Moulting Black Holes

Borun D. Chowdhury

with Iosif Bena, Jan de Boer, Masaki Shigemori, Sheer El Showk

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Black Holes emit in two ways

Hawking Radiation

Black holes evaporate away increasing total entropy but decreasing their own

Superradiance

Black holes expel angular momenta/ charge increasing their own entropy. Presumably end point a condensate outside black hole.

End point: Hairy Black Holes

Einstein-Maxwell has charged condensate [Gubser]

AdS_5 Black holes with R-charge [Bhattacharya, Minwalla, Papadodimas]

Enigmatic Black Holes in 4d N=2 SUGRA [Denef+Moore]

Look for similar phenomenon (horizon entropy increase by emission) in D1-D5 system in bulk and boundary

Plan

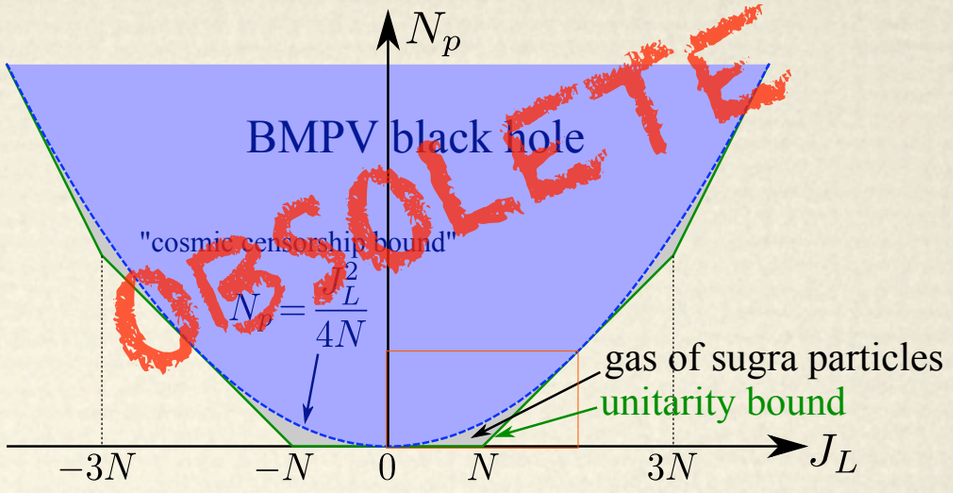
Results

D1-D5 CFT new phase

Bulk enigmatic phase in the D1-D5 system

Results

Our results make the old phase diagram obsolete

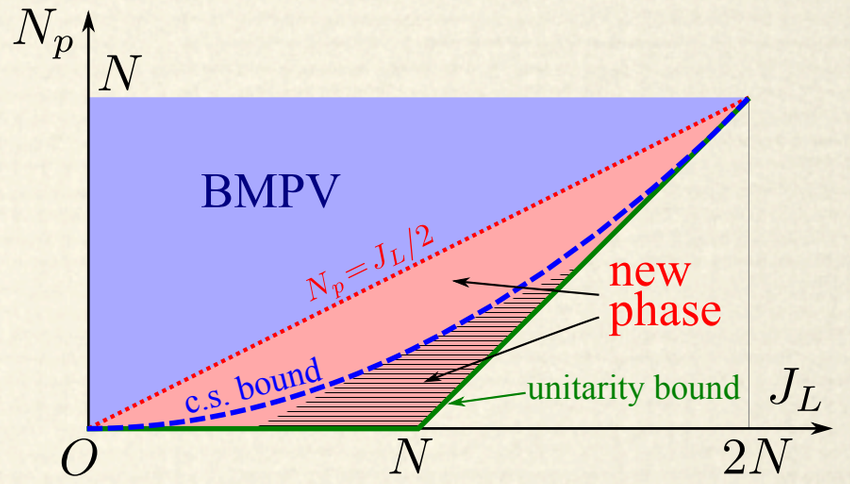


CFT:

found a new phase outside Cardy regime

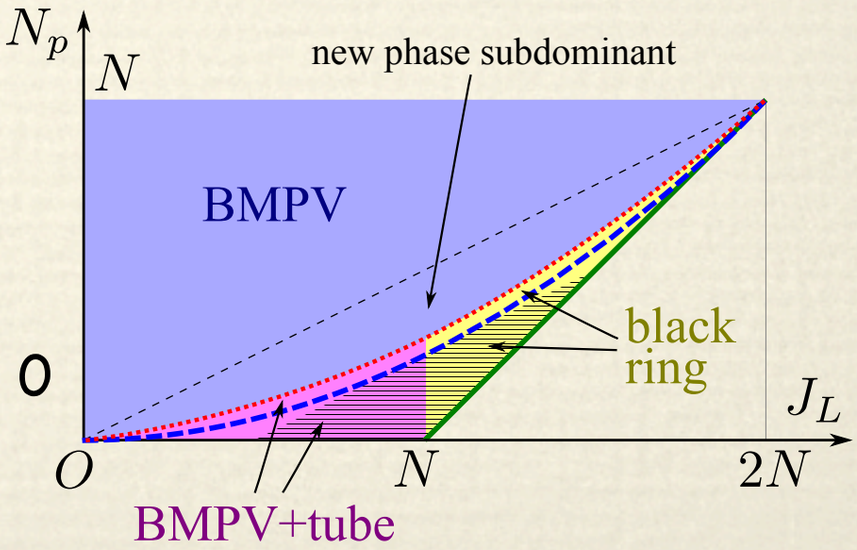
dominates over BMPV close to cosmic censorship bound

exists outside ~~cosmic censorship bound~~ and dominates over SUGRA gas



Gravity:

Phase exists in the above region and enigmatic in part of the above region viz. BMPV +supertube/ Black Ring



Phase not captured by elliptic genus, $S_{CFT} > S_{Gravity} > 0$

Even at SUGRA point only some unprotected states lifted!!!

D1-D5 System

Consider type II B on $S^1 \times M^4$ ($M^4=T^4$ or K3)

N_1 D1 branes on S^1

N_5 D5 branes on $S^1 \times M^4$

N_p units of momentum along S^1

J_L, J_R units of angular momenta

take $S^1 >> M^4$: $R^{1,4} \times S^1$ black string, near horizon $AdS_3 \times S^3$

Higgs branch of D1-D5 flows in the IR to 1+1 d N=(4,4) SCFT with target space a resolution of $(M^4)^N/S_N$

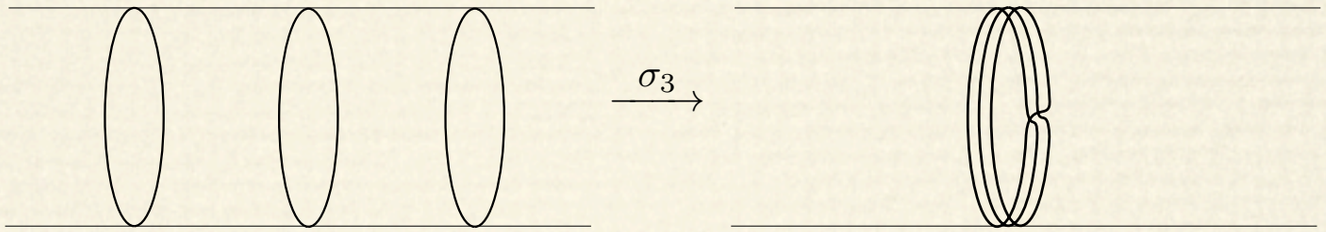
Lots of evidence for so called 'orbifold point' in the moduli space where target space is $(M^4)^N/S_N$: symmetrized copies of the CFT

D1-D5 CFT at the Orbifold Point

at the orbifold point the target space is $(M^4)^N/S_N$

orbifolding produces R-charged twist sectors for copies of CFT

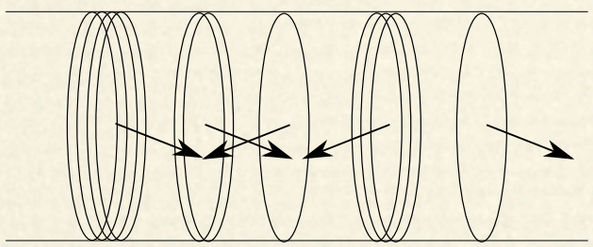
$$O^{(1)}(\sigma+6\pi) = O^{(2)}(\sigma+4\pi) = O^{(3)}(\sigma+2\pi) = O^{(1)}(\sigma)$$



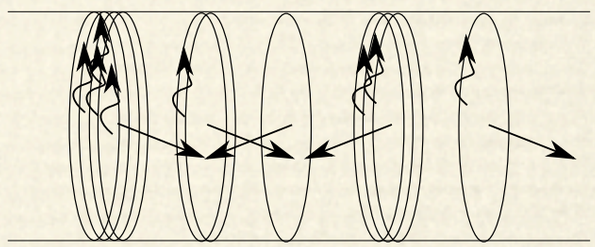
symmetry group of S^3 ($SO(4) \approx SU(2)_L \times SU(2)_R$) gives R-charge

excitations and twists can have R-charge

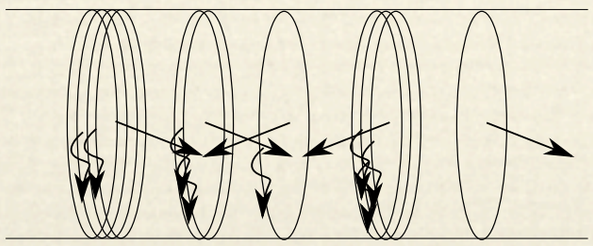
excitations have N_p



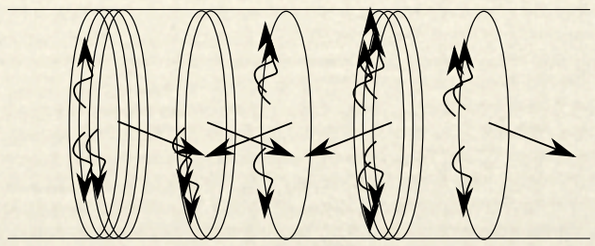
(a) A ground state



(b) A state with left excitations



(c) A state with right excitations

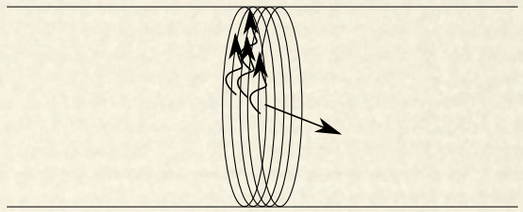


(d) A state with left and right excitations

D1-D5: BMPV and new phase

BMPV $U(1)_L \times SU(2)_R$ $\quad S_{BMPV} = 2\pi\sqrt{NN_p - J_L^2/4}.$

all excitations on one long string gives this entropy



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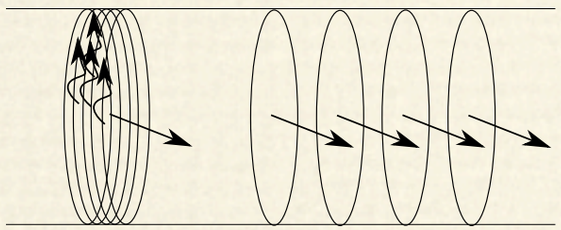
New Phase $U(1)_L \times U(1)_R$

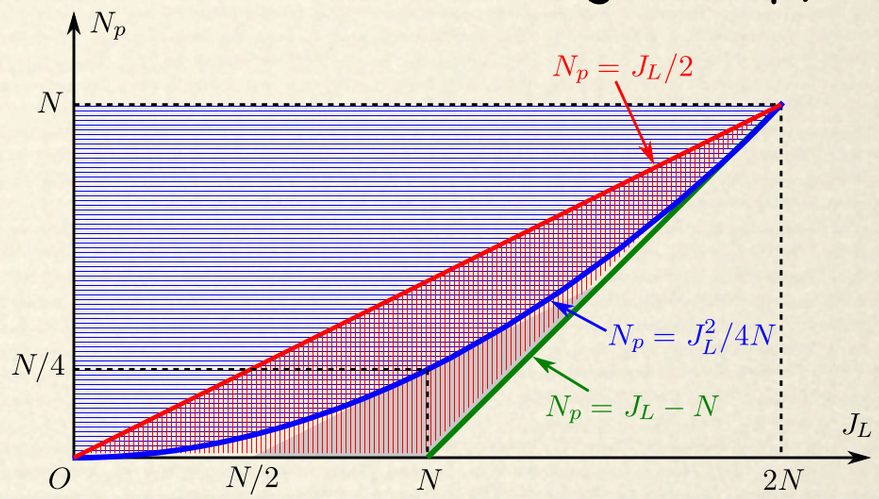
take l units of winding out

dual effect: decreases N (so also entropy), decreases J_L (increasing entropy)



winding	$(N-l)$	l
momentum	N_p	0
J_L	$J_L - l$	l
$\lvert J_R \rvert$	0	l
S	$2\pi\sqrt{(N-l)N_p - \frac{1}{4}(J_L-l)^2}$	0

maximizing S



BMPV phase Enigmatic phase

$$l = J_L - 2N_p$$

$$S_{enigma} = 2\pi\sqrt{N_p(N_p + N - J_L)}.$$

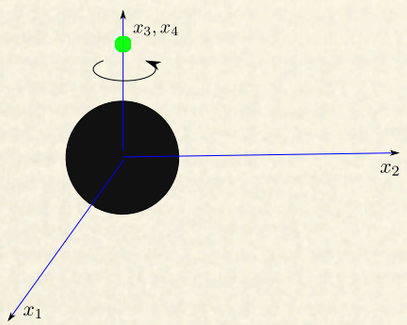
Finding solutions in bulk

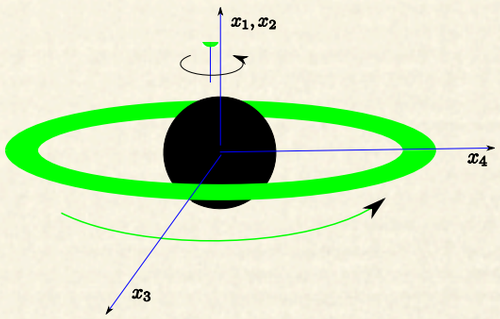
Dualize to type II A frame and look for multi-center solutions in the STU truncation (cannot capture all moduli)

From CFT we find one SU(2) multiplet for J_R so we look for two center solutions in bulk

From previous examples of entropy enigma and intuition we anticipate max. entropy if one center smooth

Using spectral flow and symmetries of problem all such two centers can be mapped to BMPV + supertube





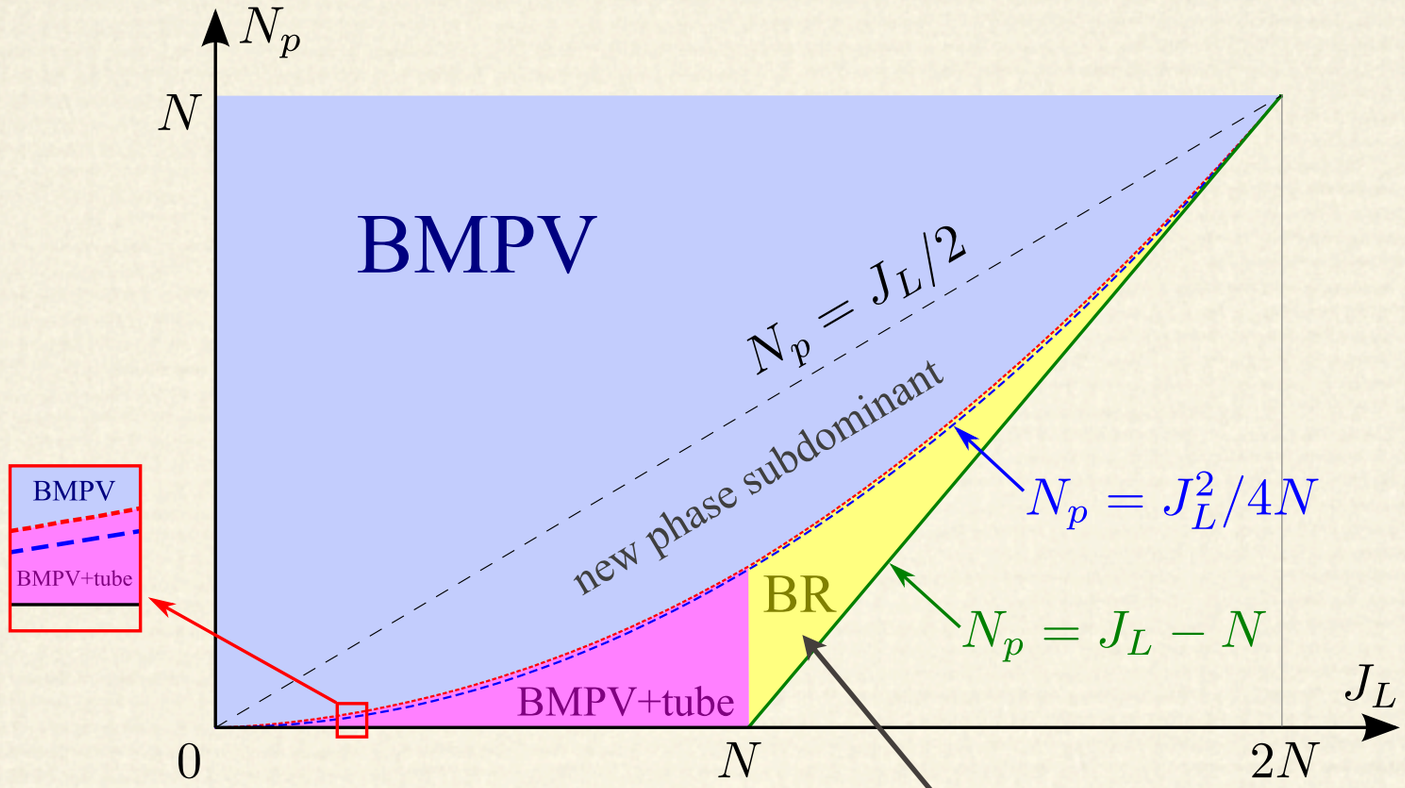
We then maximize entropy with respect to moving charges between the two centers

$$S_{\text{2-center}} = S(\Gamma - \Gamma_2) + S(\Gamma_2)$$

Spectral flow the max. entropy configuration back to original frame

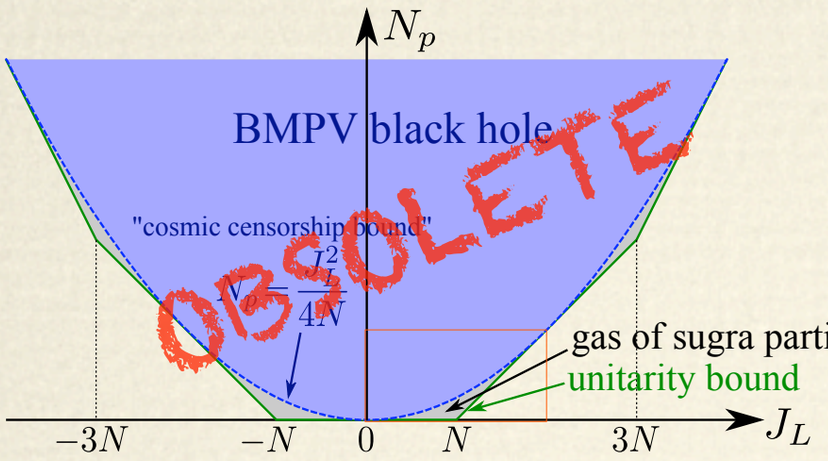
Result

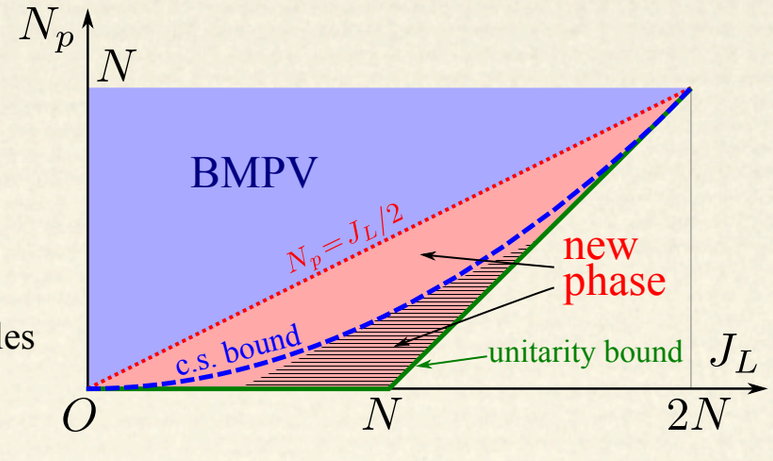
Enigmatic phase exists but region of dominance shrinks

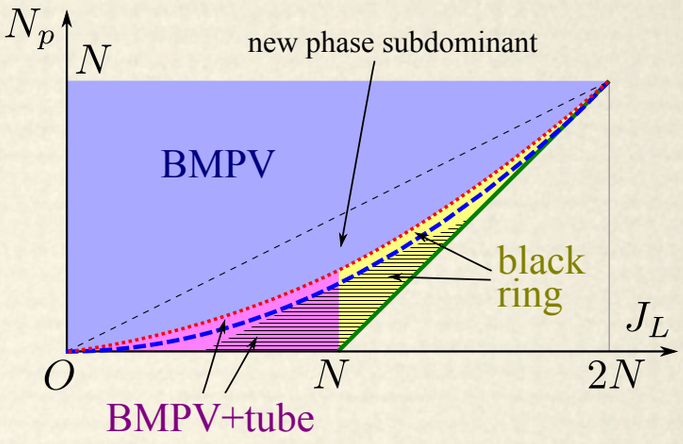


BR solution obtained from spectral flow of BMPV+tube

Conclusion







$S_{orb.\ pt.} > S_{grav.\ pt.}$

Standard lore is that bosonic and fermion short multiplets combine and lift: thats why index is a useful quantity

However this is a counter example and precisely these special states contribute to the entropy enigma

Not only are these responsible for enigmatic phase but also make up black holes outside cosmic censorship bound

Open Questions

Is there a new twisted index? Is this an artifact of moving in a submanifold of the moduli space?

Are there other systems in other dimensions which have these features (hair with dipole charge, entropy enigmas explained in dual CFT)?

Is there a non-extremal version of moulting? The CFT analyisis goes through. Partially answered (probe limit)... see Bert Vercnocke's talk.

Thank You