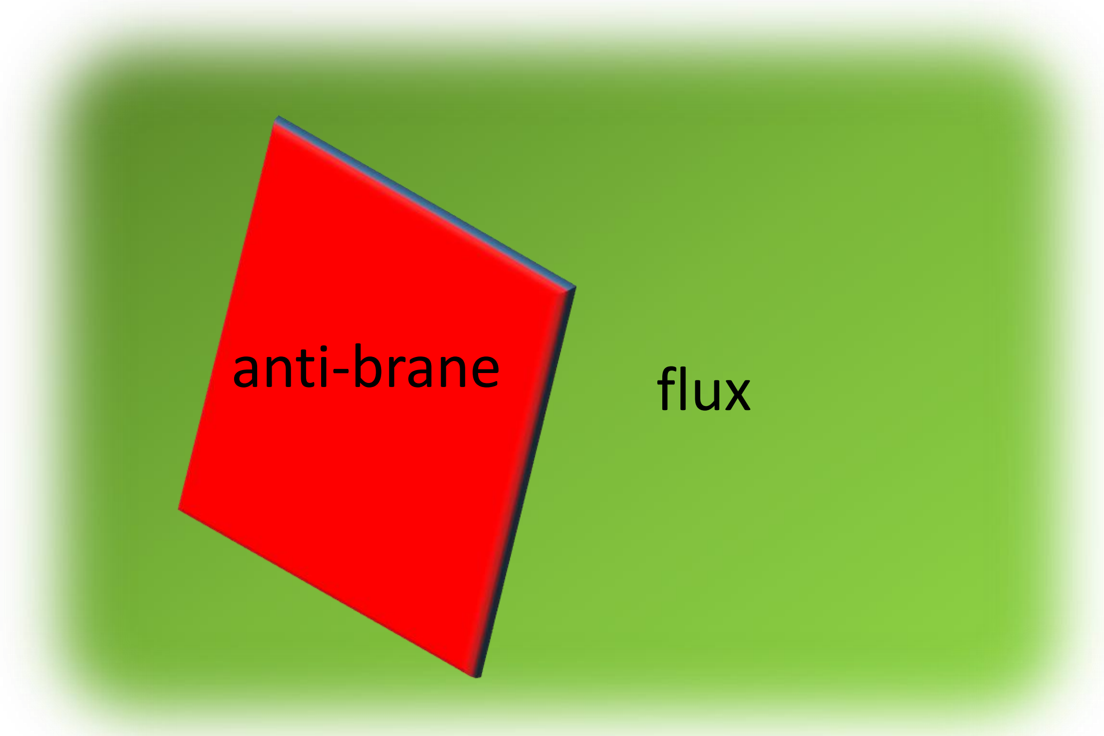
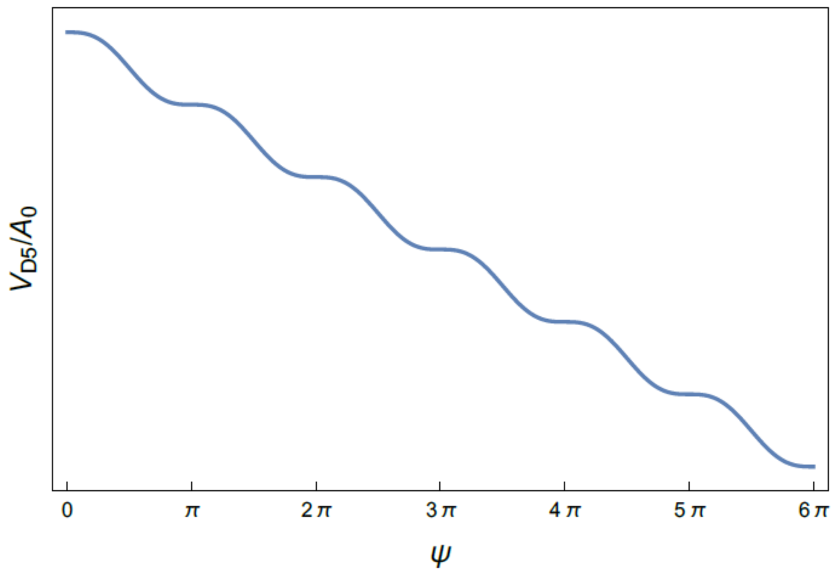
Unstable anti-branes source unwinding inflation?

Thomas Van Riet – K.U.Leuven

With Fridrik Gautason & Marjorie Schillo, arxiv:1611.07037

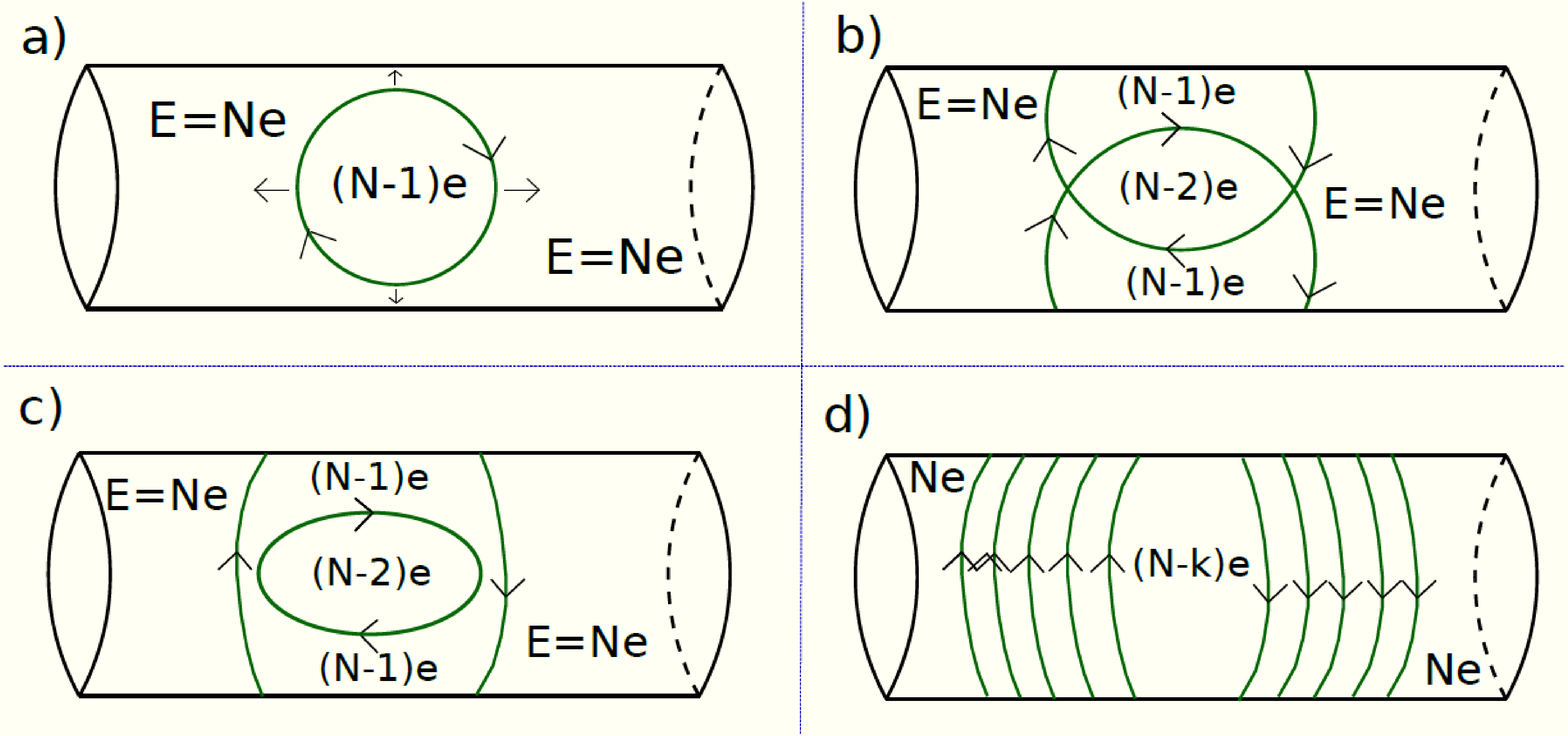




New ideas in string phenomenology, DESY, Hamburg, 2017

Unwinding inflation

[D'Amico, Gobetti, Kleban, Schillo, 2013]



Unwinding inflation in string theory?

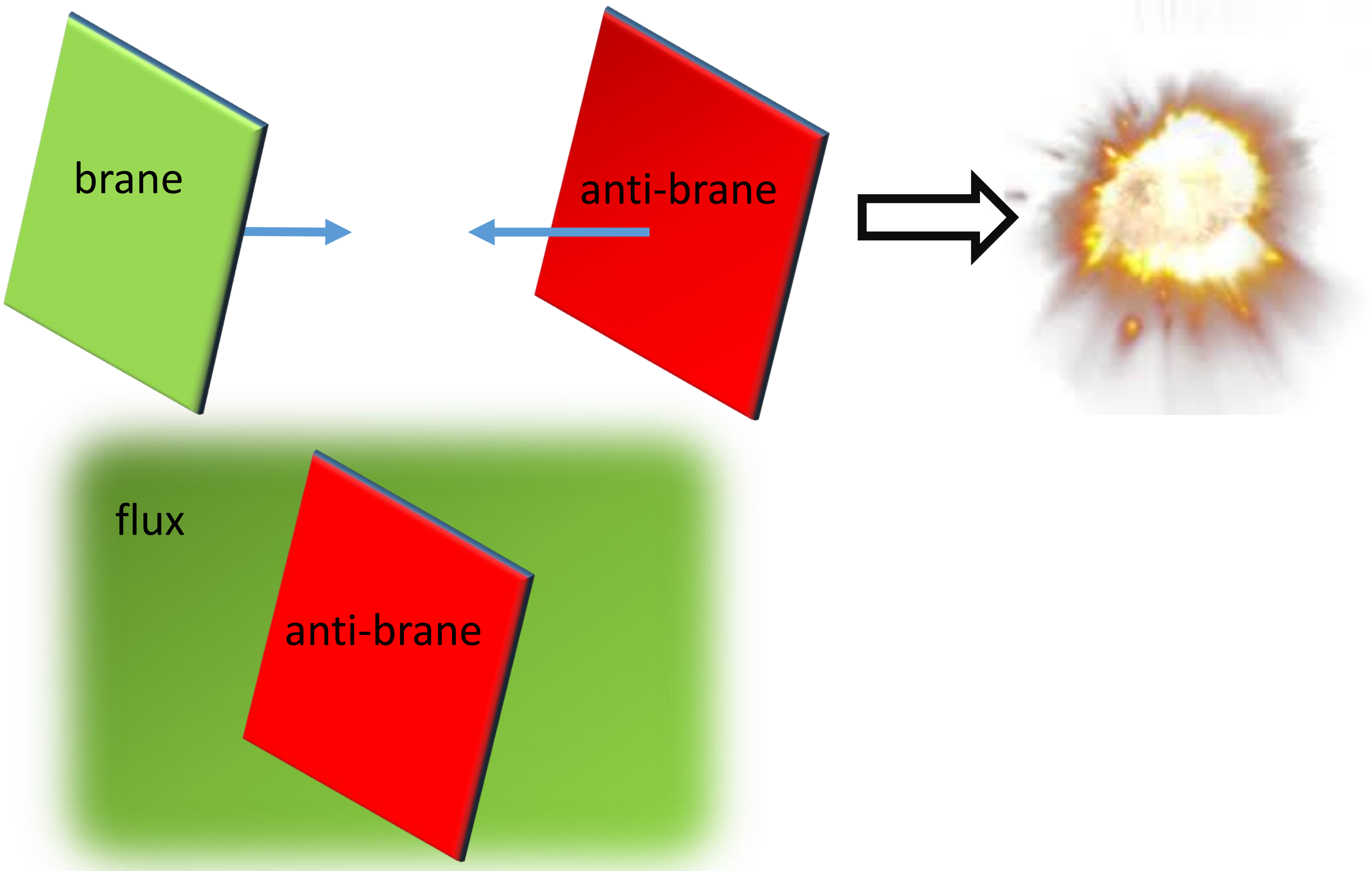
1. Fluxes typically contribute in “tadpoles”

2. Depleting fluxes does not necessarily imply depleting energy: see GKP.

3. Depleting fluxes might destabilize the manifold.

→ Issues will be solved by our embedding by using unstable anti-branes.

Uses of anti-branes: susy-breaking in 10d



Perturbatively unstable

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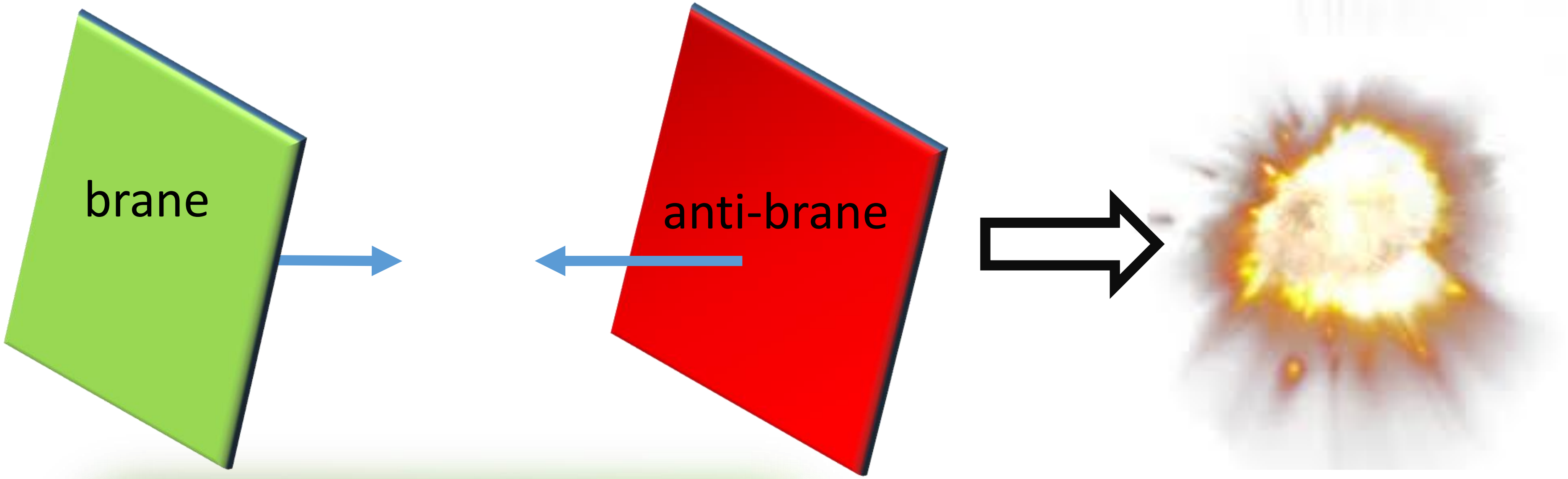

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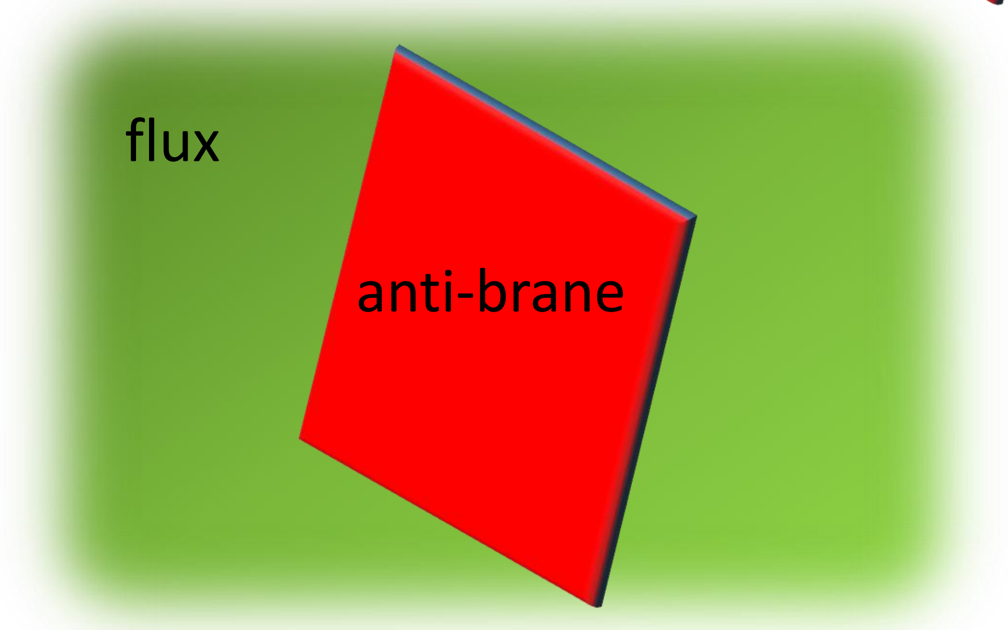
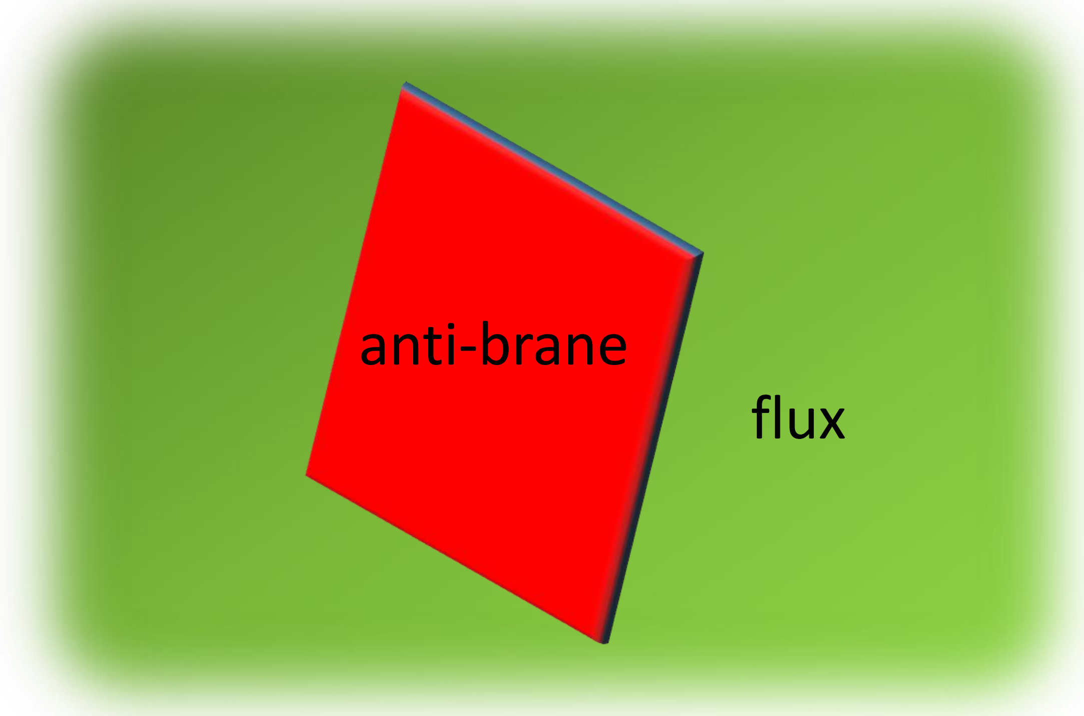


$$\mathrm{d}F_{8-p} = \underbrace{H \wedge F_{6-p}} + \underbrace{Q_p \delta}$$

Opposite orientation

(Does not necessarily breaks SUSY in AdS space)

1. Holography of dynamical susy breaking [Maldacena & Nastase 2001, KPV 2002, …]



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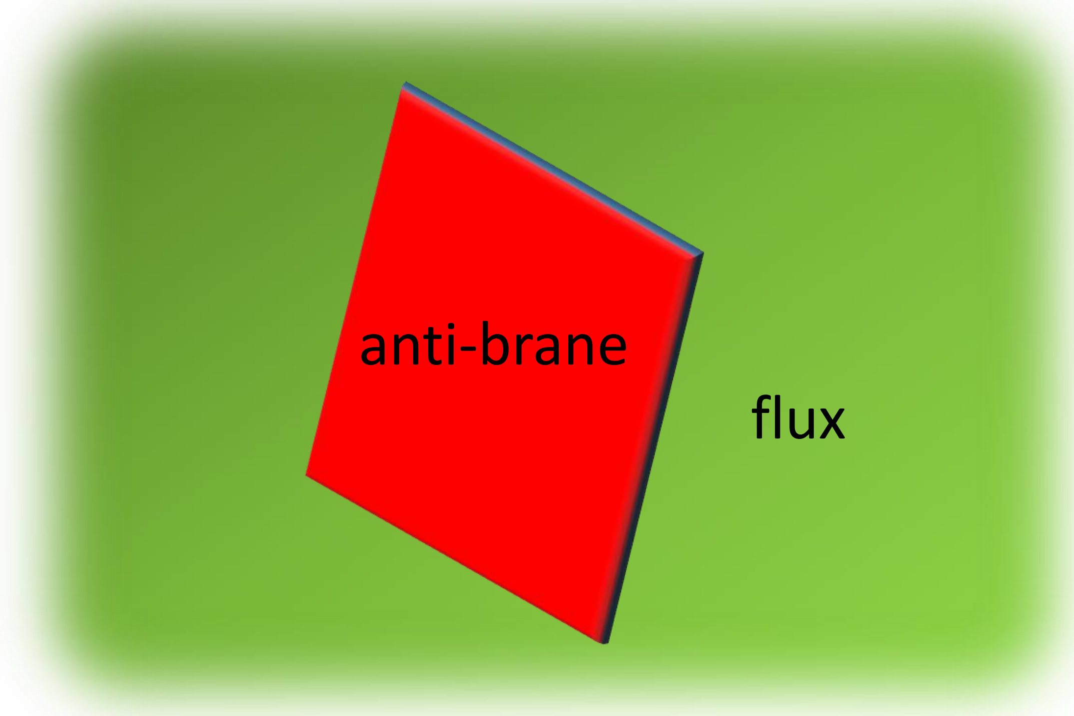

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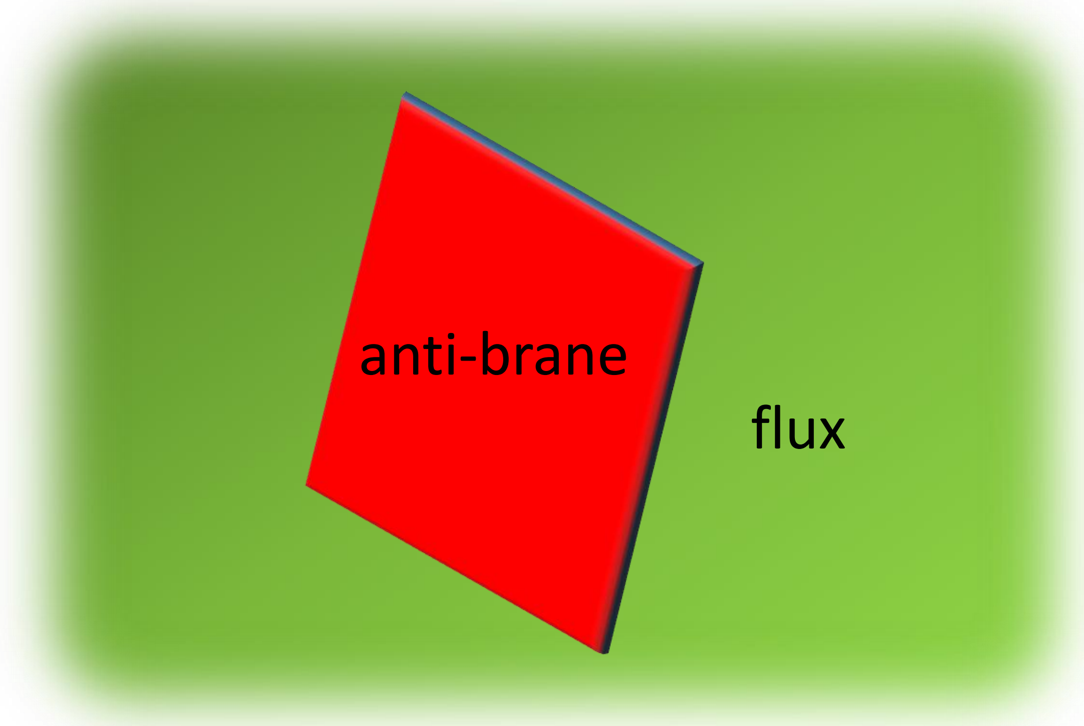

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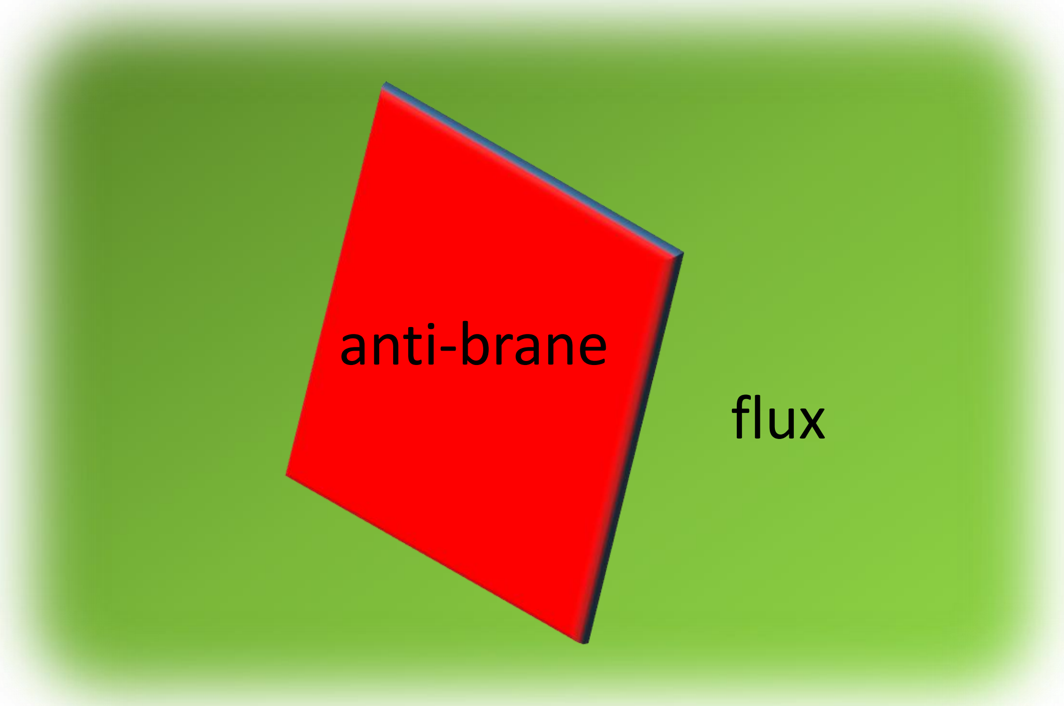
4. Brane Inflation [KKLMMT 2004,…], ***Unwinding mechanism*** [Gautason, Schillo, VR 2016]



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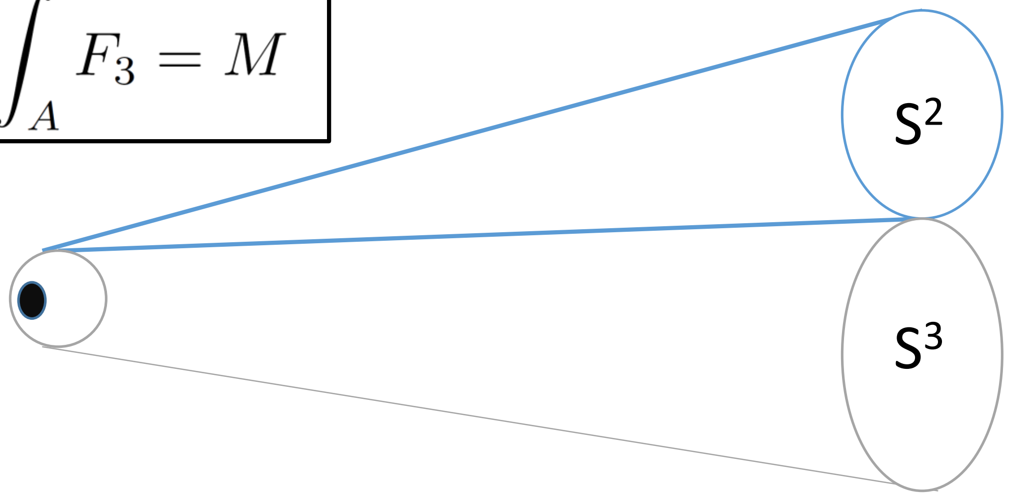
⟹ Not so relevant for "unwinding fluxes"

Brane-flux annihilation

Kachru, Pearson, Verlinde (KPV)

$$\int_A F_3 = M$$



- SUGRA IF :

$$g_s << 1\,, \quad g_s p >> 1\,, \quad g_s M >> 1$$

- Locally confined backreaction if :

$$p/M^2 << 1$$

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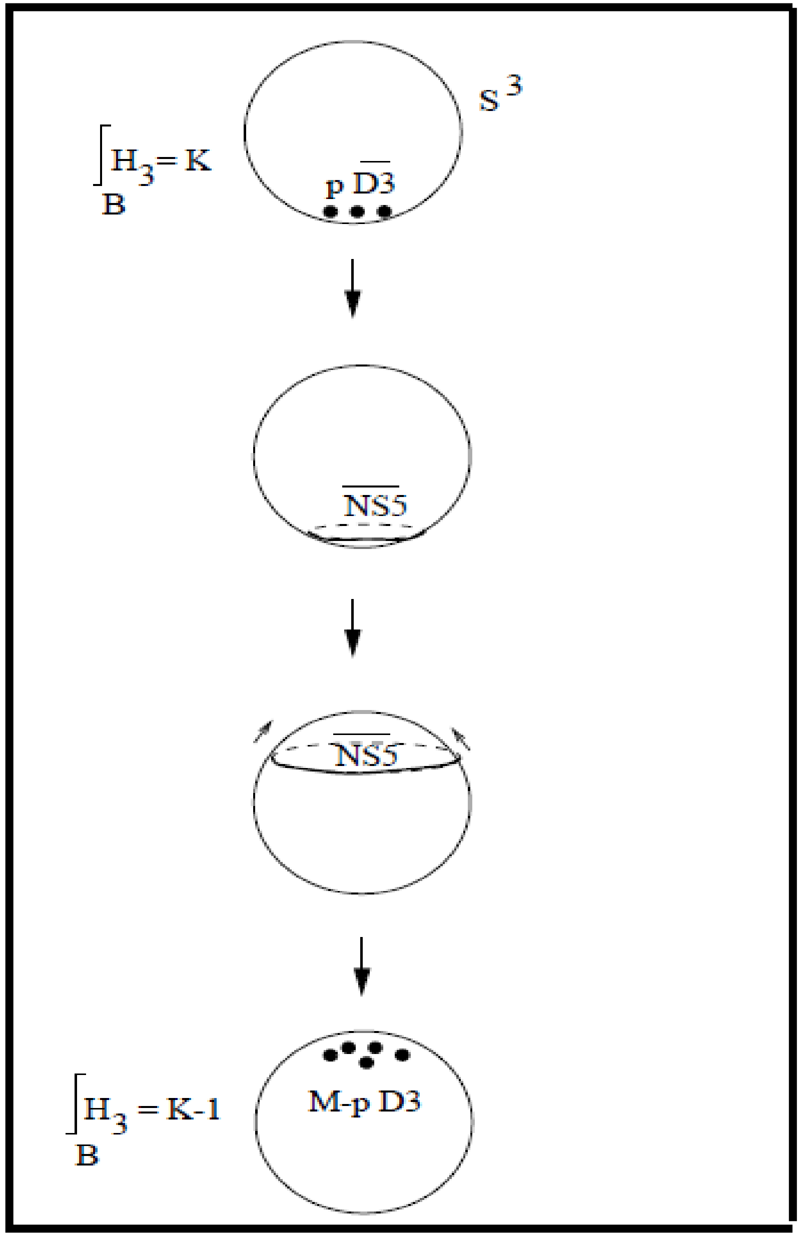

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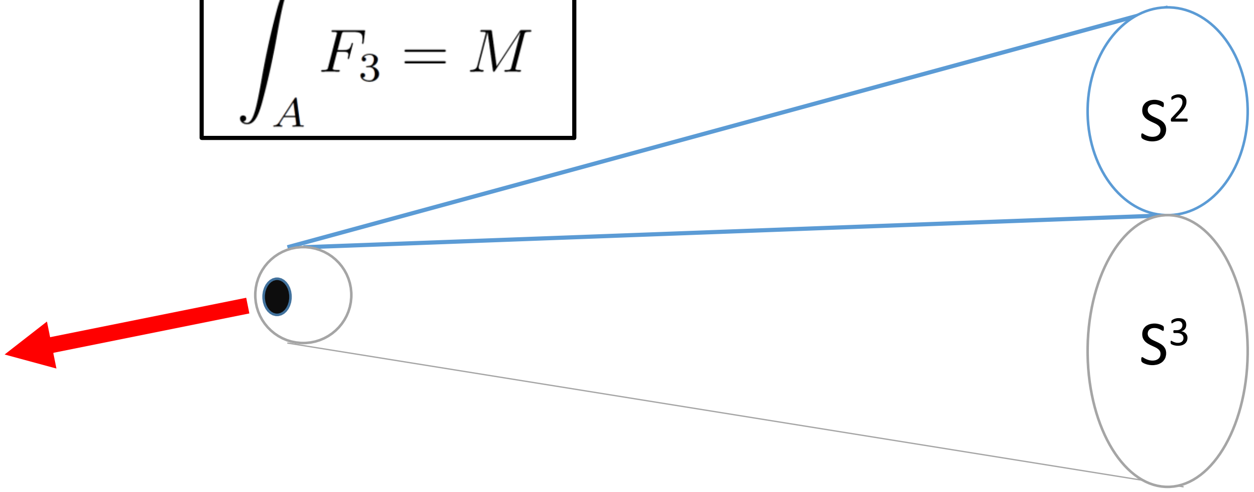

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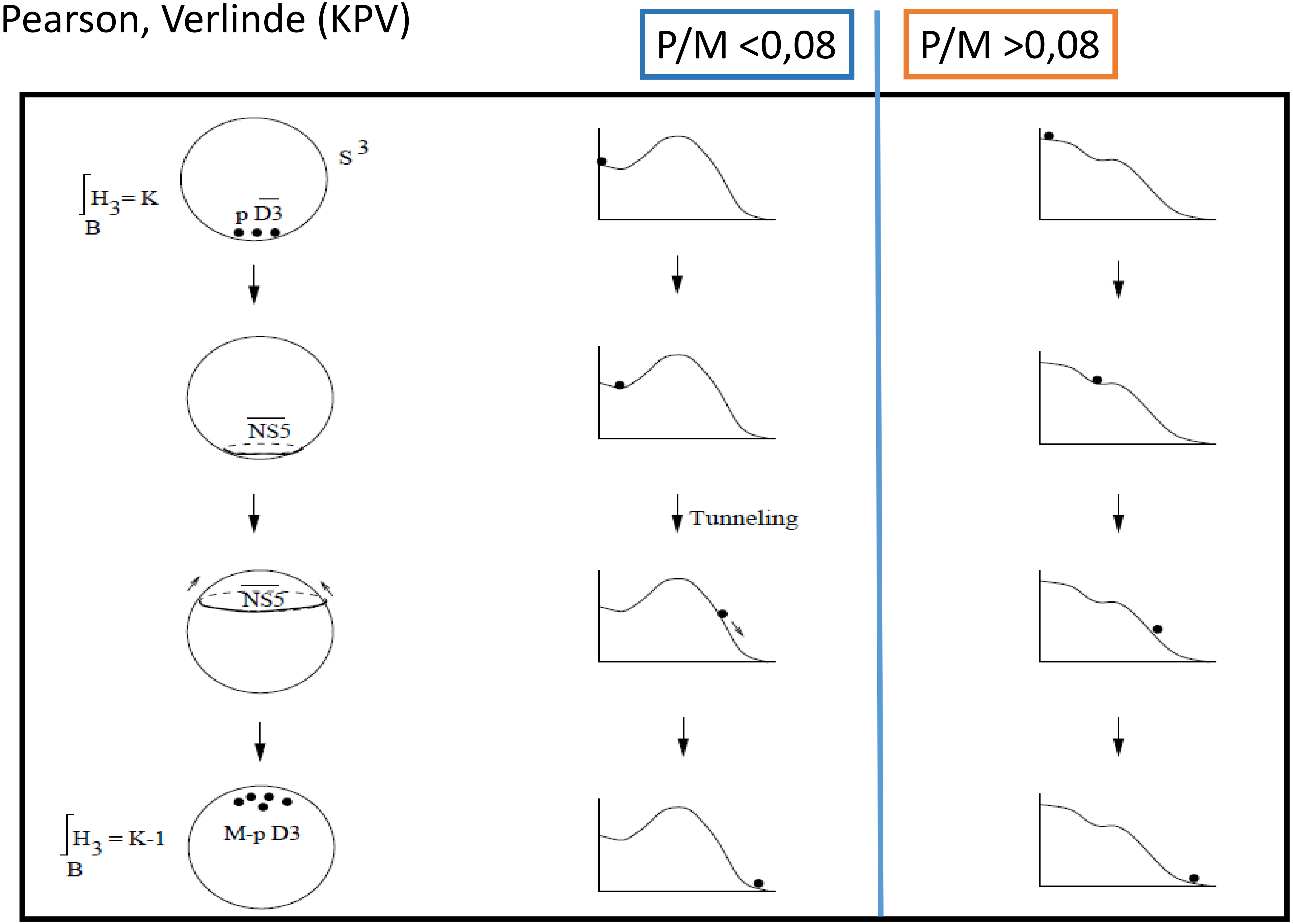


Brane-flux annihilation: some details

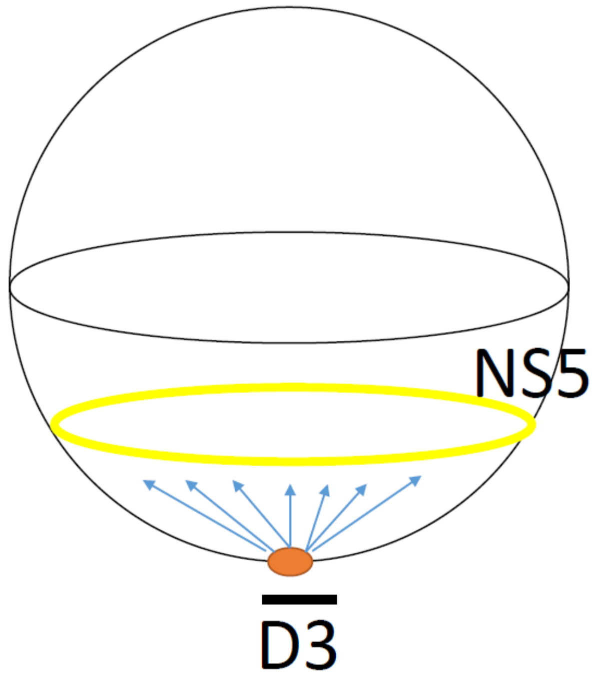
Charges? → NS5 Wess-Zumino action

$$\mu_5 \int B_6 + 2\pi \mathcal{F}_2 \wedge C_4 \quad \text{, where} \quad 2\pi \mathcal{F}_2 = 2\pi F_2 - C_2$$

$$2\pi \int_{S^2} F_2 = 4\pi^2 p \, . \qquad \int_{S^2} C_2 = 4\pi M(\psi - \tfrac{1}{2}\sin(2\psi))$$

ψ=0: p anti-D3 charges & ψ= π : M-p D3 charges

ψ = 3th Euler angle



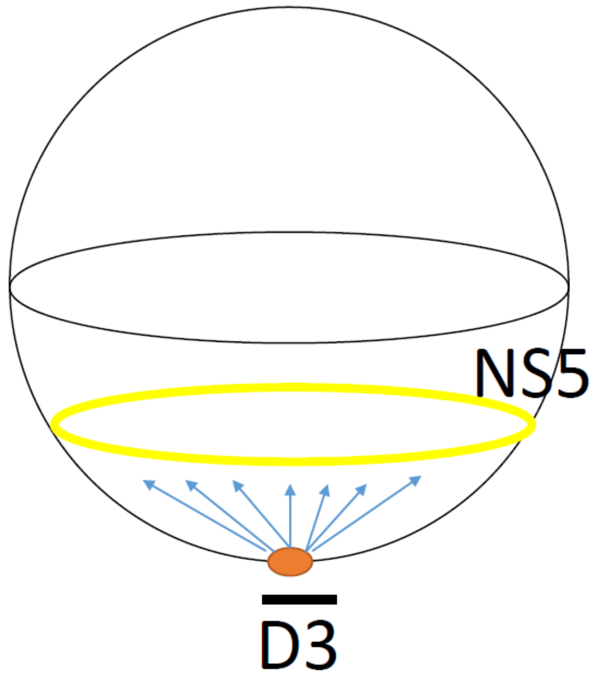
Brane-flux annihilation: some details

Energy? → NS5 DBI + WZ action

$$V_{\mathrm{NS5}}(\psi) = \frac{\mu_3}{g_s \pi} M \left[\sqrt{\frac{\mathrm{e}^{-4A}}{(M g_s)^2} \sin^4(\psi) + \tilde{U}(\psi)^2} + \tilde{U}(\psi) \right]$$

$$\tilde{U}(\psi) = \frac{\pi p}{M g_s} - \psi + \frac{1}{2} \sin(2\psi) \ .$$

ψ = 3th Euler angle



Inflation from brane-flux annihilation?

S-duality

One can S-dualise KS solution + dial to $g \ll 1$. Such throats equally occur in IIB landscape.

What changes?

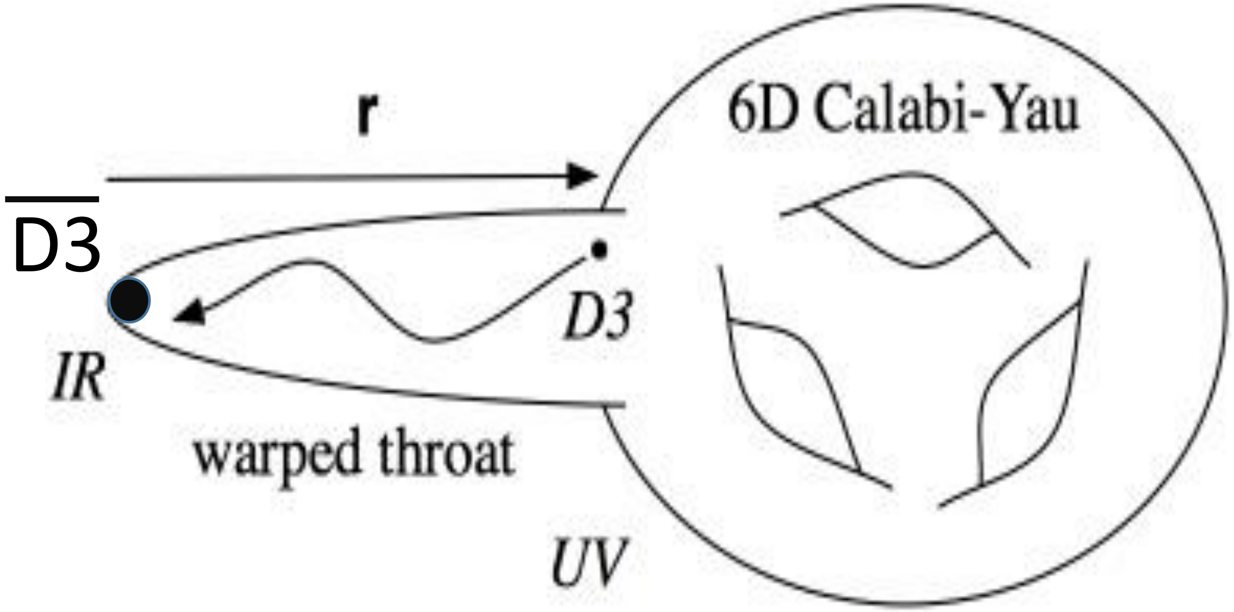
- Tip is filled with K units of NSNS flux (instead of M units of RR flux.)
- Brane-flux decay occurs via nucleation of spherical D5 branes that eat up RR flux.

Why care?

- NS5 probe action cannot really be used at weak coupling.
- KPV had to because of holography (KS gauge theory is lost after "S-duality").

Parameter regimes in warped IIB compactifications

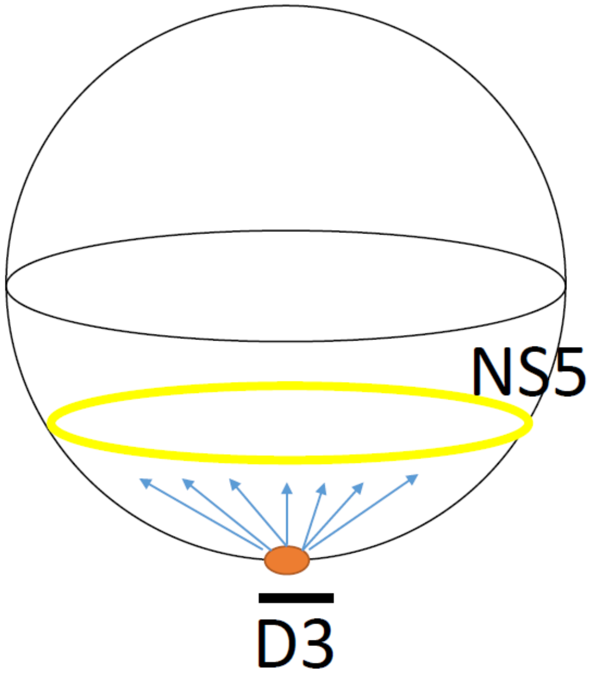
1. P/K <0,08 KKLMMT (2004):



→ Inflation caused by the dynamics of a D3 brane moving towards the tip.
→ Inflaton = D3 position.
→ Small field inflation. Range of inflaton kinematically restricted by KK scale.

2. P/K ~ 0,08 Giant Inflaton [DeWolfe, Kachru, Verlinde 2004]:

→ Inflation caused by brane-flux decay process.
→ Inflaton = 5-brane position.
→ Small field inflation. Range of inflaton kinematically restricted.
→ Model out of control. (On the border of control)



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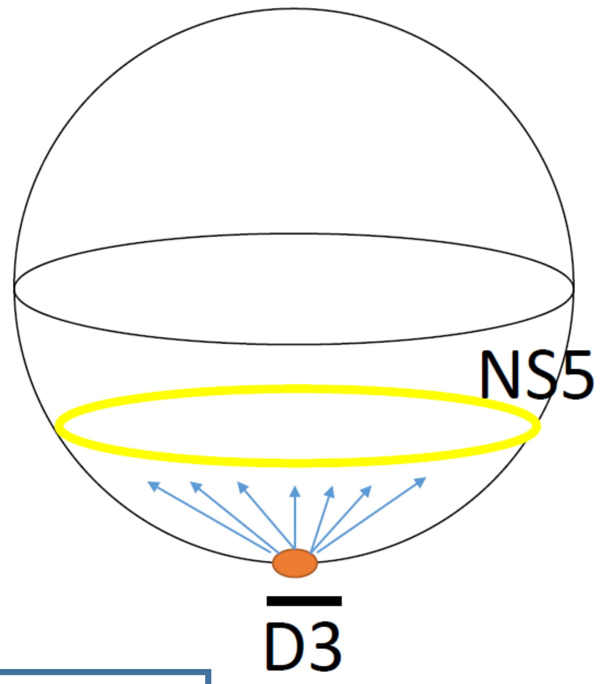


3. P/K >>1 Unwinding inflation [Gautason, Schillo, TVR 2016]:

→ Inflation caused by brane-flux decay process.
→ Inflaton = 5-brane position.
→ Large field inflation. Range of inflaton NOT kinematically restricted.
→ Model under control for a part. But moduli-stabilization is tricky.

Core idea 1

Take the KKLT potential (or LVS, or racetrack, or…)

$$V_K = \frac{a_K A_K e^{-a_K\sigma}}{2\sigma^2}\left(\frac{1}{3}\sigma a_K A_K e^{-a_K\sigma} + \mathcal{W}_0 + A_K e^{-a_K\sigma}\right) + \frac{z^{4/3}}{g_s^2\sigma^2}\frac{2p\mu_3}{g_s}$$

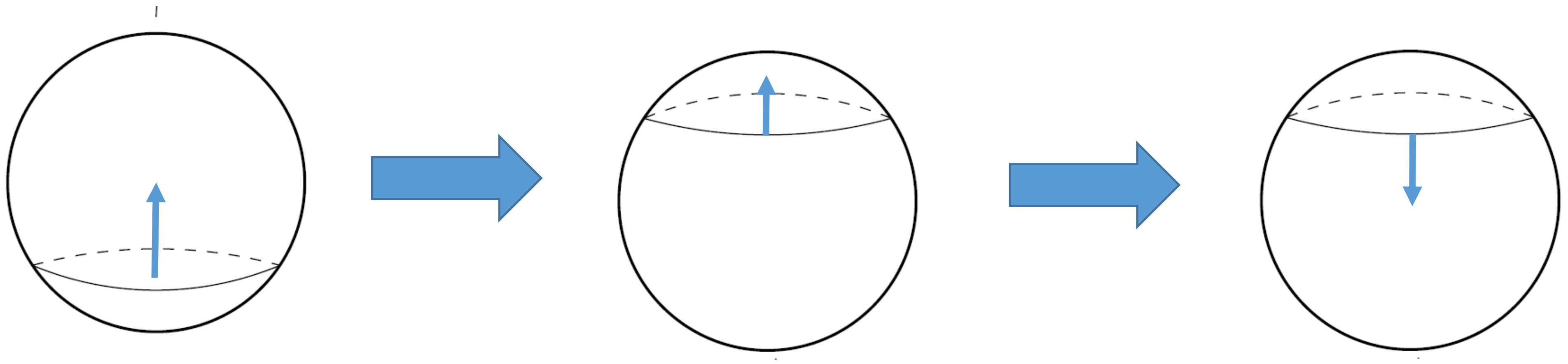
Make uplift term decay in time since anti-branes are unstable against brane-flux decay:
p = p (ψ), with ψ inflaton. (Other terms are roughly unaffected).

$$\frac{2\mu_3 p}{g_s} \to e^{-4A} V_{D5}(\psi) = K^2 V_{D5}(\psi) \ ,$$

Core idea 2

This is large field inflation if the range of ψ is "unfolded" as in axion-monodromy [McAllister, Silverstein, Westphal]

→ Then we need p>K : multiple bounces



→ We can even stay within probe approximation if

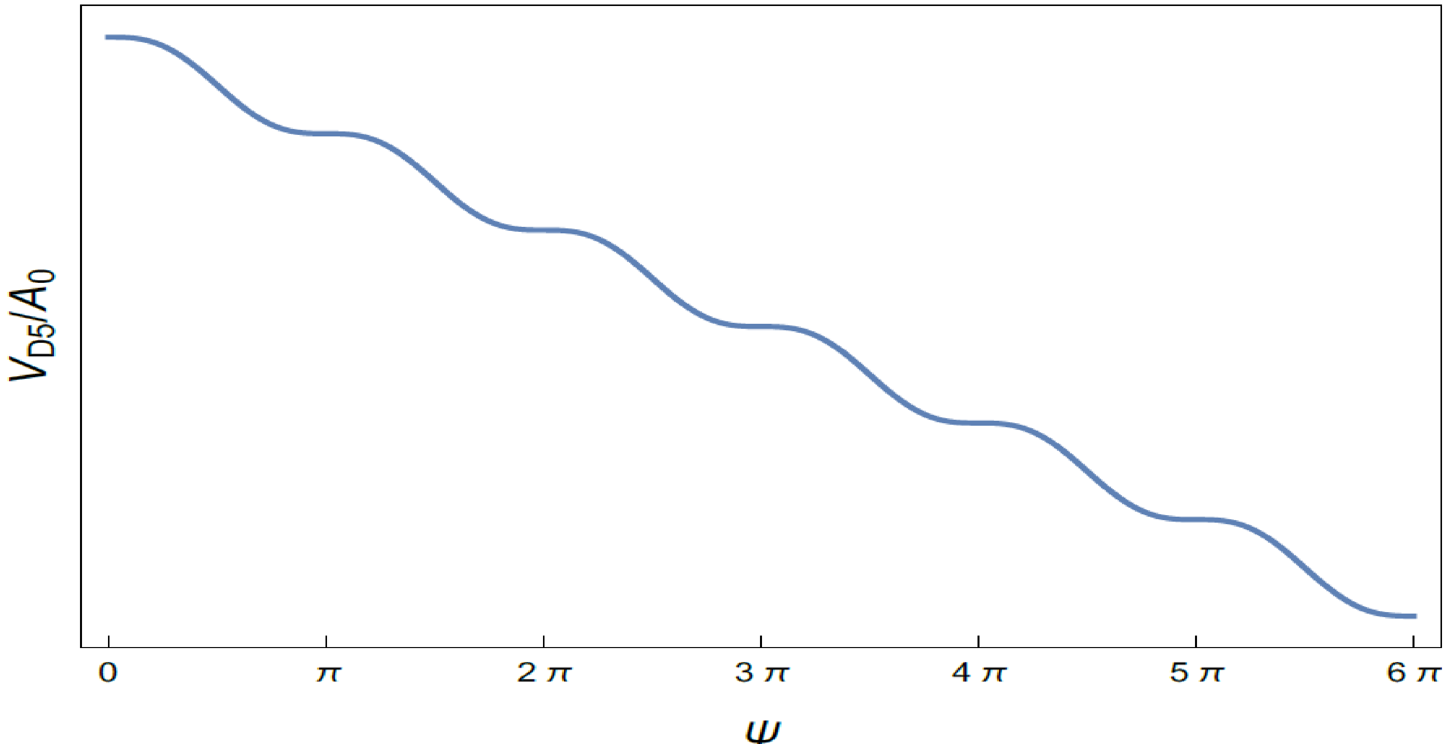
$$R_{S^3}^2 = \ell_s^2 K \gg \ell_s^2 \sqrt{g_s p} = R_{\mathrm{D3}}^2$$

This limit is possible when g<<1 and p>>K !

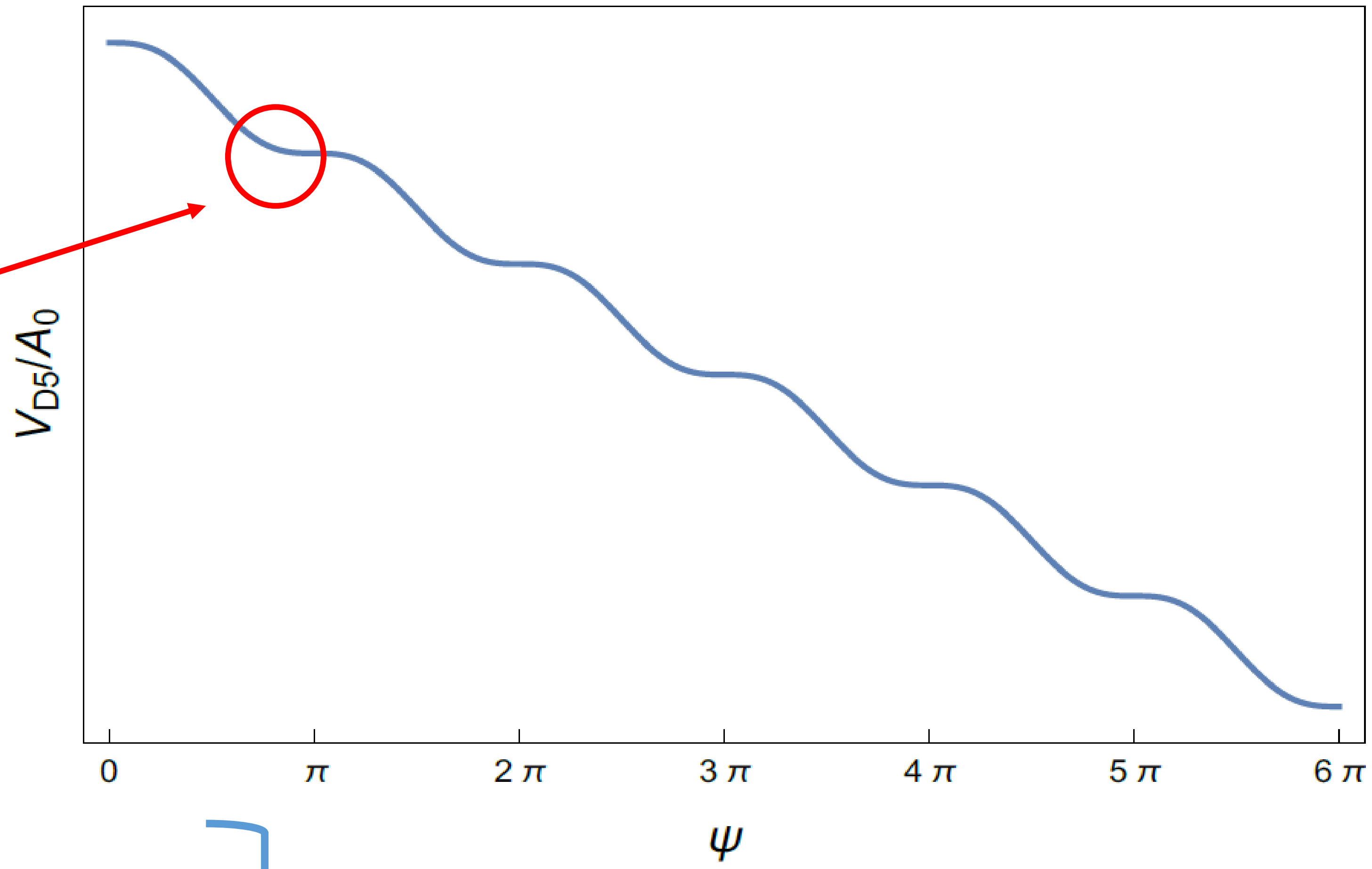
The result

- Many constraints on a 6D parameter family.
- 60- e-folds possible! But then oscillating eta & too low amplitude (10^-18)

$$V_{S^3}(\phi) = 2A_0 e^{4A}\left(\frac{\pi p}{K} - \frac{\phi}{f} + \frac{1}{2}\sin\left(\frac{2\phi}{f}\right)\right)$$



Reason; easily "stuck" at saddle points: but these regions are not to be trusted!



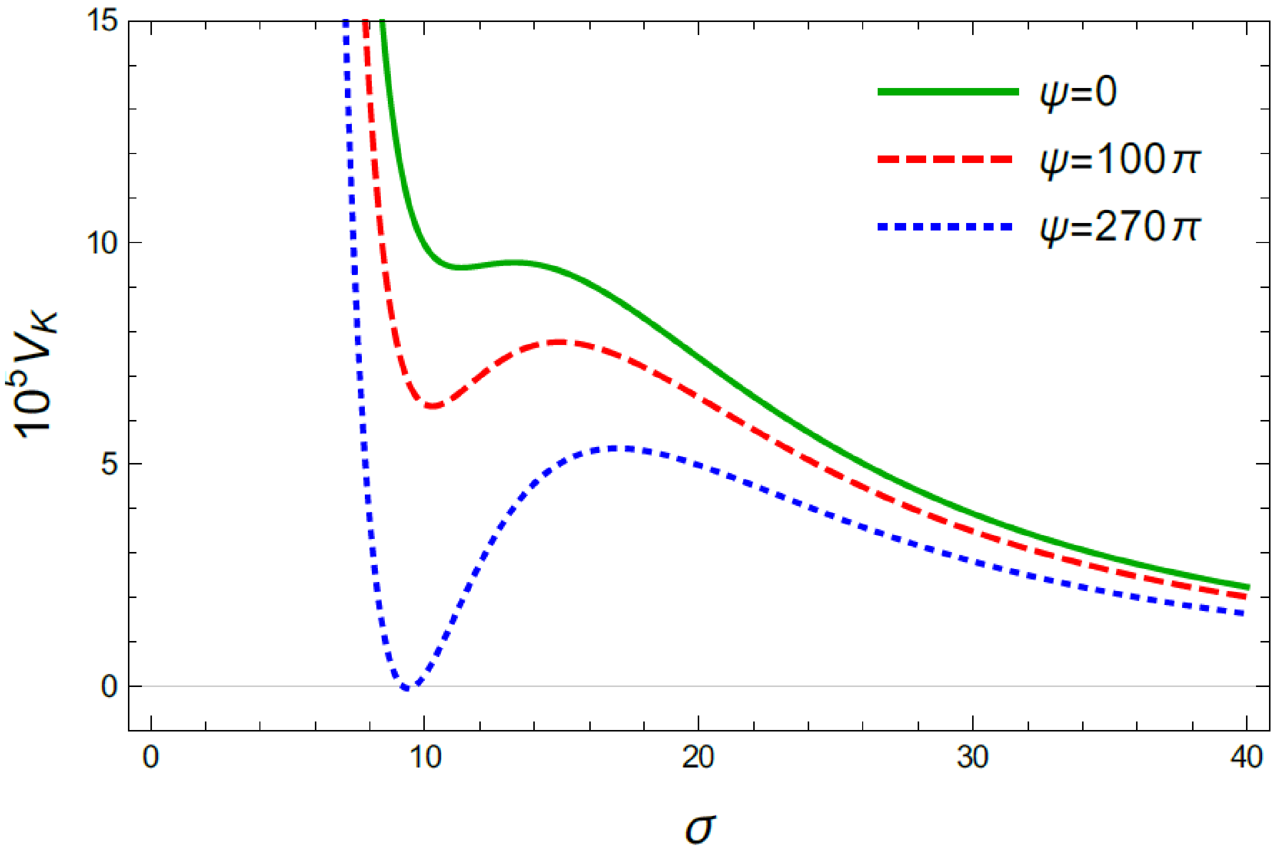
Stringy length scales (non-Abelian) & backreaction issues.

→ Polchinski-Strassler type computation?

Corrected potential will be much less oscillatory!

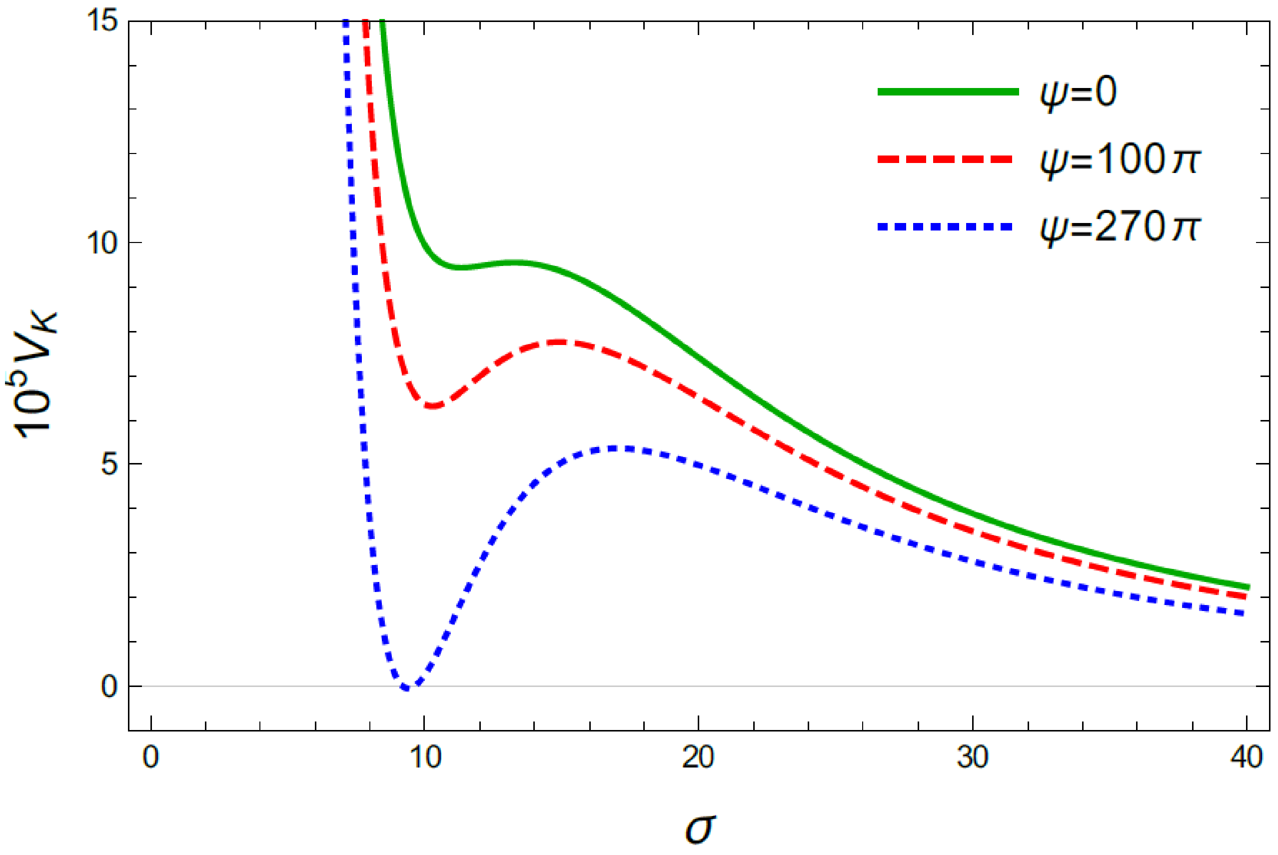
Some constraints....

- No destabilization of volume modulus during inflation



Some constraints….

- No destabilization of volume modulus during inflation
- P< K x M
- P/K > 1
- K^2 >> g P
- g<<1 & Vol>>1
- Throat volume < CY volume
- ….



Outlook

<u>Good news:</u>

- The unwinding mechanism seems very natural within string theory if one relies on brane-flux decay in warped throats.

- Ingredients are in the standard IIB settings, but different regime of charges/fluxes!

- It is *large field.* The resulting potential has the well-known universal form:

$$V_{S^3}(\phi) = 2A_0 \mathrm{e}^{4A} \left(\frac{\pi p}{K} - \frac{\phi}{f} + \frac{1}{2} \sin\left(\frac{2\phi}{f} \right) \right)$$

- Brane backreaction issues seem less worrying and can only improve the situation

Alternative facts:

- We have the best inflation model ever. Better than the rest. It’s great.

- Moduli-stabilization is a piece of cake. We have done it. It was fun. You should try once.

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Future research:

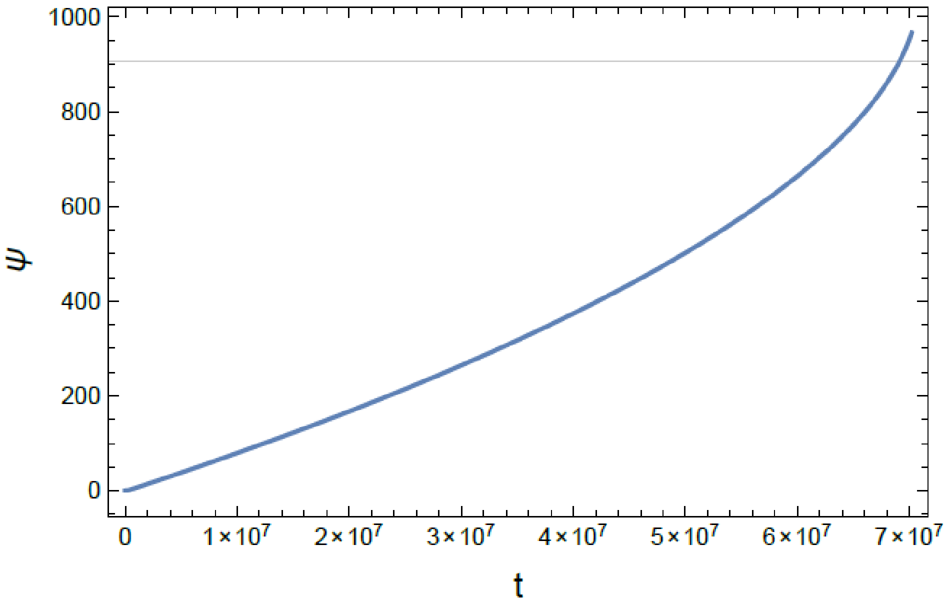
- Beyond single Kahler model to fully grasp the moduli-stabilization constraints.
- Interesting tension between large field extension and moduli-stabilization! (WGC?)
- Brane backreaction is argued to help. How to compute it?
- What about reheating?

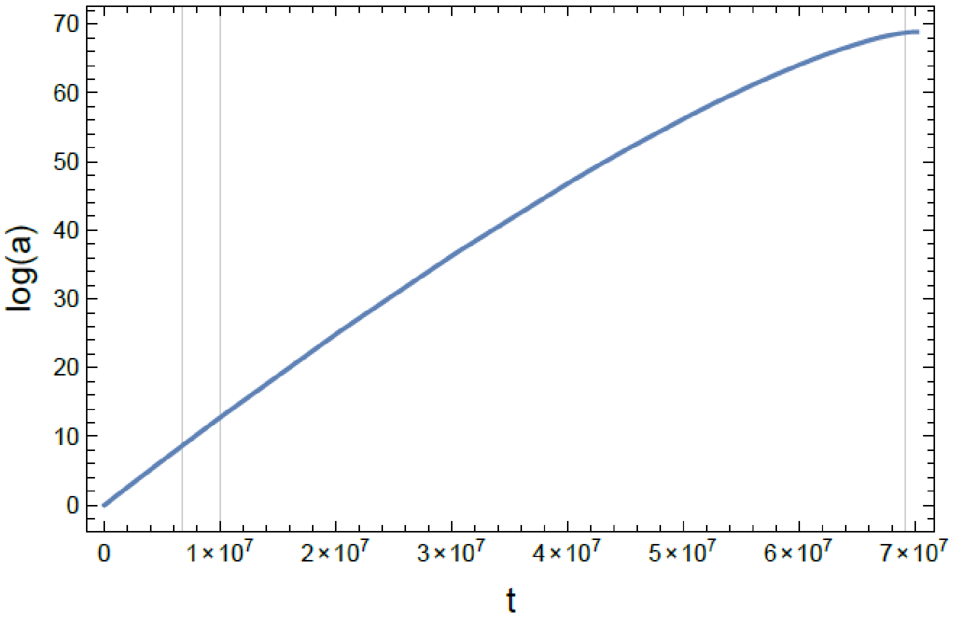
BACK UP SLIDES

The best thus far....

$\Delta\phi/M_{pl} = 12.1$	$H/M_{pl} = 6.5 \times 10^{-11}$	$H/M_{KK} = 1.7 \times 10^{-4}$	$\mathcal{V} = 5.3 \times 10^{12} \ell_s^6$
$z^{1/3} = .012$	$\mathcal{V}/\mathcal{V}_{\text{throat}} = 1.1$	$g_s p/K^2 = .06$	$p/KM = .54$
$p = 4.5 \times 10^6$	$K = 4500$	$M = 1852$	$g_s = .27$
$A_K = 3$	$a_K = 2\pi/31$	$\mathcal{W}_0 = 1.31$	$\sigma_* = 10.4$

Table 1: One set of parameters that satisfies our constraints. We have chosen the average value of σ_* throughout the cascade.





Thin versus thick wall limit

Brown-Bunster bubble