Aspects of holographic quenches

Part 1: Collapse and revival

Esperanza Lopez

J. Abajo-Arrastia, E. da Silva, E.L., J. Mas, A. Serantes, JHEP05(2014)126
E. da Silva, E.L., J. Mas, A. Serantes, JHEP04(2015)038

Motivation

out of equilibrium dynamics of isolated quantum systems

on general grounds: expected a fast approach to a stationary state

at the macroscopic level it appears as thermal equilibrium

not always the case: integrable systems, pre-thermalization plateaux

revivals of the initial state in finite size setups

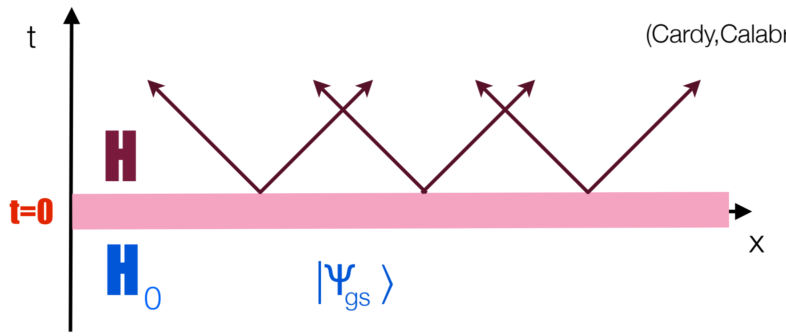
ex: RCFTs on a circle (Cardy, 2014)

can holography be a useful tool in these situations?

Holographic quenches

(Cardy,Calabrese, 2005)

quantum quench: $H_0(t<0)$, $H(t>0)$



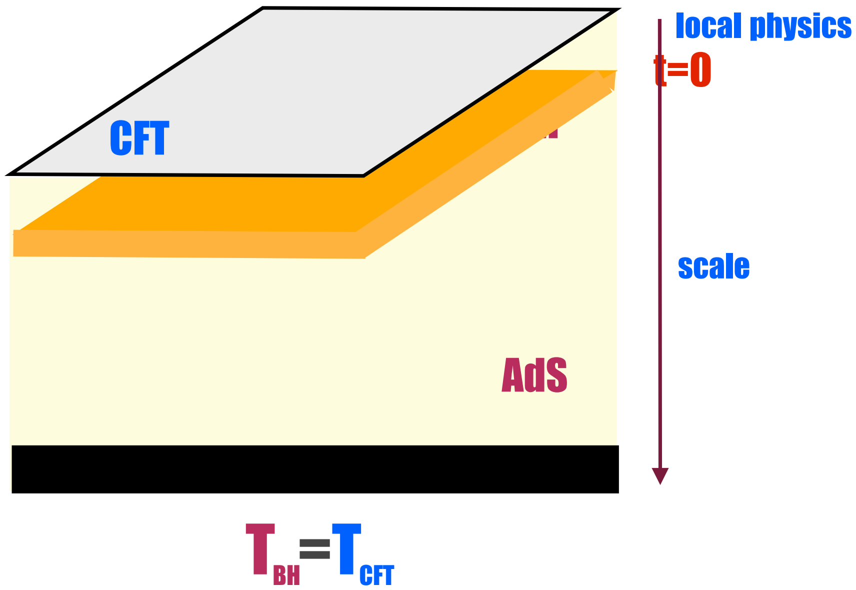
holographic quench

$t<0$, $|\Psi_{gs}\rangle_{CFT}$

$t=0$, $\varepsilon>0$ (ex: switch on-off a coupling)

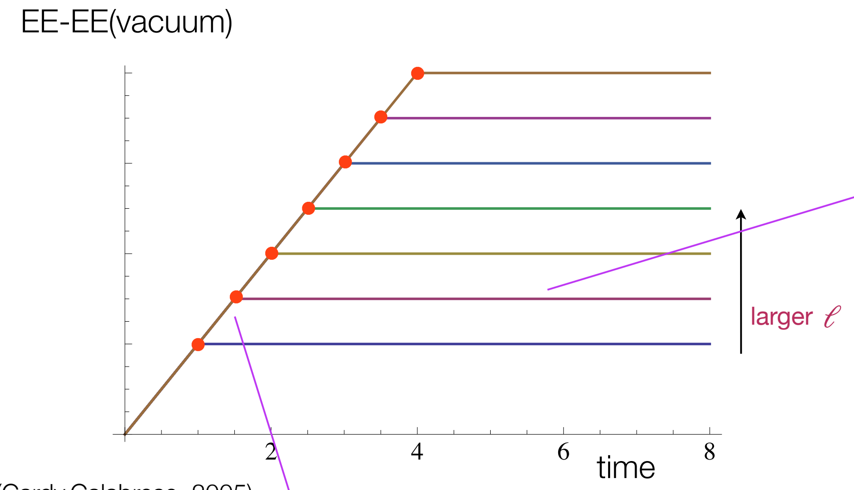
$t>0$, $|\Psi(t)\rangle_{CFT}$

shell mass=quench energy

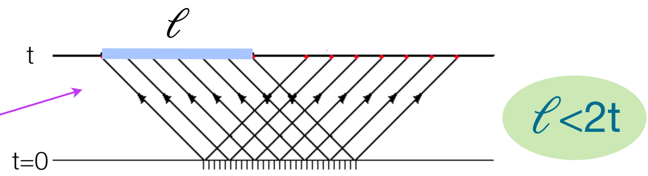


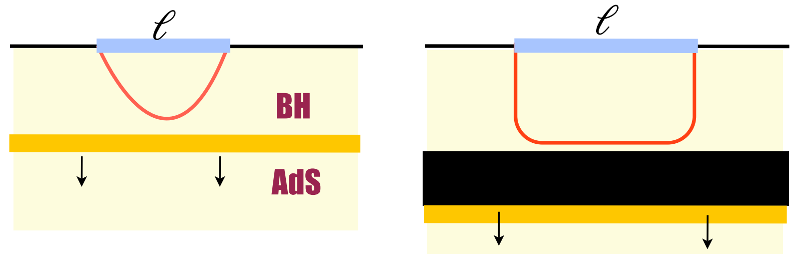
EE evolution after a quench

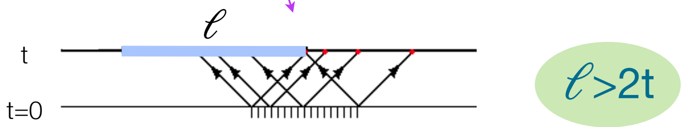
EE of a single interval 

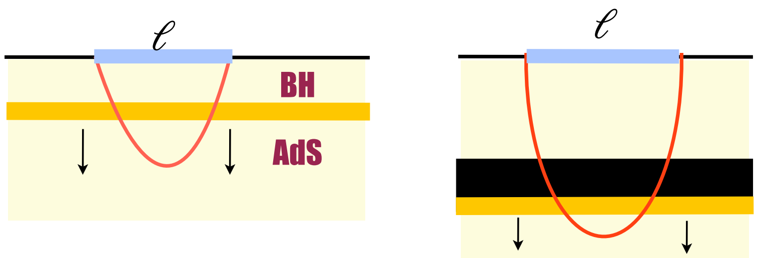


(Cardy,Calabrese, 2005)







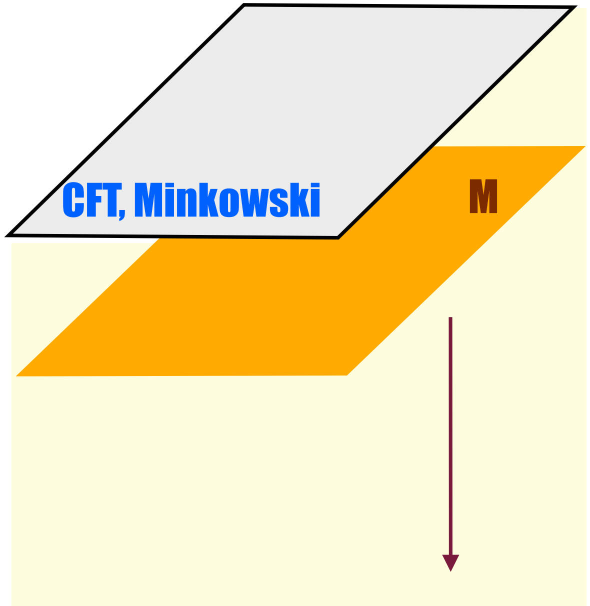


shell infall ⟷ drift away ent. excitations

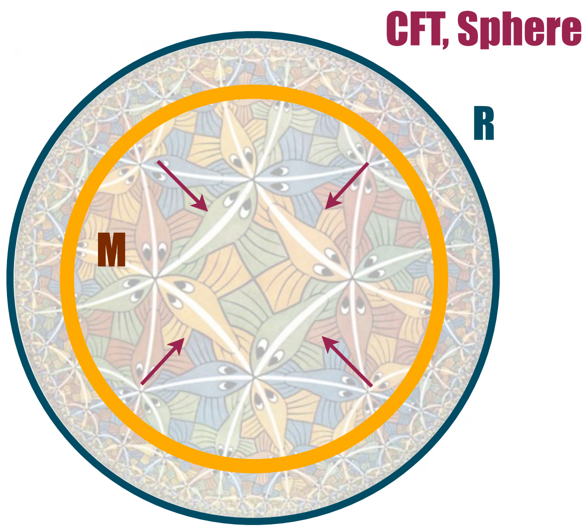
radial dir. ⟷ real space entanglement

(Abajo-Arrastia,Aparicio,EL 2010;Balasubramanian et al, 2010)

Finite size systems



BH always forms



richer phenomenology,

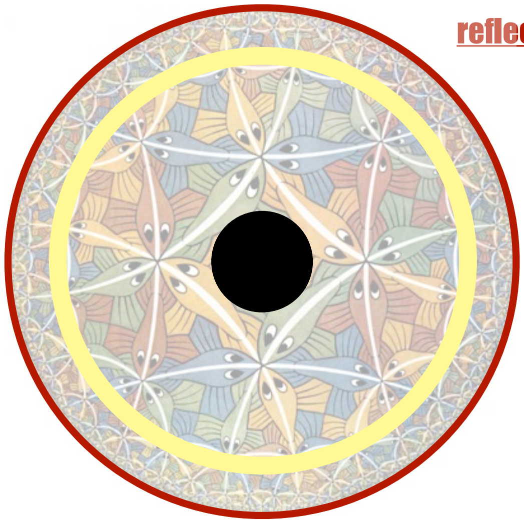
depending on **M·R**

Spherical collapse

asymptotically flat spacetime: sufficiently massive shell will form a BH (Choptuik, 1993)

below a certain mass threshold, no horizon forms

asympotically AdS:



reflecting boundary

shell mass * boundary size

>1/G horizon forms at first infall

always in AdS Minkowski

<1/G requires bounces

generically black hole forms

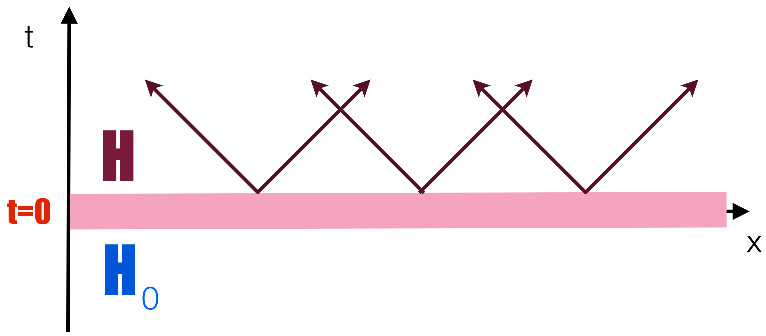
after enough bounces

(Bizon,Rostworowski, 2011)

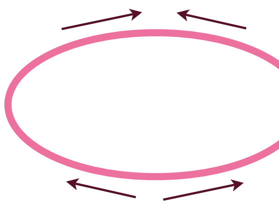
What's the FT meaning?

Field theory revivals

simple propagation model



compact space: **excitations flying apart reunite again**



propagation time: $t_0 = \dfrac{L}{2v}$

v=1 (CFT) + R=1

$t_0 = \pi$

$$|\Psi(t+\pi)\rangle = |\Psi(t)\rangle$$

Field theory revivals

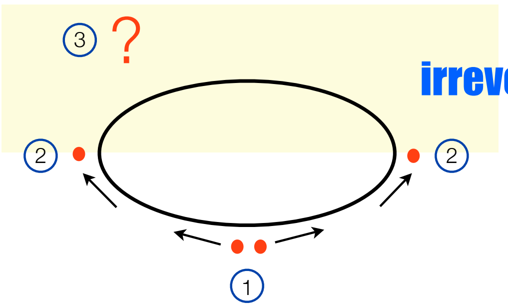
propagation model

✔ spreading of quantum correlations ①→②

✗ not enough to characterize revivals ②→③

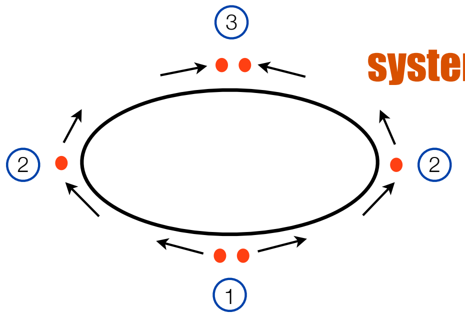
interaction

irreversible dephasing



energy*size > #dof

systems rephases

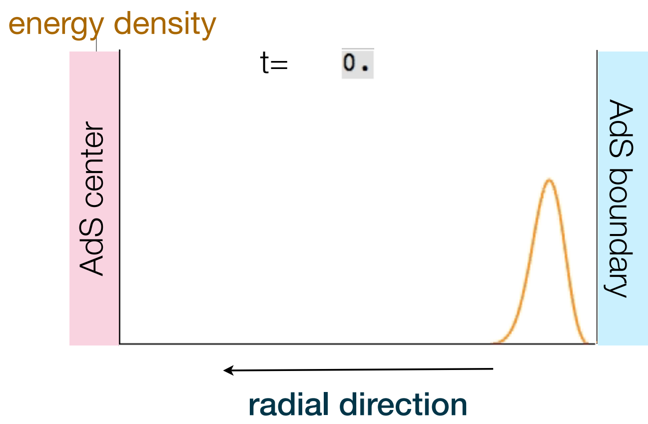


energy*size < #dof

as in the gravity dual

1/G~#dof

Holographic setup



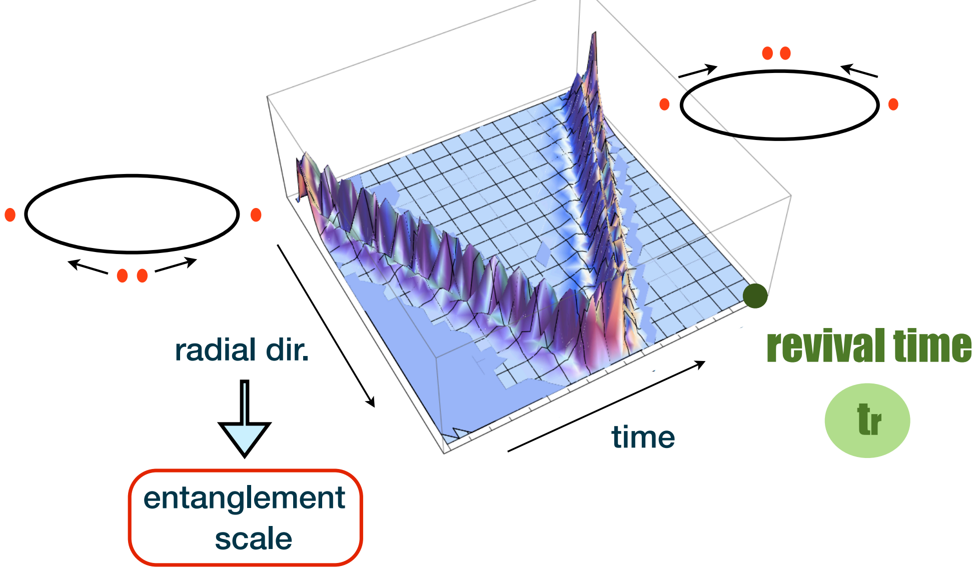
spherical sym massless scalar collapse

shell thickness $\simeq$ timespan of the quench

thin shell: sudden quench

horizon: irreversible
dephasing of some dof

first bounce:



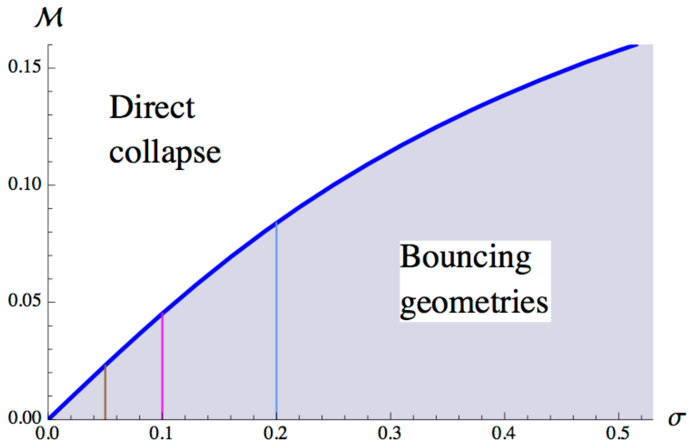
CFT3 quenches

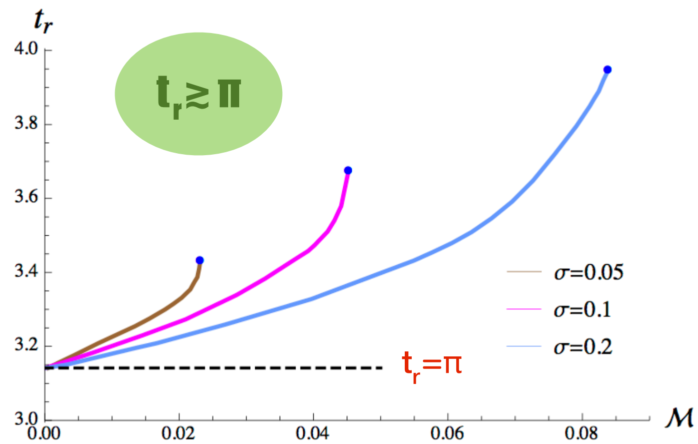
(Abajo-Arrastia,da Silva,EL,Mas,Serantes 2014)

CFT3 on a 2-sphere (R=1)

AdS4: allows BH of any mass + thin shells always collapse (Bizon,Rostworowski, 2011)

$\mathcal{M}$ = 2GM ≈ energy density per species





revival time increases with $\mathcal{M}$

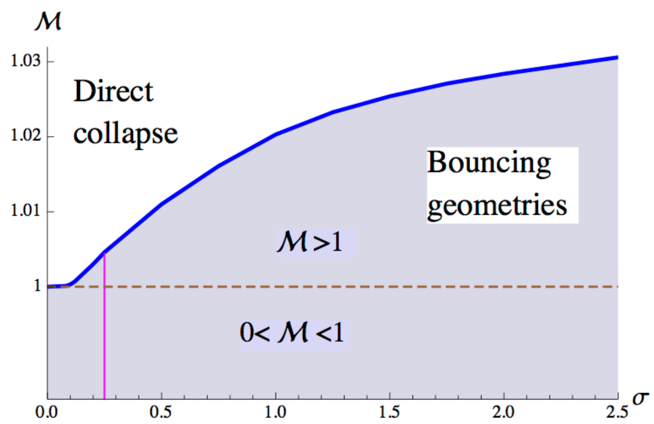
CFT2 quenches

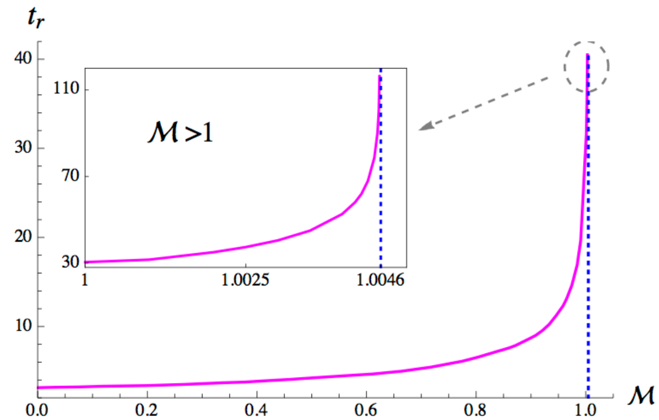
(da Silva,EL,Mas,Serantes 2014)

CFT2 on a circle (R=1)

AdS3: BH only for $\mathcal{M} > 1$

$\mathcal{M} < 1$ only compatible with naked singularities, do not form through collapse





revivals for larger $\mathcal{M}$ than in AdS4

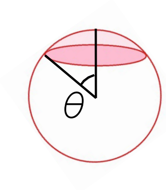
t_r tends to π for small $\mathcal{M}$

very long periods close to $\mathcal{M}=1$

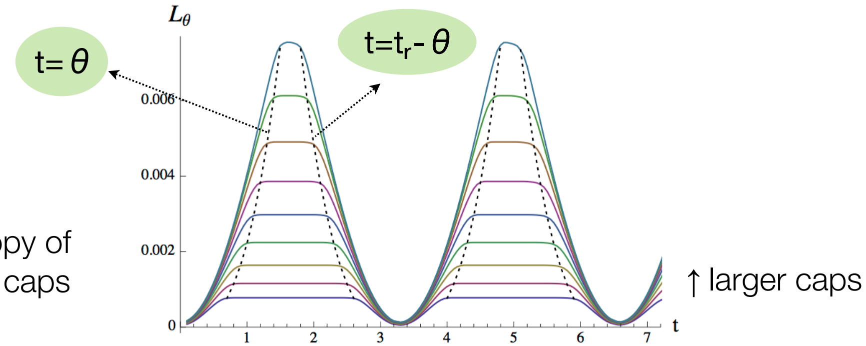
Interpretation

large quench energy → fast evolution towards equilibration, no revivals

AdS4: $t_r \simeq \pi$ revivals well described by free prop. of excitations



ent. entropy of spherical caps



$\mathcal{M}\uparrow$, $t_r > \pi$ free propagation fails, fast equilibration sets in

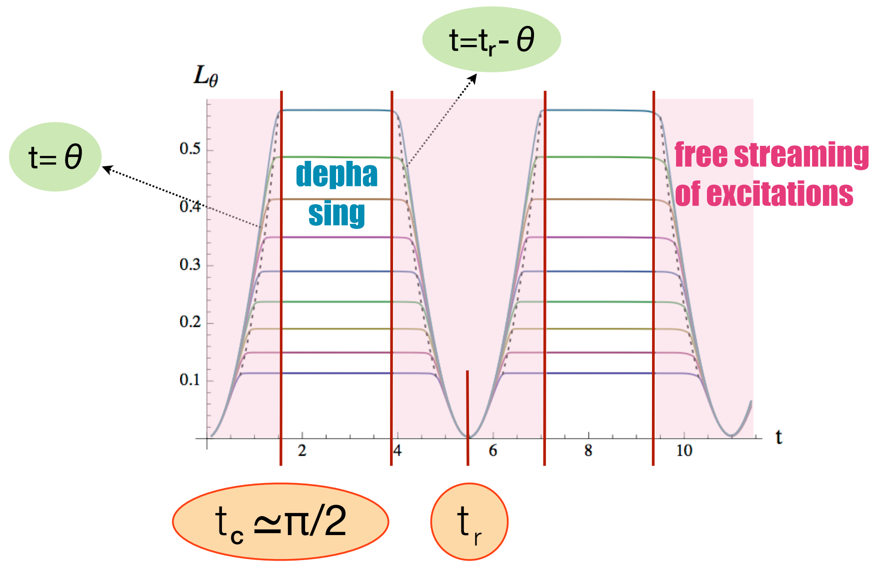
AdS3: **strong symmetry constrains** revivals for larger $\mathcal{M}$ and $t_r \gg \pi$

t_r grows with $\mathcal{M}$: interaction effect

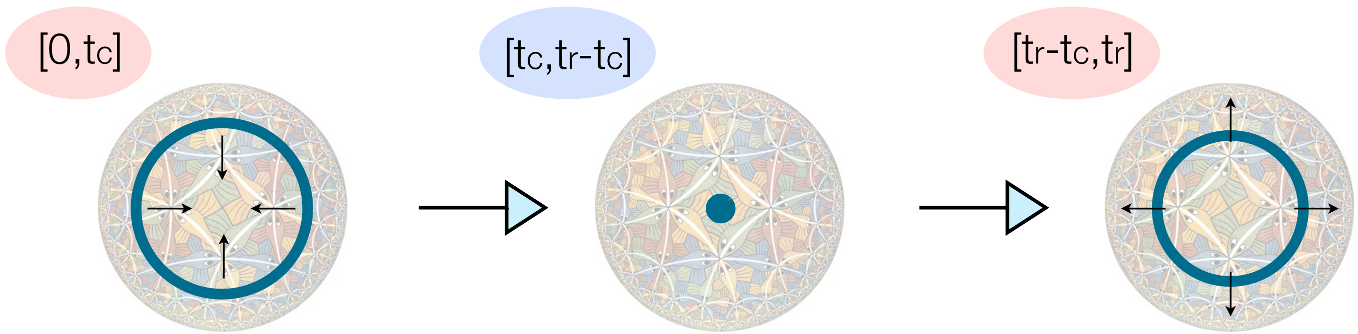
Interpretation

two timescales emerge when $\mathcal{M}\simeq 1$

- $[0,t_c]$: free streaming
- $t=t_c$: dephasing
- $t=t_r-t_c$: rephasing
- $[t_r-t_c,t_r+t_c]$: free streaming

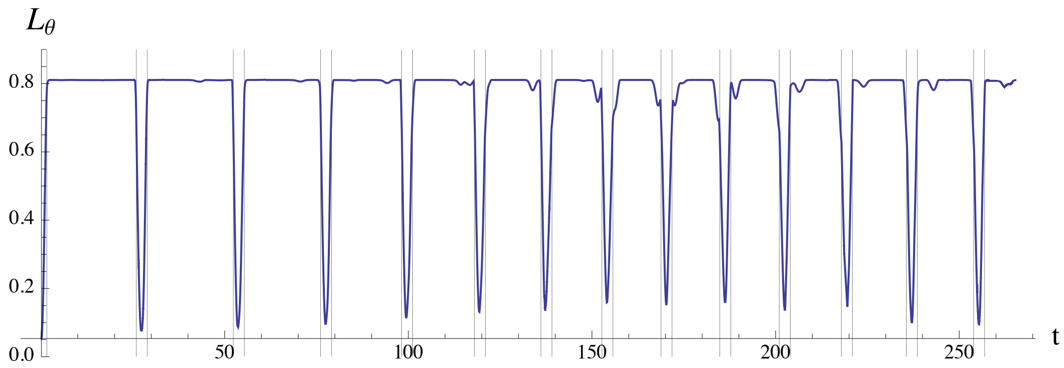


gravity counterpart

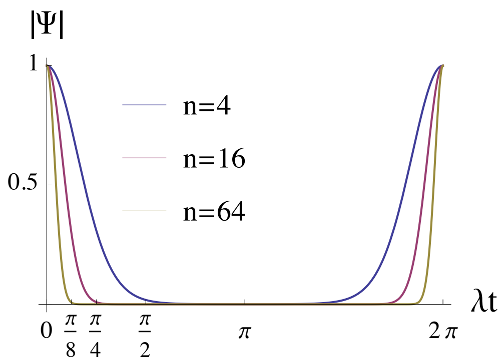


Interpretation

EE evolution suggests a series of collapse & revivals

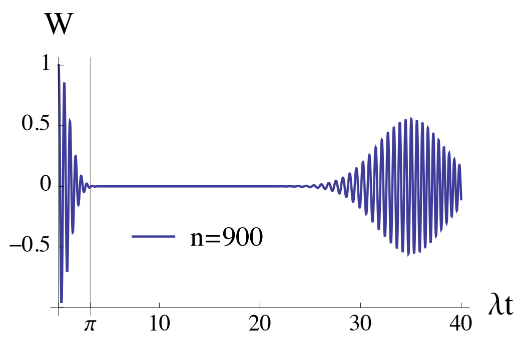


condensate of atoms on a trap



average phase coherence of the condensate

2-level atom coupled to radiation



probability of the atom excited state minus that of the ground state

system starts in a coherent state with average number n

$$\frac{t_r}{t_c} = 2\sqrt{n}$$

Conclusions

holography is a useful tool for out of equilibrium non ergodic situations

holographic predictions:

revival period generically increases with quench energy

finite # of revivals, stepwise thermalization

Thanks!

holographic dictionary in time-dependent situations

gravitational dynamics leading or not to horizon formation ⟷ dephasing/rephasing dynamics in out of equilibrium QFT

unitary evolution