Title: AdS/CFT Lecture (230417)

Speakers: David Kubiznak

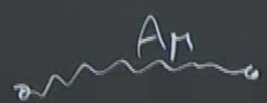
Collection: AdS/CFT (2022/2023)

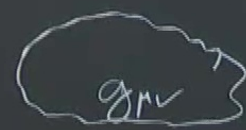
Date: April 17, 2023 - 9:00 AM

URL: https://pirsa.org/23040036

MOTIVATING AdS/CFT CORRESPONDENCE

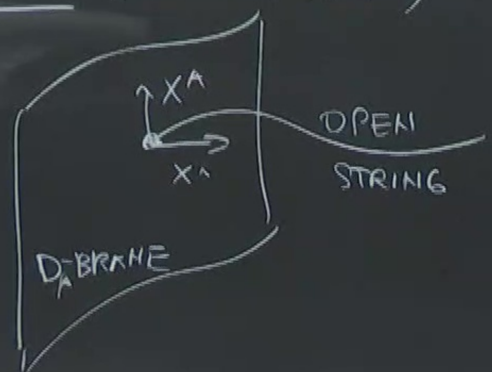
ST: OPEN CLOSED





$\boxed{l_s,\ g_s = e^{\Phi}}$

D-BRANES (DIRICHLET)



X^A ... NEUMANN DIRECTIONS $(A = 0, \dots, p)$

X^a ... DIRICHLET DIRECTIONS $(a = 1, \dots, 9-p$

A_μ <

A_A ... VECTOR FIELD ON D-BRA

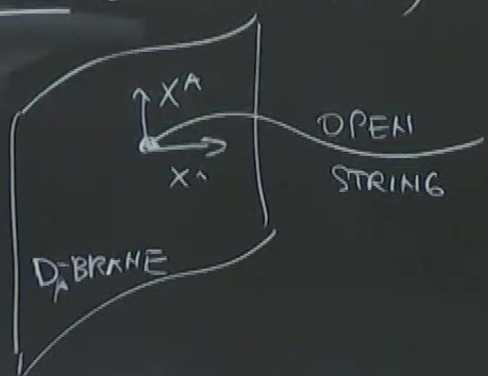
ϕ_a ... SCALARS

MOTIVATING AdS/CFT CORRESPONDENCE

ST: OPEN A_μ CLOSED $g_{\mu\nu}$

$$\boxed{l_s, \; g_s = e^{\Phi}}$$

D-BRANES (DIRICHLET)



X^A ... NEUMANN DIRECTIONS $(A = 0, \dots, p)$

X^a ... DIRICHLET DIRECTIONS $(a = 1, \dots, 9-p)$

A_μ <
- A_A ... VECTOR FIELD ON D-BRANE
- ϕ_a ... SCALARS

- MOTION OF D-BRANE GOVERNED BY DBI-ACTION.

$$\boxed{\begin{gathered} S_{DBI} = -T_{Dp} \int d\xi^{p+1} e^{-\phi} \sqrt{-\det\left(\gamma_{AB}(g) + \gamma_{AB}(B) + 2\pi\alpha' F_{AB}\right)} \\ T_{Dp} = \frac{1}{(2\pi)^p \, \ell_s^{p+1}} \end{gathered}}$$

$\ldots, g_p)$

-BRANE

- NOW CONSIDER MINKOWSKI, $B = 0$, $e^{\phi} = g_s = \text{CONST}$

$$\mu_p = \frac{T_p}{g_s} \ \ldots \text{"EFFECTIVE TENSION"}$$

$$\det(1+M) = 1 - \frac{1}{2}\mathrm{Tr}\, M^2 + \dots$$

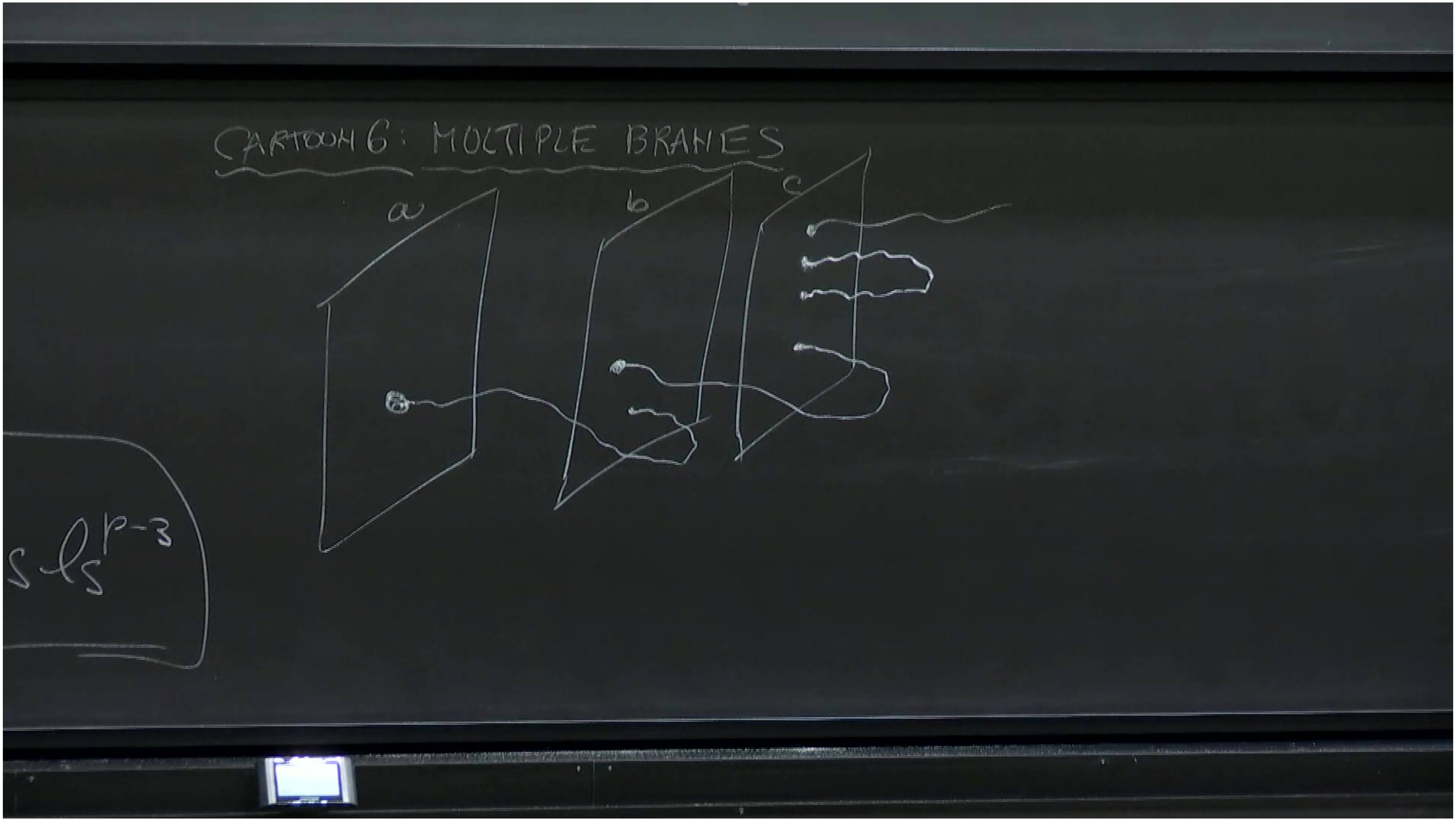
$$S_{DBI} \simeq -(2\pi\alpha')^2 \frac{T_p}{g_s} \int d^{p+1}\xi \, F_{AB}F^{AB} + \dots$$

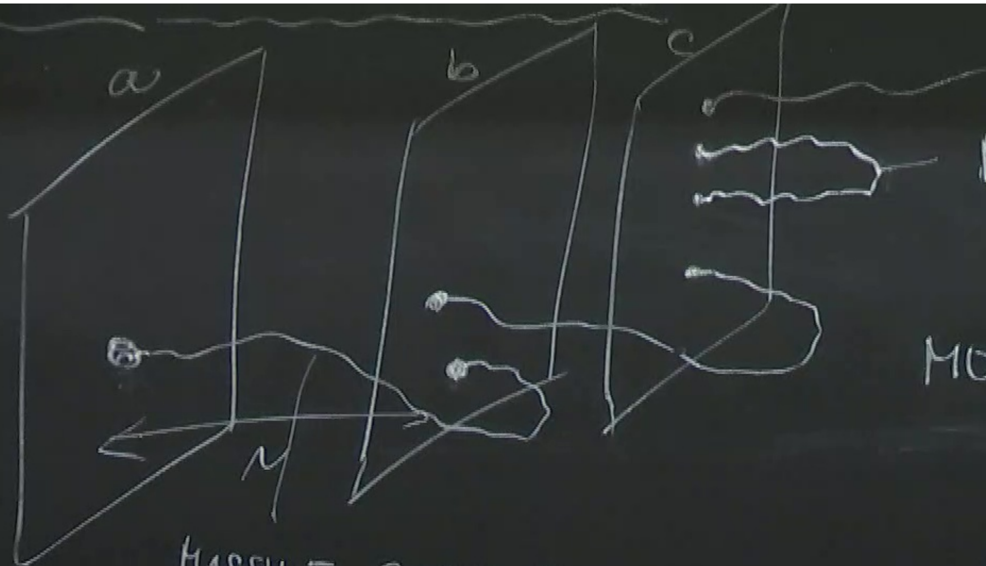
$$\sim \frac{1}{g_{YM}^2}$$

$$\alpha'^2 \sim \frac{1}{l_s^4}$$

$$T_p \sim \frac{1}{l_s^{p+1}}$$

$$\boxed{g_{YM}^2 = (2\pi)^{p-2} g_s l_s^{p-3}}$$


CARTOON 6: MULTIPLE BRANES
a
b
c



MASSLESS U(1) A_A FIELD

MORE D-BRANES.

WE HAVE EXTRA INDEX.

$(A_A)^a{}_b$ ... NON-ABELIAN GAUGE TH.

MASSIVE GAUGE FIELD

WITH $m \propto \frac{r}{2\pi\alpha'}$

SPECIFICALLY: CONSIDER N_c NUMBER OF COALESCENT D3 BRANES IN TYPE IIB S.T. .... GIVES RISE TO $\mathcal{N}=4$ $U(N_c)$ SYM IN (3+1) DIMENSIONS

$$\mathcal{L} = -\frac{1}{g_{YM}^2} \mathrm{Tr}\left(\frac{1}{4} F^{AB} F_{AB} + \frac{1}{2} D_A \phi^i D^A \phi^i + [\phi^i, \phi^j] \right)$$

+FERMIONS , $g_{YM}^2 = 2\pi g_s$

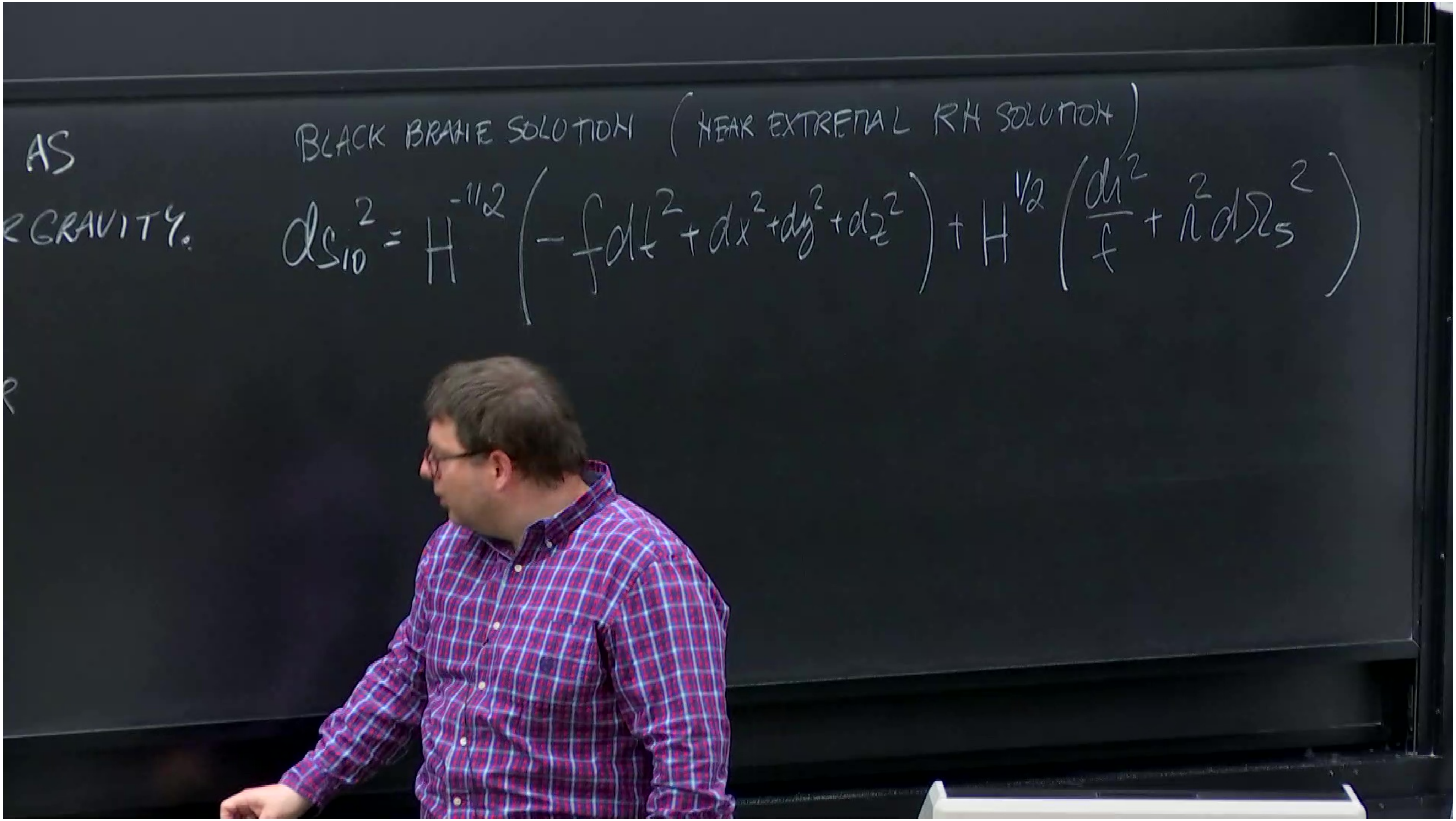
ALTERNATIVELY: D3 BRANES CAN BE VIEWED AS AS

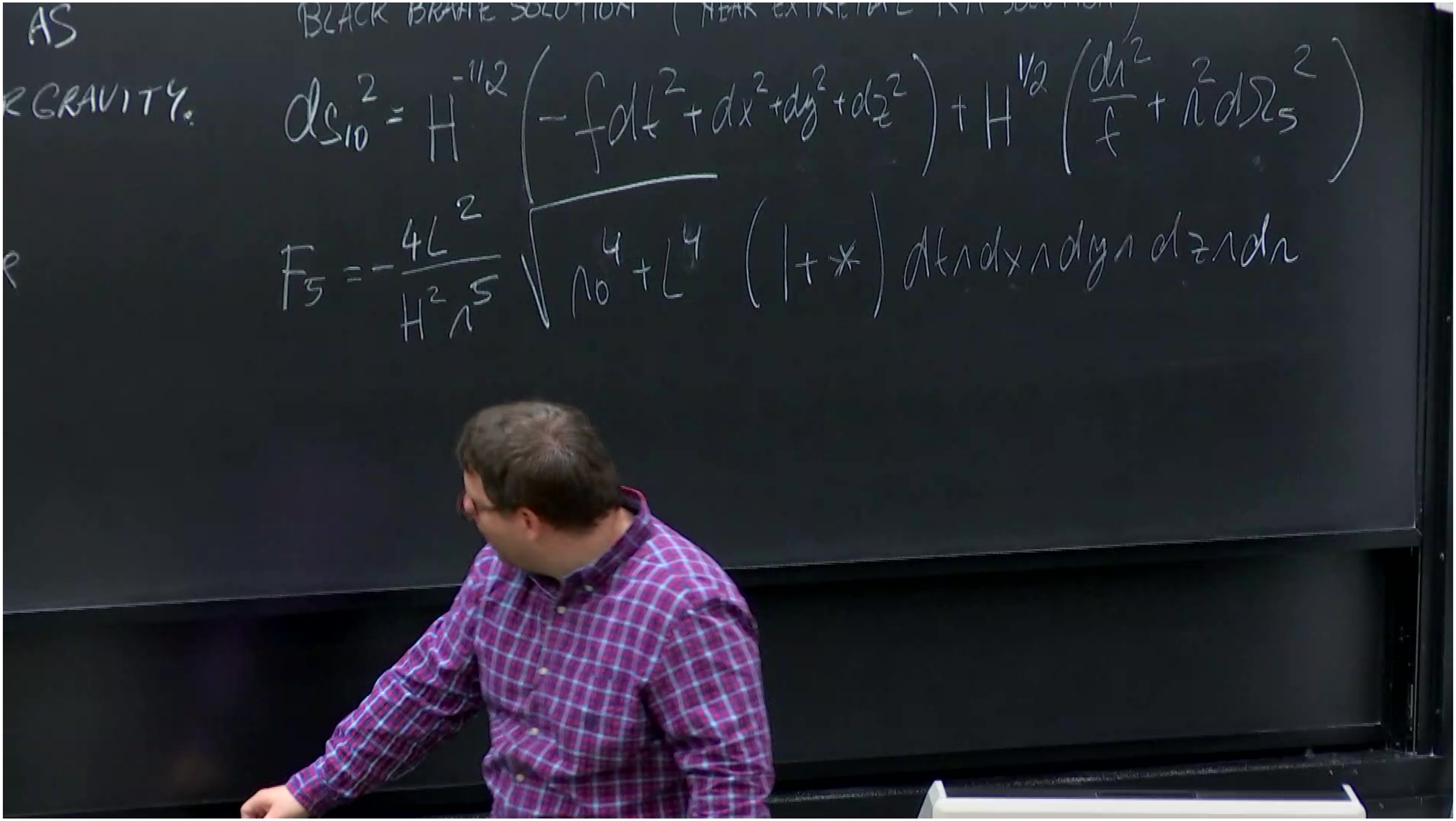
EXTREMAL BH SOLUTIONS IN IIB SUPERGRAVITY.

ASSUME ONLY $g_{\mu\nu}$, F_5, $\phi = \text{CONST.}$

$$\Rightarrow \quad R_{\mu\nu} = \frac{1}{96} F_{\mu\beta\gamma\delta\varepsilon} F_\nu{}^{\beta\gamma\delta\varepsilon}$$

$$F_5 = *F_5$$


AS
RGRAVITY.
BLACK BRANE SOLUTION (NEAR EXTREMAL RN SOLUTION)
$ds_{10}^2 = H^{-1/2}\left(-f dt^2 + dx^2 + dy^2 + dz^2\right) + H^{1/2}\left(\frac{dr^2}{f} + r^2 d\Omega_5^2\right)$
R


AS
BLACK BRANE SOLUTION (NEAR EXTREMAL
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$ds_{10}^2 = H^{-1/2}\left(-f dt^2 + dx^2 + dy^2 + dz^2\right) + H^{1/2}\left(\frac{dr^2}{f} + r^2 d\Omega_5^2\right)$
$F_5 = -\frac{4L^2}{H^2 r^5}\sqrt{r_0^4 + L^4}\,(1 + *)\, dt \wedge dx \wedge dy \wedge dz \wedge dr$

$$F_5 = -\frac{4L^2}{H^2 r^5}\sqrt{r_0^4 + L^4}\,(1+*)\,dt\wedge dx\wedge dy\wedge dz\wedge dr$$

$$H = 1 + \frac{L^4}{r^4}\,, \quad f_0 = 1 - \frac{r_0^4}{r^4}$$

2 HORIZONS $r = 0$, $r = r_0$ ← OUTER.

* ϕ ... GRAVITATIO

FOCUS ON EXTREMAL CASE

.... D3 BRANE ($r_0 = 0$)

$$f_0 = 1$$

$r = \frac{r_{10}}{r_{\text{OUTER}}}$.

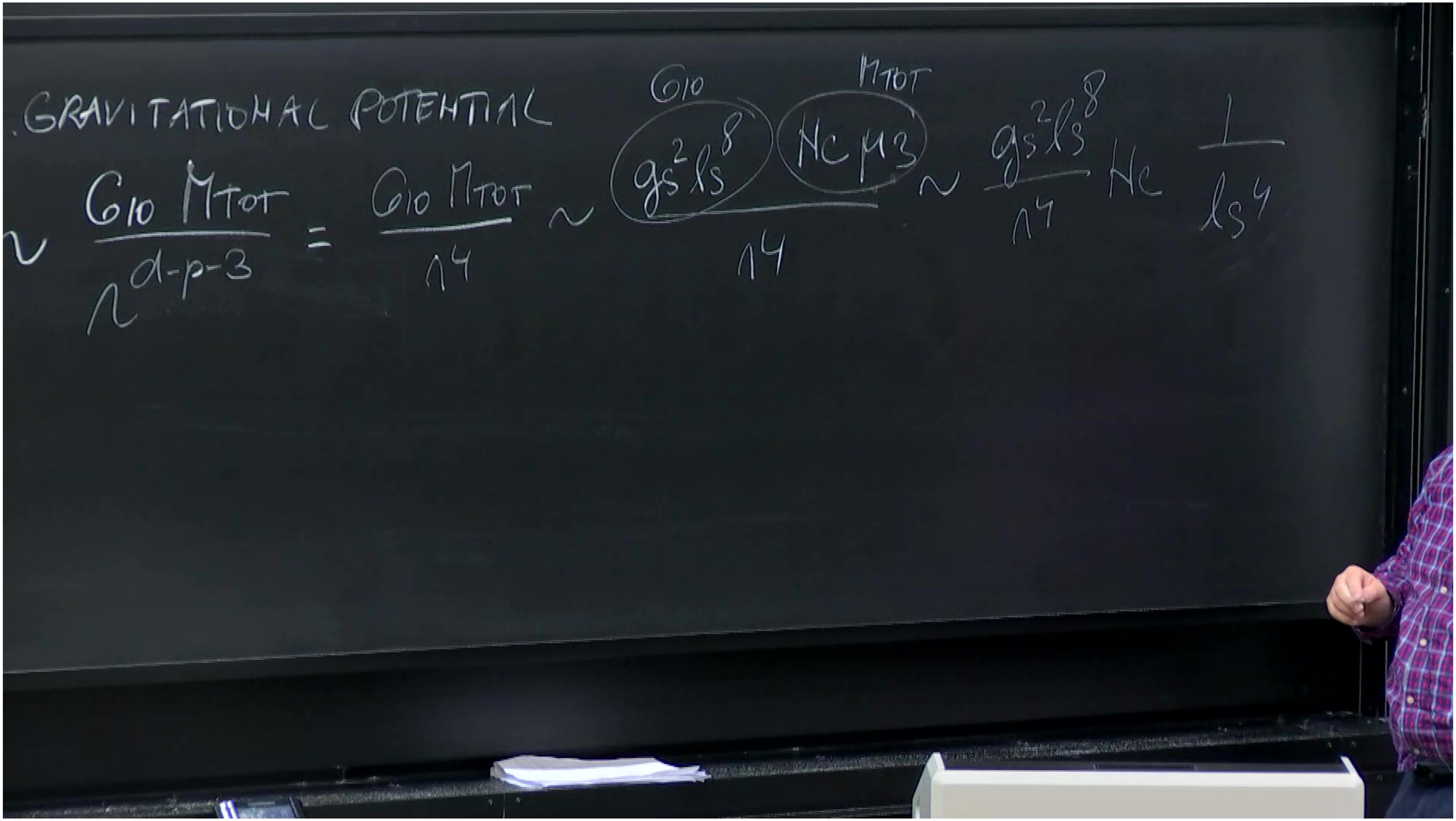
• ϕ ... GRAVITATIONAL POTENTIAL

$$\phi \sim \frac{G_{10} M_{TOT}}{r^{d-p-3}} = \frac{G_{10} M_{TOT}}{r^4}$$

re.

- ϕ ... GRAVITATIONAL POTENTIAL

$$\phi \sim \frac{G_{10} M_{TOT}}{r^{d-p-3}} = \frac{G_{10} M_{TOT}}{r^4} \sim \frac{\overbrace{g_s^2 l_s^8}^{G_{10}} \, \overbrace{N_c \mu_3}^{M_{TOT}}}{r^4}$$


GRAVITATIONAL POTENTIAL
G_{10}
M_{TOT}
$\sim \frac{G_{10} M_{TOT}}{r^{d-p-3}} = \frac{G_{10} M_{TOT}}{r^4} \sim \frac{(g_s^2 l_s^8)(N_c \mu_3)}{r^4} \sim \frac{g_s^2 l_s^8}{r^4} N_c \frac{1}{l_s^4}$

$$\sim \frac{G_{10} M_{TOT}}{r^{d-p-3}} = \frac{G_{10} M_{TOT}}{r^4} \sim \frac{g_s^2 l_s^8 \, N_c \mu_3}{r^4} \sim \frac{g_s^2 l_s^8}{r^4} N_c \frac{1}{l_s^4 g_s}$$

$$\sim g_s N_c \frac{l_s^4}{r^4}$$

λ ... 'T HOOFT COUPLING

2 HORIZONS $r = 0$, $r = r_0 = r_{\text{OUTER}}$.

FOCUS ON EXTREMAL CASE

.... D3 BRANE $(r_0 = 0)$

$$f_0 = 1$$

① $\lambda \ll 1$ .... MINK.

② $\lambda \gg 1$ ...... STRONG GRAVITY REGIME.

ϕ ... GRAVITATIO

$$\phi \sim \frac{G_{10} M_{\text{TO}}}{r^{d-p-3}}$$

2 HORIZONS $r=0,\ r=r_0$ OUTER.

US ON EXTREMAL CASE

... D3 BRANE $(r_0 = 0)$

$$f_0 = 1$$

• ϕ ... GRAVITATIONAL POTENT

$$\phi \sim \frac{G_{10} M_{TOT}}{r^{d-p-3}} = \frac{G_{10} M}{r^4}$$

① $\lambda \ll 1$ .... MINK. ... "OPEN STRING"

② $\lambda \gg 1$ ...... STRONG GRAVITY REGIME.

... "CLOSED STRING" .. BH PICTURE.

$$H = 1 + \frac{L^4}{r^4} = 1 + \phi = 1 + \lambda \frac{l_s^4}{r^4}$$

$$\boxed{\frac{L^4}{l_s^4} \sim \lambda} \qquad \boxed{\lambda = g_{YM}^2 N_c \propto g_s N_c}$$

$$H = 1 + \frac{L^4}{r^4} = 1 + \phi = 1 + \lambda \frac{\ell_s^4}{r^4}$$

$$\boxed{\frac{L^4}{\ell_s^4} \sim \lambda} \qquad \boxed{\lambda = g_{YM}^2 N_c \propto g_s N_c}$$

$$\boxed{\ell_s, g_s}$$

• CONSIDER NEAR HORIZON LIMIT OF D3 BRANE.

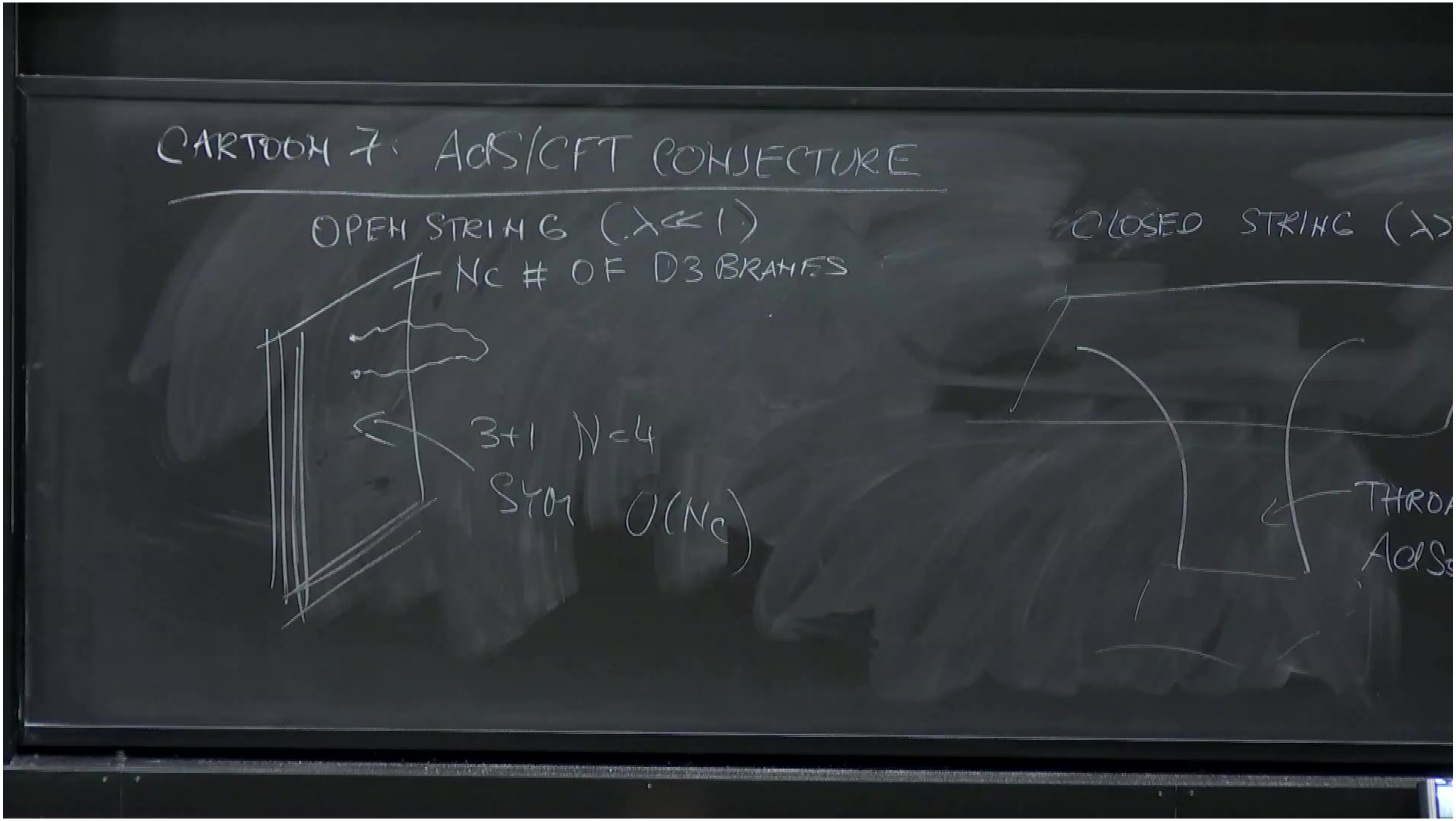
$r \to 0 \Rightarrow H \sim \frac{L^4}{r^4}$

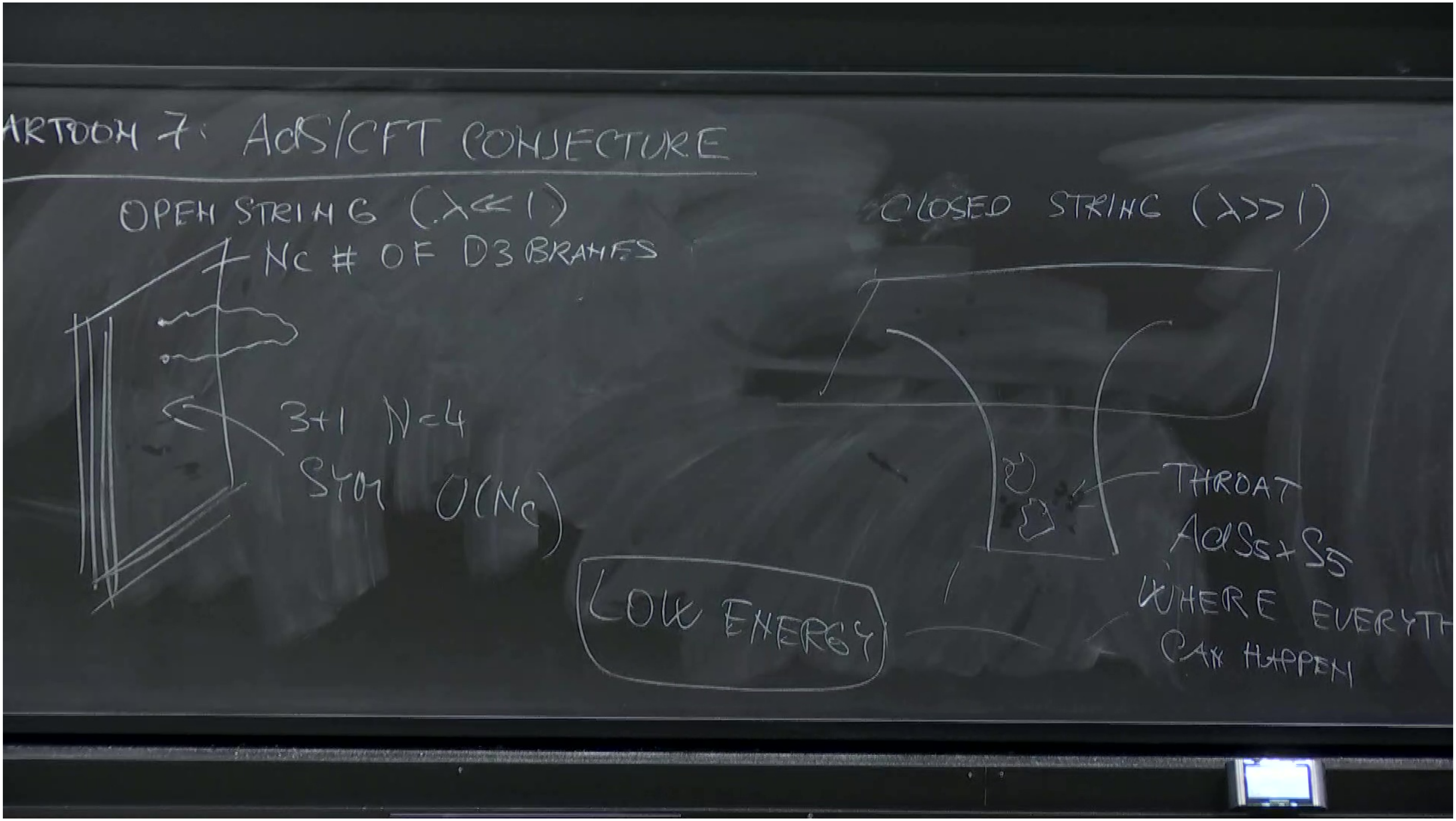
$$ds_{10}^2 \simeq \frac{r^2}{L^2} \underbrace{\eta_{\mu\nu} dx^\mu dx^\nu}_{-dt^2+dx^2+dy^2+dz^2} + \frac{L^2}{r^2} dr^2 + L^2 d\Omega_5^2$$

$z = L^2/r$

$$ds_{10}^2 = \underbrace{\frac{L^2}{z^2}\left(\eta_{\mu\nu}dx^\mu dx^\nu + dz^2\right)}_{\text{AdS}_5 \text{ OF RADIUS } \underline{L}} + \underbrace{L^2 d\Omega_5^2}_{S^5 \text{ OF RADIUS } \underline{L}}$$

$AdS_5 \times S_5$ GEOMETRY.


CARTOON 7: AdS/CFT CONJECTURE
OPEN STRING (λ≪1)
Nc # OF D3 BRANES
3+1 N=4
SYM O(Nc)
CLOSED STRING (λ
THRO
AdS


ARTOON 7: AdS/CFT CONJECTURE
OPEN STRING (λ<<1)
Nc # OF D3 BRANES
3+1 N=4
SYM U(Nc)
CLOSED STRING (λ>>1)
THROAT
AdS5 + S5
WHERE EVERYTH
CAN HAPPEN
LOW ENERGY

CONJECTURE (MALDACENA 97): TYPE IIB SUPERSTRING ON $AdS_5 \times S_5$ IS DUAL TO $\mathcal{N}=4$ $SU(N_c)$ SYM IN $d=(3+1)$ DIMS

>1)

AT

$S + S_5$

E EVERYTHING

APPEN