STRINGS 2001

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NS, Susskind and Toumbas, 0005015, 0005040

Gopakumar, Maldacena, Minwalla and Strominger, 0005048

Gopakumar, Minwalla NS and Strominger, 0006062

Bergshoeff, Berman, van der Schaar and Sundell, 0006112

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Goal: look for new theories without gravity near boundaries of moduli space of string theory

Outline

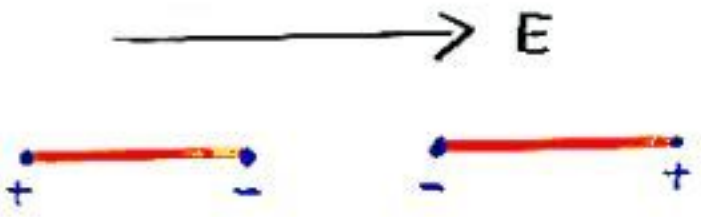
1. Critical electric field and light strings

2. M5 version and light membranes

3. Little string theory version and light D-branes

Critical Electric Field and Light Strings

(Review of old story)



$T_{eff} = T + E$ $\qquad$ $T_{eff} = T - E$

For $T \approx E$ $\quad T_{eff} \ll T$ – light open strings

Cannot have $E > T$, because then strings can materialize $\Rightarrow$ vacuum instability

Look for a scaling theory for $T \approx E$ involving only the light strings.

More quantitative Focus on directions 0,1

$$g_{\mu\nu} = g\begin{pmatrix} -1 & \\ & 1 \end{pmatrix} \qquad E_{cr} = \frac{g}{2\pi\alpha'}$$

Open string parameters (Schomerus, NS, Witten):

$$G_{\mu\nu} = g\left(1 - \left(\frac{E}{E_{cr}}\right)^2\right)\begin{pmatrix} -1 & \\ & 1 \end{pmatrix}$$

$$\theta^{\mu\nu} = \frac{E/E_{cr}^2}{1 - \left(\frac{E}{E_{cr}}\right)^2}\begin{pmatrix} & 1 \\ -1 & \end{pmatrix}$$

$$G_s = g_s\left(1 - \left(\frac{E}{E_{cr}}\right)^2\right)^{1/2}$$

Unlike magnetic background, here there is no $\alpha' \to 0$ limit with fixed $G, \theta \neq 0$.

No field theory limit with space/time noncommutativity (also Bertson and Rabinovici).

Look for a string theory $E \approx E_{cr}$.

The slope of these light strings

$$\alpha'_{eff} = \alpha' \frac{g_{11}}{G_{11}} = \frac{\alpha'}{1 - \left(\frac{E}{E_{cr}}\right)^2} \longrightarrow \infty \quad \text{for fixed } \alpha'$$

scale: $\alpha' \sim 1$

$$g_{ij} \sim 1 \qquad i,j \neq 0,1$$

$$g_{\mu\nu} \sim \frac{1}{1 - \left(\frac{E}{E_{cr}}\right)^2} \to \infty$$

$$g_s \sim \frac{1}{\left[1 - \left(\frac{E}{E_{cr}}\right)^2\right]^{1/2}} \longrightarrow \infty$$

$$\Rightarrow \Theta = \frac{2\pi\alpha'_{eff}}{g} \sim 1 \;, \; G_{\mu\nu} \sim 1 \;, \; G_s \sim 1$$

Equivalently, rescale all components of $g_{\mu\nu}$ and α' by ϵ

$g_{\mu\nu} = (-1, 1, \epsilon, \epsilon \ldots)$

$\alpha' = \alpha'_{eff}\,\epsilon$ $\qquad$ $\epsilon \to 0$

$2\pi\alpha' E = 1 - \frac{1}{2}\epsilon$ $\qquad$ α'_{eff}, G_s = fixed

$g_s = G_s\,\epsilon^{-\frac{1}{2}}$

$\Downarrow$

$\Theta = 2\pi\alpha'_{eff}$

$G_{\mu\nu} \sim \epsilon$ but $G^{eff}_{\mu\nu} = \frac{\alpha'_{eff}}{\alpha'} G_{\mu\nu} \sim 1$

Non-**C**ommutative **O**pen **S**trings

$g_s \to \infty$

To analyze:

IIB use S duality

IIA use M theory

M5 Version and Light Membranes

$g_{\mu\nu} = (-1\ 1\ 1\ \epsilon\ \epsilon\ \epsilon)$

$M_p^3 = M^3 \frac{1}{\epsilon}$

$C_{012} = M_p^3 \left(1 - \frac{1}{2}\epsilon\right)$ ← near critical

$C_{345} = M^3$

$\epsilon \to 0 \qquad M = \text{fixed}$

* Only parameter is a scale, M.
* C satisfies the nonlinear selfduality equation (Howe, Sezgin, West)
* Lorentz = $SO(2,1) \times SO(3)$
* $M_p \to \infty \Rightarrow$ Gravity and bulk physics likely to decouple

* The membranes are strongly coupled and cannot be used effectively in calculations

* Low energy theory after compactification: D4 with $\theta^{0\,i}$ and/or θ^{ij} (rank 2) $\neq 0$

Little String Theory Version and Light D-branes

Generalizes LST and previous examples.

New 6 dim. theories depending on the D-brane which becomes light.

Dp light $\rightarrow$ $C_{01\ldots p}$ near critical,

$C_{p+1,\ldots 5}$ is determined

Consider three examples:

NS5 in IIA with light D2

$g_{\mu\nu} = (-1\,1\,1\,\epsilon\epsilon\epsilon)$

$\alpha' \sim \epsilon^{1/2}$

$g_s \sim \epsilon^{1/4}$

$c_{012} = \frac{M_s^3}{g_s}(1 - \frac{1}{2}\epsilon)$ near critical

$c_{345} \sim 1$

Like previous example of M5 with light membranes, now with transverse circle (like (2,0) → LST).

NS5 in IIB with light D1

$g_{\mu\nu} = (-1\,1\,\epsilon\,\epsilon\,\epsilon\,\epsilon)$

$\alpha' \sim \epsilon^{1/2}$

$g_s \sim \epsilon^{1/2}$

$c_{01} = \frac{M_s^2}{g_s}(1 - \frac{1}{2}\epsilon)$ near critical

$c_{2345} \sim 1$

↓ S duality

D5 in IIB with light strings

$g_{\mu\nu} = (-1\,1\,\epsilon\,\epsilon\,\epsilon\,\epsilon)$

$\alpha' \sim \epsilon$

$g_s \sim \epsilon^{-1/2}$

$B_{01} = M_s^2(1 - \frac{1}{2}\epsilon)$ near critical

NCOS on D5

NS5 in IIB with light D3

$g_{\mu\nu} = (-1\,1\,1\,1\,\epsilon\,\epsilon)$

$\alpha' \sim \epsilon^{1/2}$

$g_s \sim 1$

$C_{0123} = \frac{u_s^4}{g_s}(1 - \frac{1}{2}\epsilon)$ near critical

$C_{45} \sim 1$

↓ S duality

D5 in IIB with light D3

$g_{\mu\nu} = (-1\,1\,1\,1\,\epsilon\,\epsilon)$

$\alpha' \sim \epsilon^{1/2}$

$g_s \sim 1$

$B_{45} \sim 1$

Low energies - SYM with $\theta^{45} \neq 0$

Light D3 - magnetic monopole

When compactified all these different 6 dim. theories are on the same moduli space.

T duality relates them.

Like II A / II B, LST in II A / II B.

By compactifying and/or taking a limit of parameters can find all previous examples.

Outlook

What does it mean?

What is the underlying geometry?

$\theta^{ij} \neq 0 \implies [x^i, x^j] \neq 0.$

$\theta^{i0} \neq 0$ more difficult to interpret;

space/time fuzziness ~ string fuzziness.

What does $C_{ijk} \neq 0$ mean?

nonassociative geometry?

We also had examples with higher forms $\neq 0$ and different cases are related by T duality.