Title: Warped Heterotic Axions

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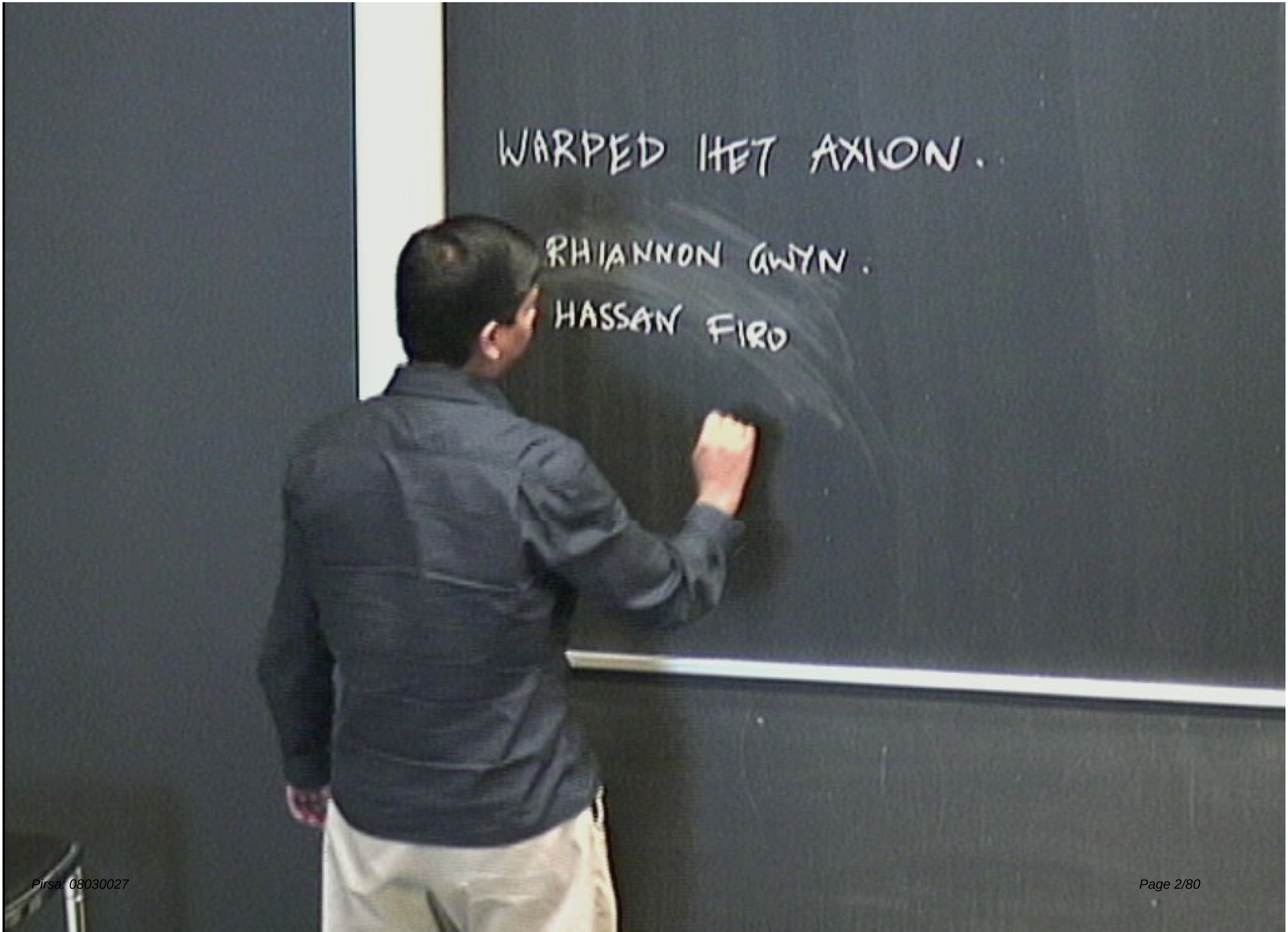
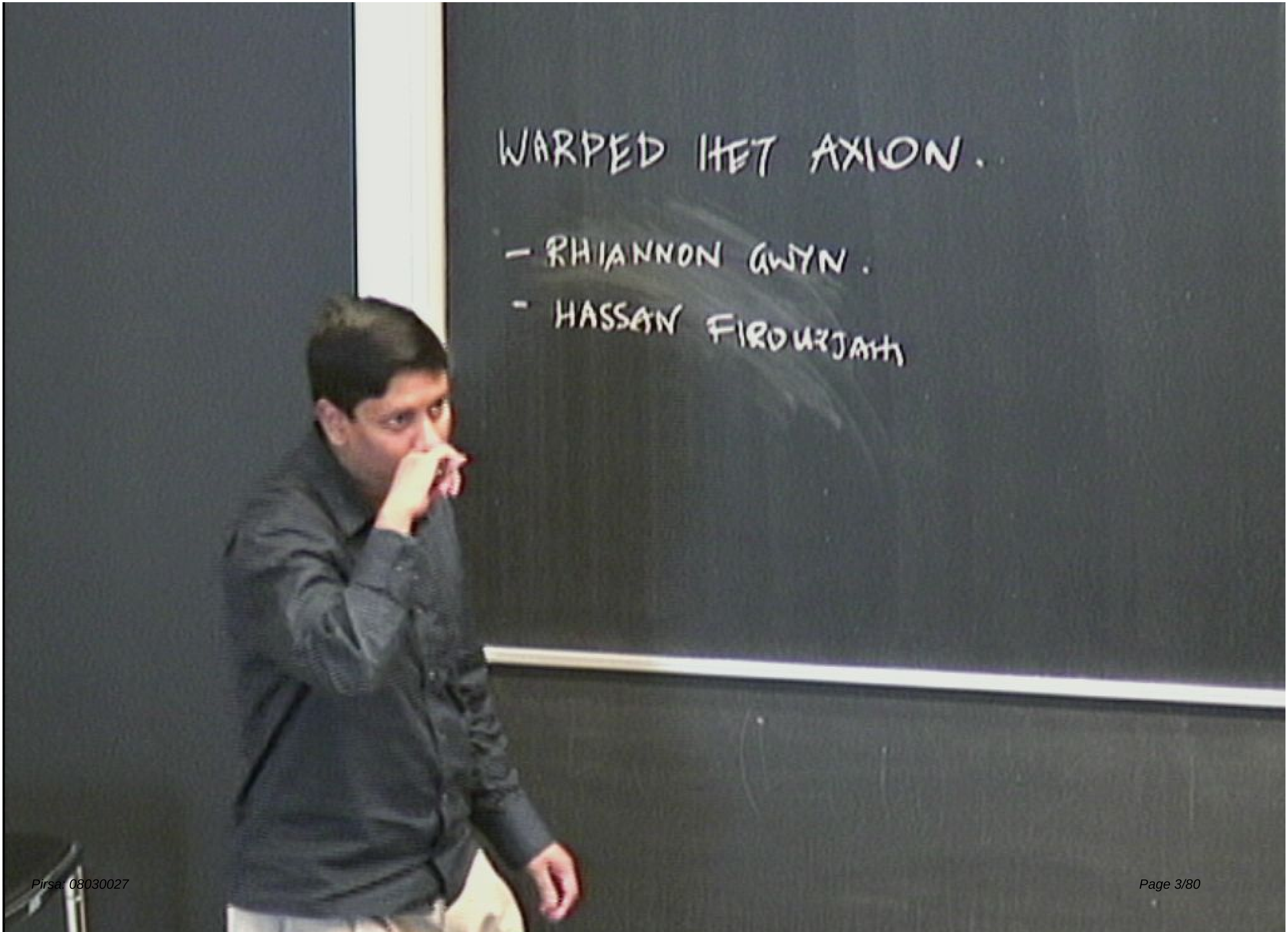
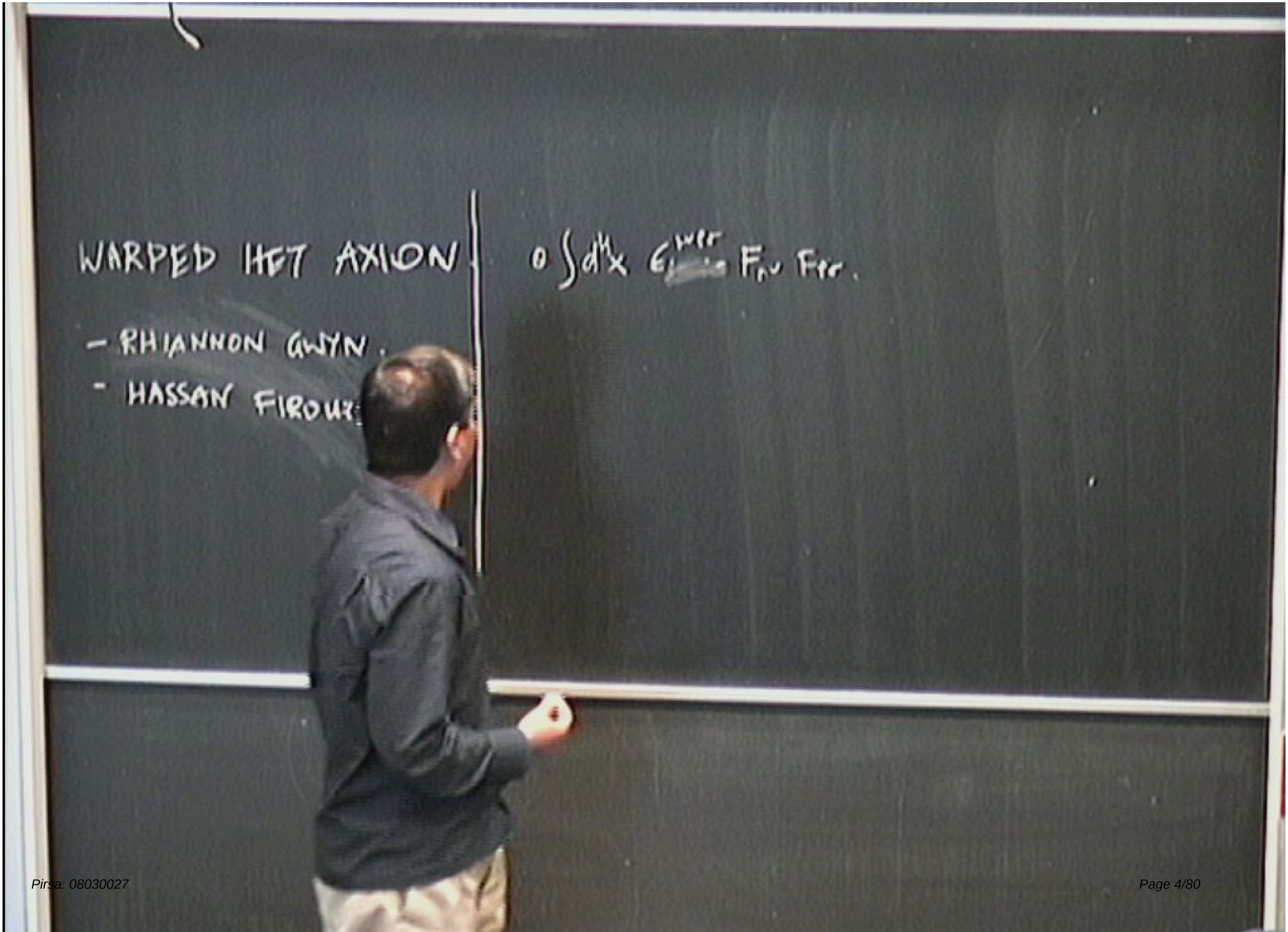
Abstract: TBA


WARPED HET AXION.
RHIANNON GWYN.
HASSAN FIRO


WARPED HET AXION.
- RHIANNON GWYN.
- HASSAN FIROUZJAH


WARPED HET AXION
- RHIANNON GWYN.
- HASSAN FIROU
$\theta \int d^4x \, \epsilon^{\mu\nu\rho\sigma} F_{\mu\nu} F_{\rho\sigma}$.

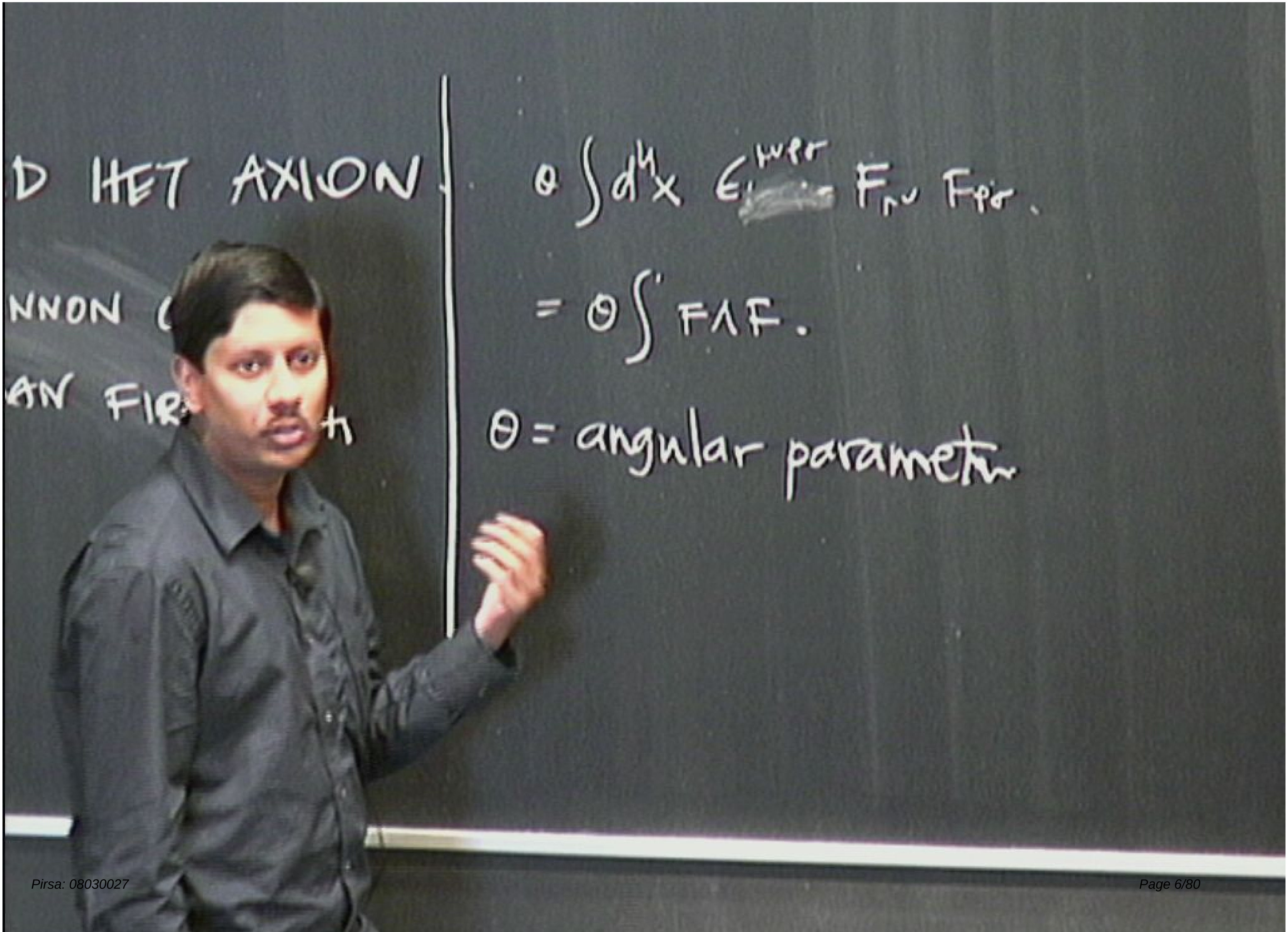
D HET AXION

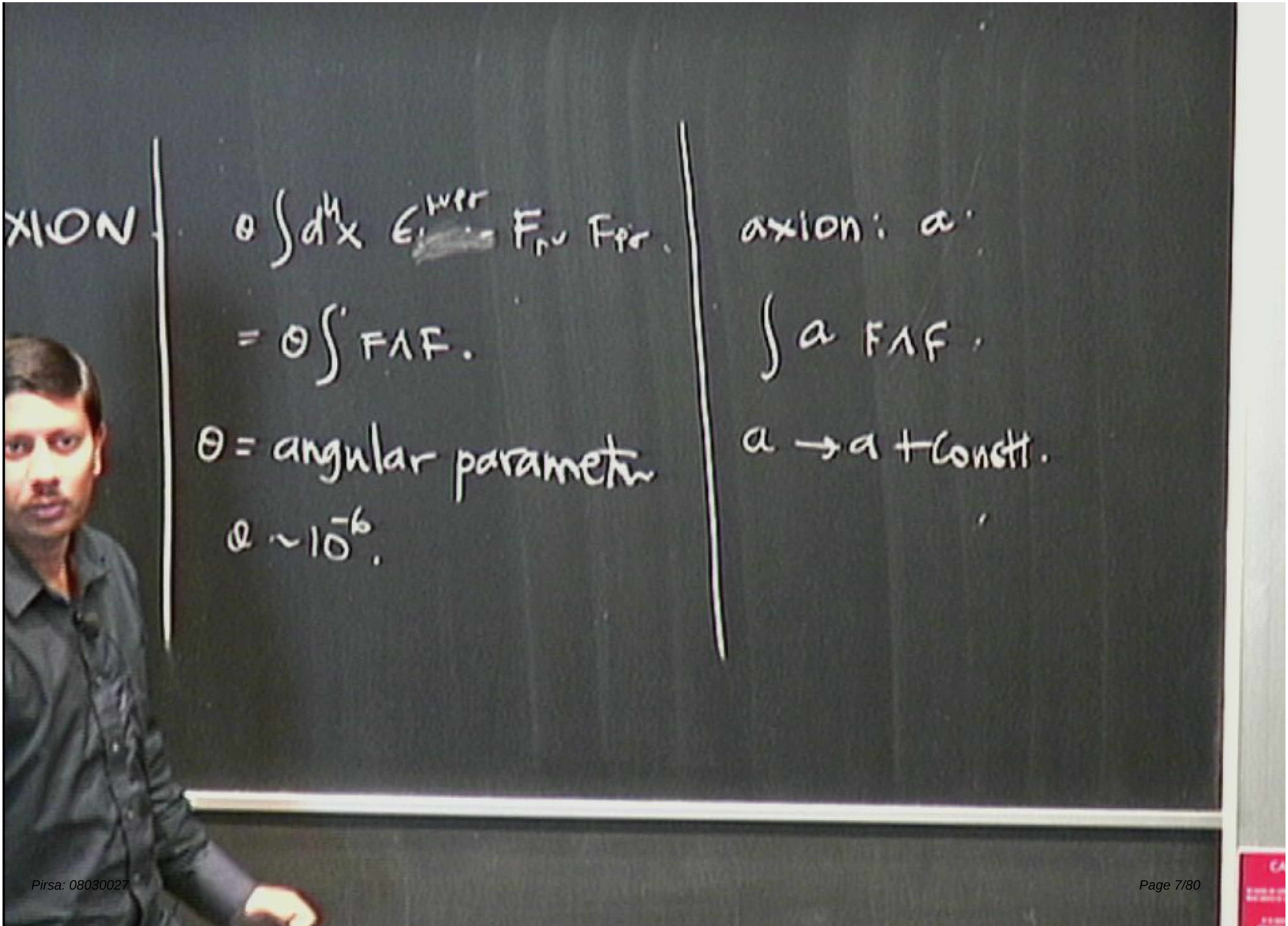
NNON GWYN.

AN FIROUZJAH

$$\theta \int d^4x \, \epsilon^{\mu\nu\rho\sigma} F_{\mu\nu} F_{\rho\sigma}.$$

$$= \theta \int F \wedge F.$$


D HET AXION
$\theta \int d^4x\, \epsilon^{\mu\nu\rho\sigma} F_{\mu\nu} F_{\rho\sigma}$.
$= \theta \int F \wedge F$.
θ = angular parameter


XION
$\theta \int d^4x \, \epsilon^{\mu\nu\rho\sigma} F_{\mu\nu} F_{\rho\sigma}$.
$= \theta \int F \wedge F$.
θ = angular parameter
$\theta \sim 10^{-6}$.
axion: a
$\int a \, F \wedge F$.
$a \to a + \text{const}$.

ON

$\theta \int d^4x \, \epsilon^{\mu\nu\rho\sigma} F_{\mu\nu} F_{\rho\sigma}$.

$= \theta \int F \wedge F$.

θ = angular parameter

$\theta \sim 10^{-6}$.

axion: a

$\int a \, F \wedge F$.

$a \to a + \text{const.}$

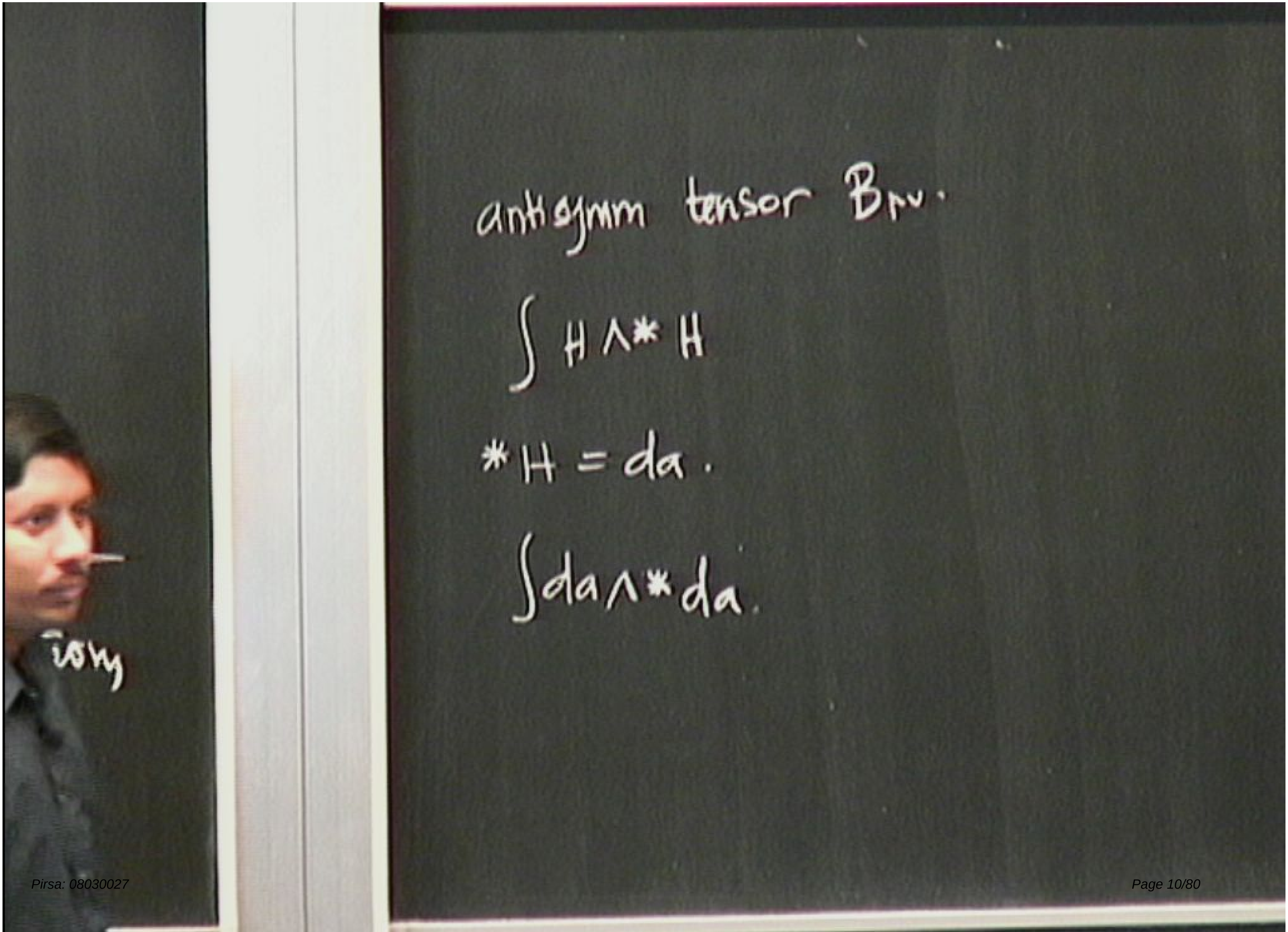
axion in string theory is very natural.

antisymm tensor $B_{\mu\nu}$.

$$\int H \wedge * H$$

$$* H = da .$$

$$\int da \wedge * da$$


antisymm tensor $B_{\mu\nu}$.
$\int H \wedge {*H}$
$*H = da$.
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$10^9\,\mathrm{GeV} < f_a < 10^{12}\,\mathrm{GeV}.$

antisymm tensor $B_{\mu\nu}$.

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$10^9\,\mathrm{GeV} < f_a < 10^{12}\,\mathrm{GeV}.$

Svrcek–Witten.

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Svrcek–Witten.

Heterotic theory.

$g_{\mu\nu}, B_{\mu\nu}, \phi$.

antisymm tensor $B_{\mu\nu}$.

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$10^9 \text{GeV} < f_a < 10^{12}\,\text{GeV}$.

Svrcek – Witten.

Heterotic theory.

$g_{\mu\nu}, B_{\mu\nu}, \phi$.

$A_\mu^a \quad SO(32), E_8 \times E_8$

$f_a < 10^{12}$ GeV.

ov – Witten.

theory.

$\ldots, \phi$.

SO(32)

E_8

$$S = \frac{1}{2\kappa^2}\int d^{10}x \sqrt{-g}\left[R + \partial_\mu\phi\,\partial^\mu\phi - \frac{1}{12}e^{-\phi}H^2 - \frac{\alpha'}{4}\mathrm{Tr}\,F^2\right]$$

$$\mathrm{Tr}\,F^2 = \mathrm{tr}\,F\wedge * F = \sum_a F^a_{\mu\nu}F^{a\,\mu\nu}$$

$\sim 10^{12}$ GeV.

Witten.

$E_8 \times E_8$

$$S = \frac{1}{2\kappa^2}\int d^{10}x \sqrt{-g}\Big[R + \partial_\mu\phi\,\partial^\mu\phi - \frac{1}{12}e^{-\phi}H^2 - \frac{\alpha'}{4}\mathrm{Tr}\,F^2\Big]$$

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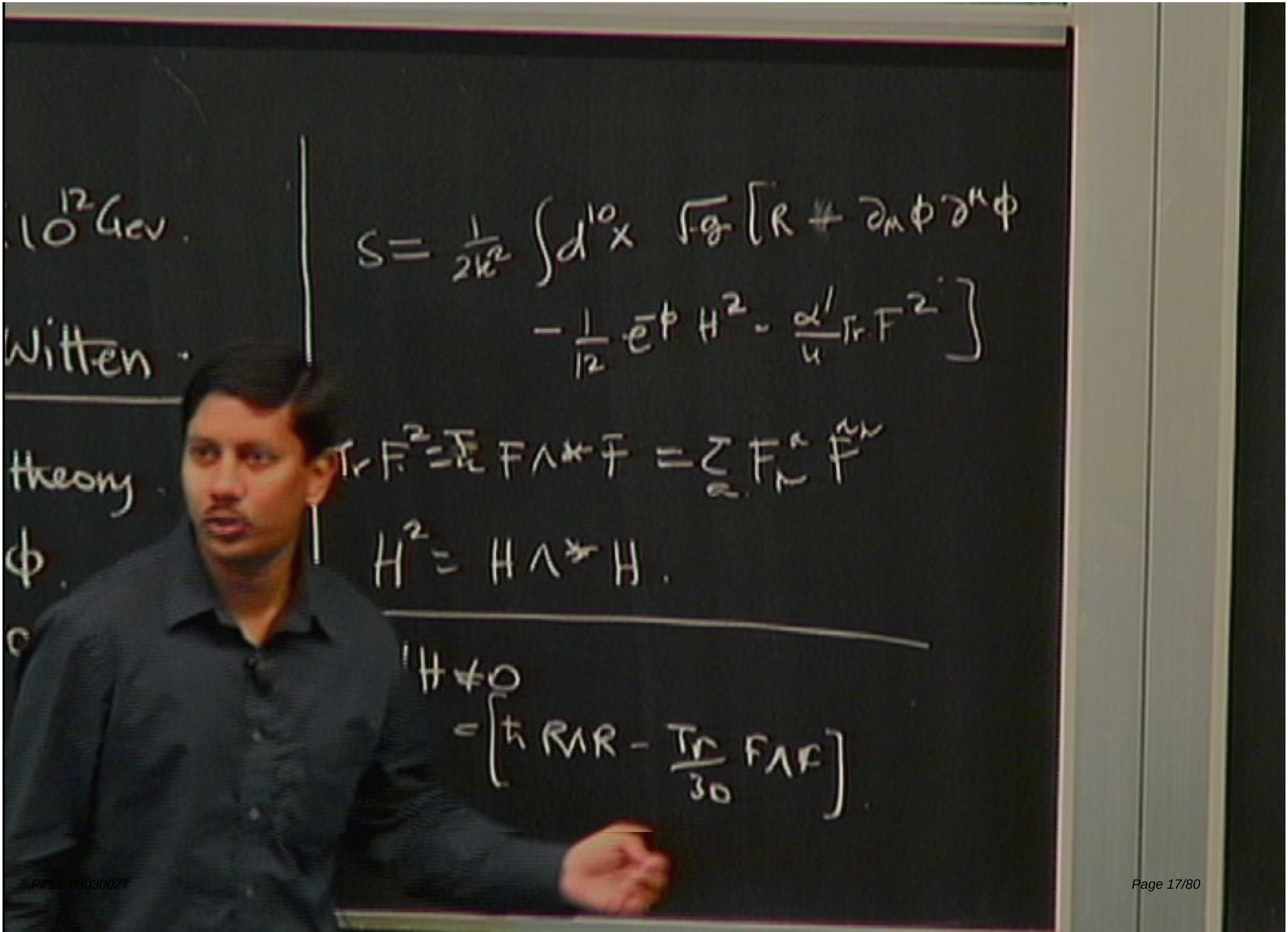
$$H^2 = H\wedge * H.$$



10^12 Gev.
Witten.
theory
φ.
$S = \frac{1}{2\kappa^2}\int d^{10}x \sqrt{-g}\left[R + \partial_\mu\phi\,\partial^\mu\phi - \frac{1}{12}e^{-\phi}H^2 - \frac{\alpha'}{4}\mathrm{Tr}\,F^2\right]$
$\mathrm{Tr}\,F^2 = \mathrm{Tr}\,F\wedge * F = \sum_a F^a_{\mu\nu}F^{a\mu\nu}$
$H^2 = H\wedge * H.$
$H \neq 0$
$= \left[\mathrm{tr}\,R\wedge R - \frac{\mathrm{Tr}}{30}F\wedge F\right].$

10^{12} GeV.

tten.

eory

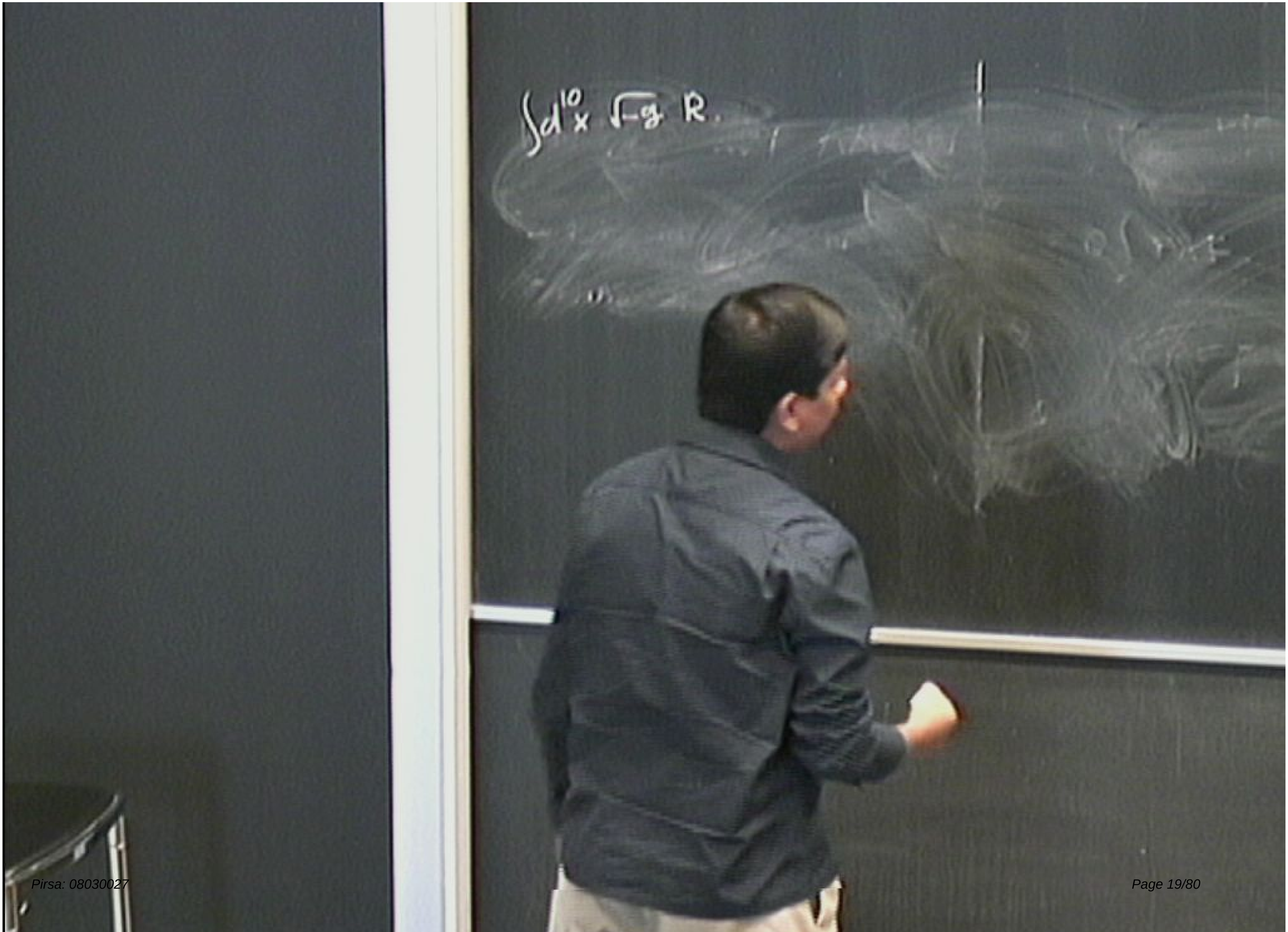
(32), $E_8 \times E_8$

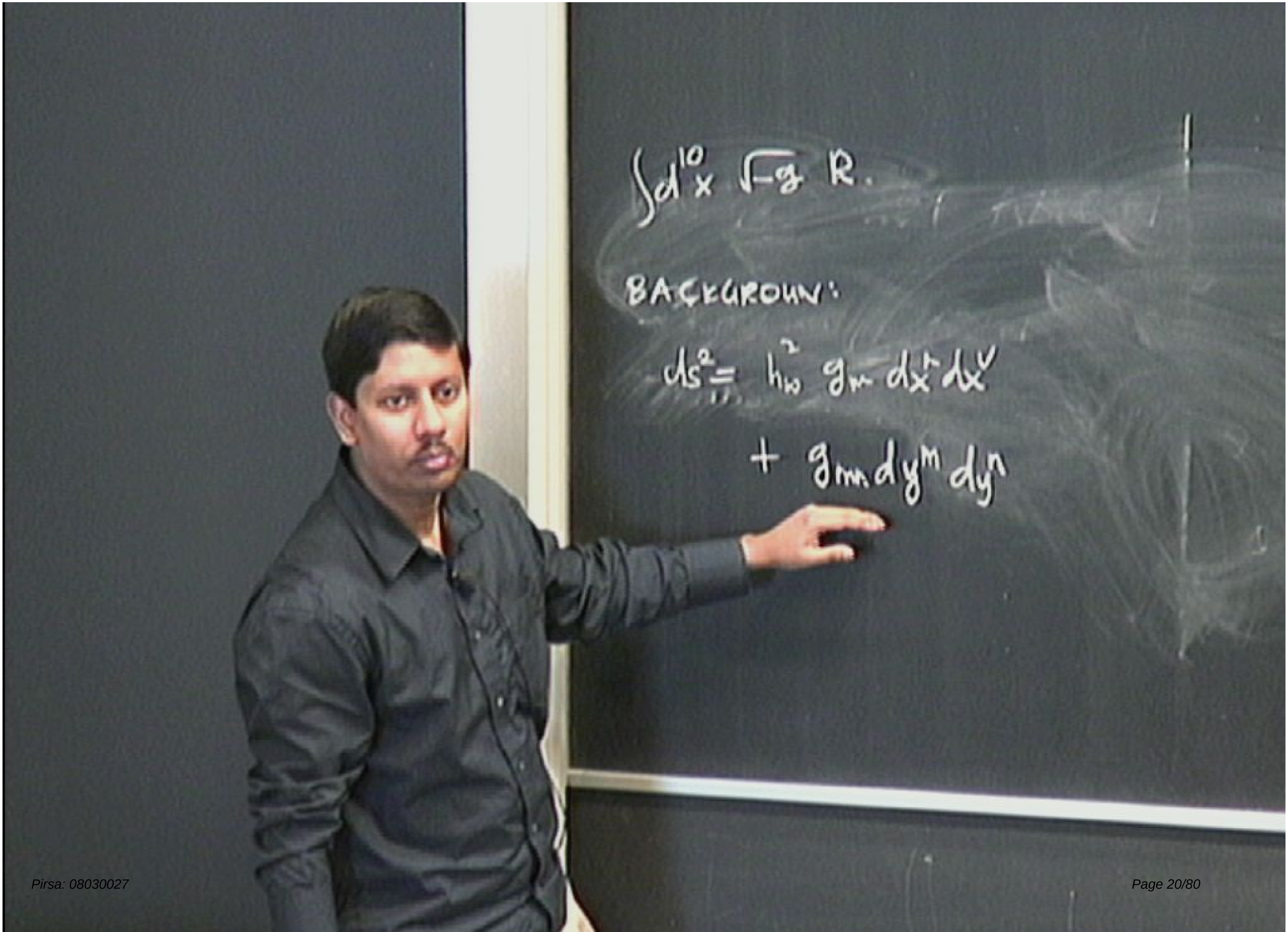
$$S = \frac{1}{2k^2} \int d^{10}x \sqrt{-g} \left[R + \partial_M \phi \partial^M \phi - \frac{1}{12} e^{\phi} H^2 - \frac{\alpha'}{4} \mathrm{Tr}\, F^2 \right]$$

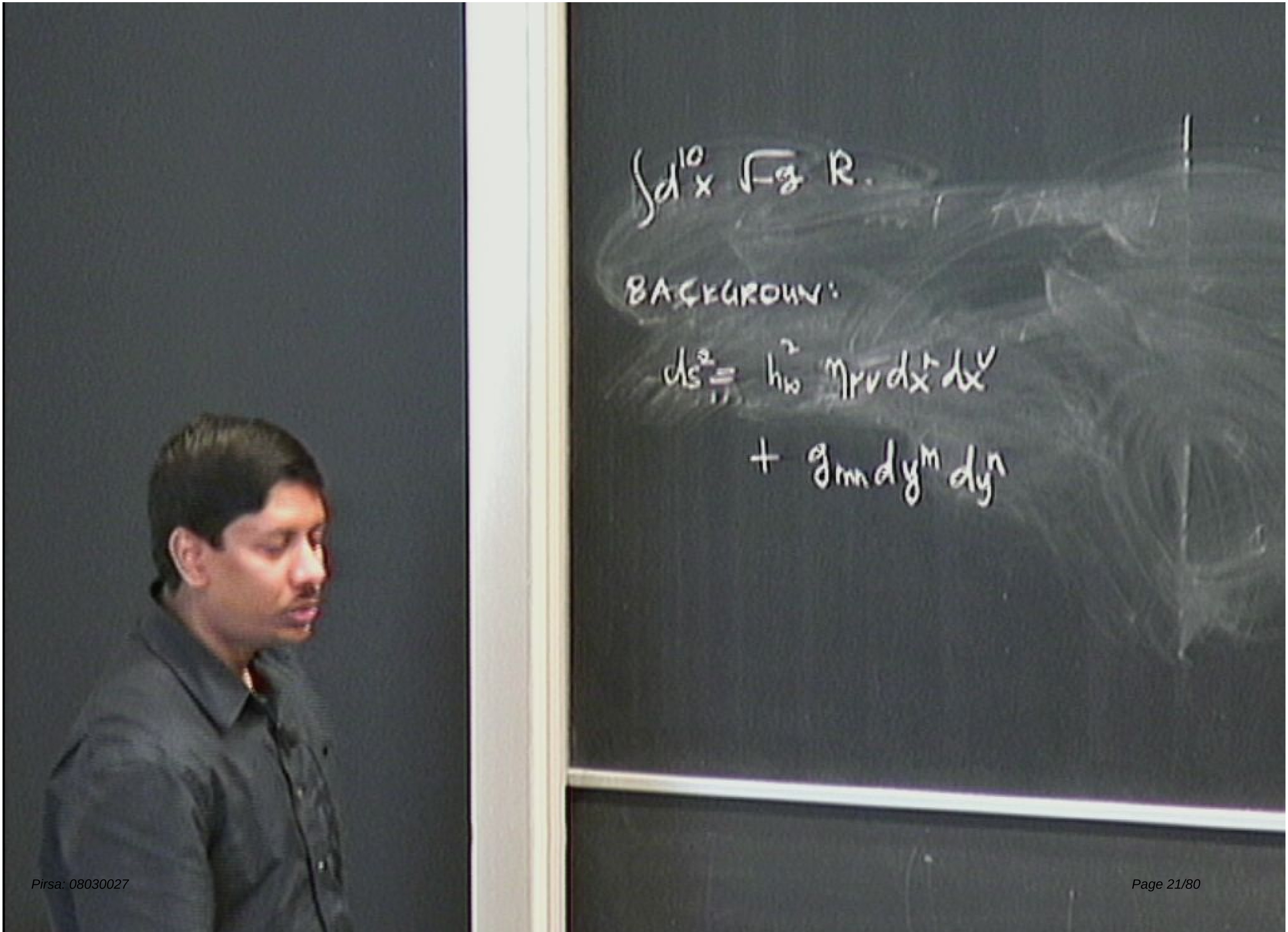
$$\mathrm{Tr}\, F^2 = \mathrm{Tr}\, F \wedge * F = \sum_a F_\mu^a F^{a\mu}$$

$$H^2 = H \wedge * H.$$

$$dH \neq 0$$
$$= \left[\mathrm{tr}\, R \wedge R - \frac{\mathrm{Tr}}{30} F \wedge F \right]$$


$\int d^{10}x \sqrt{-g}\, R$.


$\int d^{10}x \sqrt{-g}\, R.$
BACKGROUN:
$ds^2_{11} = h_w^2\, g_{\mu\nu}\, dx^\mu dx^\nu$
$+ g_{mn}\, dy^m dy^n$


$\int d^{10}x \sqrt{-g}\, R.$
BACKGROUN:
$ds^2 = h_w^2 \eta_{\mu\nu} dx^\mu dx^\nu$
$+ g_{mn} dy^m dy^n$

$$\frac{1}{2\kappa^2}\int d^{10}x\,\sqrt{-g}\,R \longrightarrow \frac{1}{2\kappa^2}\int d^4x\,\sqrt{-\bar{g}}\,\bar{R}\int d^6y\,\sqrt{g_{(6)}}\,h_w^2(y)$$

BACKGROUND:

$$ds^2 = h_w^2\,\bar{g}_{\mu\nu}\,dx^\mu dx^\nu + g^{(6)}_{mn}\,dy^m dy^n$$

$$\kappa^2 = \left(2\pi\sqrt{\alpha'}\right)^8 = M_s^{-8}$$

$$\frac{1}{2\kappa^2}\int d^{10}x\,\sqrt{-g}\,R \longrightarrow \frac{1}{2\kappa^2}\int d^4x\,\sqrt{-\bar{g}}\,\bar{R}\int d^6y\,\sqrt{g_{(6)}}\,h_w^2(y)$$

BACKGROUND:

$$\ldots{}^2_w\,\bar{g}_{\mu\nu}\,dx^\mu dx^\nu$$

$$\ldots\,g^{(6)}_{mn}\,dy^m dy^n$$

$$\kappa^2 = \left(2\pi\sqrt{\alpha'}\right)^8 = m_s^{-8}$$

$$\boxed{\frac{1}{2\kappa^2}\int d^6y\,\sqrt{g_{(6)}}\,h_w^2 = M_P^2}$$

$$\frac{1}{2\kappa^2}\int d^{10}x\,\sqrt{-g}\,R. \longrightarrow \frac{1}{2\kappa^2}\int d^4x\,\sqrt{-\bar{g}}\,\bar{R}\int d^6y\,\sqrt{g_{(6)}}\,h_w^2(y)$$

BACKGROUND:

$$ds^2 = h_w^2\,\bar{g}_{\mu\nu}\,dx^\mu dx^\nu + g^{(6)}_{mn}\,dy^m dy^n$$

$\underline{H_w}$

$$\kappa^2 = (2\pi\sqrt{\alpha'})^8 = M_s^{-8}$$

$$\boxed{\frac{1}{2\kappa^2}\int d^6y\,\sqrt{g_{(6)}}\,h_w^2 = M_P^2}$$

$$M_P^2\int d^4x\,\sqrt{\bar{g}}\,\bar{R}.$$

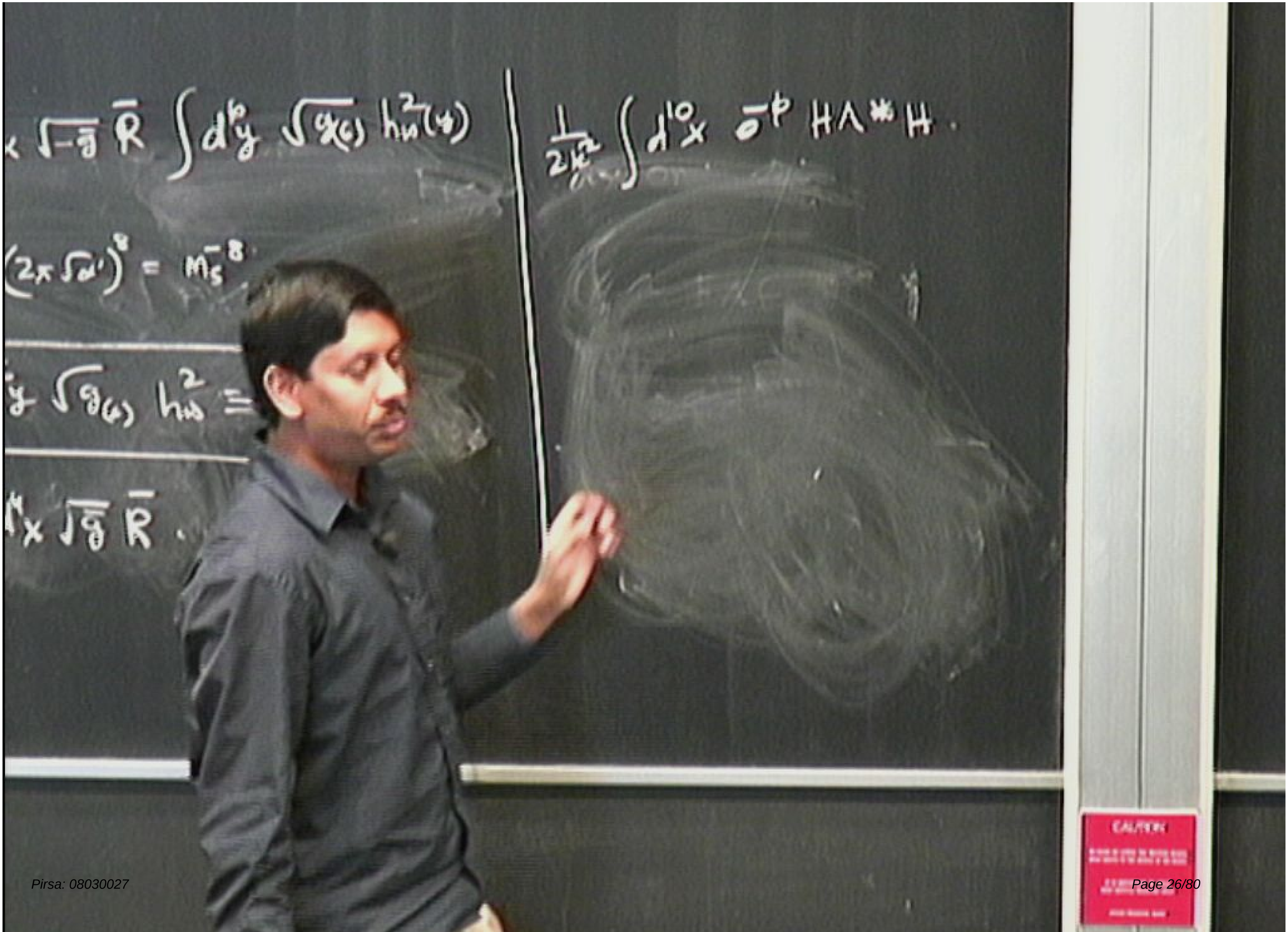
$$\frac{1}{2\kappa^2}\int d^4x\,\sqrt{-g}\,\bar{R}\int d^6y\,\sqrt{g_{(6)}}\,h_w^2(y)$$

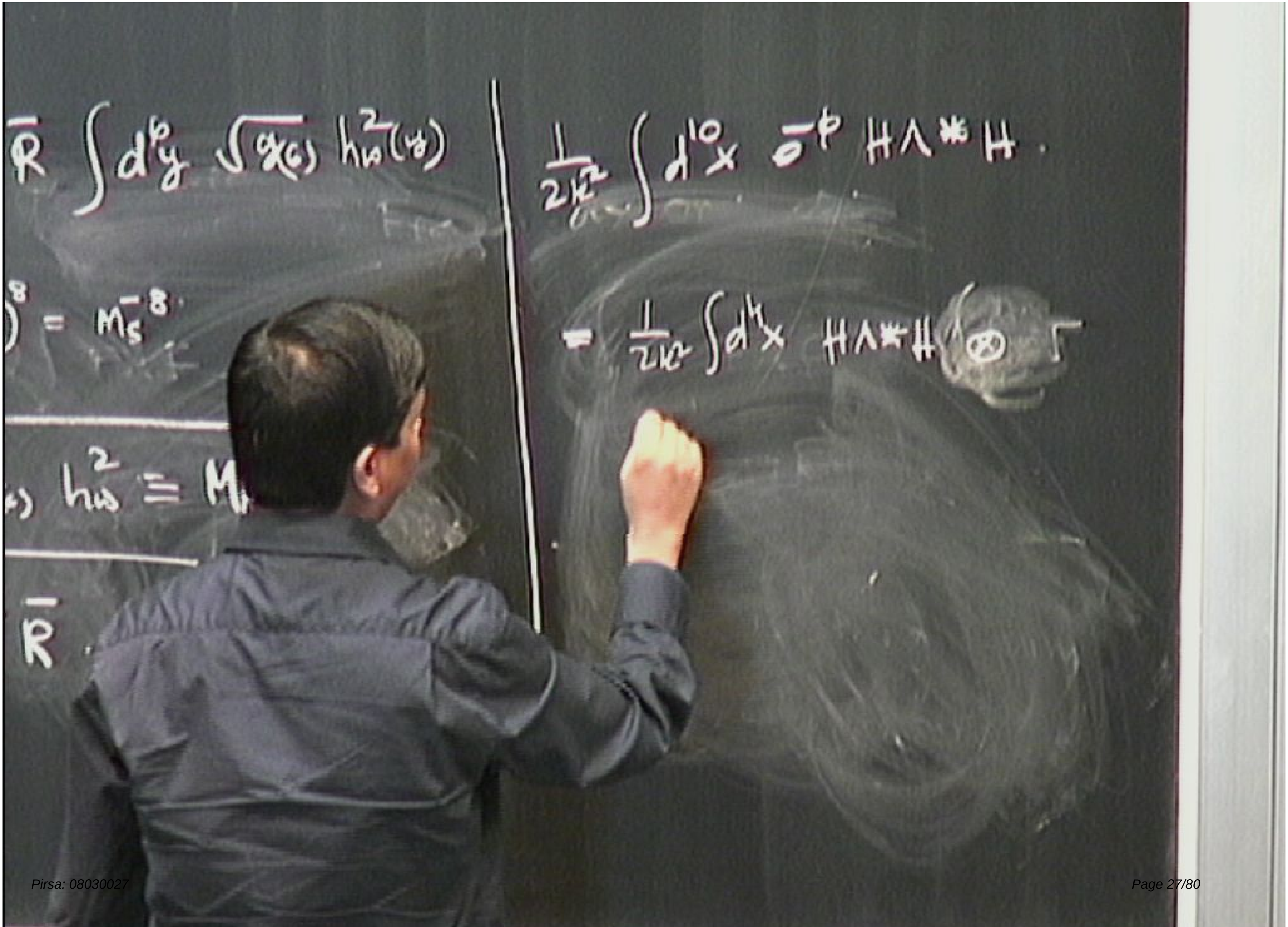
$$\frac{1}{2\kappa^2}\int d^{10}x\; e^{-\phi}\, H\wedge {}^*H$$

$$\kappa^2 = (2\pi\sqrt{\alpha'})^8 = m_s^{-8}$$

$$\boxed{\frac{1}{2\kappa^2}\int d^6y\,\sqrt{g_{(6)}}\,h_w^2 = M_p^2}$$

$$M_p^2\int d^4x\,\sqrt{g}\,\bar{R}\,.$$


$\frac{1}{2\kappa^2}\int d^{10}x\, e^{-\phi}\, H \wedge * H$
$(2\pi\sqrt{\alpha'})^8 = m_s^{-8}$
CAUTION


$\bar{R} \int d^6y \sqrt{g_{(6)}}\, h_w^2(y)$
$)^8 = M_s^{-8}$
$h_w^2 \equiv M$
$\bar{R}$
$\frac{1}{2\kappa^2} \int d^{10}x\, e^{-\phi}\, H \wedge * H$
$= \frac{1}{2\kappa^2} \int d^4x\, H \wedge * H$

$\bar{R} \int d^6y \sqrt{g_{(6)}}\, h_w^2(y)$

$)^8 = M_s^{-8}$

$\boxed{{}_{(6)}\, h_w^2 = M_p^2}$

$\bar{R}$.

$\frac{1}{2\kappa^2} \int d^{10}x\, e^{-\phi}\, H \wedge * H$.

$= \frac{1}{2\kappa^2} \int d^4x\, H \wedge * H$

$\int d^6y \sqrt{g_{(6)}}\, e^{-\phi}\, h_w^{-2}$.

$\bar{R} \int d^6y \sqrt{g_{(6)}}\, h_w^2(y))$

$)^8 = M_5^{-8}$

$\boxed{{}_{)}\, h_w^2 \equiv M_p^2}$

$\bar{R}$.

$\frac{1}{2k^2} \int d^{10}x\, e^{-\phi}\, H \wedge * H$.

$= \frac{1}{2k^2} \int d^4x\, H \wedge * H \,(\otimes \int$

$\int d^6y \sqrt{g_{(6)}}\, e^{-\phi}\, h_w^{-2}$.

$$\beta = \frac{\int d^6y \sqrt{g_{(6)}}\, e^{-\phi}\, h_w^{-2}}{\int d^6y \sqrt{g_{(6)}}\, h_w^2}.$$

$\sqrt{g_{(6)}}\, h_w^2(y)$

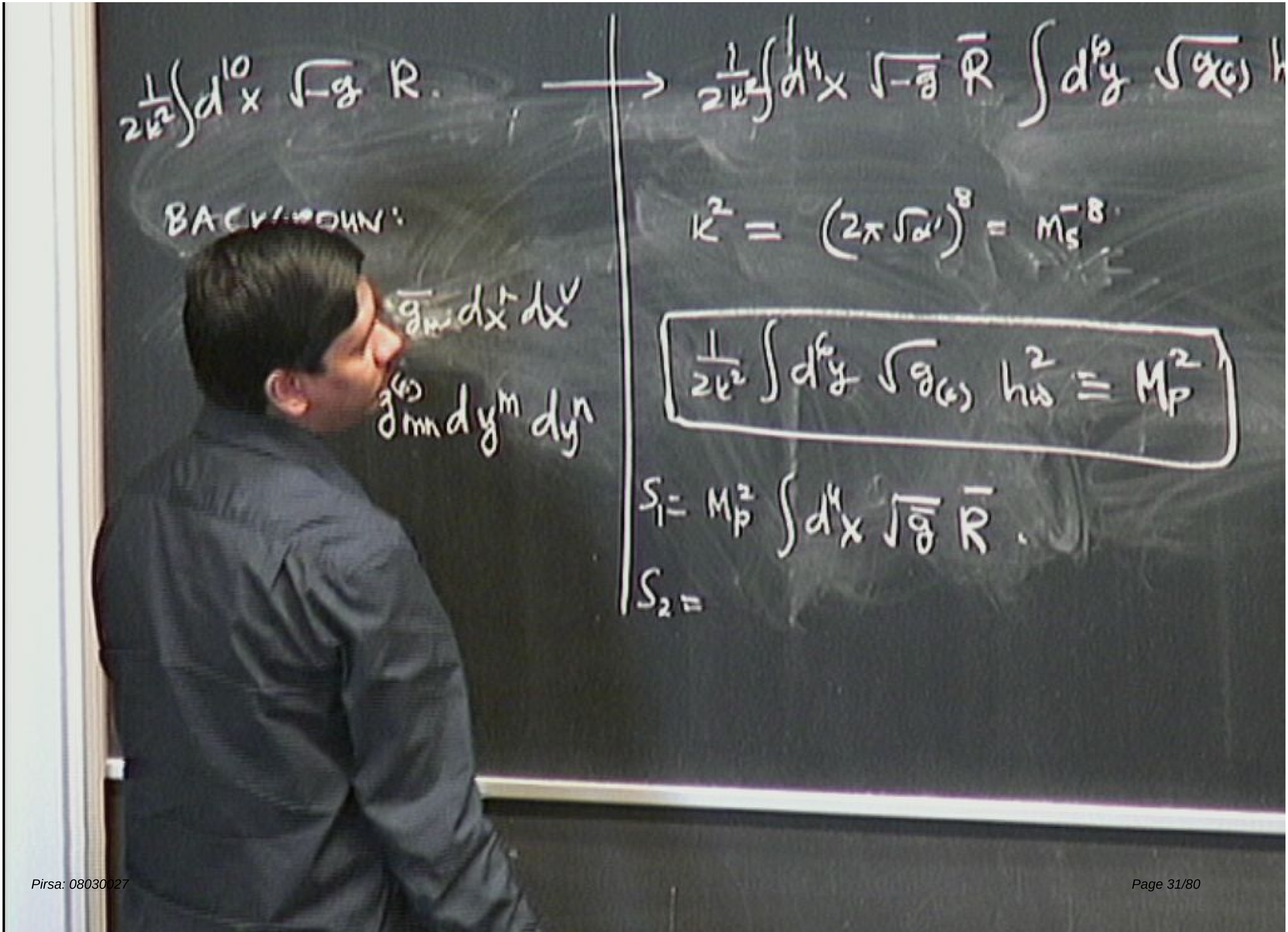
$\boxed{M_p^2}$

$\frac{1}{2\kappa^2}\int d^{10}x\; e^{-\phi}\, H \wedge * H.$

$= \frac{1}{2\kappa^2}\int d^4x\; H \wedge * H$

$\int d^6y \sqrt{g_{(6)}}\, e^{-\phi}\, h_w^{-2}.$

$$\beta = \frac{\int d^6y \sqrt{g_{(6)}}\, e^{-\phi}\, h_w^{-2}}{\int d^6y \sqrt{g_{(6)}}\, h_w^{-2}}.$$


$\frac{1}{2\kappa^2}\int d^{10}x \sqrt{-g}\, R.$
$\longrightarrow \frac{1}{2\kappa^2}\int d^4x \sqrt{-\bar{g}}\, \bar{R} \int d^6y \sqrt{g_{(6)}}\, h$
BACKGROUN:
$\bar{g}_{\mu\nu} dx^\mu dx^\nu$
$g^{(6)}_{mn} dy^m dy^n$
$\kappa^2 = (2\pi\sqrt{\alpha'})^8 = m_s^{-8}$
$\boxed{\frac{1}{2\kappa^2}\int d^6y \sqrt{g_{(6)}}\, h_w^2 \equiv M_P^2}$
$S_1 = M_P^2 \int d^4x \sqrt{\bar{g}}\, \bar{R}\,.$
$S_2 =$

BACKGROUN:

$$ds^2 = h_w^2\, \bar{g}_{\mu\nu}\, dx^\mu dx^\nu + g^{(6)}_{mn}\, dy^m dy^n$$

$\underline{H_w}$

$$\kappa^2 = \left(2\pi\sqrt{\alpha'}\right)^8 = M_s^{-8}$$

$$\boxed{\frac{1}{2\kappa^2}\int d^6y\, \sqrt{g_{(6)}}\, h_w^2 = M_p^2}$$

$$S_1 = M_p^2 \int d^4x\, \sqrt{\bar{g}}\, \bar{R}\,.$$

$$S_2 = \beta M_p^2 \int d^4x\;\; H \wedge * H$$

$R \int d^6y \sqrt{g_{(6)}}\, h_w(y)$

$\frac{1}{2\kappa^2} \int d^4x\, e^{\phi}\, H \wedge * H$

$)^8 = M_s^{-8}$

$= \frac{1}{2\kappa^2} \int d^4x\, H \wedge * H \, \left(\int d^6y \sqrt{g_{(6)}}\, e^{-\phi}\, h_w^{-2} \right)$

$$\boxed{{}_{(6)}\, h_w^2 = M_p^2}$$

$$\beta = \frac{\int d^6y \sqrt{g_{(6)}}\, e^{-\phi}\, h_w^{-2}}{\int d^6y \sqrt{g_{(6)}}\, h_w^{2}}.$$

$* H$

$$\frac{1}{2\kappa^2}\int d^{10}x \sqrt{-g}\, R \longrightarrow \frac{1}{2\kappa^2}\int d^4x \sqrt{-\bar{g}}\, \bar{R} \left(\int d^6y \sqrt{g_{(6)}}\, h_{10}^2(y)\right)$$

BACKGROUND:

$ds^2 = h_{10}^{-2} \bar{g}_{\mu\nu} dx^\mu dx^\nu$

$+ \ldots$

h_{10}

$$\kappa^2 = (2\pi\sqrt{\alpha'})^8 = M_s^{-8}$$

$$\boxed{\frac{1}{2\kappa^2}\int d^6y \sqrt{g_{(6)}}\, h_{10}^2 = M_P^2}$$

$S_1 = M_P^2 \int d^4x \sqrt{\bar{g}}\, \bar{R}$.

$S_2 = \beta M_P^2 \int d^4x \; H \wedge * H$

$$\frac{1}{2\kappa^2}\int d^{10}x\; e^{-\phi}\, H \wedge * H$$

$$= \frac{1}{2\kappa^2}\int d^4x \; H \wedge * H \left(\int d^6y \sqrt{g_{(6)}}\, e^{-\phi} h_{10}^{-2}\right)$$

$$\beta = \frac{\int d^6y \sqrt{g_{(6)}}\, e^{-\phi} h_{10}^{-2}}{\int d^6y \sqrt{g_{(6)}}\, h_{10}^2}.$$

$$\bar{R}\left(\int d^6y\,\sqrt{g_{(6)}}\,h_w^2(y)\right)$$

$$)^8 = M_s^{-8}$$

$$\boxed{{}_{(6)}\, h_w^2 \equiv M_P^2}$$

$$\bar{R}.$$

$$\frac{1}{2\kappa^2}\int d^{10}x\, e^{-\phi}\, H\wedge * H.$$

$$= \frac{1}{2\kappa^2}\int d^4x\; H\wedge * H$$

$$\left(\int d^6y\,\sqrt{g_{(6)}}\,e^{-\phi}\,h_w^{-2}\right).$$

$$\beta = \int d^6y\,\sqrt{g_{(6)}}\,e^{-\phi}\,h_w^2$$

$$S_2 = \beta M_P^2 \int d^4x \; H \wedge * H$$

$$dH = \left(\mathrm{tr}\, R \wedge R - \frac{\mathrm{Tr}}{30} F \wedge F \right)$$

$$S_2 = \beta M_P^2 \int d^4x \; H \wedge * H + \int a \left[dH - \left(\mathrm{tr}\, R \wedge R - \frac{\mathrm{Tr}}{30} F \wedge F \right) \right]$$

8

$S = \frac{1}{2\kappa^2}$

$\mathrm{Tr}\, F^2 = \mathrm{Tr}\, F$

$H^2 = H$

$dH \neq 0$

$= ($

$$S_2 = \beta M_P^2 \int d^4x \; H \wedge * H$$

$$dH = \left(\mathrm{tr}\, R \wedge R - \frac{\mathrm{Tr}}{30} F \wedge F \right)$$

$$S_2 = \beta M_P^2 \int d^4x \; H \wedge * H + \int a \left[dH - \left(\mathrm{tr}\, R \wedge R - \frac{\mathrm{Tr}}{30} F \wedge F \right) \right]$$

$$= \frac{1}{\beta M_P^2} \int da \wedge * da + \int a \left(\frac{\mathrm{Tr}}{30} F \wedge F - \mathrm{tr}\, R \wedge R \right)$$

$S = \frac{1}{2\kappa^2}$

$\mathrm{Tr}\, F^2 = \mathrm{Tr}\, F$

$H^2 = H$

$dH \neq 0$

$= [\mathrm{tr}$

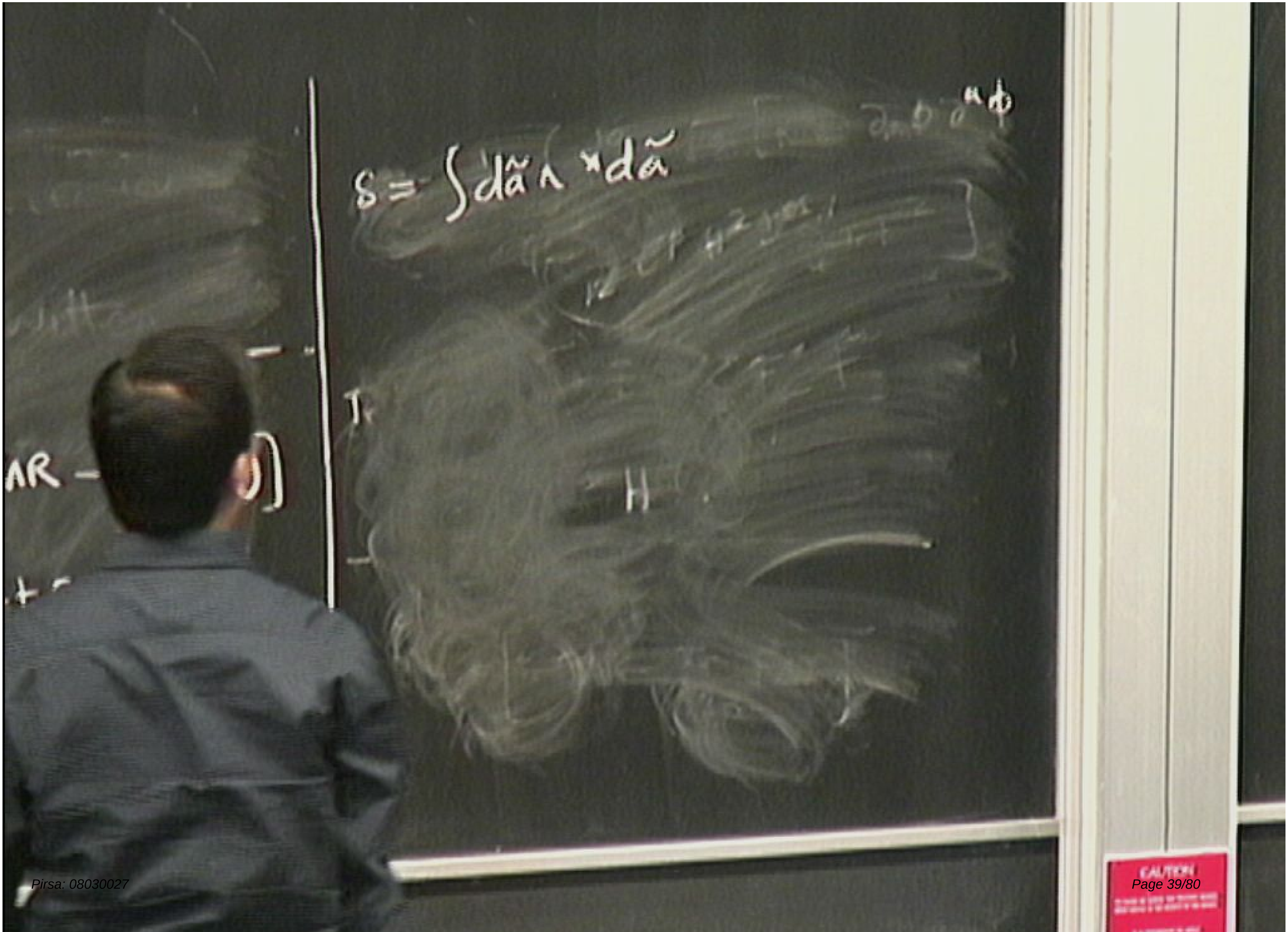
$$S_2 = \beta M_P^2 \int d^4x \; H \wedge * H.$$

$$dH = \left(\mathrm{tr}\, R \wedge R - \frac{\mathrm{Tr}}{30} F \wedge F \right)$$

$$S_2 = \beta M_P^2 \int d^4x \; H \wedge * H + \int a \left[dH - \left(\mathrm{tr}\, R \wedge R - \frac{\mathrm{Tr}}{30} F \wedge F \right) \right]$$

$$= \frac{1}{\beta M_P^2} \int da \wedge * da + \int a \left(\frac{\mathrm{Tr}}{30} F \wedge F - \mathrm{tr}\, R \wedge R \right)$$

$$\tilde{a} = \frac{1}{\sqrt{\beta M_P^2}} a.$$


S = ∫dã ∧ *dã

$$S_2 = \beta M_p^2 \int d^4x \; H \wedge * H .$$

$$dH = \left(\mathrm{tr}\, R\wedge R - \frac{\mathrm{Tr}}{30} F\wedge F \right)$$

$$S_2 = \beta M_p^2 \int d^4x \; H \wedge * H + \int a \left[dH - \left(\mathrm{tr}\, R\wedge R - \frac{\mathrm{Tr}}{30} F\wedge F \right.\right.$$

$$= \left(\frac{1}{\beta M_p^2}\right)^{-1} \int da \wedge * da + \int a \left(\frac{\mathrm{Tr}}{30} F\wedge F - \mathrm{tr}\, R\wedge R \right)$$

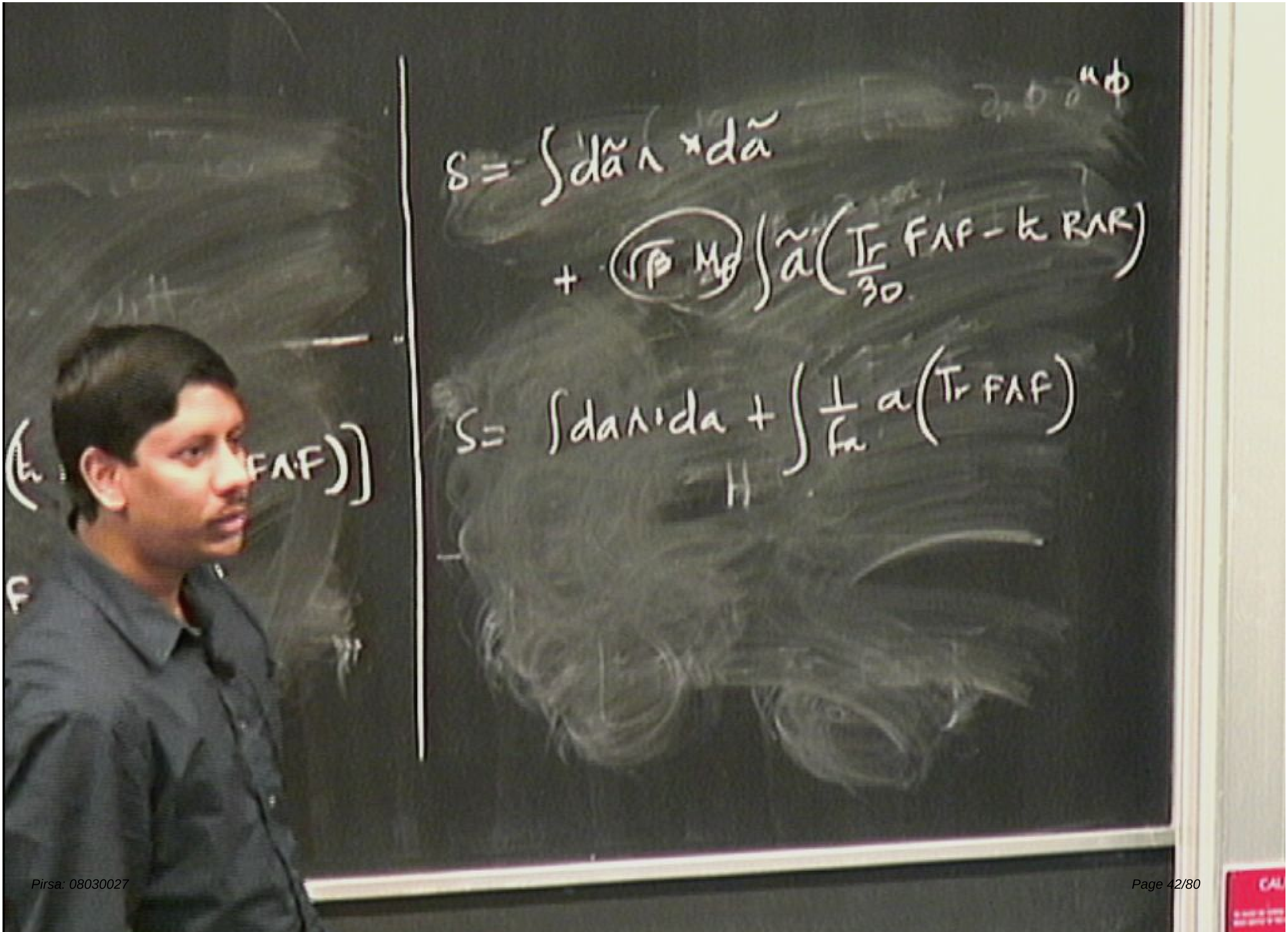
$$\tilde{a} = \left(\frac{1}{\sqrt{\beta M_p^2}}\right)^{-1} a .$$

$$S = \int d\tilde{a} \wedge * d\tilde{a}$$

$$+ \sqrt{\beta}\, M_p \int \tilde{a} \left(\frac{\mathrm{Tr}}{30} F\wedge F - \mathrm{tr}\, R\wedge R \right)$$

$$- \left(\mathrm{tr}\, R\wedge R - \frac{\mathrm{Tr}}{30} F\wedge F \right) \Big]$$

$$F\wedge F - \mathrm{tr}\, R\wedge R)$$



$S = \int d\tilde{a} \wedge {*d\tilde{a}}$
$+ \sqrt{\beta}\, M_p \int \tilde{a} \left(\frac{Tr}{30} F \wedge F - tr\, R \wedge R \right)$
$S = \int da \wedge {*da} + \int \frac{1}{f_a}\, a \left(Tr\, F \wedge F \right)$
H

$\partial_\mu \phi\, \partial^\mu \phi$

$$S = \int d\tilde{a} \wedge * d\tilde{a} + \sqrt{\beta}\, M_P \int \tilde{a} \left(\frac{\mathrm{Tr}}{30} F\wedge F - \mathrm{tr}\, R\wedge R \right)$$

$$S = \int da \wedge * da + \int \frac{1}{f_a}\, a \left(\mathrm{Tr}\, F\wedge F \right)$$

$$f_a \sim \frac{1}{\sqrt{\beta}\, M_P}.$$

$$\left(\mathrm{tr}\, R\wedge R - \frac{\mathrm{Tr}}{30} F\wedge F \right) \Big]$$

$$F - \mathrm{tr}\, R\wedge R)$$

$F \wedge F)]$

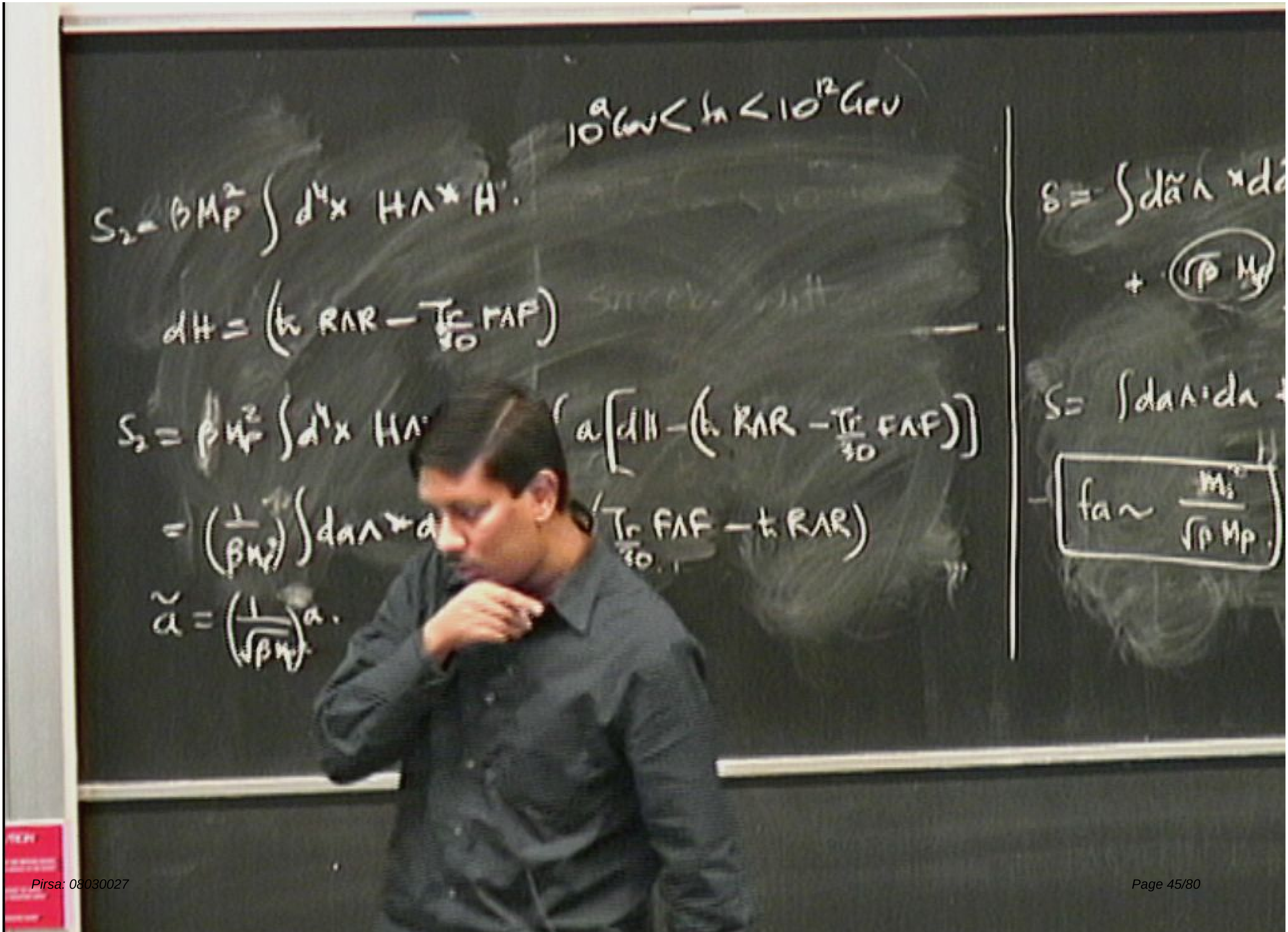
$\partial_\mu \phi\, \partial^\mu \phi$

$$S = \int d\tilde{a} \wedge {}^{*}d\tilde{a} + \sqrt{\beta}\, M_p \int \tilde{a} \left(\frac{\mathrm{Tr}}{30} F \wedge F - k\, R \wedge R \right)$$

$$S = \int da \wedge {}^{*}da + \int \frac{1}{f_a}\, a \left(\mathrm{Tr}\, F \wedge F \right)$$

$$\boxed{f_a \sim \frac{M_s^2}{\sqrt{\beta}\, M_p}}$$

CAUTION


$10^9\,\text{GeV} < f_a < 10^{12}\,\text{GeV}$
$S_2 = \beta M_P^2 \int d^4x\, H \wedge * H$
$dH = (\mathrm{tr}\, R\wedge R - \frac{\mathrm{Tr}}{30} F\wedge F)$
$S_2 = \beta M_P^2 \int d^4x\, H\wedge$
$a[dH - (\mathrm{tr}\, R\wedge R - \frac{\mathrm{Tr}}{30} F\wedge F)]$
$= (\frac{1}{\beta M_P^2}) \int da \wedge * da$
$(\frac{\mathrm{Tr}}{30} F\wedge F - \mathrm{tr}\, R\wedge R)$
$\tilde{a} = (\frac{1}{\sqrt{\beta M_P^2}}) a.$
$S = \int d\tilde{a} \wedge * d\tilde{a}$
$+ \sqrt{\beta} M_P$
$S = \int da \wedge * da$
$f_a \sim \frac{M_s^2}{\sqrt{\beta} M_P}$

eg! heterotic theory on CY3.

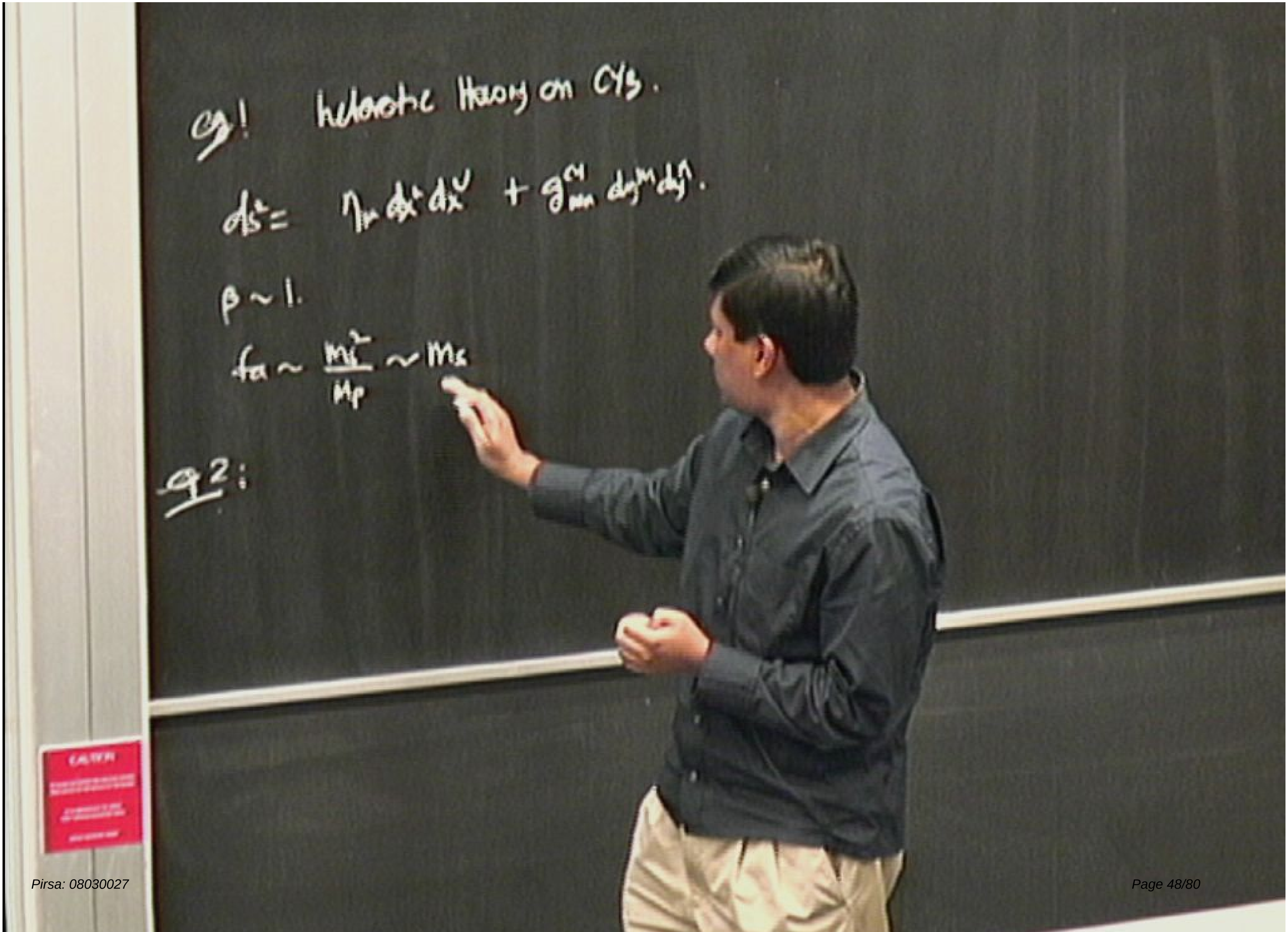
$$ds^2 = \eta_{\mu\nu} dx^\mu dx^\nu + g^{CY}_{mn} dy^m dy^n .$$

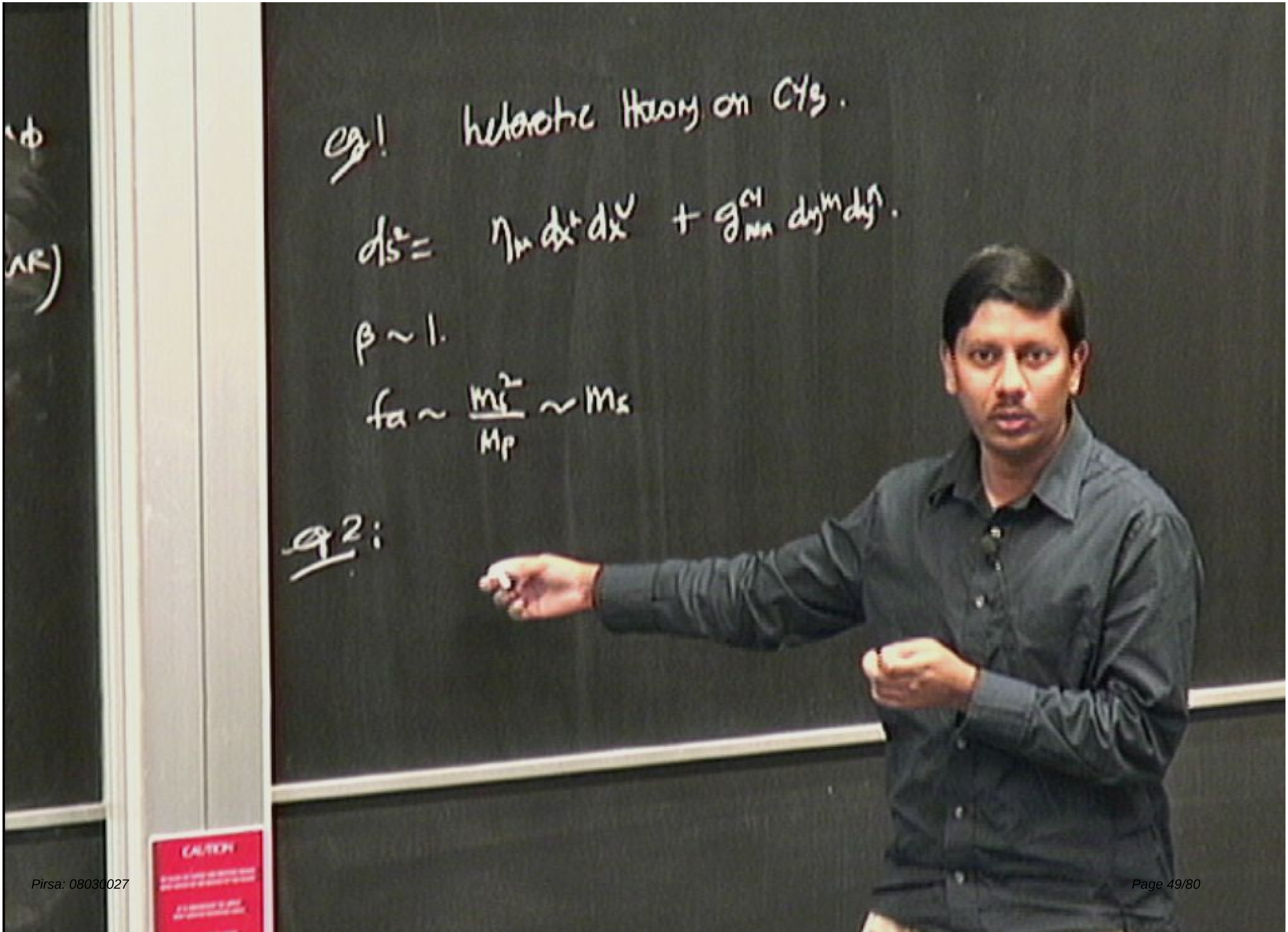
eg! heterotic theory on CY3.

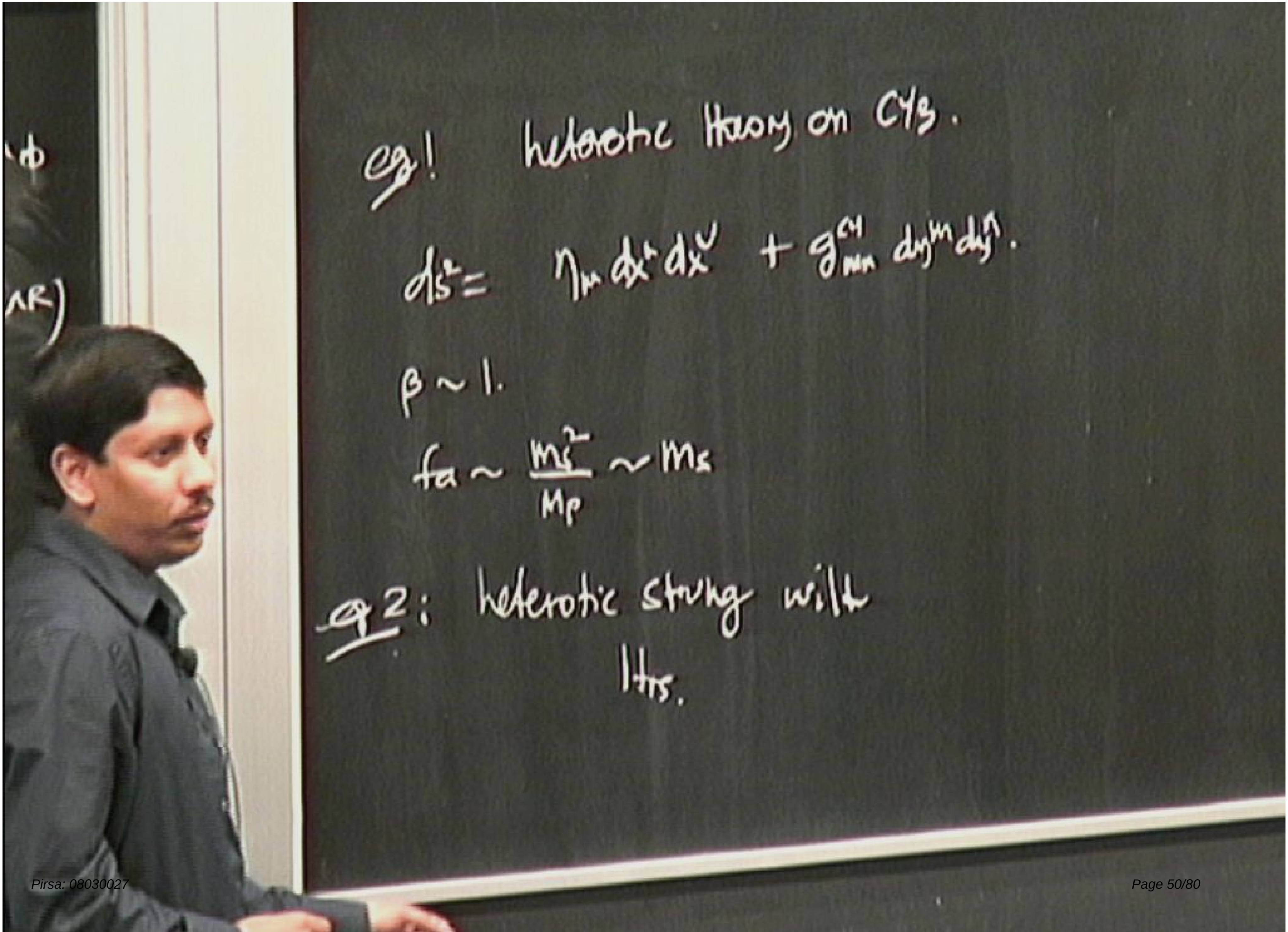
$$ds^2 = \eta_{\mu\nu} dx^\mu dx^\nu + g^{CY}_{mn} dy^m dy^n.$$

$\beta \sim 1.$

$$f_a \sim \frac{m_s^2}{M_P} \sim m_s$$


eg! heterotic theory on CY3.
$ds^2 = \eta_{\mu\nu} dx^\mu dx^\nu + g^{CY}_{mn} dy^m dy^n.$
$\beta \sim 1.$
$f_a \sim \frac{M_s^2}{M_p} \sim M_s$
eg 2:


eg! heterotic theory on CY3.
$ds^2 = \eta_{\mu\nu} dx^\mu dx^\nu + g^{CY}_{mn} dy^m dy^n.$
$\beta \sim 1.$
$f_a \sim \frac{M_s^2}{M_p} \sim M_s$
eg 2:
CAUTION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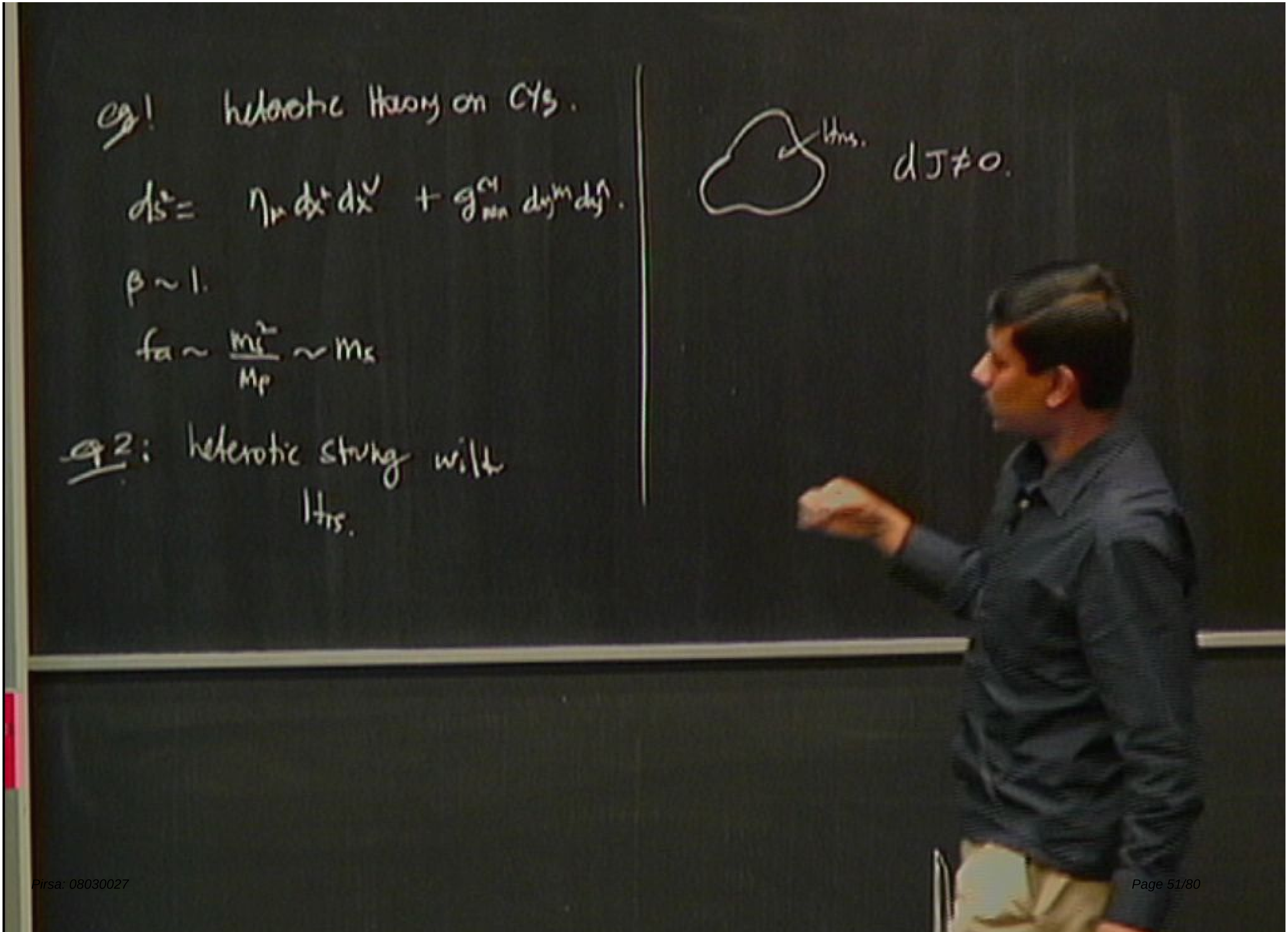
eg 2: heterotic string with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eg 2: heterotic string with
flxs.
flxs.
$dJ \neq 0$.

eg! heterotic theory on CY3.

$$ds^2 = \eta_{\mu\nu}\, dx^\mu dx^\nu + g^{CY}_{mn}\, dy^m dy^n.$$

$\beta \sim 1.$

$$f_a \sim \frac{m_s^2}{M_P} \sim m_s$$

eg 2: heterotic string with H_{ns}.

$dJ \neq 0.$

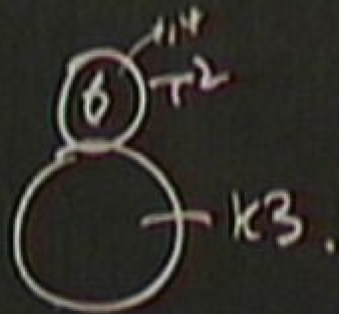
$$ds^2_{(6)} = \phi^{-1/2}\left[(dx+\alpha)^2 + (dy+\beta)^2\right] + \phi^{1/2} ds^2_{K3}.$$

(α, β) = 1-forms on K3.

CY3.

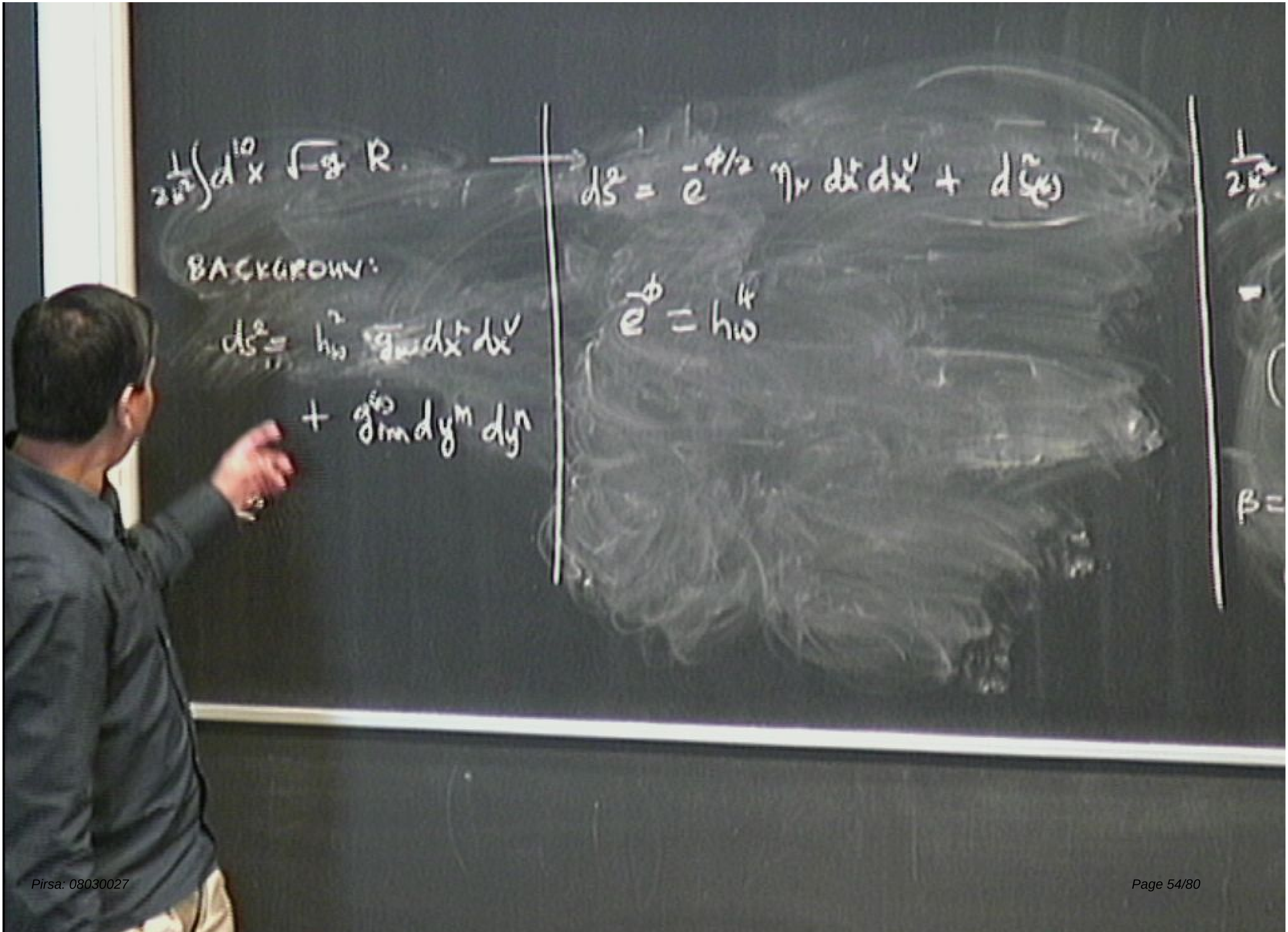
$dy^m dy^n$.

$dJ \neq 0$.

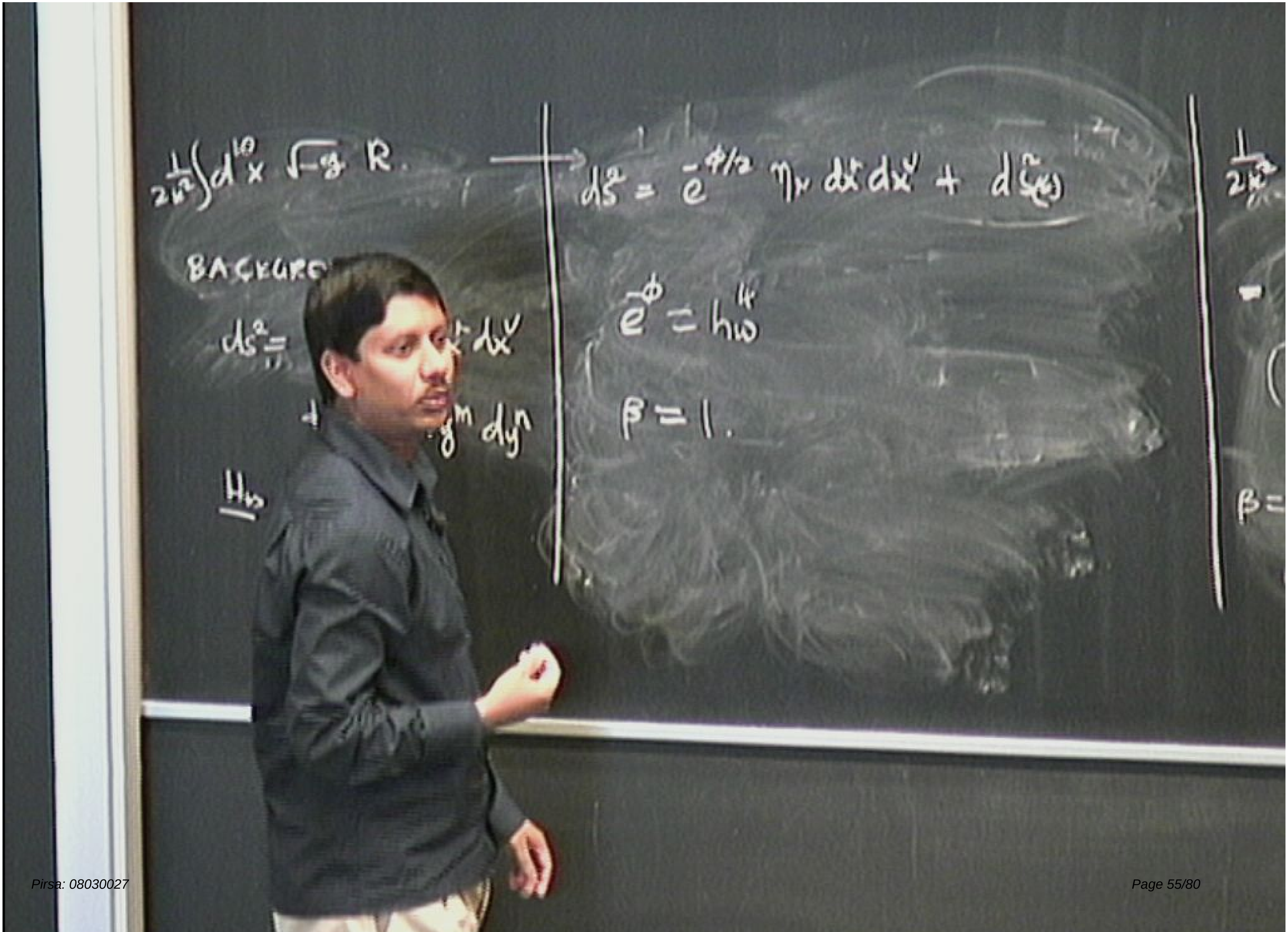


$$ds^2_{(6)} = e^{-\phi/4}\left[(dx+\alpha)^2 + (dy+\beta)^2\right] + e^{3\phi/4} ds^2_{K3}.$$

(α, β) = 1-forms on K3.



$\frac{1}{2\kappa^2}\int d^{10}x \sqrt{-g}\, R$
BACKGROUND:
$ds^2 = h_\omega^{-1/2}\, \eta_{\mu\nu}\, dx^\mu dx^\nu$
$+ \, g^{(6)}_{mn}\, dy^m dy^n$
$ds^2 = e^{-\phi/2}\, \eta_{\mu\nu}\, dx^\mu dx^\nu + d\tilde{s}^2_{(6)}$
$e^{\phi} = h_\omega^{4}$



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BACKGRO
$ds^2 = e^{-\phi/2}\eta_{\mu\nu}dx^\mu dx^\nu + d\tilde{s}^2_{(6)}$
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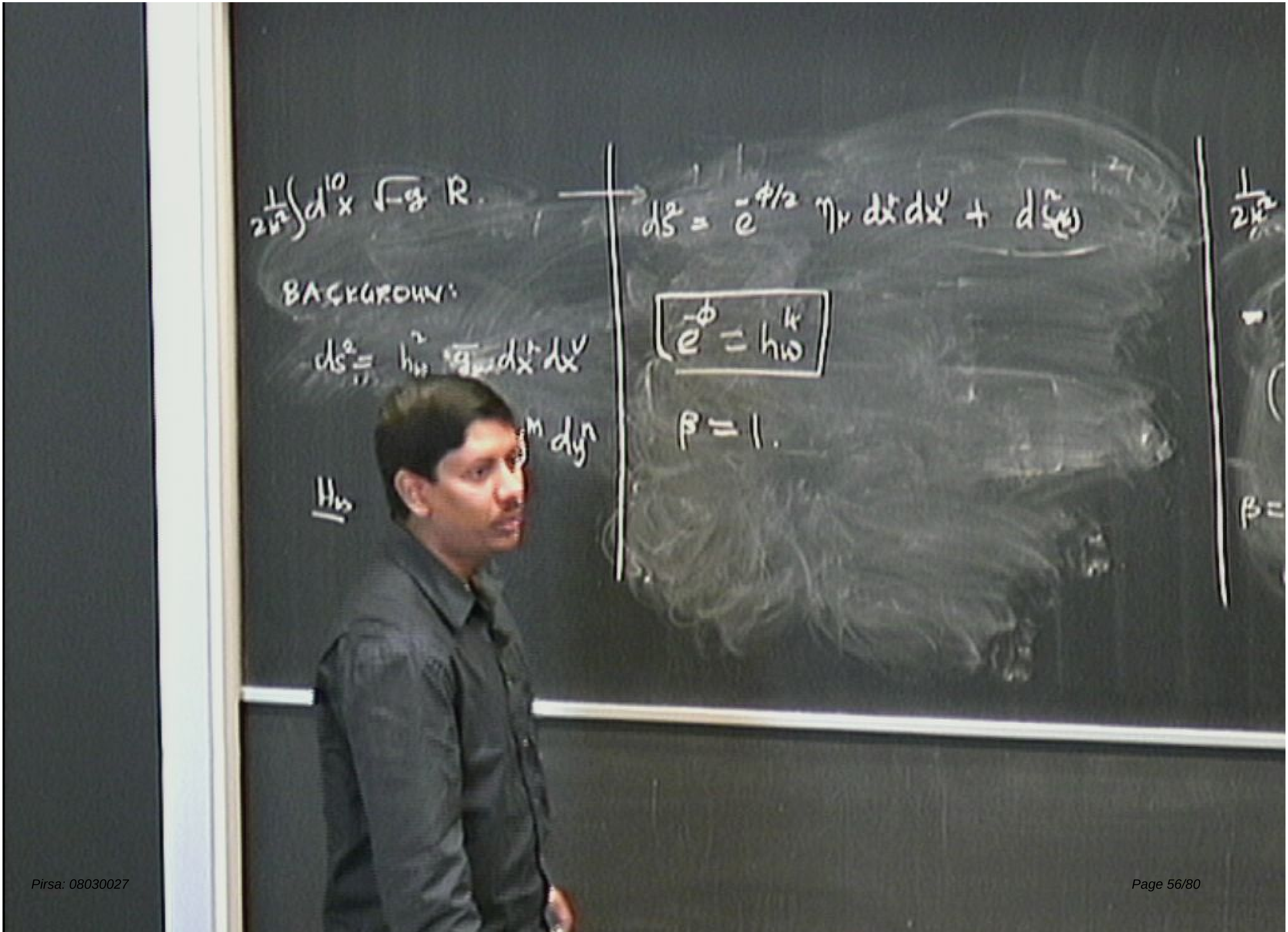
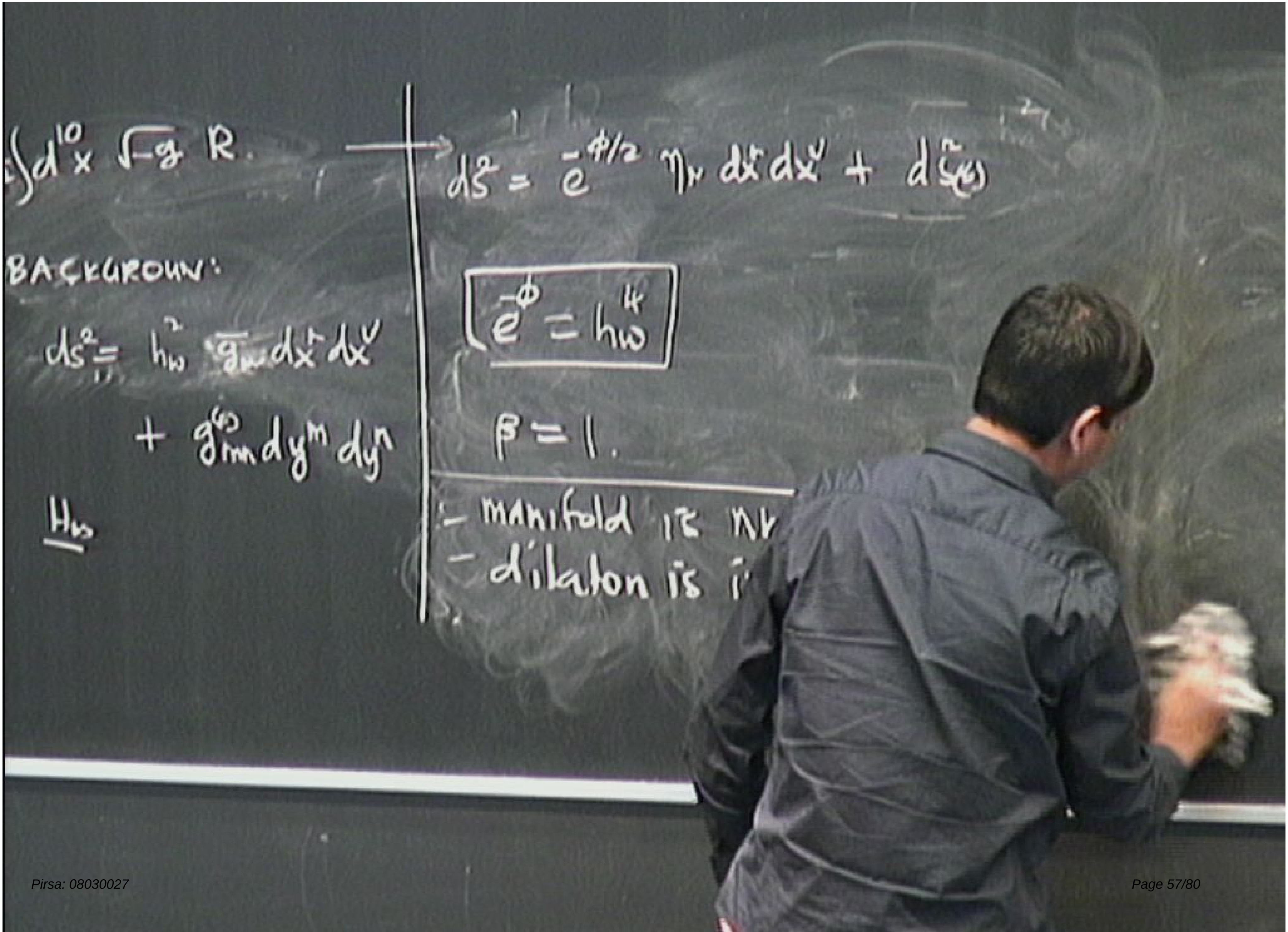

$\frac{1}{2\kappa^2}\int d^{10}x \sqrt{-g}\, R$.
BACKGROUND:
$ds^2 = e^{-\phi/2}\eta_{\mu\nu}\, dx^\mu dx^\nu + d\tilde{s}^2_{(6)}$
$e^{-\phi} = h_w^k$
$\beta = 1$.


∫d^10x √-g R.
ds² = e^{-φ/2} η_μν dx^μ dx^ν + ds̃²(6)
BACKGROUN:
ds² = h_w^2 ḡ_μν dx^μ dx^ν
+ g^(6)_mn dy^m dy^n
H_w
e^{-φ} = h_w^4
β = 1.
– manifold is
– dilaton is

$\int d^{10}x\,\sqrt{-g}\,R$

BACKGROUN:

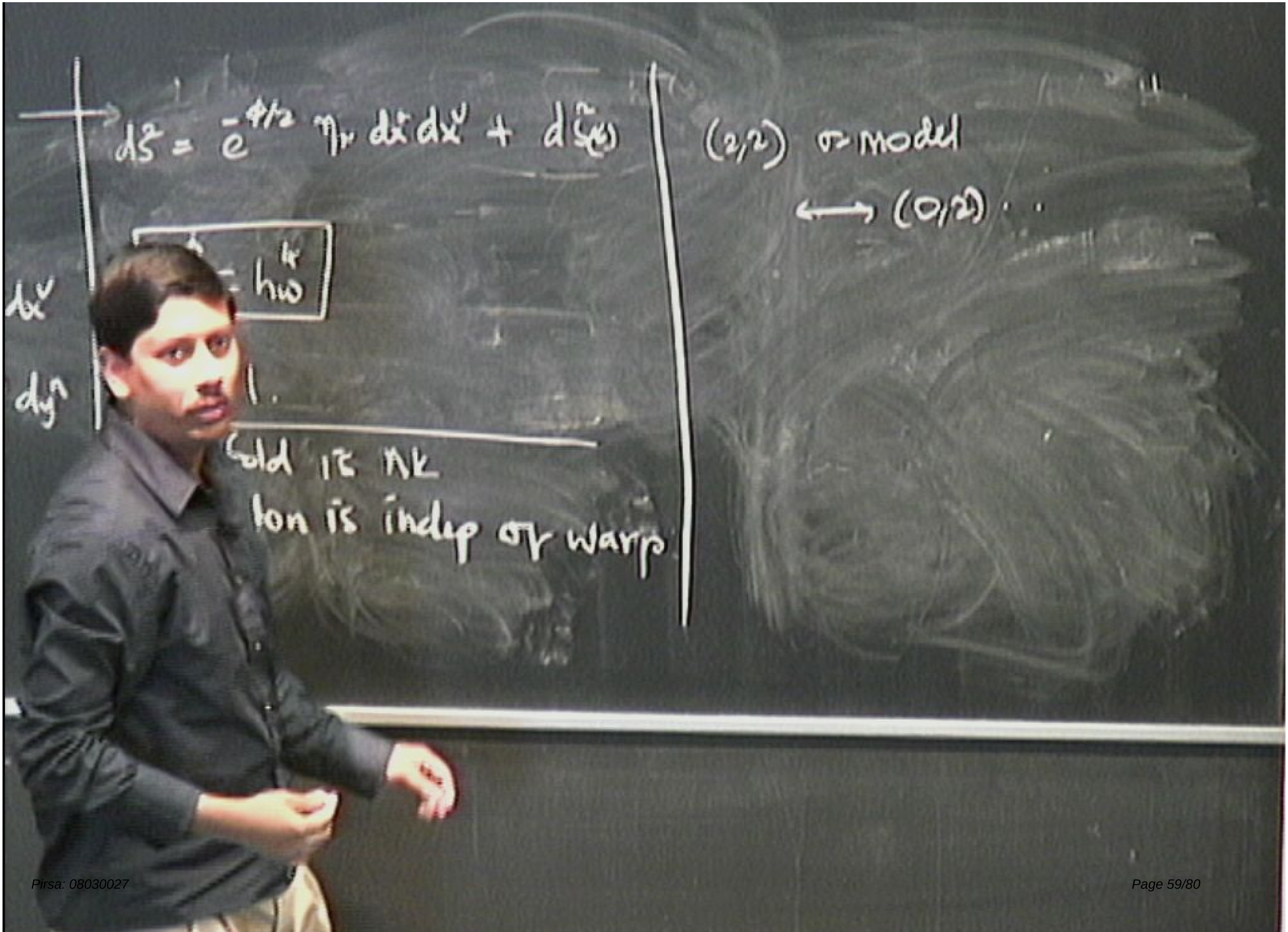
$= h_w^{2}\,\bar{g}_{\mu\nu}\,dx^\mu dx^\nu + g^{(6)}_{mn}\,dy^m dy^n$

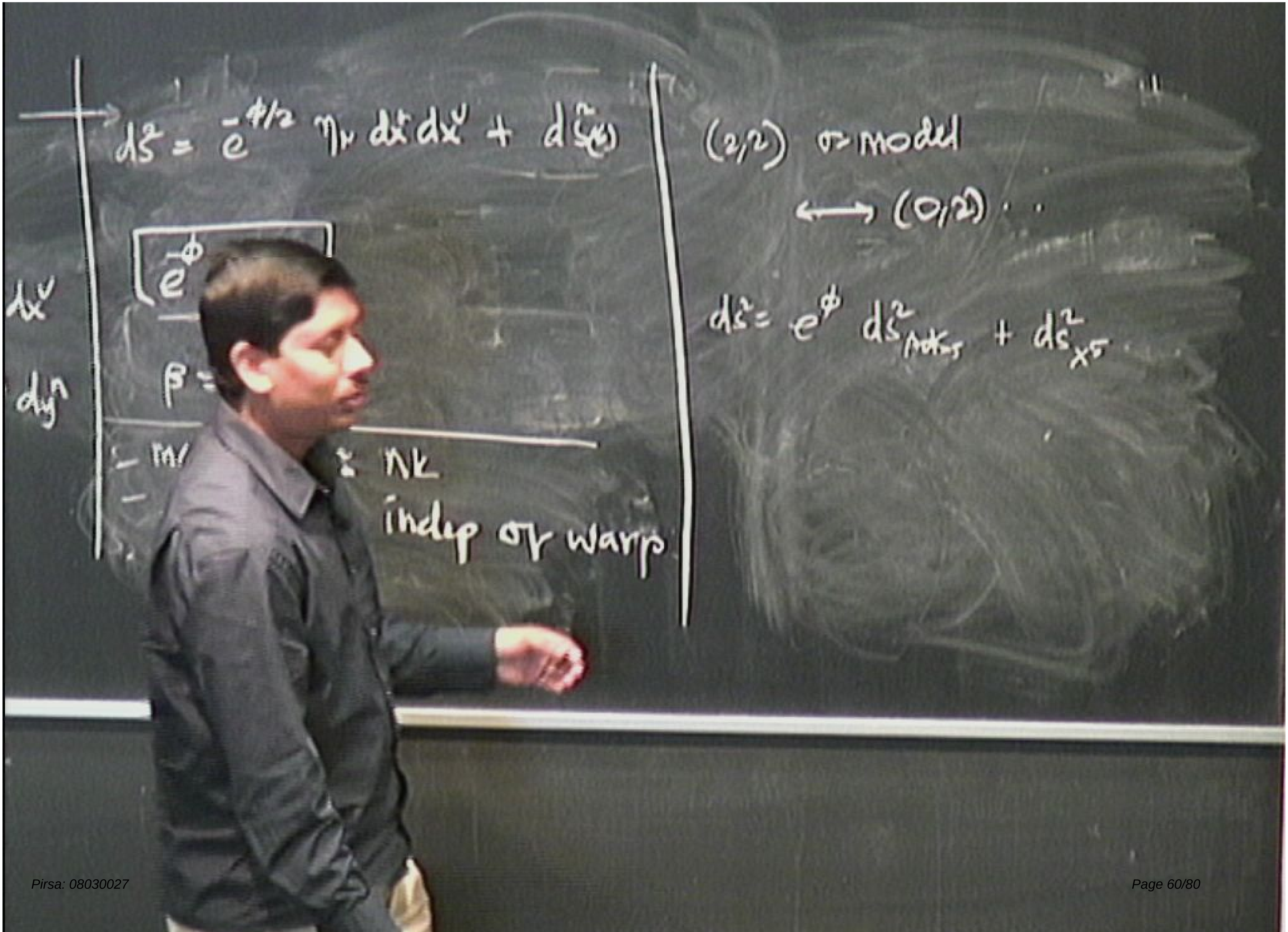
$$ds^2 = e^{-\phi/2}\,\eta_{\mu\nu}\,dx^\mu dx^\nu + d\tilde{s}^2_{(6)}$$

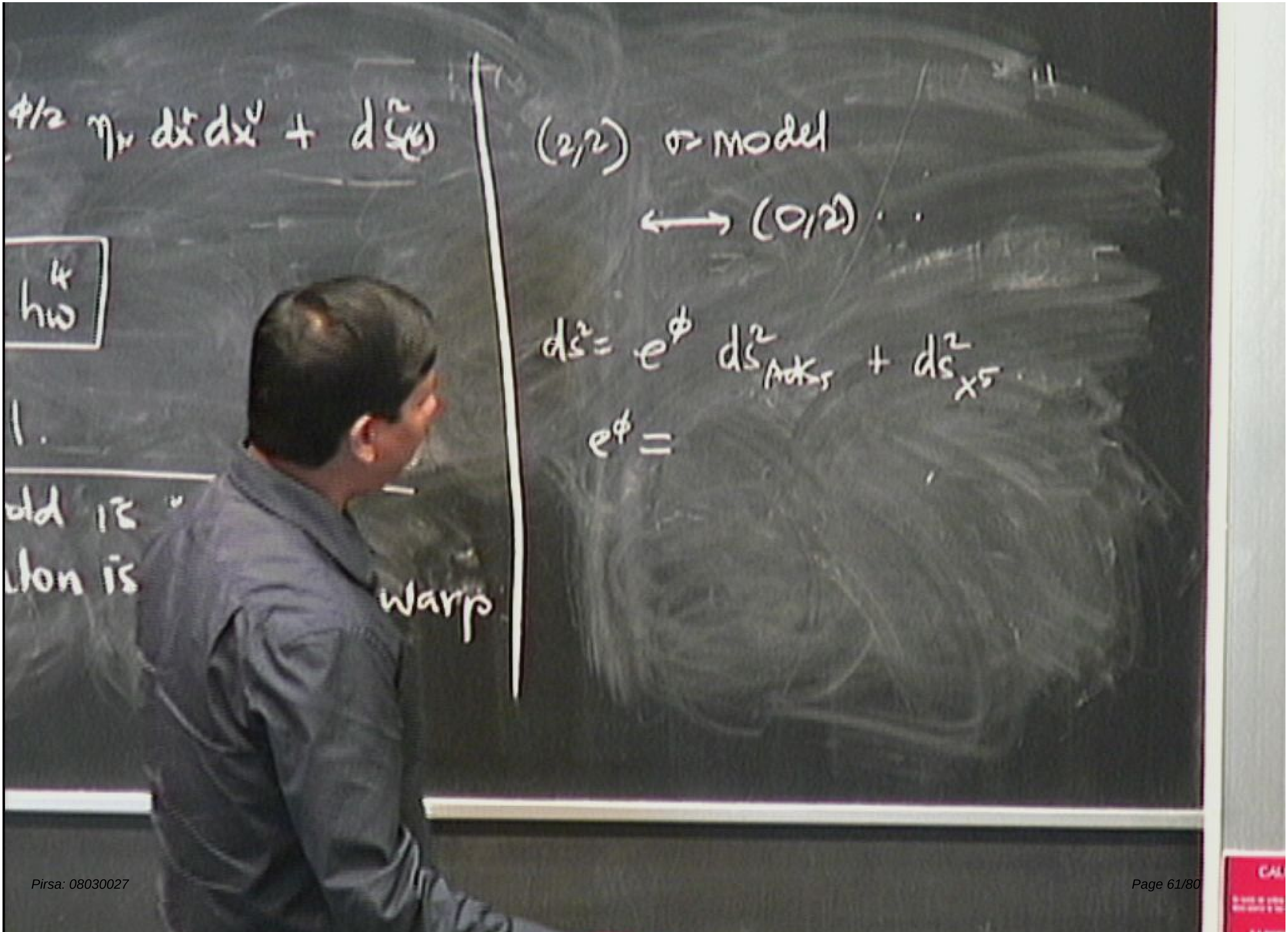
$$\boxed{e^{-\phi} = h_w^{4}}$$

$$\beta = 1.$$

- manifold is NK
- dilaton is indep of warp


ds² = e^{-φ/2} η_{μν} dx^μ dx^ν + ds̃²_{(6)}
(2,2) σ-model
⟷ (0,2) . .
ion is indep of warp


ds² = e^{-φ/2} η_{μν} dx^μ dx^ν + ds̃²_(6)
(2,2) σ-model
⟷ (0,2) · ·
ds² = e^φ ds²_{AdS5} + ds²_{X5}
indep of warp


φ/2 η_μν dx^μ dx^ν + d s̃²_(6)
h^4_ω
warp
(2,2) σ-model
⟷ (0,2) . .
ds² = e^φ ds²_AdS5 + ds²_X5 .
e^φ =

$+ \; d\tilde{s}^2_{(6)}$

or warp

(2,2) σ-model

$\longleftrightarrow$ (0,2) . .

$$ds^2 = e^{\phi}\, ds^2_{AdS_5} + ds^2_{X^5}$$

$$\Updownarrow$$

$$AdS_5 \times S^5$$

$r, \phi_1, \phi_2, \psi, \phi_3$

$+ \; ds^2_{(6)}$

or warp

(2,2) σ-model

$\longleftrightarrow$ (0,2) . .

$$ds^2 = e^{\phi}\, ds^2_{AdS_5} + ds^2_{X^5}.$$

$\Updownarrow$

$AdS_5 \times S^5$

$r, \phi_1, \phi_2, \psi, \phi_3$

$$ds^2 = \sin r\sqrt{\sin\psi\cos\psi}\,\Big[\frac{r^2}{R}\,dx^\mu dx_\mu + \alpha' R^3\Big(\frac{dr^2}{r^2} + dr^2 + \cos^2 r\, d\varphi_3^2 + \sin^2 r\, d\psi^2\Big)\Big]$$

$$+ \frac{\alpha'\sqrt{\sin\psi}}{R\cos^{3/2}\psi\cos r}\, d\varphi_1^2 + \frac{\alpha'\sqrt{\cos r}}{R\sin^{3/2}\psi\sin r}\, d\varphi_3^2.$$

$\delta =$

$S =$

$\boxed{\mathrm{fa}}$

$$ds^2 = \underbrace{\sin r\sqrt{\sin\psi\cos\psi}}\left[\frac{r^2}{R}\,dx^\mu dx_\mu + \alpha' R^3\left(\frac{dr^2}{r^2} + dr^2 + \cos^2 r\, d\varphi_3^2 + \sin^2 r\, d\psi^2\right)\right]$$

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$S=$

$S=$

$$ds^2 = \sin r \underbrace{\sqrt{\sin\psi\cos\psi}} \Big[\frac{r^2}{R} dx^\mu dx_\nu + \alpha' R^3 \Big(\frac{dr^2}{r^2} + dr^2$$

$$+ \cos^2 r \, d\varphi_3^2 + \sin^2 r \, d\psi^2 \Big) \Big]$$

$$+ \frac{\alpha' \sqrt{\sin\psi}}{R \cos^{3/2}\psi \sin r} d\varphi_1^2 + \frac{\alpha' \sqrt{\cos r}}{R \sin^{3/2}\psi \sin r} d\varphi_3^2$$

GeV

$$ds^2 = \underbrace{\sin r\sqrt{\sin\psi\cos\psi}}\left[\frac{r^2}{R}dx^\mu dx_\nu + \alpha' R^3\left(\frac{dr^2}{r^2} + dr^2\right.\right.$$

$$\left.\left. + \cos^2 r\, d\varphi_3^2 + \sin^2 r\, d\psi^2\right)\right]$$

$$+ \frac{\alpha'\sqrt{\sin\psi}}{R\cos^{3/2}\psi\sin r}\, d\varphi_1^2 + \frac{\alpha'\sqrt{\cos r}}{R\sin^{3/2}\psi\sin r}\, d\varphi_3^2.$$

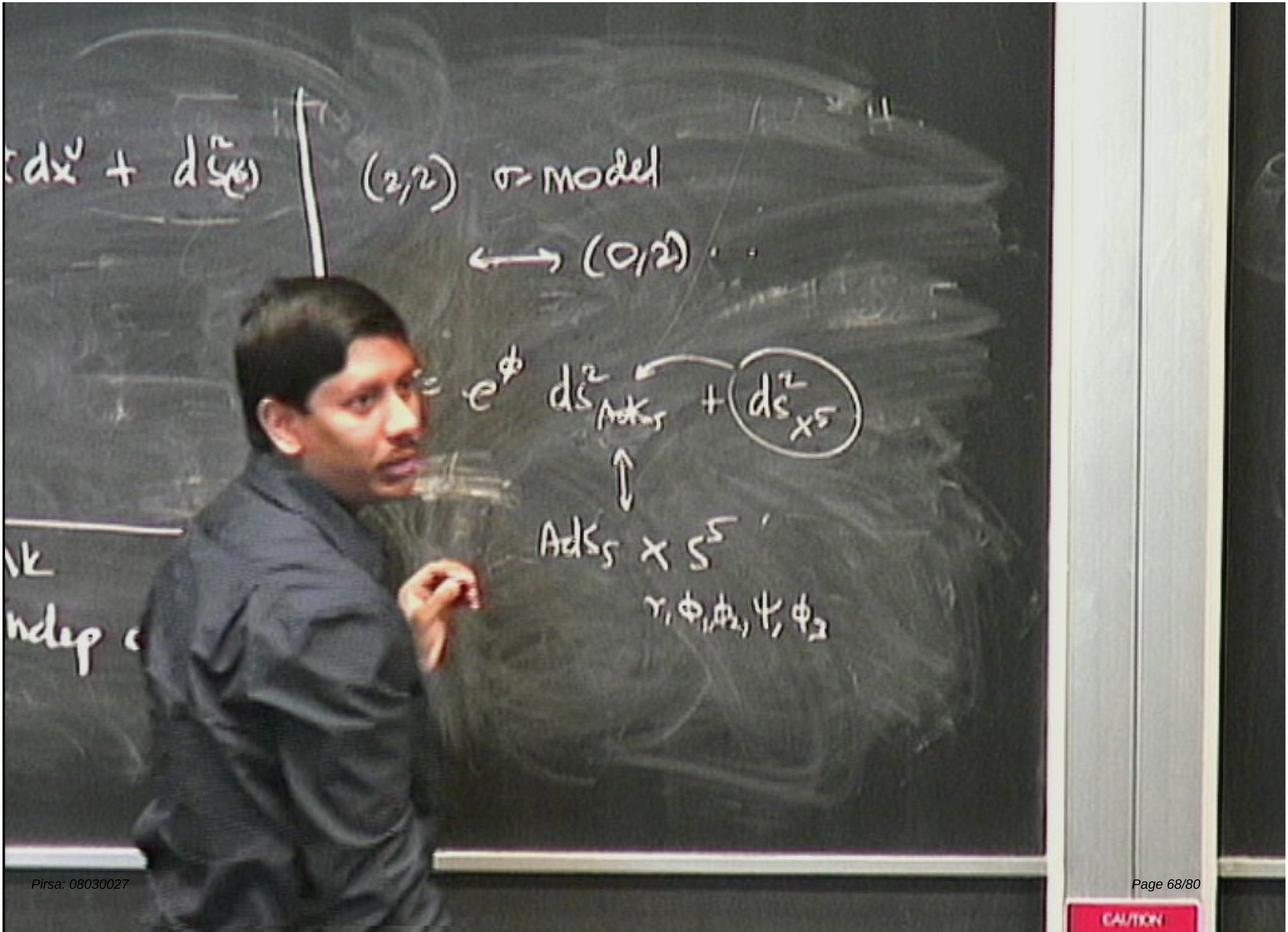
$$e^\phi = \frac{R}{2}\sin^2 r\,\sin 2\psi.$$

H_{NS} = torsion

$$R = \sqrt{4\pi g_s N}$$

$S =$

$S =$


dx^ν + ds^2_(6)
(2,2) σ-model
⟷ (0,2) . .
= e^φ ds^2_AdS5 + ds^2_X5
⟷
AdS5 × S5
r, φ1, φ2, ψ, φ3
k
indep

$$ds^2 = \sin r\sqrt{\sin\psi\cos\psi}\left[\frac{r^2}{R}\,dx^\mu dx_\mu + \alpha' R^3\left(\frac{dr^2}{r^2}\right) + dr^2\right.$$

$$\left. + \cos^2 r\, d\varphi_3^2 + \sin^2 r\, d\psi^2\right)\Big]$$

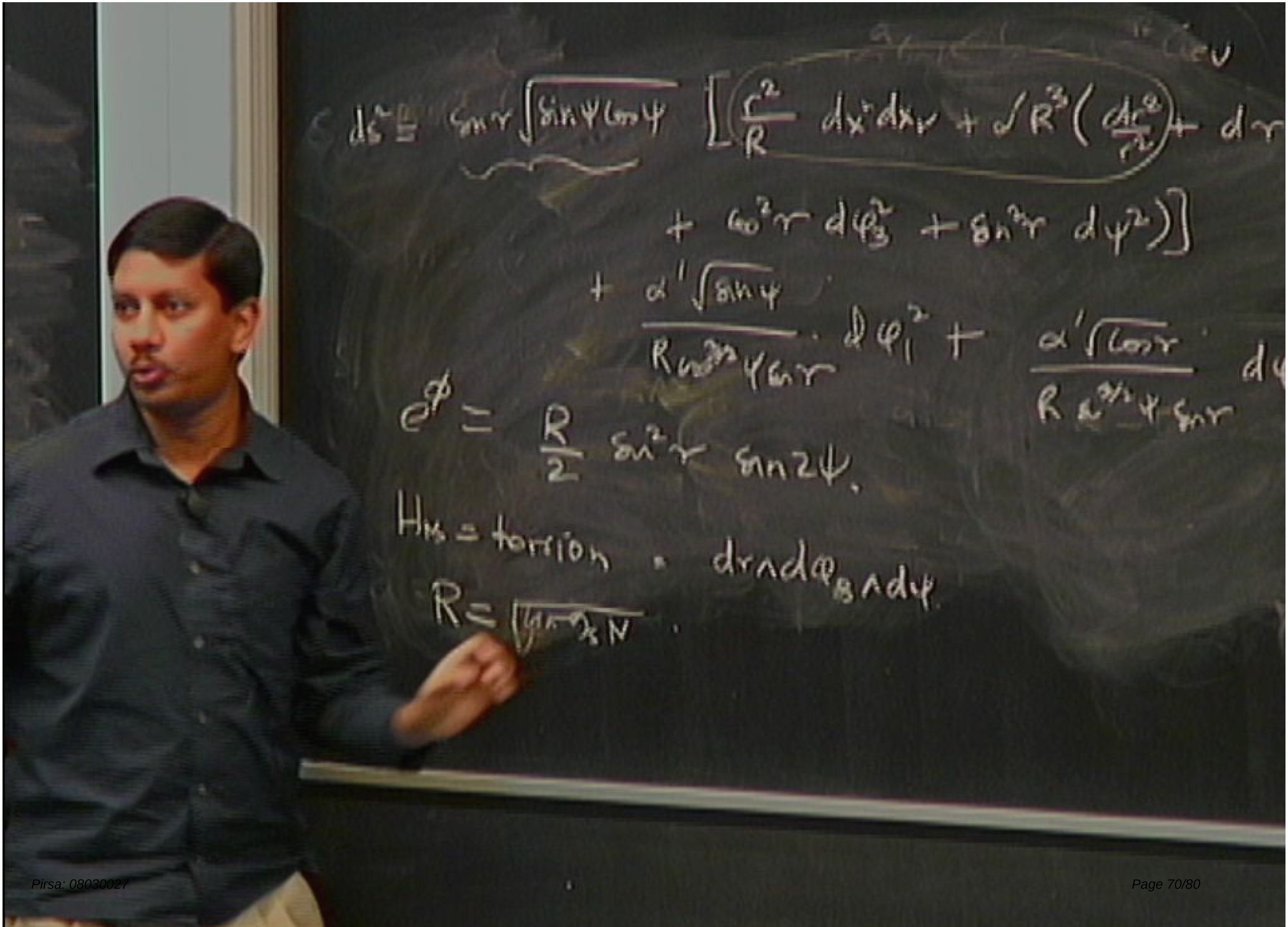
$$+ \frac{\alpha'\sqrt{\sin\psi}}{R\cos^{3/2}\psi\cos r}\, d\varphi_1^2 + \frac{\alpha'\sqrt{\cos r}}{R\sin^{3/2}\psi\sin r}\, d\varphi_3^2.$$

$$e^\phi = \frac{R}{2}\sin^2 r\,\sin 2\psi.$$

H_{NS} = torsion $\cdot$ $dr\wedge d\varphi_3\wedge d\psi$

$$R = \sqrt{g_{\rm str} N}.$$

near


$e^{\phi} = \frac{R}{2} \sin^2 r \, \sin 2\psi$.
H_{NS} = torsion

$$ds^2 = \underbrace{\sin r \sqrt{\sin\psi \cos\psi}} \left[\left(\frac{r^2}{R}\, dx^\mu dx_\mu + \alpha' R^3 \left(\frac{dr^2}{r^2} \right) + dr^2 + \cos^2 r \, d\varphi_3^2 + \sin^2 r \, d\psi^2 \right) \right]$$

$$+ \frac{\alpha' \sqrt{\sin\psi}}{R \cos^{3/2}\psi \sin r}\, d\varphi_1^2 + \frac{\alpha' \sqrt{\cos r}}{R \sin^{3/2}\psi \sin r}\, d\varphi_3^2 .$$

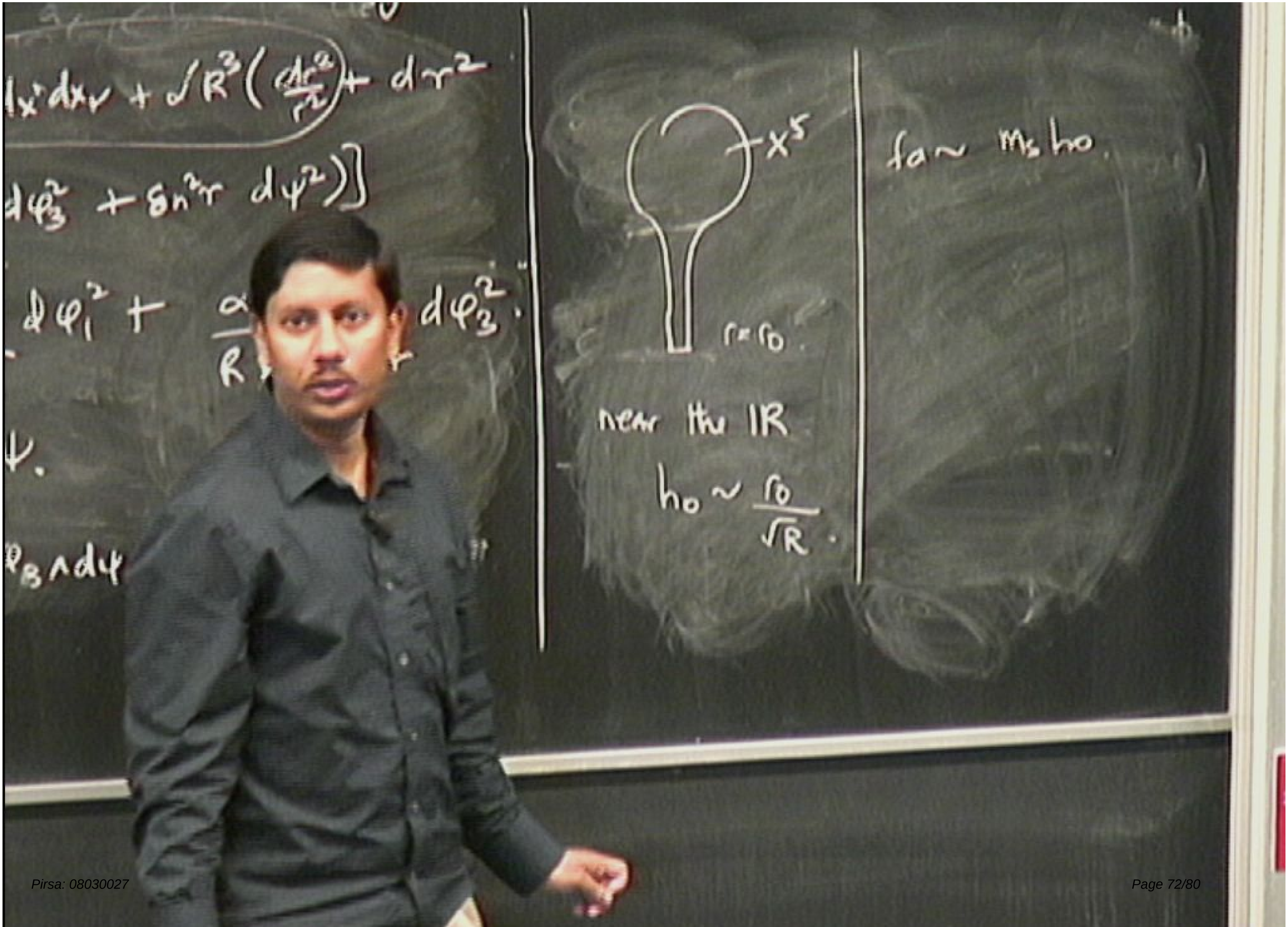
$$e^\phi = \frac{R}{2} \sin^2 r \, \sin 2\psi .$$

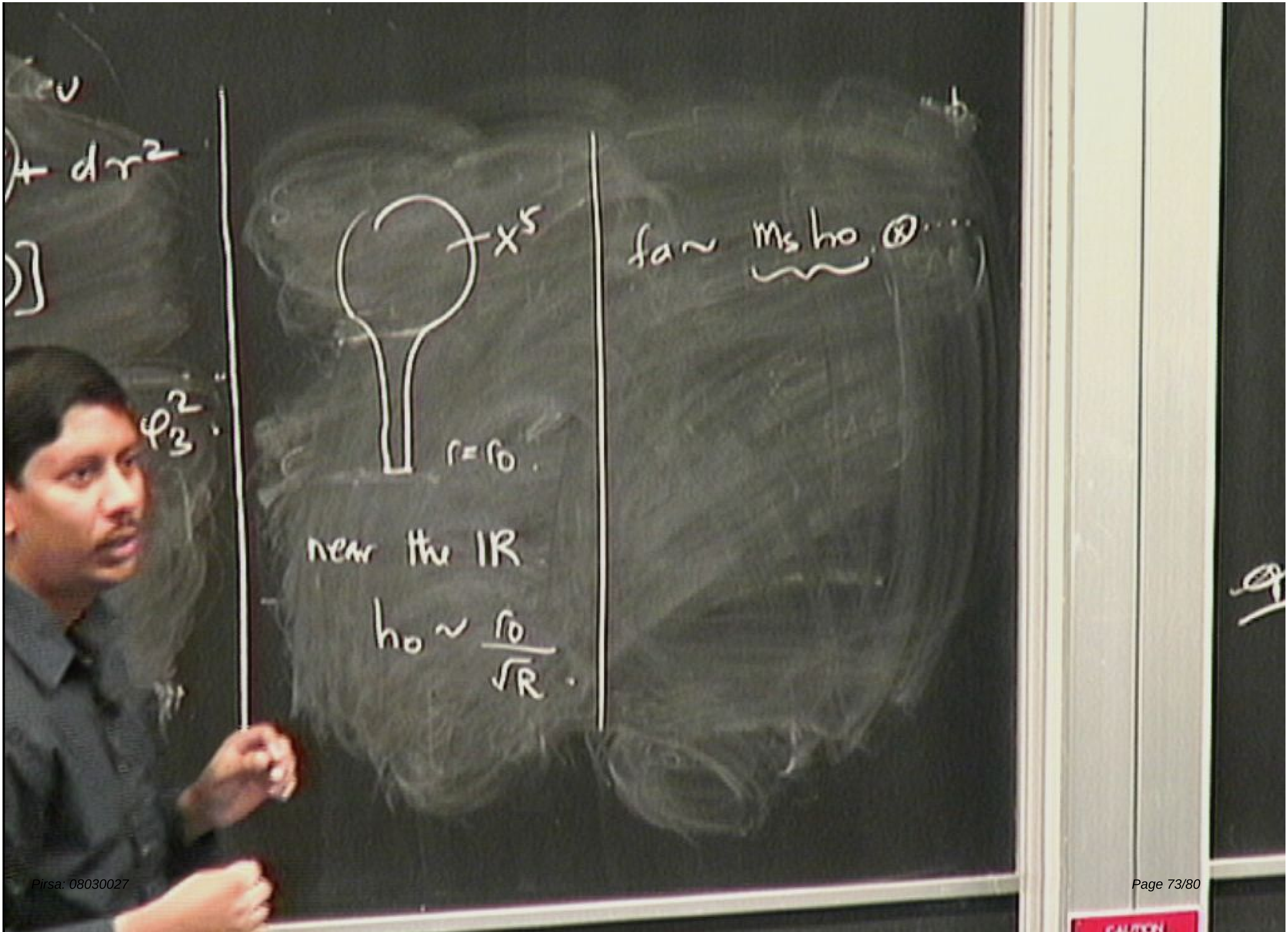
H_{NS} = torsion $\cdot$ $dr \wedge d\varphi_B \wedge d\psi$

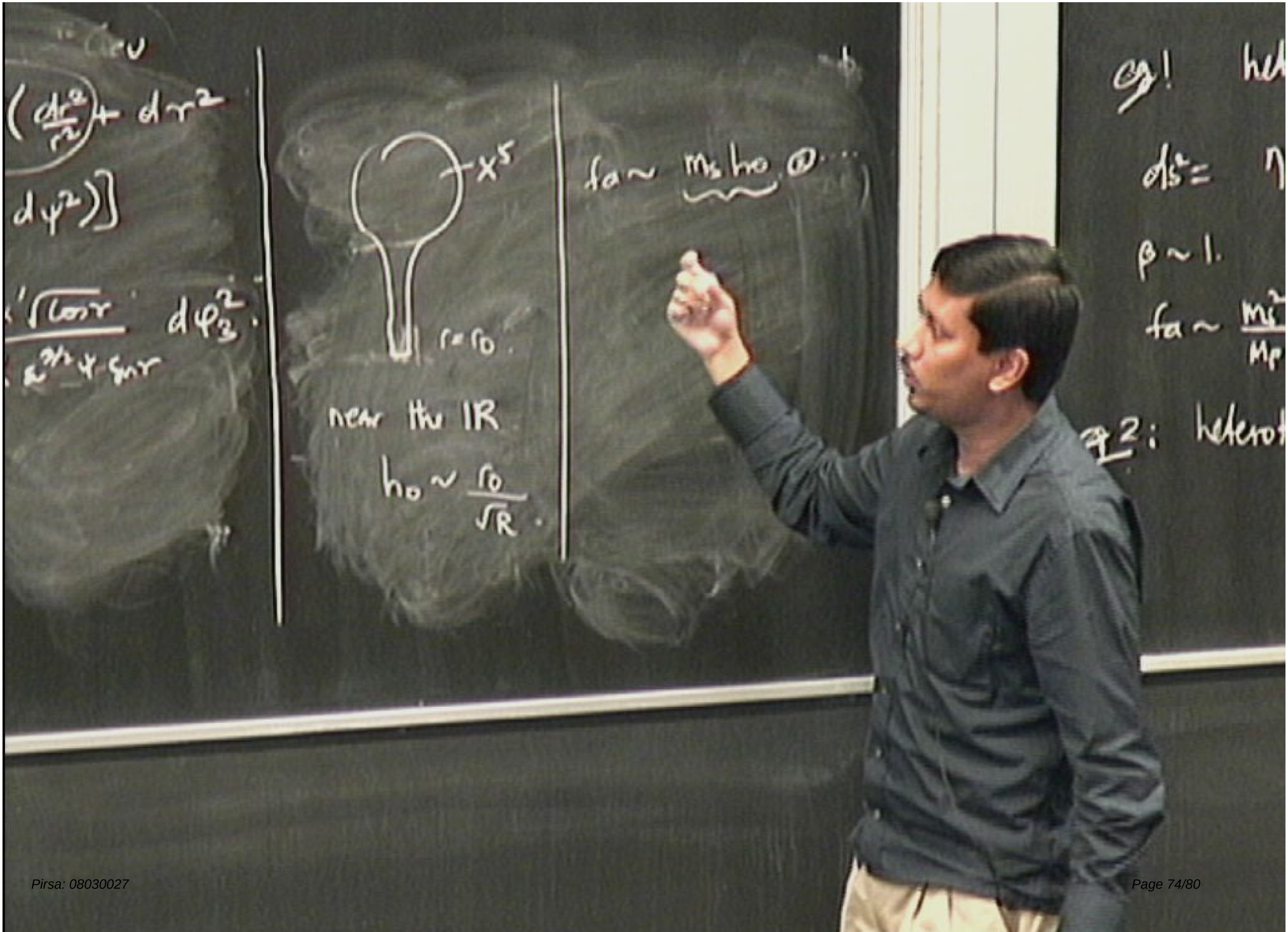
$R = \sqrt{4\pi g_s N}$.

near the IR

$$h_0 \sim \frac{r_0}{\sqrt{R}} .$$


x^5
$r = r_0$
near the IR
$h_0 \sim \frac{r_0}{\sqrt{R}}$
$f_a \sim m_s h_0$


+ dr^2
x^5
r = r0
near the IR
h0 ~ r0 / √R
fa ~ ms h0


x^5
$r = r_0$
near the IR
$h_0 \sim \frac{r_0}{\sqrt{R}}$
$f_a \sim m_s h_0$
$\beta \sim 1.$

v

dr^2

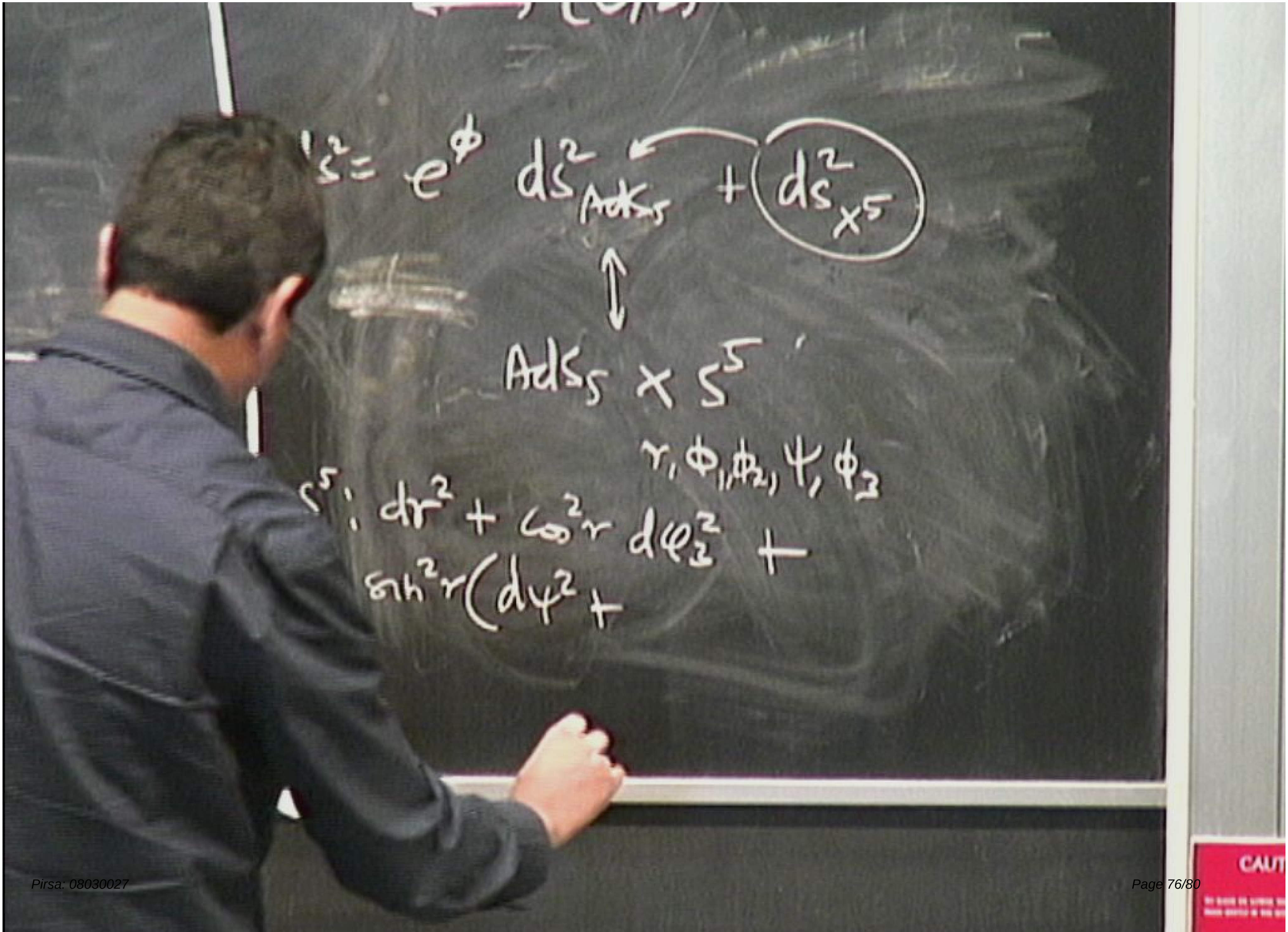
$d\varphi_3^2$

nr

near the IR

$$h_0 \sim \frac{r_0}{\sqrt{R}}$$

$f_a \sim m_s h_0 \otimes \ldots$


$ds^2 = e^{\phi}\, ds^2_{AdS_5} + ds^2_{X^5}$
$AdS_5 \times S^5$
$r, \phi_1, \phi_2, \psi, \phi_3$
$S^5: dr^2 + \cos^2 r\, d\varphi_3^2 +$
$\sin^2 r (d\psi^2 +$

r warp

$$ds^2 = e^{\phi}\, ds^2_{AdS_5} + ds^2_{X^5}$$

$$\Updownarrow$$

$$AdS_5 \times S^5$$

$$r, \phi_1, \phi_2, \psi, \phi_3$$

$$S^5: \; dr^2 + \cos^2 r\, d\varphi_3^2 + \sin^2 r \left(d\psi^2 + \cos^2\psi\, d\varphi_1^2 + \sin^2\psi\, d\varphi_3^2 \right)$$

$$ds^2 = e^{\phi}\, ds^2_{AdS_5} + ds^2_{X^5}$$

$$\Updownarrow$$

$$AdS_5 \times S^5$$

$$r, \phi_1, \phi_2, \psi, \phi_3$$

$$S^5 : dr^2 + \cos^2 r \, d\varphi_3^2 + \sin^2 r \left(d\psi^2 + \cos^2\psi \, d\varphi_1^2 + \sin^2\psi \, d\varphi_3^2 \right)$$

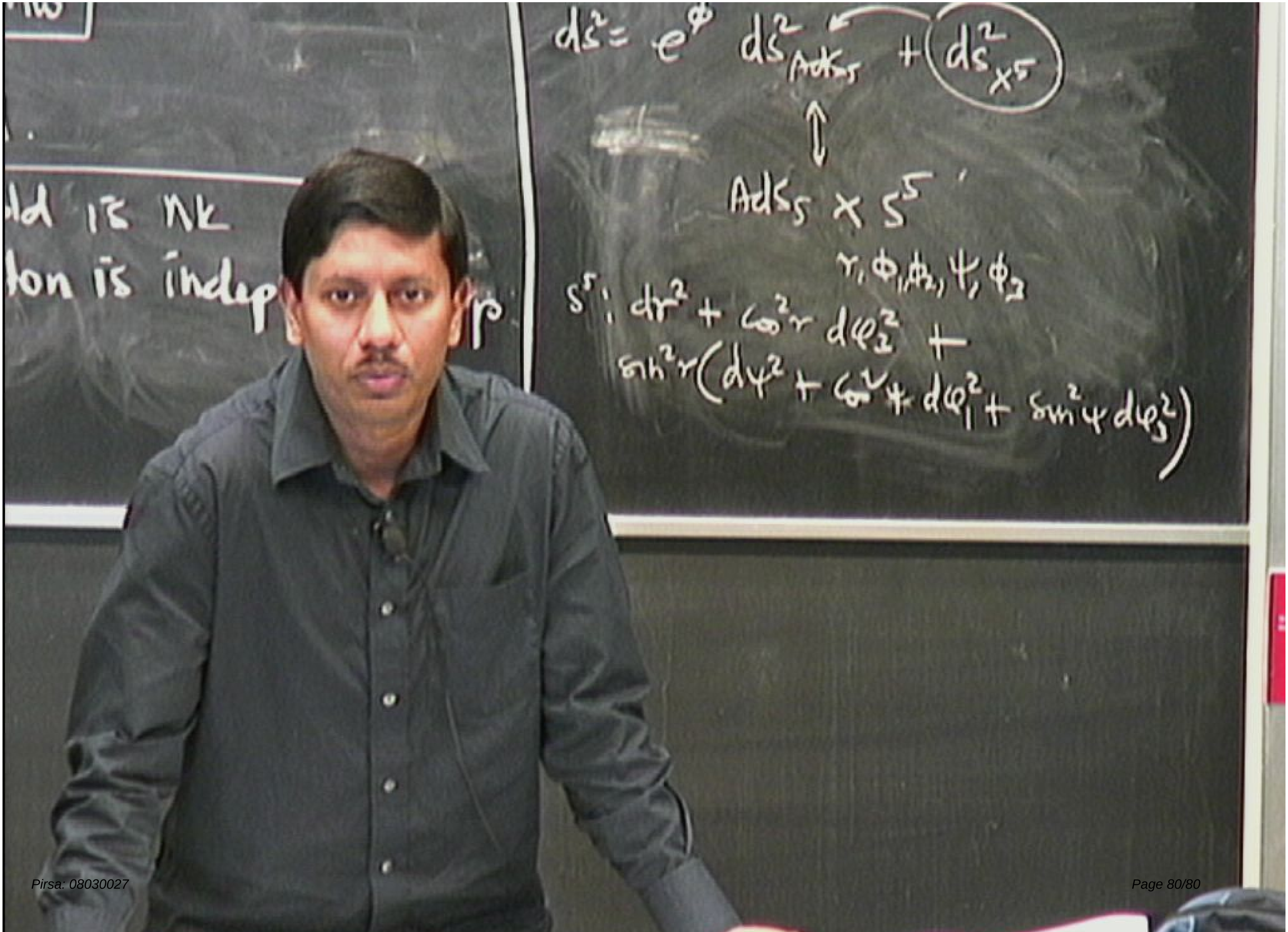
$$+ \cos^2 r \, d\varphi_3^2 + \sin^2 r \, d\psi^2)]$$

$$+ \frac{\alpha' \sqrt{\sin\psi}}{R \cos^{3/2}\psi \sin r} d\varphi_1^2 + \frac{\alpha' \sqrt{\cos r}}{R \sin^{3/2}\psi \sin r} d\varphi_3^2 .$$

$$e^{\phi} = \frac{R}{2} \sin^2 r \, \sin 2\psi .$$

$$H_{NS} = \text{torsion} \propto dr \wedge d\varphi_3 \wedge d\psi + O(\alpha')$$

$$R = \sqrt{4\pi g_s N} .$$


ld is NK
ton is indep
$ds^2 = e^{\phi} ds^2_{AdS_5} + ds^2_{X^5}$
$AdS_5 \times S^5$
$r, \phi_1, \phi_2, \psi, \phi_3$
$S^5: dr^2 + \cos^2 r \, d\varphi_3^2 +$
$\sin^2 r (d\psi^2 + \cos^2\psi \, d\varphi_1^2 + \sin^2\psi \, d\varphi_3^2)$