STILL:

1- CONFINEMENT IN 3D AND 4D.
(WITTEN, BISY)

2- SCREENING OF THE MAGNETIC CHARGE IN 4D (BISY; LI; GROSS OOGURI)

3- GLUEBALL MASS
(CSAKI, OOGURI, OZ, TERNING; KOCH, JEVICKI, MIHAILESCU, NUNES)

NEAR EXTREMAL D3-BRANES CAN BE USED TO STUDY YM IN 3D. (WITTEN)

AT THE IR $LT \gg 1$ THE THEORY IS THREE DIMENSIONAL.

IT IS A NON-SUSY THEORY BECAUSE OF THE TEMPERATURE WHICH INDUCES A MASS TO THE FERMIONS AND SCALARS OF THE ORDER OF $\sim T$.

BUT, THERE IS NO CURVATURE SINGULARITY AT $u \to \infty$ WHILE YM IS A.F.

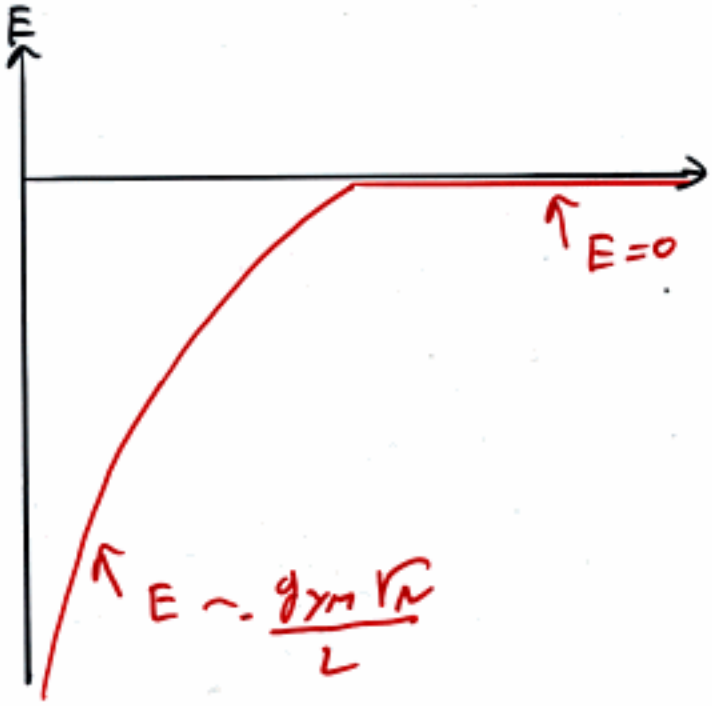
4D $\quad R \sim \log(u)$.

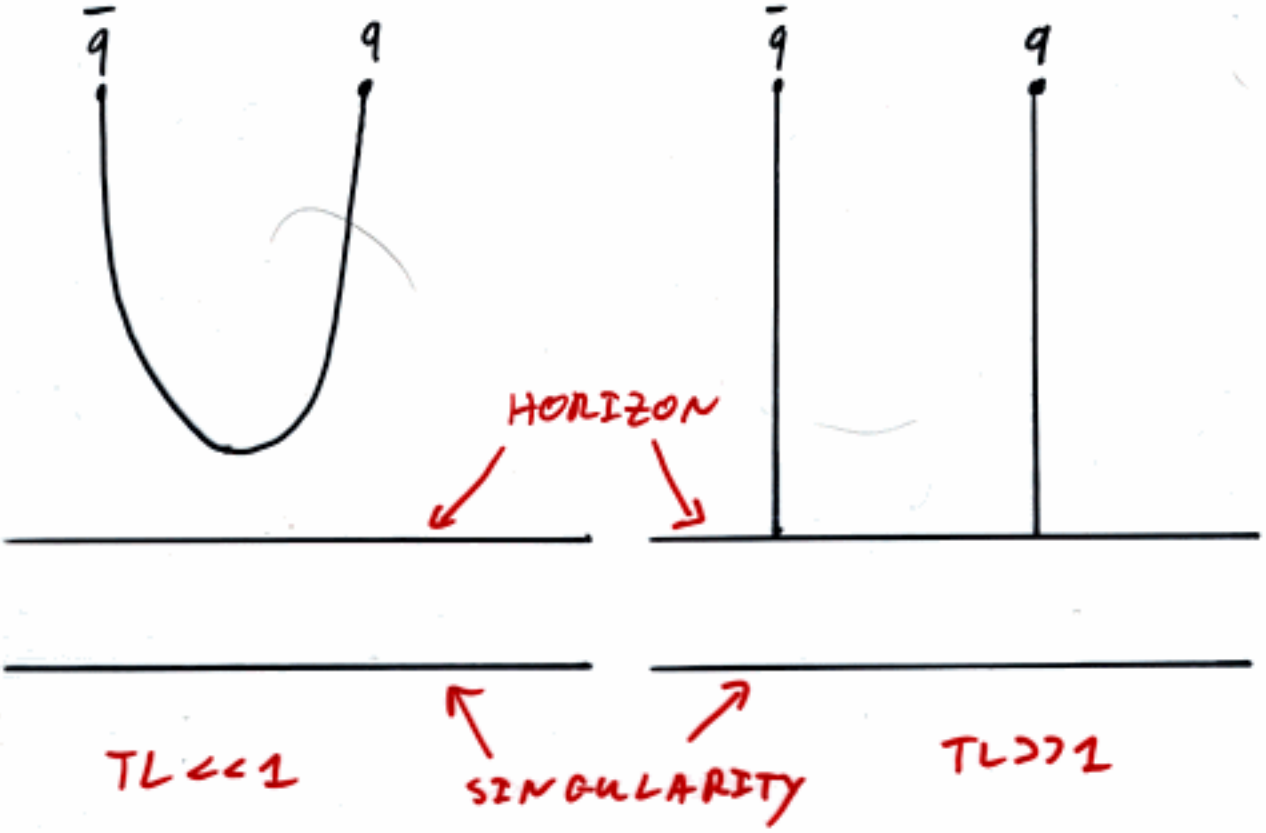
3D $\quad R \sim \sqrt{u}$.

THE SPATIAL WILSON LINE YIELDS

$$E = T_{YM} L \quad , \quad T_{YM} = g_4 \sqrt{N}\, T^2$$

BUT, THE QCD STRING CAN PROBE THE KK DIRECTION WHEN $g_{YM}\sqrt{N} \gg 1$ SO THE THEORY "KNOWS" ABOUT ITS 4D ORIGIN.


E
E=0
E ~ $\frac{g_{YM}\sqrt{N}}{L}$


$\bar{q}$
q
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q
HORIZON
TL<<1
SINGULARITY
TL>>1

$N=4$ AT FINITE TEMPERATURE

(REY, THEISEN, YEE)

THE UNDERLINE THEORY IS CONFORMAL BUT THE TEMPERATURE INTERDUCES A SCALE TO THE SYSTEM.

WE NEED TO CONSIDER THE NEAR-EXTREMAL SOLUTION OF A COLLECTION OF N D3-BRANES.

THE SOLUTION CONTAINS A CURVATURE SINGULARITY AT $u=0$ BEHIND THE HORIZON AT $u=u_T$.

THE ENERGY OF THE QUARK ANTI-QUARK IS

FOR $TL \ll 1$, $E \sim -\frac{1}{L}\left(1+\mathcal{O}(L^4T^4)\right)$

FOR $TL \gg 1$, $E = \text{const.}$

WHICH MEANS SCREENING OF THE CHARGES.

D2-BRANES $\longrightarrow$ SYM IN 2+1

PERTURBATIVE SYM CAN BE TRUSTED AT THE UV $u \gg g_{YM}^2 N$.

10D SUGRA CAN BE TRUSTED AT

$$g_{YM}^2 N^{1/5} \ll u \ll g_{YM}^2 N .$$

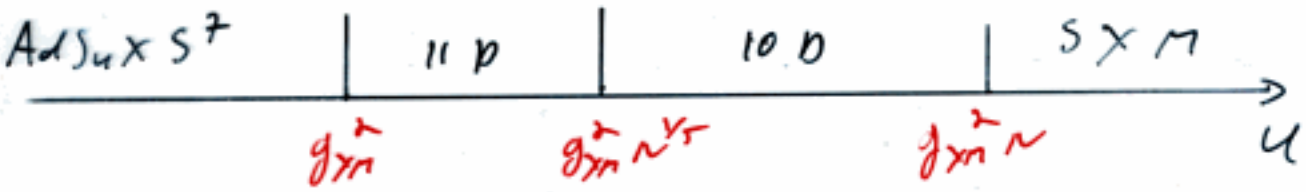
AT $u < g_{YM}^2 N^{1/5}$ THE DILATON IS LARGE AND WE HAVE TO USE THE 11D SOLUTION.

WE HAVE TWO OPTIONS:

1- TRANSLATION INVARIAT (ALONG x_1)

2- LOCALIZED SOLUTION.

BY CONSIDERING THE ENTROPIES OF THE NEAR-EXTREMAL SOLUTION ONE FINDS THAT FOR $u < g_{YM}^2$ WE SHOULD USE THE LOCALIZED M2-BRANE SOLUTION WHOSE R-SYMMETRY IS SO(8).

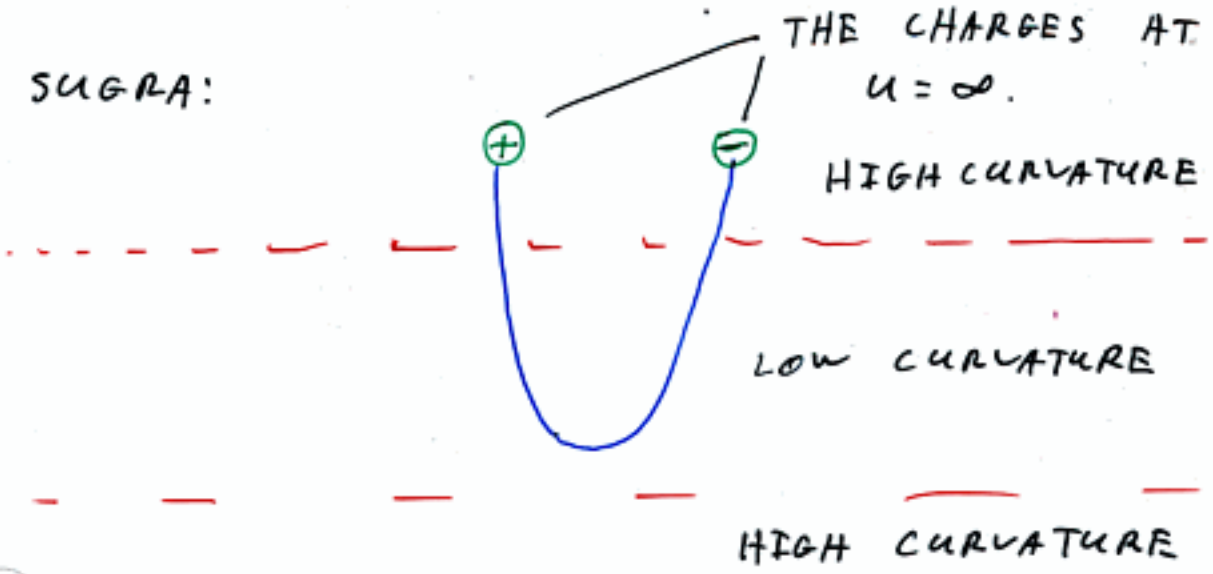


CHECKS WORK AGAIN.

2- WILSON LINE: (MALDACENA)

SYM : $E_{YM} \sim g_{YM}^2 N L$

SUGRA:



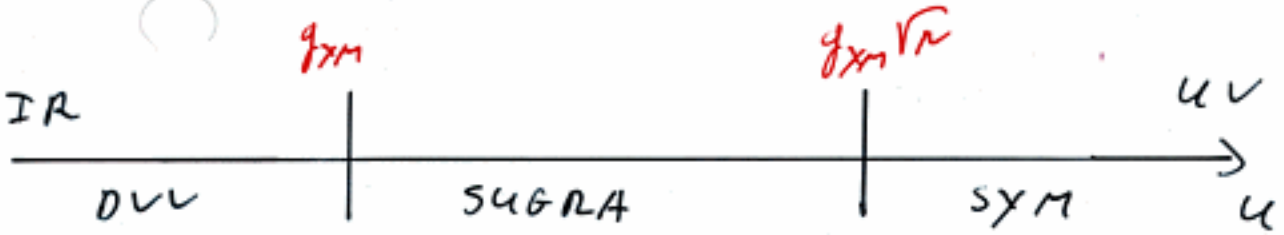
THE D-BRANES AT $u=0$

$$E_{sg} \sim -\sqrt{\frac{g_{YM}}{L}}\, N^{1/4}$$

$E_{sg} \sim E_{YM}$ AT THE TRANSITION

AT THE IR WE HAVE ORBIFOLD $(R^8)^N/S_N$ CONFORMAL FIELD THEORY WITH A VERTEX.
(DIJGRAAF - VERLINDE - VERLINDE)

THE VERTEX DESCRIPTION BREAKS DOWN AT $u = g_{YM}$ WHERE THE SUGRA TAKES OVER.



CHECKS:

1- ENTROPY: (HOROWITZ, POLCHINSKI)

SYM - $E \sim N V T^{2+1}$, $S \sim N V T^{0}$
$\hookrightarrow S_{sy} \sim N\sqrt{LE}$

SUGRA - $S = \frac{A}{4} \Rightarrow S_{sg} \sim \frac{\sqrt{N}}{g_{YM}^{1/3}} E^{2/3} V^{1/3}$

DVV - $S_{orb} \sim \sqrt{NLE}$

THEY ARE OF THE SAME ORDER AT THE TRANSITION POINTS.

TO TRUST A SUPERGRAVITY SOLUTION WE ALSO NEED

$$\left.\begin{array}{l} e^{\phi} \ll 1 \longrightarrow g_{eff}^2 \ll N^{\frac{4}{7-p}} \\ \alpha' R \ll 1 \longrightarrow g_{eff}^2 \gg 1 \end{array}\right\} N \gg 1$$

D1-BRANES AND 1+1 SYM

AT THE UV $u \gg g_{YM}\sqrt{N}$ WE TRUST P.T.

AT THE REGION $g_{YM} N^{1/6} \ll u \ll g_{YM}\sqrt{N}$ WE TRUST SUGRA.

IN THE REGION $u < g_{YM} N^{1/6}$ THE STRING COUPLING IS LARGE AND WE USE S-DUALITY.

N D1-BRANES $\longrightarrow$ N FUNDAMENTAL STRINGS

THE CURVATURE OF THIS SOLUTION IS

$$\alpha' R = \frac{g_{YM}^2}{u^2} \xrightarrow[u \to 0]{} \infty$$

AT THE VERY IR THERE SHOULD BE A FIELD THEORY DESCRIPTION

INDEED,

THE "FIELD THEORY" SOLUTION

$$ds^2 = \alpha' \left[\frac{u^{\frac{7-p}{2}}}{g_{YM}\sqrt{N}} dx_\parallel^2 + \frac{g_{YM}\sqrt{N}}{u^{\frac{7-p}{2}}} du^2 + g_{YM}\sqrt{N}\, u^{\frac{p-3}{2}} d\Omega_{8-p}^2 \right]$$

$$e^\phi = g_{YM}^2 \left(\frac{g_{YM}^2 N}{u^{7-p}} \right)^{\frac{3-p}{4}}$$

1- AGAIN α' IN FRONT OF THE METRIC $\Rightarrow$ $\alpha' R$ = FINITE

2- e^ϕ FINITE

3- $T_{0\infty} = \int \left(\frac{dT}{du}\right) du$ = FINITE.

4- $E^2 > p_\parallel^2 + u^{\frac{7-p}{2}} m^2$

THE CURVATURE IS $\alpha' R = \sqrt{\frac{u^{3-p}}{g_{YM}^2 N}} = \frac{1}{g_{eff}}$

SO AT THE IR WE CAN TRUST THE SUGRA SOLUTION AT THE UV THERE IS A CURVATURE SINGULARITY WHICH IMPLIES THAT THE FIELD THEORY IS FREE.

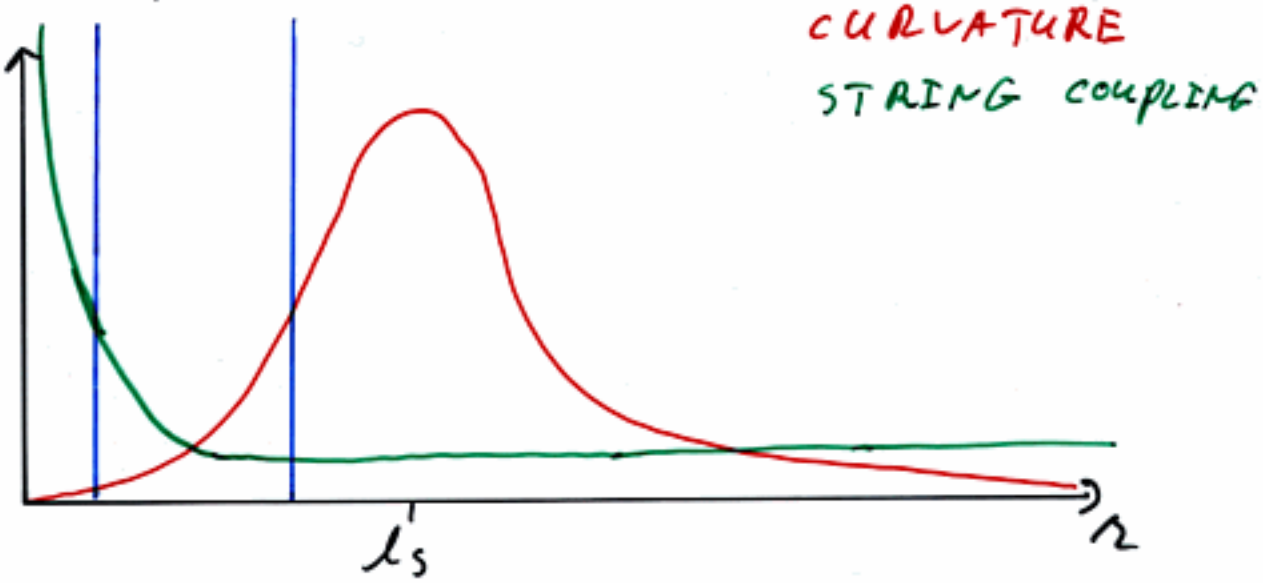
ON THE SUPERGRAVY SIDE

$$ds^2 = f_p^{-1/2}\left[-dt^2 + dx_{\parallel}^2\right] + f_p^{1/2}\, dx_T^2$$

$$e^{-2\phi} = g_s^{-2} f_p^{(p-3)/2}$$

WHERE $$f_p = 1 + \frac{g_s N (\alpha')^{\frac{7-p}{2}}}{r^{7-p}}$$

THE CURVATURE AND STRING COUPLING ARE



THE FIELD THEORY LIMIT

$$u = \frac{r}{\alpha'} = \text{fixed}, \quad g_{YM}^2 = g_s\, \alpha'^{\left(\frac{p-3}{2}\right)}, \quad \alpha' \to 0$$

GIVES

$$g_s \to 0, \quad \frac{r}{l_s} \to 0$$

Dp-BRANES p<3

ON THE FIELD THEORY SIDE THE EFFECTIVE COUPLING CONSTANT IS

$$g_{eff}^2 = g_{YM}^2 N u^{p-3}$$

WHERE u IS AN ENERGY SCALE (THE HIGGS EXPECTATION VALUE, $\sqrt{s}$ IN SCATTERING...)

PERTURBATION THEORY CAN BE TRUSTED AT THE UV REGION

$$u \gg (g_{YM}^2 N)^{\frac{1}{3-p}}.$$

AT THE IR P.T BREAKS DOWN.

WE GET $AdS_5 \times S^5$

$$ds^2 = \alpha' \left[\frac{u^2}{g_{YM}\sqrt{N}} \left(-dt^2 + dx_{\parallel}^2\right) + \frac{g_{YM}\sqrt{N}}{u^2} du^2 + g_{YM}\sqrt{N}\, d\Omega_5^2 \right]$$

1- α' infront OF THE METRIC.

SO, α' CORRECTIONS ARE $\frac{1}{g_{eff}}$ CORRECTIONS (STRING LOOPS CORRECTIONS YIELD THE $1/N$ EXPANSION).

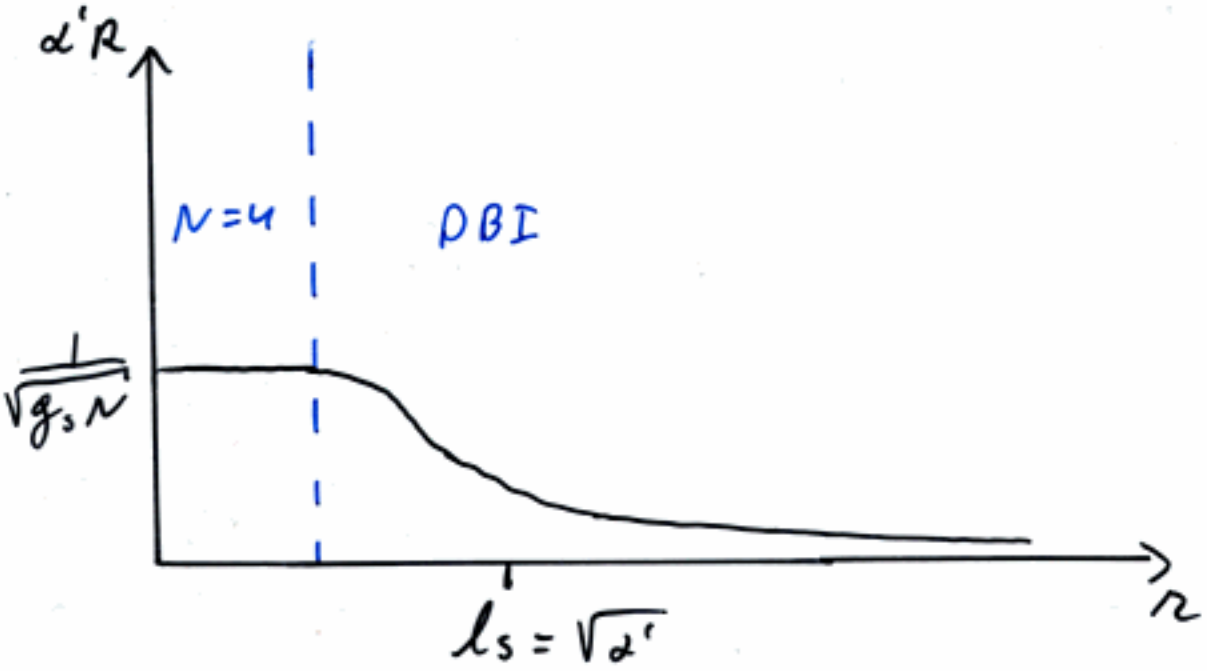
2- $T_{0,\infty} < \infty$ THE FIELD THEORY IS ON THE BOUNDARY $u = \infty$.

3- MASSIVE MODES CANNOT PROPAGATE TO THE BOUNDARY.

D3-BRANES $\to$ $N=4$ 4D SYM (MALDACENA)

ON THE FIELD THEORY SIDE THE EFFECTIVE COUPLING CONSTANT IS $g^2_{eff} = g^2_{YM} N$.

ON THE SUPERGRAVITY SIDE WE HAVE A SOLUTION WHOSE CURVATURE IS



TO OBTAIN THE FIELD THEORY LIMIT WE NEED TO TAKE

$$u = \frac{r}{\alpha'} = \text{FIXED}, \quad \alpha' \to 0$$

$\hookrightarrow$ $r \ll l_s$

NON-CONFORMAL FIELD THEORIES AND SUPERGRAVITY

hep-th/9802042

N. I
J. MALDACENA
J. SONNENSCHEIN
S. YANKIELOWICZ

hep-th/9803135/263

A. BRANDHUBER
N. I
J. SONNENSCHEIN
S. YANKIELOWICZ