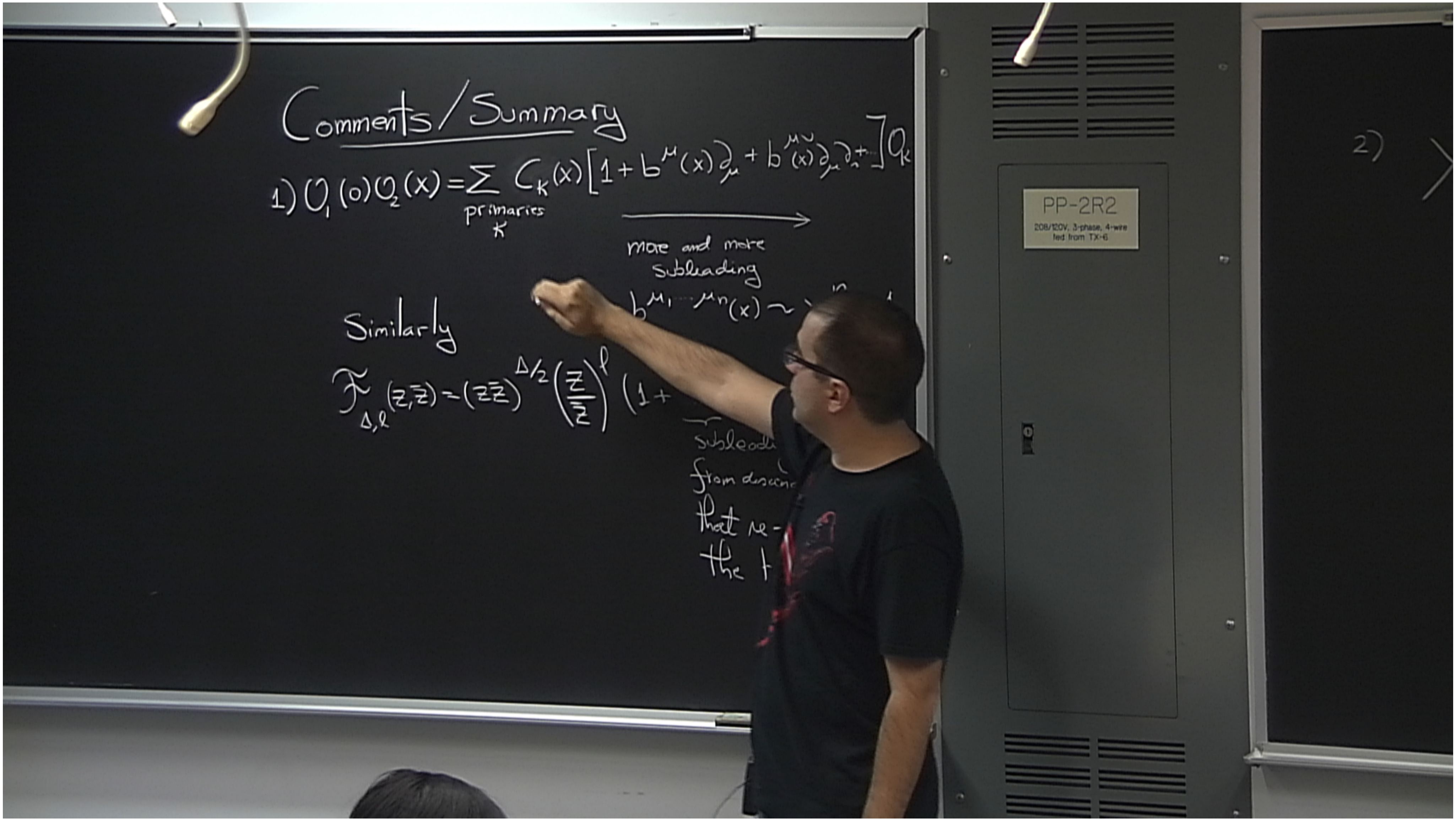
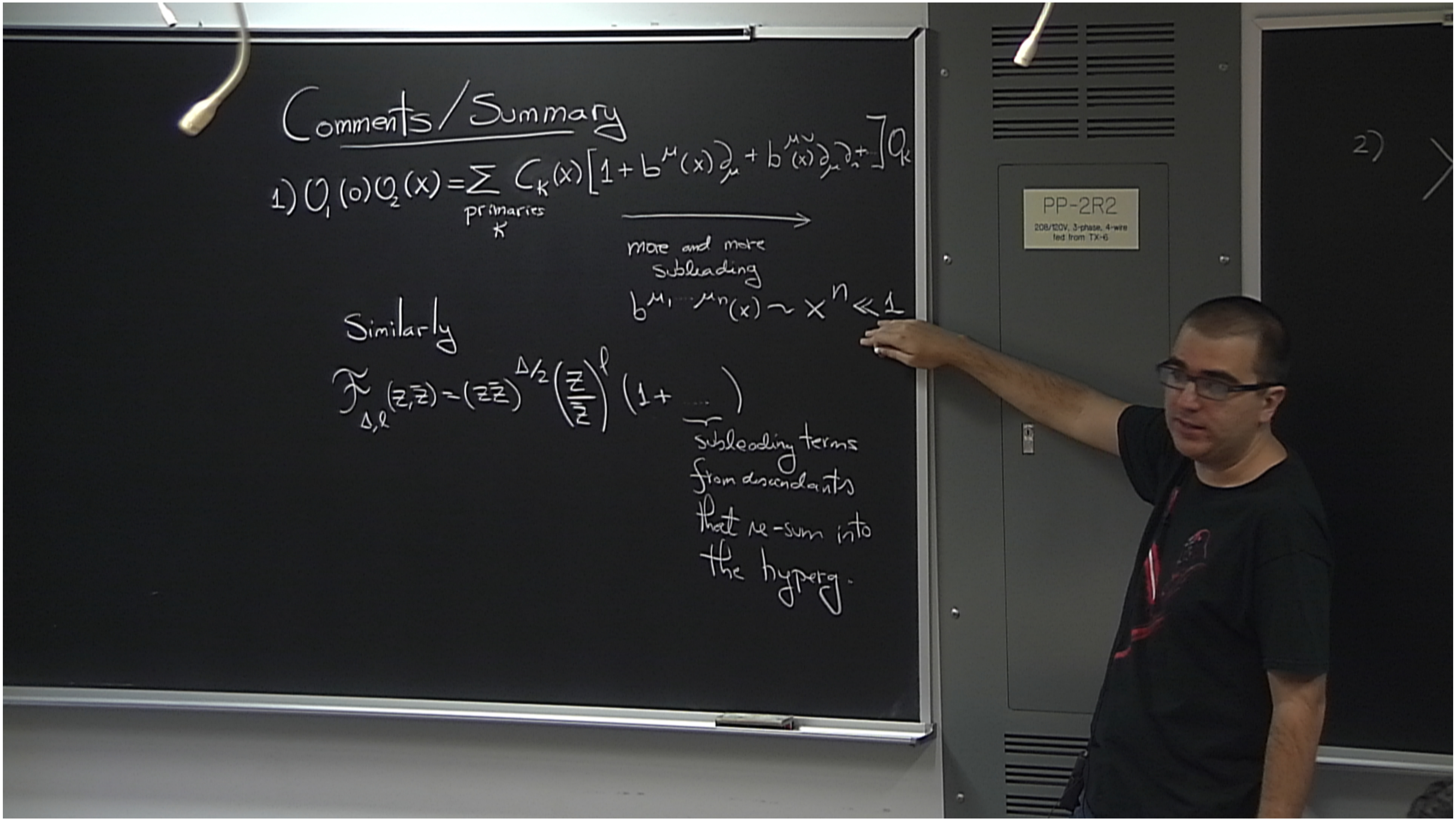
Title: 14/15 PSI - Conformal Field Theory - Lecture 8

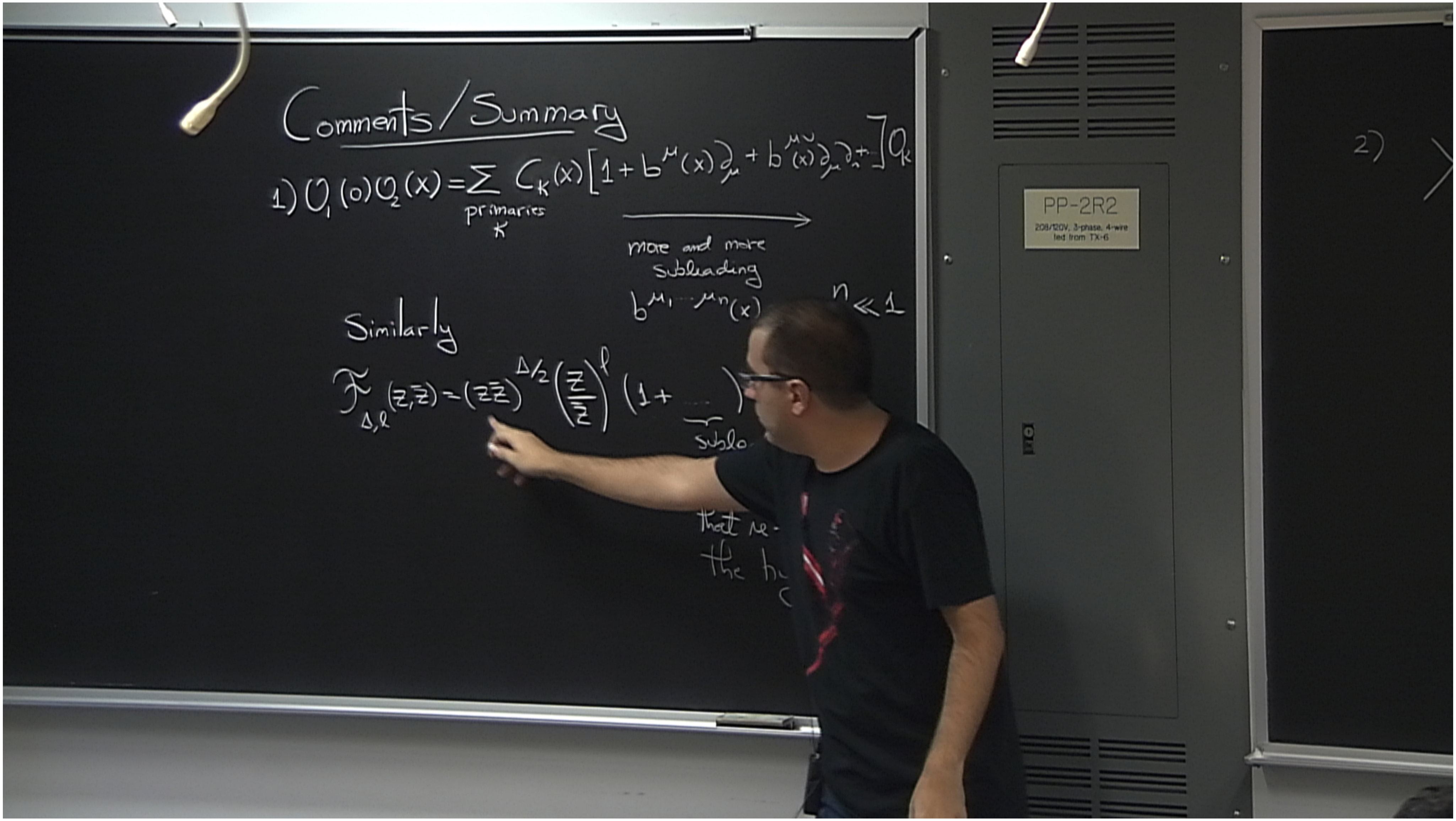
Date: Oct 16, 2014 03:30 PM

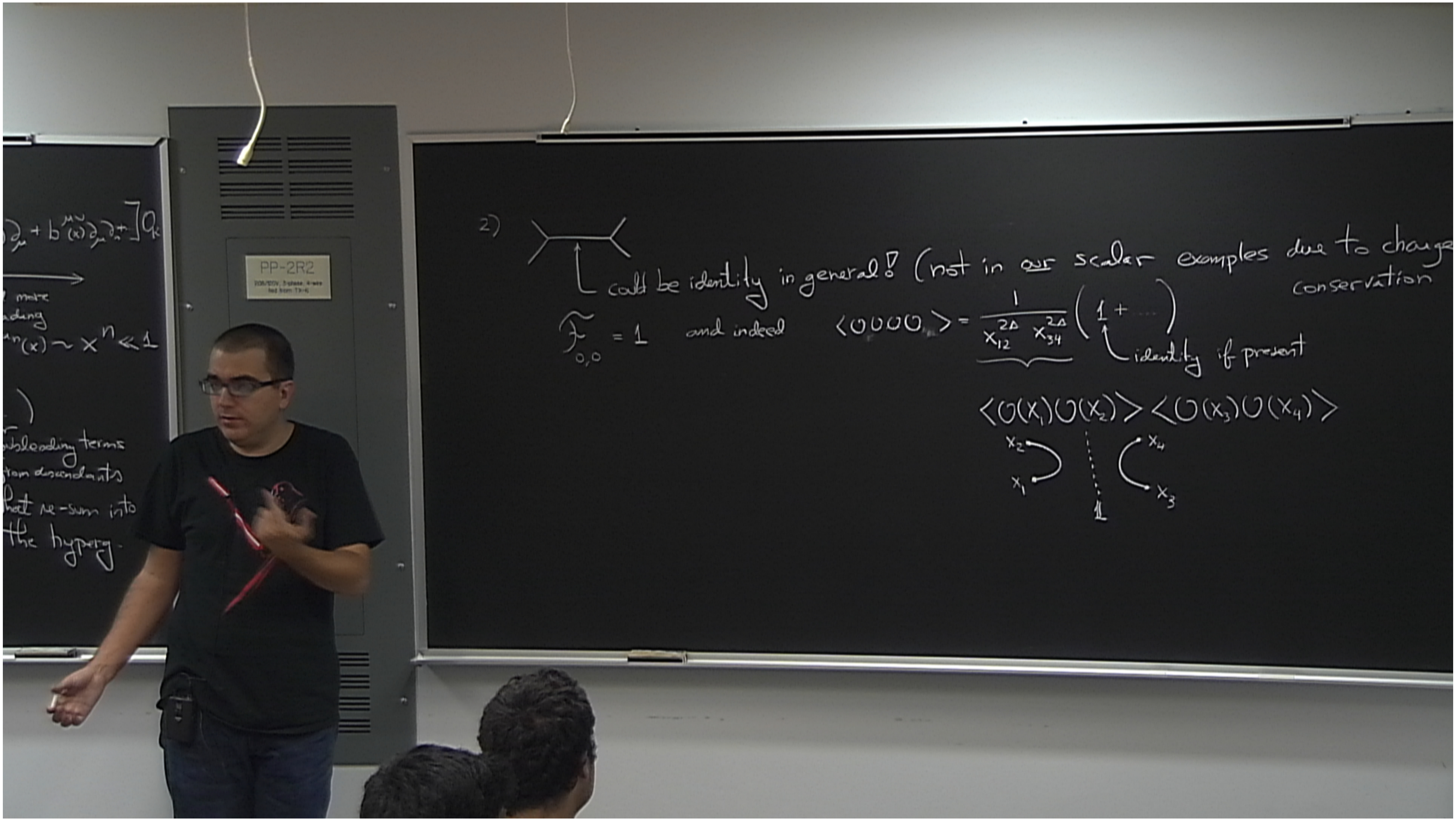
URL: http://pirsa.org/14100018

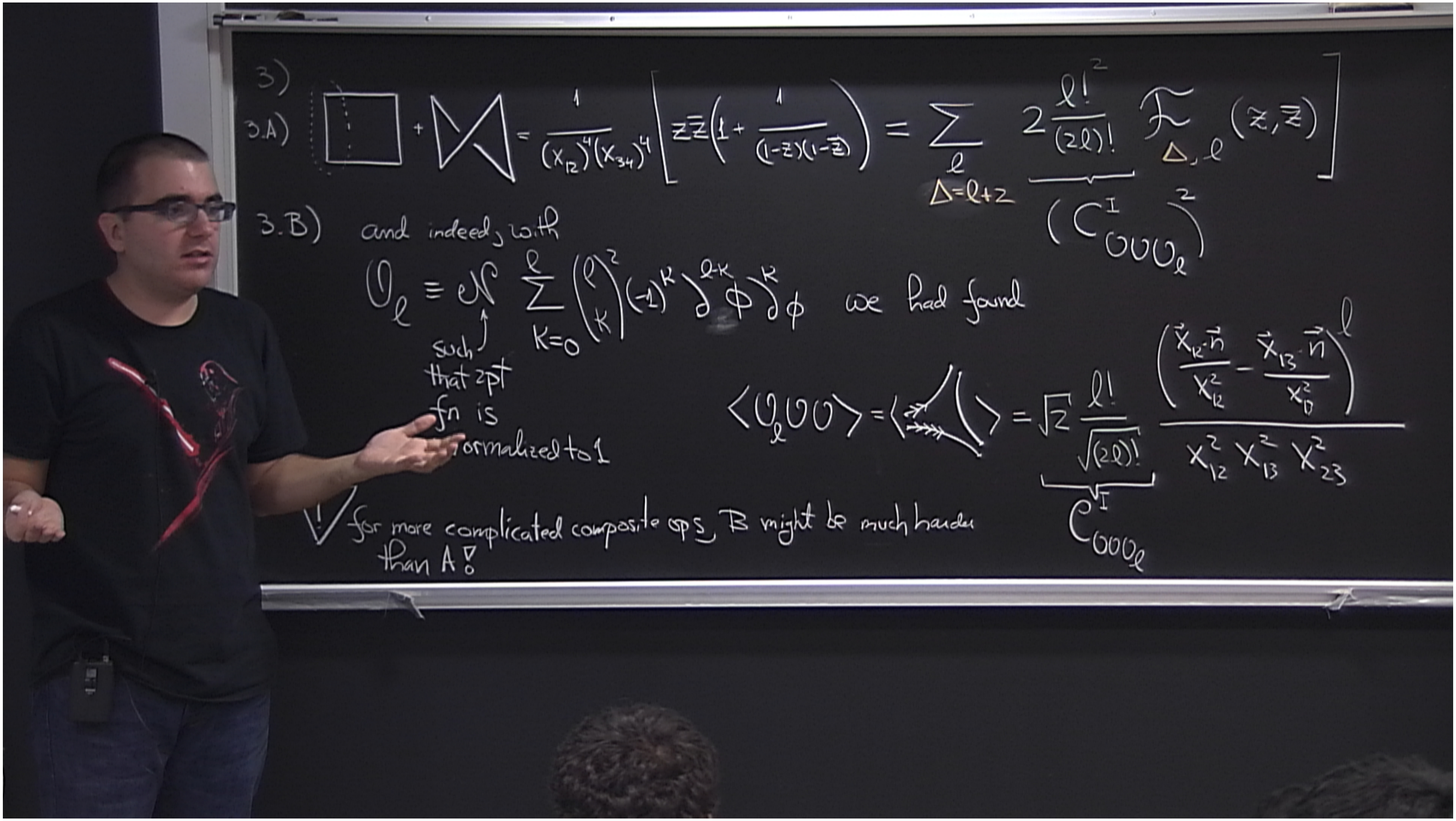
Abstract:

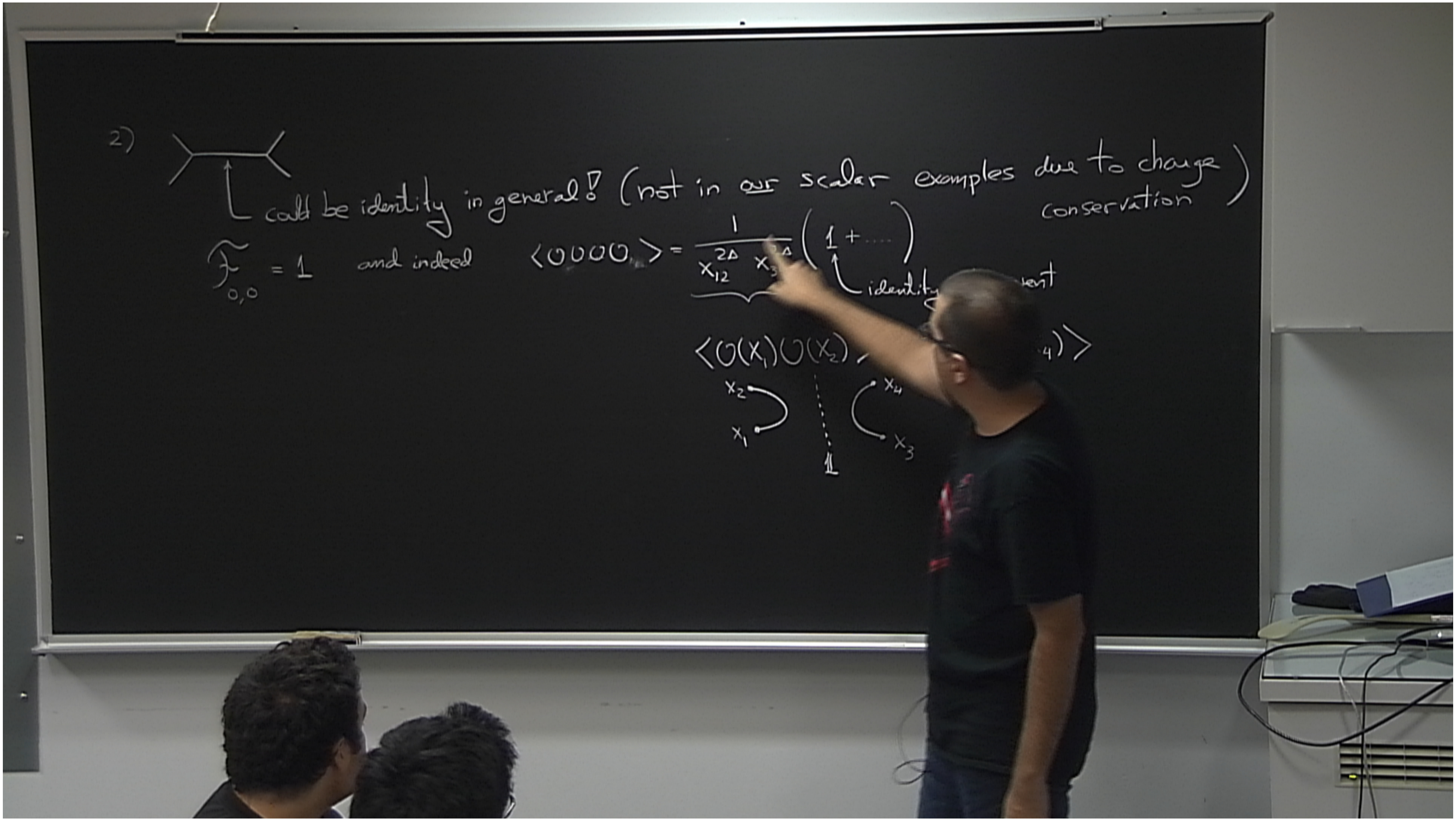

Comments/Summary
1) O1(0)O2(x) = Σ Ck(x)[1 + b^μ(x)∂μ + b^μν(x)∂μ∂ν + ...]Ok
primaries k
more and more subleading
Similarly
F_Δ,l(z,z̄) = (zz̄)^Δ/2 (z/z̄)^l (1 +
PP-2R2
208/120V, 3-phase, 4-wire fed from TX-6
2)

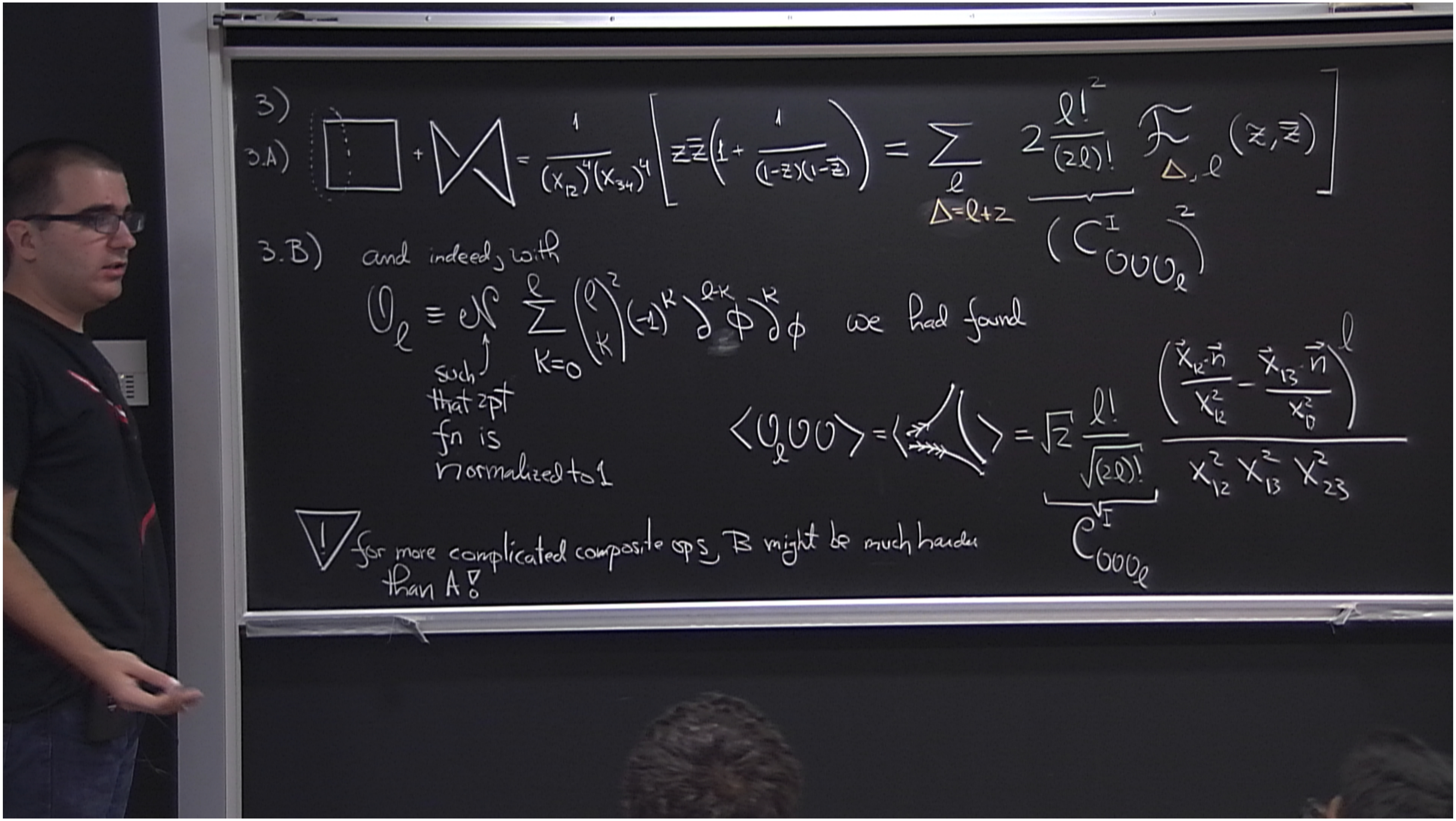

Comments / Summary
1) $O_1(0)O_2(x) = \sum_{\text{primaries } k} C_k(x)\left[1 + b^{\mu}(x)\partial_\mu + b^{\mu\nu}(x)\partial_\mu\partial_\nu + \cdots\right]O_k$
more and more subleading
$b^{\mu_1\cdots\mu_n}(x) \sim x^n \ll 1$
Similarly
$\mathcal{F}_{\Delta,\ell}(z,\bar{z}) = (z\bar{z})^{\Delta/2}\left(\frac{z}{\bar{z}}\right)^{\ell}(1 + \ldots)$
subleading terms from descendants that re-sum into the hyperg.
2)
PP-2R2
208/120V, 3-phase, 4-wire
fed from TX-6


Comments/Summary
1) $O_1(0)O_2(x) = \sum_{\text{primaries } k} C_k(x)[1 + b^{\mu}(x)\partial_\mu + b^{\mu\nu}(x)\partial_\mu\partial_\nu + \dots]O_k$
more and more subleading
$b^{\mu_1\cdots\mu_n}(x)$
$n \ll 1$
Similarly
$\mathcal{F}_{\Delta,\ell}(z,\bar{z}) = (z\bar{z})^{\Delta/2}\left(\frac{z}{\bar{z}}\right)^{\ell}(1 + \dots)$
2)
PP-2R2
208/120V, 3-phase, 4-wire
fed from TX-6


2)
could be identity in general! (not in our scalar examples due to charge conservation
= 1 and indeed
identity if present
subleading terms
from descendants
that re-sum into
the hyperg.
PP-2R2


3)
3.A)
3.B) and indeed, with
we had found
such that 2pt fn is normalized to 1
for more complicated composite ops, B might be much harder than A!


2)
could be identity in general! (not in our scalar examples due to charge conservation)
= 1 and indeed
identity


3)
3.A)
3.B) and indeed, with
such that 2pt fn is normalized to 1
we had found
Δ=ℓ+2
for more complicated composite ops, B might be much harder than A!

3)

3.A) $\square + \bowtie = \frac{1}{(x_{12})^4 (x_{34})^4} \left[z\bar{z}\left(1 + \frac{1}{(1-z)(1-\bar{z})}\right) = \sum_{\substack{\ell \\ \Delta = \ell + 2}} \underbrace{2\frac{\ell!^2}{(2\ell)!}}_{(C^I_{\mathcal{O}\mathcal{O}\mathcal{O}_\ell})^2} F_{\Delta,\ell}(z,\bar{z}) \right] = \sum$

3.B) and indeed, with

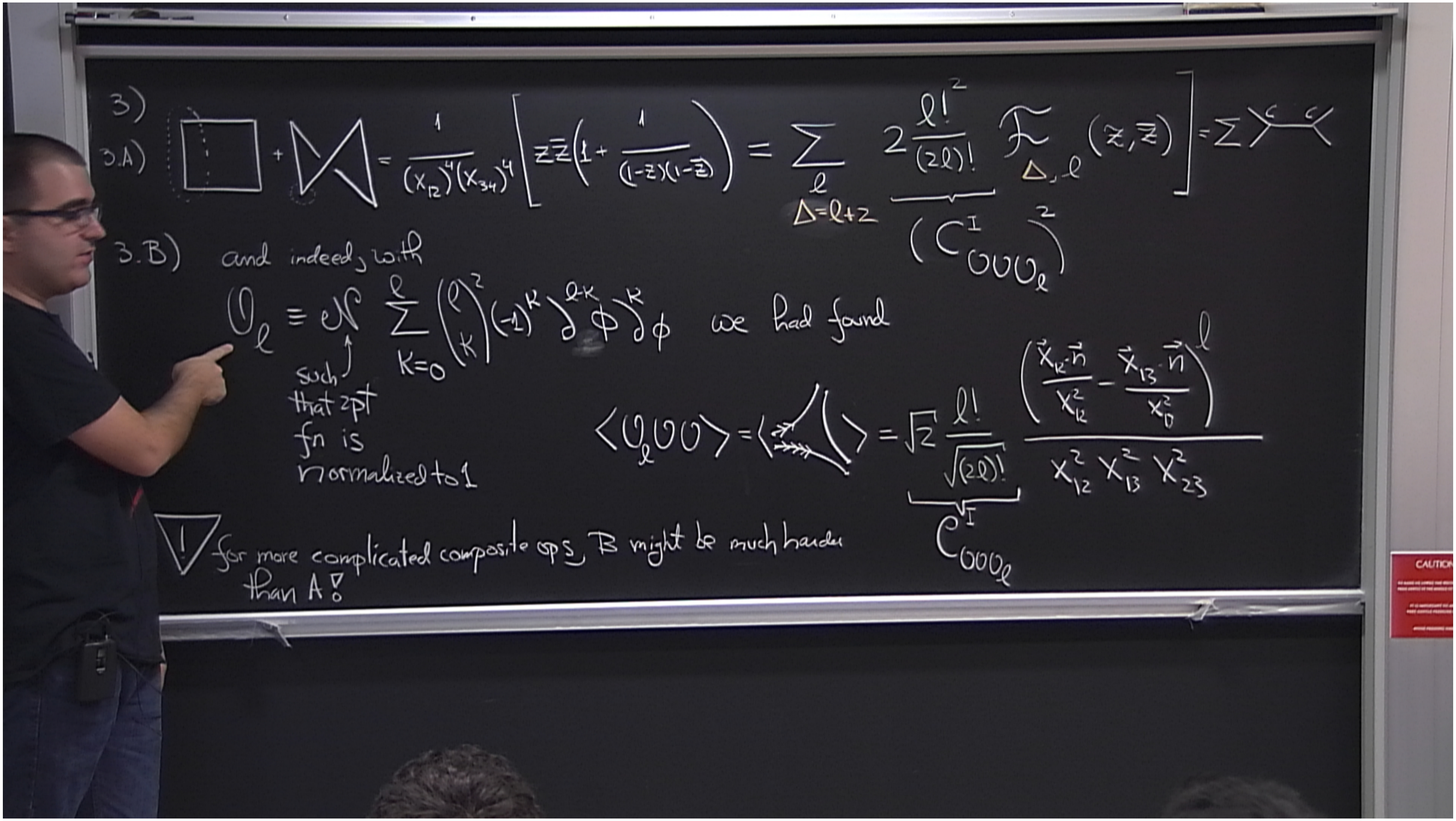
$$\mathcal{O}_\ell \equiv \mathcal{N} \sum_{k=0}^{\ell} \binom{\ell}{k}^2 (-1)^k \partial^{\ell-k}\phi\, \partial^k \phi$$

we had found

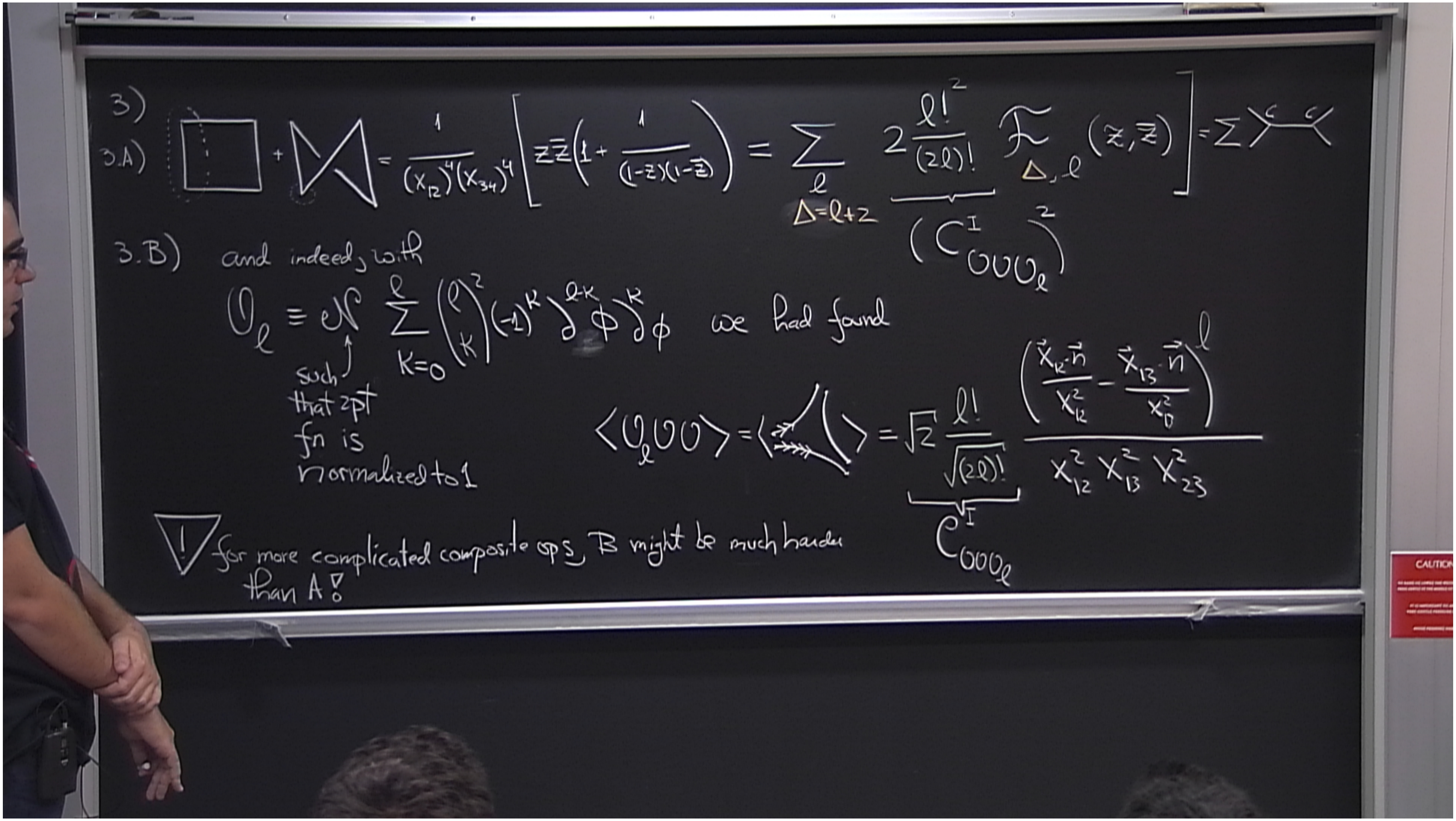
$\mathcal{N}$ such that 2pt fn is normalized to 1

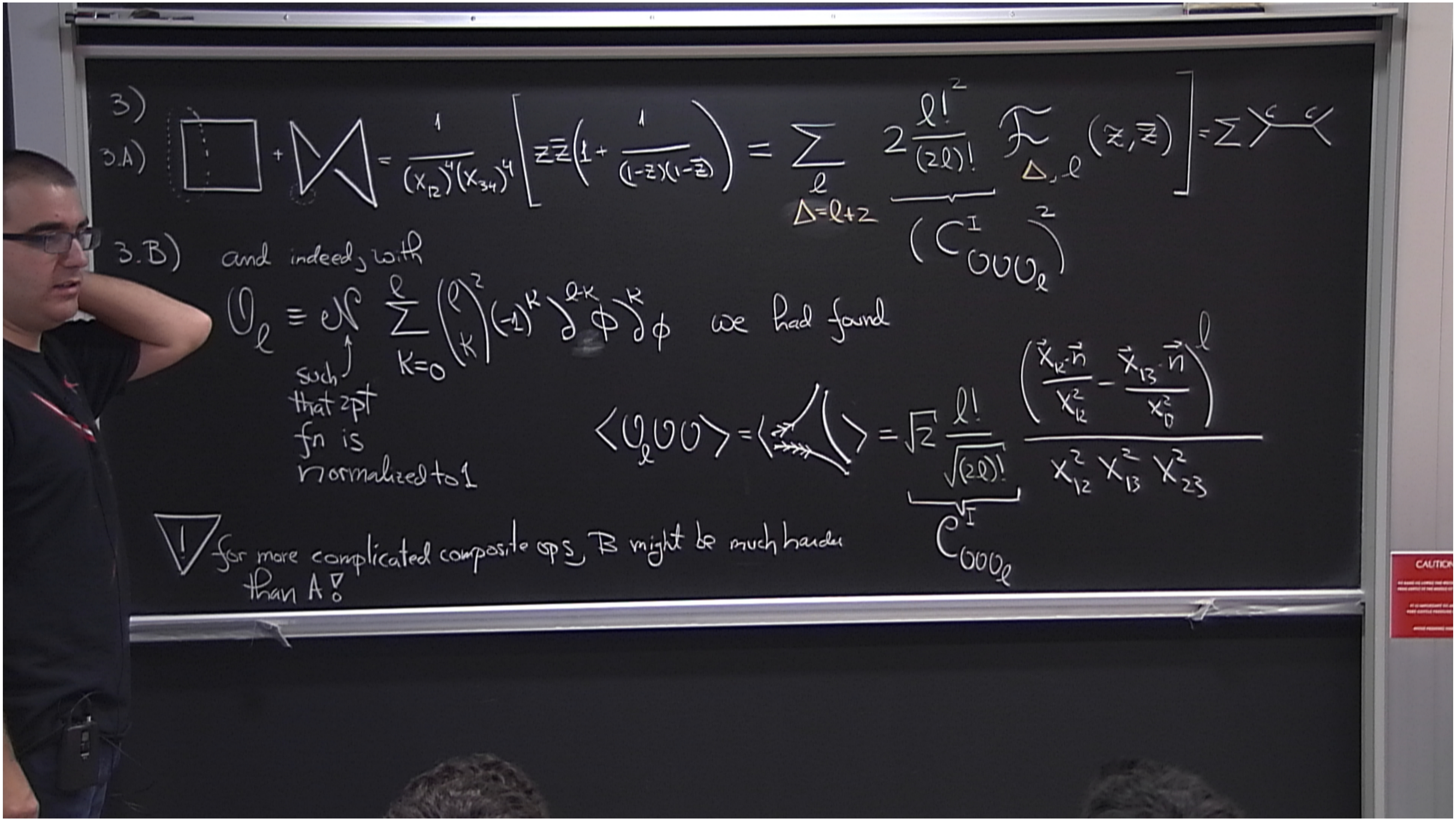
$$\langle \mathcal{O}_\ell \mathcal{O}\mathcal{O} \rangle = \langle \cdots \rangle = \underbrace{\sqrt{2}\frac{\ell!}{\sqrt{(2\ell)!}}}_{C^I_{\mathcal{O}\mathcal{O}\mathcal{O}_\ell}} \frac{\left(\frac{\vec{x}_{12}\cdot\vec{n}}{x_{12}^2} - \frac{\vec{x}_{13}\cdot\vec{n}}{x_{13}^2}\right)^\ell}{x_{12}^2 x_{13}^2 x_{23}^2}$$

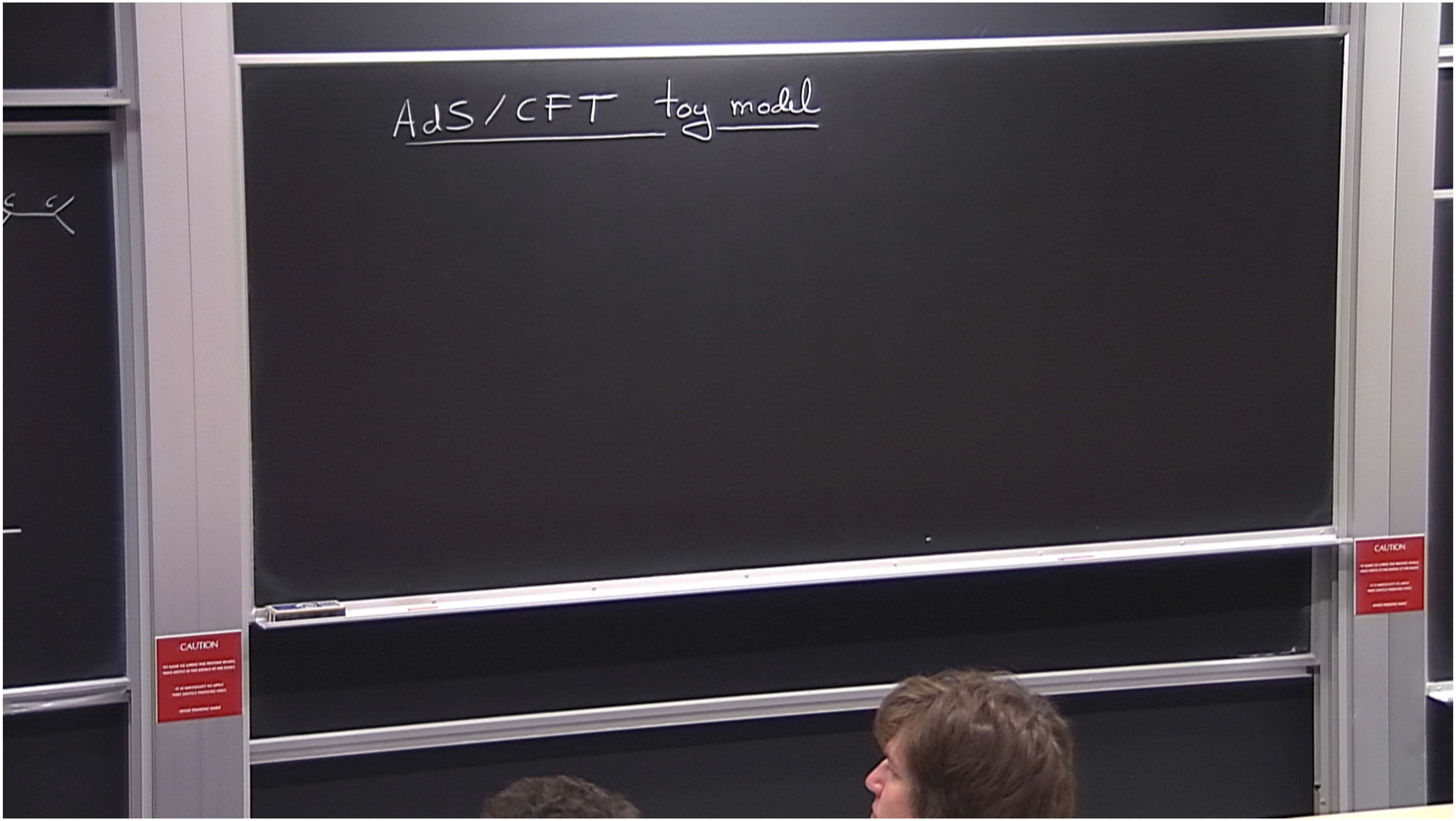
⚠ for more complicated composite ops, B might be much harder than A!

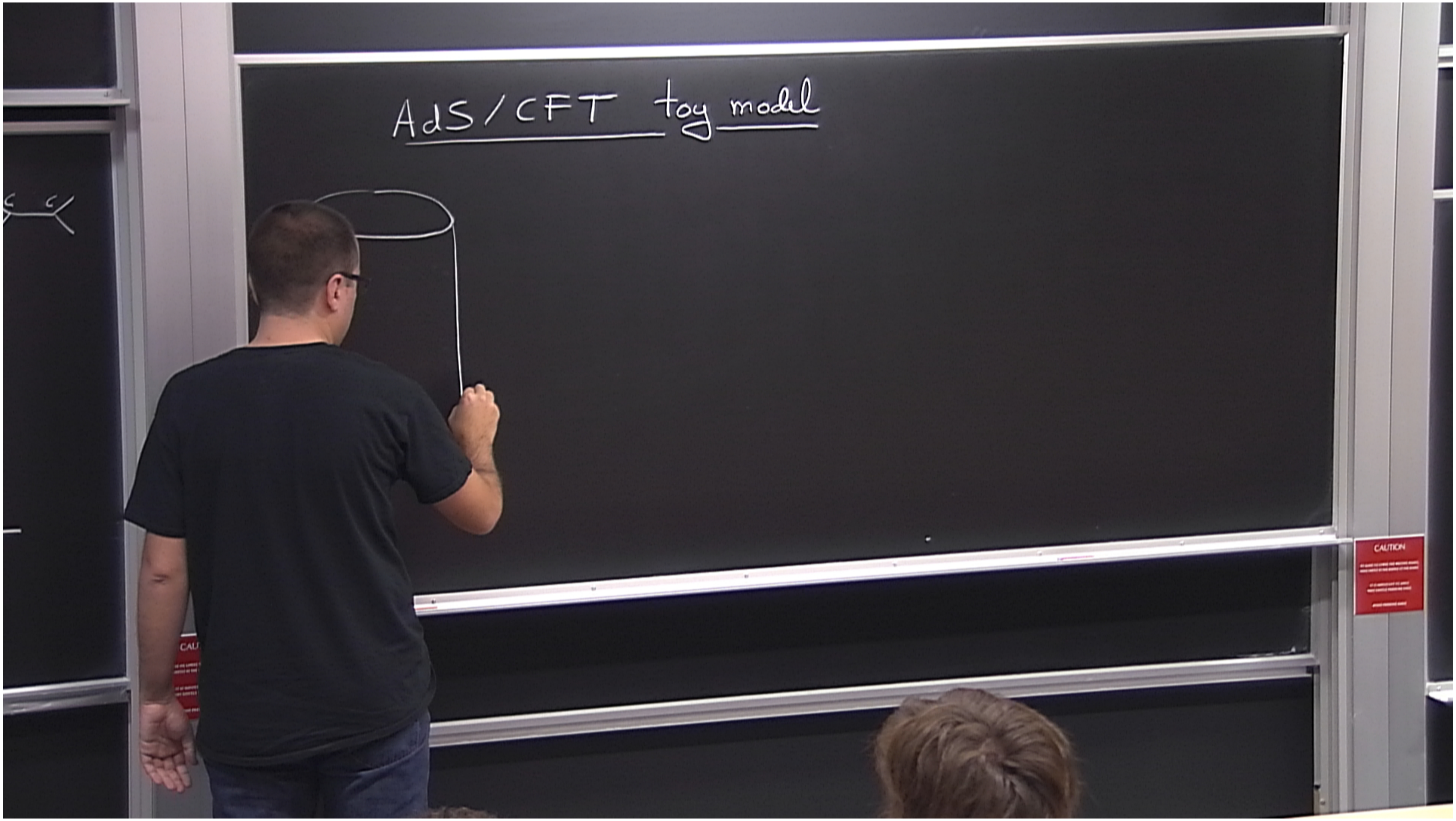


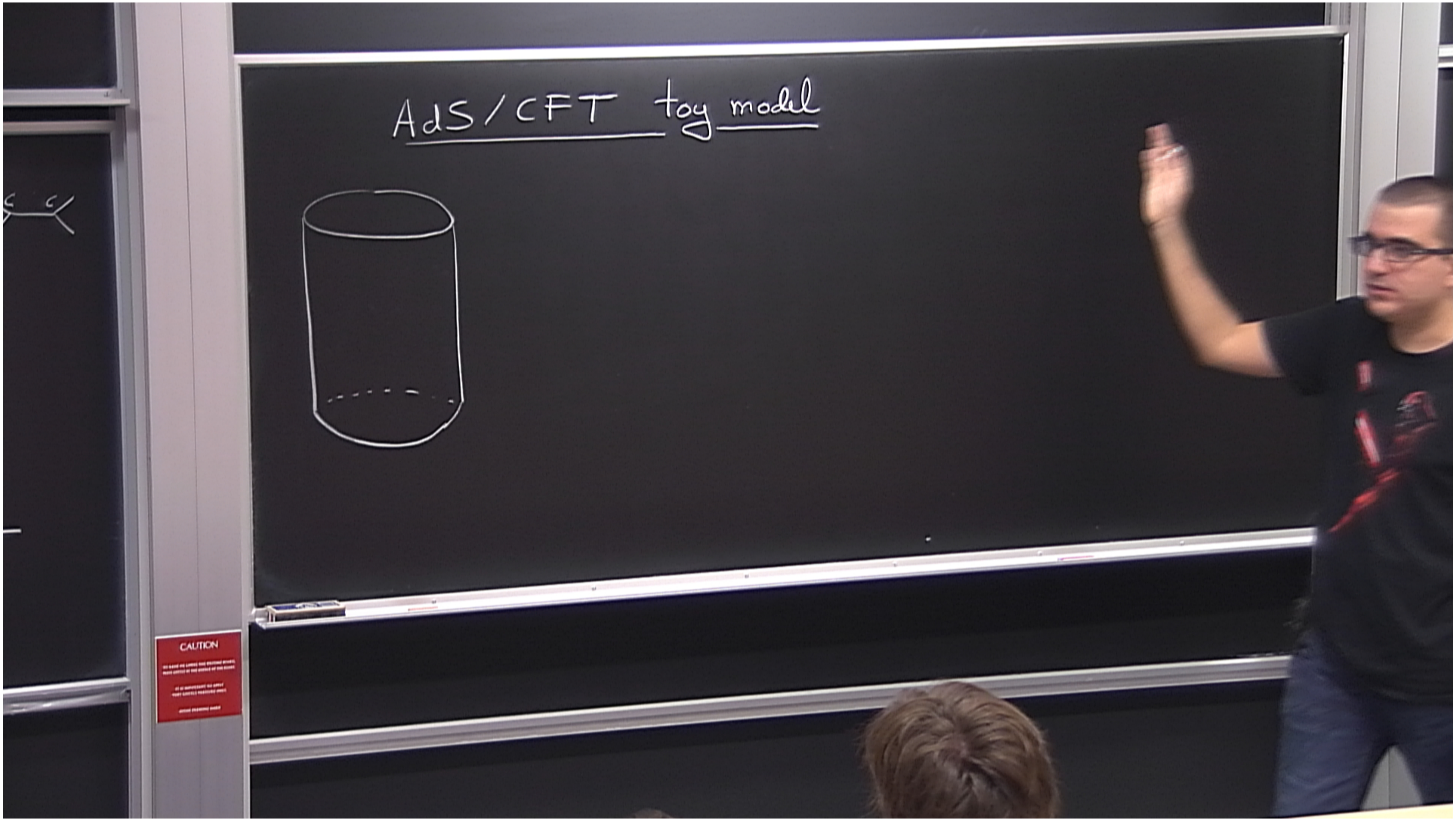
3)
3.A) $\square + \bowtie = \frac{1}{(x_{12})^4 (x_{34})^4} \left[z\bar{z}\left(1 + \frac{1}{(1-z)(1-\bar{z})}\right) = \sum_{\ell,\ \Delta=\ell+2} 2\frac{\ell!^2}{(2\ell)!} F_{\Delta,\ell}(z,\bar{z}) \right] = \sum$
$\frac{\ell!^2}{(2\ell)!} = (C^I_{OOO_\ell})^2$
3.B) and indeed, with
$O_\ell \equiv \mathcal{N} \sum_{k=0}^{\ell} \binom{\ell}{k}^2 (-1)^k \partial^{\ell-k}\phi\, \partial^k \phi$ we had found
such that 2pt fn is normalized to 1
$\langle O_\ell O O \rangle = \sqrt{2}\, \frac{\ell!}{\sqrt{(2\ell)!}} \frac{\left(\frac{\vec{x}_{12}\cdot\vec{n}}{x_{12}^2} - \frac{\vec{x}_{13}\cdot\vec{n}}{x_{13}^2}\right)^\ell}{x_{12}^2 x_{13}^2 x_{23}^2}$
$\sqrt{2}\frac{\ell!}{\sqrt{(2\ell)!}} = C^I_{OOO_\ell}$
! for more complicated composite ops, B might be much harder than A!
CAUTION

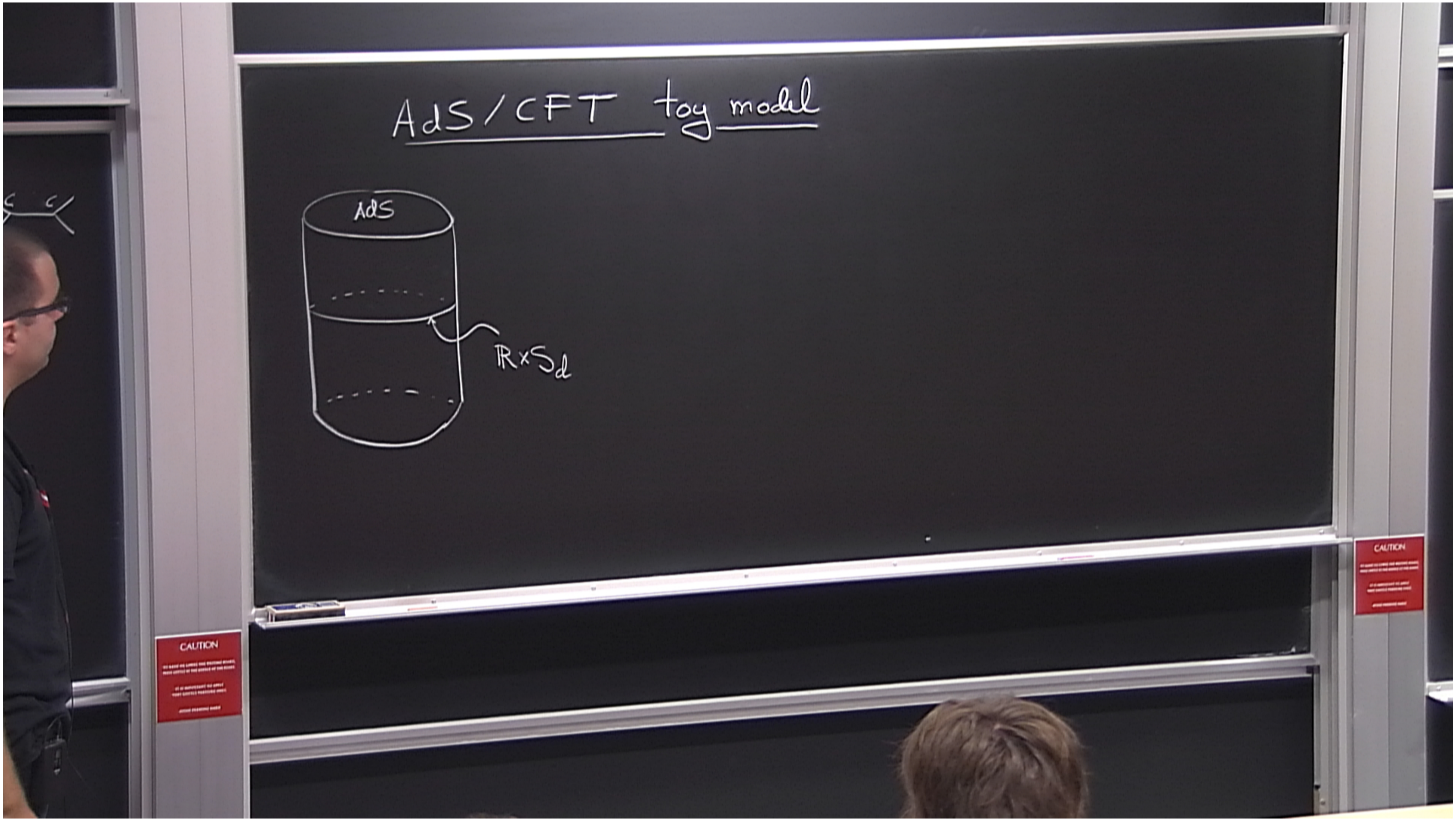

3)
3.A)
$= \frac{1}{(x_{12})^4 (x_{34})^4} \left[z\bar{z}\left(1 + \frac{1}{(1-z)(1-\bar{z})}\right) = \sum_{\substack{\ell \\ \Delta = \ell + 2}} 2 \frac{\ell!^2}{(2\ell)!} F_{\Delta,\ell}(z,\bar{z}) \right] = \sum$
$(C^{I}_{\mathcal{O}\mathcal{O}\mathcal{O}_\ell})^2$
3.B) and indeed, with
$\mathcal{O}_\ell \equiv \mathcal{N} \sum_{k=0}^{\ell} \binom{\ell}{k}^2 (-1)^k \partial^{\ell-k}\phi\, \partial^k \phi$ we had found
such that 2pt fn is normalized to 1
$\langle \mathcal{O}_\ell \mathcal{O}\mathcal{O} \rangle = \langle \; \rangle = \sqrt{2} \frac{\ell!}{\sqrt{(2\ell)!}} \frac{\left(\frac{\vec{x}_{12}\cdot\vec{n}}{x_{12}^2} - \frac{\vec{x}_{13}\cdot\vec{n}}{x_{13}^2} \right)^\ell}{x_{12}^2 x_{13}^2 x_{23}^2}$
$C^{I}_{\mathcal{O}\mathcal{O}\mathcal{O}_\ell}$
for more complicated composite ops, B might be much harder than A!

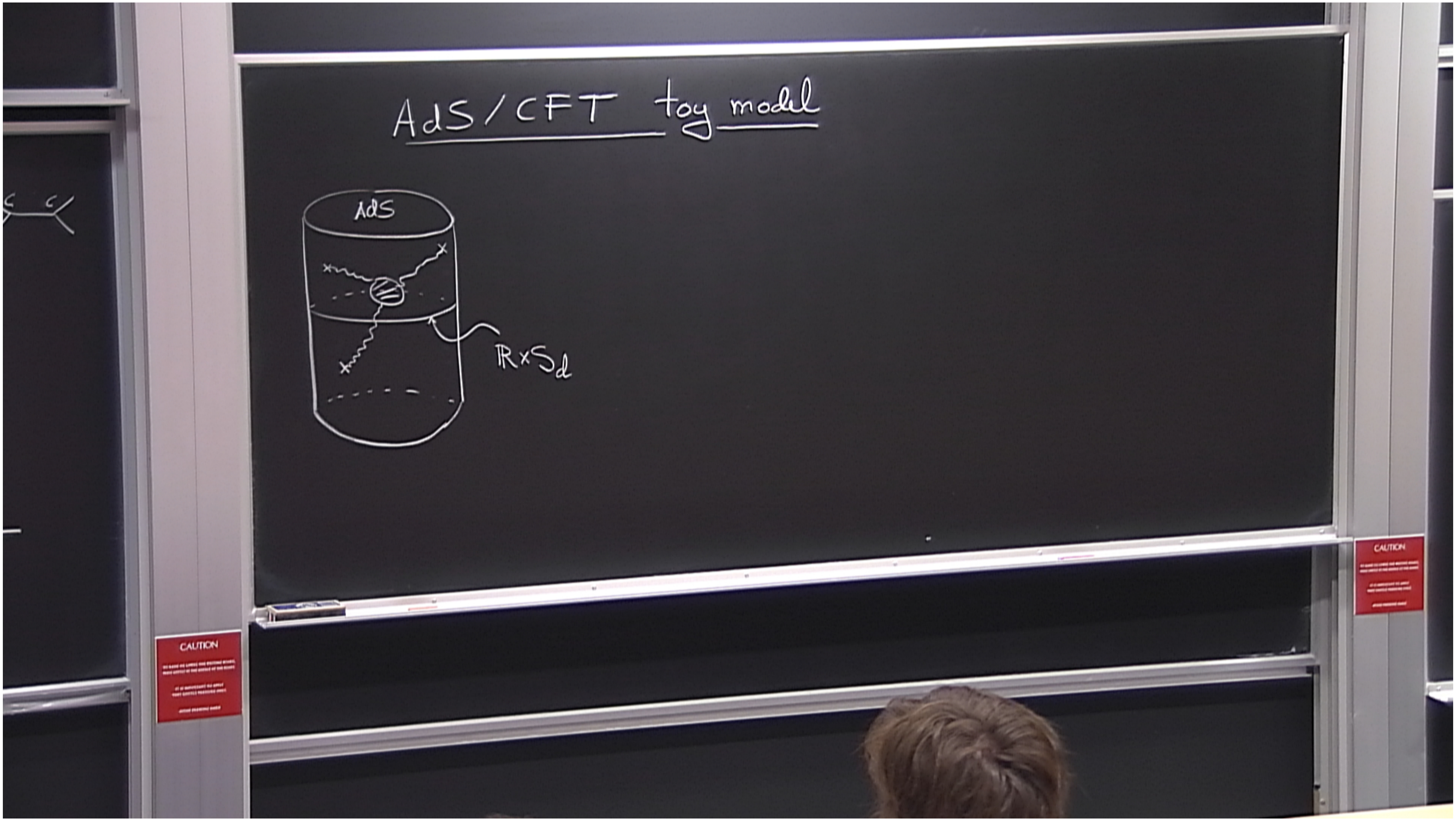

3)
3.A)
3.B) and indeed, with
we had found
such that 2pt fn is normalized to 1
for more complicated composite ops, B might be much harder than A!
CAUTION

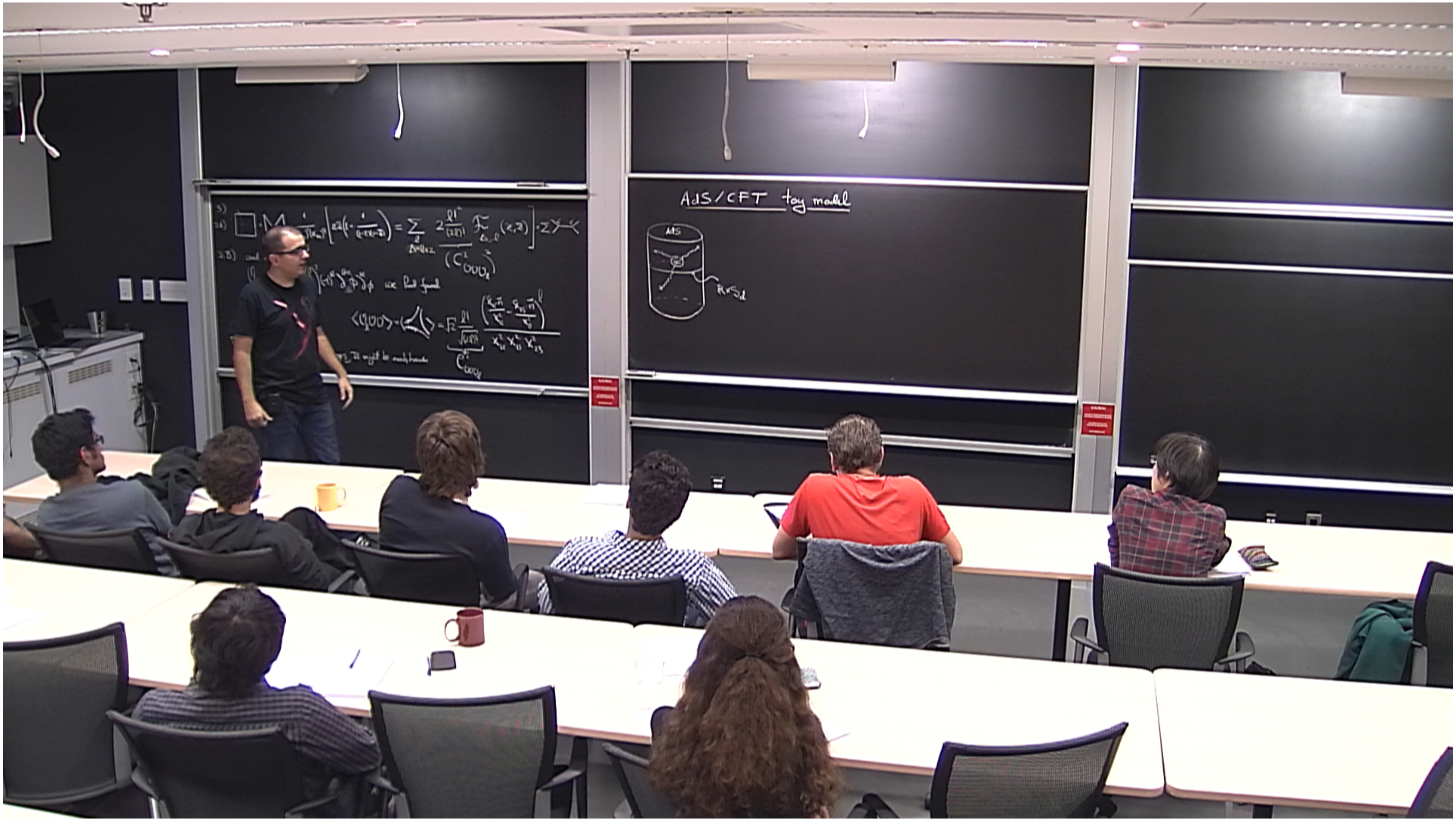

AdS/CFT toy model

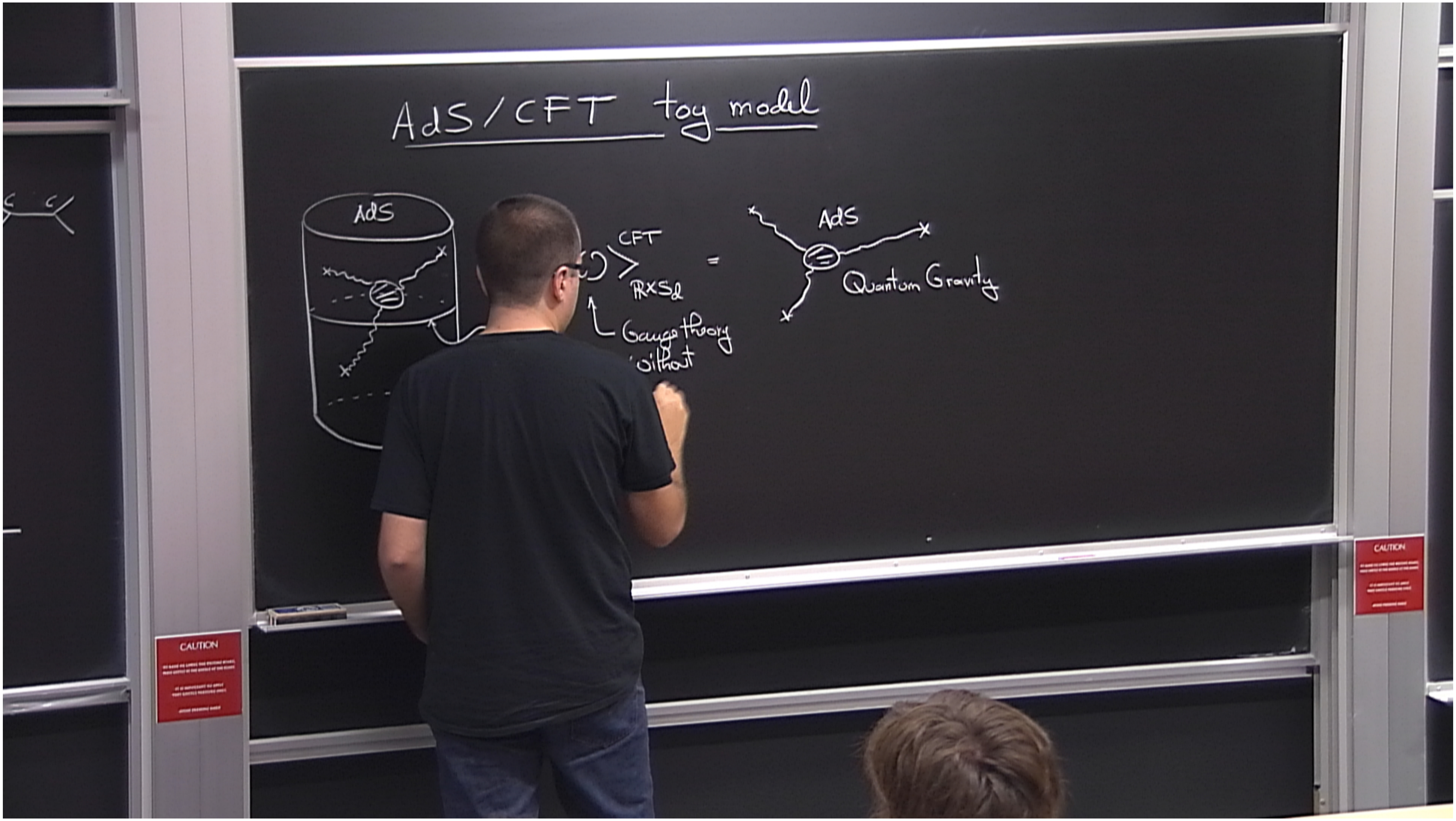

AdS/CFT toy model

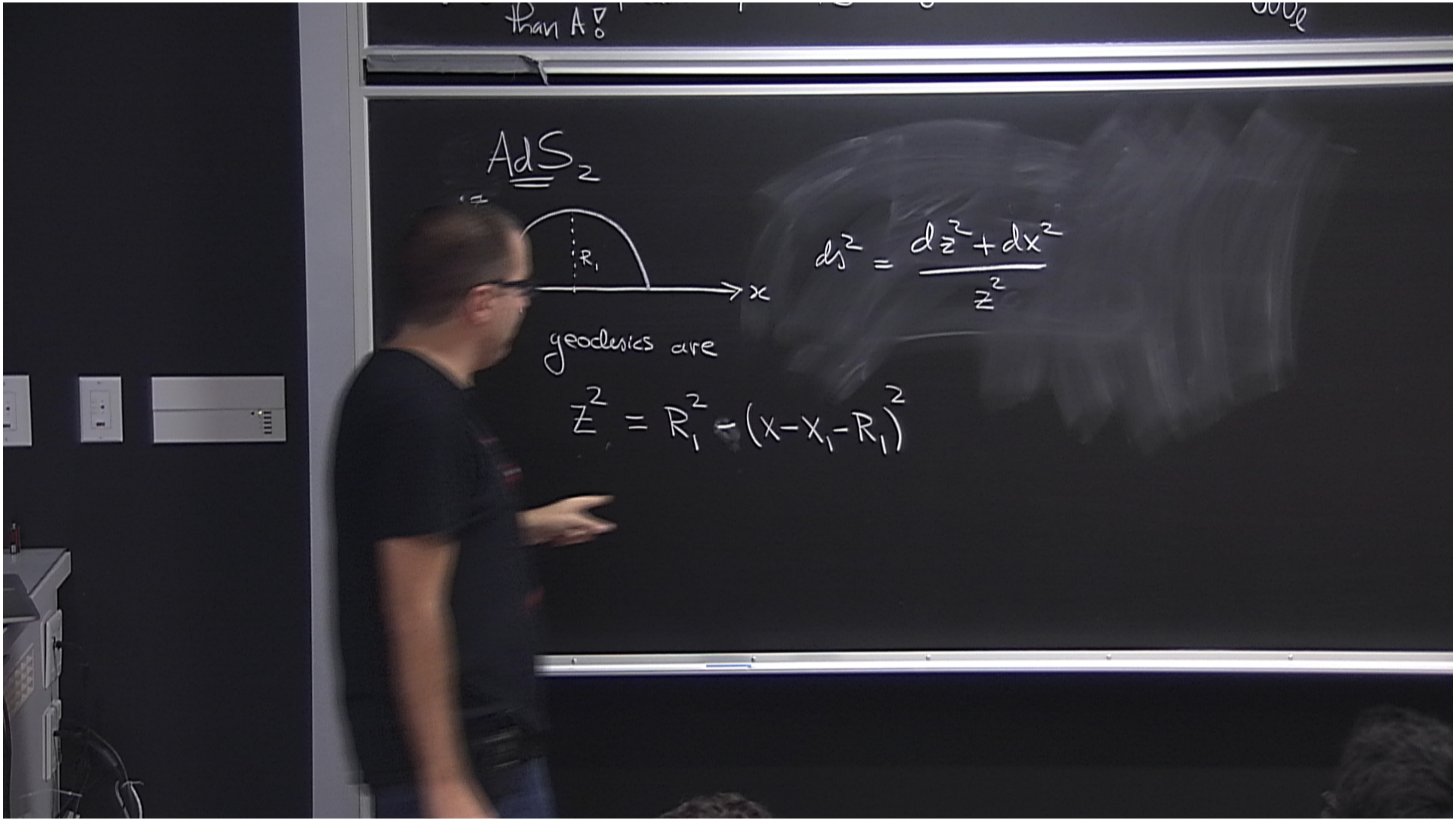

AdS/CFT toy model
CAUTION

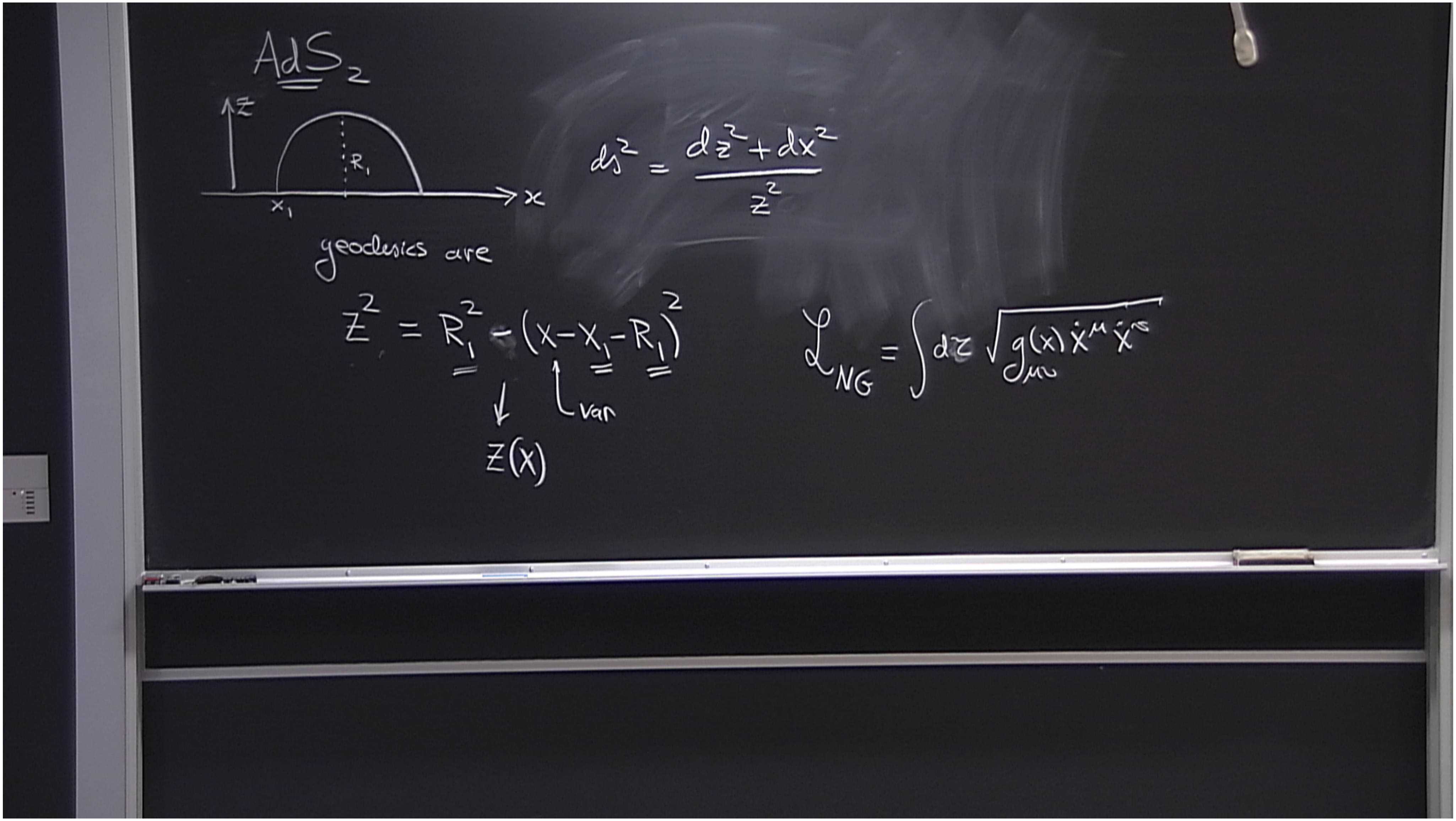

AdS/CFT toy model
AdS
R×S_d
CAUTION
CAUTION

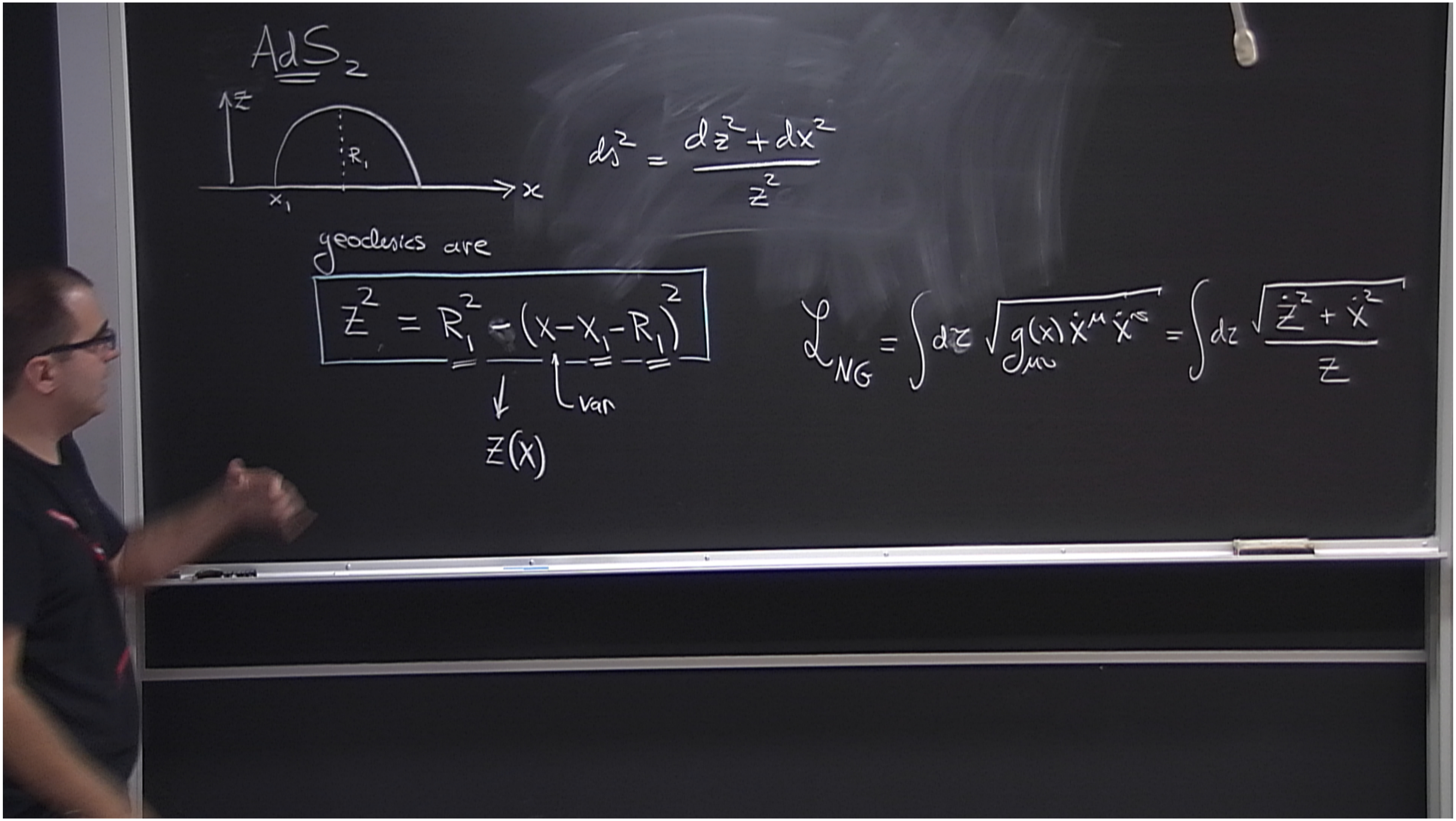

AdS/CFT toy model
AdS
R×S_d
CAUTION
CAUTION

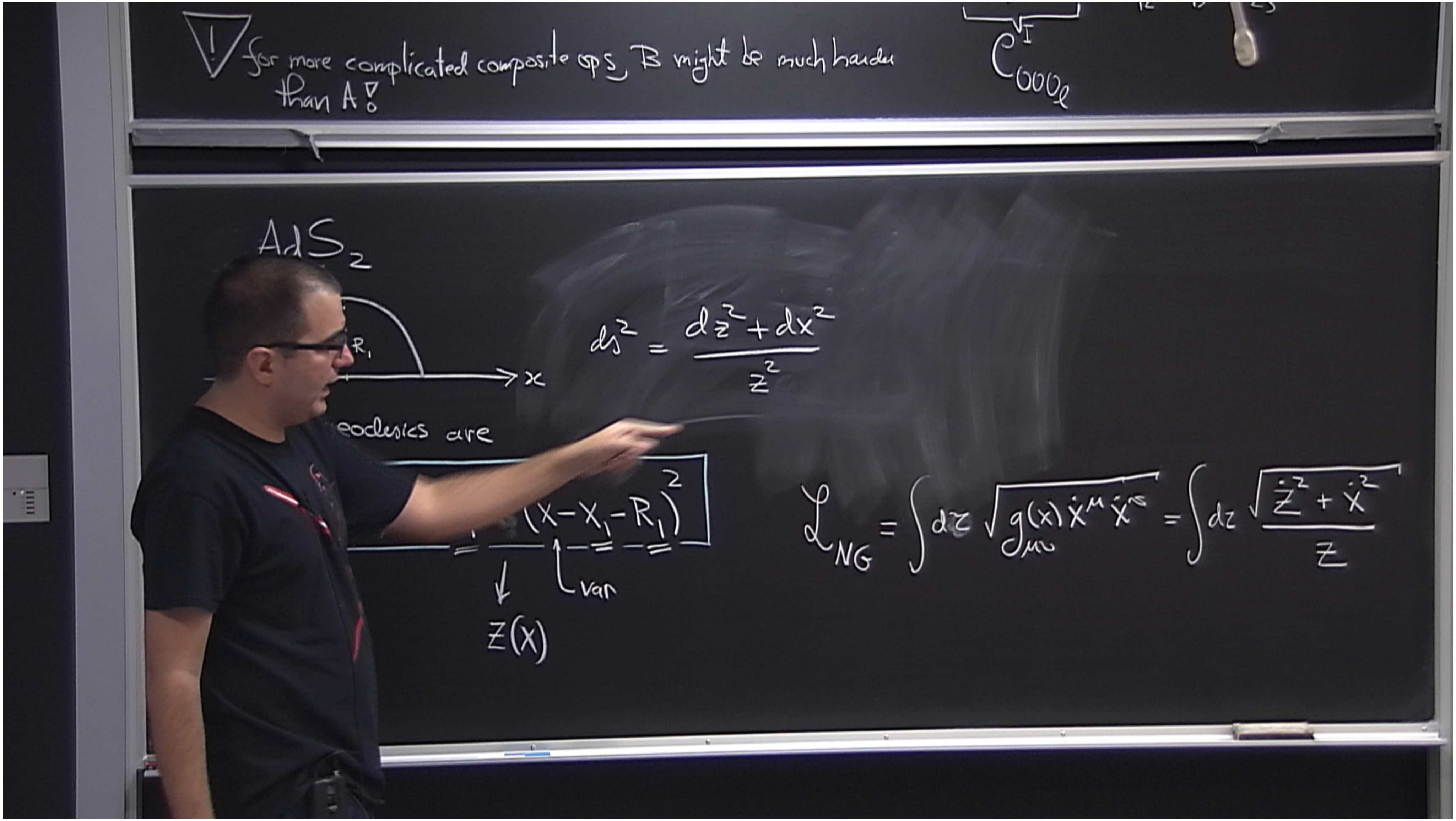

AdS/CFT toy model

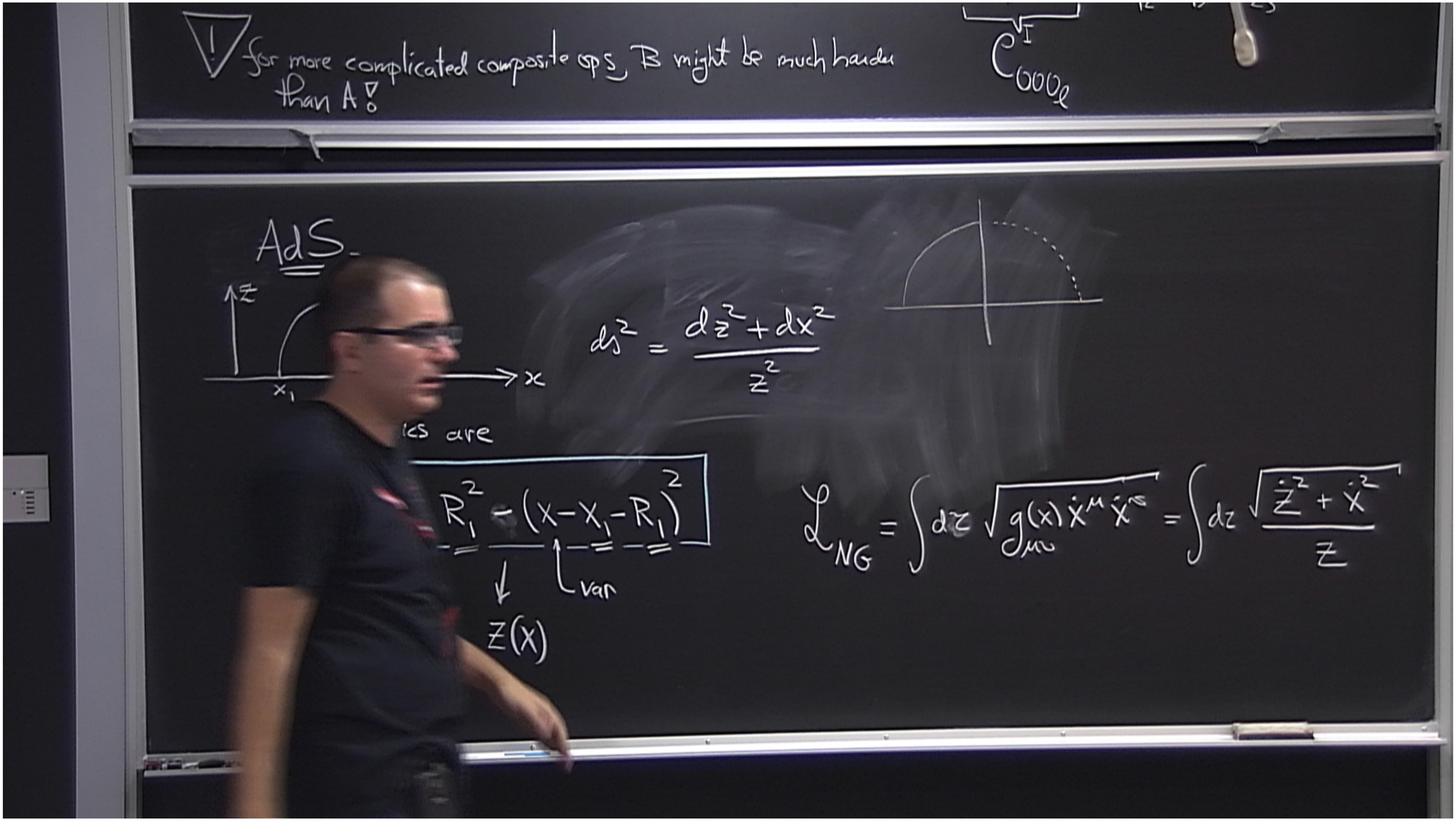

AdS/CFT toy model
AdS
CFT
R×Sd
=
AdS
Quantum Gravity
Gauge theory
without

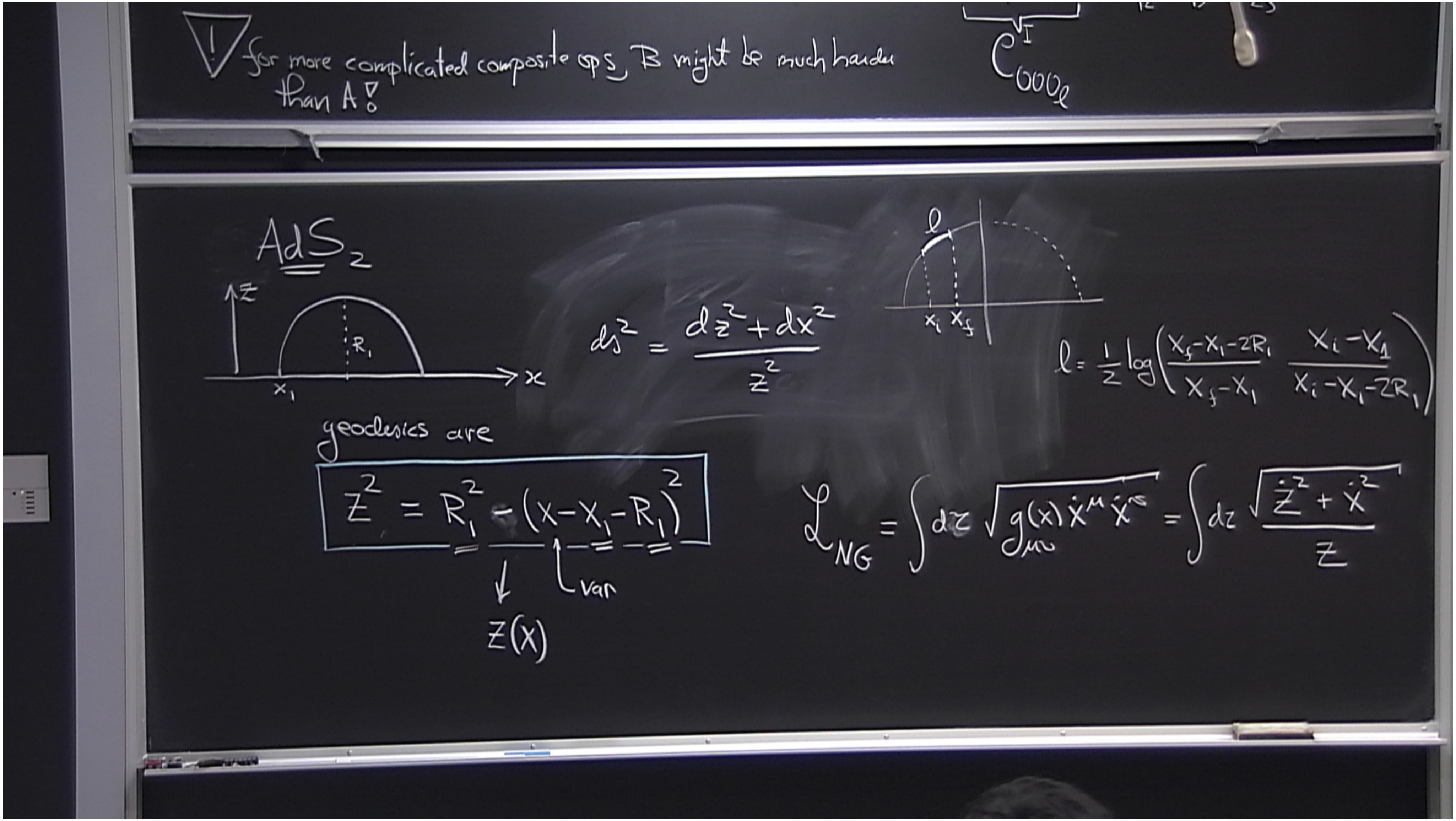

than A!
AdS2
R1
x
ds^2 = (dz^2 + dx^2) / z^2
geodesics are
z^2 = R1^2 - (x - x1 - R1)^2

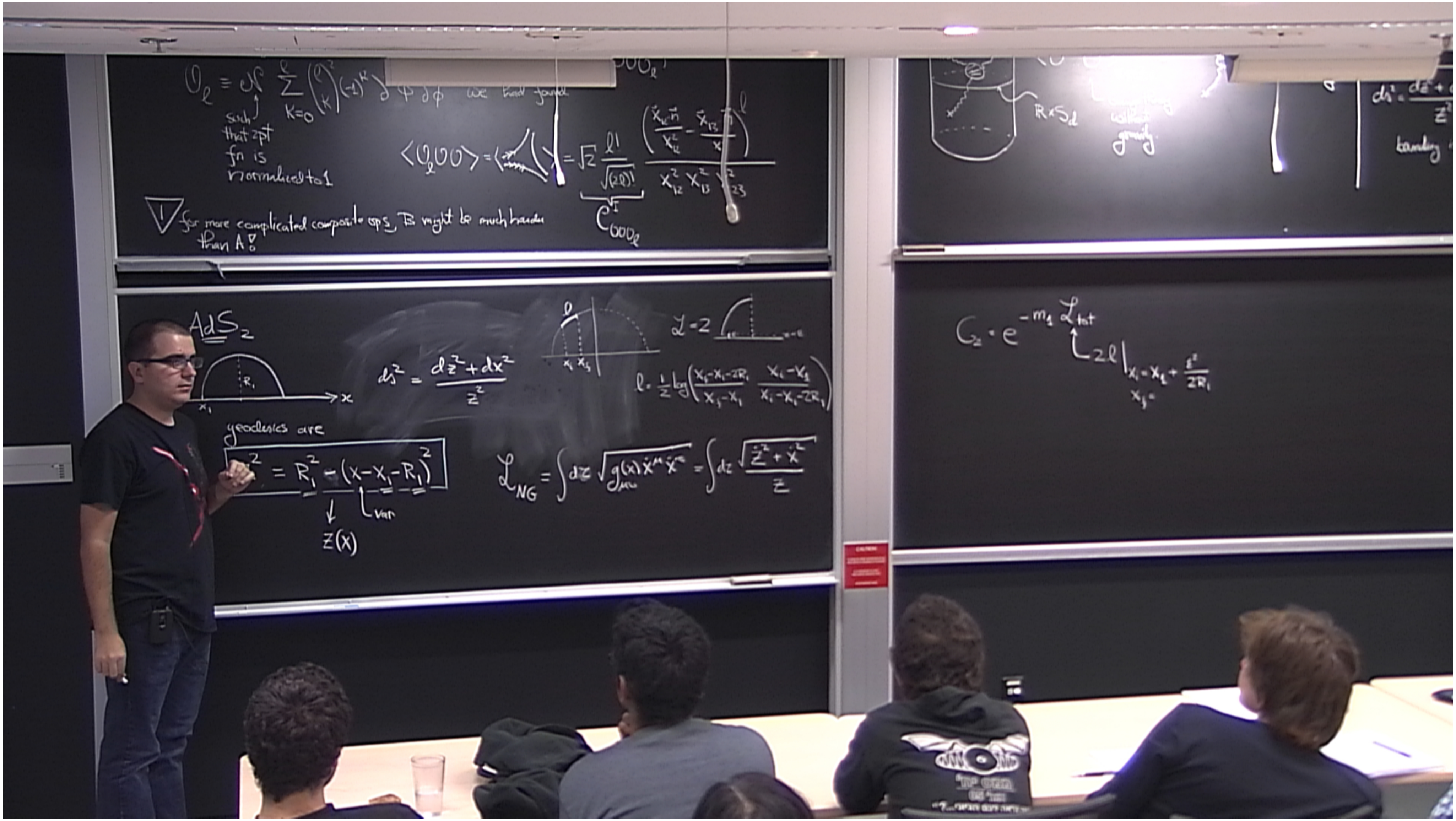

AdS$_2$
z
R_1
x_1
x
$ds^2 = \frac{dz^2 + dx^2}{z^2}$
geodesics are
$z^2 = R_1^2 - (x - x_1 - R_1)^2$
$z(x)$
var
$\mathcal{L}_{NG} = \int dz \sqrt{g_{\mu\nu}(x)\, \dot{x}^\mu \dot{x}^\nu}$

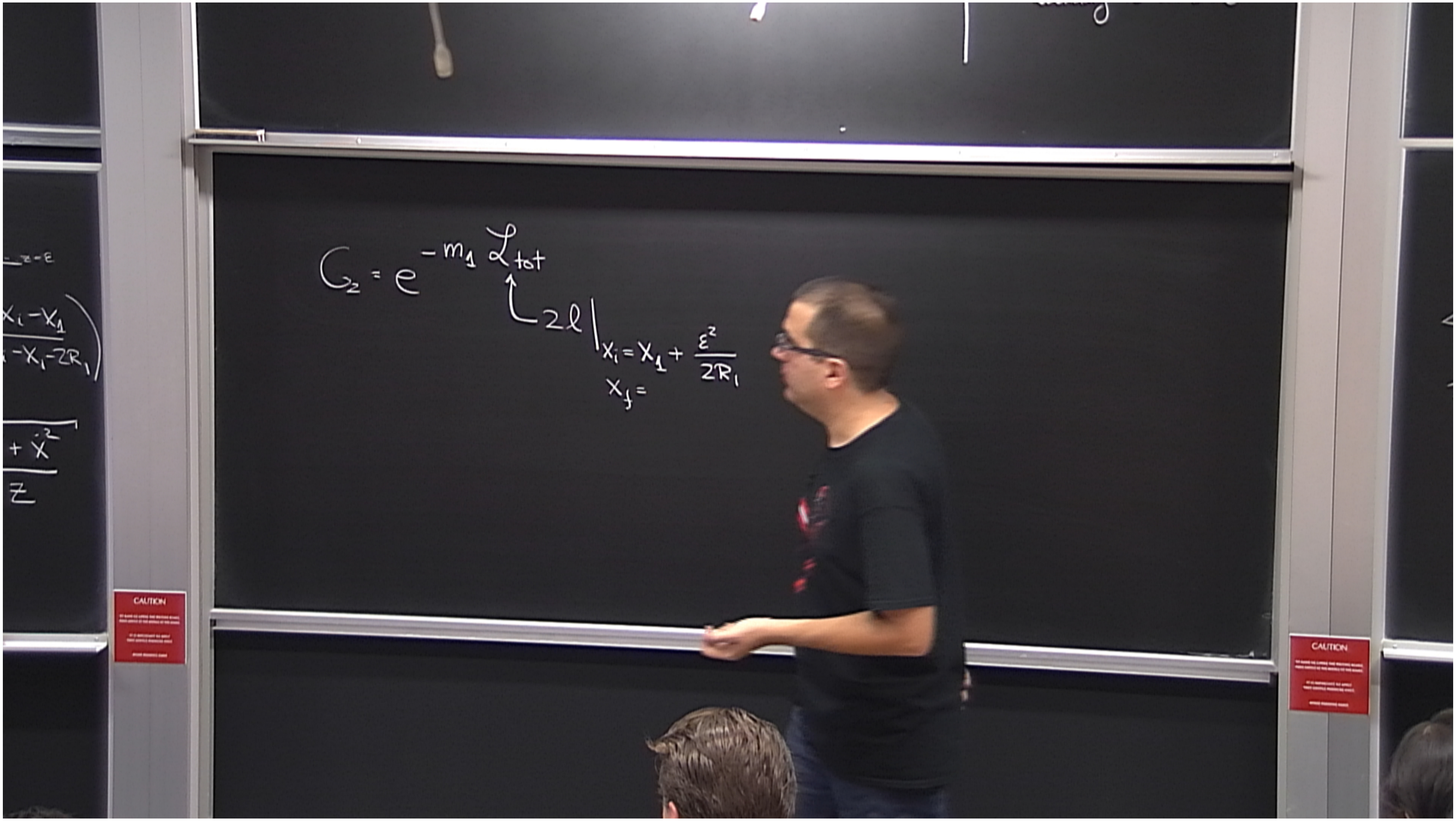

AdS2
z
R1
x1
x
ds² = (dz² + dx²) / z²
geodesics are
Z² = R1² − (x − x1 − R1)²
var
Z(x)
L_NG = ∫dτ √(g_μν(x) ẋ^μ ẋ^ν) = ∫dz √(ż² + ẋ²) / z

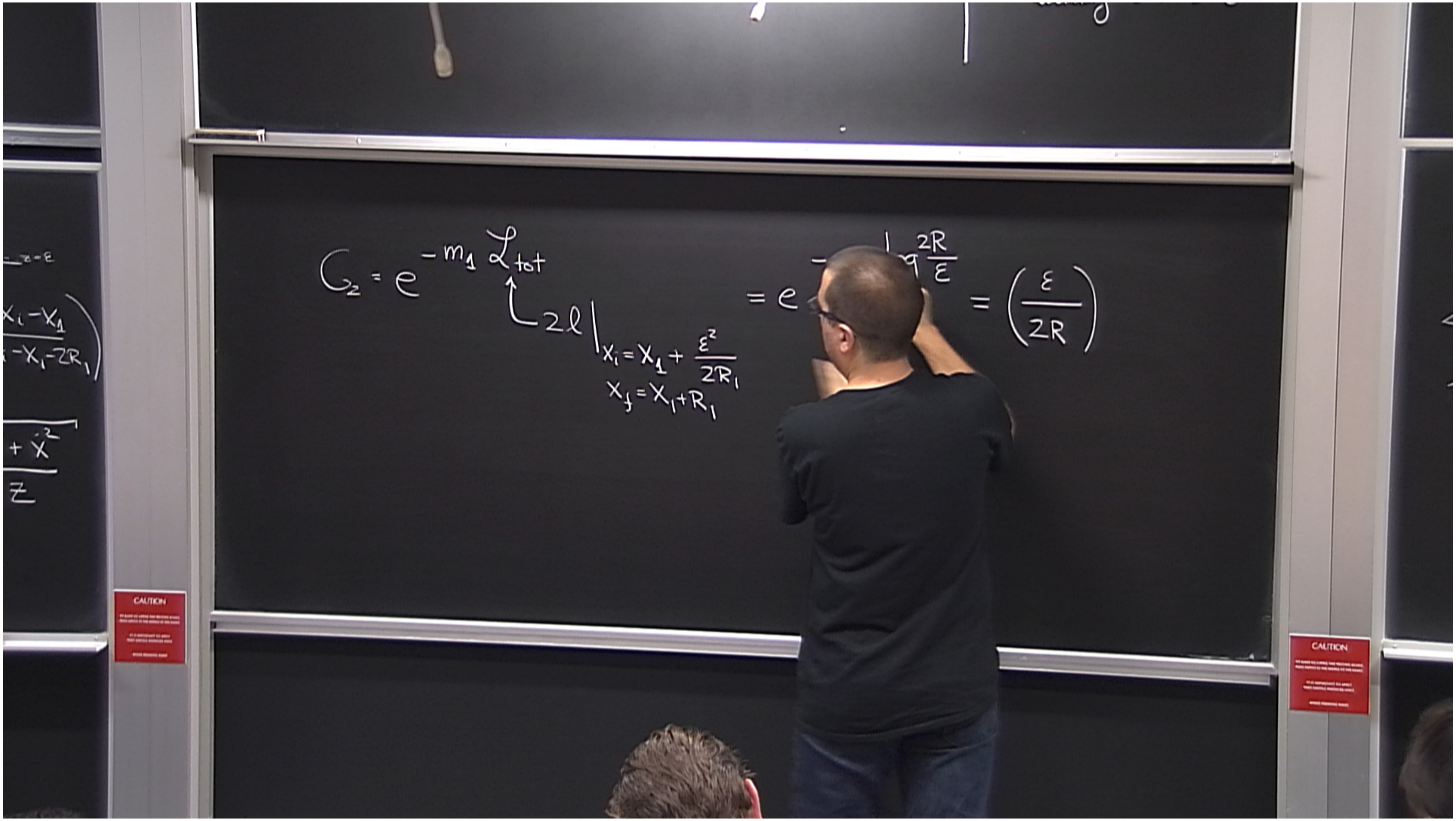

for more complicated composite ops, B might be much harder than A!
AdS2
geodesics are
Z(X)
var

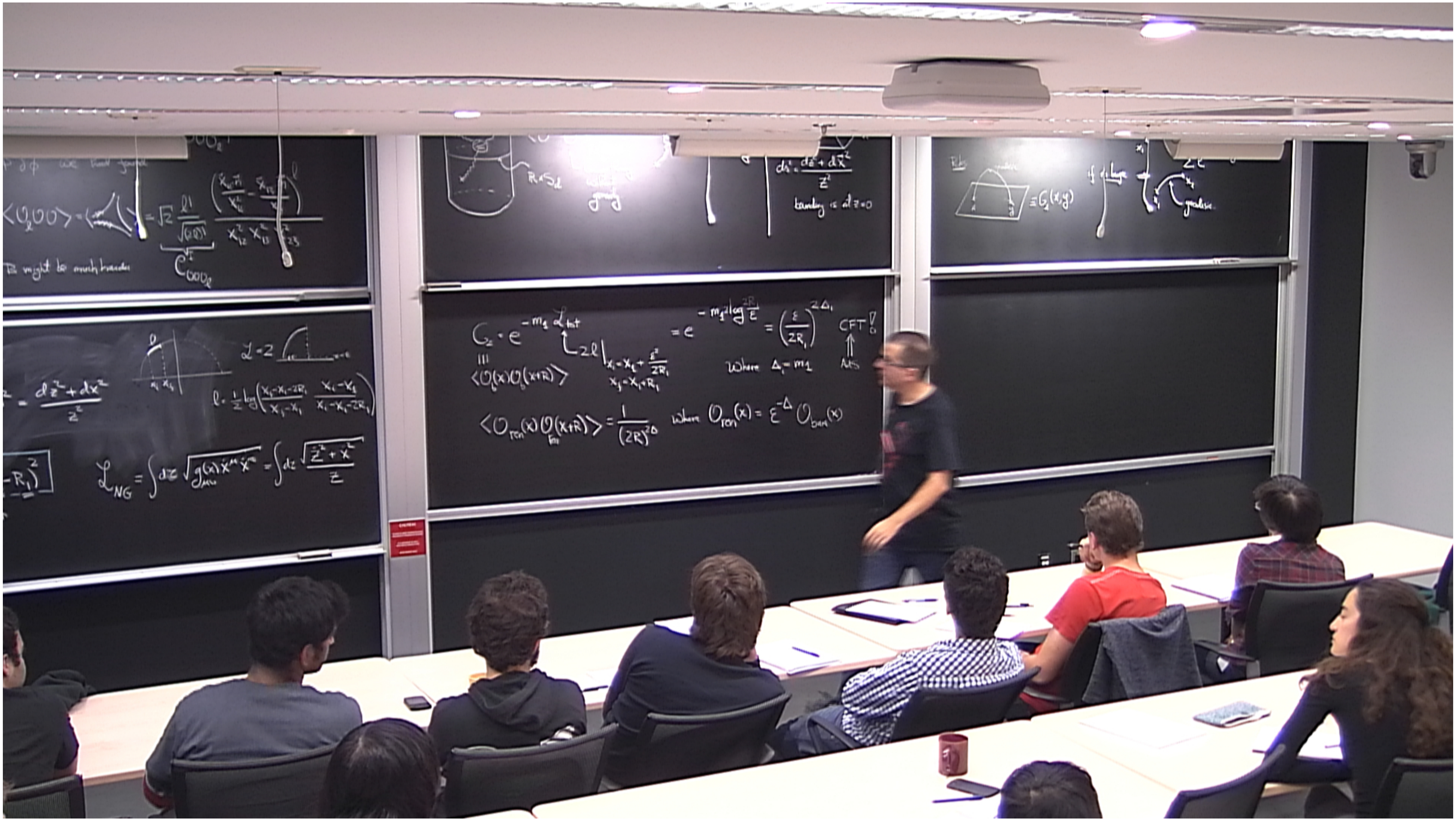

for more complicated composite ops, B might be much harder than A!
AdS
z
x
x_1
$ds^2 = \frac{dz^2 + dx^2}{z^2}$
are
$R_1^2 - (x - x_1 - R_1)^2$
var
$z(x)$
$\mathcal{L}_{NG} = \int dz \sqrt{g_{\mu\nu}(x)\dot{x}^\mu \dot{x}^\nu} = \int dz \frac{\sqrt{\dot{z}^2 + \dot{x}^2}}{z}$

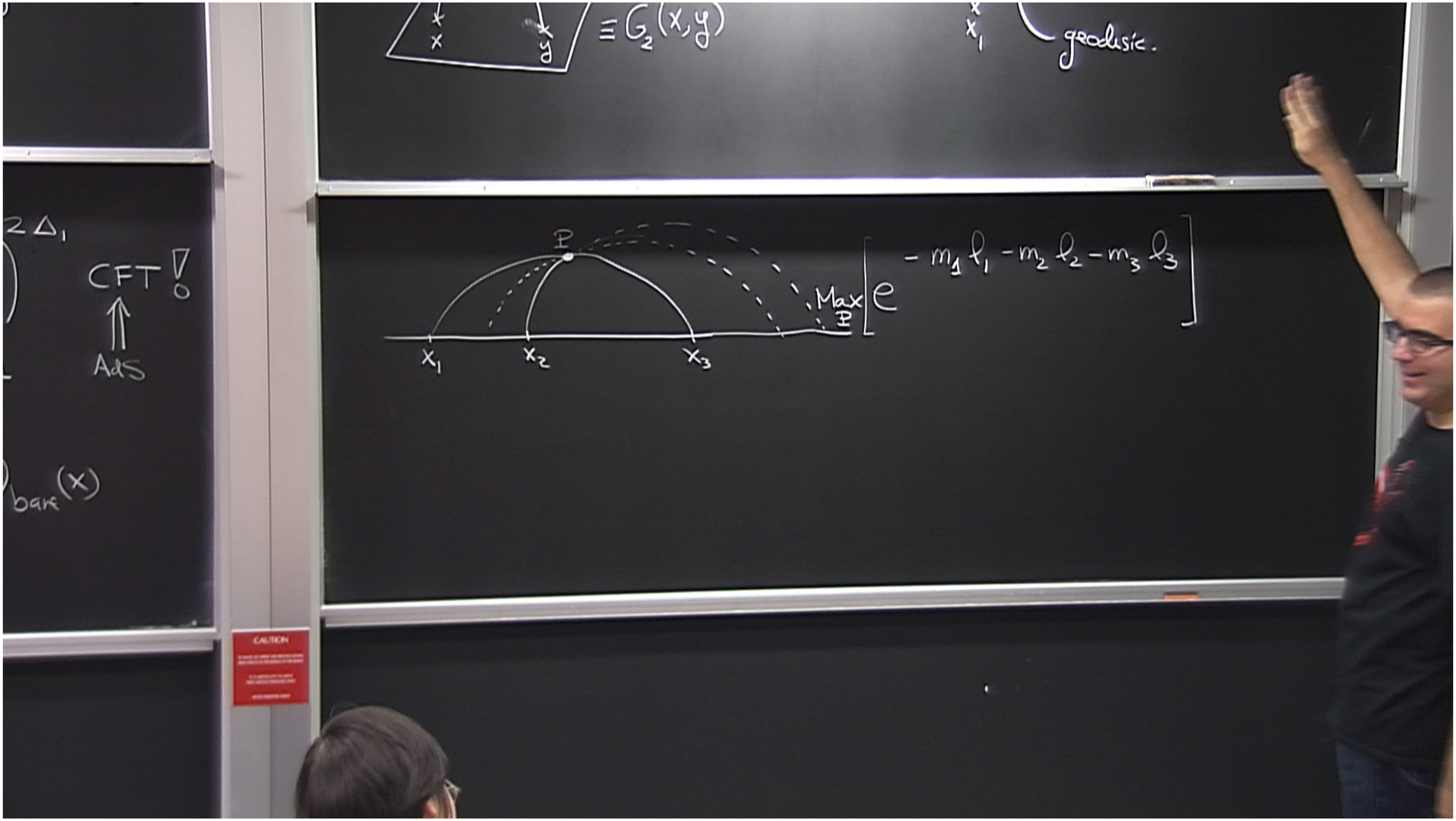

for more complicated composite ops, B might be much harder than A!
$C^{I}_{OOO_\ell}$
AdS_2
z
R_1
x_1
x
$ds^2 = \frac{dz^2 + dx^2}{z^2}$
ℓ
x_i x_f
$\ell = \frac{1}{2}\log\left(\frac{x_f - x_1 - 2R_1}{x_f - x_1} \frac{x_i - x_1}{x_i - x_1 - 2R_1}\right)$
geodesics are
$Z^2 = R_1^2 - (x - x_1 - R_1)^2$
var
$Z(X)$
$\mathcal{L}_{NG} = \int d\tau \sqrt{g_{\mu\nu}(x)\dot{x}^\mu \dot{x}^\nu} = \int dz \frac{\sqrt{\dot{z}^2 + \dot{x}^2}}{z}$


we had found
such that 2pt fn is normalized to 1
for more complicated composite ops, B might be much harder than A!
AdS2
geodesics are
Z(x)

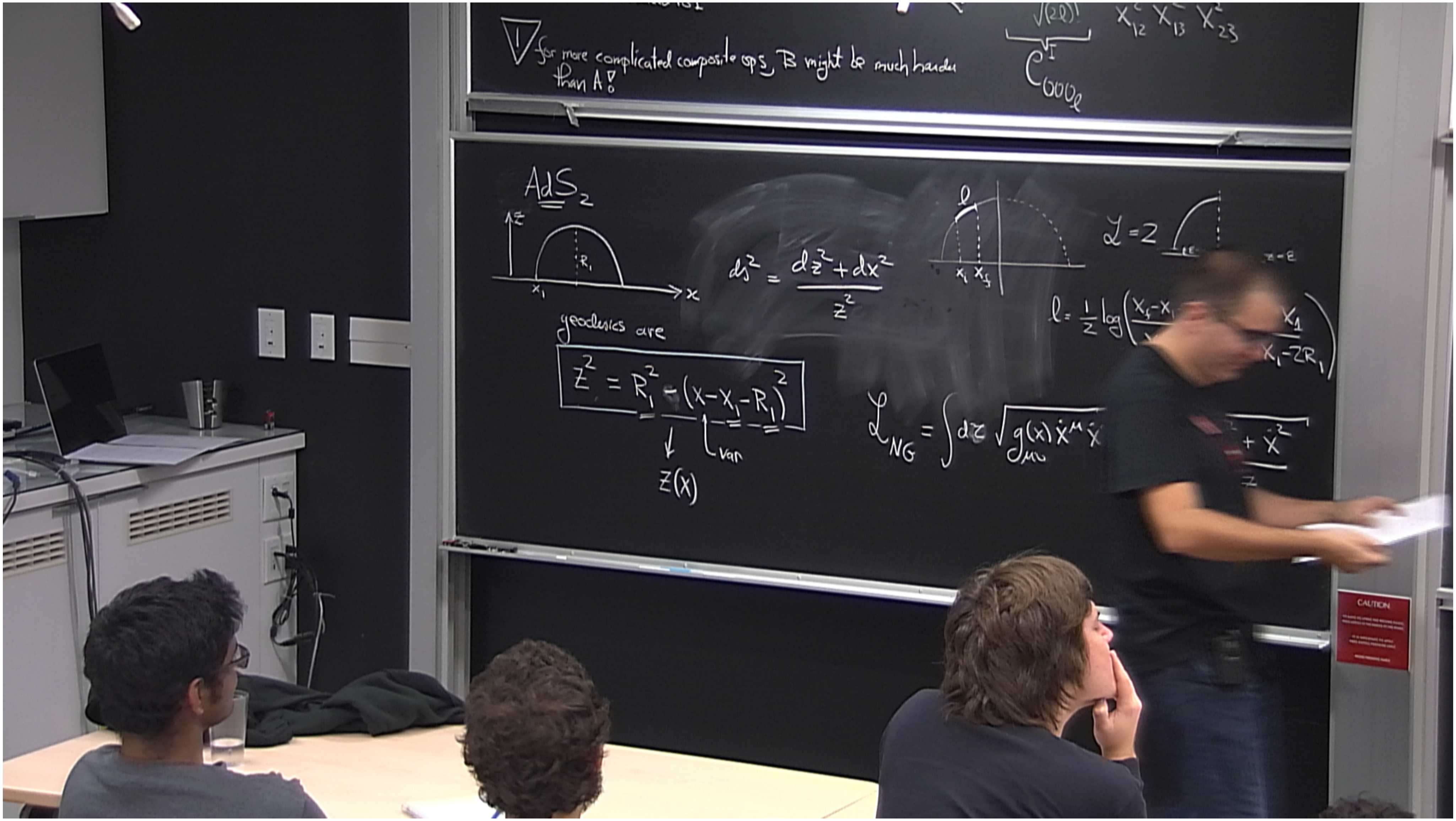

$G_2 = e^{-m_1 \mathcal{L}_{tot}}$
$2\ell \,\Big|_{x_i = x_1 + \frac{\varepsilon^2}{2R_1}}$
$x_f =$
CAUTION
CAUTION

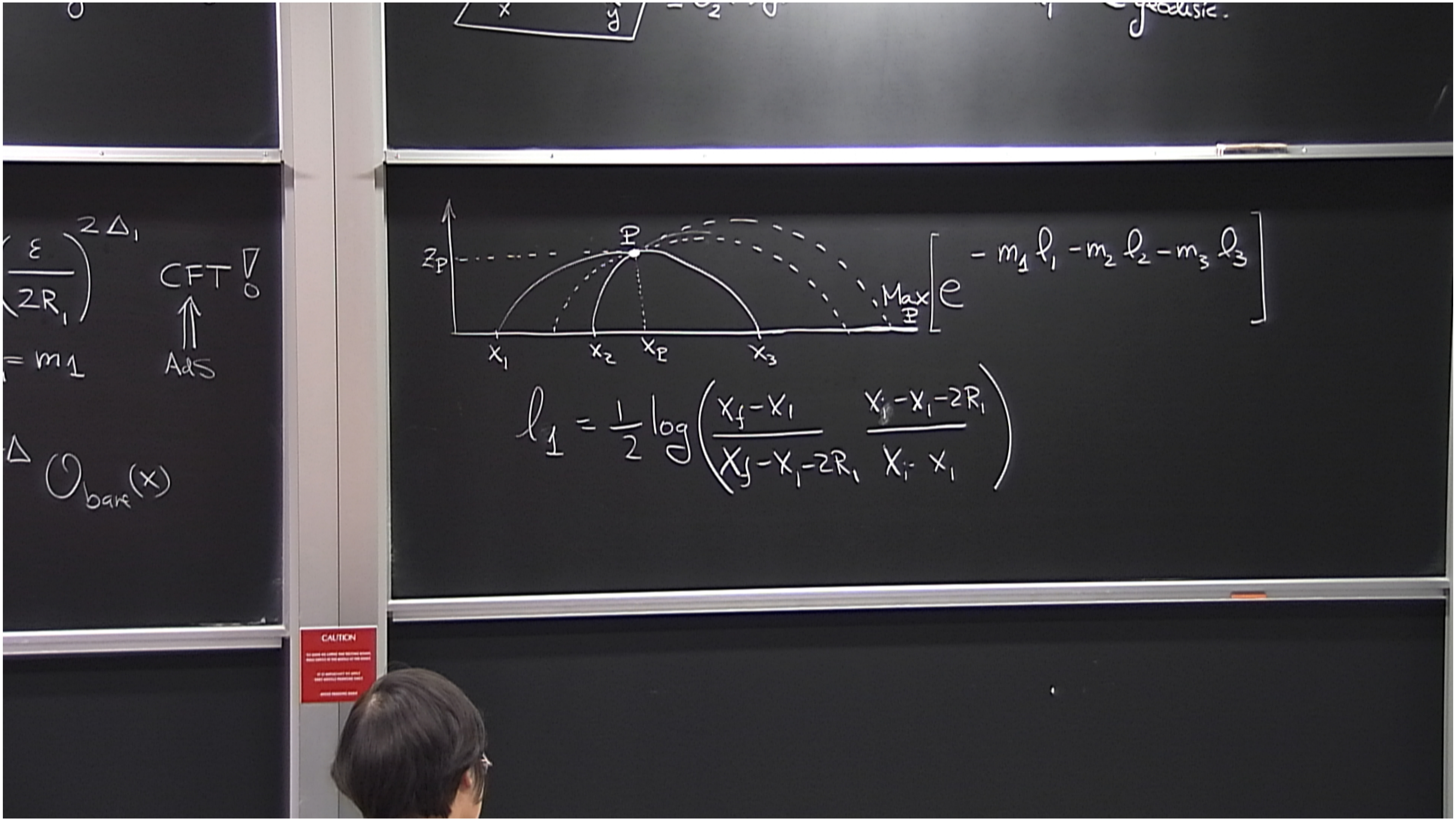

C₂ = e^{-m₁ L_tot}
2ℓ | x_i = x_1 + ε²/2R₁, x_f = x_1 + R_1
= e
2R/ε
= (ε/2R)
CAUTION
CAUTION

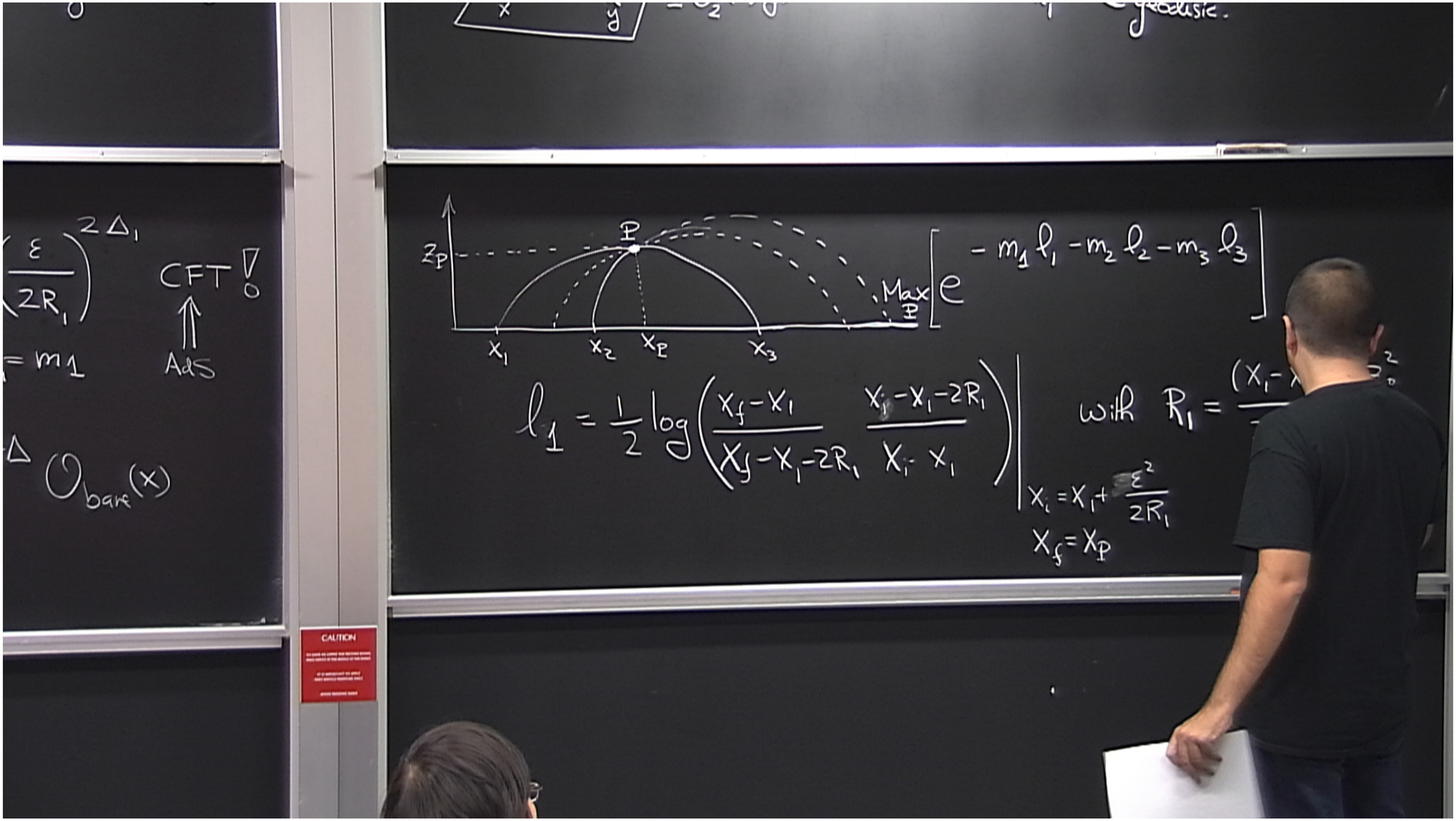


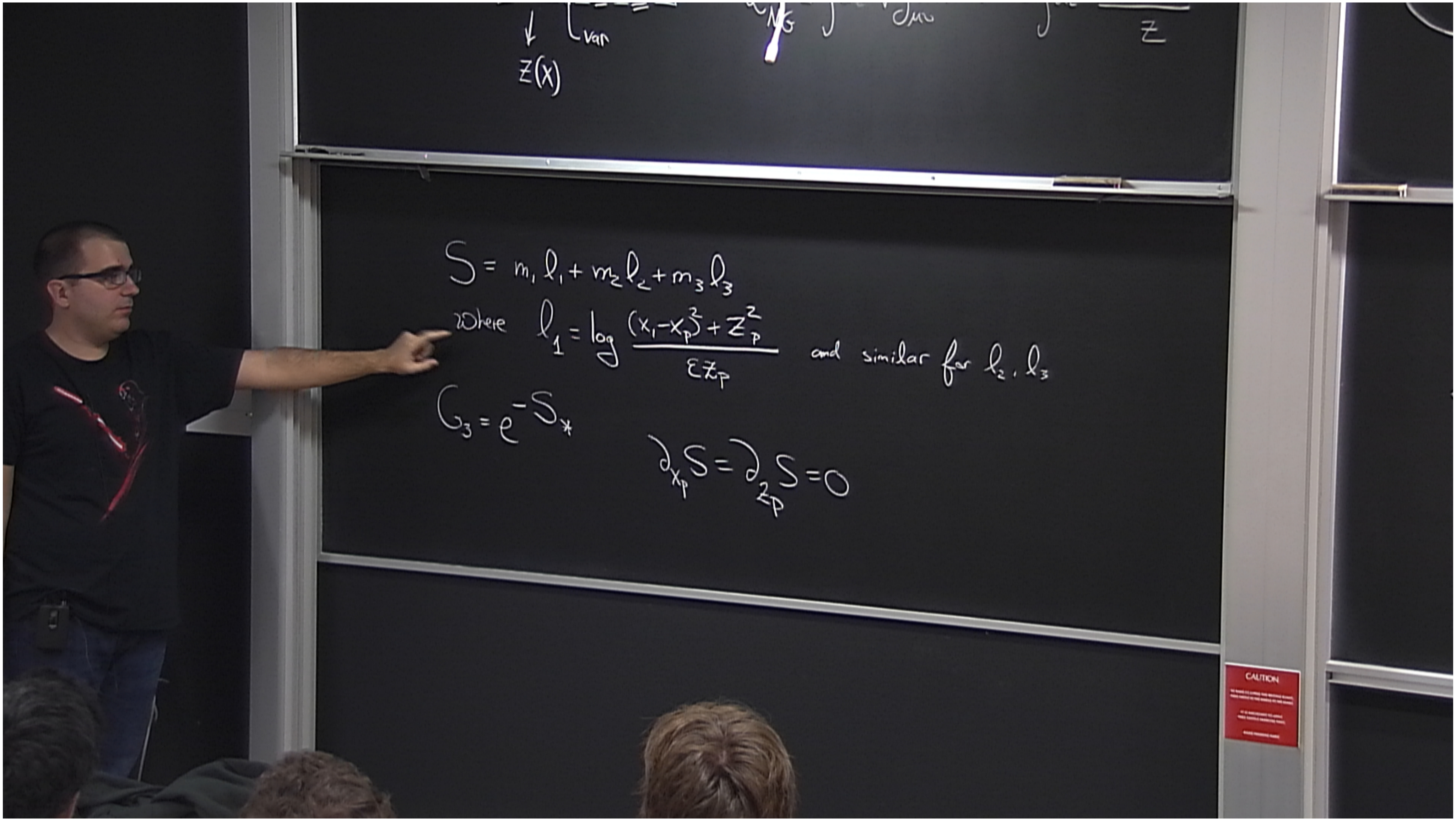


$\equiv G_2(x,y)$
geodesic.
$2\Delta_1$
CFT !
AdS
$_{bare}(x)$
P
x_1 x_2 x_3
$\underset{P}{\mathrm{Max}}\left[e^{-m_1\ell_1-m_2\ell_2-m_3\ell_3}\right]$


for more complicated composite ops, B might be much harder than A!
AdS₂
geodesics are
z² = R₁² − (x − x₁ − R₁)²
z(x)
var
ds² = (dz² + dx²) / z²
L_NG = ∫dτ √(g_μν(x) ẋ^μ ẋ^ν


geodesic.
CFT
AdS
$= m_1$
$\mathcal{O}_{bare}(x)$
z_P
x_1 x_2 x_P x_3
$\mathrm{Max}_P \left[e^{-m_1 \ell_1 - m_2 \ell_2 - m_3 \ell_3} \right]$
$\ell_1 = \frac{1}{2} \log \left(\frac{x_f - x_1}{x_f - x_1 - 2R_1} \frac{x_i - x_1 - 2R_1}{x_i - x_1} \right)$


CFT
AdS
O_bare(x)
z_P
P
x_1 x_2 x_P x_3
Max_P [e^(-m_1 l_1 - m_2 l_2 - m_3 l_3)]
l_1 = 1/2 log((x_f - x_1)/(x_f - x_1 - 2R_1) · (x_i - x_1 - 2R_1)/(x_i - x_1))
with R_1 =
x_i = x_1 + ε^2/2R_1
x_f = x_P
CAUTION


Z(x)
S = m1 l1 + m2 l2 + m3 l3
where l1 = log ((x1-xp)^2 + Zp^2) / (ε zp)   and similar for l2, l3
G3 = e^(-S*)
∂xp S = ∂zp S = 0

Mathematica File Edit Insert Format Cell Graphics Evaluation Palettes Window Help Thu 4:30 PM Pedro Vieira

new notebook

In[324]:=

$$\text{PowerExpand@FullSimplify}\left[\frac{\sqrt{D\left[\sqrt{R1^2-(x-x1-R1)^2},x\right]^2+1}}{\sqrt{R1^2-(x-x1-R1)^2}}\right]//$$

```
Integrate[#, {x, xi, xf}, GenerateConditions → False] &
```

Out[324]=

$$\frac{1}{2}\left(\text{Log}[-x1+xf]-\text{Log}[-2\,R1-x1+xf]-\text{Log}[-x1+xi]+\text{Log}[-2\,R1-x1+xi]\right)$$

$$\text{action}=m[1]\,\text{Log}\left[\frac{(x1-xp)^2+zp^2}{zp\,\epsilon}\right]+m[2]\,\text{Log}\left[\frac{(x2-xp)^2+zp^2}{zp\,\epsilon}\right]+m[3]\,\text{Log}\left[\frac{(x3-xp)^2+zp^2}{zp\,\epsilon}\right]$$

300%

Mathematica File Edit Insert Format Cell Graphics Evaluation Palettes Window Help Thu 4:30 PM Pedro Vieira

new notebook

In[324]:=

$$\text{PowerExpand@FullSimplify}\left[\frac{\sqrt{D\left[\sqrt{R1^2-(x-x1-R1)^2},x\right]^2+1}}{\sqrt{R1^2-(x-x1-R1)^2}}\right]\ //$$

```
Integrate[#, {x, xi, xf}, GenerateConditions → False] &
```

Out[324]=

$$\frac{1}{2}\left(\text{Log}[-x1+xf]-\text{Log}[-2\,R1-x1+xf]-\text{Log}[-x1+xi]+\text{Log}[-2\,R1-x1+xi]\right)$$

In[326]:=

$$\text{action}=m[1]\,\text{Log}\left[\frac{(x1-xp)^2+zp^2}{zp\,\epsilon}\right]+m[2]\,\text{Log}\left[\frac{(x2-xp)^2+zp^2}{zp\,\epsilon}\right]+m[3]\,\text{Log}\left[\frac{(x3-xp)^2+zp^2}{zp\,\epsilon}\right];$$

300%

Mathematica File Edit Insert Format Cell Graphics Evaluation Palettes Window Help Thu 4:30 PM Pedro Vieira

new notebook

In[327]:=

$$\text{action} = m[1]\,\text{Log}\left[\frac{(x1 - xp)^2 + zp^2}{zp\,\epsilon}\right] + m[2]\,\text{Log}\left[\frac{(x2 - xp)^2 + zp^2}{zp\,\epsilon}\right] + m[3]\,\text{Log}\left[\frac{(x3 - xp)^2 + zp^2}{zp\,\epsilon}\right];$$

300%

Mathematica File Edit Insert Format Cell Graphics Evaluation Palettes Window Help Thu 4:31 PM Pedro Vieira

new notebook

$$\text{action} = m[1]\,\text{Log}\left[\frac{(x1-xp)^2+zp^2}{zp\,\epsilon}\right] + m[2]\,\text{Log}\left[\frac{(x2-xp)^2+zp^2}{zp\,\epsilon}\right] + m[3]\,\text{Log}\left[\frac{(x3-xp)^2+zp^2}{zp\,\epsilon}\right];$$

In[331]:=

$$\text{eqs} = \{\partial_{zp}\,\text{action},\ \partial_{xp}\,\text{action}\}\ //\ \text{FullSimplify};$$

```
Solve[eqs
```

Out[332]=

$$\left\{-\frac{\frac{\left((x1-xp)^2-zp^2\right)m[1]}{(x1-xp)^2+zp^2}+\frac{\left((x2-xp)^2-zp^2\right)m[2]}{(x2-xp)^2+zp^2}+\frac{\left((x3-xp)^2-zp^2\right)m[3]}{(x3-xp)^2+zp^2}}{zp},\right.$$

$$\left.2\left(\frac{(-x1+xp)\,m[1]}{(x1-xp)^2+zp^2}+\frac{(-x2+xp)\,m[2]}{(x2-xp)^2+zp^2}+\frac{(-x3+xp)\,m[3]}{(x3-xp)^2+zp^2}\right)\right\}$$

300%

Mathematica File Edit Insert Format Cell Graphics Evaluation Palettes Window Help   Thu 4:32 PM Pedro Vieira

new notebook

$$\texttt{action} = \texttt{m[1] Log}\left[\frac{(x1 - xp)^2 + zp^2}{zp\,\epsilon}\right] + \texttt{m[2] Log}\left[\frac{(x2 - xp)^2 + zp^2}{zp\,\epsilon}\right] + \texttt{m[3] Log}\left[\frac{(x3 - xp)^2 + zp^2}{zp\,\epsilon}\right];$$

In[331]:=

$$\texttt{eqs} = \{\partial_{zp}\,\texttt{action},\ \partial_{xp}\,\texttt{action}\} \ \texttt{//}\ \texttt{FullSimplify};$$

```
eqs /. {m[2] → α m[1], m[3]
```

Out[334]=

$$\left\{-\frac{\frac{\left((x1-xp)^2-zp^2\right)m[1]}{(x1-xp)^2+zp^2}+\frac{\left((x2-xp)^2-zp^2\right)m[2]}{(x2-xp)^2+zp^2}+\frac{\left((x3-xp)^2-zp^2\right)m[3]}{(x3-xp)^2+zp^2}}{zp},\ 2\left(\frac{(-x1+xp)\,m[1]}{(x1-xp)^2+zp^2}+\frac{(-x2+xp)\,m[2]}{(x2-xp)^2+zp^2}+\frac{(-x3+xp)\,m[3]}{(x3-xp)^2+zp^2}\right)\right\}$$

300%

Mathematica File Edit Insert Format Cell Graphics Evaluation Palettes Window Help — Thu 4:33 PM Pedro Vieira

new notebook

```
sol = Solve[0 == eqs2, {xp, zp}] // First // Simplify // PowerExpand //
  Simplify
```

Out[338]=

$$\Big\{xp \to \Big(-x2\, x3\, (-1+\alpha+\beta)\, (x2\, (-1+\alpha-\beta) + x3\, (-1-\alpha+\beta)) + x1^2\, (-1+\alpha+\beta)\, (x2\, (1+\alpha-\beta) + x3\, (1-\alpha+\beta)) + x1\, \Big(-x2^2\, \left(-1+\alpha^2-2\,\alpha\,\beta+\beta^2\right) - x3^2\, \left(-1+\alpha^2-2\,\alpha\,\beta+\beta^2\right) + 2\, x2\, x3\, \left(\alpha^2+(-1+\beta)^2-2\,\alpha\,(1+\beta)\right)\Big)\Big) \Big/ \Big(2\, \Big(x3^2\, (1+\alpha-\beta)\,\beta + x2^2\,\alpha\,(1-\alpha+\beta) + x1^2\,(-1+\alpha+\beta) + x2\, x3\, \left(-1+\alpha^2-2\,\alpha\,\beta+\beta^2\right) + x1\,(-1+\alpha+\beta)\,(x2\,(-1+\alpha-\beta) + x3\,(-1-\alpha+\beta))\Big)\Big),$$

$$zp \to -\left(i\,(x1-x2)\,(x1-x3)\,(x2-x3)\,\sqrt{\alpha^4+\left(-1+\beta^2\right)^2-2\,\alpha^2\,\left(1+\beta^2\right)}\right) \Big/ \Big(2\,\Big(x3^2\,(1+\alpha-\beta)\,\beta + x2^2\,\alpha\,(1-\alpha+\beta) + x1^2\,(-1+\alpha+\beta) + x2\,x3\,\left(-1+\alpha^2-2\,\alpha\,\beta+\beta^2\right) + x1\,(-1+\alpha+\beta)\,(x2\,(-1+\alpha-\beta)+x3\,(-1-\alpha+\beta))\Big)\Big)\Big\}$$

Mathematica File Edit Insert Format Cell Graphics Evaluation Palettes Window Help Thu 4:34 PM Pedro Vieira

new notebook

$$2\left(\frac{-x1+xp}{(x1-xp)^2+zp^2}+\frac{(-x2+xp)\,\alpha}{(x2-xp)^2+zp^2}+\frac{(-x3+xp)\,\beta}{(x3-xp)^2+zp^2}\right) m[1]\}$$

```
sol = Solve[0 == eqs2, {xp, zp}] // First // Simplify // PowerExpand //
   Simplify;
```

```
action /. sol /. {α → m[2] / m[1], β → m[3] /
```

Out[340]=

$$\mathrm{Log}\Big[\left(2\,i\left(x3^2(1+\alpha-\beta)\beta+x2^2\alpha(1-\alpha+\beta)+x1^2(-1+\alpha+\beta)+x2\,x3\left(-1+\alpha^2-2\alpha\beta+\beta^2\right)+x1(-1+\alpha+\beta)(x2(-1+\alpha-\beta)+x3(-1-\alpha+\beta))\right)\right.$$
$$\left(-\left((x1-x2)^2(x1-x3)^2(x2-x3)^2\left(\alpha^4+\left(-1+\beta^2\right)^2-2\alpha^2\left(1+\beta^2\right)\right)\right)\Big/\right.$$
$$\left(4\left(x3^2(1+\alpha-\beta)\beta+x2^2\alpha(1-\alpha+\beta)+x1^2(-1+\alpha+\beta)+x2\,x3\left(-1+\alpha^2-2\alpha\beta+\beta^2\right)+\right.\right.$$
$$x1\,(-1+\alpha+\beta)\,(x2\,(-1+\alpha-\beta)+x3\,(-1-\alpha+\beta)))^2)+$$

300%

Mathematica File Edit Insert Format Cell Graphics Evaluation Palettes Window Help — Thu 4:36 PM Pedro Vieira

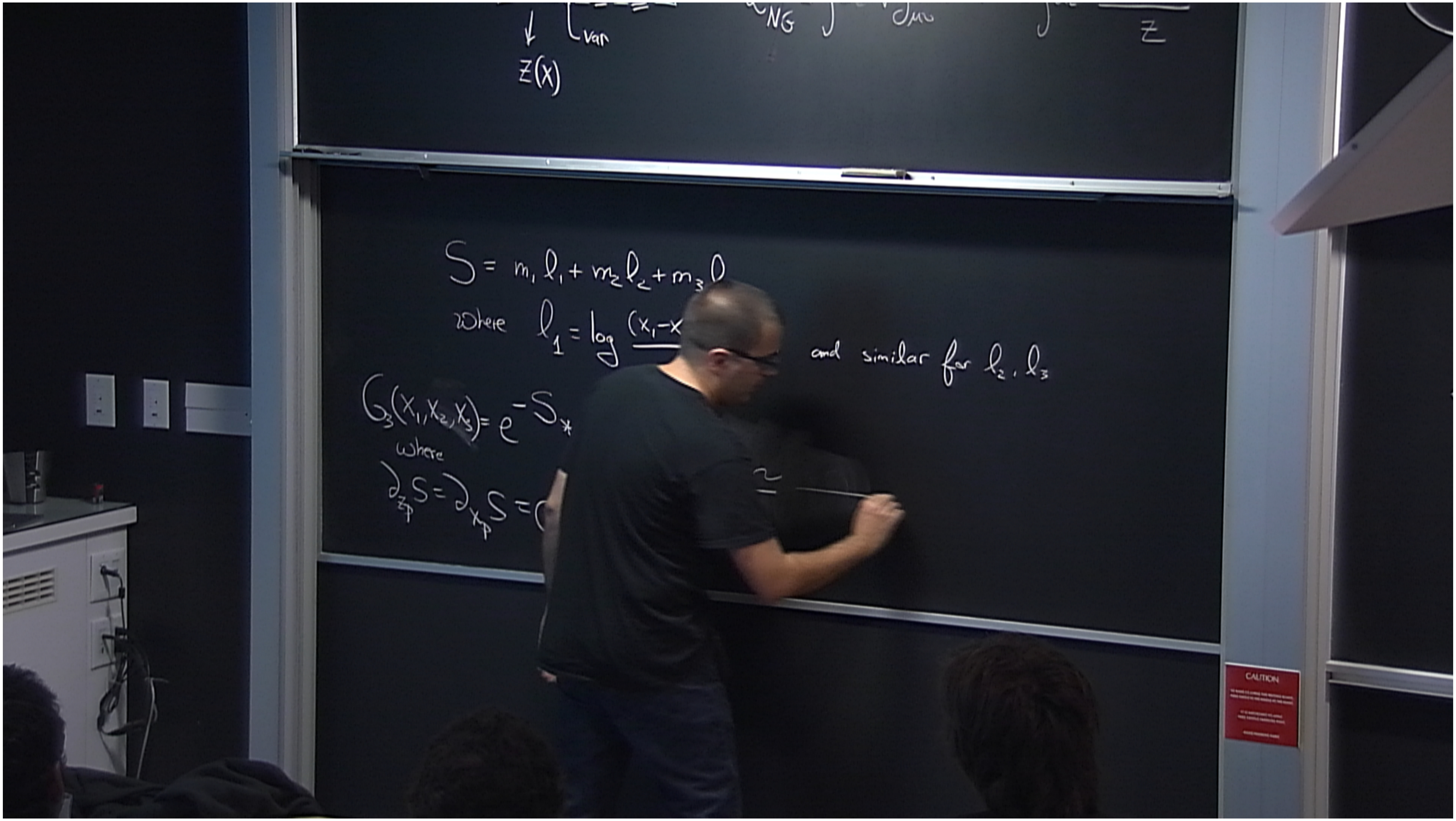
new notebook

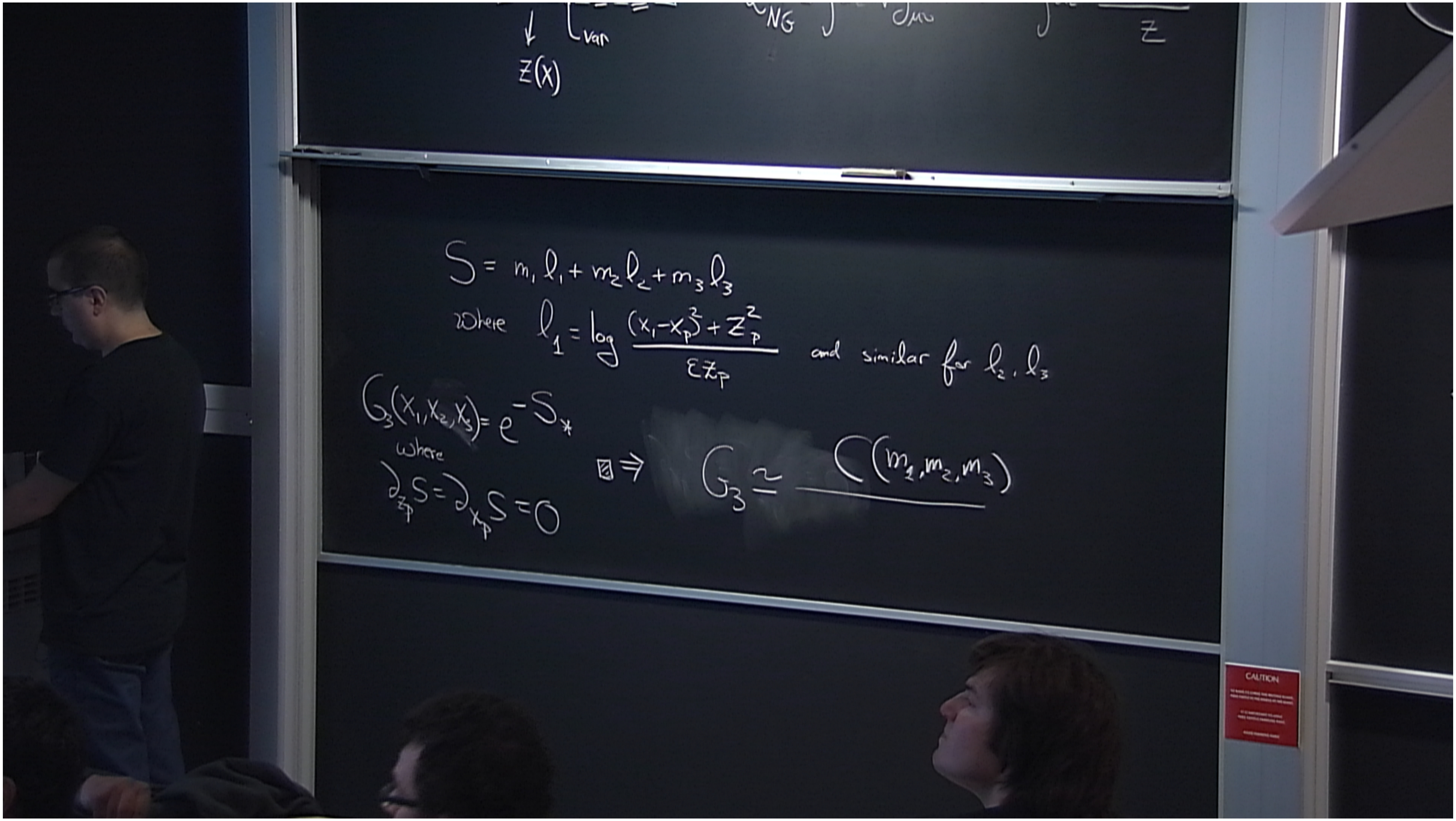
```
actionCrit
```

Out[344]=

$$\begin{aligned}&\Big(-\frac{i\pi}{2}+\mathrm{Log}[2]+\mathrm{Log}[x1-x2]+\mathrm{Log}[x1-x3]-\mathrm{Log}[x2-x3]-\mathrm{Log}[\epsilon]-\mathrm{Log}[m[1]]+\mathrm{Log}[m[1]-m[2]-m[3]]+\frac{1}{2}\Big(4\,\mathrm{Log}[m[1]]-\mathrm{Log}\Big[m[1]^4+\big(m[2]^2-m[3]^2\big)^2-2\,m[1]^2\,\big(m[2]^2+m[3]^2\big)\Big]\Big)\Big)\,m[1]\\&+\Big(\frac{i\pi}{2}+\mathrm{Log}[2]+\mathrm{Log}[x1-x2]-\mathrm{Log}[x1-x3]+\mathrm{Log}[x2-x3]-\mathrm{Log}[\epsilon]-2\,\mathrm{Log}[m[1]]+\mathrm{Log}[m[2]]+\mathrm{Log}[m[1]-m[2]+m[3]]+\frac{1}{2}\Big(4\,\mathrm{Log}[m[1]]-\mathrm{Log}\Big[m[1]^4+\big(m[2]^2-m[3]^2\big)^2-2\,m[1]^2\,\big(m[2]^2+m[3]^2\big)\Big]\Big)\Big)\,m[2]\\&+\Big(\frac{i\pi}{2}+\mathrm{Log}[2]-\mathrm{Log}[x1-x2]+\mathrm{Log}[x1-x3]+\mathrm{Log}[x2-x3]-\mathrm{Log}[\epsilon]-2\,\mathrm{Log}[m[1]]+\mathrm{Log}[m[1]+m[2]-m[3]]+\mathrm{Log}[m[3]]+\frac{1}{2}\Big(4\,\mathrm{Log}[m[1]]-\mathrm{Log}\Big[m[1]^4+\big(m[2]^2-m[3]^2\big)^2-2\,m[1]^2\,\big(m[2]^2+m[3]^2\big)\Big]\Big)\Big)\,m[3]\end{aligned}$$

300%


Z(X)
S = m1 l1 + m2 l2 + m3 l3
where
and similar for l2, l3
where



Z(X)
S = m1 l1 + m2 l2 + m3 l3
where l1 = log ((x1 - xp)^2 + Zp^2) / (ε Zp)   and similar for l2, l3
G3(X1, X2, X3) = e^-S*
where
∂zp S = ∂xp S = 0
⇒ G3 ≃ C(m1, m2, m3)
CAUTION

Mathematica File Edit Insert Format Cell Graphics Evaluation Palettes Window Help

new notebook

Full result is D[withα,α]+(withα/.$\alpha \to 0$)

In[349]:=

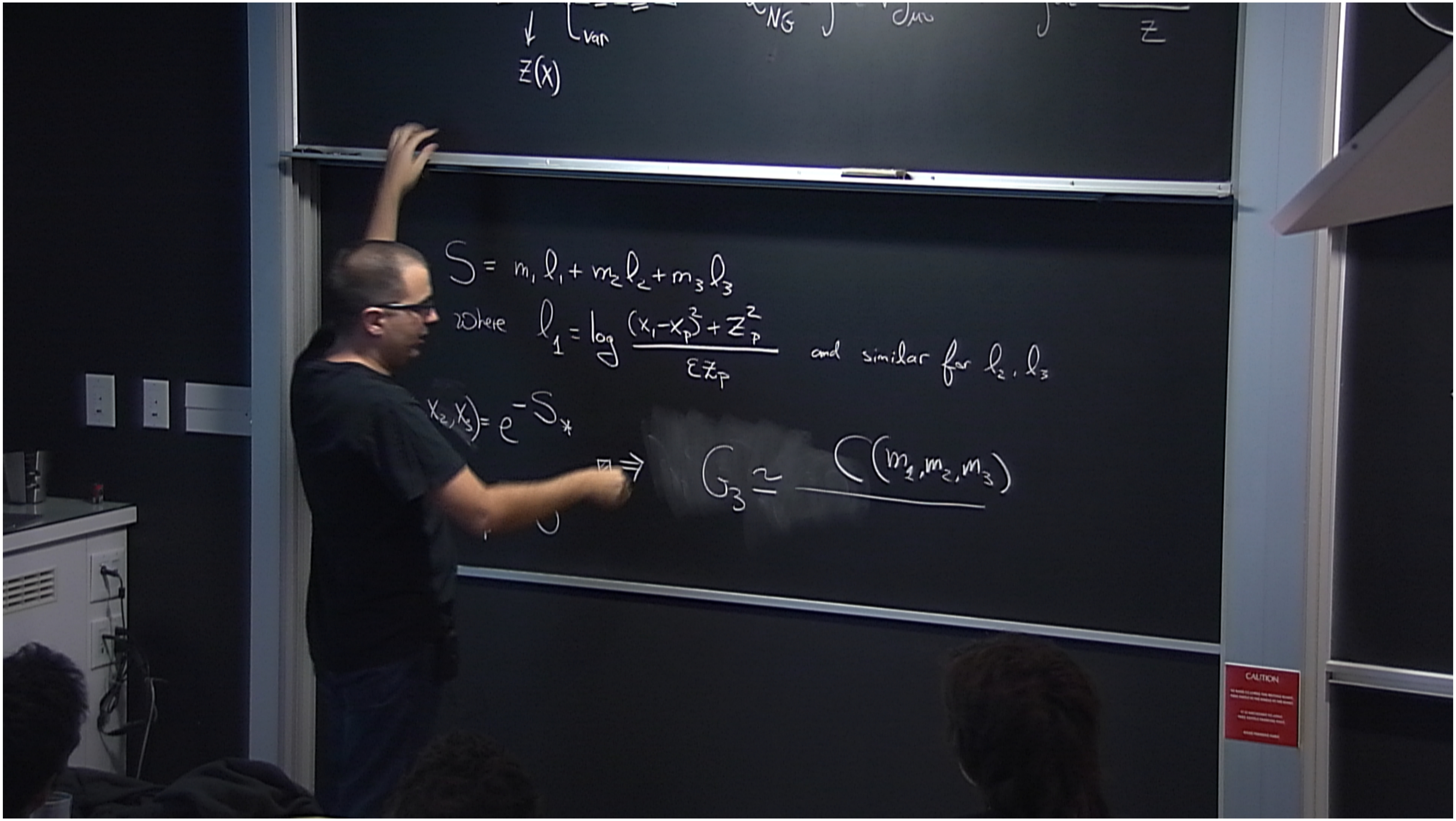
```
withα /. α → 0 // Simplify;
```

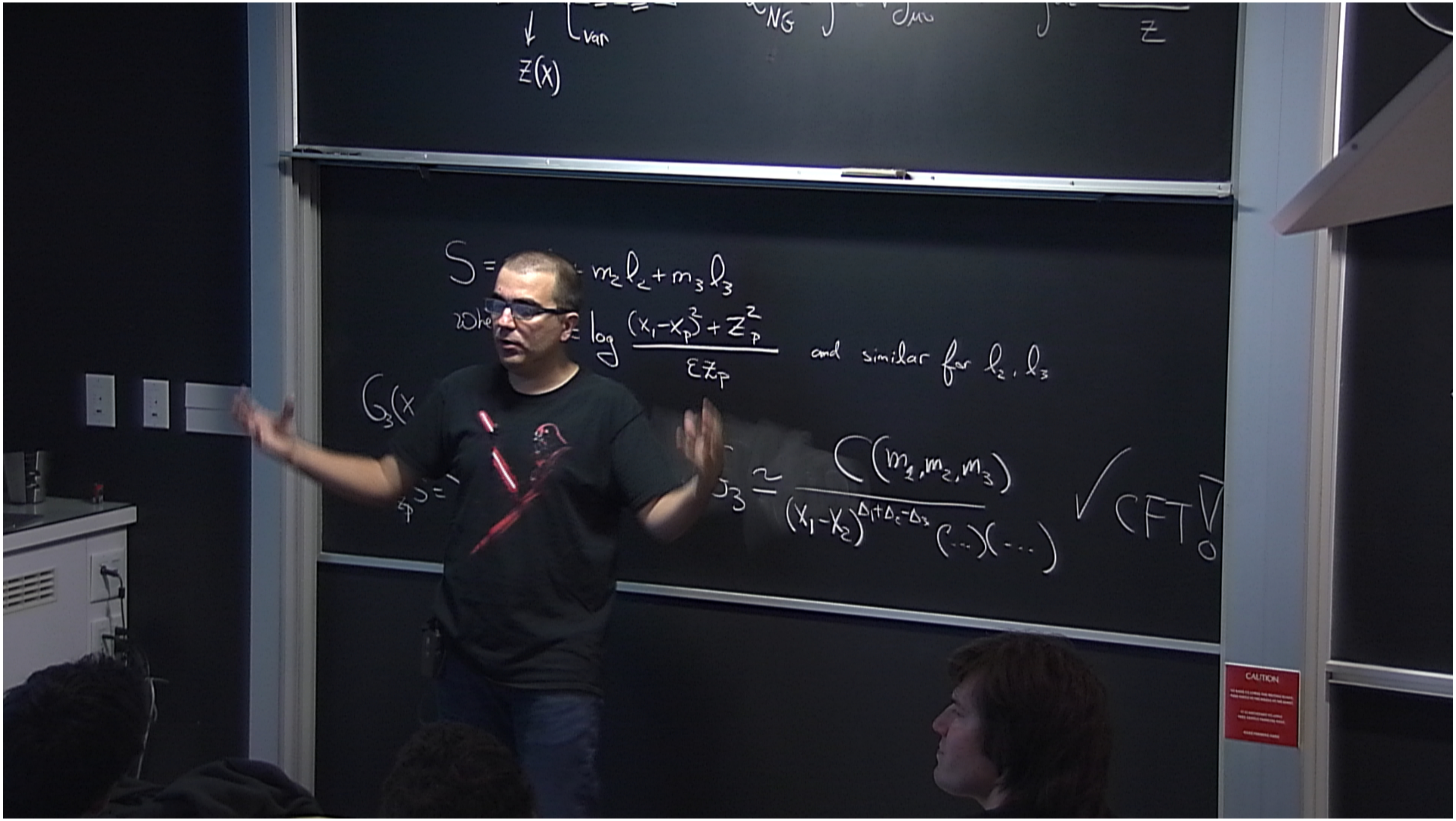
In[350]:=

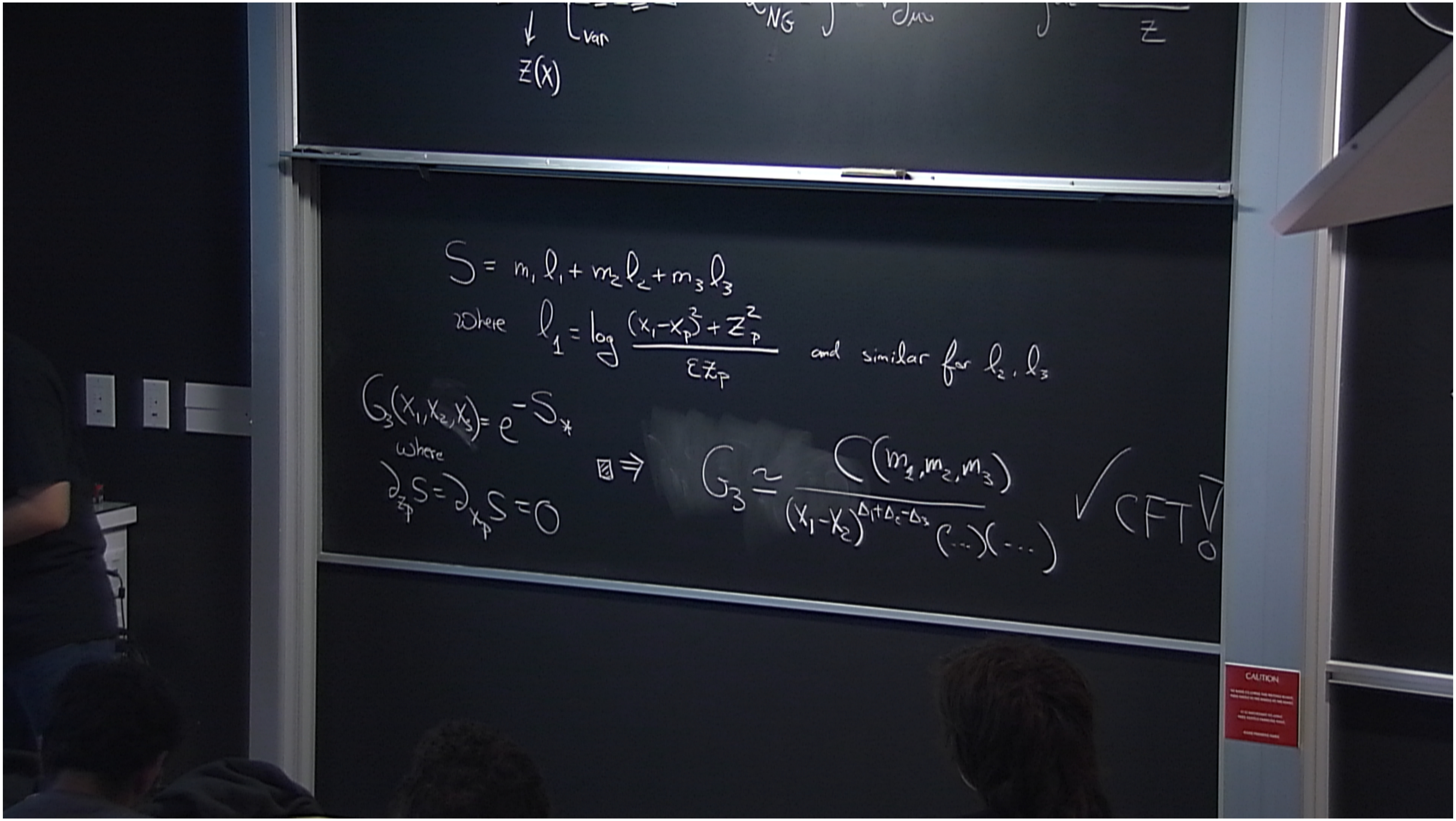
```
D[withα, α]
```

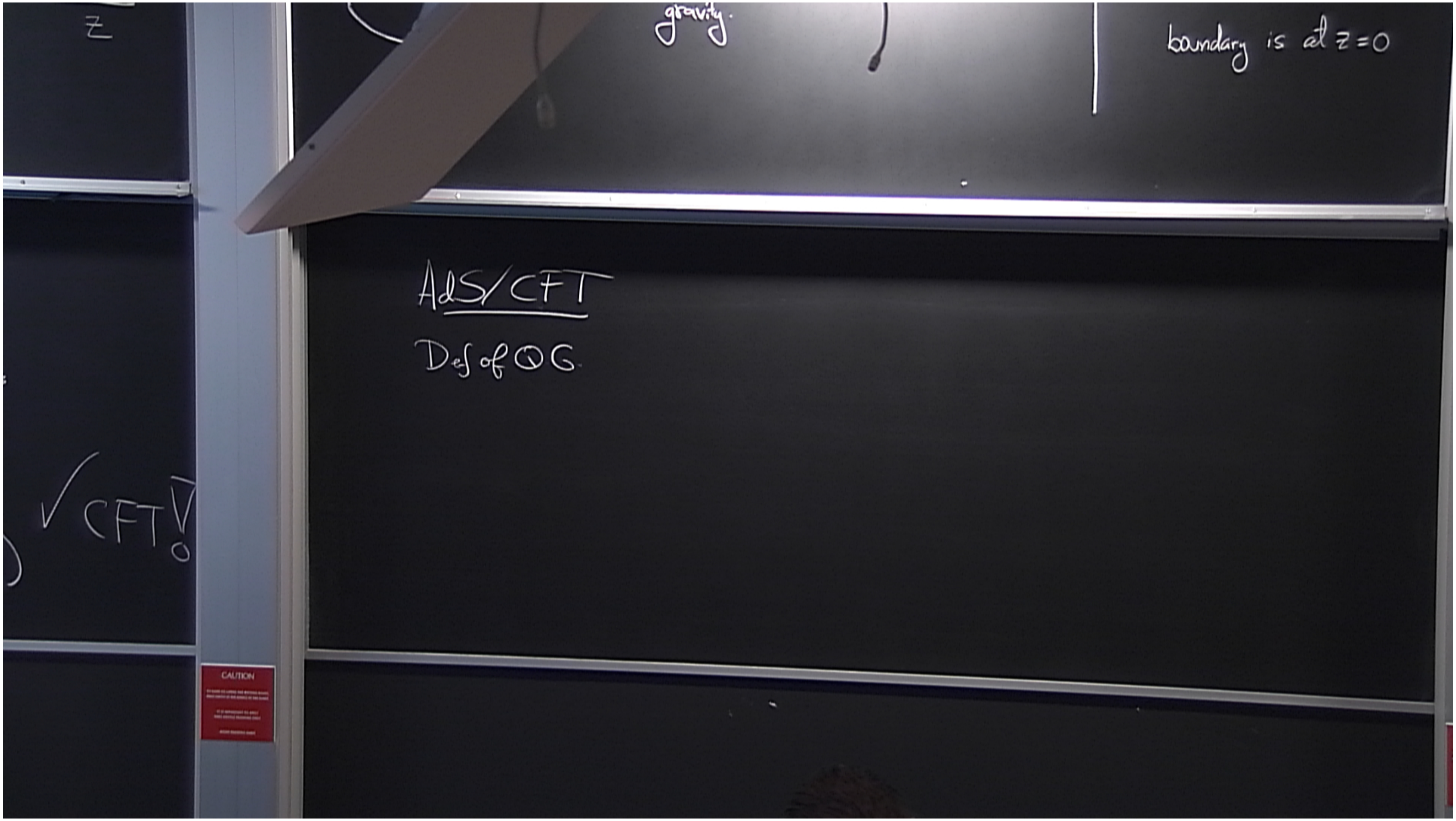
Out[350]=

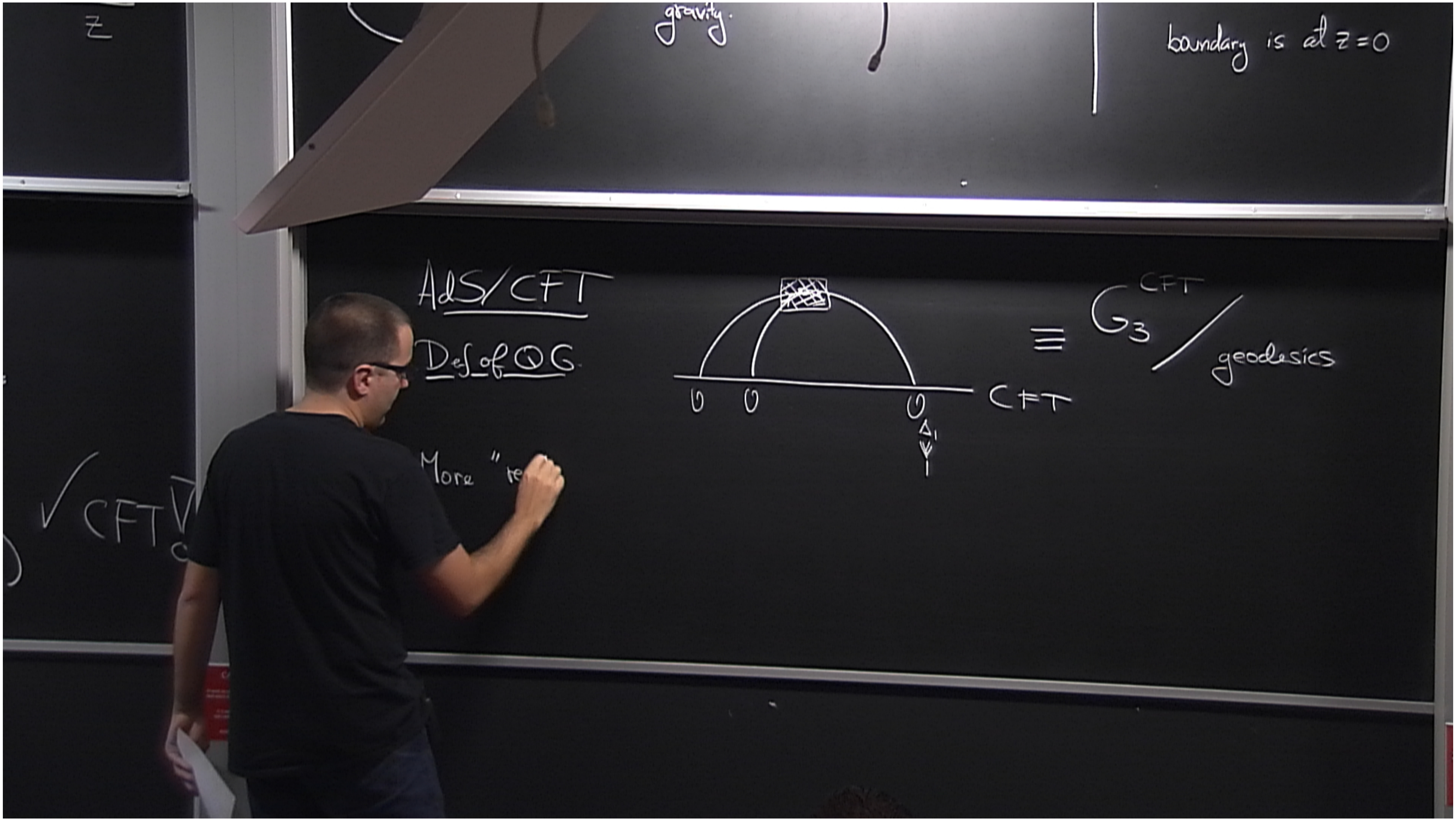
```
(Log[x1 - x2] + Log[x1 - x3] - Log[x2 - x3]) m[1] +
 (Log[x1 - x2] - Log[x1 - x3] + Log[x2 - x3]) m[2] +
 (-Log[x1 - x2] + Log[x1 - x3] + Log[x2 - x3]) m[3]
```

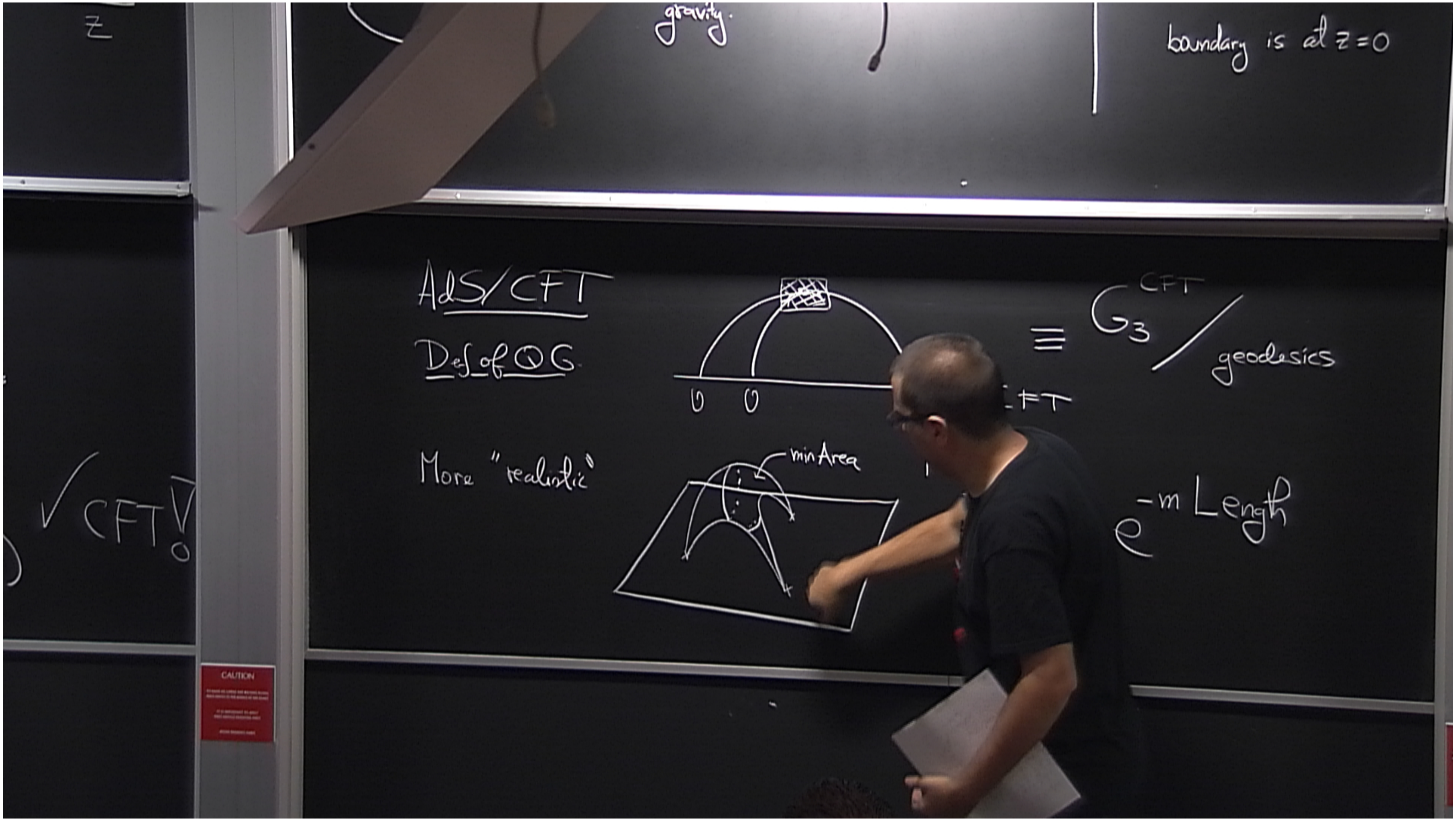

Z(X)
S = m1 l1 + m2 l2 + m3 l3
where l1 = log (x1 - xp)^2 + Zp^2 / εZp
and similar for l2, l3
x2, x3) = e^-S*
G3 ≃ C(m1, m2, m3)


Z(X)
and similar for l2, l3
CFT

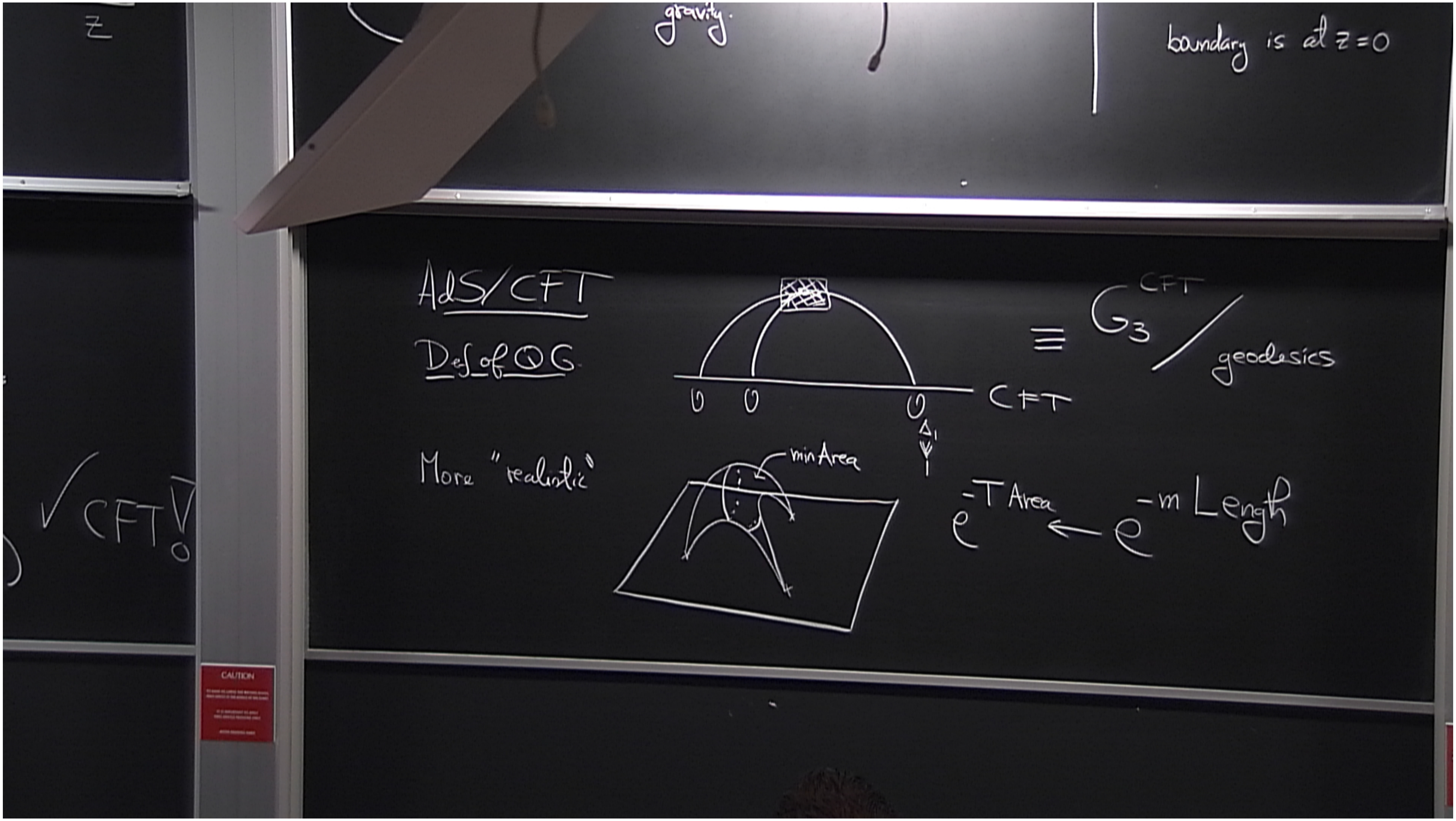

Z(X)
S = m1 l1 + m2 l2 + m3 l3
where l1 = log ((x1-xp)^2 + Zp^2) / (ε zp)   and similar for l2, l3
G3(X1,X2,X3) = e^-S*
where
∂zp S = ∂xp S = 0
⇒ G3 ≃ C(m1,m2,m3) / ((X1-X2)^(Δ1+Δ2-Δ3) (...)(...))
✓ CFT!
CAUTION

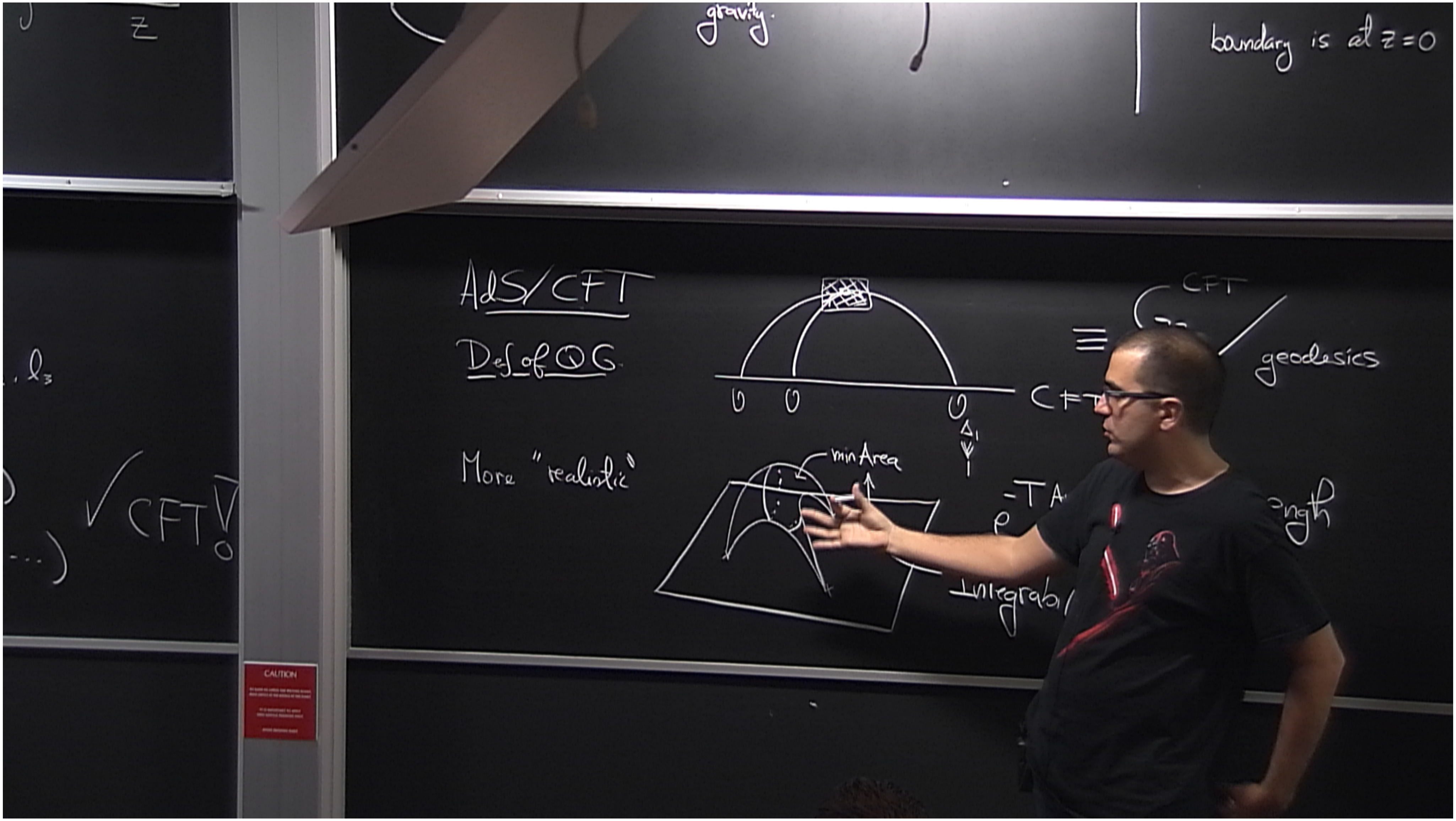

z
gravity.
boundary is at z=0
AdS/CFT
Def of QG
CFT
CAUTION

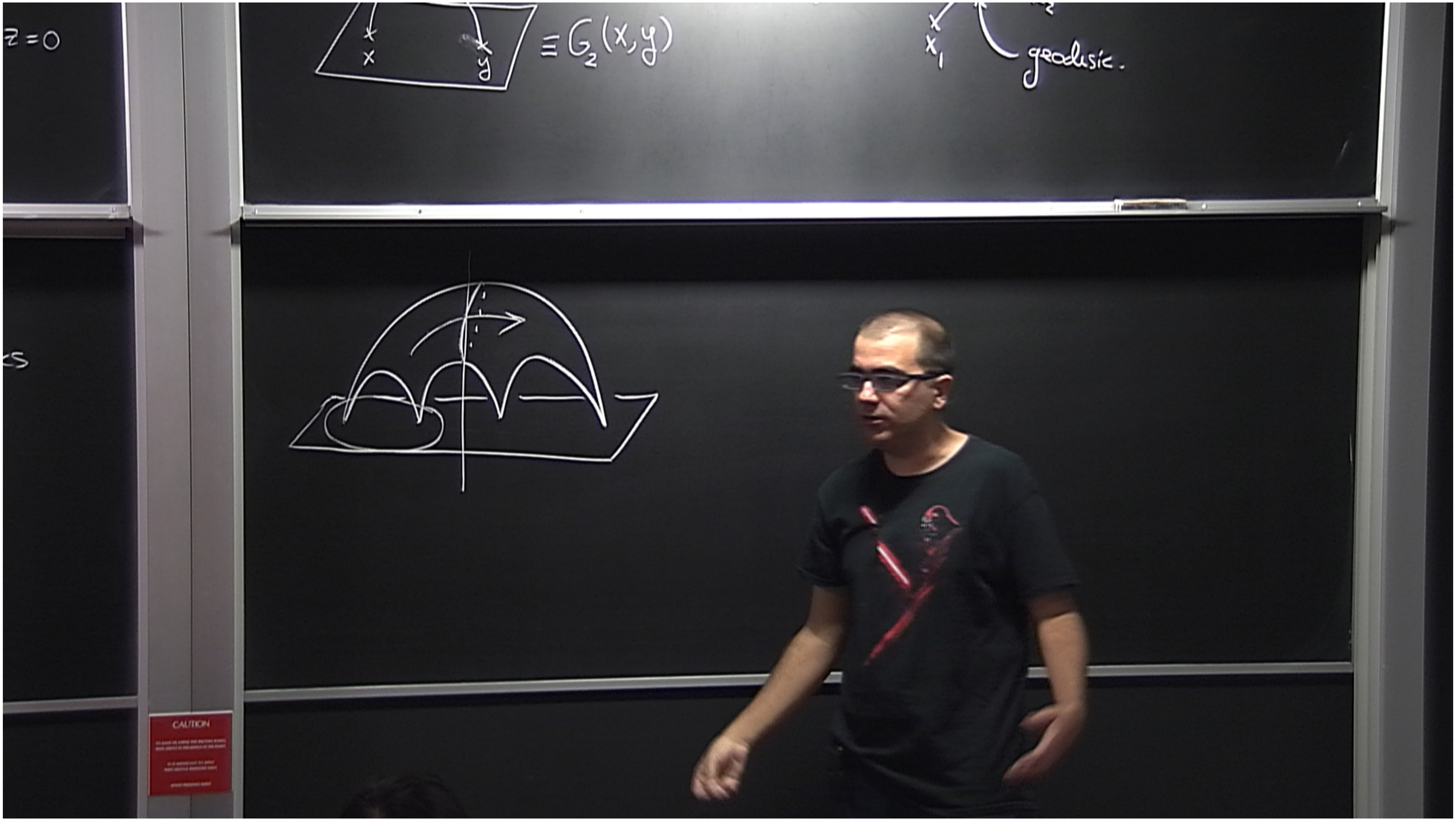

boundary is at z=0
AdS/CFT
Def of QG
More "re
CFT
geodesics
CFT

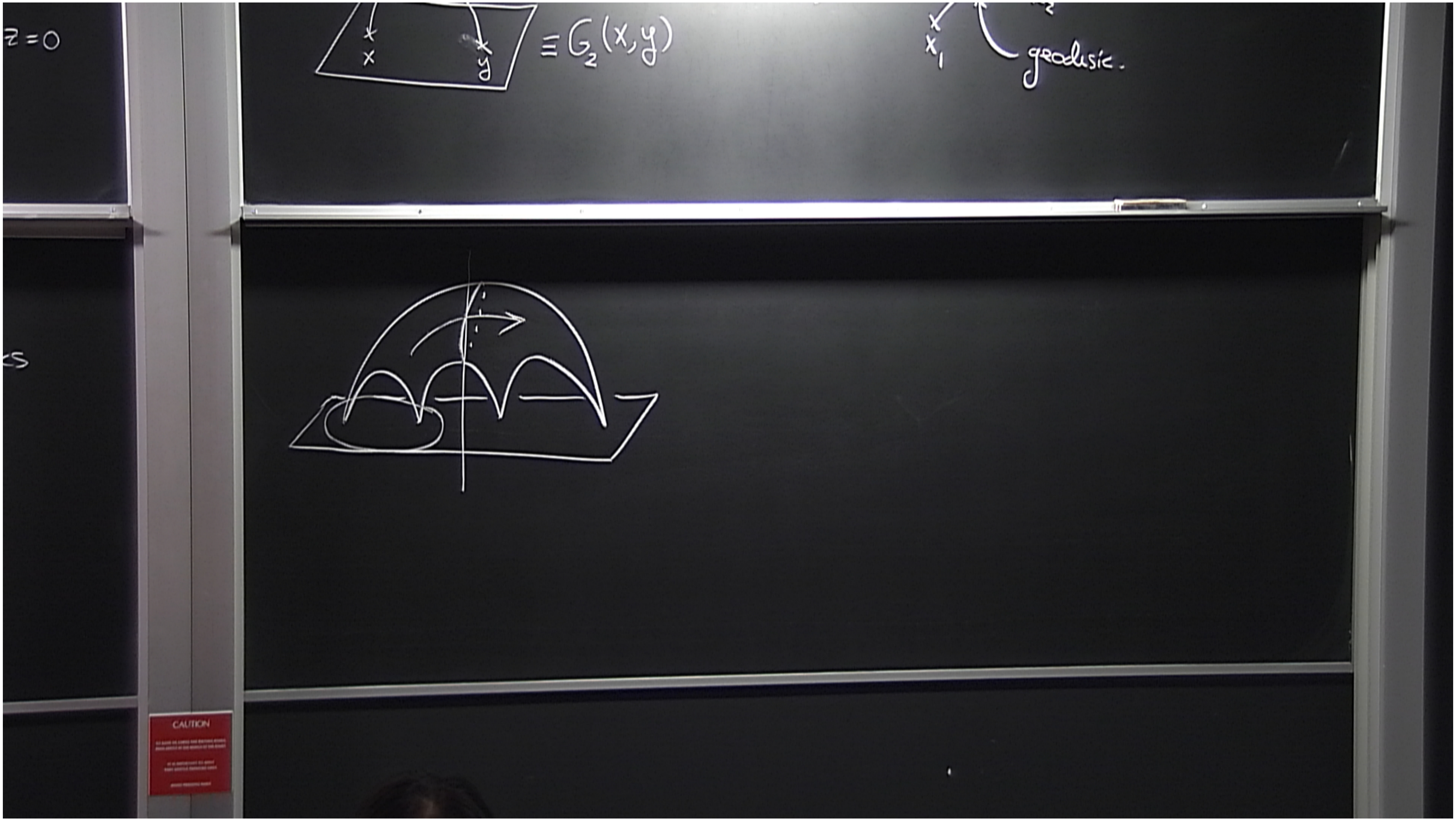


boundary is at z=0
AdS/CFT
Def of QG
More "realistic"
≡ G_3^{CFT} / geodesics
min Area
$e^{-m\,Length}$
CFT


gravity.
boundary is at z = 0
z
AdS/CFT
Def of QG
≡ G3 CFT / geodesics
CFT
Δ
More "realistic"
min Area
e^-T Area ← e^-m Length
√CFT !


gravity
boundary is at z=0
AdS/CFT
Def of QG
More "realistic"
min Area
CFT
geodesics
√CFT!
Integrab


z = 0
≡ G2(x,y)
x
y
x1
geodesic.


z = 0
x
y
≡ G2(x,y)
x1
geodesic.
CAUTION