Challenges and new Perspectives for dS vacua:

α' corrections to KPV

Simon Schreyer

Based on 2208.02826 with Arthur Hebecker and Gerben Venken and 2212.07437 with Gerben Venken

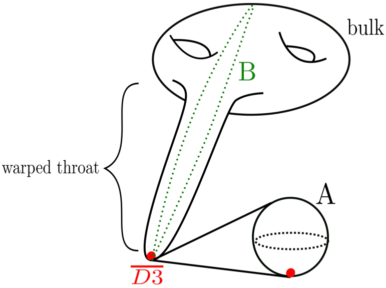
String Pheno July 6 2023

Motivation

Accelerated expanding universes from controlled dS vacua in string theory?

$\Rightarrow$ Important player: anti-D3-brane uplift:

- $\overline{D3}$ at tip of KS throat to avoid runaway
- M units of F_3 (K units of H_3) flux on A-cycle (B-cycle)



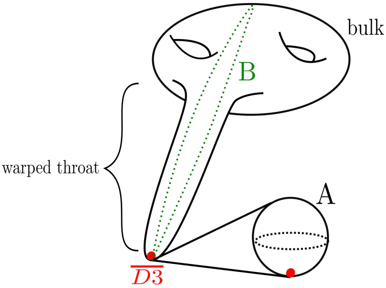
Motivation

Accelerated expanding universes from controlled dS vacua in string theory?

$\Rightarrow$ Important player: anti-D3-brane uplift:

- $\overline{D3}$ at tip of KS throat to avoid runaway
- M units of F_3 (K units of H_3) flux on A-cycle (B-cycle)
- At tip: A-cycle topologically S^3
- Small positive vacuum energy:

$$|V_{\text{AdS,LVS}}| \sim \mathcal{V}^{-3} \overset{!}{\approx} V_{\text{up}} \sim \frac{e^{-N/g_s M^2}}{\mathcal{V}^{4/3}}$$
$$\Rightarrow N = KM \gg g_s M^2$$



Motivation (continued)

Problem: Classical decay channel to SUSY minimum [KPV '01]

- $p\ \overline{D3}$s puff up into fluxed NS5 wrapping S^2 inside S^3
- NS5 can annihilate with flux to form SUSY minimum
- $R_{S^3} \sim \sqrt{g_s M \alpha'}$

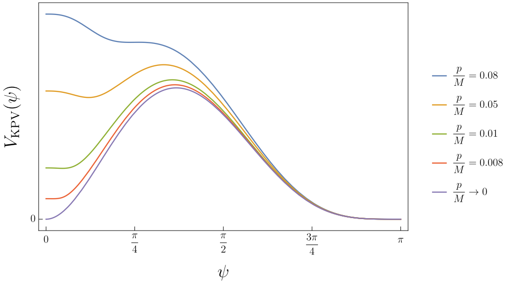


Figure: Normalized NS5-brane potential for different p/M.

Motivation (continued)

Problem: Classical decay channel to SUSY minimum [KPV '01]

- $p\ \overline{D3}$s puff up into fluxed NS5 wrapping S^2 inside S^3
- NS5 can annihilate with flux to form SUSY minimum
- $R_{S^3} \sim \sqrt{g_s M \alpha'}$
- $p/M < 0.08$ for metastability
- KPV performed leading order in α' analysis

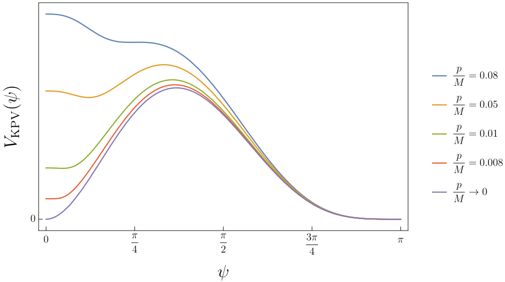


Figure: Normalized NS5-brane potential for different p/M.

Why consider α'^2 corrections on NS5?

- Metastability *per se* $\Rightarrow \alpha'$ corrected version of KPV bound $p/M < 0.08$
- Lower bound on $g_s M^2$ important for LVS pheno:

Why consider α'^2 corrections on NS5?

- Metastability *per se* $\Rightarrow \alpha'$ corrected version of KPV bound $p/M < 0.08$
- Lower bound on $g_s M^2$ important for LVS pheno:
  - Remember: require $N \gg g_s M^2$ to uplift to dS
  - Problem with tadpole cancellation: Negative contribution to tadpole limited

Why consider α'^2 corrections on NS5?

- Metastability *per se* $\Rightarrow \alpha'$ corrected version of KPV bound $p/M < 0.08$
- Lower bound on $g_s M^2$ important for LVS pheno:
  - Remember: require $N \gg g_s M^2$ to uplift to dS
  - Problem with tadpole cancellation: Negative contribution to tadpole limited
- KPV: $p/M < 0.08$, $g_s M > 1$ (control α' corrections) and $p = 1 \Rightarrow$ $g_s M^2 > 12$
- Problem: R^2 curvature corrections suppressed by $R^4_{S^3} \sim (g_s M)^2$
  $\Rightarrow \alpha'$ corrections important in pheno relevant, smallish $g_s M^2$ regime

$\Rightarrow$ Quantify control over α' corrections by including them into KPV analysis

α'^2 corrections on NS5-branes [Schreyer, Venken '22]

- Many (not all!) α'^2 correction to Dp-branes known [Bachas, Bain, Green '99, Garousi + Jalali, Karimi, Babaei Velni, Mir, Mashhadi '09-22, Robbins, Wang '14], we dualized them to corrections on NS5

α'^2 corrections on NS5-branes [Schreyer, Venken '22]

- Many (not all!) α'^2 correction to Dp-branes known [Bachas, Bain, Green '99, Garousi + Jalali, Karimi, Babaei Velni, Mir, Mashhadi '09-22, Robbins, Wang '14], we dualized them to corrections on NS5
- Schematically, they are of the form

$$S_{\text{DBI,NS5}} \supset \frac{\mu_5}{g_s^2}\alpha'^2 \int_{\mathcal{M}_6} \mathrm{d}^6 x \sqrt{-(g + 2\pi\alpha' g_s \mathcal{F}_2)} \Big[(-g_s F_3)^4 + (-g_s F_3)^2 R + \Omega^4 (2\pi\alpha' g_s \mathcal{F}_2)^2 + (2\pi\alpha' g_s \mathcal{F}_2)\Omega^2 \nabla(-g_s F_3) \Big] ,$$

$$S_{\text{CS,NS5}} \supset \frac{\mu_5}{g_s^2}\alpha'^2 \int_{\mathcal{M}_6} \mathrm{d}^6 x \Big[-\epsilon_{(6)} (g_s \mathcal{F}_2) R \nabla (g_s \tilde{F}_5) + \epsilon_{(6)} (g_s \mathcal{F}_2) \nabla(-g_s F_3) \nabla (g_s^2 H_7) \Big] ,$$

α'^2 corrected KPV potential [Schreyer, Venken '22]

$$V = \frac{4\pi\mu_5 M}{g_s}\sqrt{b_0^4 \sin^4(\psi) + \left(p\frac{\pi}{M} - \psi + \frac{1}{2}\sin(2\psi)\right)^2} \times \Bigg[1 + \frac{1}{(g_s M)^2}\Bigg(c_3 - c_1 + (c_4 - 2c_2)\cot^2\psi - c_2\cot^4\psi + \frac{c_5\cot^4\psi}{\sin^4\psi}\left(\frac{\pi p}{M} - \left(\psi - \frac{\sin(2\psi)}{2}\right)\right)^2 - \frac{c_6\cot^3\psi}{\sin^2\psi}\left(\frac{\pi p}{M} - \left(\psi - \frac{\sin(2\psi)}{2}\right)\right)\Bigg)\Bigg] + \left[\frac{4\pi^2 p\mu_5}{g_s} - \frac{4\pi\mu_5 M}{g_s}\left(\psi - \frac{\sin(2\psi)}{2}\right)\right]\left(1 + \frac{c_7}{(g_s M)^2} + \frac{c_8\cot\psi}{(g_s M)^2\sin\psi}\right)$$

- $c_1, \cdots, c_8$ numerical constants, explicitly calculated
- Potential enjoys expansion in $g_s M$ and p/M

Plot for fixed $g_s M^2 = 20$

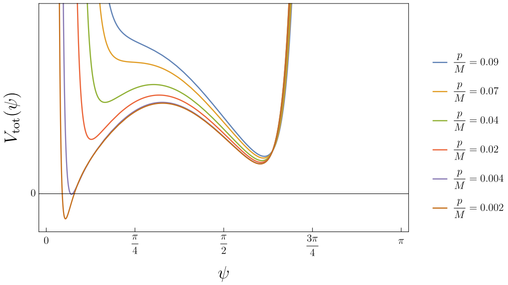


Figure: α'^2 corrected KPV potential for $g_s M = 20$.

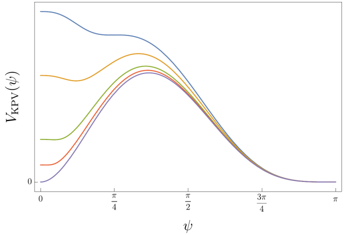
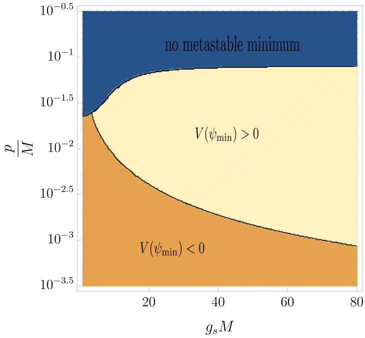


Figure: Tree level KPV potential.

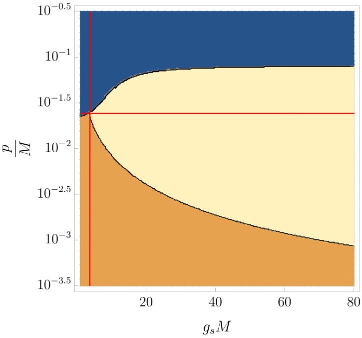
- Divergences at $\psi = 0, \pi$ should be cured by summing over all α' corrections

Scan $(g_s M, p/M)$ parameter space



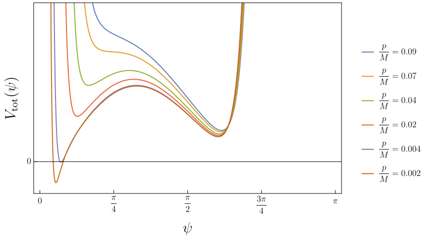
Scan $(g_s M, p/M)$ parameter space

- Minimal bound on $g_s M$:
  $g_s M > 3.6, p = 1 \Rightarrow g_s M^2 > 144$
  (compare to $g_s M^2 > 12$ from KPV!)
  $\Rightarrow$ need much more flux in throat for consistent uplift
- Minimal negative contribution in LVS: $|Q_{3,\text{min}}| \sim \mathcal{O}(10^3)$ using PTC of [Gao, Hebecker, Schreyer, Venken '22]
- Very constraining: currently highest constructed $|Q_{3,\text{min}}| = \mathcal{O}(3000)$ [Crinò, Quevedo, Schachner, Valandro '22]



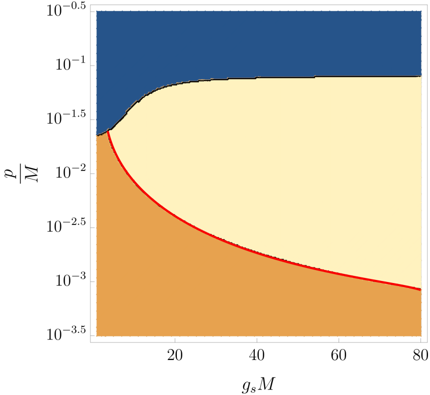
Uplifting without exponentially large warping

- Observation: Tuning α' corrections by $g_s M$, p/M tunes value of potential at metastable minimum!



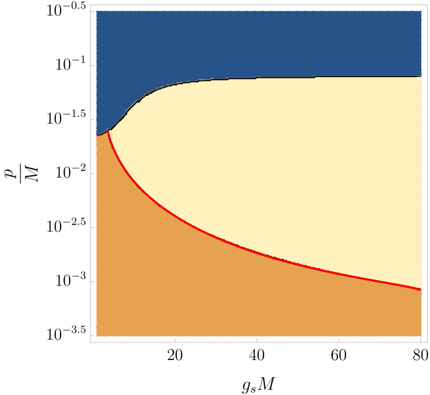
Uplifting without exponentially large warping

- Observation: Tuning α' corrections by $g_s M$, p/M tunes value of potential at metastable minimum!
- No need to warp down T_{D3}, as itself tunable to exponentially small value!
- No large flux and large $|Q_{3,\text{min}}|$ needed, e.g. $N = 40$
- Not only applicable in LVS



Uplifting without exponentially large warping

- Observation: Tuning α' corrections by $g_s M$, p/M tunes value of potential at metastable minimum!
- No need to warp down T_{D3}, as itself tunable to exponentially small value!
- No large flux and large $|Q_{3,\mathrm{min}}|$ needed, e.g. $N = 40$
- Not only applicable in LVS
- Problem: works only at boundary of control as $R^2_{\mathrm{NS5}}(\psi_{\mathrm{min}}) \approx 1$



Summary

- α' corrections worsen the control issue in LVS with standard $\overline{D3}$-uplift by order of magnitude
  $\Rightarrow$ need models with tadpole of $\mathcal{O}(10^3)$ which require much more work to prove existence of controlled dS vacua
- Proposed new uplifting mechanism circumventing constraints, but works at very boundary of control

Summary

- α' corrections worsen the control issue in LVS with standard $\overline{D3}$-uplift by order of magnitude
  $\Rightarrow$ need models with tadpole of $\mathcal{O}(10^3)$ which require much more work to prove existence of controlled dS vacua
- Proposed new uplifting mechanism circumventing constraints, but works at very boundary of control
- Need to improve understanding at boundary of control (small $g_s M$ regime) by studying setup from different perspectives:
  - Calculate higher order α' effects
  - Nonabelian $\overline{D3}$-stack and holographic perspective (reliable when our NS5-brane perspective breaks down)

Summary

- α' corrections worsen the control issue in LVS with standard $\overline{D3}$-uplift by order of magnitude
  $\Rightarrow$ need models with tadpole of $\mathcal{O}(10^3)$ which require much more work to prove existence of controlled dS vacua
- Proposed new uplifting mechanism circumventing constraints, but works at very boundary of control
- Need to improve understanding at boundary of control (small $g_s M$ regime) by studying setup from different perspectives:
  - Calculate higher order α' effects
  - Nonabelian $\overline{D3}$-stack and holographic perspective (reliable when our NS5-brane perspective breaks down)

Thank you!