

Title: Inviolable energy conditions from entanglement inequalities

Date: Feb 19, 2015 11:00 AM

URL: <http://pirsa.org/15020087>

Abstract: <p>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."</p>



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

AdS/CFT

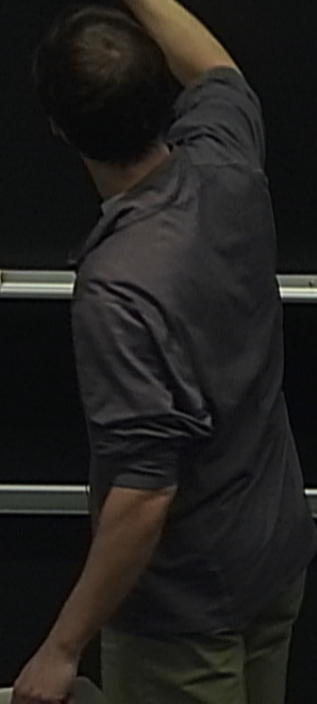
1412.3514 w Lashkari, Rabideau, Sabella-Garnier
"Inviolable Energy conditions from entanglement
inequalities"

AdS/CFT

1912.2011 W. LASHKARI, RADHAKRISHNAN, SABINA CARLIP
"Inviolable Energy conditions from entanglement inequalities"

AdS/CFT

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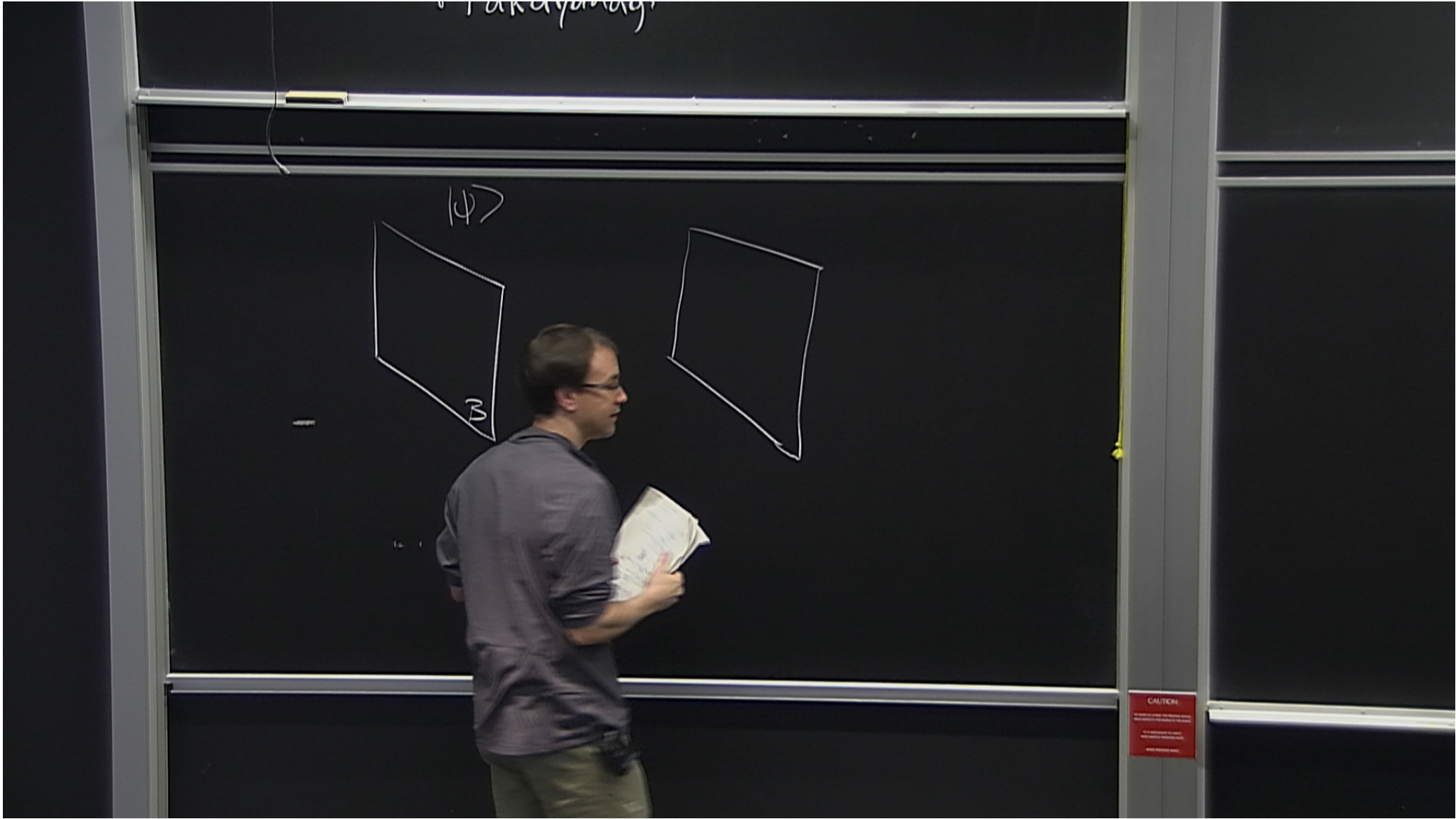


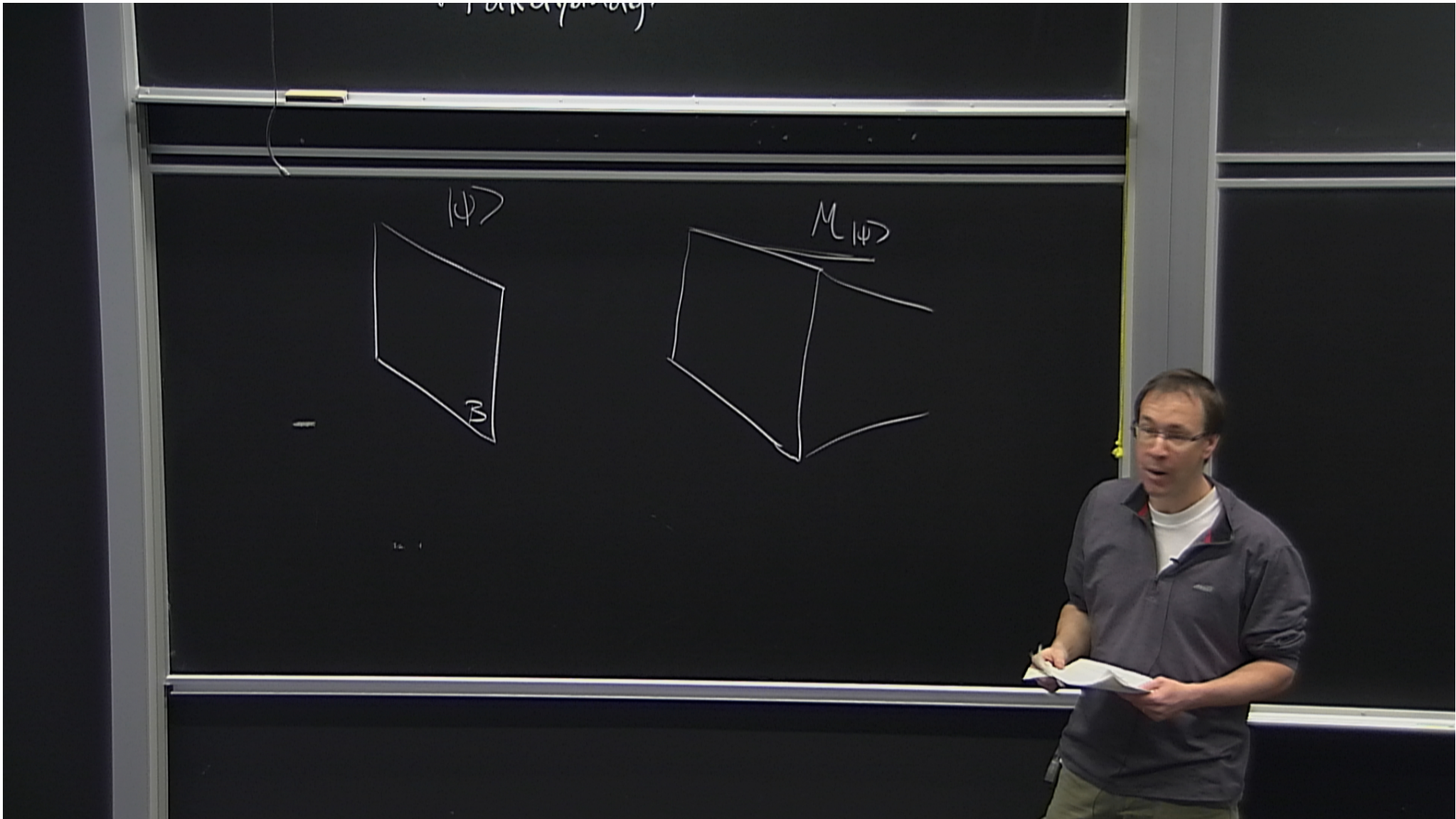
CAUTION
WARNING: HIGH VOLTAGE
DO NOT TOUCH THE SURFACE
OR THE SURROUNDING AREA
UNLESS YOU ARE A QUALIFIED
PERSONNEL MEMBER

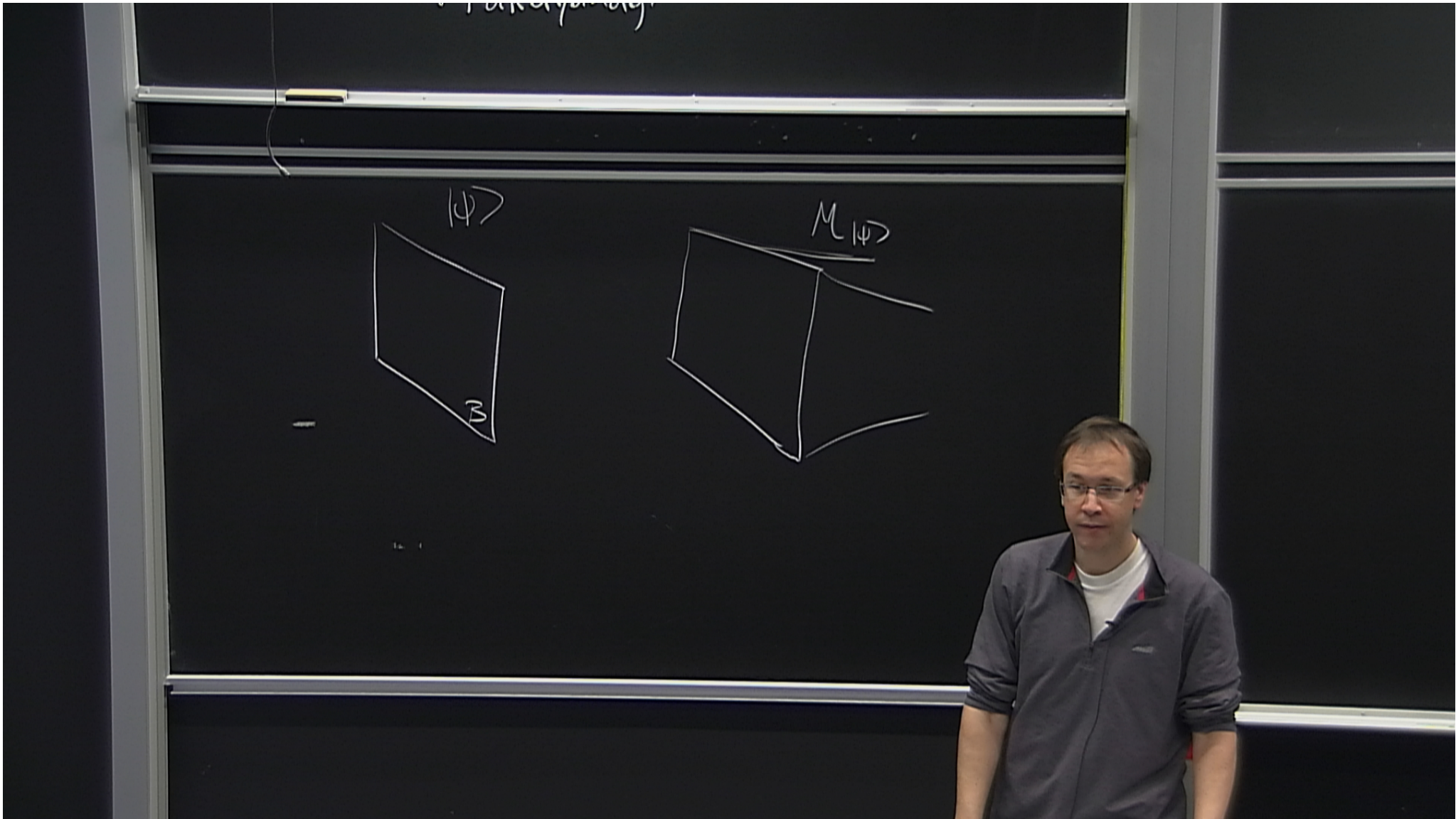
1912.2011 W. Luskrant, Radhika, Sabina
"Inviolable Energy conditions from entanglement inequalities"

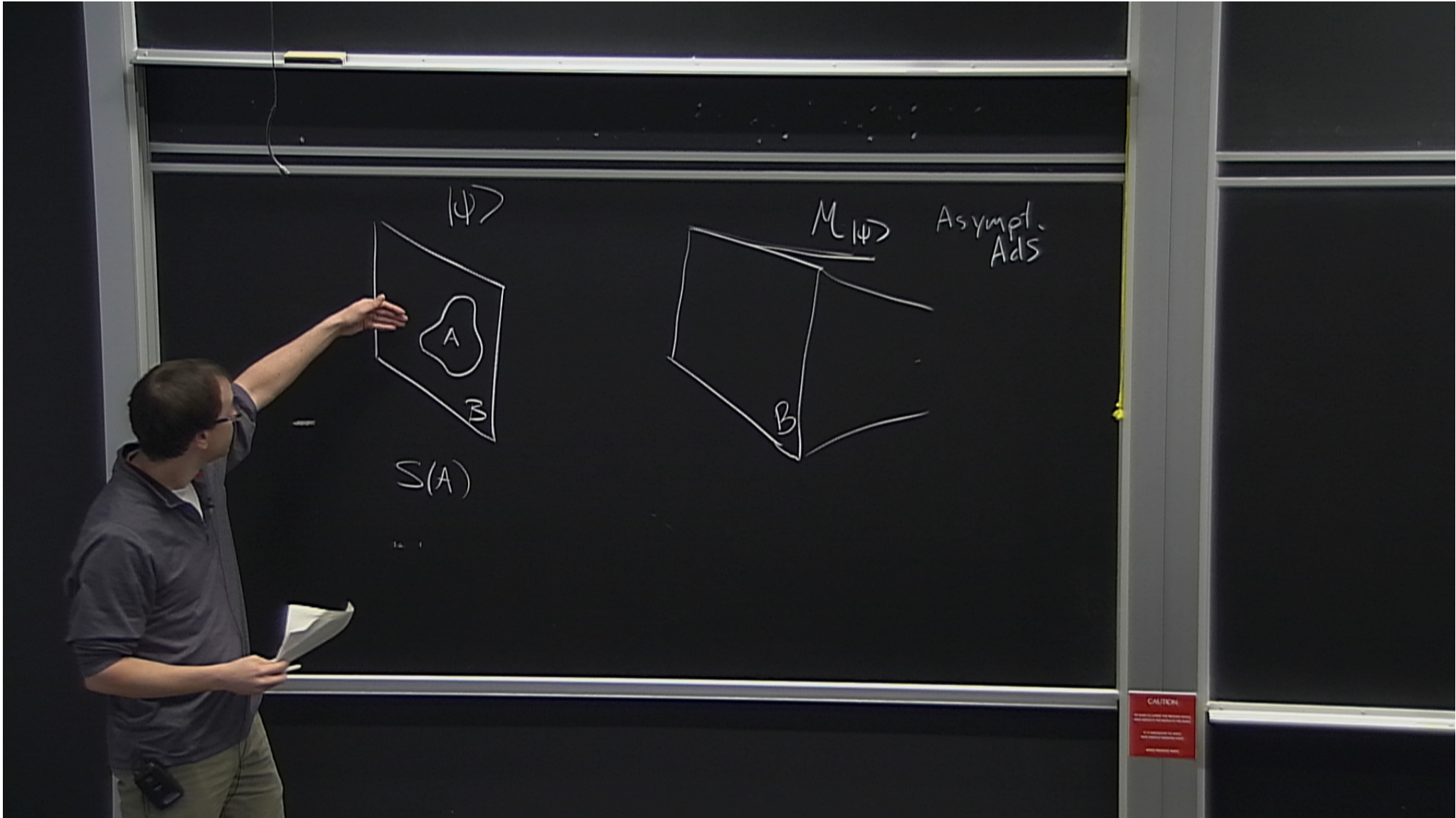
AdS/CFT

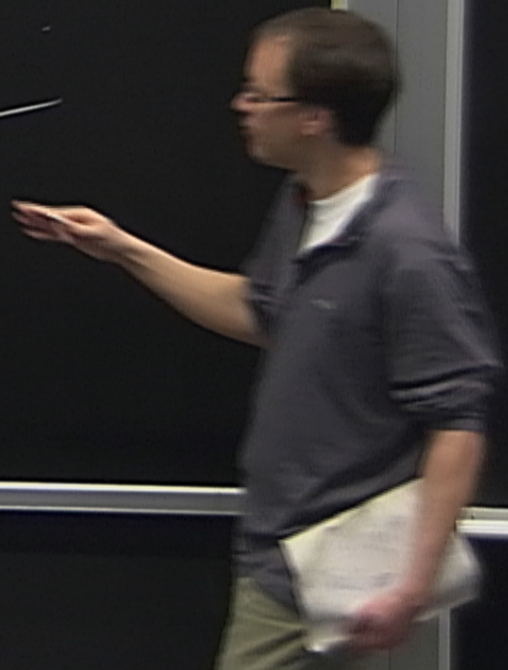
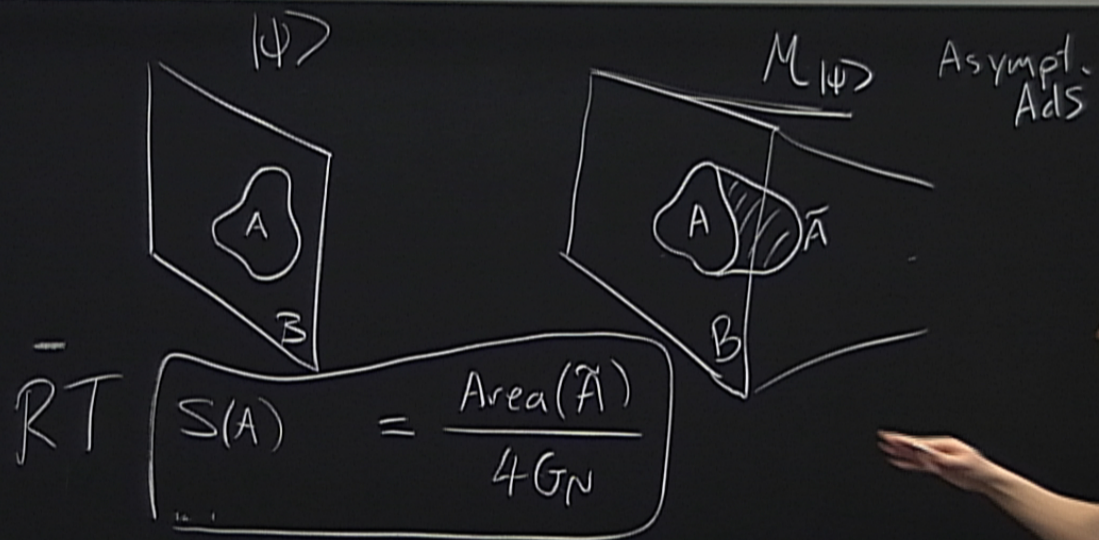
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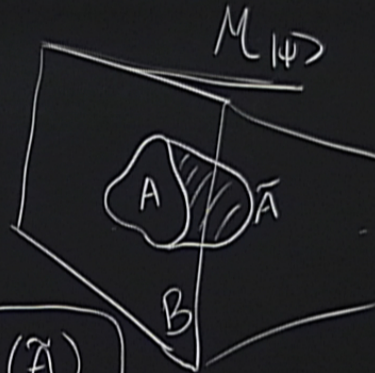






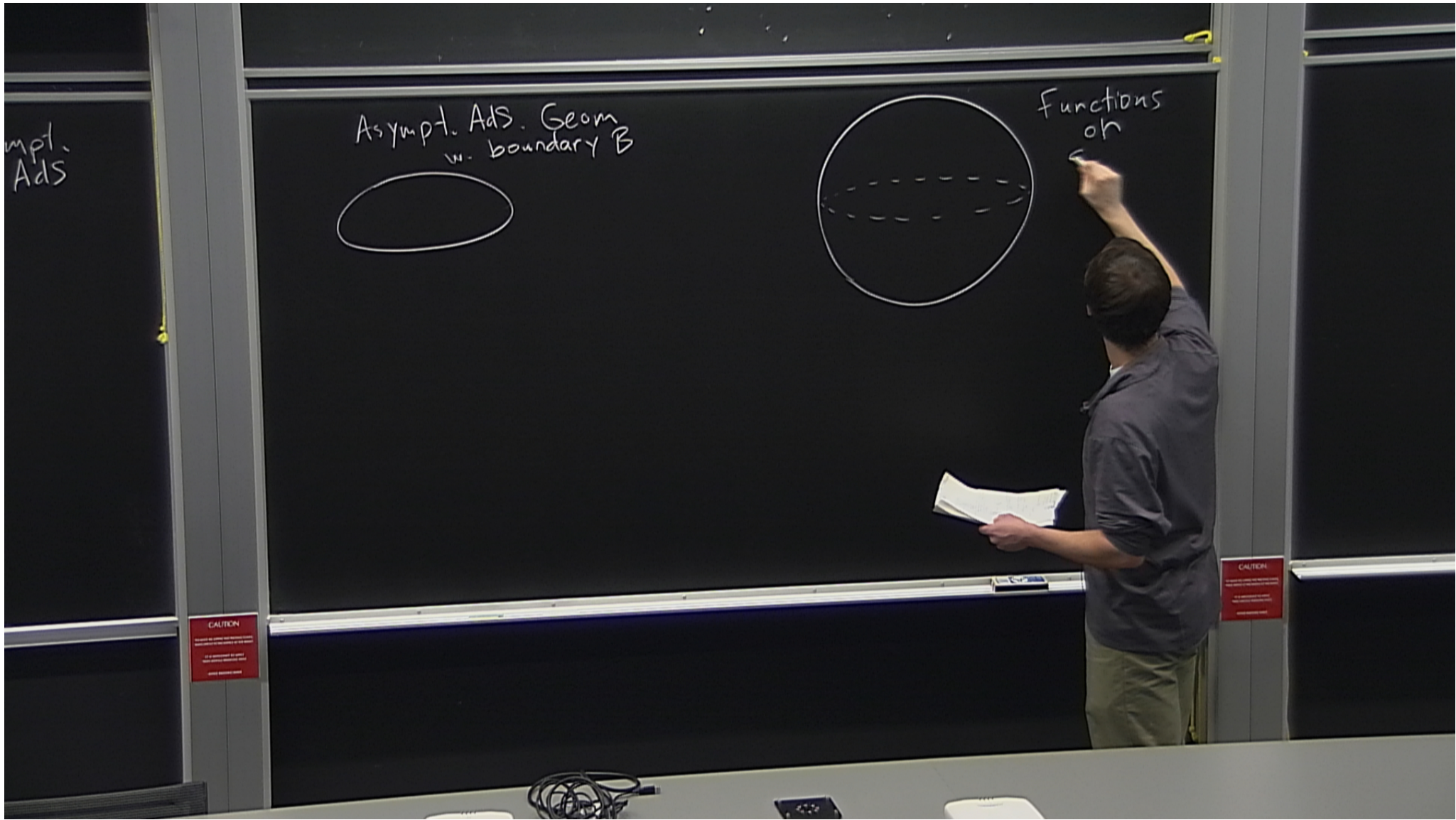


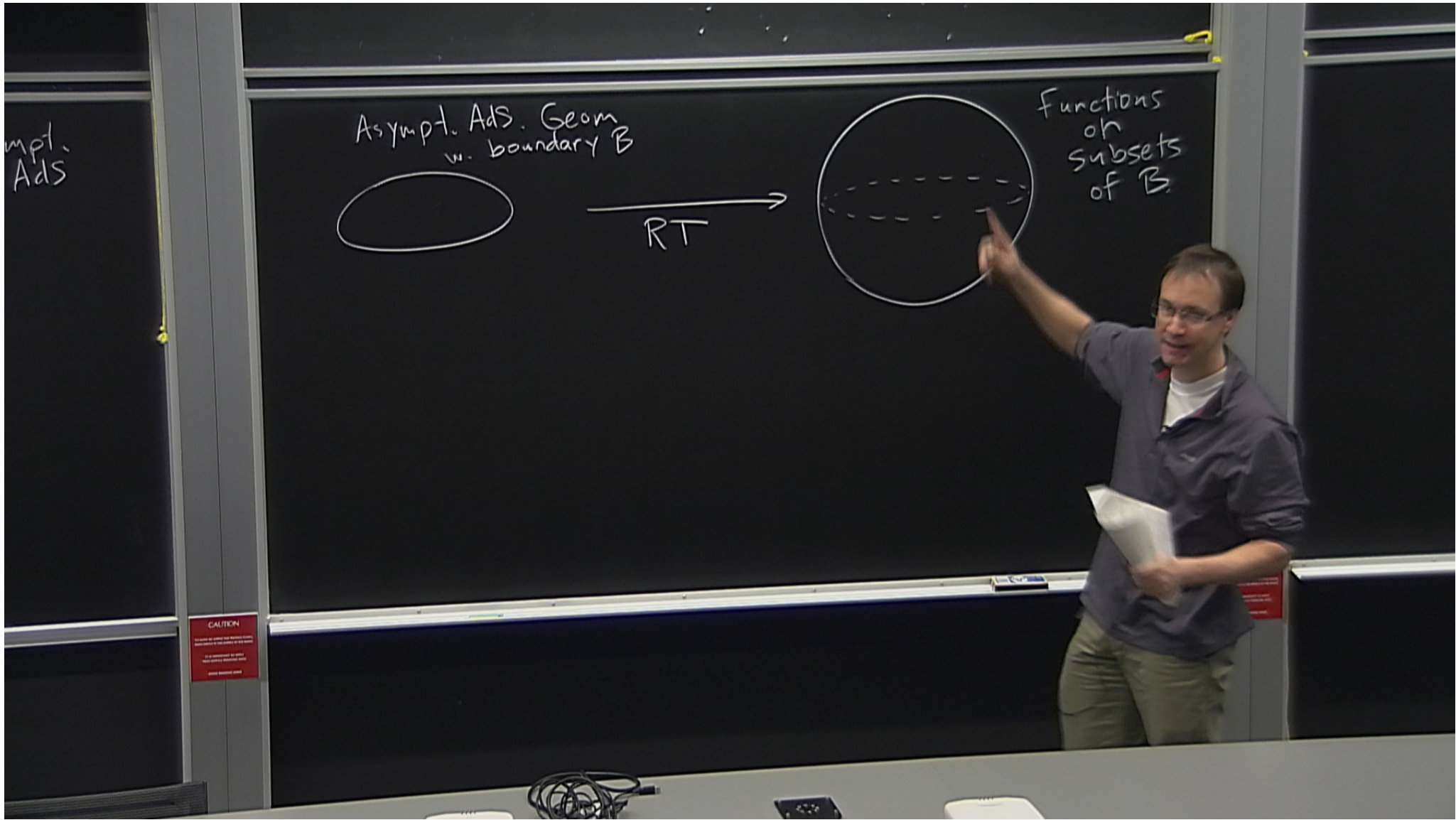


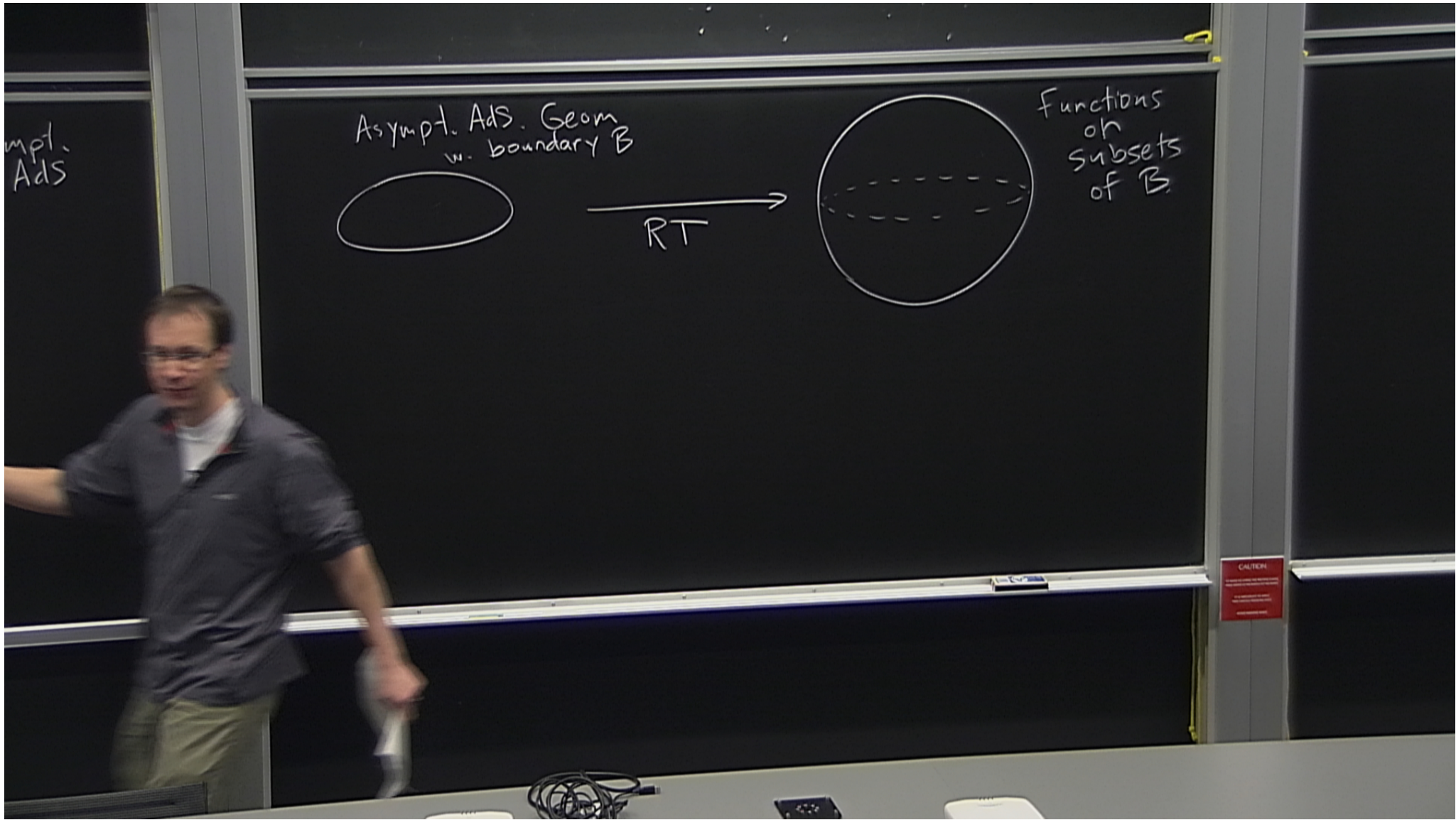


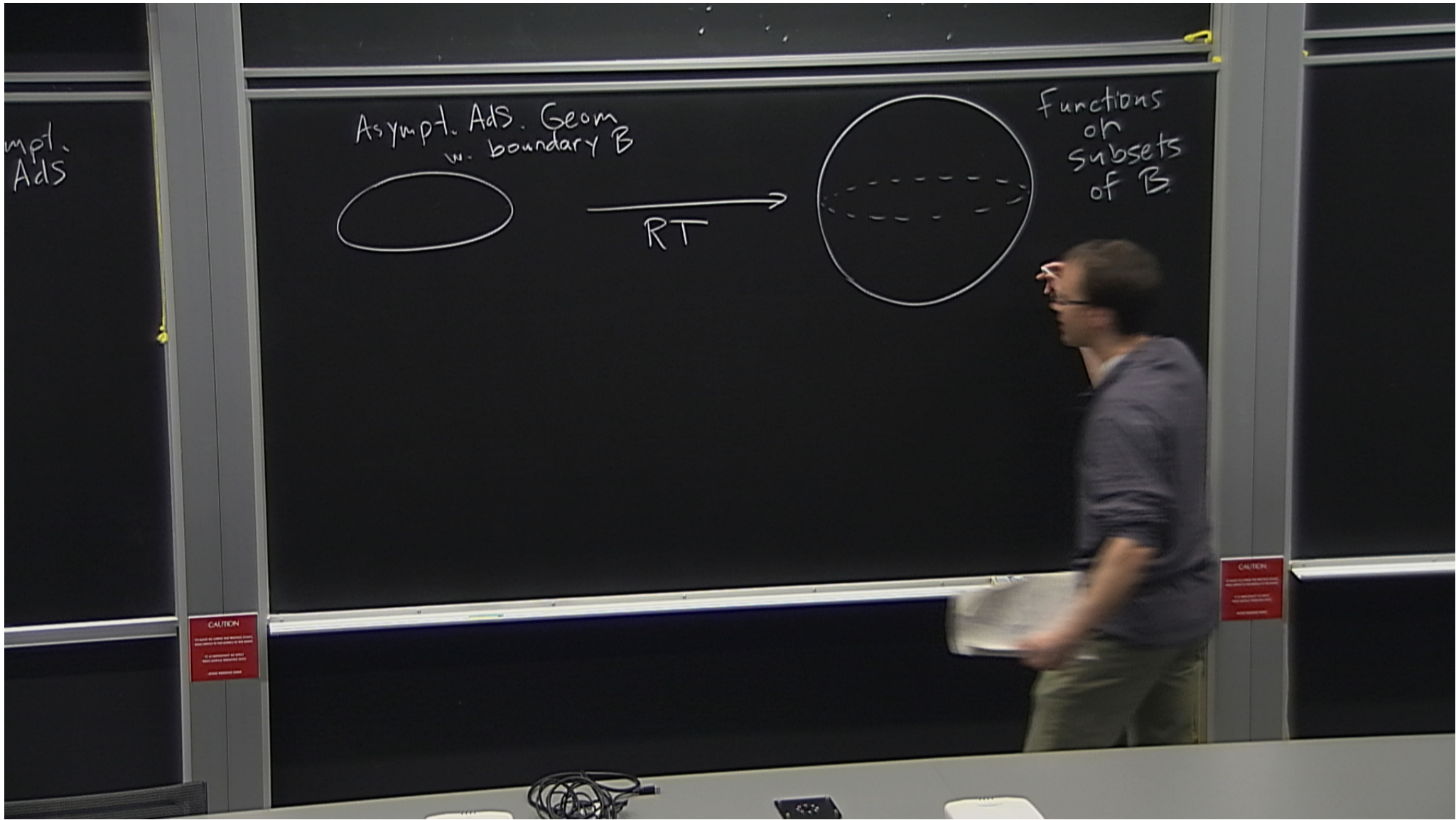
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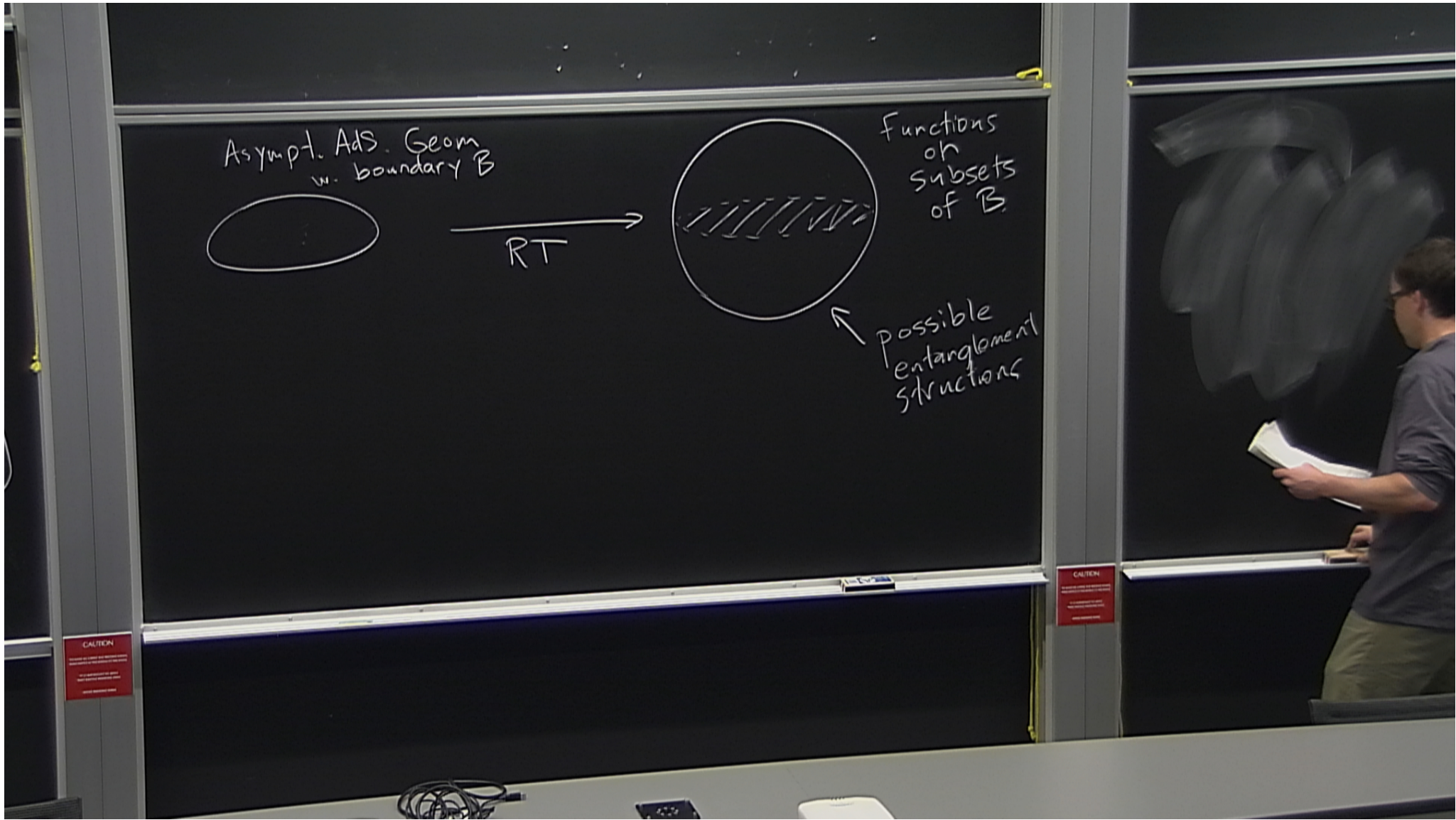
$$S(A) = \frac{\text{Area}(\bar{A})}{4G_N}$$

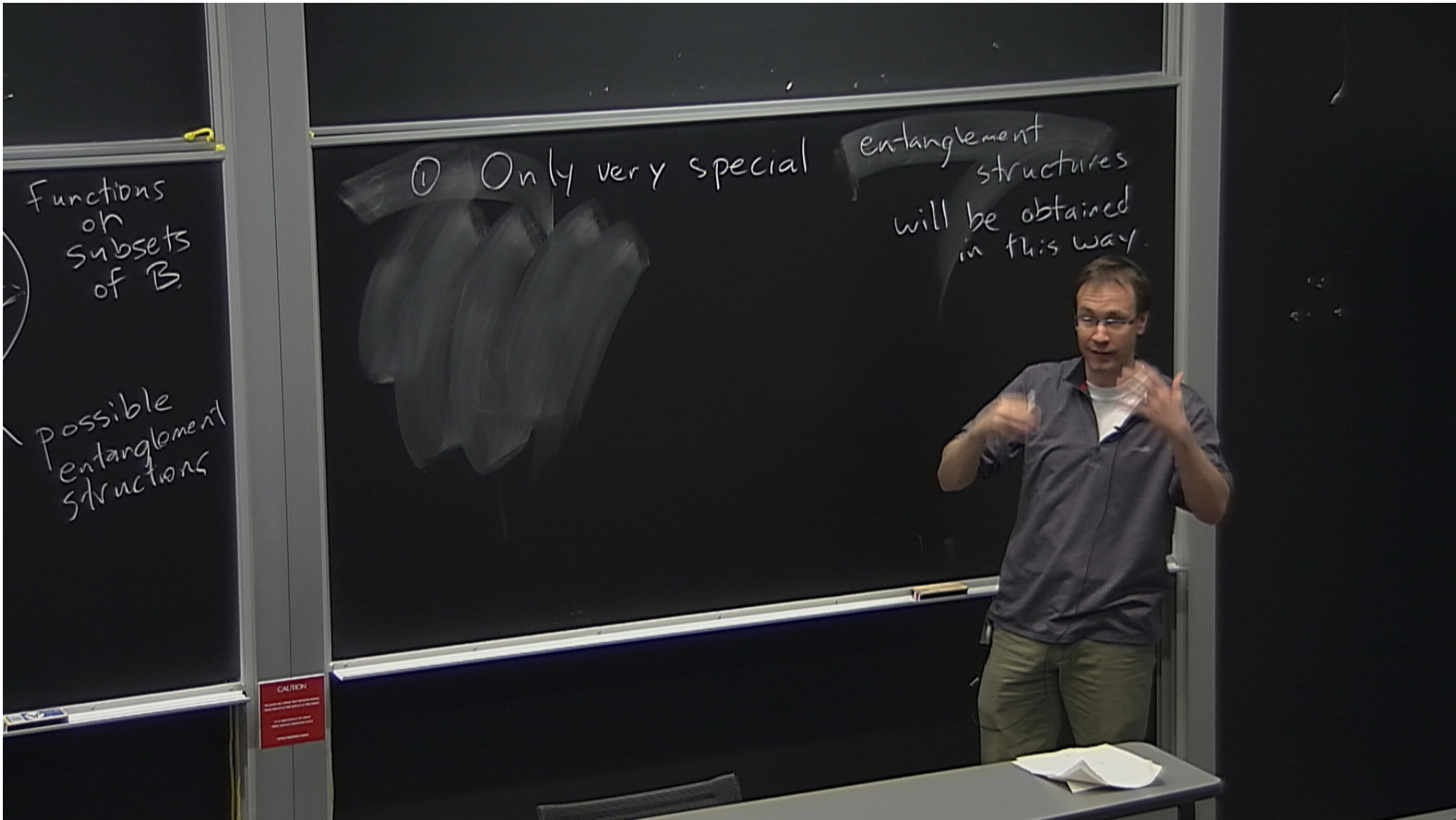










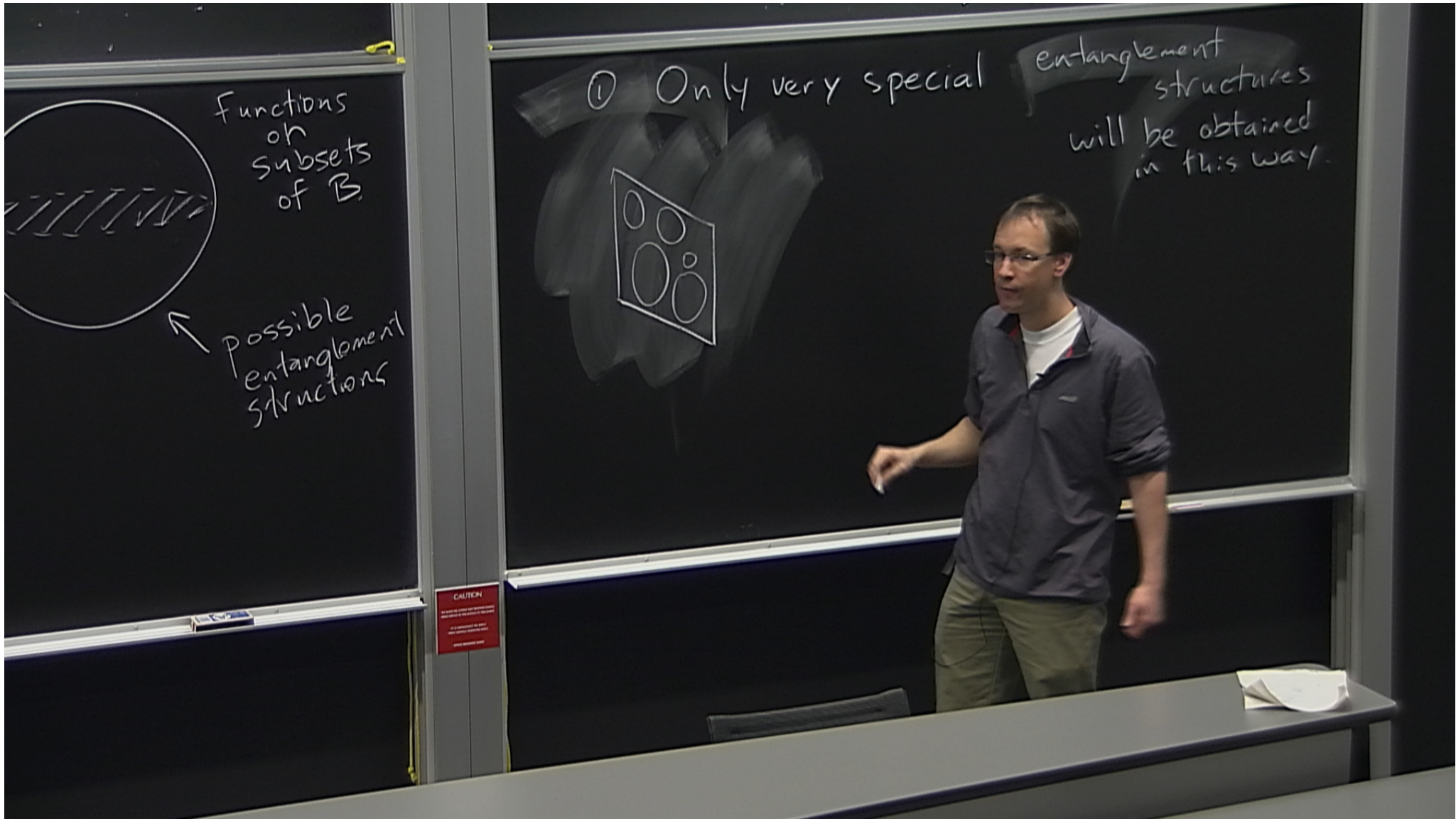


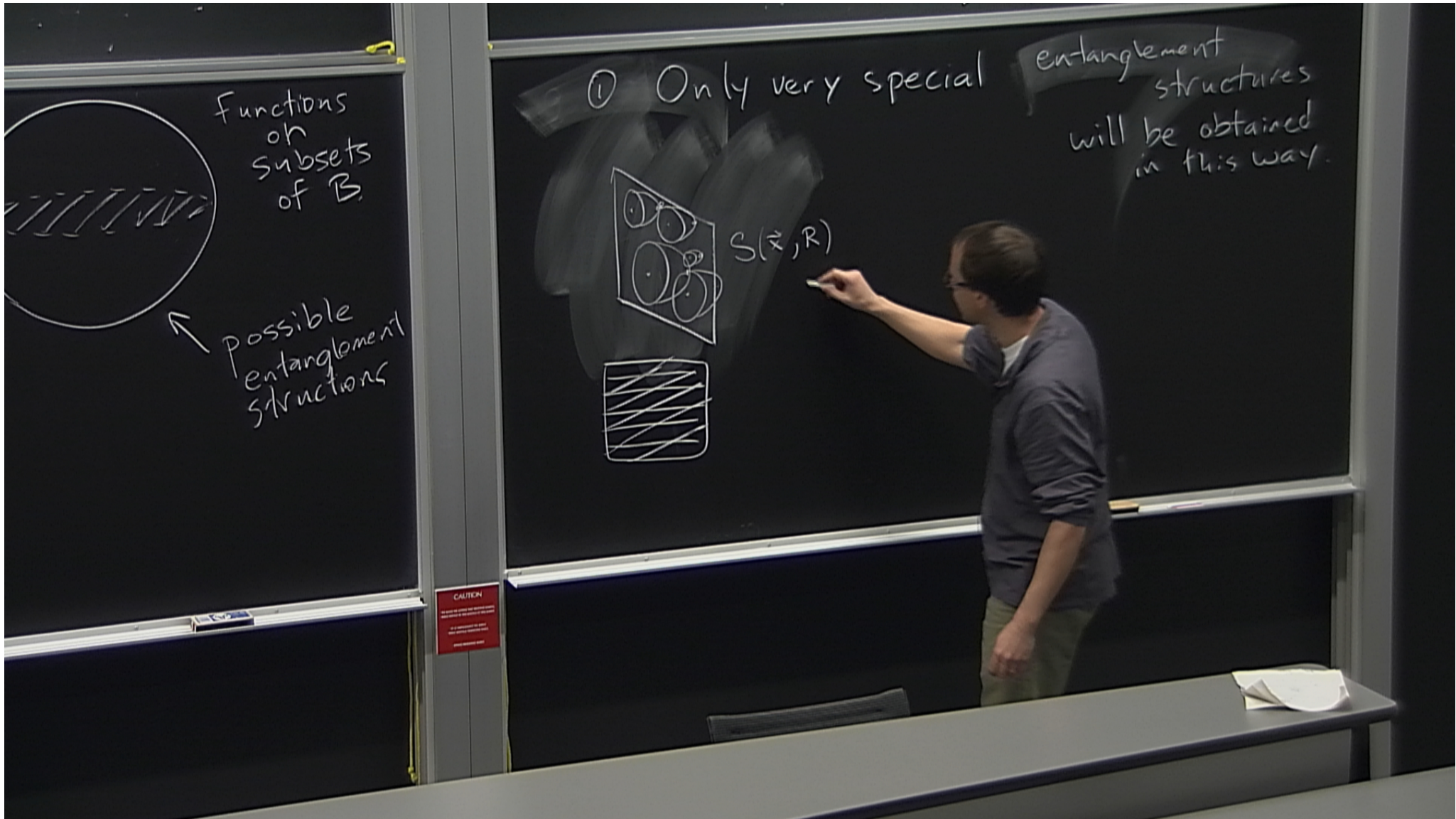
Functions on subsets of B .

Possible entanglement structures

① Only very special

entanglement structures will be obtained in this way.

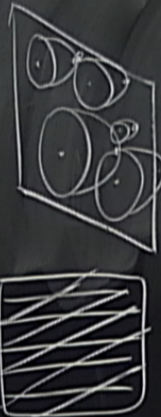




Functions on subsets of B.

possible entanglement structures

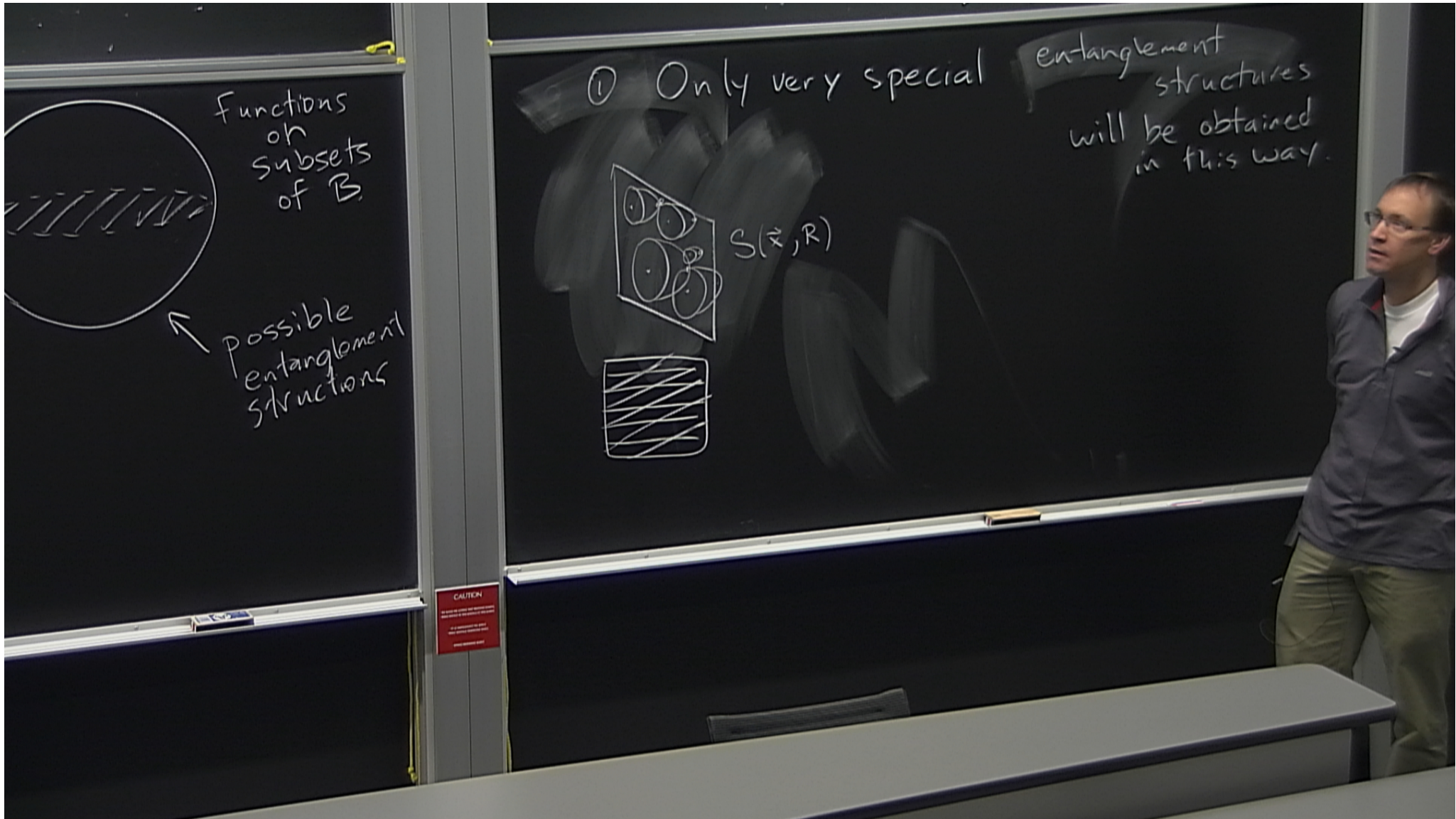
① Only very special



$S(x, R)$

entanglement structures will be obtained in this way.

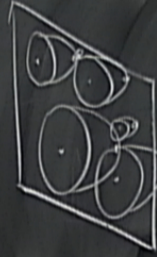
CAUTION



Functions on subsets of B .

possible entanglement structures

① Only very special

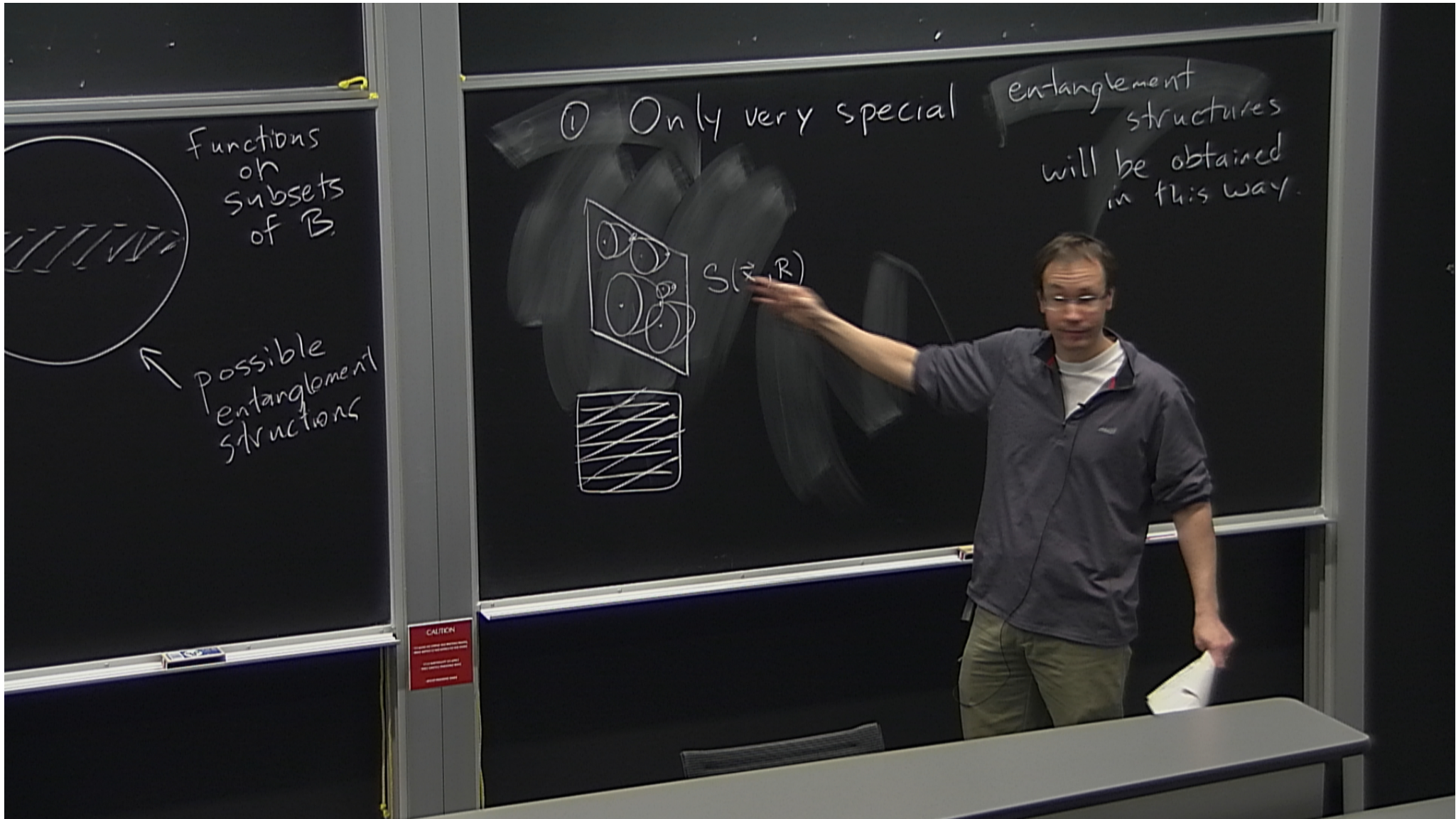


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entanglement structures will be obtained in this way.

CAUTION



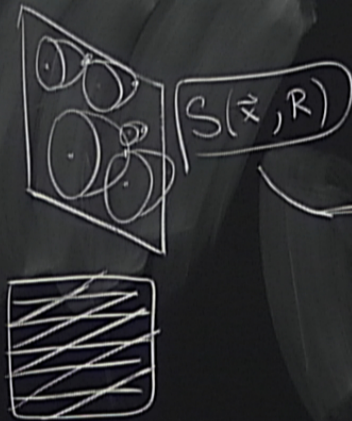


Functions
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$$M \rightarrow S(A)$$

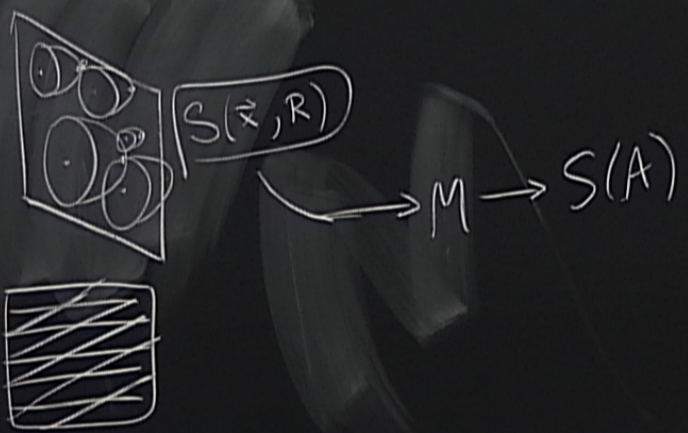
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CAUTION
Do not touch the blackboard
with your hands or feet.
Do not use the blackboard
as a desk or table.

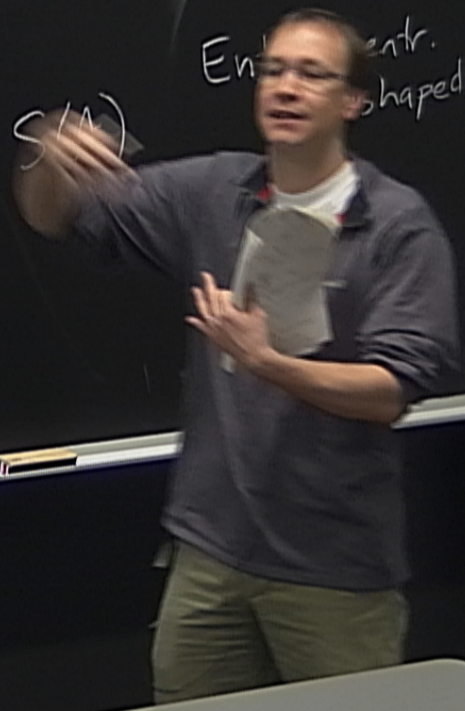
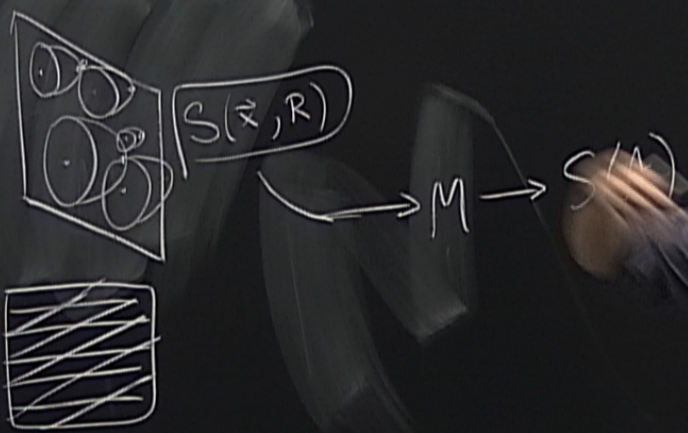
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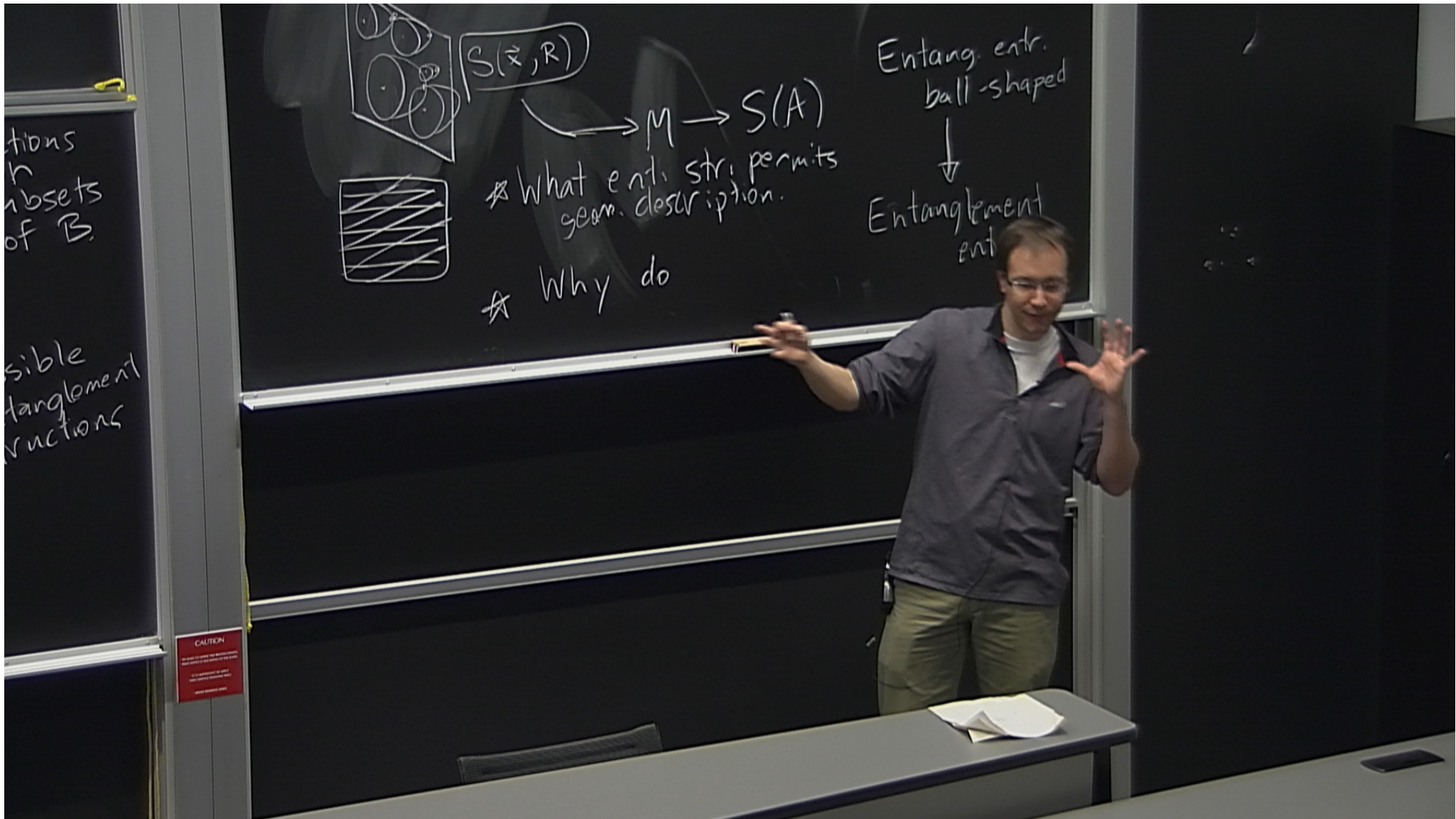
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in this way.

Entangl.
shaped



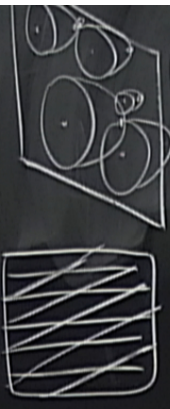
CAUTION





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$$S(\vec{x}, R)$$

$$M \rightarrow S(A)$$

- * What ent. str. permits geom. description.
- * Why do

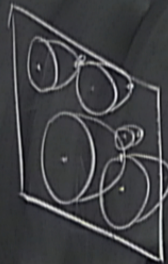
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Entanglement
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CAUTION
DO NOT TOUCH THE BOARD SURFACE
OR THE BOARD FRAME
OR THE BOARD MOUNTING
OR THE BOARD WIRING

① Only very special

entanglement structures will be obtained in this way.



$S(\mathbb{R}, \mathbb{R})$

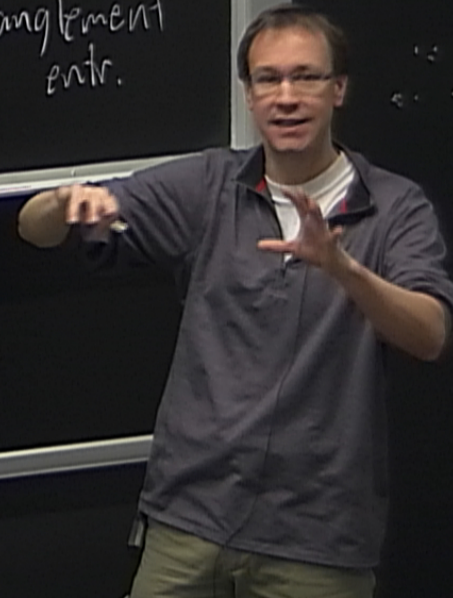
$M \rightarrow S(A)$

* What ent. str. permits geom. description.

* Why do ho

Entang. entr. ball-shaped

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Entanglement entr.



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entanglement structures will be obtained in this way.



$S(\vec{x}, R)$

$M \rightarrow S(A)$

* What ent. str. permits geom. description.

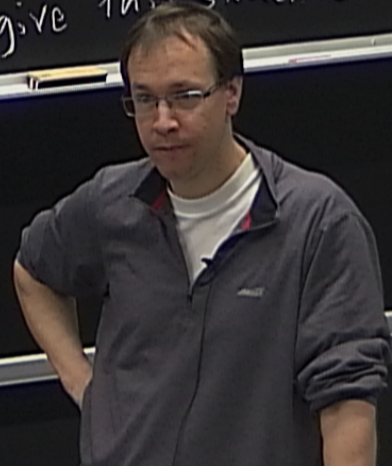
* Why do holographic H's give this structure.

Entang. entr. ball-shaped

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Entanglement entr.

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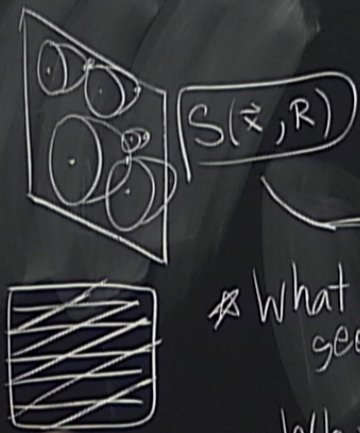


Functions on subsets of B

possible entanglement structures

① Only very special

entanglement structures will be obtained in this way.



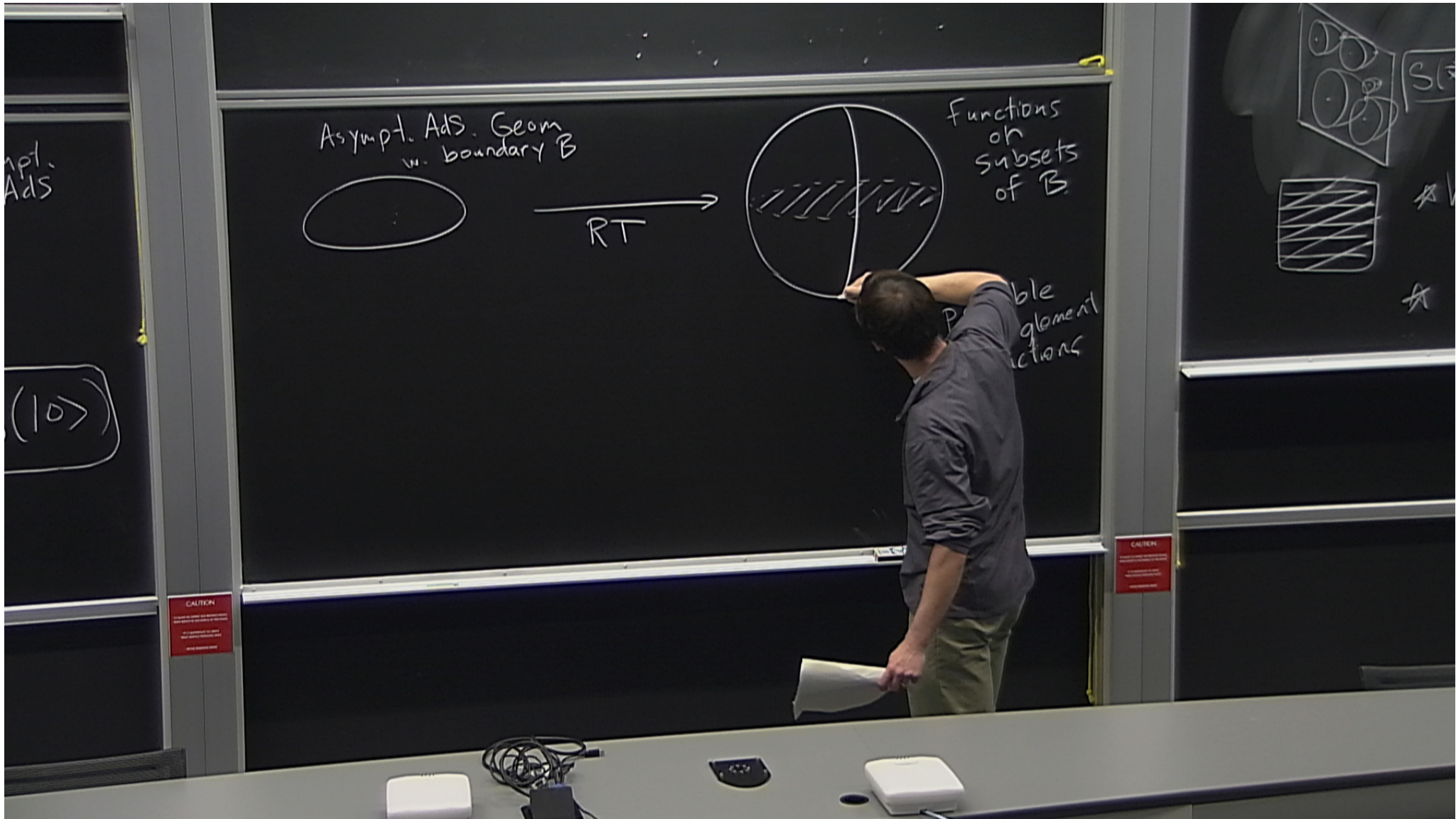
$$M \rightarrow S(A)$$

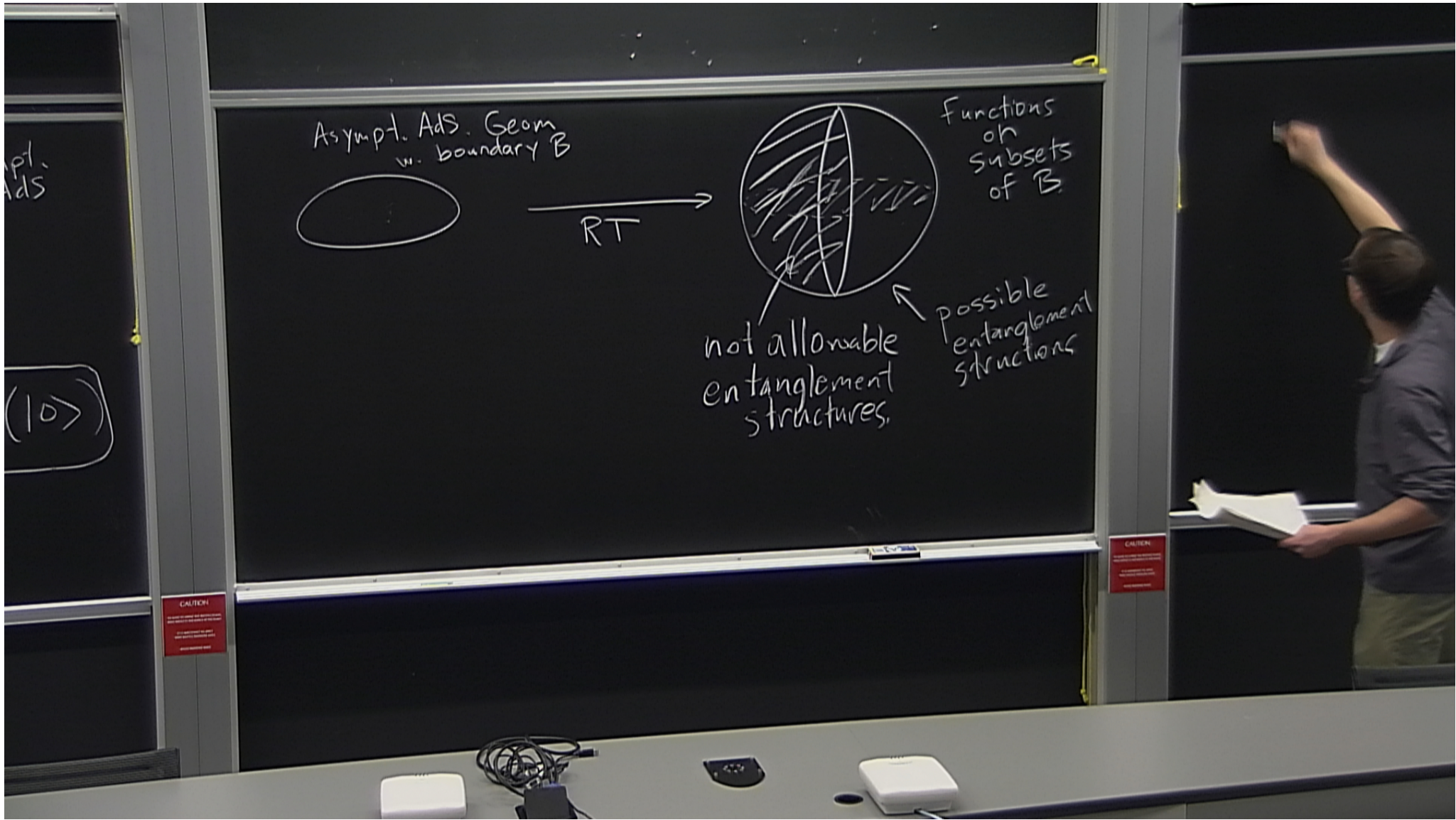
* What ent. str. permits geom. description.

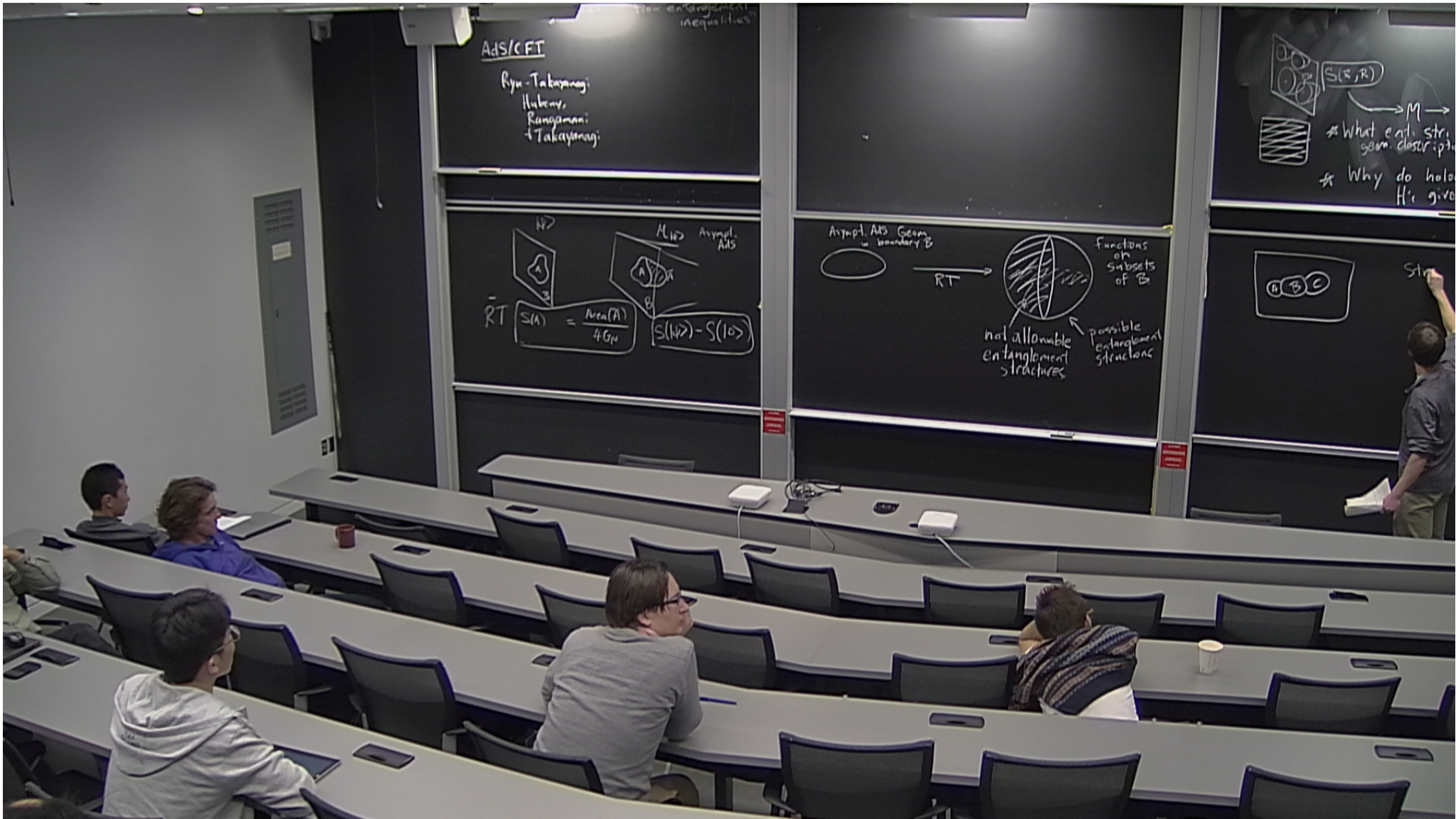
* Why do holographic H's give this structure.

Entang. entr. ball-shaped

Entanglement entr.

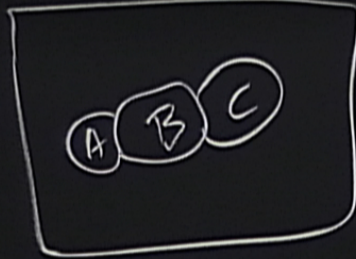






Functions
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Subsets
of B .

Possible
entanglement
structures



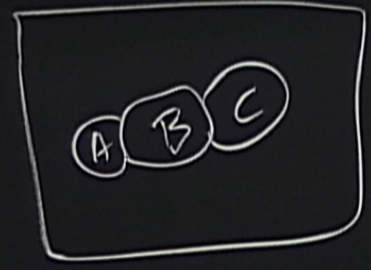
Strong subadditivity

$S(A|B)$

CAUTION
DO NOT TOUCH THE BOARD
OR THE BOARDER
AS IT MAY BE HOT
OR OTHERWISE DAMAGED

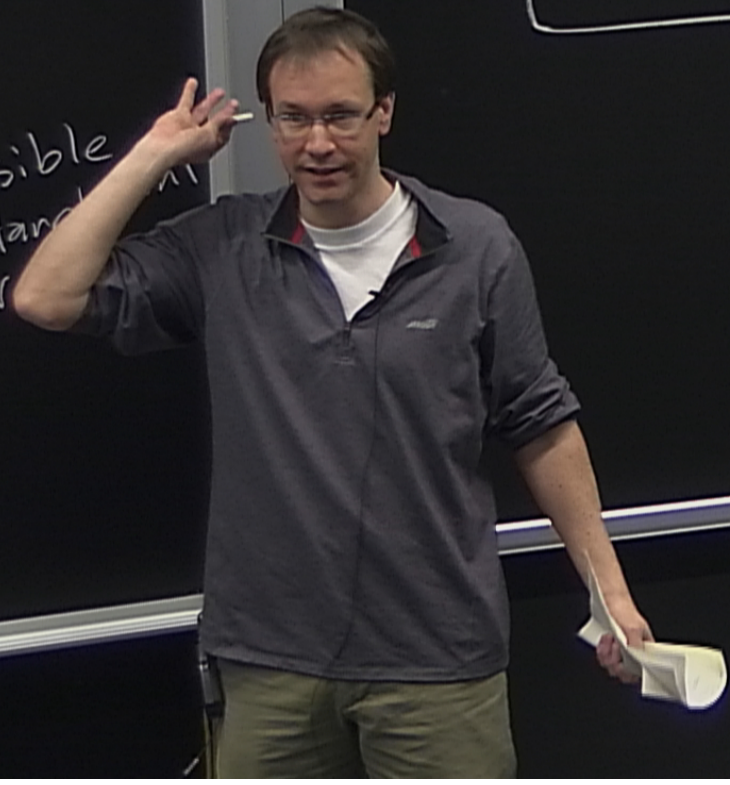
functions
on
subsets
of B .

possible
entanglements



Strong subadditivity

$$S(A \cup B) + S(B \cup C) \geq S(B) + S(A \cup B \cup C)$$



$|\psi\rangle$

$M|\psi\rangle$ Asympt. Ads

$S(A) = \frac{\text{Area}(\tilde{A})}{4G_N}$

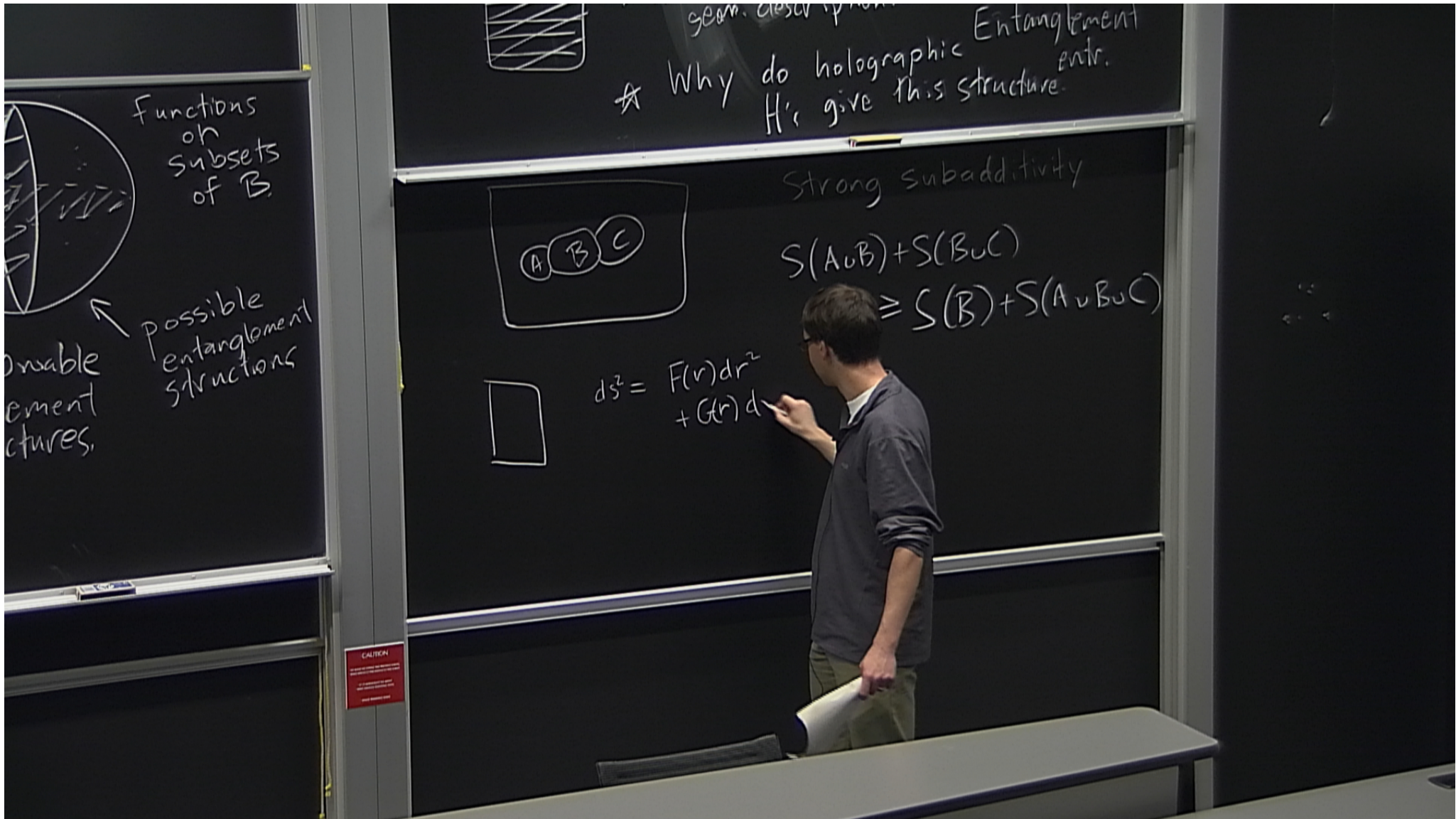
$S(|\psi\rangle) - S(|\phi\rangle)$

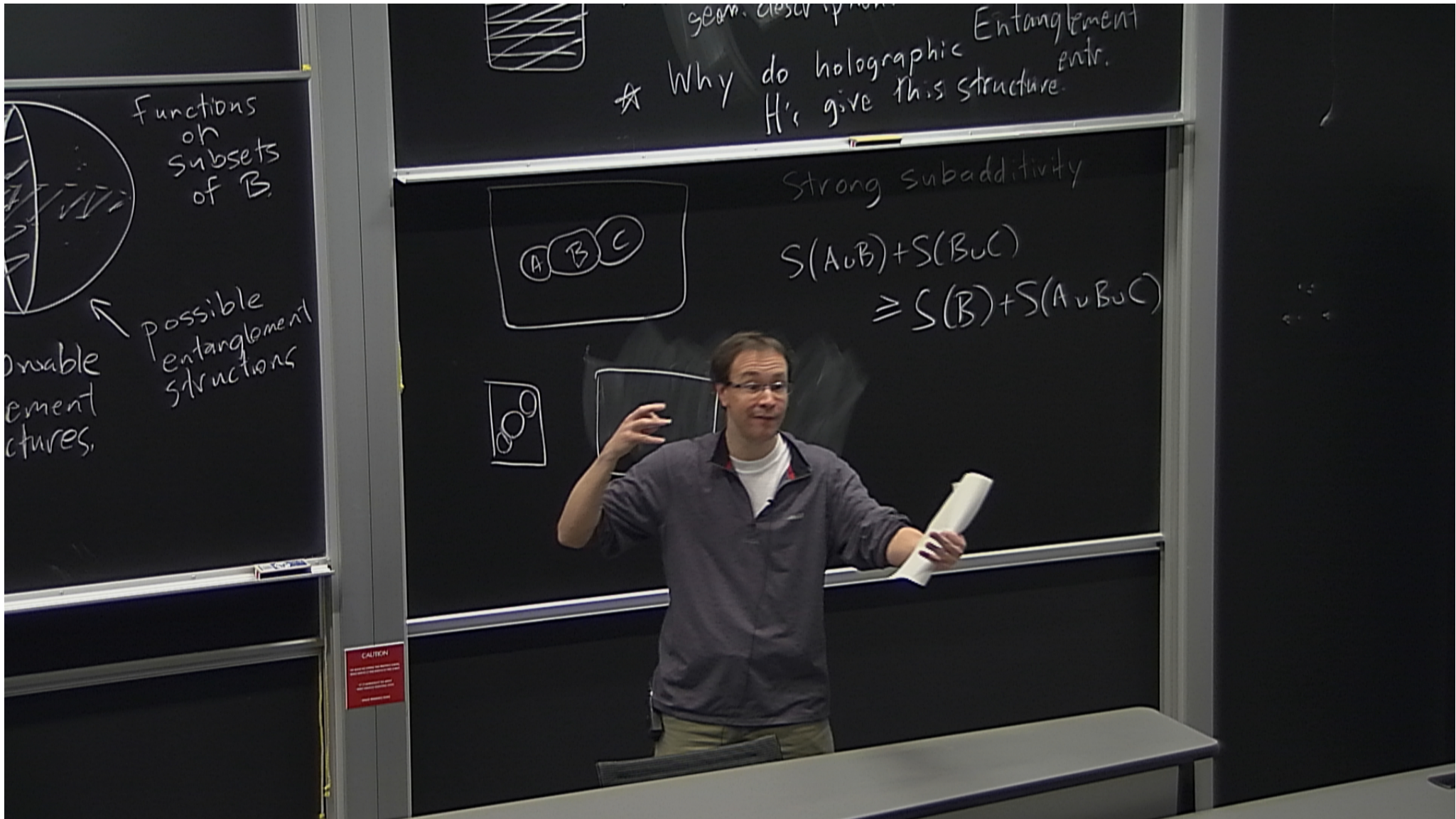
Asympt. Ads. Geom
 w. boundary B

non-physical

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CAUTION
 PLEASE DO NOT TOUCH THE BOARD SURFACE
 AND AVOID THE AREA OF THE BOARD SURFACE
 AT ALL TIMES TO AVOID INJURY.

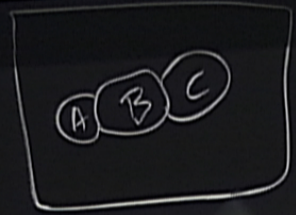




geom. description
★ Why do holographic
H's give this structure. Entanglement
entr.

Functions
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subsets
of B.

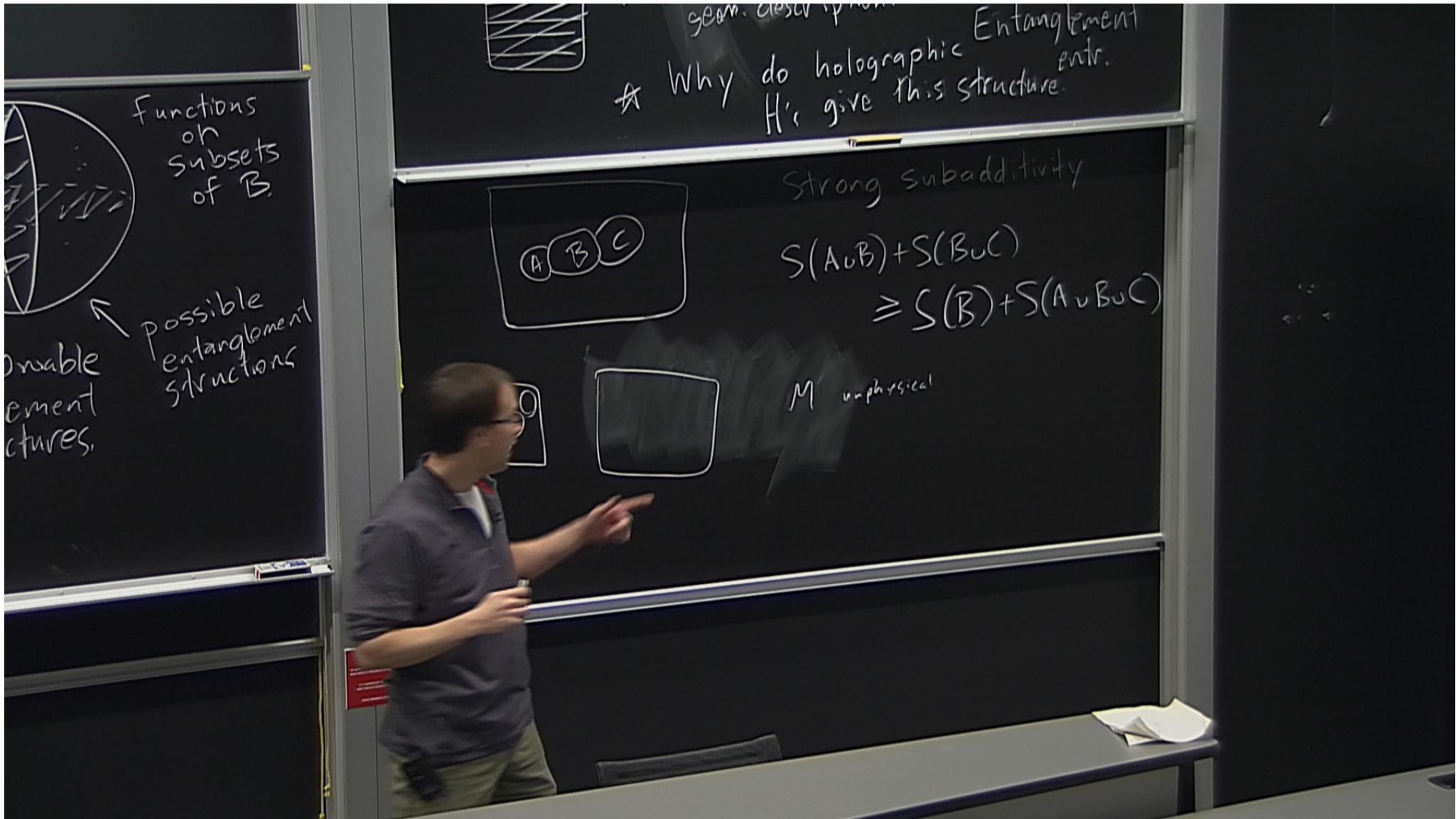
possible
entanglement
structures



Strong subadditivity

$$S(A \cup B) + S(B \cup C) \geq S(B) + S(A \cup B \cup C)$$





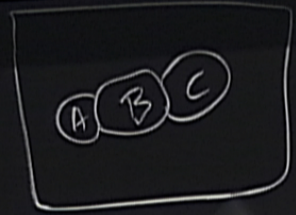
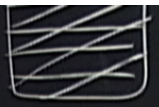
geom. description

* Why do holographic Entanglement
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Functions
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subsets
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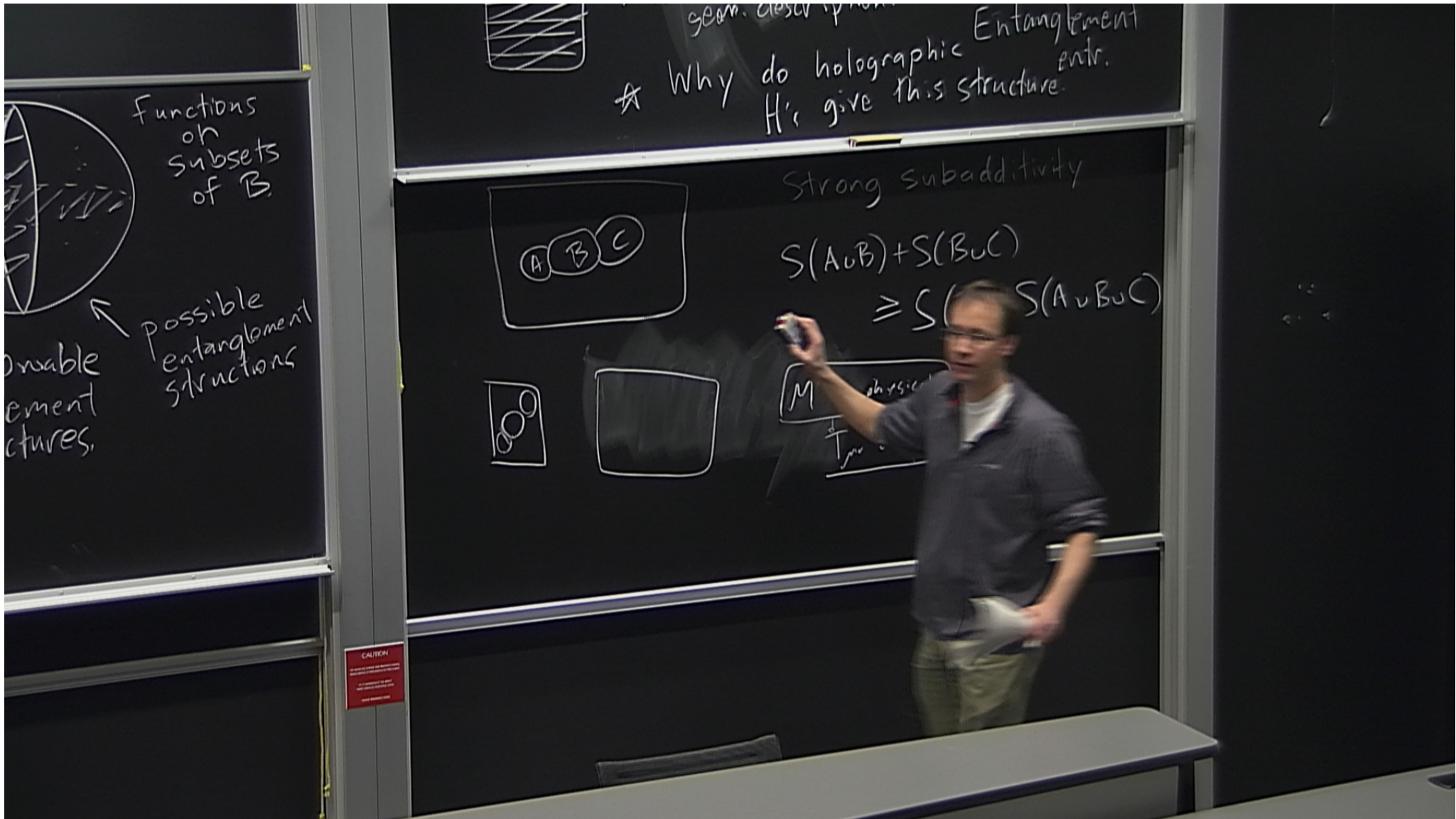


Strong subadditivity

$$S(A \cup B) + S(B \cup C) \geq S(B) + S(A \cup B \cup C)$$

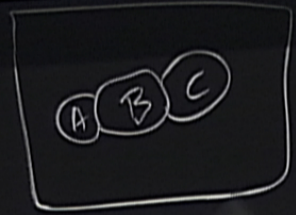


M unphysical

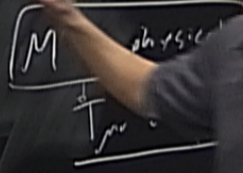


geom. description
★ Why do holographic H's give this structure? Entanglement entr.

Functions on subsets of B
possible entanglement structures



Strong subadditivity
 $S(A \cup B) + S(B \cup C) \geq S(A \cup B \cup C)$



CAUTION

Asympt.
Ads

Strong subadditivity.



$S(10)$



CAUTION
All eyes on board the lecture hall
Do not drink or eat during the lecture
Do not use mobile phones during the lecture
Do not use laptops during the lecture

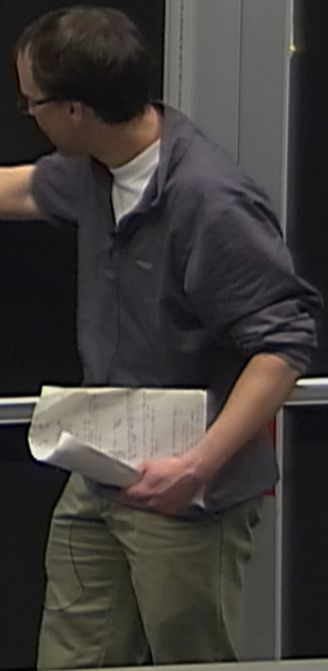
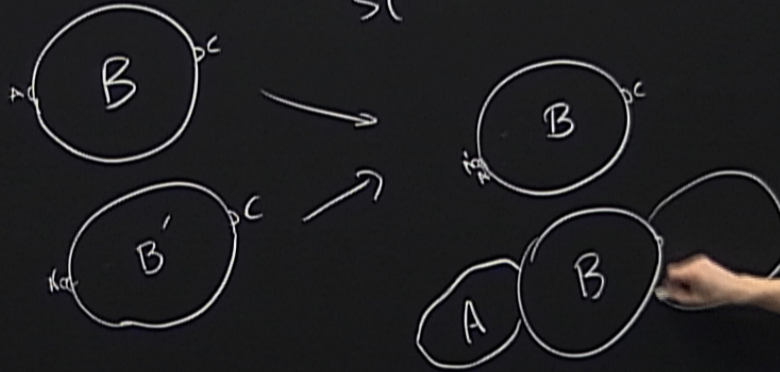
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Asympt.
Ads

$S(10)$

Strong subadditivity.

SC



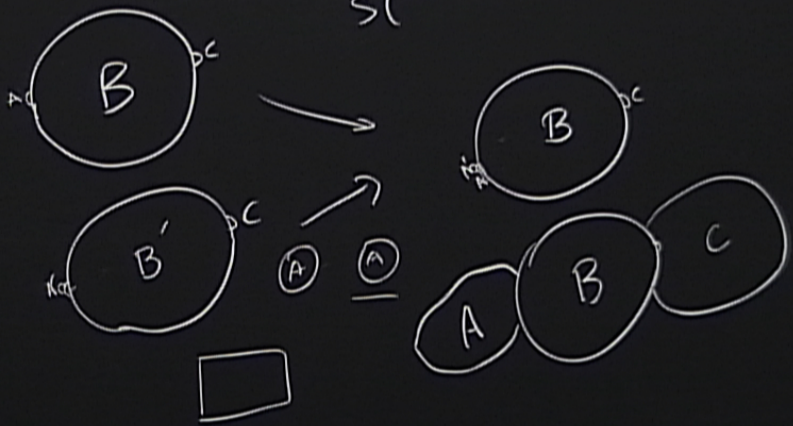
CAUTION

Asympt.
Ads

$S(10)$

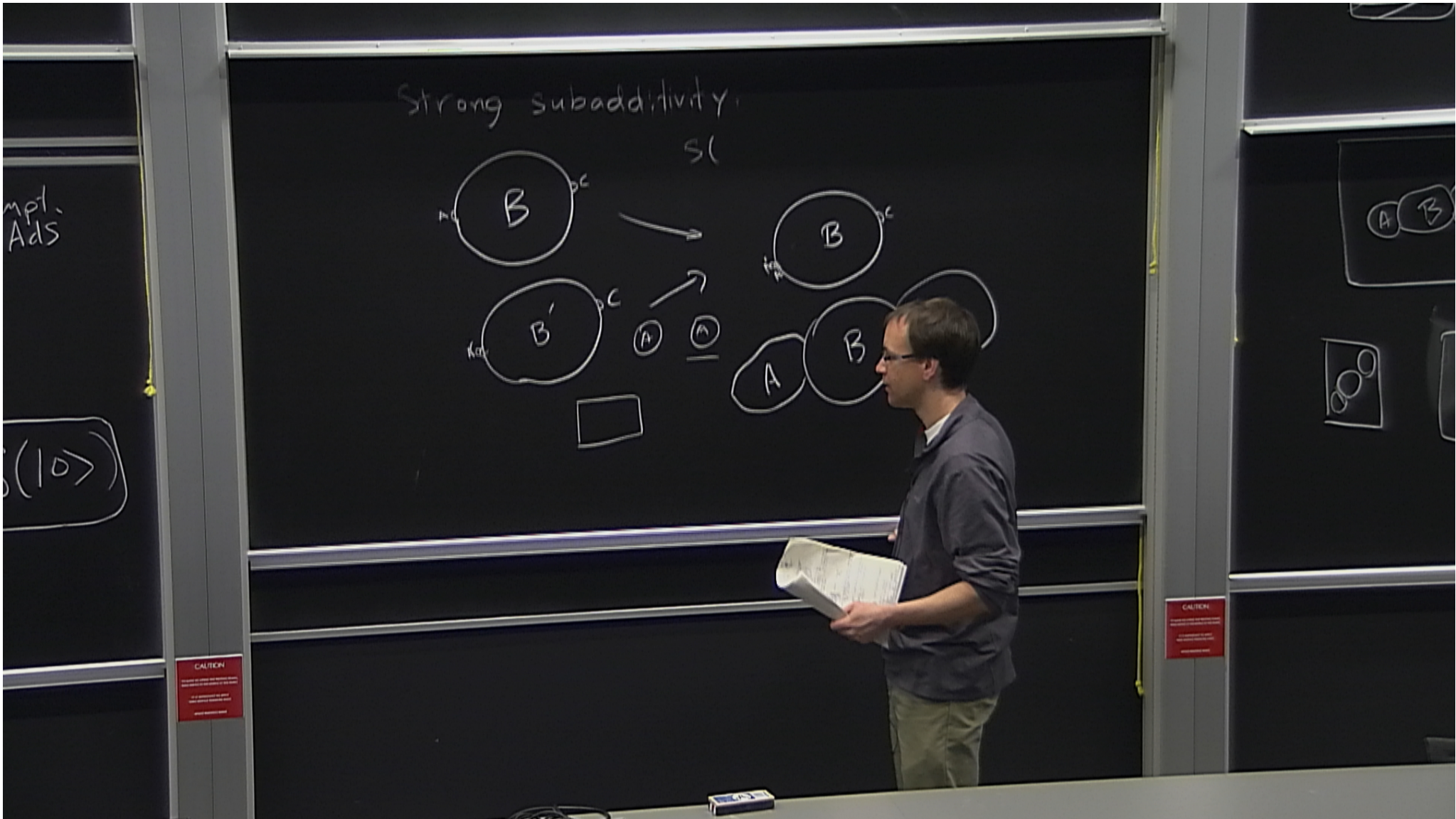
Strong subadditivity.

SC

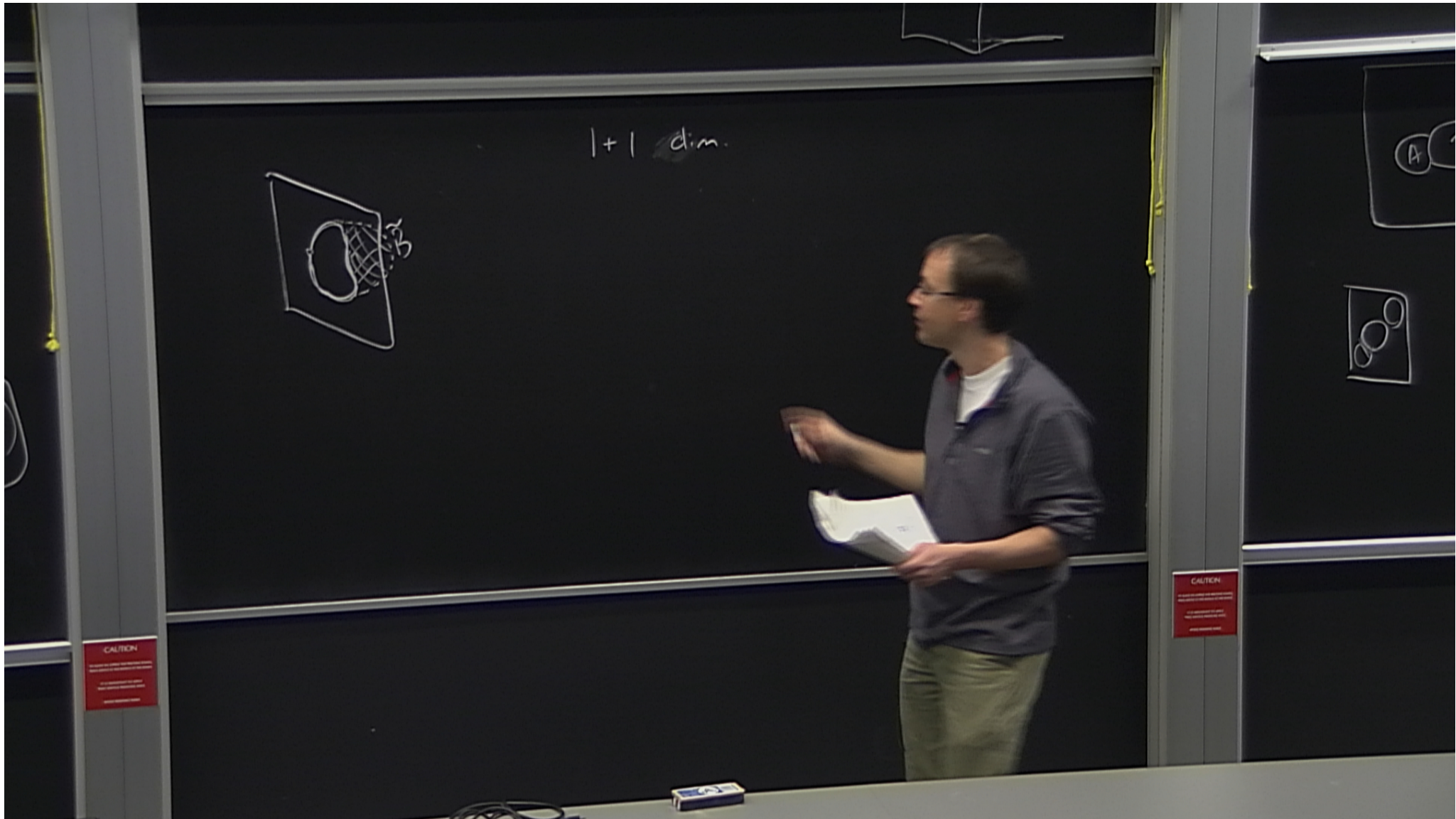


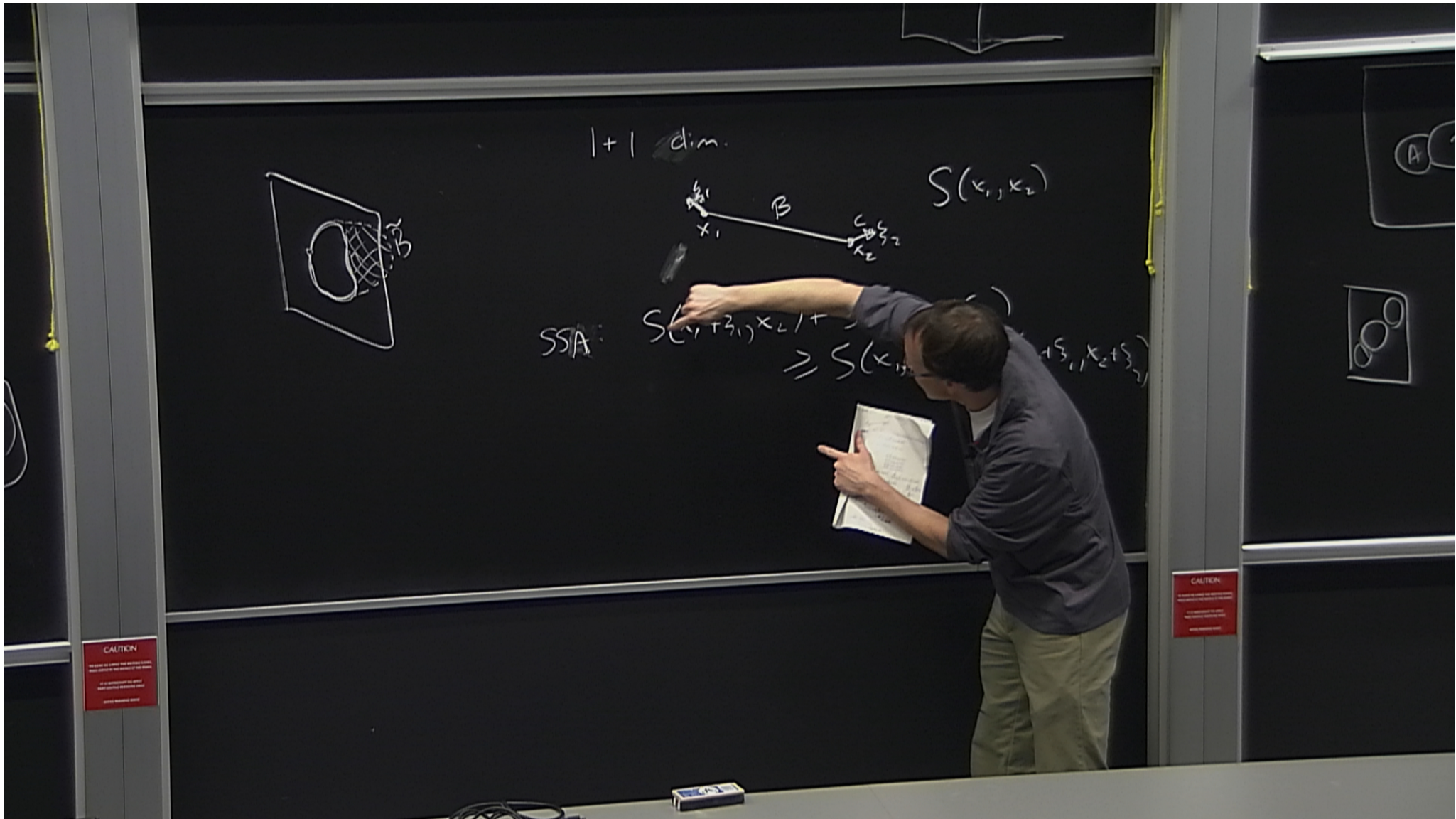
CAUTION

CAUTION



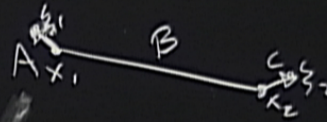






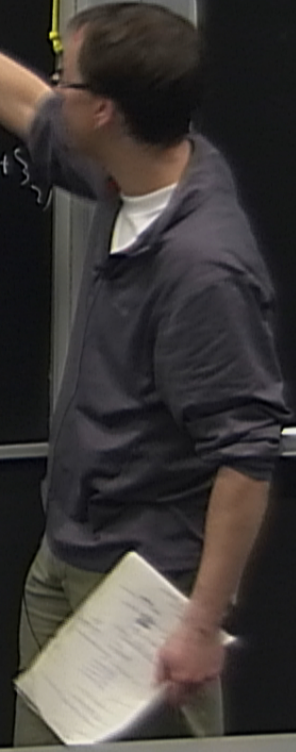


1+1 dim.

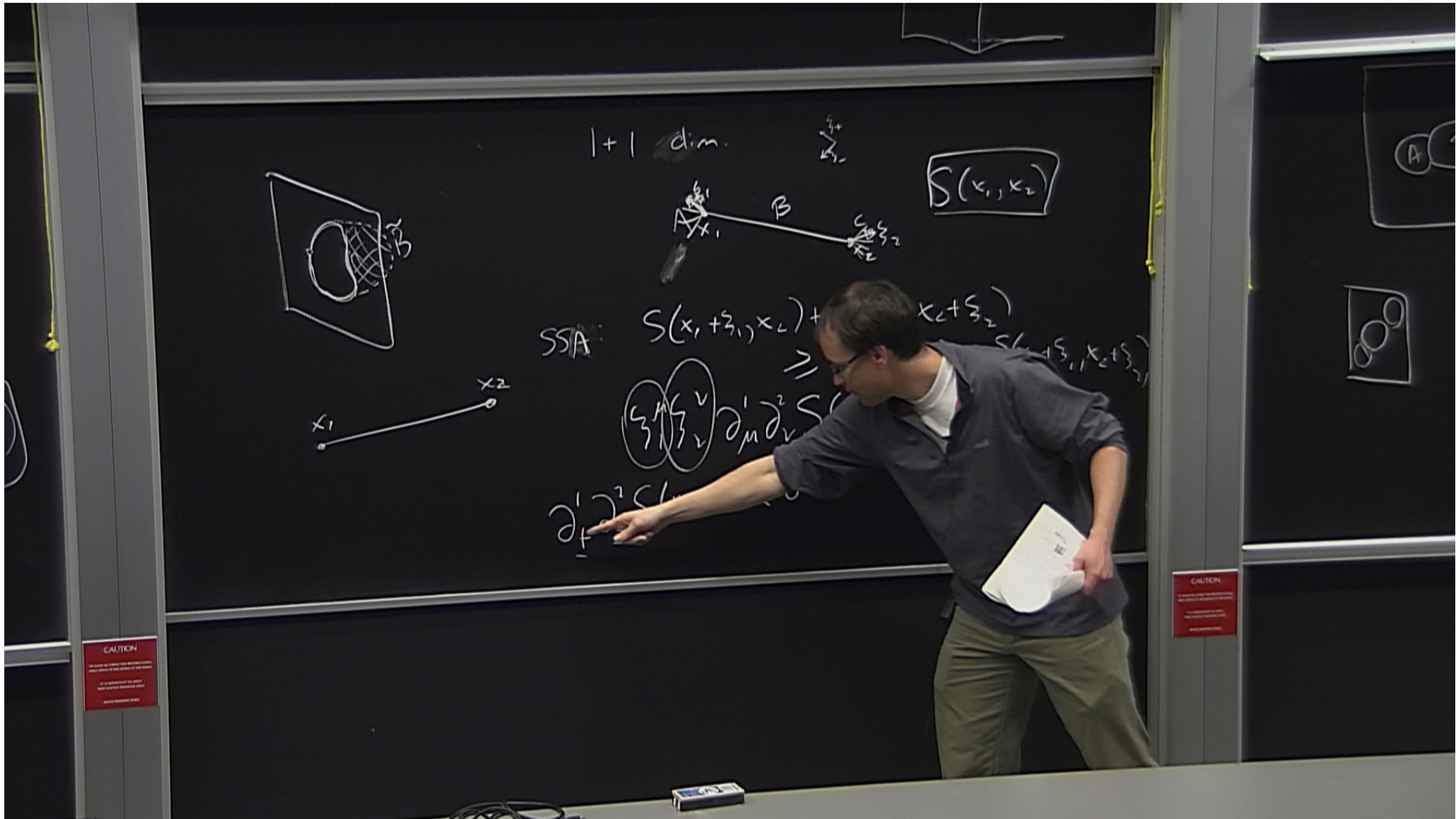


$S(x_1, x_2)$

SSA: $S(x_1 + \delta_1, x_2) + S(x_1, x_2 + \delta_2)$
 $\geq S(x_1, x_2) + S(x_1 + \delta_1, x_2 + \delta_2)$
 $\sum_{i,j} \delta_i \delta_j \partial_i \partial_j S(x_1, x_2) \leq 0$



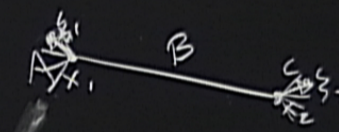
CAUTION
 THE BOARD IS A HEAVY GLASS PANEL
 WHICH SHOULD BE TREATED WITH CARE
 TO AVOID BREAKAGE AND INJURY
 PLEASE REPORT ANY DAMAGE TO THE
 MAINTENANCE DEPARTMENT





1+1 dim.

$\begin{matrix} \xi_1 \\ \xi_2 \end{matrix}$



$$S(x_1, x_2)$$

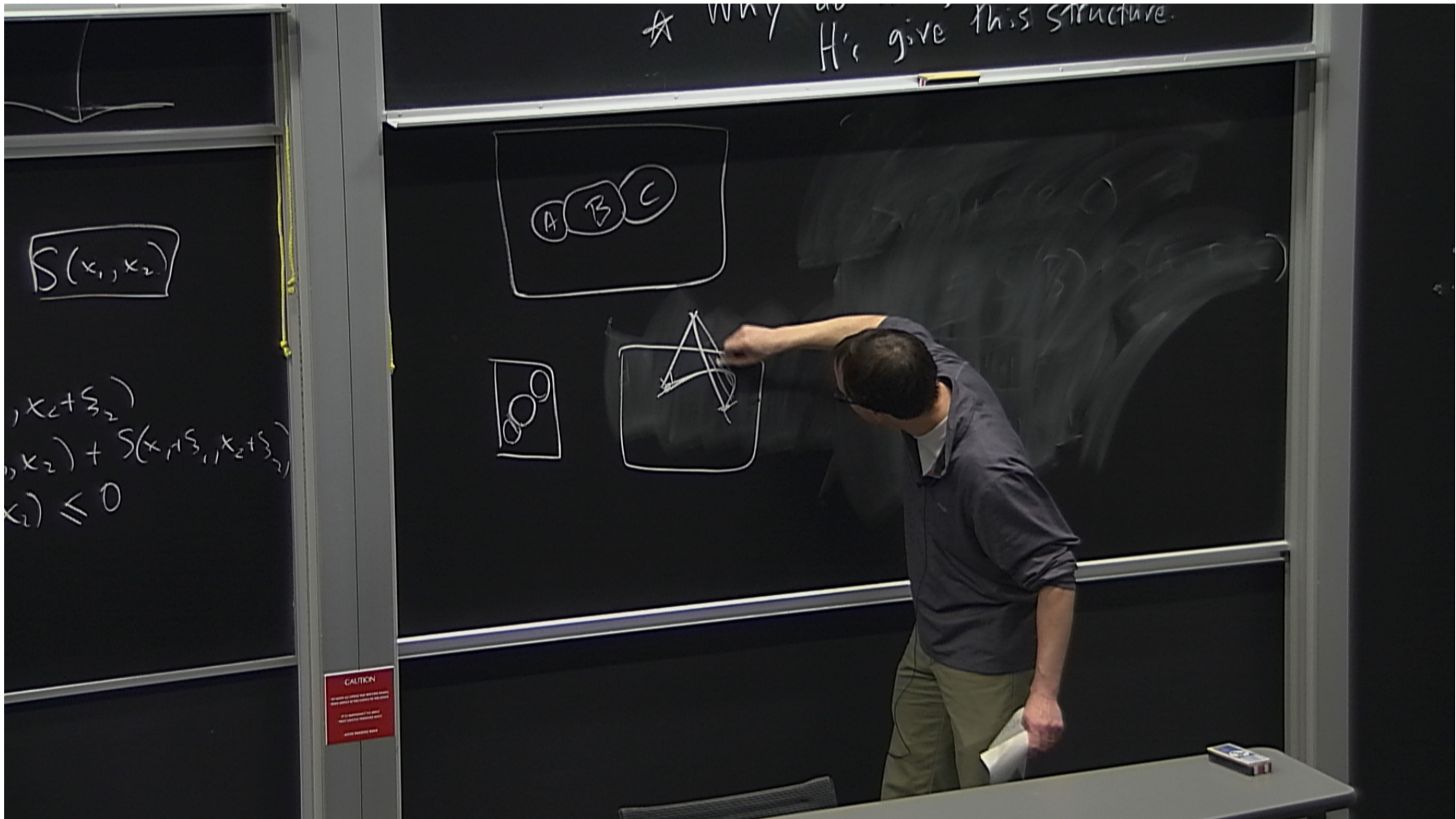
SSA: $S(x_1 + \xi_1, x_2) + S(x_1, x_2 + \xi_2) \geq S(x_1, x_2) + S(x_1 + \xi_1, x_2 + \xi_2)$

$$\begin{pmatrix} \xi_1 & \xi_2 \\ \xi_1 & \xi_2 \end{pmatrix} \partial_m \partial_n S(x_1, x_2) \leq 0$$

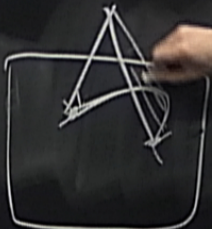
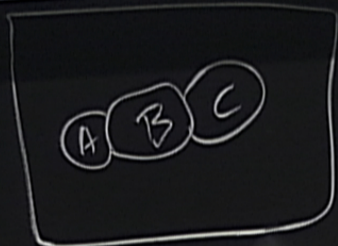
$$\partial_+^1 \partial_+^2 S(x_1, x_2) \leq 0$$

CAUTION

CAUTION



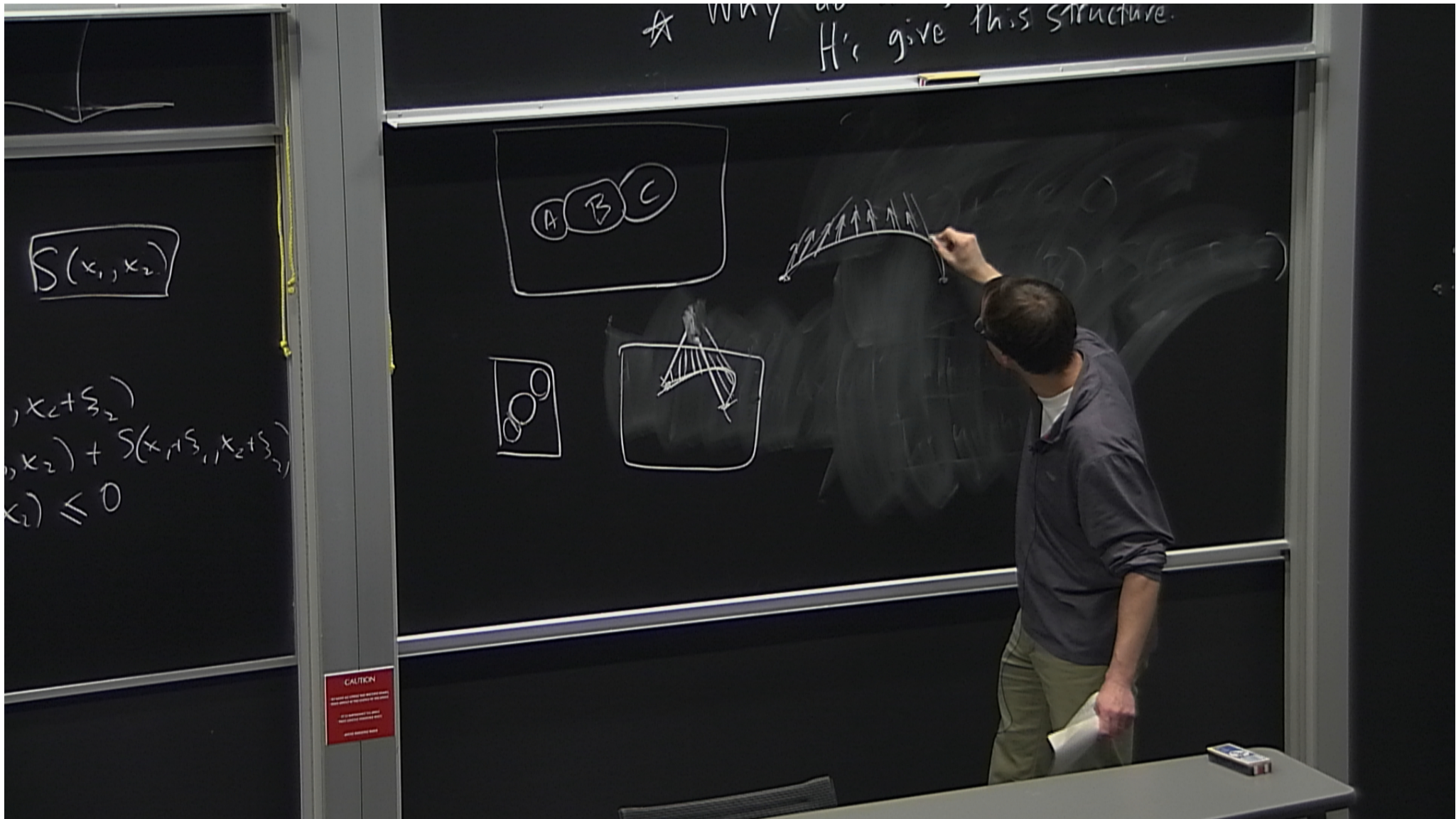
A Why do H: give this structure.



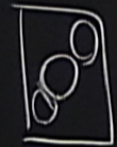
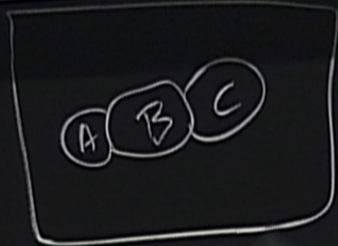
$$S(x_1, x_2)$$

$$S(x_1, x_2) + S(x_1+s_1, x_2+s_2) \leq 0$$

CAUTION



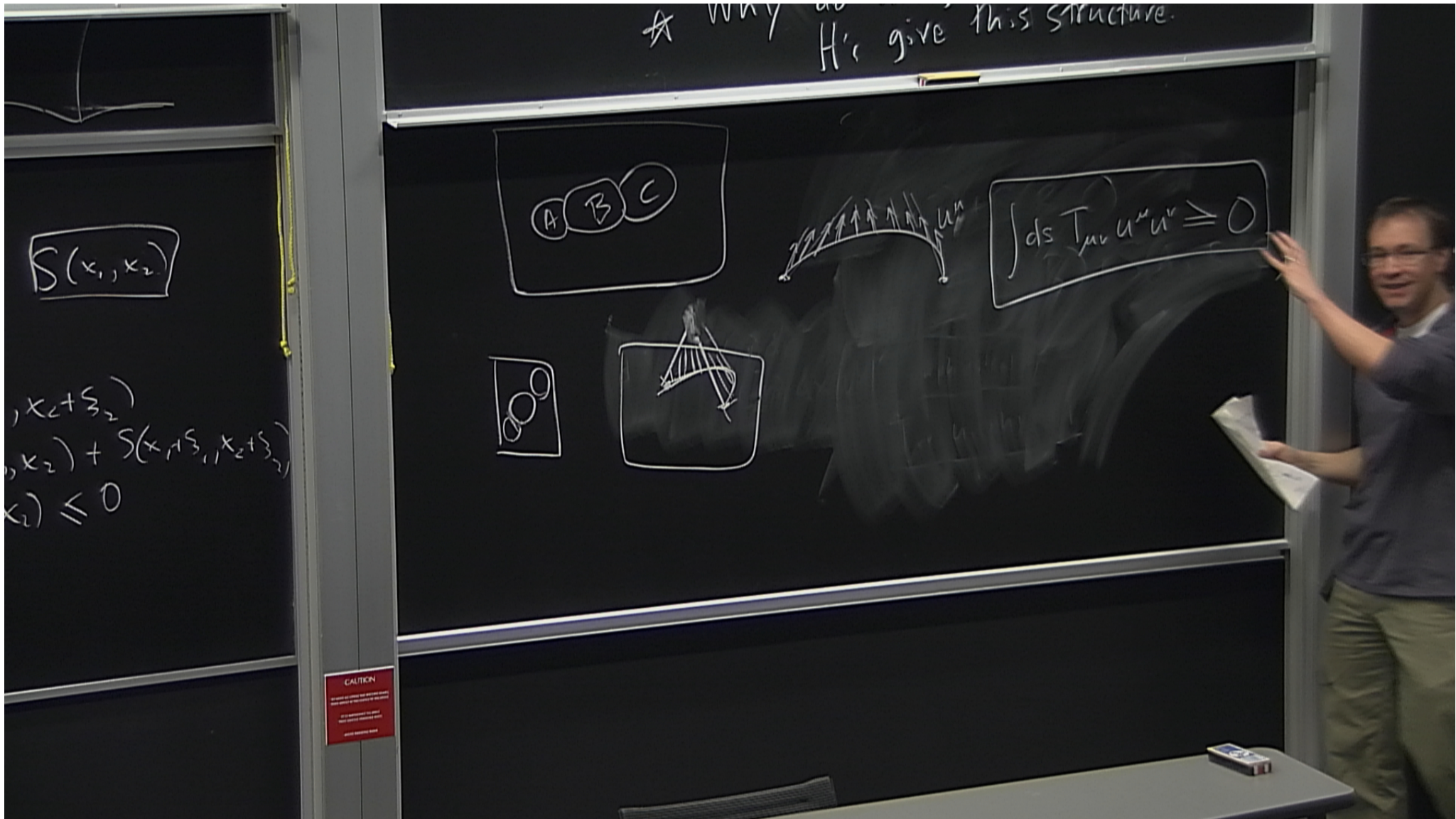
A Why do H's give this structure.



$$S(x_1, x_2)$$

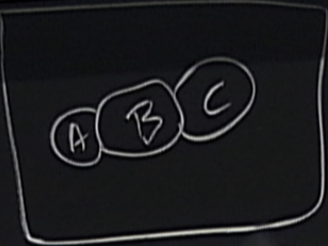
$$S(x_1, x_2) + S(x_1 + s_1, x_2 + s_2) \leq 0$$

CAUTION
DO NOT TOUCH THE BOARD
OR THE CHALK OR ERASER
OR THE CHALK OR ERASER
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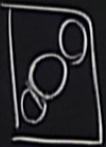


A way to give this structure.

$$S(x_1, x_2)$$

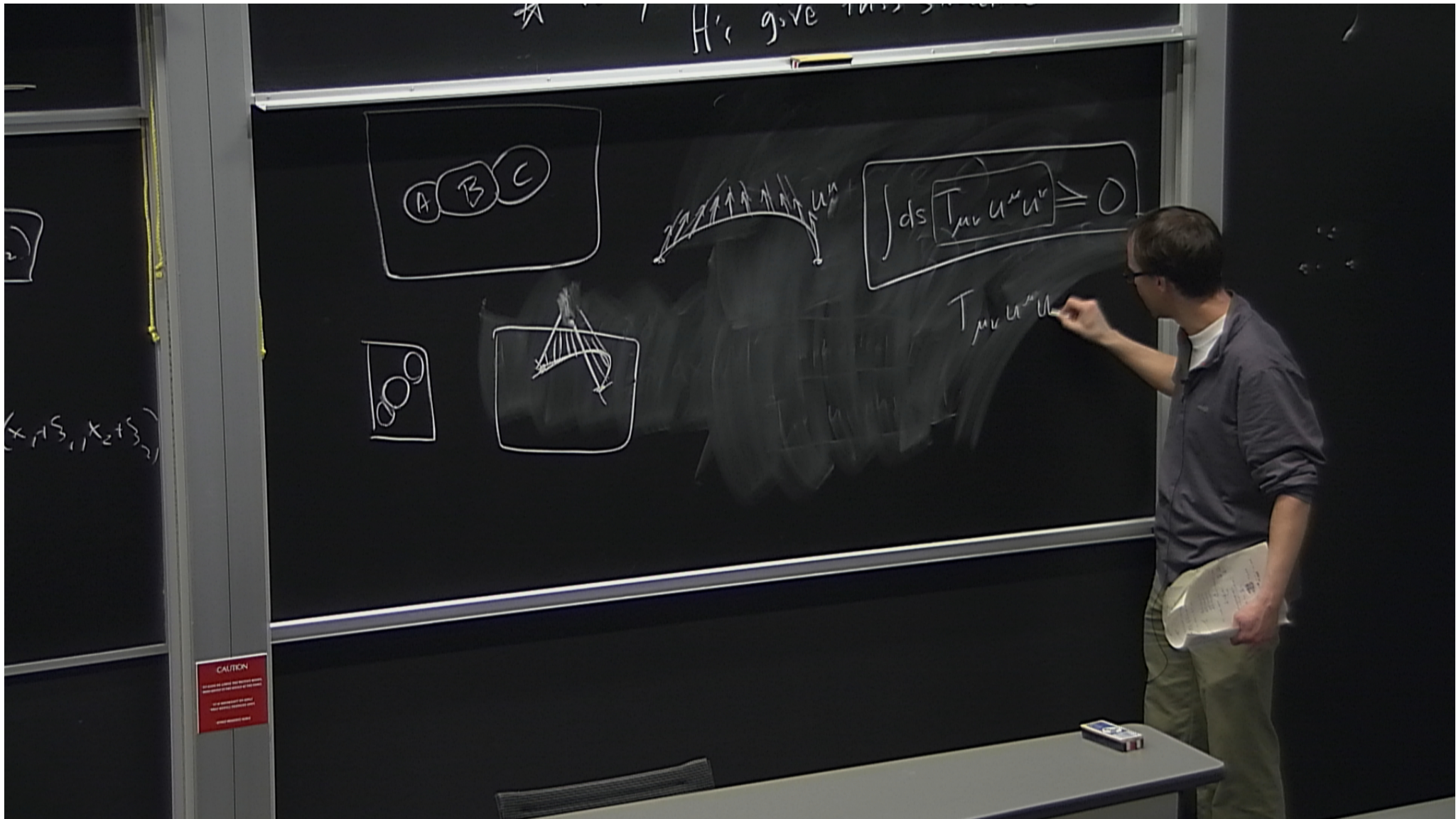


$$\int ds T_{\mu\nu} u^\mu u^\nu \geq 0$$



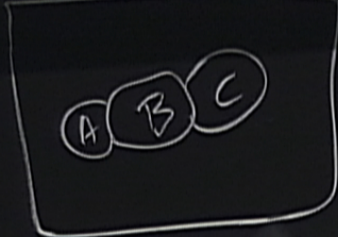
$$S(x_1, x_2) + S(x_1 + \delta x_1, x_2 + \delta x_2) \leq 0$$

CAUTION

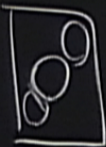


$(x_1 + s_1, x_2 + s_2)$

H: give this...

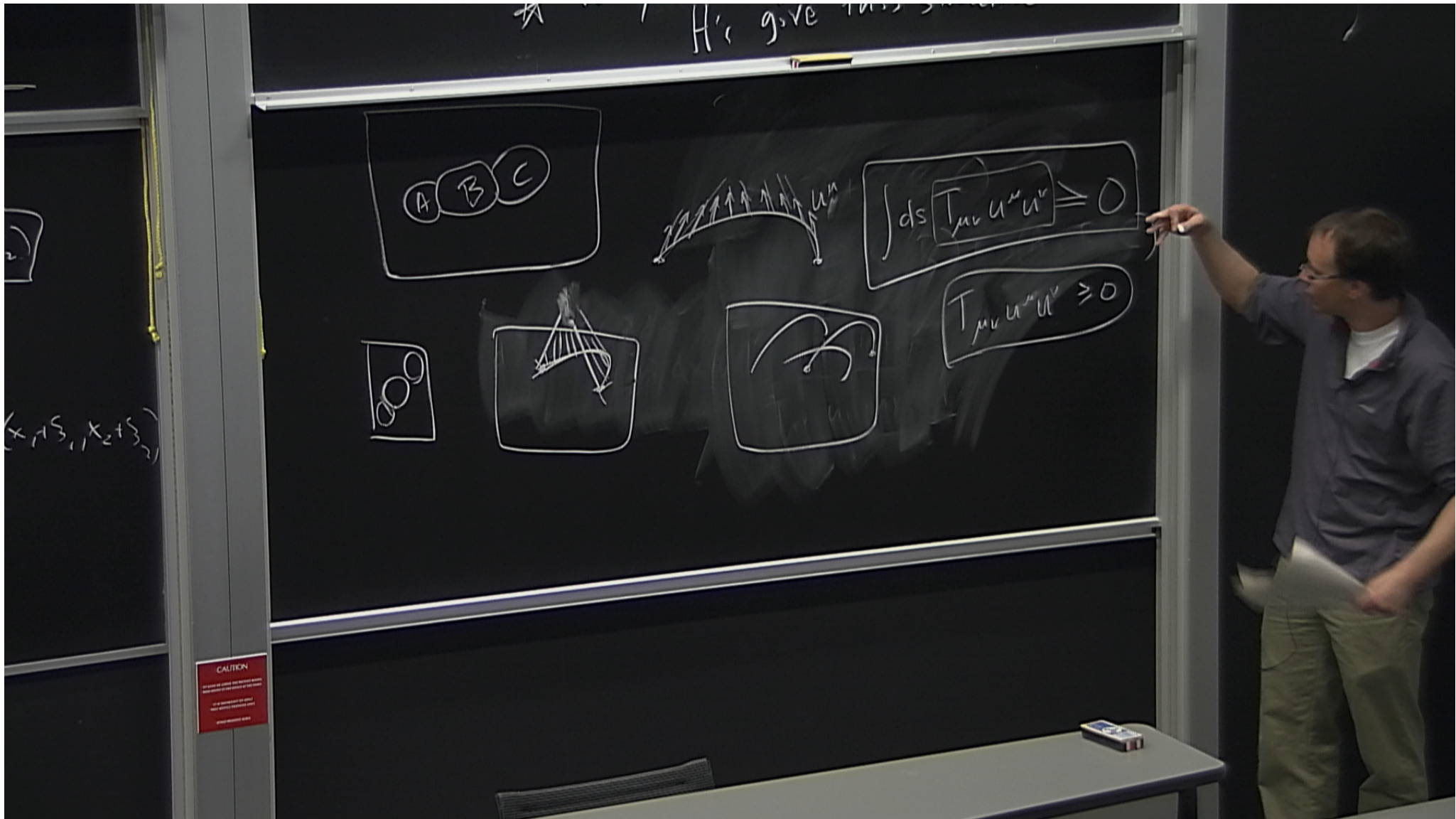


$$\int ds T_{\mu\nu} u^\mu u^\nu \geq 0$$



$$T_{\mu\nu} u^\mu u^\nu$$

CAUTION
DO NOT TOUCH THE BOARD WHEN
TEACHING IS IN PROGRESS
IF NECESSARY DO ONLY
WHAT YOU HAVE BEEN TOLD
TO DO

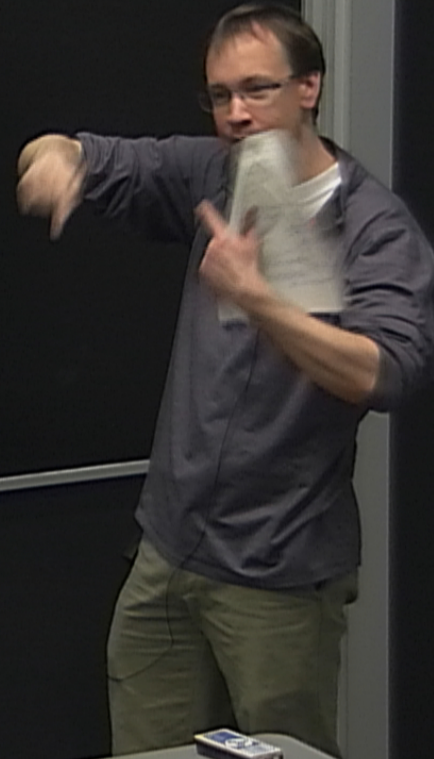
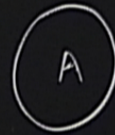
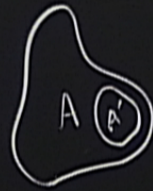




$$S(\rho \parallel \sigma) = \text{tr}(\rho \log \rho) - \text{tr}(\rho \log \sigma)$$

$$S \geq 0$$

$$S_{A'} \leq S_A$$

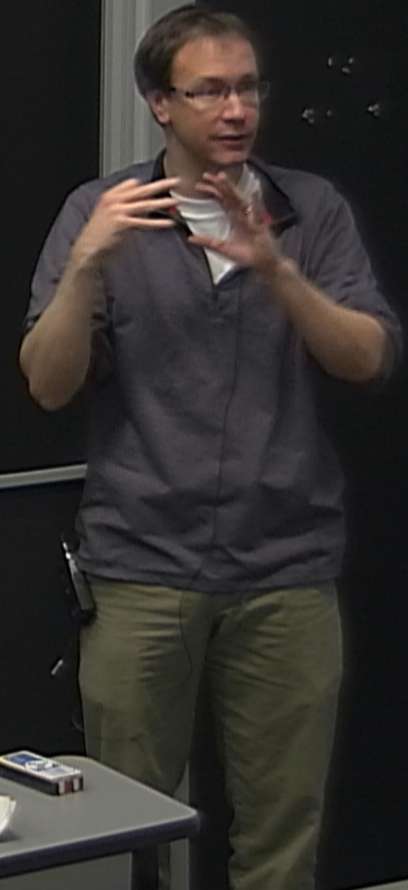
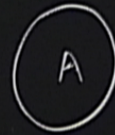
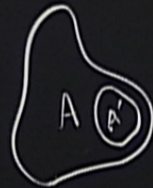


CAUTION
Do not lean on the chalkboard
as it may be damaged or
fall and cause injury.
Please do not touch the
board surface.

$$S(\rho \parallel \sigma) = \text{tr}(\rho \log \rho) - \text{tr}(\rho \log \sigma)$$

$$S \geq 0$$

$$S_{A'} \leq S_A$$

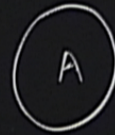
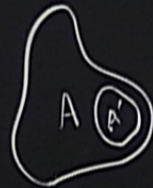


CAUTION
Do not lean on the chalkboard
as it may be damaged or fall over.
Do not use the chalkboard
as a desk or storage area.
Please respect the board.

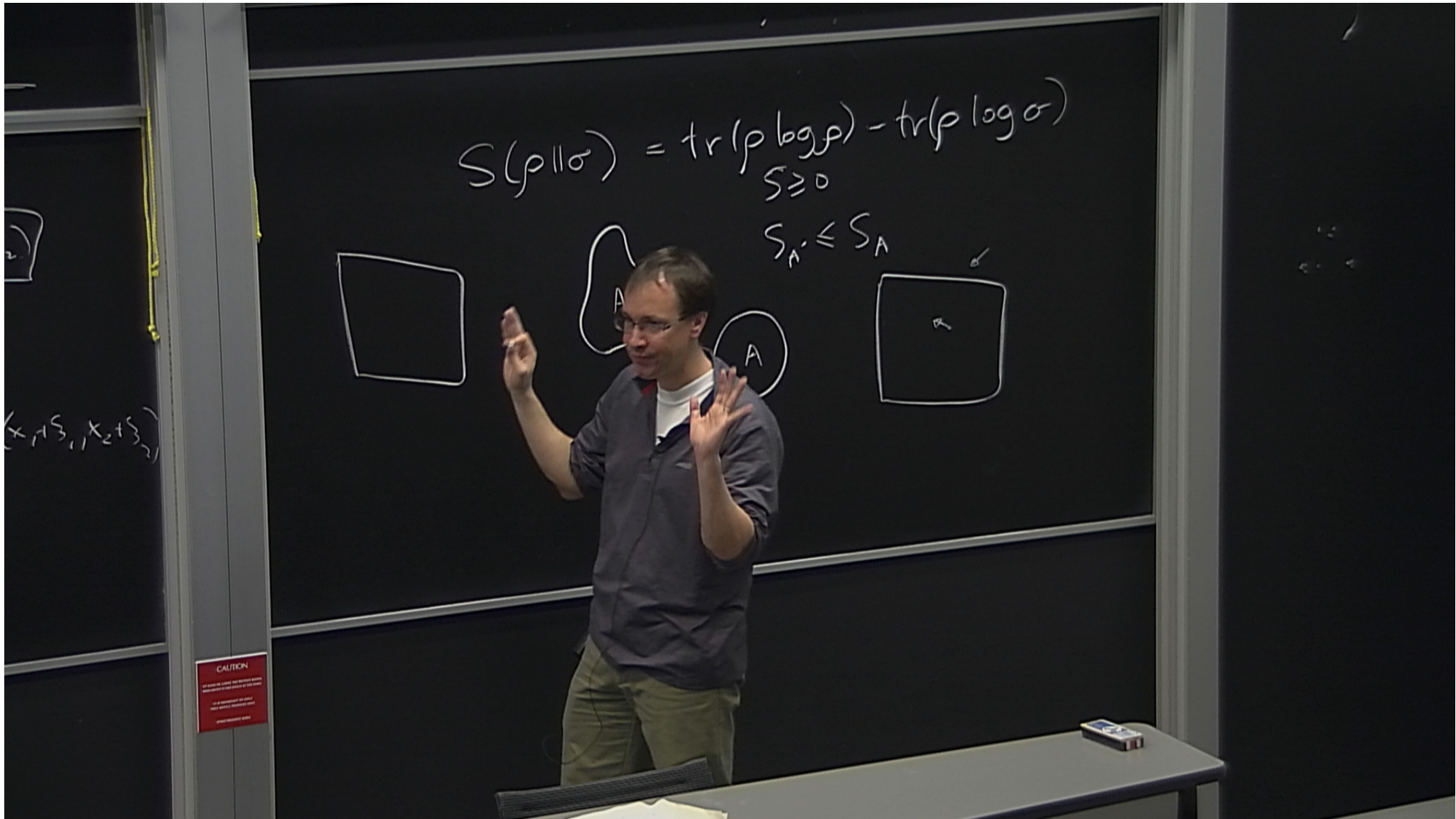
$$S(\rho \parallel \sigma) = \text{tr}(\rho \log \rho) - \text{tr}(\rho \log \sigma)$$

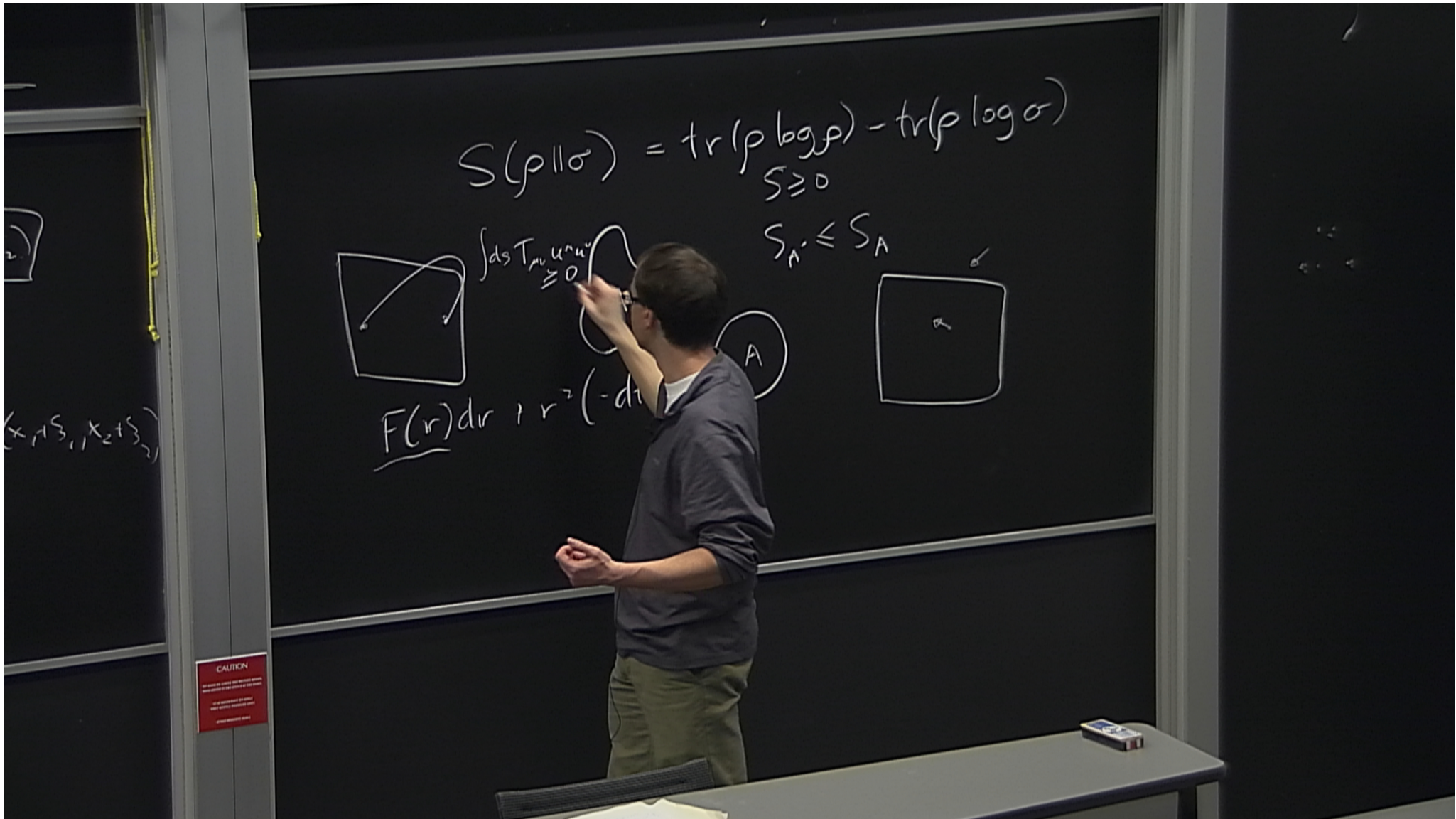
$$S \geq 0$$

$$S_{A'} \leq S_A$$



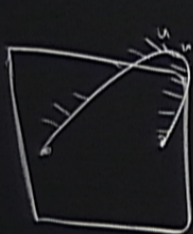
CAUTION
DO NOT TOUCH THE BOARD WHEN
THE BOARD IS BEING USED BY
THE BOARD OPERATOR



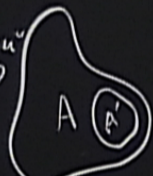


$$S(\rho || \sigma) = \text{tr}(\rho \log \rho) - \text{tr}(\rho \log \sigma)$$

$$S \geq 0$$



$$\int ds T_{\mu\nu} u^\mu u^\nu \geq 0$$

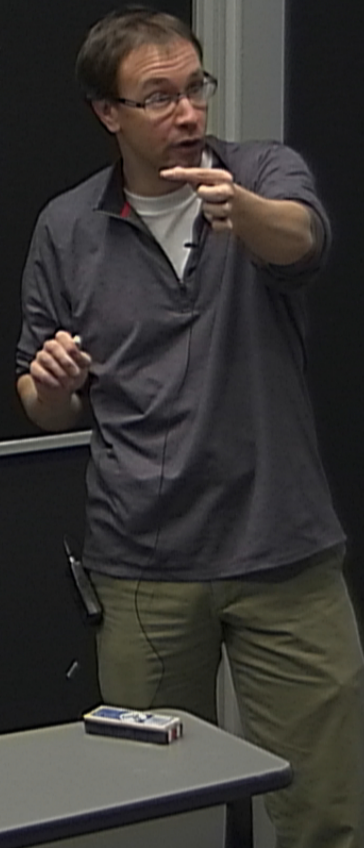


$$S_{A'} \leq S_A$$

$$G_{\mu\nu} T^{\mu\nu}$$



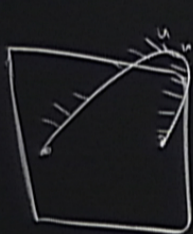
$$F(r) dr + r^2(-dt^2 + dx^2)$$



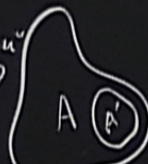
CAUTION
 Please do not touch the blackboard unless instructed by the lecturer or demonstrator.
 If a student touches the blackboard without permission, they will be asked to leave the lecture.

$$S(\rho || \sigma) = \text{tr}(\rho \log \rho) - \text{tr}(\rho \log \sigma)$$

$$S \geq 0$$

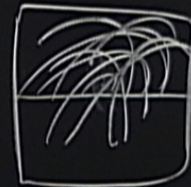


$$\int ds T_{\mu\nu} u^\mu u^\nu \geq 0$$

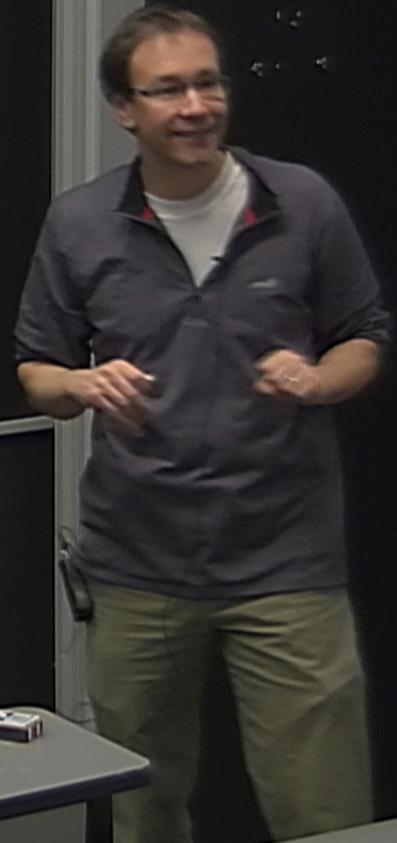
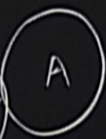


$$S_{A'} \leq S_A$$

$$G_{\mu\nu} T^{\mu\nu}$$



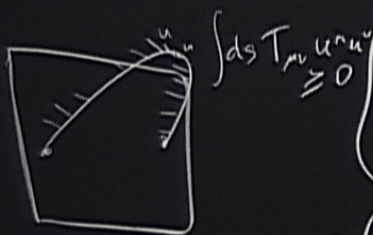
$$F(r) dr + r^2(-dt^2 + dx^2)$$



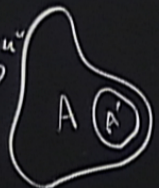
CAUTION
 Please do not touch the chalkboard unless instructed by the instructor.

$$S(\rho || \sigma) = \text{tr}(\rho \log \rho) - \text{tr}(\rho \log \sigma)$$

$$S \geq 0$$

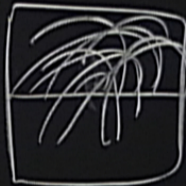


$$\int ds T_{\mu\nu} u^\mu u^\nu \geq 0$$

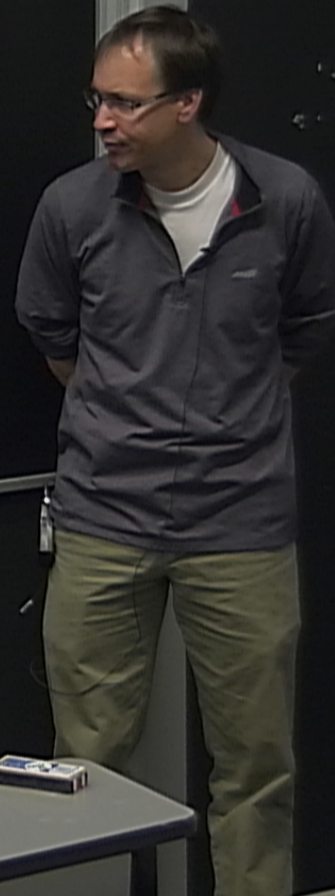


$$S_{A'} \leq S_A$$

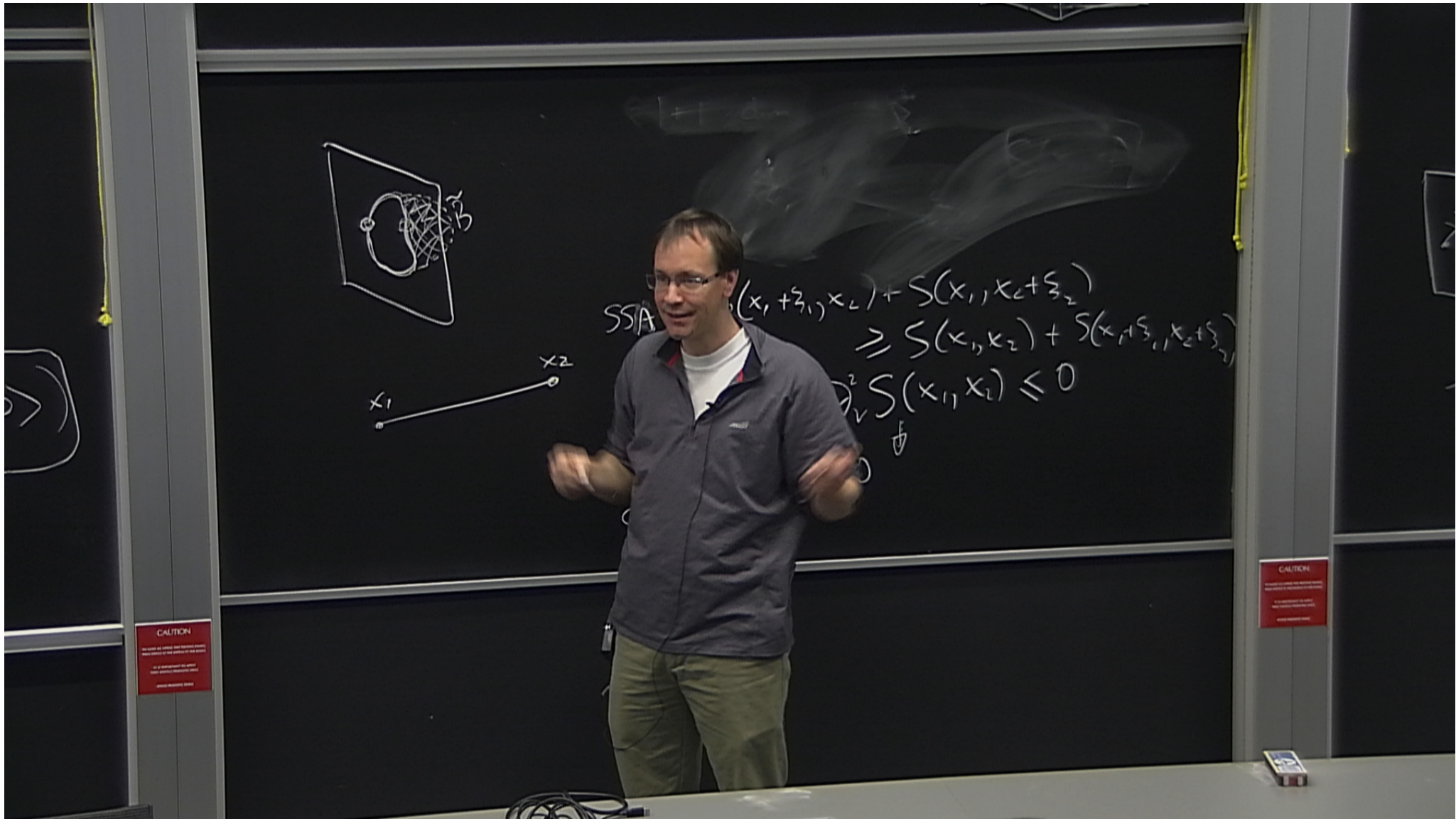
$$G_{\mu\nu} T^{\mu\nu}$$

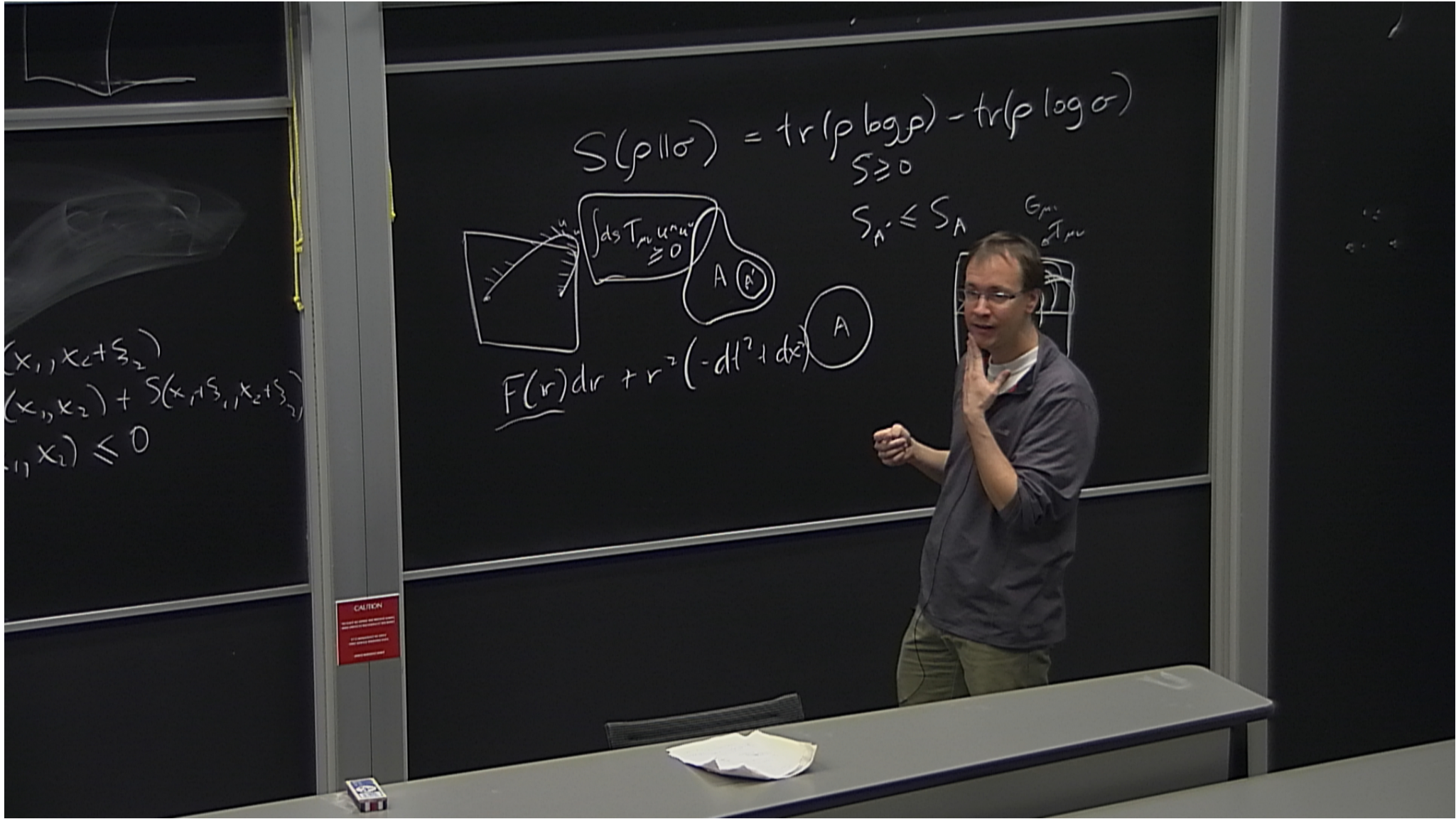


$$F(r) dr + r^2(-dt^2 + dx^2)$$



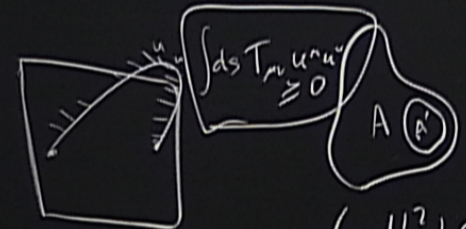
CAUTION
DO NOT TOUCH THE BOARD OR BOARDER
IF YOU HAVE ANY QUESTIONS
PLEASE ASK THE LECTURER





$$S(\rho || \sigma) = \text{tr}(\rho \log \rho) - \text{tr}(\rho \log \sigma)$$

$$S \geq 0$$



$$S_{A'} \leq S_A$$

$$F(r) dr + r^2 (-dt^2 + dx^2)$$

$$(x_1, x_2 + \delta x_2)$$

$$(x_1, x_2) + S(x_1, \delta x_1, x_2 + \delta x_2)$$

$$(x_1, x_2) \leq 0$$

CAUTION