Title: AdS/CFT Lecture (230505)

Speakers: David Kubiznak

Collection: AdS/CFT (2022/2023)

Date: May 05, 2023 - 9:00 AM

URL: https://pirsa.org/23050009

BACK TO BH INFORMATION PARADOX

BASED ON: ARXIV: 2006.06872

BACK TO BH INFORMATION PARADOX

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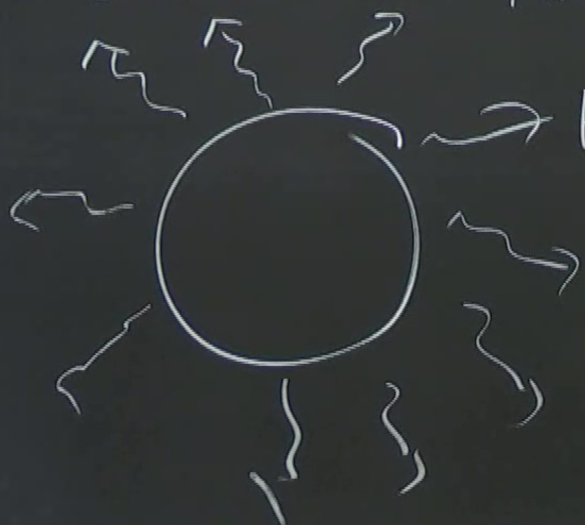
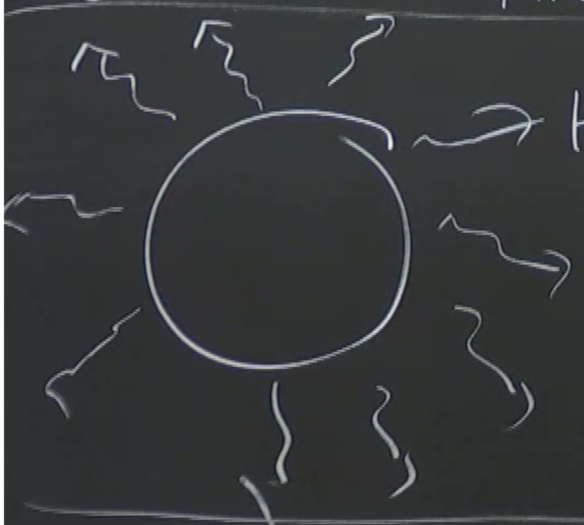


HAWKING RADIATION

BACK TO BH INFORMATION PARADOX

BASED ON: ARXIV: 2006.06872



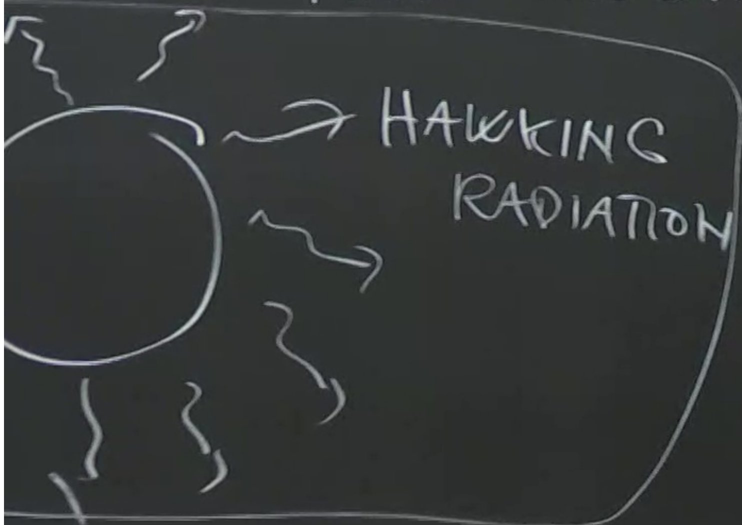
HAWKING RADIATION

- DUE TO AdS/CFT EVOLUTION SHOULD BE UNITARY.
- CONTRADICTION, IF BH EVAPO

TO BH INFORMATION PARADOX

a)T

ED ON: ARXIV: 2006.06872



- DUE TO AdS/CFT EVOLUTION SHOULD BE UNITARY.
- CONTRADICTION, IF BH EVAPORATES COMPLETELY. SEEM TO HAVE MIXED.

a) TWO TYPES OF ENTROPIES

- QUANTUM MECHANICAL – VON-NEUMANN (FINE GRAINED)

$$\boxed{S_{VN} = -\operatorname{Tr} \rho \log \rho}$$

- INVARIANT UNDER TIME EVOLUTION

TES

IXED,

$$\boxed{S_{VN} = -\mathrm{Tr}\,\rho \log \rho}$$

- INVARIANT UNDER TIME EVOLUTION
- PURE STATE: $\mathcal{H} = \mathcal{H}_A \otimes \mathcal{H}_{B=\bar{A}}$

$$S(A) = S(B), \quad S(A \cup B) = \emptyset$$

TES

MIXED,

• THERMODYNAMIC (COARSE-GRAINED)

$$\boxed{S_{TD}} = \max_{\rho}\left(-\mathrm{Tr}(\rho \log \rho)\right)$$

CONSISTENT WITH $\quad a_i = \mathrm{Tr}(\rho A_i)$

$$E = \mathrm{Tr}(\rho H)$$

... TO HAVE MIXED, ...

- MEASURES DOF. AVAILABLE TO SYSTEM (CONSISTENT WITH THE OBSERVATION)

$$\boxed{S_{vN} \leq S_{TD}}$$

A_i)

• MEASURES DOF. AVAILABLE TO SYSTEM
(CONSISTENT WITH THE OBSERVATION)

$$\boxed{S_{VN} \leq S_{TD}}$$

• RECALL: IN THE PRESENCE OF BHS.

(CONSISTENT WITH THE OBSERVATION)

$$\boxed{S_{VH} \leq S_{TD}}$$

...LL: IN THE PRESENCE OF BHS: GENERALIZED ENTROPY

$$S_{GEN} = S_{BH} + S_{OUTSIDE}$$

(CONSISTENT WITH THE OBSERVATION)

$$\boxed{S_{VN} \leq S_{TD}}$$

LL: IN THE PRESENCE OF BHS: GENERALIZED ENTROPY

$$\boxed{S_{GEN} = S_{BH} + S_{OUTSIDE}}$$: OBEY 2ND LAW

$$\Delta S_{GEN} \geq 0$$

(CONSISTENT WITH THE OBSERVATION)

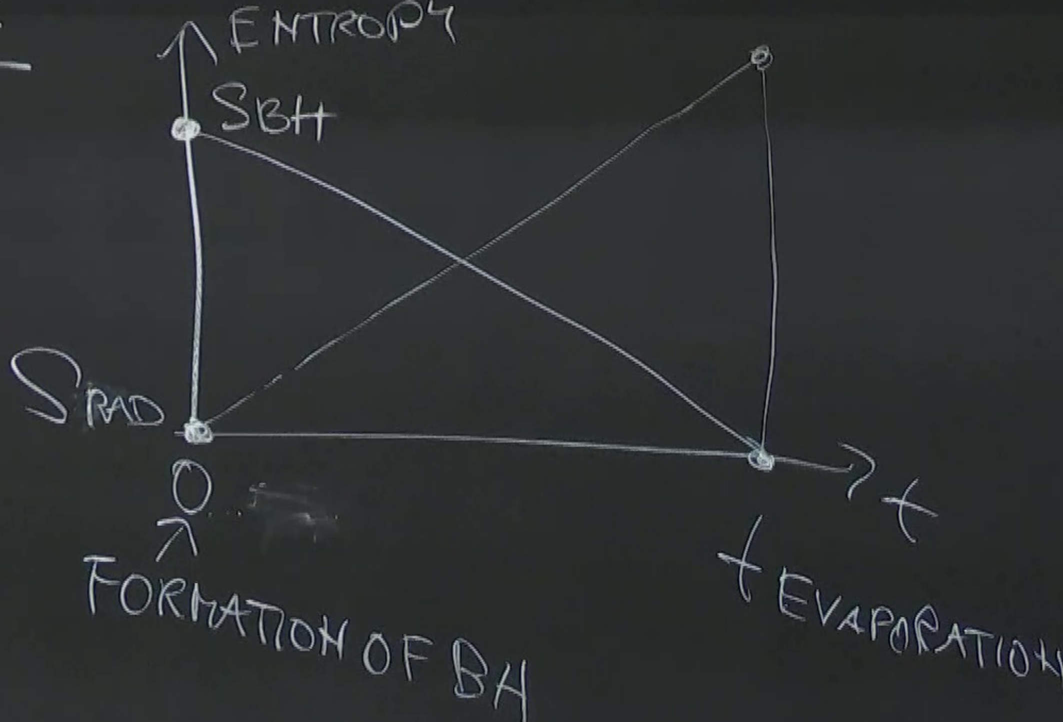
$$\boxed{S_{VN} \leq S_{TD}}$$

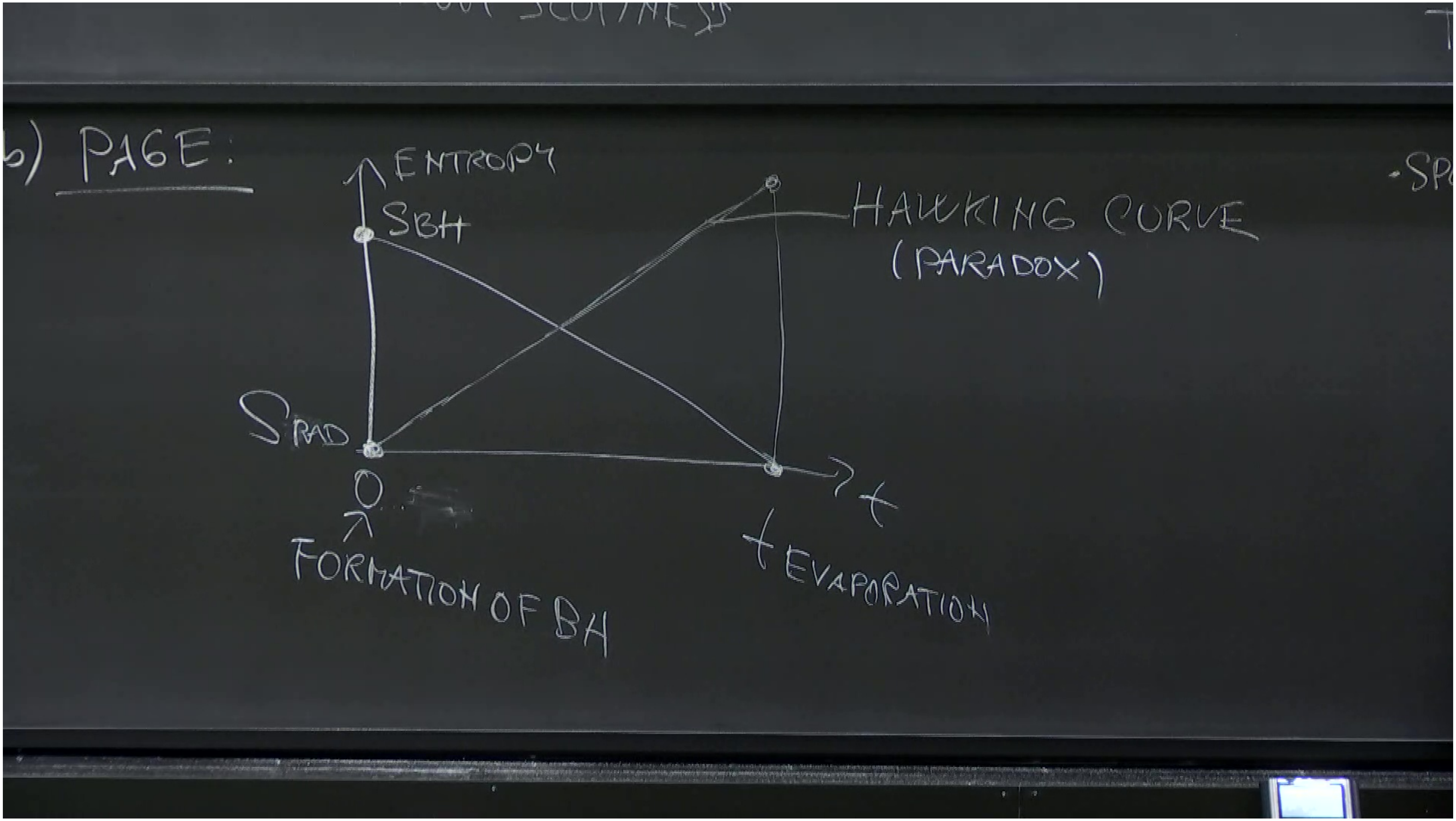
LL: IN THE PRESENCE OF BHS: GENERALIZED ENTROPY

$$\boxed{\underset{\uparrow \atop TD}{S_{GEN}} = \underset{\uparrow \atop TD}{S_{BH}} + S_{OUTSIDE}} \text{ : OBEY 2ND LAW}$$

$$\Delta S_{GEN} \geq 0$$

b) PAGE:




b) PAGE:
ENTROPY
S_{BH}
HAWKING CURVE
(PARADOX)
S_{RAD}
0
t
FORMATION OF BH
$t_{EVAPORATION}$

• SPLIT SPACETIME INTO 2 REGIONS: A: BH

B: OUTSIDE OF BH.

IF UNITARY EVOLUTION:

$$S(A) = S(B) \Leftrightarrow S_{BH} = S_{RAD}$$

• SPLIT SPACETIME INTO 2 REGIONS: A: BH

B: OUTSIDE OF BH.

IF UNITARY EVOLUTION:

$$\tilde{S}(A) = \tilde{S}(B) \Leftrightarrow \boxed{\tilde{S}_{BH} = \tilde{S}_{RAD}}$$

VON NEUMANN ?

$$\tilde{S}_{BH} \leq S_{BH}$$

VON. N.

BEKENSTEIN-HAW.

· SPLIT SPACETIME INTO 2 REGIONS: A: BH

B: OUTSIDE OF BH.

IF UNITARY EVOLUTION:

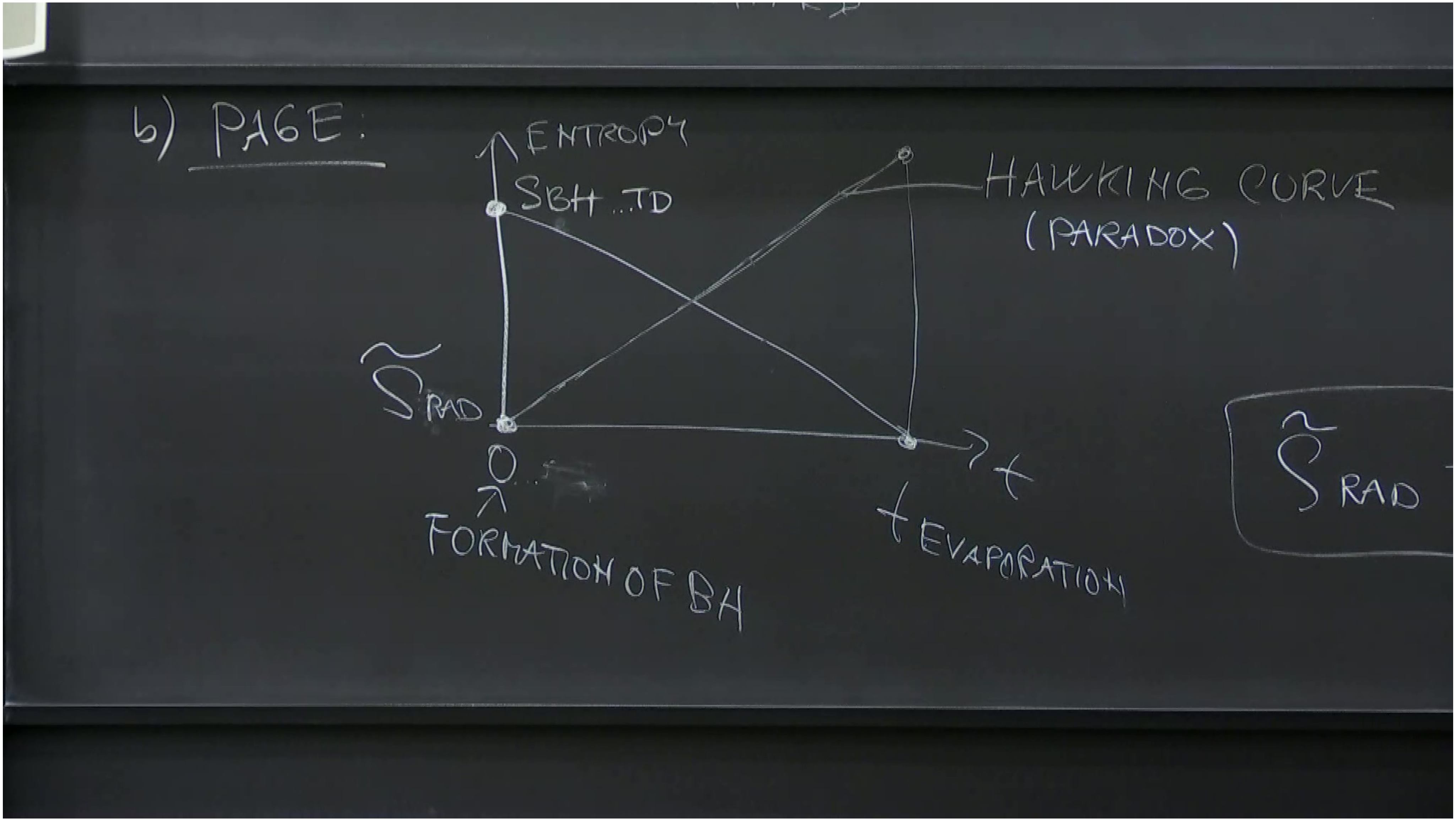
$$\tilde{S}(A) = \tilde{S}(B) \iff \boxed{\tilde{S}_{BH} = \tilde{S}_{RAD}}$$

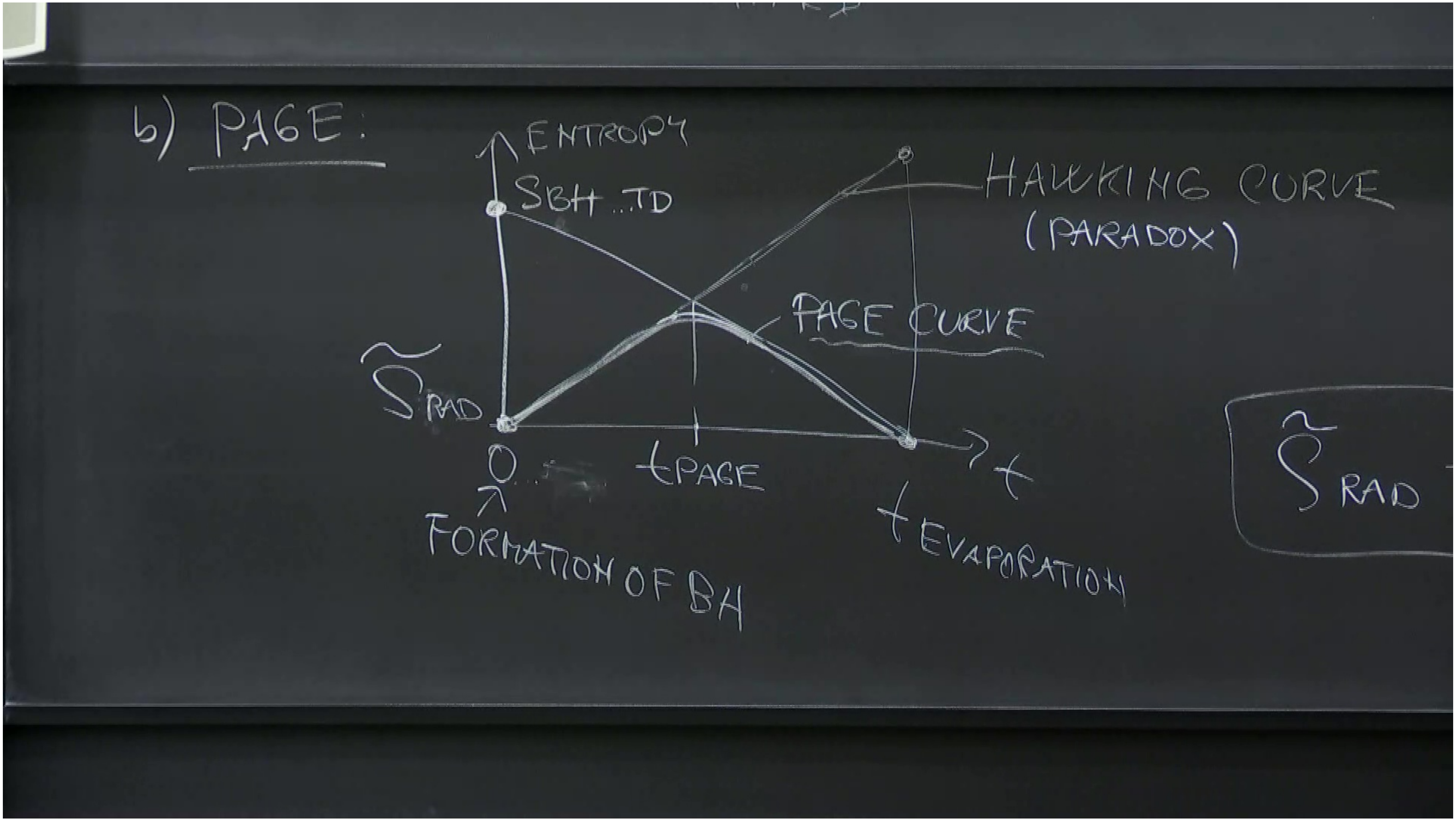
VON NEUMANN

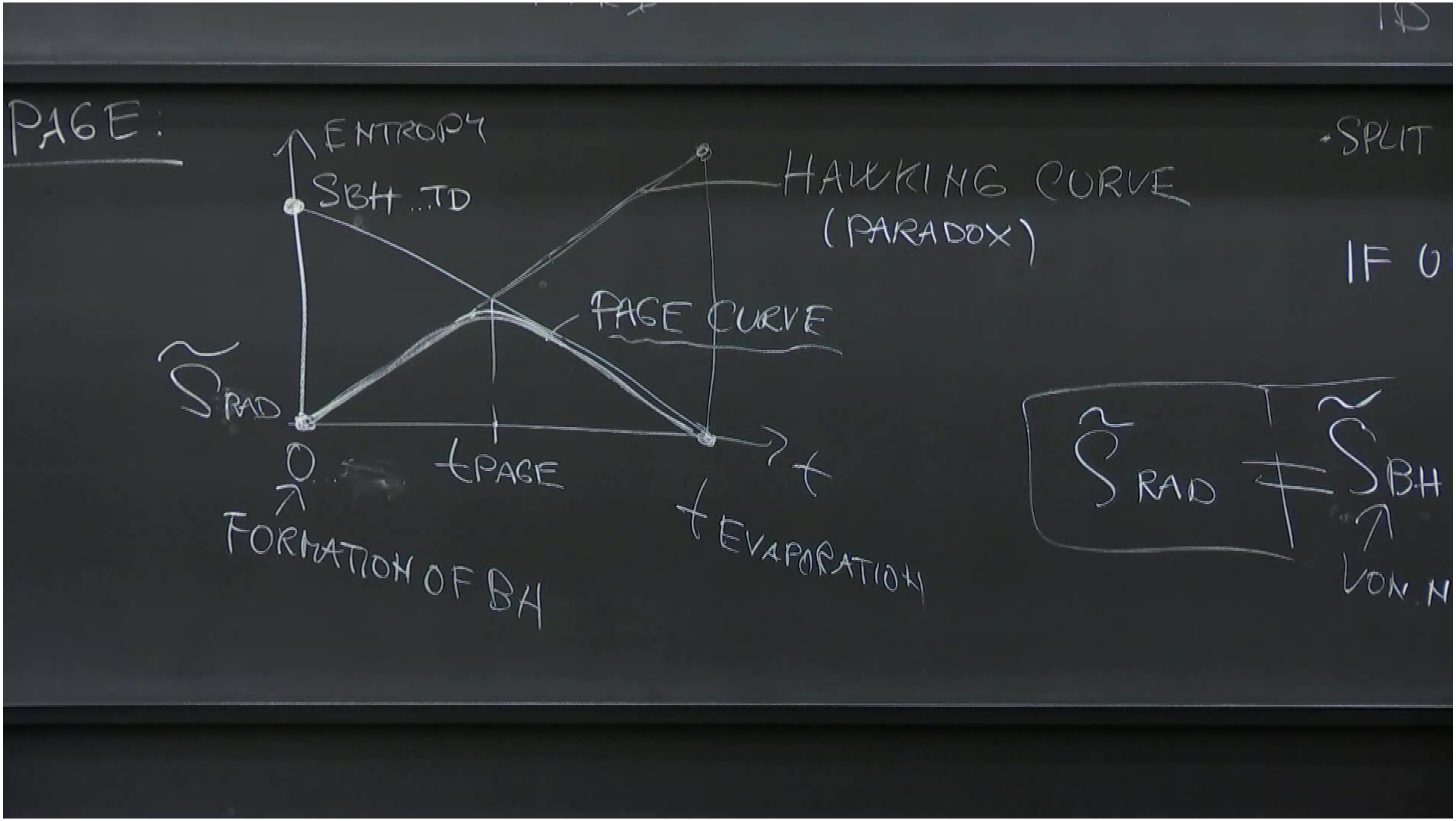
$$\tilde{S}_{BH} \leq S_{BH}$$

VON. N. BEKENSTEIN-HAW.

$$\boxed{\tilde{S}_{RAD} \leq S_{BEK\ HAWK}}$$


b) PAGE:
ENTROPY
SBH ...TD
HAWKING CURVE
(PARADOX)
$\tilde{S}_{RAD}$
0
t
FORMATION OF BH
$t_{EVAPORATION}$
$\tilde{S}_{RAD}$

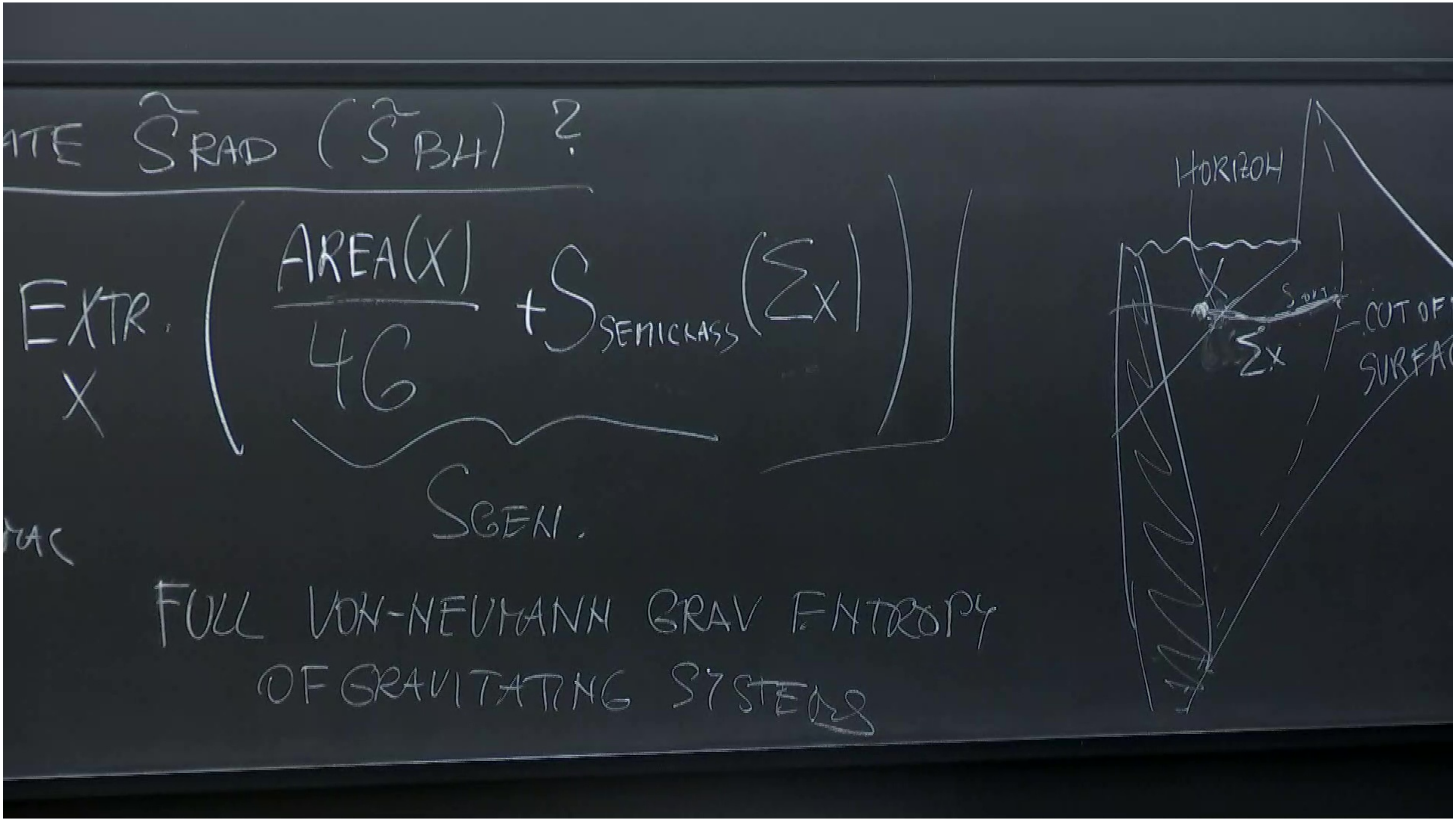

b) PAGE:
ENTROPY
SBH ...TD
HAWKING CURVE
(PARADOX)
PAGE CURVE
S̃RAD
0
tPAGE
t
tEVAPORATION
FORMATION OF BH
S̃RAD


PAGE:
ENTROPY
SBH ..TD
HAWKING CURVE
(PARADOX)
PAGE CURVE
S̃RAD
0
tPAGE
t
FORMATION OF BH
tEVAPORATION
SPLIT
IF
S̃RAD ≠ S̃BH
VON N

c) HOW DO WE CALCULATE $\tilde{S}_{RAD}$ ($\tilde{S}_{BH}$) ?

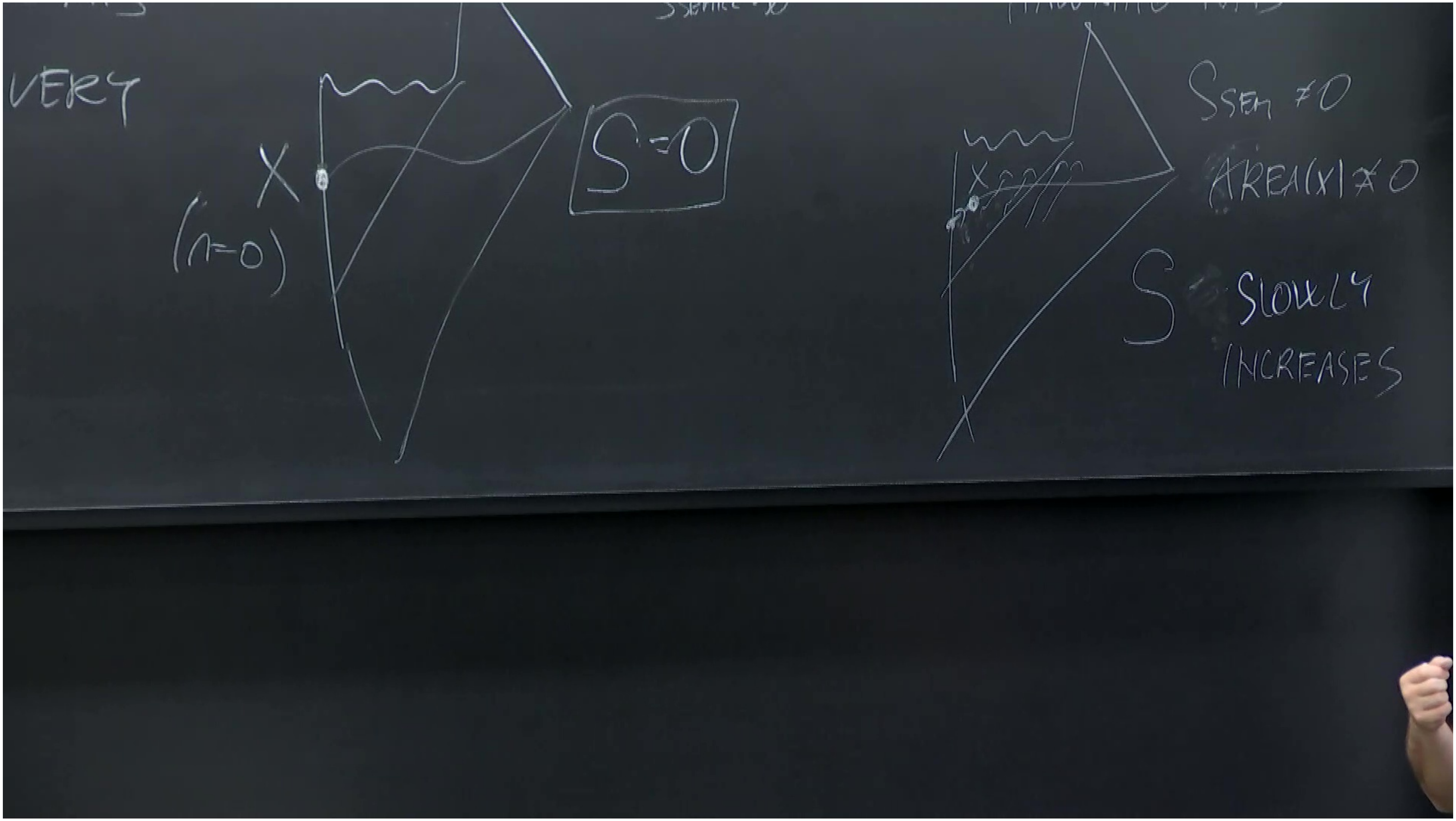
$$S = \underset{X}{\mathrm{MIN}} \left(\underset{X}{\mathrm{EXTR.}} \left(\frac{\mathrm{AREA}(X)}{4G} + S_{\mathrm{SEMICLASS}}(\Sigma_X \right.\right.$$

QUANTUM EXTREMAL SURFACE

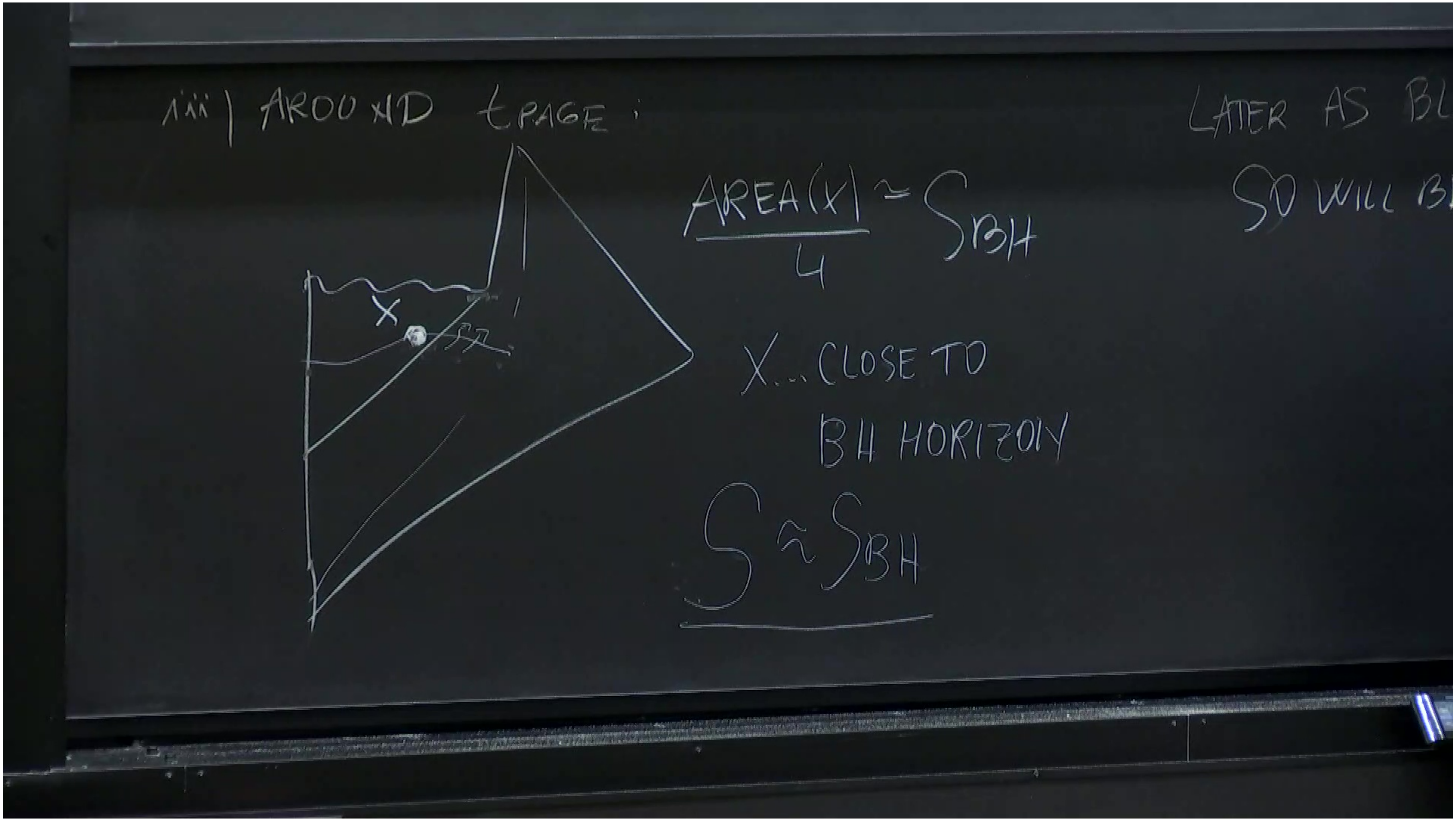

ATE $\tilde{S}_{RAD}$ ($\tilde{S}_{BH}$) ?
EXTR. X
$\frac{AREA(X)}{4G} + S_{SEMICLASS}(\Sigma_X)$
SGEN.
FULL VON-NEUMANN GRAV ENTROPY
OF GRAVITATING SYSTEMS
HORIZON
X
Σ_X
CUT OFF
SURFAC

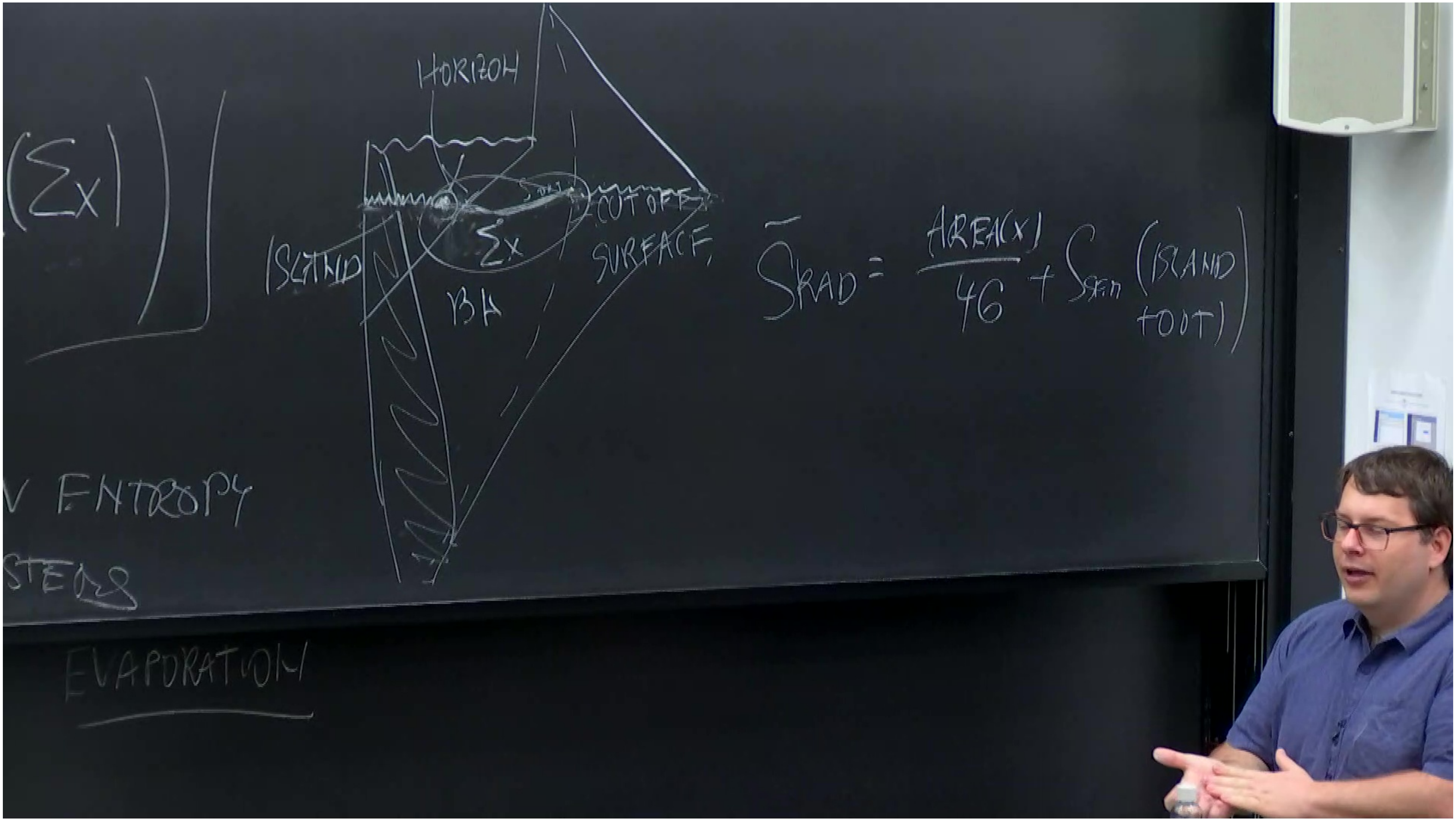
d) PAGE CURVE RECOVERY: FAIRY TALE.

WE DO NOT NEED QG TO RECOVER THIS AS AT t_{PAGE}, BH IS STILL VERY BIG & CLASSICAL.



VERY
X
(r=0)
S=0
AREA(X) ≠ 0
S
SLOWLY
INCREASES


iii) AROUND t PAGE :
AREA(X) / 4 ≃ S BH
X... CLOSE TO BH HORIZON
S ≃ S BH
LATER AS
SO WILL
X


HORIZON
ISLAND
Σ_X
BH
CUTOFF
SURFACE
$\bar{S}_{RAD} = \frac{AREA(X)}{4G} + S_{sc,m}(\text{ISLAND} + \text{OUT})$
ENTROPY
EVAPORATION