Massive gravity from type II string compactifications

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Outline

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Motivation

1. Boulware-Desser ghost in massive gravity models.
2. String theory is UV complete.
3. Van Dam-Veltman-Zakharov discontinuity.

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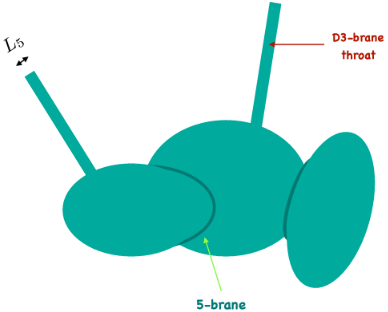
The model

To embed massive gravity in string theory, type II string theory is compactified on a semi-compact surface resembles a 6D Scottish bagpipes with AdS_4 as the non compact part.



The model

The surface can be divided into three parts

1. A compact part called the bag which contribute to the norm of mass eigenstates.
2. Semi infinite throats called pipes contributing to the graviton's mass.
3. the joint part joining the bag and the pipes with no contributions.

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Graviton's Mass

A general mass eigenstate can be factorized as follows

$$\Psi(x, y) = \chi(x)\psi(y),$$

where x are the coordinated on AdS_4, y are the coordinates on the semi compact surface, $\chi(x)$ is the mass eigenstate on AdS_4 and $\psi(y)$ is the eigenstate on the semi compact surface.

Graviton's mass

KK mass eigenstates on the semi compact surface are determined by the elliptic operator

$$\mathcal{M}^2\psi(y) = -\frac{1}{\sqrt{g}}\partial_\mu(\sqrt{g}g^{\mu\nu}\partial_\nu\psi(y)) = m^2\psi(y),$$

We are interested in the minimum eigenstate of this operator i.e. the graviton's mass.

Graviton's mass

A naive guess of the minimization problem would be

$$m^2 = min_\psi(\int d^6y\sqrt{g}L^2 g^{\mu\nu}\partial_\mu\psi^*\partial_\nu\psi),$$

with the constraint $\int d^6y\sqrt{g}L^2|\psi|^2 = 1$, where L is a characteristic size related to the size of the bag, and the constraint is the normalization condition for ψ.

Graviton's mass

The problem with this minimization problem is that ψ can not be normalizable. If so it would converge to zero at infinity on the semi infinite pipes and the graviton would be massless.

Graviton's mass

To solve this problem we impose an alternate constraint on the eigenstate which fixes it to a constant value ψ_{bag} on the compact bag and the beginning of the throats, and zero at infinity, and we integrate over the throats only. Thus, the bag contribute by a constant to the eigenfunction but not to the graviton's mass and the throats contribute only to the graviton's mass.

Graviton's mass

The new minimization problem is

$$m^2 = min_\psi\left(\int_{throats} d^6y\sqrt{g}L^2 g^{\mu\nu}\partial_\mu\psi^*\partial_\nu\psi\right),$$

with the constraint

$$\psi = \begin{cases} \psi_{bag} & \text{at the beginning of the throats,} \\ 0 & \text{at infinity} \end{cases}$$

Graviton's mass

The solution of this optimization problem for the graviton eigenstate is

$$\psi_{min} \approx \frac{\psi_{bag}}{2}(1 - \frac{I(x,a)}{I(\infty,a)}),$$

where a is a parameter related to the size of the bag and

$$I(x,a) = \frac{a^3}{a(a^2-1)^{3/2}} \ln(\frac{\sqrt{a+1} + \sqrt{a-1}\tanh x}{\sqrt{a+1} - \sqrt{a-1}\tanh x})$$

$$-\frac{a^2}{a^2-1}\frac{\tanh x}{a+1-(a-1)\tanh x}.$$

Graviton's mass

The solution for the graviton's mass is

$$m^2 = \frac{\pi^3 L^6}{8} \frac{\psi_{bag}^2}{I(\infty, a)}.$$

From this formula we see that the graviton's mass only depends on the geometry of the semi compact surface and can be sent smoothly to zero if we contract the throats to points on the compact bag.

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Conclusions

1. We can get a consistent massive gravity models from string compactifications.
2. The graviton's mass solely depends on the internal manifold's geometry.

References

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Thank you