STRONGLY COUPLED GRAVITY AND CONFORMAL INVARIANCE

hep-th/0004195
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REVIEWS IN CONFERENCE PROCEEDINGS:

hep-th/0011171

J. SCHWARZ: 0008009

Strong Coupling Limits

→ Dual Theory

(Compactified) String Theory:

$$\lambda = e^{\langle \phi \rangle} \longrightarrow \infty$$

⇝ Boundary of Moduli Space, Losing Scalars

Strong Gravity

Limit $l_{Planck} \longrightarrow \infty$

Keeping All Scalars

i.e. Consider Energies

$$E >> 1 / l_{Planck}$$

Dual Theory ?

D=5 N=4 SYM

$g_{YM}^2 \to \infty$:- (ROZALI)

D = 6 (2, 0) CFT

FOR FREE (ABELIAN) THEORY

$A_N \to B^+_{MN}$

D = 5 N = 8 SUPERGRAVITY

$l_{PLANCK} \to \infty$:

D = 6 (4, 0) CFT

FOR FREE THEORY

$g_{NV} \to C^+_{MNPQ}$

NON-RENORMALIZABLE LOW ENERGY EFFECTIVE THEORIES OF CONSISTENT THEORIES

N=4 SUPER YANG-MILLS

D=4: $SL(2;\mathbb{Z})$

S-DUALITY GOVERNS STRONG COUPLING BEHAVIOUR

D=5

$g_{YM}^2 = L$ LENGTH SCALE

NON-RENORMALIZABLE, EFFECTIVE THY $E \ll 1/g_{YM}^2$

REGARD AS SECTOR OF CONSISTENT THEORY

e.g. D=5 HETEROTIC STRING

D4-BRANE

(MODEL FOR GRAVITY)

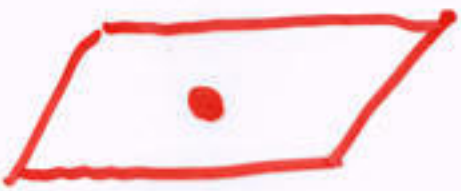
$D=5$ $\quad g_{YM}^2 \to \infty$ $\quad (E \gg 1/g_{YM}^2)$

- Expect to keep(?)

16 SUSY's, SO(5) R-Symmetry,

All $5 \times \dim(G)$ Scalars

- But Extra Light States



Instanton in $\mathbb{R}^4$

$F = *F$

0-Brane in

4 + 1 Dims

$$\text{Mass} \propto n/g_{YM}^2 \to 0$$

Kaluza Klein Tower for

6'th Dimension, Radius $= g_{YM}^2$

Strong Coupling Limit:—

D=6 (2,0) CFT (Rozali)

- Unique D=6 theory with 16 susys, $SO(5)_R$
- 5+dim(G) scalars
- Superconformal
- $g_{YM}^2 = R$ Compactification Modulus

On S^1_R, get D=5 SYM for Ett $1/R$

D4-BRANE

$\longrightarrow$ M5-BRANE WRAPPED ON S^1_R

D=5 HETEROTIC STRING

$\longrightarrow$ IIB ON $K3 \times S^1_R$

D=5 SYM SECTOR

$\longrightarrow$ D=6 (2,0) CFT SECTOR

WHICH CAN BE CONSIST. DECOUPLED

ABELIAN SYM

D=4: SL(2) SYMMETRY OF FIELD EQUATIONS

D=5

ABELIAN (2,0) D=6:

$(B_{MN}, \lambda, \phi^i)$

$dB \simeq *(dB)$, $i = 1, \ldots, 5$

REDUCE ON S^1_R:

D=5 SYM

$$S \sim \int \frac{1}{R} F^2 + \ldots$$

EXPLICIT CHECKS

NON-ABELIAN SYM

D=4 SL(2) NOT SYMMETRY OF FIELD THEORY

D=5 NO LOCAL COVARIANT

D=6 (2,0) INTERACTIONS THAT CAN GIVE D=5 SYM

GOOD EVIDENCE FOR DUALITIES ⇝

LOCAL CONVENTIONAL FIELD THEORY NOT COMPLETE DESCRIPTION?

NEW KIND OF THEORY

IN $D = 6$ WITH "M-INTERACTIONS"

$\downarrow T^2$

$D = 4$ THEORY WITH "M-INTS"

- MANIFEST $SL(2;\mathbb{Z})$
- REDUCES TO SYM

OTHER CORNERS OF

M-THEORY WITH

M-INTERACTIONS?

D=5 N=8 SUGRA

SECTOR OF M-THEORY ON T^6

E_6 RIGID $\times$ $USp(8)$ LOCAL

$\hookrightarrow$ $E_6(\mathbb{Z})$

$g_{\mu\nu}$

A_μ 27 ABELIAN

ϕ 42 IN $E_6/USp(8)$

$$L \sim \frac{1}{l_p^3} R + \frac{1}{l_p} F^2 + \dots$$

5-D PLANCK LENGTH l_p

STRONG COUPLING $l_p \to \infty$

- SEEK DUAL THEORY WITH 32 SUSYS, 42 SCALARS, USp(8) SYMM

$N=8 \longrightarrow N=4$ MULTIPLETS

EACH $N=4$ VECTOR MULT

$\longrightarrow D=6$ (2,0) MULT $B^+_{MN}, \ldots$

$USp(8) \Rightarrow$ ALL 27 $A_\mu \to B^+_{MN}$

$\Rightarrow D=6$ THEORY WITH 27 SELF-DUAL B^+_{MN}, 42 ϕ

SUPERCONFORMAL

BUT UNIQUE $D=6$ "$N=8$" SUGRA FAILS ALL THESE POINTS

(4,0) SUPERMULT IN D=6

- 42 SCALARS, 27 B^+_{MN}
- $USp(8)$ R-SYMMETRY
- SUPERCONFORMAL

$OSp^*(8/8) \supset SO(6,2) \times USp(8)$

32 + 32 SUSY's !

- REDUCTION ON S^1_R OF FREE (4,0) THEORY

→ LINEARISED D=5 SUGRA

L_p = RADIUS

IMMEDIATE CANDIDATE FOR STRONG COUPLING LIMIT

NO GRAVITON, BUT
FIELD IN $(\underline{5},1)$ OF $SU(2) \times SU(2)$

$\rightarrow$ GAUGE FIELD

C_{MNPQ} SYMMS OF RIEMANN TENSOR

FIELD STRENGTH

$G_{MNP\,QRS} = G_{[MNP][QRS]}$

$\sim \partial\partial C$

SELF-DUAL

$G = *G = G*$

$G_{MNP\,QRS} = \frac{1}{6} \epsilon_{MNP\,TUV}$

$G^{TUV}{}_{QRS}$

FREE (4, 0) THEORY IN FLAT D = 6 SPACETIME BACKGROUND EXISTS.

INTERACTING FORM ?

AS FOR (2, 0), NO LOCAL COVARIANT INTS.

M - INTERACTIONS ?

THERE SHD BE NO ROLE FOR D=6 METRIC IN SUCH A THEORY

D=5 LINEARISED GRAVITY :

$$\delta h_{\mu\nu} = \partial_{(\mu} \xi_{\nu)}$$

LIFTS TO D=6 GAUGE INV

$$\delta C_{MNPQ} = \partial_{[M} \chi_{N]PQ} + \partial_{[P} \chi_{Q]MN}$$

$$\chi_{MPQ} = -\chi_{MQP}, \quad \chi_{[MPQ]} = 0$$

LINEARISED D=6 THEORY ALSO HAS SYMMETRY UNDER DIFFEOS OF BACKGROUND SPACETIME.

NOT CLEAR (!) IF INTERACTING THEORY SHOULD BE A DIFFEO THEORY ON A D=6 SPACETIME MANIFOLD

ANY $D=6$ DIFFEO THEORY REDUCED ON T^2 GIVES $D=4$ THEORY WITH $SL(2;\mathbb{Z})$

ABELIAN (2,0): $D=4$ $F_{\mu\nu}$

$$\mathcal{F} \sim \begin{pmatrix} F \\ *F \end{pmatrix} \qquad \mathcal{F} \to S\mathcal{F}$$

LINEAR (4,0): $D=4$ $R_{\mu\nu\rho\sigma}$

$$\mathcal{R} \sim \begin{pmatrix} R & *R \\ R* & *R* \end{pmatrix}$$

$$\mathcal{R} \to S\mathcal{R}S^t$$

S-DUALITY

SYMMETRIES OF FREE $D=4$:

ABELIAN SYM,

LINEARISED SUGRA

NOT SYMMETRIES OF INTERACTING D=4 FIELD THEORIES - N=4 SYM, N=8 SUGRA

IF M-INTERACTING DIFFEO (2,0) OR (4,0) EXIST, REDUCTION ON T^2 GIVES M-INTERACTING D=4 THEORIES WITH MANIFEST S-DUALITY

CONVENTIONAL SYM OR SUGRA WOULD BE LIMITS?

GRAVITATIONAL S-DUALITY?

BPS STATES

27 0-BRANES &

27 STRINGS IN $D=5$ (A_μ)

$\longrightarrow$ 27 SELF-DUAL STRINGS IN $D=6$ (B^+_{MN})

$D=6$ MOMENTUM MODES

$\sim$ $D=5$ "INSTANTONIC" 0-BRANES.

(SINGULAR) SOLUTIONS OF $D=5$ SUGRA

IMPORTANT CHECK: THESE SHD CORRESPOND TO STATES IN BPS SPECTRUM

- STRONG COUPLING LIMIT OF $D=5$ LINEARISED SUGRA

$\longrightarrow$ $D=6$ FREE $(4,0)$

- CAN $l_p \to 0$ LIMIT OF INTERACTING $D=5$ THEORY GIVE NON-TRIVIAL M-INTERACTING THEORY?
- IF SO, MANY IMPLICATIONS FOR PLANCK SCALE GRAVITY & M-THEORY

$g_{\mu\nu} \longrightarrow C^{+}_{MNPQ}$

GEOMETRY $\longrightarrow$?

- VAST SYMMETRY

- LIMITS OF M-THEORY ONTO IN WHICH 0-BRANES BECOME MASSLESS WOULD LIFT TO TENSIONLESS STRING LIMITS IN D=6
- POSSIBILITY OF A (4,0) SCFT WITH "TENSIONLESS STRINGS" GIVING QUANTUM SUPERGRAVITY ON REDUCTION
- CLOSELY RELATED TO (2,0) THEORY, AND UNDERSTANDING THIS WD BE AN IMPORTANT STEP
- M-INTS, NOT FIELD THY!