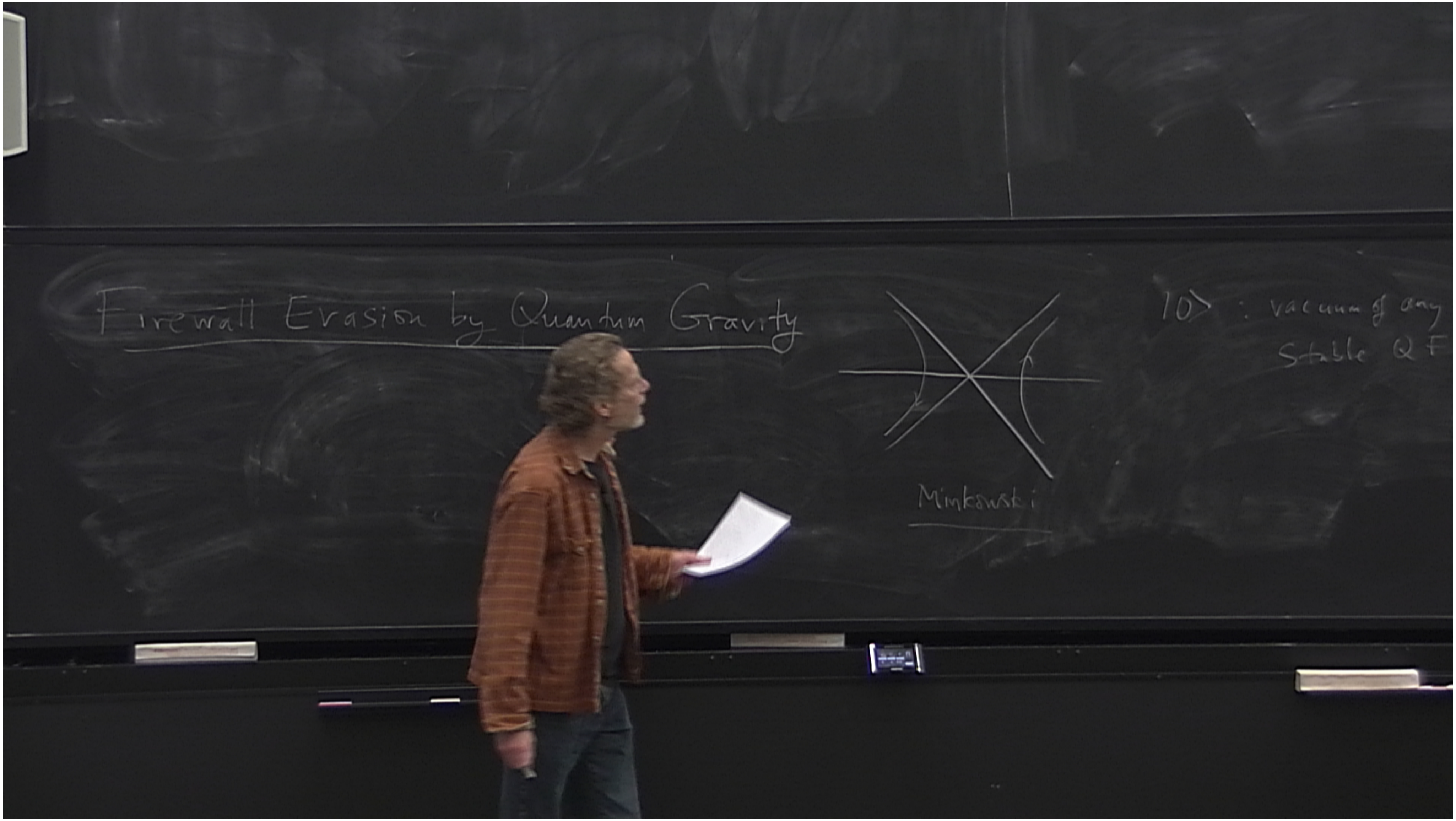
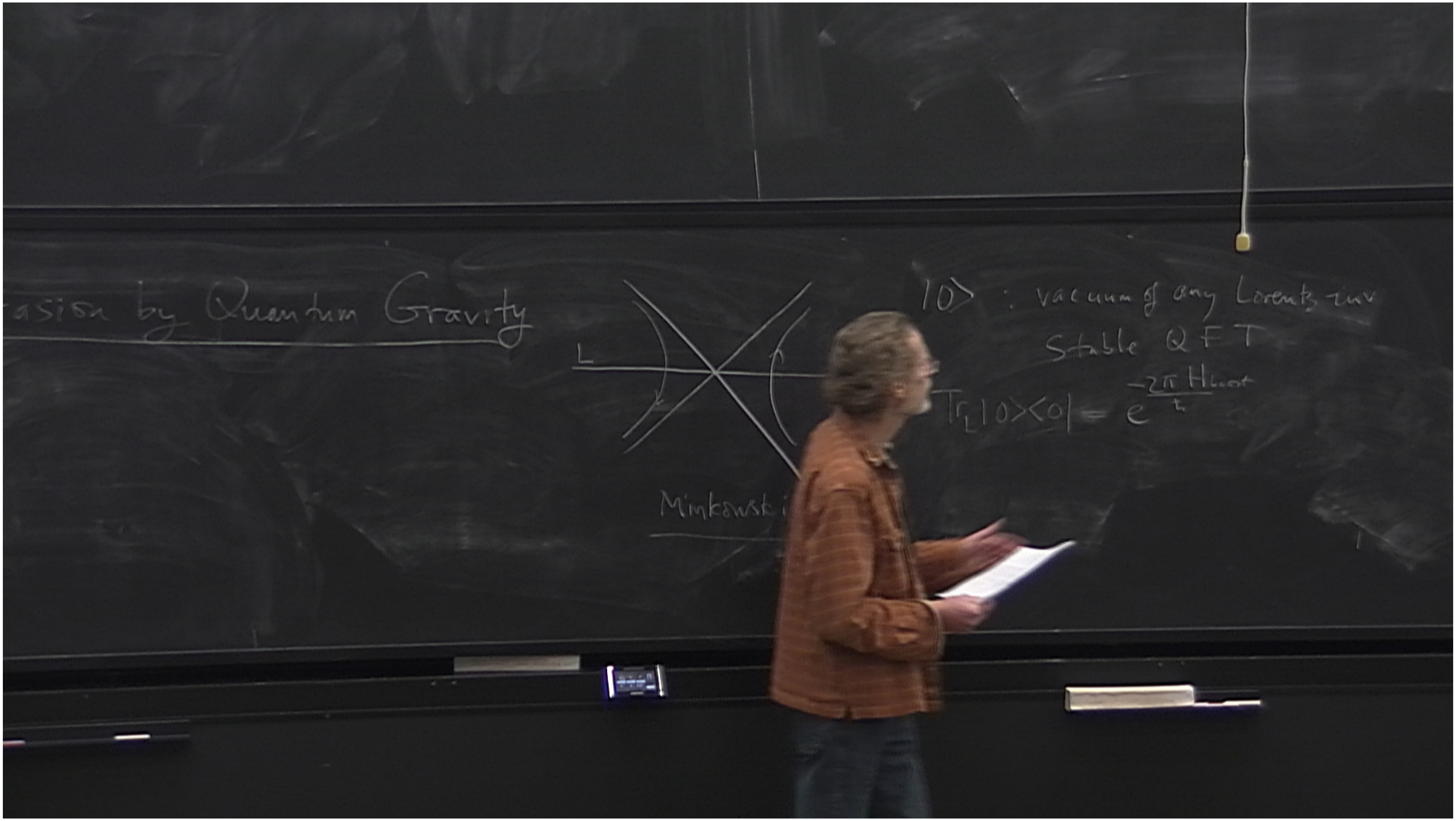
Title: Firewall evasion by quantum gravity

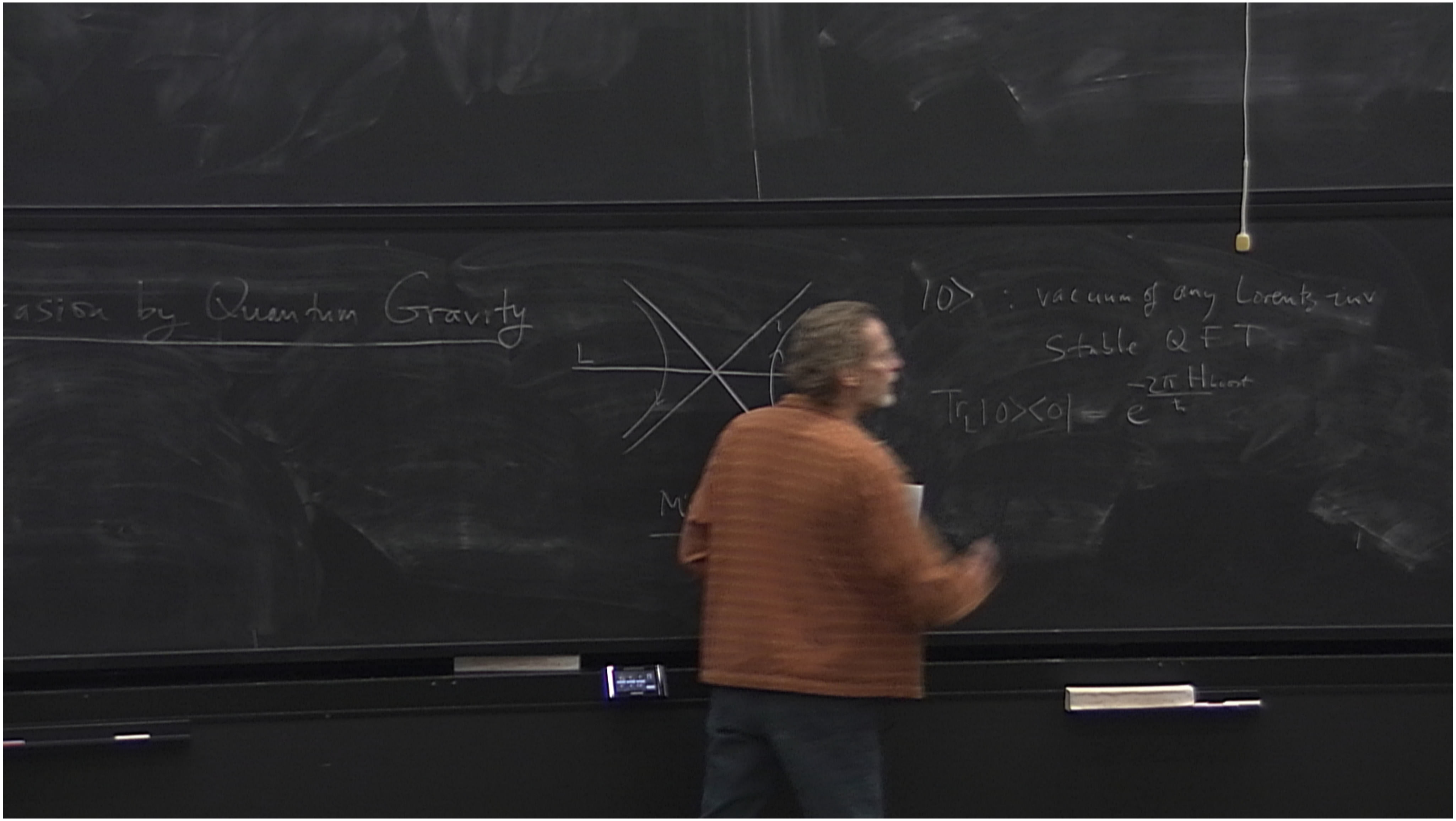
Date: Feb 13, 2014 02:30 PM

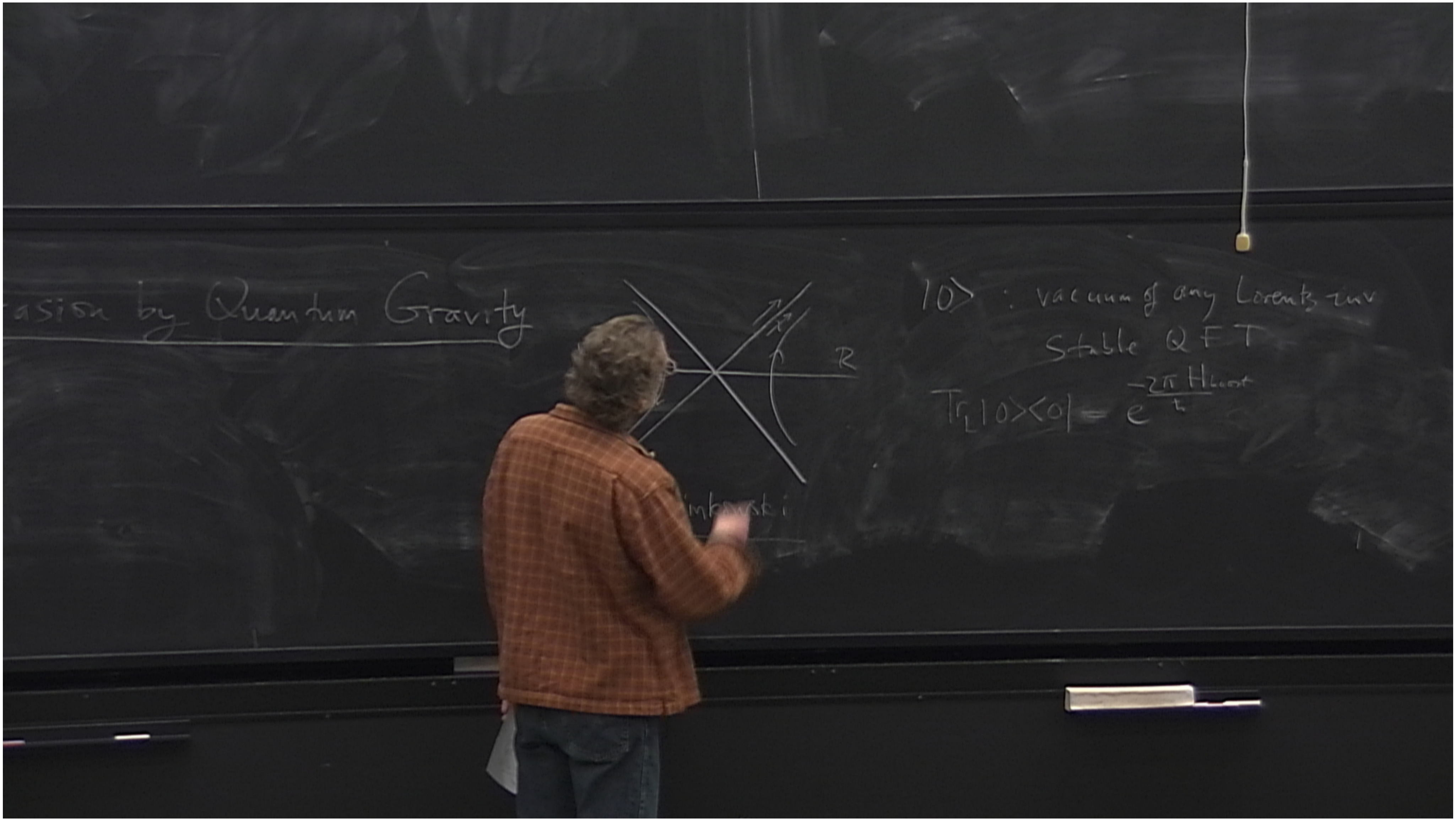
URL: http://pirsa.org/14020136

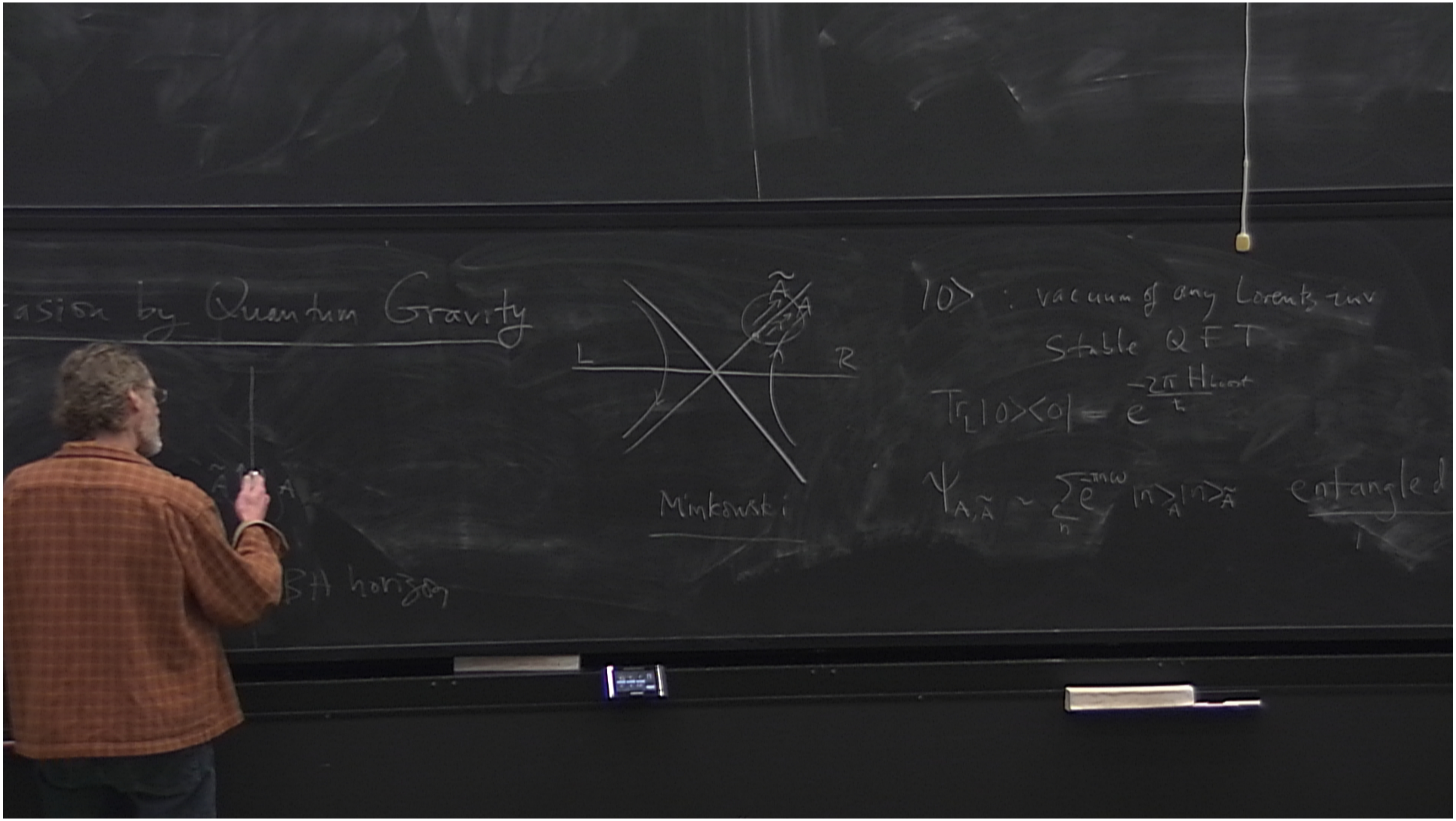
Abstract: It has been argued that if black hole evaporation is a unitary quantum process, then a black hole horizon must be cloaked by a "firewall", i.e. a highly excited state of local quantum fields. This reasoning is based on factorizing the Hilbert space into interior and exterior degrees of freedom. Such factorization ignores the Wheeler-deWitt constraint equation, which arises from the diffeomorphism invariance of quantum gravity. I will argue that this constraint evades the firewall.

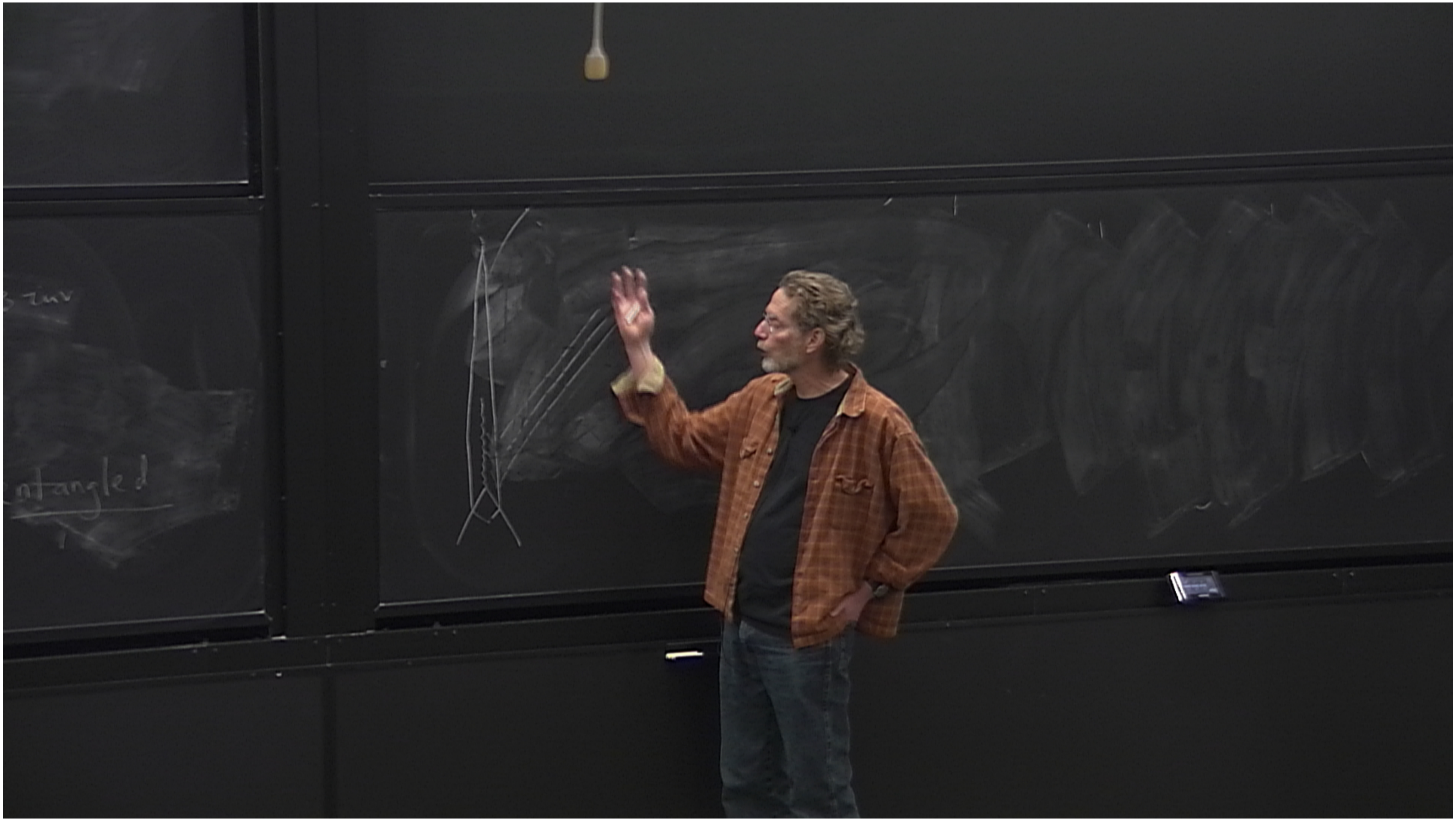

Firewall Evasion by Quantum Gravity
Minkowski
|0⟩ : vacuum of any
Stable Q F

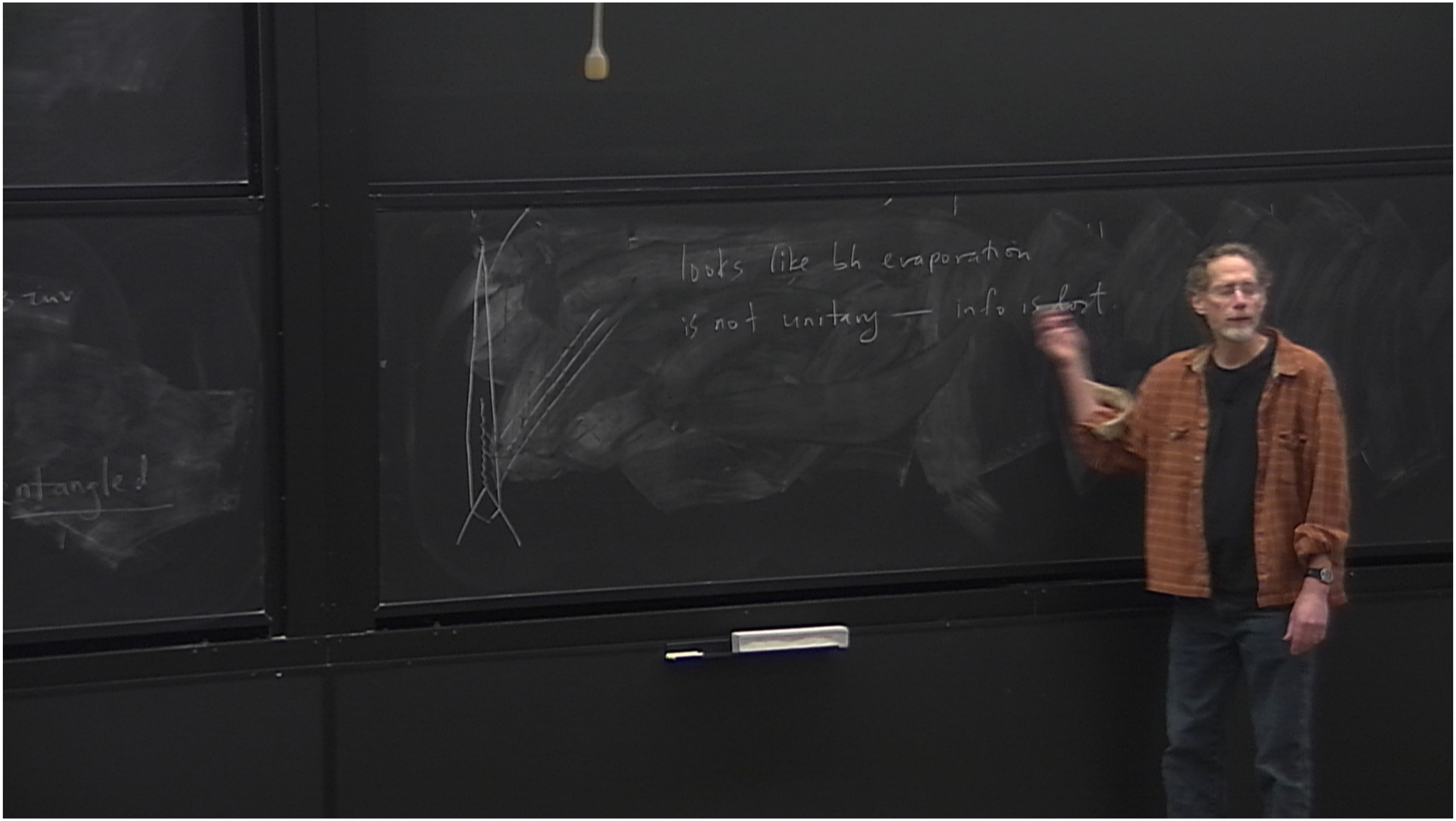

asion by Quantum Gravity
L
Minkowski
$|0\rangle$: vacuum of any Lorentz inv
Stable QFT
$\mathrm{Tr}_L|0\rangle\langle 0| = e^{-\frac{2\pi}{\hbar}H_{boost}}$


asion by Quantum Gravity
L
|0> : vacuum of any Lorentz inv
Stable QFT

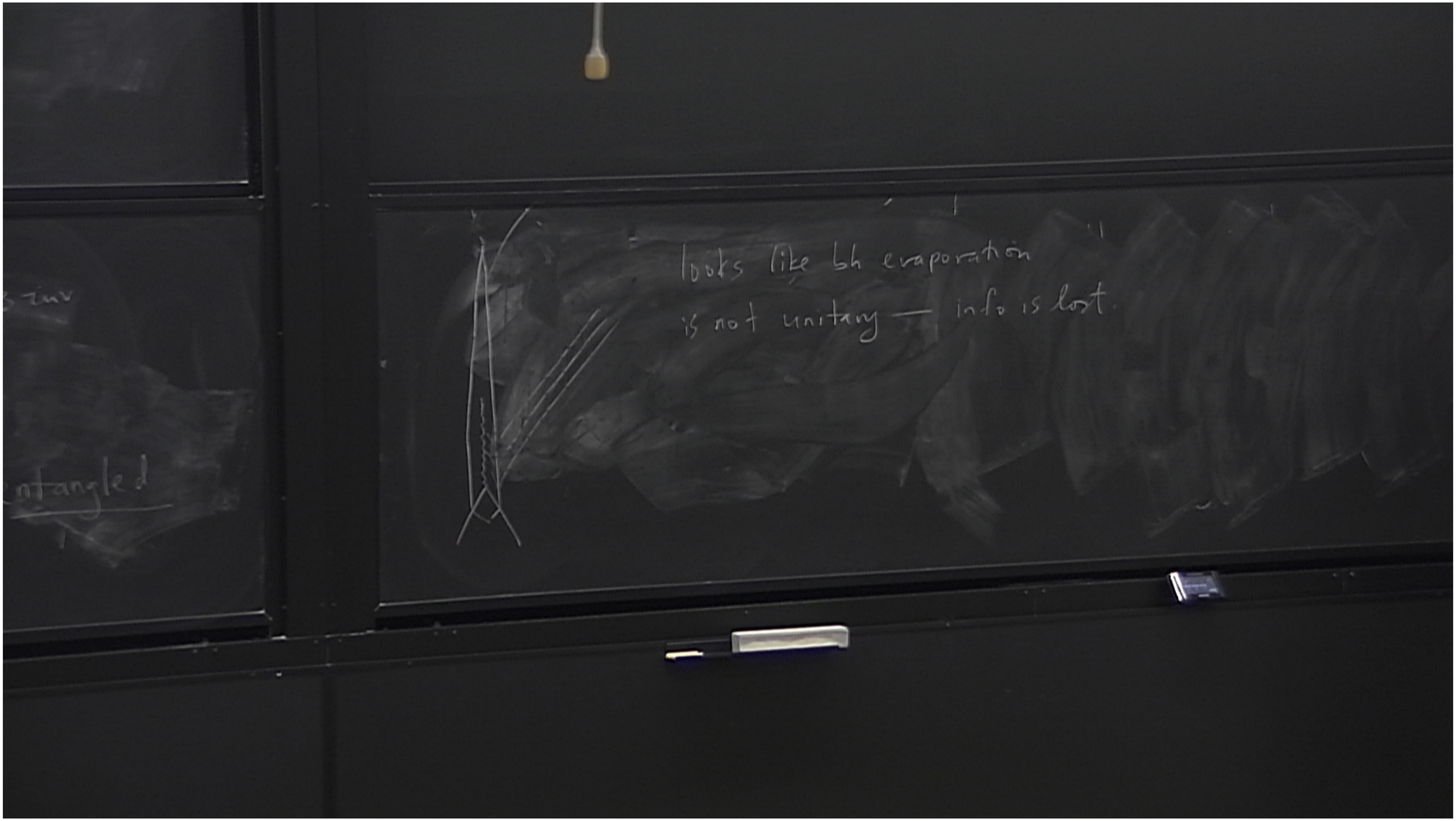

asion by Quantum Gravity
R
|0⟩ : vacuum of any Lorentz inv
Stable QFT
$Tr_L |0\rangle\langle 0| = e^{-\frac{2\pi}{\hbar} H_{boost}}$

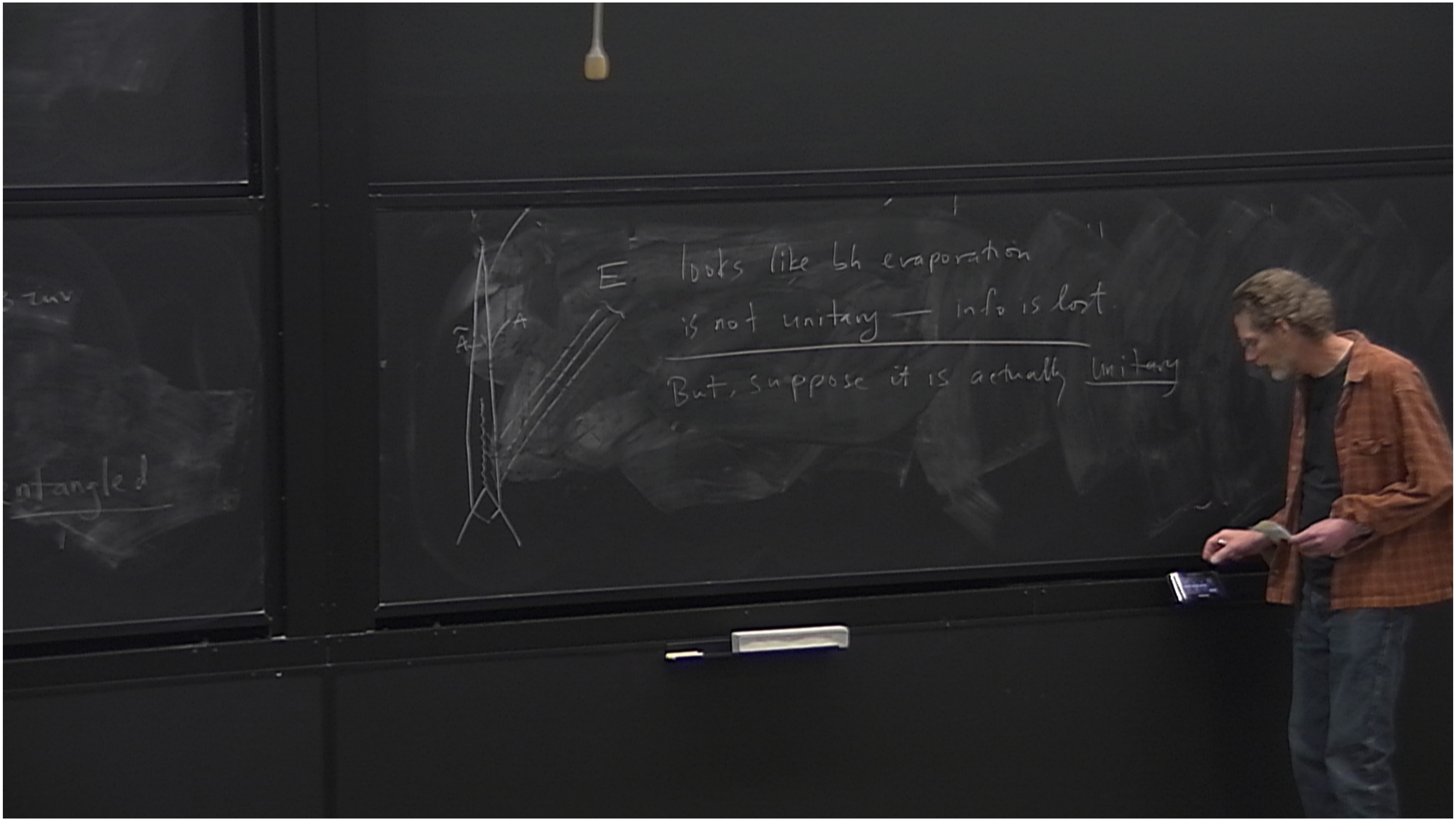

asion by Quantum Gravity
L
R
Minkowski
BH horizon
|0> : vacuum of any Lorentz inv
Stable QFT
Tr_L |0><0| = e^{-2π H_boost / ħ}
Ψ_{A,Ã} ~ Σ_n e^{-πnω} |n>_A |n>_Ã
entangled

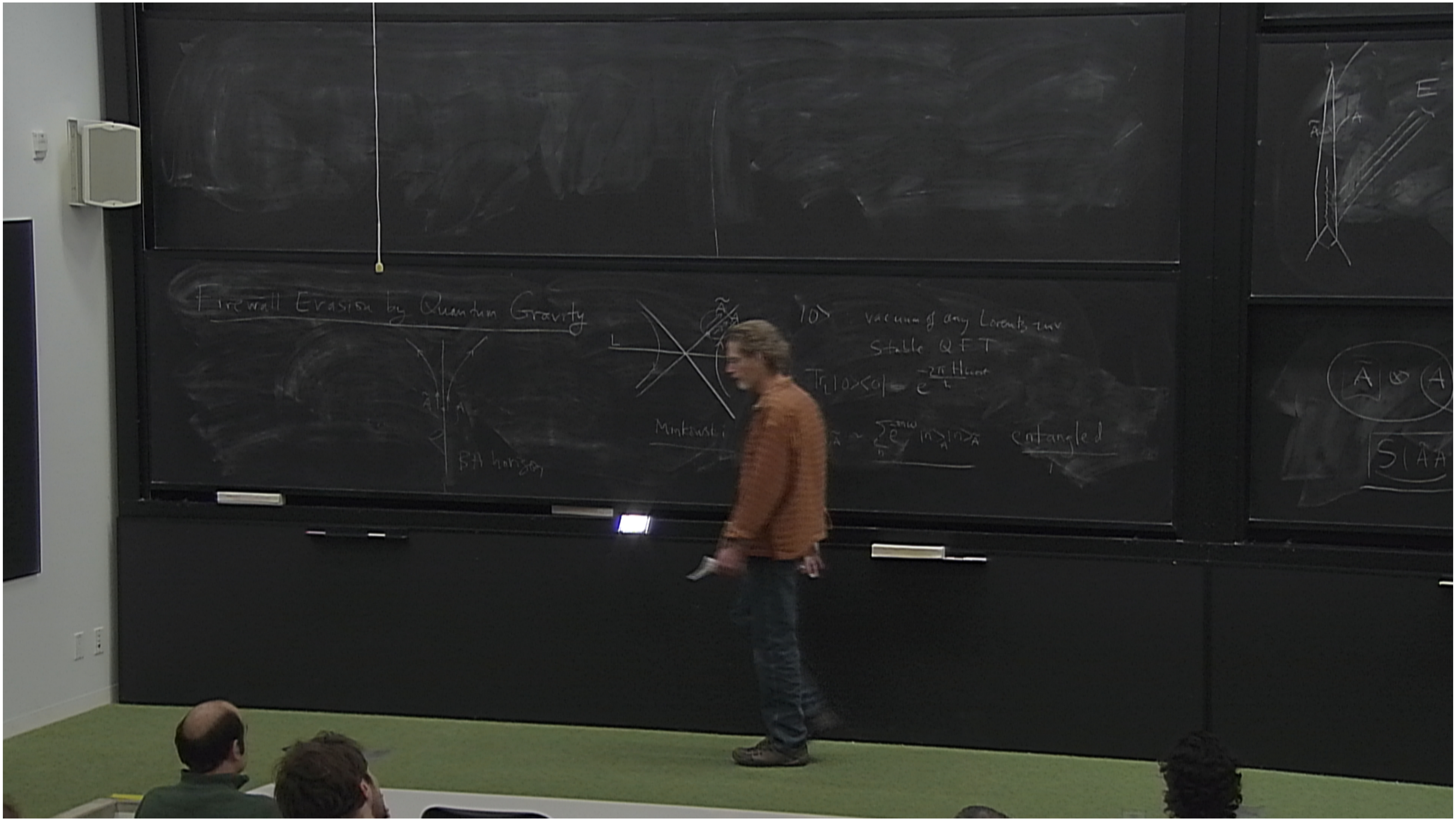


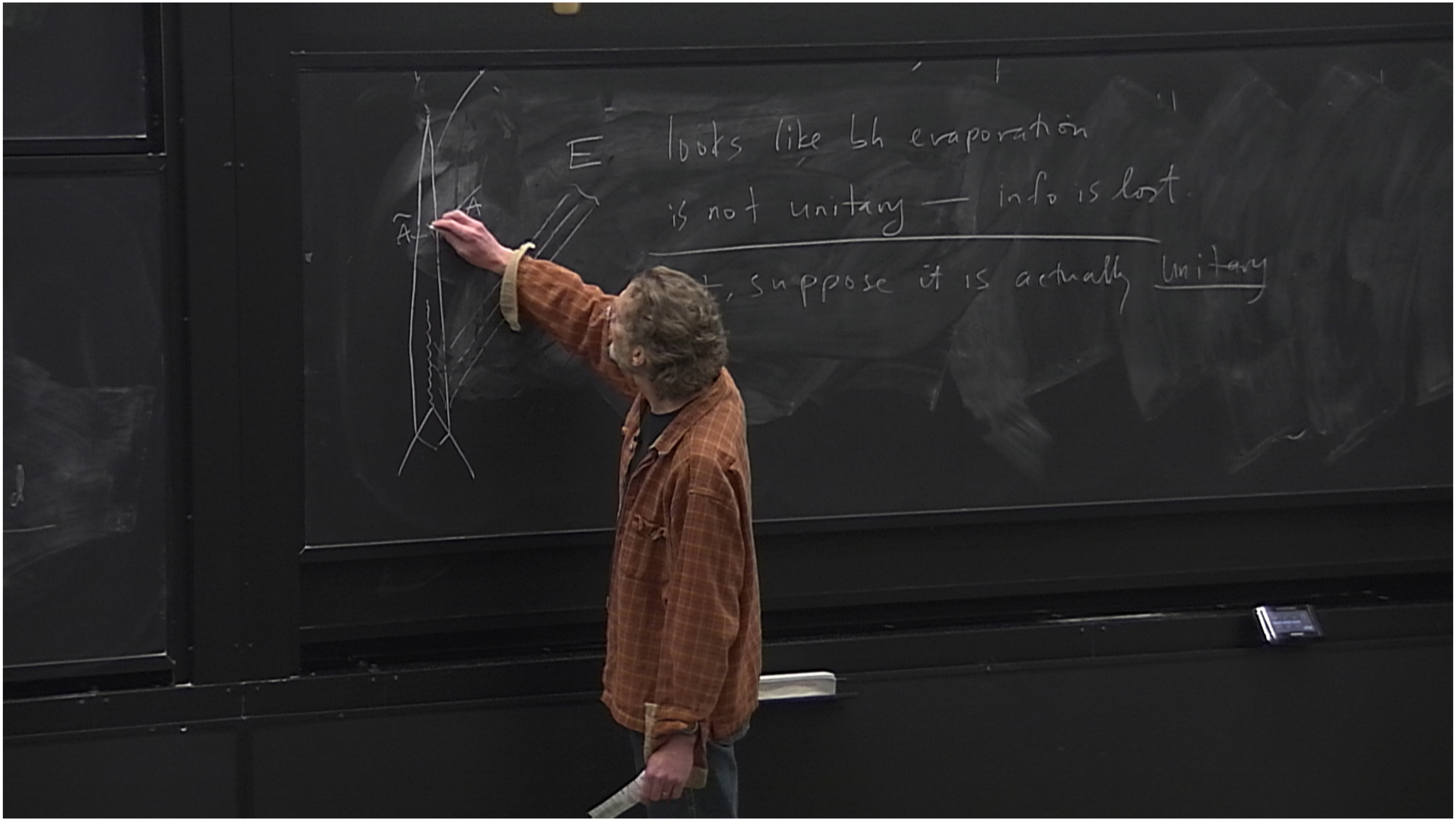


looks like bh evaporation
is not unitary — info is lost.
entangle!

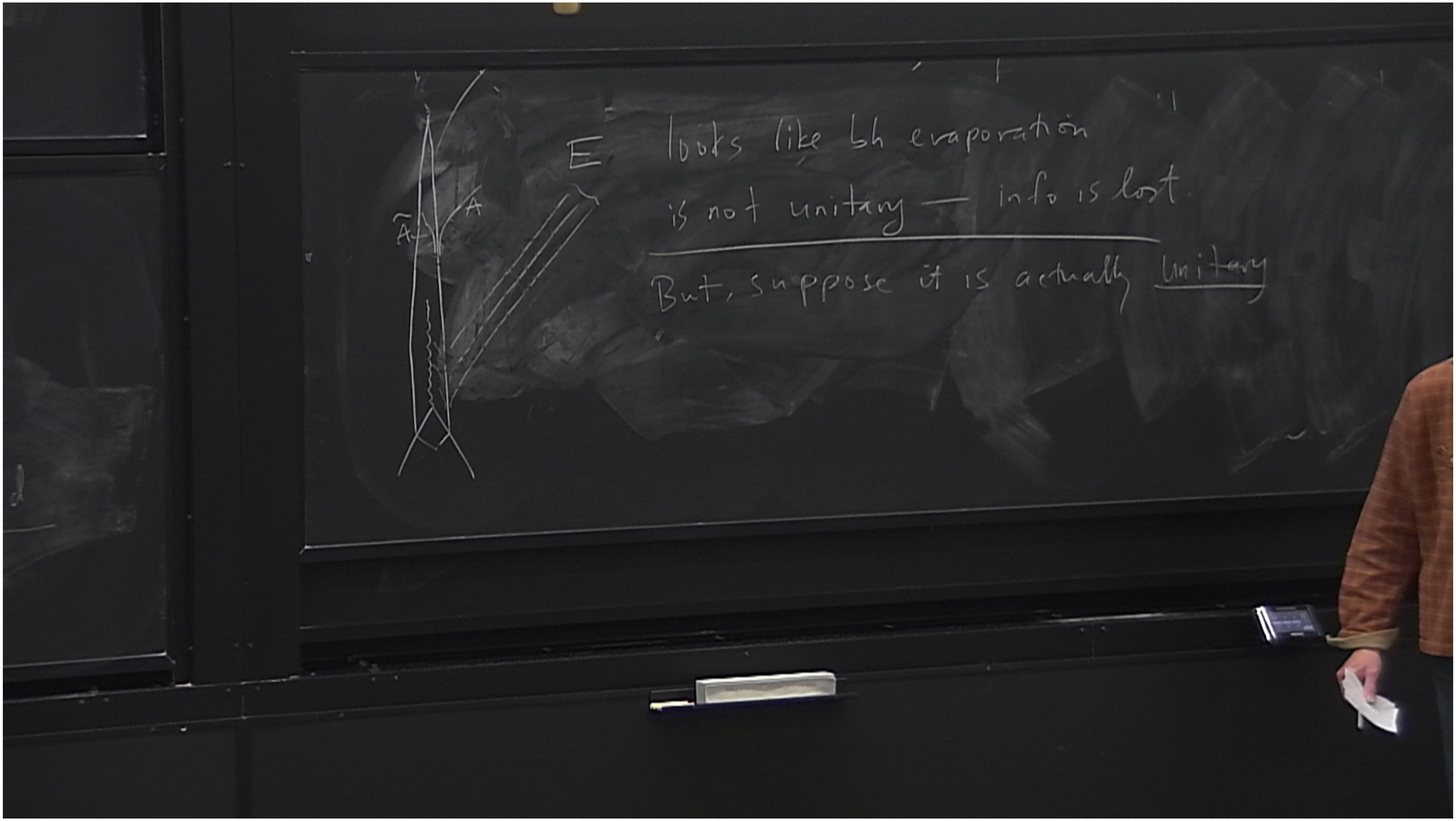

looks like bh evaporation
is not unitary — info is lost.

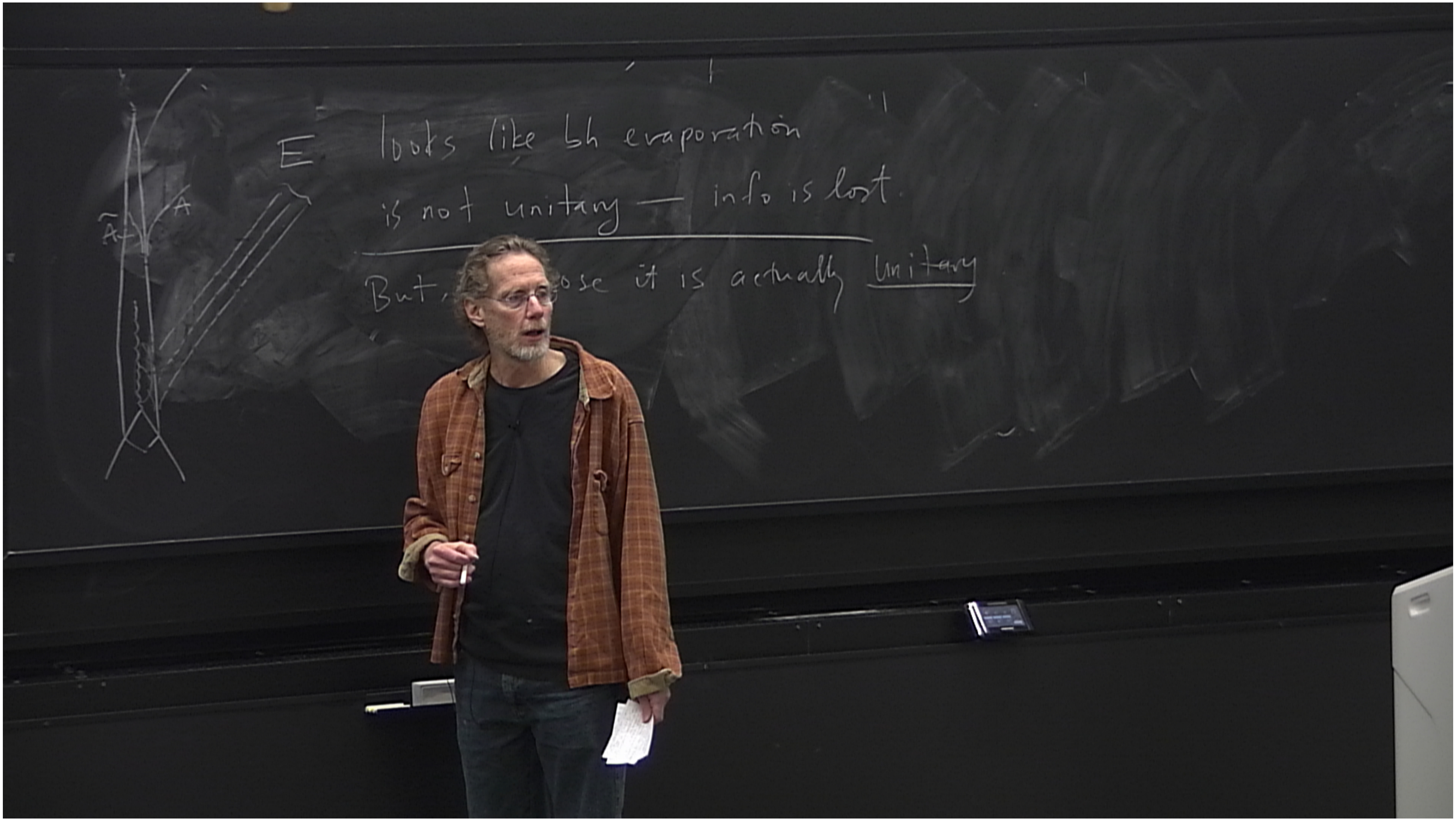

E
looks like bh evaporation
is not unitary — info is lost
But, suppose it is actually unitary
entangled

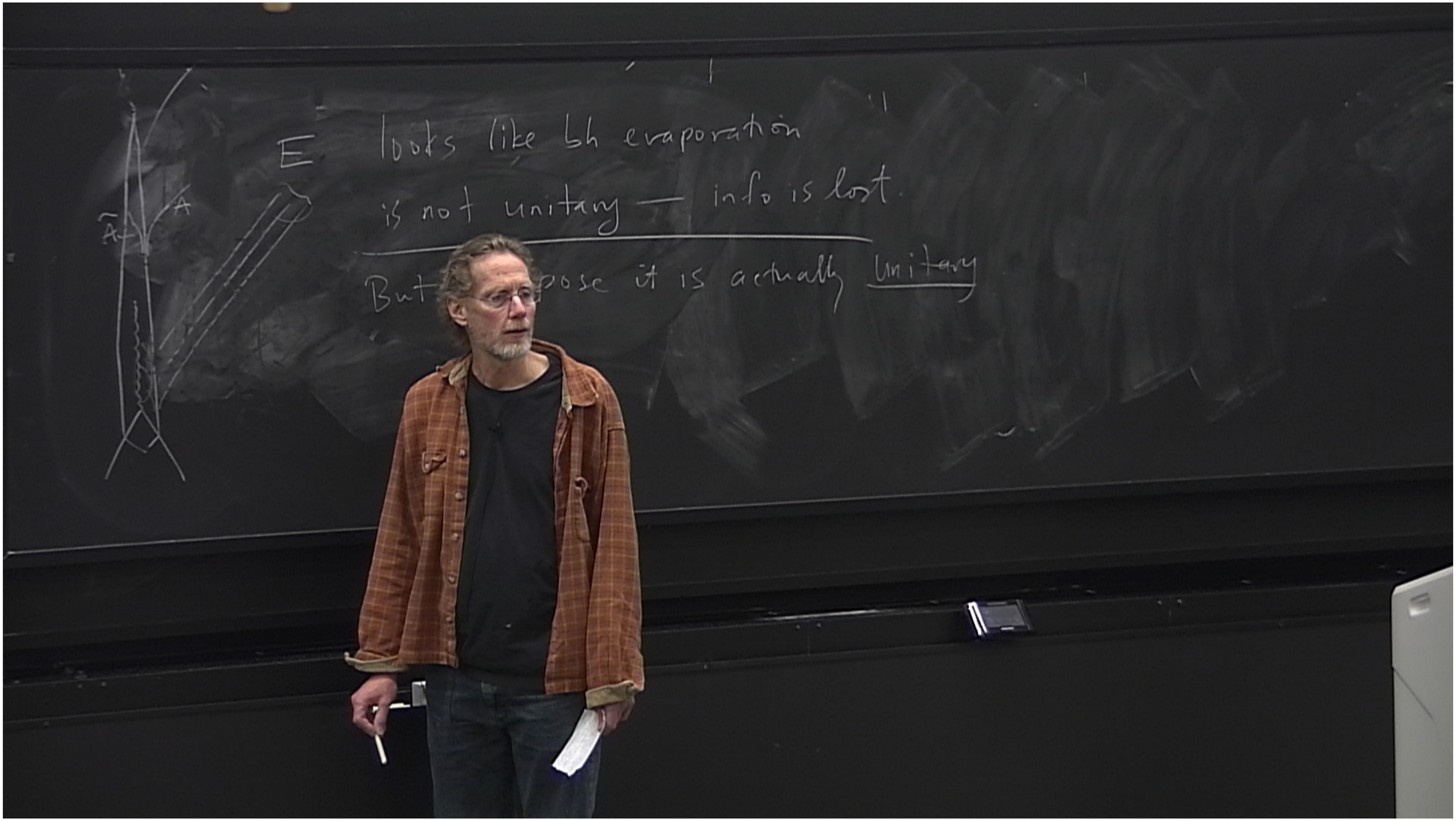

Firewall Erasure by Quantum Gravity
BH horizon
Minkowski
|0⟩ vacuum of any Lorentz inv
Stable QFT
entangled
E



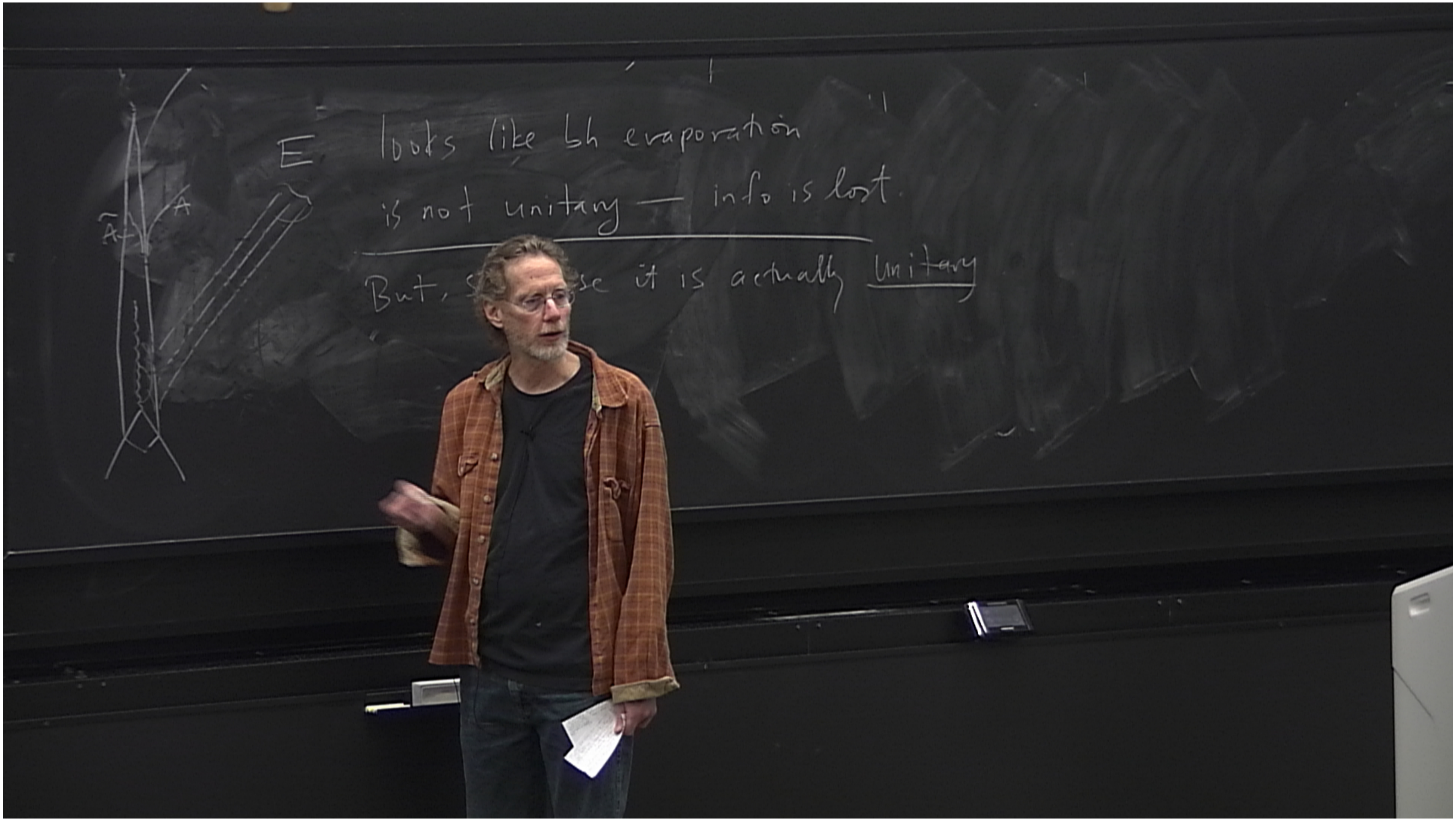
E
looks like bh evaporation
is not unitary — info is lost.
suppose it is actually unitary


E
looks like bh evaporation
is not unitary — info is lost.
But, suppose it is actually unitary
Ã
A

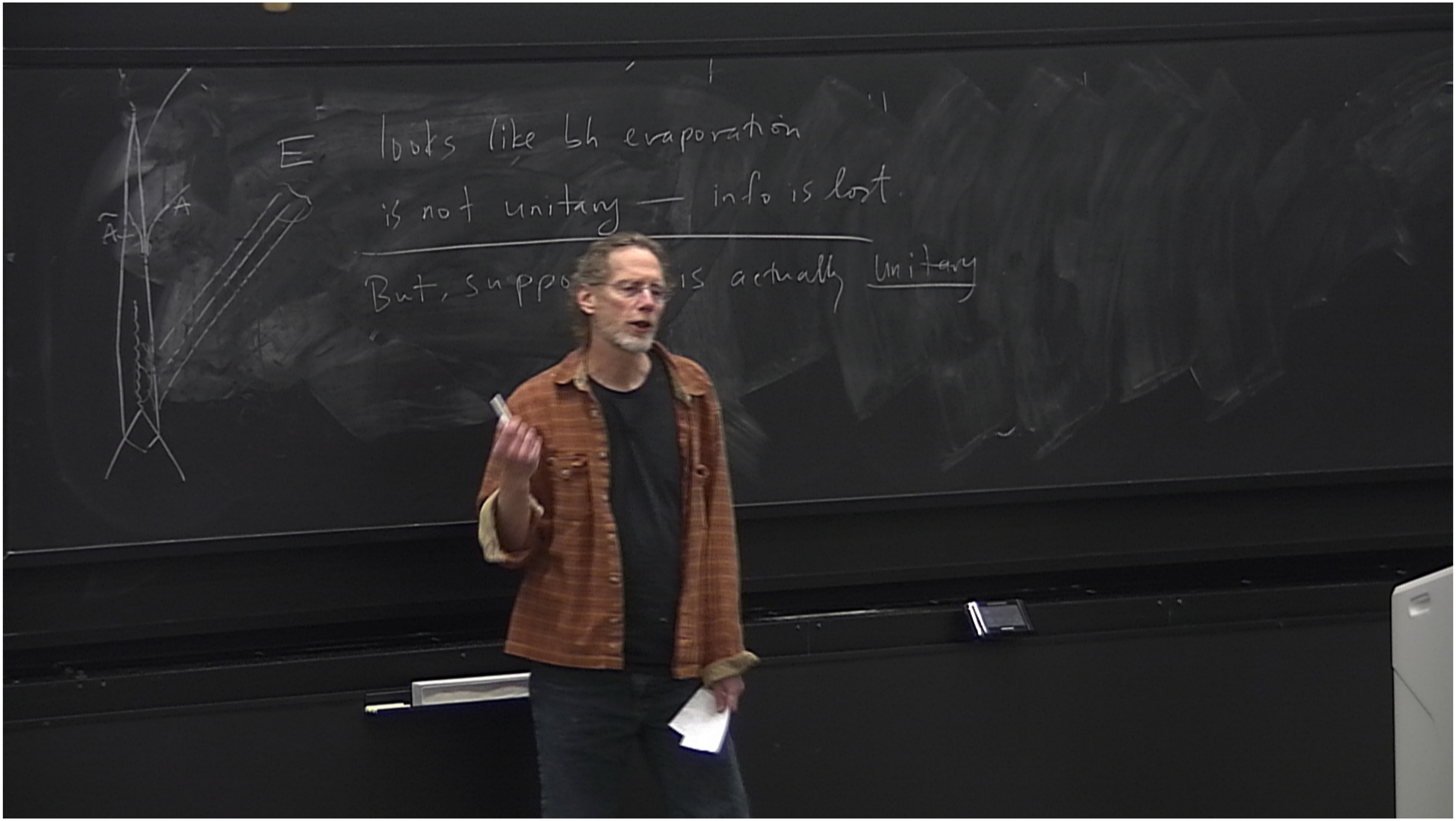

E
looks like bh evaporation
is not unitary — info is lost.
$\tilde{A}$
A

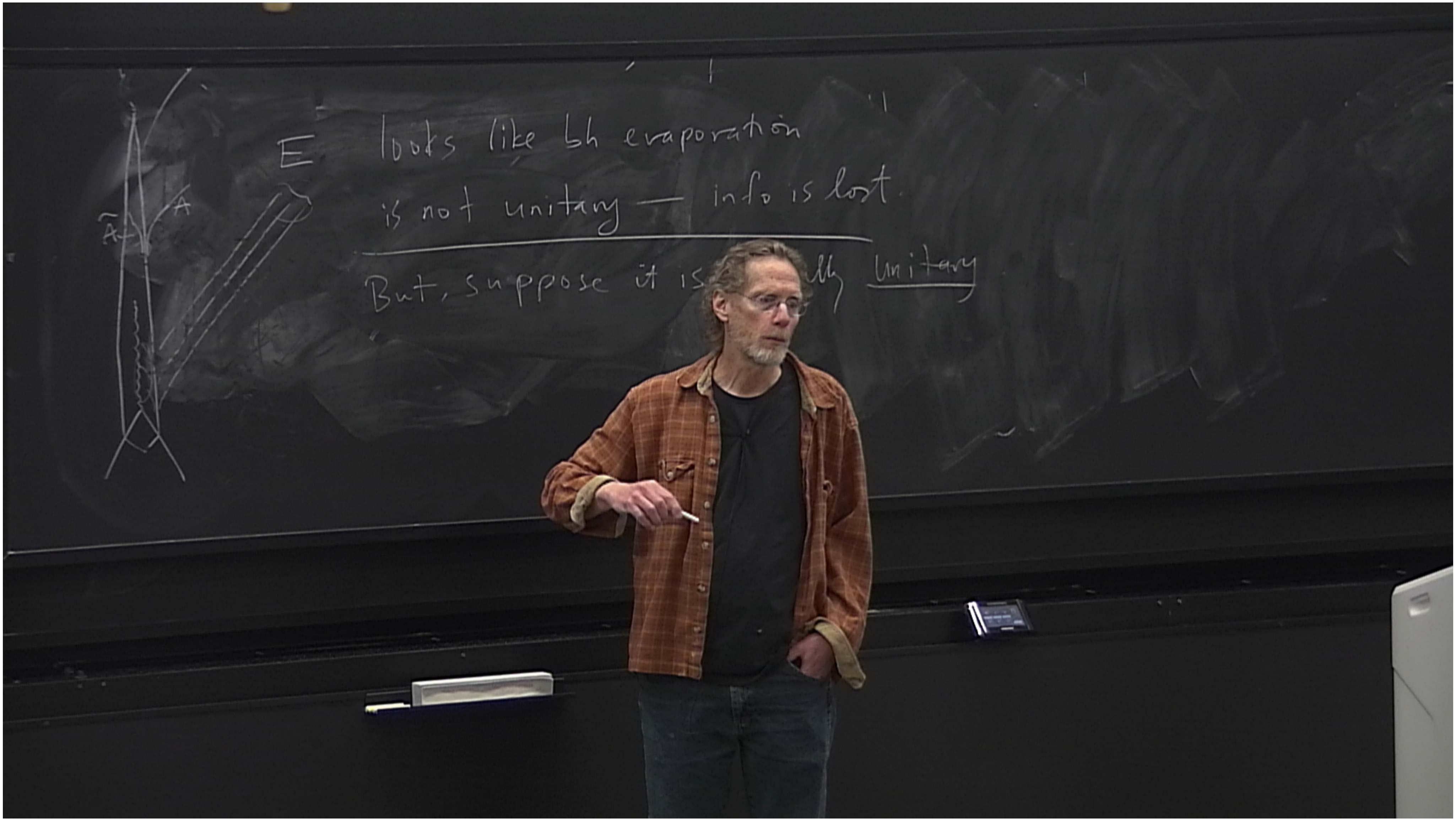


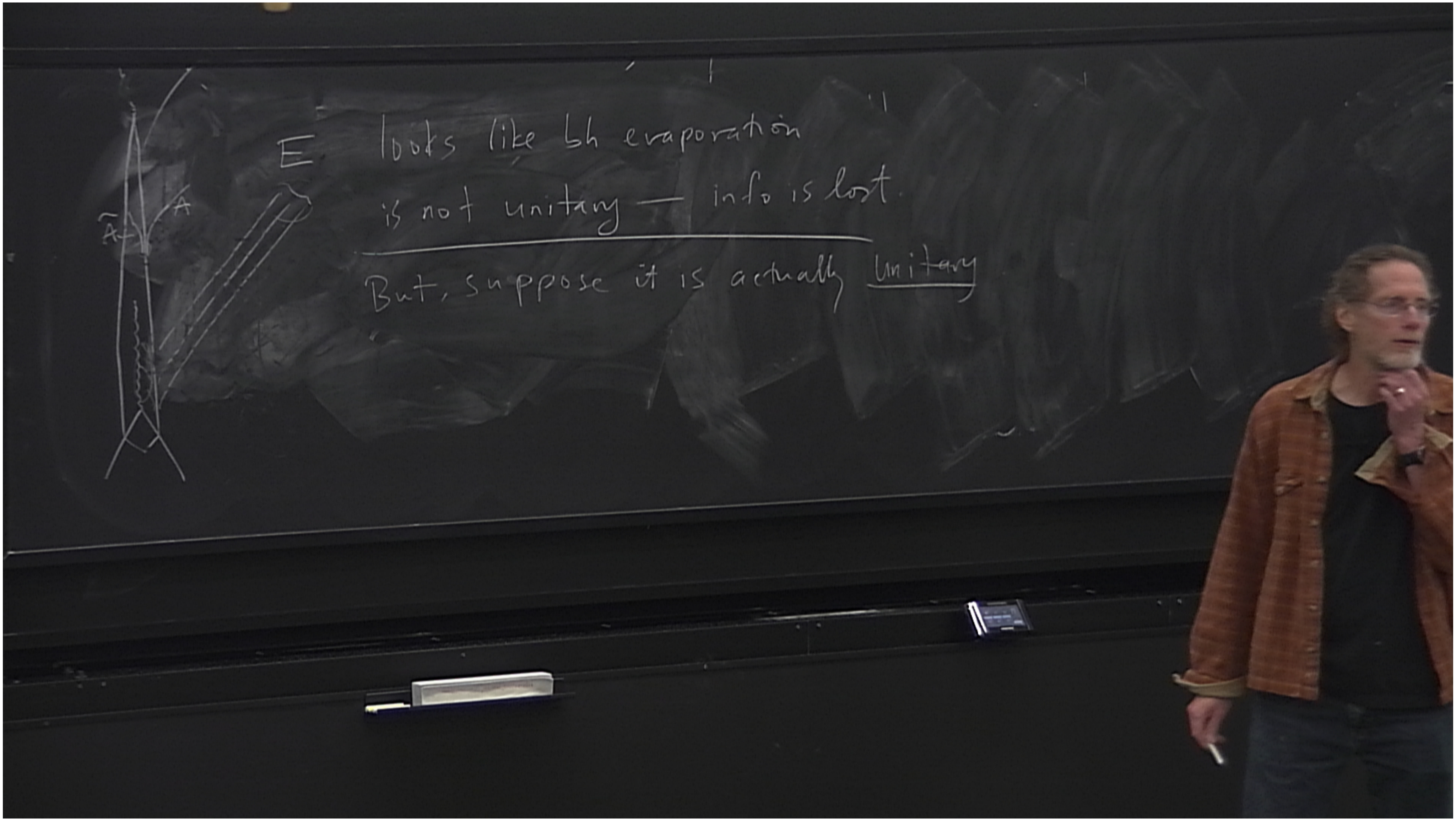
E
looks like bh evaporation
is not unitary — info is lost.
A
Ã

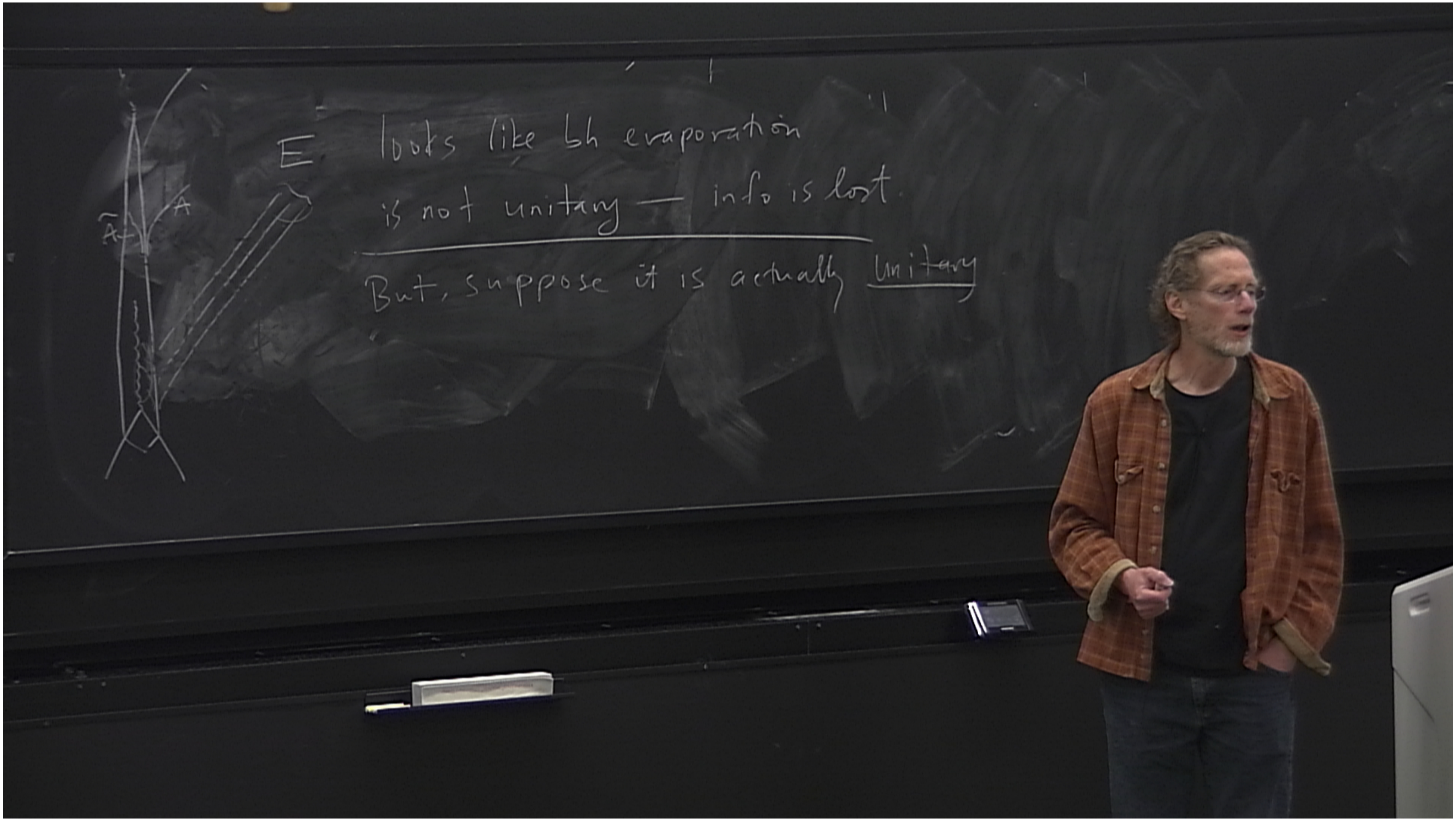


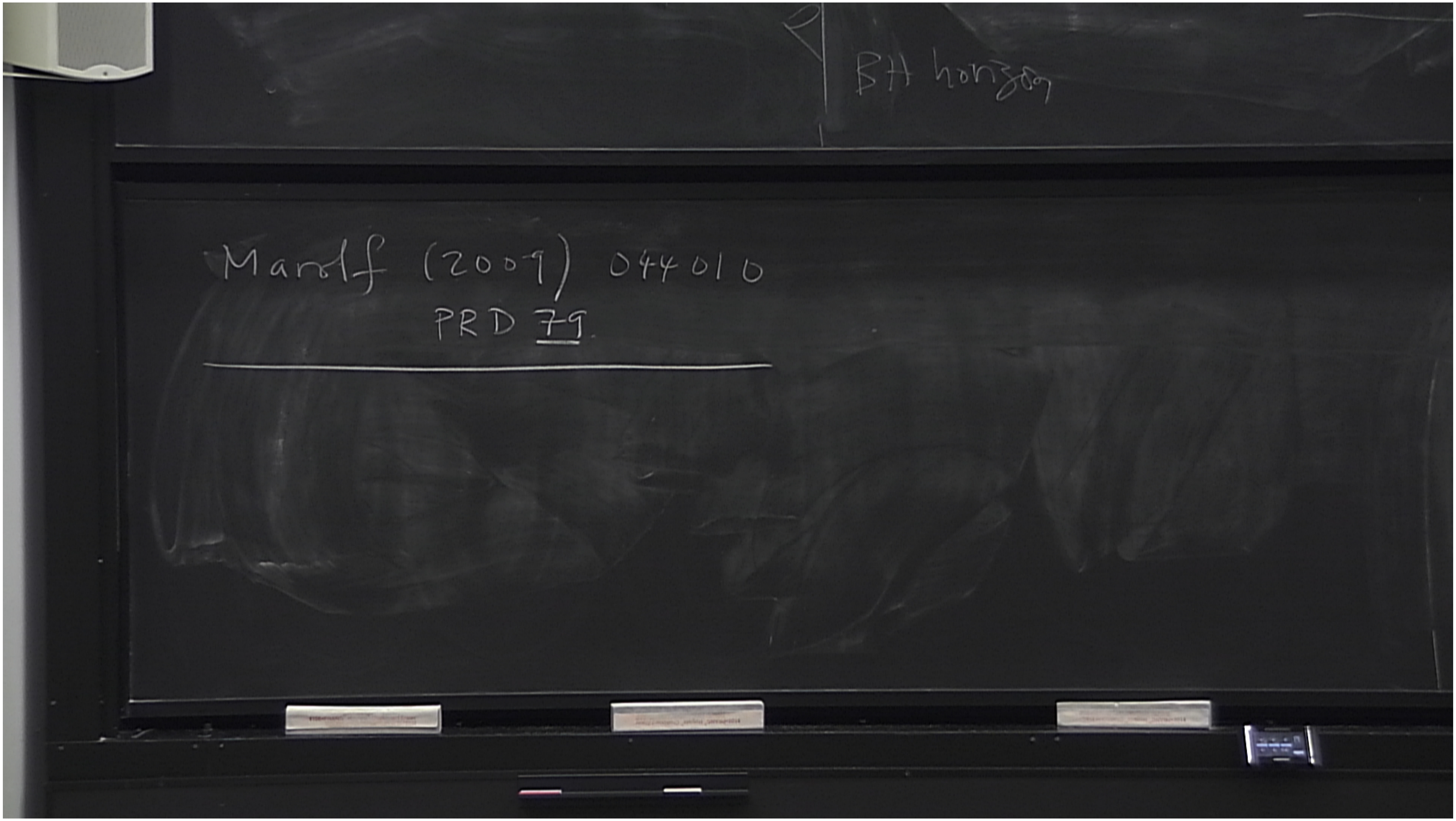
E
looks like bh evaporation
is not unitary — info is lost.
But,
it is actually unitary


looks like bh evaporation
is not unitary — info is lost.
But, suppo is actually unitary
E
A
Ã


E
looks like bh evaporation
is not unitary — info is lost.
But, suppose it is ally unitary
A
Ã


E
looks like bh evaporation
is not unitary — info is lost.
But, suppose it is actually unitary
A
Ã

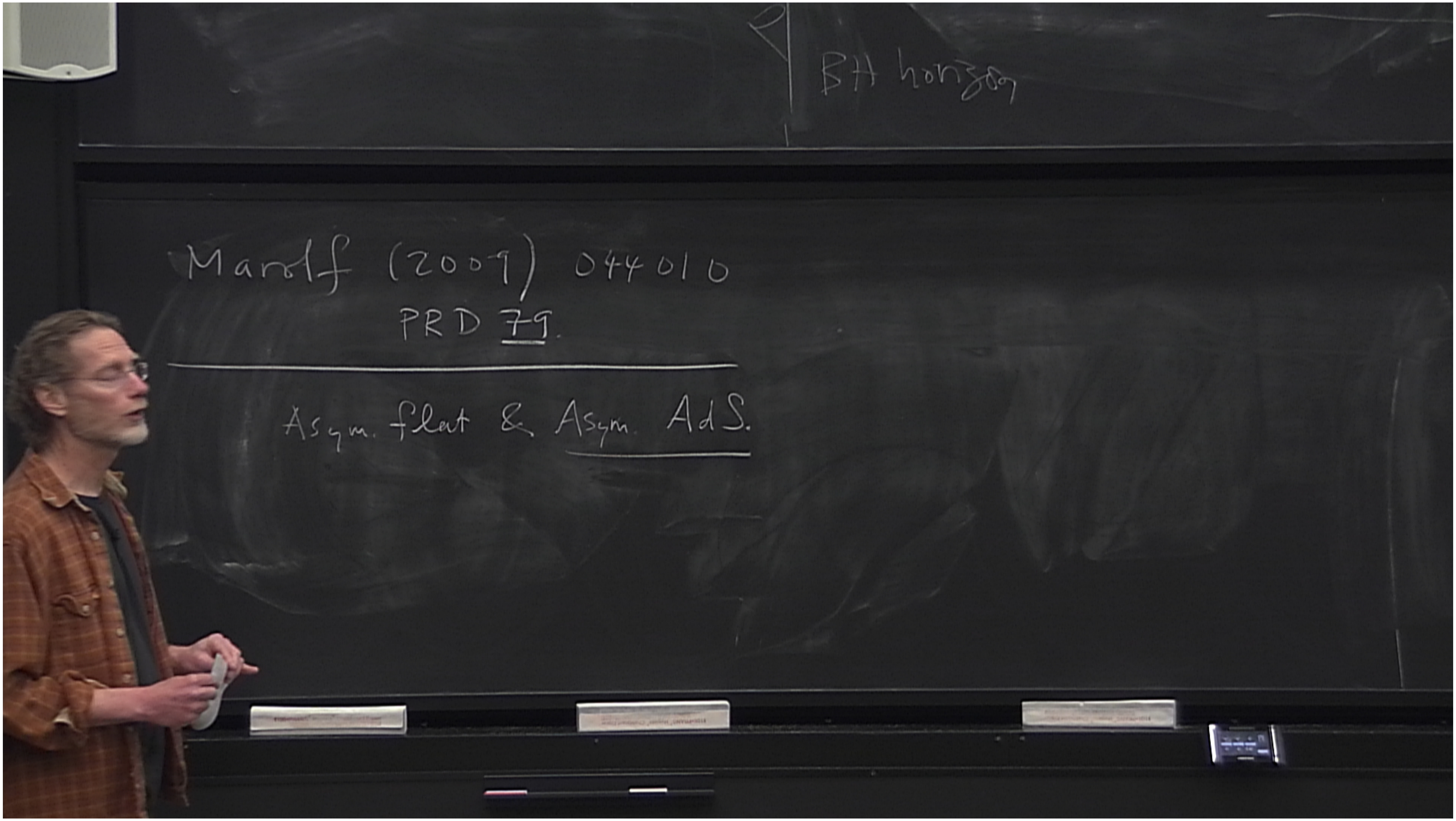

E
looks like bh evaporation
is not unitary — info is lost.
But, suppose it is actually unitary
A
Ã

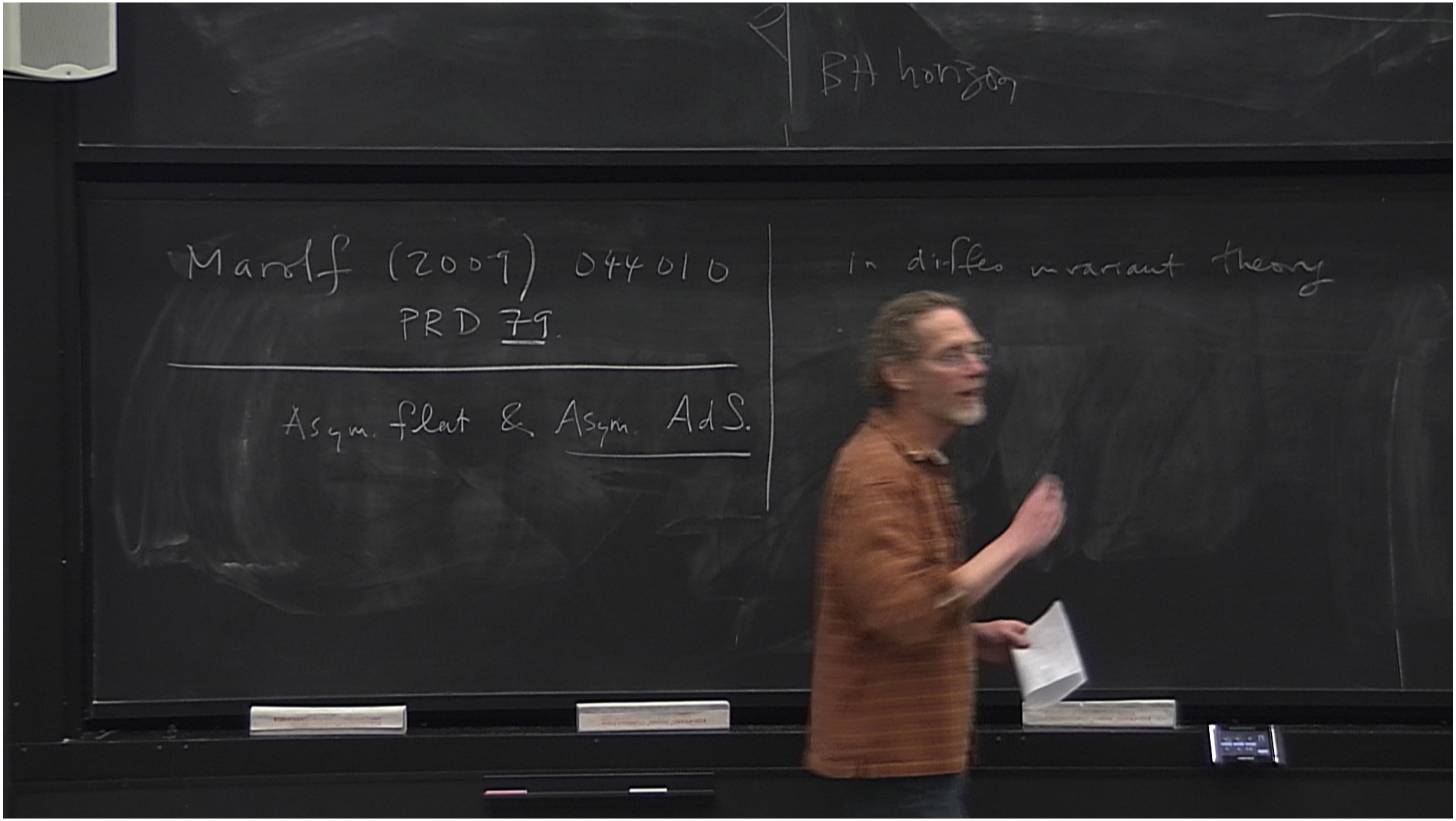

BH horizon
Marolf (2009) 044010
PRD 79

BH horizon

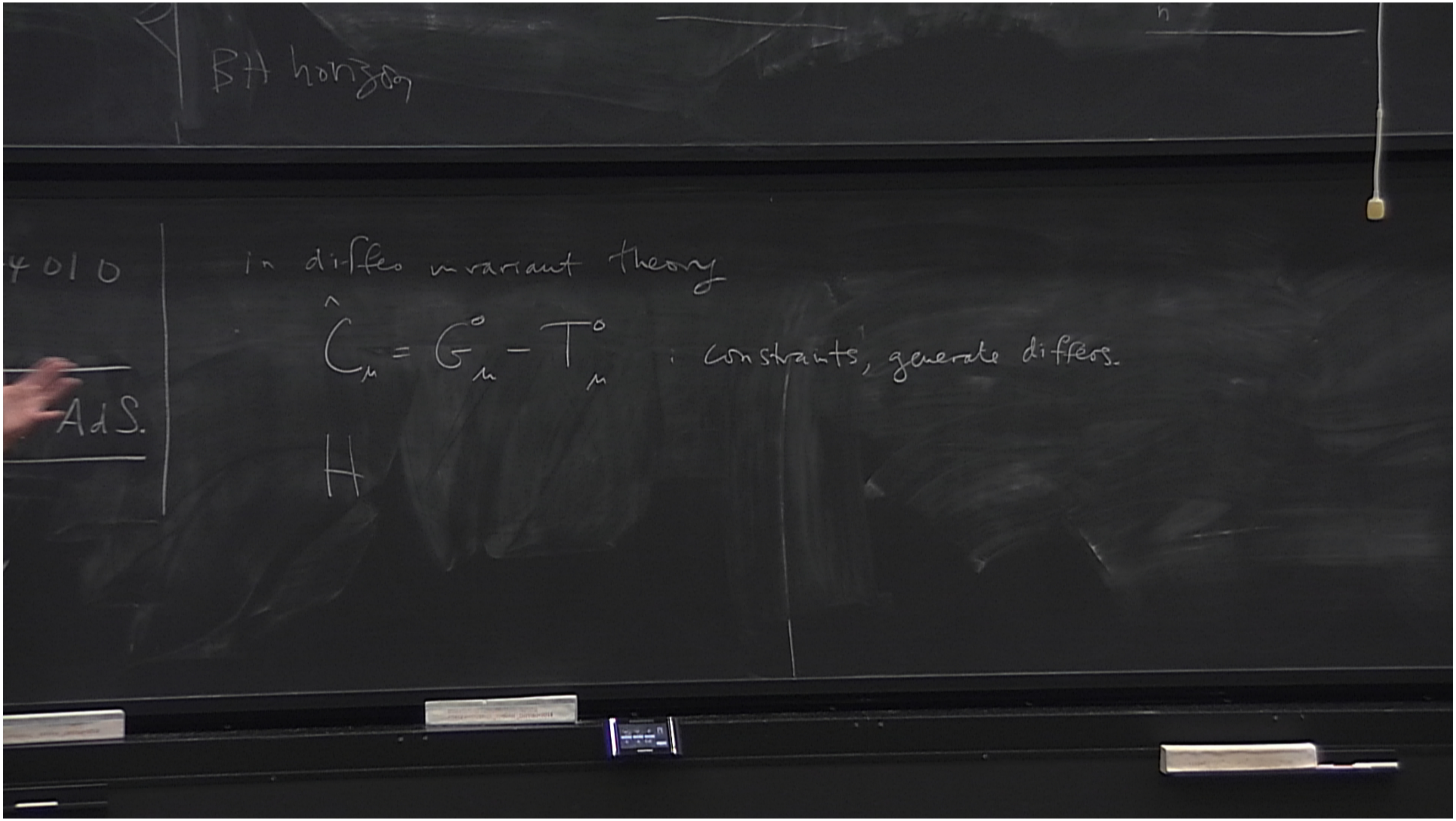
Marolf (2009) 044010
PRD **79**

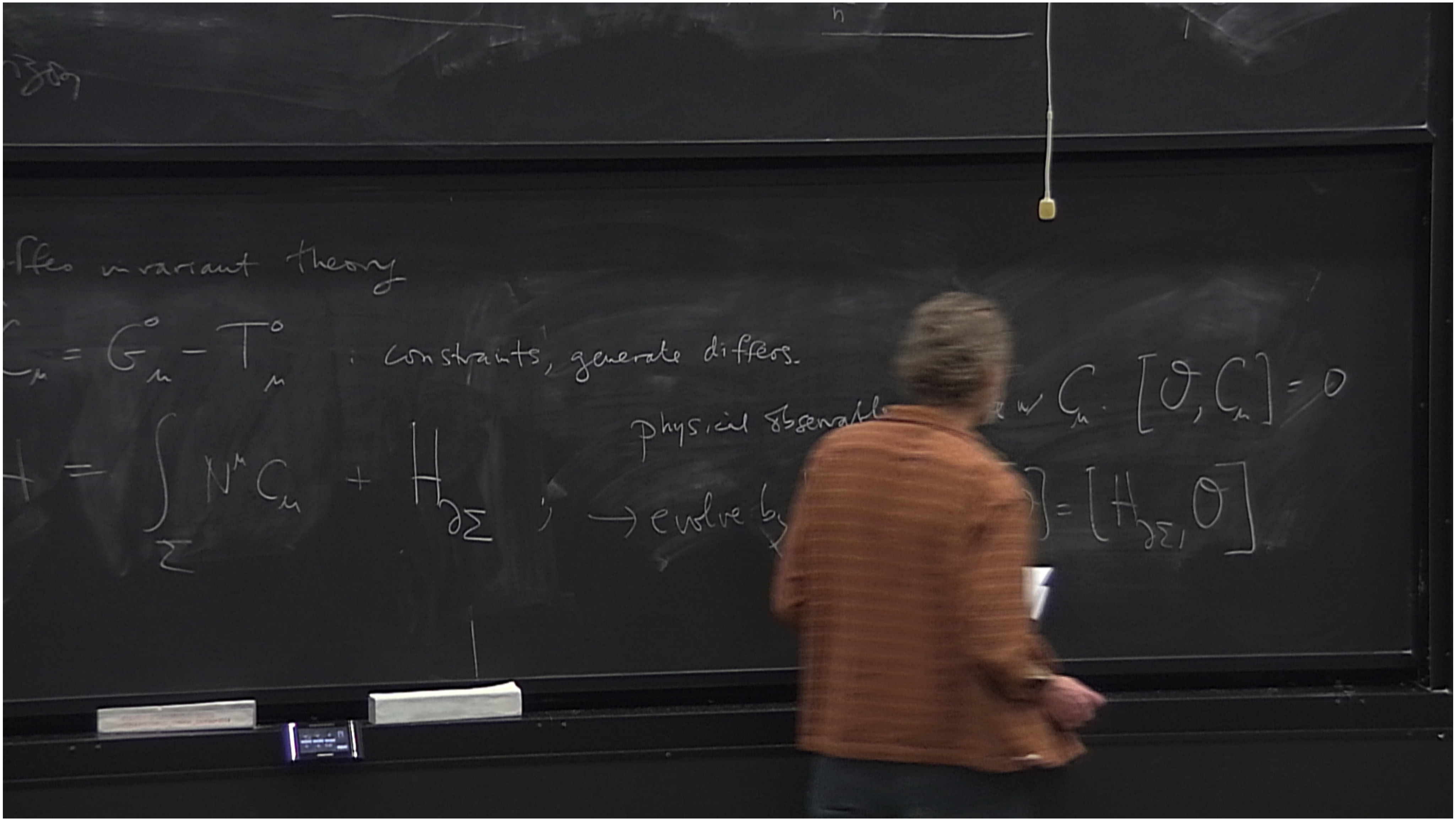
Asym. flat & Asym. AdS.

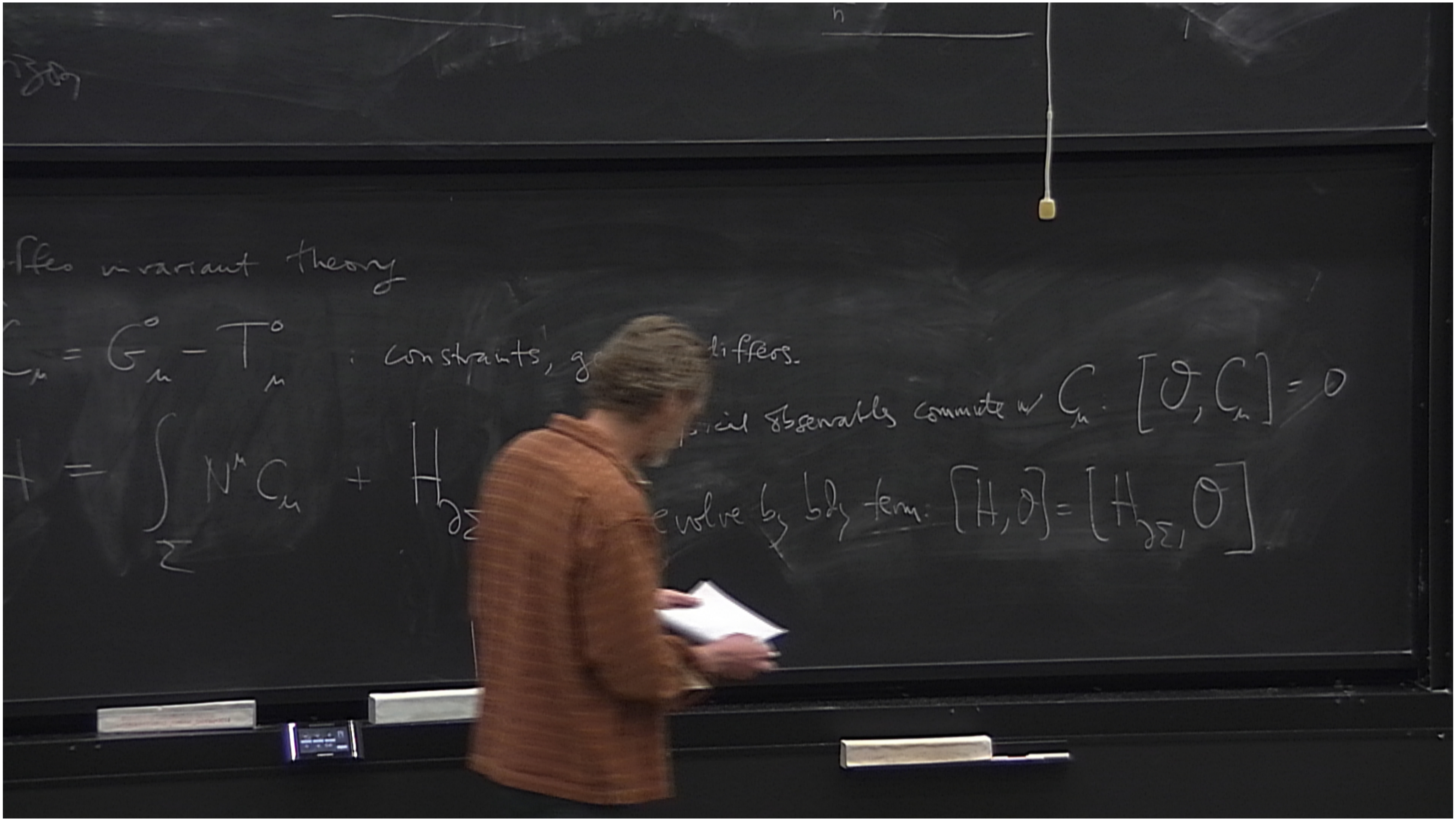

BH horizon
Marolf (2009) 044010
PRD 79.
Asym. flat & Asym. AdS.



BH horizon
Marolf (2009) 044010
PRD 79.
Asym. flat & Asym. AdS.
in diffeo invariant theory


BH horizon
4010
AdS.
in diffeo invariant theory
$\hat{C}_\mu = G^0_\mu - T^0_\mu$: constraints, generate diffeos.
H

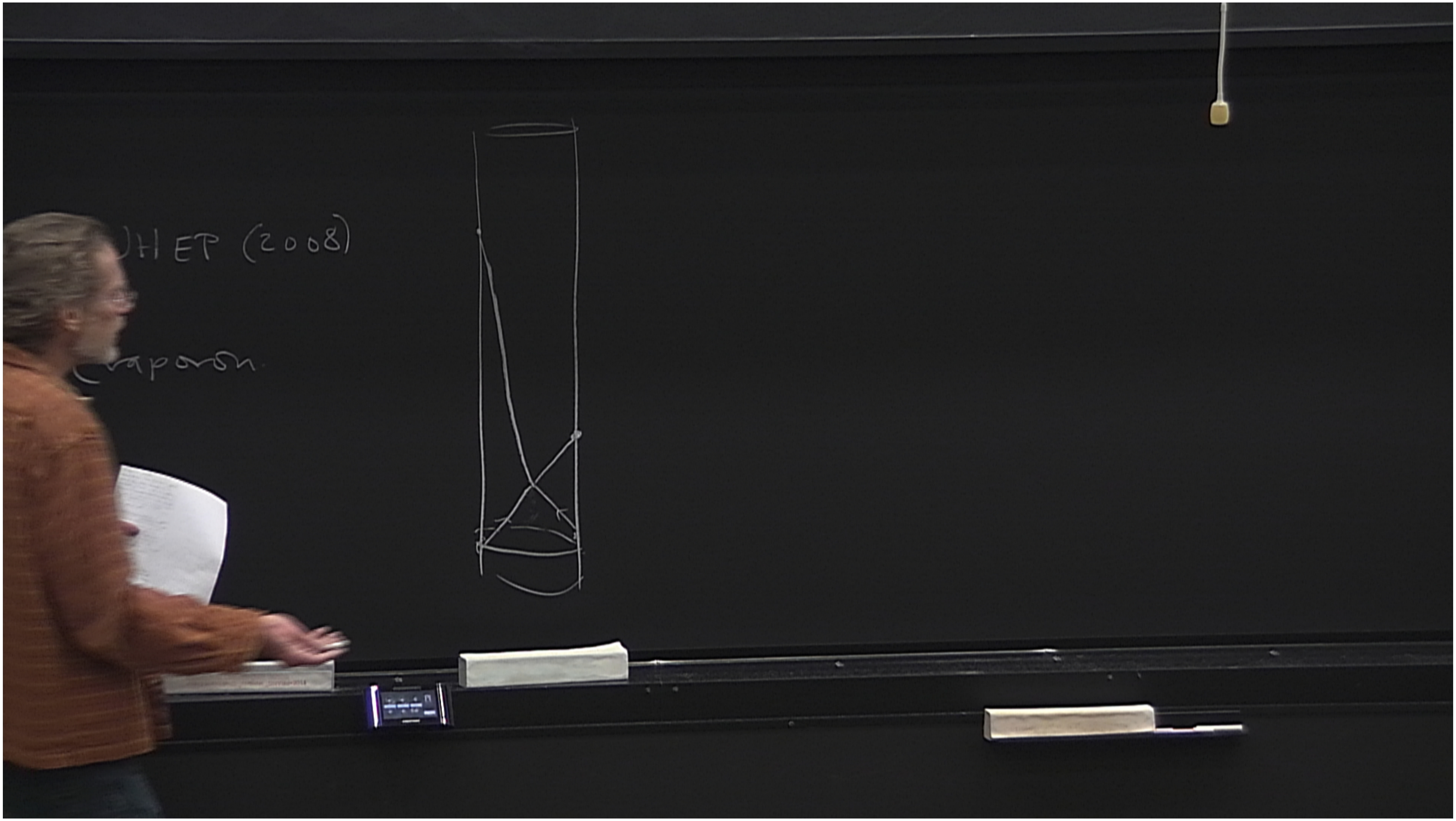

invariant theory
constraints, generate diffeos.
physical observable
evolve by

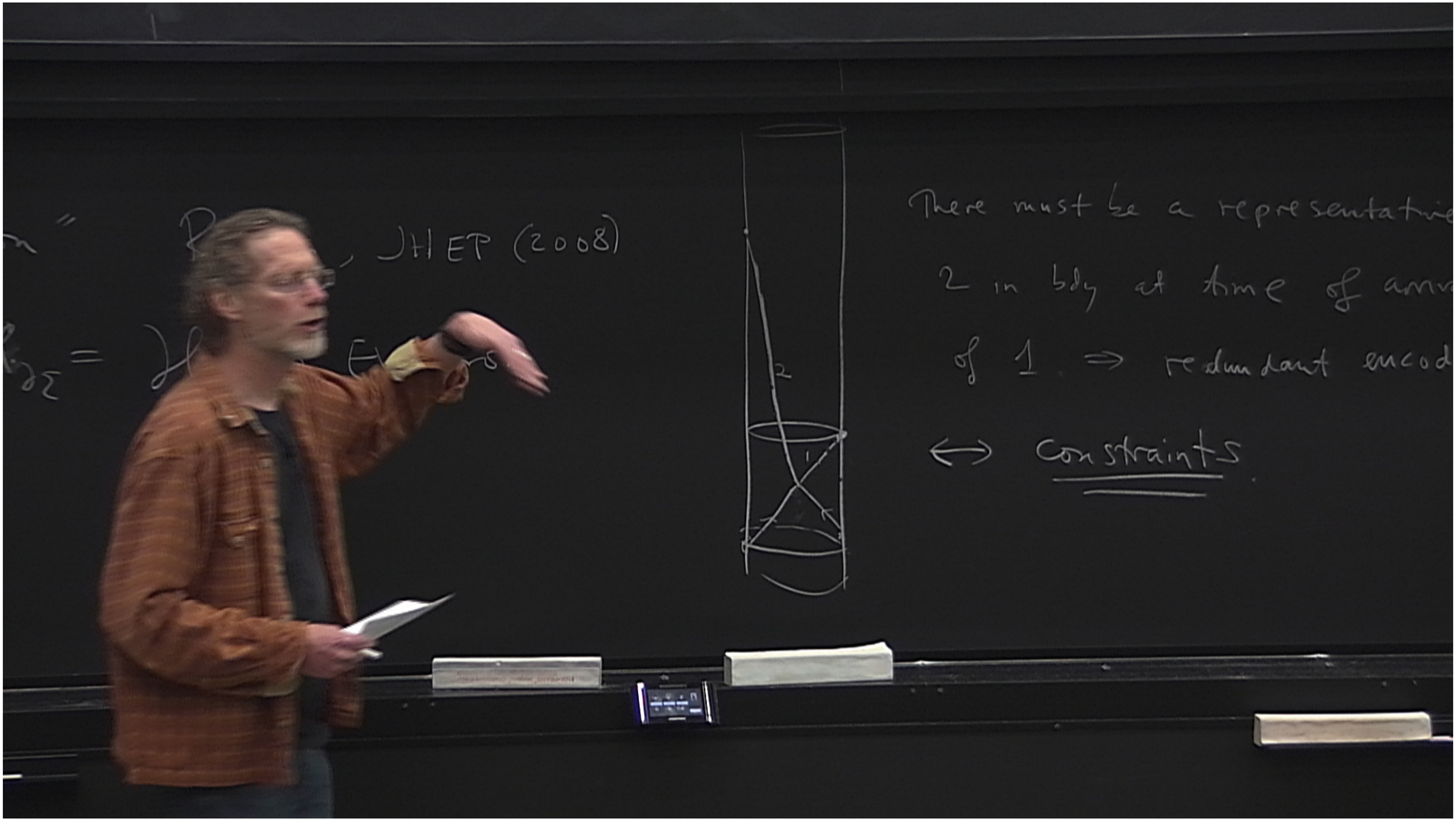


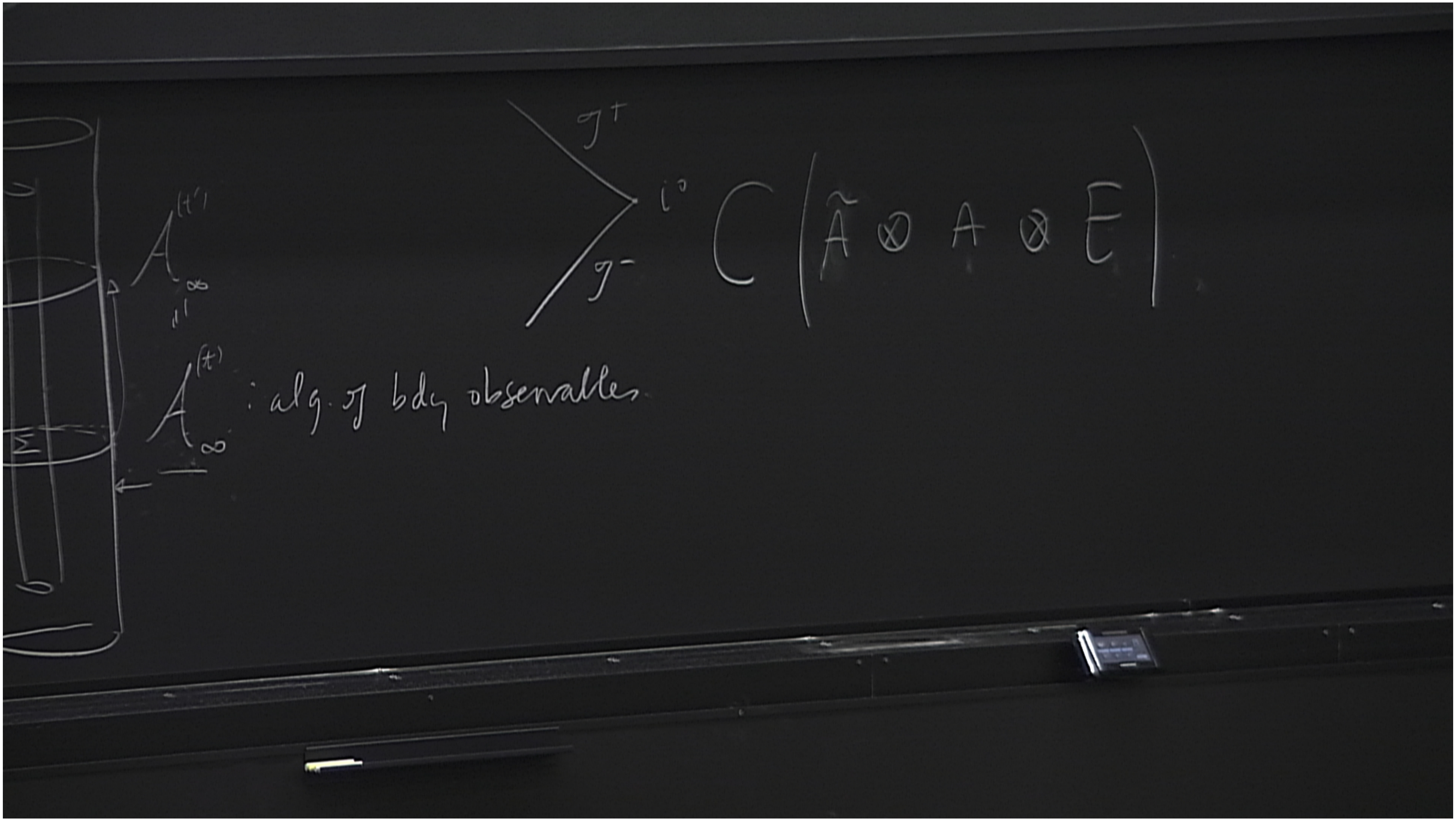
ffeo invariant theory
$C_\mu = G^0_\mu - T^0_\mu$: constraints,
iffeos.
observables commute w/ C_μ: $[O, C_\mu] = 0$
$H = \int_\Sigma N^\mu C_\mu + H_{\partial\Sigma}$
evolve by bdy term: $[H, O] = [H_{\partial\Sigma}, O]$

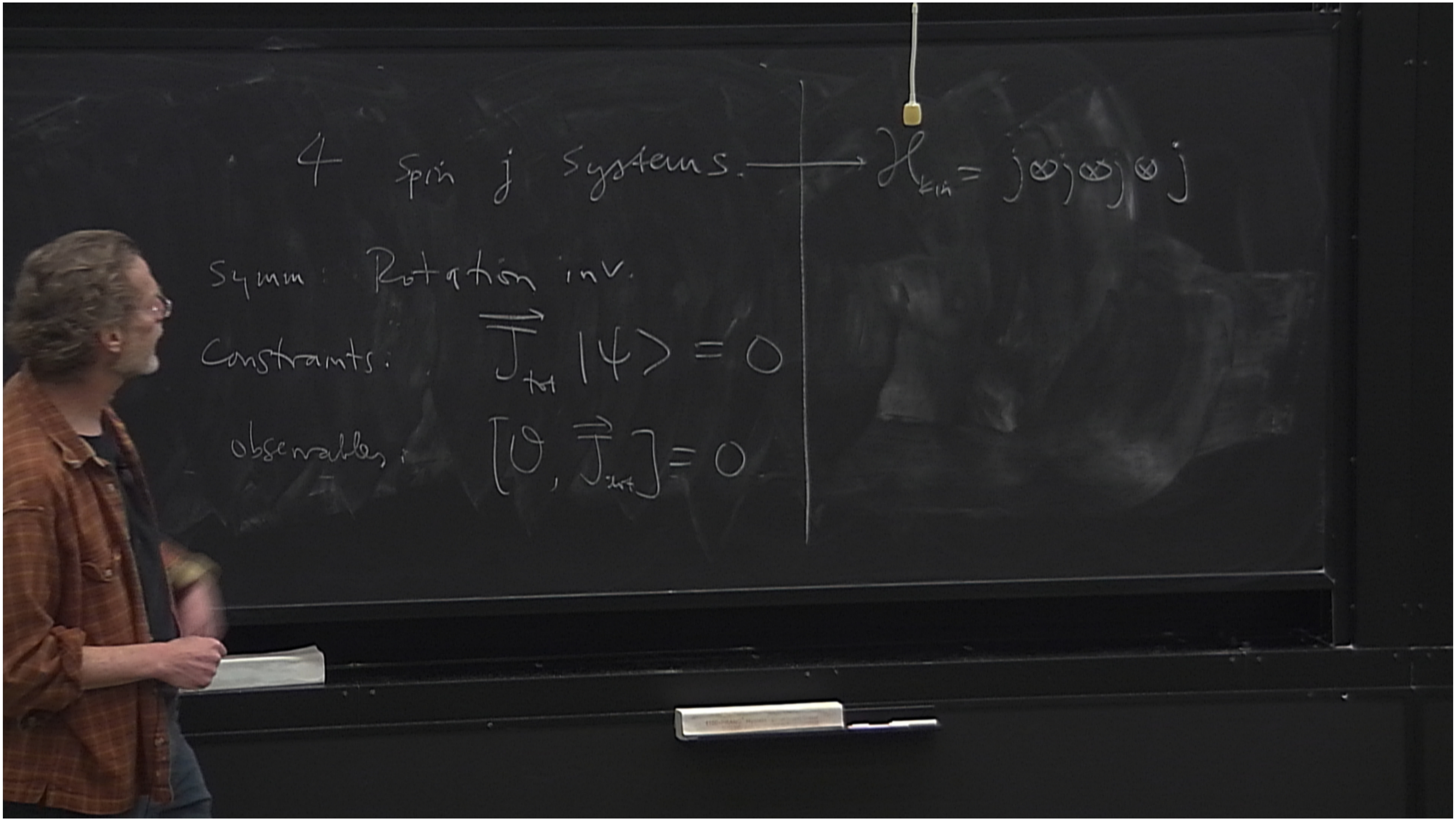
"Evaporon" Rocha, JHEP (2008)

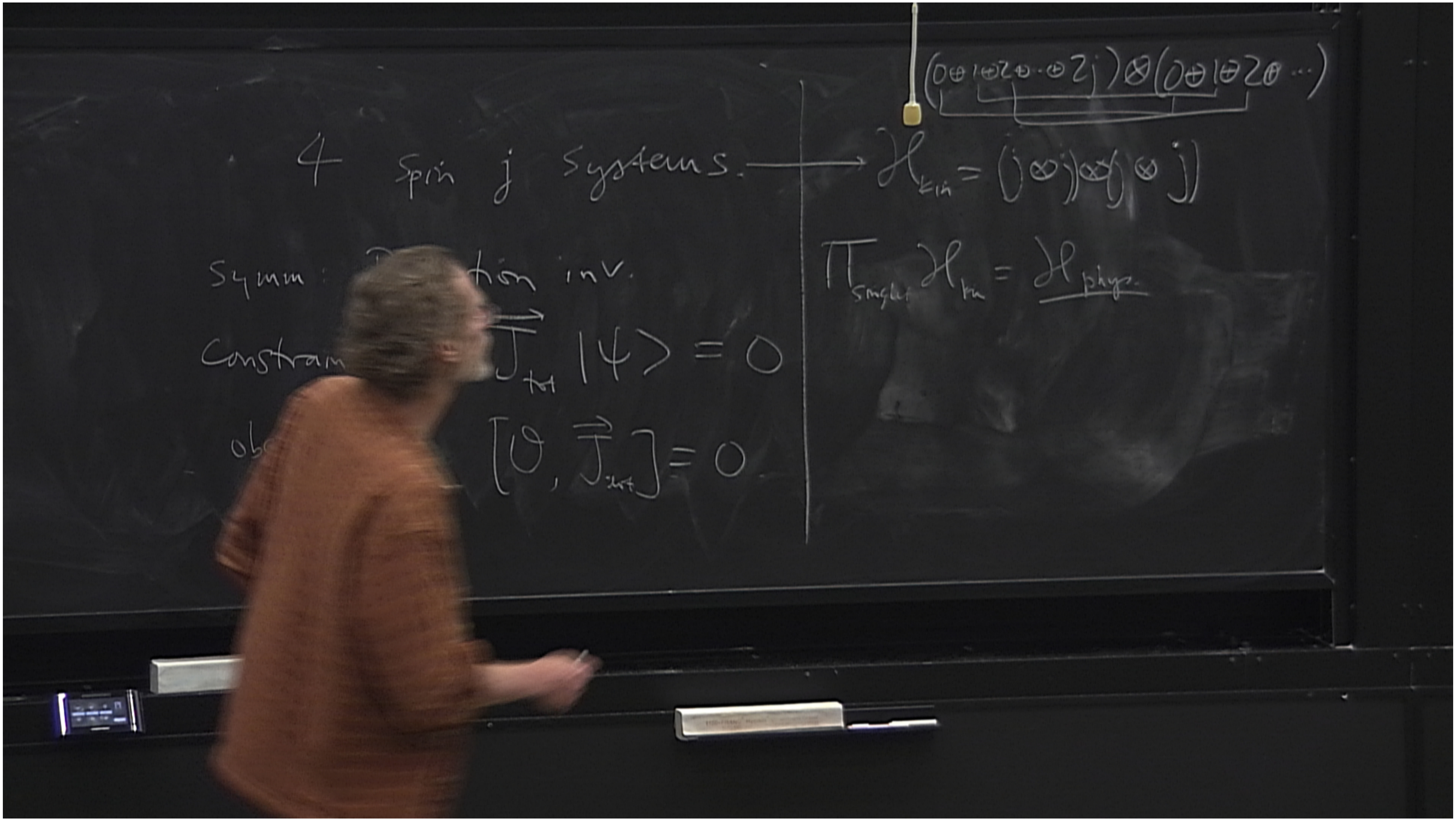
let $\mathcal{H}_{\partial\Sigma} = \mathcal{H}_{A\partial\Sigma} \otimes$ Evaporon




JHEP (2008)
There must be a representative
2 in bdy at time of arrival
of 1 ⇒ redundant encod
⟺ constraints


$\mathcal{J}^+$
i^0
$\mathcal{J}^-$
$C(\tilde{A} \otimes A \otimes E)$
$A^{(t')}_\infty$
$\shortparallel$
$A^{(t)}_\infty$: alg. of bdy observables.
Σ


4 Spin j Systems. → $\mathcal{H}_{kin} = j\otimes j\otimes j\otimes j$
Symm: Rotation inv.
Constraints: $\vec{J}_{tot}|\psi\rangle = 0$
observables: $[O, \vec{J}_{tot}] = 0$


$(0\oplus 1\oplus 2\oplus\cdots\oplus 2j)\otimes(0\oplus 1\oplus 2\oplus\cdots)$
4 Spin j Systems.
$\mathcal{H}_{kin} = (j\otimes j)\otimes(j\otimes j)$
Symm:
tion inv.
$\Pi_{singlet}\mathcal{H}_{kin} = \mathcal{H}_{phys.}$
$\vec{J}_{tot}|\psi\rangle = 0$
$[\mathcal{O}, \vec{J}_{tot}] = 0$

4 Spin j Systems $\longrightarrow \mathcal{H}_{kin} = (j \otimes j) \otimes (j \otimes j)$

$(0 \oplus 1 \oplus 2 \oplus \cdots \oplus 2j) \otimes (0 \oplus 1 \oplus 2 \oplus \cdots)$

Symm: Rotation inv.

Constraints: $\vec{J}_{tot} |\psi\rangle = 0$

observables: $[\mathcal{O}, \vec{J}_{tot}] = 0$

$\Pi_{singlet} \mathcal{H}_{kin} = \underline{\mathcal{H}_{phys.}}$

$= \mathcal{O}_0 \oplus \mathcal{O}_1 \oplus \mathcal{O}_2 \oplus \cdots \oplus \mathcal{O}_{2j} \oplus$ NON SINGLET