynamics

Universal "Abrupt Quench" Scaling

$$\langle \hat{T}_{tt} \rangle_F \sim \frac{\tilde{\delta}^2}{\tilde{\tau}^2} = \boxed{\frac{\tilde{\delta}^2}{\tilde{\tau}^{2\Delta - d}}}$$

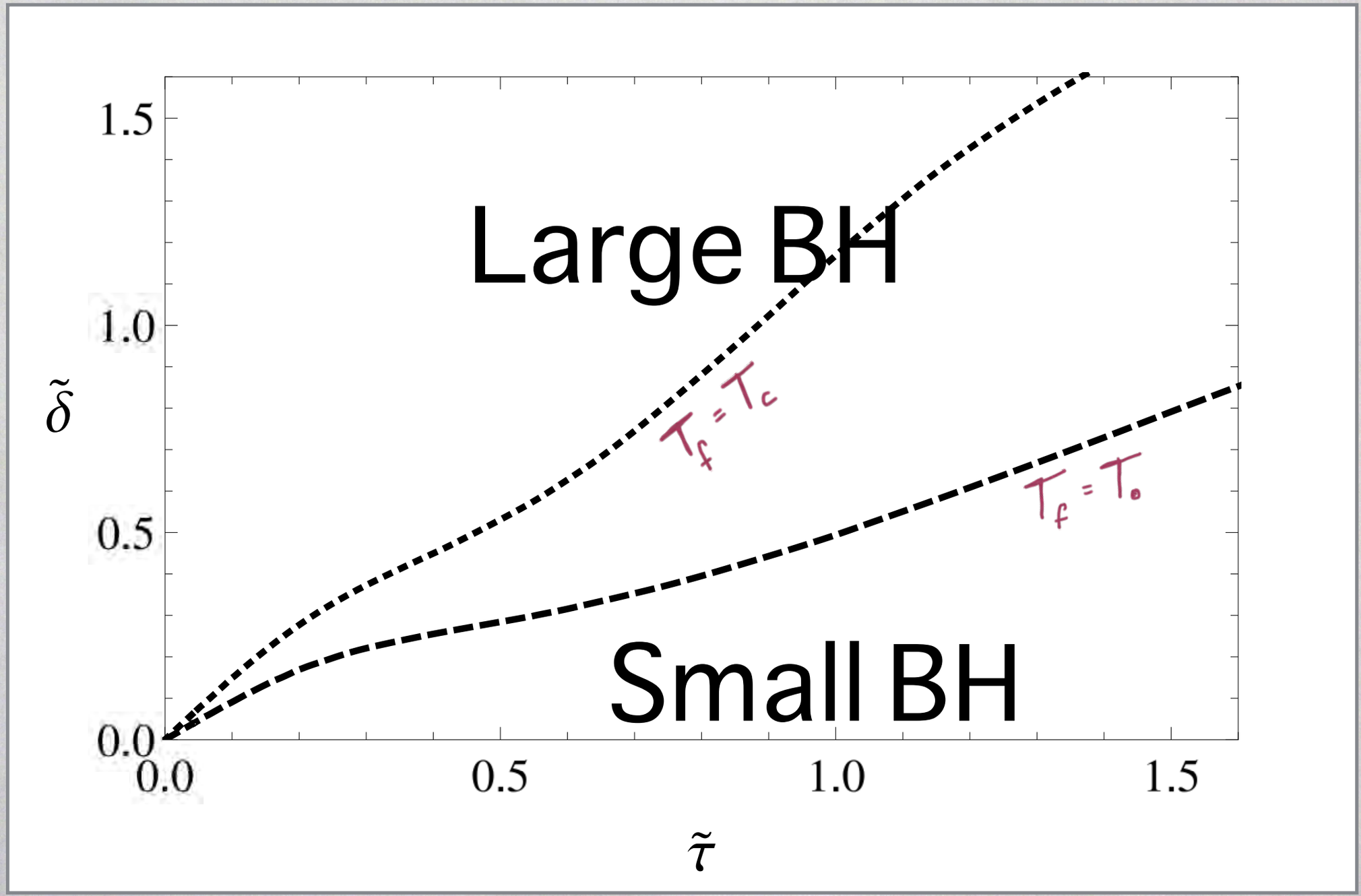
[1307.4740]





Quench Dynamics

Towards a Dynamical Phase Diagram



Quench Dynamics

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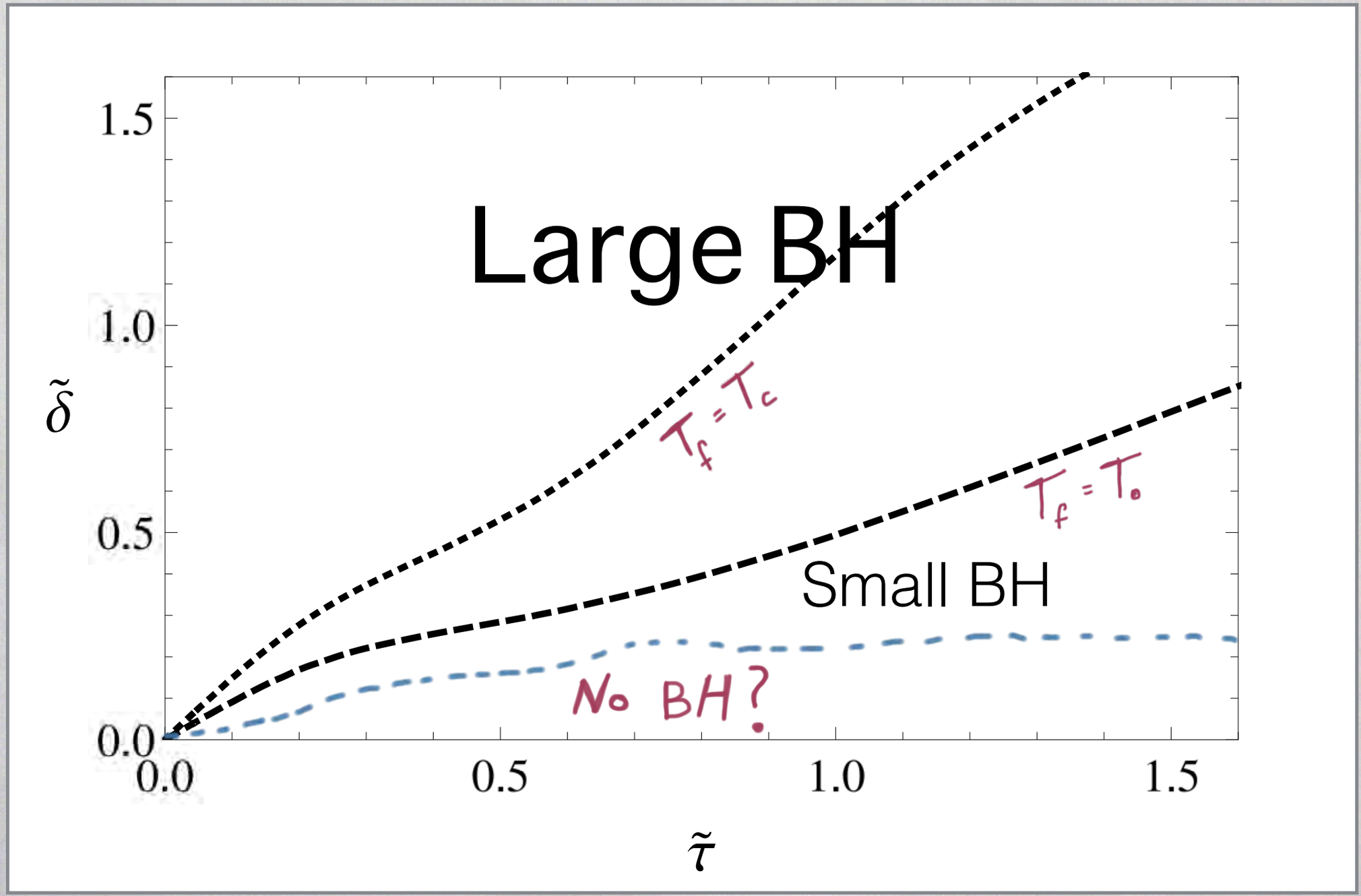


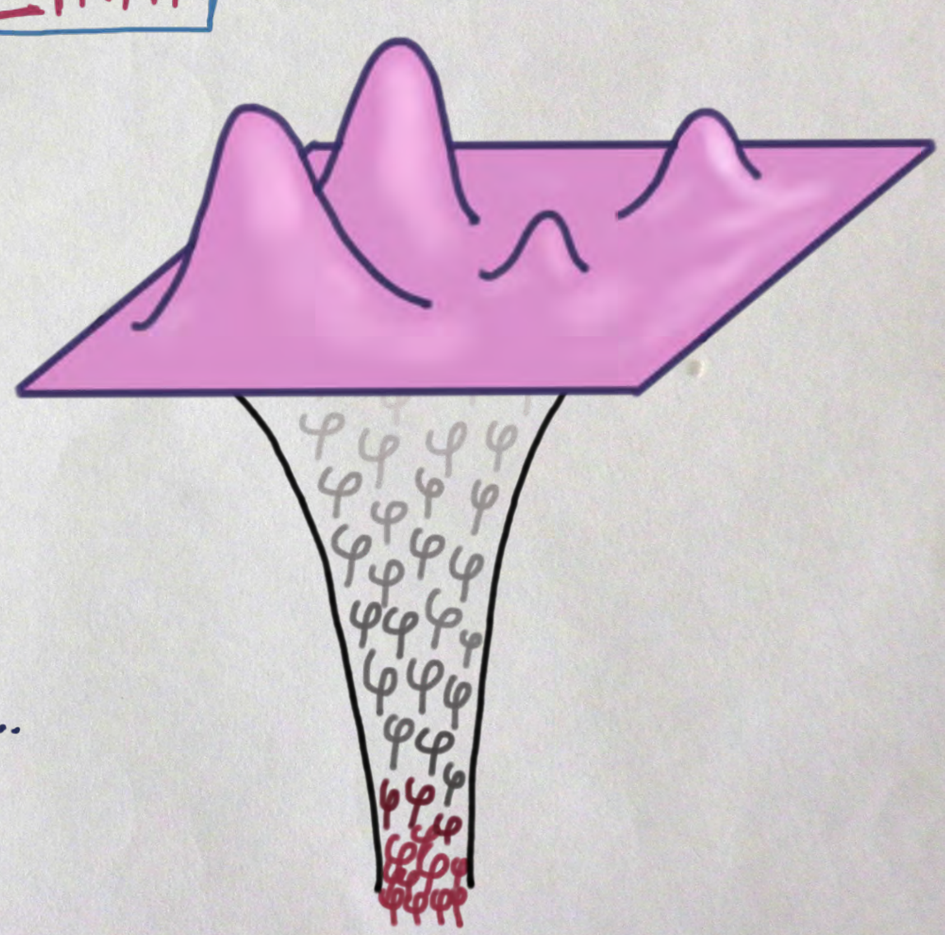
Lessons Learned

Rapid Transition to the Linear Regime

- Confinement Scale plays little role in perturbations of states with $\langle \hat{T}_{tt} \rangle / f_0^4 \gtrsim 1$

Universal Scaling in the Abrupt Limit

- Jives with expectations: fast processes are insensitive to IR details



Evolving Further

- The vacuum limit + Choptuik behavior... Other probes of thermalization...

Holographic Matters

Thank You!

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MANAGING AUTHORITY

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Quench Dynamics