News on the anti-D3-brane uplift

KPV decay at higher order in α'

Simon Schreyer

Based on 2402.13311
and older work 2208.02826, 2212.07437 w/ Arthur Hebecker and Gerben Venken

String Pheno June 25 2024

Motivation

Key challenge: Accelerated expanding universes in String Theory?

- Via $\Lambda > 0$ and $\overline{D3}$-brane uplift?

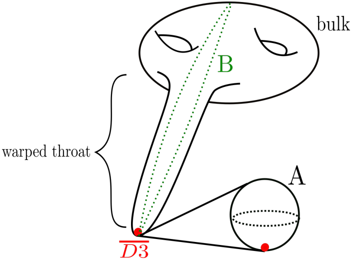

Figure: KS throat with M units of F_3 (K units of H_3) flux on A-cycle (B-cycle) glued into compact CY.

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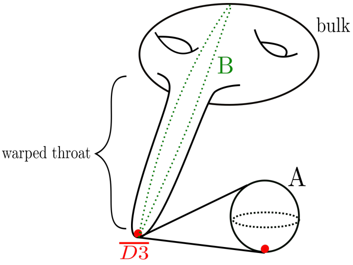

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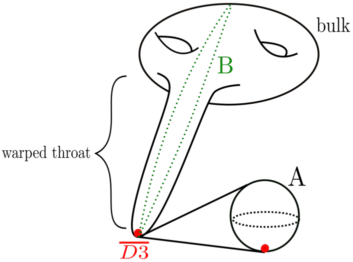
- Problem: Tadpole cancellation $\Rightarrow$ lower bound on $g_s M^2$ key
- Stability against KPV decay: $g_s M^2 > 12$



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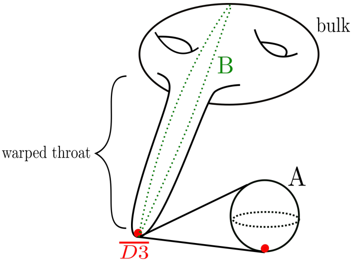

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Problem: Small $g_s M^2$: α' corrections large $\Rightarrow$ study KPV at higher order in α'

KPV decay at leading order [KPV '01]

Classical instability: brane-flux annihilation

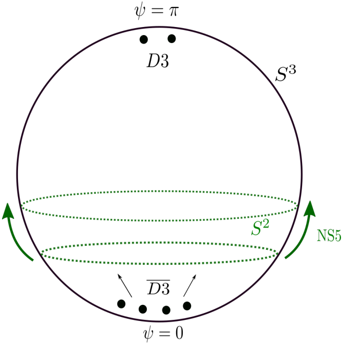

Figure: The tip of the throat.

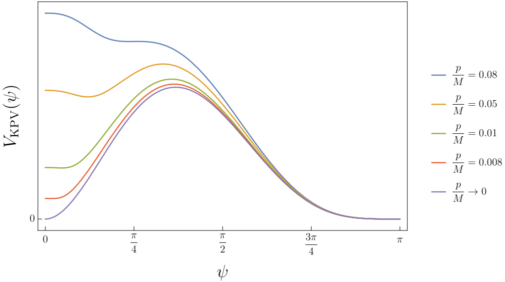

Figure: NS5-brane potential.

$\Rightarrow$ Metastable minimum if $p/M < 0.08$, leading order in α' analysis!

Two perspectives to study the KPV decay

1. NS5-brane perspective, controlled if $R_{S^2} \approx \sqrt{g_s M \frac{p}{M}}\, l_s \gg l_s$
    - Study single NS5 w/ p units of worldvolume flux wrapping S^2 inside S^3 at tip

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   - Study nonabelian Dp-brane action [Myers '99]
   - Crucial nonabelian feature: Transverse displacement of branes described by noncommutative scalars Φ^i (live in adjoint rep of $U(p)$)
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$\Rightarrow$ at $\sqrt{g_s p} \lesssim \mathcal{O}(1)$: opposite regimes of validity, at $\sqrt{g_s p} \gtrsim \mathcal{O}(1)$: overlapping regimes of validity

$\Rightarrow$ Possibility to study KPV decay in broad region of parameter space

The NS5-brane picture [Hebecker, SJS, Venken '22, SJS, Venken '22]

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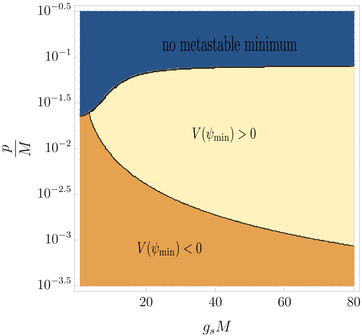
- New way of uplifting w/o large warping by tuning tree-level against α' corrections?



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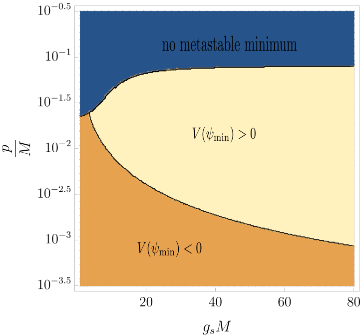

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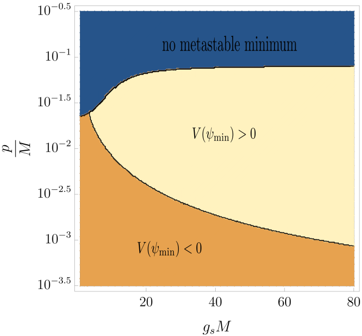
- New bound and new uplift work at boundary of control



$\Rightarrow$Advance into region not controlled from NS5 perspective by studying stack of $\overline{D3}$-branes (valid for $R_{S^2} \ll \sqrt{g_s p}\, l_s$)

Nonabelian $\overline{D3}$-brane stack picture [SJS '24]

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- Compare $(g_s M^2)_{\text{min}}$ in Table w/ NS5 for $p = 1$: $(g_s M^2)_{\text{min,NS5}} = 144$

c_m	$(g_s M^2)_{\text{min}}$	$(g_s M)_{\text{min}}$
0.1	$302p$	3.23
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- $V_{\text{min}} > 0 \ \forall g_s M > 2.25 \Rightarrow$ No new way of uplifting at large $g_s M$

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Summary: Comparison of both pictures

- KPV setup can (and should!) be studied from 2 perspectives

- Advantage NS5 picture:
  - Control for large $g_s M$, $p/M \Longleftrightarrow R_{s^2} \gg l_s$
  - See decay explicitly (requires control for $R_{S^2} \approx R_{S^3}$)
- Advantage $\overline{D3}$-stack picture:
  - Control for large $g_s M$, small $p/M \Longleftrightarrow R_{S^2} \ll \sqrt{g_s p} l_s$
  - Includes pheno relevant regime of string size S^2 (smallish $g_s M$)

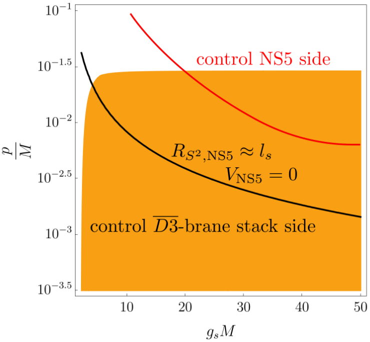

Figure: Regions of control in the $(g_s M, p/M)$ plane.

Summary

- $(g_s M^2)_{\text{min}} \approx \mathcal{O}(100)$ from both perspectives (tree level: $g_s M^2 > 12$)
  $\Rightarrow$ Crucial to take α' corrections into account
  $\Rightarrow$ Controlled uplift requires much larger flux contribution to D3 tadpole
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- New way of uplifting proposed in [Hebecker, SJS, Venken '22] can (if at all) work for small $g_s M$ where α' expansion breaks down
- Main limitations of stack analysis: Worked in flat space approx. ($R_{S^3} \gg R_{S^2}$), do not control small $g_s M$ since α' expansion breaks down
- Future: Extend stack analysis to KPV background, sum up all order commutators to access regime of larger p/M

Thank you!

Questions?

Nonabelian $\overline{D3}$-brane stack at higher order [SJS '24]

- Nonabelian $\overline{D3}$-brane stack dynamics in S-dual frame (Myers action supplemented by α' corrections):

$$S = -\frac{T_3}{g_s}\int d^4\sigma\, \mathrm{STr}\left(\sqrt{\det\left(G_{ab}\right)\det(Q^i{}_j)}\left(1+\alpha'^2\mathcal{L}_{\alpha'^2}\right)\right) + S_{\mathrm{CS},\alpha'^2}$$

$$- T_3\int \mathrm{STr}\left(P\left[i\lambda \mathrm{i}_\Phi \mathrm{i}_\Phi C_2\wedge C_4 - \frac{\lambda^2}{4}(\mathrm{i}_\Phi \mathrm{i}_\Phi)^2 C_2\wedge C_2\wedge C_4 + \dots\right]\right)$$

- Nonabelian features: Φ noncommutative scalars, $Q^i{}_j = \delta^i{}_j + \frac{i\lambda}{g_s}[\Phi^i,\Phi^k]\left(G_{kj} + g_s C_{kj}\right)$, interior product i_Φ, symmetric trace STr
- Two types of higher order corrections:
  - Higher commutator corrections ($(p/M)^2$ expansion)
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Higher order scalar potential

$$V_{\text{tot}} = V_{\text{DBI},\mathcal{O}(\lambda^4)}\left(1-\frac{c}{(g_s M)^2}\right) + V_{\text{CS},\mathcal{O}(\lambda^4)} + \frac{T_3\, p}{g_s}\,\frac{c_2}{(g_s M)^2}\,,$$

$$V_{\text{CS},\mathcal{O}(\lambda^4)} = -\frac{T_3}{g_s}\left(\frac{i\lambda^2}{6}F_{ikl}\,\text{tr}\left([\Phi^i,\Phi^k]\Phi^l\right) + \frac{\lambda^4}{72}\text{STr}\left([\Phi^i,\Phi^j]\Phi^k[\Phi^l,\Phi^m]\Phi^n\right)F_{kji}F_{nml}\right),$$

$$V_{\text{DBI},\mathcal{O}(\lambda^4)} = \frac{T_3}{g_s}\Bigg(\text{tr}(\mathbb{1}) + \frac{\lambda^2}{4g_s^2}\text{tr}\left([\Phi^i,\Phi^j][\Phi^j,\Phi^i]\right) - \frac{i\lambda^2}{6}F_{ikl}\text{tr}\left([\Phi^i,\Phi^k]\Phi^l\right)$$

$$-\frac{\lambda^4}{72}\text{STr}\left([\Phi^i,\Phi^k]\Phi^l[\Phi^j,\Phi^m]\Phi^p\right)F_{lki}F_{pmj} + \frac{\lambda^4}{36}\text{STr}\left([\Phi^i,\Phi^k]\Phi^l[\Phi^j,\Phi^m]\Phi^p\right)F_{lkj}F_{pmi}$$

$$+\frac{i\lambda^4}{24g_s^2}\text{STr}\left([\Phi^i,\Phi^k]\Phi^l[\Phi^j,\Phi^m][\Phi^m,\Phi^j]\right)F_{lki} - \frac{\lambda^4}{32g_s^4}\text{STr}\left(\left([\Phi^i,\Phi^j][\Phi^j,\Phi^i]\right)^2\right)$$

$$-\frac{i\lambda^4}{6g_s^2}\text{STr}\left([\Phi^i,\Phi^j][\Phi^j,\Phi^m][\Phi^m,\Phi^k]\Phi^l F_{lki}\right)\Bigg).$$