Superconformal Quantum Mechanics for Black Holes

Strings 2005

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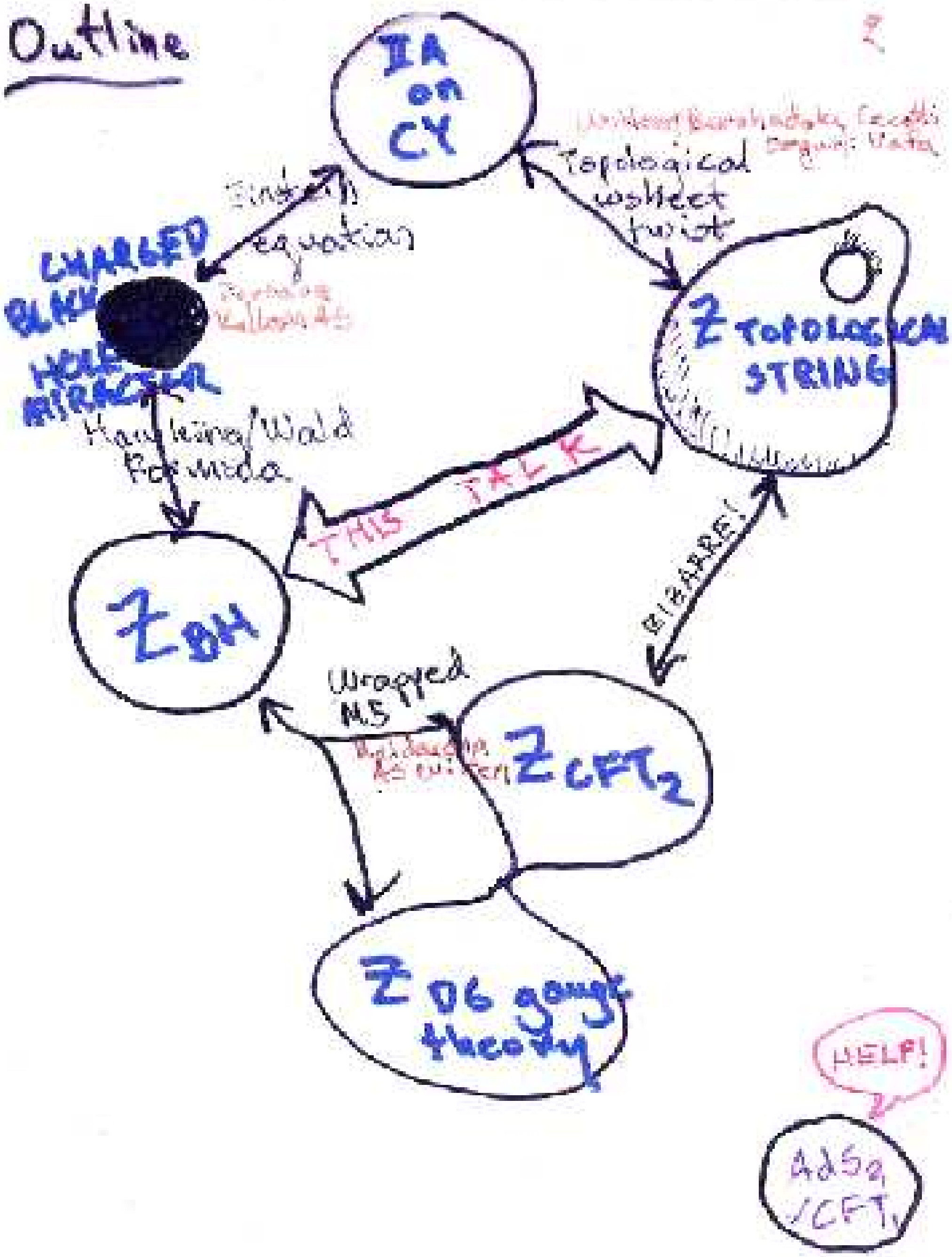
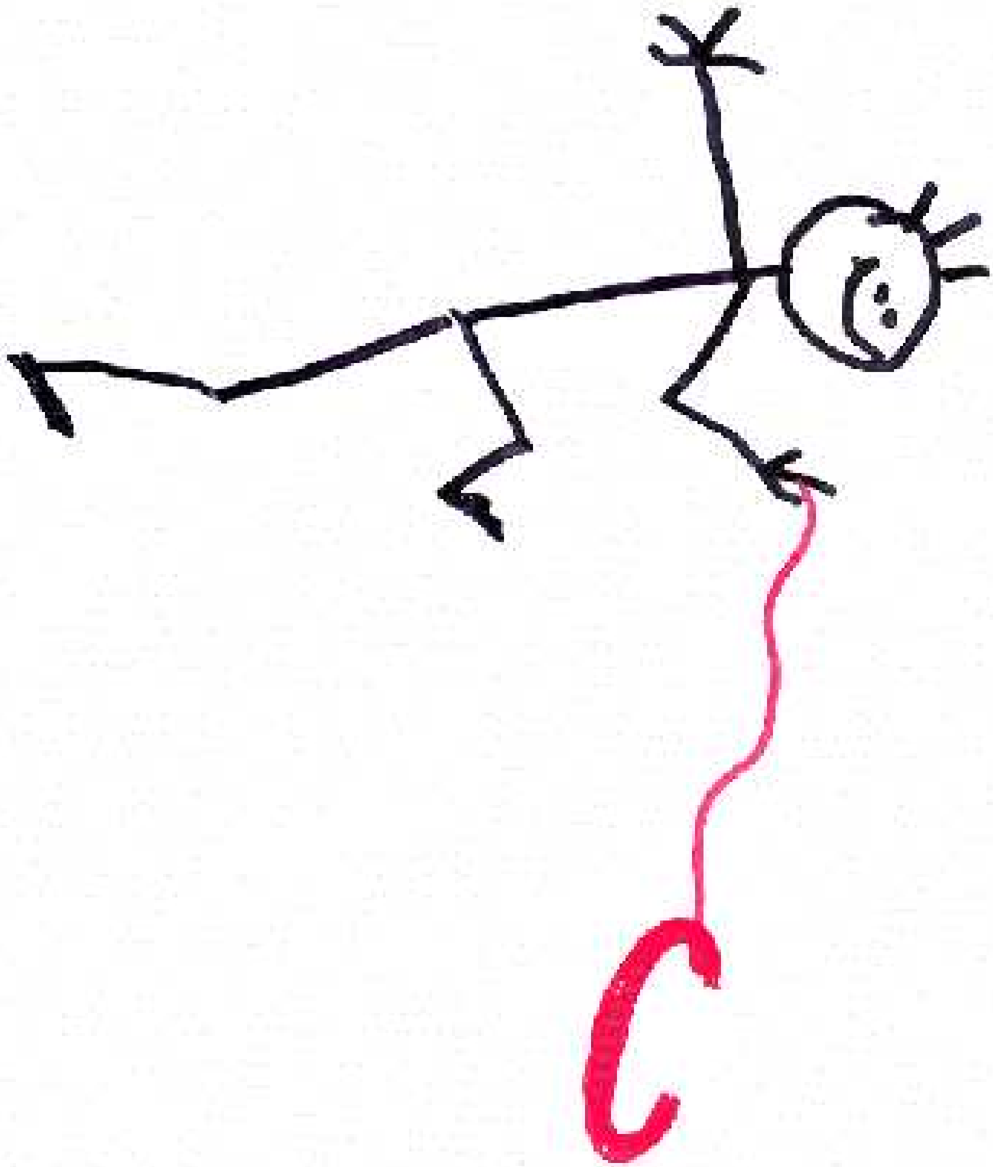
Black holes have been an unending source of fun and surprises for nearly a century. The last several years are no exception, with a number of interesting connections emerging.

Outline



IIA on CY
Einstein's equation
Topological worldsheet twist
CHARGED BLACK HOLE ATTRACTOR
Z TOPOLOGICAL STRING
Hawking/Wald formula
THIS TALK
BIZARRE!
Z BH
Wrapped M5
Z CFT2
Z D6 gauge theory
HELP!
AdS2 /CFT1



Strings O$ Toronto

Basic Idea

BH is composed of branes. CFT = QM of interacting branes. BH entropy = bound state degeneracy

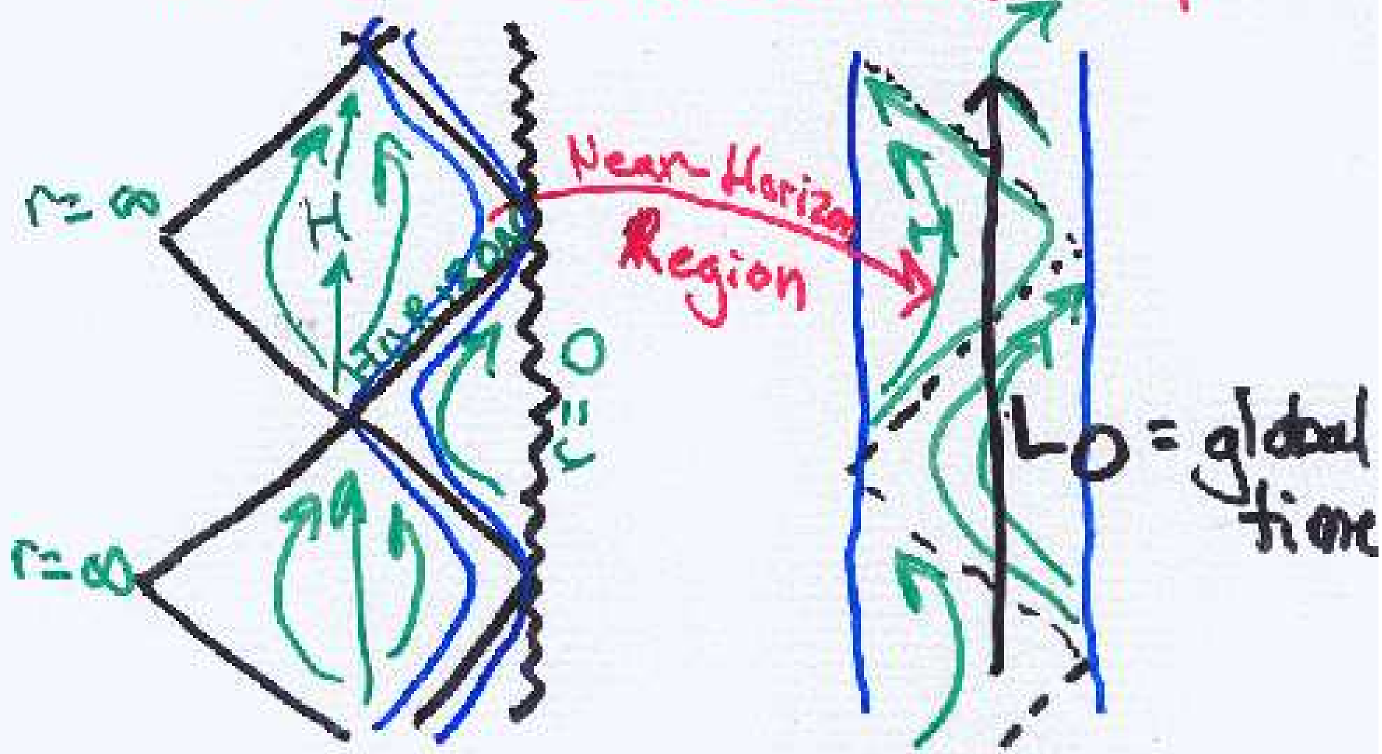
↑why?

Going to show

1) D0 probe in D0-D4 attractor described by SCQM
2) ∃ peculiar near-horizon SC bound states pop in/out of BH
3) Degeneracy $\sim e^{S_{BH}}$

Gibbons Kallosh Townsend Claus AS
Michelson Britto Maloney Volovich
Spradlin V. Prasanth Kumar Denef

D0-D4 CalabiYau BH



Black Hole

$AdS_2 \times S^2 \times CY_3$ Attractor

$$(q_0, q_A, p^A, p^0) = (\underbrace{q_0}_{\text{D0 charge}}, 0, \underbrace{p^A}_{\text{D4 charge}}, 0)$$

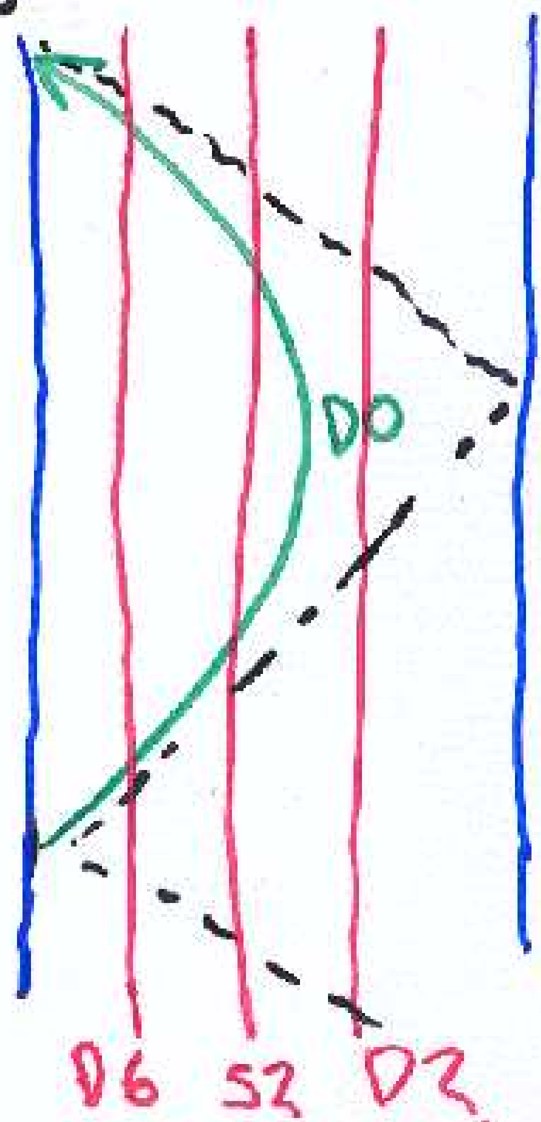
$$F_{RR}^{(4)} = \omega_{S_2} \wedge p^A \omega_A$$

$$F_{RR}^{(2)} = q_0\, \omega_{AdS_2}$$

$$R_{AdS}^2 = Q^2 = \sqrt{D\, q_0}$$

$$D = D_{ABC}\, p^A p^B p^C$$

Classic susic probe configurations exist



-wrapped D2 w/ D0 charge

for generic charges Radial position function of Z.

MYSTERY: Relation to Denef et.al

AS Guica
S:mons

More precisely let

$Z(\text{probe}) = p^\Lambda F_\Lambda - q_\Lambda X^\Lambda$

$Z_{BH} = \text{real}$

$ds^2 = Q^2(-\cosh^2\chi\, dt^2 + d\chi^2)$

$\phi \equiv$ phase of Z, $Z = |Z| e^{i\phi}$

then the supersymmetric trajectory is at

$$\boxed{\tanh \chi = \cos\phi}$$

(unwrapped probe)

Note $\phi \to 0$, $\chi \to \infty$.

Q M STORY

Horizon-wrapped D2 w/
D0 charge $= n$

$$F^{(4)}_{RR} = \omega_{S_2} \wedge p^A \omega_A$$

$$\text{Tension} \approx \sqrt{Q^2 + n^2} \sim Q$$

$$ds^2 = Q^2\left(\frac{-dt^2 + \xi^2 d\xi^2}{\xi^4}\right)$$

$$\xi \sim \frac{1}{r^2}$$

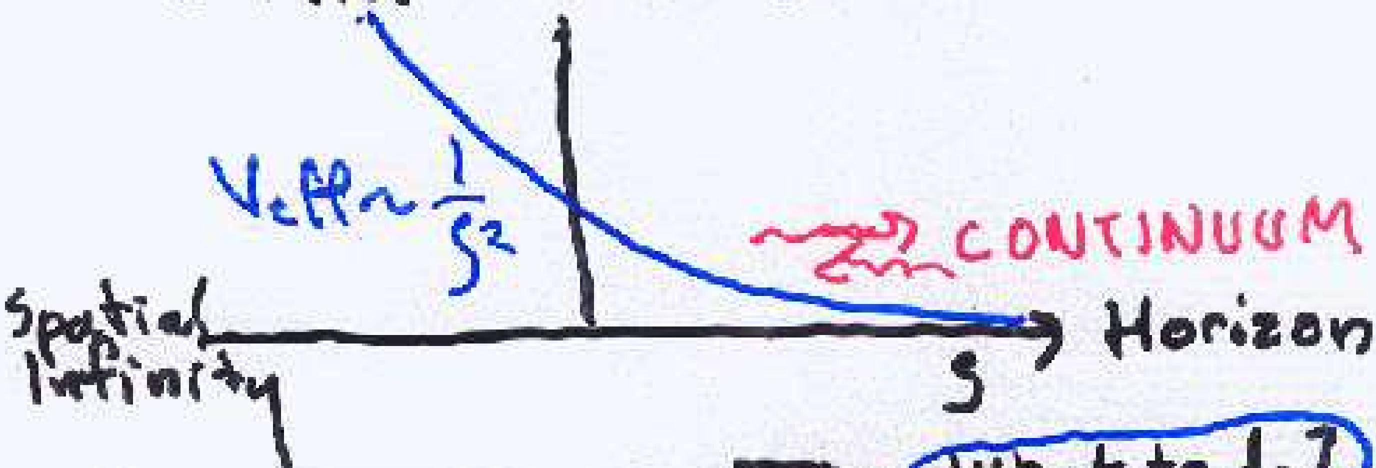
$$H = \frac{p^2}{Q^2} + \frac{Q^3}{\xi^2} + \frac{1}{Q\xi^2} g_{a\bar{b}}(p^a - A^a)(p^b - A^b$$

$$dA = p^A \omega_A$$

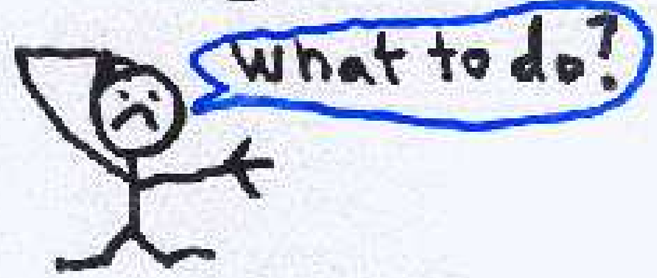
SUPERCONFORMAL!

H
$D = p\xi$
$K = Q^3 \xi^2$

Want to count probe-BH bound states



Old problem.

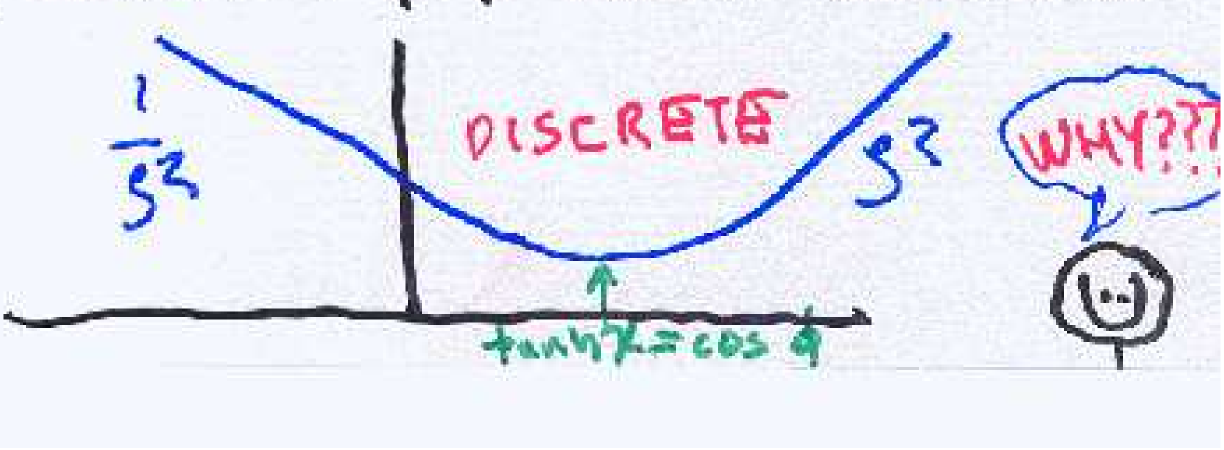


Better Problem

Count superconformal primaries, which are

$$L_0 = H + K$$

eigenstates & pop in/out horizon.



Answer

SC chiral primaries correspond to lowest landau levels tiling $S_2 \times CY_3$. There are order

$$\int_{CY_3} F\wedge F\wedge F = D_{ABC}\, p^A p^B p^C \equiv D$$

More precisely ~~there~~ they are elements of $H^0(CY_3, \mathcal{L}\otimes\Omega^p)$

and

$$N_B \simeq 4D - \frac{2}{3} c_2\cdot p + \frac{\chi}{2} \approx 4D$$

$$N_F \simeq 4D - \frac{2}{3} c_2\cdot p - \frac{\chi}{2} \approx 4D$$

Note independent of q_0, and n, so we can count "bound states ~~of~~ D0s w/ "small" $q_0 = 0$ black hole.

Question: What is the SC bound state degeneracy with total D0 number N?

A cluster of n D0 branes can, via the Myers effect, form a horizon-wrapped D2 with flux n. Partition into

$$\sum_{i=1}^{k} n_i = N$$

k such clusters, and place each into one of the 4D bosonic or 4D fermionic bound states. This is the state counting of a c = 6D 1+1 CFT at $h_0 \approx N$.

One thereby finds for large N

$$S = 2\pi\sqrt{\frac{cN}{6}}$$

$$= 2\pi\sqrt{D_{ABC}\,p^A p^B p^C N}$$

$$= S_{\text{Bekenstein-Hawking}}$$

Hence these bound states can account for the macroscopic black hole entropy.

Also Balasubramanian
Larsen Maldacena
AS Witten

Summary

It is proposed that

CFT_1 dual of flux (N, p^A) $AdS_2 \times S^2 \times CY_3$

$=$

N D0-brane SCQM in D4 BH attractor

Identifying BH microstates w/ SC chiral primaries indeed reproduces the Bekenstein-Hawking area law.