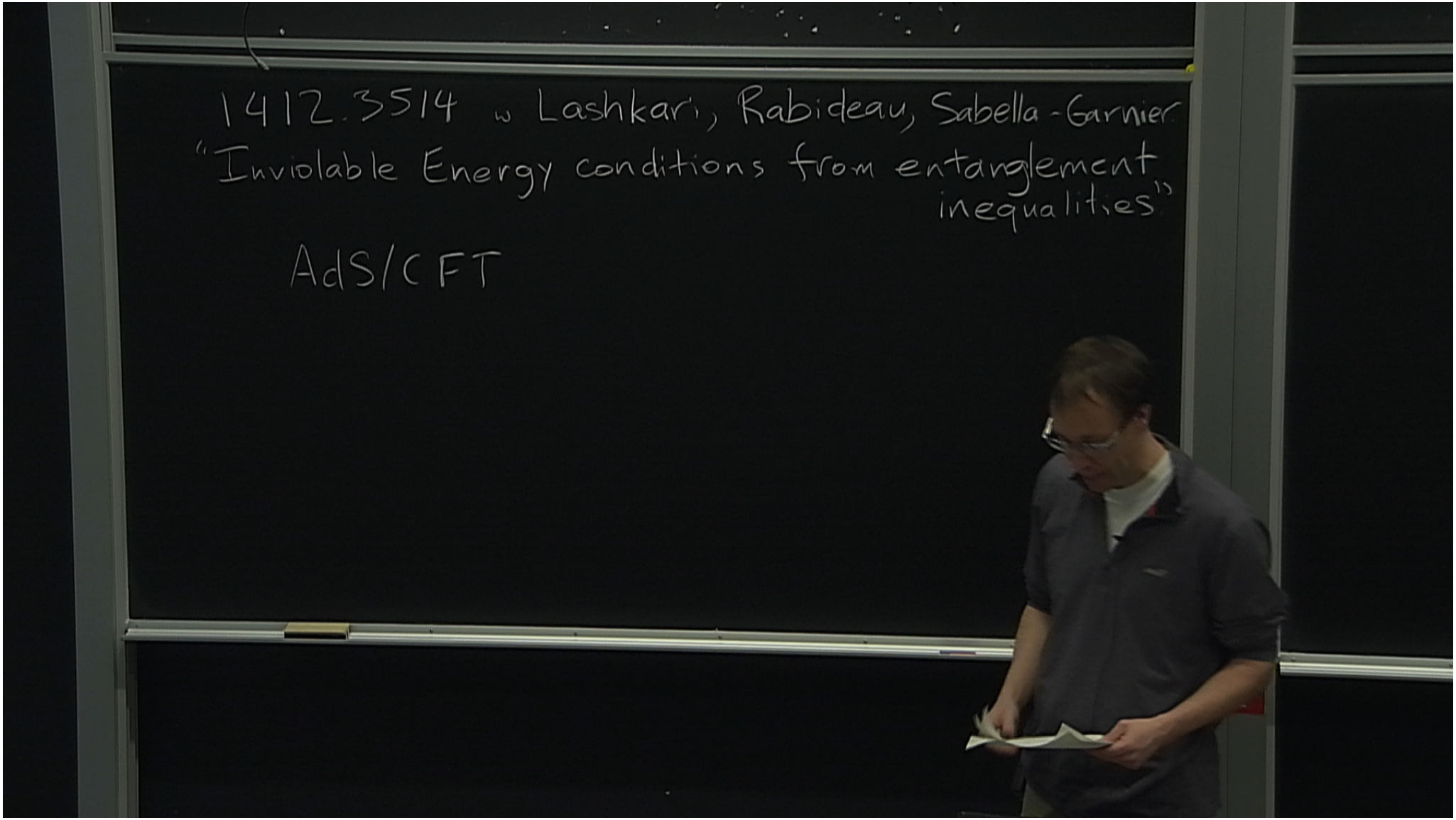
Title: Inviolable energy conditions from entanglement inequalities

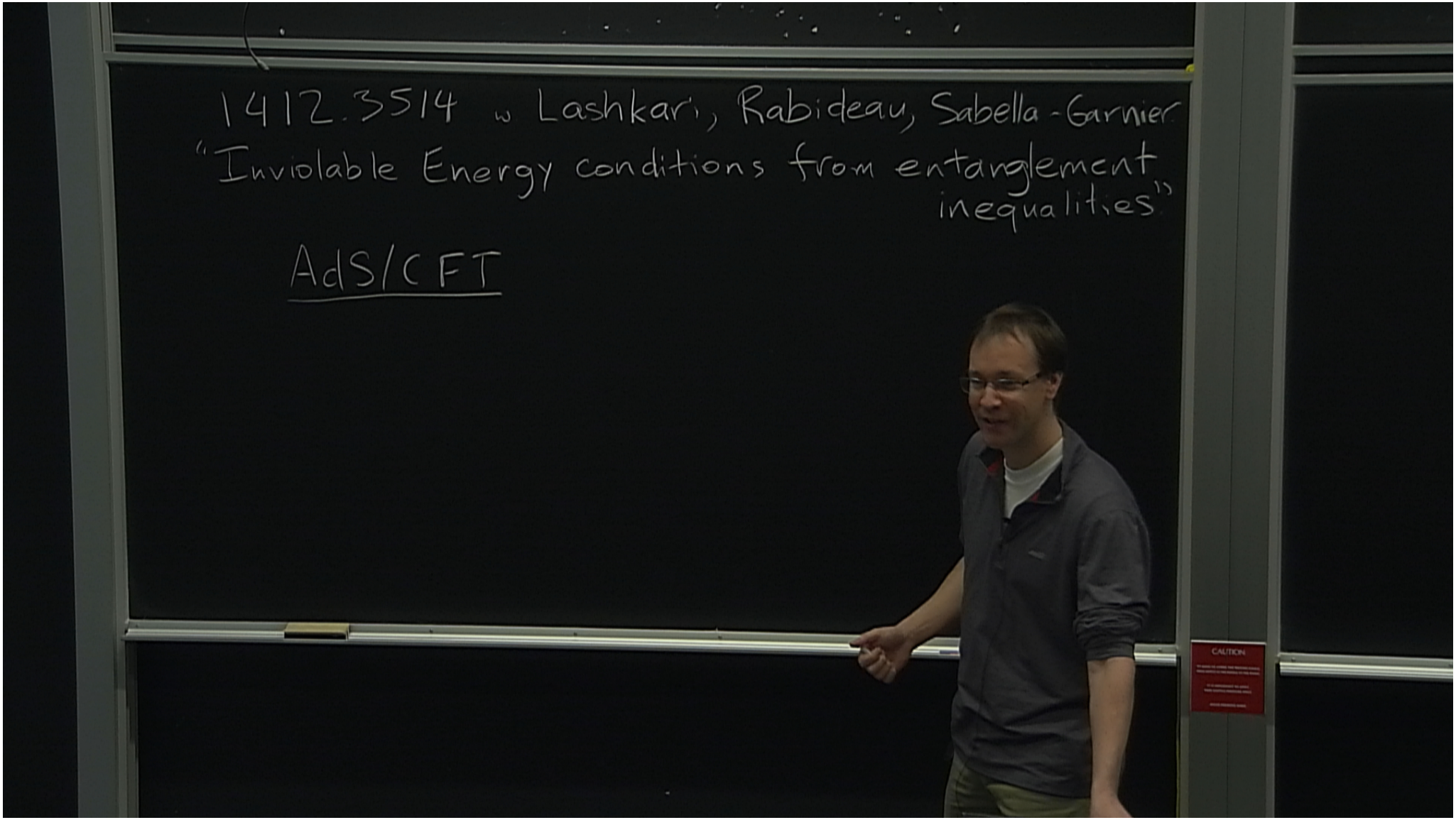
Date: Feb 19, 2015 11:00 AM

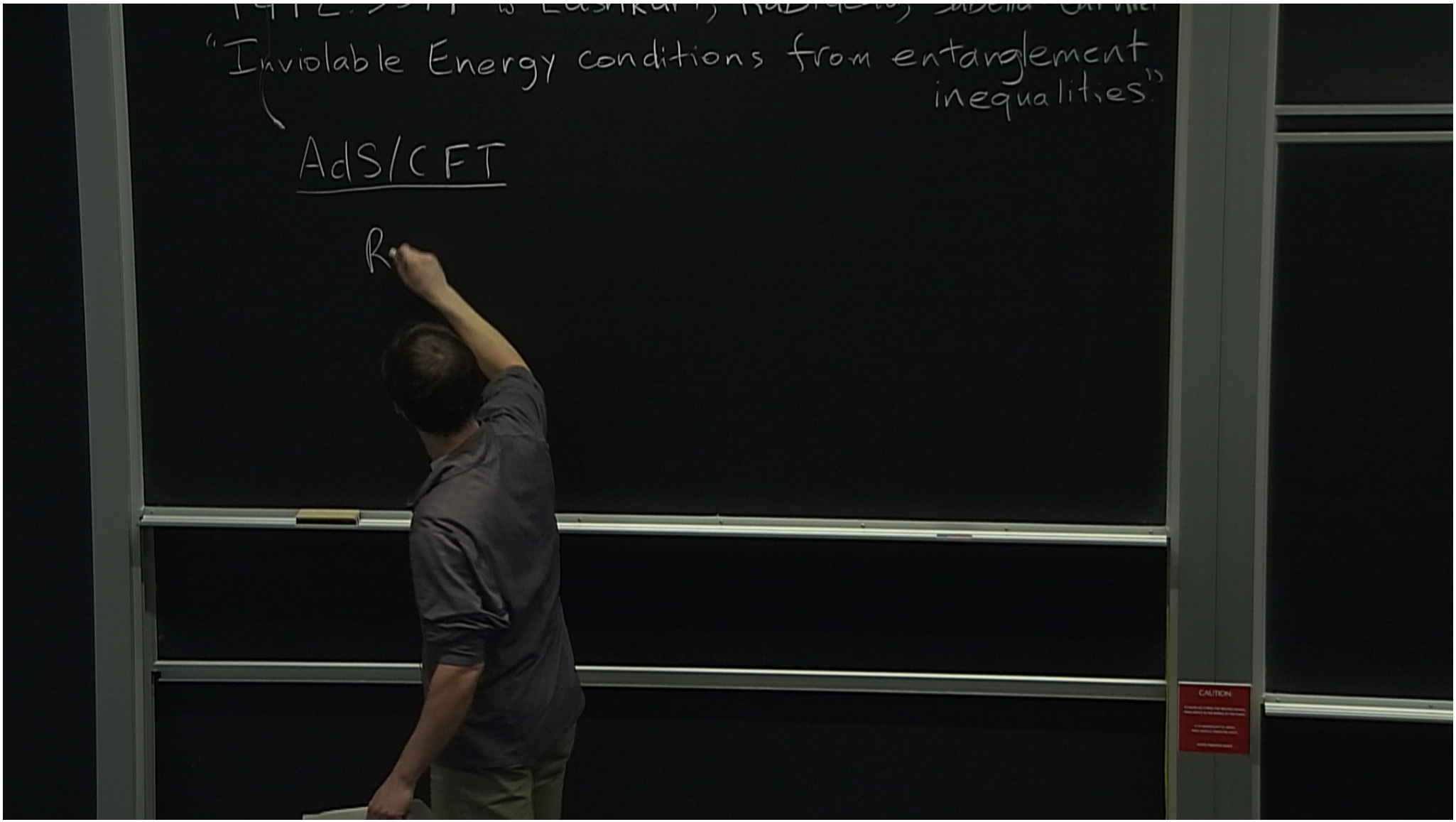
URL: http://pirsa.org/15020087

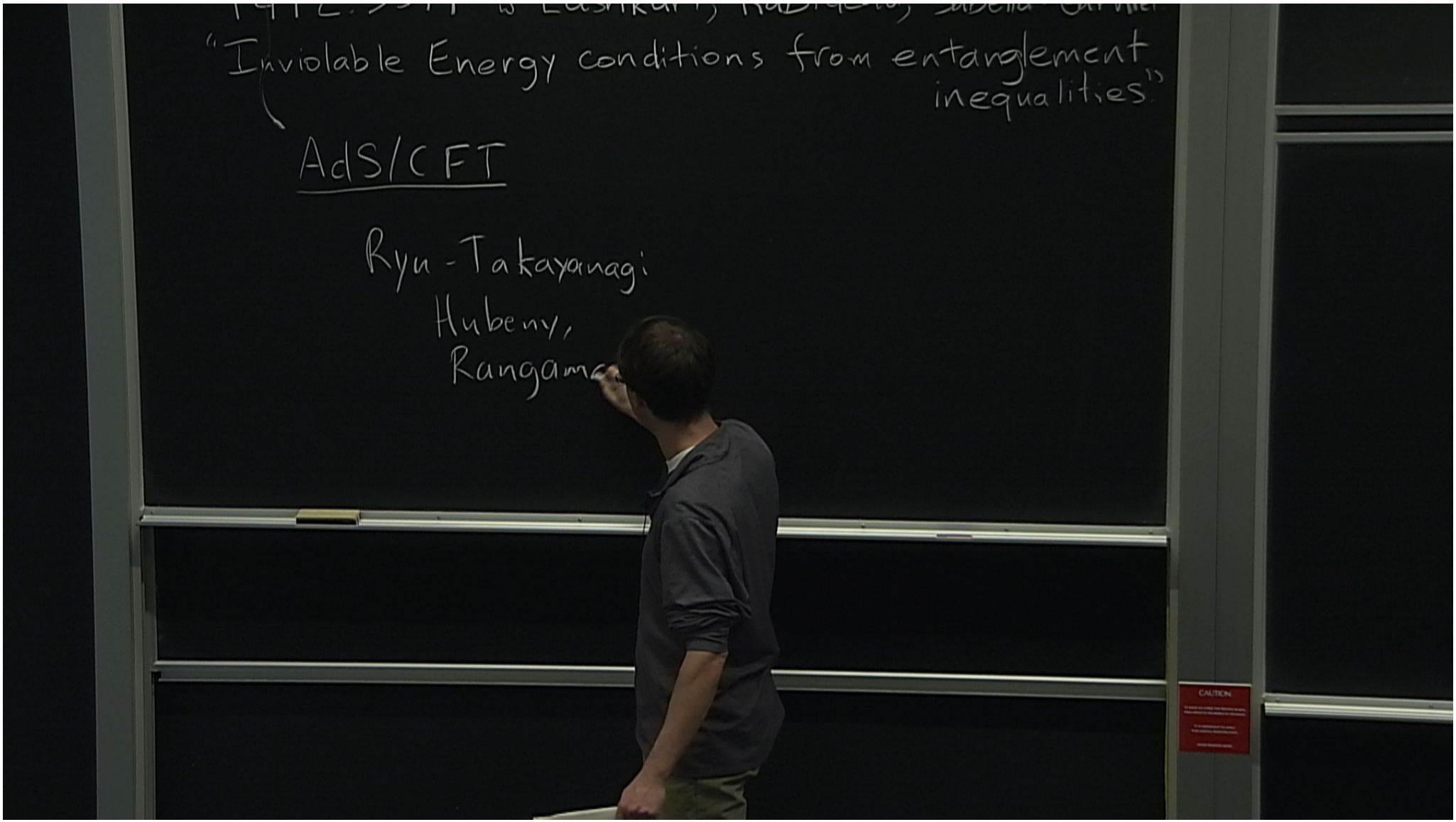
Abstract: Via the AdS/CFT correspondence, fundamental constraints on the entanglement structure of quantum systems translate to constraints on spacetime geometries that must be satisfied in any consistent theory of quantum gravity. In this talk, we describe some of the constraints arising from strong subadditivity and from the positivity and monotonicity of relative entropy. Our results may be interpreted as a set of energy conditions restricting the possible form of the stress-energy tensor in consistent theories of Einstein gravity coupled to matter."

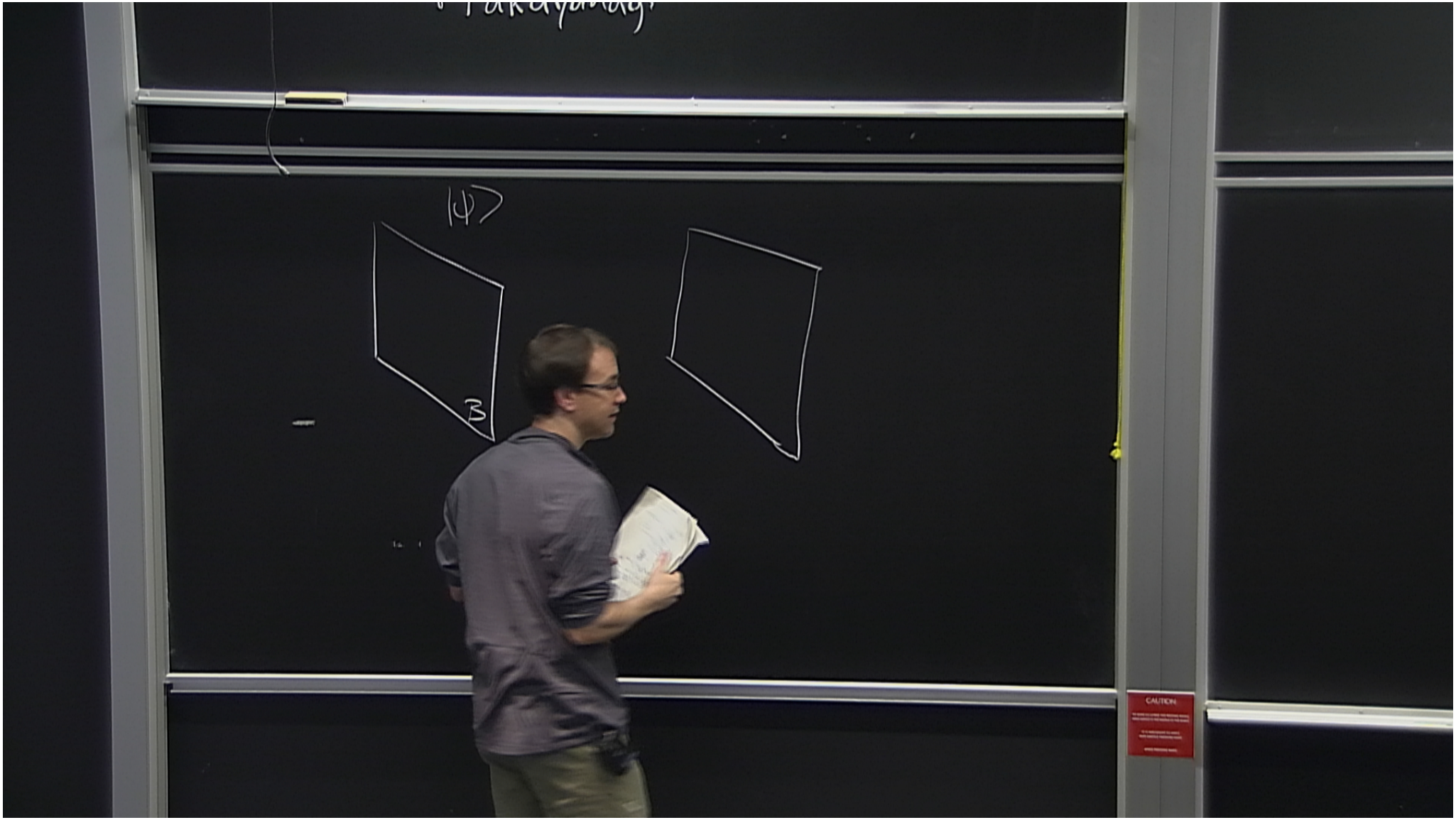

1412.3514 - Lashkari, Rabideau, Sabella-Garnier
"Involable Energy conditions from entanglement inequalities"

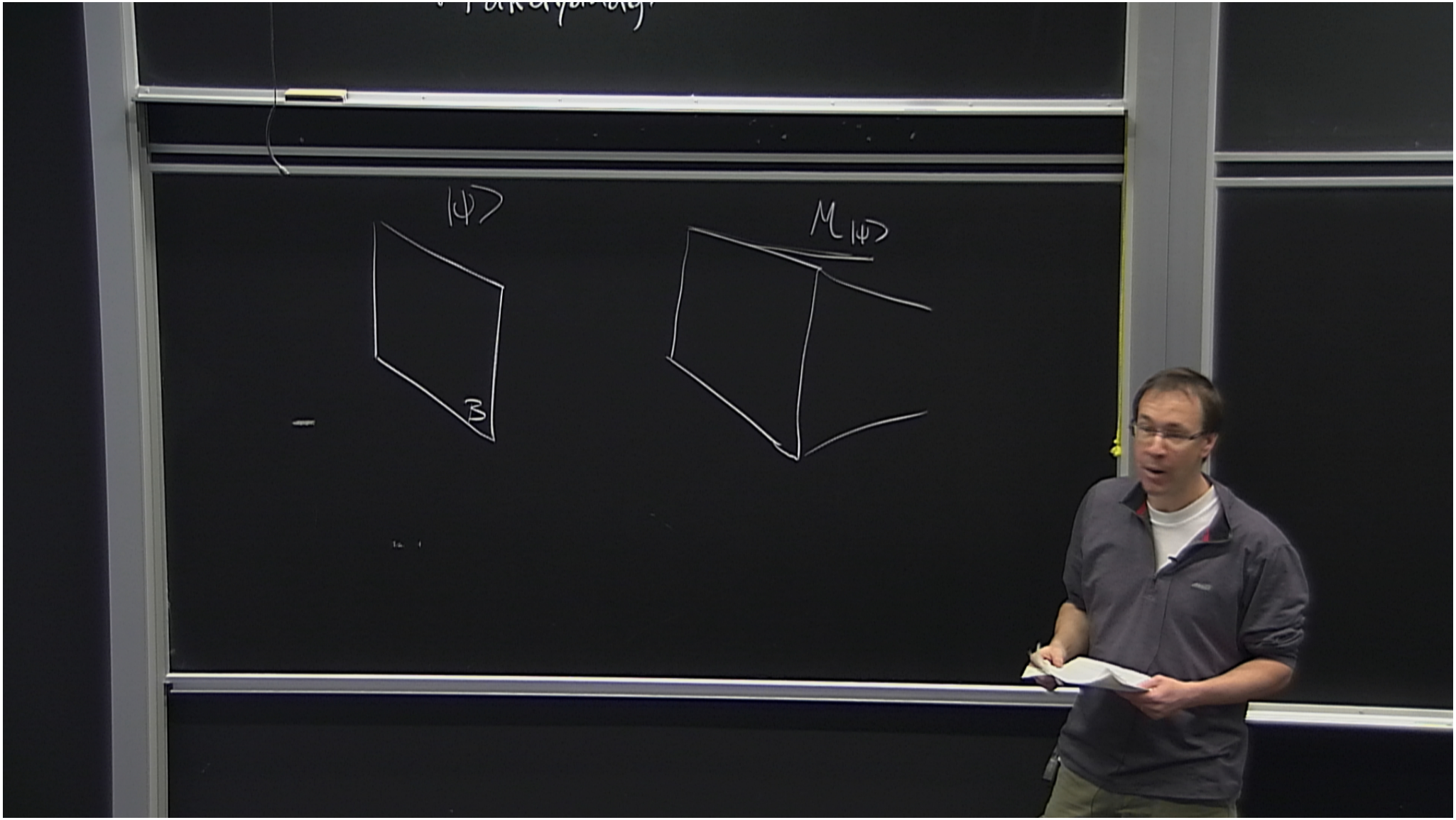

1412.3514 w Lashkari, Rabideau, Sabella-Garnier
"Inviolable Energy conditions from entanglement inequalities"
AdS/CFT

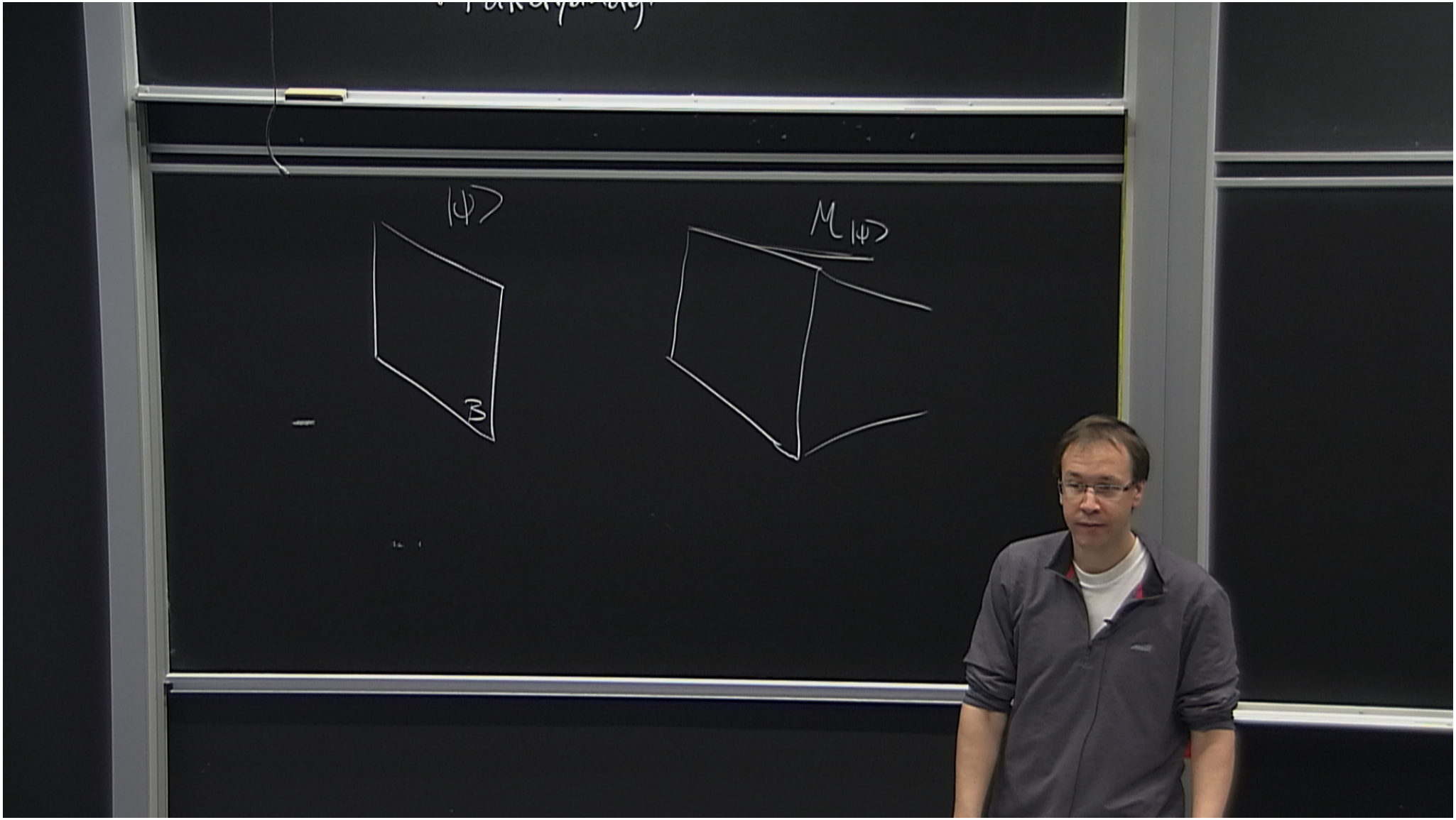

1412.3514 w Lashkari, Rabideau, Sabella-Garnier
"Inviolable Energy conditions from entanglement inequalities"
AdS/CFT
CAUTION

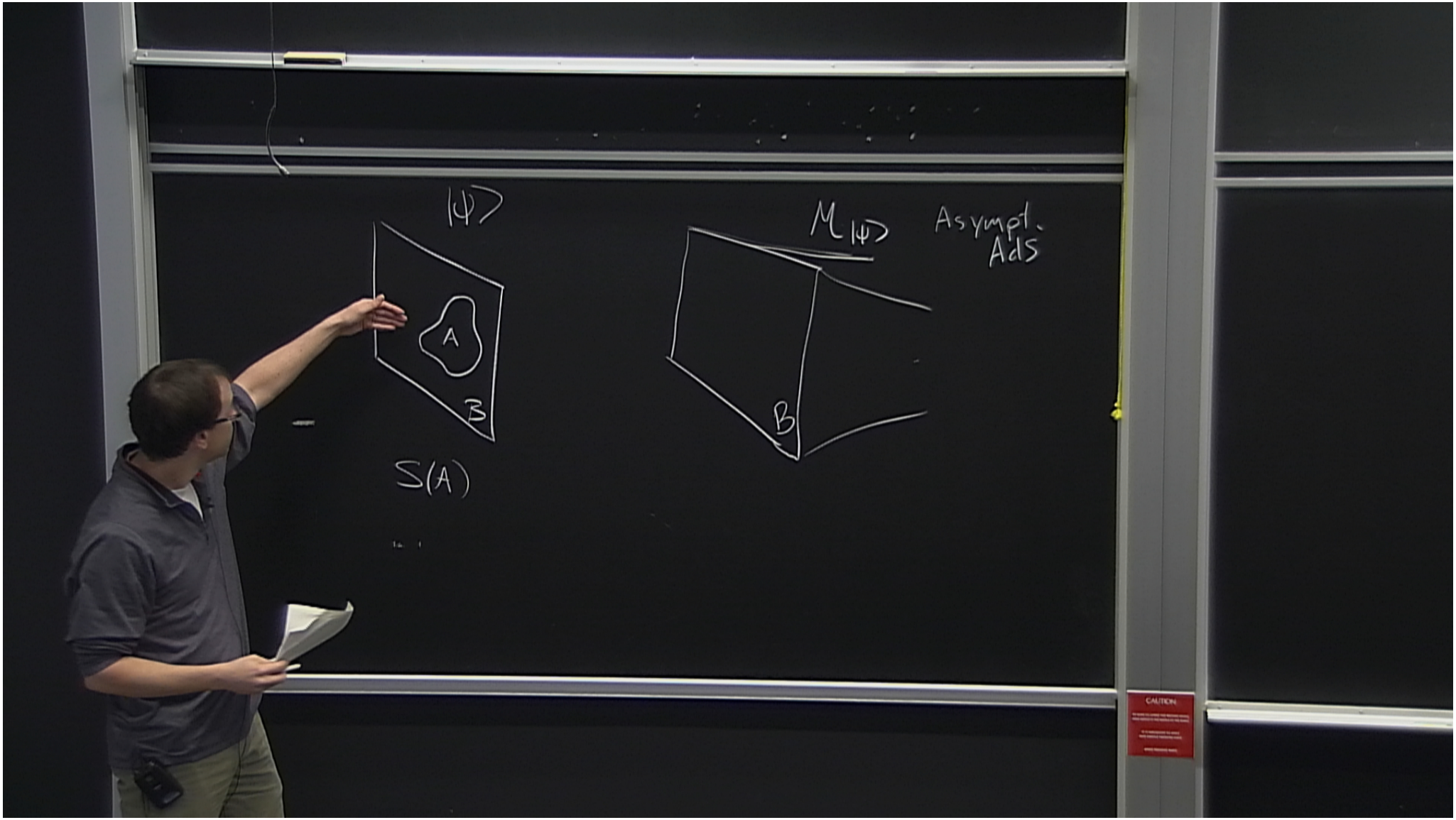

"Inviolable Energy conditions from entanglement inequalities"
AdS/CFT
CAUTION

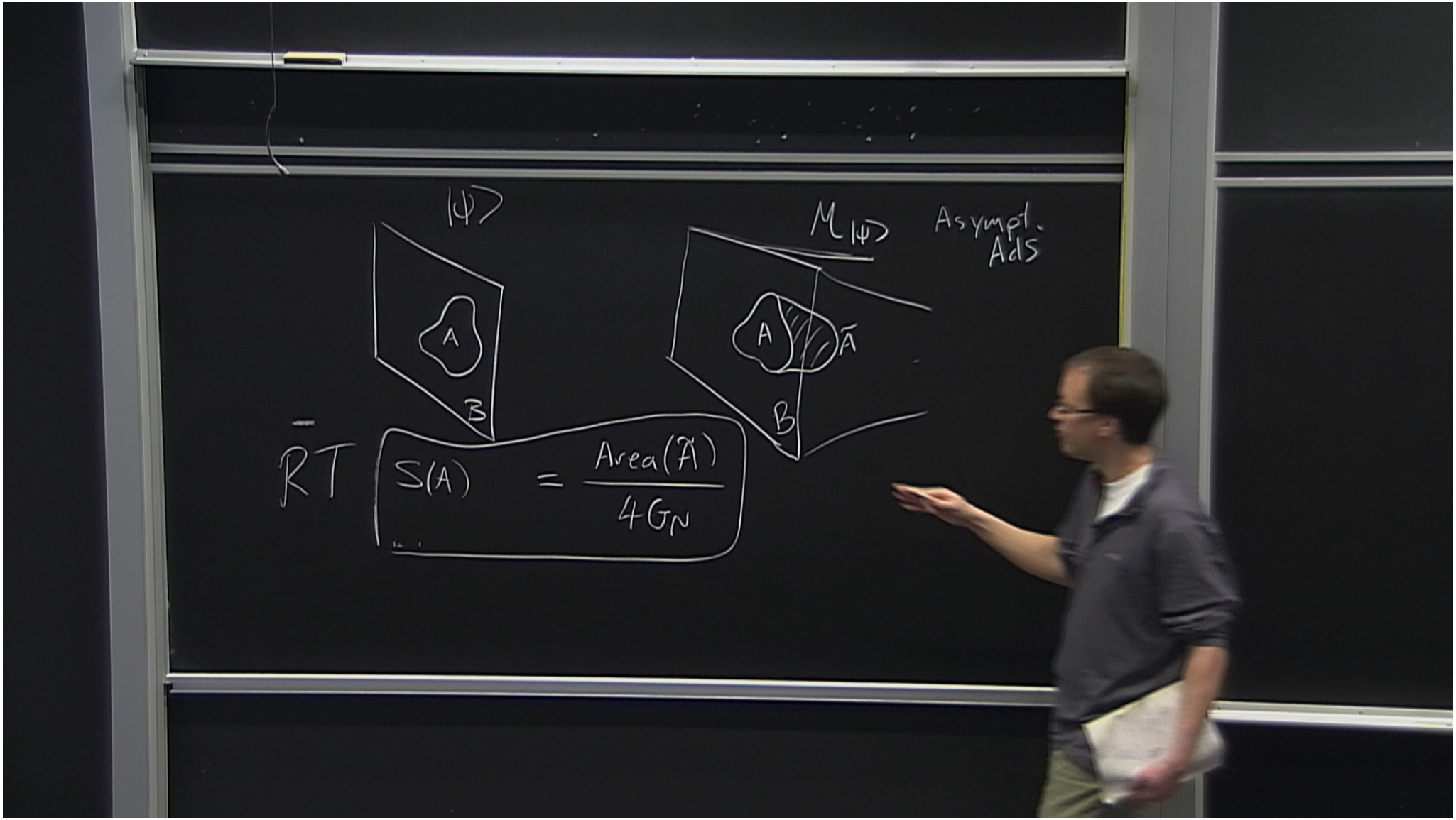

"Inviolable Energy conditions from entanglement inequalities"
AdS/CFT
Ryu-Takayanagi
Hubeny,
CAUTION

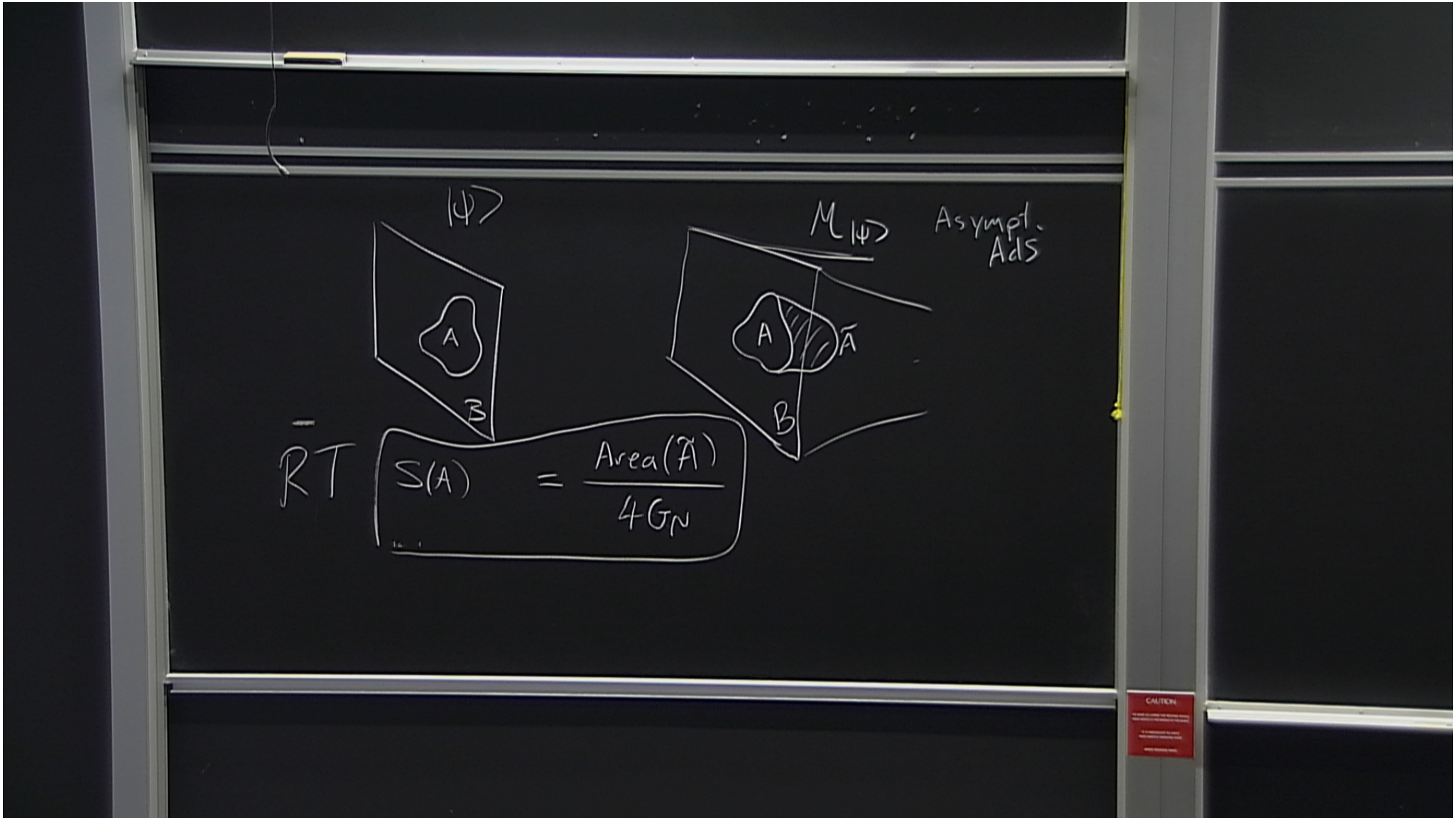

|ψ⟩
3
CAUTION

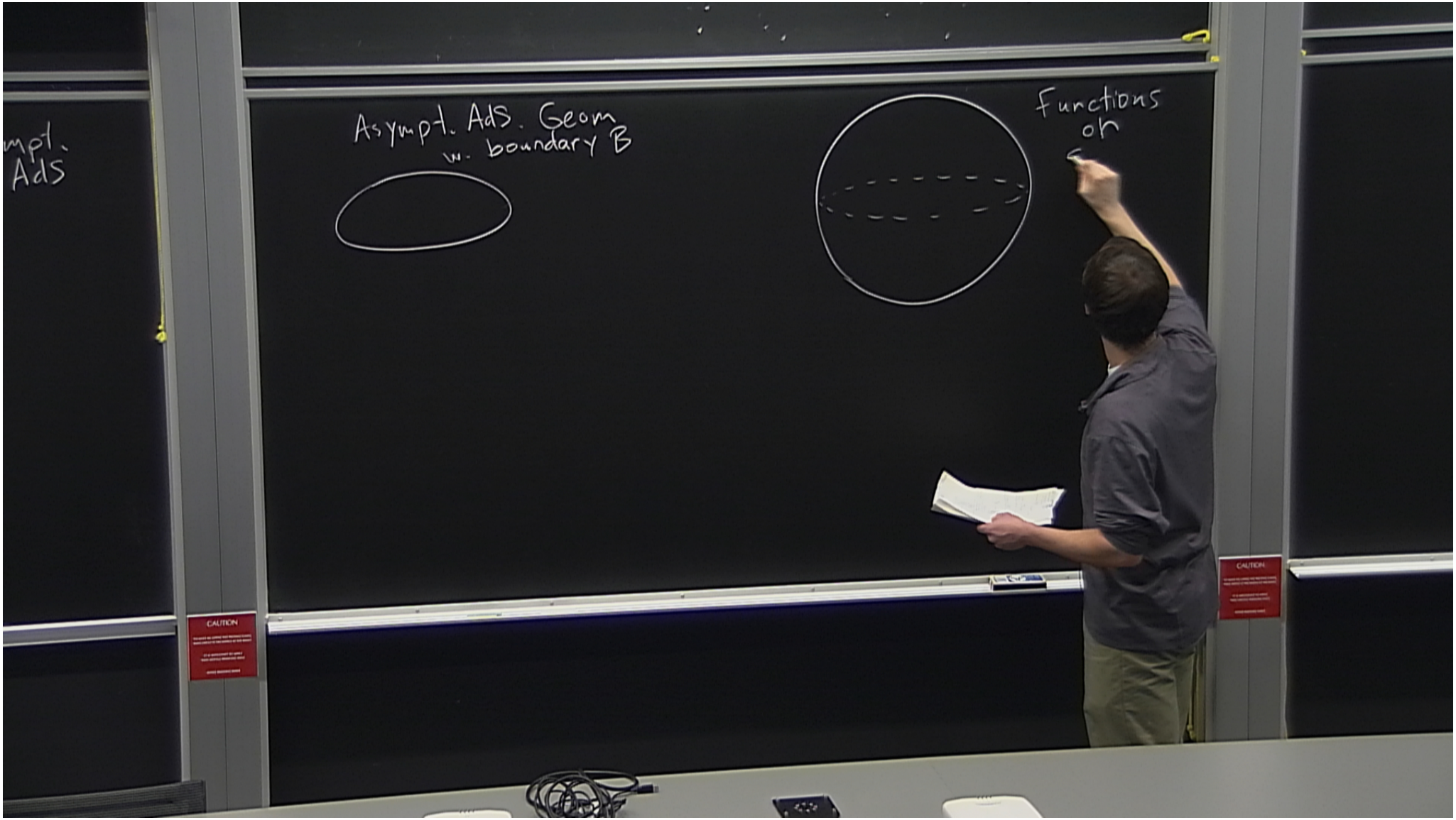

|ψ⟩
3
M|ψ⟩

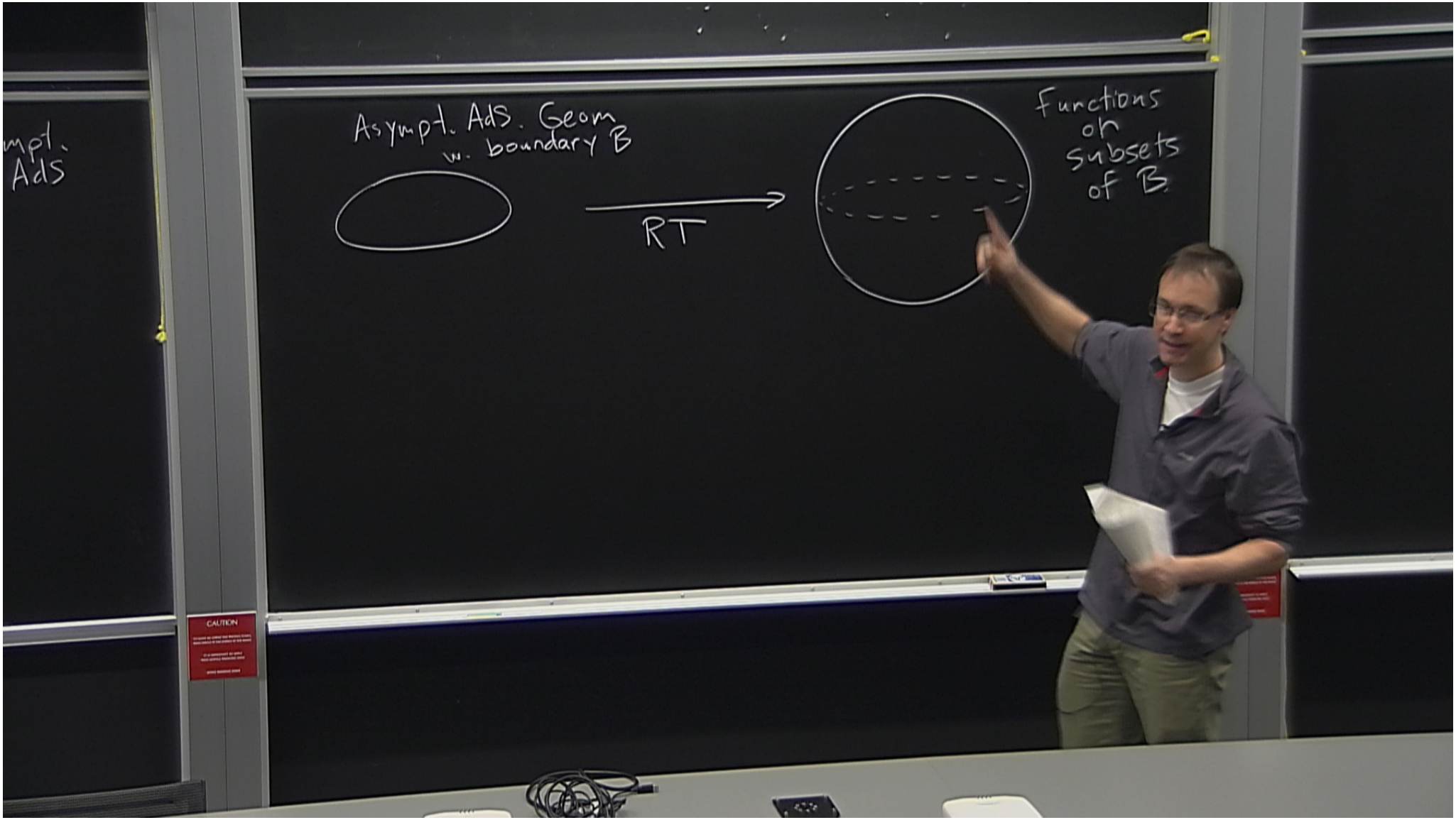

|ψ⟩
3
M|ψ⟩

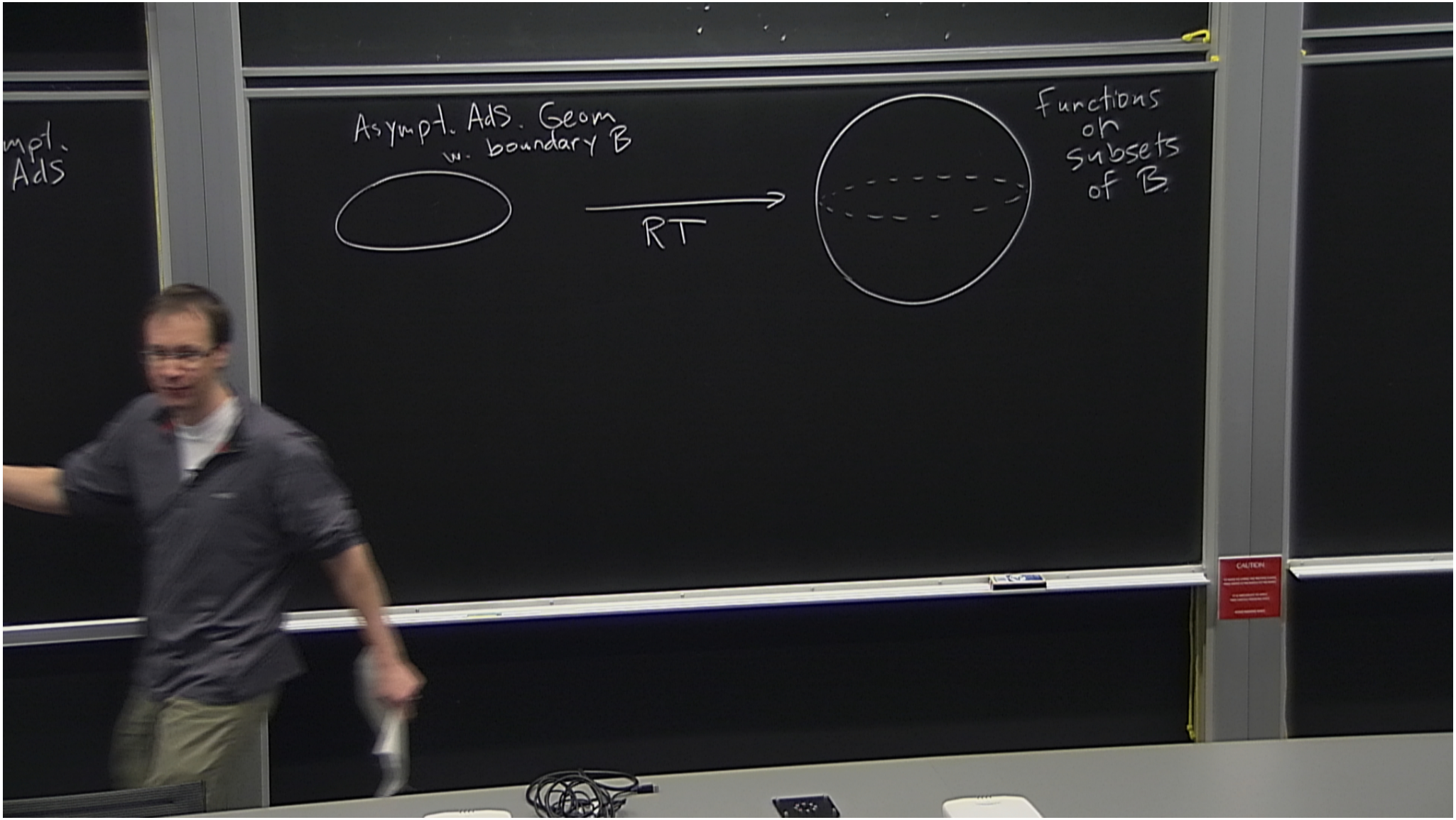

|ψ⟩
A
B
S(A)
M |ψ⟩
Asympt.
AdS
B
CAUTION

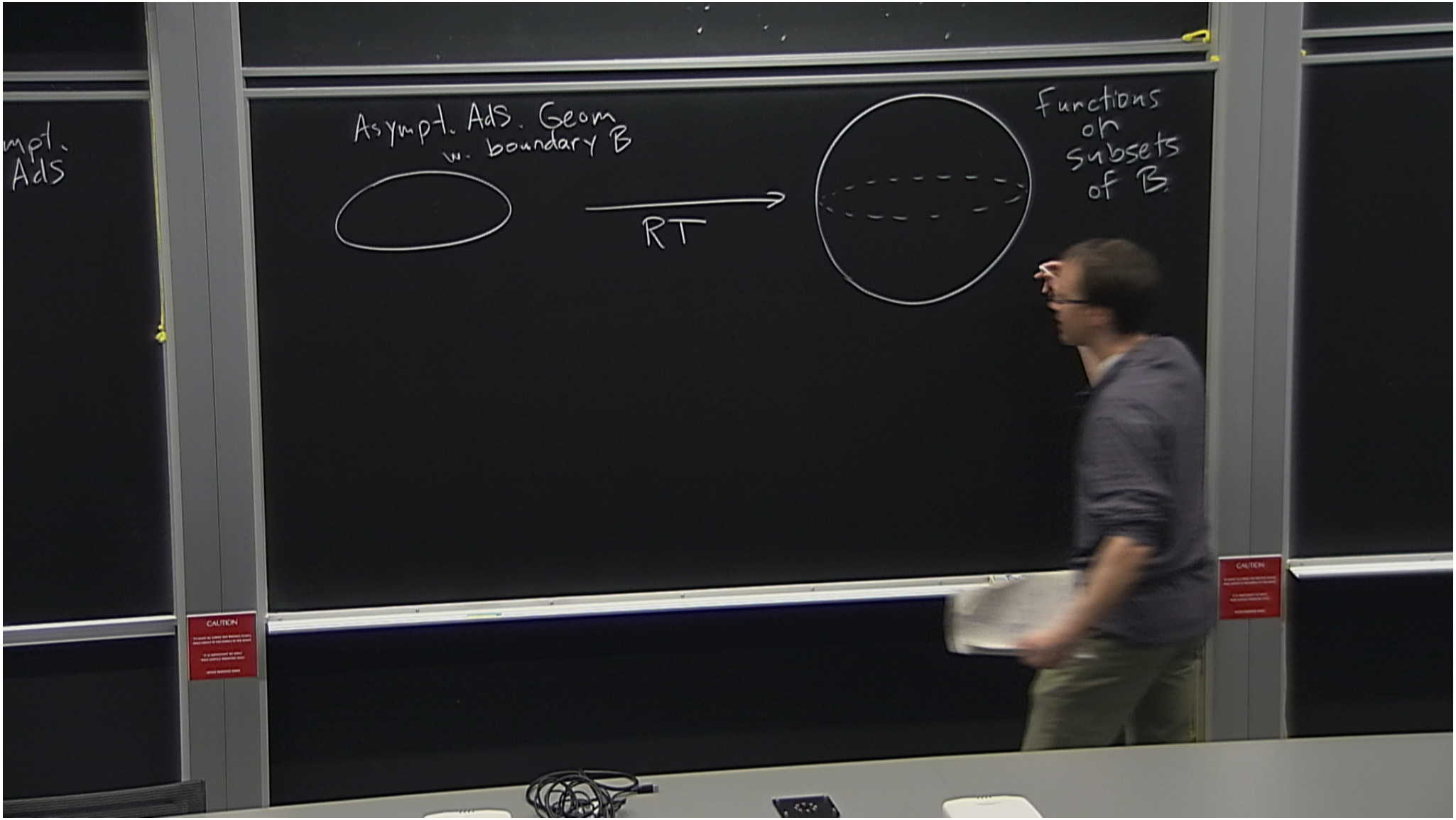

|ψ⟩
A
B
$M_{|\psi\rangle}$
Asympt. AdS
A
$\bar{A}$
B
RT
$S(A) = \frac{\text{Area}(\bar{A})}{4G_N}$

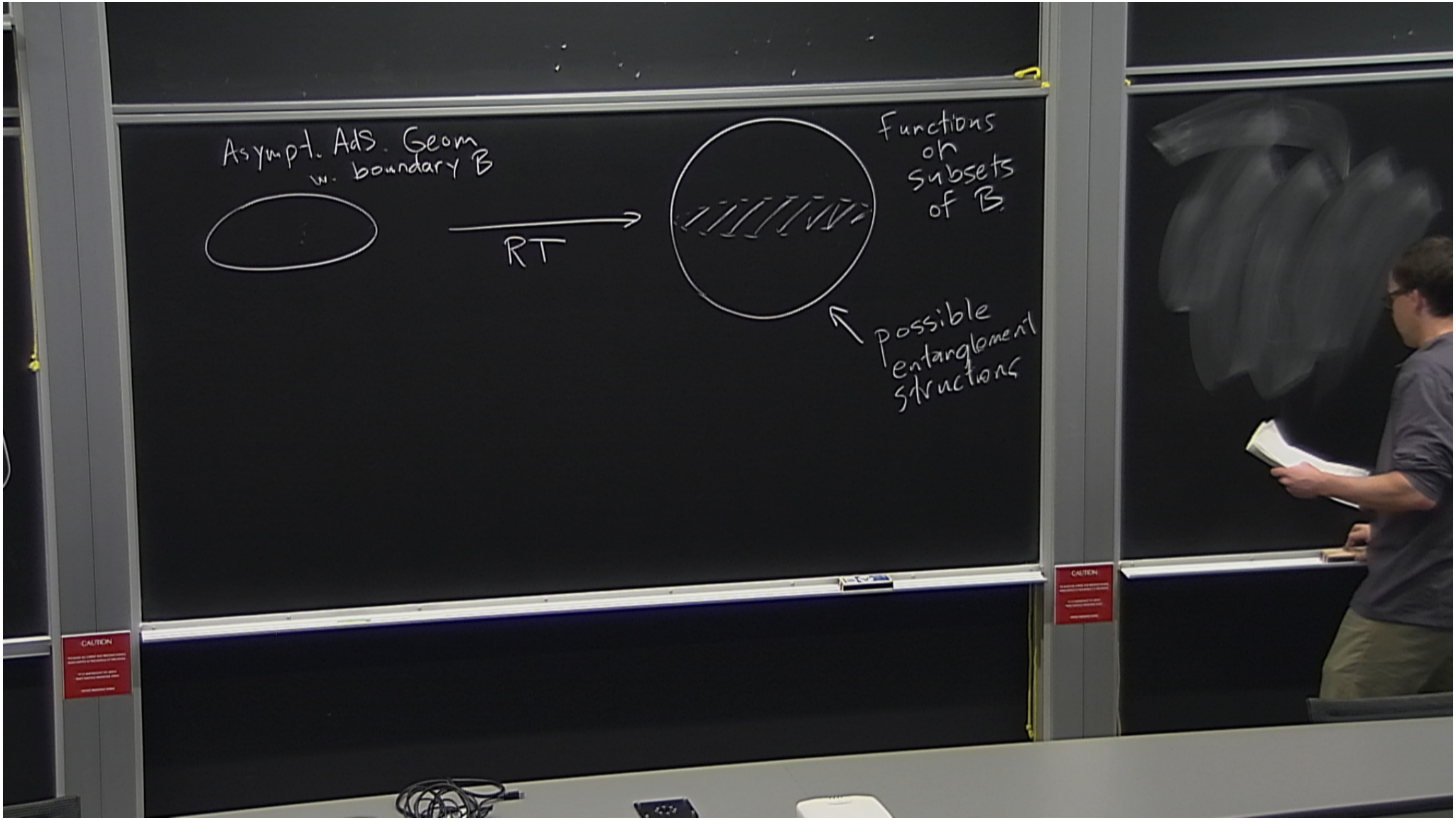

$|\psi\rangle$
$M_{|\psi\rangle}$
Asympt. AdS
A
B
$\bar{A}$
RT
$S(A) = \frac{\text{Area}(\bar{A})}{4G_N}$


Asympt. AdS. Geom
w. boundary B
Functions
on
CAUTION
CAUTION

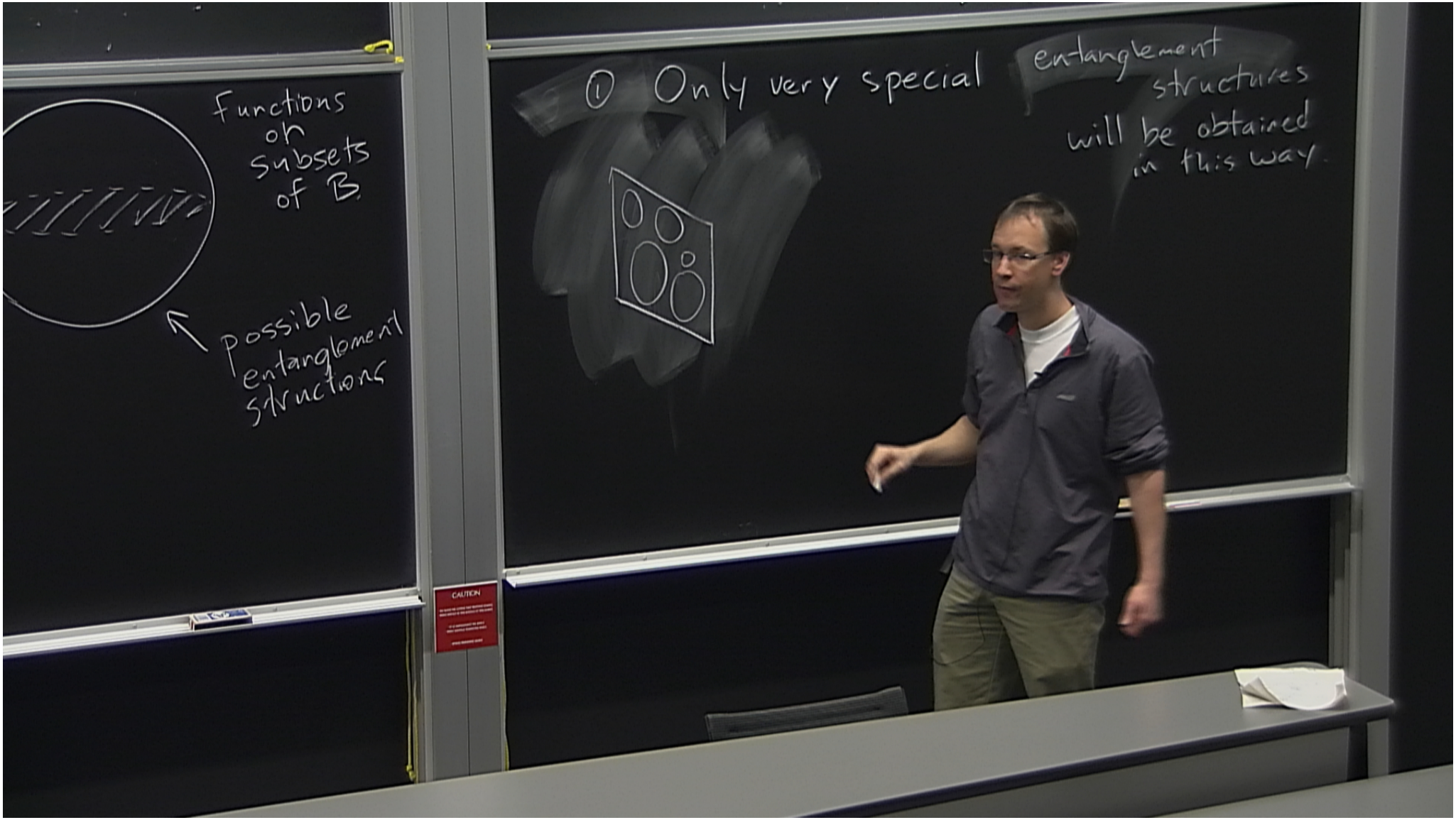

Asympt. AdS. Geom
w. boundary B
RT
Functions
on
subsets
of B.
CAUTION

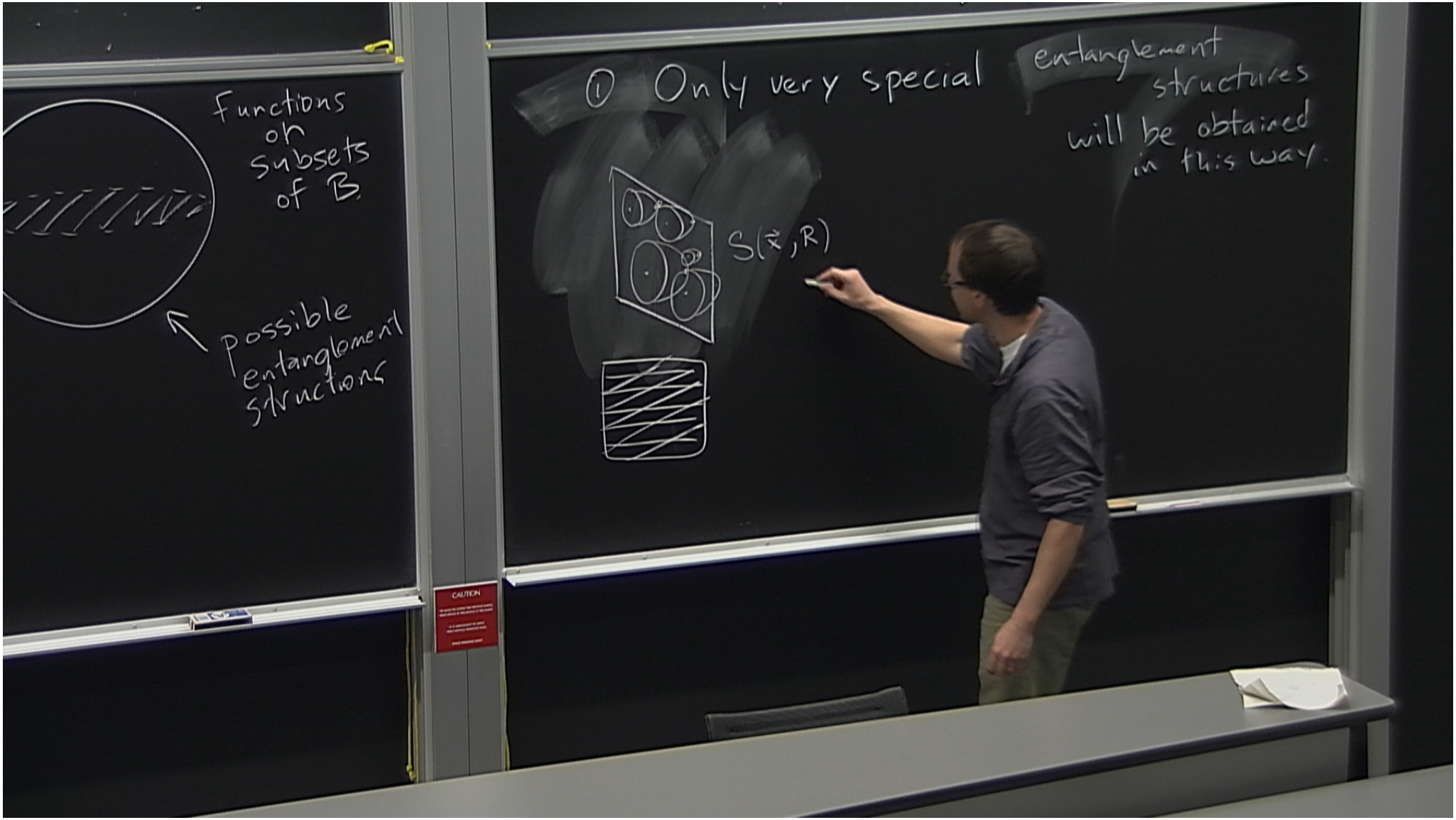

Asympt. AdS. Geom
w. boundary B
RT
Functions
on
subsets
of B.

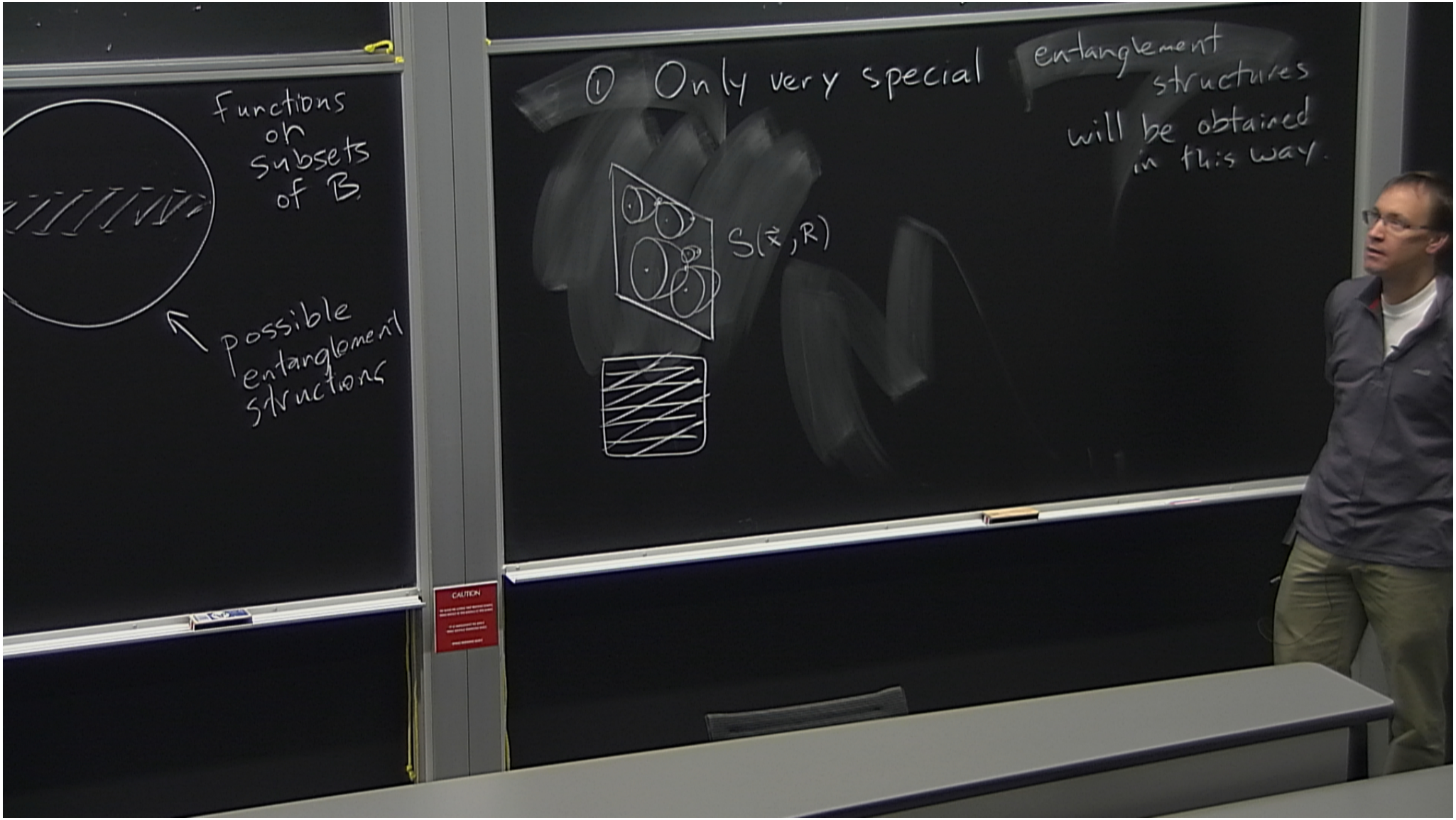

Asympt. AdS. Geom
w. boundary B
RT
Functions
on
subsets
of B.
CAUTION

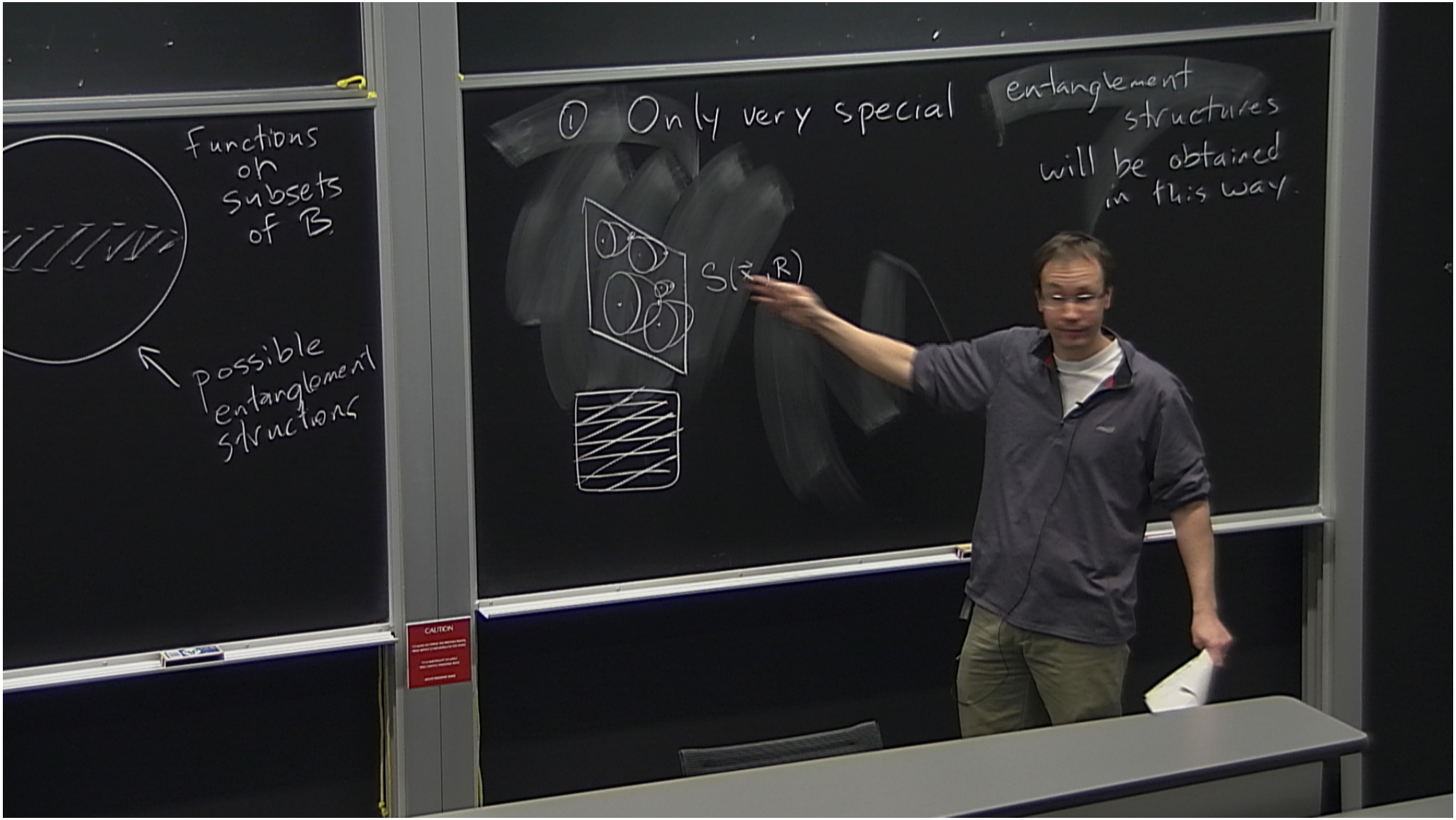

Asympt. AdS Geom
w. boundary B
RT
Functions on subsets of B.
possible entanglement structures

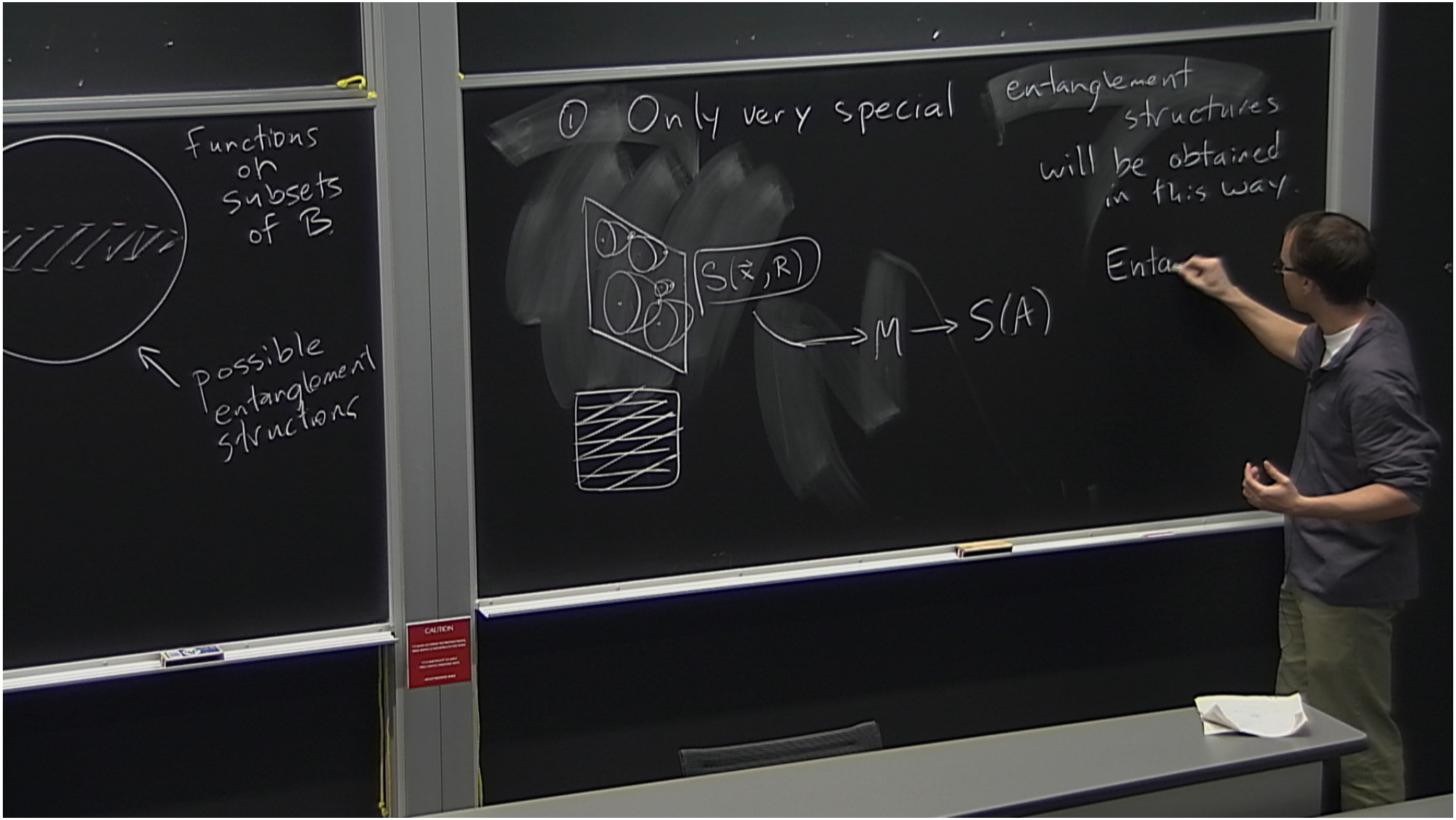

Functions on subsets of B.
Possible entanglement structures
① Only very special entanglement structures will be obtained in this way.
CAUTION

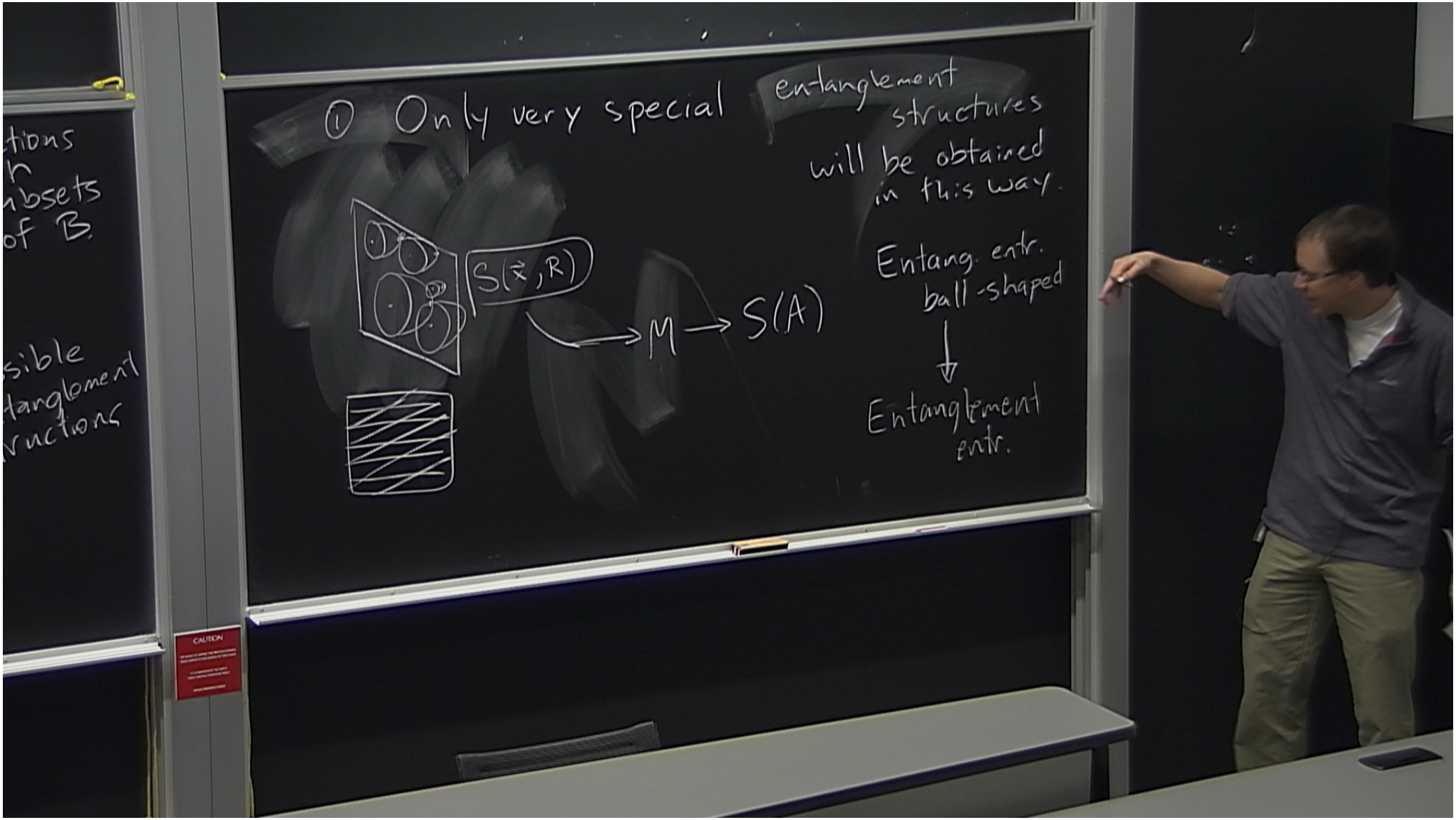

Functions on subsets of B
Possible entanglement structures
① Only very special entanglement structures will be obtained in this way.
CAUTION

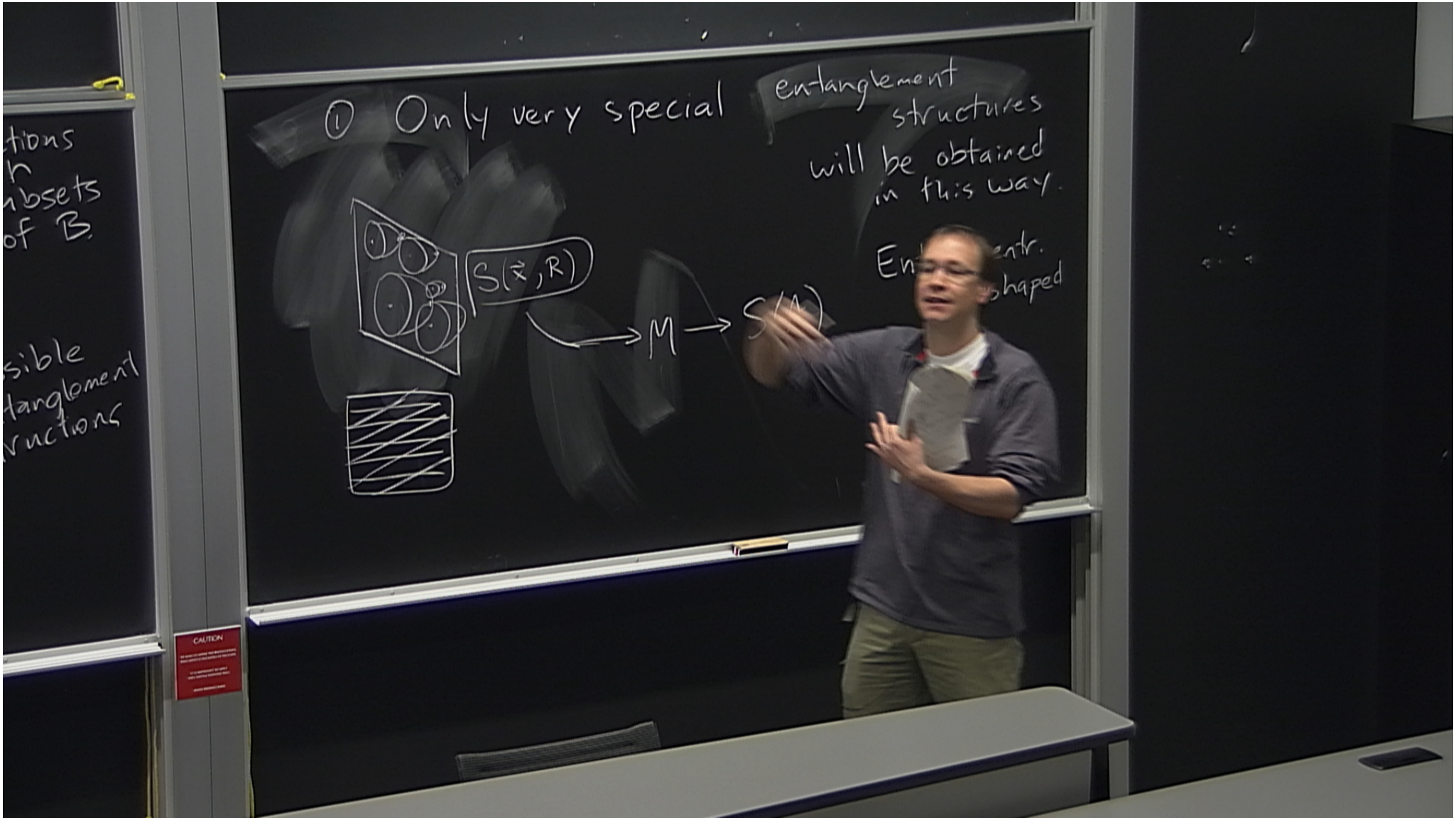

Functions on subsets of B
Possible entanglement structures
① Only very special entanglement structures will be obtained in this way.
S(x̃, R)
CAUTION

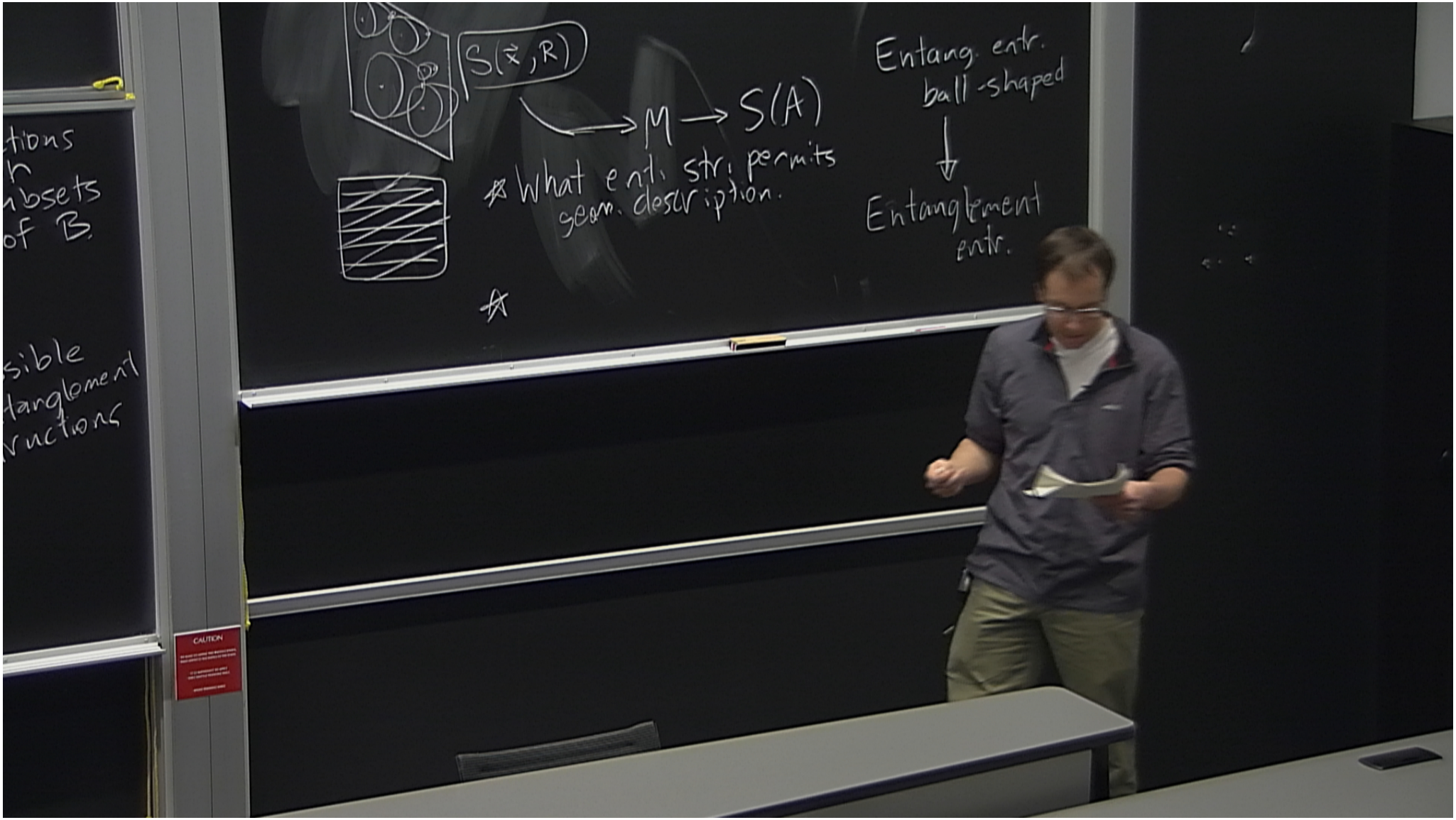

Functions on subsets of B
Possible entanglement structures
① Only very special entanglement structures will be obtained in this way.
S(x, R)
CAUTION


Functions or subsets of B
possible entanglement structures
① Only very special entanglement structures will be obtained in this way.
S(ρ, R)

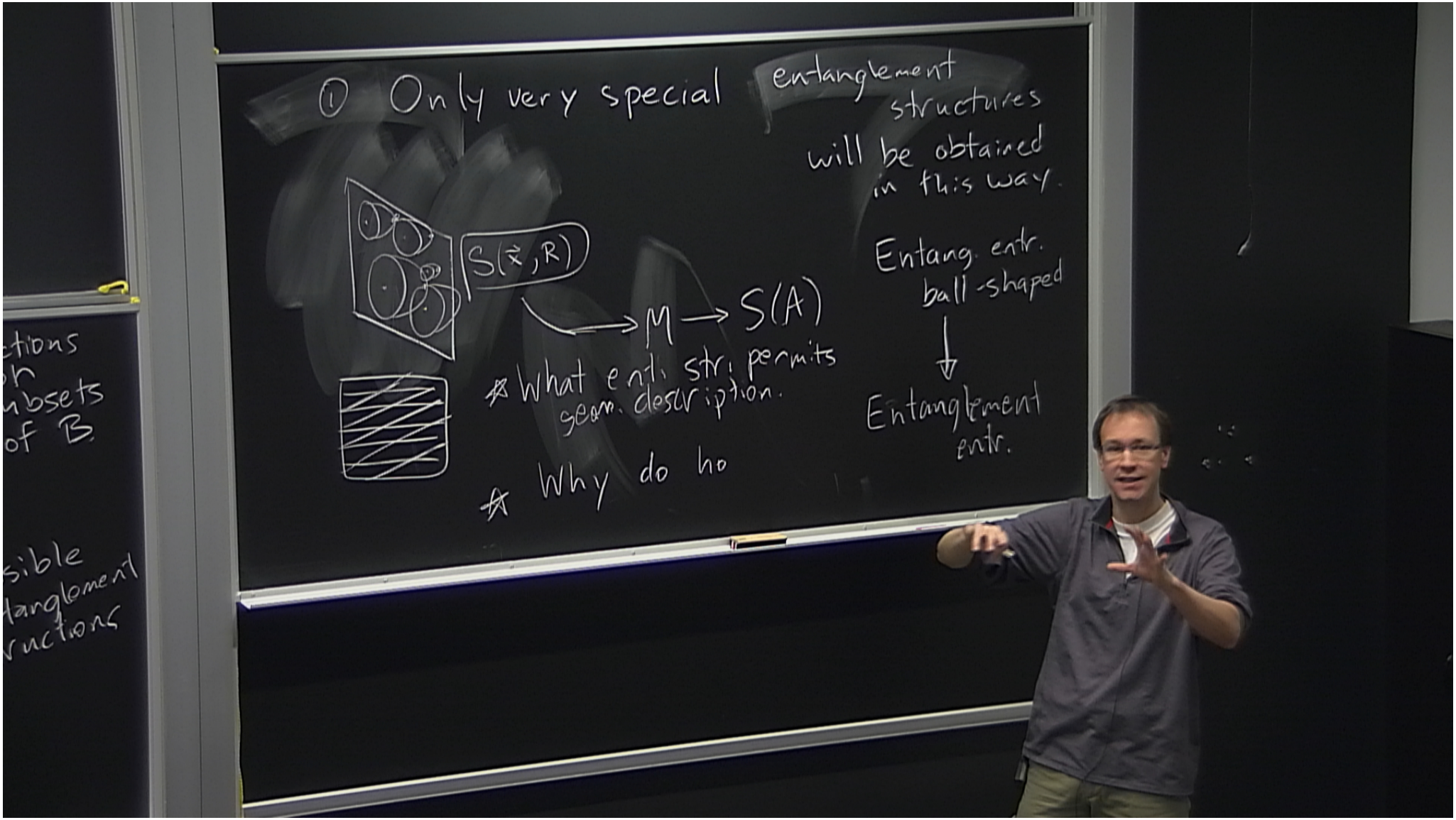

Functions or subsets of B
possible entanglement structures
① Only very special entanglement structures will be obtained in this way.
S(x,R)
M → S(A)
Enta
CAUTION

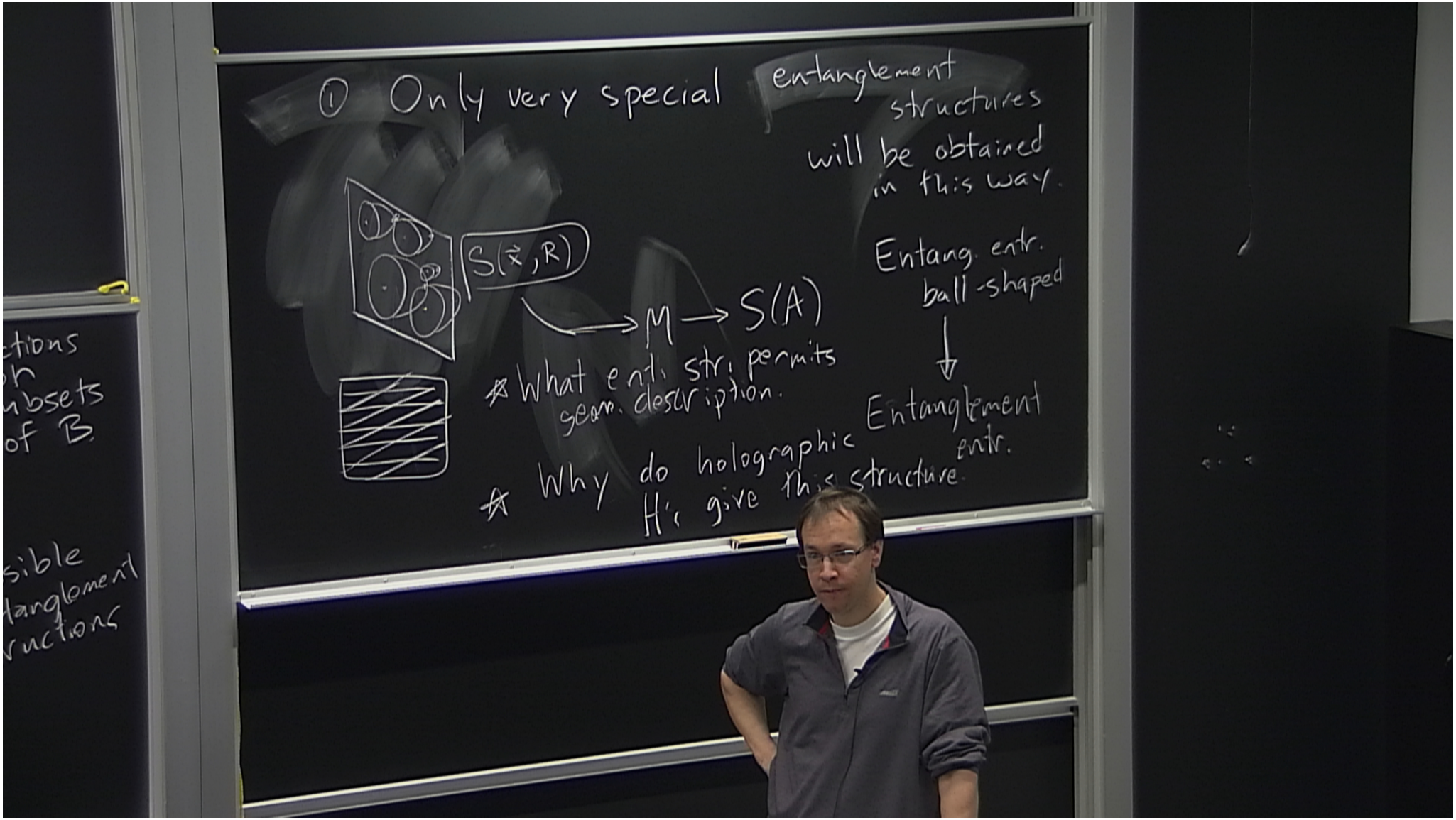

① Only very special entanglement structures will be obtained in this way.
S(x,R)
M → S(A)
Entang. entr. ball-shaped
Entanglement entr.

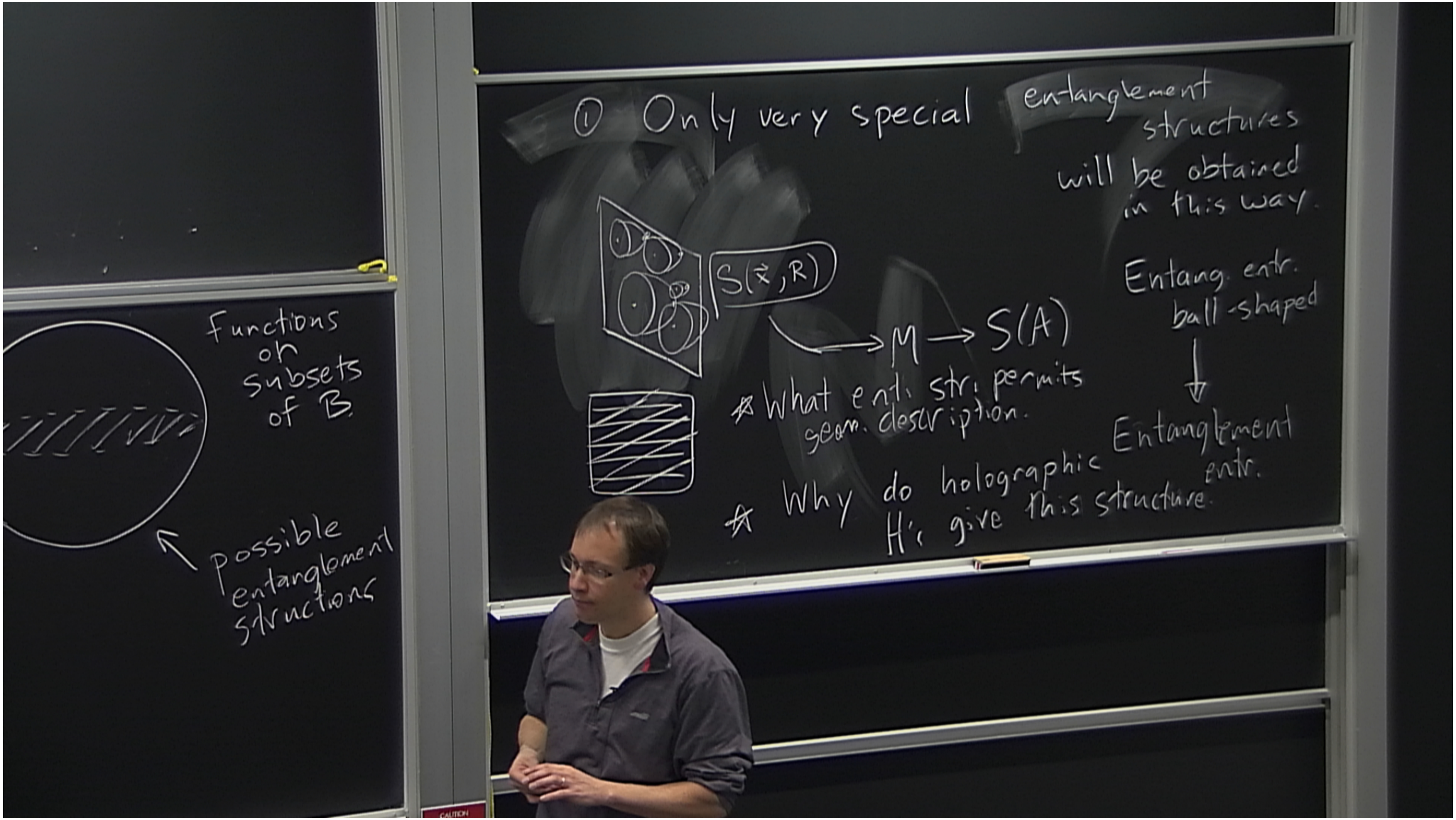

① Only very special entanglement structures will be obtained in this way.
S(x,R)
M
CAUTION

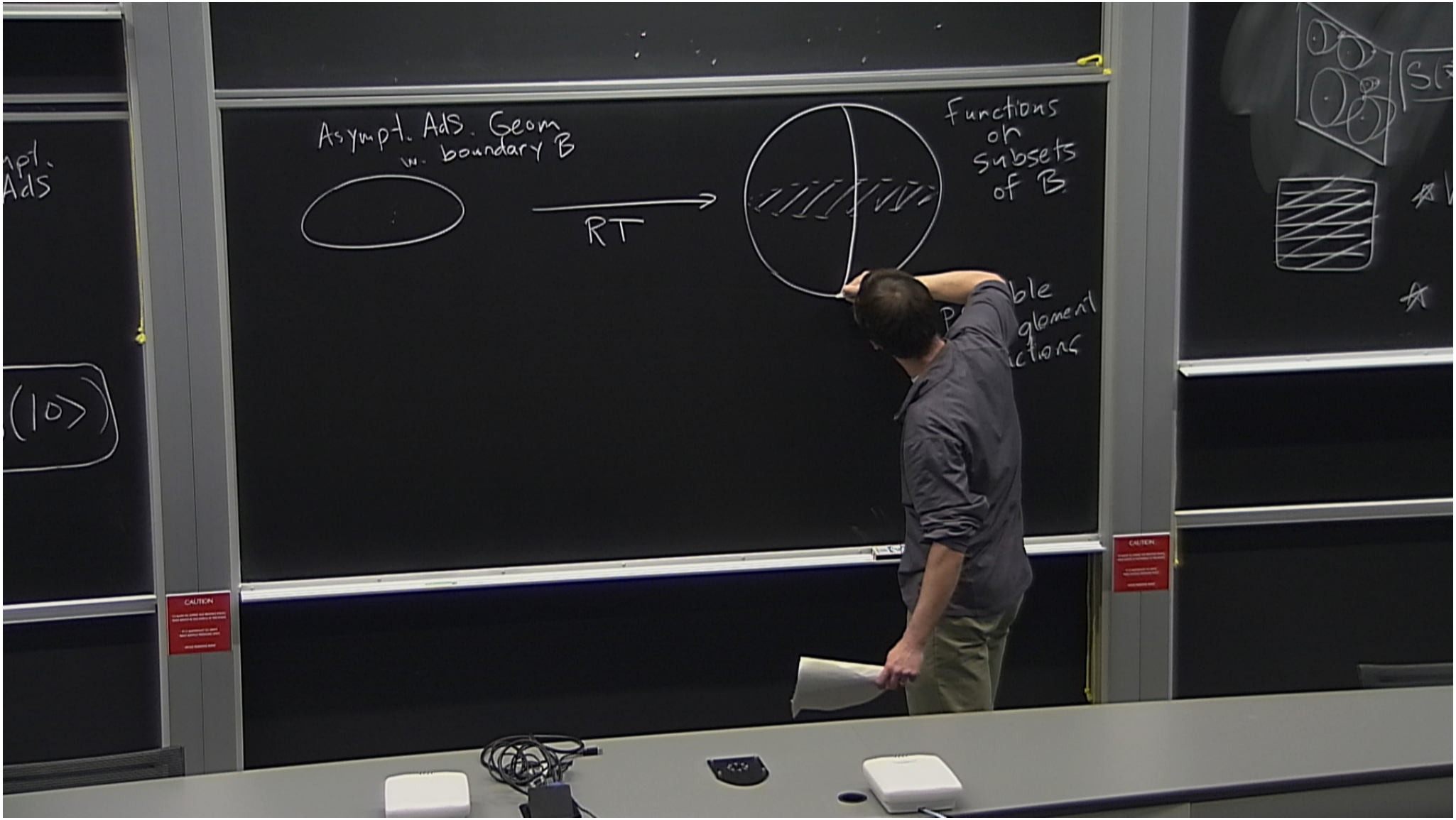

S(x, R)
M → S(A)
What ent. str. permits geom. description.
Entang. entr. ball-shaped
Entanglement entr.
CAUTION

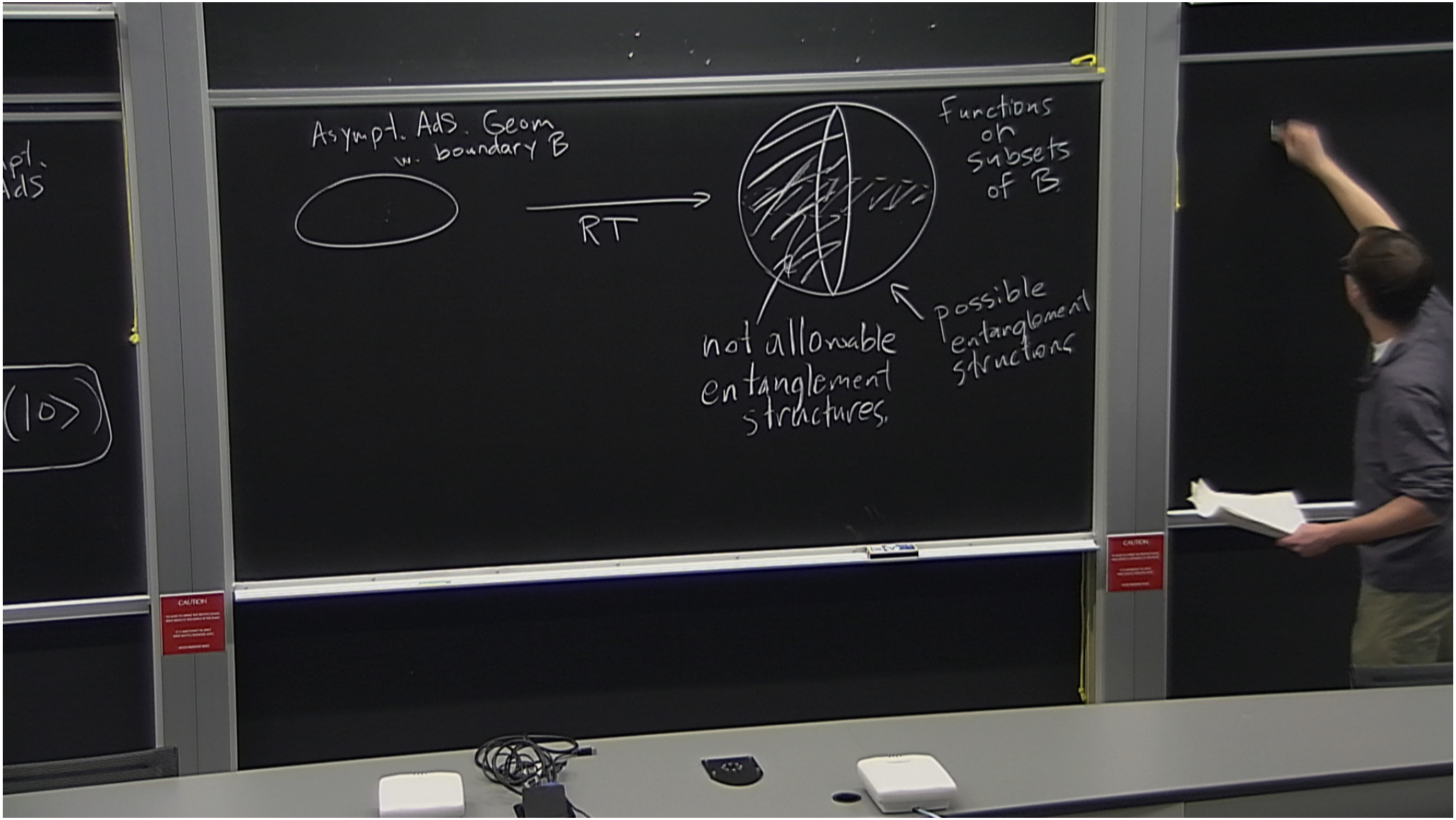

S(x, R)
M
S(A)
Entang. entr.
ball-shaped
What ent. str. permits
geom. description.
Why do
Entanglement
CAUTION

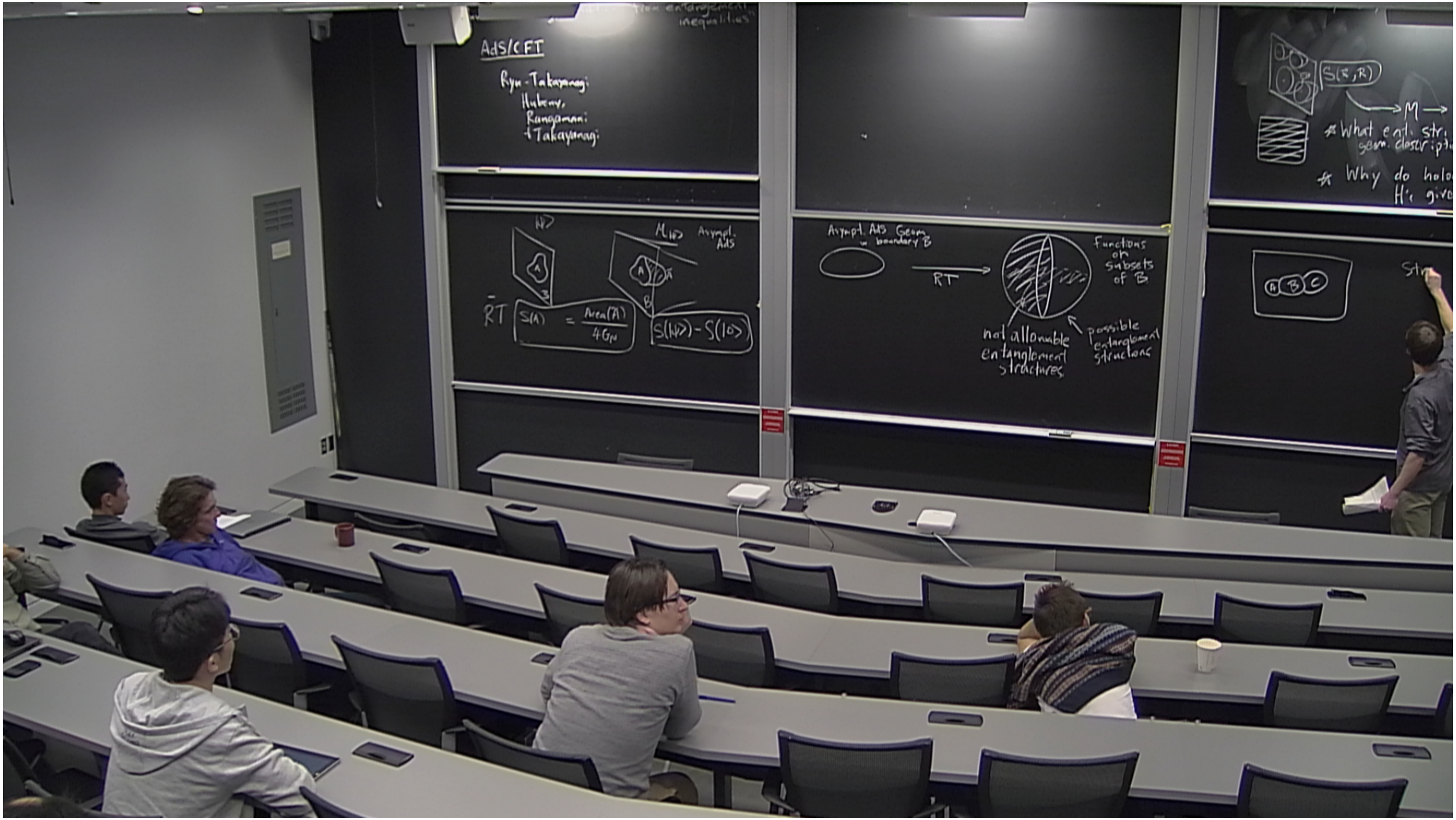

① Only very special entanglement structures will be obtained in this way.
S(x̃, R)
M → S(A)
* What entl. str. permits geom. description.
* Why do ho
Entang. entr. ball-shaped
Entanglement entr.

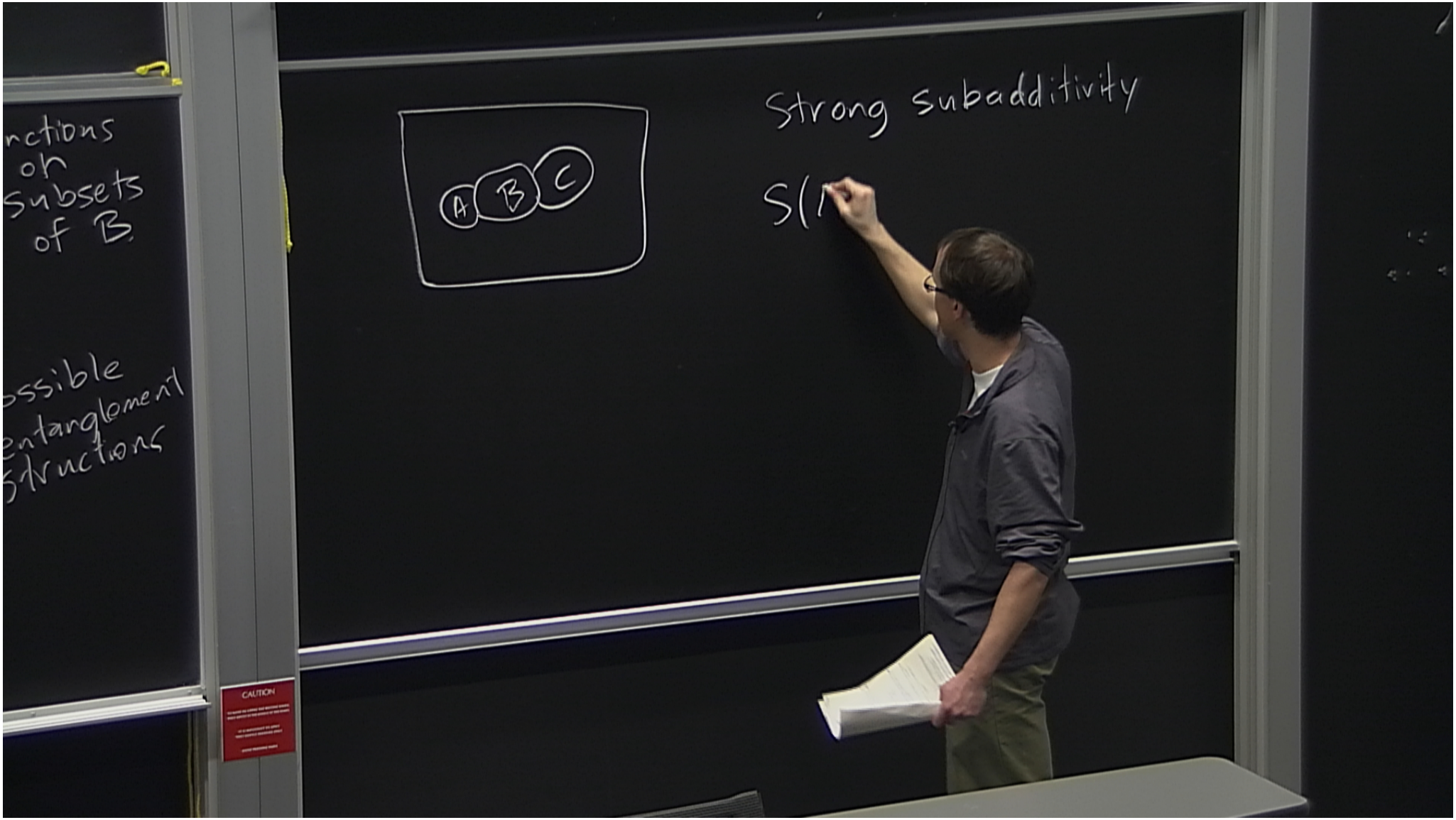

① Only very special entanglement structures will be obtained in this way.
S(x, R)
M → S(A)
* What entl. str. permits geom. description.
* Why do holographic H's give this structure.
Entang. entr. ball-shaped
Entanglement entr.

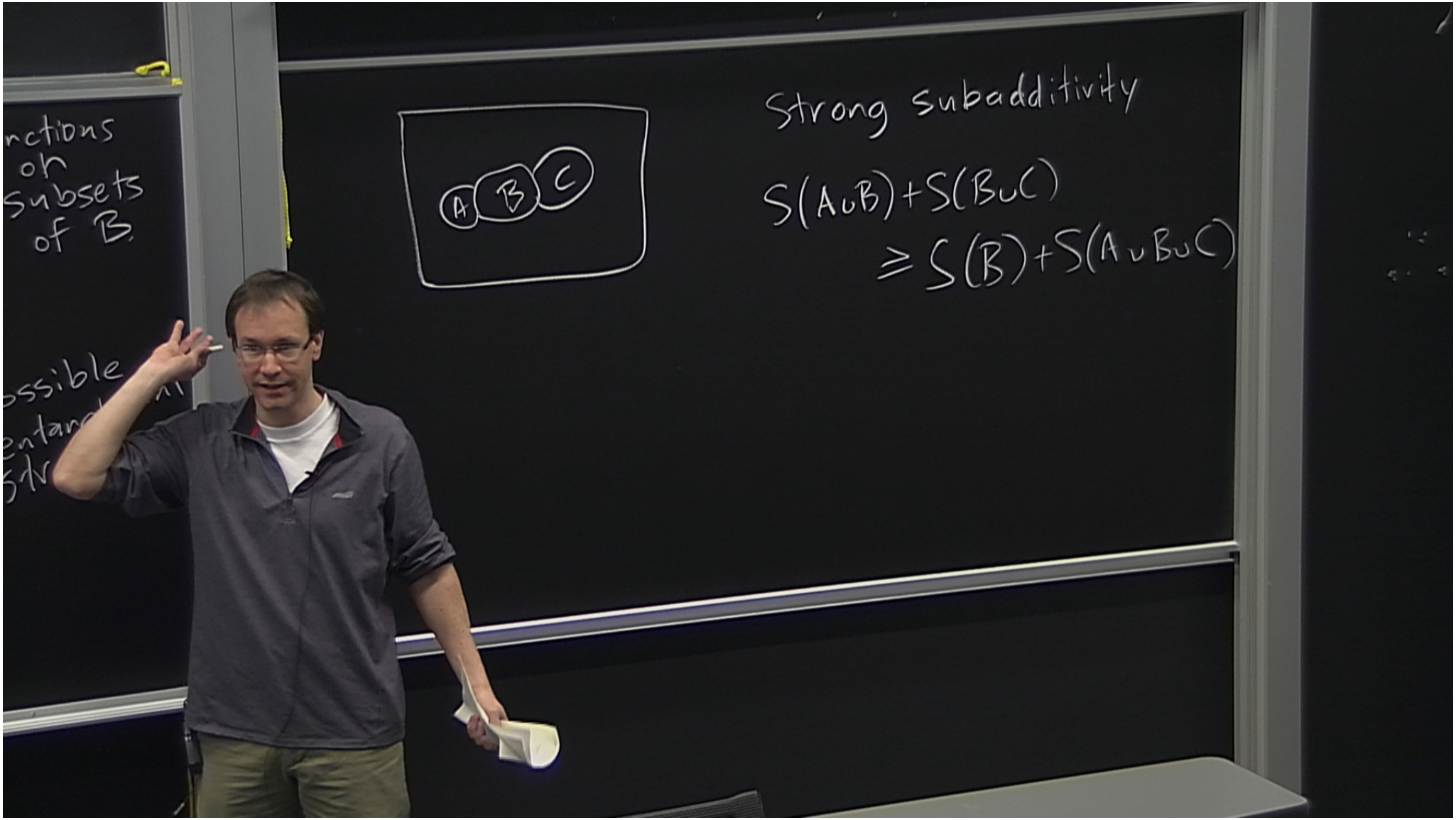

Functions on subsets of B
Possible entanglement structures
① Only very special entanglement structures will be obtained in this way.
S(x,R)
M → S(A)
★ What ent. str. permits geom. description.
★ Why do holographic H's give this structure.
Entang. entr. ball-shaped
Entanglement entr.

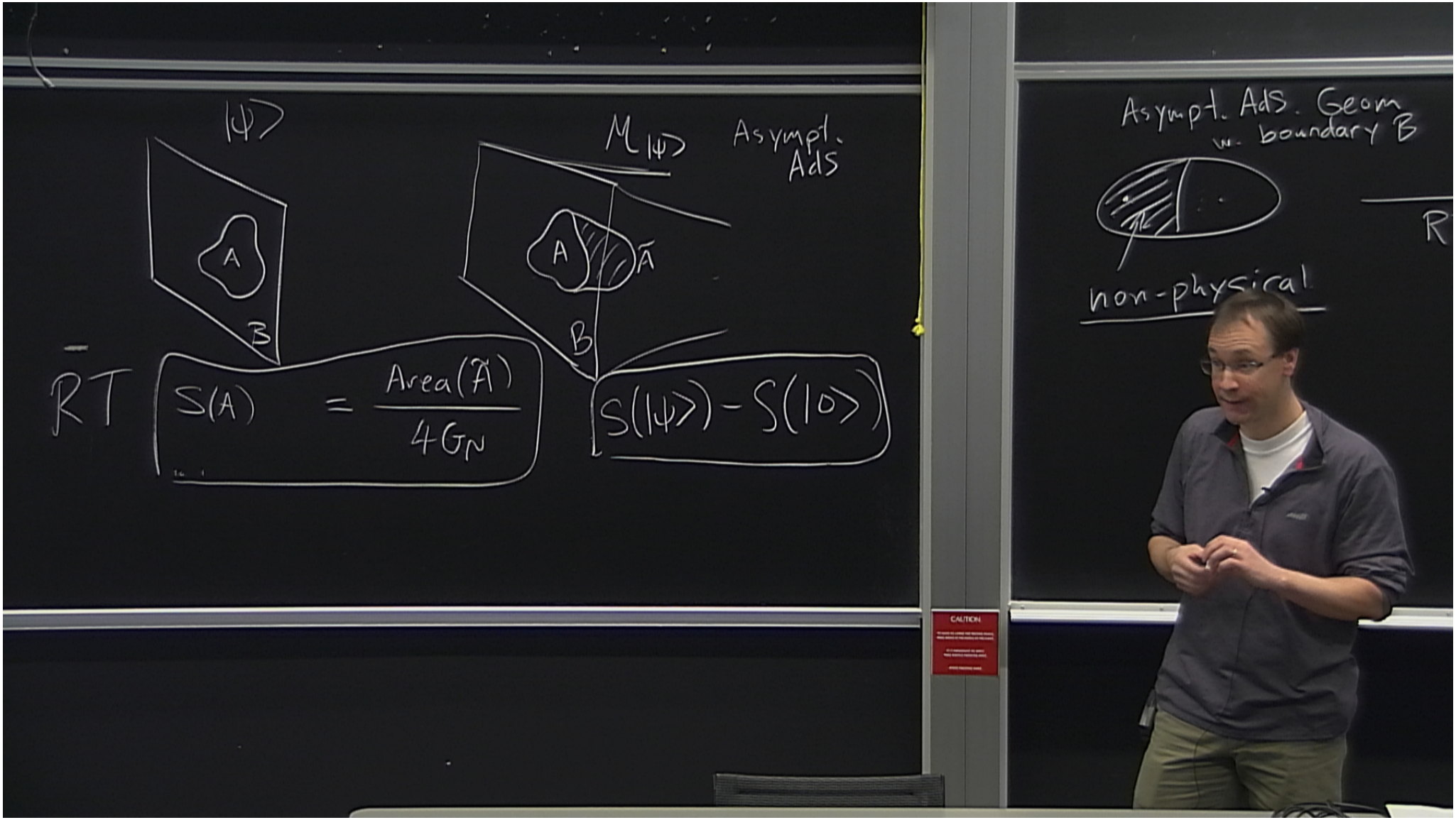

Asympt. AdS. Geom
w. boundary B
RT
Functions
on
subsets
of B

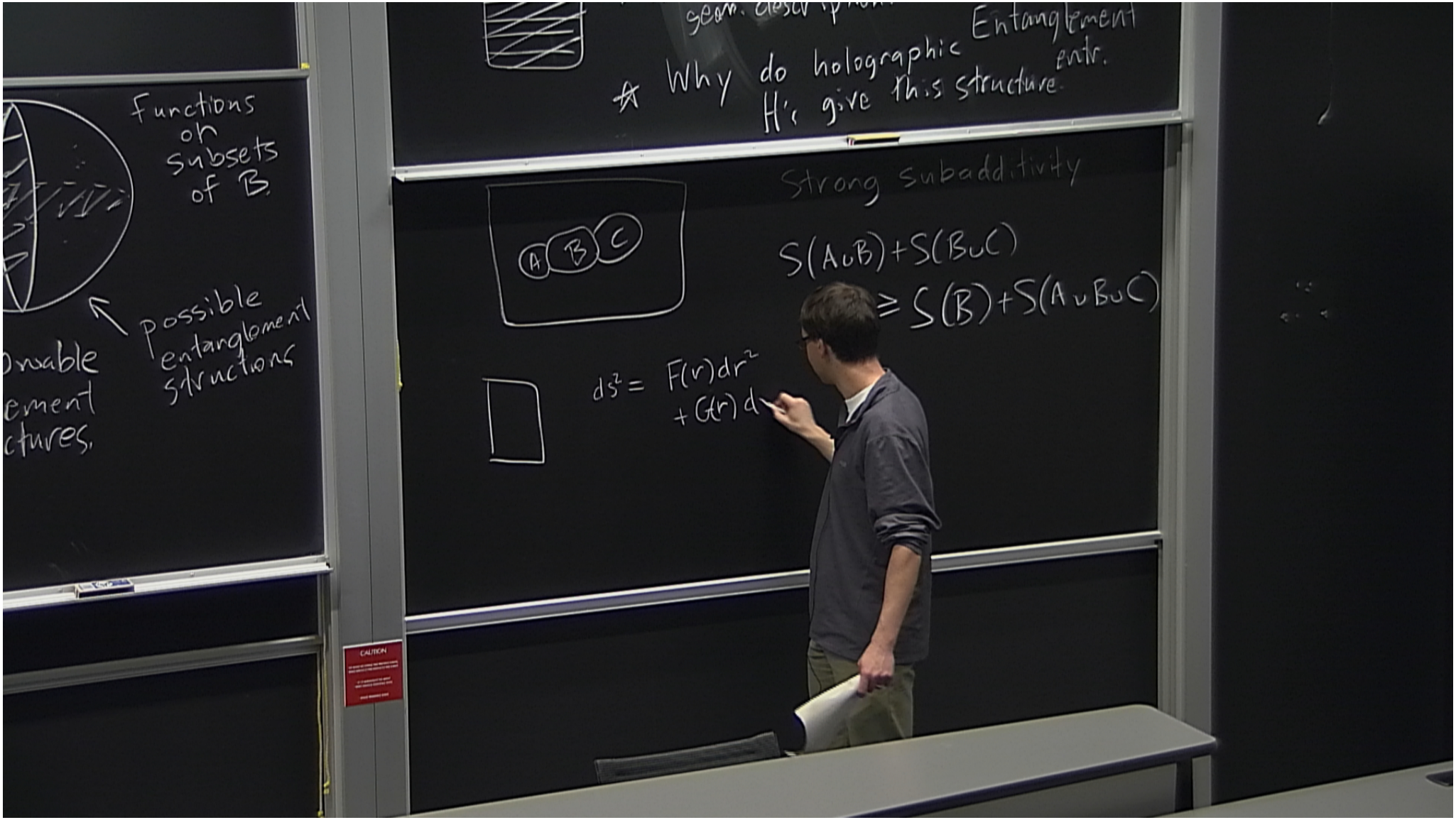

Asympt. AdS. Geom
w. boundary B
RT
Functions on subsets of B.
not allowable entanglement structures.
possible entanglement structures

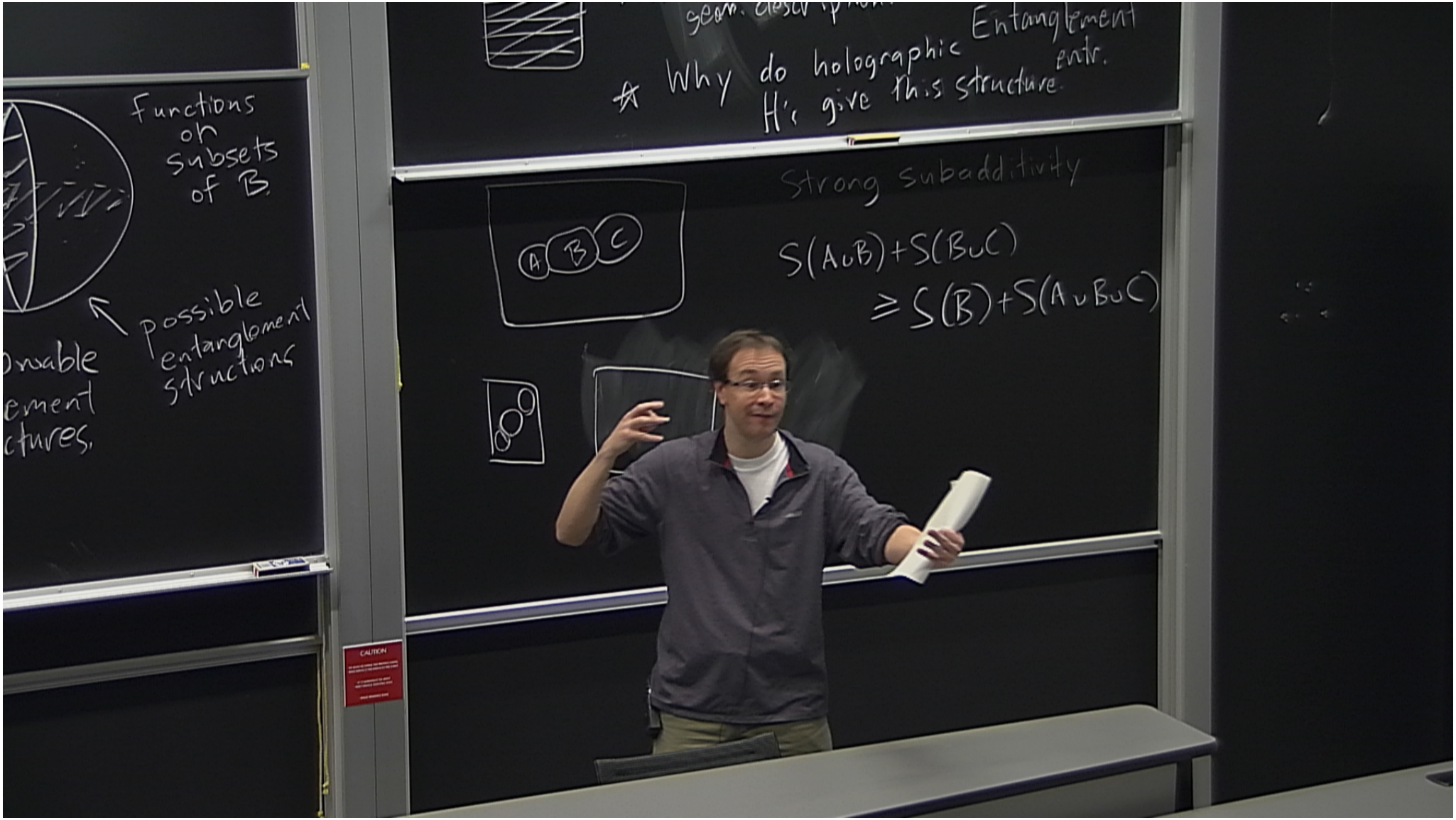

AdS/CFT
Ryu-Takayanagi:
Hubeny,
Rangamani:
+Takayanagi:
RT
Asympt. AdS
Functions or subsets of B
RT
not allowable entanglement structures
possible entanglement structures
What
Why do

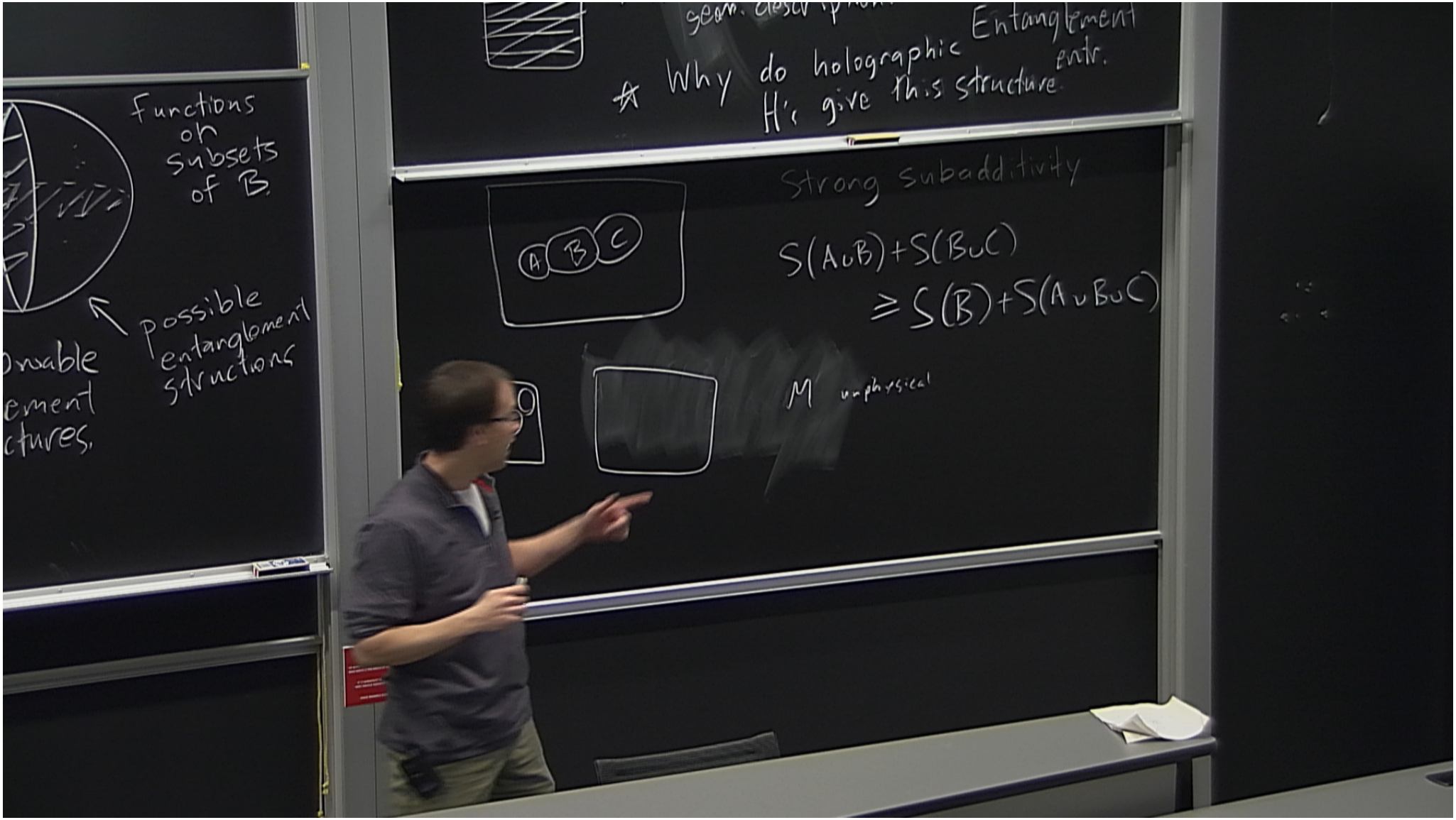

nctions
on
subsets
of B.
ssible
entanglement
structions
A B C
Strong subadditivity
S(
CAUTION

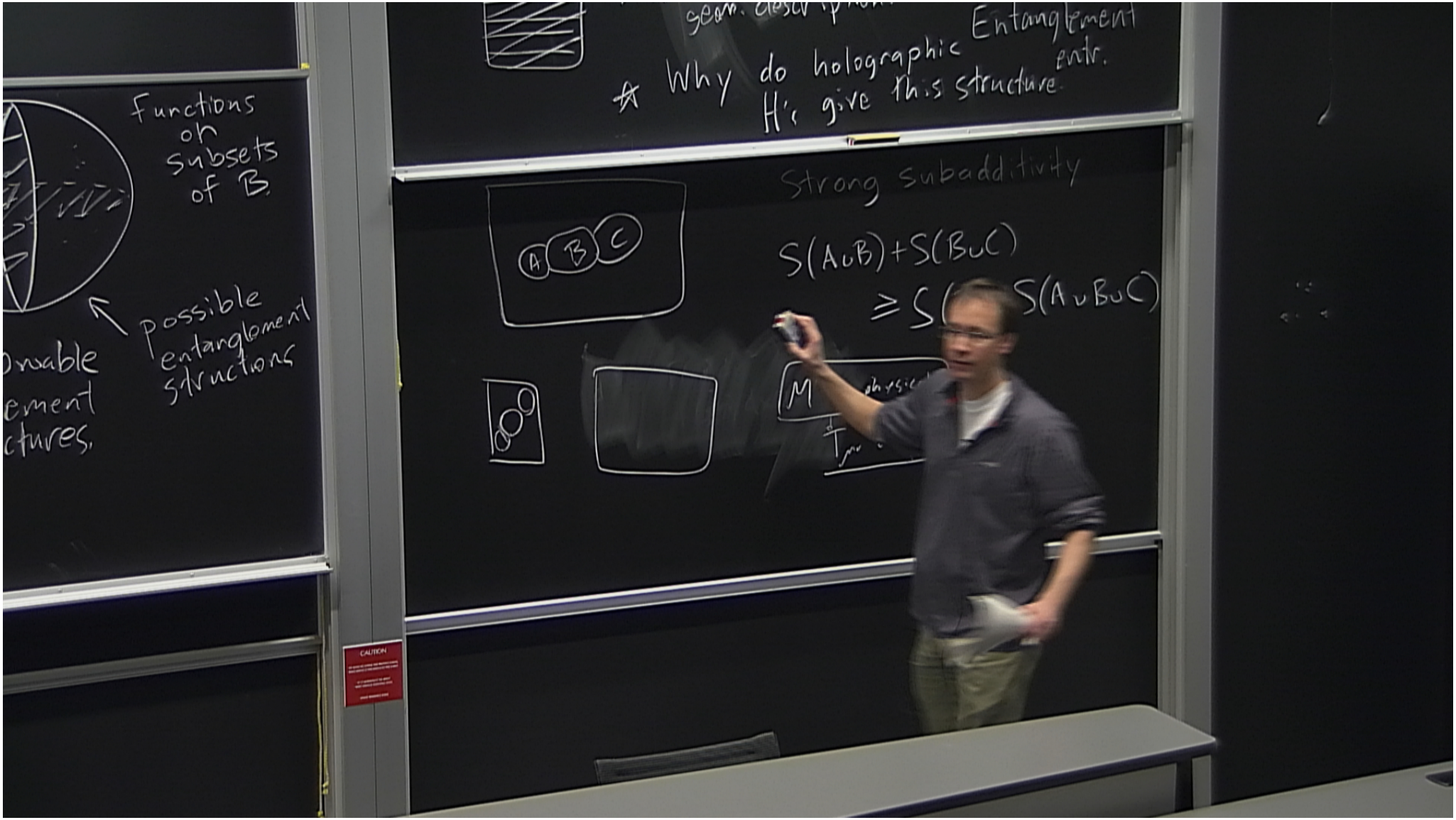

nctions
on
subsets
of B.
ssible
A
B
C
Strong subadditivity
S(AuB)+S(BuC)
≥ S(B)+S(AuBuC)

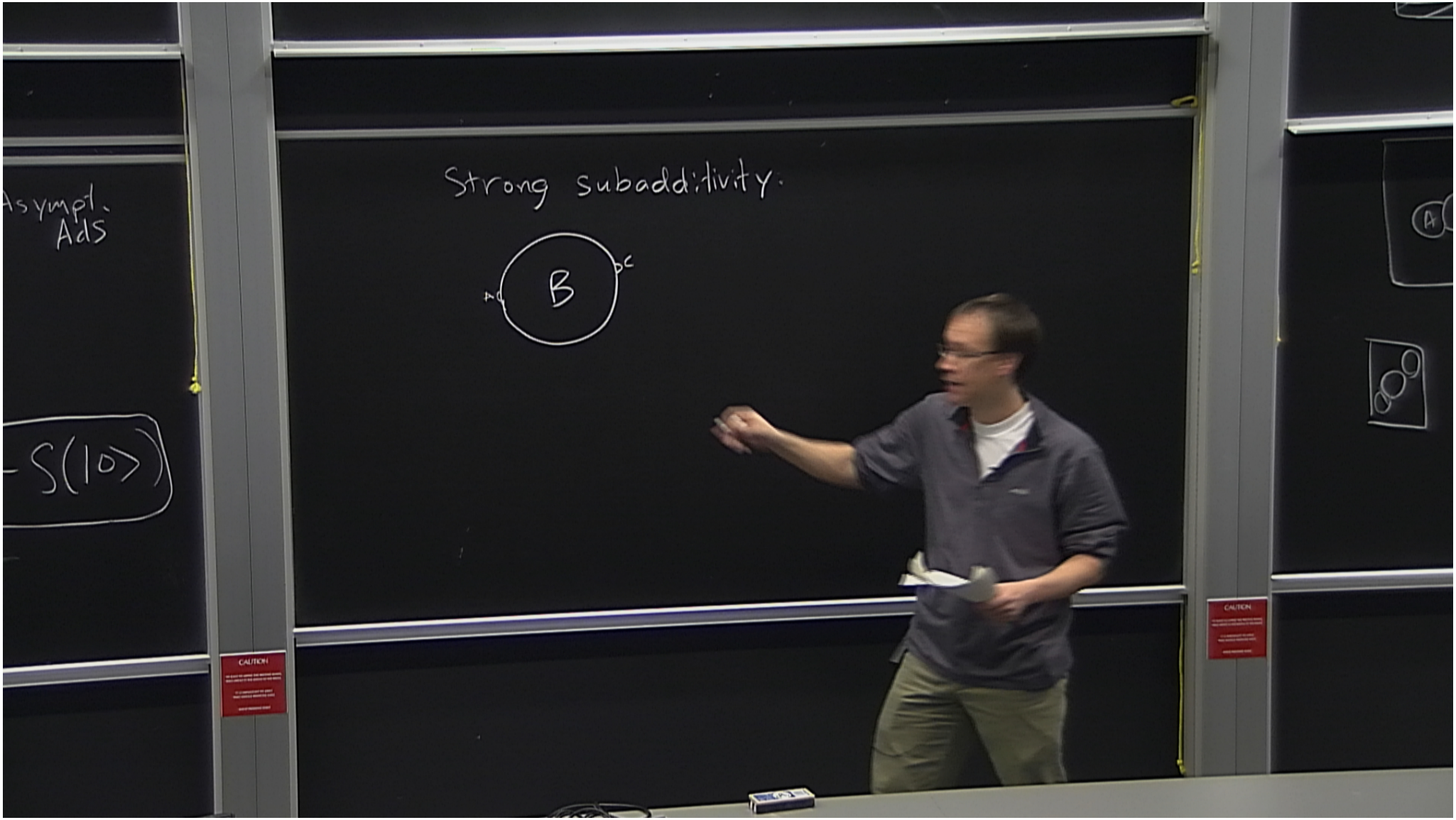

|ψ⟩
M|ψ⟩
Asympt. AdS
A
B
Ā
RT
S(A) = Area(Ā) / 4G_N
S(|ψ⟩) - S(|0⟩)
Asympt. AdS. Geom
w. boundary B
non-physical
CAUTION

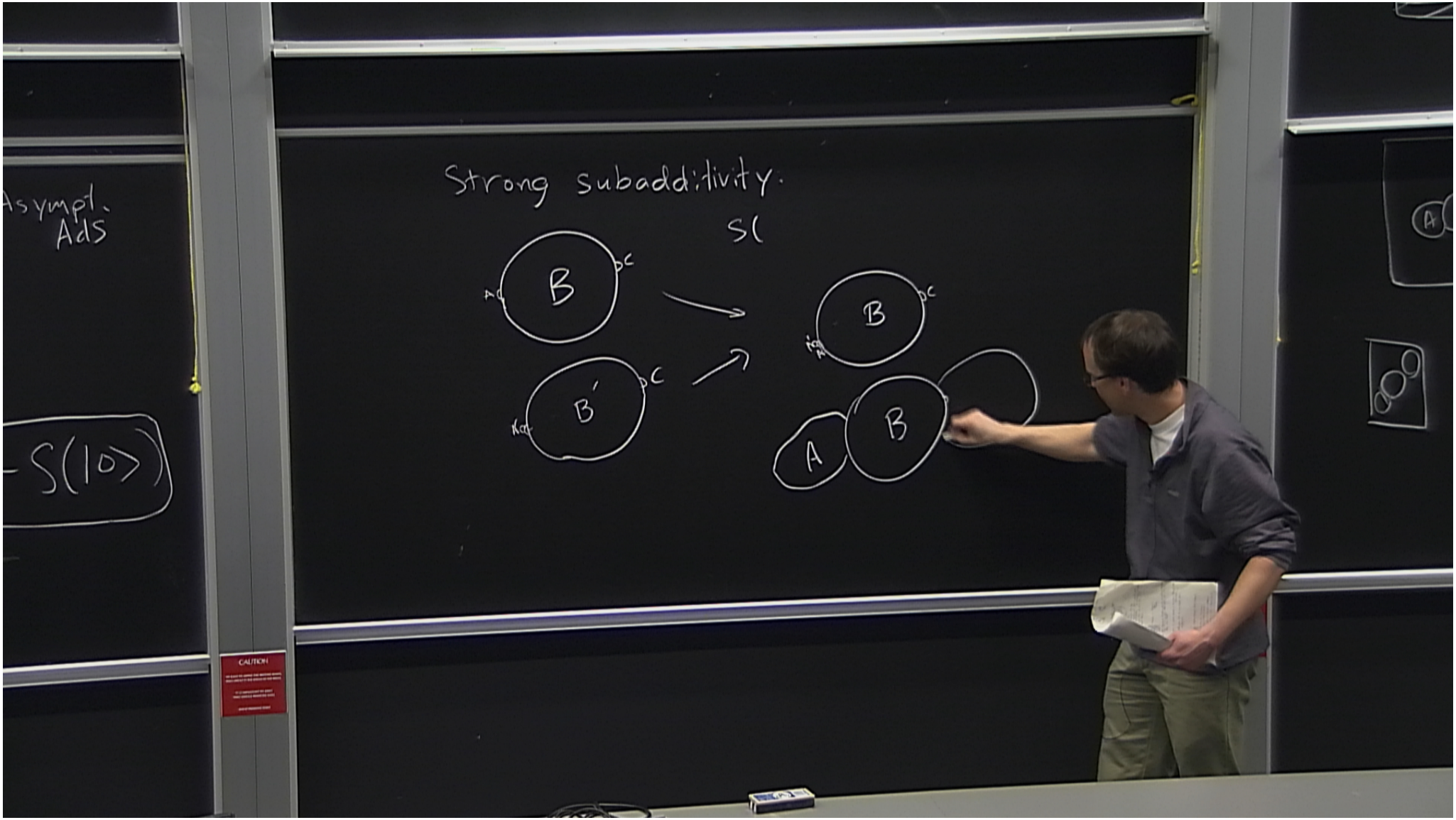

Functions on subsets of B.
possible entanglement structures
Why do holographic Entanglement H's give this structure entr.
Strong subadditivity
A B C
S(AuB)+S(BuC)
≥ S(B)+S(AuBuC)
ds² = F(r)dr²
+ G(r)d
CAUTION

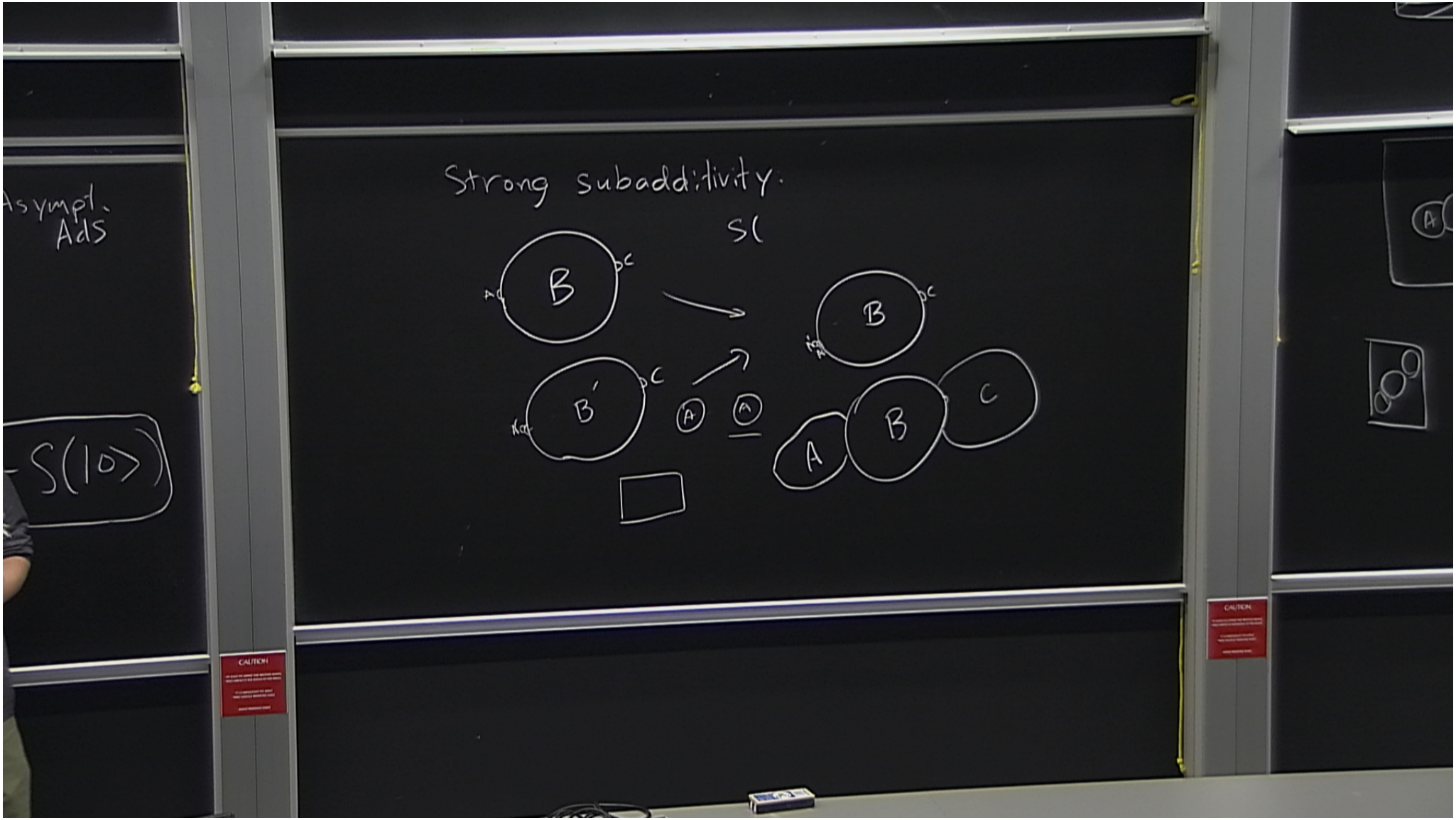

Functions on subsets of B.
possible entanglement structures
Why do holographic Entanglement H's give this structure entr.
Strong subadditivity
S(AuB)+S(BuC)
≥S(B)+S(AuBuC)
A
B
C

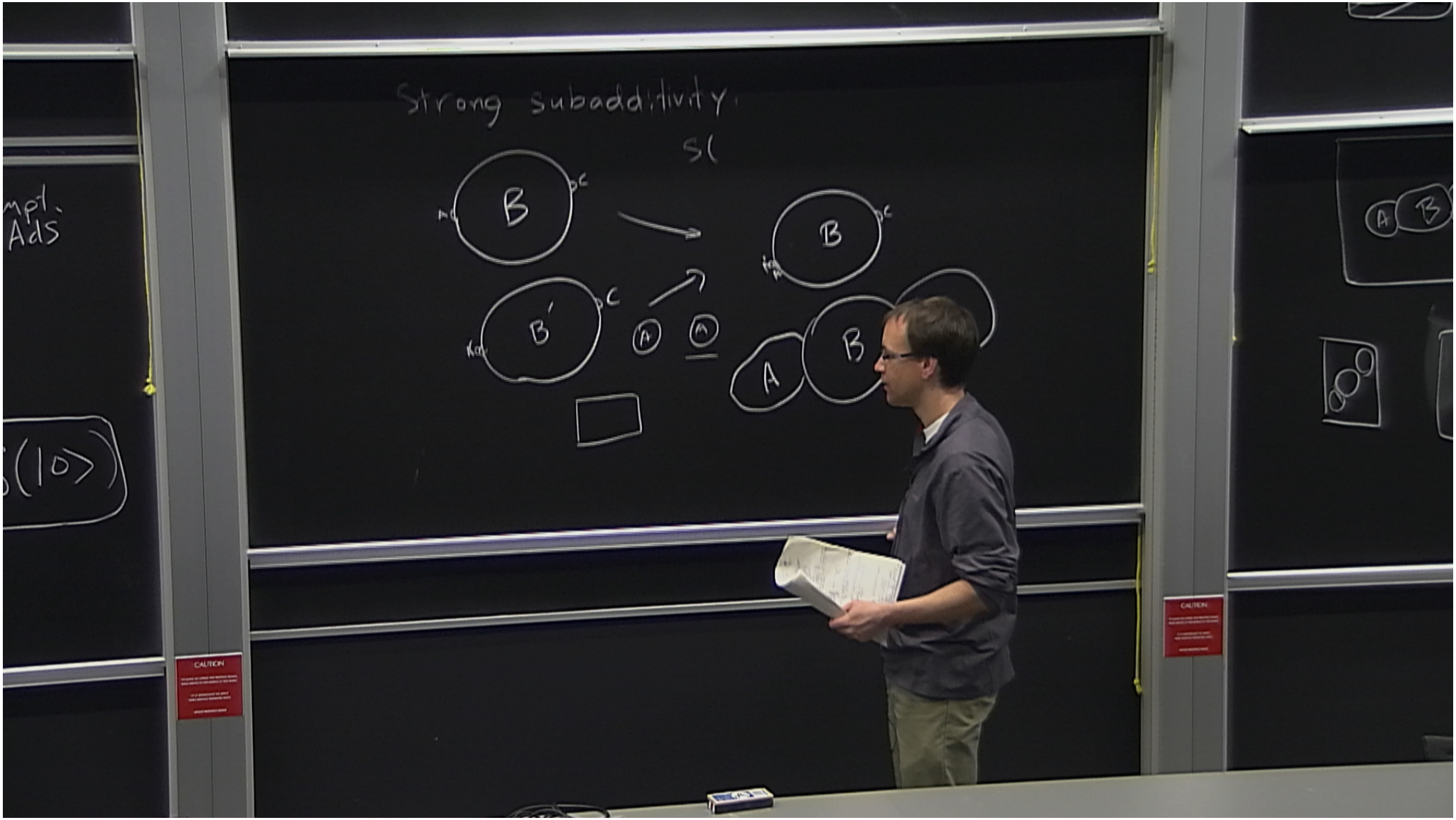

Functions on subsets of B
possible entanglement structures
Why do holographic Entanglement H's give this structure
Strong subadditivity
S(AuB)+S(BuC)
≥S(B)+S(AuBuC)
A
B
C
M unphysical

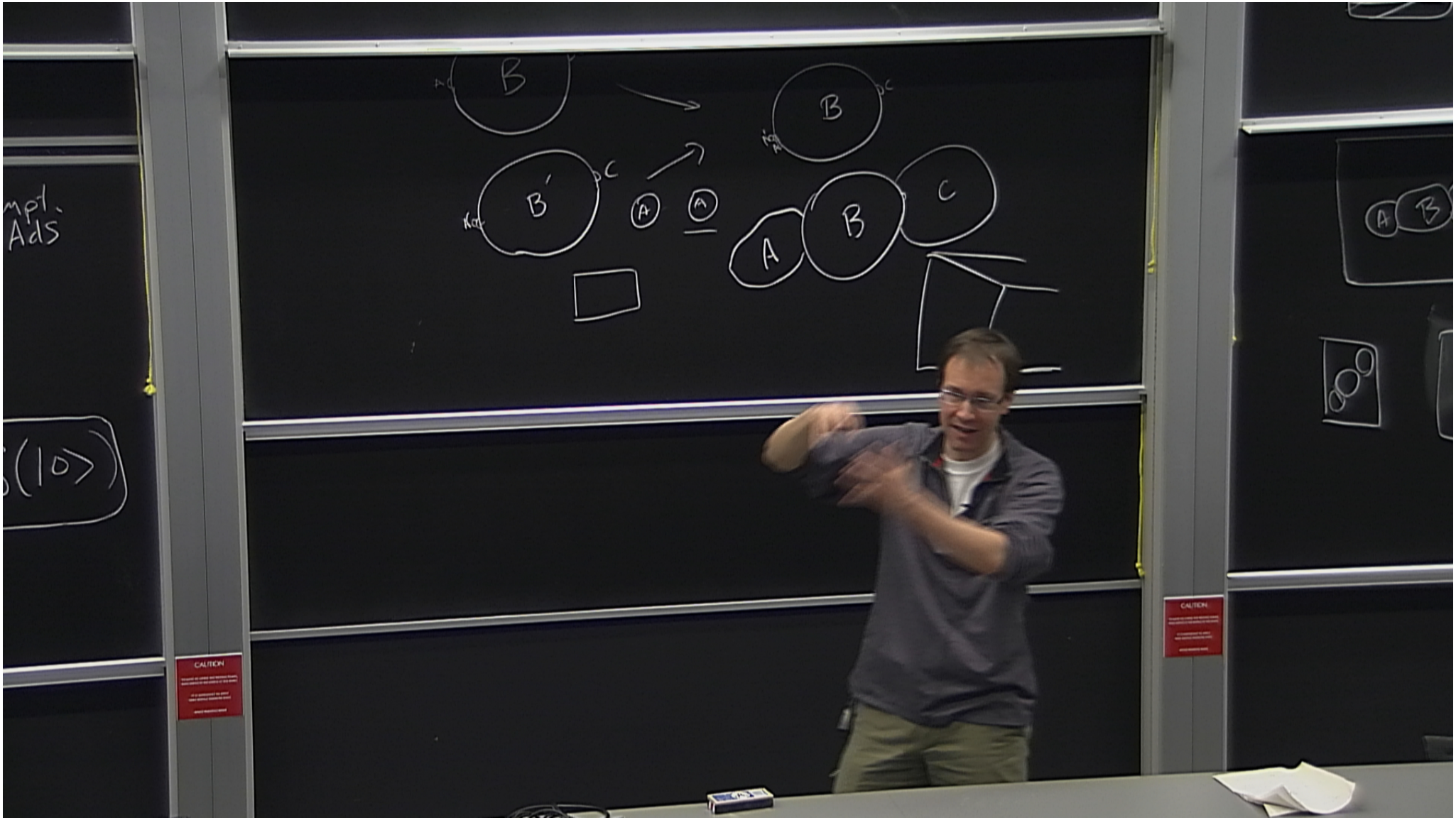

Functions on subsets of B
possible entanglement structures
Why do holographic Entanglement H's give this structure
entr.
Strong subadditivity
S(AuB)+S(BuC)
≥S(
S(AuBuC)
A
B
C

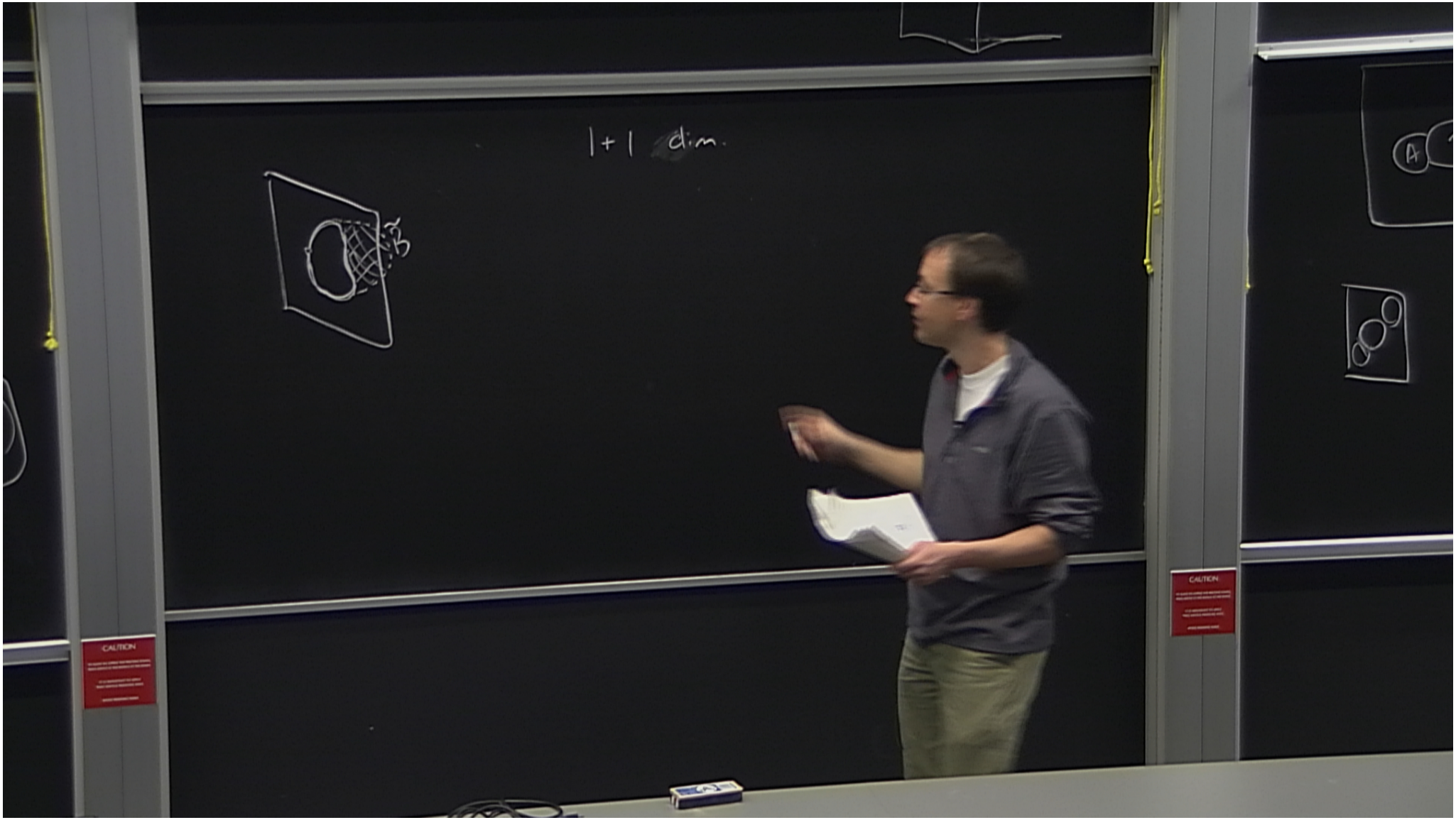

Strong subadditivity.
B
Asympt.
Ads
CAUTION

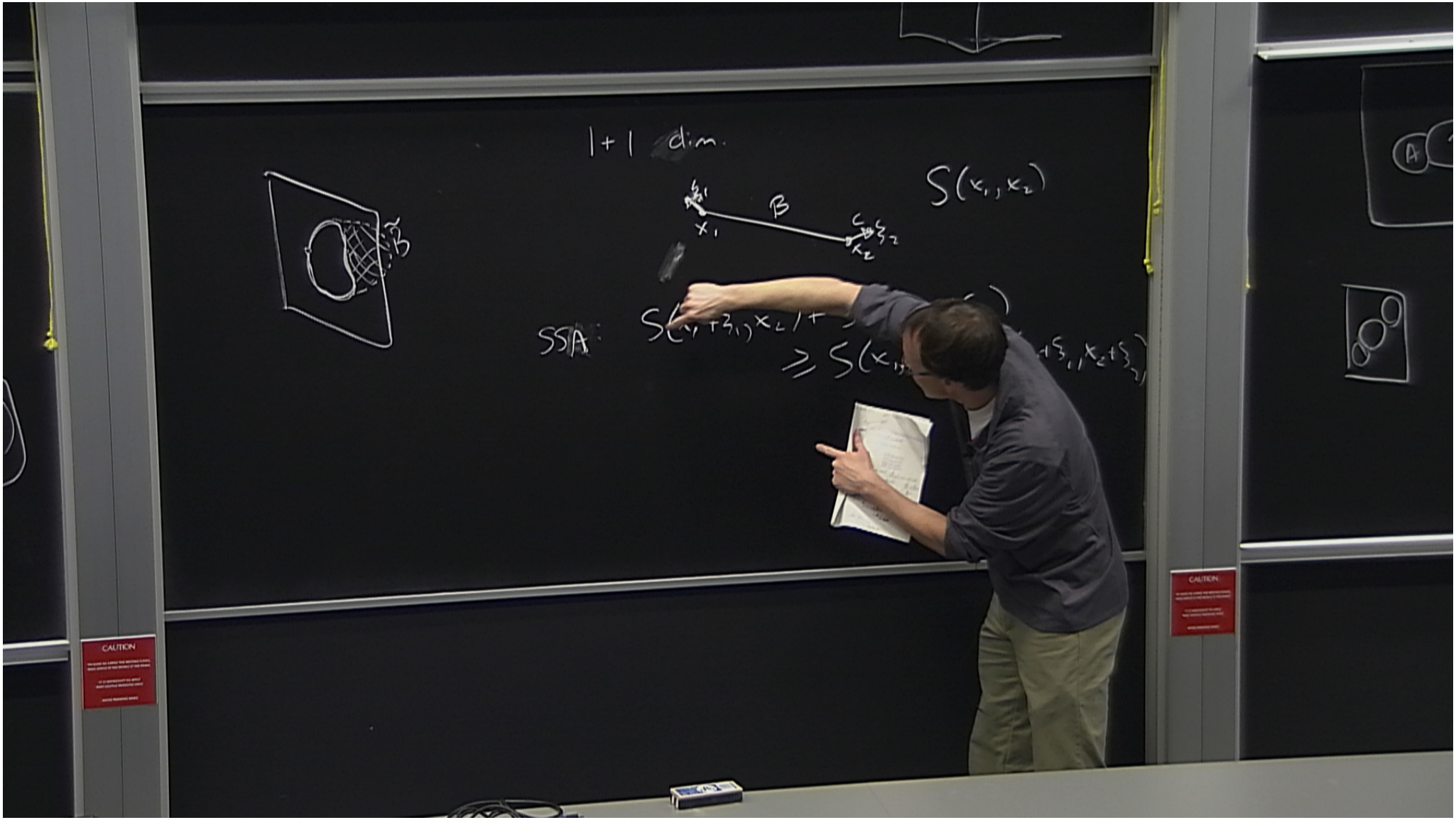

Strong subadditivity.
S(
B
B'
B
A
B
Asympt.
Ads
S(10)

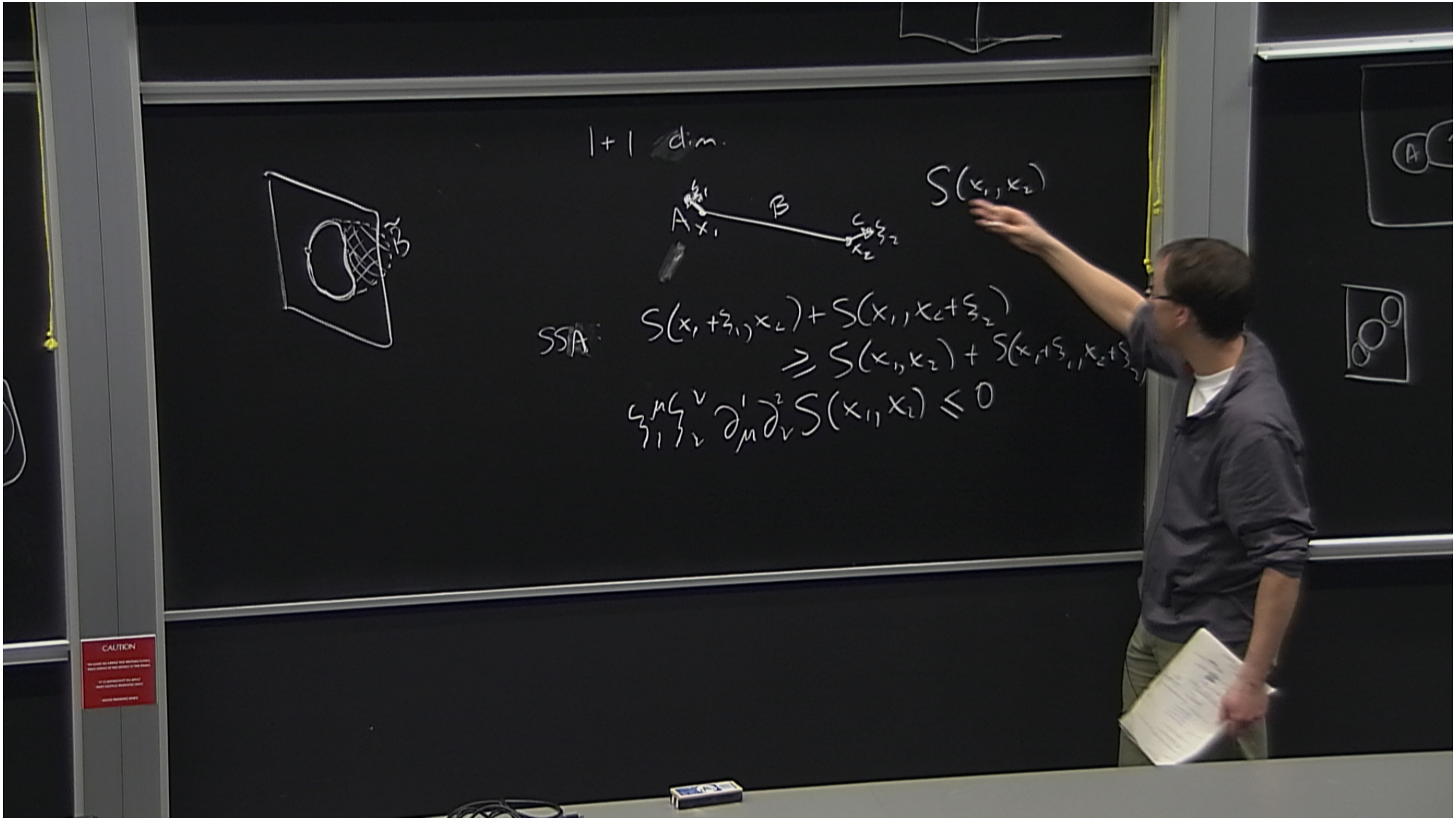

Strong subadditivity.
S(
B
B'
B
A
A
A
B
C
Asympt.
Ads
S(10>
CAUTION
CAUTION

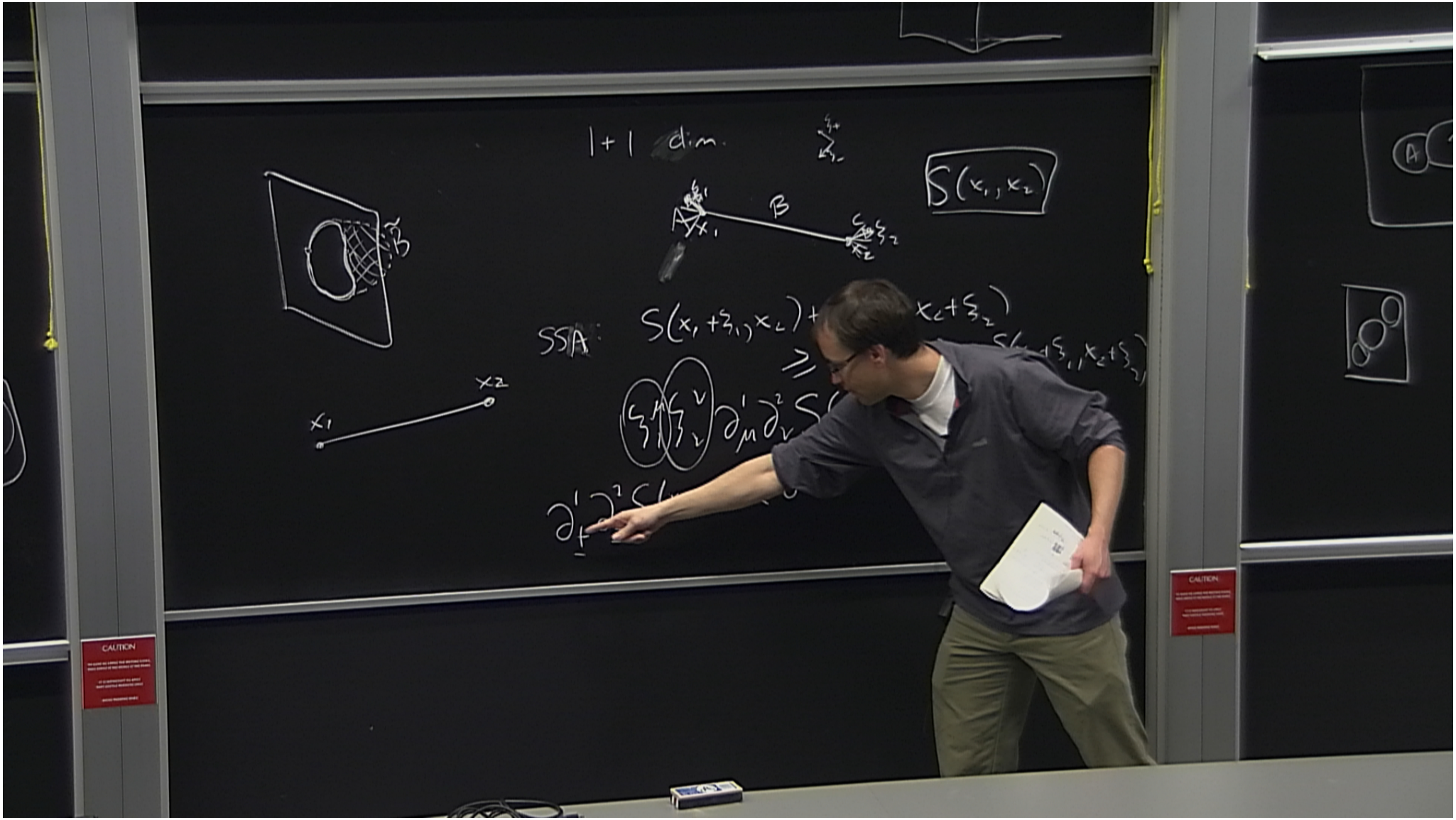

Strong subadditivity:
S(
B
B'
B
A
B
A
A
B
CAUTION
CAUTION

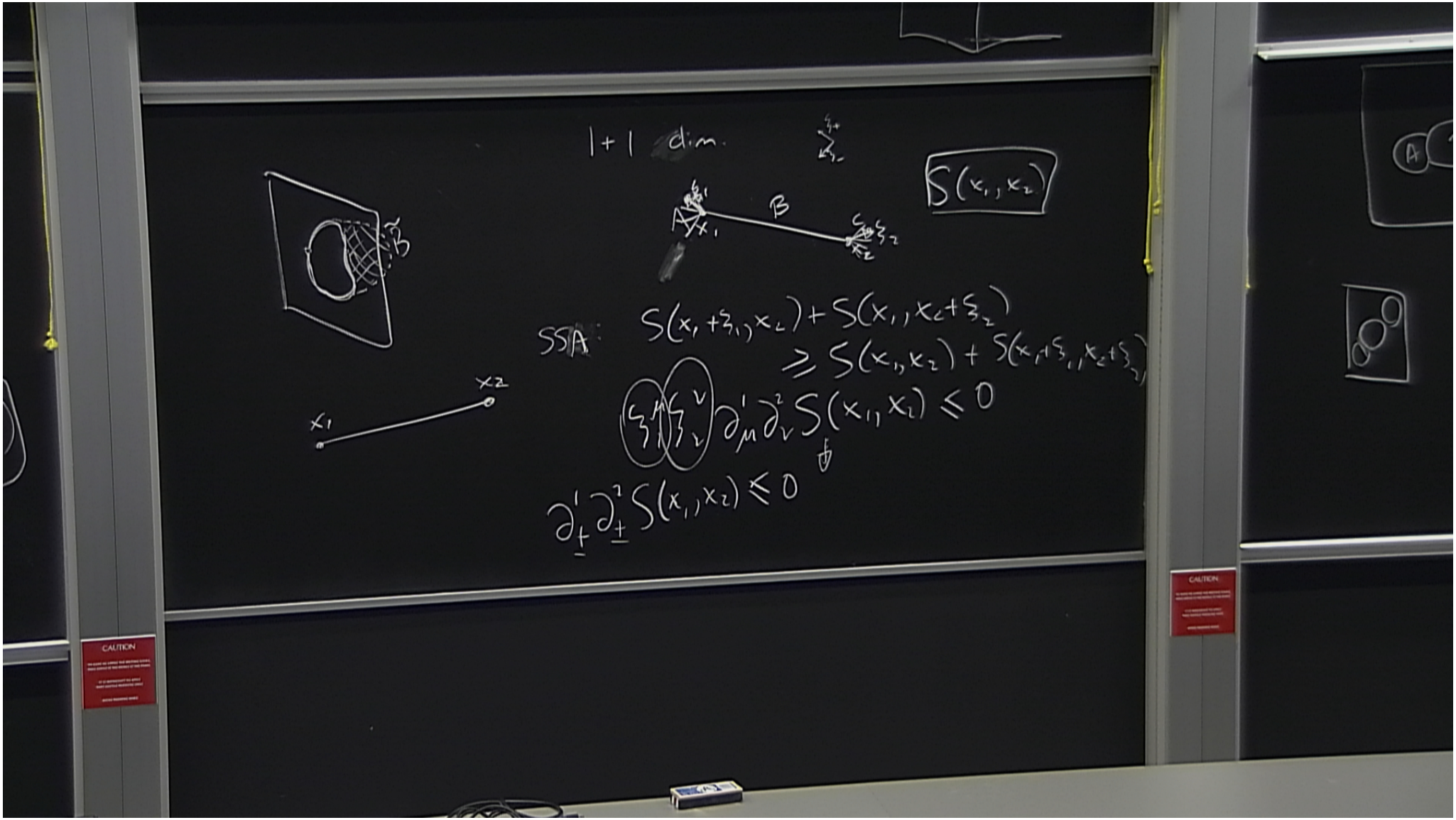

B
B'
C
A
A
B
C
A
B
mpl.
Ads
CAUTION
CAUTION

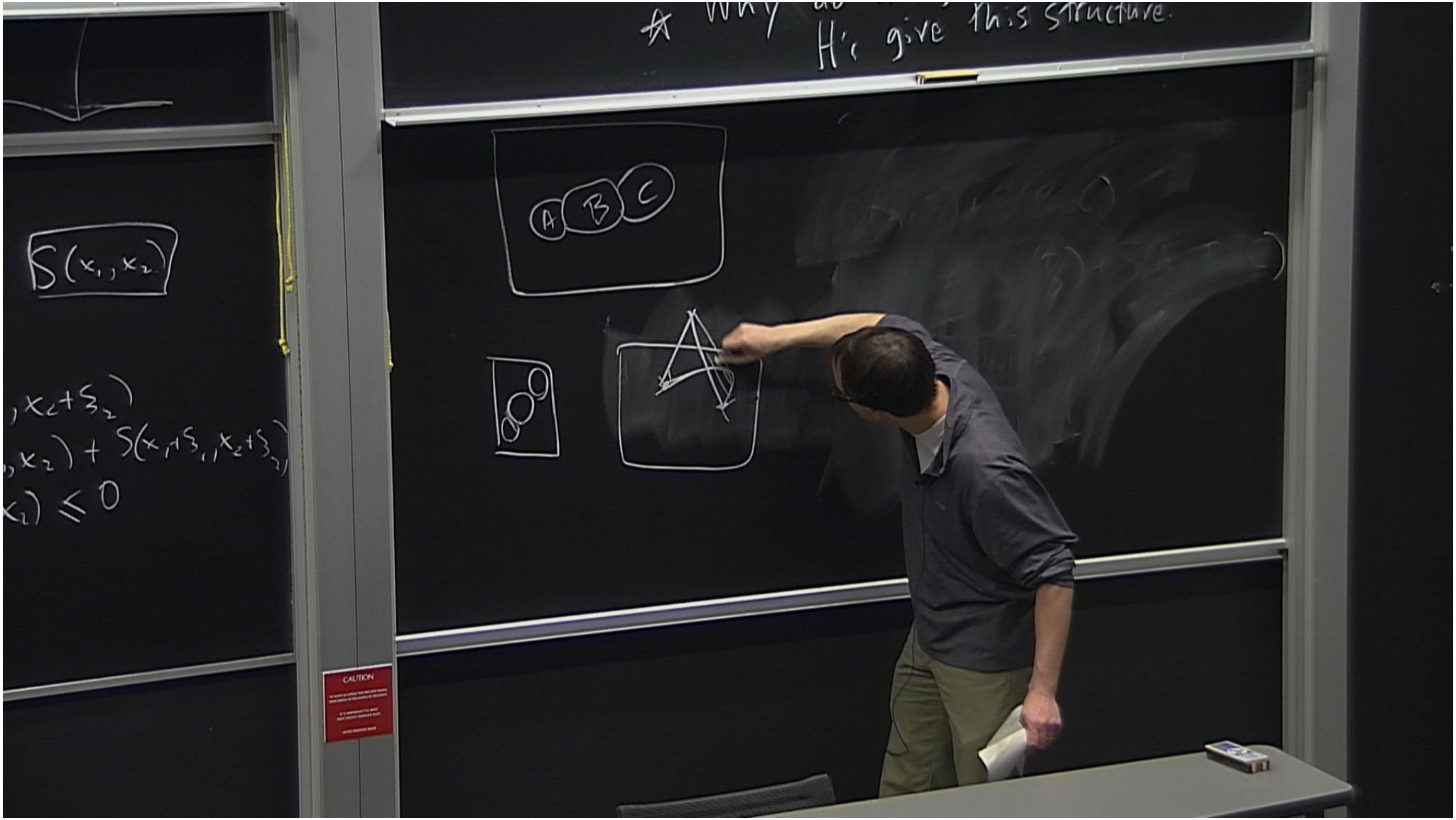

1+1 dim.
CAUTION
CAUTION

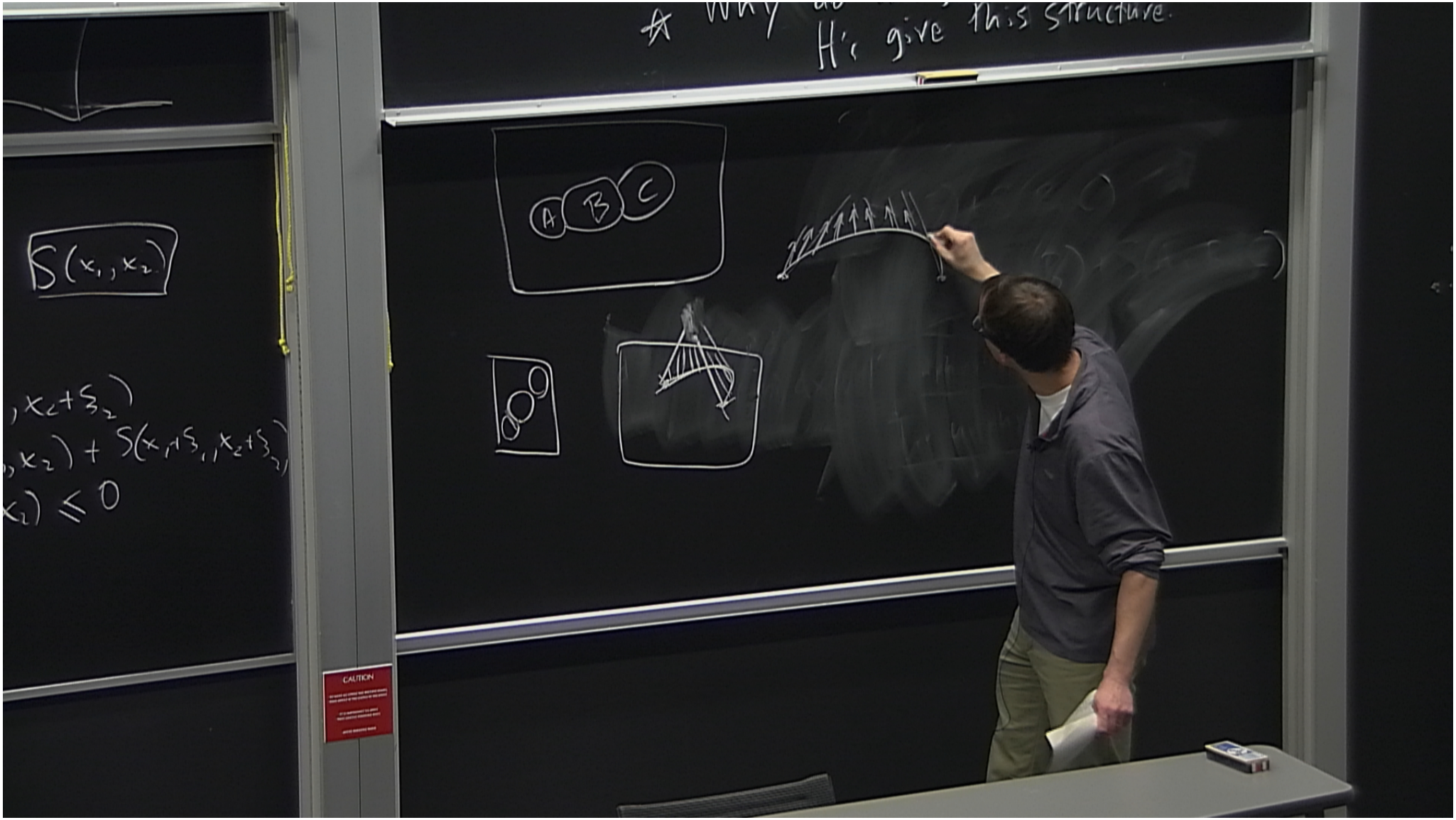

1+1 dim.
B
x_1
x_2
$S(x_1, x_2)$
SSA:
CAUTION

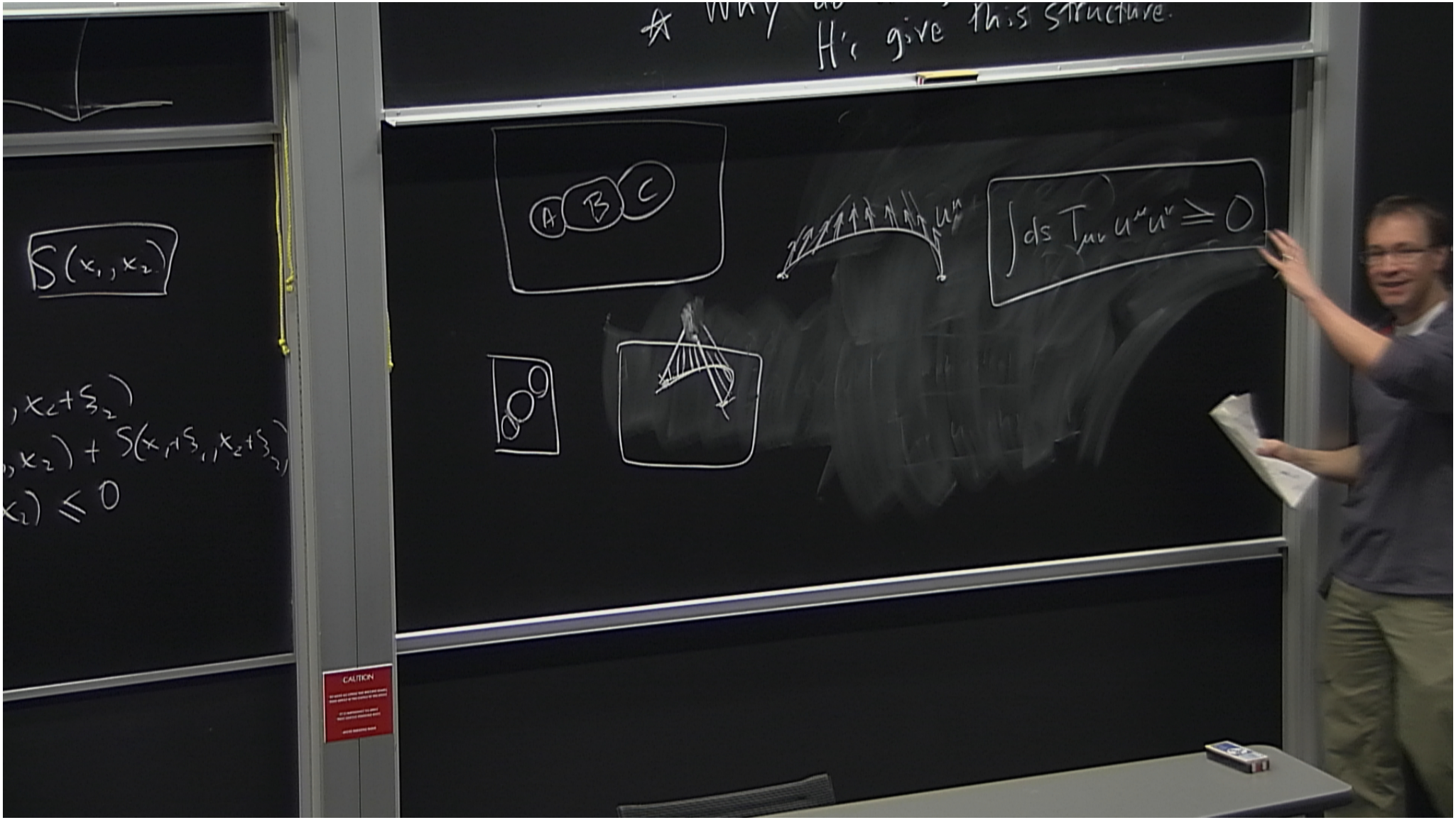

1+1 dim.
A
B
C
x_1
x_2
ξ_2
$S(x_1, x_2)$
SSA:
$S(x_1+\xi_1, x_2) + S(x_1, x_2+\xi_2)$
$\geq S(x_1, x_2) + S(x_1+\xi_1, x_2+\xi_2)$
$\xi_1^\mu \xi_2^\nu \partial_\mu^1 \partial_\nu^2 S(x_1, x_2) \leq 0$
CAUTION

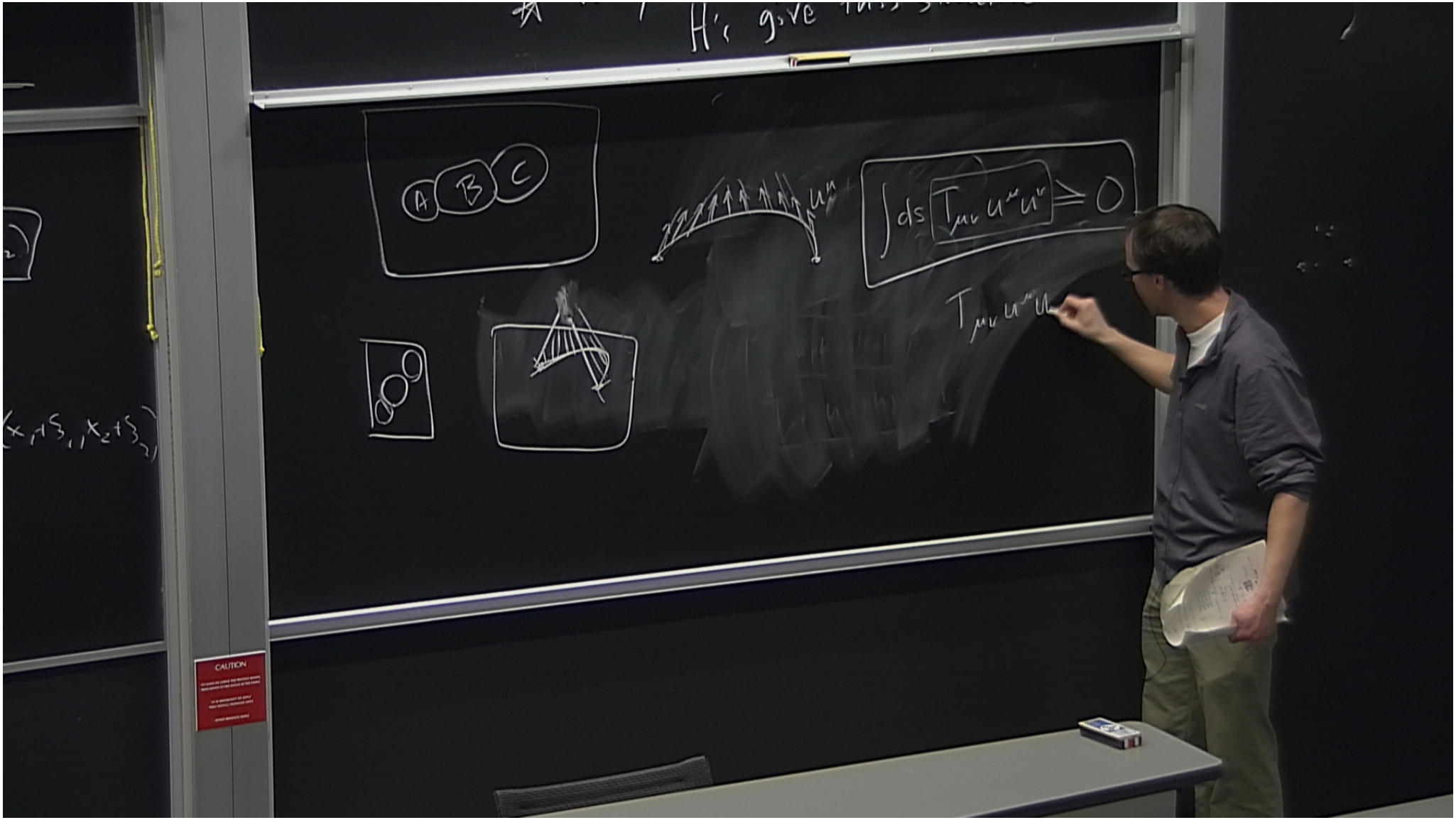

1+1 dim.
S(x1, x2)
A
B
C
x1
x2
SSA:
S(x1+ξ1, x2)+
x2+ξ2)
x1
x2
CAUTION
CAUTION

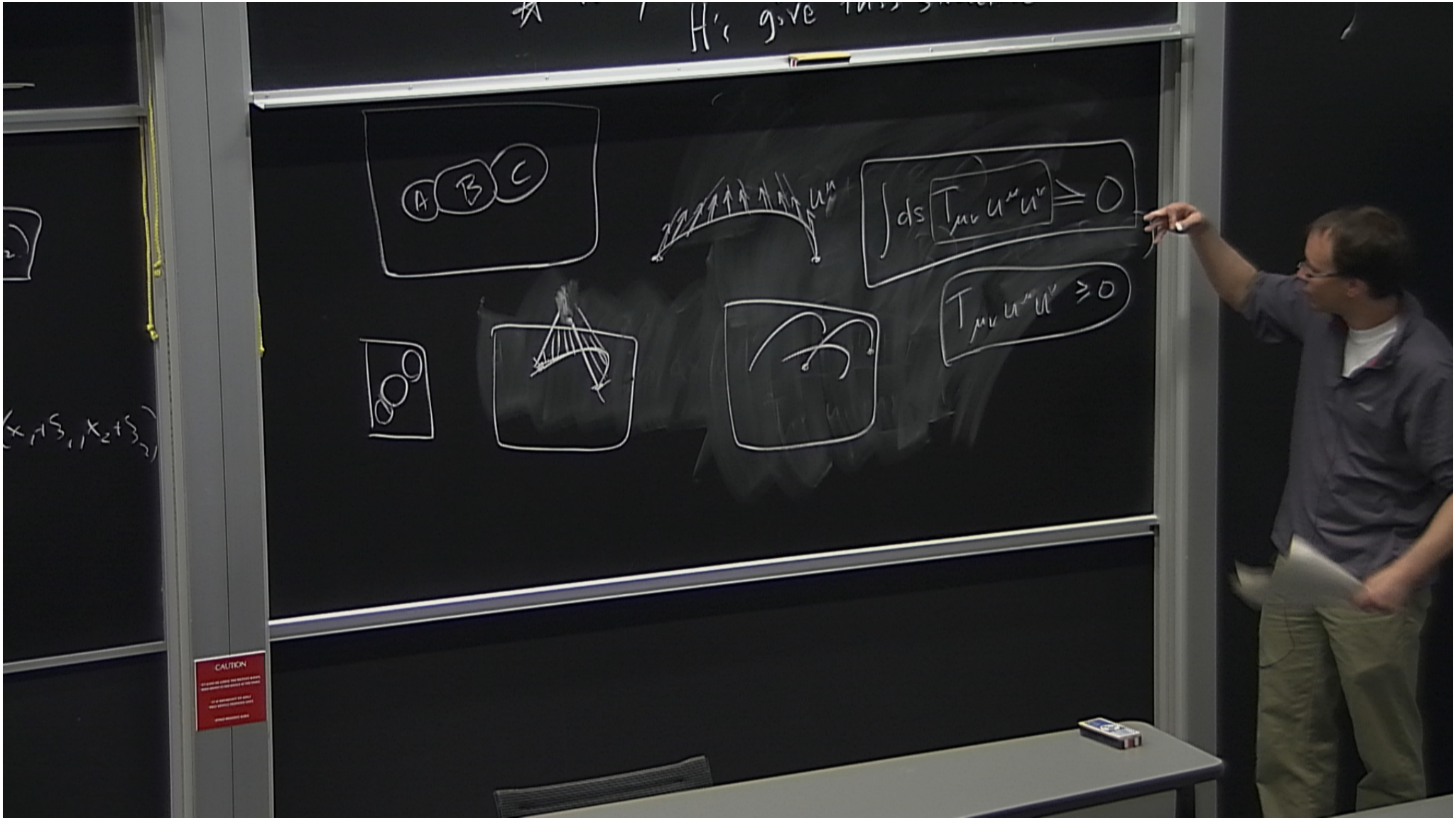

1+1 dim.
S(x1, x2)
A
B
x1
x2
SSA: S(x1 + ξ1, x2) + S(x1, x2 + ξ2)
≥ S(x1, x2) + S(x1 + ξ1, x2 + ξ2)
∂+ ∂+ S(x1, x2) ≤ 0
CAUTION


H, give this structure.
A
B
C
CAUTION

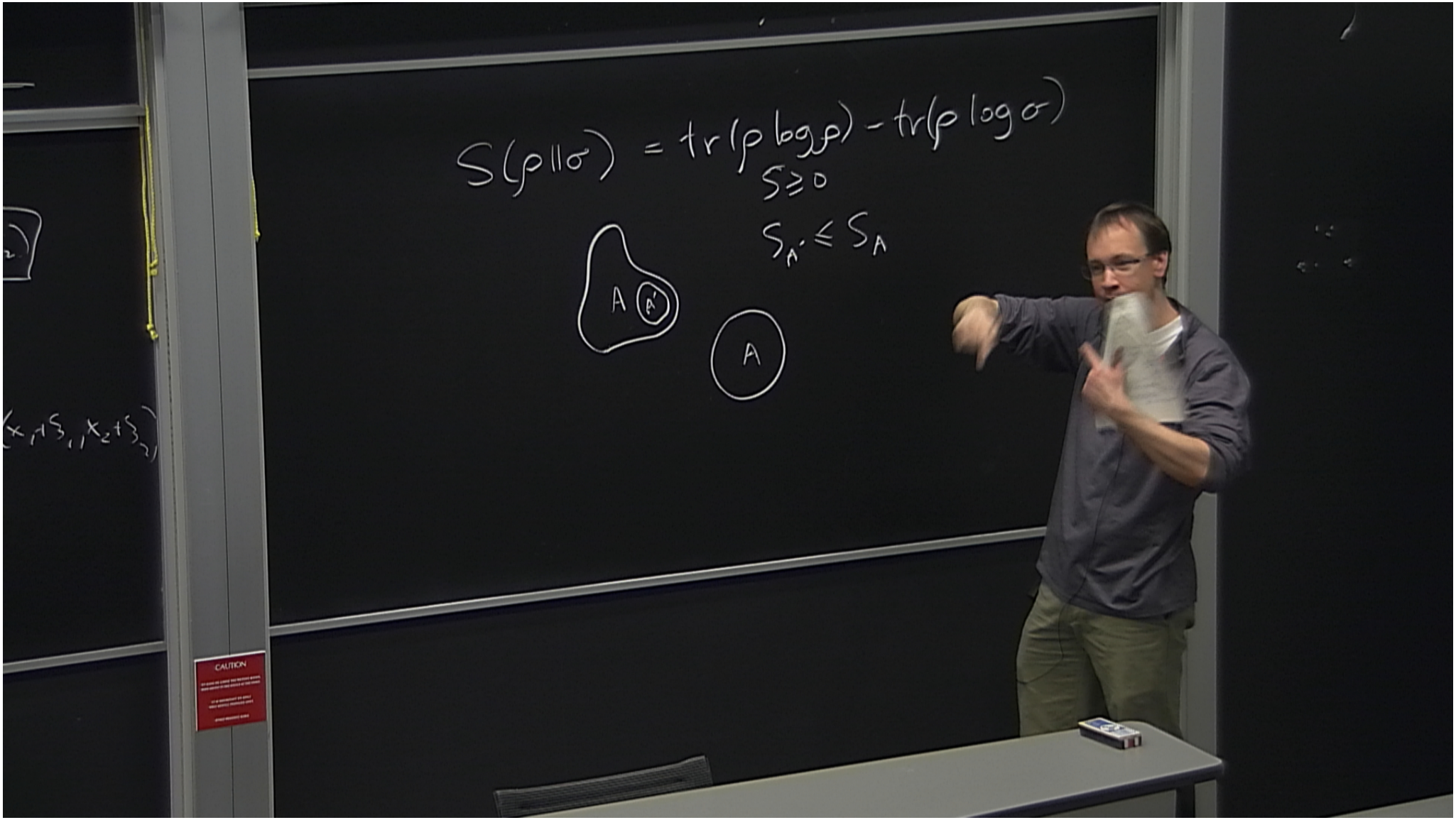

H, give this structure.
A B C
CAUTION

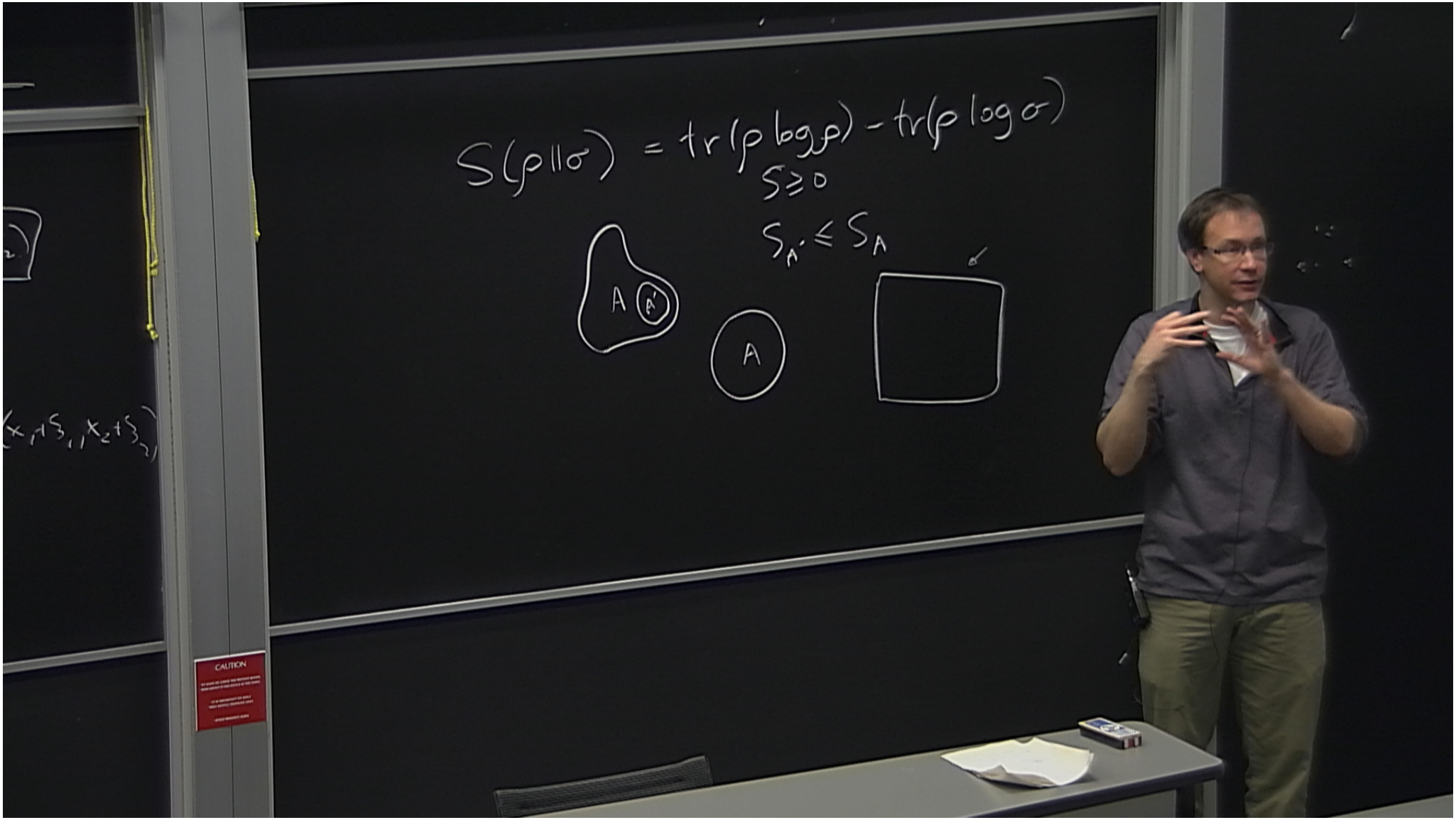

H, give this structure.
A B C
$\int ds\, T_{\mu\nu} u^\mu u^\nu \geq 0$
$S(x_1, x_2)$
CAUTION

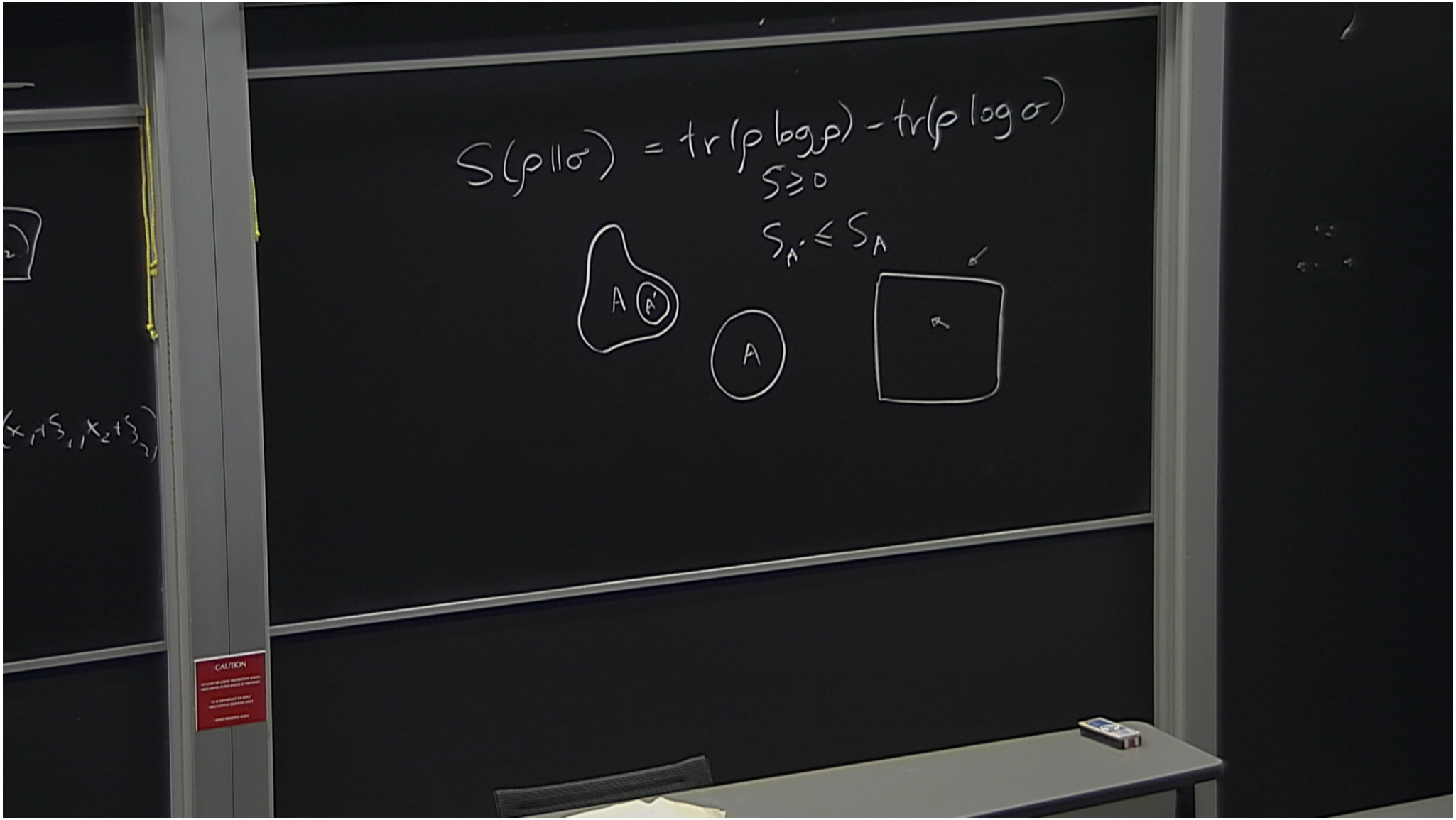

A
B
C
CAUTION

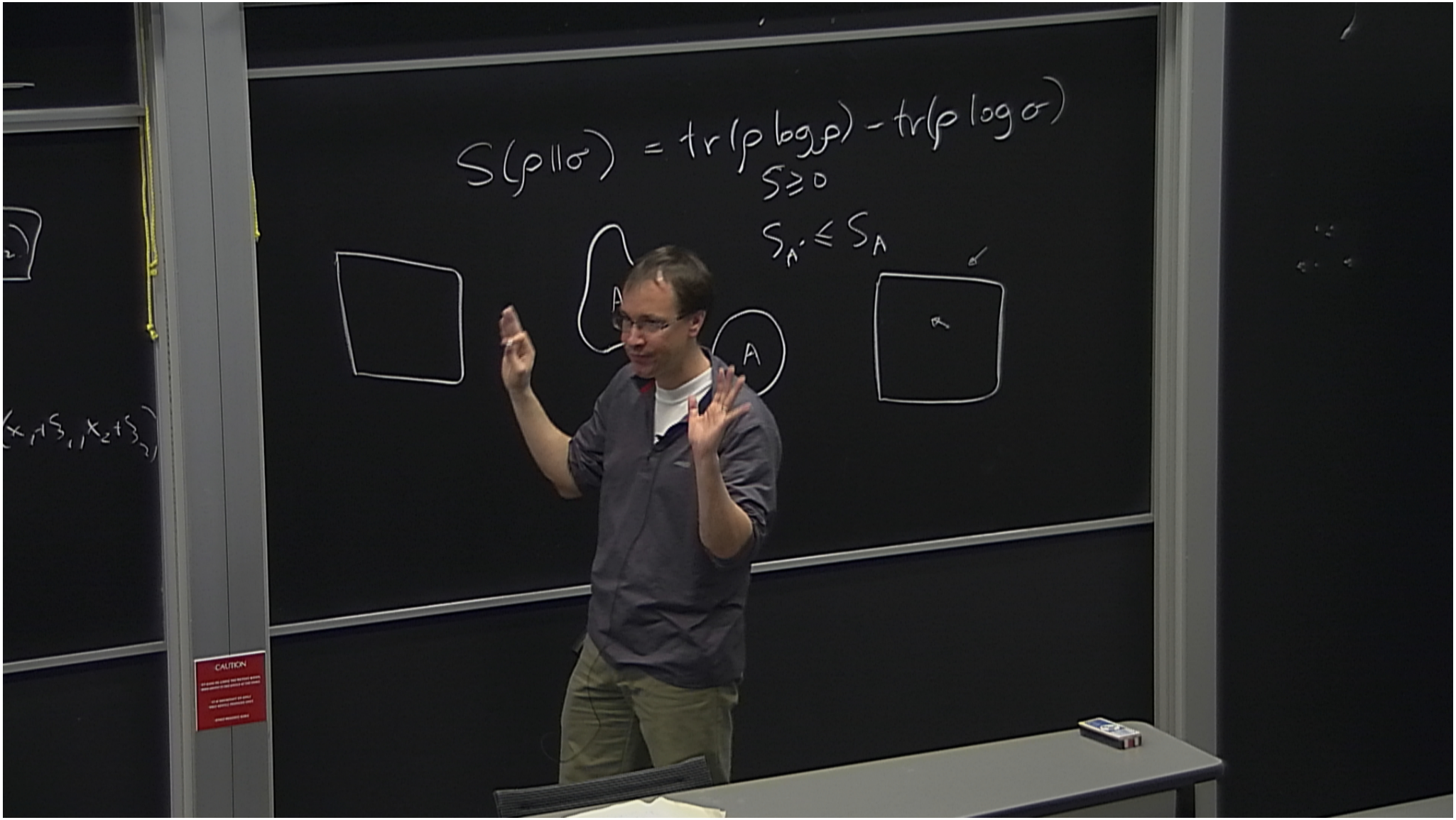

A
B
C
$\int ds\, T_{\mu\nu} u^\mu u^\nu \geq 0$
$T_{\mu\nu} u^\mu u^\nu \geq 0$
CAUTION

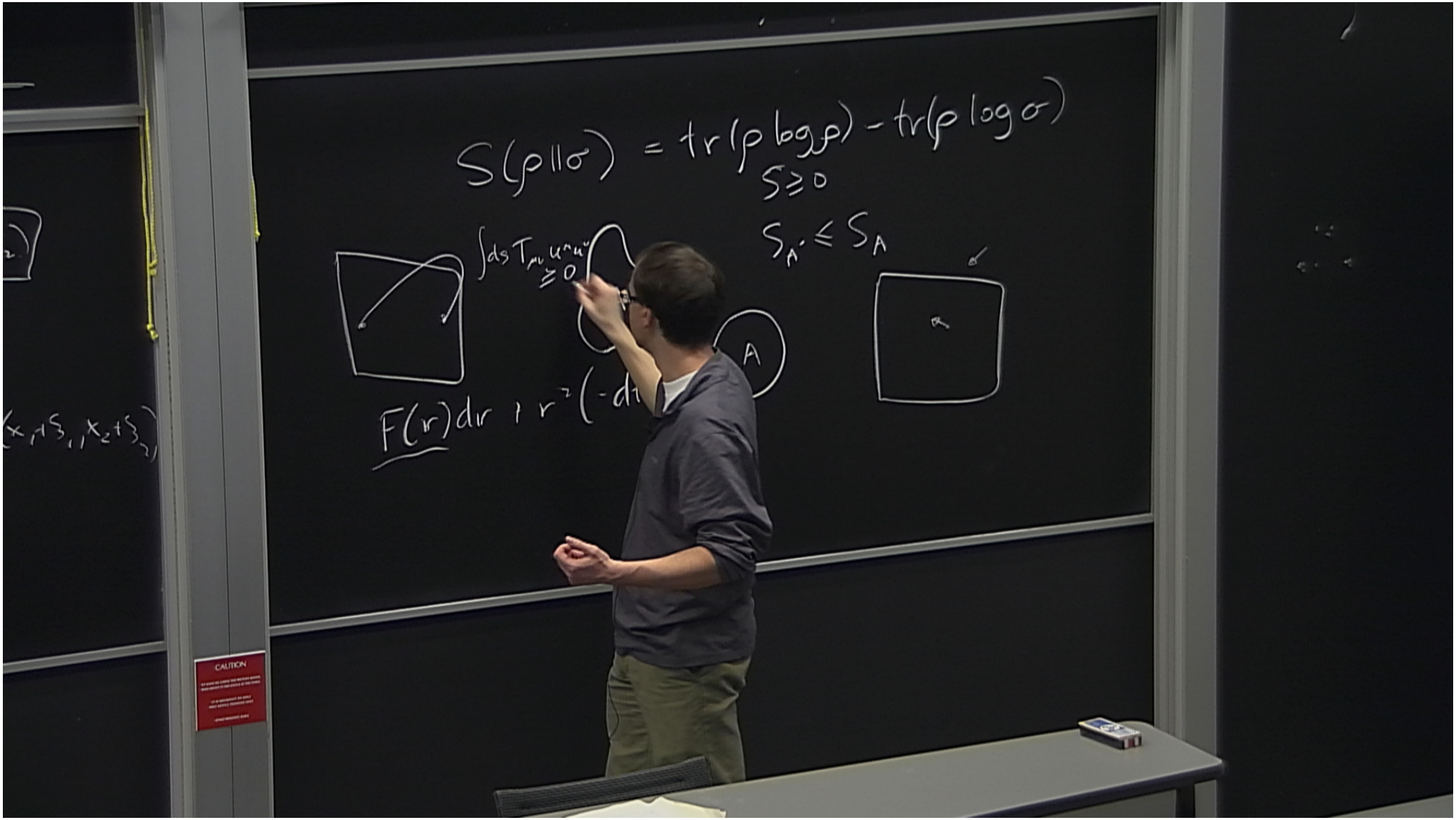

S(ρ||σ)
CAUTION

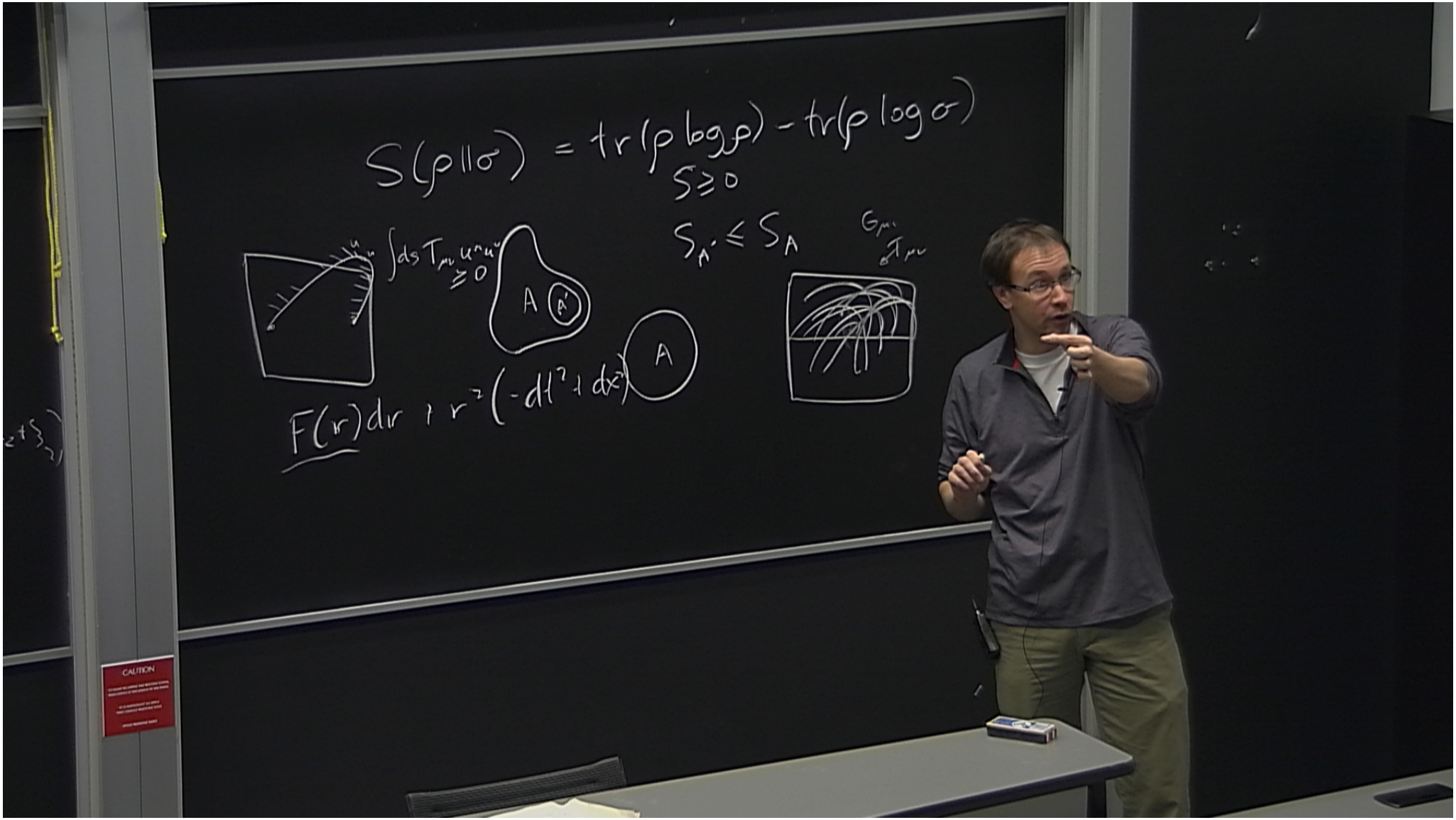

$S(\rho\|\sigma) = \mathrm{tr}(\rho \log \rho) - \mathrm{tr}(\rho \log \sigma)$
$S \geq 0$
$S_{A'} \leq S_A$
A
A'
A
CAUTION

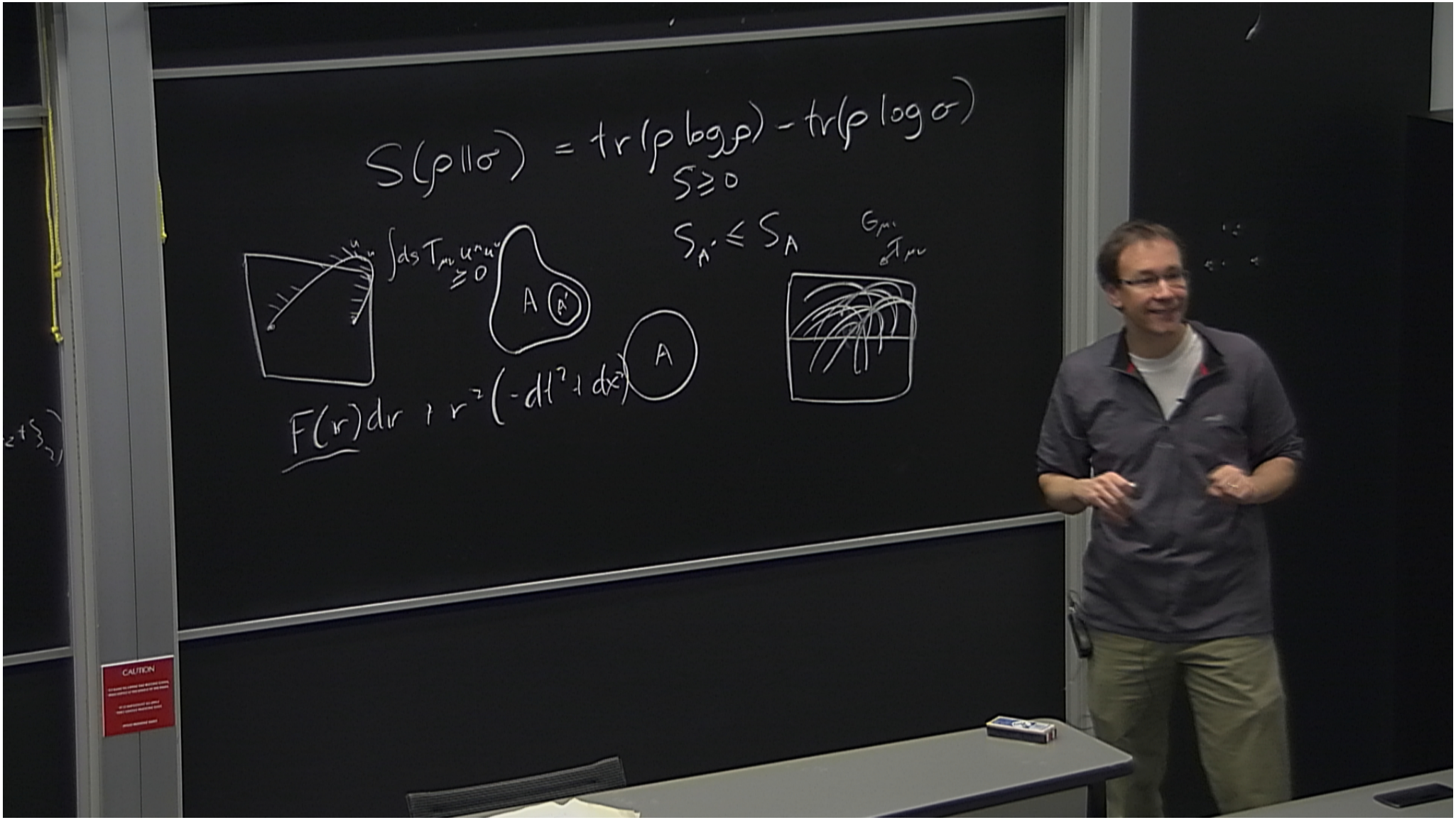

$S(\rho\|\sigma) = \mathrm{tr}(\rho \log \rho) - \mathrm{tr}(\rho \log \sigma)$
$S \geq 0$
$S_{A'} \leq S_A$
A
A'
A
CAUTION

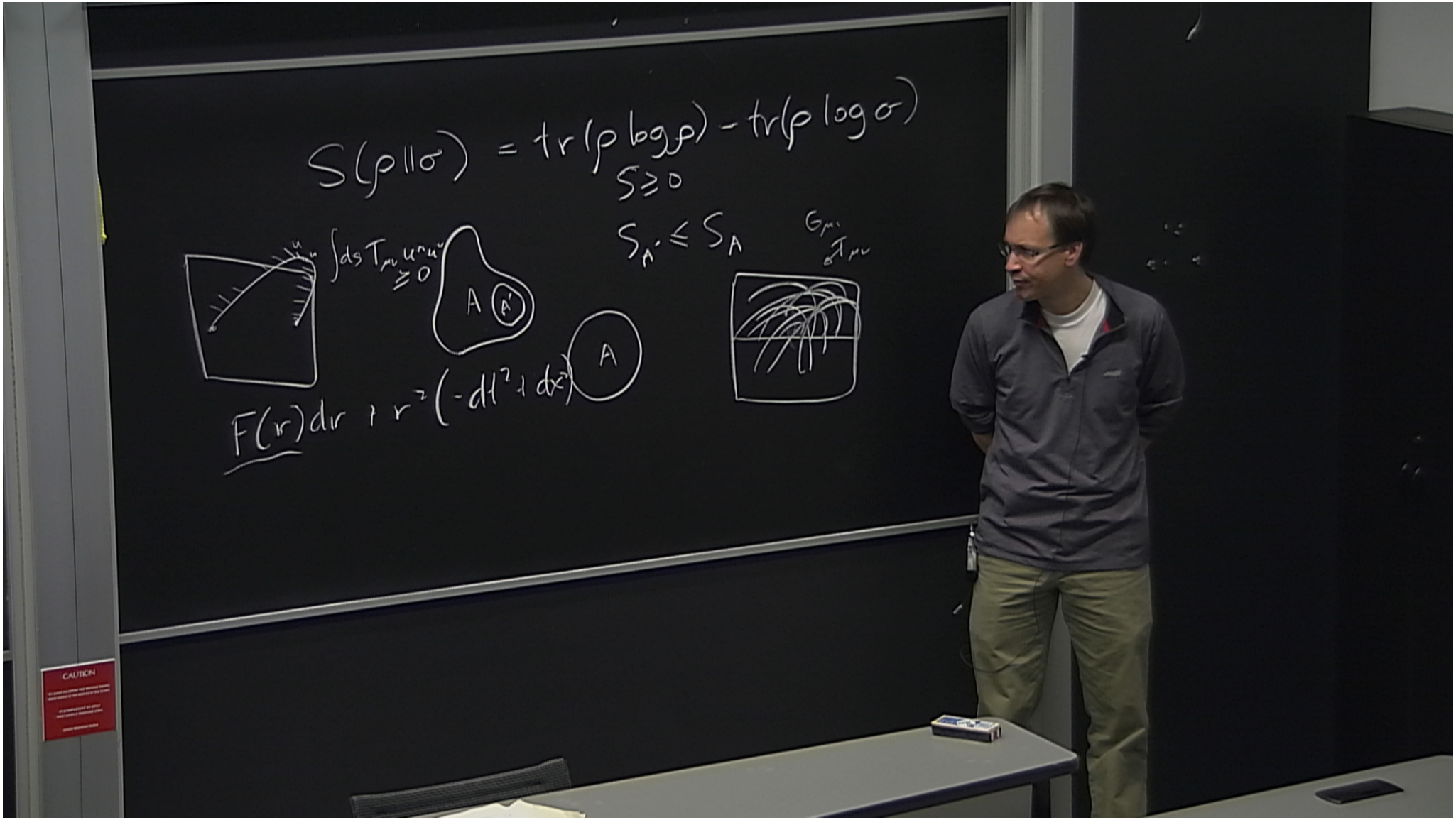

$S(\rho\|\sigma) = \mathrm{tr}(\rho \log_2 \rho) - \mathrm{tr}(\rho \log \sigma)$
$S \geq 0$
$S_{A'} \leq S_A$
A
A'
A
CAUTION

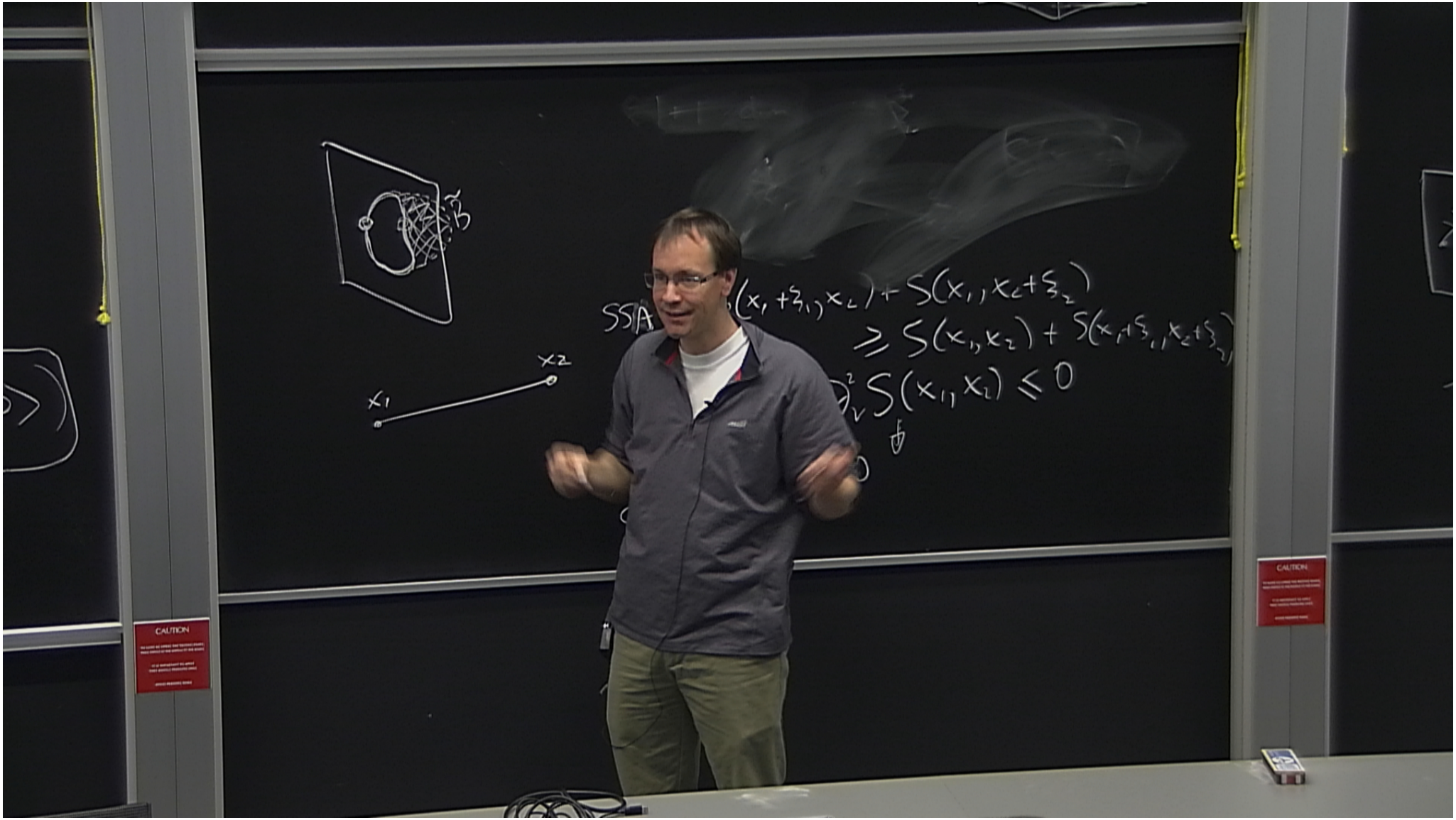

$S(\rho\|\sigma) = \mathrm{tr}(\rho \log_2 \rho) - \mathrm{tr}(\rho \log \sigma)$
$S \geq 0$
$S_{A'} \leq S_A$
A
A
CAUTION

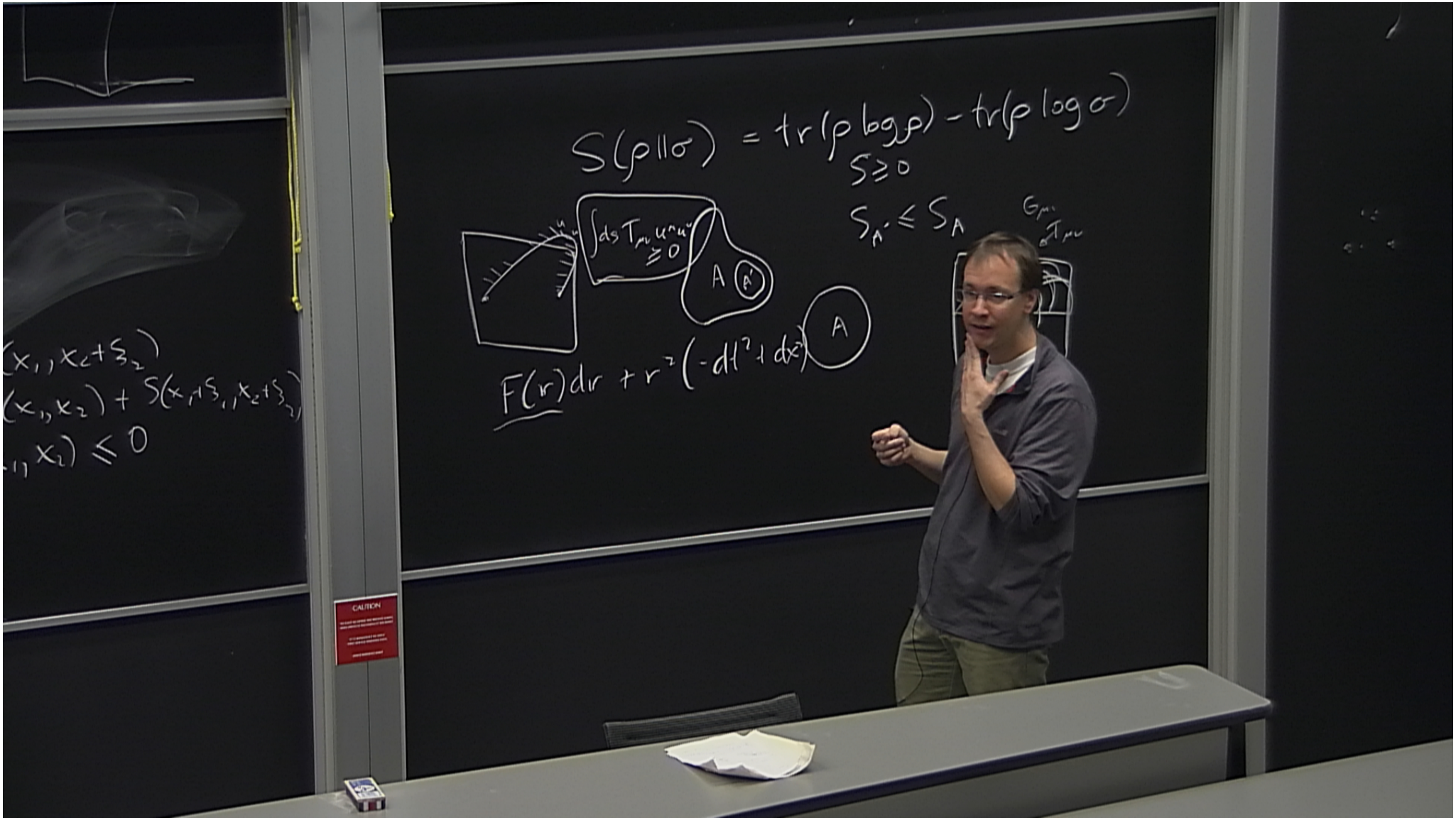

$S(\rho\|\sigma) = \mathrm{tr}(\rho \log_2 \rho) - \mathrm{tr}(\rho \log \sigma)$
$S \geq 0$
$\int ds\, T_{\mu\nu} u^\mu u^\nu \geq 0$
$S_{A'} \leq S_A$
A
$F(r)dr$
CAUTION


$S(\rho\|\sigma) = \mathrm{tr}(\rho \log \rho) - \mathrm{tr}(\rho \log \sigma)$
$S \geq 0$
$\int ds\, T_{\mu\nu} u^\mu u^\nu \geq 0$
$S_{A'} \leq S_A$
$G_{\mu\nu} \propto T_{\mu\nu}$
A
A'
A
$F(r)dr^2 + r^2(-dt^2 + dx^2)$
CAUTION


$S(\rho\|\sigma) = \mathrm{tr}(\rho \log \rho) - \mathrm{tr}(\rho \log \sigma)$
$S \geq 0$
$\int ds\, T_{\mu\nu} u^\mu u^\nu \geq 0$
$S_{A'} \leq S_A$
$G_{\mu\nu} \propto T_{\mu\nu}$
A
A'
A
$F(r)dr^2 + r^2(-dt^2 + dx^2)$
CAUTION


$S(\rho\|\sigma) = \mathrm{tr}(\rho \log \rho) - \mathrm{tr}(\rho \log \sigma)$
$S \geq 0$
$\int ds\, T_{\mu\nu} u^\mu u^\nu \geq 0$
$S_{A'} \leq S_A$
A
A'
A
$F(r)dr^2 + r^2(-dt^2 + dx^2)$
CAUTION


SSA
$S(x_1+\xi_1, x_2) + S(x_1, x_2+\xi_2)$
$\geq S(x_1, x_2) + S(x_1+\xi_1, x_2+\xi_2)$
$\partial_1^2 \partial_2^2 S(x_1, x_2) \leq 0$
x_1
x_2
CAUTION
CAUTION


$S(\rho\|\sigma) = \mathrm{tr}(\rho \log \rho) - \mathrm{tr}(\rho \log \sigma)$
$S \geq 0$
$S_{A'} \leq S_A$
$\int ds\, T_{\mu\nu} u^\mu u^\nu \geq 0$
A
A
A
$F(r)dr + r^2(-dt^2 + dx^2)$
CAUTION