de Sitter String Vacua from Perturbative Kähler Corrections and Consistent D-terms

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OUTLINE

- Introduction: Moduli stabilization in IIB and uplifting
- Kähler corrections to the volume modulus
  and volume stabilization
- D-terms from magnetized D7-branes
- de Sitter vacua
- Conclusions and Outlook

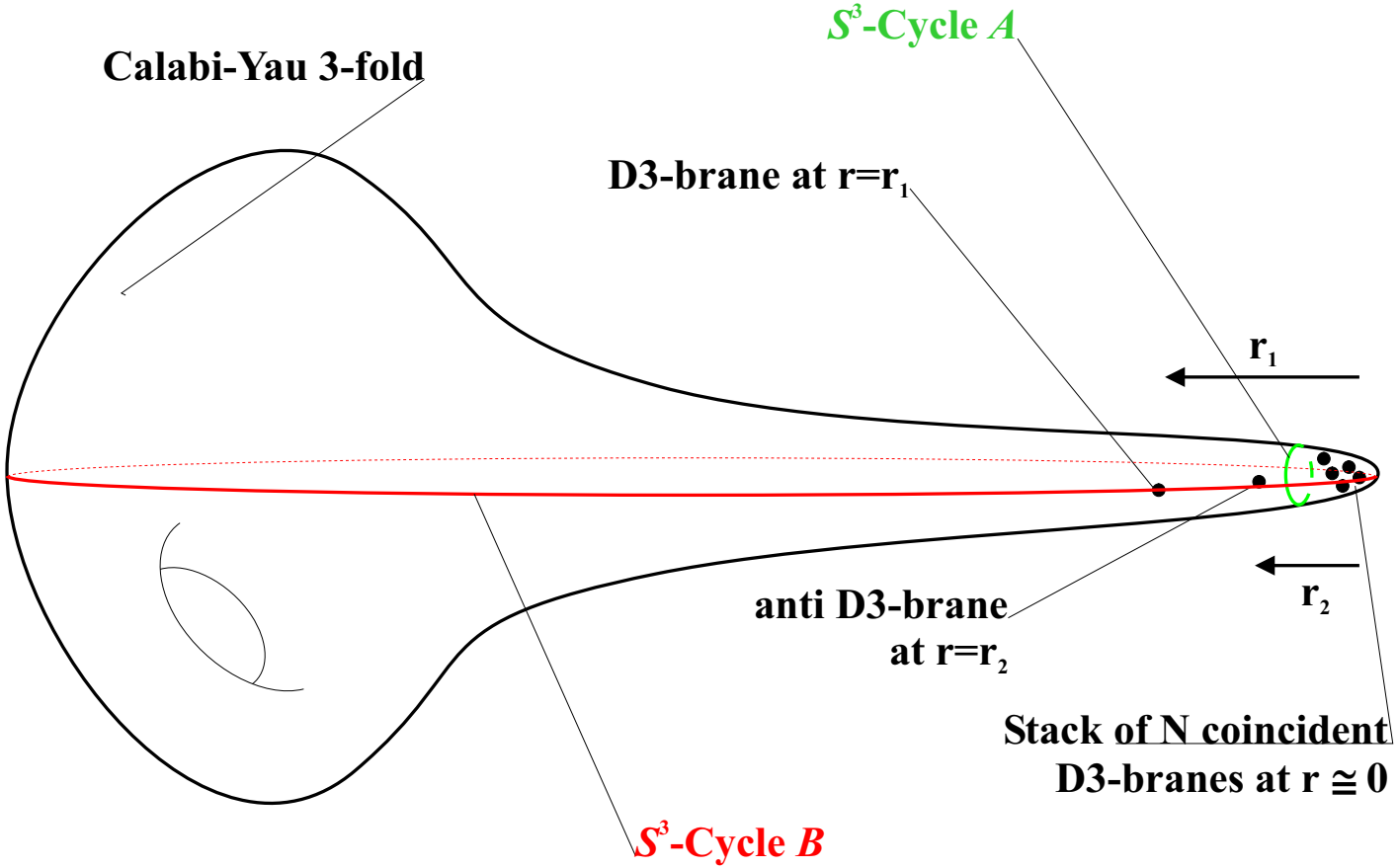
Moduli stabilization by fluxes

Turning on flux:

$$\int_A F_3 = M$$

$$\int_B H_3 = K$$

gives warped geometry:



$$ds_{10}^2 = e^{2A}\, ds_4^2 + e^{-2A}\, ds_6^2$$

fixes dilaton $S = e^{-\phi} + i\, C_0$ and complex structure moduli U^I.

Giddings-Kachru-Polchinski 01

Uplifting ...

- In type IIB: Vast landscape of dS-vacua along KKLT proposal

  $\Rightarrow$ **Fluxes & non-perturbative** effects fix (S, U, T) in **AdS-minima** uplifting to dS-minima by $\overline{D3}$-branes

- However: $\overline{D3}$-branes break SUSY explicitly

  Burgess-Kallosh-Quevedo 03

  $\Rightarrow$ **alternative:** D-terms from $D7$-branes gauging shift symmetry

  - $T \to T + i\,\epsilon$ of $K = -3\ln(T+\bar{T})$, $T = \mathcal{V}_{CY}^{2/3} + i\,b$

- **Problem:** Does not work with KKLT superpotential Villadoro-Zwirner 05

$$W = W_0(\text{flux}) + A\,e^{-a\,T} \quad \textbf{breaks} \quad \bullet$$

See, however, Achucarro-de Carlos-Casas-Doplicher 06; Lebedev-Nilles-Ratz 06; Mambrini-Dudas 06 for de Sitter vacua with consistent gauge invariant superpotentials with charged matter.

Kähler stabilization

- Perturbative α'- and string loop Kähler corrections

  Becker-Becker-Haack-Louis 02; Berg-Haack-Körs 05

$$\Delta K = -\frac{\alpha'^3\, A}{(T+\bar{T})^{3/2}} - \frac{B}{(T+\bar{T})^2} \qquad \begin{cases} A \sim -\chi \cdot (\mathrm{Re}\, S)^{3/2} \\ B \sim (\mathrm{Re}\, U)^2 \end{cases}$$

- Fluxes fix S and U. Calculate V_F

$$V_F(T) \sim |W_0|^2 \cdot \left(\frac{A}{(T+\bar{T})^{3/2}} + \frac{B}{(T+\bar{T})^2} \right)$$

- fixes T in non-SUSY AdS-vacuum if $A < 0 < B$ Gersdorff-Hebecker 05
- Example $\Rightarrow T^6/\mathbb{Z}_6'$ orientifold where $\chi = 48$ Berg-Haack-Körs 05

Kähler stabilization & Consistent D-terms

Parameswaran & AW 06

- $K + \Delta K$ and $W = W_0$ preserve the axionic shift symmetry.

  $\Rightarrow$ Gauged by $F_{(2)}$-flux on $D7$-brane wrapping 4-cycle Γ

$$S_{D7} \supset \int_{\mathbb{R}^4 \times \Gamma} C_4 \wedge F_2 \wedge F_2 \sim \int_{\mathbb{R}^4} q\, A^\mu \partial_\mu b$$

- Induces a consistent D-term

$$D_T = i X^T \cdot \frac{\partial K}{\partial T} = \frac{3\,q}{T + \bar{T}} \cdot \left(1 + \mathcal{O}(\alpha'^3, g_{\rm S}^2)\right) \ , \ X^T = iq$$

dS string vacua from consistent D-term uplifting

Parameswaran & AW 06

- This yields a positive semi-definite uplifting D-term scalar potential

$$V_D(T) = \frac{1}{2}\,(\mathrm{Re}\, f_T^{\mathrm{D7}})^{-1} D_T^2 \quad \text{where:} \quad f_T^{\mathrm{D7}} = T + k\,S$$

$$k = k(F_2)$$

Lüst-Reffert-Stieberger 05

- $\Rightarrow$ Full scalar potential $V_F + V_D$

$$V = \frac{|W_0|^2}{(T+\bar{T})^3}\left(\frac{A}{(T+\bar{T})^{3/2}} + \frac{B}{(T+\bar{T})^2}\right) + \frac{9\,q^2}{(T+\bar{T})^3}\,(1+\ldots)$$

- q^2 is quantized. Tuning $|W_0|^2$ allows to achieve $V_F + V_D \approx 0$.

dS string vacua from consistent D-term uplifting

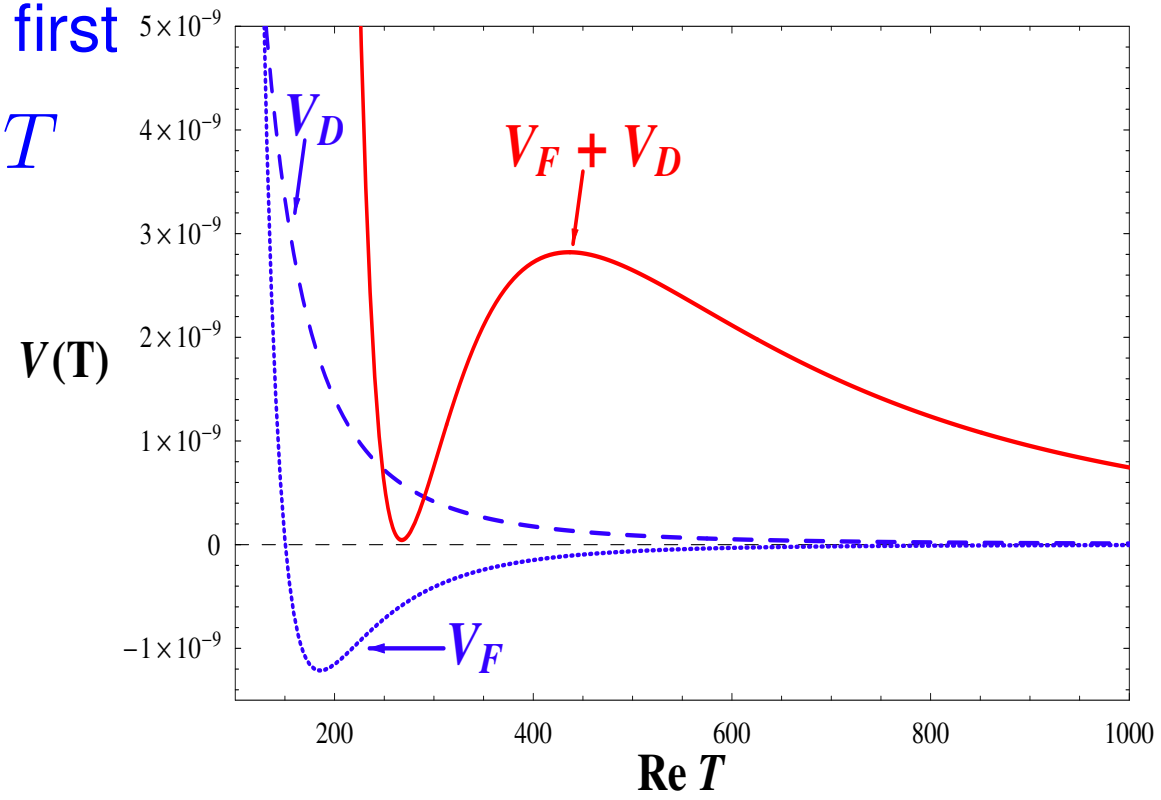
Parameswaran & AW 06

- Stable 2-step procedure — Can first integrate out S, U before fixing T

$$V(S,U) \sim \frac{|DW|^2}{\mathcal{V}^2}$$

$$\sim \mathcal{O}(+\frac{1}{\mathcal{V}^2})$$

$$V_{\Delta K}(T) \sim \mathcal{O}(-\frac{1}{\mathcal{V}^3})$$



Numerical example for $T^6/\mathbb{Z}_6'$

- Thus the minima $D_S W = D_U W = 0$ remain in the full theory.

Conclusions and Outlook

- Fixing all closed string moduli with just fluxes and perturbative Kähler corrections allows for consistent D-term uplifting.
- Manifest 4d $\mathcal{N} = 1$ SUSY $\Rightarrow$ significantly enhanced control
- Need considerable fine-tuning for large volume and small Λ
- Warping and presence of magnetized $D7$-branes neglected in present string loops. $\Rightarrow$ Requires further studies
- Interesting: $\Rightarrow$ how to embed inflation in this dS construction

  $\Rightarrow$ low-energy SUSY breaking phenomenology,

  see e.g. Choi-Jeong hep-th/0605108