Energy transfer in a multi-throat world

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Outline:

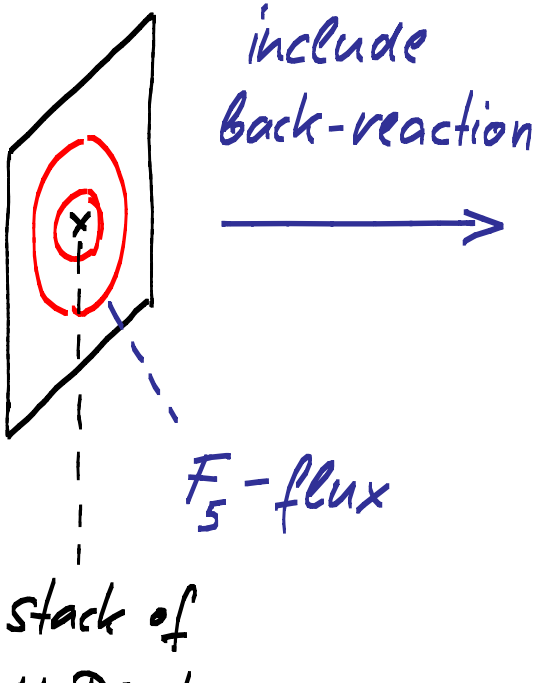
- What are throat?
- Why should we be interested in throats?
- Cosmology with throats
- Energy loss by a heated throat
- Decay of throat-localized KK-modes

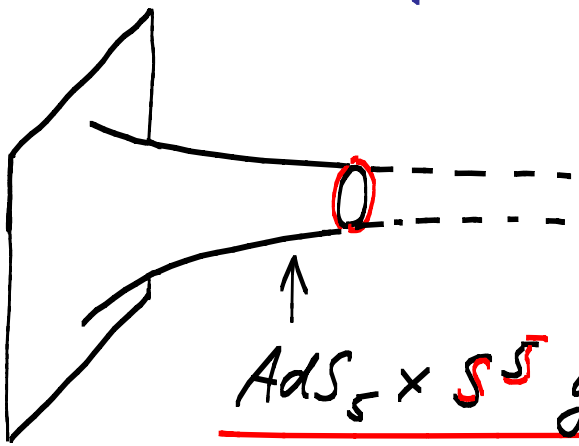
Randall-Sundrum-like models in string theory

(Verlinde '99 ... Klebanov et al. ~'00 ... GKP, '01)

- consider type IIB supergravity
- focus on F_5 5-form field strength sourced by D3-branes

($\hat{=}$ F_2 sourced by electrons)





$AdS_5 \times S^5$ geometry

$$e^{2ky} dx^2 + dy^2 + k^{-2} d\Omega_5^2$$

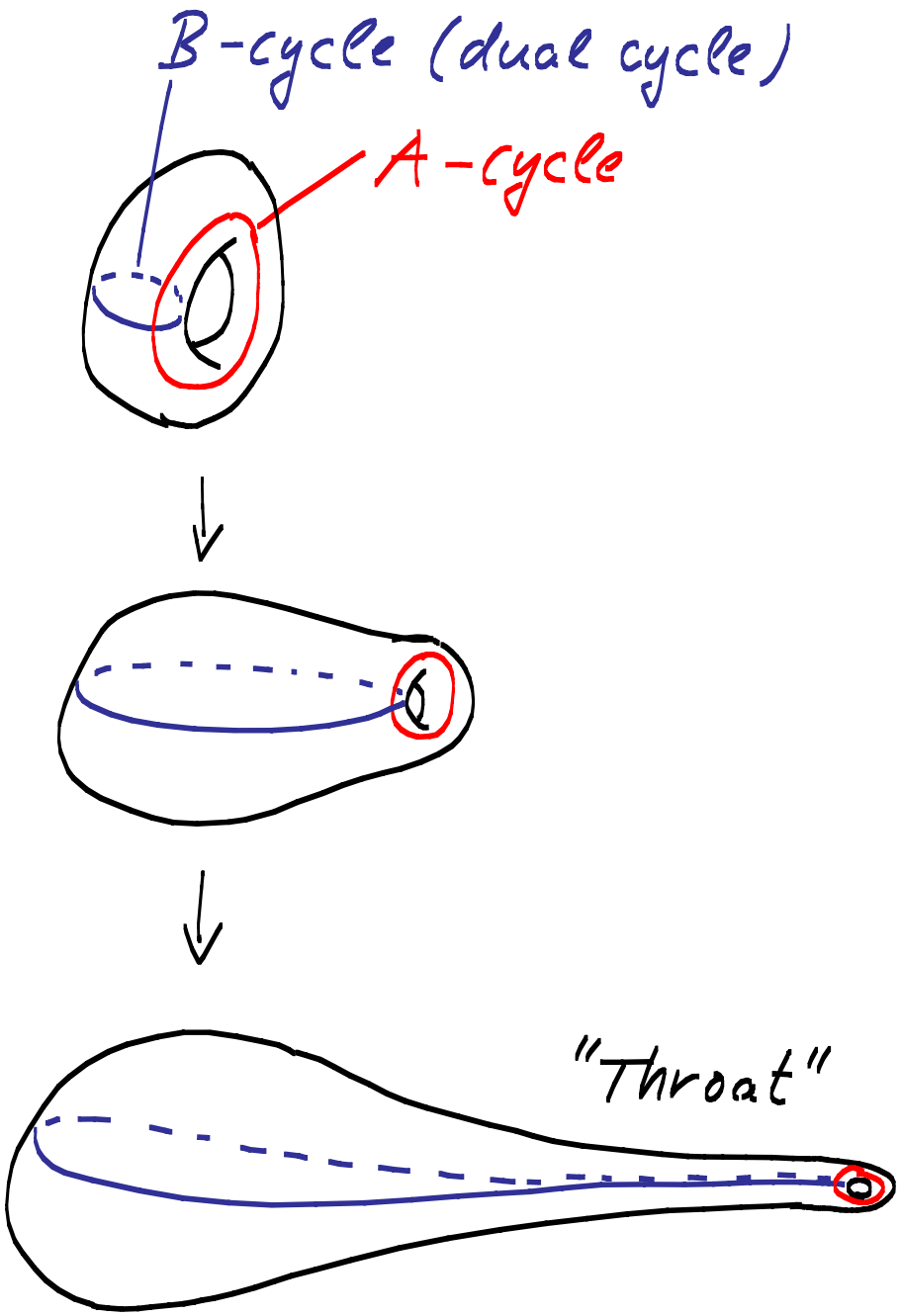
exactly as in RS model

Finite throats

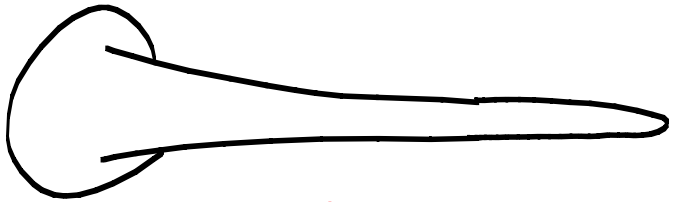
- Consider a space with two 3-cycles

- The fluxes stabilize the cycle-volume
(more flux → larger volume)

- A large ratio of fluxes on B & A-cycle can lead to
"throat geometries"



This "throat geometry" allows for a 5d interpretation:



"UV-brane" — "5d Bulk" — "IR-Brane"

- Geometry of throat region: $\sim AdS_5 \times T^{1,1}$ $(T^{1,1} \sim S^2 \times S^3)$
- Effective 5d geometry:

  (2-brane RS model)

$$ds^2 = \underbrace{e^{2A(y)}}_{\text{"warp factor"}} dx_\mu dx^\mu + dy^2$$

The cosmological constant problem and its flux "solution"

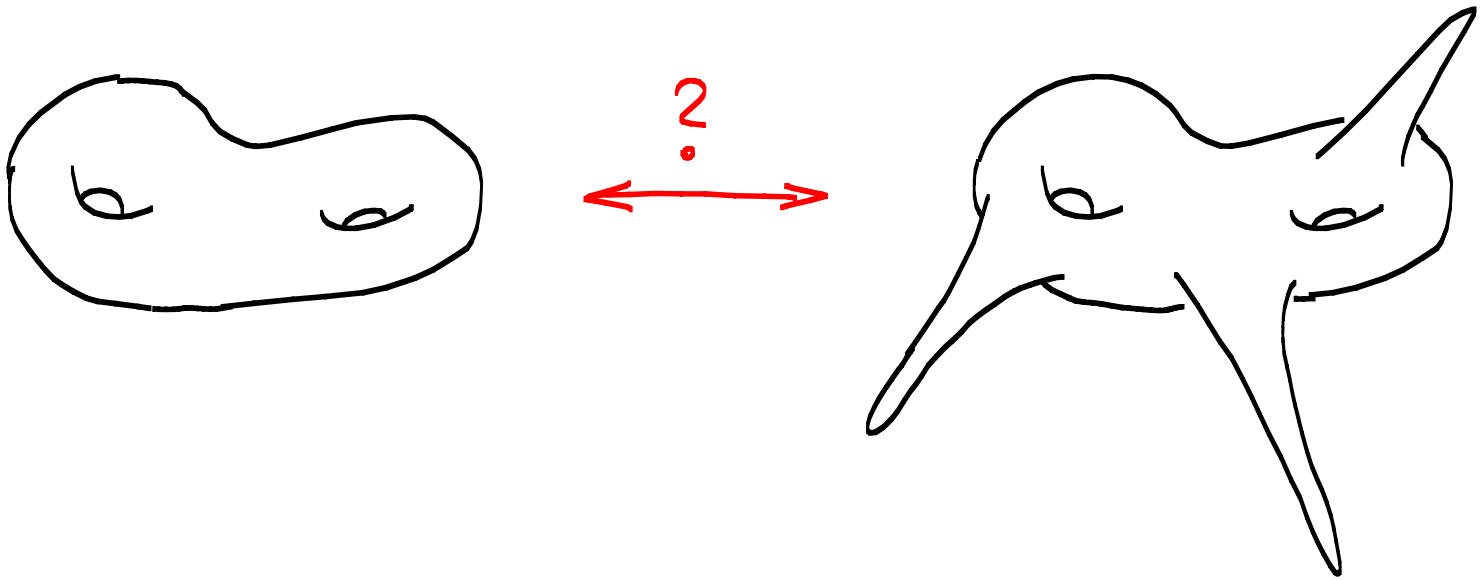
- string models with ~~susy~~ : $\Lambda_4 \sim M_{string}^4$ (generically)

- type IIB flux compactifications :
  - $\sim 10^{200}$ models (from discreet flux choices on ~100 cycles of CY's)
  - under certain conditions, a dense discretuum of Λ_4-values (with no special features at $\Lambda_4 = 0$) exists

$\Rightarrow$ very likely, there are string models with $\Lambda_4 \sim \Lambda_{obs.}$ & ~~susy~~

One can quantify the statement that "throats are common in the type IIB landscape".

(→ recent paper "The Ubiquitous Throat" with J. March-Russell)



Basic idea of analysis

- Expect orientifold with many 3-cycles (since otherwise the choice of fluxes will be too limited to allow for a sufficiently small cosm. constant Λ)
- Random flux numbers $\Rightarrow$ some 3-cycles carry small flux numbers $\Rightarrow$ those cycles stabilized at small volume
- Generically, these small-volume cycles give rise to throats

$\Rightarrow$ Distribution of number & length of throats becomes a well-defined statistical question (→ Douglas et al.)

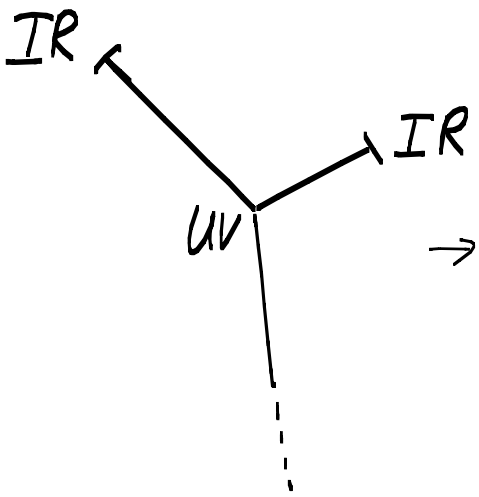
Result:

binomial distribution → e.g.

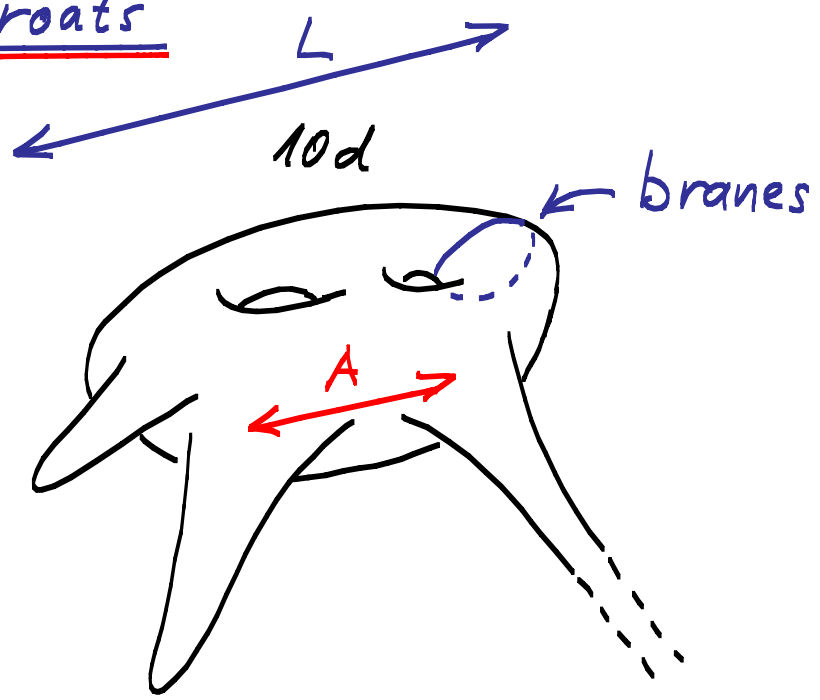
$$\bar{n}\,(h > h_*) = \frac{K}{3c \log h_*}$$

Cosmology with throats

5d models



→ Dimopoulos et al., '01
Barnaby et al., '04
Grojean et al., '06
...
Chen, Tye '06
Langfelder '06



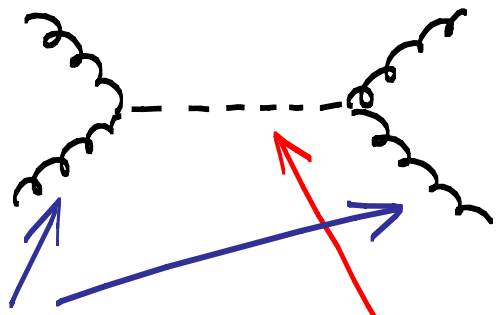
Natural expectation: Throats (≙ gauge theories with low IR scale) will be heated

Important question: Energy transfer rates between throats & between throats and brane sectors

Our approach: Describe throat by large-N brane stack

(including coupling to bulk SUGRA fields)

- Calculate energy transfer via



gauge fields on 2 brane stacks

dilaton

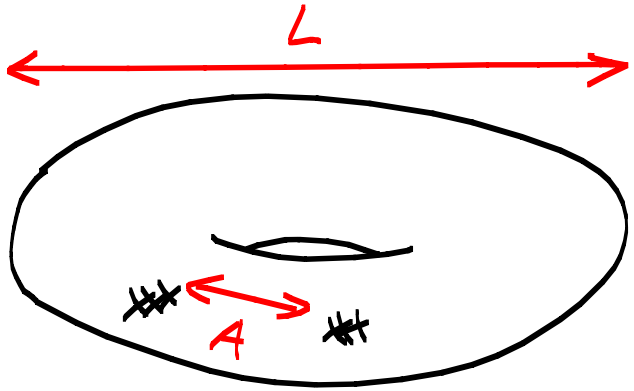
(exact results at $T=0$ (Klebanov, Gubser, ... '97) extend to $T \neq 0$ with only $O(1)$ corrections; this is OK since we only need order-of-magnitude estimates)

- D3 brane stacks: $N \sim R^4$ (R - throat radius)
- energy transfer rate:

$$\dot{\varepsilon} \sim R_1^8 R_2^8 \left(\frac{T^{13}}{A^8} + \frac{T^9}{L^{12}} \right)$$

bulk-kk-tower

bulk-zero-mode ($\hat{=}$ 4d gravitational coupling)

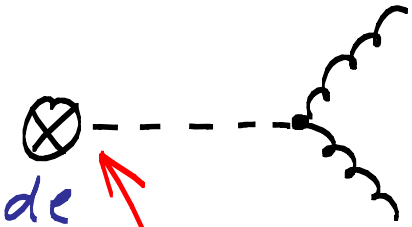


easy to see:

$$\frac{1}{A^8} \sim \left(\frac{1}{A^4}\right)^2$$

propagator in $d = 6$

After the throat has cooled, the last kk modes decay (non-thermally).



kk-mode
≙ glueball

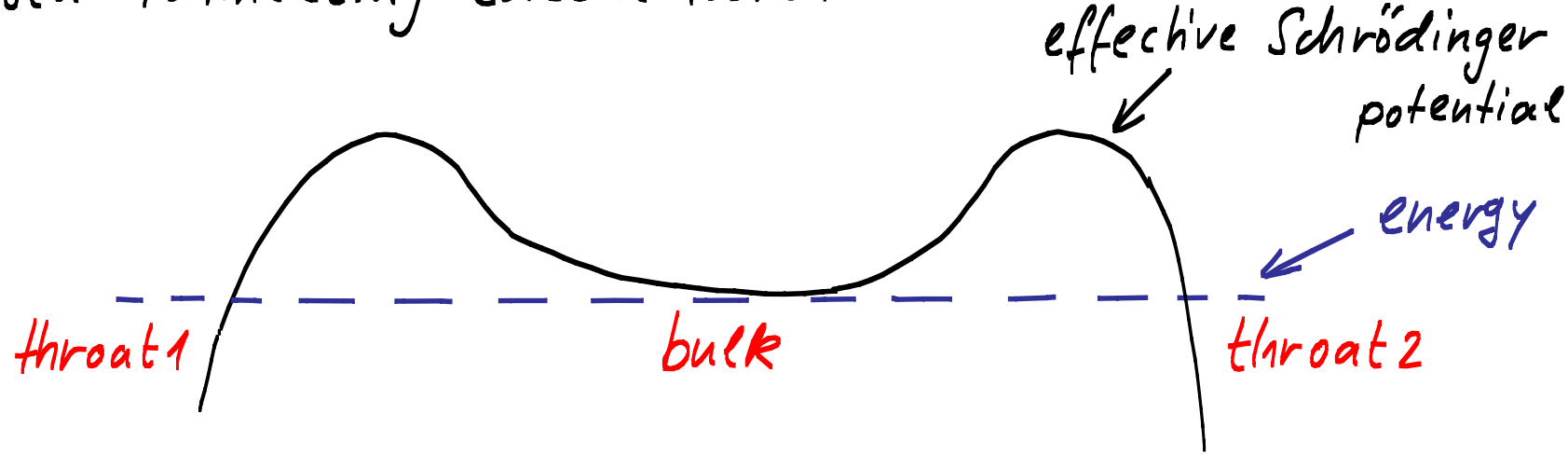
this vertex can be obtained by tunnelling calculation in gravity picture

After that, a gauge-picture calculation gives decay rate:

$$\Gamma \sim (R_1 m)^{8+4\ell} R_2^{\,8} m_{IR} \left(\frac{1}{A^8} + \frac{1}{m^4 L^{12}} \right)$$

(ℓ - angular excitation on S^5 or $T^{1,1}$)

- previous results attempting to go beyond the RS model used tunnelling calculations:



- However: hard to justify conceptually (really one has a multi-dimensional tunneling problem!)

(→ e.g. Firouzjahi, Tye '05
Chen, Tye '06)

[indeed, our results agree only in very specific regions of parameter space]

Conclusions and Outlook

- Our energy loss / decay rates are generically smaller than in 5d RS models
- This effect is partially compensated if throats are close ($\sim 1/A^8$ rather than $\sim 1/L^{12}$)
- Our formulae are easily generalized to processes

  throat $\longrightarrow$ bulk-D-brane sector

  Bulk-D-brane sector $\longrightarrow$ throat
- Need to investigate consequences for reheating, KK-dark-matter etc.