Horizons in M-theory

- Old horizons: interpolating solitons
- Non horizons: domain walls
- 'Squashed' horizons: adding rotation
- 'Intersecting' horizons: $\text{adS}_3 \times S^3 \times S^3$
- New horizons: 'squashed' $\text{adS}_2 \times S^3 \times S^3$

P. Townsend
Stony 98
Branes as Interpolating Solitons

KK compactification with constant scalars (if any)

e.g. M2 \(\text{ads}_4 \times S^7\) \(\text{osp}(8|4;\mathbb{R})\)

H5 \(\text{ads}_7 \times S^4\) \(\text{osp}(8^*|4)\)

D3 \(\text{ads}_5 \times S^5\) \(\text{su}(2,2|4)\)

KK vacuum

\(\Rightarrow\) su(8) doubling near horizon

\(\text{ads}\) isometry supergroup
KK with non-constant dilaton

e.g. NS-Sbrane \quad (Gibbons, PKT)

\begin{itemize}
  \item $O(8)$ distance
  \item $SO(8)$ symmetry
\end{itemize}

$B^3$ comp. to $D=7$ domain wall spacetime

For $N=1$ get $SU(2)$-gauged $D=7$ supergravity + $SU(2)$ SYM
(Cowdell, PKT)

Conjecture: For $N=2$ get $SO(1,4)$ gauged $D=7$ supergravity
(Brown, Skenderis, PKT)

N.B. No SUSY doubling
\[ R\text{-symmetry} = \text{Gauge symmetry} \]

\[ \text{R-sym. of NS-5-brane action} = \text{SO}(4) = \text{gauge symmetry of bulk supergravity} \ (\text{SO}(4,1) \to \text{SO}(4) \text{ in domain wall vacuum}) \]

Another example: \( D\text{-6-brane} \). \[ R\text{-sym} = \text{SU}(2) \]

\[ e^{-2\phi} ds^2_{10} \sim \frac{1}{r} ds^2(E^4,1) + \frac{dr^2}{r^2} + ds^2(S^2) \]

\( S^2\)-sym domain wall

\( A \) effective \( D=8 \)

\( S^2\)-compatif.

\( \Phi \)

\( A \) II A

\( F_2 \sim \text{vol}(S^2) \Rightarrow \text{can view as } S^3 \)

compactification of \( D=11 \)

super \( \rightarrow \text{SU}(2) \) gauged

\( D=8 \) super \( A \) Schon-Sezgin
Intersecting brane horizons

Add $IIB$-string to NS-5-brane to cancel dilatino dependence. Dualize to $IIA$ and lift to $D=11$ to get $(1|M_2, HS)$ intersection.

\[ \text{Hik}_{11} \xrightarrow{(1|M_2, HS)} \text{ads}_3 \times S^3 \times \text{IE}^4 \]

\[ \frac{\lambda}{2} \text{ susy} \]

\[ \text{susy doubling} \]

Add $M$-brane

\[ \text{Hik}_{11} \xrightarrow{(1|HW, M_2, HS)} \text{ads}_3 \times S^3 \times \text{IE}^4 \]

\[ \frac{q}{\lambda} \text{ susy} \]

\[ \text{4-fold increase in susy near horizon!} \]

\[ \text{(Gentile) (Myers) (KST)} \]
Tangerlini BH in D=5

Duality \((1|\text{MW, H}_2, \text{M}_5)\) to \((0|\text{H}_2, \text{H}_2, \text{H}_2)\) \& wrap \text{H}_2's on \(T^6\) to get extreme \(D=5\) BH

\[ \text{M}_5 \xrightarrow{Tangerlini} \text{ads}_2 \times S^3 \]

\[ \text{any doubling} \]

But what is near-horizon supergroup?

- Find Killing spinors \(\mathbf{E}\)
- \(\mathbf{E} \in \mathfrak{e} \rightarrow \text{Killing vectors in } \{\mathbf{Q, Q}\} \)

Result \(\text{(HAMILTON, MEYERS, PKT)}\)

\[ \text{SU}(1,1|2) \times \text{SU}(2) \]

- exactly same as for \(D=4\) RN BH
- not in any algebra
Add rotation (Breckenridge, Myers, Pest\textsuperscript{x} Vafa)

\[ D = 4 \quad \text{rotation group} = \text{SO}(3) \Rightarrow 1 \quad \text{rotation parameter} \]
\[ D = 5 \quad \text{"} = \text{SO}(4) \Rightarrow 2 \quad \text{" parameters} \]

But \( \text{sway + non-singlet \& horizon} \Rightarrow 1 \quad \text{constraint} \)

\[ \therefore \quad J = 0 \quad \text{if} \quad D = 4 \quad \text{but one-parameter (}J\text{) family} \]

\( \uparrow \) rotating suay \( D = 5 \) BHs.

[N.B. Sway \( \Rightarrow \) horizon has zero angular velocity \( \therefore \) Any \( \text{man.} \)

\( \text{carried by fields outside horizon} \)]

\[ ds^2 \quad \overset{\text{near horizon}}{\approx} \quad - \left( p \, dt + \frac{i}{2} \, \sigma_3 \right)^2 + \left( \frac{dp}{p} \right)^2 + dS_3^2 \]

\[ \uparrow \]

one of 3 left invariant forms of \( \text{SU}(2) \approx S^3 \)

\[ \Rightarrow \text{Horizon (at fixed } t) \text{ is squashed 3-sphere} \]

\( |J| < 1 \)
Near-horizon supersymmetry

Supergravity is restored near horizon for all $|J| < 1$ (Kallosh-Rejnows-Weg.)

Supergroup can be deduced from Killing spinors, as in $J=0$ case. Result is

\[
SU(1,1|2) \times U(1)
\]

exactly as for $J=0$. $J \neq 0$ has broken $SU(2)$ to $U(1)$.

Still have isometry supergroup of adS$_2$ ($\Rightarrow$ superconformal mechanics on boundary) even though spacetime does not have adS$_2$ factor.
'Intersecting' horizons (Coward, PKT)

Return to $\text{IIB-1, NS-5}$ and add $\text{NS-5-brane}$

Can approach just one $5$-brane or both

(String basis: $f_{\alpha} = H_5 H_5'$)

Now one $5$-brane recover previous $\text{ads}_3 \times S^3$

in both $5$-branes we find

$\text{ads}_3 \times S^3 \times S^3 \times E$

\[\text{ratio of radii } \equiv \text{ ratio of charges } = \alpha\]

$\text{ads supergroup } = \frac{D(2, 1, \alpha) \times D(2, 1, \alpha')}{\text{Boonstra, Reiter, Skenderis}}$
$S^3 \times S^3$ compactifications

$S^3 \times S^3$ compact. of $N=1$ D=10 super yields $SO(4)$ gauge

D = 4 super of Freedman-Schwarz + $SO(4)$ SYM

(Antoniadis, Bouchay & Sagnotti)

Chansemine & Volkov.

\[ V \sim (g_a^2 + g_b^2) e^\phi \]

\[ su(2)_A \times su(2)_B \cong so(4) \] coupling constants

This theory has 1-brane and 2-brane (domain wall).
Combine to eliminate $\phi$-dependence $\Rightarrow$ 'intersecting'
brane of FS model with $adS_3 \times \mathbb{R}^1$ near horizon

Q. What is effective D=4 super for $S^3 \times S^3$ compactification
of IIB theory? Need $SO(4) \times SO(4)$ gauged theory
that truncates to FS model. Candidate is Hull's
$SO(4,4)$ gauged $\mathcal{N}=8$ super
Add H-wave x dim. reduce to get $D = 8$ generalization

& $D = 5$ rotating BH

For zero rotation, near horizon, geometry is

\[ \text{ads}_2 \times S^3 \times S^3 \]

Supergroup is $D(2,1,\alpha) \times SU(2) \times SU(2)$

\[ U \]

$SE(4|4) \times SU(2) \times SU(2)$

$\alpha =$ relative weight

Conjecture (Calc. in progress). With rotation, $J, J_1 \neq 0$ horizons are squashed $S^3 \times S^3$, and supergroup is

\[ D(2,1,\alpha) \times U(1) \times U(1) \]
New horizons (Gentle, Myers, PRT)

Start from M-theory dual

\[ \text{Mat}_{11} \xrightarrow{(11\, M2, M5, H5)} \text{ads}_3 \times S^3 \times S^3 \times \mathbb{R}^2 \]

and add rotation.

Each 4-plane \( \rightarrow \) 1 sugy rotation parameter

\( \Rightarrow \) two parameters, \( J, J' \)

New horizon metric is

\[ ds^2 \sim \left( \varphi^2 du + J_0 \Delta + J_0' \Delta' \right)^2 du + \left( \frac{d\varphi}{f} \right)^2 + ds^2(\mathbb{R}^2) \]

\[ + R^2 d\Omega_2^2 + R' \, d\Omega_2'^2 \]

radii \( R/R' = \alpha \)

No longer a product of \( \text{ads}_3 \times \ldots \sqrt{ } \) when either \( J \) or \( J' \) is non-zero.

(\text{after } S^1\text{-compactification:})

(see next transparency)