HIGHER SPIN EXTENSION OF AdS SUPERGRAVITIES IN DIVERSE DIMENSIONS

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PLAN

- HIGHER SPIN GAUGE THEORIES AS HOLOGRAPHIC DUALS OF CFT'S
- STRUCTURE OF HIGHER SPIN GAUGE THS.

work with Per Sundell.

Supergravity @25, Stony Brook, Dec. 1-2, 2001.

$\boxed{\text{TYPE IIB}}$

The strong form of Maldacena conjecture states that: $\mathcal{N}=4$ $U(N)$ SYM theory in 3+1 dims. is the same as (or dual to) type IIB superstring theory on $AdS_5 \times S^5$.

Usually one works in the regime

$\lambda = \sqrt{g_s N} = \sqrt{g_{YM}^2 N} \gg 1$, $N \gg 1$ where classical AdS_5, $\mathcal{N}=8$ SUGRA is a good approximation.

Q: What about the limit in which :

$$\boxed{g_{YM}^2 N = 0, \quad N \gg 1} \quad ?$$

In this limit the $\alpha' \sim \frac{1}{\sqrt{g_{YM}^2 N}}$ corrections blow up and, as such, Maldacena conj. does not offer any specific description of type IIB in this limit.

$\boxed{\text{Proposal}}$:

The $\lambda = 0$, $N \gg 1$ limit of $SU(N)$ $\mathcal{N}=4$ SYM theory is holographic dual to higher spin gauge theory in AdS_5 based on $hs(2,2|4)$ which is an infinite dimensional extension of the AdS_5 superalgebra $PSU(2,2|4)$.

Witten, private communication
Sundborg, hep-th/0103247
E.S. & Sundell, hep-th/0105001
Witten, talk given at JHS 60 conf., Nov. 2-3, 2001
Vasiliev, hep-th/0106149 ← generalized HS CFT_4/AdS_5 chain of dualities.

SUPPORTIVE ARGUMENTS

- Free $SU(N)$ $\mathcal{N}=4$ SYM $\equiv CFT_4$ has conserved tensors of arbitrary spin formed as traces of bilinears in SYM fields.

Schematically: $\quad \mathcal{O}_{\mu_1 \cdots \mu_s} \sim \mathrm{Tr}\, \Phi \overleftrightarrow{\partial}_{\mu_1} \cdots \overleftrightarrow{\partial}_{\mu_s} \Phi$

$$\partial^{\mu_1} \mathcal{O}_{\mu_1 \cdots \mu_s} = 0$$

Group theoretical meaning:

$\mathcal{N}=4$ SYM multiplet is $s_{max}=1$ doubleton irrep. of AdS_5 superalgebra $PSU(2,2|2)$ and

doubleton $\otimes$ doubleton $= \sum$ infinitely many massless H.S. irreps of $PSU(2,2|2)$.

Flato & Fronsdal, Günaydin.

Symmetric tensor product of two $\mathcal{N}=4$ SYM doubletons arranged into levels $\ell = 0, 1, 2, \ldots$ of $\mathcal{N}=8$, AdS_5 superalgebra multiplets:

$\ell \backslash s$	0	$\frac{1}{2}$	1	$\frac{3}{2}$	2	$\frac{5}{2}$	3	$\frac{7}{2}$	4	$\frac{9}{2}$	5	$\frac{11}{2}$	6	…
0	42	48	27	8	1									
1	1	8	28	56	70	56	28	8	1					
2	↑!				1	8	28	56	70	56	28	8	1	
3									1	8	28	56	70	…
4													1	…
⋮														

$USp(8)$ irreps: $8, 27, 42, 48$ ⟸ irreducible

reducible
$$\begin{cases} 28 = 27 + 1 \\ 56 = 48 + 8 \\ 70 = 42 + 27 + 1 \end{cases}$$

Under $SU(4) \times U(1)_Y$: $\left(Y = -2 (J_L - J_R) \right)$.

$$\begin{cases} 8 = 4_1 + \bar{4}_{-1} \\ 27 = 15_0 + 6_2 + \bar{6}_{-2} \\ 42 = 20'_0 + 10_2 + \overline{10}_{-2} + 1_4 + \bar{1}_{-4} \\ 48 = 20_1 + \overline{20}_{-1} + 4_3 + \bar{4}_{-3} \end{cases}$$

- The <u>free</u> CFT_4 depends on N, and as the correlators <u>factorize</u> <u>for</u> $\underline{N \to \infty}$, as Witten has argued, there exists a <u>local</u> description in AdS_5:

e.g. $$\langle \mathcal{O}_1 \mathcal{O}_2 \mathcal{O}_3 \mathcal{O}_4 \rangle = \langle \mathcal{O}_1 \mathcal{O}_2 \rangle \langle \mathcal{O}_3 \mathcal{O}_4 \rangle + \sum_i \frac{\langle \mathcal{O}_1 \mathcal{O}_2 \mathcal{O}_i \rangle \langle \bar{\mathcal{O}}_i \mathcal{O}_3 \mathcal{O}_4 \rangle}{\langle \bar{\mathcal{O}}_i \mathcal{O}_i \rangle}$$

+ perms

free propagation in AdS.

suppressed by powers of $1/N$

- For $\lambda \gg 1$, string tension $T_s \sim \frac{\sqrt{\lambda}}{R^2_{AdS}}$

Naively $T_s \to 0$ as $\lambda \to 0$, however we'll present a scenario in which

$$T_s \to T_{s,\,crit} \sim \frac{1}{R^2_{AdS}} \quad \text{as} \quad \lambda \to 0 .$$

i.e. type IIB string on $AdS_5 \times S^5$ with <u>critical</u> <u>tension</u>.

Where do the massless HS fields come from in type IIB string on $AdS_5 \times S^5$ for $g_s N = 0$?

If we assume that they come from the massive perturbative string spectrum by an inverse Higgs mechanism, one does not expect any singularity in the effective string action as the # of degrees of freedom does not change. Hence we expect

$$\boxed{\begin{aligned} T_s &\sim \frac{f_s(\lambda)}{R^2_{AdS}}\,, \\ T_s &\to T_{s,\mathrm{crit}} \sim \frac{f_s(0)}{R^2_{AdS}} > 0 \quad \text{as} \quad \lambda \to 0\,. \end{aligned}}$$

E.S. & Sundell, to appear.

- $\boxed{\text{MASSIVE STATES IN HS GAUGE THEORY}}$:

$\boxed{n \geq 3}$

$$\underbrace{\text{doubleton} \times \text{doubleton} \times \cdots \times \text{doubleton}}^{n\text{-times}} =$$

$$= \sum \text{infinitely many } \underline{\text{massive}} \text{ irreps of } PSU(2,2|4).$$

These contain KK states of the ordinary AdS_5 SUGRA and their H.S. cousins. For each $n \geq 3$ the r.h.s. forms a representation of $hs(2,2|4)$ and must also be included in the HS gauge theory.

- The HS gauge theory cannot be consistently truncated to ordinary AdS_5 supergravity! Need spontaneous breaking of HS symmetry followed by sending the sym. breaking parameter to infinity.

- If $g_{YM}^2 N$ is small but non-zero, then:

$$\partial_\mu J^\mu \sim \lambda^{1/2} \Sigma$$

spin s current ↕ massless bulk field $W_{\hat\mu}$.

spin $s-1$ operator ⟷ massive bulk field H

Coupling: $\delta S_{CFT} = \int d^4x \left(W_\mu J^\mu + H \Sigma \right)$

⇒ Stueckelberg symmetry given by:

$$\delta W_{\hat\mu} = \nabla_{\hat\mu} \epsilon + \cdots \, , \quad \delta H = -\lambda^{1/2} \epsilon$$

Hence the covarian derivative:

$$\nabla_{\hat\mu} H + \lambda^{1/2} W_{\hat\mu}$$

⟵ $W_{\hat\mu}$ "eats" H to develop mass:

$$\boxed{\delta m_W^2 \sim \lambda R_{AdS}^{-2}}$$

<u>Note</u>: $m_W^2 = m_{W,crit}^2 + \delta m_W^2$.

Higher spin doubletons

- $PSU(2,2|4)$ has infinitely many doubleton irreps. with ever increasing s_{max}. (Günaydin)

$\lvert Z\rvert \backslash s$	0	1/2	1	3/2	2	5/2	3	...
0	6	4	1 ⇐ SYM					
1	1	4	6	4	1 ⇐ SUGRA			
2			1	4	6	4	1	
3					1	4	6	...
⋮								

Similar table exists for $J_{max} = s + \frac{1}{2}$, $s = 1, 2, \ldots$

- Product of any two of these produces ∞'ly many massless irreps. of $PSU(2,2|4)$. (Günaydin).
  All the doubletons form an irrep. of $Sp(8,\mathbb{R})$.

- HS CFT in $d=4$? Vasiliev '01

$$PSU(2,2|4) \longrightarrow OSp(8|8) \supset \underset{\substack{\cup \\ SU(4)}}{SO(8)} \times \underset{\substack{\cup \\ SU(2,2)}}{Sp(8,\mathbb{R})}.$$

Leads to the generalization of the HS algebra:

$$hs(2,2|4) \rightarrow ho(8,8|8)$$
$$\cup$$
$$osp(8|8)$$

Vasiliev '01

<u>Free</u> HS CFT based on $ho(8,8|8)$ has been constructed by Vasiliev.

- The role of the HS doubletons in string theory?

  Does the open string give rise to HS CFT in the $g_{YM}N = 0$, $N \gg 0$ limit?

- HS gauge theory in $D=11$, based on HS extension of $osp(1|32)$?

$\boxed{\text{M-THEORY}}$

$\boxed{\text{Proposal}}$ E.S. & Sundell, to appear

(a) M-theory on $AdS_7 \times S^4$ has a HS gauge theory phase which is antiholographic dual of <u>free</u> $(N-1)$ $(2,0)$ tensor multiplets CFT in $d=6$ for large N.

(b) M-theory on $AdS_4 \times S^7$ has a HS gauge theory phase which is antiholomorphic dual of <u>free</u> (N^2-1) $\mathcal{N}=8$ scalar multiplet CFT in $d=3$ for large N.

Historic note :

- Singleton-brane connection :

  Duff, Class & Quantum Grav. 5 (1988) 189

  Duff & Blencowe, PLB 203 (1988) 229

  Nicolai, E.S. & Tanii, NPB 305 (1988) 483

- Brane – HS gauge theory connection :

  Bergshoeff, Salam, E.S. & Tanii, PLB 205 (1988) 237.

- Crucial missing ingredient back then was that we didn't know about N-coincident branes. ($N=1$).

Current HS gauge theories

HS AdS_4, $\mathcal{N}=8$ — Full eqs. of motion known
Vasiliev '90

HS AdS_5, $\mathcal{N}=8$ — HS algebra, Linearized eqs. of motion known
E.S. & Sundell '01

Some bosonic cubic couplings known
Vasiliev '01

HS AdS_7 — Bosonic HS algebra & eqs. of motion known.
E.S. & Sundell, to appear

HS AdS_3 + matter + SUSY — Vasiliev et al.
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