Shockwave and Complexity in dS_3

Takanori Anegawa

[arXiv: 2304-xxxxx] To appear

w/ Norihiro Iizuka

Motivation-1

What is holographic description of de Sitter?

- One suggestion is dS/CFT. (Analytic continuation from AdS/CFT)

Recently, it is conjectured that

- Two-dim dS $\Leftrightarrow$ DSSYK_{∞} [Susskind]
- Holographic screen is stretched horizon.
- De Sitter shows the exponential expansion $\Rightarrow$ Complexity shows "hyperfast"
- Let us consider more about dS complexity

Motivation-2

- In particular, we would like to study the responses from shockwave.

- OTOC calculation [Stanford,Shenker]
- Created S-AdS case [Chapman, Marrochio, Myers]
- De sitter without shockwave [Jørstad ,Myers, Ruanc]
- This holographic complexity calculation shows hyperfast

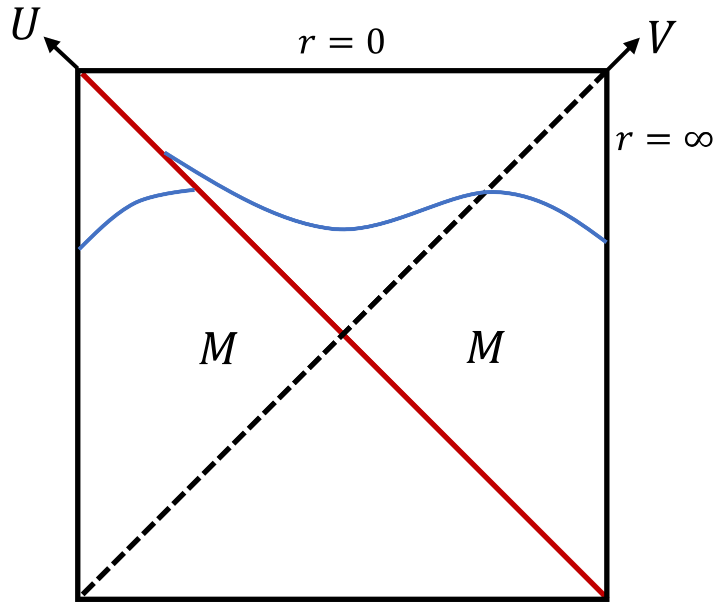
- Let us discuss about how small perturbations can change this property

Shockwave geometry-1

- AdS+single shockwave

$$T_{VV} = \frac{\alpha}{4\pi G_N}\delta(V)$$

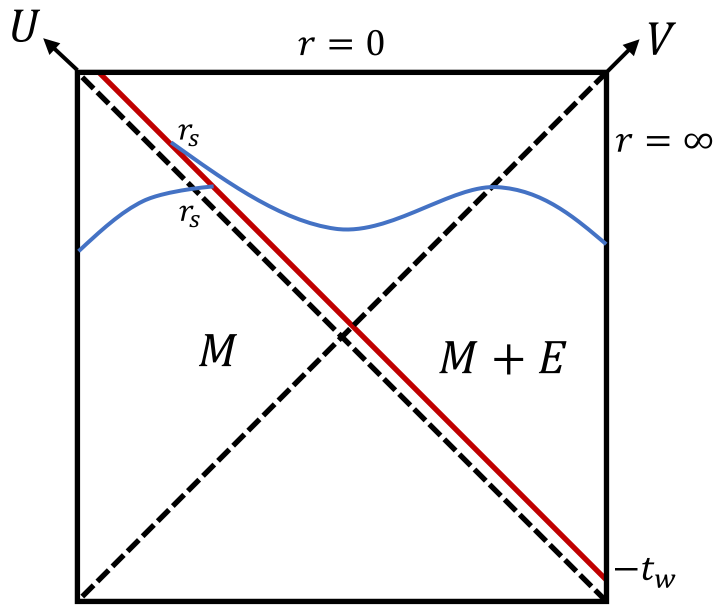
- This spacetime is devided by shockwave
- when shockwave is localized on horizon, the solution is well known.
- This is bh spacetime of the same mass pasted together with a constant shift $\alpha > 0$



$$\alpha = \frac{E}{4M} e^{\frac{R}{\ell^2} t_w}$$

under the limit $E \to 0$.

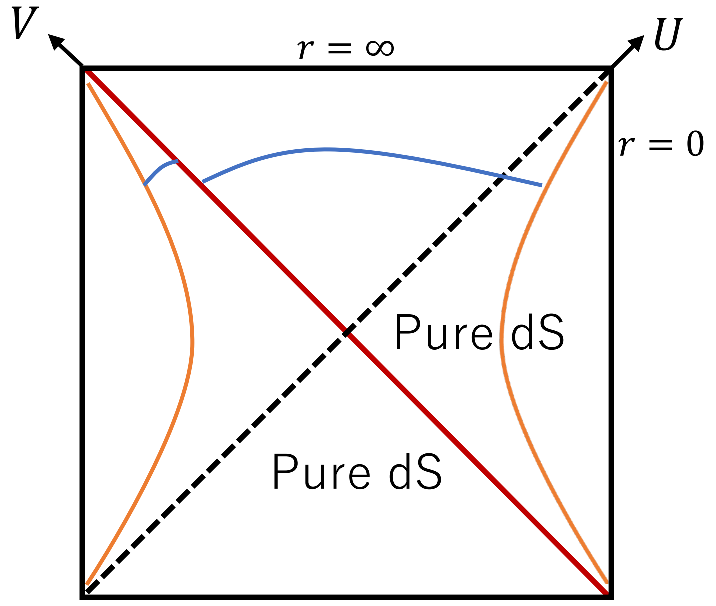
- If the shockwave is not localized on horizon, the mass of the black hole in the two patches is different.
- On the shockwave, the continuity of r is imposed. And there is a shift, although it is not simple.



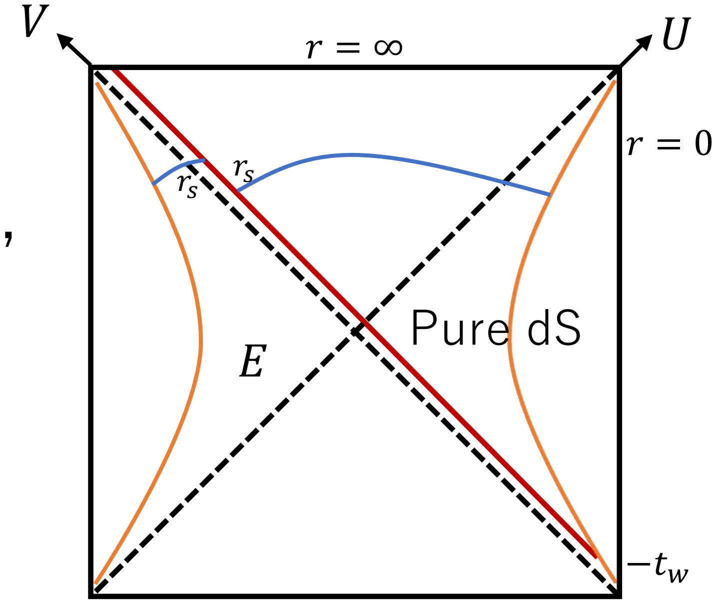
Shockwave geometry-2

- pure dS+single shockwave $T_{UU} = \frac{\alpha}{4\pi G_N \ell^2}\delta(U)$
- when shockwave is localized on horizon, This is pure de Sitter pasted together with a negative constant shift $-\alpha$ under the certain limit

$$\alpha = 2EG_N \ell e^{t_w/\ell}$$



- If the shockwave is not localized on horizon, the pure dS and S-dS patches are pasted together.
- To be consistent with the positive energy insertion, the lower patch must be S-dS. Otherwise, we can derive that the energy insertion is negative.
- On the shockwave, the continuity of r is imposed. And there is a shift, although it is not simple.



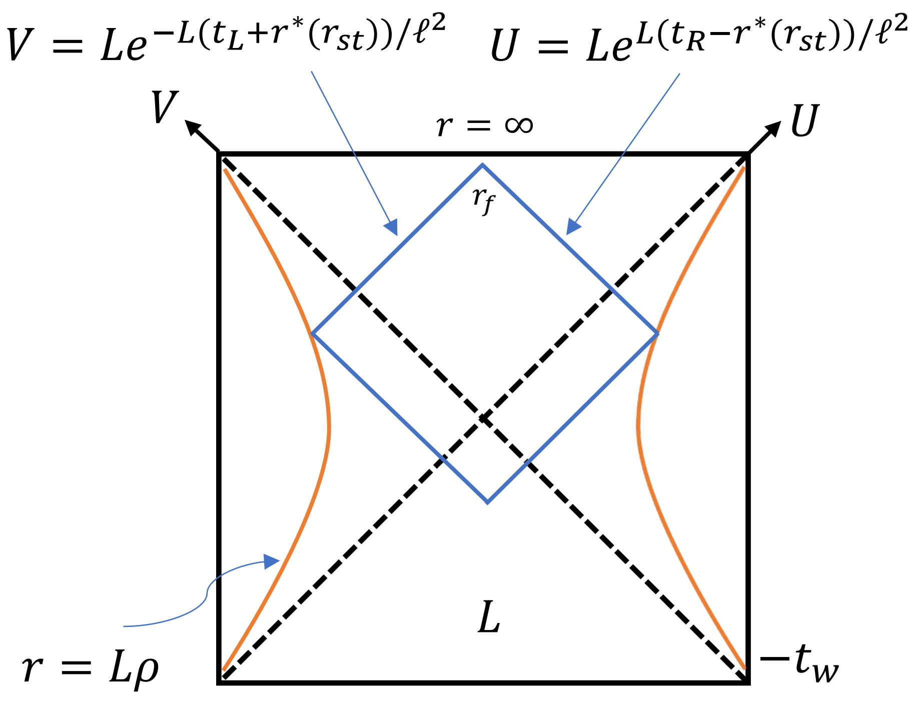
Hyperfast from Volume

- Let us consider the dependence of time on the Stretched horizon[Jørstad ,Myers, Ruanc]
- CV2.0 argument in $\mathrm{dS}_{d+1\geq 3}$

$$\lim_{\tau\to\tau_\infty} \mathcal{C}_V \to \infty, \quad \lim_{\tau\to\tau_\infty} \frac{d\mathcal{C}_V}{d\tau} \to \infty.$$

- Intuitively, The main contribution to this comes from the point r_f in WdW where r is the largest
- We can calculate τ_∞ as the time for the WdW patch to reach $r_f = \infty$

$$\tau_\infty = \mathrm{Arctanh}\rho$$



CV2.0 argument

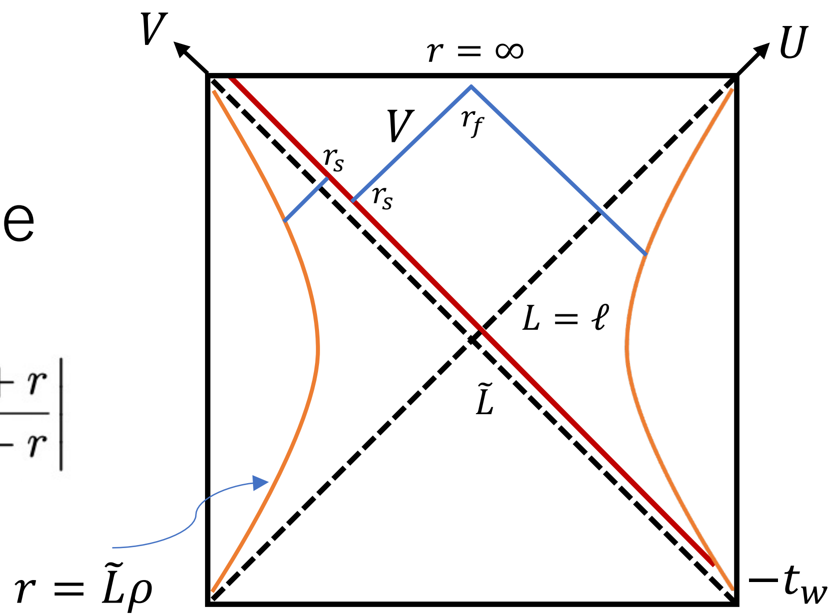
- When there is a shockwave, the future boundary of the WdW patch is shifted.
- Variation of τ_∞ can be calculated, and the general formula is

$$\Delta\tau_\infty \propto r_1^*(r_s) - r_2^*(r_s) \qquad r^*(r) = \int \frac{dr}{f(r)} = \frac{\ell^2}{2L}\log\left|\frac{L+r}{L-r}\right|$$

- If we consider the horizon limit

$$\Delta\tau_\infty \propto \alpha > 0$$

- Therefore, the critical time was found to be delayed
- Based on the method of finding geodesic in the Vaidya, CV reproduces the same result.



Summary

- With shockwave, dS behaves exactly opposite to AdS. In particular, the constant shift of the patches is exactly opposite.
- According to CV(2.0), critical time can be easily delayed by a shockwave with positive Energy. Thus, it is indeed affected by small perturbations.
- We can expect to observe similar behavior in the calculations from CA. It would also be interesting to examine the general time dependence, not limited to late time.