Energy Transfer and Kaluza-Klein Mode Decay between Throats

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Based on work
with A. Hebecker
and T. Noguchi.

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Introduction

- Flux compactifications of type IIB string theory have nice features, e.g. moduli stabilization.
- Backreaction of fluxes can create strongly warped regions $\Rightarrow$ throats.
- Throats are common in the string theory landscape, see e.g. Hebecker, March-Russell '06 on the distribution of Klebanov-Strassler throats.

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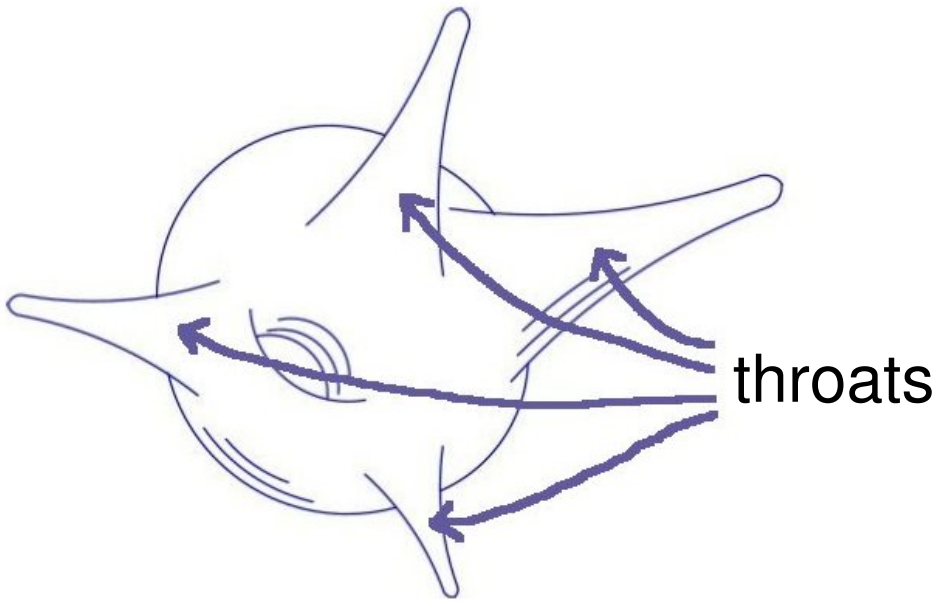

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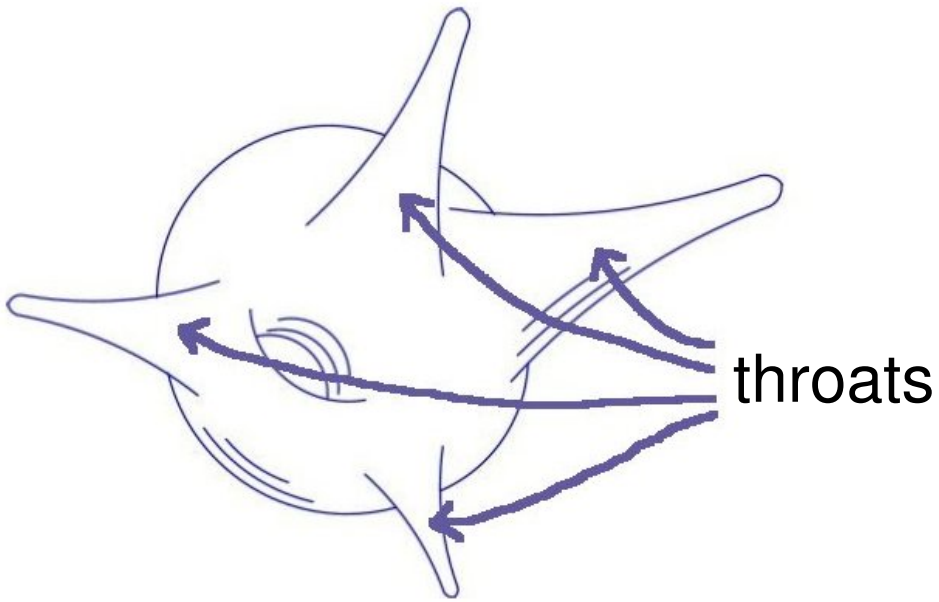

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  - brane-antibrane annihilation after inflation à la KKLMMT.
  - energy flow from the heated standard model sector.
- Interesting for cosmology: Energy transfer rate from a heated throat to other throats.

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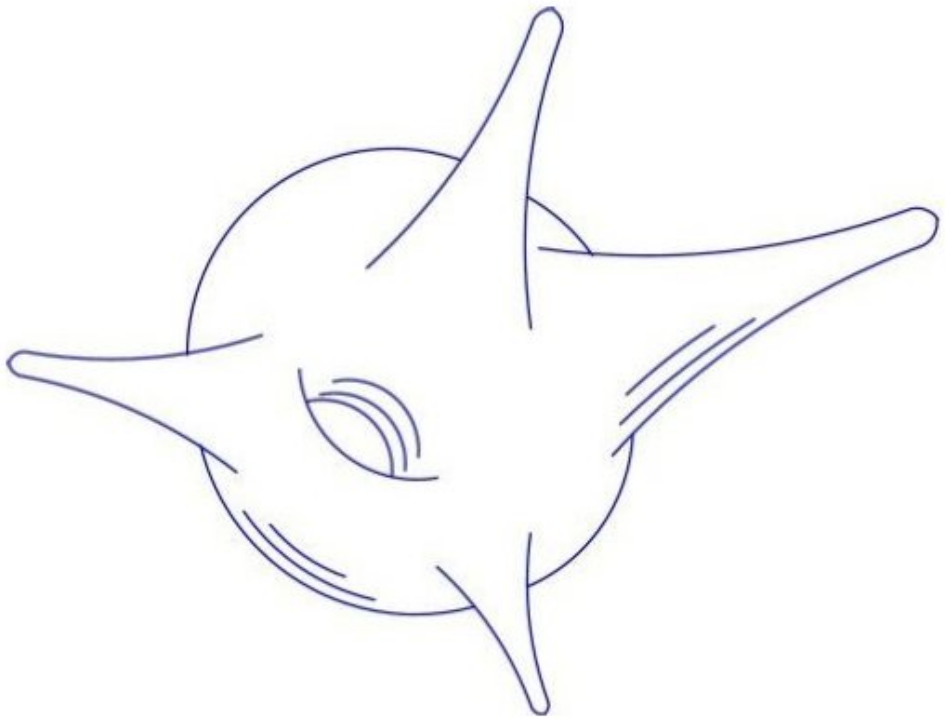

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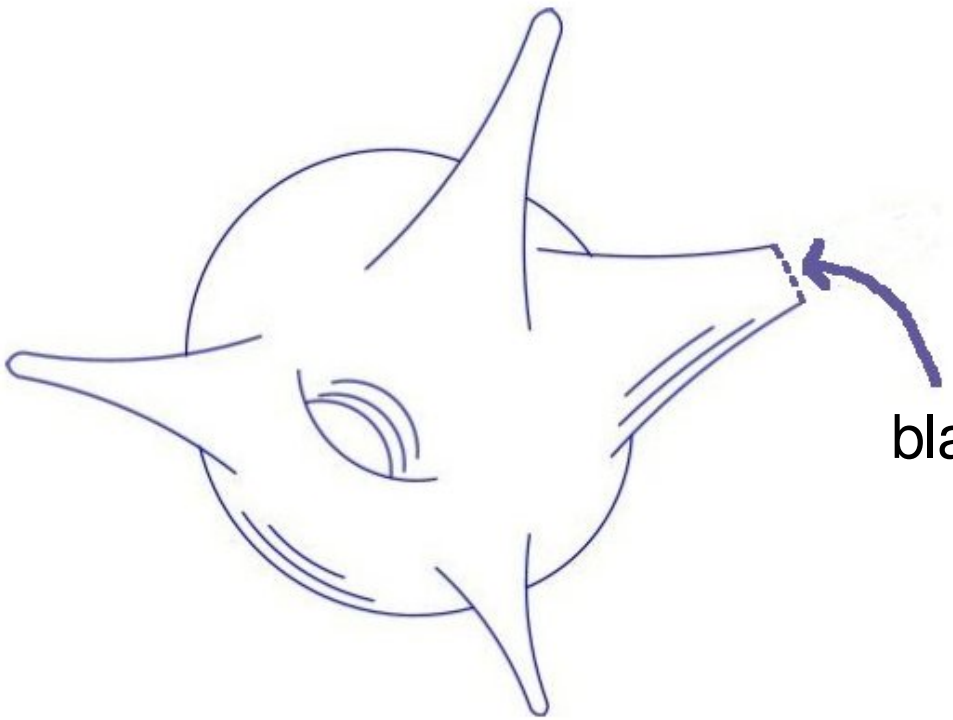

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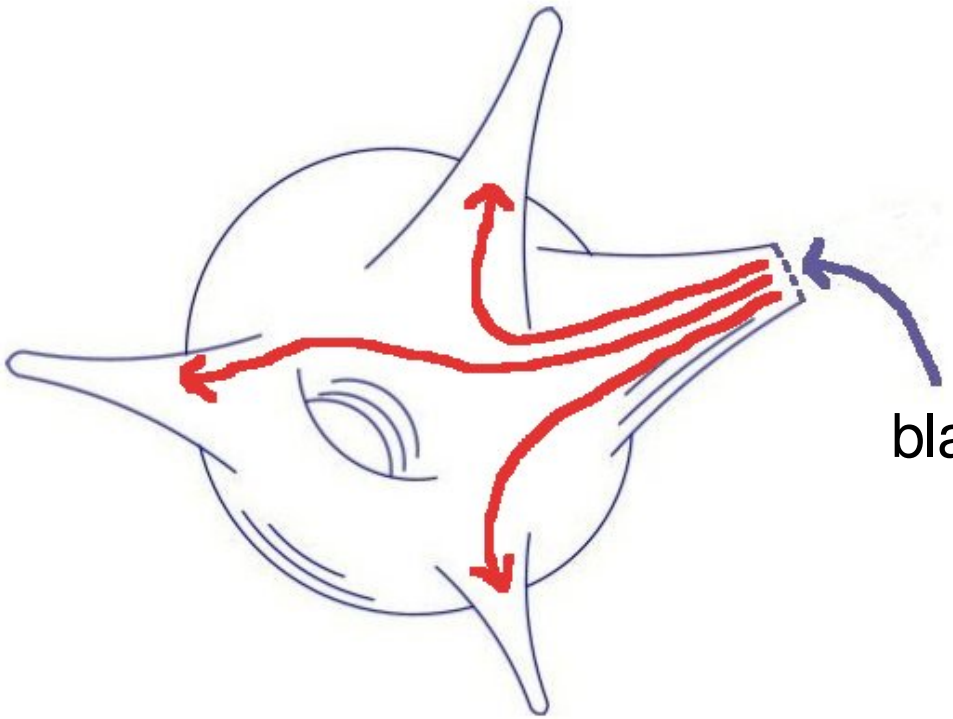
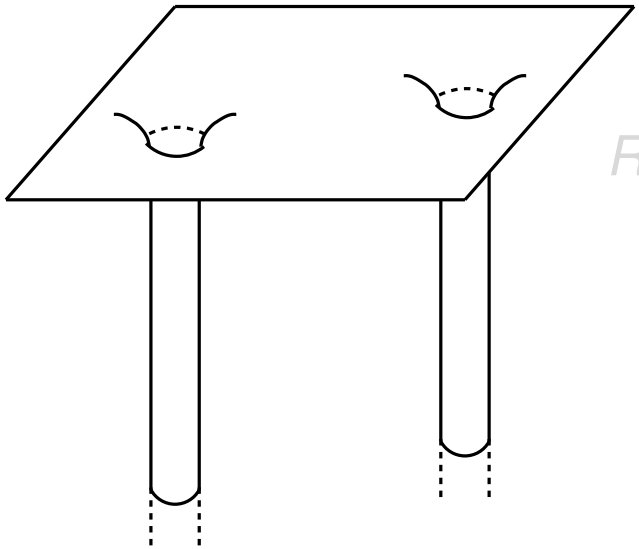


black hole horizon

The Calculation



$$R^4 = \frac{N}{2\pi^{5/2} M_{10}^4}$$

D3-brane stacks

- Simple setup: Two $AdS_5 \times S^5$ throats embedded in a 6d torus.
- Energy transfer rate determined by transition probability of Hawking radiation between the two throats.
- Restrict to the dilaton. Its equation of motion can be written in form of a Schrödinger equation $\Rightarrow$ multi-dimensional tunneling problem $\Rightarrow$ difficult.
- Way out: $AdS_5 \times S^5$ throats are near-horizon geometry of black 3-branes, equivalent to stack of D3-branes.

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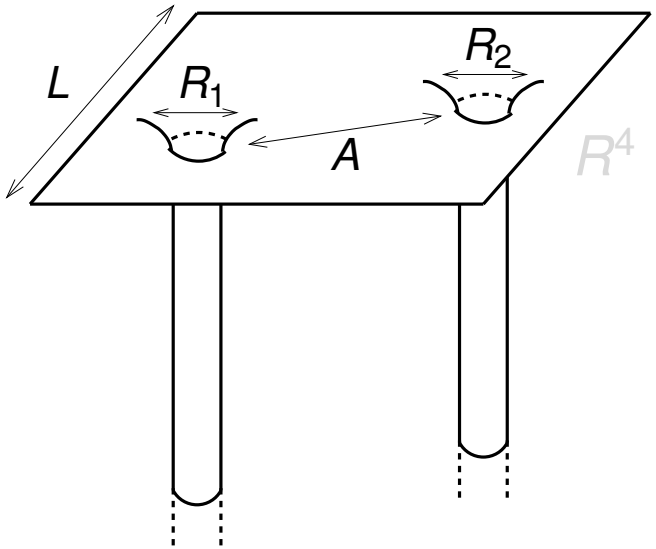

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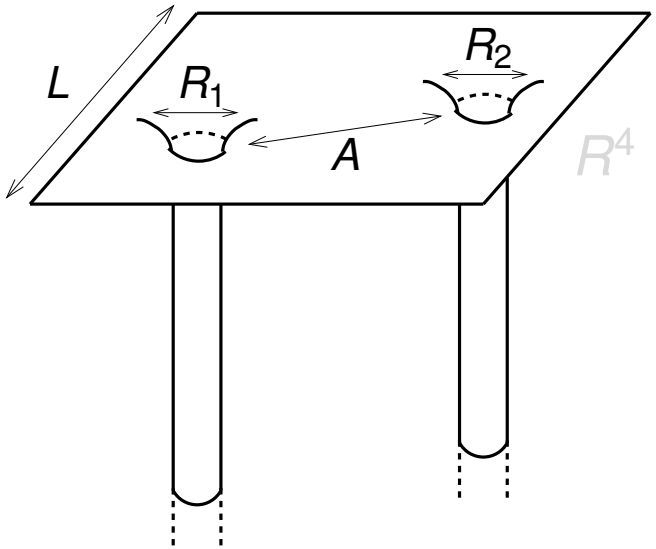

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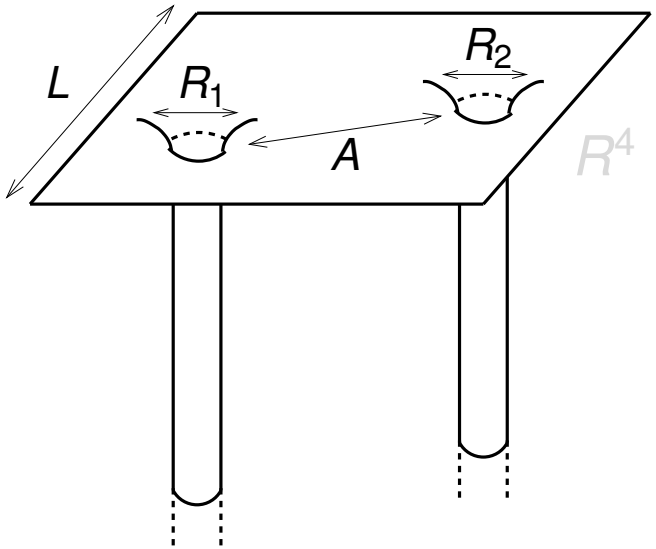

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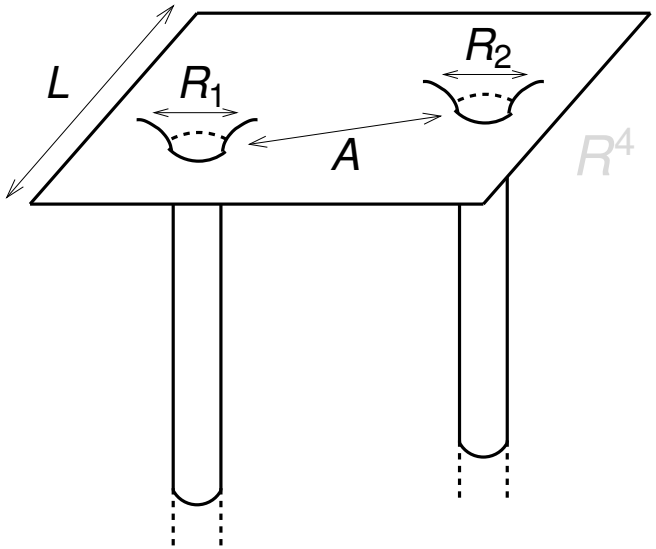

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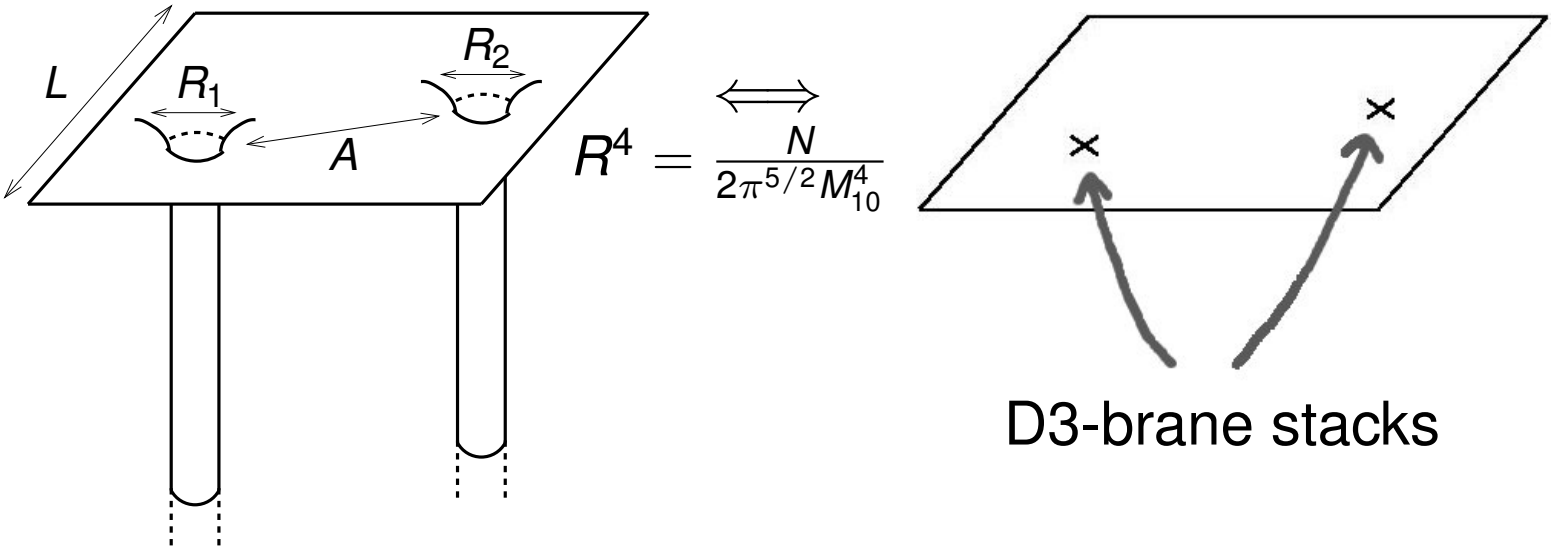

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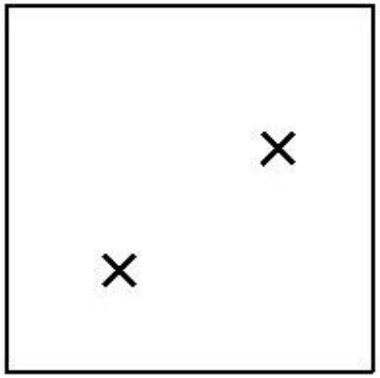

- World-volume theory on stack of N D3-branes is a $\mathcal{N} = 4$ U(N) super Yang-Mills.
- The two brane stacks are coupled by the supergravity fields in the embedding space.
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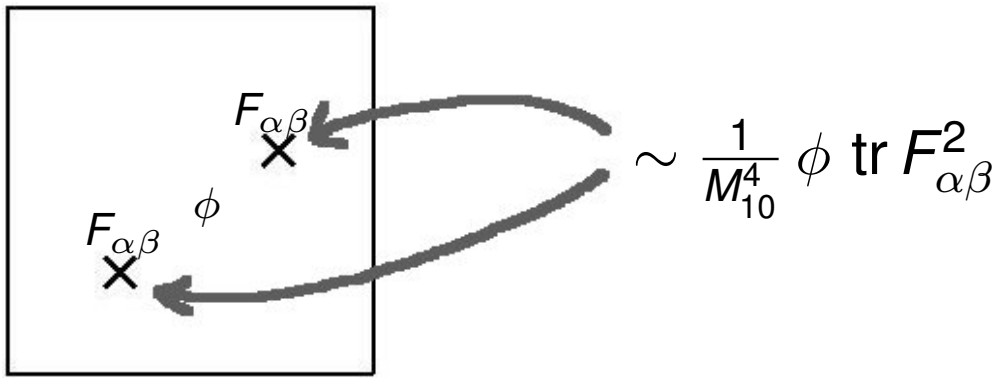

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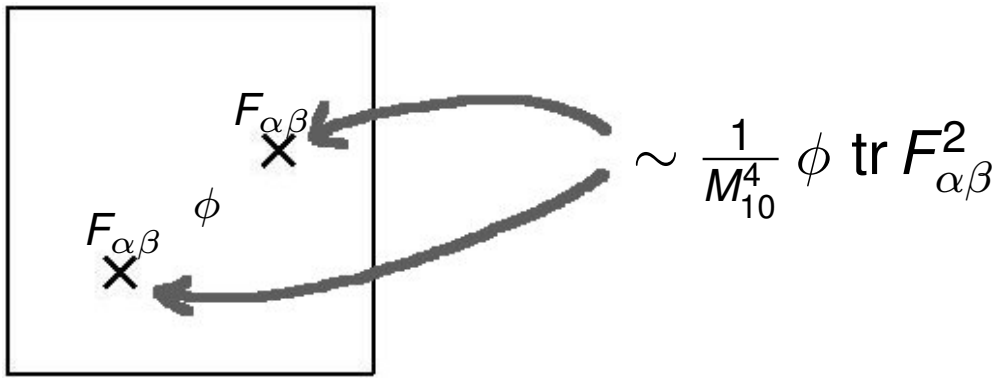

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The Calculation

- KK expansion of the dilaton $\Rightarrow$ from 4d viewpoint there are two gauge theories coupled by tower of KK modes.
- Heated throat corresponds to heated gauge theory. Energy transfer due to processes of the type

$$\xrightarrow[\text{over KK modes}]{\text{summing}} \mathcal{M} \sim \frac{s^2}{M_{10}^8 L^6} \sum_{\vec{n}\in\mathbb{Z}^6} \frac{e^{2\pi i \vec{n}\vec{A}/L}}{s - m_{\vec{n}}^2 + i\epsilon} \sim \frac{s^2}{M_{10}^8 A^4} + \frac{s}{M_{10}^8 L^6}.$$

- Thermally averaging the above process gives energy transfer rate (per 4d volume):

$$\dot{\rho} \sim \frac{R_1^8 R_2^8}{A^8} T^{13} + \frac{R_1^8 R_2^8}{L^{12}} T^9.$$

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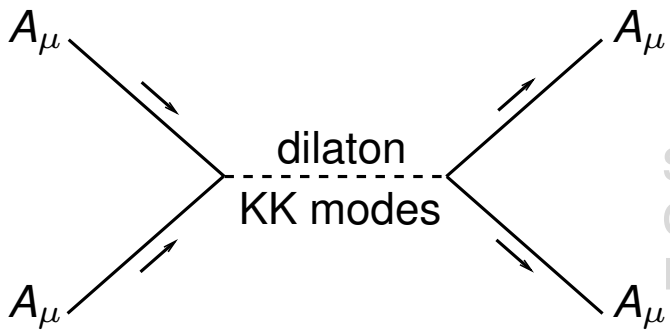

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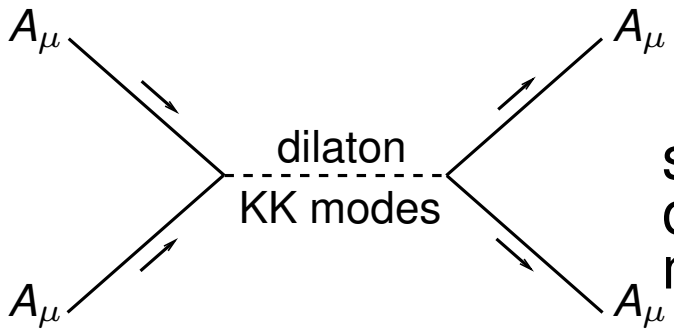

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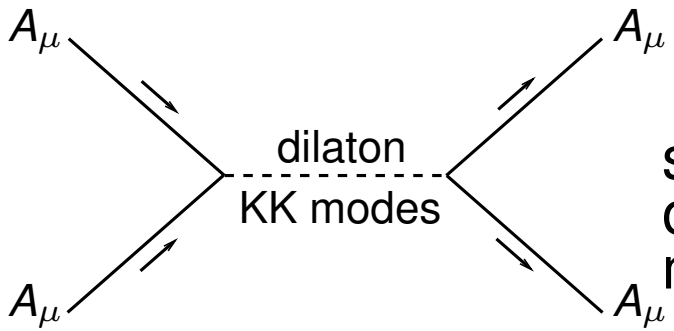

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KK Mode Decay Rate

- When throat temperature drops below IR scale $\Rightarrow$ black hole horizon is replaced by IR cutoff region $\Rightarrow$ from 4d viewpoint there is a non-relativistic gas of throat-localized KK modes.
- KK modes localized in one throat can decay to other throats $\Rightarrow$ decay rate.
- Throat-localized KK mode is dual to glueball state on equivalent stack of D-branes. Decay rate given by the process:

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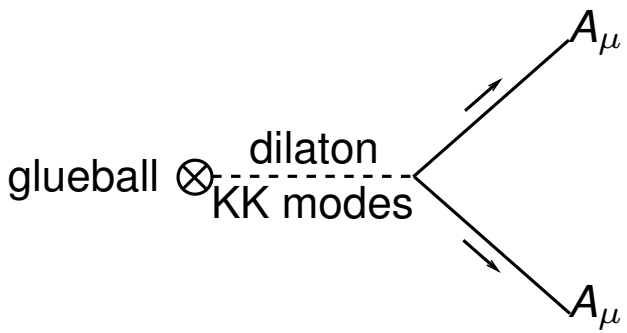

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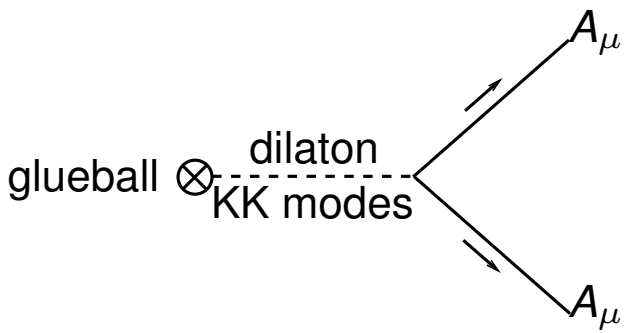

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Decay Rate/Comparison with Literature

- Same steps as before (ℓ angular quantum number, m_{IR} IR scale):

$$\Rightarrow \quad \Gamma \sim \frac{R_1^{8+4\ell} R_2^8}{A^8} m_{\mathrm{IR}} m^{8+4\ell} + \frac{R_1^{8+4\ell} R_2^8}{L^{12}} m_{\mathrm{IR}} m^{4+4\ell}.$$

- From a 5d model with $R_1 = R_2$ and $\ell = 0$, Dimopoulos et al. '01 get

$$\Gamma \sim (mR)^4 m_{\mathrm{IR}}.$$

- In which case is a 5d model a good approximation? If the compact embedding manifold is very small. Minimal size $L \sim R_1, R_2$, since otherwise throats could not be glued into compact manifold.
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- Genuine 10d calculation using the dual gauge theory picture. Simple setup, but order of magnitude stays correct for more general geometries.
- Results also applicable to small brane stacks $\Rightarrow$ e.g. standard model branes in the bulk.
- Interesting for cosmology with multi-throat manifolds:
  - Throat-localized KK particles are dark matter candidate.
  - Can be very light $\Rightarrow$ constraints from cosmology.
- We reproduce existing result by Dimopoulos et al. '01 in a limiting case. In general the decay rate is much lower $\Rightarrow$ important for reheating after brane-antibrane inflation.

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