# Multi-Throat String Compactification and Spectrum of Cosmic String Tension

Henry Tye

HKUST and Cornell University

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# String theory has 10 dimensions

- 6 of the spatial dimensions are compactified;
- Flux compactification into a Calabi-Yau like manifold yields a stabilized 6-dim. internal space;
- There are D3-branes that span our uncompactified 3-dimensional space; they appear as points in the internal space;
- We may live in a stack of these D3-branes.

# A typical flux compactification in Type IIB

$$\chi(M) = 2(h^{1,1} - h^{2,1})$$

| *Manifold* | $h^{1,1}$ | $h^{2,1}$ | $\chi$ |
|---|---|---|---|
| $\mathcal{P}^4_{[1,1,1,6,9]}$ | 2 | 272 | $-540$ |
| $\mathcal{F}_{11}$ | 3 | 111 | $-216$ |
| $\mathcal{F}_{18}$ | 5 | 89 | $-168$ |
| $\mathcal{CP}^4_{[1,1,1,1,1]}$ | 1 | $\mathcal{O}(100)$ | $\mathcal{O}(-200)$ |

A manifold has $h^{1,1}$ number of Kähler moduli and $h^{2,1}$ number of complex structure moduli.

A typical flux compactification has hundreds of warped throats, each described by a complex structure modulus.

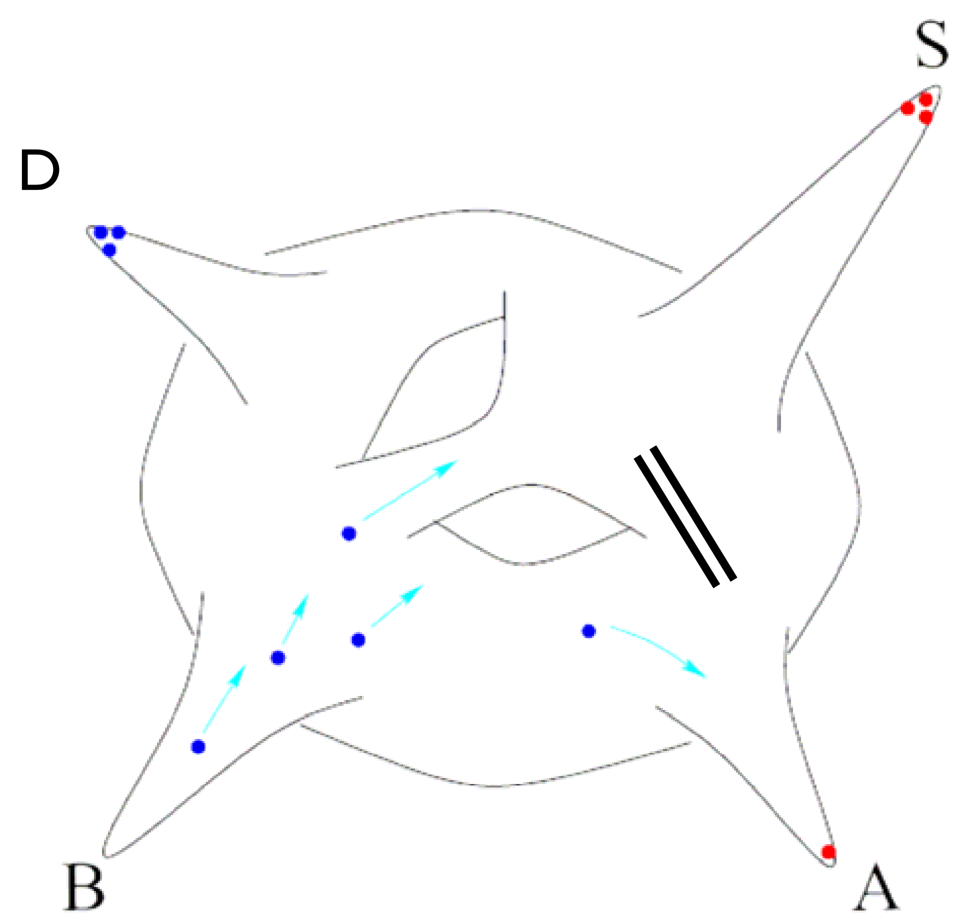
Example :

# P(11169)

$$p = a_1 x_1^{18} + a_2 x_2^{18} + a_3 x_3^{18} + a_4 x_4^{3} + a_5 x_5^{2}$$
$$+ \phi_1 x_1^6 x_2^6 x_3^6 + \phi_2 x_1 x_2 x_3 x_4 x_5 + \ldots$$

$$x_1 \to \lambda x_1$$
$$x_2 \to \lambda x_2$$
$$x_3 \to \lambda x_3$$
$$x_4 \to \lambda^6 x_4$$
$$x_5 \to \lambda^9 x_5$$
$$p \to \lambda^{18} p$$

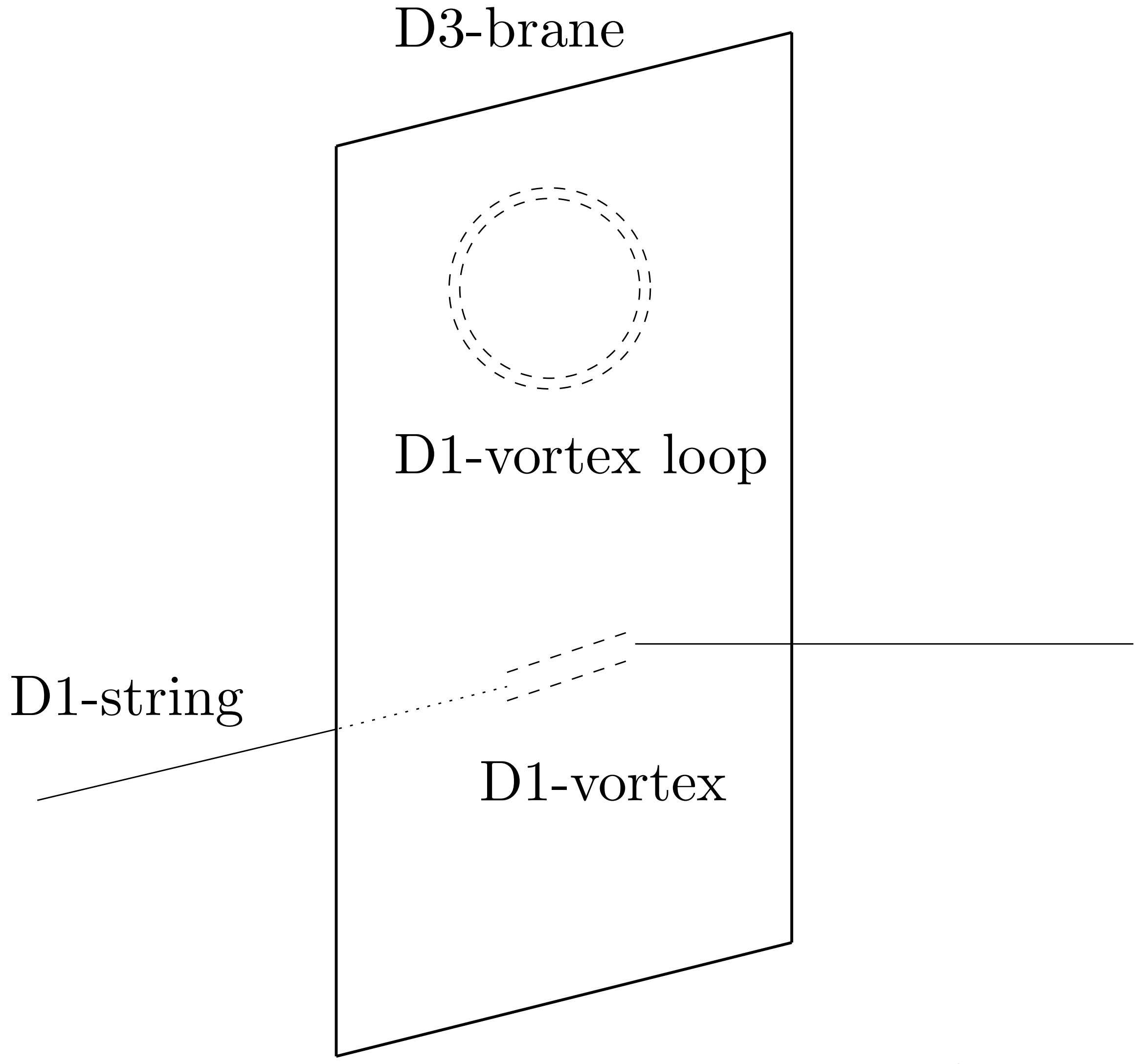
# Manifold with warped throats and D3-branes




Each warped throat has a warped factor h.

Energetically, D3-branes, D1-strings and F1 strings like to move to the bottom of the warped throats

# D1 and F1 strings




F1 strings break up into pieces inside D3-branes

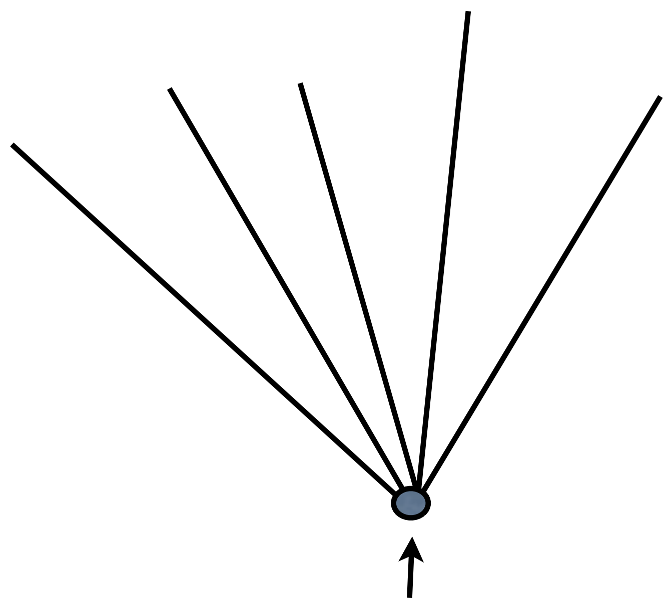
D1-strings become (metastable) vortices

Size of vortex $r \sim \dfrac{\sqrt{\alpha'}}{h\sqrt{g_s}}$

# Cosmic string tension spectrum in a warped deformed throat

E.g. Klebanov-Strassler Throat :

A baryon with mass $\sim M^{3/2} h_A / \sqrt{\alpha'}$



$$T_{p,q} \simeq \frac{h_A^2}{2\pi\alpha'} \sqrt{\frac{q^2}{g_s^2} + (\frac{bM}{\pi})^2 \sin^2(\frac{\pi p}{M})}, \qquad b = 0.93266$$

b=0 in the presence of branes

Very large M in bulk

Leblond, Firouzjahi, HT, hep-th/0603161
Herzog, Klebanov, hep-th/0111078

# Possibilities

- Cosmic strings may fall into the throats. Each warped throat (with no D3-branes in its bottom) has its own (p,q) spectrum.
- A throat with D3-branes at its bottom will only have D1 vortices.
- Presumably most if not all the throats have their own cosmic string networks. Each throat has its own tension scale, typically some orders of magnitude below the string scale.
- This results in high cosmic string density (i.e., sum of cosmic string networks).

# Another possibility

- Cosmic strings may continue to oscillate in the internal space because the damping into a throat is too weak.

  Avgoustidis, 0712.3224
  Avgoustidis, Chadburn, Gregory, 1204.0973

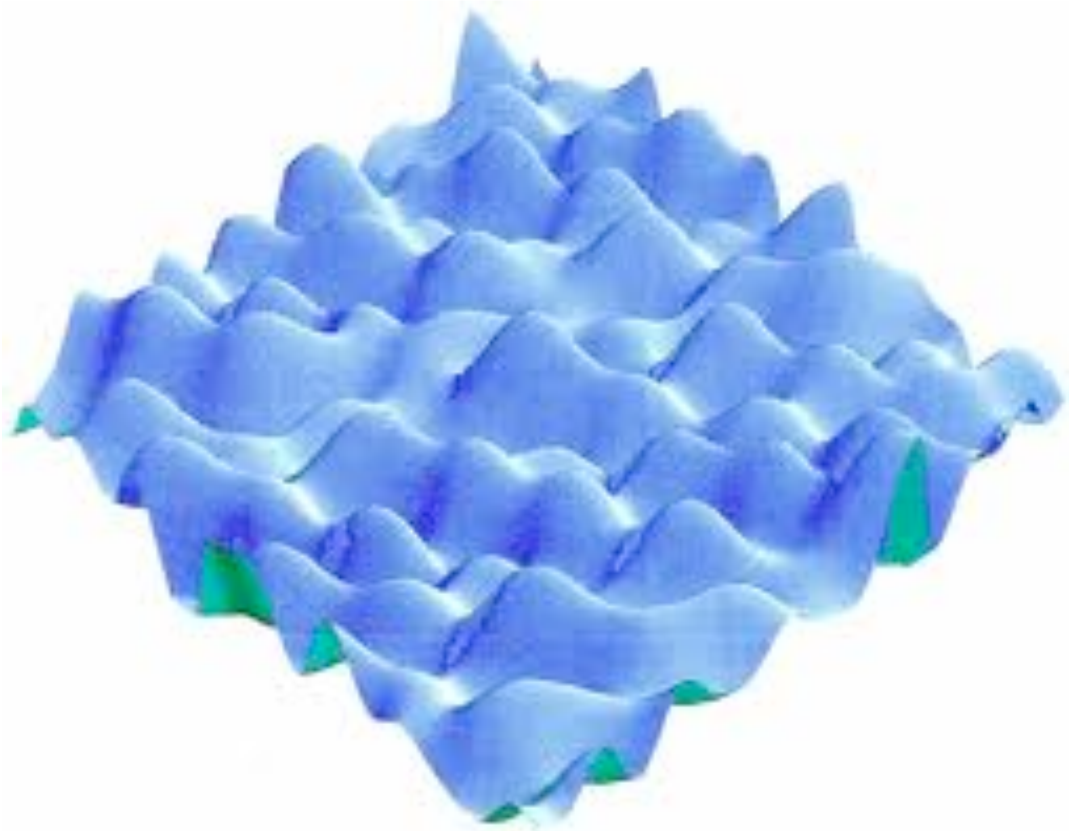
- Strings moving in 9 spatial dimensions do not see each other, so intercommutation probability is small and the cosmic string density is very high.

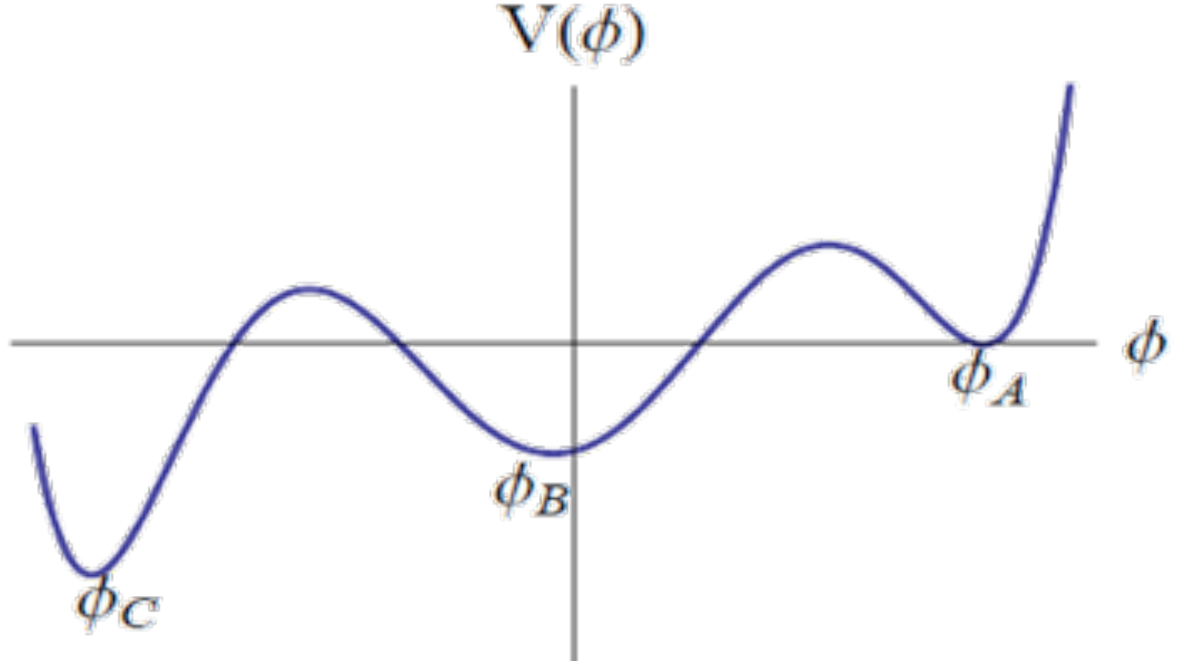
# 3 properties to consider

- If a throat has no branes, the beads and junctions can slow down the strings.
- If a throat has D-3 branes, or D7-branes are around, the thickness of the D1-vortex

$$r \sim \frac{\sqrt{\alpha'}}{h\sqrt{g_s}}$$

- Many throats





# Summary

The cosmic string density can be much
higher than expected,
either
as a sum of cosmic string networks,
or
as strings moving in internal space.

In both cases, one should detect
different string tensions.