Title: Quantum Information and holography

Speakers: Aaron Szasz, Beni Yoshida

Collection: Quantum Information and holography (2021/2022)

Date: April 12, 2022 - 9:00 AM

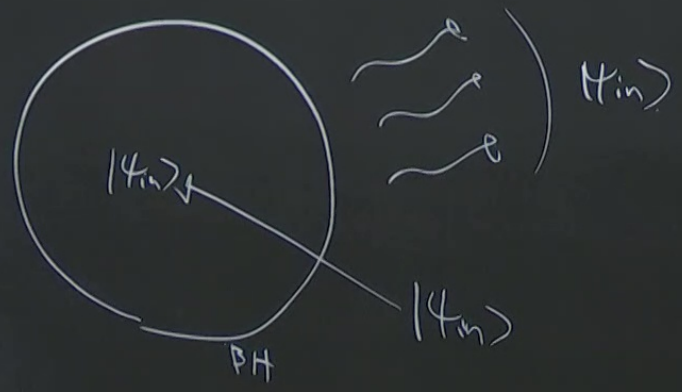
URL: https://pirsa.org/22040047

Abstract: Topics will include (but are not limited to):
- Quantum error correction in quantum gravity and condensed matter
- Quantum information scrambling and black hole information
- Physics of random tensor networks and random unitary circuits

Cloning Puzzle

$|\psi_{in}\rangle \rightarrow |\psi_{in}\rangle \otimes |\psi_{in}\rangle$
inside outside.

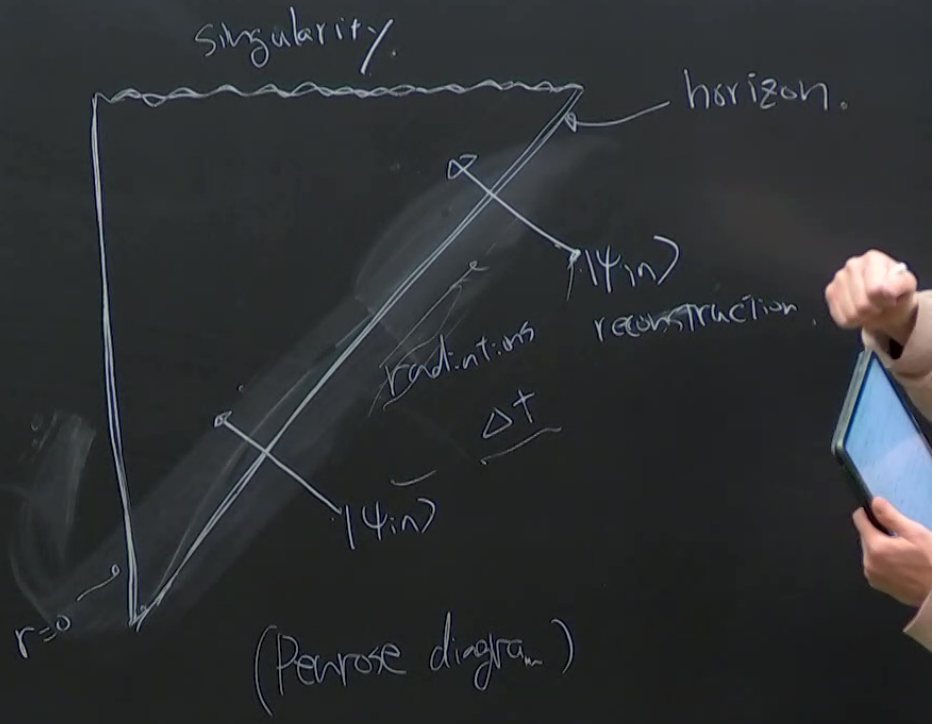
Cloning!!



(Unitary
Finite S_{BH}

Black hole complementarity

- Can we really verify cloning?

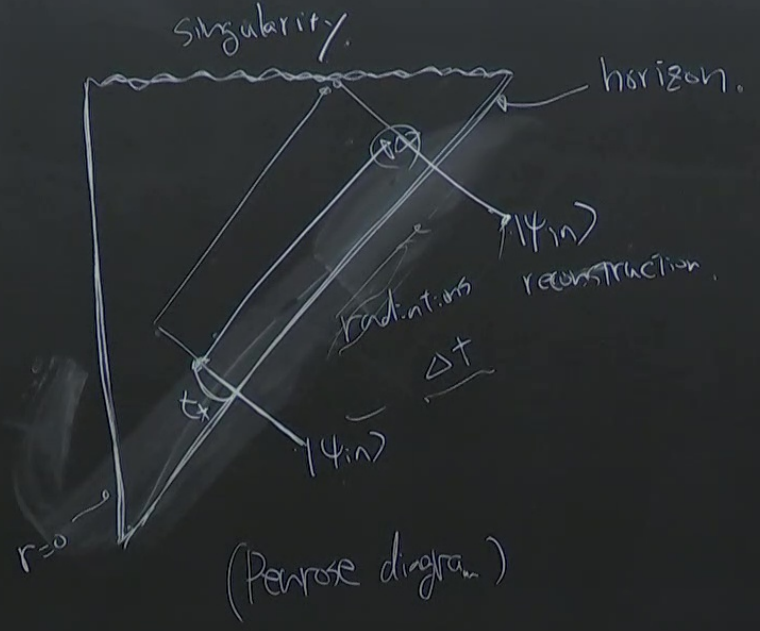


Black hole complementarity

- Can we really verify cloning?

$\Delta t \simeq$ Page time

- t_* needs to be very small.



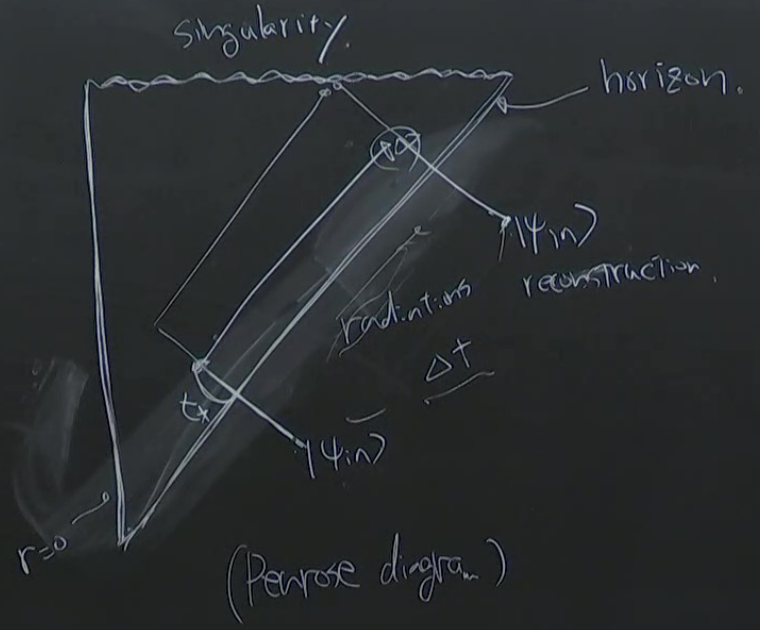
Black hole complementarity

- Can we really verify cloning?

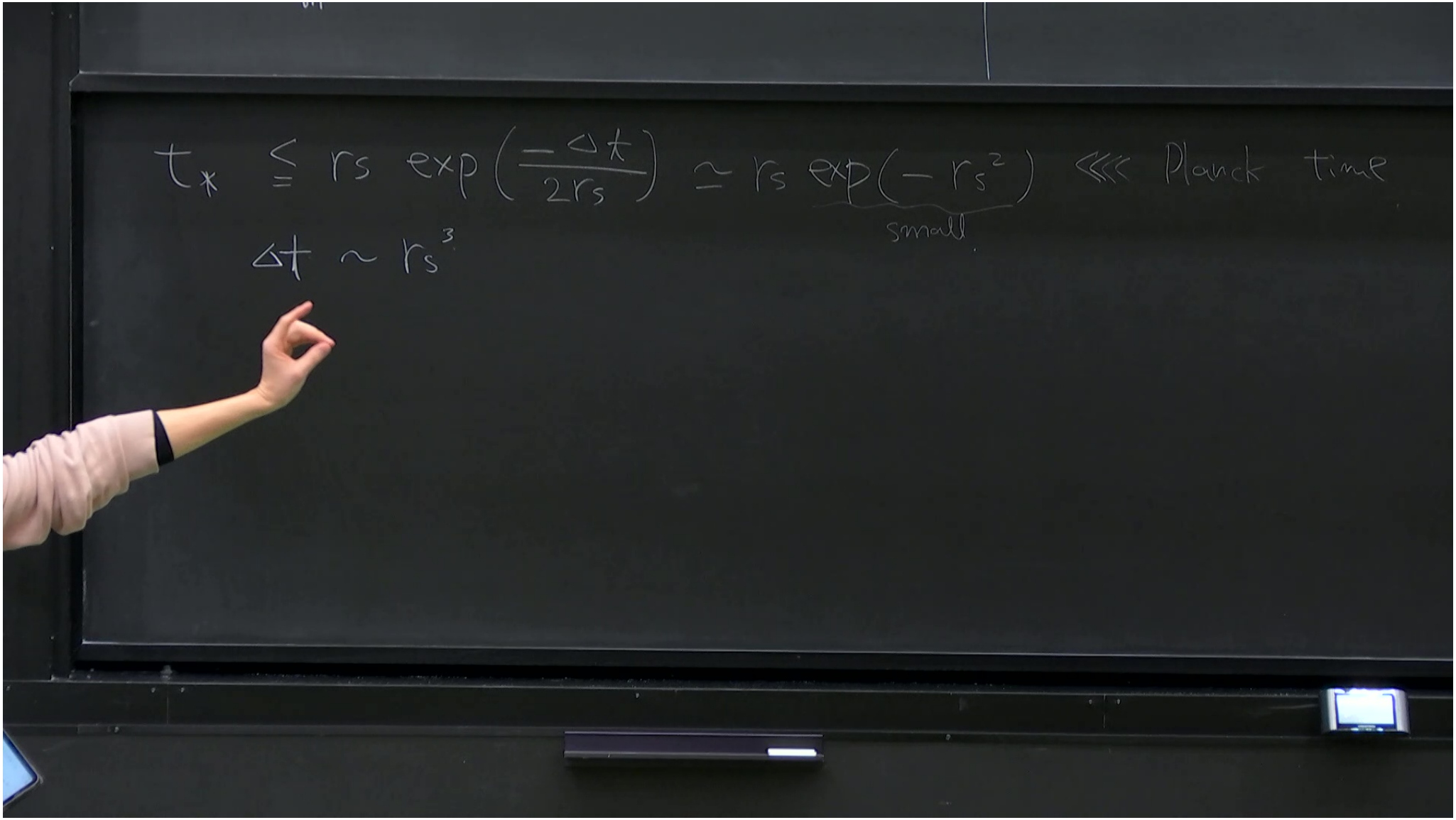
  $\Delta t \simeq$ Page time

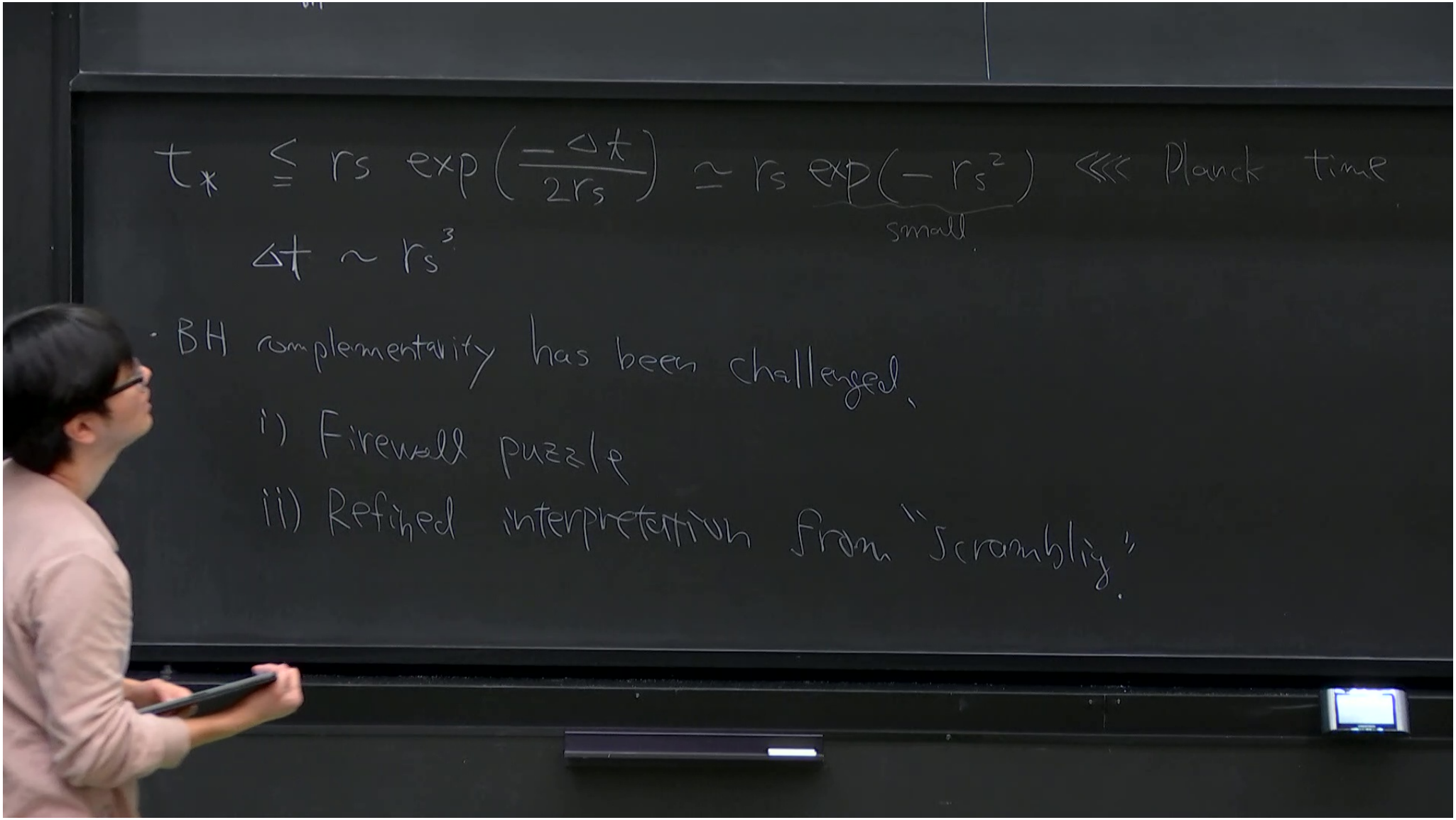
- t_x needs to be very small.

  Otherwise, they will reach singularity before they meet.



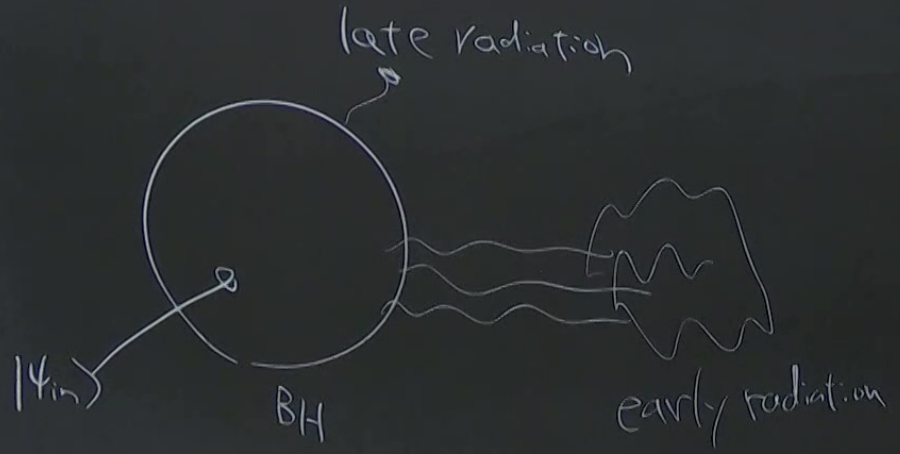
(Penrose diagram)


$t_* \leq r_s \exp\left(\frac{-\Delta t}{2r_s}\right) \simeq r_s \exp(-r_s^2)$ <<< Planck time
small
$\Delta t \sim r_s^3$


$t_* \leq r_s \exp\left(\frac{-\Delta t}{2r_s}\right) \simeq r_s \exp(-r_s^2) \ll$ Planck time
small
$\Delta t \sim r_s^3$
· BH complementarity has been challenged.
i) Firewall puzzle
ii) Refined interpretation from "scrambling"

Hayden-Preskill thought experiment

- Throw $|\psi_{in}\rangle$ to BH after Page time

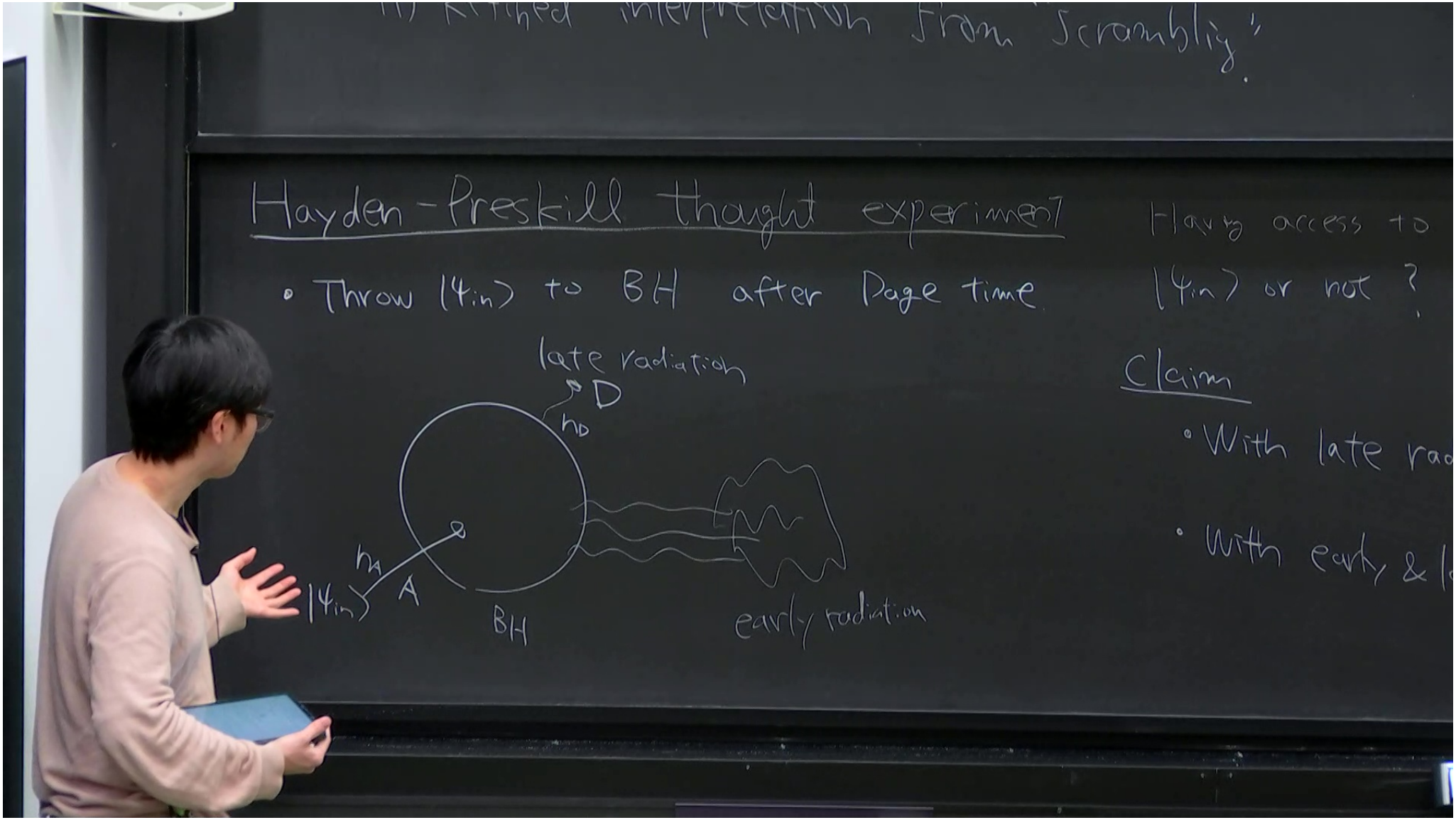


ramblig:

Having access to <u>both</u> early and late radiation, can we reconstruct $|\psi_{in}\rangle$ or not?

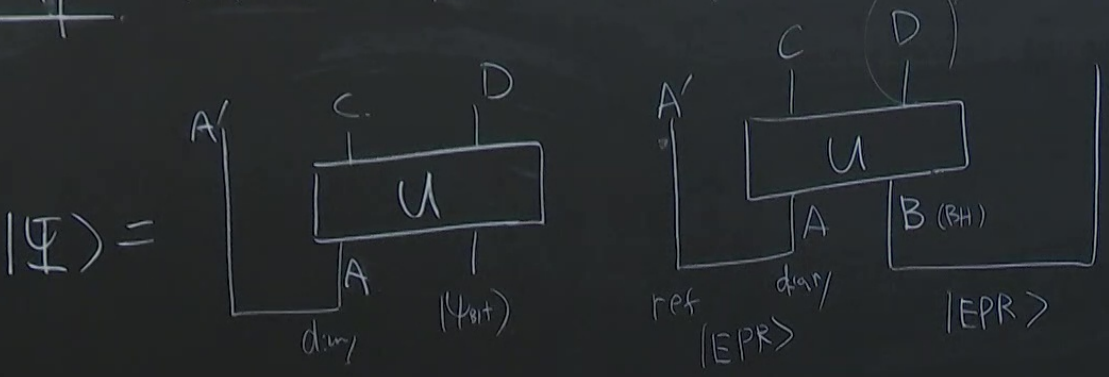
<u>Claim</u>

- With late radiation only, we need $n_D \simeq n$. (whole BH)
- With early & late radiation, we need $n_D \geq n_R$


Hayden-Preskill thought experiment
• Throw |ψ_in⟩ to BH after Page time
late radiation
D
h_D
h_A
|ψ_in⟩
A
BH
early radiation
Claim
• With late ra
• With early &

Set up Reference system Trick

late radiation



Page,

$I(A'; D)$

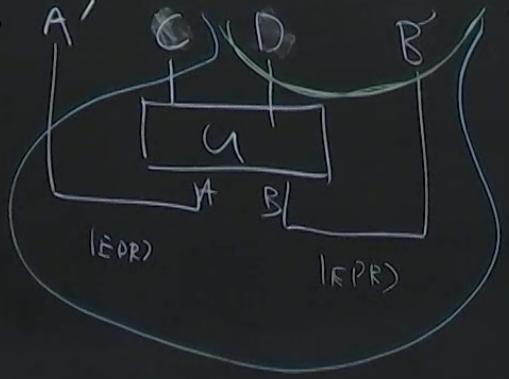
Hayden-Preskill.

$I(A'; DB') \overset{?}{\simeq} \max \Leftrightarrow I(A', C) \overset{?}{\approx} 0$

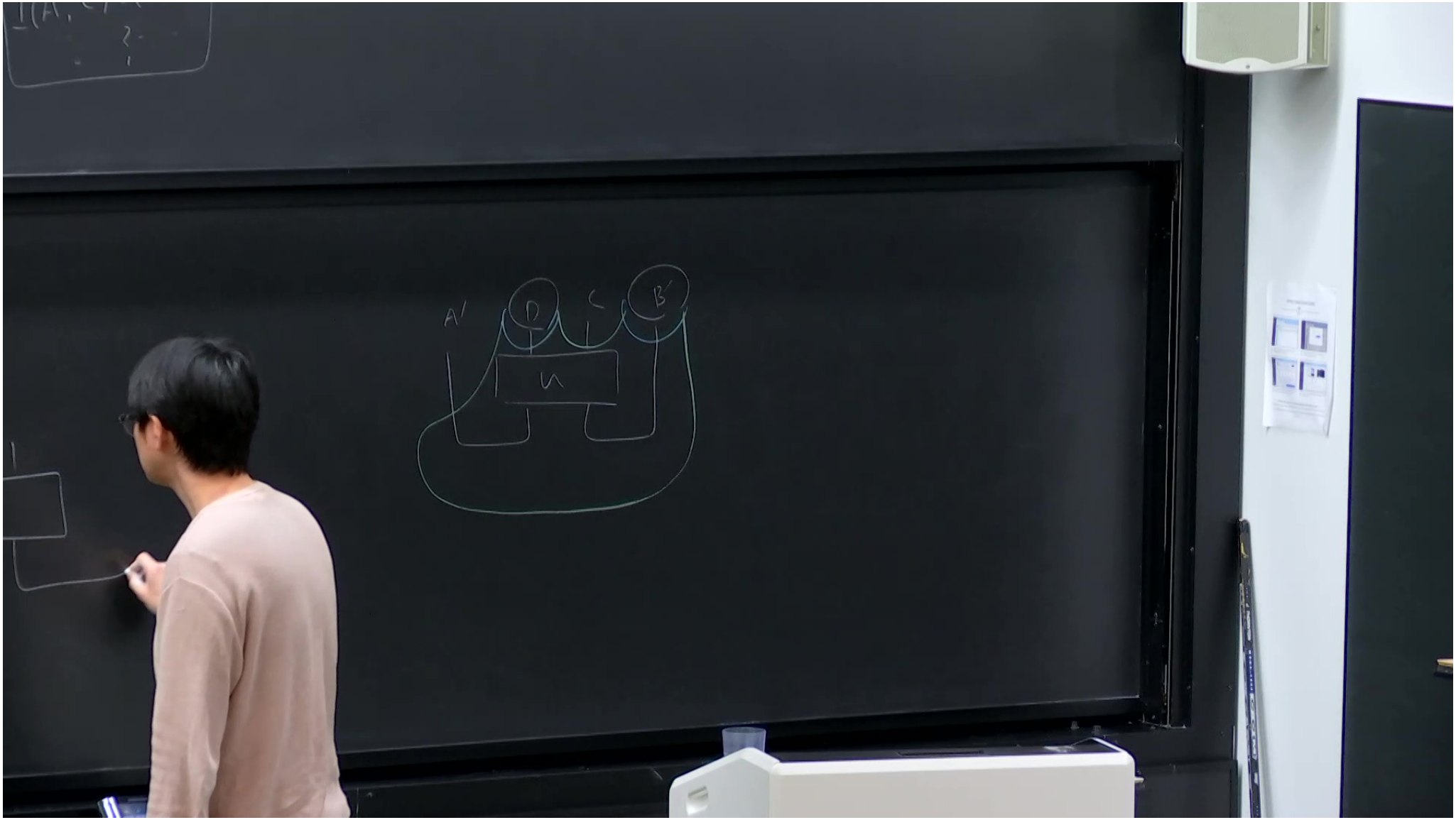
Minimal Surface estimate

$$I(A', DB') = \underbrace{S_{A'}}_{\| \; n_A} + S_{DB'} - \underbrace{S_{A'DB'}}_{\| \; S_C}$$

$S_{DB'}$



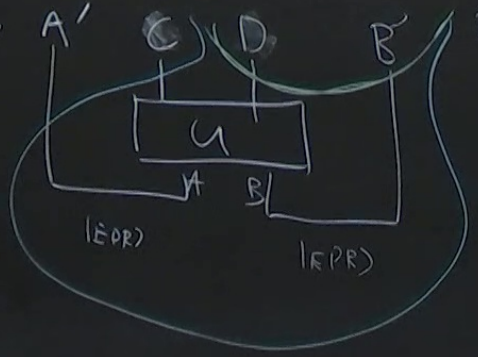
$= \min\left(n_D + n_B, n_A + n_C\right)$, S_C.

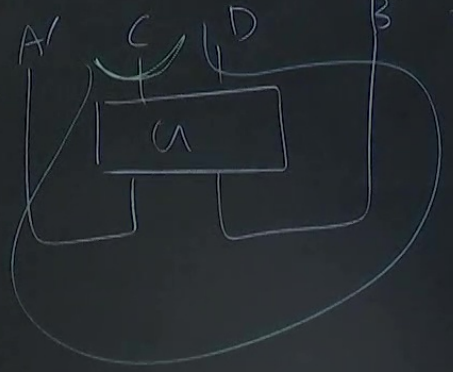

A'
B'
U

Minimal Surface estimate

$$I(A', DB') = \underbrace{S_{A'}}_{= n_A} + S_{DB'} - \underbrace{S_{A'DB'}}_{= S_C} \leq 2n_A$$

$n_D > n_A$

$S_{DB'}$ 

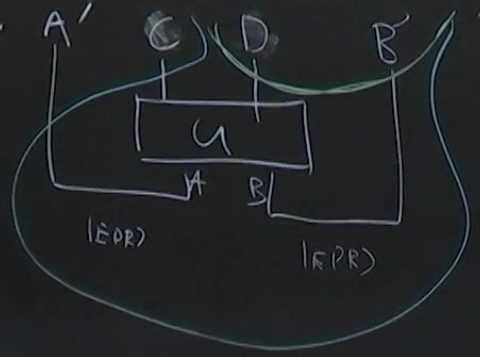
$\min(n_D + n_B, n_A + n_C)$, S_C 

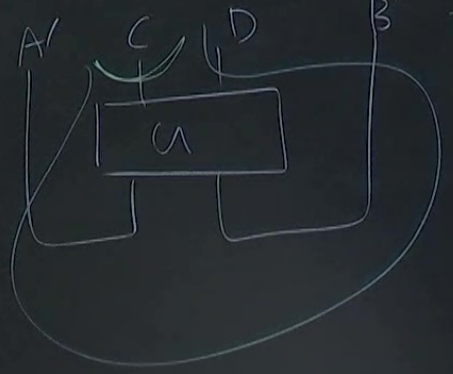
$\min(n_C, n_A + n_D + n_B)$

Minimal Surface estimate

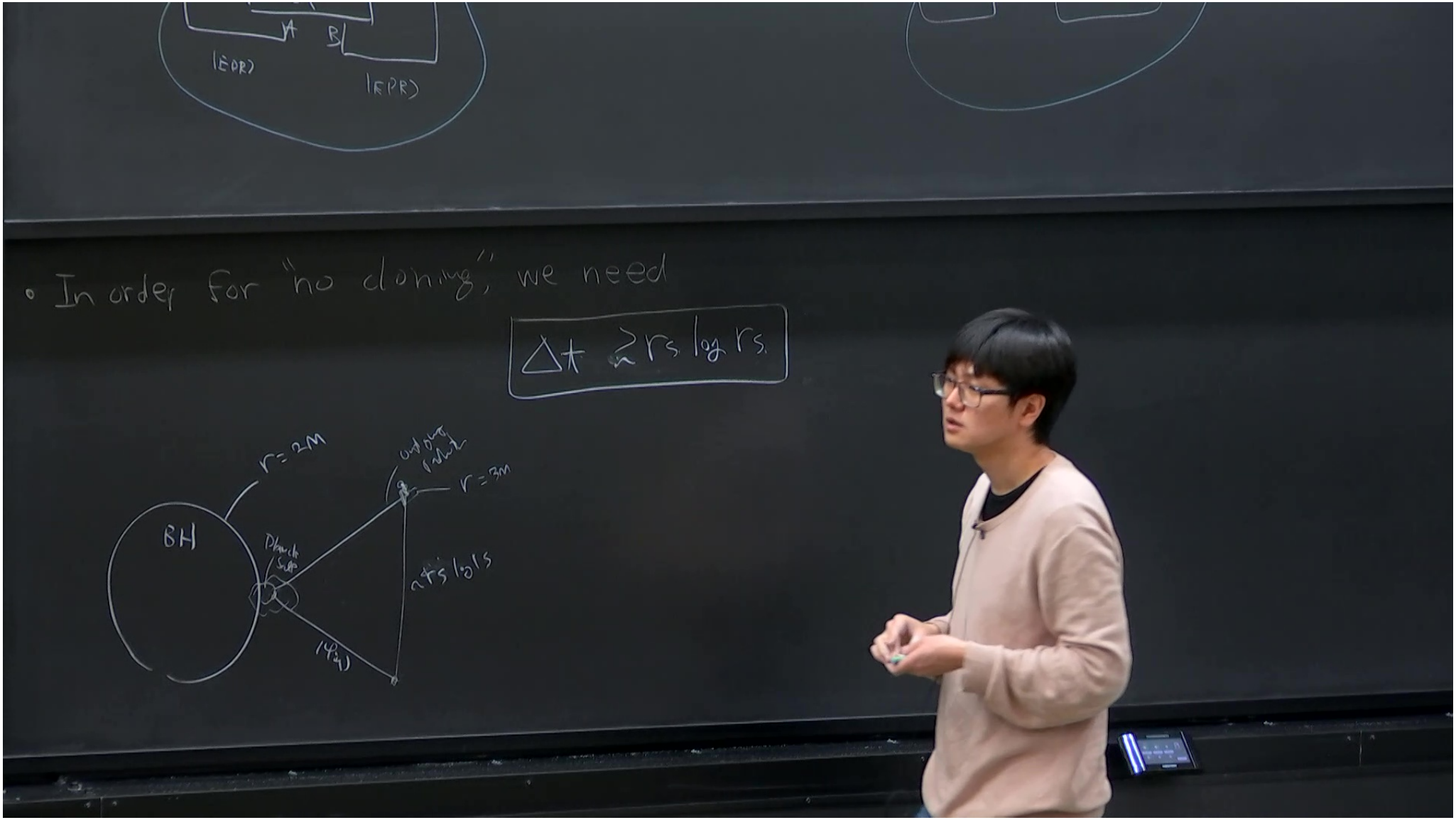
$$I(A', DB') = \underbrace{S_{A'}}_{= n_A} + S_{DB'} - \underbrace{S_{A'DB'}}_{= S_C} \simeq 2n_A$$

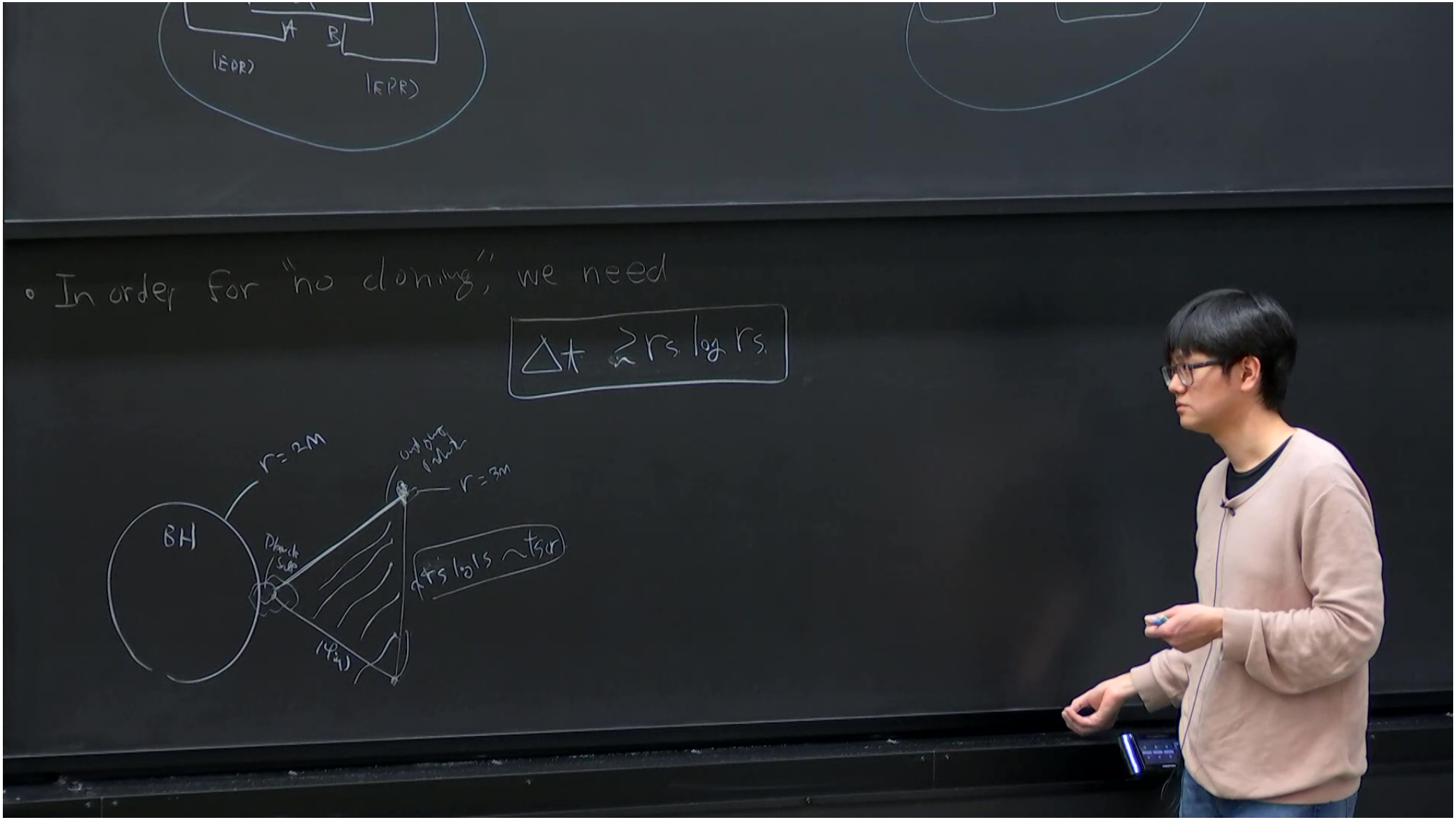
$n_D > n_A$ → (4in) reconstruction is possible.

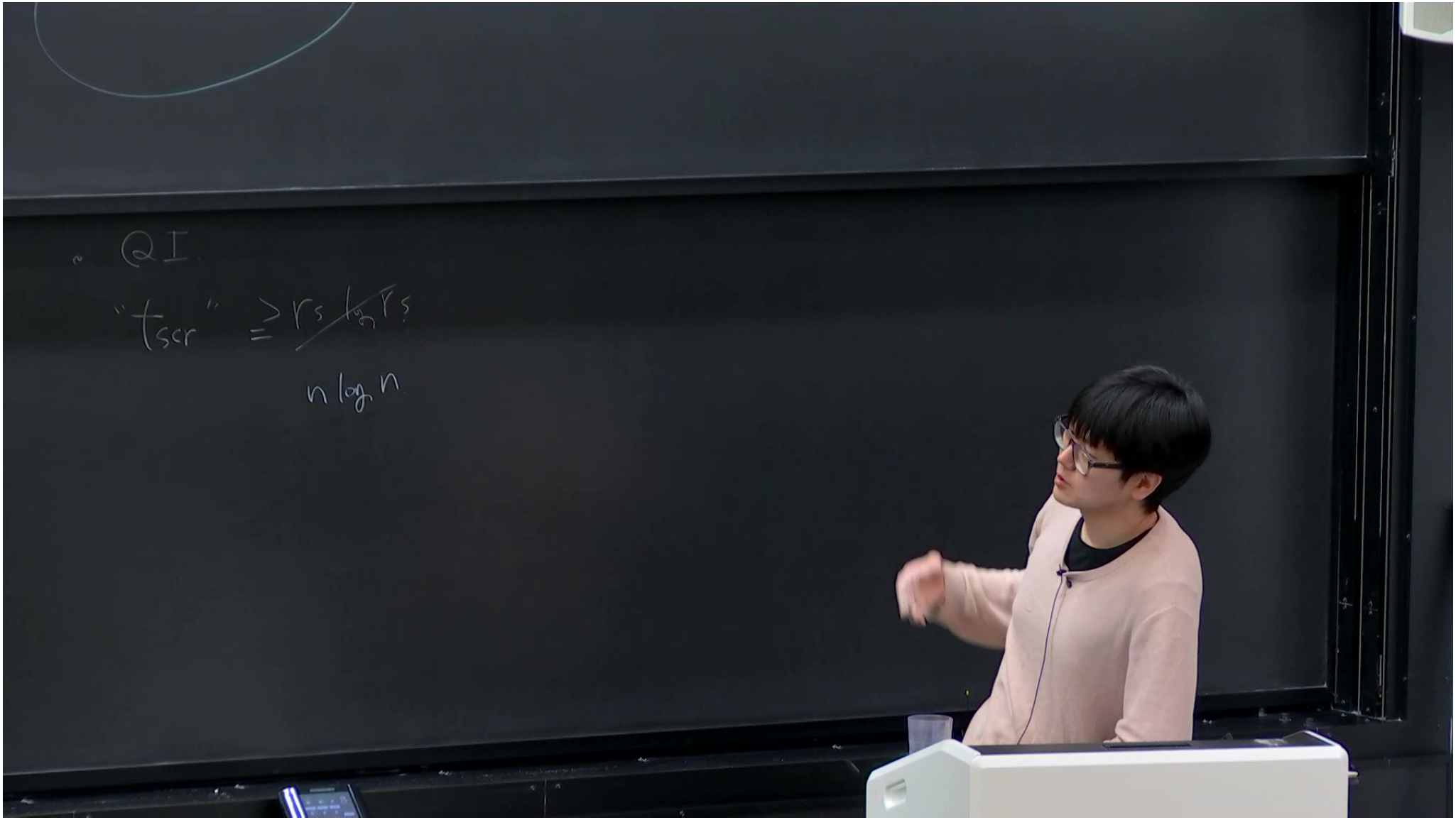
$S_{DB'}$ 

$\min(n_D + n_B, n_A + n_C)$, S_C. 

$\min((n_C), n_A + n_D + n_B)$


A
B
|EPR⟩
|EPR⟩
• In order for "no cloning", we need
$\Delta t \gtrsim r_s \log r_s$
r = 2M
outgoing radial
r = 3M
BH
Photon Sphere
$\sim r_s \log r_s$
(ψ_{in})


A
B
|EPR⟩
|EPR⟩
• In order for "no cloning", we need
$\Delta t \gtrsim r_s \log r_s$
r = 2M
r = 3M
BH
t_{sr}


QI
"t_{scr}" $\geq \frac{r_s}{\log r_s}$
$n \log n$