Title: One Ring to Rule Them All and in the Darkness Bind Them

Date: Oct 19, 2004 10:00 AM

URL: http://pirsa.org/04100014

Abstract:

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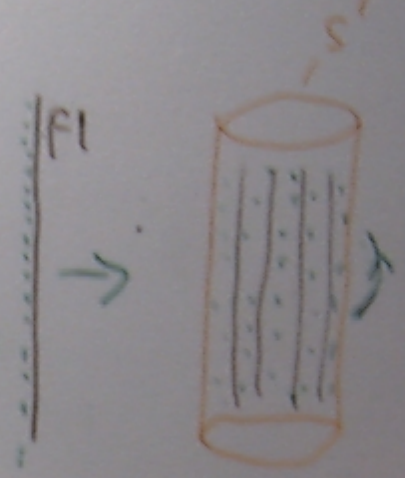
OUTLINE

- BACKGROUND + MOTIVATION
- HOW TO CONSTRUCT BLACK RINGS AND 3 CHARGE SUPERTUBES
  - D BRANE PHYSICS
  - SUPERGRAVITY SOLUTIONS
- HOW TO DESCRIBE THEM IN M
- WHAT DO THEY TELL US ABOUT BLACK HOLE PHYSICS
- WHY THE TITLE

AS 2 CHARGE SUPERTUBES

D0
F1
(J)

→ D2 BRANE

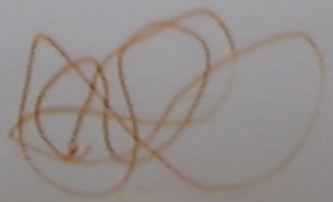


$H = Q_1 + Q_0$

8 SUPERCHARGES

SUPERTUBES PRESERVE THE SAME SUSY AS THEIR COMPONENTS

CROSS SECTION NEEDS NOT BE S^1. ANY CLOSED CURVE GIVES A BPS CONFIGURATION



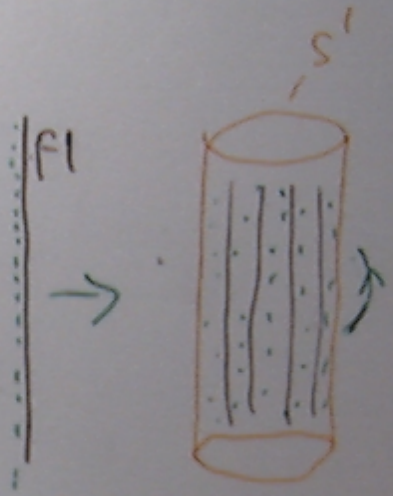
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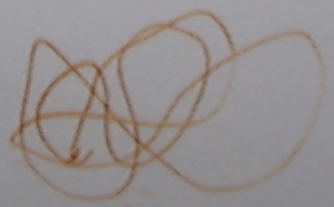


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BPS
8 SUPERCHARGES
(D0, F1)
$H = Q_1 + Q_0$

D0 BRANE DIPOLE CHARGE HAS NO EFFECT

(3) DUALIZE

D0 - F1 → D2

D4 - F1 → D6

D0 - D4 → NS5

D1 - D5 → KKM

F - P → WAVE

MATHUR + FRIENDS:

MICROSTATES OF D1-D5 SYSTEM ARE IN 1 TO 1 CORRESPONDANCE WITH CLASSICAL GEOMETRIES

DIFFERENT SHAPES OF THE CURVE ON WHICH KKM IS WRAPPED

$1000 QUESTION:

CAN WE SAY THE SAME ABOUT MICROSTATES OF THE D1-D5-P SYSTEM ???

A4 IF SO, THIS WOULD CHANGE OUR UNDERSTANDING OF BLACK HOLES.....

BLACK HOLE ~ "STATISTICAL AVERAGE" OF REGULAR GEOMETRIES

HAIR

- THESE GEOMETRIES START DIFFERING FROM EACH OTHER AROUND THE RADIUS WHERE BH HORIZON IS
- OTHER "AVERAGES" OF REGULAR GEOMETRIES GIVE OTHER OBJECTS WITH BLACK HOLE PROPERTIES

IMMEDIATE QUESTIONS:

- CONSTRUCT "HAIR" ✓ PK IB
- COMPARE SIZES ✓ PK IB
- COUNT CAN BE DONE
- FIND FULL SOLUTION V E.E.M.R. G.G., G.M.

(FOR ARBITRARY SHAPES) V NW. IB

- DO BPS BLACK RINGS (OF PERHAPS ARBITRARY SHAPES) V EEMR BW

UNDERSTANDING OF BLACK HOLES.....

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(FOR ARBITRARY SHAPES)

- DO BPS BLACK RINGS (OF PERHAPS ARBITRARY SHAPE) EXIST ✓ EEMR, BW
- ENTROPY OF BLACK RINGS ✓ PK. IB

UNDERSTANDING OF BLACK HOLES.....

BLACK HOLE ~ "STATISTICAL AVERAGE" OF REGULAR GEOMETRIES

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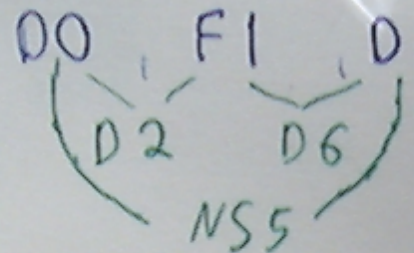
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AG 3 CHARGE SUPERTUBES



CHARGES
DIPOLE MOMENTS

	1	2	3	4	5	θ
D0						
F1	x					
D4		x	x	x	x	
D2	x					x
D6	x	x	x	x	x	x
NS5		x	x	x	x	x

D6 BORN INFELD ACTION
D4 NONABELIAN B.I. ACTION > 2 DESCRIPTIONS

NO NS5 CHARGE, ONLY 2 DIPOLES
CAN BE DUALIZED INTO ANY OTHER
3 CHARGE TUBE WITH 2 DIPOLES - D2·D6
D2·NS5
D6·NS5

C5

D6 WORLDVOLUME

F_{01} F1 CHARGE

F_{10} D4

$F_{23} \wedge F_{45}$ D2

$F_{10} \wedge F_{23} \wedge F_{45}$ D0

ABSENT FOR 2 CHARGES

$$S = -T_6 \int d^7x \sqrt{(1-F_{01}^2) g_{00} + F_{10}^2} \sqrt{(1+F_{23}^2)(1+F_{45}^2)}$$

$$Q_1 \sim \frac{F_{01} g_{00}}{\sqrt{(1-F_{01}^2) g_{00} + F_{10}}} \sqrt{(1+F_{23}^2)(1+F_{45}^2)}$$

CHOSE $F_{01} = 1$, $F_{23} = F_{45}$

$$H = \int Q_1 F_{01} - L = \int Q_1 + F_{10}(1 + F_{23} F_{45})$$

$$= \int Q_1 + Q_4 + Q_0$$

BPS INDEPENDENT ON g_{00} !!!

CIRCULAR

AG $H = \int Q_1 + Q_0 + Q_4$ - BPS INDEPENDENT OF SHAPE

$$R^2 \simeq g_s^2 \frac{Q_1 Q_4^2}{Q_0 + Q_4} \sim g_s \frac{N_1 N_4^2}{N_0 + N_4}$$

REMARK:

AS g_s INCREASES, THE RADIUS OF THE TUBES INCREASES!!!

HENCE NO "CORRESPONDENCE POINT".

GEOMETRIES SHOULD DESCRIBE B.H. MICROSTATES IN REGIME WHERE GRAVITY IS WEAK.

IF MORE THAN 1 D6 BRANE

$$R^2 \sim \frac{g_s}{n_6} \frac{N_1 N_4^2}{N_0 + N_4}$$

ALSO, D2 AND D6 DIPOLE MOMENTS ARE RELATED BY

$$\frac{d_2}{d_6} = \frac{Q_0}{Q_4}$$

GENERALIZED

D2-D6 $\rightarrow$ D2-NS5 , D6-NS5

3 DIPOLE CHARGE TUBE CAN BE DESCRIBED

A7 TUBES CAN ALSO BE CONSTRUCTED USING NBI ACTION OF D4 BRANES

(FIELD STRENGTHS = DIAGONAL - INDEPENDENT OF SYMMETRIZED TRACE)

COMPARE TUBES TO BLACK HOLES

ROTATING D1-D5-P SYSTEM $\leftrightarrow$ BMPV BLACK HOLE

$$J_{23}^{BH} = J_{45}^{BH} \leq (N_1 N_5 N_p)^{1/2} \qquad S = 2\pi\sqrt{N_1 N_5 N_p - J^2}$$

$$J_{23}^{T} = 0 \,, \quad J_{45} \leq N_1 N_5 / m_K$$

PROPER LENGTH OF HORIZON CIRCUMFERENCE

$$R^2_{BMPV} \sim g_s \frac{N^3 - J^2}{N^2} \qquad N_1 = N_5 = N_p = N$$

SAME GROWTH

$$R^2 \sim g_s \frac{J^2}{N}$$

USING NBI ACTION OF D4 BRANES

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$$\Lambda^2_{BMPV} \sim g_s \frac{N^3 - J^2}{N^2} \qquad N_1 = N_5 = N_P = N$$

$$\Lambda^2_{TUBE} \sim g_s \frac{J^2}{N^2}$$

SAME GROWTH ☑

A8

A BIT OF AdS-CFT

$J_{BMPV} \leq \sqrt{N_p N_1 N_5} < N_1 N_5$

CONSIDER $N_p < N_1 N_5$

THERE ARE QUITE A FEW C.F.T. STATES WITH $J > J_{BMPV}$

THESE STATES ARE DUAL TO GEOMETRIES CONTAINING SUPERTUBES (AT LEAST FOR SMALL N_p)

HENCE, SOME CFT STATES MAPPED TO B.H.

SOME ARE DUAL TO GEOMETRIES CONTAINING SUPER TUBES.

DISTINCTION IS RATHER ARBITRARY !!!

THE "ONE GEOMETRY PER MICROSTATE" PICTURE MAKES MUCH MORE SENSE.

Q: IF B.H. CAN BE THOUGHT AS "STATISTICAL AVERAGE" OF GEOMETRIES WITH $J < J_{BMPV}$, IS THERE ANOTHER BLACK OBJECT (BPS BLACK RING PERHAPS) WHICH CAN BE THOUGHT

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LOOKING FOR SOLUTIONS

SWITCH

- 3 CHARGE SUPERTUBE SOLUTIONS ARE HARD TO GET WITH USUAL SOLUTION GENERATING TECHNIQUES.

(PROBLEM CAN BE TRACED TO BOOSTING KKM)

MORE POWERFUL METHODS NEEDED

KEY INGREDIENT : SUPERTUBES PRESERVE SAME SUSY AS THEIR COMPONENT BRANES

KEY METHOD (WARNER, NEMESCHANSKY, PILCH 2.00)

USE KILLING SPINORS AND THEIR PROJECTORS TO FIND FIRST ORDER RELATIONS BETWEEN METRIC AND FORMS

METHOD IS VERY POWERFUL. CAN BE USED FOR MUCH MORE COMPLICATED SETUPS.

- FIND METRIC OF FLAT 3-CHARGE 3-DIPOLE CHARGE TUBE + BLACK RING
- FIND SOLUTION FOR ARBITRARY

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- FIND METRIC OF FLAT 3-CHARGE 3-DIPOLE CHARGE TUBE + BLACK RING

FIND SOLUTION FOR ARBITRARY SHAPE

A 10

STRATEGY:

LOOK FOR SOLUTIONS PRESERVING SAME SUSY AS 3 CHARGE B.H.

ONCE YOU KNOW THE SPINORS YOU CAN FIND SOLUTIONS VERY EASILY

	1	2	3	4	5	6	7	8	9	10	11	
M2	x	x	x									Q_1
M2	x			x	x							Q_2
M2	x					x	x					Q_3
M5	x			x	x	x	x		x			d_1
M5	x	x	x			x	x		x			d_2
M5	x	x	x	x	x				x			d_3

$$\ell^1 = \ell^{-2A_1-2A_2-2A_3}(dx^1 + \vec{K}\cdot d\vec{y})$$

$$\ell^{2,3} = \ell^{-2A_1+A_2+A_3} dx^{2,3}$$

$$\ell^{4,5} = \ell^{+A_1+2A_2+A_3} dx^{4,5}$$

$$\ell^{6,7} = \ell^{A_1+A_2-2A_3} dx^{67}$$

$$\ell^{7+i} = \ell^{A_1+A_2+A_3} dy^i$$

FLAT BASE - MODIFY LATER

$$C^3 = \ell^1\ell^2\ell^3 = \ell^1\ell^{4,5} = \ell^1\ell^6\ell^7 + 2(\vec{a}_i\cdot d\vec{y})dx^a dx^3$$

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	1	2	3	4	5	6	7	8	9	θ	10	11	
M2	x	x	x										Q_1
M2	x			x	x								Q_2
M2	x					x	x						Q_3
M5	x			x	x	x	x			x			d_1
M5	x	x	x			x	x			x			d_2
M5	x	x	x	x	x					x			d_3

$$e^1 = e^{-2A_1-2A_2-2A_3}(dx^1 + \vec{K}\cdot d\vec{y})$$

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FLAT BASE - MODIFY LATER

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$$+ 2(\vec{a}_2 \cdot d\vec{y}) dy^4 \wedge dy^5 + 2(\vec{a}_3 \cdot d\vec{y}) \wedge dy^6 \wedge dy^7$$

A
10

$G_i = *G_i$ $\quad G_i = da_i$ $\quad z_i = e^{6A_i}$

$d*dz_i = 2|\varepsilon^{ijk}|\, G_j \wedge G_k$ ← FLUXES HAVE DISSOLVED CHARGE

$(1+*)dK = 2z_1 G_1 + 2 z_2 G_2 + 2 z_3 G_3$

BASE CAN BE MODIFIED TO ANY HALF FLAT 4-MANIFOLD

QUICK ARGUMENT

$(1+\Gamma^{123})\varepsilon = 0$
$(1+\Gamma^{145})\varepsilon = 0$
$(1+\Gamma^{167})\varepsilon = 0$

$\Rightarrow$

$(1-\Gamma^{89\,10\,11})\varepsilon = 0$

$(\Gamma^{89} + \Gamma^{10\,11})\varepsilon = 0$

- HALF FLAT

SOLUTIONS HAVE 4 LAYERS

- BASE - HALF FLAT
- DIPOLE FIELDS G_i
- $G_i \wedge G_j$ + BRANE DENSITY SOURCE z_K

A
11

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- ANGULAR MOMENTUM

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SYSTEM IS LINEAR!!!

A12

FLAT LIMIT OF BLACK RINGS AND SUPERTUBES REVEALS A LOT OF THEIR PHYSICS

$Q_1\ Q_2\ Q_3\ \ d_1\ d_2\ d_3\ \ J$

DUALIZE ALONG THE TUBE

→ 4d BLACK HOLE

$$S = 2\pi\sqrt{J_4}$$

$$J_4 = X^{ij}y_{jk}X^{kl}y_{li} - \frac{X^{ij}y_{ij}X^{kl}y_{kl}}{4} + \varepsilon^{ijklmnop}\left(X^{ij}X^{kl}X^{mn}X^{op} + y^{ij}y^{kl}y^{mn}y^{op}\right)$$

$X_{12} = Q_1$ $\quad y_{12} = d_1$

$X_{34} = Q_2$ $\quad y_{34} = d_2$

$X_{56} = Q_3$ $\quad y_{56} = d_3$

$X_{78} = 0$ $\quad y_{78} = J$

$J_4 = 0$ - SUPERTUBE

$J_4 > 0$ - BLACK RING

$J_4 < 0$ - C.T.C's

$$ds^2 \sim 2\frac{\Lambda}{R_0}\,dt\,dz + \frac{R_0^2}{\Lambda^2}\,d\Lambda^2 + R_0^2\,d\Omega_2^2 + ds_{T^6}^2$$

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$$J_4 = Q^2d^2 - 16d^4$$

A13

$J_4 > 0$ - REGULAR EVENT HORIZON

$J_4 = 0$ - AdS COMPACTIFIED ALONG NULL DIRECTION

MILD SINGULARITY - WORKING ON RESOLUTION

CURVATURE $\sim \frac{1}{R_0} \sim \frac{1}{(d_1 d_2 d_3)^{1/3}}$

WHAT IS THE REASON FOR WHICH THESE TUBES EXIST ?

LOCALLY THEY ARE DUAL TO 4D BLACK HOLE.

CHARGES J, d_1, d_2, d_3 ARE RELATED

$J = (d_1 + d_2 + d_3) R^2$

THIS ENSURES THAT THE KILLING

$J_4 = 0$ - AdS COMPACTIFIED ALONG NULL DIRECTION

MILD SINGULARITY - WORKING ON RESOLUTION

CURVATURE $\sim \frac{1}{R_0} \sim \frac{1}{(d_1 d_2 d_3)^{1/3}}$

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$J = (d_1 + d_2 + d_3) R^2$

THIS ENSURES THAT THE KILLING SPINORS OF EACH "BIT OF RING" POINT IN THE SAME DIRECTION, REGARDLESS OF ORIENTATION → CAN BE LINKED INTO RINGS OF ANY SHAPE

C
13 WHY SINGULARITY? $J_4 = 0$

AdS_3 ALONG t, r, z

z = DIRECTION ALONG TUBE

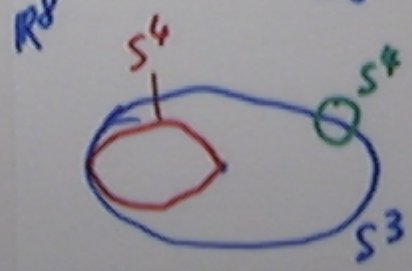
- PERIODIC $z \sim z + 2\pi R$

ONE ENCOUNTERS SUCH SINGULARITIES WHENEVER BRANES WRAPPED ON COMPACT CYCLE

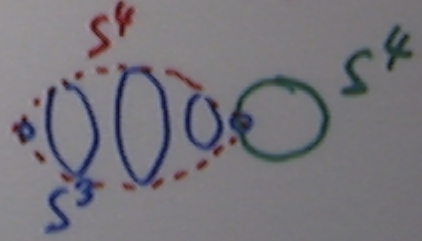
EXAMPLE BEST UNDERSTOOD:

L.L.M. M2 POLARIZED IN $M\bar{5}/S^3$

OPEN STRING (BRANE) PICTURE



CLOSED STRING (GRAVITY) PICTURE



$\int_{S^4} F_4 = N_{M\bar{5}}$

$M\bar{5}$ BRANES / S^3

GEOMETRIC TRANSITION

NO MORE BRANES

TOPOLOGY CHANGE

ONE EXPECTS SAME

Pirsa: 04100014

C 13

WHY SINGULARITY? $J_4 = 0$

AdS_3 ALONG t, r, z

z = DIRECTION ALONG TUBE

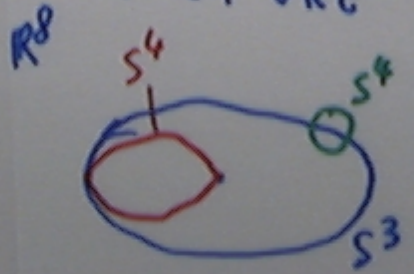
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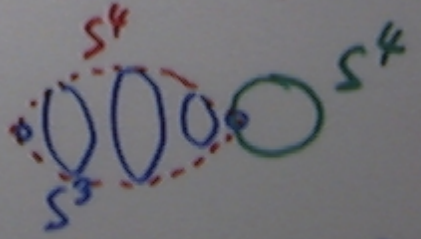
EXAMPLE BEST UNDERSTOOD:

L.L.M. M2 POLARIZED IN $M5/S^3$

OPEN STRING (BRANE) PICTURE



CLOSED STRING (GRAVITY) PICTURE



C
13 WHY SINGULARITY? $J_4 = 0$

AdS_3 ALONG t, r, z

z = DIRECTION ALONG TUBE

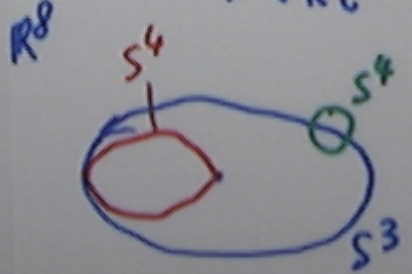
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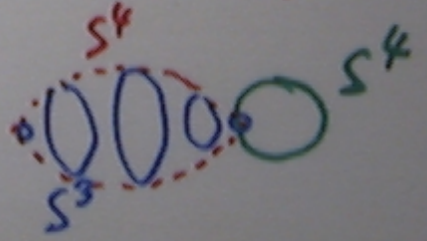
EXAMPLE BEST UNDERSTOOD:

L.L.M. M2 POLARIZED IN $M\bar{5}/S^3$

OPEN STRING (BRANE) PICTURE



CLOSED STRING (GRAVITY) PICTURE



$\int_{S^4} F_4 = N_{M\bar{5}}$

GEOMETRIC TRANSITION

NO MORE BRANES TOPOLOGY CHANGE

AdS_3 ALONG $x_1, \ldots, x_6$

z = DIRECTION ALONG TUBE

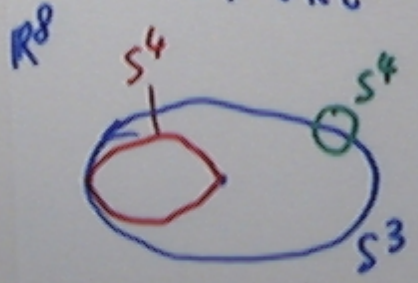
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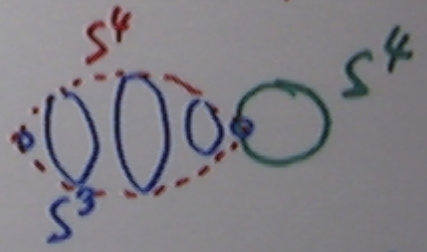
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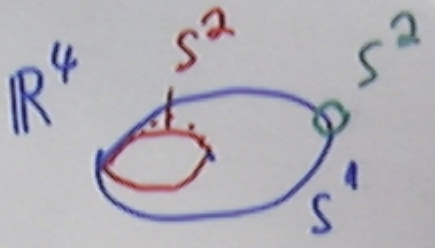


GEOMETRIC TRANSITION

NO MORE BRANES TOPOLOGY CHANGE

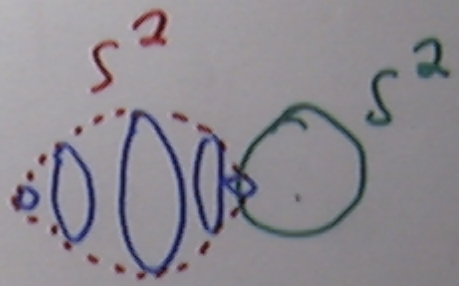
ONE EXPECTS SAME PICTURE HERE

0
13



RING ON S^1

$\int_{S^2} F_{03}\, i_8 = d_{03}$ ETC



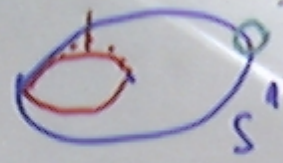
NC MORE BRANES
TOPOLOGY CHANGE
$S^2 . S^2$ - NON CONTRACTIBLE

.THUS BASE SPACE CHANGES TOPOLOGY
- BRANES - GONE JUST FLUXES

IN U(1)xU(1) CASE - THIS MATCHES SOLUTIONS FOUND BY MATHUR ET AL BY DIFFERENT METHODS

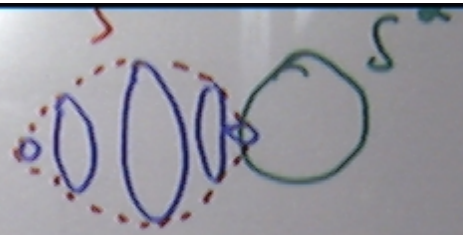
NEW BASE - GIBBONS HAWKING WITH 2 CENTERS.

13 $\mathbb{R}^4$ S^1



RING ON S^1

$\int_{S^2} F_{23}\, ig = d_{23}$ ETC



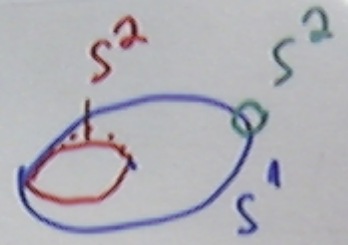
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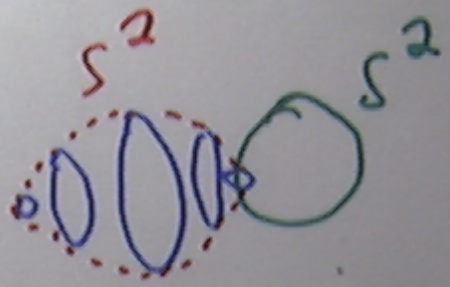
NEW BASE - GIBBONS HAWKING WITH 2 CENTERS.

0
13



RING ON S^1

$\int_{S^2} F_{33}\, ig = d_{33}$ ETC



NC MORE BRANES
TOPOLOGY
CHANGE
$S^2 . S^2$ - NON CONTRACTIBLE

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IN U(1)xU(1) CASE - THIS MATCHES
SOLUTIONS FOUND BY MATHUR ET AL
BY DIFFERENT METHODS

NEW BASE - GIBBONS HAWKING
WITH 2 CENTERS.

A14 CHARGES ON RING DIFFERENT FROM CHARGES AT INFINITY

$$Q_1 = \bar{Q}_1 + d_2 d_3$$
$$Q_2 = \bar{Q}_2 + d_1 d_3$$
$$Q_3 = \bar{Q}_3 + d_1 d_2$$
$$J_{23} = J_T + J_{BMPV}$$
$$J_{45} = J_{BMPV}$$

CHARGES DISSOLVED IN FLUXES VIA SUGRA C.S. TERM

LIKE IN THE JSEYTOV KLEBANOV STRASSLER FLOWS

REMEMBER $\Box Z_1 = *(G_2 \wedge G_3)$ ETC.

HUGE NUMBER OF CHOICES FOR SAME CHARGES AT ∞ !!!

JUST FOR $U(1) \times U(1)$ INVARIANT RINGS

NON CIRCULAR BLACK RINGS - VIOLATE B.H. UNIQUENESS EVEN

FROM CHARGES AT INFINITY

$$Q_1 = \bar{Q}_1 + d_2 d_3$$
$$Q_2 = \bar{Q}_2 + d_1 d_3$$
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JUST FOR $U(1) \times U(1)$ INVARIANT RINGS

NON CIRCULAR BLACK RINGS - VIOLATE B.H. UNIQUENESS EVEN MORE COPIOUSLY

AM

SUPERTUBES WITH S=0

SPECIFY 7 FUNCTIONS:

$\vec{\rho}_1(\psi)$ $\rho_2(\psi)$ $\rho_3(\psi)$ — CHARGE DENSITIES

$x_8(\psi)$ $x_{10}(\psi)$
$x_9(\psi)$ $x_{11}(\psi)$ — SHAPE MODES

1 LOCAL CONSTRAINT

$J_4(\rho_1, \rho_2, \rho_3, d_1, d_2, d_3) = 0$ | 6 FUNCTIONS

FOR BLACK RINGS

$J_4 > 0$ | 7 FUNCTIONS

A LOT MORE BLACK RINGS THAN MICROSTATE GEOMETRIES

2 OPTIONS

- SUPERTUBES ARE A SMALL SUBSET OF STATES
- A BLACK RING IS DUAL TO SET OF MICROSTATES

SPECIFY 7 FUNCTIONS:

$\bar{Q}_1(\psi)$ $Q_2(\psi)$ $Q_3(\psi)$ — CHARGE DENSITIES

$X_8(\psi)$ $X_{10}(\psi)$
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1 LOCAL CONSTRAINT

$J_4(Q_1, Q_2, Q_3, d_1, d_2, d_3) = 0$ | 6 FUNCTIONS

FOR BLACK RINGS

$J_4 > 0$ 7 FUNCTIONS

A LOT MORE BLACK RINGS THAN MICROSTATE GEOMETRIES

2 OPTIONS

- SUPERTUBES ARE A SMALL SUBSET OF STATES
- A BLACK RING IS DUAL TO SET OF MICROSTATES

NUMBER OF SETS > NUMBER OF POINTS

~~18~~ A 16

HOW WOULD WE COUNT

$Q<4d$

NO REGULAR GEOMETRY

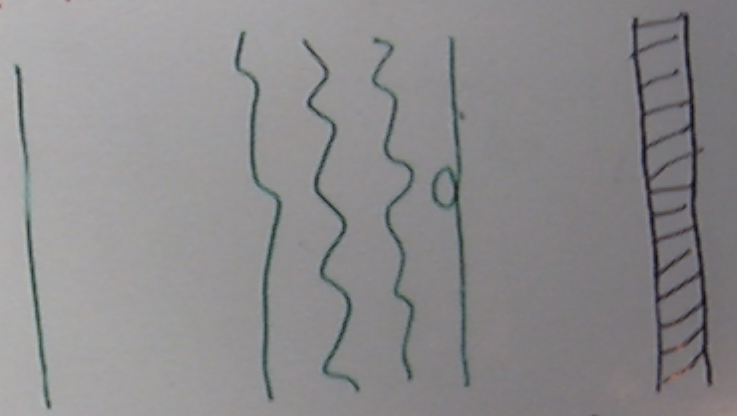
$Q_i = Q$

$d_i = d$

$J_4 = Q^2 d^2 - 16 d^4$

$Q=4d$

$Q>4d$



STRAIGHT TUBE

WIGGLY TUBES

BLACK RING

$Q=4d$ - 1 GEOMETRY $S=0$

$Q>4d$ - NR. OF GEOMETRIES STARTS INCREASING

HORIZON AREA ALSO STARTS INCREASING

IF THE "ONE GEOMETRY PER MICROSTATE" PICTURE IS TRUE, THEN COUNTING OF TUBES SHOULD GIVE BLACK RING ENTROPY.

DON + BELKIS COUNTED USING BI ACTION

HOW WOULD WE COUNT

A 16

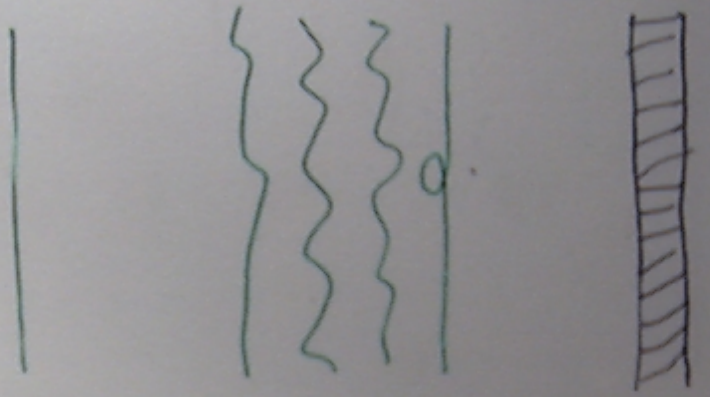
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DON + BELKIS COUNTED USING BI ACTION PER KRAUS → OPEN STRING COUNT

MASAKI SHIGEMORI

~~A~~ HOW WOULD WE COUNT

A 16

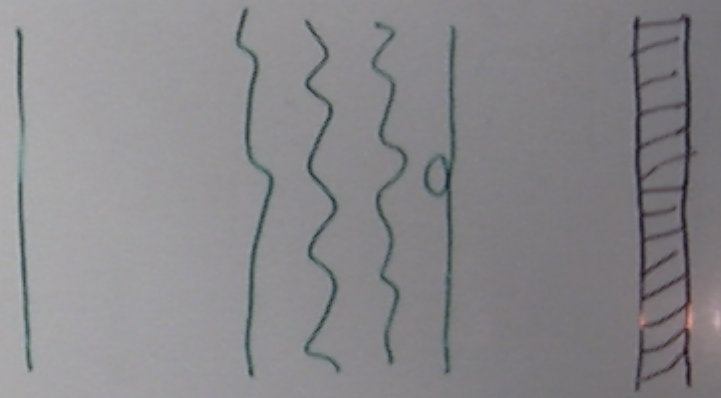
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STRAIGHT TUBE

WIGGLY TUBES

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HOW WOULD WE COUNT

A 16

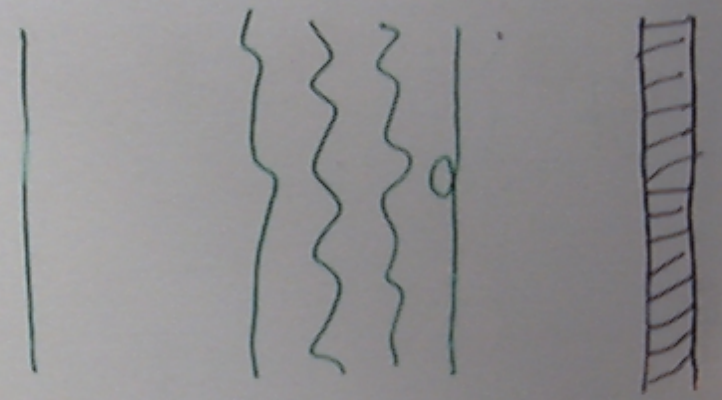
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STRAIGHT TUBE

WIGGLY TUBES

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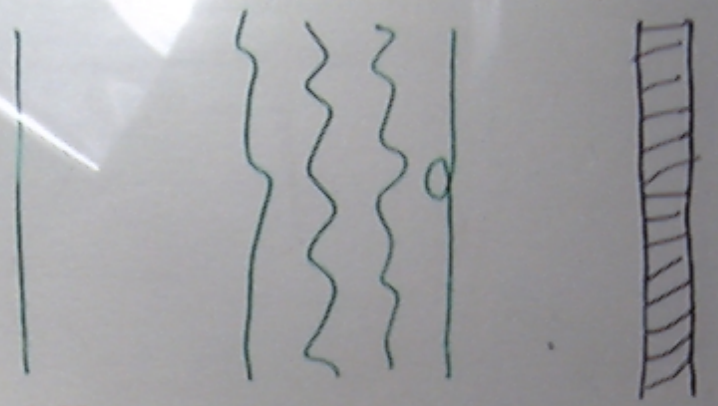
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16 NO REGULAR GEOMETRY

$Q_i = Q$

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$J_4 = Q^2 d^2 - 16 d^4$



STRAIGHT TUBE

WIGGLY TUBES

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$Q = 4d$ - 1 GEOMETRY $S = 0$

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IF THE "ONE GEOMETRY PER MICROSTATE" PICTURE IS TRUE, THEN COUNTING OF TUBES SHOULD GIVE BLACK RING ENTROPY.

DON + BELKIS COUNTED USING BI ACTION PER KRAUS → OPEN STRING COUNT MASAKI SHIGEMORI

NONE WORKS FOR 3 DIPOLE CHARGES (NS5 BRANES) COUNT IN GEOMETRY

17

BLACK RINGS IN AdS-CFT

DUALIZE TO D1-D5-P

$Q_1 = D1 \quad Q_2 = D5 \quad Q_3 = P$

$d_1 = D5 \quad d_2 = D1 \quad d_3 = KKM$

REMEMBER $\quad Q_1^{\infty} = \bar{Q}_1 + d_2 d_3$

$$J_\phi \equiv J_{BMPV} = -\frac{1}{2}(\bar{Q}_1 d_1 + \bar{Q}_2 d_2 + \bar{Q}_3 d_3) - d_1 d_2 d_3$$

$$J_\psi = -J_{BMPV} + J_{TUBE}$$

$$J_{TUBE} = (\ )(d_1 + d_2 + d_3) R^2$$

TAKE NEAR HORIZON LIMIT



DUALIZE TO D1-D5-P

$Q_1 = D1 \quad Q_2 = D5 \quad Q_3 = P$

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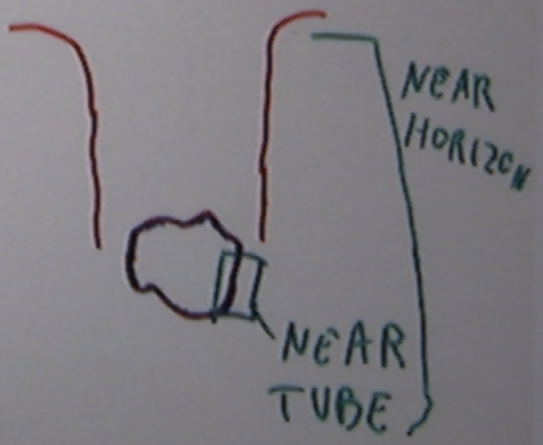
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$$J_\psi = -J_{BMPV} + J_{TUBE}$$

$$J_{TUBE} = (\ )(d_1 + d_2 + d_3) R^2$$

TAKE NEAR HORIZON LIMIT



C 17

LIGHTNING REVIEW OF D1-D5-P SYSTEM

AT ORBIFOLD POINT

EFFECTIVE STRING OF LENGTH $N_1 N_5$

BROKEN INTO INTEGER LENGTH PARTS

EACH COMPONENT HAS 4 FERMIONS

2 - DOUBLET OF $SU(2)_R$

2 - —1— $SU(2)_L$

$SO(4) = SU(2)_L \times SU(2)_R$ $\quad J_L = J_\psi - J_\phi$

$J_R = J_\psi + J_\phi$

GROUND STATE

$J_L = \pm 1 \quad J_R = \pm 1$ PER COMPONENT

ADD MOMENTUM

$J_L = 0 \quad J_R \neq 0$

A 18

LUMIN MATHUR

D1-D5 → KKM SUPER TUBE

$Q_3 = d_1 = d_2 = 0$

$J_\phi = 0 \qquad J_\psi = \frac{Q_1 Q_2}{d_3} \qquad R = \frac{\sqrt{Q_1 Q_2}}{d_3}$

BREAK EFFECTIVE STRING IN $\frac{Q_1 Q_2}{d_3}$ COMPONENTS OF LENGTH d_3

SINCE EACH COMPONENT CAN HAVE ITS J_0 IN ANY WAY, ONE CAN GET ALL VALUES OF $J < J_\psi$

- $U(1) \times U(1)$ INVARIANT TUBE HAS J_0'S OF ALL COMPONENTS ALIGNED

BMPV BLACK HOLE

ONE COMPONENT STRING

MOMENTUM CARRIED BY LEFTMOVING FERMIONS

$-J_\phi = J_\psi \qquad S = 2\pi\sqrt{Q_1 Q_2 Q_3 - J_\phi^2}$

$Q_3 = d_1 = d_2 = 0$

$J_\phi = 0 \qquad J_\psi = \frac{Q_1 Q_2}{d_3} \qquad R = \frac{\sqrt{Q_1 Q_2}}{d_3}$

BREAK EFFECTIVE STRING IN $\frac{Q_1 Q_2}{d_3}$ COMPONENTS OF LENGTH d_3

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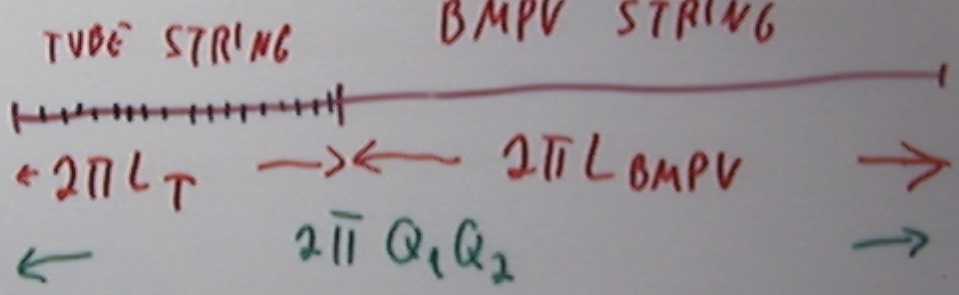
A 19

WHAT ABOUT BLACK RING

ITS ANGULAR MOMENTUM HAS BOTH BMPV-LIKE AND SUPERTUBE-LIKE PARTS

MACROSCOPIC ENTROPY DOES NOT COME FROM SHORT COMPONENT STRINGS, OF THE TYPE SUPERTUBE HAS.

DIVIDE EFFECTIVE STRING



TUBE STRING HAS COMPONENTS OF LENGTH ℓ_c $\quad \frac{L_{TUBE}}{\ell_c} = J_{TUBE}$

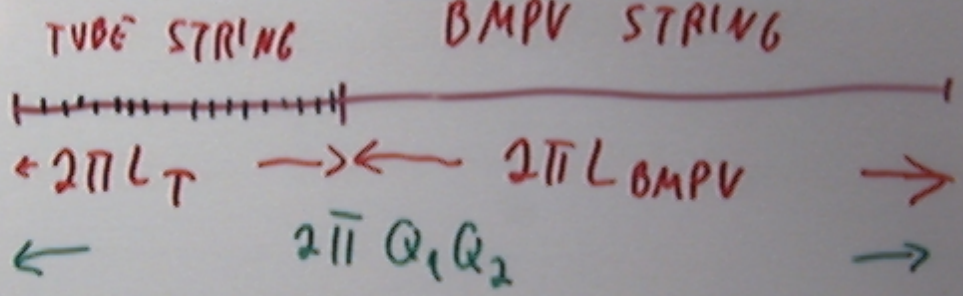
BMPV STRING CARRIES MOMENTUM, J_{BMPV}, AND HAS ENTROPY

$$S = 2\pi\sqrt{L_{BMPV} Q_3 - J_{BMPV}^2}$$

ITS ANGULAR MOMENTUM HAS BOTH BMPV-LIKE AND SUPERTUBE-LIKE PARTS

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BMPV STRING CARRIES MOMENTUM, J_{BMPV}, AND HAS ENTROPY

$$S = 2\pi\sqrt{L_{BMPV} Q_3 - J_{BMPV}^2}$$

A 20

PARAMETERIZE ANGULAR MOMENTA

$$J_{TUBE} = \frac{\bar{Q}_1 \bar{Q}_2}{d_3} - \delta \qquad J_{BMPV} = -d_3 Q_3 + \nu$$

$$S = 2\pi\sqrt{\mathcal{I}_4} = 2\pi\sqrt{d_1 d_2 d_3 \delta - \nu^2}$$

INCREASE COMPLEXITY

$\delta = \nu = 0$ $\quad \ell_c = d_3$ - LIKE IN SUPERTUBE WITH 2 CHARGES

$$L_{TUBE} = \bar{Q}_1 \bar{Q}_2 \qquad L_{BMPV} = Q_1 Q_3 - \bar{Q}_1 \bar{Q}_2 = d_3^2 Q_3$$

J_{BMPV} COMES FROM FILLING UP FERMI SEA: $J_{BMPV} = -\sqrt{L_{BMPV} Q_3} = -Q_3 d_3$

$S = 0$

$\nu = 0, \delta \neq 0$ $\quad S = 2\pi\sqrt{d_1 d_2 d_3 \delta}$

ℓ_c IS NOT EQUAL TO d_3 ANY MORE

PHENOMENOLOGICAL ASSUMPTION:

TESTABLE VIA TIME

A 20 PARAMETERIZE ANGULAR MOMENTA

$$J_{TUBE} = \frac{\bar{Q}_1 \bar{Q}_2}{d_3} - \delta \qquad J_{BMPV} = -d_3 Q_3 + \nu$$

$$S = 2\pi\sqrt{J_4} = 2\pi\sqrt{d_1 d_2 d_3 \delta - \nu^2}$$

INCREASE COMPLEXITY

$\delta = \nu = 0$ $\quad \ell_c = d_3$ - LIKE IN SUPERTUBE WITH 2 CHARGES

$$L_{TUBE} = \bar{Q}_1 \bar{Q}_2 \qquad L_{BMPV} = Q_1 Q_3 - \bar{Q}_1 \bar{Q}_2 = d_3^2 Q_3$$

J_{BMPV} COMES FROM FILLING UP FERMI SEA: $J_{BMPV} = -\sqrt{L_{BMPV} Q_3} = -Q_3 d_3$

$S = 0$

$\nu = 0, \delta \neq 0$ $\quad S = 2\pi\sqrt{d_1 d_2 d_3 \delta}$

ℓ_c IS NOT EQUAL TO d_3 ANY MORE

A 21

SAME PHENOMENOLOGICAL ASSUMPTION COMES FROM MATCHING ℓ_c FOR ZERO ENTROPY STATES

$\gamma \neq 0, \delta \neq 0$ $\quad S_{RING} = S_{CFT}$

NEAR RING GEOMETRY (IIB FRAME) $\quad AdS_3 \times T^4 \times S^2 \times S^1$

UV CFT $\quad c_{UV} = 6 Q_1 Q_2$

IR CFT $\quad c_{IR} = 6 d_1 d_2 d_3$

$Q_1 > d_2 d_3 \quad (\bar{Q}_1 > 0)$

$Q_2 > d_1 d_3$

$d_3 > 1$

$c_{UV} > c_{IR}$

RG FLOW BETWEEN 2 AdS_3 SPACES

CONCLUSIONS + FUTURE DIRECTIONS

- 3 CHARGE SUPERTUBES AND BLACK RINGS - D BRANES
  - SIZE GROWS WITH g_s
- SUGRA SOLUTIONS
  - LINEAR SYSTEM
  - CHARGES DISSOLVED IN FLUXES
  - ARBITRARY SHAPED BLACK RINGS
  - 4D BLACK HOLE BITS
  - BLACK HOLE UNIQUENESS DOWN THE DRAIN
- AdS-CFT DESCRIPTION
  - EFFECTIVE STRING BREAKS INTO TWO PARTS (TUBE ΔJ / BMPV ENTROPY)

TO DO

- SINGULARITY RESOLUTION (4D BH TRANSITION)
- COUNT
- IMPROVE AdS-CFT DESCRIPTION
- MORE SOLUTIONS
- PROTEC[illegible] (MAY HAVE SAME FATE AS BH UNIQUENESS)

22.

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$\Pi = \sum Q_1 + Q_0 + Q_4$ - BPS INDEPENDENT OF SHAPE

$$\Pi^2 \simeq g_s^2 \frac{Q_1 Q_4^2}{Q_0 + Q_4} \sim g_s \frac{N_1 N_4^2}{N_0 + N_4}$$

REMARK:

AS g_s INCREASES, THE RADIUS OF THE TUBES INCREASES!!!

HENCE NO "CORRESPONDENCE POINT".

GEOMETRIES SHOULD DESCRIBE B.H. MICROSTATES IN REGIME WHERE GRAVITY IS WEAK.

IF MORE THAN 1 D6 BRANE

$$\Pi^2 \sim \frac{g_s}{N_6} \frac{N_1 N_4^2}{N_0 + N_4}$$

ALSO, D2 AND D6 DIPOLE MOMENTS ARE RELATED BY

$$\frac{d_2}{d_6} = \frac{Q_0}{Q_4}$$

GENERALIZED

D2-D6 $\rightarrow$ D2-$\overline{\text{NS5}}$, D6-$\overline{\text{NS5}}$

3 DIPOLE CHARGE TUBE CAN BE DESCRIBED AS BOUND STATE OF 2 OF THESE TUBES.

OF SHAPE

$$R^2 \simeq g_s^2 \frac{Q_1 Q_4^2}{Q_0 + Q_4} \sim g_s \frac{N_1 N_4^2}{N_0 + N_4}$$

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