Title: Lecture - AdS/CFT, PHYS 777

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Collection/Series: AdS/CFT (Elective), PHYS 777, March 31 - May 2, 2025

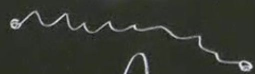
Subject: Quantum Fields and Strings, Quantum Gravity

Date: April 09, 2025 - 9:00 AM

URL: https://pirsa.org/25040028

MOTIVATING AdS/CFT CORRESPONDENCE

• ST: OPEN



A_μ

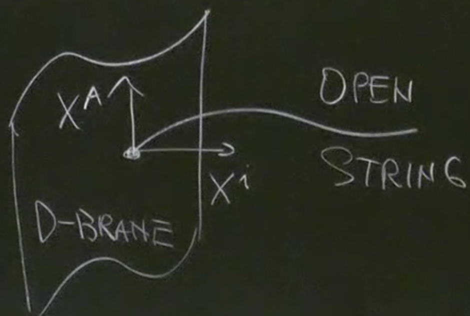
CLOSED

$g_{\mu\nu}$

2 PARAMETERS: $\boxed{l_s,\ g_s = e^{\phi}}$

$$\left(G_{10} \simeq g_s^2 l_s^8 \right)$$

• D-BRANES (DIRICHLET)



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

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

A_μ < A_A ... VECTOR FIELD ON D-BRANE

ϕ_i SCALARS

• MOTION OF A SINGLE D-BRANE GOVERNED BY DBI-ACTION

$$\boxed{S_{DBI} = -\underbrace{T_p}_{= \frac{1}{(2\pi)^p \, l_s^{p+1}}} \int d^{p+1}\xi \, e^{-\phi} \sqrt{-\det\left(\gamma_{AB}(g) + \gamma_{AB}(B) + 2\pi\alpha' F_{AB}\right)}}$$

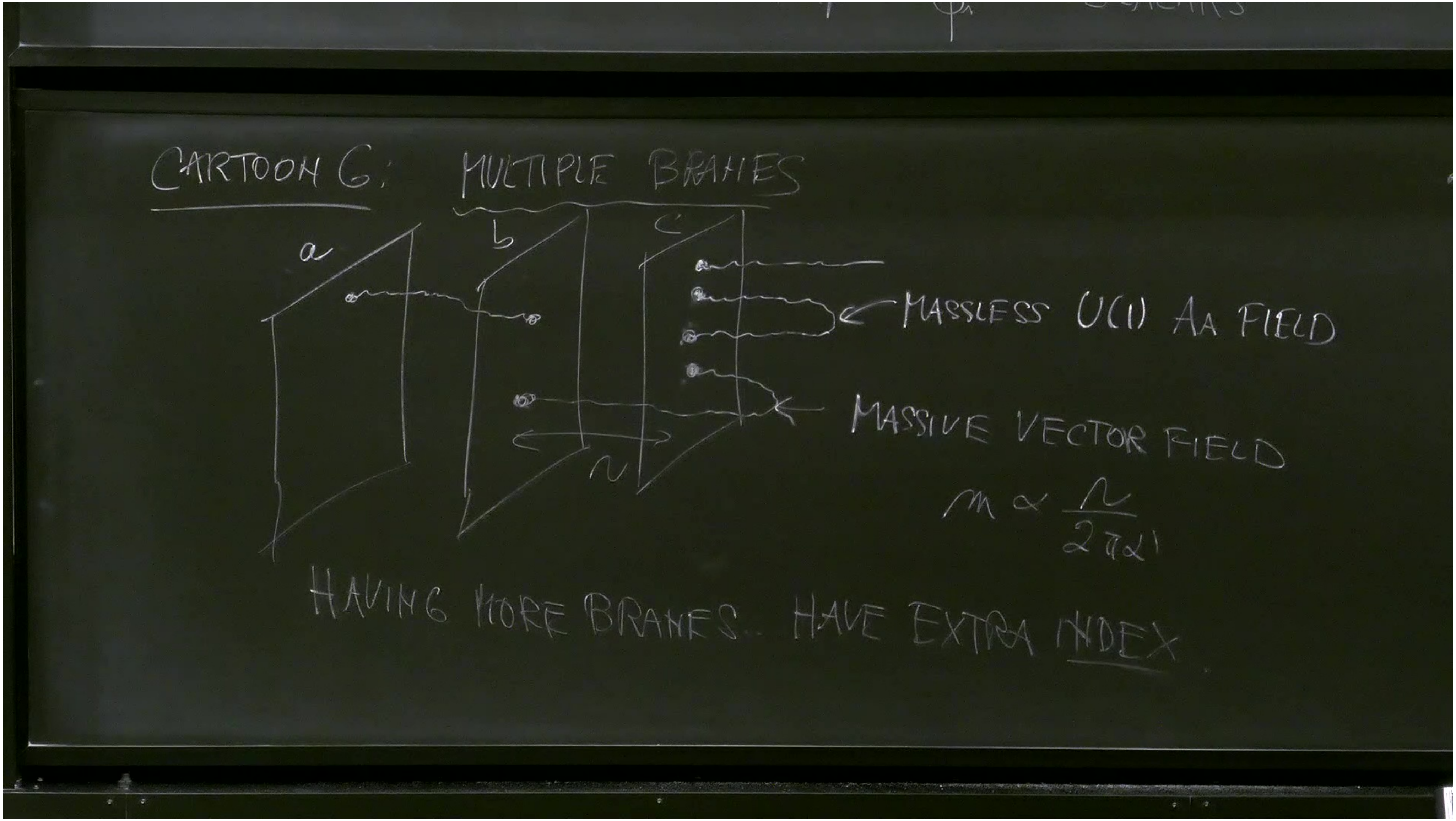
SPEC: MINKOWSKI, $B=0$, $e^{\phi} = g_s = \text{CONST}$, $M_p = \frac{T_p}{g_s}$ ... EFFECTIVE TENSION, F_{AB} WEAK

$$\Rightarrow S_{DBI} \simeq \underbrace{(2\pi\alpha')^2 M_p}_{= \frac{1}{g_{YM}^2}} \int d^{p+1}\xi \, F_{AB} F^{AB} + O(F^4)$$

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

$p=3$ SPECIAL (CONFORMAL)

RANE


CARTOON 6: MULTIPLE BRANES
a
b
c
MASSLESS U(1) A_A FIELD
MASSIVE VECTOR FIELD
$m \propto \frac{r}{2\pi\alpha'}$
HAVING MORE BRANES.. HAVE EXTRA INDEX

g_{YM}^2 $\quad g_{YM}^2 = (2\pi)^{\dots} g_s l_s^{\dots}$ (CONFORMAL)

• COALESCENT LIMIT ($\Lambda \to 0$)

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

• SPEC: CONSIDER N_c NUMBER OF COALESCENT D3-BRANES IN TYPE IIB ST... GIVES RISE TO $\mathcal{N}=4$ $U(N_c)$ SYM IN $d=(3+1)$ DIMENSIONS (ADJOINT REP)

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

$i = 1,\dots,6$

• <u>ALTERNATIVELY</u>: D3-BRANES CAN BE VIEWED AS CLASSICAL BH SOLUTIONS OF IIB SUPERGRAVITY.

ASSUME ONLY $g_{\mu\nu}$, F_5 ARE NONTRIVIAL ($\phi = \text{CONST}$)

... CONSISTENT TRUNCATION

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

$$F_5 = * F_5$$

VITY.

ST)

• NEAR EXTREMAL BLACK BRANE SOLUTION ("RN")

$$ds_{10}^2 = H^{-1/2}\left(-f\,dt^2 + dx^2 + dy^2 + dz^2\right) + H^{1/2}\left(\frac{dr^2}{f} + r^2 d\Omega_5^2\right)$$

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

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

"BLACKENING FACTOR"

(RN: $H = 1 + \frac{M}{r}$, $f = 1$, $r = 0$ .. HORIZON)

GENERALLY 2 HORIZONS. $r = 0$, $r = r_0$

INNER (at $r = 0$)   OUTER HORIZON (at $r = r_0$)

FINITE TEMPERATURE

NOW: CONSIDER EXTREMAL CASE

$r_0 = 0 \Rightarrow f = 1$

ZERO TEMPERATURE.

• ϕ .. NEW

$\phi \sim$

$\approx$

RECALL $g_{YM}^2 N$

4 HO

RIZON

• Φ .. NEWTONIAN GRAV POTENTIAL (M/r IN 4D FOR POINT LIKE SOURCE

OUR CASE

$$\Phi \sim \frac{G_{10} M_{TOT}}{r^{d-p-3}} \simeq \frac{G_{10} M_{TOT}}{r^4} \simeq \frac{\overbrace{g_s^2 l_s^8}^{G_{10}} \; \overbrace{N_c T_3}^{M_{TOT}}}{r^4}$$

$$\frac{T_3}{g_s} \simeq \frac{1}{l_s^4 g_s}$$

$$\simeq \frac{g_s^2 l_s^8}{r^4} N_c \frac{1}{l_s^4 g_s} \simeq \underbrace{g_s N_c}_{g_{YM}^2 N_c} \frac{l_s^4}{r^4} \simeq \lambda \frac{l_s^4}{r^4}$$

RECALL $\boxed{g_{YM}^2 N_c = \lambda}$

↳ 't HOOFT COUPLING

2 LIMITS: ① $\lambda \ll 1$ ... MINKOWSKI (OPEN STRING PICTURE) ...... 2 DIMEN

② $\lambda \gg 1$ ... STRONG GRAVITY REGIME (CLOSED STRING PICTURE) 2
BH PICTURE

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

$$\boxed{\frac{L^4}{l_s^4} \sim \lambda}$$

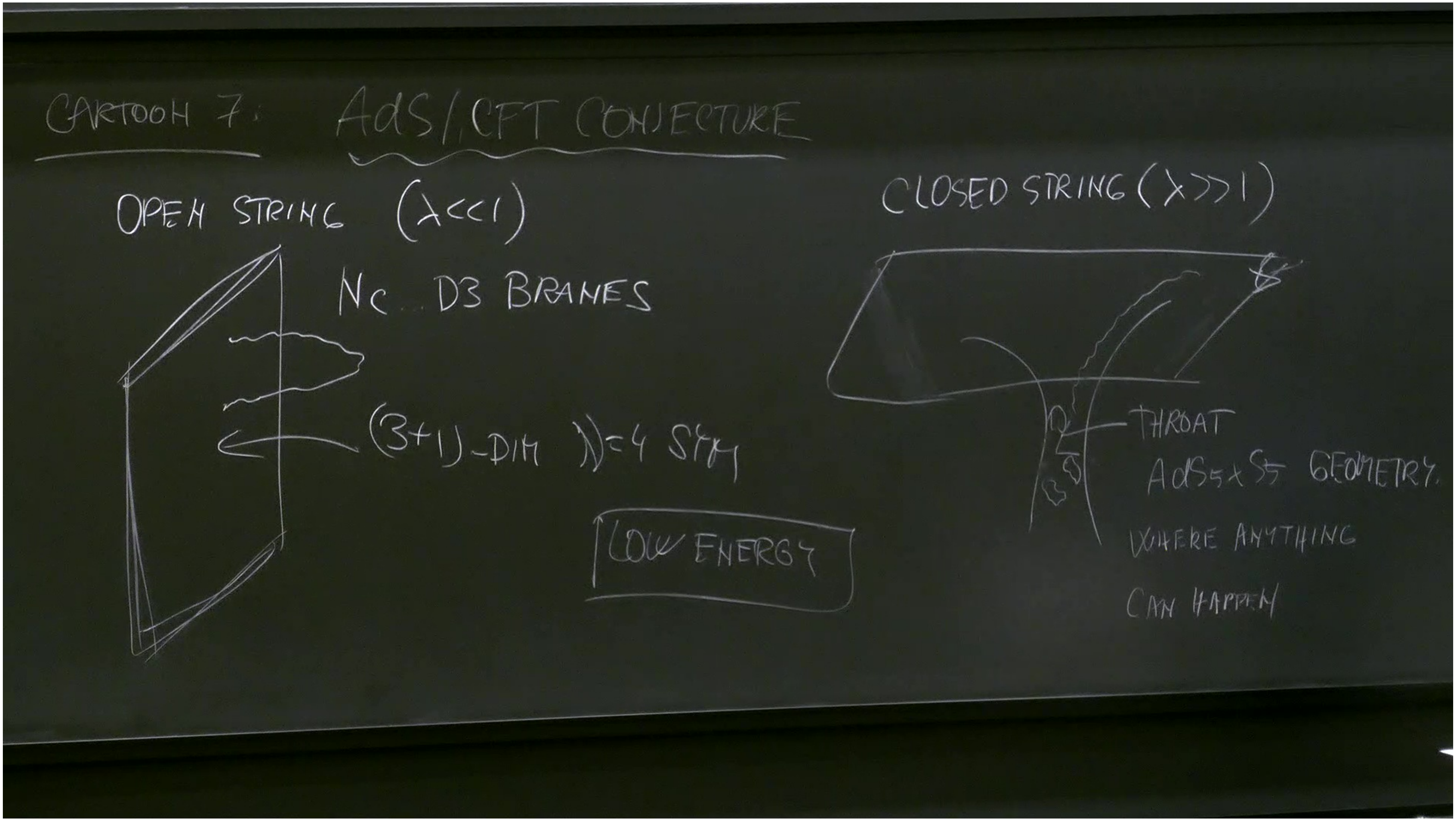
• CONSIDER NEAR HORIZON LIMIT OF BRANE $(r \to 0)$

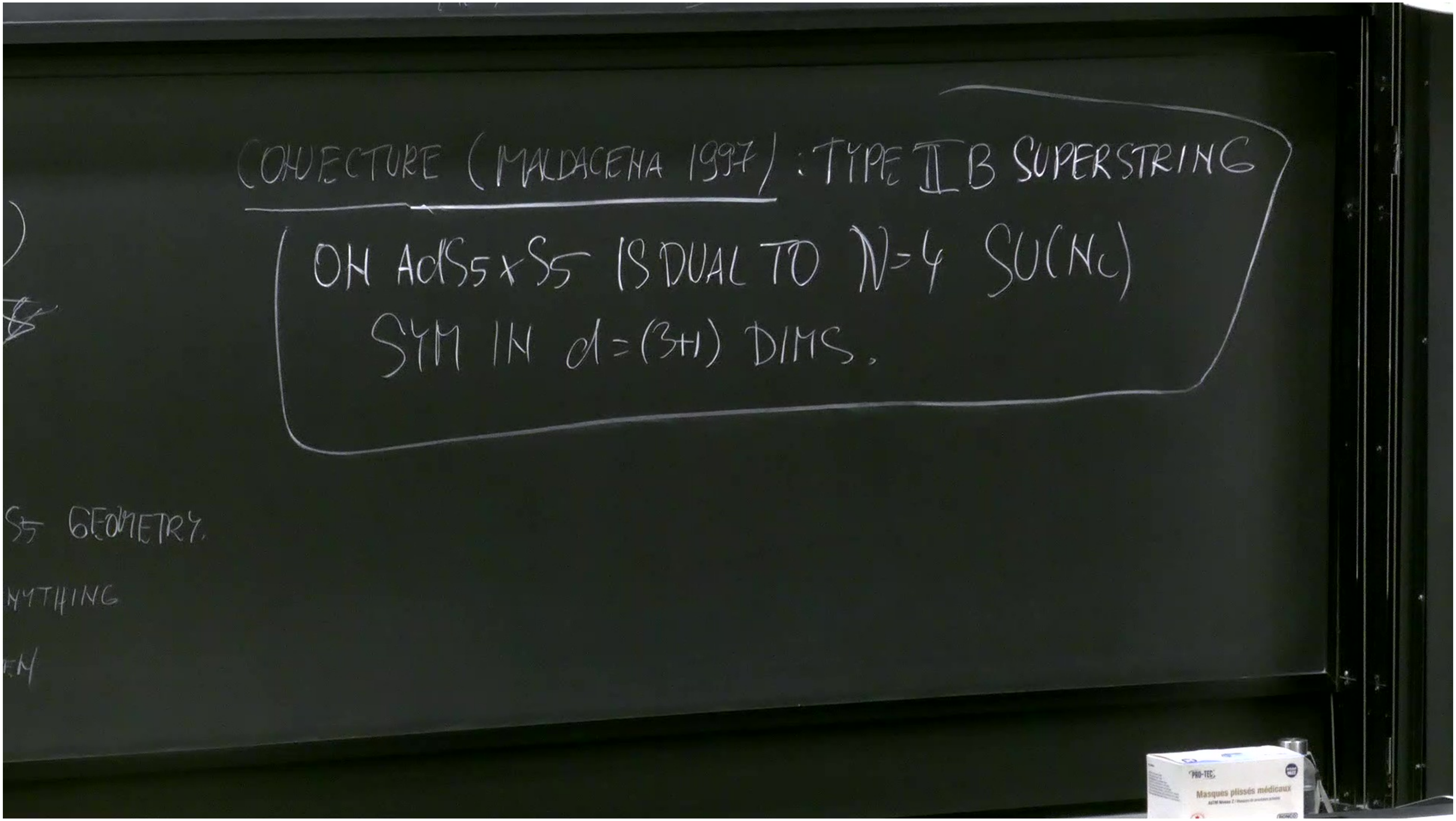
$H \simeq \frac{L^4}{r^4}$ $\qquad ds_{10}^2 \simeq \frac{r^2}{L^2}\left(\eta_{\mu\nu} dx^\mu dx^\nu\right) + \frac{L^2}{r^2} dr^2 + \frac{L^2}{\cancel{r^2}} \cancel{r^2} d\Omega_5^2 \simeq$

CTURE) ..... 2 DIMENSIONLESS PARAMS: $\boxed{\frac{L}{l_s},\ g_s}$

$$\left| \tilde{z} = \frac{L^2}{r} \right|$$

$$d\Omega_5^2 \approx \underbrace{\frac{L^2}{\tilde{z}^2}\left(\eta_{\mu\nu}dx^\mu dx^\nu + d\tilde{z}^2\right)}_{\text{AdS}_5 \text{ WITH RAD. } L} + \underbrace{L^2 d\Omega_5^2}_{S^5 \text{ WITH RADIUS } L}$$


CARTOON 7: AdS/CFT CONJECTURE
OPEN STRING (λ<<1)
Nc .. D3 BRANES
(3+1)-DIM N=4 SYM
LOW ENERGY
CLOSED STRING (λ>>1)
THROAT
AdS5×S5 GEOMETRY.
WHERE ANYTHING
CAN HAPPEN


CONJECTURE (MALDACENA 1997): TYPE IIB SUPERSTRING
ON $AdS_5 \times S_5$ IS DUAL TO $\mathcal{N}=4$ $SU(N_c)$
SYM IN $d=(3+1)$ DIMS.
S_5 GEOMETRY.
NYTHING
EM
PRO-TEC
Masques plissés médicaux