Title: Mathematica Presentations

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Abstract:

(4) Conformal gauge

(7) Further points

What do we mean by an effective (long) string?

- Solution, any theory, string-like profile
  - IR Classical solution, soliton, → fluctuation
  - Quantum string-state

Examples

Vortex solution in AHM/...

Any domain wall 3d

Conformal gauge

(6) Comparisons

(7) Further points

What do we mean by an effective (long) string?

Solution, any theory, string-like profile

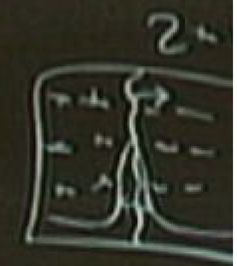
- IR Classical solution, soliton, → fluctuation
- Quantum string-state

Examples

→ Vortex solution in $AHM|_{4d}$

Any domain wall 3d

→ QCD flux tubes ($\bar{q}q$-potential)



③ Open strings
④ Conformal gauge
⑥ Comparisons
⑦ Further points

What do we mean by an effective (long) string?

- Solution, any theory, string-like profile
  - IR Classical solution, soliton, → fluctuation
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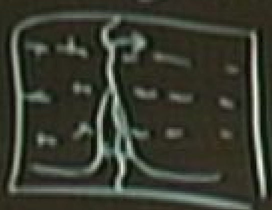
Examples
→ Vortex solution in AHM
Any domain wall 3d
→ QCD flux tubes ($\bar{q}q$-potential) confining

$\bar{q}$ q

2+1



- Approximate 1d string
- Defined at IR
- Stable, free

(large N)

- among strings
- with bulk field (mass gap)

- Space-time symmetries

certain pattern

- Curiosity
- Applicative : Cosmic String, flux tubes
- Theoretical : help to better understand QST

- Compare w/ LGT
- AdS/CFT

The philosophy

bulk: IR field config. string-like

$\Updownarrow$

thick string config.

The philosophy

bulk: IR field config. string-like

$\Updownarrow$

thick string config. (inner/structural dof)

$\Updownarrow$

W.S.: 1d string + Massive modes

The philosophy

bulk: IR field config. string-like

$\Updownarrow$

~~[illegible]~~ thick string config. (inner/structural dof)

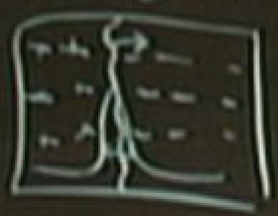
$\Updownarrow$

W.S.:

1d string + Massive modes

$\xrightarrow{IR}$ 1d string w/ eff. action

2+1



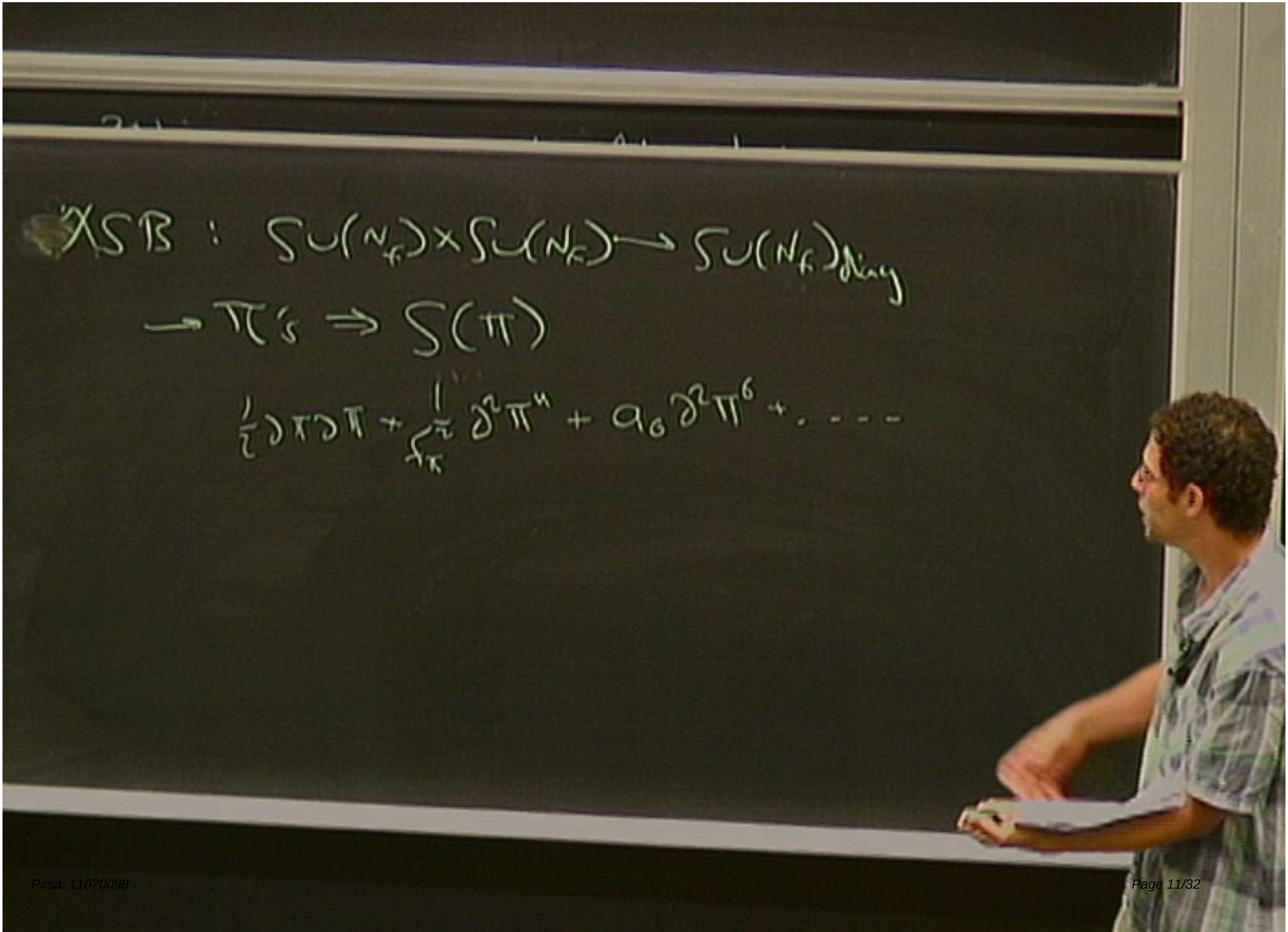
- Approximate 1d string
- Defined at IR (large N)
- Stable, free
  - among strings
  - with bulk field (mass gap)
- Space-time symmetries

certain pattern

Method: EFT (Weinberg)

'guess' dof

+ symmetries



$\chi SB: \; SU(N_f) \times SU(N_f) \longrightarrow SU(N_f)_{diag}$
$\longrightarrow \pi\text{'s} \Rightarrow S(\pi)$
$\frac{1}{2}\partial\pi\partial\pi + \frac{1}{f_\pi^2}\partial^2\pi^4 + a_6\partial^2\pi^6 + \dots$

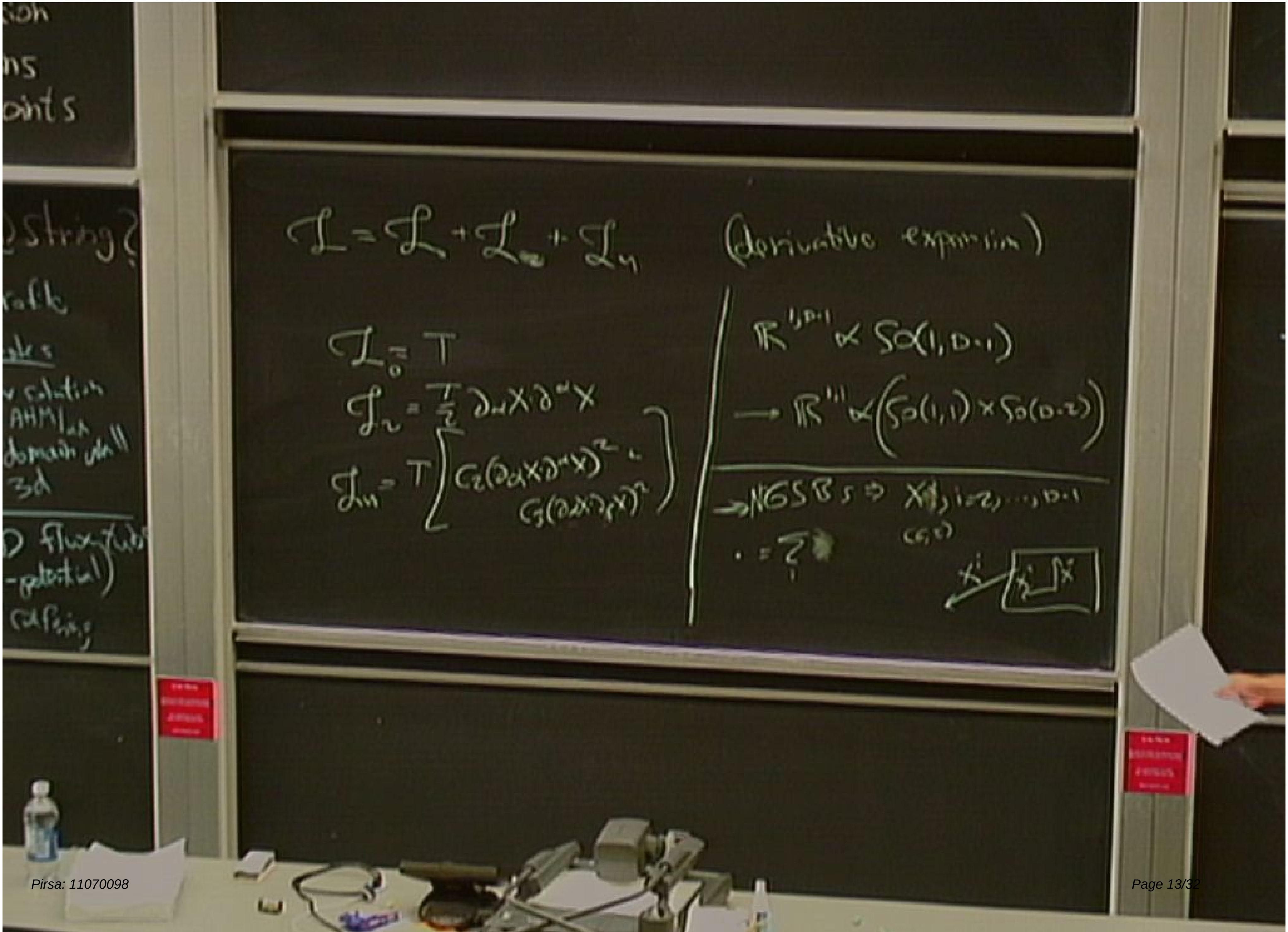
χSB : $\underline{SU(N_f)\times SU(N_f)} \longrightarrow SU(N_f)_{diag}$

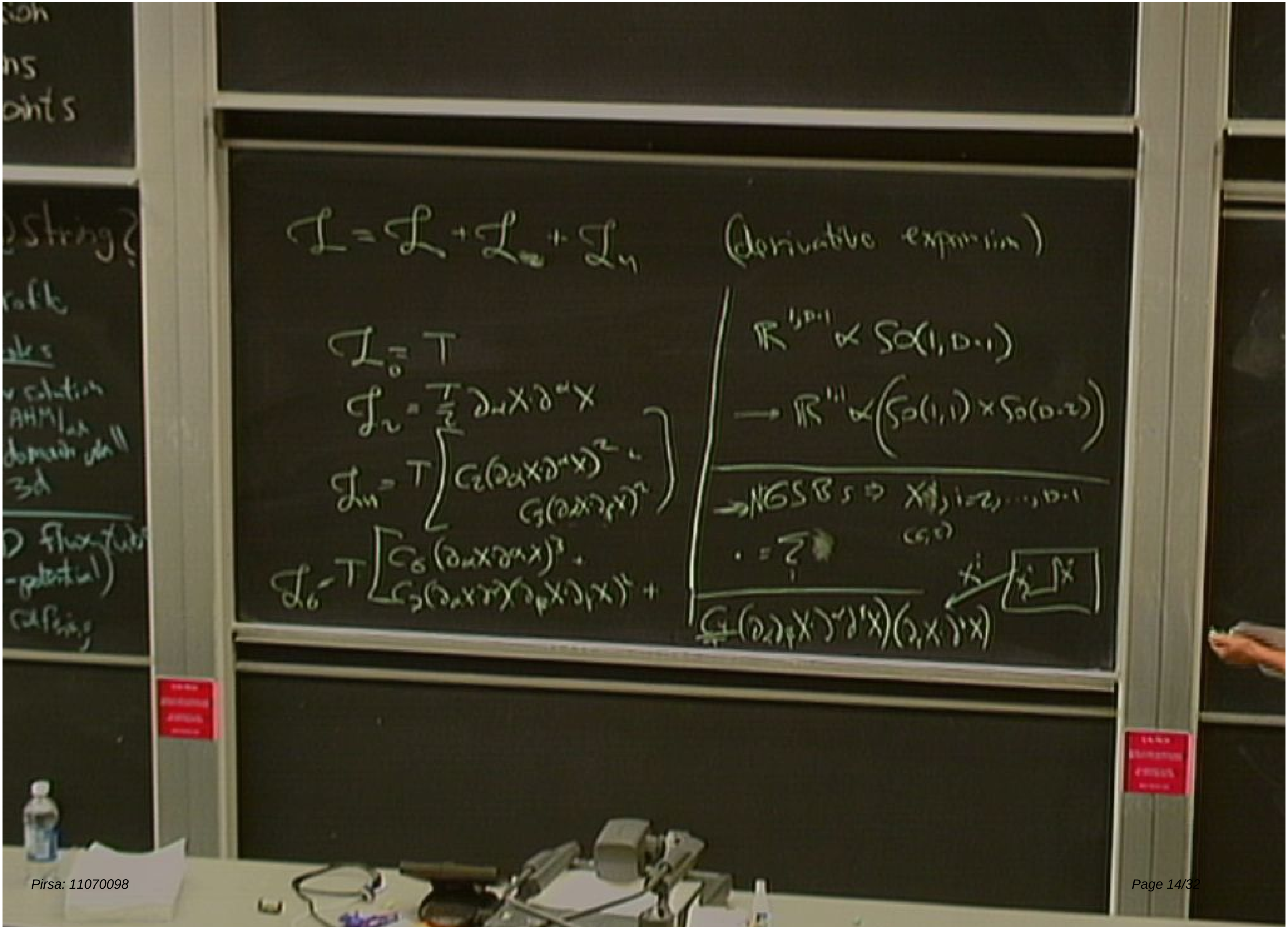
$\longrightarrow \pi\text{'s} \Rightarrow S(\pi)$

$$\frac{1}{2}\partial\pi\partial\pi + \frac{1}{\underline{f_\pi^2}}\partial^2\pi^4 + a_6\partial^2\pi^6 + \dots = \mathcal{L}_2 = f_\pi^2\,\mathrm{Tr}(\partial_\mu U\,\partial^\mu U^\dagger)$$

$\delta\pi$ = non-linear

$$\boxed{U = e^{\frac{i}{f_\pi}\pi^a T^a}}$$


L = L_0 + L_2 + L_4 (derivative expansion)
L_0 = T
L_2 = T/2 ∂_α X·∂^α X
L_4 = T [c_2 (∂_α X·∂^α X)^2 + c_3 (∂_α X·∂_β X)^2]
R^{1,D-1} ⋉ SO(1,D-1)
→ R^{1,1} ⋉ (SO(1,1) × SO(D-2))
→ NGSBs ⇒ X^i, i = 2, ..., D-1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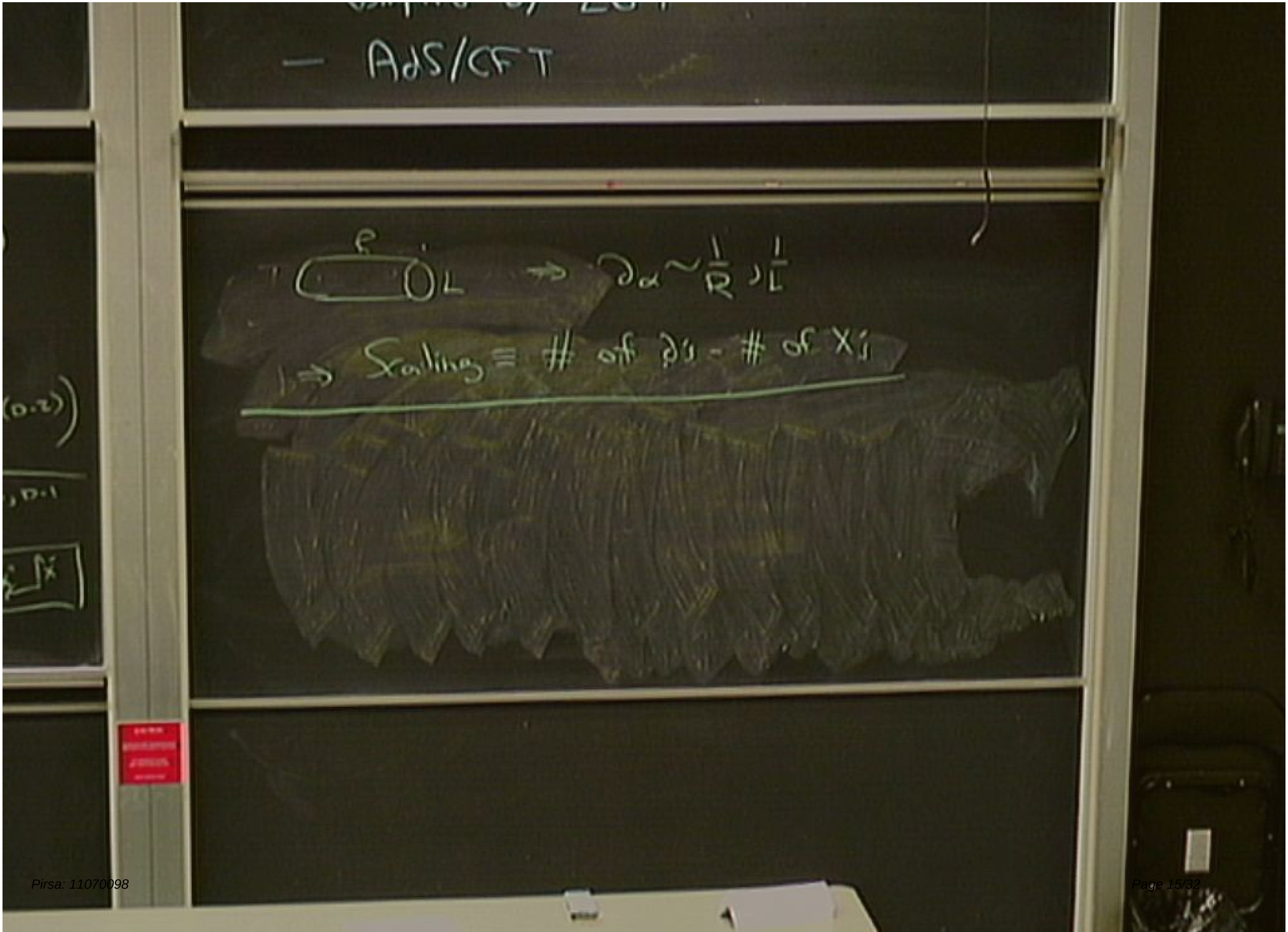
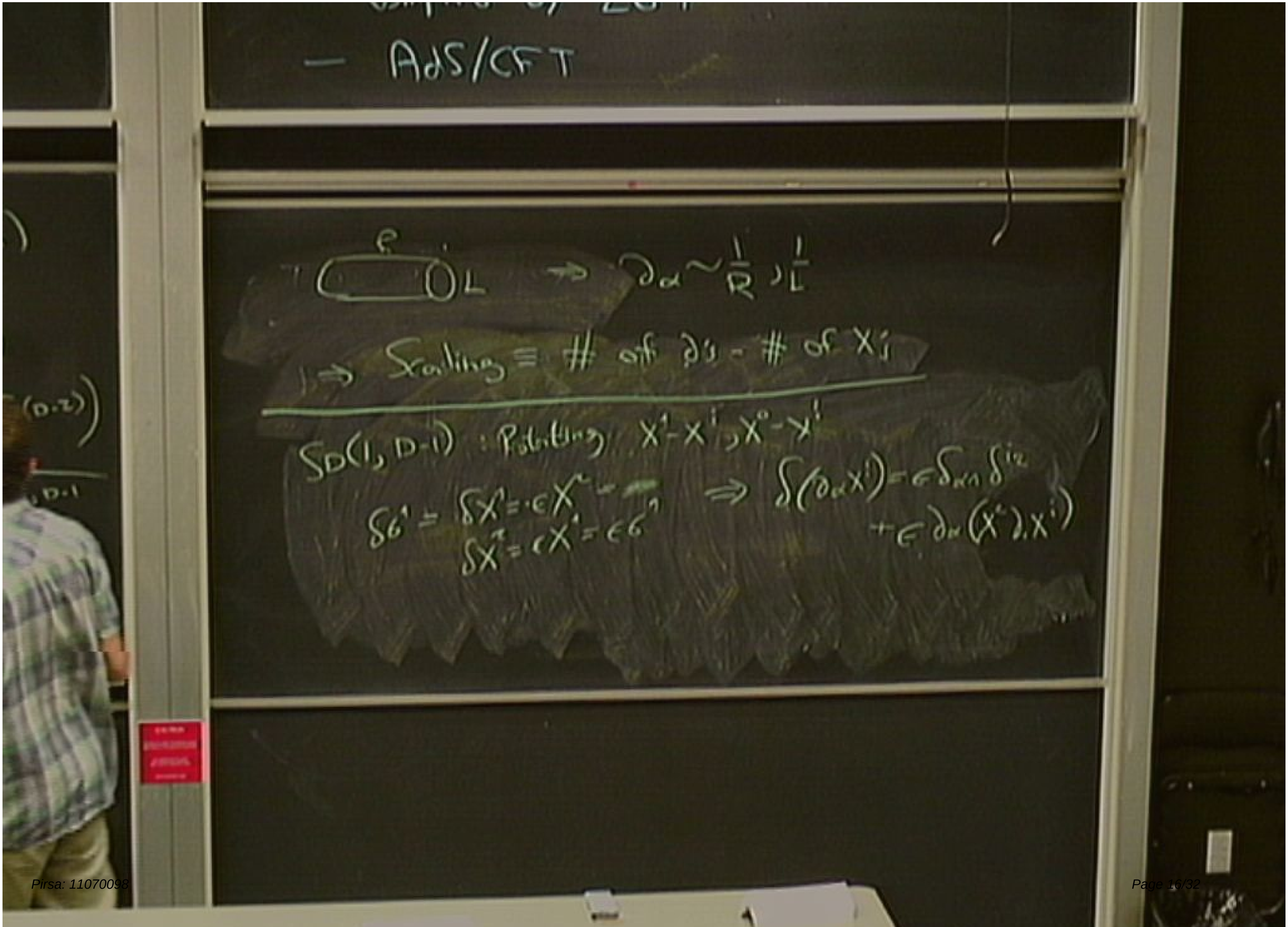
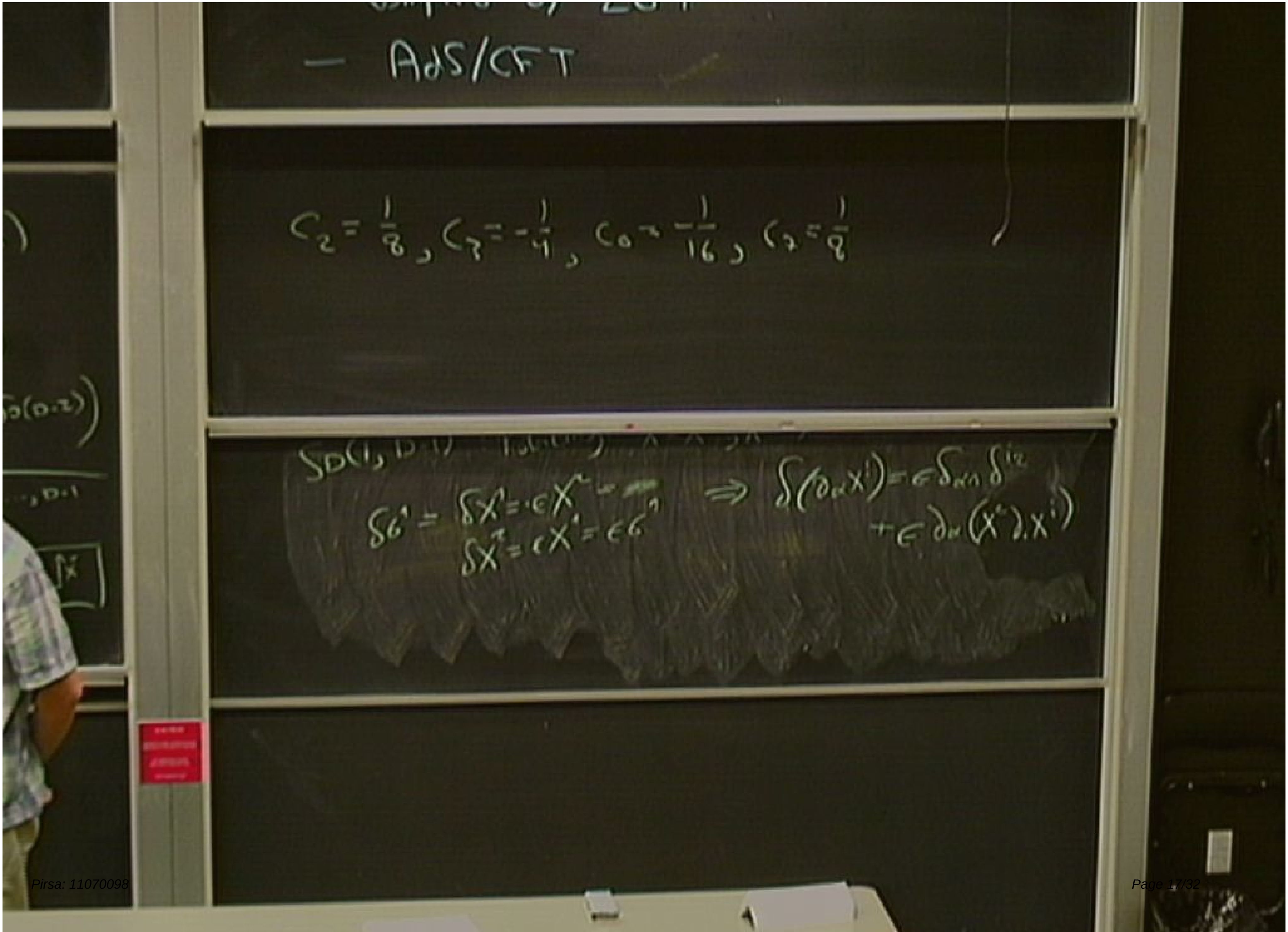
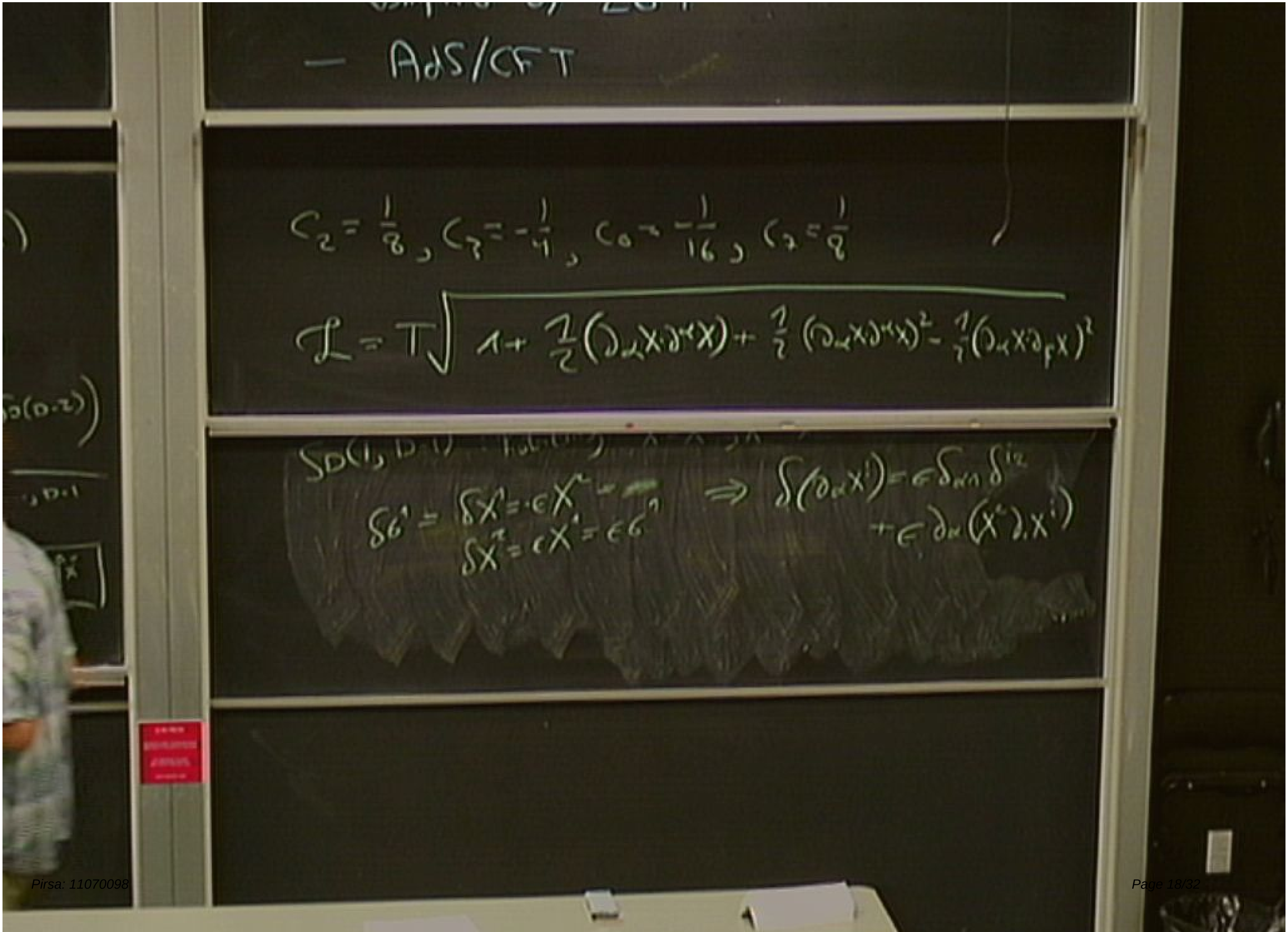
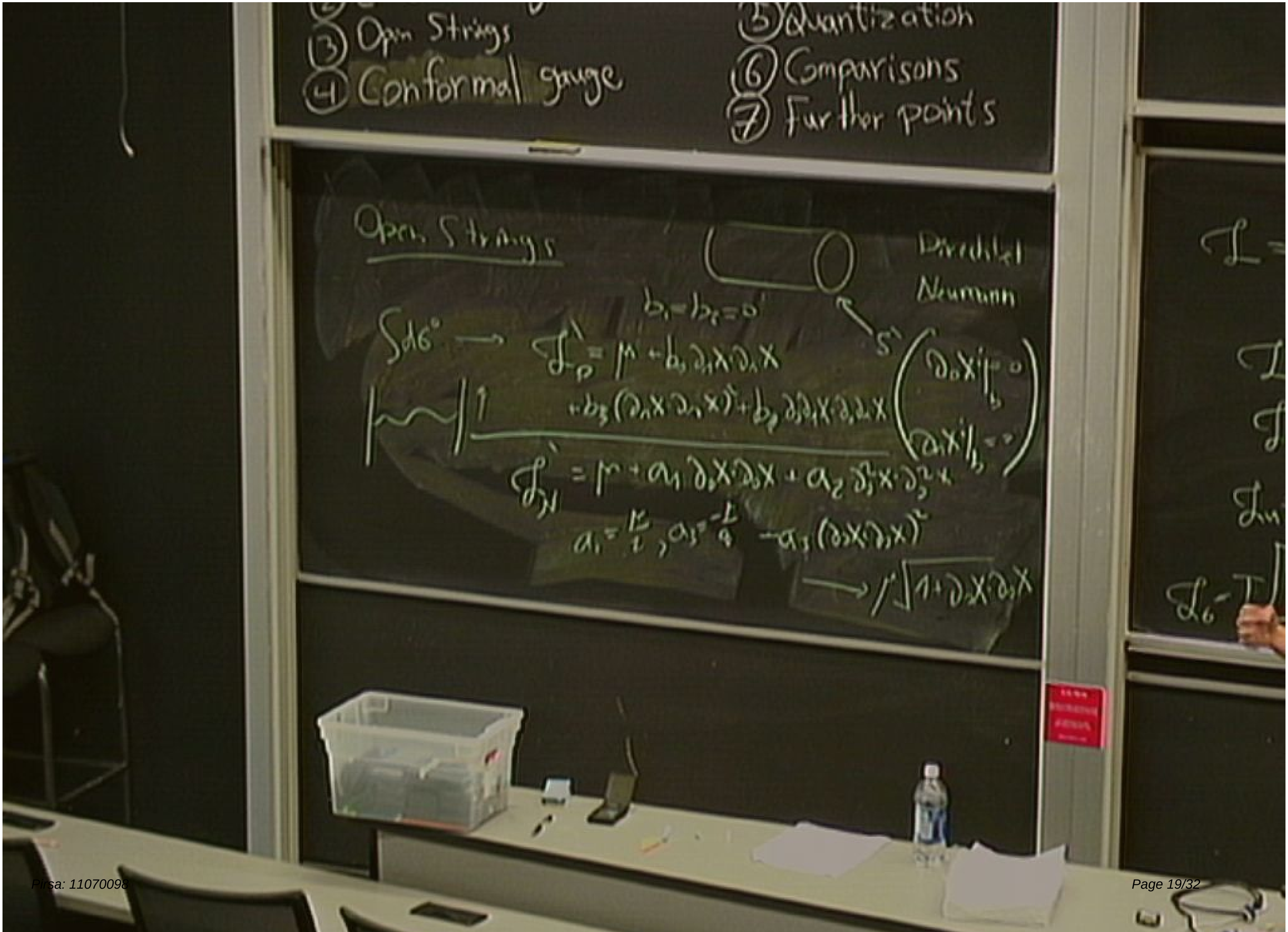
L_6 = T [c_5 (∂_a X·∂^a X)^3 + c_7 (∂_a X·∂^a X)(∂_b X·∂_c X)^2 +
R^{1,D-1} ⋉ SO(1,D-1)
→ R^{1,1} ⋉ (SO(1,1) × SO(D-2))
→ NGSBs ⇒ X^i, i=2,...,D-1
c_4 (∂_a ∂_b X·∂^a ∂^b X)(∂_c X·∂^c X)


— AdS/CFT
R
L
⇒ ∂α ~ 1/R , 1/L
⇒ Scaling ≡ # of ∂i − # of Xi


— AdS/CFT
R
L
→ ∂α ~ 1/R , 1/L
⇒ Scaling ≡ # of ∂'s − # of X's
SO(1, D−1) : Rotating
δσ¹ = δX¹ = εX²
δX² = εX¹ = εσ¹
⇒ δ(∂αX^i) = ε δα1 δ^i2 + ε ∂α(X²), X^i)


— AdS/CFT
C2 = 1/8 , C3 = -1/4 , C0 = -1/16 , C7 = 1/8
δσ1 = δX1 = εX2
δX2 = εX1 = εσ2
⇒ δ(∂αX1) = εδα1δi2
+ ε∂α(X2)X1


— AdS/CFT
$c_2 = \frac{1}{8},\ c_3 = -\frac{1}{4},\ c_0 = -\frac{1}{16},\ c_7 = \frac{1}{8}$
$\mathcal{L} = T\sqrt{1 + \frac{1}{2}(\partial_\alpha X \cdot \partial^\alpha X) + \frac{1}{?}(\partial_\alpha X \cdot \partial^\alpha X)^2 - \frac{1}{?}(\partial_\alpha X \cdot \partial_\beta X)^2}$
$\delta\sigma^1 = \delta X^1 = \epsilon X^2$
$\delta X^2 = \epsilon X^1 = \epsilon\sigma^1$
$\Rightarrow \delta(\partial_\alpha X^i) = \epsilon\,\delta_{\alpha 1}\delta^{i2} + \epsilon\,\partial_\alpha(X^2)\partial_1 X^i$



3 Open Strings
4 Conformal gauge
5 Quantization
6 Comparisons
7 Further points
Open Strings
Dirichlet
Neumann

— AdS/CFT

$X^\mu(\sigma,\tau)$, re-parametrization invariance

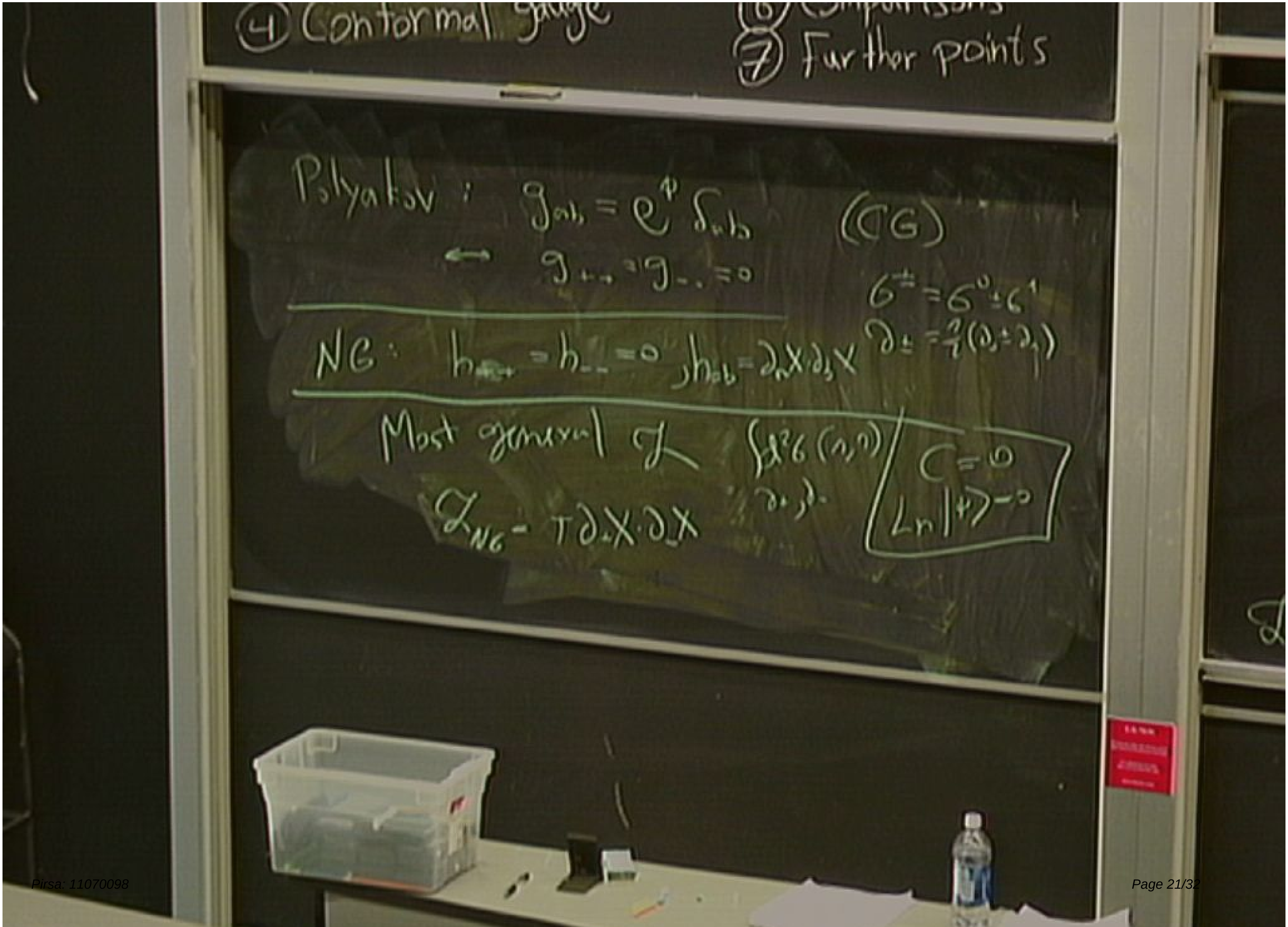
— diff inv. formalism $\left(g_{\alpha\beta} = \partial_\alpha X^i \partial_\beta X^i, F^i_{\alpha\beta}\right)$

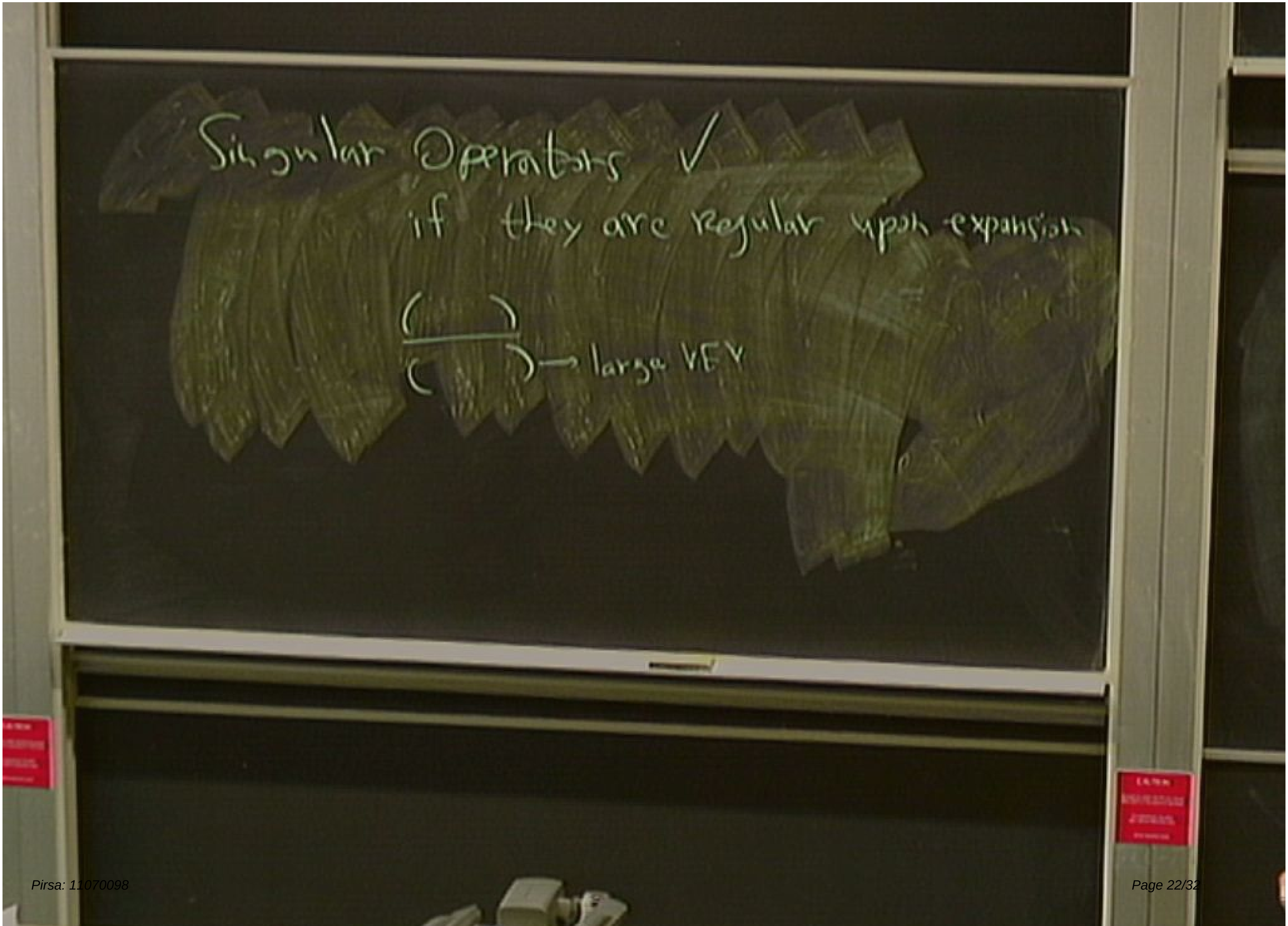
$R \frac{1}{\Box} R \xrightarrow{cG} \checkmark$ $\quad \cdot = \frac{\delta}{\delta}$ $\quad \sqrt{g} R, g^{kk}$

$\xrightarrow{SG}$?

— $X^\alpha = \sigma^\alpha \Rightarrow \checkmark$

— Conformal gauge


④ Conformal gauge
⑦ Further points
Polyakov : $g_{ab} = e^{\phi} \delta_{ab}$ (CG)
$\leftrightarrow$ $g_{++} = g_{--} = 0$
$\sigma^{\pm} = \sigma^0 \pm \sigma^1$
$\partial_\pm = \frac{1}{2}(\partial_0 \pm \partial_1)$
NG : $h_{++} = h_{--} = 0$, $h_{ab} = \partial_a X \cdot \partial_b X$
Most general $\mathcal{L}$ $\int d^2\sigma\,(\partial,\partial)$
∂_+, ∂_-
$\mathcal{L}_{NG} = T \partial_+ X \cdot \partial_- X$
$C = 0$
$L_n|\psi\rangle = 0$


Singular Operators ✓
if they are regular upon expansion
large VEV

$$\mathcal{L} = T\sqrt{1 + \frac{1}{2}(\partial_\alpha X\cdot\partial^\alpha X) + \frac{1}{?}(\partial_\alpha X\cdot\partial^\alpha X)^2 - \frac{1}{?}(\partial_\alpha X\cdot\partial_\beta X)^2}$$

$\mathcal{L}_{NG} \sim R^0$ unique

$\longrightarrow R^{-n}$: $\rho\,\frac{\partial_+\partial_- Z}{Z} \longleftrightarrow \rho\,\frac{\partial_+ Z\,\partial_- Z}{Z^2}$ (ibp)

$$\mathcal{L} = T\sqrt{1 + \frac{1}{2}(\partial_\alpha X\cdot\partial^\alpha X) + \frac{1}{2}(\partial_\alpha X\cdot\partial^\alpha X)^2 - \frac{1}{2}(\partial_\alpha X\cdot\partial_\beta X)^2}$$

$\mathcal{L}_{NG} \sim R^0$ unique

$\longrightarrow R^{-2}: \ \beta\,\frac{\partial_+\partial_- Z}{Z} \longleftrightarrow \beta\,\frac{\partial_+ Z\,\partial_- Z}{Z^2}$ (ib.p)

– Conf. at the q-level $\Rightarrow \beta = \frac{26-D}{12}$

$\mathcal{L}_{NG} \sim R^{0}$ unique

$\longrightarrow R^{-1}$: $\rho\,\frac{\partial_+\partial_- Z}{Z} \longleftrightarrow \rho\,\frac{\partial_+ Z\,\partial_- Z}{Z^2}$ (i.b.p.)

– Conf. at the q-level $\Rightarrow$ $R = \frac{26-D}{12}$

$\Rightarrow$ Only physical dof

$\frac{26-D}{48\pi}\int d^2\sigma\left(\partial_+\phi\,\partial_-\phi + \mu^2 e^{\phi}\right)$

$g_{\alpha\beta} = e^{\phi}\delta_{\alpha\beta}$ $\qquad e^{\phi} \longrightarrow Z$

– Conformal

$X^\mu(\sigma,\tau)$, re-parametrization invariance

- diff inv. formalism $\left(g_{\alpha\beta} = \partial_\alpha X \partial_\beta X,\ K^i_{\alpha\beta}\right)$

$R \frac{1}{\Box} R$ $\frac{\delta G}{\delta g}$ ✓ ? $\cdot = \Sigma$ $\sqrt{g} R$, $\sqrt{g} KK$

- $X^\alpha = \sigma^\alpha \Rightarrow$ ✓ $p^2 \to T/\beta$

- Conformal gauge

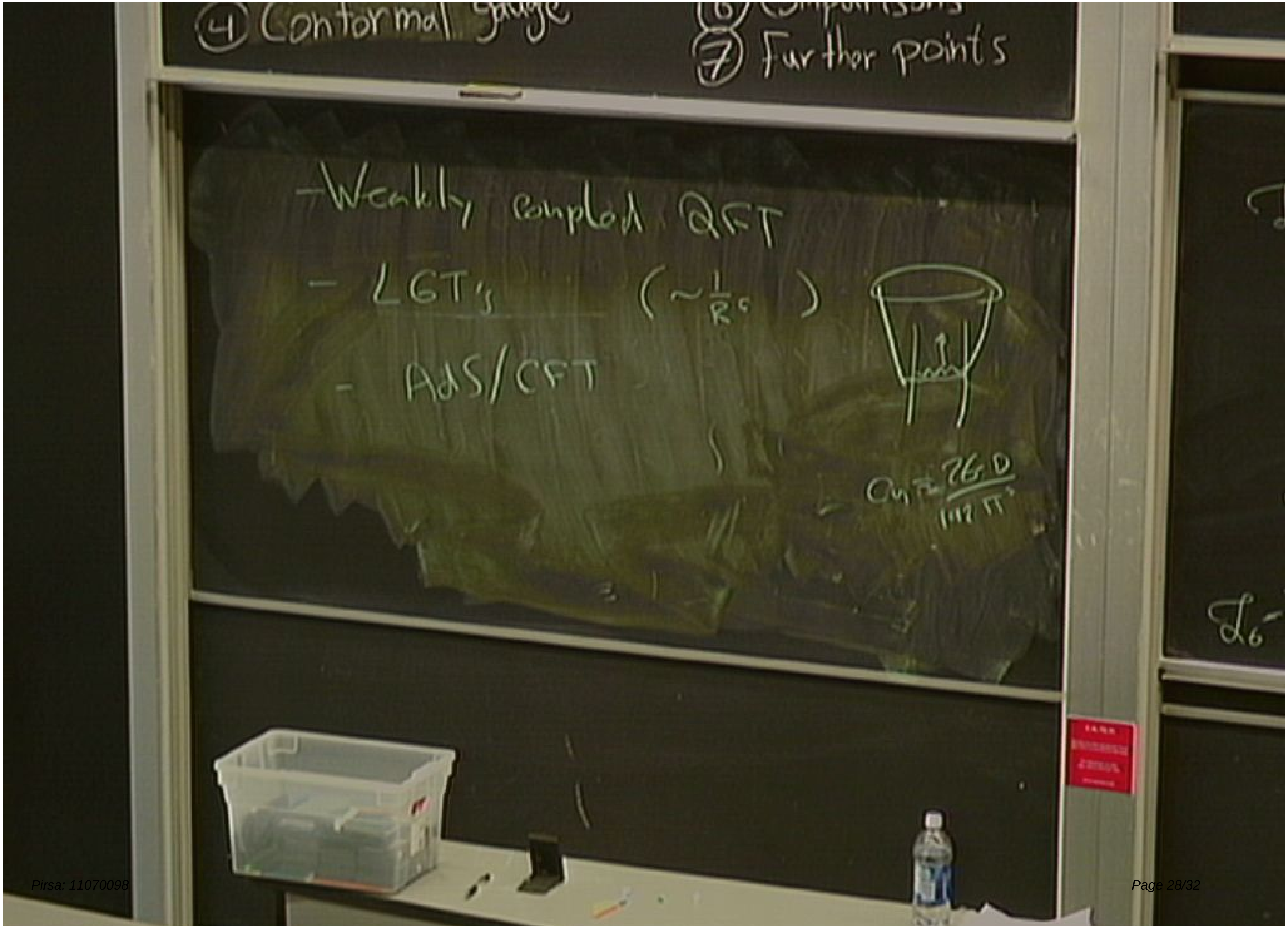
$X^\mu(\sigma,\tau)$, Re-parametrization invariance

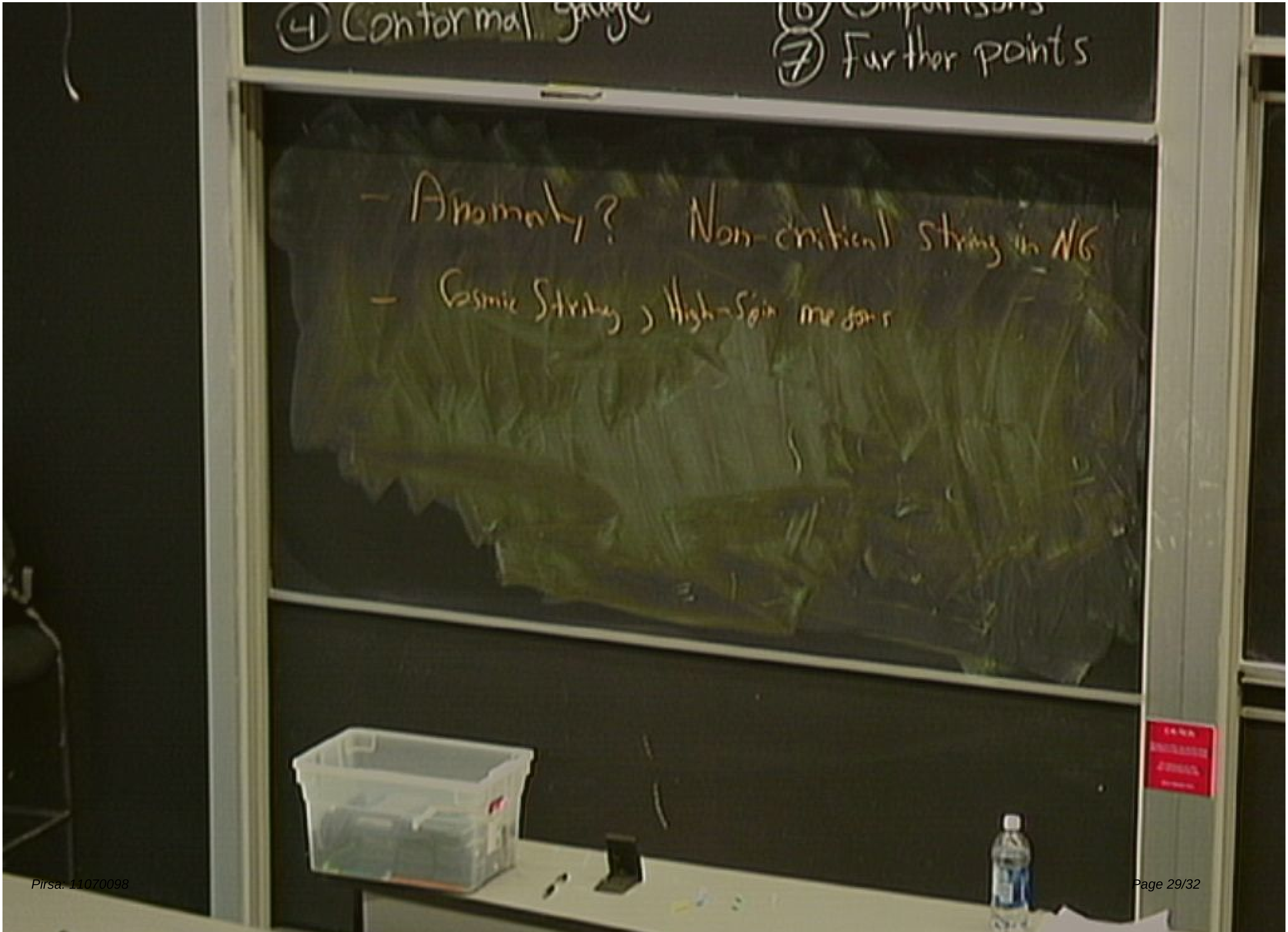
– diff inv. formalism ($g_{\alpha\beta} = \partial_\alpha X \cdot \partial_\beta X$, $K^i_{\alpha\beta}$)

$R \frac{1}{\Box} R \xrightarrow[\sqrt{g}]{\text{c.c.}}$ ✓ ? $\cdot = \sum_i$ $\sqrt{g} R$, $\sqrt{g} K K$

– $X^\alpha = \sigma^\alpha \Rightarrow$ ✓ $\mu^2 \to T/\beta$

– Conformal gauge


4 Conformal gauge
7 Further points
- Weakly coupled QFT
- LGT's
- AdS/CFT



4 Conformal gauge
7 Further points
– Anomaly? Non-critical string in NG
– Cosmic String, High-Spin mesons

$X^\mu(\sigma,\tau)$, Re-parametrization invariance

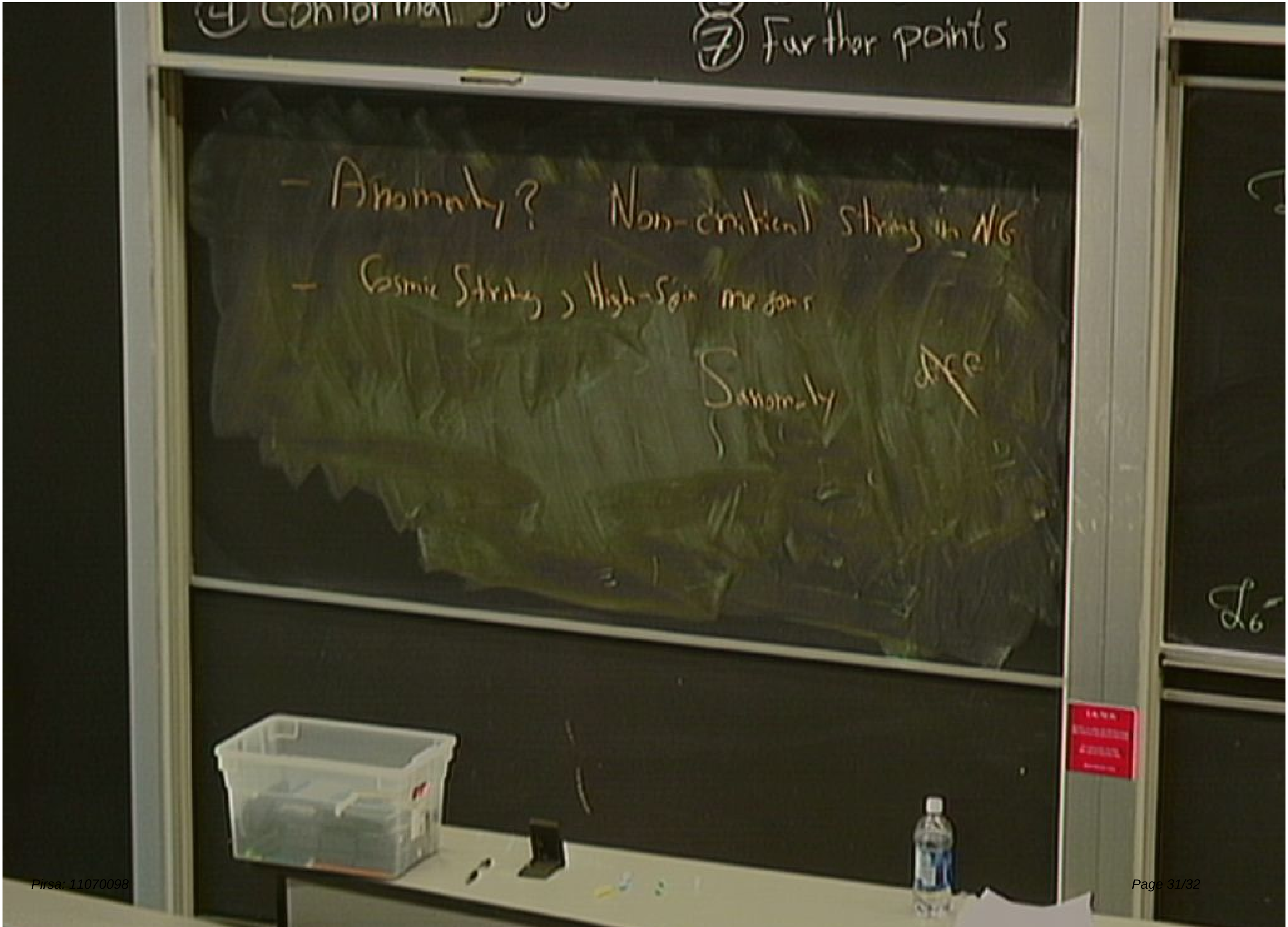
R^{-S}

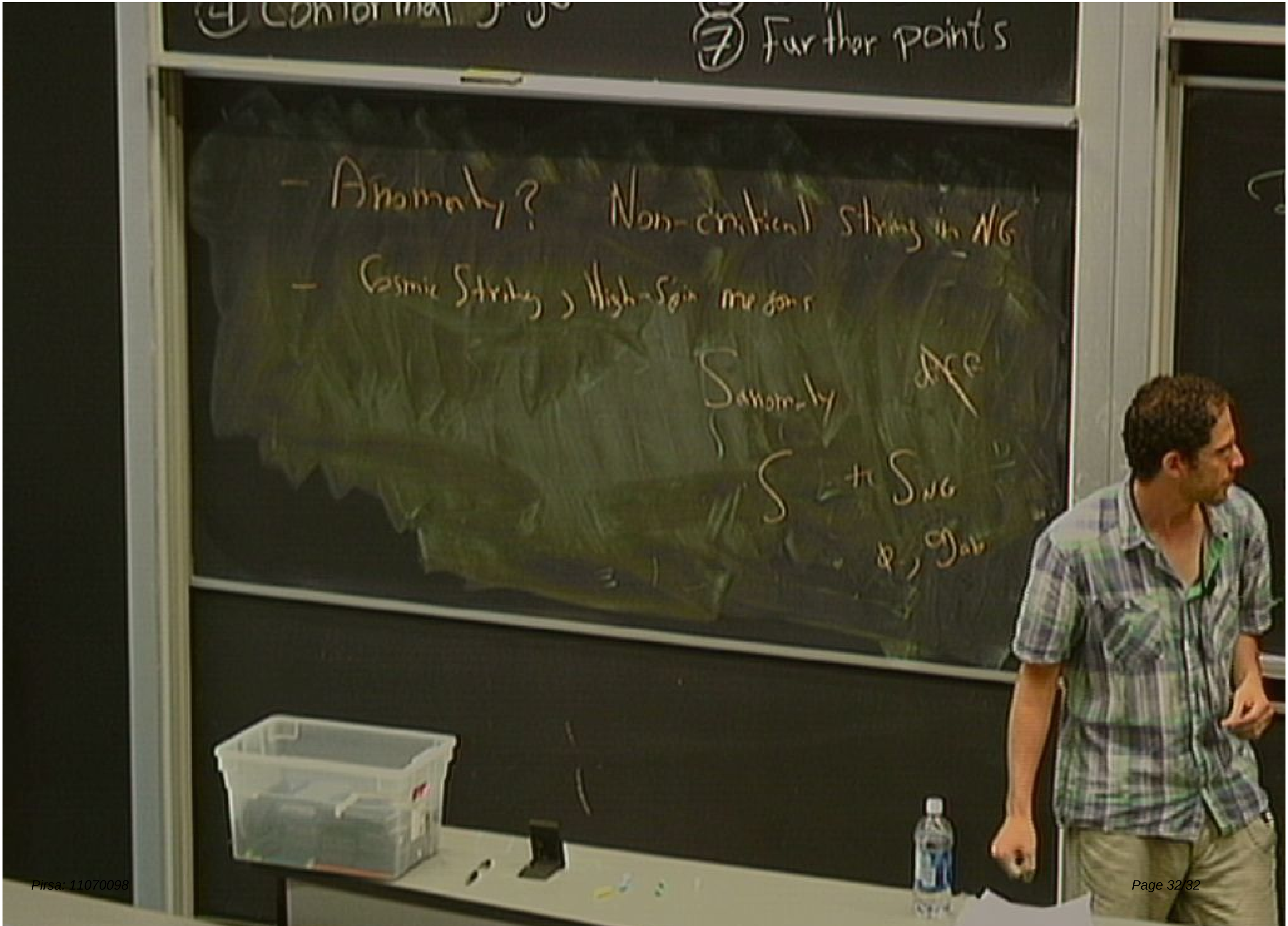
— diff inv. formalism $\left(g_{\alpha\beta} = \partial_\alpha X \partial_\beta X,\ K^i_{\alpha\beta}\right)$

$R \frac{1}{\Box} R \xrightarrow[\delta g]{\delta S}$ ✓ ? $\cdot = \sum$ $\sqrt{g} R$, $\sqrt{g} KK$

— $X^\alpha = \sigma^\alpha \Rightarrow$ ✓ $\mu^2 \to T/\beta$

— Conformal gauge


⑦ Further points
- Anomaly? Non-critical string in NG
- Cosmic Strings, High-Spin mesons
S anomaly


7 Further points
- Anomaly? Non-critical string in NG
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S anomaly
S L + S NG