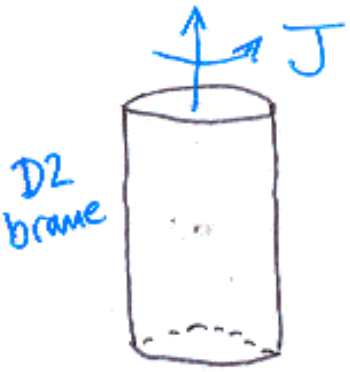
BLACK RINGS

Henriette Elvang

WORK WITH:

Roberto Emparan
Harvey Reall
David Mateos
Pau Figueras

Two new objects discovered in 2001:

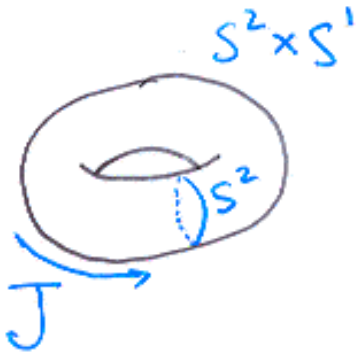


2-charge supertube

D0-F1 system blown up to D2-brane by angular momentum.

- Worldvolume description [Mateos & Townsend '02]
- 10D supergravity description [Emparan, Mateos & Townsend '01]

RELATED? YES!



Black ring

5D vacuum solution
Asymptotically flat
black hole with $S^2 \times S^1$ horizon
[Emparan & Reall]

OUTLINE:

§1. BLACK RINGS AND SUPERTUBES

→ how 2-charge supertubes are related to non-supersymmetric black rings.

§2: NON-SUPERSYMMETRIC BLACK RINGS WITH 3 CHARGES

→ known solutions and conjectures.

§3: SUPERSYMMETRIC 3-CHARGE BLACK RINGS

→ properties

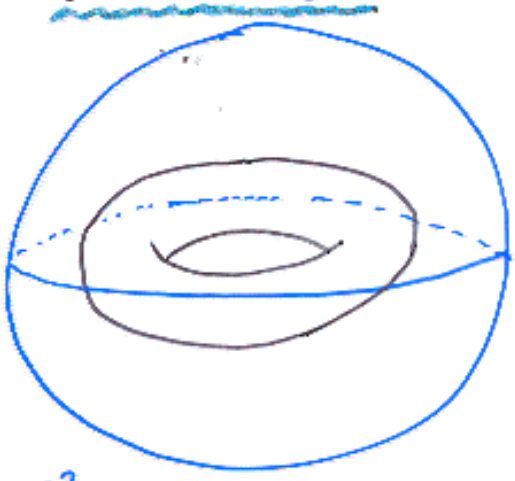
→ AdS / CFT

§4: SUMMARY & OUTLOOK

§1. CHARGES OF 4+1D BLACK RINGS

Two electric charges:

CONSERVED:



S^3

$$Q = \int_{S^3} * F$$

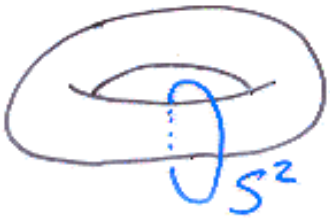
2-form F

ex. D0-brane charge

NON-CONSERVED

"local charge"

"dipole charge"



$$q = \int_{S^2} * H$$

3-form H

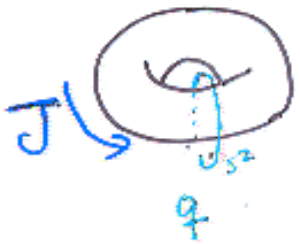
ex. brane wrapping the CONTRACTIBLE S^1 of the black ring.

- Vacuum black ring: $Q = q = 0$
- Dipole black ring: $Q = 0$, $q \neq 0$

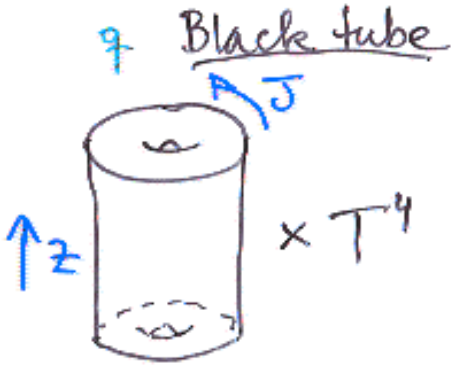
[Emparan '04]

FROM BLACK RINGS TO SUPERTUBES

Dipole black ring

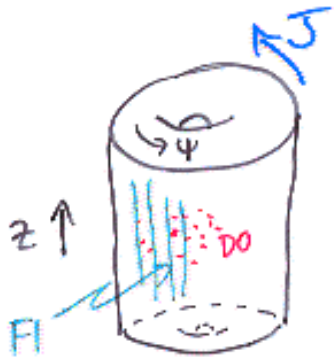


LIFT TO 10D



BOOSTS + DUALITIES

$P_z - T_z - P'_z - S - T_z$



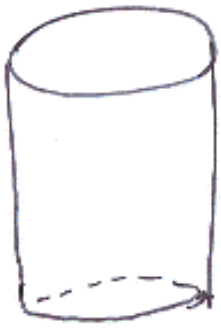
2-CHARGE BLACK TUBE

D0+F1 NET CHARGES

$D2_{\psi z}$ dipole charge

SUPERSYMMETRIC LIMIT

$A_H \to 0$



$M = Q_{D0} + Q_{F1}$

$\frac{1}{4}$ BPS SUPERGRAVITY SUPERTUBE

[Emparan, Mateos, Townsend '01]

[Emparan, Figueras, HE '04]

So:

2-CHARGE NEAR-SUPERSYMMETRIC BLACK RINGS ARE THERMALLY EXCITED 2-CHARGE SUPERTUBES

[Emparan, Figueras, H.E. '04, Emparan, HE '03, HE. '03]

QUESTION: Can the entropy of near-susy 2-charge black ring be reproduced from a microscopic (supertube) model?

?

REMARK: Recent discussions of R^2-corrections to this (and a related) 2-charge system
(different from above question)

[Kraus & Larsen '05]

[Iizuka & Shigemori '05]

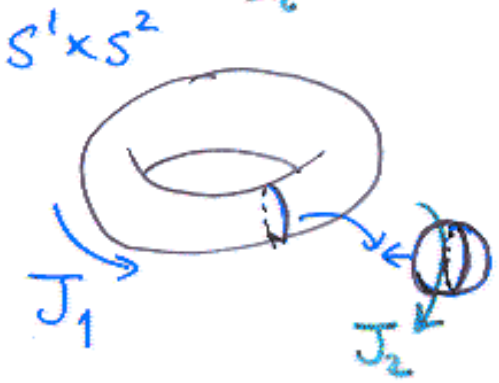
§2. NON-SUPERSYMMETRIC 3-CHARGE BLACK RINGS

Apply 3 × boosts + dualities to dipole black ring

↓

7 PARAMETER FAMILY OF NON-SUPERSYMMETRIC 3-CHARGE / 3-DIPOLE BLACK RINGS

Q_i $\quad$ γ_i



6 CONSERVED CHARGES

$M, J_1, J_2, Q_{1,2,3}$

↓ SUPERSYMMETRIC LIMIT

$M = Q_1 + Q_2 + Q_3$

SINGULAR RING

3 CHARGES, 2 DIPOLES

CONJECTURE: ∃ 9 PARAMETER NON-SUSY 3-CHARGE / 3-DIPOLE BLACK RINGS

[EMPARAN, MATEOS, REALL, HE '04a ; EMPARAN, FIGUERAS, HE. '04]

LARSEN '05 : ∃ 21 PARAMETERS

§3 SUPERSYMMETRIC BLACK RINGS

THE FIRST SUPERSYMMETRIC BLACK RING FOUND IN D=5 MINIMAL SUPERGRAVITY

[EMPARAN, MATEOS, REALL, H.E. '04a]

SCHEMATICALLY:

$$S = \int R - F^2 - F \wedge F \wedge A \quad , \quad F = dA$$

← CONSISTENT TRUNCATION OF 11d SUGRA ON T^6

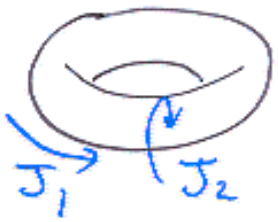
$$ds^2 = -f^2 (dt + w)^2 + f^{-1} dx^2(\mathbb{R}^4)$$

$$A = f(dt + w) - \beta$$

w, β : 1-forms on $\mathbb{R}^4$

[Gauntlett, Gutowski, Hull, Pakis, Reall '02]

f = 1 + harmonic + non-harmonic



$$Q = \int_{S^3} *F$$

$$q = \int_{S^2} F$$

- EXISTENCE OF SUSY BLACK RING WAS CONJECTURED BY BENA & KRAUS '04

LIFT SOLUTION TO 10D AND GENERALIZE

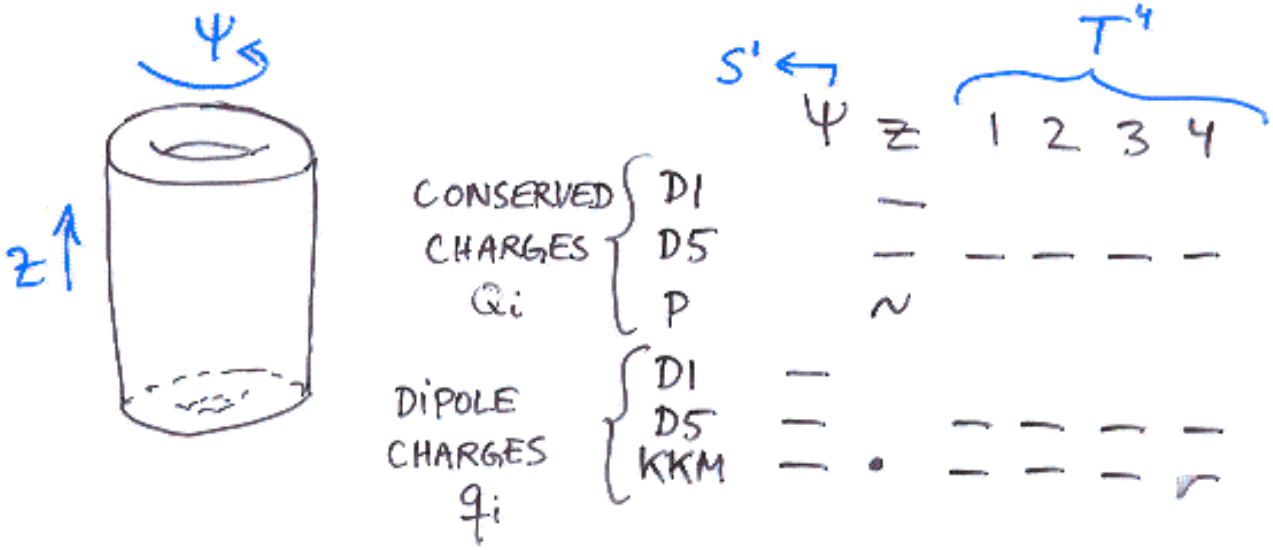
[Emparan, Mateos, Reall, HE '04b]
[Bena & Warner '04]
[Gauntlett & Gutowski '04]

3-CHARGE / 3-DIPOLE BLACK RING (TUBE)

TYPE IIB ON T^4

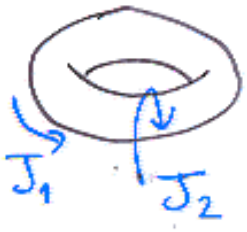
Q_i CONSERVED CHARGES : D1-D5-P

q_i DIPOLE CHARGES : D1-D5-KKM
(KALUZA-KLEIN MONOPOLE)



NOTE: • REDUCE TO 5D
• SET $Q_i = Q$ AND $q_i = q$
→ SUSY BLACK RING IN MINIMAL SUGRA

PROPERTIES OF SUSY BLACK RINGS



7 PARAMETER FAMILY

5 CONSERVED CHARGES

Q_{D1} Q_{D5} Q_P , $J_1 \geq J_2$

2-fold continuous non-uniqueness (classically)

↑

FIRST EXAMPLE OF NON-UNIQUENESS OF SUPERSYMMETRIC BLACK HOLES!

ENTROPY: DEPENDS EXPLICITLY ON THE NON-CONSERVED CHARGES.

MICROSCOPIC ENTROPY:

- Cyrier, Guica, Mateos, Strominger '04:
  → M-theory on T^6; a la Maldacena, Strominger, Witten '97 4d BH entropy calc.
- Bena & Kraus '04: $E_{7(7)}$ invariant
- Kraus & Larsen '05: Attractor mechanism.

BLACK RINGS AND AdS/CFT : D1-D5-P

Type IIB on T^4

DECOUPLING LIMIT : $\alpha' \to 0$

BMPV BH [BRECKENRIDGE, MYERS, PEET; VAFA]

↓

$AdS_3 \times S^3$ locally everywhere

SUSY BLACK RING

↓

Near-horizon

$r \to 0$

$AdS_3 \times (S^3/\mathbb{Z}_n)$

$\ell_{nh} = \sqrt{q_{KK}}\,(q_{D1} q_{D5})^{\frac{1}{4}}$

$r \to$

Asymptotics

$r \to \infty$

$AdS_3 \times S^3$

$\ell_\infty = (Q_{D1} Q_{D5})^{\frac{1}{4}}$

IS THIS THE GRAVITY DUAL OF AN RG FLOW ?

HOW ?

§4. SUMMARY:

NON-SUSY BLACK RINGS

2 CHARGES: THERMALLY EXCITED SUPERTUBES = NEAR-SUSY BLACK RINGS

3 CHARGES: 3CH/3DIP BLACK RINGS KNOWN

→ EXPECT MORE GENERAL SOLUTIONS

→ ENTROPY [LARSEN '05]

→ RELATIONSHIP TO 3-CHARGE (WORLD-VOLUME) SUPERTUBES.

SUSY BLACK RINGS

- LABORATORY FOR STUDYING MICROSCOPICS OF BLACK HOLES IN STRING THEORY
- AdS/CFT
- MATHUR CONJECTURE
- HIGHER CURVATURE CORRECTIONS ?
- 4D BLACK HOLES FROM 5D BLACK RINGS IN TAUB-NUT

  [EMPARAN, MATEOS, REALL, H.E. '05]
  [GAIOTTO, STROMINGER, YIN '05a, b, ..]
  [BENA, KRAUS, WARNER '05]

NEW BLACK HOLE SURPRISES?

EX. • PURE GRAVITY $D = 5+1$

• ASYMPTOTICALLY FLAT

• STATIONARY, NON-STATIC

→ POSSIBLE HORIZON TOPOLOGIES

• S^3 [MYERS-PERRY '86]

• $S^1 \times S^3$, $S^1 \times S^1 \times S^2$, $S^2 \times S^2$???

EX. • 4D SUGRA + $(R^2 + \dots)$

• ASYMPTOTICALLY FLAT

→ HORIZON TOPOLOGIES:

• S^2

• $S^1 \times S^1$???