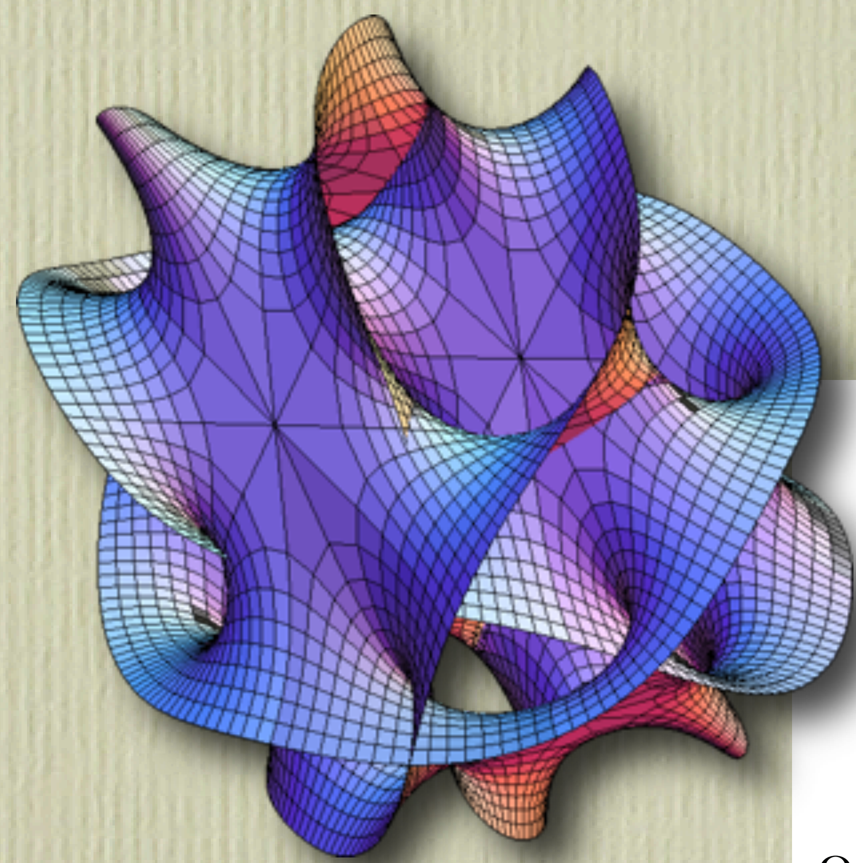
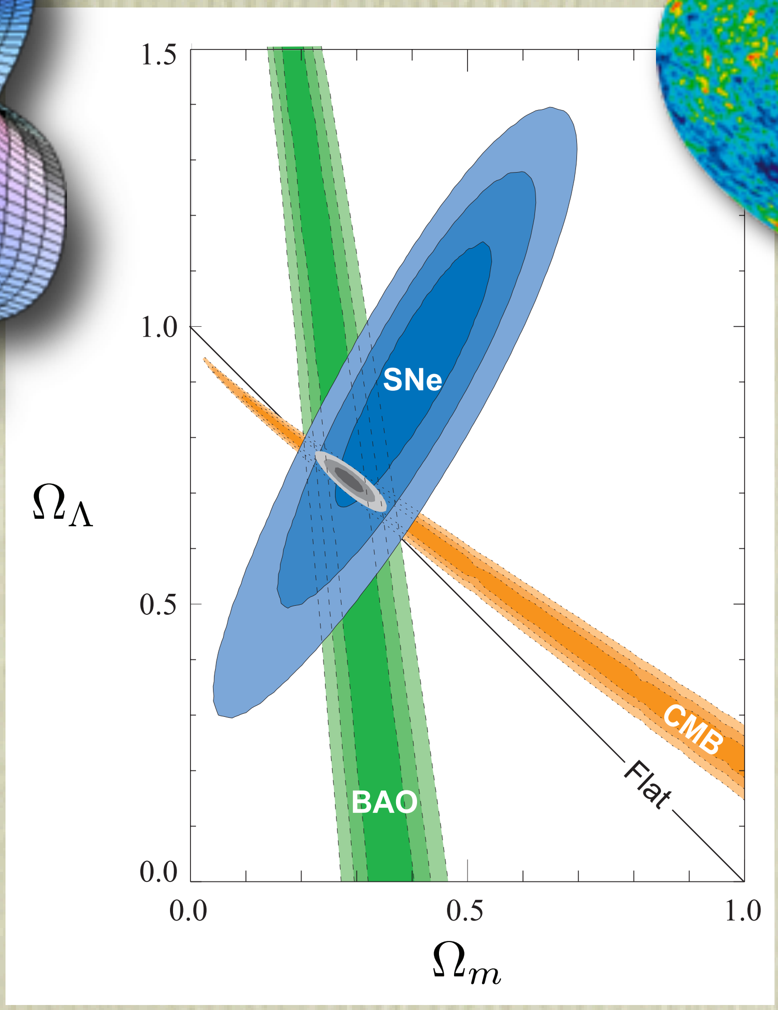
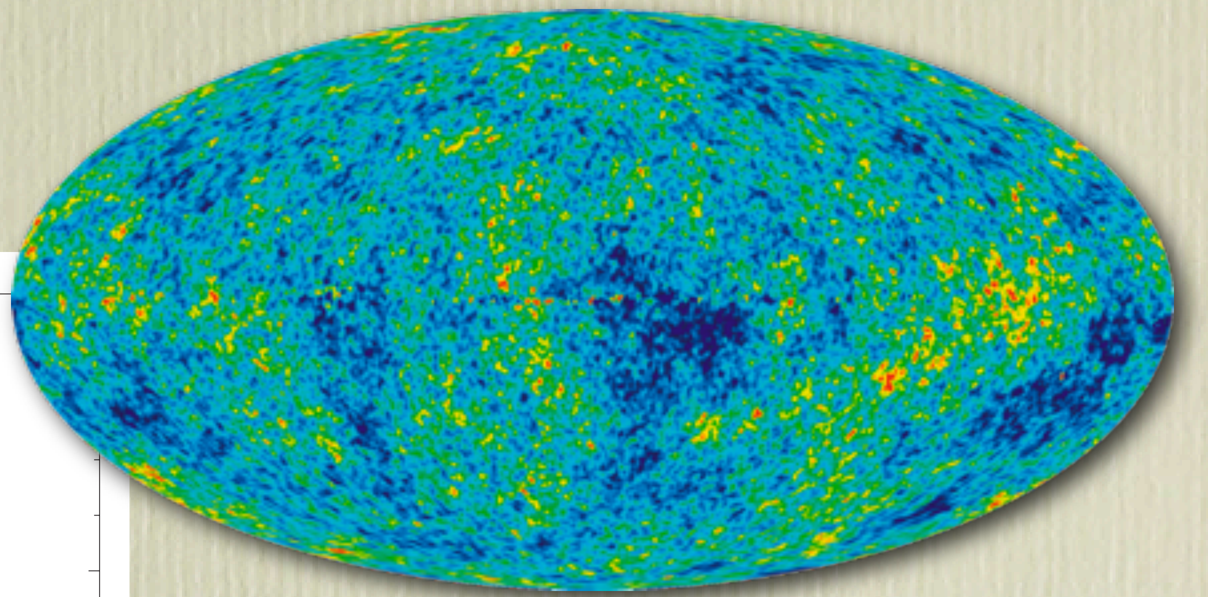
Towards explicit dS vacua ...



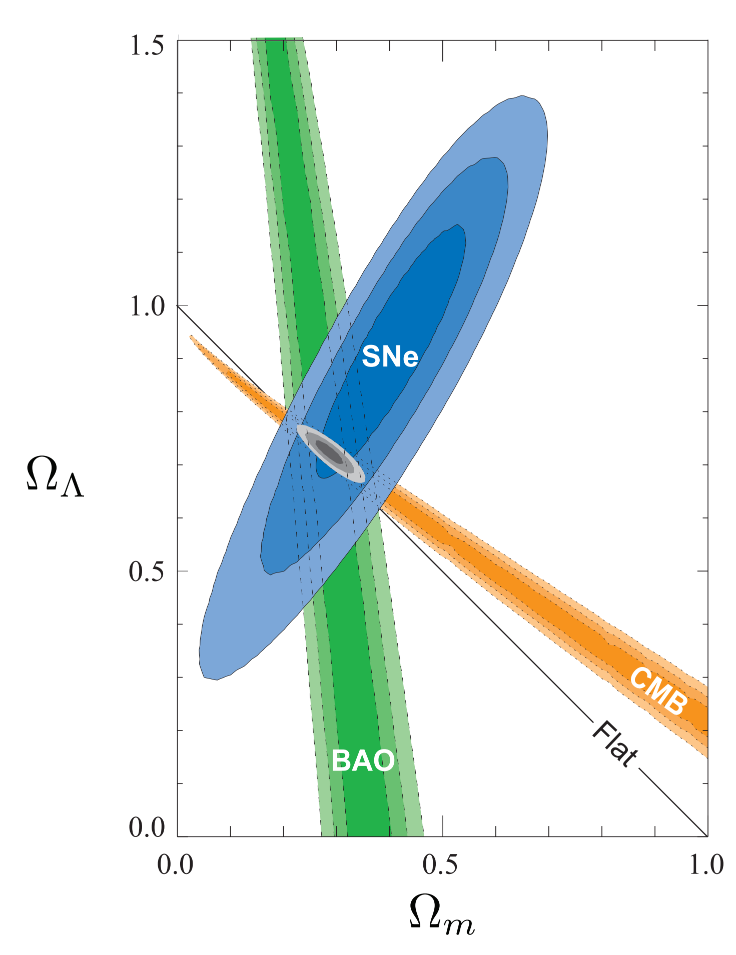




Jan Louis, Markus Rummel, Roberto Valandro & AW:
(arXiv:1107.2115) & work in progress (arXiv:1208.xxxx)
University of Hamburg & DESY Hamburg

- the observation:

  ➡ the Universe expands speeding up
   - $\Lambda > 0$ ... we live in de Sitter space!



- a task:

  ➡ there is a <u>necessary dS condition</u> in supergravity - positive sectional curvature of the Kahler potential

  [Covi, Gomez-Reino, Gross, Louis, Palma, Scrucca]

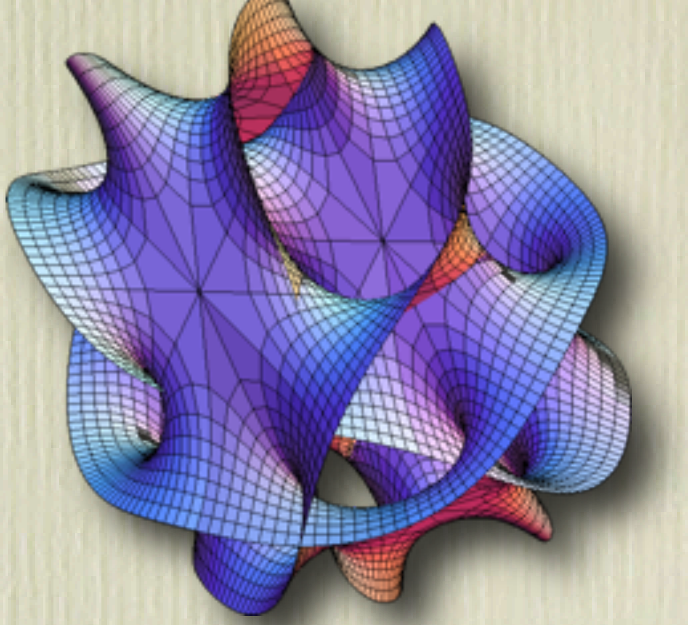
  ➡ it may be worthwhile to get dS from a 'clean' system:

  - dS vacua purely from topological data determining the F-term 4d supergravity in F-theory/IIB

  - find explicit examples in F-theory on compact elliptic CY 4-folds

dS vacua from F-theory/type IIB ...

- Try to use just the closed string moduli sector of a 4d N=1 F-theory compactification on an elliptically fibered CY 4-fold



$$\text{dilaton } S$$
$$h^{1,1} \text{ volume moduli } T_i$$
$$h^{2,1} \text{ complex structure moduli } U_a$$

  to get a dS vacuum from spontaneous F-term breaking

- key ingredient: the leading perturbative $O(\alpha'^3)$ correction

- leads to 'Kähler uplifted' dS vacua - checked for one volume modulus + dilaton S and one complex structure U

[Balasubramanian & Berglund '04][AW '06]

the general setup ...

- Kähler potential (KK-reduction on a CY 3-fold):

$$K = -2\ln(\mathcal{V} + \alpha'^3 \xi) - \ln(S + \bar{S}) - \ln\left(-i\int \Omega \wedge \bar{\Omega}\right)$$

$$\xi = \xi(S, \bar{S}) \sim -\chi(CY_3) \cdot (S + \bar{S})^{3/2}$$

- superpotential
  - 3-form fluxes stabilize the c.s. moduli & the dilaton
  - Euclidean D3-branes or 7-brane stacks contribute non-perturbatively

$$W = \int_{CY_3} G_3 \wedge \Omega \quad + \quad \sum_i A_i e^{-a_i T_i}$$

some relationships ...

$|W_0| \ll 1$, $\alpha'-$correction negligible

$W_0 \neq 0$, $\alpha'-$correction

$\hat{\mathcal{V}} >>> \hat{\xi}$
W_0 arbitrary

$\hat{\mathcal{V}} >>> \hat{\xi}$
$|W_0| \sim \mathcal{O}(1 \ldots 100)$

KKLT
[KKLT '03]

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

Kähler uplifting
[Balasubramanian, Berglund '04]
[Westphal '06]

- $\bar{D}3$ branes
- F-terms from matter fields [Lebedev,Nilles,Ratz'06]
- F-terms from metastable vacua in gauge theories [Intriligator,Seiberg,Shih'07]

- $\bar{D}3$ branes
- D-terms [Burgess,Kallosh,Quevedo'03, Haack,Krefl,Lüst,Van Proyen,Zagermann'06]
- F-terms from dilaton dep. non-pert. effects [Cicoli,Maharana,Quevedo,Burgess'12]

- F-terms from Kähler moduli + α'-correction sufficient for dS

de Sitter vacua from 'Kahler uplifting' at large volume

[Rummel & AW '11]

- 4d *N*=1 supergravity - scalar potential:

$$V = e^K \left\{ K^{T\bar{T}}[a^2 e^{-2aT_r} + (-ae^{-aT_r}\overline{WK_T} + c.c)] + 3\xi \frac{\xi^2 + 7\xi\mathcal{V} + \mathcal{V}^2}{(\mathcal{V}-\xi)(\xi+2\mathcal{V})^2}|W|^2 \right\}$$

- expand to leading order in ξ/V and e^{-aT}:

$$V \simeq 4AW_0 \frac{ate^{-at}}{\mathcal{V}^2}\cos(a\tau) + \frac{3\xi W_0^2}{4\mathcal{V}^3} \sim \frac{2C}{9x^{9/2}} - \frac{e^{-x}}{x^2}$$

$$x \equiv at \quad , \quad T = t + i\tau \quad , \quad C \equiv -\frac{27}{64}\sqrt{\frac{2}{3}}\frac{W_0}{A}\frac{\xi a^{3/2}\sqrt{\kappa}}{A}$$

de Sitter vacua from 'Kahler uplifting' at large volume

there is a de Sitter existence window for C :

- C is bounded from below:

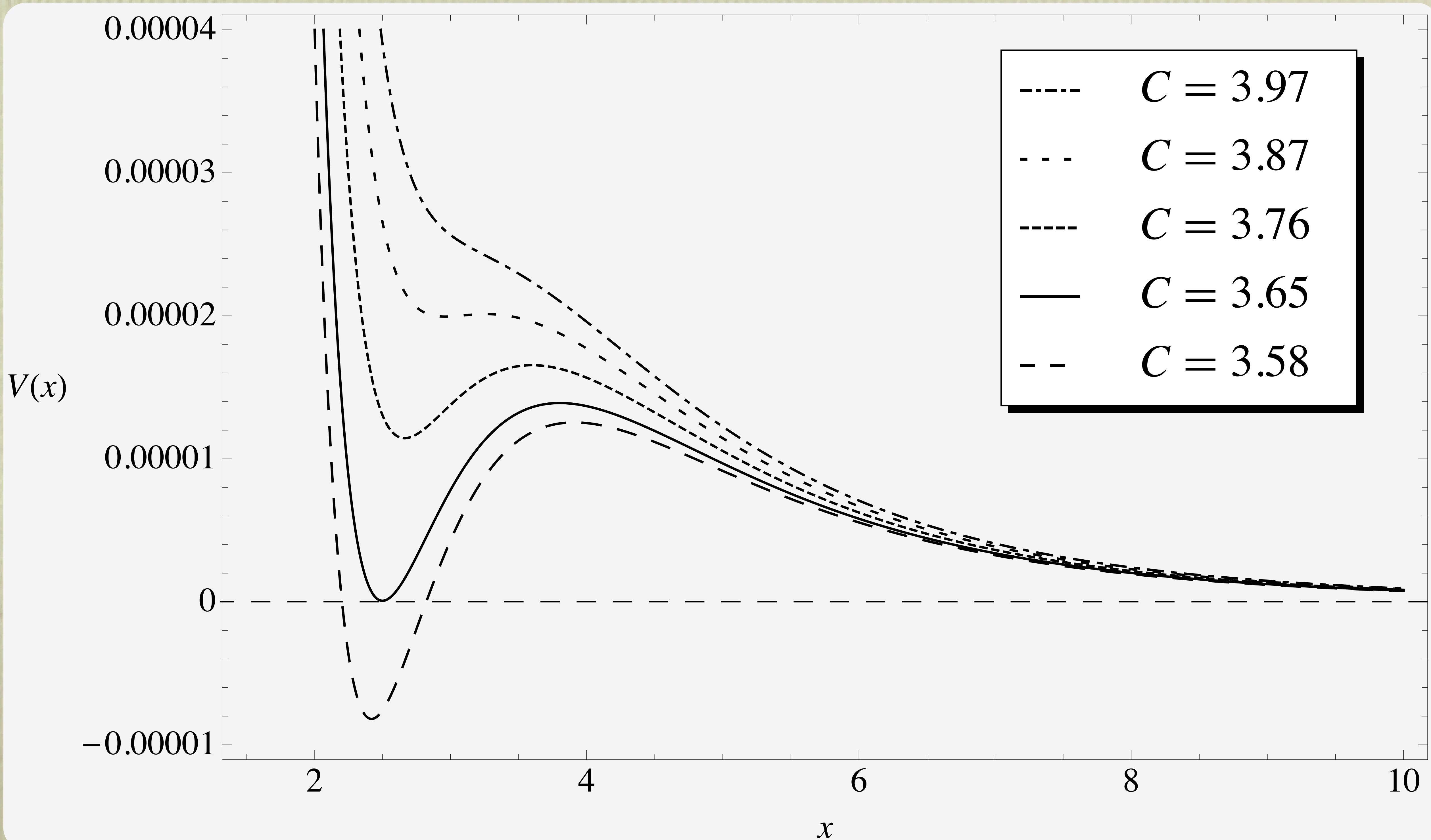
V = V' = 0 (Minkowski point)

- C is bounded from above:

V' = V'' = 0 (run-away limit)

$$\Rightarrow \quad C \simeq 3.75 \pm 0.1 \quad , \quad x \sim 2.5$$

de Sitter vacua from 'Kahler uplifting' at large volume



this works for arbitrary $h^{1,1}$ on Swiss-cheese CYs!

- resulting scalar potential

$$V = \frac{4W_0}{\mathcal{V}^2}\left(atAe^{-at}\cos(a\tau) + \sum_{i=2}^{h^{1,1}} a_i t_i A_i e^{-a_i t_i}\cos(a_i\tau_i)\right) + \frac{3\xi W_0^2}{4\mathcal{V}^3}$$
$$+ \sum_{i=2}^{h^{1,1}} \frac{2\sqrt{2}}{3}\frac{a_i^2 A_i^2}{\mathcal{V}^2}\frac{\sqrt{t_i}}{\gamma_i}e^{-2a_i t_i}\mathcal{V}$$

of $O(\xi^2/V^2)$
at the minimum

all $V_{\tau_I\tau_I} > 0$ if $W_0 < 0$ at $\tau_I = 0$;

or if $W_0 > 0$ at $\tau_I = \pi/a_I$

$V_{t_I\tau_J} = 0$ at these points, thus all axions are massive

what about the other moduli?

- Starting point: *S* and U_a at SUSY locus, T stabilization breaks SUSY

$$W = W_0 + Ae^{-aT} = C_1 - C_2\, S + Ae^{-aT}$$

expand *S* and U_a in ξ/V & check that shifts are small - first the dilaton ...

what about the other moduli?

$$\Rightarrow \quad V \sim e^K \left(K^{S\bar{S}} |D_S W_0|^2 + K^{T\bar{T}} |D_T W|^2 + K^{T\bar{S}} D_T W \overline{D_S W_0} \right)$$

V_0

δV perturbs S away from S_0 ...

$$S_0 = -\frac{C_1}{C_2} \ : \ D_S W_0 \big|_{S_0} = 0 \ , \quad \frac{\partial V}{\partial S} = 0 \quad \Rightarrow \ \frac{\delta S}{S_0} \sim \frac{\xi}{\mathcal{V}}$$

what about the other moduli?

- mass scales:

$$m_t^2 \sim \frac{\hat{\xi}}{\mathcal{V}^3} \qquad m_{\mathrm{Re}\,S}^2 \sim \frac{1}{\mathcal{V}^2}$$

$$m_\tau^2 \sim \frac{\hat{\xi}}{\mathcal{V}^3} \qquad m_{\mathrm{Im}\,S}^2 \sim \frac{1}{\mathcal{V}^2}$$

$$m_{3/2}^2 = e^K |W|^2 \sim \frac{1}{\mathcal{V}^2}$$

$$m_{KK} = \frac{1}{L\sqrt{\alpha'}} \sim \frac{1}{\hat{\mathcal{V}}^{2/3}}$$

➡ SUSY is broken at the GUT scale, but below KK-scale!

what about the other moduli?

$\tilde{\xi} = 0.1733 \quad (\chi = -200)$

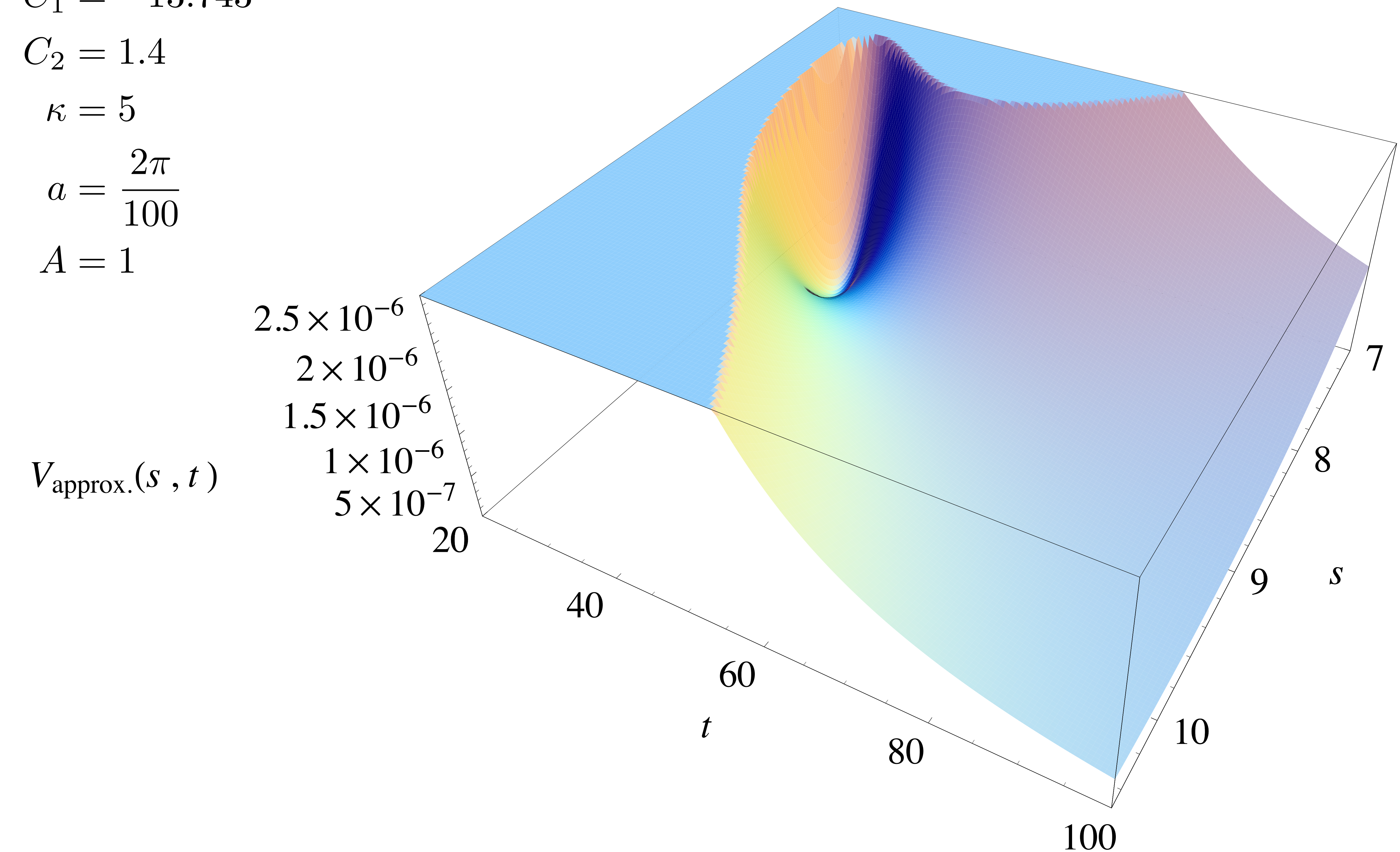
$C_1 = -13.743$

$C_2 = 1.4$

$\kappa = 5$

$a = \frac{2\pi}{100}$

$A = 1$



what about the other moduli?

- similarly for the complex structures U_a ...

$$K = \ldots - \ln \left(\int_{CY_3} \Omega(U_a) \wedge \bar{\Omega}(\overline{U_a}) \right)$$

C_1, C_2 become functions of U_a

what about the other moduli?

$$\Rightarrow \quad V \sim e^K (K^{a\bar{b}} D_{U_a} W_0 \overline{D_{U_b} W_0} + K^{T\bar{T}} |D_T W|^2 + K^{T\bar{S}} D_T W \overline{D_S W_0})$$

V_0

δV perturbs U away from U_0 ...

$$U_{a,0} \ : \ D_{U_a} W_0 \big|_{U_{a,0}} = 0 \ , \qquad \frac{\partial V}{\partial U_a} = 0 \quad \Rightarrow \ \frac{\delta U_a}{U_{a,0}} \sim \frac{\xi}{\mathcal{V}}$$

[c.f. also: Gallego & Serone]

what about the other moduli?

need $(\partial_a \partial_{\bar{b}} V_0) > 0$

but this is guaranteed:

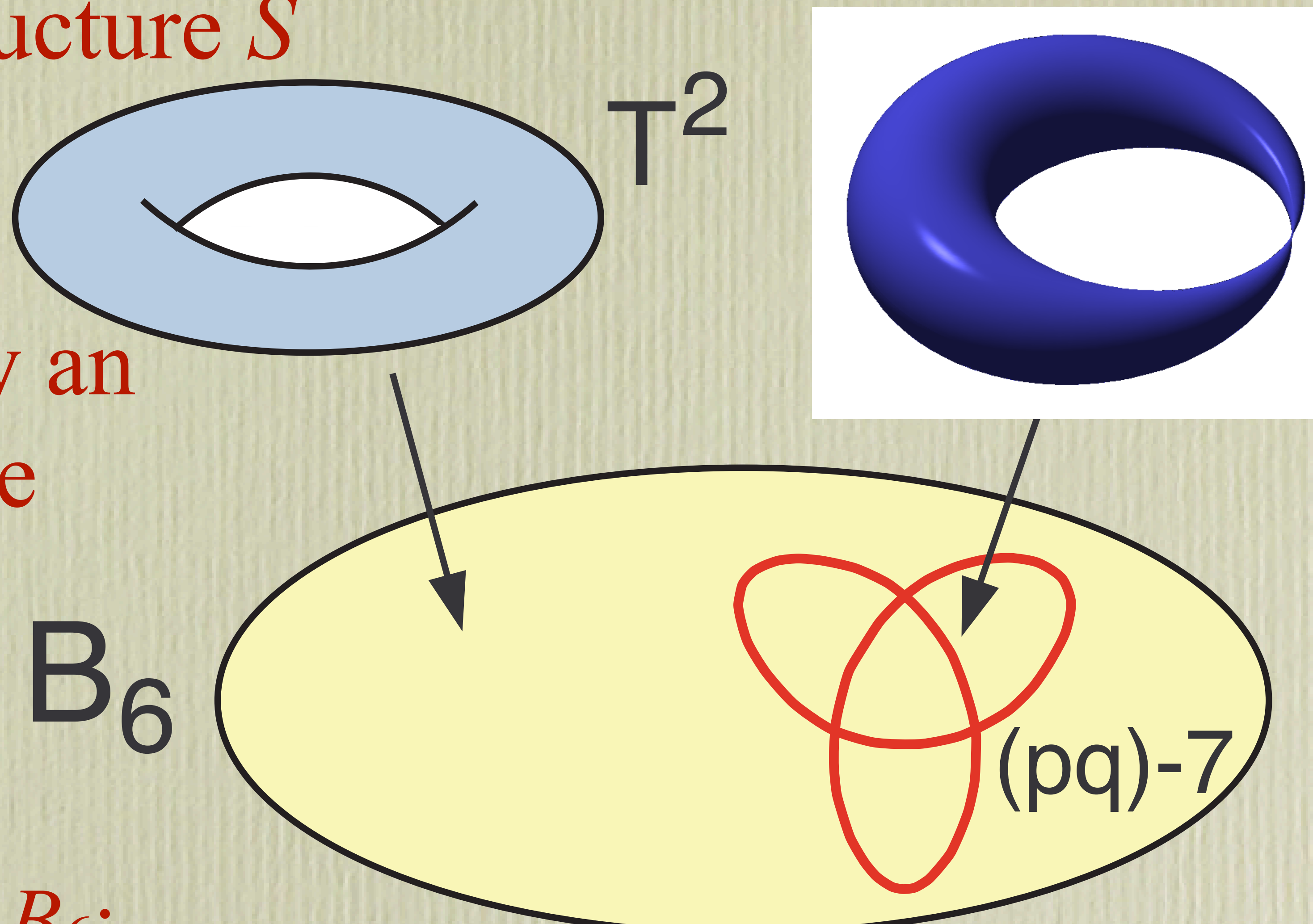
- flux alone gives a no-scale vacuum

- V_0 positive semidefinite
  $\rightarrow$ stable

- no-scale breaking is volume suppressed
  $\rightarrow$ stability survives

F-theory ...

torus fiber with
complex structure S



described by an
elliptic curve

elliptic Calabi-
Yau 4-fold of
F-theory type:

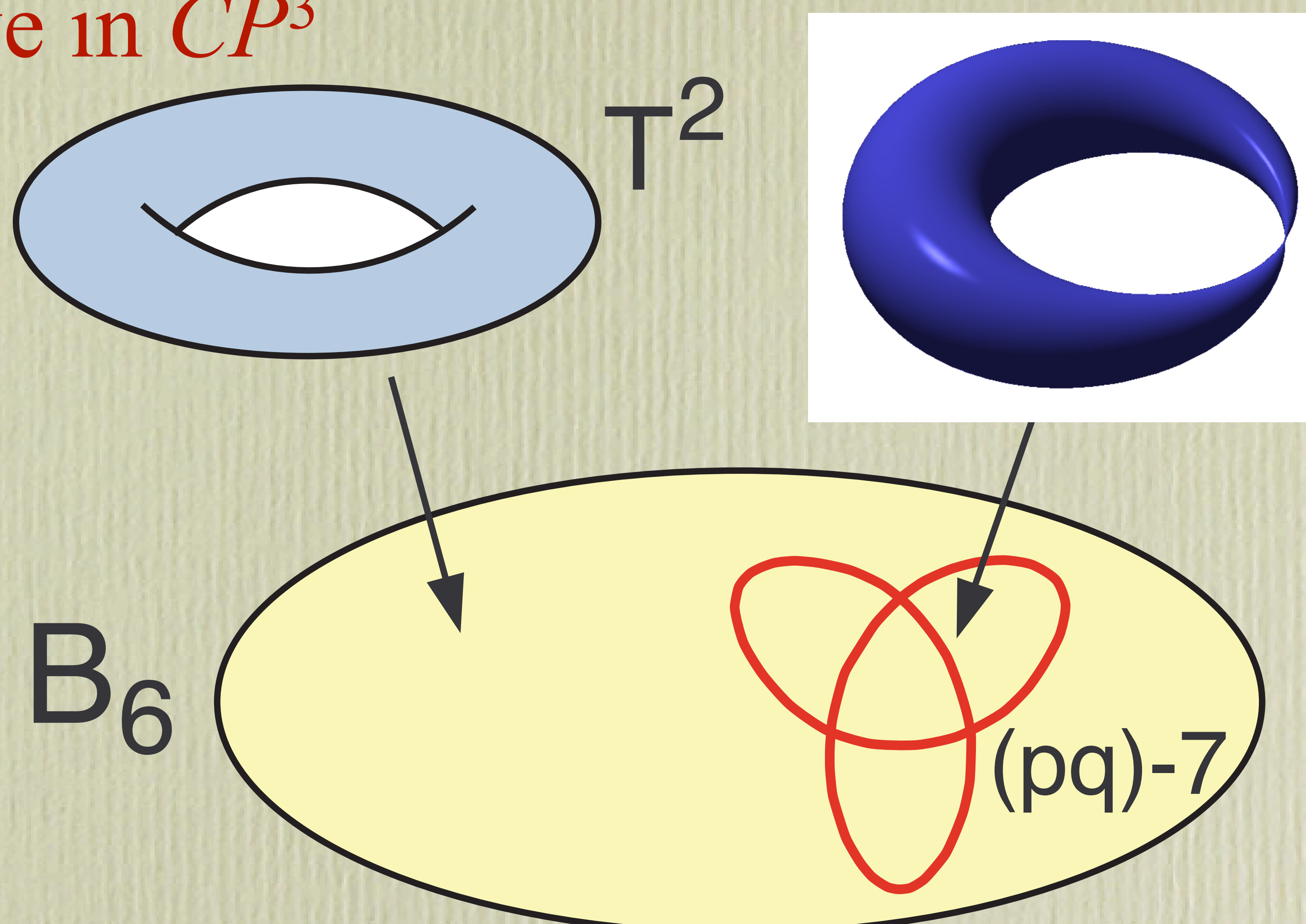
an elliptically
fibered bundle

base B_6:

- 3-complex dimensional compact space
- simplest case: complex projective space CP^4
- more general class: hypersurfaces described by polynomial equations in an ambient toric variety

F-theory ...

described by an elliptic curve in CP^3 w/ coord. (X,Y,Z)



elliptic Calabi-Yau 4-fold of F-theory type:

an elliptically fibered bundle

elliptic curve of fiber described a 'Weierstrass model':

$$Y^2 = X^3 + f\,XZ^4 + g\,Z^6$$

f and g are sections of $4\bar{K}$ and $6\bar{K}$

(deg. 4 and 6 polynomials in the coord.s on B_6)

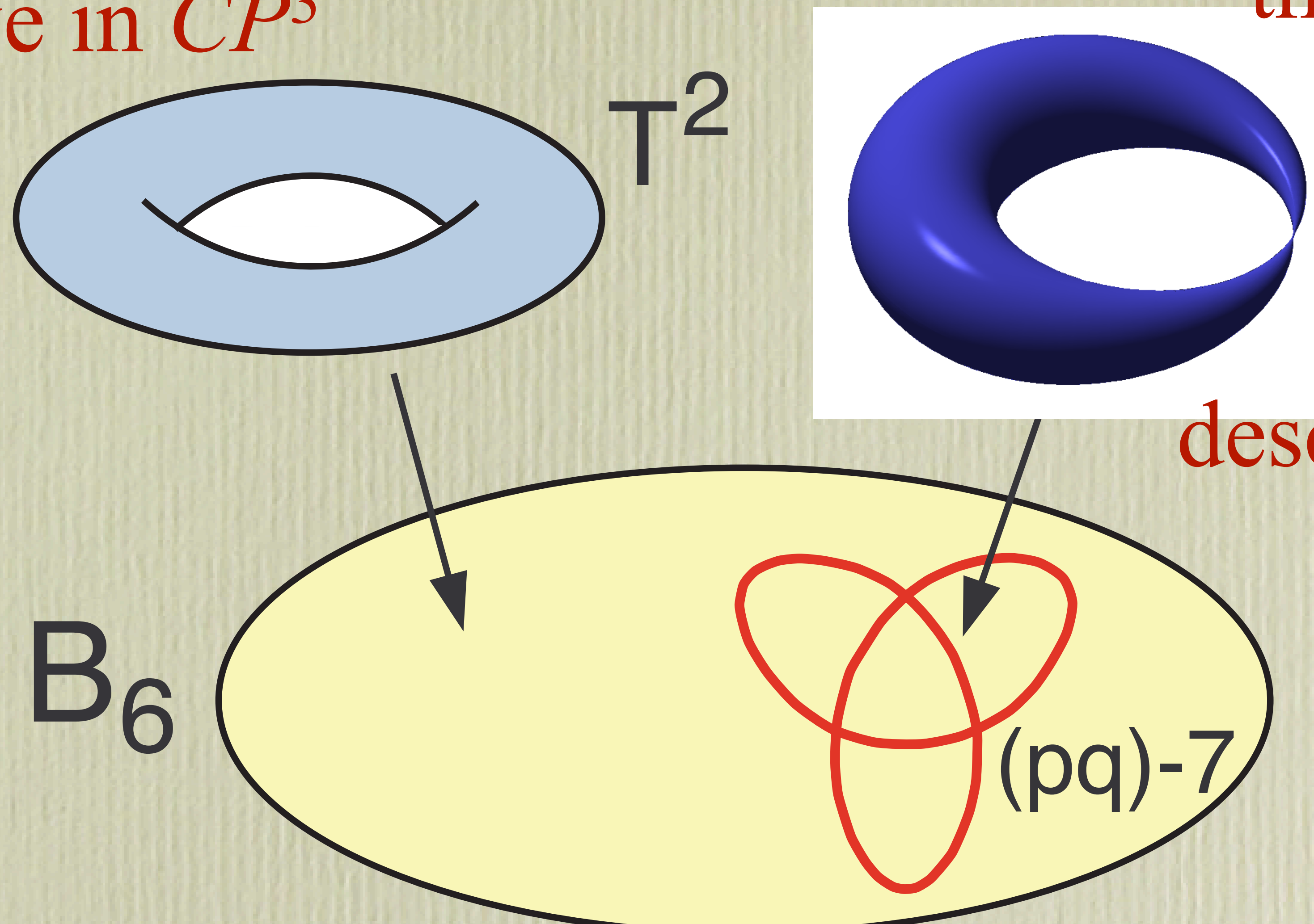
$\bar{K} = c_1(B_6)$ is the anti-canonical bundle of B_6

F-theory ...

described by an elliptic curve in CP^3 w/ coord. (X,Y,Z)

the elliptic curve can degenerate:

vanishing fiber describes a 7-brane



degenerate fiber: zeros of discriminant of 'Weierstrass model':

$$\Delta = 27\,g^2 + 4\,f^3$$

order of zero = rank of gauge group = # (stacked 7-branes)
order of zeros in f,g = gauge group type

A_n ($SU(n)$) , D_n ($SO(n)$), E (E_6,E_7,E_8)

Explicit models ...

- search for:
  - elliptically fibered CY 4-folds
  - with good Sen limit to weakly coupled type IIB
  - Kähler uplifting $\longrightarrow$ large-rank 7-brane gauge group

- tool:
  - 'mini'-landscape of 7,602 four-folds of F-theory type from the Kreuzer-Skarke classification with distinct Hodge number pairs $(h^{1,1}, h^{2,1})$

  - 3,040 of those give type IIB on a CY3 with negative Euler number

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Explicit models ...

'Mini' landscape: 97,036 models of the F-theory type: [Kreuzer,Skarke '00]

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

$$\mathbb{CP}_{n_1 n_2 n_3 n_4 n_\xi} : \quad 0 < n_1 \leq n_2 \leq n_3 \leq n_4 < n_\xi = \sum_i^4 n_i$$

$$\frac{u_1 \;\; u_2 \;\; u_3 \;\; u_4 \;\; \xi}{n_1 \;\; n_2 \;\; n_3 \;\; n_4 \;\; n_5} \qquad \text{with} \qquad 0 < n_1 \leq n_2 \leq n_3 \leq n_4 \leq n_5$$

$$(u_1, ..., u_4, \xi) \sim (\lambda^{n_1} u_1, ..., \lambda^{n_4} u_4, \lambda^{n_5} \xi) \,, \qquad \text{with} \;\; \lambda \in \mathbb{C}^*$$

Explicit models ...

- the toric divisors D_i , D_ξ are hypersurfaces (4-cycles) given by holomorphic equations:

$$D_i : \{u_i = 0\} \qquad\qquad D_\xi : \{\xi = 0\}$$

- for N=1 supersymmetry in 4D we need to orientifold - 1 possible orientifold projection:

$$\sigma : \quad \xi \mapsto -\xi \, ,$$

Explicit models ...

- a CY 3-fold is then a hypersurface describing a double-cover of B6 in the complex-4d toric ambient space

$$\xi^2 = P_{(2\sum_i^4 n_i,\dots)}$$

if its degree = $2n_\xi$ and

$$n_\xi \equiv n_5 = \sum_{i=1}^{4} n_i \quad \Rightarrow \quad \bar{K}(CY_3) = c_1(CY_3) = 0$$

Explicit models ...

- can do this in F-theory with a Weierstrass model fibered over the toric base B_6 :

$$\begin{array}{cccc} u_1 & u_2 & u_3 & u_4 \\ \hline n_1 & n_2 & n_3 & n_4 \end{array} \qquad\qquad \mathbb{CP}^3_{n_1 n_2 n_3 n_4}$$

- rewrite the Weierstrass equation in Tate form:

$$Y^2 + a_1 XYZ + a_3 YZ^3 = X^3 + a_2 X^2 Z^2 + a_4 XZ^4 + a_6 Z^6$$

a_i are functions of the u_i on the base such, that they are sections of $i\bar{K}$

Explicit models ...

- to construct the 7-brane singularity for a given gauge group on divisor D_j, a_i have to scale in u_j with certain weights

$$a_i = u_j^{w_i} a_{i,w_i}$$

- Kodaira classification gives weights:

	a_1	a_2	a_3	a_4	a_6	Δ
$Sp(N)$	0	0	N	N	$2N$	$2N$
$SU(2N)$	0	1	N	N	$2N$	$2N$
$SU(2N+1)$	0	1	N	$N+1$	$2N+1$	$2N+1$
$SO(4N+1)$	1	1	N	$N+1$	$2N$	$2N+3$
$SO(4N+2)$	1	1	N	$N+1$	$2N+1$	$2N+3$
$SO(4N+3)$	1	1	$N+1$	$N+1$	$2N+1$	$2N+4$
$SO(4N+4)$	1	1	$N+1$	$N+1$	$2N+1$	$2N+4$

Explicit models ...

- the toric base B_6 of the 4-fold has anti-canonical class

$$\bar{K} = [D_\xi] = \sum_{i-1\ldots4} [D_i] = n_\xi [D_1] \quad \Rightarrow \quad n_\xi = \sum_{i=1\ldots4} n_i$$

- because a_i is in $i\bar{K}$ we have:

$$a_i = u_j^{w_i} a_{(in_\xi - w_i n_j, \ldots)} \quad j = 1 \ldots 4$$

Explicit models ...

- because the $a_{i,w}$ must be holomorphic:

$$N = rank(gauge\ group) = w_i \leq \frac{i\, n_\xi}{n_j}$$

- strongest constraint from a_3 , a_6:

$$N_{lg} \leq \frac{3n_\xi}{n_j}$$

Explicit models ...

- Sen limit - rescale the a_i :

$$a_3 \mapsto \epsilon\, a_3\,, \qquad a_4 \mapsto \epsilon\, a_4\,, \qquad a_6 \mapsto \epsilon^2\, a_6$$

such that:

$$g_s \sim -\frac{1}{\log|\epsilon|} \to 0 \qquad \text{as} \qquad \epsilon \to 0$$

Explicit models ...

- then we get (complete square & cube in Tate-extended Weierstrass equation):

$$f = -\frac{1}{48}(h^2 - 24\epsilon\eta)\,, \qquad g = -\frac{1}{864}(-h^3 + 36\epsilon h\,\eta - 216\epsilon^2\chi)$$

$$h = a_1^2 + 4a_2\,, \qquad \eta = a_1a_3 + 2a_4\,, \qquad \chi = a_3^2 + 4a_6$$

Explicit models ...

- the discrimant becomes:

$$\Delta = \frac{1}{16}\left(\epsilon^2 h^2 P_{D7} + 8\epsilon^3\eta^3 + 27\epsilon^4\chi^2 - 9h\epsilon^3\eta\chi\right) \sim \frac{1}{16}\epsilon^2\, h^2 P_{D7} + \mathcal{O}(\epsilon^3)$$

where $P_{D7} = -\frac{1}{4}(\eta^2 - h\chi)$

Explicit models ...

- O7: $$h = 0$$

- D7: $$P_{D7} = 0$$

- CY 3-fold is a double cover of B_6:

$$X_3 : \;\; 0 = \xi^2 - h = \xi^2 - (a_1^2 + 4a_2)$$

- so, we are now in type IIB ...

Explicit models ...

- the D7-brane equation becomes:

$$\eta^2 - \xi^2 \chi = 0$$

- this is a holomorphic D7-brane called Whitney (umbrella) for its shape ...

Explicit models ...

- a large-rank gauge group requires a large stack of coincident D7-branes - need to factorize in divisor coordinate

$$\eta = u_i^{N_i} \tilde{\eta} \,, \qquad \qquad \chi = u_i^{2N_i} \tilde{\chi}$$

- and thus

$$u_i^{2N_i} \left(\tilde{\eta}^2_{(4n_\xi - n_i N_i, \dots)} - \xi^2 \tilde{\chi}_{(6n_\xi - 2n_i N_i, \dots)} \right) = 0$$

- so, by holomorphy again: $N_i \leq 3 \dfrac{n_\xi}{n_i}$

Explicit models ...

- thus, large rank needs large orientifold class n_ξ

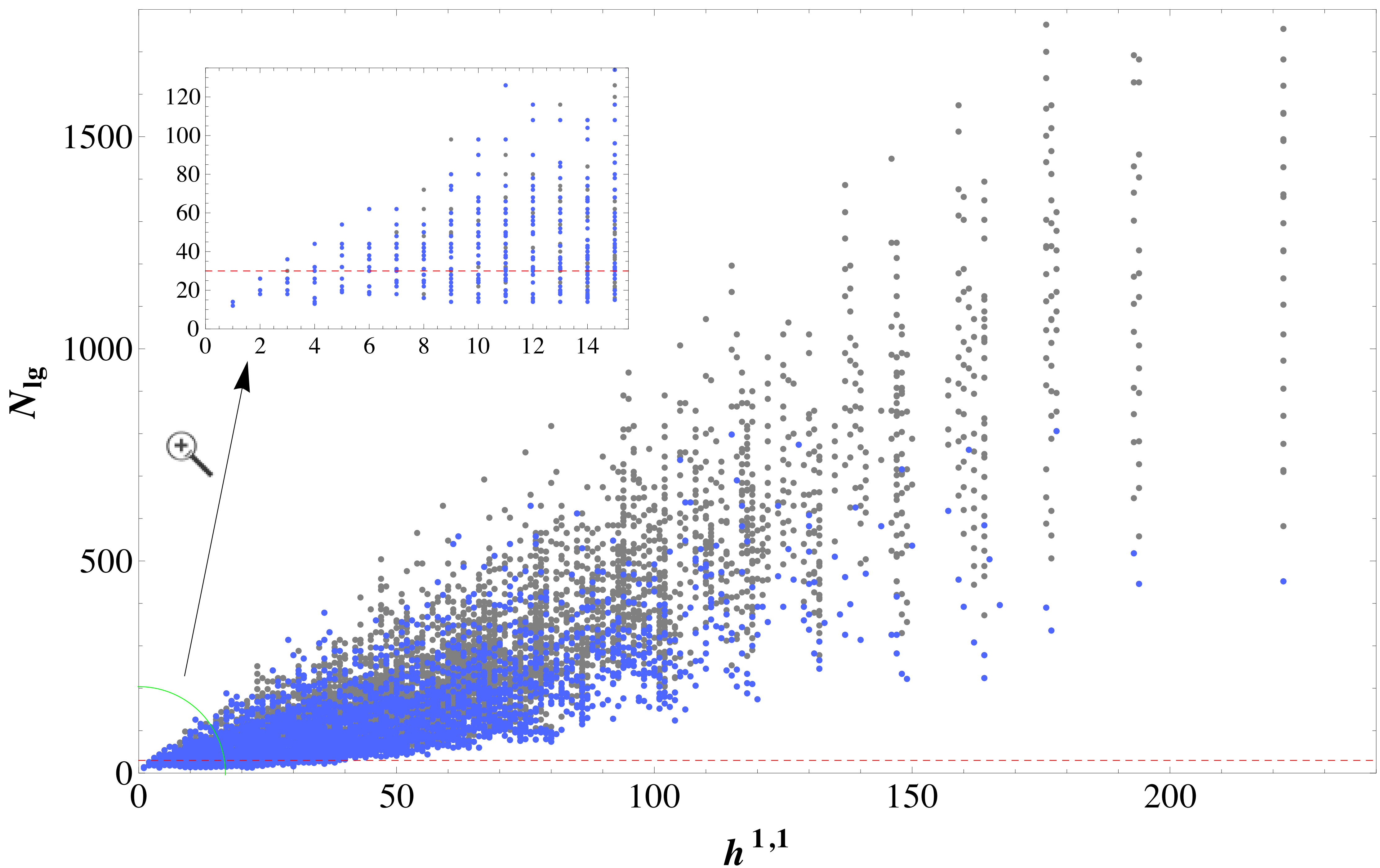
- if any $n_i > 1$, then B_6 has singularities

- resolution (blow-up) adds new lines to weight system (GLSM) $\longrightarrow$ each new line is a new independent divisor, and thus new Kähler modulus

- so maximal rank will increase with $h^{1,1}$

Explicit models ...

- can plot this for F-theory type Kreuzer-Skarke set:



Explicit models ...

- thus, because (naively):

$$\mathcal{V} \sim N_{lg}^{3/2}$$

- volumes > 10^3 are possible in a large fraction of CY space

- this ensures control & separation of Kähler and complex structure moduli mass scales $\longrightarrow$ justifies treating the instanton prefactors as constant!

Explicit models ...

Constraints on a consistent 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?
- Flux: Freed-Witten anomalies?[Minasian,Moore'96, Freed,Witten'97]
- $N_1 \gg 1$ enforces factorization of D7 brane equation in coordinates $u_i \neq u_1$ [Cicoli,Mayrhofer,Valandro'11]?

Explicit models ...

Constraints on a consistent model

- Stabilization inside the Kähler cone?
- Chiral matter at brane intersections that might destroy $A \neq 0$ [Blumenhagen,Moster,Plauschinn'08]?
- D3 tadpole: $Q^{D7-\text{stacks}} + Q^{O7} = Q^{\mathcal{F}} + Q^{RR,NS-NS} + Q^{D3-\text{branes}}$?
- Complex structure moduli stabilized such that sufficient condition for de Sitter is fulfilled: $W_0 \cdot \mathrm{Re}(S)^{3/2}$ in right interval?

Explicit dS example: $\mathbb{CP}_{11169}$

Some geometric properties:

- Calabi-Yau: $0 = \xi^2 = P_{18,4}(u_i)$ in

u_1	u_2	u_3	u_4	u_5	ξ
1	1	1	6	0	9
0	0	0	1	1	2

- $h^{1,1} = 2,\ h^{2,1} = 272$

- Divisors:

	$h^{0,0}$	$h^{1,0}$	$h^{2,0}$	$h^{1,1}$	χ_0
D_1	1	0	2	30	3
D_5	1	0	0	1	1

Explicit models ...

Explicit dS example: $\mathbb{CP}_{11169}$

- $\hat{\mathcal{V}} = \sqrt{\frac{2}{3}} \left(\hat{\mathcal{V}}_1 + \frac{1}{3} \hat{\mathcal{V}}_5 \right)^{3/2} - \frac{\sqrt{2}}{9} \hat{\mathcal{V}}_5^{3/2} \Rightarrow$ 'Approx. swiss-chesse'

- Complex structure moduli: $\mathbb{Z}_6 \times \mathbb{Z}_{18}$ modding: $h^{2,1}_{\text{inv.}} = 2$. with known prepotential. [Greene,Plesser'89], [Candelas,Font,Katz,Morrison'94]

  $G(z)$ via mirror symmetry in the large complex structure limit:

$$G(z_1, z_2) = \sum_{i+j \leq 3} c_{ij} z_1^i z_2^j + \xi + G_{\text{instanton}}(e^{-2\pi z_1}, e^{-2\pi z_2})$$

Explicit models ...

- 1st step - 3-form flux fixes the 2 invariant complex structure moduli supersymmetrically:

Stabilizing the $h^{2,1}_{\text{inv.}} = 2$ moduli effectively fixes all other C.S. moduli at $D_i W = 0$ since V positive definite up to corrections $\mathcal{O}(\hat{\xi}/\hat{\mathcal{V}})$ [Giryavets,Kachru,Tripathy,Trivedi '03]

- the 270 $Z_6 \times Z_{18}$ non-invariant c.s. moduli are stabilized by invariant higher-order terms in W (from invariant higher-order terms in the 4 invariant periods)

Explicit models ...

Strategy to find $\langle W_0 \rangle$, $\langle S \rangle$ suitable for Kähler uplifting: [DDF'04]

- Solve $(W_0, D_S W_0, D_{U_1} W_0, D_{U_2} W_0) = 0$, for the flux quanta $f_1, \ldots, f_6,\ h_1, \ldots, h_6$

- Include instanton corrections in the prepotential: shifts in $\langle W_0 \rangle$, $\langle S \rangle$, $\langle U_1 \rangle$ and $\langle U_2 \rangle$

  generates $W_0 \neq 0$, then check VEVs of W_0 and S

  $\Rightarrow$ have to fall into dS window

Explicit models ...

A solution:

$$(f, h) = (-16, 0, 0, 0, -4, -2; 0, 0, 2, -8, -3, 0)\,, \qquad Q^{RR,NS-NS} = 66\,,$$

$$\langle S \rangle = 6.99\,, \quad \langle U_1 \rangle = 1.01\,, \quad \langle U_2 \rangle = 0.967\,, \quad \langle W_0 \rangle = 0.812\,,$$

$m^2_{u_1}$	$m^2_{u_2}$	m^2_s	$m^2_{\nu_1}$	$m^2_{\nu_2}$	m^2_σ
0.24	$1.8 \cdot 10^{-4}$	$5.6 \cdot 10^{-6}$	0.24	$1.8 \cdot 10^{-4}$	$5.7 \cdot 10^{-6}$

Explicit models ...

- 2^{nd} step - Kähler moduli:

- Brane config. ($N_{lg} = 27$): $Sp(24)$ on D_1 forces $SO(24)$ on D_5.

- D_5 rigid, D_1 can be 'rigidified' by gauge flux $\Rightarrow Sp(24) \to SU(24)$.

- 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: $Q^{\text{tot}}_{D3} = Q^{\text{O7s}}_{D3} + Q^{\text{stacks}}_{D3} + Q^{W}_{D3} = \begin{cases} -104 & \text{for } Q^W_{D3} = -81 \\ -96 & \text{for } Q^W_{D3} = -73 \end{cases}$

Explicit models ...

- 2nd step - Kähler moduli:

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

▸ If in the complex structure sector:

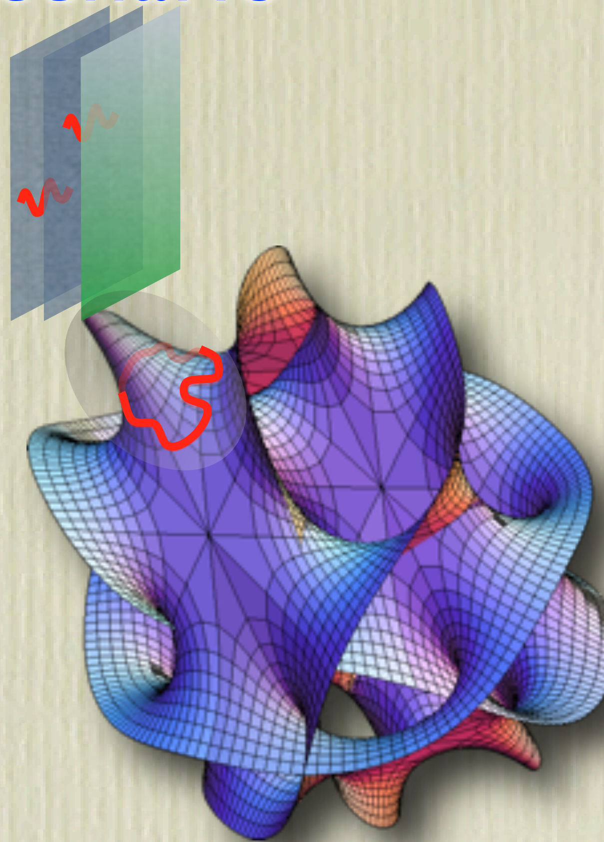
$$\langle W_0 \rangle = 0.812\,,\ \langle S \rangle = 6.99\,,\ \langle A \rangle = 1.11\,,\ \langle B \rangle = 1.00\,.$$

▸ **stable dS vacuum** with $\langle T_1 \rangle = 10.76$, $\langle T_2 \rangle = 12.15$ and $\hat{\mathcal{V}} = 52$.

$m^2_{\tau_1}$	$m^2_{\tau_2}$	$m^2_{\zeta_1}$	$m^2_{\zeta_2}$	$m^2_{3/2}$
$5.24 \cdot 10^{-9}$	$4.55 \cdot 10^{-8}$	$1.13 \cdot 10^{-7}$	$6.40 \cdot 10^{-8}$	$4.08 \cdot 10^{-7}$

Conclusions

- We have explicit constructions of dS vacua in type IIB string theory/F-theory in the 'Kähler uplifting' scenario



- They are fully determined by the 4-fold data:

  - the Euler characteristic
  - choice of ADE-type singularities,
  - and choice of fluxes

- They break SUSY by Kähler moduli F-terms at the GUT scale. No extra source of uplifting is needed

- A whole *'mini'-landscape* of explicit examples (Kreuzer-Skarke) is available. One example is shown to satisfy all known F-theory/IIB consistency constraints.