Emergent string geometry from particle species

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Work in collaboration with Gia Dvali and Cesar Gomez

Corfu, 15. September 2011

I) Introduction

What is gravity? $\Leftrightarrow$ 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)

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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:

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

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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 : $M = M(\phi)$

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

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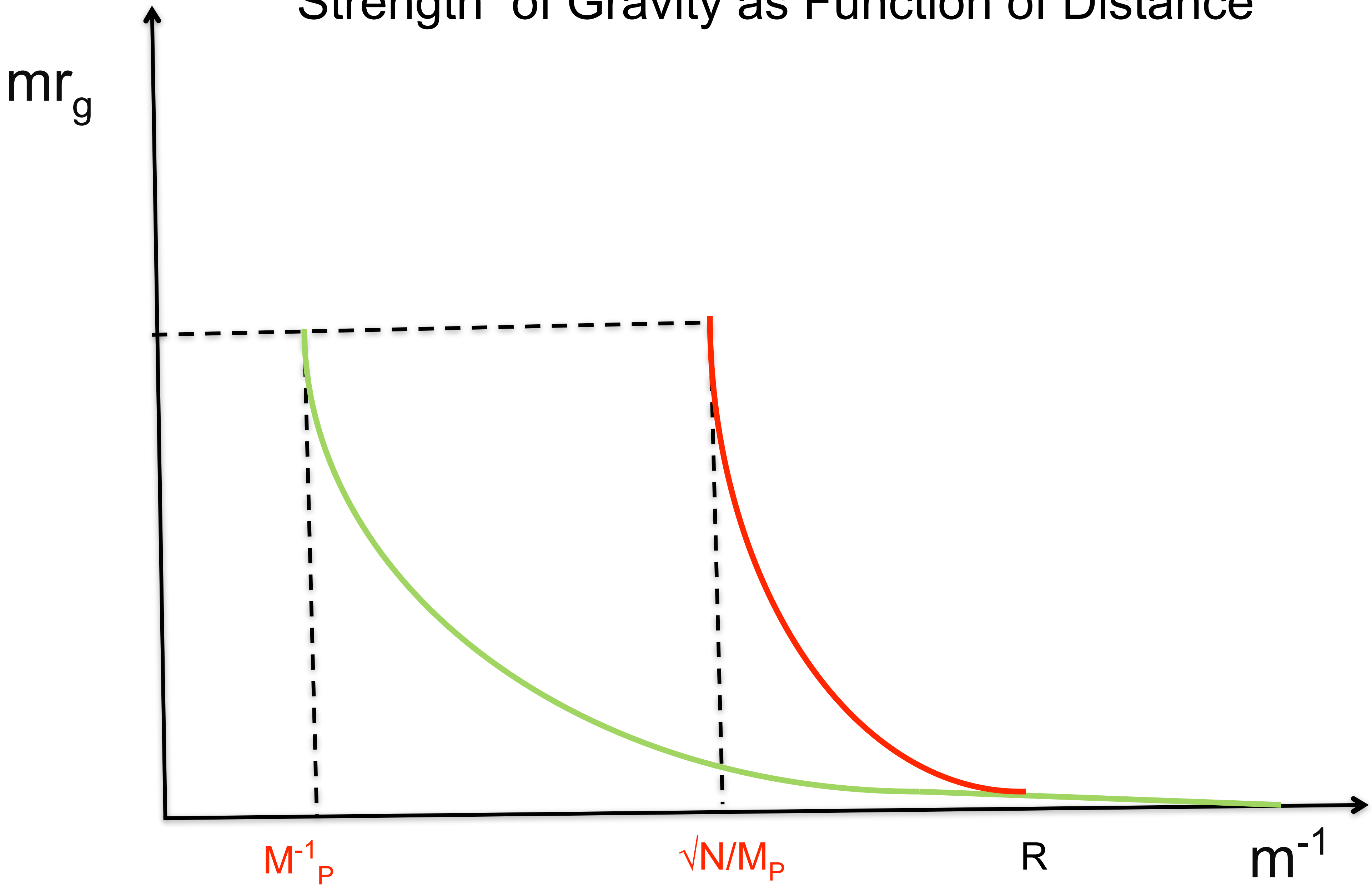
This bound gives also a possible explanation of the hierarchy problem → low (TeV) scale gravity:

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

Strength of Gravity as Function of Distance



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(i) Gravitational (closed string) species:

Assume that there are N_{KK} 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.

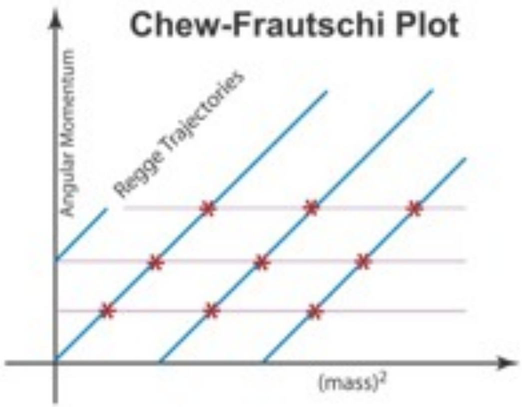
Their number corresponds to the volume of the emergent higher-dimensional space:

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

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:

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

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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:

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

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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.)

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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 $\quad j = 1, \ldots, N_0$.

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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.

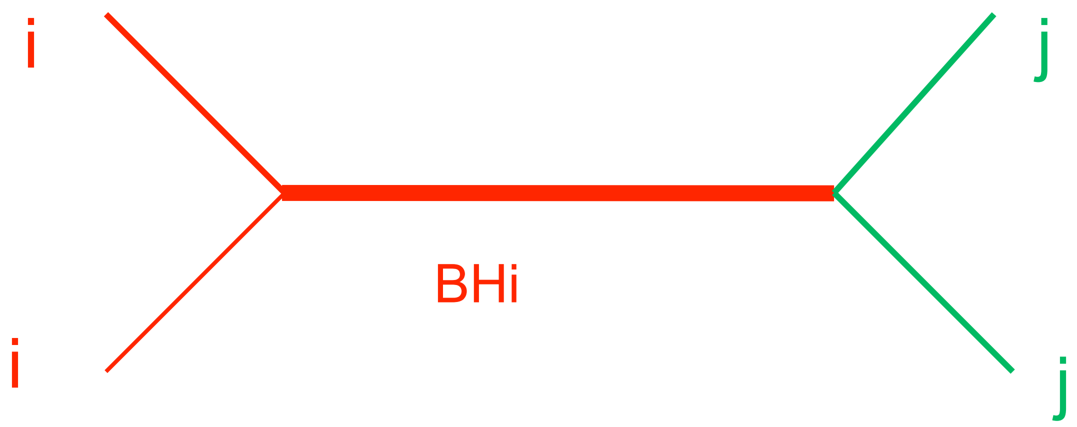
Picture is such as if light species are separated in true extra dimensions!

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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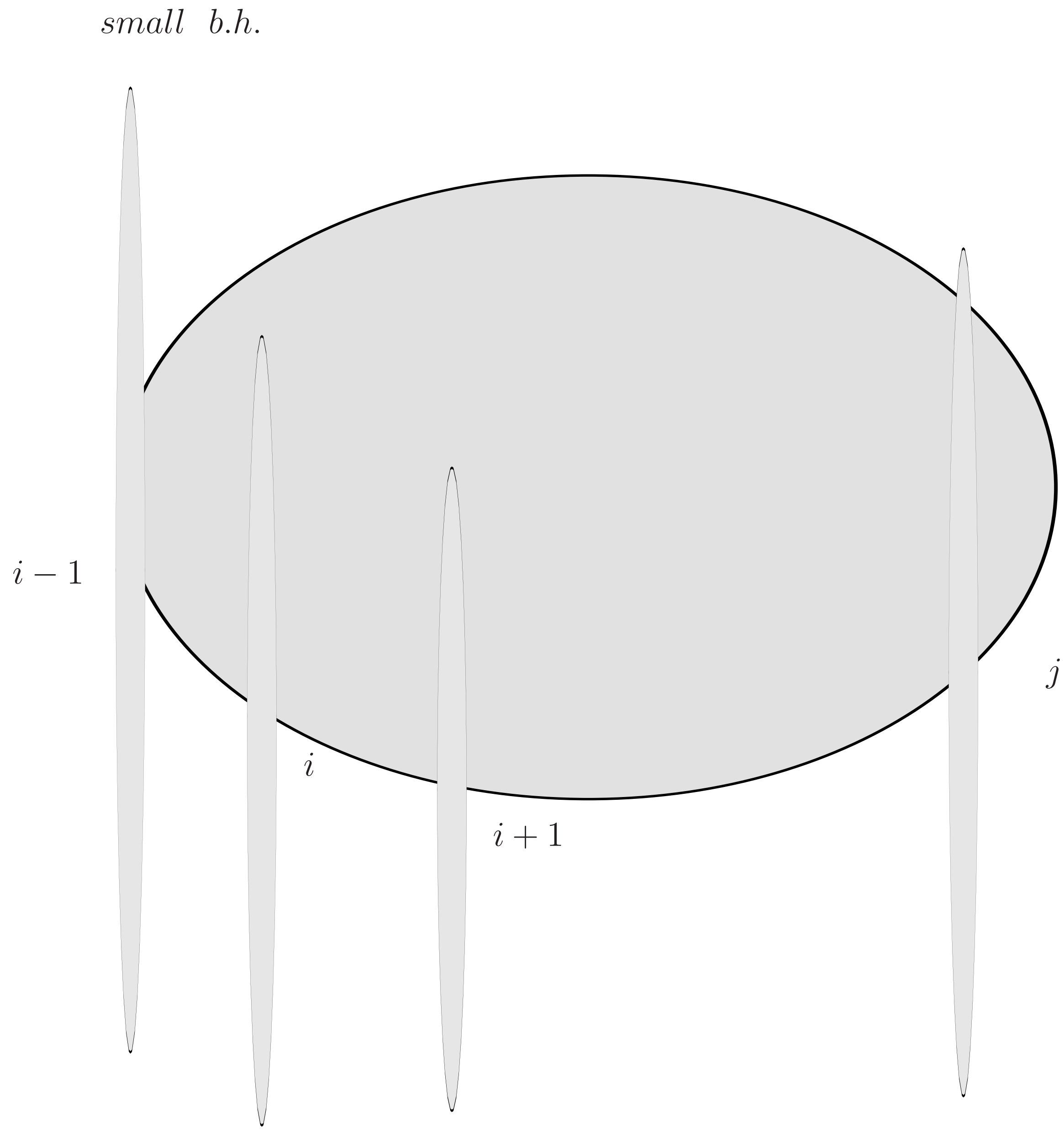
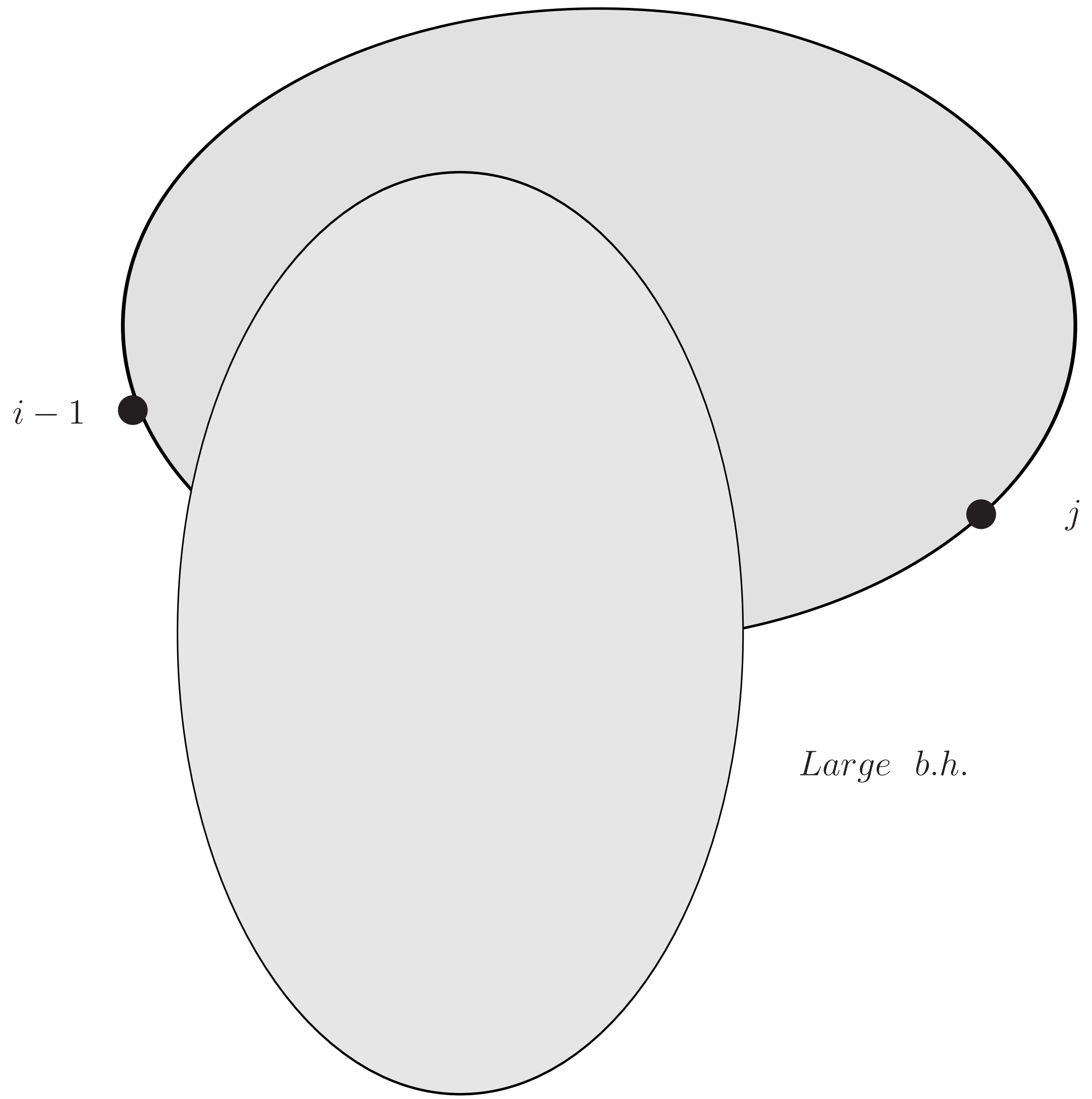
- The species index j acts as geometric coordinate in the transversal space.

Small black holes:



Large black hole:



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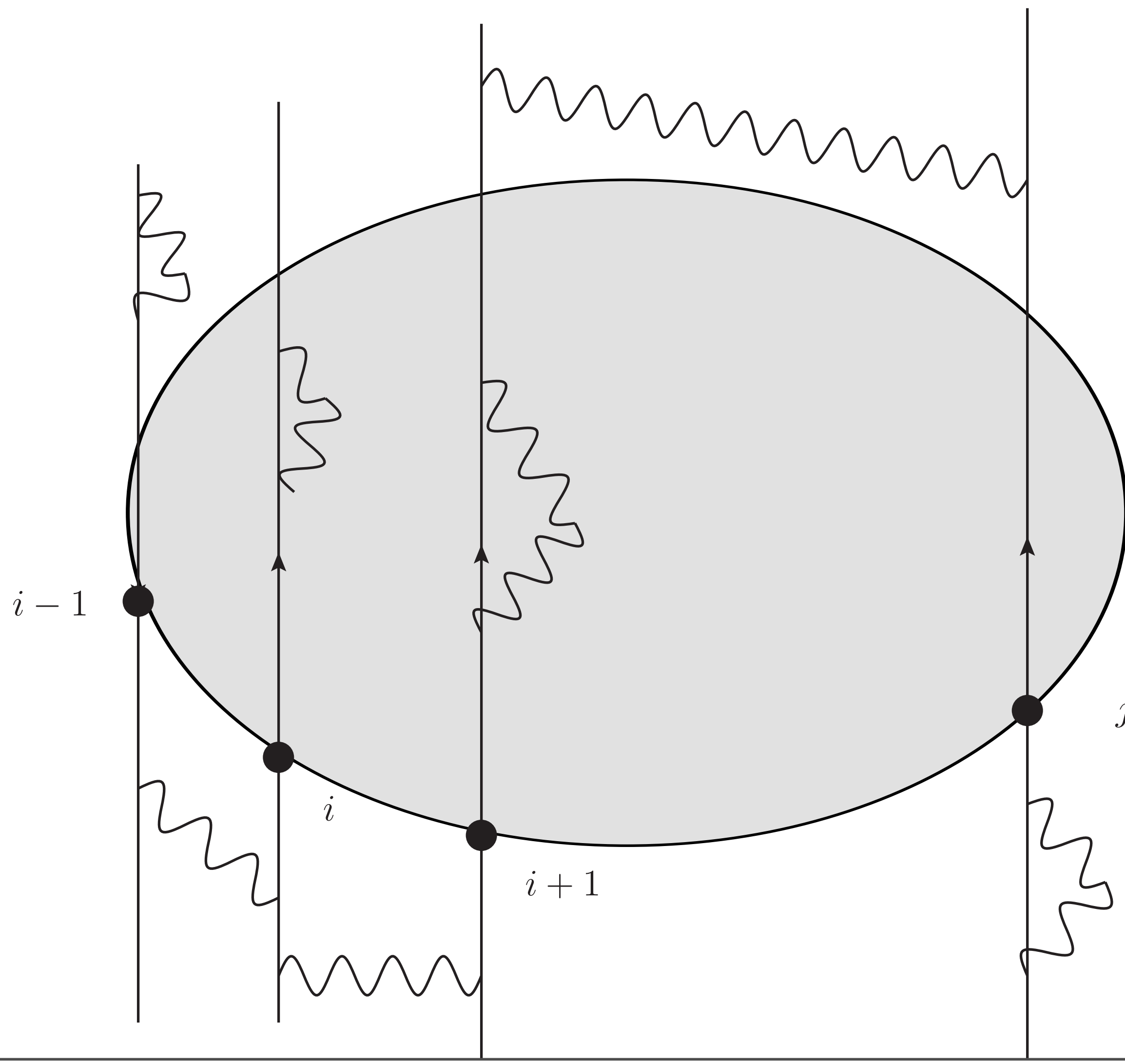


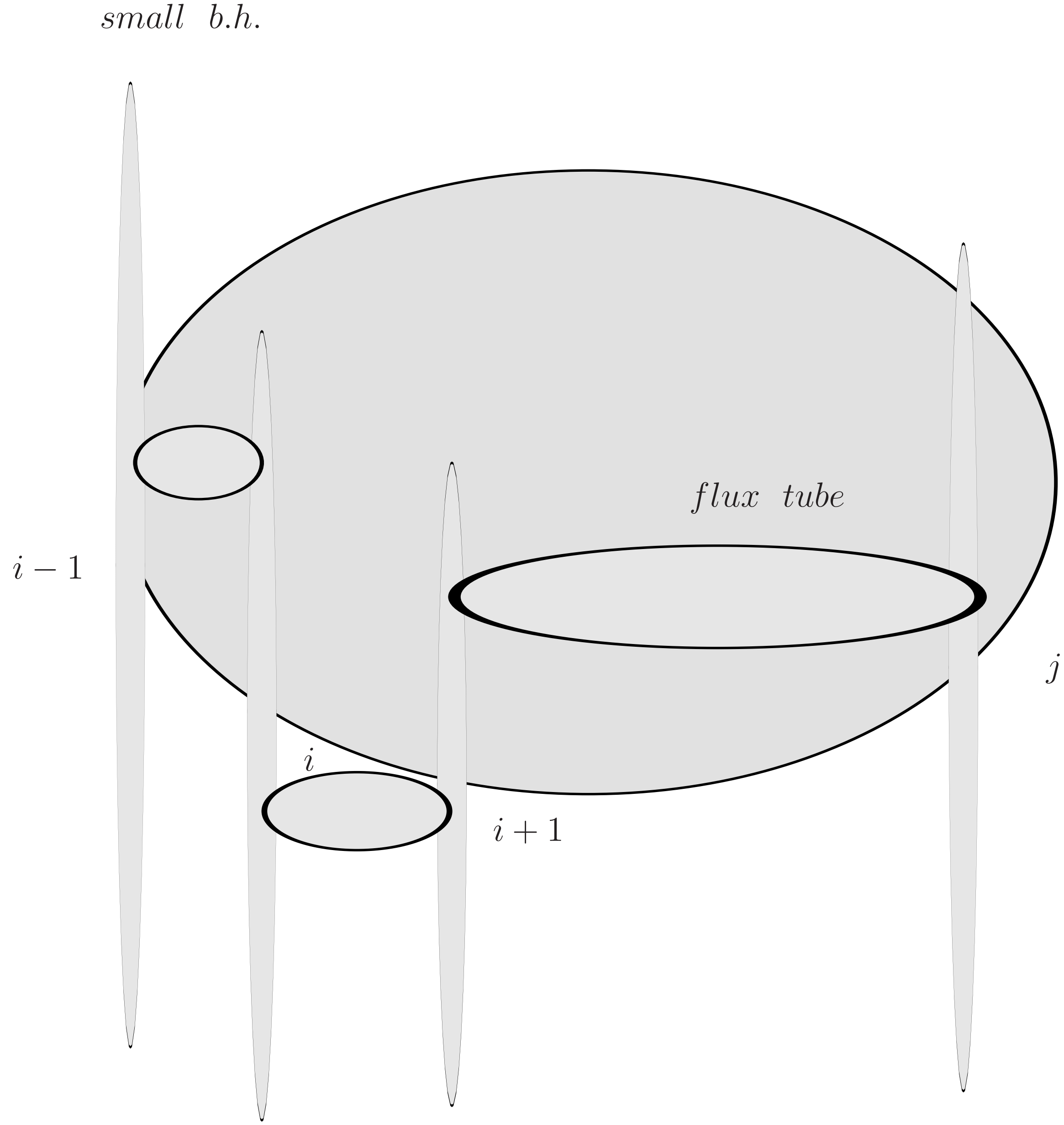
Important test for the picture to be correct:

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:



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