Title: Why I think Double-scaled SYK at infinite Temperature is a Theory of de Sitter Space

Speakers: Leonard Susskind

Series: Colloquium

Date: November 29, 2023 - 2:00 PM

URL: https://pirsa.org/23110079

Abstract: Abstract TBA

Zoom link https://pitp.zoom.us/j/98123499206?pwd=QWlHcFBJWE8zRTlyT1A5WUVsQS9NUT09

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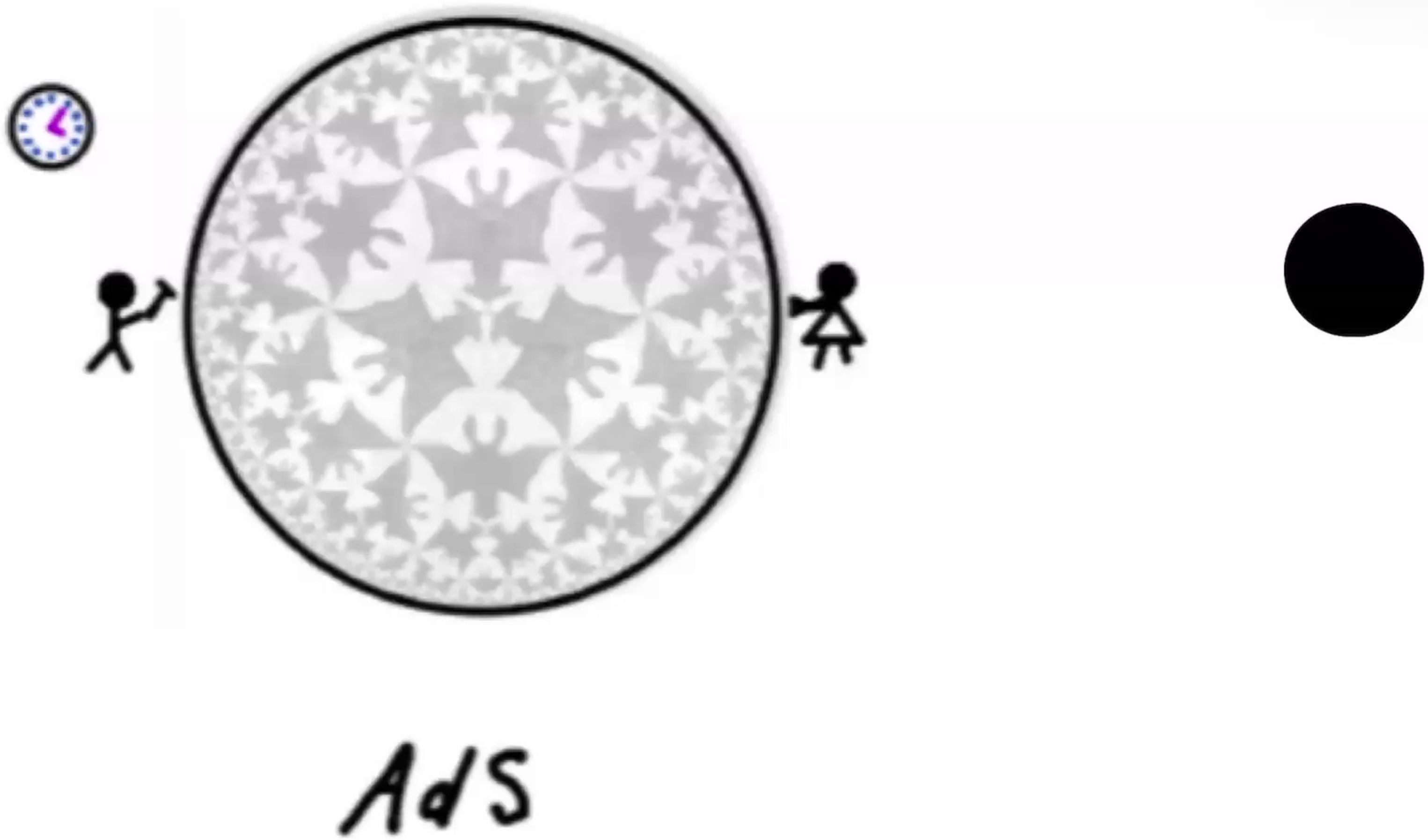

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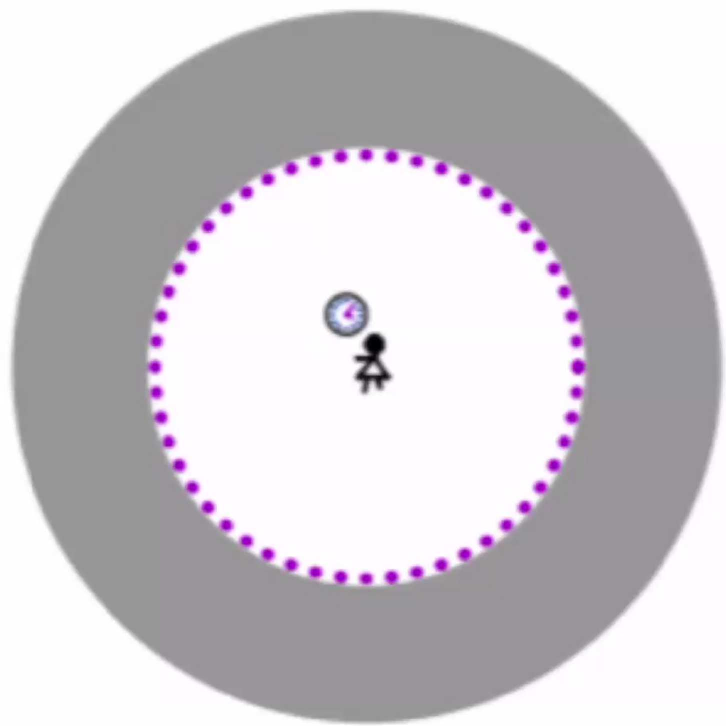

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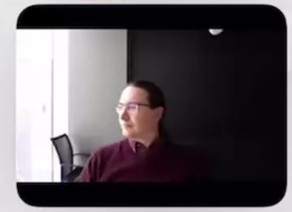

Principles ?

Holographic

Concrete Example

$$DSSYK_{\infty} \stackrel{?}{=} JT-dS$$

Not Maldacena, Turiaci, Yang

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JT-dS = dim reduction of dS_3

$$ds^2 = -f(r)\,dt^2 + \frac{dr^2}{f(r)} + r^2 d\alpha^2$$

Dilaton $= \Phi$

$= r = $ "area"

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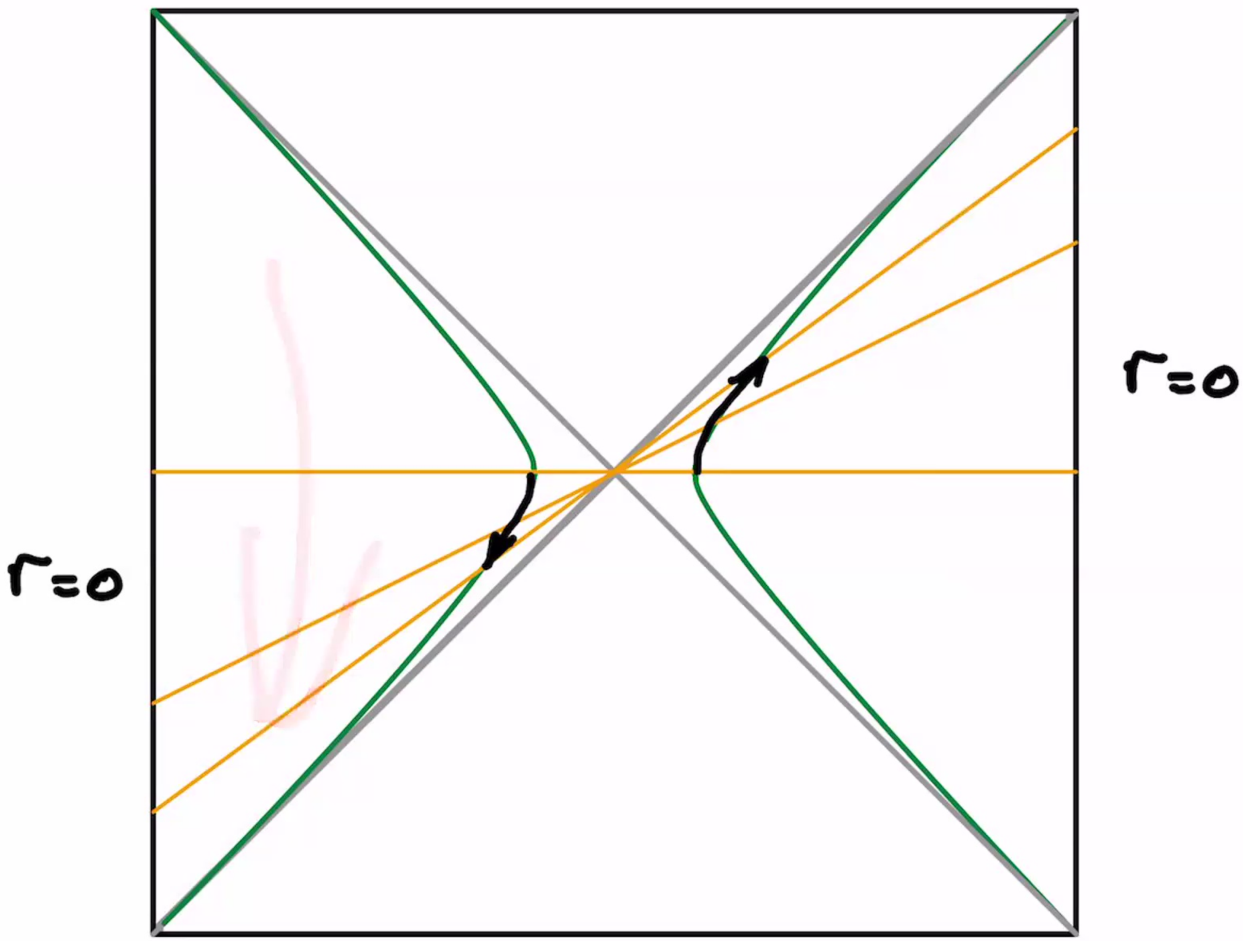

$$H = i\partial_t$$

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100%

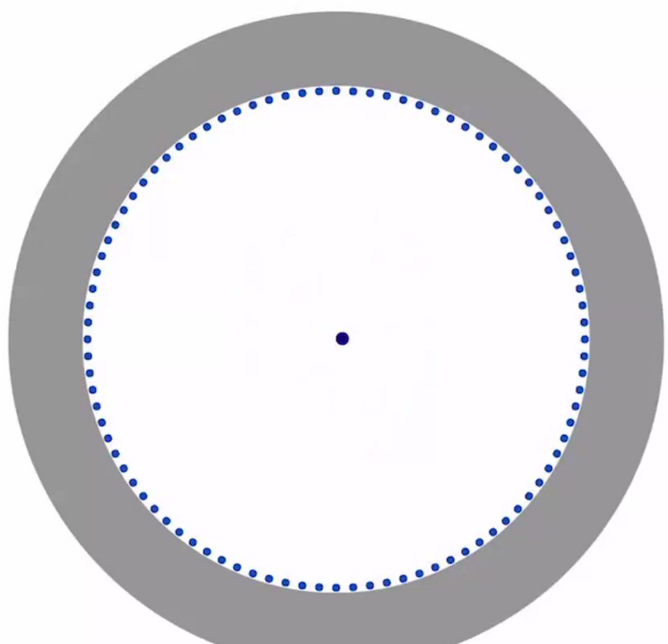
De Sitter Holography

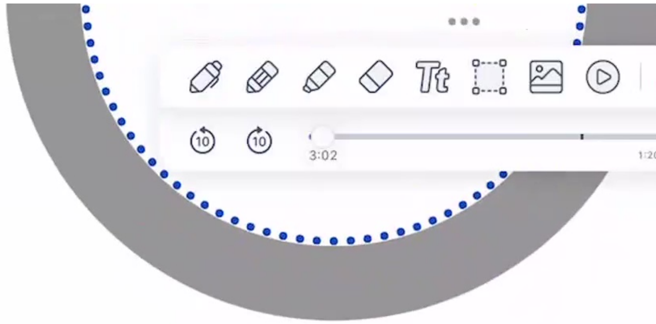
Where is the hologram?

Stretched Horizon

Where is the hologram?

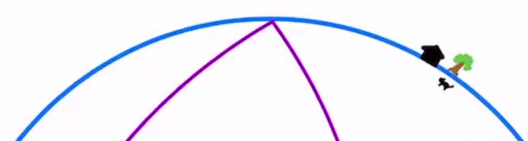
Stretched Horizon



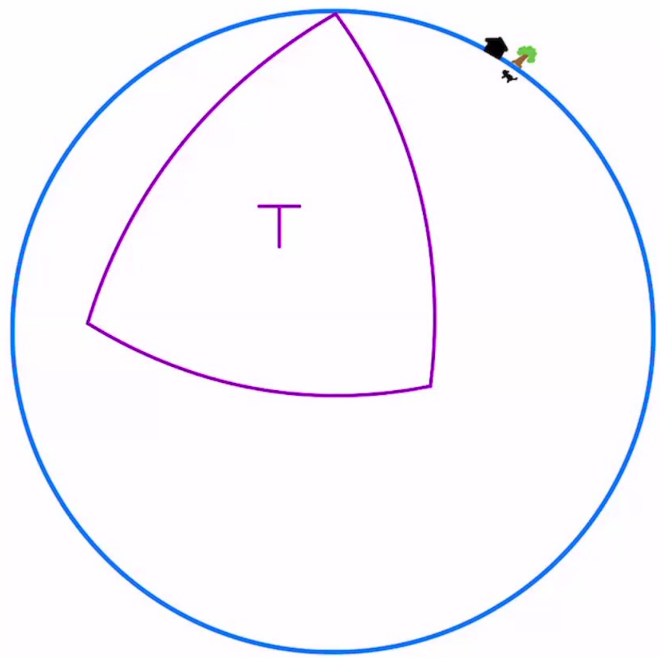


Unlike AdS Observer is part of the system.

Separation of scales



Separation of scales



$$\frac{\ell_E}{\ell_{\ldots}} \longrightarrow \infty$$

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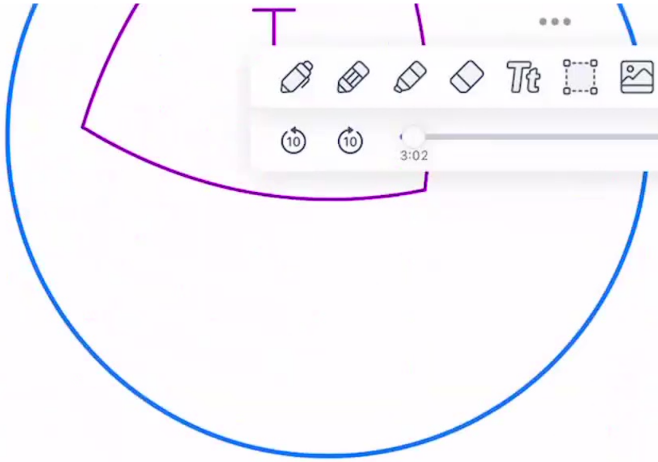


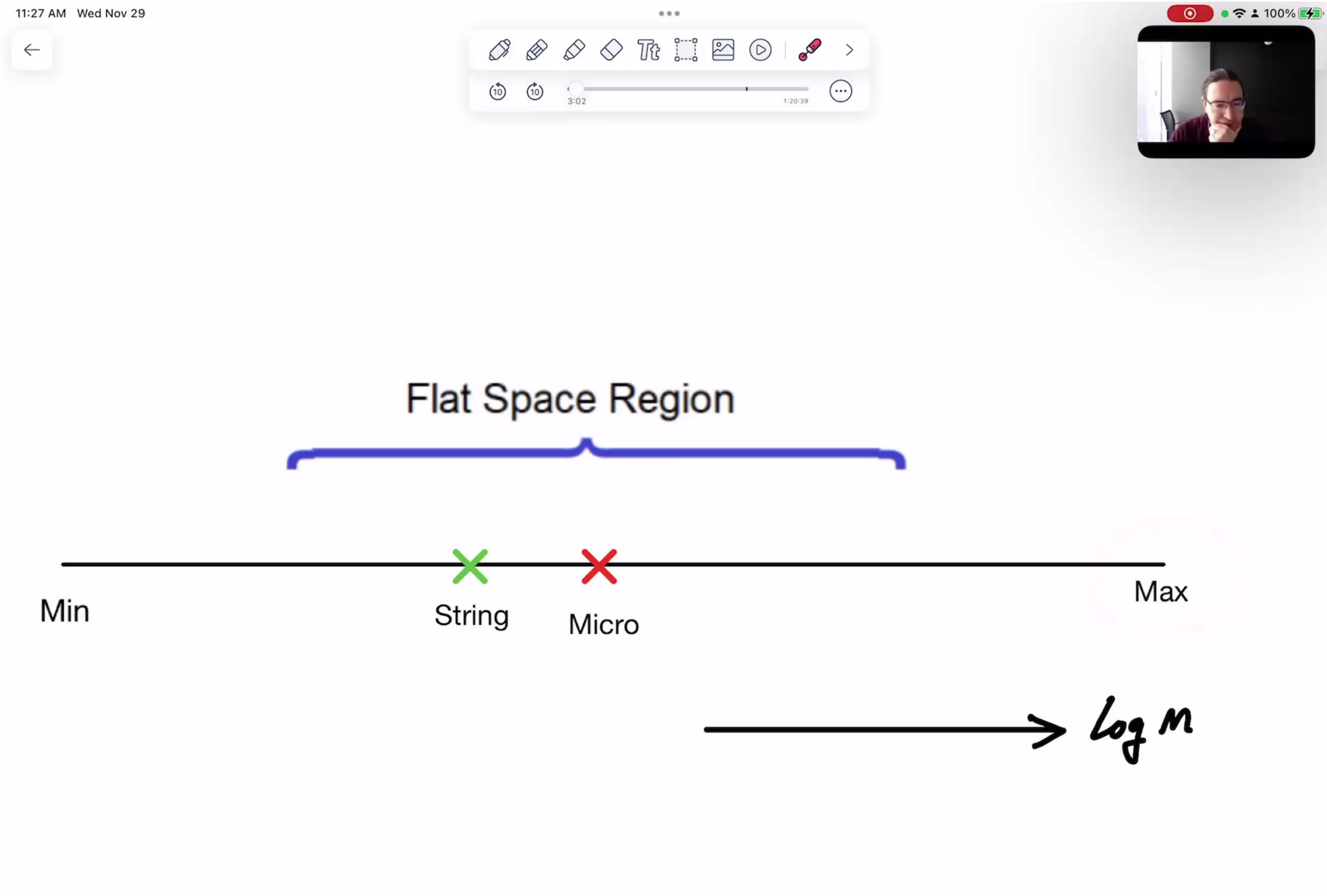
$$\frac{l_E}{l_H} \rightarrow \infty$$

$$\frac{l_c}{l_H} \rightarrow \text{finite}$$

$$\frac{A_T(\theta)}{A_E} \rightarrow \text{finite}$$

Separation of scales

$S \to \infty$ (semiclassical gravity)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Flat Space Region
Min
String
Micro
Max
Log M

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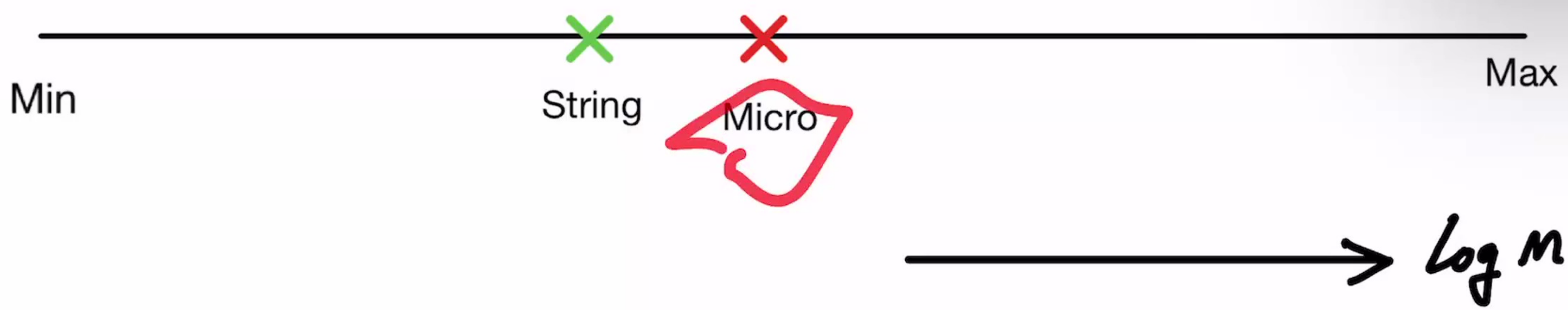
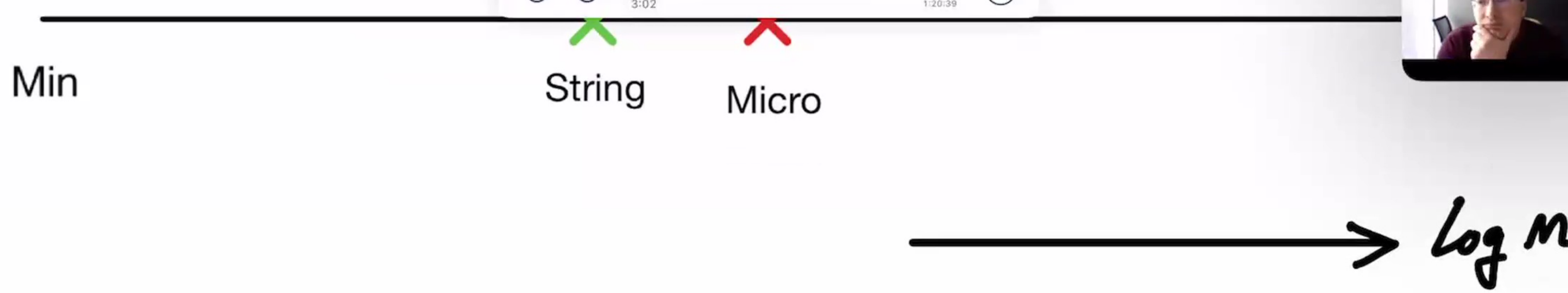


$$\frac{M_{max}}{M_{micro}} = \frac{M_{micro}}{M_{min}} \longrightarrow \infty$$



$$\frac{M_{max}}{M_{micro}} = \frac{M_{micro}}{M_{min}} \longrightarrow \infty$$

$$\left(\frac{M_{string}}{M_{micro}}\right)^2 = \lambda$$

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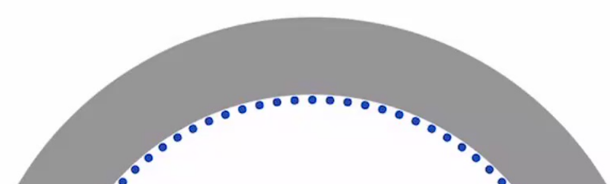
$$\frac{M_{max}}{M_{micro}} = \frac{M_{micro}}{M_{min}} \longrightarrow \infty$$

$$\left(\frac{M_{string}}{M_{micro}}\right)^2 = \lambda$$

Sub - Cosmic locality

Sub-Cosmic locality



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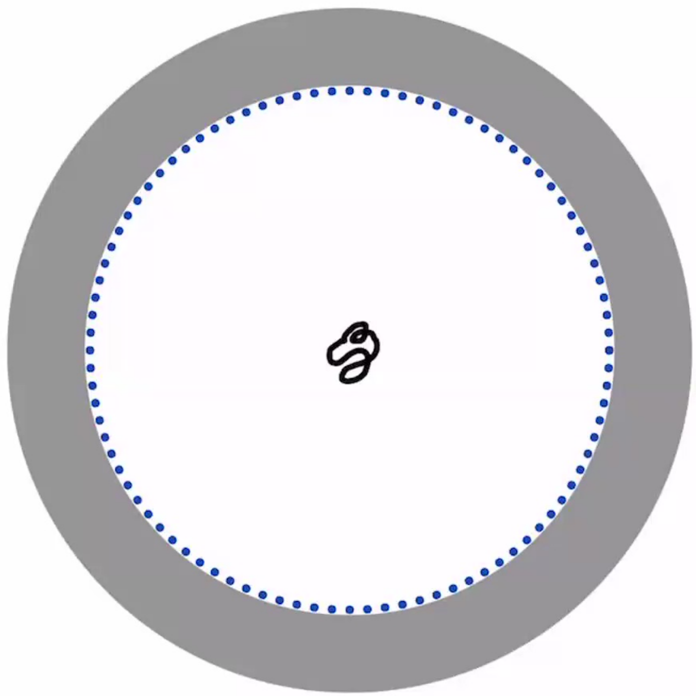

$$\frac{M_{string}}{M_{min}} \to \infty$$

$$\frac{l_s}{l} \to 0$$

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$$\left(\frac{M_{string}}{M_{micro}}\right)^2 = \lambda = \text{finite}$$

$$\frac{M_{string}}{M_{mm}} = \frac{M_{string}}{M_{micro}} \frac{M_{micro}}{M_{mm}} = \sqrt{\lambda N}$$

SYK

$$H = i^{q/2} \sum_{i_1 < i_2 \cdots i_q} J^{i_1 \cdots i_q} \psi_{i_1} \psi_{i_2} \cdots \psi_{i_q}$$

$$\langle J^2 \rangle = \mathcal{J}^2 N \binom{N}{q}^{-1}$$

$$\approx \mathcal{J}^2 \frac{q!}{N^{q-1}}$$

$DSSYK_\infty$

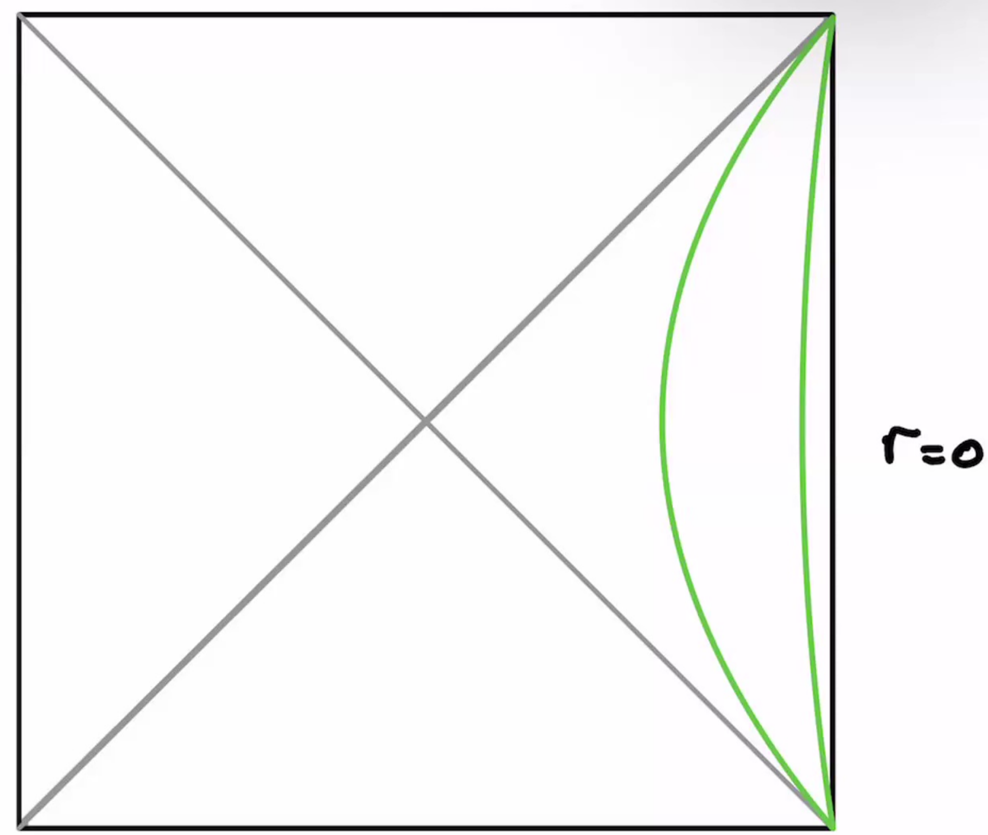
$T = \infty$

$S = N$

$M_{min} = J \sim 1/\ell$

$M_{max} = NJ$

$M_{micro} = \sqrt{N}\, J$



Perturbation Theory

Fermion Propagator

$= \epsilon(t_2 - t_1)$

$\langle J^{\cdots} \; J^{\cdots} \rangle$

$= \mathcal{J}^2 \dfrac{q!}{N^{q-1}}$

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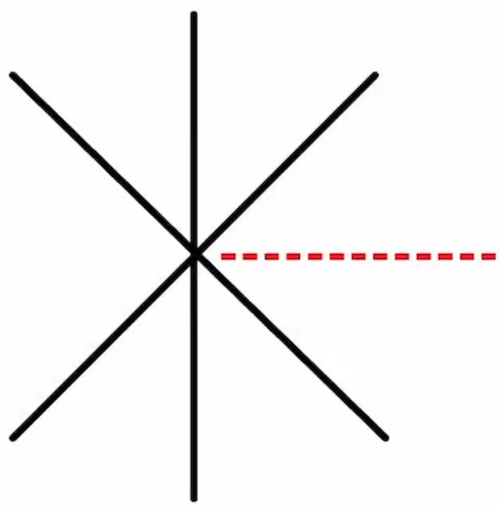
Fermion Prop... t_2 $= \epsilon(t_2$...

$$\langle J^{\cdots} \; J^{\cdots} \rangle \quad - - - - - - - - \quad = J^2 \frac{q!}{N^{q-1}}$$



$q = 6$

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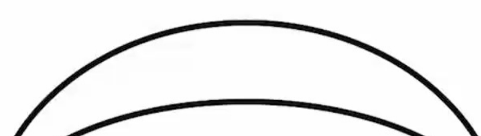
$\frac{1}{N}$ expansion

$$A = \sum_n \frac{P_n(g)}{N^n}$$

$n = 0$ Melons



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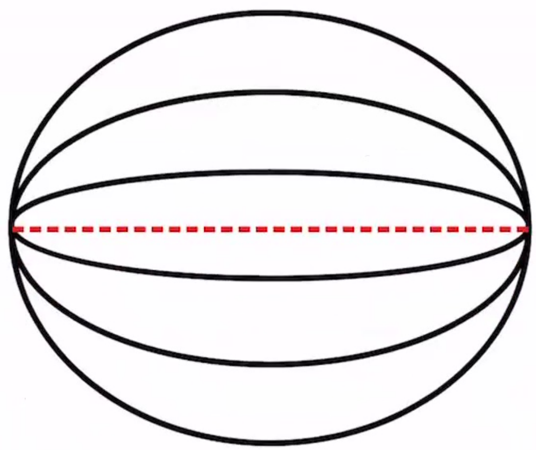
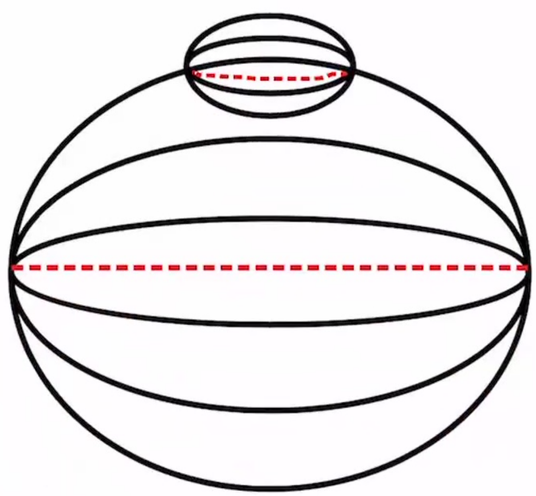
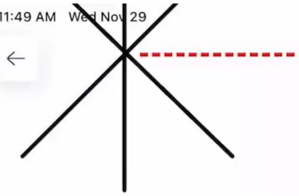


N^0

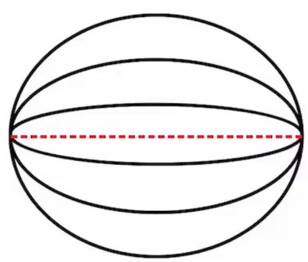


$g^2 N^0$

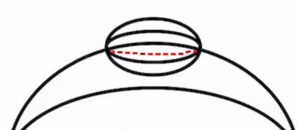


$\frac{1}{N}$ expansion

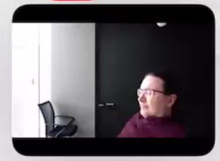
$$A = \sum_n \frac{P_n(g)}{N^n} \qquad n=0 \quad \text{Melons}$$



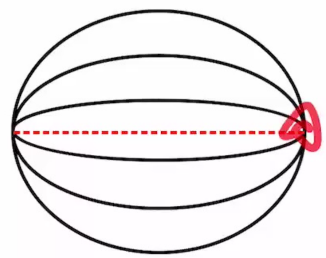
N^0



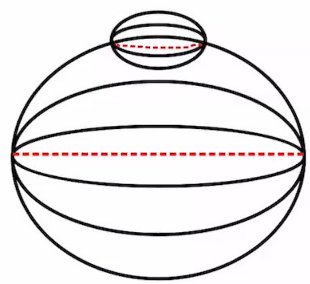
$g^2 N^0$



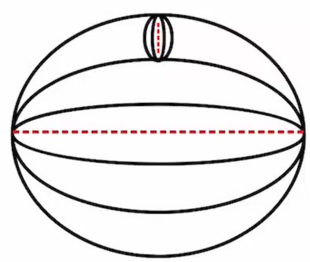
Gauge Theory	$DSSYK_{\infty}$
N_{YM}^2	N
't Hooft α	g
$g_{YM}^2 = \frac{\alpha}{N_{YM}}$ → $g_{YM}^4 = \frac{\alpha^2}{N_{YM}^2}$	$\frac{g^2}{N} = \lambda$



N^0



$g^2 N^0$



$\frac{g^4}{N}$

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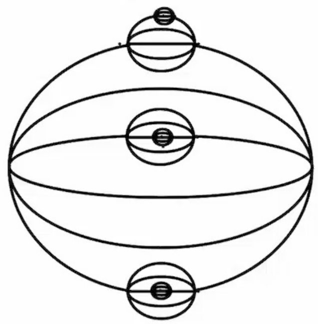
Min String Micro

Schwinger Dyson



$$\int e^{-gJt}\, dt$$

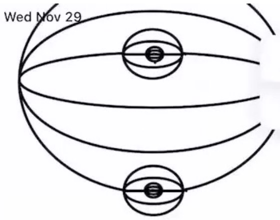
$$l_{string} = \frac{1}{gJ}$$

IR s

$$M_{string} = gJ$$

$$= M_{chord}$$ Berkooz ...

$$M_{string} = gJ$$



$$\ell_{string} = \frac{1}{g\mathcal{J}}$$

IR scale

$$M_{string} = g\mathcal{J}$$

$$= M_{chord}$$

Berkooz ...

$$M_{string} = g\mathcal{J}$$

$$M_{micro} = \sqrt{N}\,\mathcal{J}$$

$$\left(\frac{M_{string}}{M_{micro}}\right)^2 = \frac{g^2}{N} = \lambda$$

$DSSYK_{\infty}$

$$\left(\frac{M_{string}}{M_{micro}}\right)^2 = \frac{g^2}{N} = \lambda$$

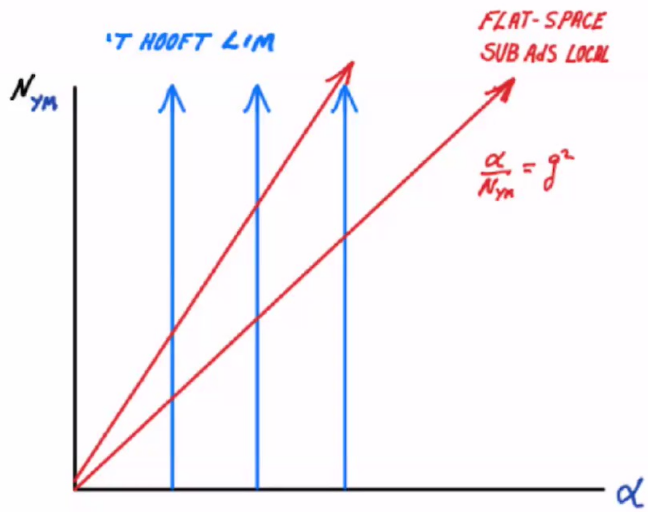
$DSSYK_\infty$

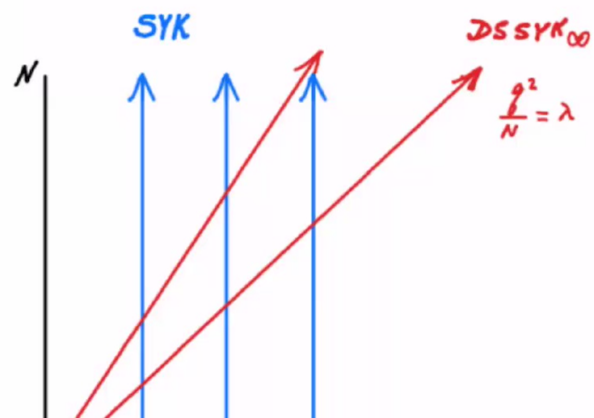
$T = \infty$

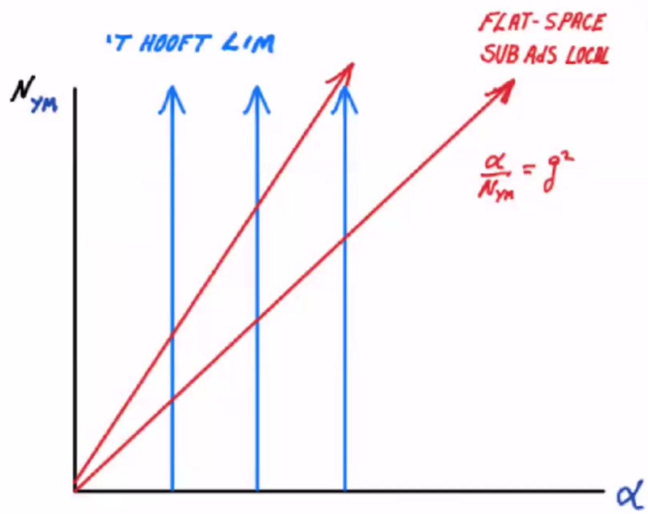
$N \to \infty$

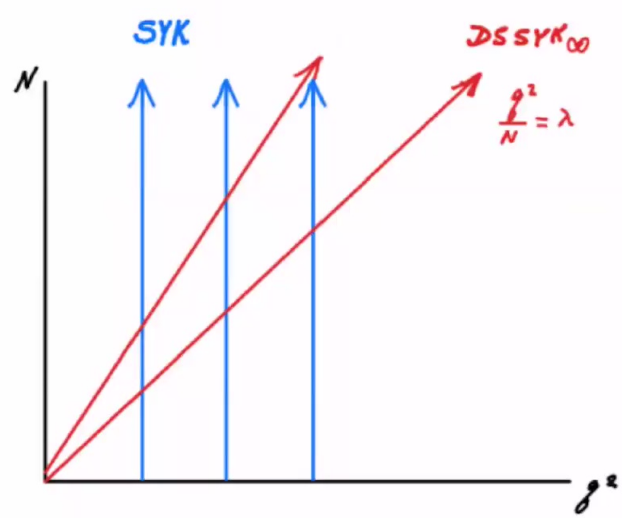
$\frac{g^2}{N} = \lambda$ = fixed + finite

Sub-Cosmic Locality


'T HOOFT LIM
FLAT-SPACE
SUB AdS LOCAL
N_{YM}
$\frac{\alpha}{N_{YM}} = g^2$
α

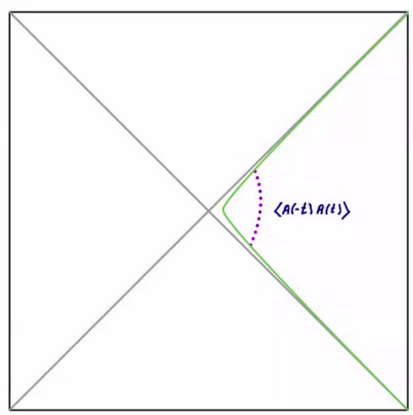

SYK
DSSYK$_\infty$
N
$\frac{g^2}{N} = \lambda$

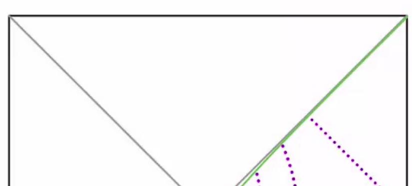

'T HOOFT LIM
FLAT-SPACE
SUB AdS LOCAL
N_{YM}
$\frac{\alpha}{N_{YM}} = g^2$
α

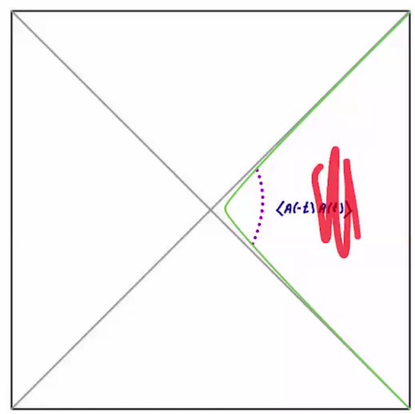

SYK
DSSYK$_\infty$
N
$\frac{g^2}{N} = \lambda$
g^2

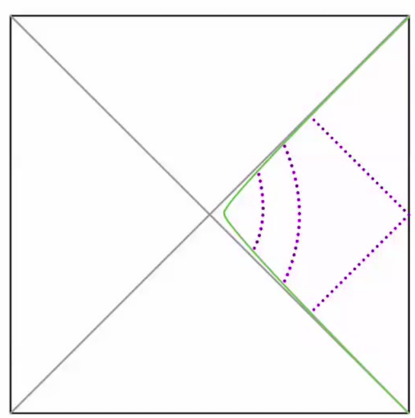
Cosmic Scale

Hawking Radiation (wavelength $\sim \ell$)

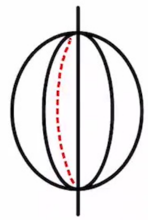








No. Too many

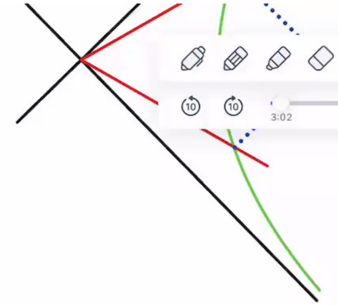


$= 2J$

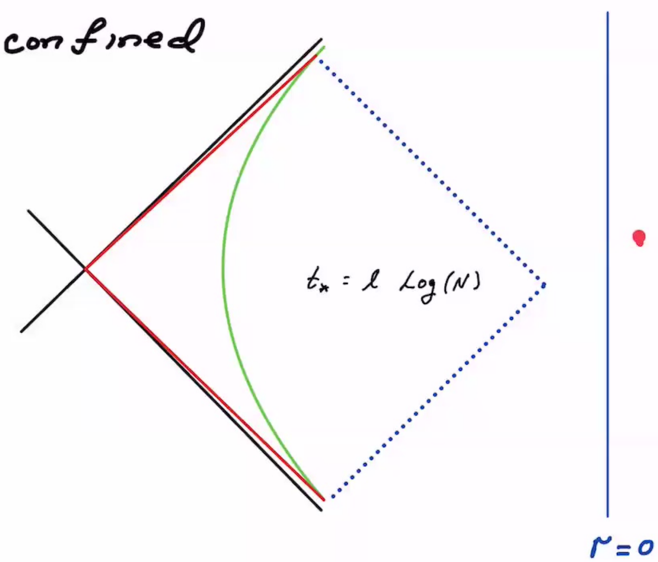
$$\langle \psi(0)\, \psi(t) \rangle \sim e^{-2Jt}$$

$$= e^{-\frac{2t}{\ell}} = e^{-\tau}$$

confined



Unconfined



$r = 0$

Gravitons

Photons

Complex $U(1)$ SYK $\longrightarrow$ Photons

$\bar{\psi}_i \, , \; \psi^i \qquad i = 1 \dots N$

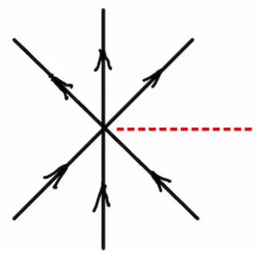
$U(N)$ SYMMETRY

$$\psi^i \longrightarrow U^i{}_j \, \psi^j$$

$$J^{i \cdots}_{\cdots} \longrightarrow U U U \cdots U^\dagger U^\dagger U^\dagger \cdots J^{\cdots}_{\cdots}$$

ψ

$$J^{\cdot\cdots}_{\cdots} \to UUU\cdots U^\dagger U^\dagger U^\dagger \cdots J^{\cdots}_{\cdots}$$



SU(N) multiplets degenerate

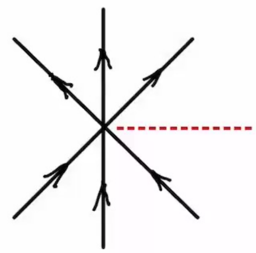
ψ^i is in the fundamental

It's confined

Fermion pairs

ψ

$$J^{\,\cdot\,\cdots}_{\cdots\,\cdot} \rightarrow UUU\cdots\, U^\dagger U^\dagger U^\dagger \cdots\, J_{\cdots}$$



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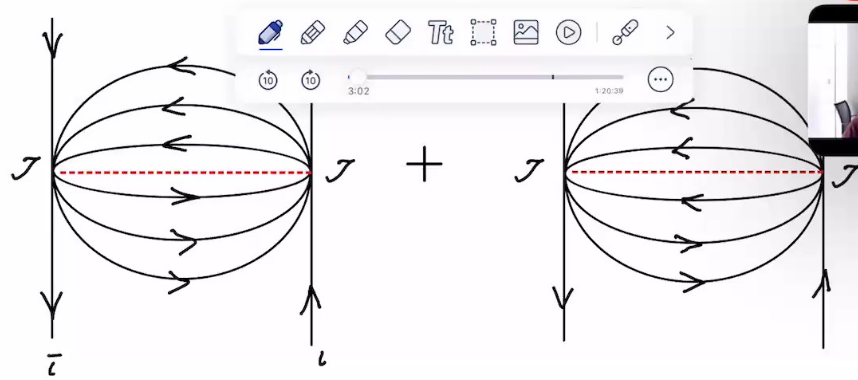
Fermion pairs



Adjoint

$$\langle a(0)\, a(t) \rangle \sim e^{-\gamma t}$$

$$\gamma_A = 4J$$

Confined

Singlet

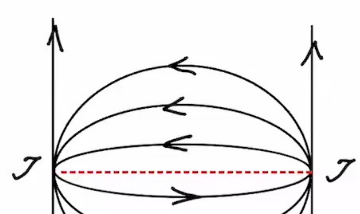
$$\langle s(0)\, s(t) \rangle \sim e^{-\gamma t}$$

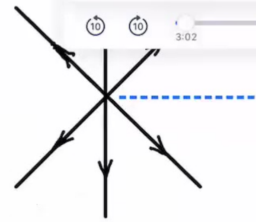
$$\gamma_s \to \frac{\mathcal{K}^2}{J}$$

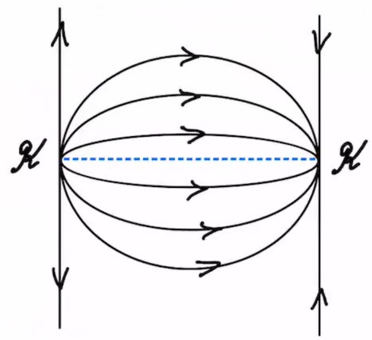
$$\gamma_A \to 4J + \mathcal{O}\frac{1}{N}$$

Conjecture

SU(N) charge is confined. only singlets can propagate into the static patch.







 $= \frac{\mathcal{J}^2}{q} \frac{q!}{N^{q-1}}$

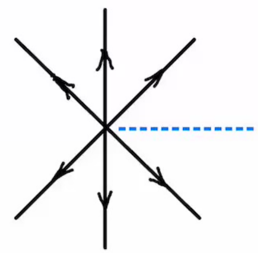
$$\gamma_S \to \frac{\mathcal{J}^2}{J}$$

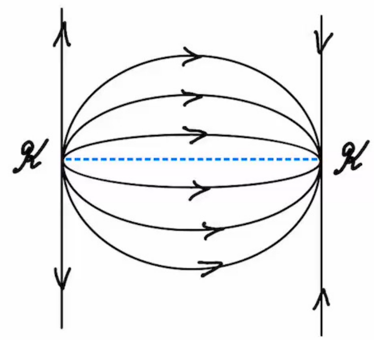
$$\gamma_A \to 4J + O\frac{1}{N}$$

Conjecture

Higgs

Break $U(1)$





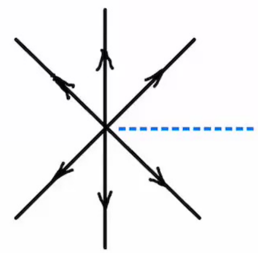
$$- - - - = \frac{\mathcal{K}^2}{q}\frac{q!}{N^{q-1}}$$

$$\gamma_S \to \frac{\mathcal{K}^2}{J}$$

$$\gamma_A \to 4J + \mathcal{O}\frac{1}{N}$$

Higgs

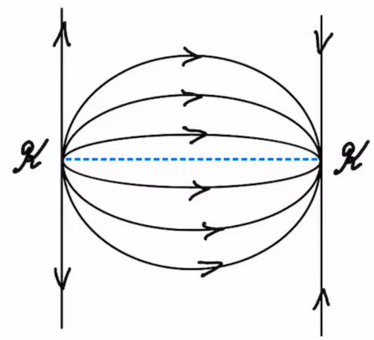
Break $U(1)$



$\psi^\dagger \dot{\psi}$

$\psi^\dagger [H \psi]$

...



$\psi^\dagger \psi \, J J J J$

$\psi_i \psi_i$

$\psi_i \dot{\psi}_i$

- - - - - - $= \frac{\mathcal{K}^2}{q} \frac{q!}{N^{q-1}}$

$\gamma_s \to \frac{\mathcal{K}^2}{J}$

$\gamma_A \to 4J + \mathcal{O}\frac{1}{N}$