



Construction of explicit de Sitter vacua in type IIB flux compactifications

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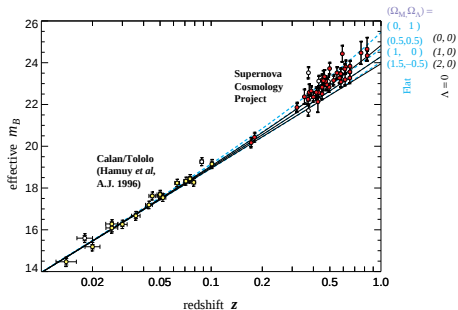
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Outline:

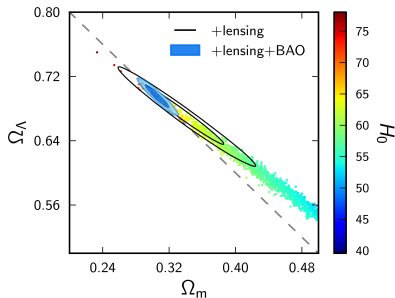
1. Introduction: De Sitter vacua in string theory
2. Brief summary of an explicit IIB de Sitter vacuum
 - 5 min break -
3. Complex structure moduli stabilization of $\mathbb{CP}_{11169}$ [18]
- ...

1. Introduction: De Sitter vacua in type IIB

Motivation: The cosmological constant problem (I)



[Perlmutter et al. 1998], [Riess et al. 1998]



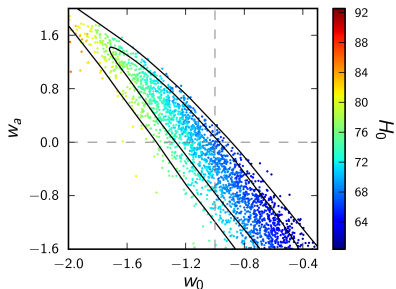
[Planck 2013]

$$\Rightarrow \Omega_\Lambda \simeq 0.68 \quad \Leftrightarrow \quad \rho_\Lambda \sim 10^{-120} M_{\text{P}}^4 \quad \text{Tiny!}$$

Motivation: The cosmological constant problem (II)

What is dark energy?

- ▶ Equation of state $w = \frac{p}{\rho}$ is consistent with -1
- ▶ Simplest explanation:
 $G_{\mu\nu} = T_{\mu\nu}^{\Lambda} = -\Lambda\eta_{\mu\nu}$
(Cosmological constant Λ)
 $\Rightarrow$ de Sitter space
- ▶ For scalar field ϕ at local minimum ϕ_0 : $\Lambda = V_{\text{eff}}(\phi_0)$



[Planck '13]

Parametrize $w = w_0 + (1 - a)w_a$

Motivation: The string theory landscape

- ▶ 10D $\rightarrow$ 4D: Typically $\mathcal{O}(100)$ scalar moduli fields ϕ_i with $V_{\text{eff}}(\phi_i)$
- ▶ ϕ_i : Kähler $T_i = t_i + i \tau_i$, Complex structure $U_i = v_i + i u_i$, Axio-dilaton $\tau = \sigma + i s$, $s = g_s^{-1}$
- ▶ String theory seems to contain an enormous number of vacua: Flux quanta $-5 \leq n_i \leq 5$ for 100 moduli $\Rightarrow \sim 10^{100}$ vacua
[Bousso, Polchinski '00] $\Rightarrow$ Lots of tuning available in principle!
- ▶ **Does string theory provide such an extremely tunable example = our universe?** $\Rightarrow$ Highly non-trivial constraint on the theory!
- ▶ *Why* is Λ so small?
 - ▶ Anthropic explanation? [Weinberg '89], [Susskind '05]
 - ▶ Statistical preference? [Feldstein, Hall, Watari '05], [Sumitomo, Tye '11 & '12]

$\Rightarrow$ **Try to find an explicit examples of dS vacua in string theory!**

Effective supergravity description of type IIB string theory

$\mathcal{N} = 1$, 4D effective potential completely determined by Kähler potential K and superpotential W :

$$V = e^K \left(K^{\alpha\bar{\beta}} D_{\alpha} W \overline{D_{\beta} W} - 3|W|^2 \right)$$

For $\hat{\xi} \ll \hat{\mathcal{V}}$ this is to 0-th order the positive semi-definite potential

[Balasubramanian, Berglund, Conlon, Quevedo'05], [Westphal, MR'11]

$$V = e^K \left(K^{\tau\bar{\tau}} |D_{\tau} W_0|^2 + K^{a\bar{b}} D_a W_0 \overline{D_b W_0} \right) + \mathcal{O}\left(\frac{\hat{\xi}}{\hat{\mathcal{V}}}\right)$$

due to no-scale structure [Cremmer, Ferrara, Kounnas, Nanopoulos'83]

- ▶ **Every SUSY extremum for the τ , U_a is a minimum for $\hat{\mathcal{V}} \gg \hat{\xi}$**
- ▶ **Separation of scales $\Rightarrow$ Stabilize U_a first**

Ingredients for de Sitter vacua in type IIB/F-theory

What is the structure of K and W ?

- ▶ Quantized RR and NS-NS fluxes $\int F_3, H_3 \in \mathbb{Z}$

$$\Rightarrow \text{Flux superpotential } W_0 \propto \int F_3 - \tau \int H_3$$

$$\Rightarrow \text{SUSY vacua } (D_a W = 0) \text{ for the } U_a \text{ and } \tau$$

[Giddings, Kachru, Polchinski '01]

- ▶ Non-perturbative effects $W = W_0 + A_i e^{-a_i T_i}$

[Kachru, Kallosh, Linde, Trivedi '03]

- ▶ Leading α' -corr. to the Kähler pot. $K = -2 \ln \left[\hat{\mathcal{V}}(T_i) + \alpha'^3 \hat{\xi}(\tau) \right]$

[Becker, Becker, Haack, Louis '02]

Uplifting to de Sitter

$W_0 \ll 1$, α' -correction
negligible [KKLT '03]



KKLT

- ▶ $\bar{D}3$ branes
- ▶ F-terms from matter fields
- ▶ F-terms from metastable vacua in gauge theories
[Intriligator, Seiberg, Shih '07],
[Marsano, Ooguri, Ookouchi, Park '07], [Nakayama, Yamazaki, Yanagida '07]

$W_0 \neq 0$, α' -correction

[Balasubramanian, Berglund '05]

$\hat{V} \gg \hat{\xi}$
 W_0 arbitrary ↙ ↘ $W_0 \sim \mathcal{O}(1 - 100)$

LVS [Balasubramanian,
Berglund, Conlon, Quevedo '05]

Kähler uplifting
[Westphal '06]

- ▶ $\bar{D}3$ branes
- ▶ D-terms
[Burgess, Kallosh, Quevedo '03,
Haack, Krefl, Lüst, Van
Proyen, Zagermann '06]
[Cicoli, Krippendorff, Mayrhofer, Quevedo, Valandro '12]
- ▶ F-terms from Kähler moduli + α' -correction sufficient for dS

2. Brief summary of an explicit IIB de Sitter vacuum

Complex structure moduli ($h^{2,1}$) stabilization

Find explicit solutions to $D_a W = 0$ for particular Calabi-Yau
($h^{1,1} = 2, h^{2,1} = 272$) [Martinez-Pedrer, Mehta, Westphal, MR '12]

- ▶ Reduce to small $h_{\text{effective}}^{2,1} = 2$ dimensional moduli space
- ▶ Estimate distribution of e.g., $\langle W_0 \rangle$ and $\langle s \rangle$
- ▶ Extrapolate to larger number of $h^{2,1}$ (functional form is known)
 $\Rightarrow$ Cosmological constant can be tuned to $\mathcal{O}(10^{-120})$ for
 $h^{2,1} \sim \mathcal{O}(50)$
- ▶ Number of vacua agrees with statistical analysis of [Ashok, Douglas'04],
[Denef, Douglas'04]

Kähler moduli ($h^{1,1}$) stabilization (I)

Bottom up analysis of Kähler uplifting $\Rightarrow$ **Sufficient for de Sitter in type IIB effective SUGRA:** [Westphal,MR '11]

- ▶ Non-perturbative effects $A_i e^{-a_i T_i}$ with $a_i = 2\pi/N_i$
- ▶ Volume $\hat{\mathcal{V}} \sim (T_1 + \bar{T}_1)^{3/2} \sim N_1^{3/2} \Rightarrow$ Need large N_1
- ▶ Numerical condition on the parameters $\langle W_0 \rangle, \langle s \rangle, a_i, \dots$

Large Volume limit:

- ▶ Scan over $\sim 10,000$ Calabi-Yau's of [Kreuzer,Skarke '00]
 $\Rightarrow$ Large enough N_1 is easily possible, especially for large $h^{1,1}$

Kähler moduli stabilization (II)

Study consistency constraints for example Calabi-Yau

($h^{1,1} = 2, h^{2,1} = 272$) [Louis,Valandro,Westphal,MR '12]

- ▶ Brane configuration [Collinucci,Denef,Esole'09]
- ▶ Non-perturbative effects: $A_1, A_2 \neq 0$?
- ▶ Anomaly and tadpole cancellations [Freed,Witten'97, Maldacena,Nunez'00]

Combine with explicit complex structure moduli stabilization:

- ▶ How many SUSY vacua ($D_a W = 0$) can be uplifted via Kähler uplifting? $\Rightarrow$ Fraction $\sim 10^{-4}$

$\Rightarrow$ **Consistent global de Sitter model on particular Calabi-Yau!**

...5 min break...

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1. Introduction: De Sitter vacua in string theory
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3. Complex structure moduli stabilization of $\mathbb{CP}_{11169}$ [18]
4. Kähler uplifted de Sitter vacua
5. A consistent global model on $\mathbb{CP}_{11169}$ [18]
6. Conclusions

3. Complex structure moduli stabilization of $\mathbb{CP}_{11169}$ [18]

$$\mathbb{CP}_{11169} : (x_1, x_2, x_3, x_4, x_5) \sim (\lambda x_1, \lambda x_2, \lambda x_3, \lambda^6 x_4, \lambda^9 x_5)$$

$$\text{e.g. } x_1^{18} + x_2^{18} + x_3^{18} + x_4^3 + x_5^2 = 0 \quad (h^{1,1} = 2 \text{ and } h^{2,1} = 272)$$

Complex structure moduli stabilization of $\mathbb{CP}_{11169}$ [18] (I)

Need to find $f = \int F_3 \in \mathbb{Z}$ and $h = \int H_3 \in \mathbb{Z}$ with

$$D_a W = 0, a = 1, \dots, h^{2,1} = 272 \text{ [Giddings, Kachru, Polchinski'01]}$$

Effective theory completely determined by $\mathcal{N} = 2$ prepotential:

$$\mathcal{G}(U_1, \dots, U_{h^{2,1}}) = \sum_{i+j \leq 3} c_{ij} U_a^i U_b^j + \xi + \mathcal{G}_{\text{instanton}}(e^{-2\pi U_1}, \dots, e^{-2\pi U_{h^{2,1}}})$$

- ▶ $W_0 = \int (F_3 - \tau H_3) \wedge \Omega(U_a) = (f - \tau h) \cdot (\mathcal{G}_{U_a}, U_a)$ [Gukov, Vafa, Witten'00]
- ▶ $K_{\text{CS}} = -\ln [i(\bar{U}_a \mathcal{G}_{U_a} - U_a \bar{\mathcal{G}}_{U_a})]$
- ▶ **Large complex structure limit:** $\left| \frac{\mathcal{G}_{\text{instanton}}}{\mathcal{G}_{\text{cubic}}} \right| \leq \epsilon_{\text{LCS}}$

Complex structure moduli stabilization of $\mathbb{CP}_{11169}$ [18] (II)

- ▶ Discrete symmetry $\mathbb{Z}_6 \times \mathbb{Z}_{18}$: U_a , $a = 1, \dots, h_{\text{inv.}}^{2,1} = 2$ and $\tilde{U}_a$, $a = 3, \dots, 272$ [Greene,Plesser'89], [Candelas,Font,Katz,Morrison'94]
- ▶ Switch on flux only on $h_{\text{inv.}}^{2,1} = 2$ [Giryavets,Kachru,Tripathy,Trivedi '03]
- ▶ Symmetry $\Rightarrow D_{\tilde{U}_a} W_0 = 0$ at $\tilde{U}_a = 0$ for $a = 3, \dots, 272$
- ▶ $\Rightarrow$ **Only need to solve $D_\phi W|_{\tilde{U}_a=0} = 0$ for $\phi = \tau, \mathbf{U}_1, \mathbf{U}_2$**
- ▶ $\Rightarrow V \sim |D_a W|^2$ ensures stable minimum for all 272 U_a in the large volume limit!

Scanning all vacua with paramotopy

see e.g. [Li '03], [Sommese, Wampler '05]

Have to solve polynomial system $P(x) = (p_1(x), \dots, p_m(x))^T = 0$ with $x = (x_1, \dots, x_m)^T$

- ▶ Maximal number of isolated solutions in $\mathbb{C}^m$: $\prod_{i=1}^m d_i$, with d_i the degree of the i th polynomial. (*Classical Bézout bound*)
- ▶ Construct homotopy $H(x, t) = \gamma(1 - t)Q(x) + t P(x)$, with e.g. $Q(x) = (x_1^{d_1} - 1, \dots, x_m^{d_m} - 1) \Rightarrow$ **Easy to solve.**
- ▶ Follow paths $H(x, t) = 0$ for $0 \leq t \leq 1$ for all solutions to $Q(x) = 0$

$\Rightarrow$ **Will find all solutions to $P(x) = 0$**

The scan

Use to solve $D_\phi W(\mathbf{f}) = 0$ for all fluxes $\mathbf{f}$ with $L \sim \mathbf{f}^2 \leq L_{\max}$

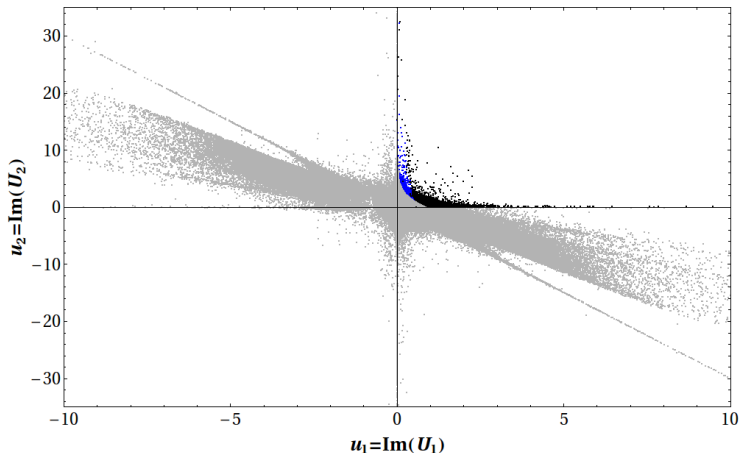
[Martinez-Pedrera, Mehta, Westphal, MR '12]

- ▶ The 10D IIB action is $SL(2, \mathbb{Z})$ invariant: $\tau \rightarrow \frac{a\tau + b}{c\tau + d}$,

$$G_3 = F_3 - \tau H_3 \rightarrow \frac{G_3}{c\tau + d} \quad \text{with} \quad a, b, c, d \in \mathbb{Z}, \quad ad - bc = 1$$

- ▶ Make sure to only consider physically inequivalent configurations!
- ▶ Our scan: ~ 50.000 parameter points ($L \leq 35$).

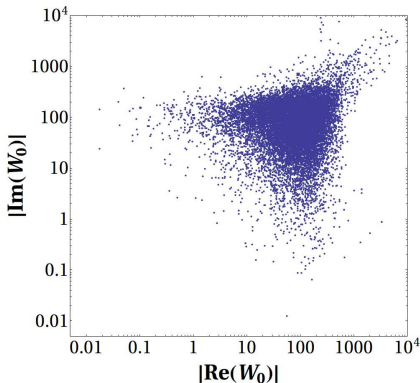
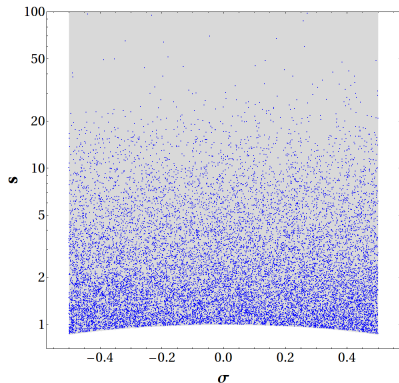
Scan results: The limit of large complex structure



$$\left| \frac{\mathcal{G}_{\text{instanton}}}{\mathcal{G}_{\text{cubic}}} \right| \leq \epsilon_{LCS} = \begin{cases} 10^{-1} & \text{(blue)} \Rightarrow 25.000 \text{ of } 500.000 \\ 10^{-2} & \text{(black)} \Rightarrow 15.000 \text{ of } \quad \quad \end{cases}$$

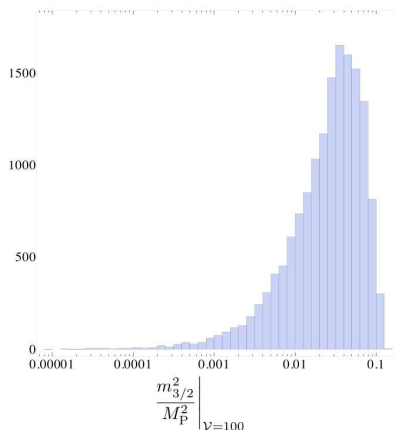
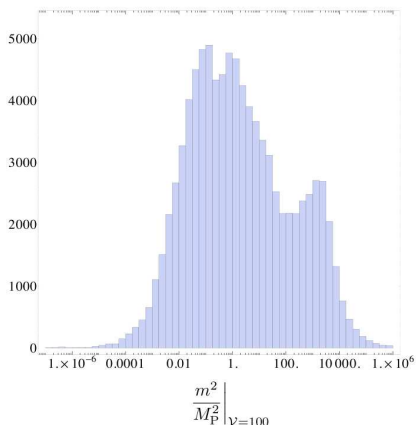
Scan results: $\tau = \sigma + i s$ and W_0

- ▶ $SL(2, \mathbb{Z})$ fundamental domain: $-\frac{1}{2} \leq \text{Re}(\tau) \leq \frac{1}{2}$ and $|\tau| > 1$
- ▶ Transformations: $\tau \rightarrow \tau + b$, $G_3 \rightarrow G_3$ and $\tau \rightarrow -1/\tau$, $G_3 \rightarrow G_3/\tau$



Scan results: Mass scales

Masses $\frac{M^2}{M_{\text{P}}^2} \Big|_{\hat{\nu}=100} \left(\frac{100}{\hat{\nu}} \right)^2$ for 6 real moduli fields and gravitino:

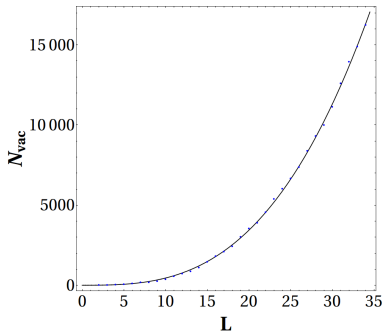


Scan results: Number of vacua N_{vac}

$$\begin{aligned} \blacktriangleright N_{vac}^{\text{stat}} &= \frac{(2\pi L)^3}{3!} \int \det(-\mathcal{R} - \mathbf{1} \cdot \omega) \\ &\simeq 0.03 L^3 \end{aligned}$$

[Ashok,Douglas'04],[Denef,Douglas,Florea'04]

$$\blacktriangleright N_{vac} \simeq (0.50 \pm 0.04) L^{2.94 \pm 0.03}$$



Scan results: Tuning of the cosmological constant

- ▶ Untuned cosmological constant (cc): $\Lambda \sim \frac{m_{3/2}^2}{\hat{v}}$
- ▶ Spacing in cc: $\frac{\Delta\Lambda}{\Lambda} \sim 2 \frac{\Delta m_{3/2}}{m_{3/2}} \sim \frac{C}{L^a (h_{\text{eff}}^{2,1} + 1)}$
- ▶ Fit, **Extrapolate** $\Rightarrow \frac{\Delta\Lambda}{\Lambda} \simeq (6.0 \pm 0.3) L^{-(0.95 \pm 0.005)} (h_{\text{eff}}^{2,1} + 1)$

$h_{\text{eff}}^{2,1}$	L	$\Delta\Lambda/\Lambda$
2	34	$7 \cdot 10^{-3} \pm 5 \cdot 10^{-4}$
2	500	$5 \cdot 10^{-5} \pm 4 \cdot 10^{-6}$
40	34	$3 \cdot 10^{-58} \pm 2 \cdot 10^{-58}$
40	500	$10^{-102} \pm 10^{-102}$

3. Kähler uplifted de Sitter vacua

Bottom up SUGRA analysis: Kähler uplifting

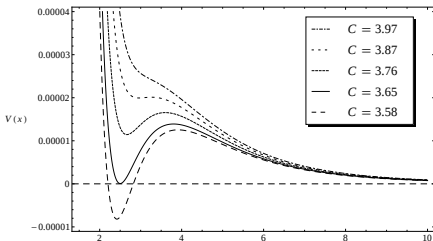
If a 3-fold is 'swiss-cheese', i.e. $\hat{V}(T_i) = \gamma_1 \text{Re}(T_1)^{3/2} - \sum_{i=2}^{h^{1,1}} \gamma_i \text{Re}(T_i)^{3/2}$

one can perform a complete perturbative moduli stabilization in the limit

- ▶ $\hat{V} \gg \hat{\xi} \Rightarrow$ Large but not LARGE Volume $\hat{V}$.
- ▶ $|W_0| \gg A_i e^{-a_i t_i}$, $a_i = 2\pi/N_i \Rightarrow$ Non-perturbative effects are small.
- ▶ $D_i W(\tau, U_j) \simeq 0 \Rightarrow$ Supersymmetric stabilization to 0-th order.

Sufficient for a de Sitter vacuum: [MR, Westphal '11], [de Alwis, Givens '11]

- ▶ $3.65 < \frac{27|W_0|\hat{\xi}a^{3/2}}{64\sqrt{2}\gamma A} < 3.89$.
- ▶ $\hat{V} \simeq \gamma N_1^{3/2} \Rightarrow$ Need $N_1 \gtrsim 30$.



Large gauge group ranks in the landscape

Kreuzer-Skarke 'Mini-landscape': [Kreuzer,Skarke '00]

- ▶ 473,800,776 reflexive polyhedra $\sim CY_3$
- ▶ 184,206 maximal polytopes (weight system given in PALP)
- ▶ 97,036 models of the F-theory type $\Rightarrow$ **our laboratory**

F-theory type models:

- ▶ Ambient toric variety described by (resolution of) weight system

$$\mathbb{CP}_{n_1 n_2 n_3 n_4 n_\xi} : (u_1, \dots, u_4, \xi) \sim (\lambda^{n_1} u_1, \dots, \lambda^{n_4} u_4, \lambda^{n_\xi} \xi), \quad \text{with } \lambda \in \mathbb{C}^*$$

$$\text{and } 0 < n_1 \leq n_2 \leq n_3 \leq n_4 < n_\xi = \sum_i^4 n_i.$$

- ▶ Holomorphic involution: $\sigma : \xi \mapsto -\xi$
- ▶ CY hypersurface $\xi^2 = P_{(2n_\xi, \dots)} = 0$.

D7 branes from the type IIB perspective

- ▶ $[D7] = -8[O7] = -8(n_\xi, \dots)$
- ▶ More specifically for polynomials η of $\deg(4n_\xi)$ and χ of $\deg(6n_\xi)$:
[Collinucci, Denef, Esole'09, Braun, Hebecker, Triendl'08, Sen'96]

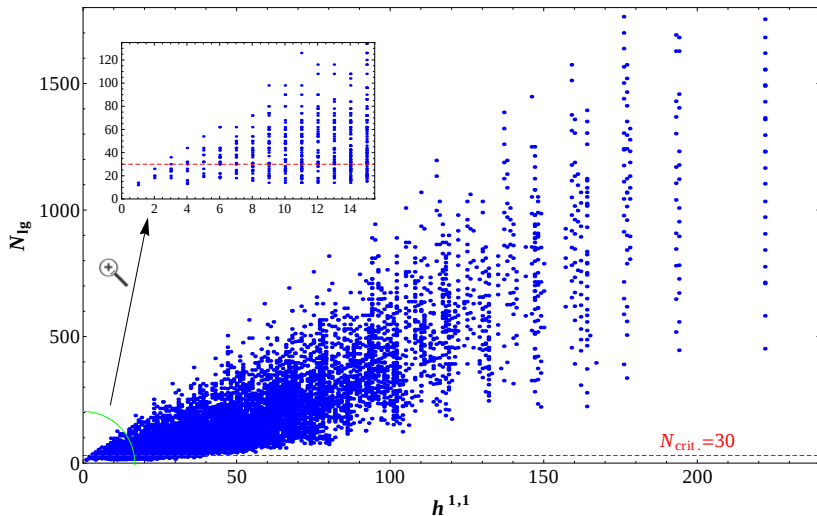
$$[D7]: \quad 0 = \eta^2 - \xi^2 \chi = u_1^{2N_1} \left(\tilde{\eta}_{(4n_\xi - n_1 N_1, \dots)}^2 - \xi^2 \tilde{\chi}_{(6n_\xi - 2n_1 N_1, \dots)} \right)$$

- ▶ i.e. for $Sp(N_1)$ Whitney brane splits of $2N_1$ branes wrapping $D_1: \{u_1 = 0\}$ via factorizations

$$\eta = u_1^{N_1} \tilde{\eta}, \quad \chi = u_1^{2N_1} \tilde{\chi}$$

- ▶ $\Rightarrow$ Maximal gauge group $Sp(N_1)$ with rank $N_1 < N_{lg} \equiv 3 \frac{n_\xi}{n_1}$.

Maximal gauge group ranks



$\Rightarrow N_{\text{ig}} > 30$ quiet natural for larger $h^{1,1}$!

Constraints on a consistent global model

- ▶ Contribution of gaugino condensation to the superpotential, $A \neq 0$:
 - ▶ Rigid divisor? [Witten'96]
 - ▶ Can it be 'rigidified' by gauge flux $\mathcal{F}$? [Martucci'06, Bianchi, Collinucci, Martucci'11]
- ▶ Swiss-cheese?
- ▶ $N_1 \gg 1$ enforces factorization of D7 brane equation in coordinates $u_i \neq u_1$ [Cicoli, Mayrhofer, Valandro'11]?
- ▶ Flux: Freed-Witten anomalies? [Minasian, Moore'96, Freed, Witten'97]
- ▶ Chiral matter at brane intersections that might destroy $A \neq 0$ [Blumenhagen, Møster, Plauschinn'08]?
- ▶ Stabilization inside the Kähler cone?
- ▶ D3 tadpole: $Q^{D7\text{-stacks}} + Q^{O7} = Q^{\mathcal{F}} + Q^{RR, NS-NS} + Q^{D3\text{-branes}}$?
- ▶ $A \neq \text{constant}$ but $A(\phi_i)$, see e.g., [DeWolfe, McAllister, Shiu, Underwood'07]

4. A consistent global model on $\mathbb{CP}_{11169}$ [18]

A consistent global model on $\mathbb{CP}_{11169}$ [18]

[Louis,Valandro,Westphal,MR '12]

- ▶ $\hat{\mathcal{V}} = \sqrt{\frac{2}{3}} \left(\hat{\mathcal{V}}_1 + \frac{1}{3} \hat{\mathcal{V}}_5 \right)^{3/2} \Rightarrow$ 'Approx. swiss-cheese'
- ▶ Brane config. ($N_{I_g} = 27$): $Sp(24)$ on D_1 forces $SO(24)$ on D_5 .
- ▶ D_5 rigid, D_1 can be 'rigidified' by gauge flux $\Rightarrow Sp(24) \rightarrow SU(24)$.
- ▶ Brane intersections: Switch on gauge flux $F_{1/5} + c_1(D_{1/5})/2$ to cancel Freed-Witten anomalies and tune F_1 , F_5 and B such that $\mathcal{F}_{1/5} = F_{1/5} - B$ is 'trivial' $\Rightarrow$ No chiral matter or D-terms.
- ▶ D3 tadpole: $Q^{RR, NS-NS} + Q^{D3-branes} = 114$.

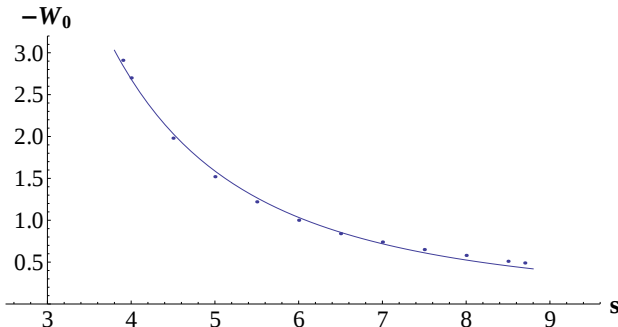
$$\Rightarrow W = W_0 + A_1 e^{-2\pi/24 T_1} + A_2 e^{-2\pi/22 T_2}, A_1, A_2 \neq 0.$$

Kähler uplifted de Sitter vacua (I)

Global model for Kähler moduli stabilization in a de Sitter vacuum on $\mathbb{CP}_{11169}$ [18] via non-perturbative effects: [\[Louis,Valandro,Westphal,MR '12\]](#)

$$V = e^K \left(K^{T_i \bar{T}_j} [W_{T_i} \overline{W_{T_j}} + W_{T_i} \cdot \overline{W K_{T_j}}] + 3 \hat{\xi} \frac{\hat{\xi}^2 + 7 \hat{\xi} \hat{\mathcal{V}} + \hat{\mathcal{V}}^2}{(\hat{\mathcal{V}} - \hat{\xi})(\hat{\xi} + 2 \hat{\mathcal{V}})^2} |W|^2 \right)$$

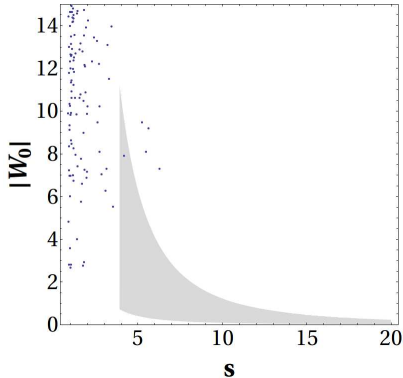
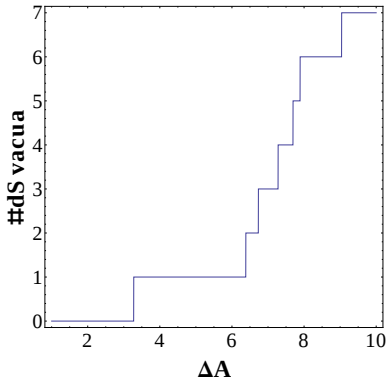
Numerically: Stable de Sitter solutions for $A_1, A_2 \sim 1$



Kähler uplifted de Sitter vacua (II)

Parametrize missing knowledge of A_1, A_2 by ΔA with scaling relations:

$$W_0 \rightarrow W_0 \cdot \Delta A, \quad A_1 \rightarrow A_1 \cdot \Delta A, \quad A_2 \rightarrow A_2 \cdot \Delta A \quad \Rightarrow \quad V \rightarrow V \cdot \Delta A^2$$



(Uplifting can be applied in the shaded region for $\Delta A = 4$)

5. Conclusions

Conclusions

- ▶ All flux vacua of reduced moduli space have been constructed for given D3-tadpole ($L = 35$) in the large complex structure limit
- ▶ $g_s \lesssim 1$ and $W_0 \sim \mathcal{O}(10^1 - 10^3)$ are preferred in our solutions
- ▶ N_{vac} and $\Delta\Lambda/\Lambda \sim 10^{-100}$ for $h_{\text{eff}}^{2,1} = 40$ and $L = 500$ consistent with semi-analytical predictions [Ashok,Douglas'04],[Denef,Douglas,Florea'04]
- ▶ Sufficient condition for de Sitter with all moduli stabilized
- ▶ Large gauge groups are quite natural for many Kähler moduli
- ▶ Consistent global model of Kähler uplifting on $\mathbb{CP}_{11169}$ [18]
 $\Rightarrow \sim 10^{-4}$ flux vacua can be uplifted
- ▶ Only the dependence of the 1-loop determinant A remains implicit but negligible due to mass scale separation

Outlook

Higher order α' corrections:

- ▶ Some α'^4 corrections to V_{eff} recently computed
[Grimm,Savelli,Weissenbacher'13]
- ▶ Suppressed by $\hat{\mathcal{V}}^{1/3}$ w.r.t. α'^3 but seems to have big coefficient in V_{eff}
- ▶ $\Rightarrow$ Corrections could be dangerous for Kähler uplifting and even LARGE Volume scenario, however absent in some geometries
[Pedro,Westphal,MR (to appear)]

Furthermore:

- ▶ Extend to Kähler uplifted global chiral model
- ▶ Include inflationary sector