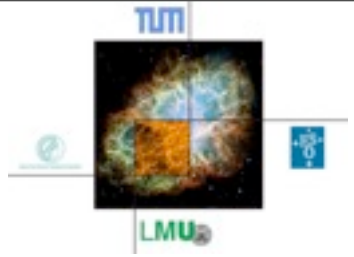

Emergent string geometry from particle species

Dieter Lüst, LMU (Arnold Sommerfeld Center)
and MPI München

Work in collaboration with Gia Dvali and Cesar Gomez

Corfu, 15. September 2011

I) Introduction

What is gravity? ⇔ What is space-time?

How does a string see space ?

Non-geometrical string backgrounds !

Non-commutative & non-associative geometry !

D.L., arXiv:1010.1361;

R. Blumenhagen, A. Deser, D.L., E. Plauschinn, F. Rennecke, arXiv:1106.0316;

D. Andriot, M. Larfors, D.L., P. Patalong: arXiv:1106.4015;

D. Andriot, M. Larfors, D.L., P. Patalong: work in progress

See talks by Erik Plauschinn and
Peter Patalong (on Saturday)

Corfu, 15. September 2011

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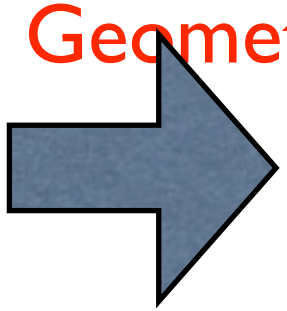

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Outline:

II) Black holes and species

III) Species and emergent geometry

- KK species and closed string geometry
- Heavy string species
- Light matter species and open string geometry

IV) Conclusions

II) Black holes and species (G. Dvali, arXiv:0706.2050)

Consider a theory with N species of particles with mass M:

Bounds from black hole decays:

$$N < N_{max} = \frac{M_{Planck}^2}{M^2}$$

(A quantum black hole can emit at most N_{max} different particles)

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Time dependent backgrounds: G. Dvali, D. Lüst, arXiv:0801.1287

If a scalar field in the effective potential gives mass to N particles in some inflationary theory : $M = M(\phi)$

$$M(\phi)^2 < \frac{M_{Planck}^2}{N}$$

Bound forbids essentially large trans-planckian vevs:

In any theory with N particle species, which are coupled to gravity, the following bound on the shortest possible length scale has to hold:

$$L > L_* = \sqrt{N} L_P$$

$M_* = 1/L_*$ can be seen as the fundamental scale of gravity being decreased by the presence on the N particle species.

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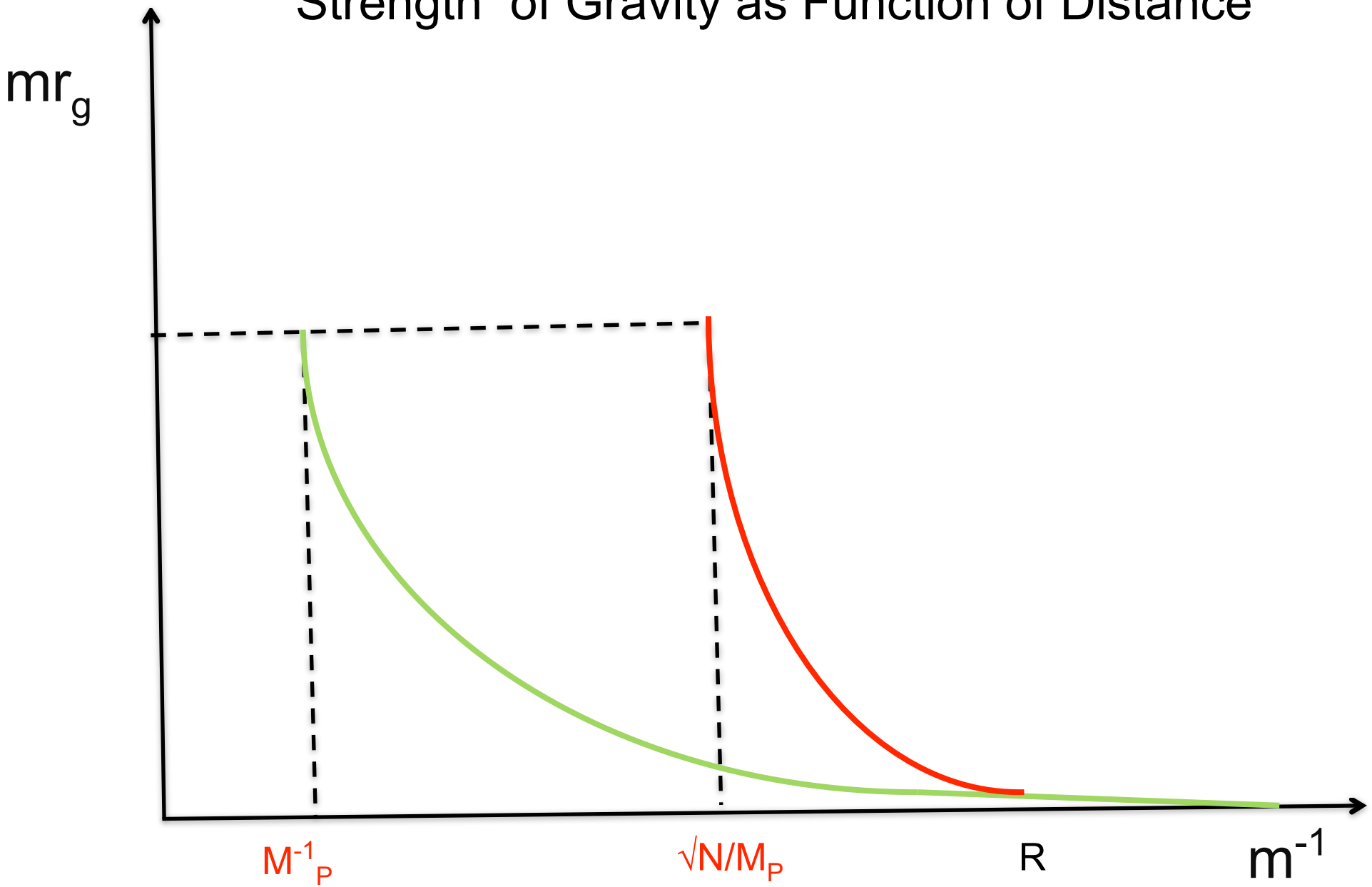
At L_* gravity becomes strong and deviates from Newtonian gravity.

This bound gives also a possible explanation of the hierarchy problem → low (TeV) scale gravity:

$$N = 10^{32} \quad \Longrightarrow \quad M_* = 10^{-16} M_P \simeq 1\ TeV$$

Strength of Gravity as Function of Distance



III) Species and emergent geometry

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(i) Gravitational (closed string) species:

Assume that there are N new massive poles in the graviton propagator.

Masses: $M_n = n/R\,, \quad (n = 1, \ldots, \frac{R}{L_*}) \;\Rightarrow\; N_{KK} = R/L_*$

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Emergent geometry: the new states are KK gravitons.

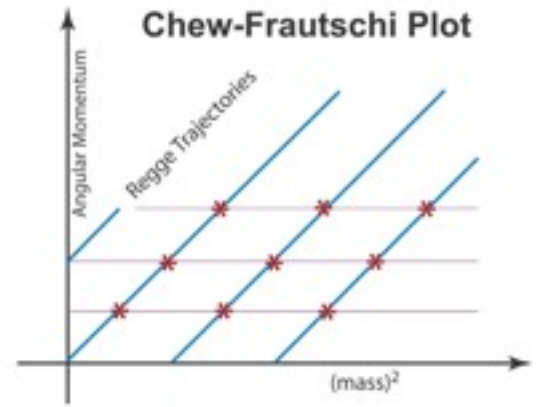
Their number corresponds to the volume of the emergent higher-dimensional space:

$$N_{KK} = V_{D-4} = \#\text{ of KK states}$$

L_* is scale of higher dimensional gravity: AADD scenario!

(ii) Heavy string excitations as species:

(G. Dvali, D. L., arXiv:0912.3167; G. Dvali, C. Gomez, arXiv:1004.3744)



$$M_n = \sqrt{n}\, M_s$$

Most string excitations are unstable and do not contribute fully to the black hole bound!

N_s is the effective number of string states that contribute to the black hole bound:

$$N_s = \frac{1}{g_s^2}\,, \qquad L_s = \frac{1}{g_s}\, L_P$$

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- Super weakly coupled strings with $N_s = \frac{1}{g_s^2} = 10^{32}$ with a TeV string scale and with NS 5-branes were recently considered by

I. Antoniadis, A. Arvanitaki, S. Dimopoulos, A. Giveon, arXiv:1102.4043.

(iii) Light matter fields as species:

Now consider N_0 light (massless) matter fields.

They put the following lower bound on the scale of gravity:

$$L_* \geq L_0 = \sqrt{N_0} L_P$$

(Therefore, the scale of gravity is already lowered in the SM.)

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Size of an Einstein black hole: $r_g(m) = m L_P^2$

Parameter that describes strength of gravity at distance L_*:

$$g^2 = r_g(L_*^{-1})/L_*$$

(g^2 tells how different the size of the smallest black hole is compared to its Compton wave length.)

Assume that gravity becomes strong at scale $L_* > L_P$,

i.e. $g^2 = 1$ at L_* .

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In addition we associate to each species a label j with a C_{N_0} permutation symmetry (related to a conserved charges).

E.g. N_0 U(1) gauge fields $A_j \quad j = 1, \ldots, N_0$.

Then there exist two types of black holes:

- Large black holes:
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- Small black holes:

Unitarity $\Rightarrow$ they do not decay democratically, but

they can rather decay only into a specific species A_j .

(G. Dvali)

$\Rightarrow$ Small Black holes are also labeled by the species label j.

(This fact is also important for the search after mini-black holes at LHC.)

The species label exhibits locality properties.

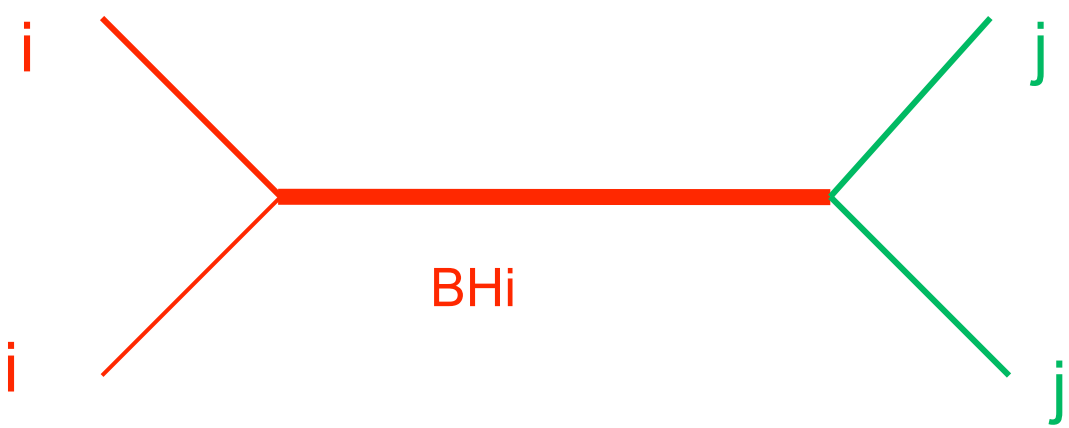
Picture is such as if light species are separated in true extra dimensions!

Consider a microscopic black hole of mass $\sim M_*$, produced in a particle-anti-particle annihilation of i-th flavor of species at energies $\sim M_*$.

By unitarity decay rate of such a black hole back to i-th species is

$$\Gamma \sim M_*$$

And the decay rate into all other flavors $j \neq i$ must be suppressed by 1/N.



So the species label (i,j) behaves like a coordinate!

Size and mass of smallest possible black hole:

$$r_g = R_\perp / N_0 \,, \quad M = r_g^2 / L_{N_0}^2$$

It is therefore localized in the transversal space and can only decay into the species j.

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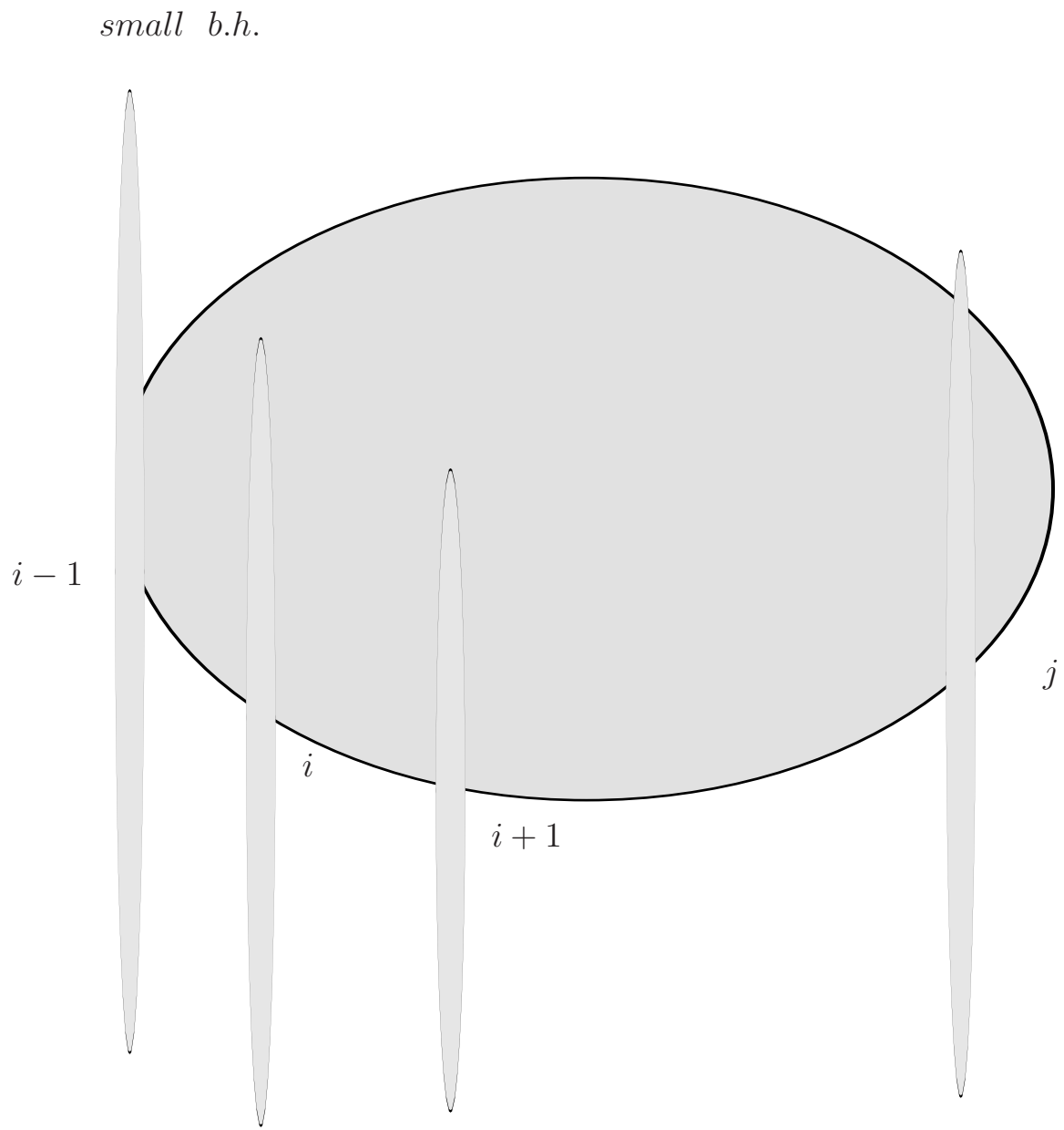
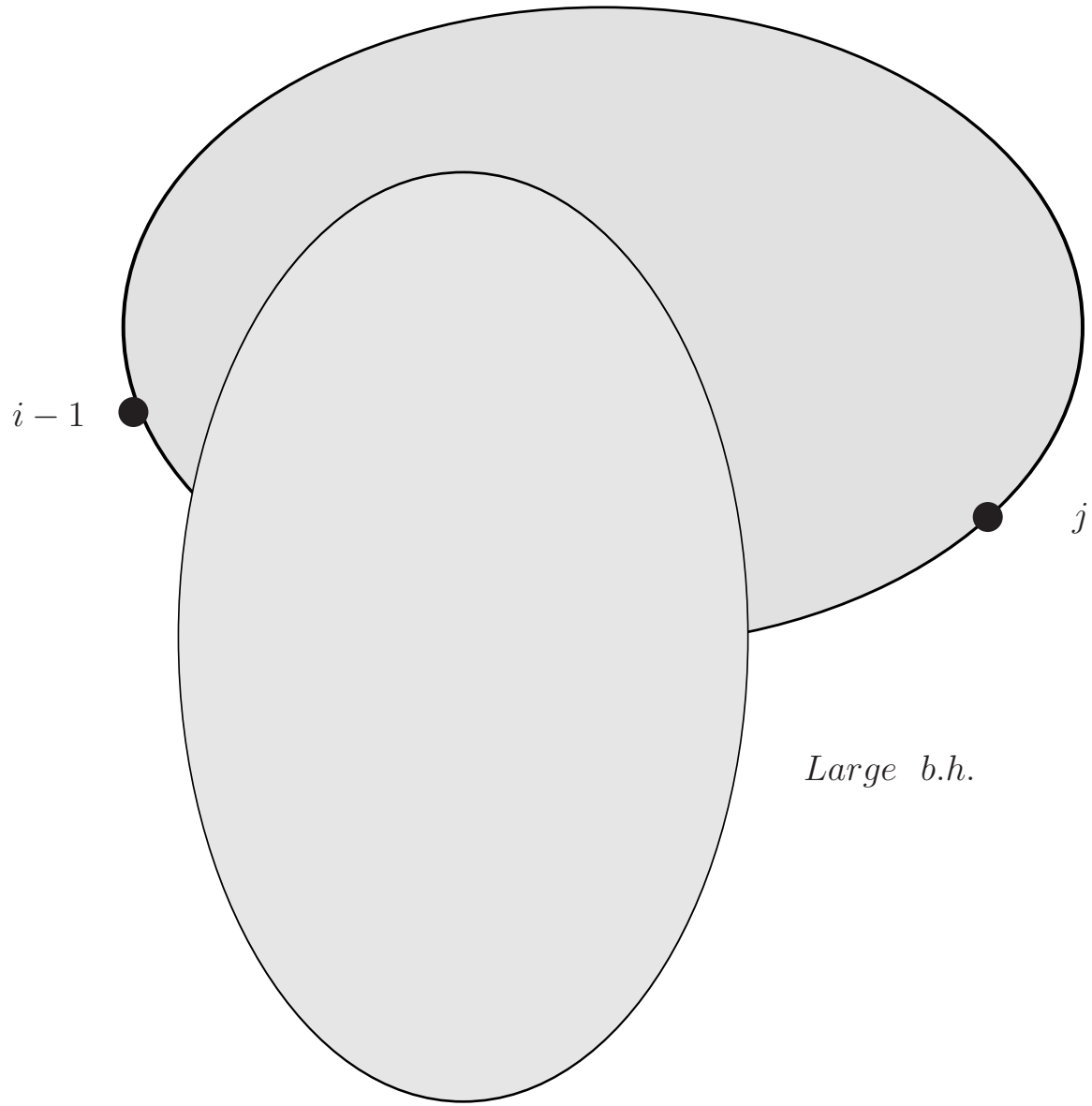
- The black hole decay is teaching us that the j-th. light species and the associated small black hole are located at the j-th. site in the transversal space.
- The species index j acts as geometric coordinate in the transversal space.

Small black holes:



Large black hole:



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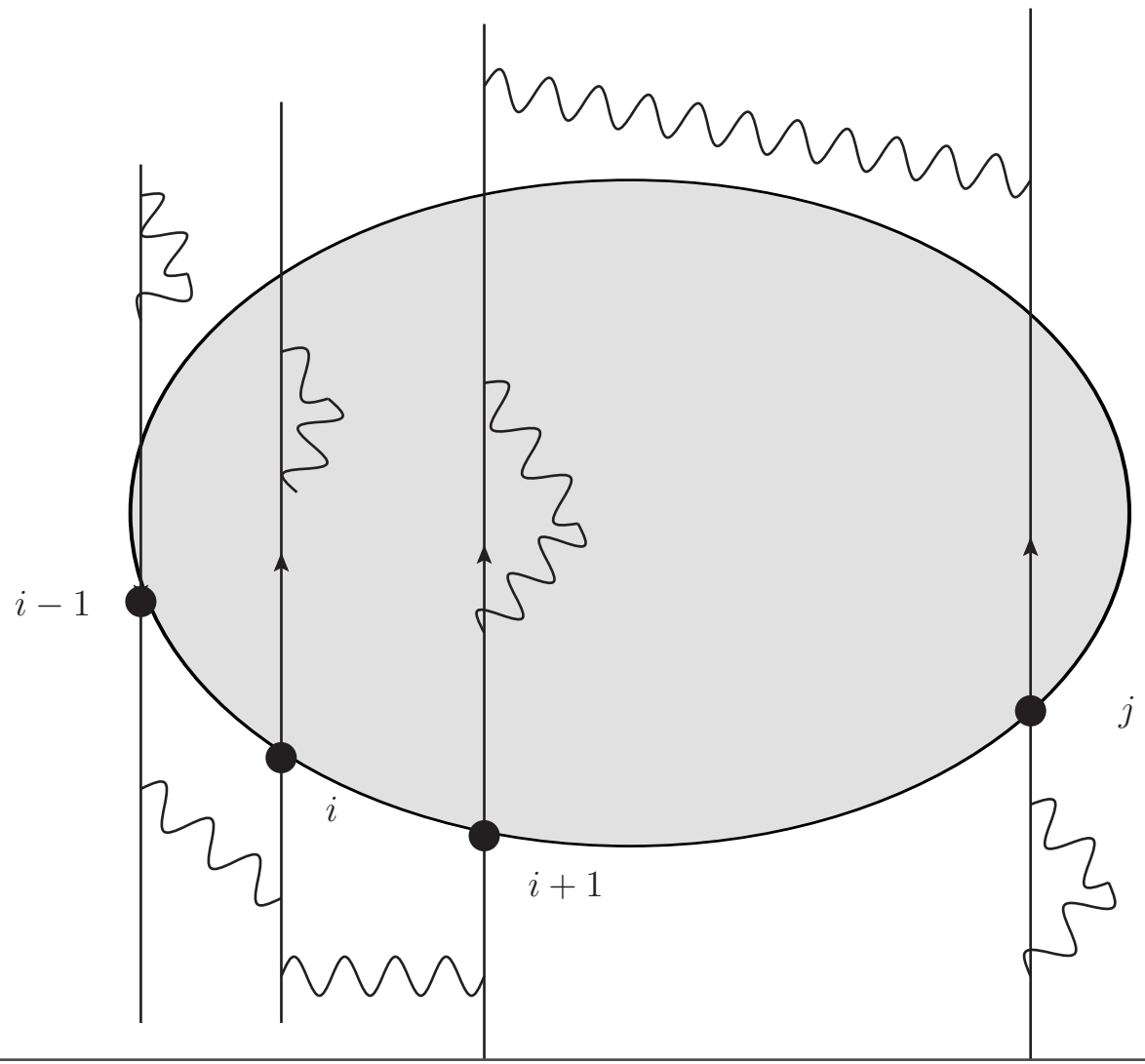


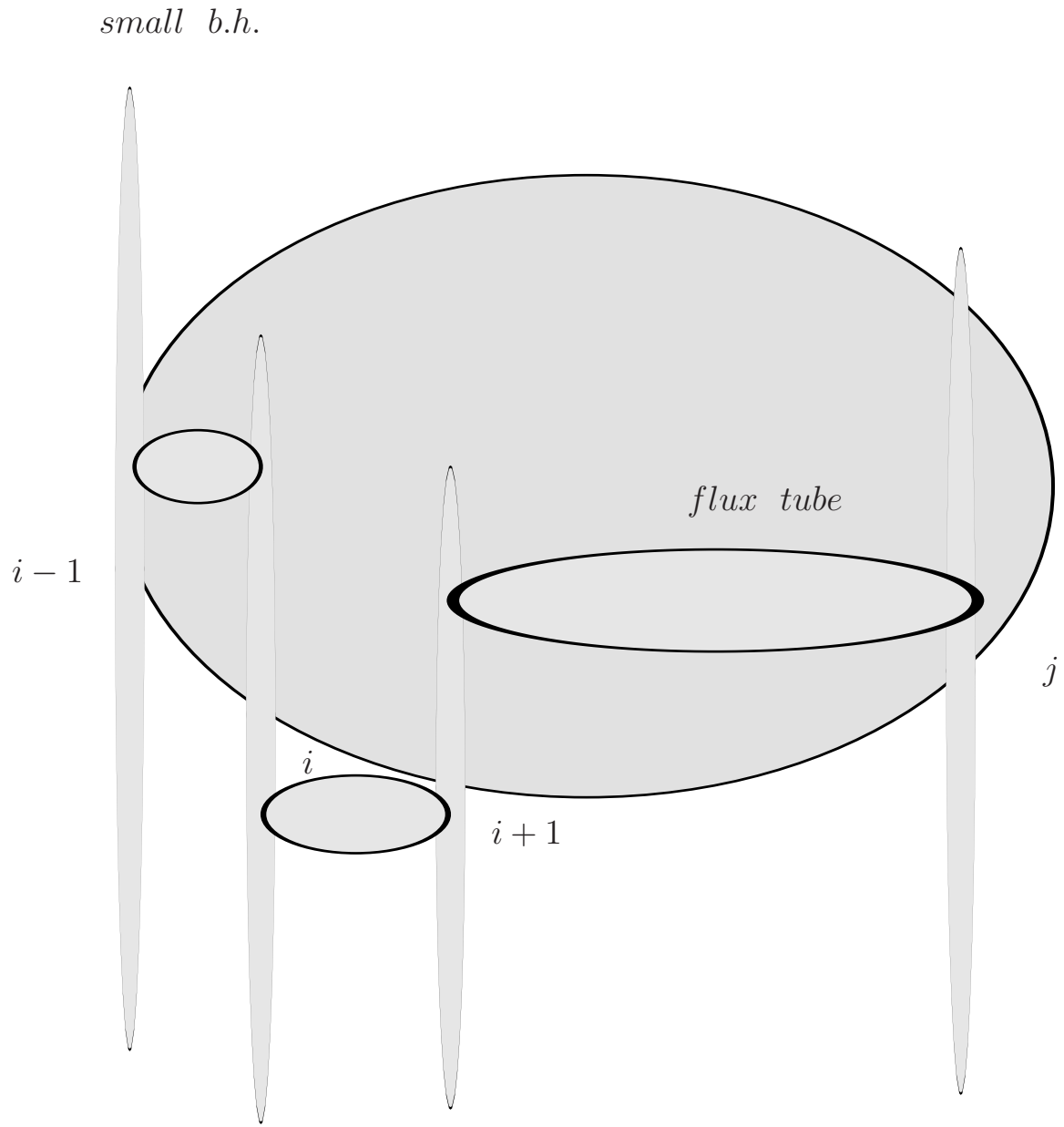
Important test for the picture to be correct:

Are there also heavy open strings
that stretch between different cites, i.e. different D3-branes?

Yes, in the b.h. /species picture these bi-fundamental open strings correspond to heavy flux tubes that stretch between different small black holes.

$$M_{ij} = (i-j) M_*^2 R_\perp / N_0$$

Flux tubes:



IV) Summary & Outlook

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$\Rightarrow$ (Mirage) gauge coupling unification at high scales for low scale gravity scenarios