De Sitter Vacua in Global String Models

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Rudolf Peierls Centre for Theoretical Physics
Theoretical Physics Seminar, Liverpool, 29/10/2014

References

- Geometric requirements for combining both mechanisms
  (moduli stabilisation & D-brane model building, models with(out) flavour branes)
  M. Cicoli, SK, C. Mayrhofer, F. Quevedo, R.Valandro [1304.0022, 1206.5237]

- Models with explicit flux stabilisation (scan)
  M. Cicoli, D. Klevers, SK, C. Mayrhofer, F. Quevedo, R.Valandro [1312.0014]

- Local model building
  C. Burgess, M. Dolan, SK, A. Maharana, F. Quevedo
  [1106.6039, 1102.1973, 1002.1790]

- SUSY breaking for local models
  R. Blumenhagen, J. Conlon, SK, S. Moster, F. Quevedo [0906.3297]
  L.Aparicio, M. Cicoli, SK, A. Maharana, F. Muia, F. Quevedo[1409.1931]

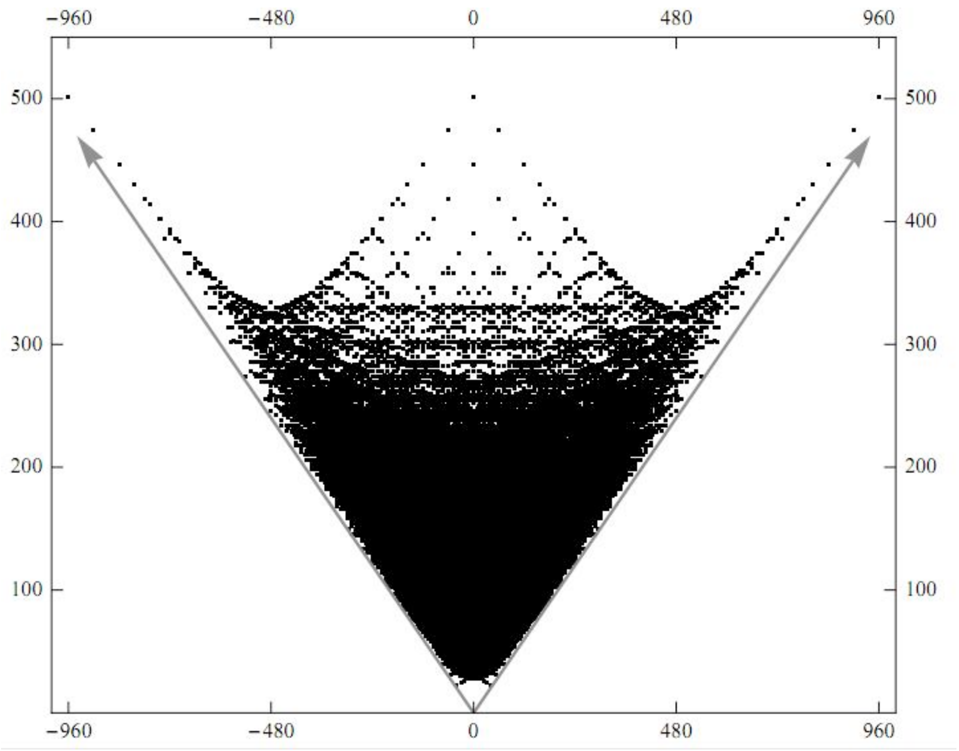
… this talk is about how far we can go towards the key (long-term) challenge in string phenomenology:

Construct an explicit viable string vacuum

satisfying all particle physics and cosmological observations.

…hopefully leading to measurable predictions (in the future)

10^{500} vs {.}



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400
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200
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Challenges/Experimental Data for String Models (checklist for model building)

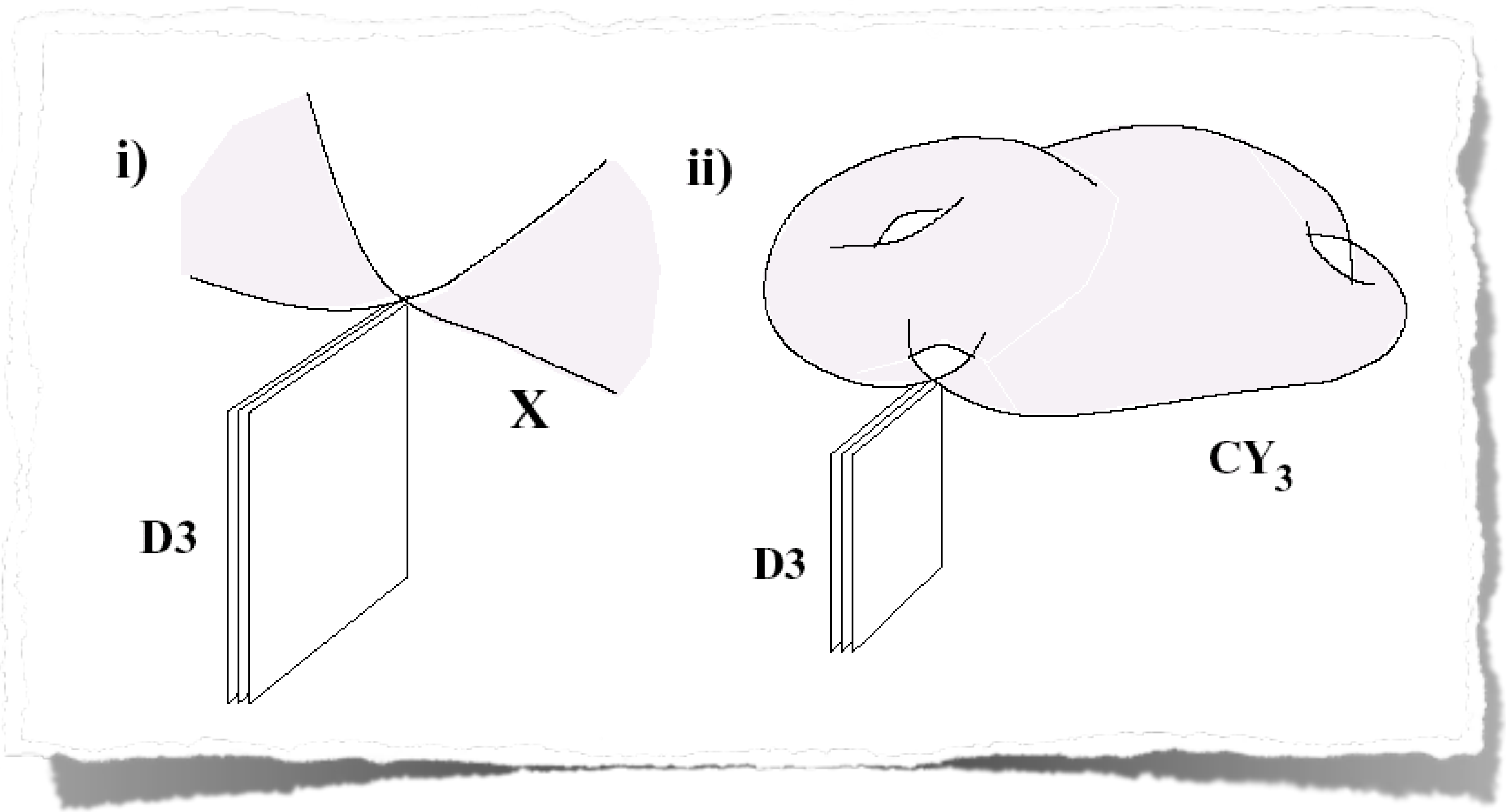
- Gauge and matter structure of SM
- Hierarchy of masses (including neutrinos)
- Flavour structure (CKM, PMNS, CP), absence of FCNC
- Hierarchy of gauge couplings (unification)
- Stable proton
- ....

If one of them does not work, this rules out the model!!!

... for this talk we focus on
type IIB string theory

(and only parts of a complete construction)

Global vs. local bulk properties



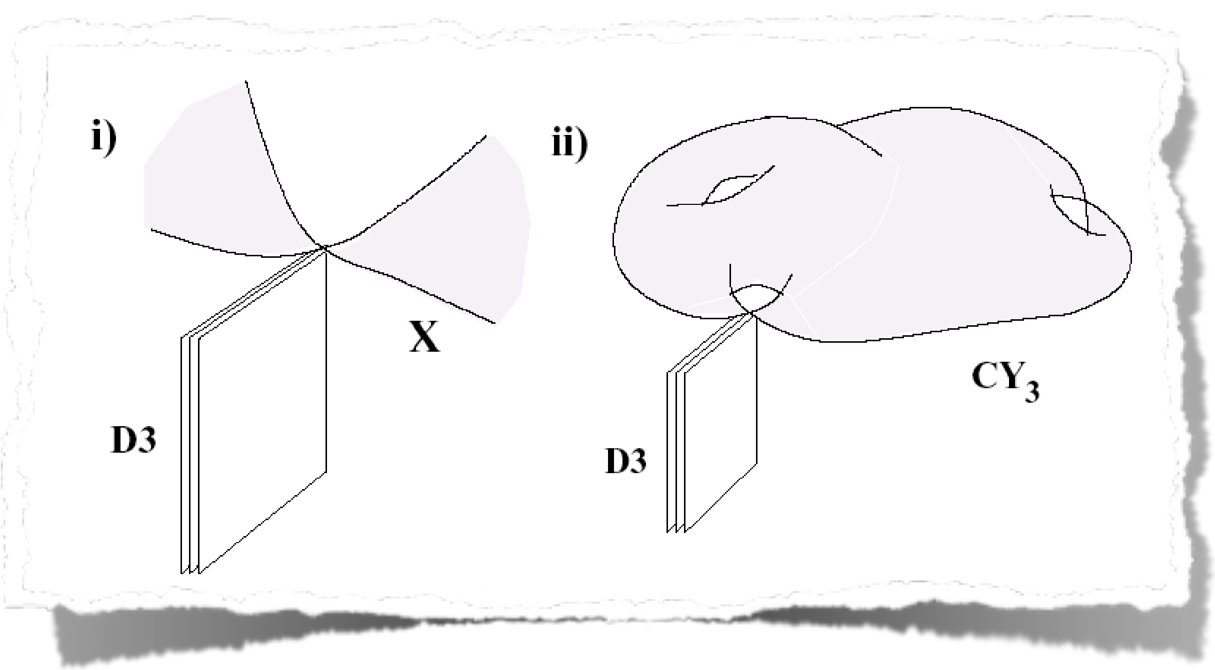
Aldazabal, Ibanez, Uranga, Quevedo

hep-th/0005067

Bottom up approach to string model building

Local Brane Properties

- Gauge group
- Chiral Spectrum
- Tree-level Yukawa couplings
- Gauge couplings
- Proton Stability
- Flavour symmetries



Global (bulk) properties

- Moduli Stabilisation
- SUSY Breaking
- Scales (unification)
- Cosmological Moduli Problem
- Inflation
- Bulk influence on Yukawa couplings

Aldazabal, Ibanez, Uranga, Quevedo

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Status/Approach in type IIB?

... the bottom-up approach to string model building

AIQU: hep-th/0005067

various mechanisms have
been constructed

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Moduli stabilisation

Kähler moduli: perturbative + non-perturbative corrections (e.g. KKLT, LVS 0502058)

Complex structure + dilaton: fluxes (e.g. GKP)

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Inflation

open string

closed string

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D-brane SM model

magnetised branes

D-branes at singularities

1002.1790, 1102.1973, 1106.6039

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Complex structure + dilaton: fluxes (e.g. GKP)

chirality (BPM 0711.3389), ~~SUSY~~

various mechanisms have been constructed

control of eft,
uv sensitivity

Inflation

open string
closed string

re-heating, dark radiation

D-brane SM model

magnetised branes
D-branes at singularities
1002.1790, 1102.1973, 1106.6039

Can these mechanisms
be combined leading to
a realistic string vacuum?

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$A(\phi)e^{-aT}$

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Focus on combining moduli stabilisation with D-brane model building

D-brane SM model

magnetised branes

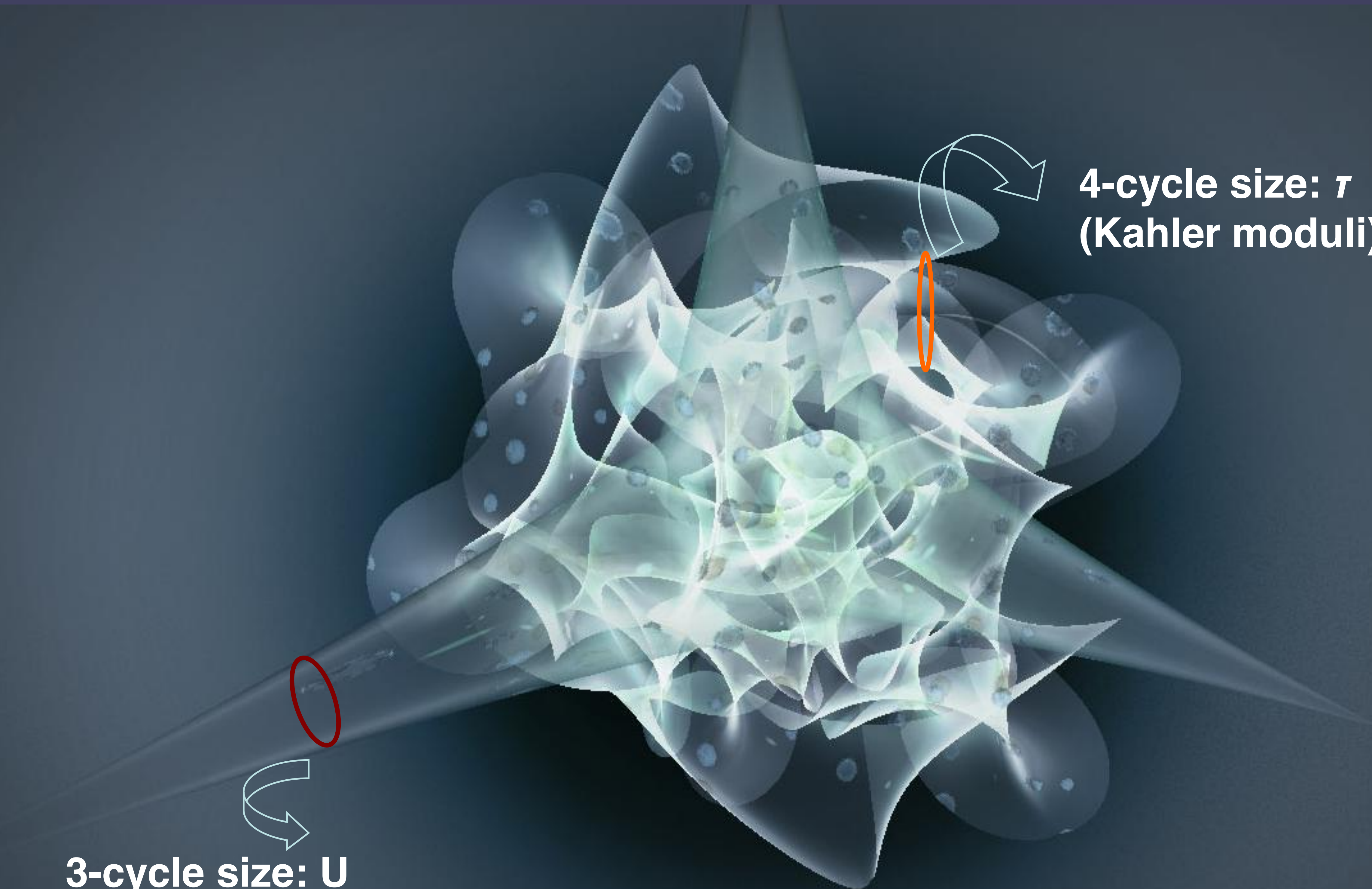
D-branes at singularities

Content

- Review of Moduli Stabilisation in IIB
- Review of D-brane model building
- Geometric requirements for combining both mechanisms
- Models with(out) flavour branes
- Models with explicit flux stabilisation (scan)
- Phenomenological implications (e.g. SUSY breaking)

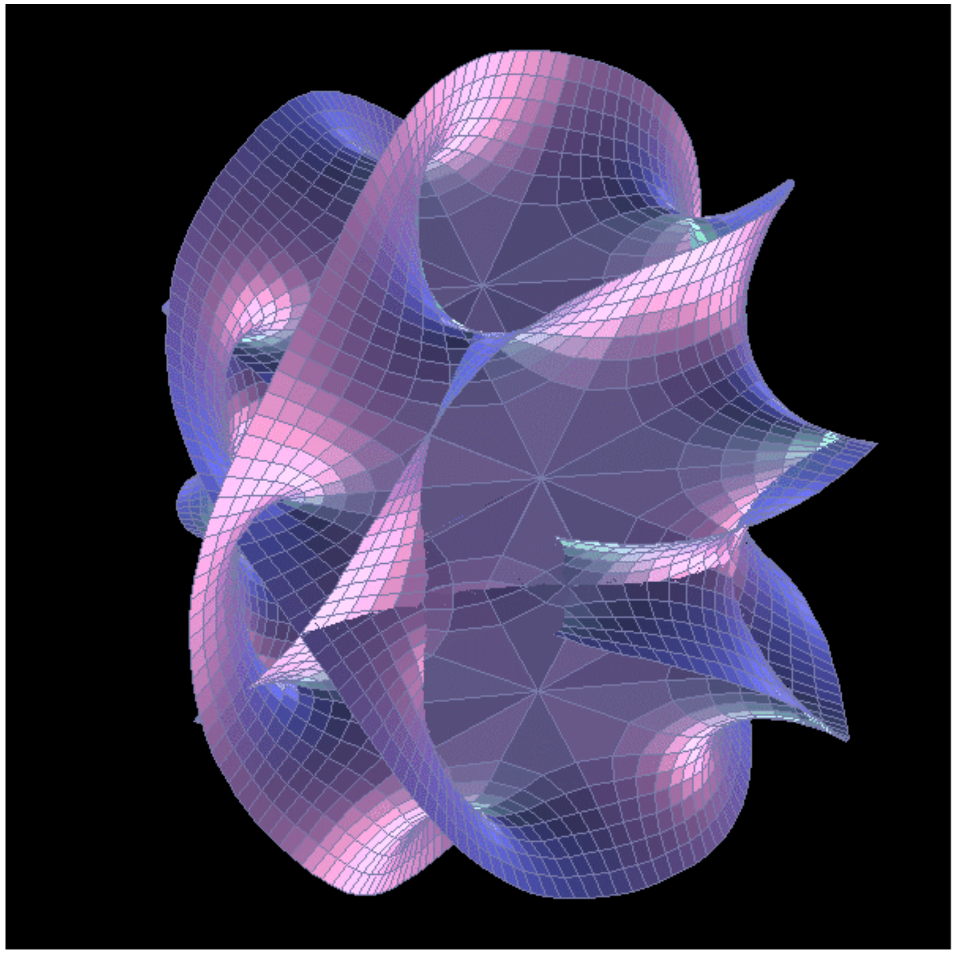
Moduli Stabilisation

MODULI STABILISATION



+ String Dilaton: S

Moduli Stabilisation in type IIB



- CY: Kähler moduli (T_i, τ_i), complex structure moduli (U), dilaton (S). 4D N=1 supergravity EFT description.

- GKP: turn on fluxes (→ stabilise cs, dilaton at susy minimum $D_iW=0$)

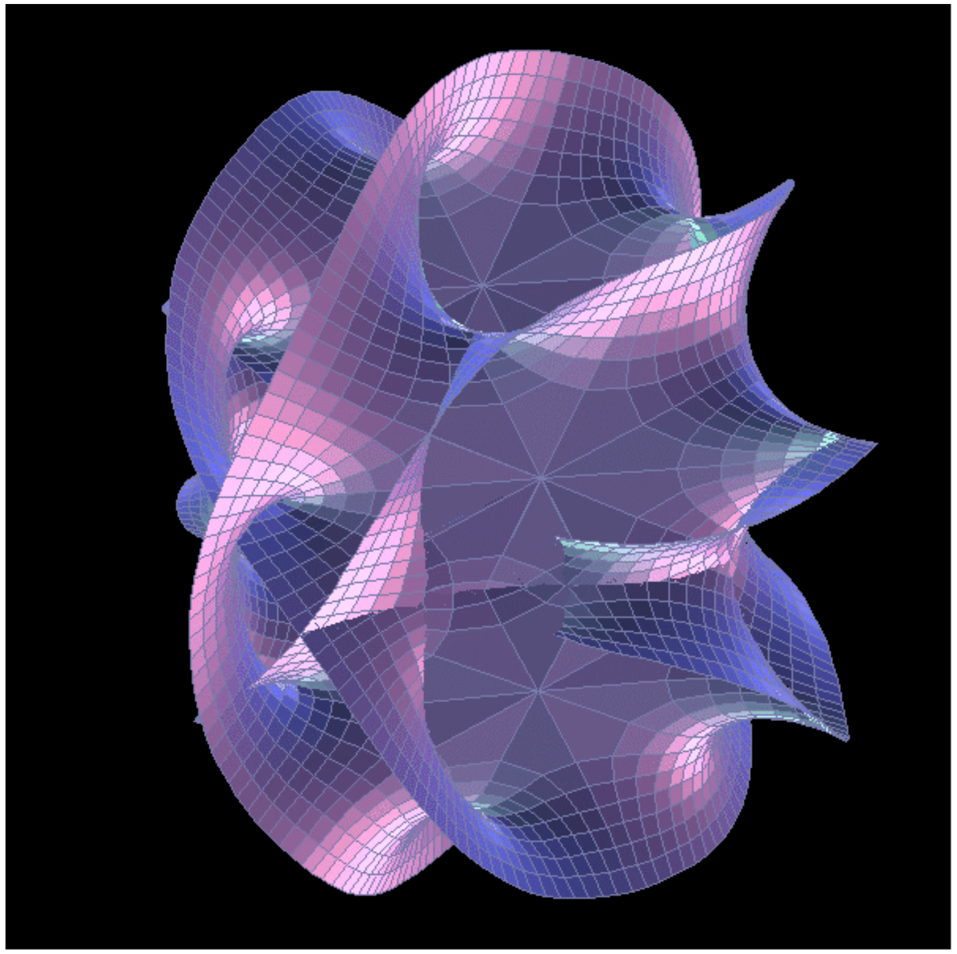
- KKLT: non-perturbative effects (E3 branes, gaugino condensation on D7) stabilise Kähler moduli at susy AdS minimum, but $W_0=10^{-15}$. [1-modulus, SUSY broken through uplifting]

- LVS: systematic inclusion of corrections to Kähler and superpotential (alpha', n.p. superpotential, gs)

$$K = -2\log\left(\mathcal{V}(T_i,\bar{T}_i)\right) - \log\left(S+\bar{S}\right) - \log\left(\int_M \Omega\wedge\bar{\Omega}\right) + K_{g_s} + K_{\alpha'} + K_{\text{n.p.}}$$

$$W = 0_{\text{tree}} + \underbrace{\int G_3\wedge\Omega}_{=:W_0} + A_i e^{-a_i T_i} + W_{\text{matter}}$$

Moduli Stabilisation in type IIB



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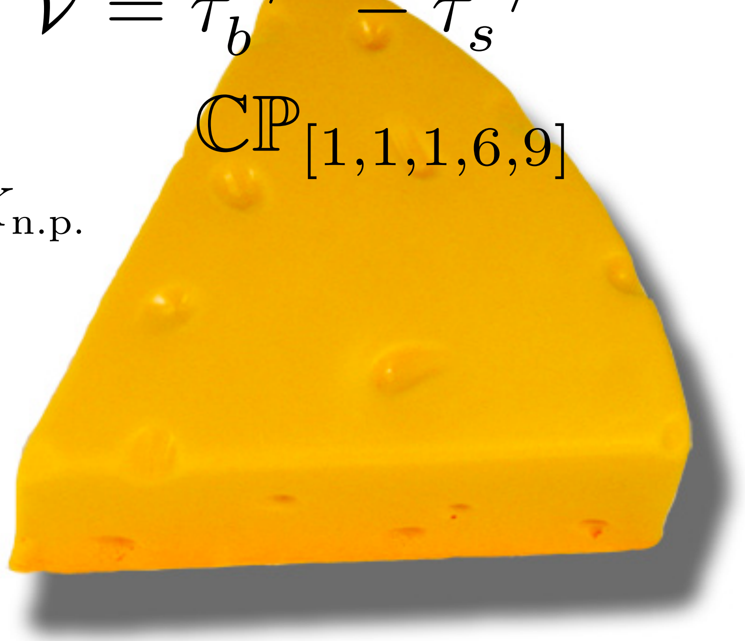
$$\mathcal{V} = \tau_b^{3/2} - \tau_s^{3/2}$$

$$\mathbb{CP}_{[1,1,1,6,9]}$$



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Balasubramanian, Berglund,
Cicoli, Conlon, Quevedo, Suruliz

LVS

- simplest example CP_{11169} (2-moduli): alpha', n.p. correction to superpotential. General: shrinkable blow-up divisor with n.p. effect

$$K = -2\log\left(\mathcal{V}+\xi\right)$$
$$W = W_0 + Ae^{-aT_s}$$

$$V = \lambda \frac{(aA)^2\sqrt{\tau_s}\, e^{-2a\tau_s}}{\mathcal{V}} - \mu \frac{a|AW_0|\,\tau_s\, e^{-a\tau_s}}{\mathcal{V}^2} + \nu \frac{\xi\,|W_0|^2}{g_s^{1/2}\,\mathcal{V}^3}$$

- minimum at exponentially large volume (AdS), volume becomes overall expansion parameter which sets scales

$$\mathcal{V} \sim e^{a\tau_s} \gg 1 \qquad M_{\text{string}} \sim \frac{M_P}{\sqrt{\mathcal{V}}}$$
$$\tau_s \sim \frac{\xi^{2/3}}{g_s} \qquad m_{3/2} \sim \frac{M_P}{\mathcal{V}}$$

- SM localised on local 4-cycle setup, not on large cycle (++ local models)

- SUSY broken at minimum (uplifting matters), depending on brane construction (flavour branes present or not) potentially sequestered soft-masses

$$m_{\text{soft}} \sim \frac{M_P}{\mathcal{V}^2} \qquad m_{\text{soft}} \sim \frac{M_P}{\mathcal{V}} = m_{3/2}$$

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Balasubramanian, Berglund,
Cicoli, Conlon, Quevedo, Suruliz

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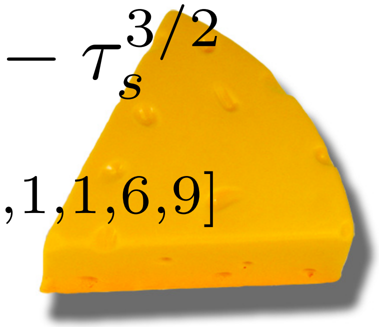

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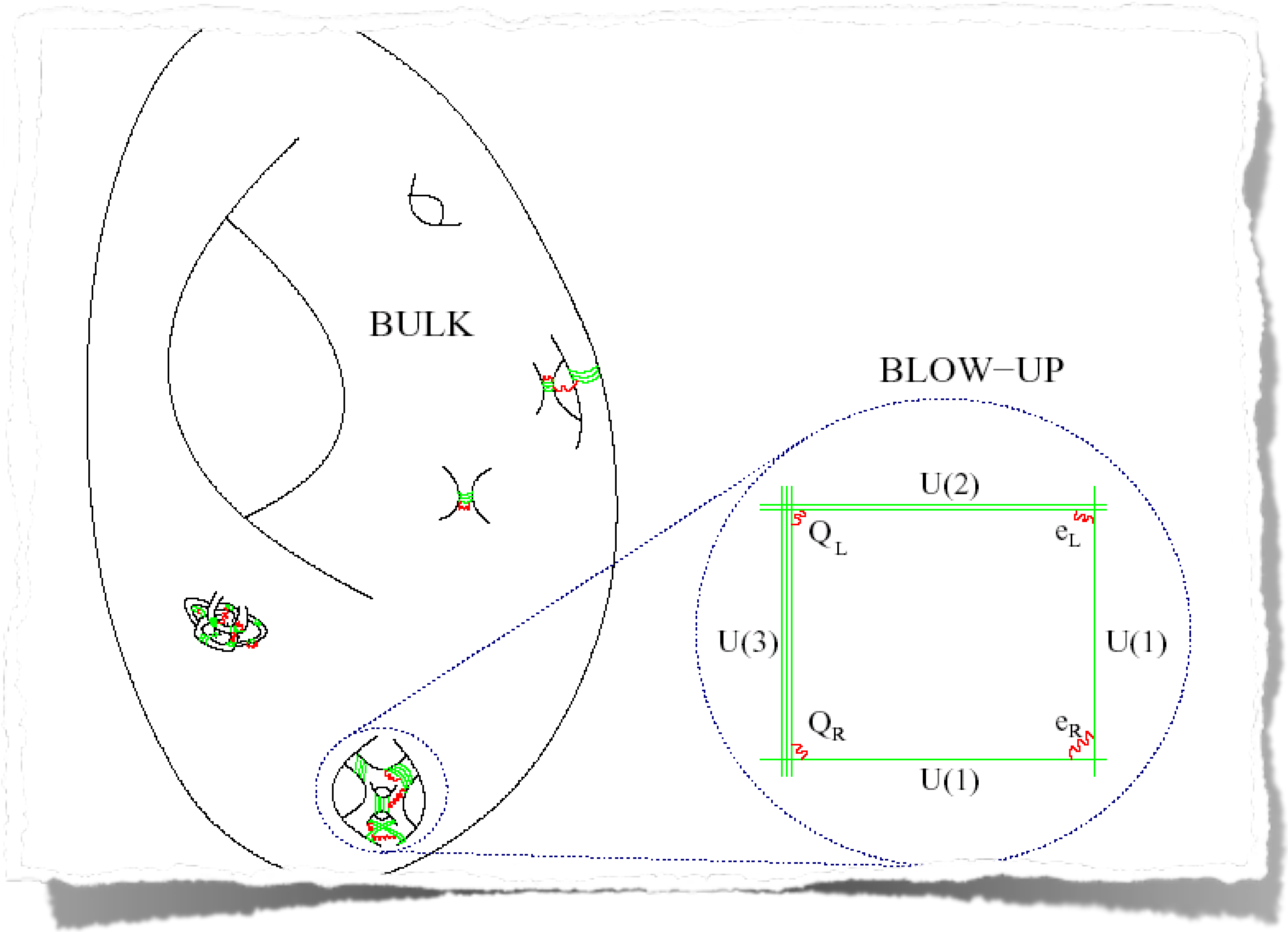
The Standard Model in the CY



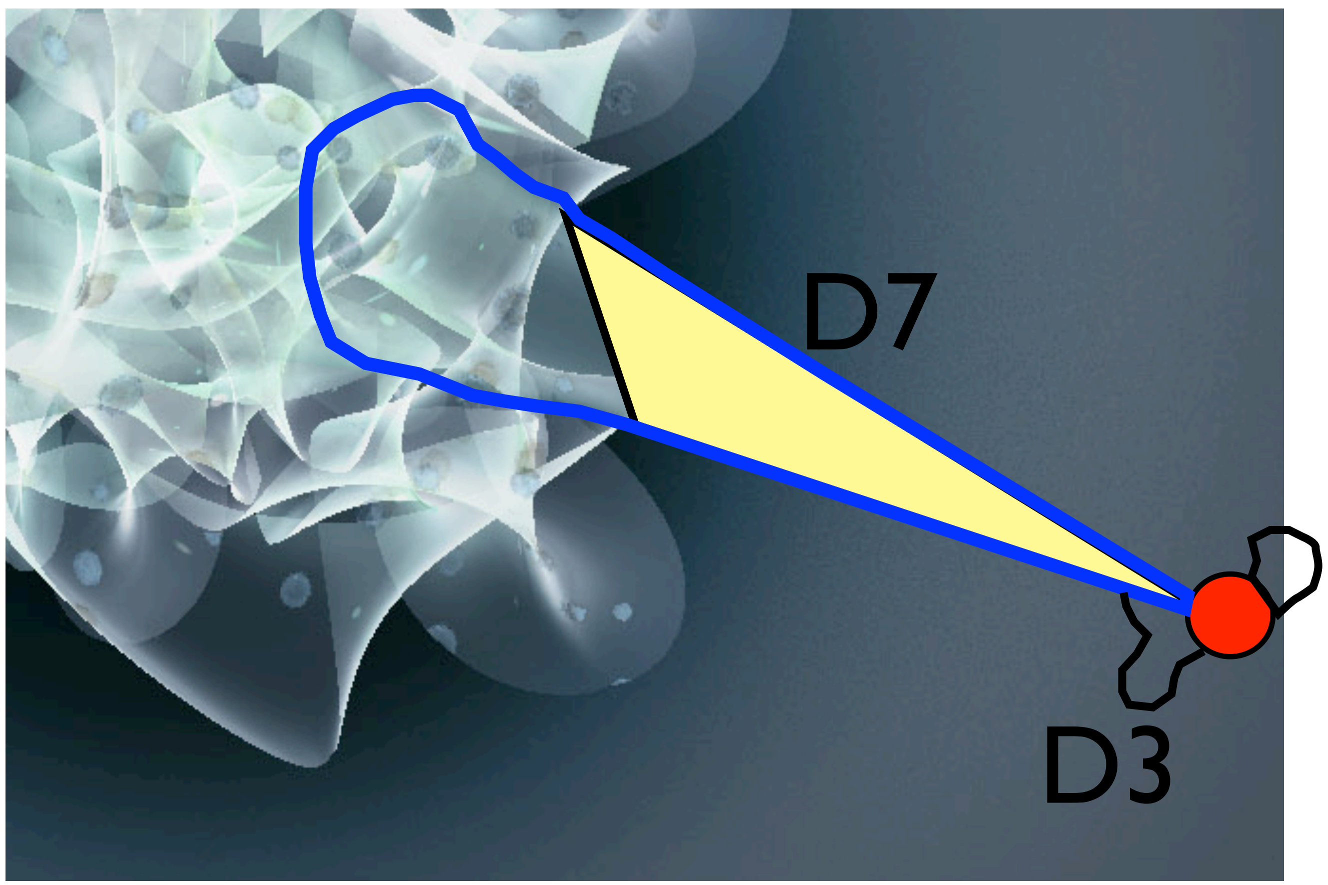
here Standard Model from D3 branes:

$$K_{\text{matter}} = K_{\alpha\bar{\beta}}(T_i, \bar{T}_i, U, \bar{U}, S, \bar{S})\, C_\alpha \bar{C}_{\bar{\beta}} = \frac{1}{\mathcal{V}^{2/3}}(c + f(T_s, T_b))\tilde{K}_{\alpha\bar{\beta}}(U, \bar{U}, S, \bar{S})\, C_\alpha \bar{C}_{\bar{\beta}}$$

CCQ: Invariance of physical Yukawas on Kähler moduli

Model Building with
D3 branes @ singularities

Branes@singularities



- Local 4-cycles can shrink (typical geometries are del-Pezzo surfaces).

- Gauge theory arises from D3 branes at singularities and D7 branes intersecting with singularities. SM gauge groups from D3 branes.

- Gauge theory studied in "decoupling" limit, some bulk effects are known (e.g. dP0 A. Maharana 1111.3047).

What types of singularities are there?

- Orbifold Singularities
- del Pezzo singularities (P^2 blown-up), Conifold

  → TORIC SINGULARITIES

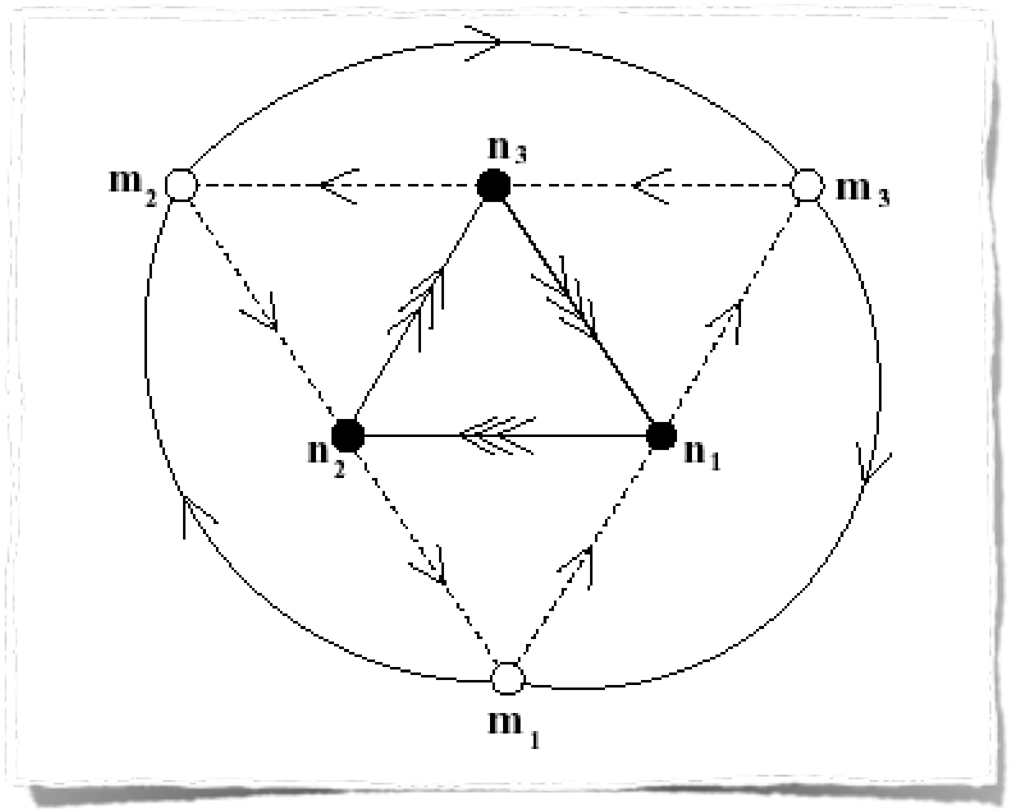
- non-toric singularities

What types of singularities are there?

- Orbifold Singularities — few suitable for model building
- del Pezzo singularities (P^2 blown-up), Conifold

  → **TORIC SINGULARITIES** — infinite class, techniques (i.e. we know the gauge superpotential)
- non-toric singularities — limited techniques

Classic Example:



- n_i D3-branes: $U(n_1) \times U(n_2) \times U(n_3)$
- m_i D7-branes: $U(m_1) \times U(m_2) \times U(m_3)$
- Arrows: bi-fundamental matter
- Anomaly cancellation

$$m_2 = 3(n_3 - n_1) + m_1$$
$$m_3 = 3(n_3 - n_2) + m_1$$

- Hypercharge:

$$Q_{\text{anomaly}-\text{free}} = \sum_i \frac{Q_i}{n_i}$$

D3 matter content:

$$3 \times [(n_1, \bar{n}_2, 1), (1, n_2, \bar{n}_3), (\bar{n}_1, 1, n_3)]$$

$$W = \epsilon_{ijk} X^i_{12} Y^j_{23} Z^k_{31}$$

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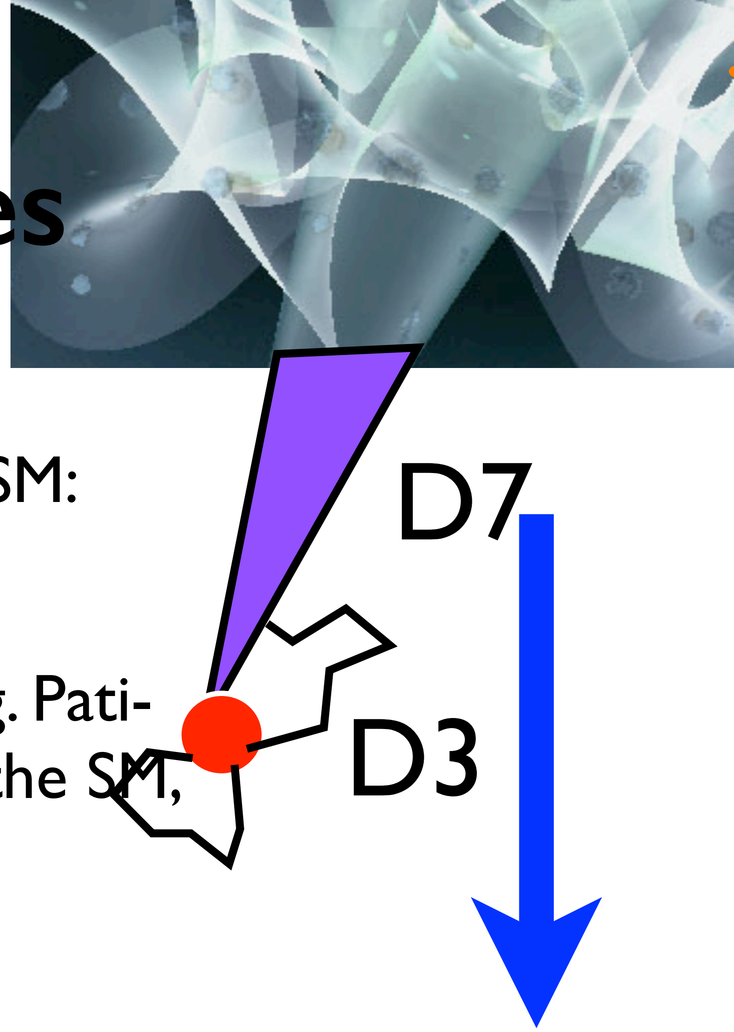
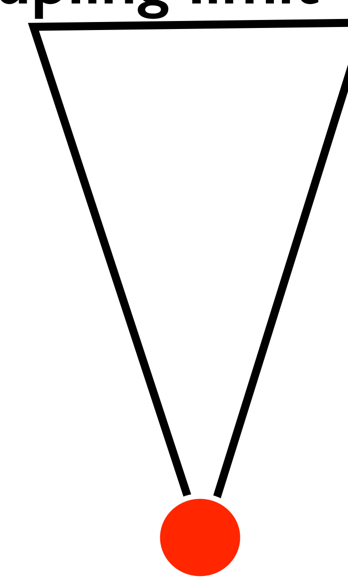
bulk

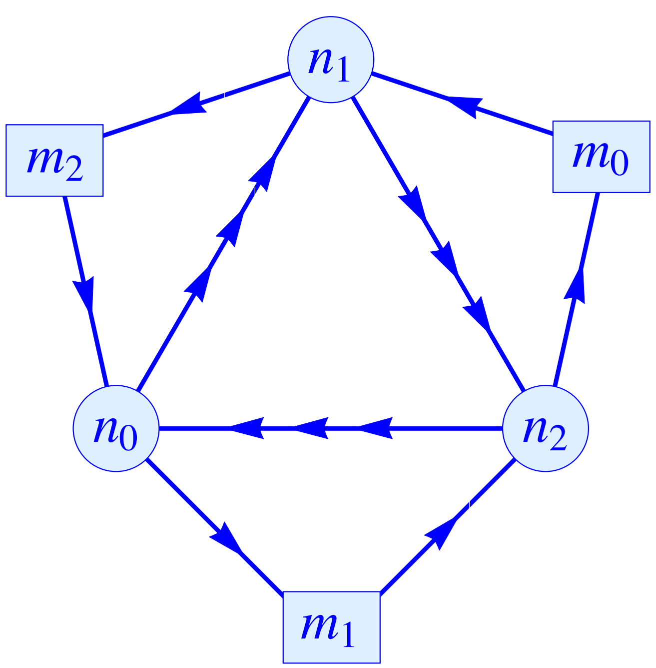
Local models with branes@singularities

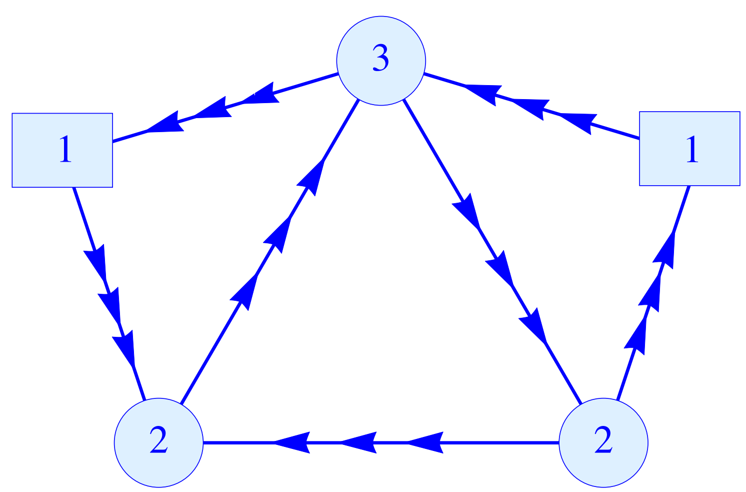


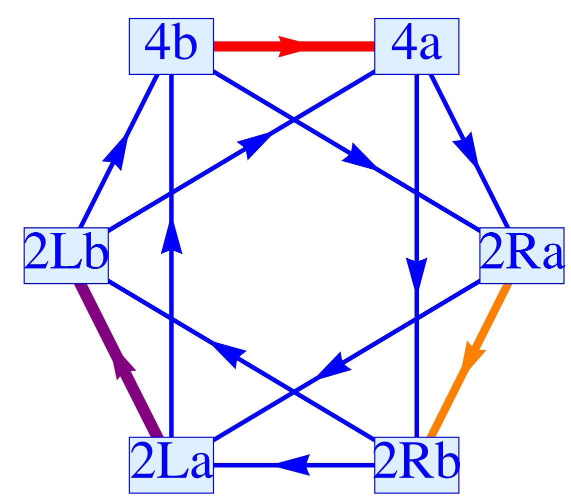
- developed phenomenology of dP_n singularities (models beyond MSSM: higgs sector, gauge extensions)
- phenomenology: choose your favourite gauge groups (non GUT, e.g. Pati-Salam) to embed SM matter content in dPn singularity; break it to the SM, study flavour structure of couplings, proton decay etc.
- hierarchies of masses, flavour structure, proton stability, mu-term, gauge coupling unification
- long-term goal: make these models completely realistic (dynamics of flavour & Higgs sector and explicitly embed them in a compact CY)

study local model in decoupling limit









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Combine model building and moduli stabilisation

Geometric Requirements for CY

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- Visible sector with D-branes at del Pezzo singularities
  (2 dPn's mapped on top of each other with O-involution)
- Mechanism for explicit Kähler moduli stabilisation: here LVS
  (1 additional divisor allowing for non-perturbative effect)
- No intersection between the two sectors
  (BPM, chirality + moduli stabilisation)
- Calabi-Yau manifolds with $h^{11} \geq 4$ ($h^{11-} \geq 1$), search in available list of CYs (Kreuzer-Skarke list)

1002.1790, 1102.1973, 1106.6039

models with D-branes @ singularities

alternative setups: magnetised branes

Search in Kreuzer-Skarke database

$h^{1,1} = 4 : 1197$ polytopes	Σ	dP_0	dP_1	dP_2	dP_3	dP_4	dP_5	dP_6	dP_7	dP_8
There are 2 dP_n + O-involution	82	9	5	-	-	-	2	10	31	25
The 2 dP_n do not intersect	68	9	2	-	-	-	2	10	27	18
Further rigid divisor	21	3	-	-	-	-	-	4	9	5

$h^{1,1} = 5 : 4990$ polytopes	Σ	dP_0	dP_1	dP_2	dP_3	dP_4	dP_5	dP_6	dP_7	dP_8
There are 2 dP_n & O-involution	386	27	60	21	7	3	13	40	121	94
The 2 dP_n do not intersect	327	27	55	7	3	1	11	39	112	72
Further rigid divisor	168	14	16	-	-	-	5	28	68	37

more Kähler moduli = more computing time

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let’s take one example,
add some D-branes,
check consistency conditions,
and stabilise Kähler moduli

dP0 example: $h^{1,1}$=4, $h^{1,2}$=112

- charge matrix, SR-ideal

z_1	z_2	z_3	z_4	z_5	z_6	z_7	z_8	D_{eqX}
1	1	1	0	3	3	0	0	9
0	0	0	1	0	1	0	0	2
0	0	0	0	1	1	0	1	3
0	0	0	0	1	0	1	0	2

$$\mathrm{SR} = \{z_4\, z_6,\ z_4\, z_7,\ z_5\, z_7,\ z_5\, z_8,\ z_6\, z_8,\ z_1\, z_2\, z_3\}$$

- basis of divisors

$$\Gamma_b = D_4 + D_5 = D_6 + D_7, \qquad \Gamma_{q_1} = D_4, \qquad \Gamma_{q_2} = D_7, \qquad \Gamma_s = D_8$$

- triple intersection form, volume

$$I_3 = 27\Gamma_b^3 + 9\Gamma_{q_1}^3 + 9\Gamma_{q_2}^3 + 9\Gamma_s^3 \qquad \mathcal{V} = \frac{1}{9}\sqrt{\frac{2}{3}}\left[\tau_b^{3/2} - \sqrt{3}\left(\tau_{q_1}^{3/2} + \tau_{q_2}^{3/2} + \tau_s^{3/2}\right)\right]$$

- 3 dP0's at z_4=0, z_7=0, z_8=0

Orientifold projection

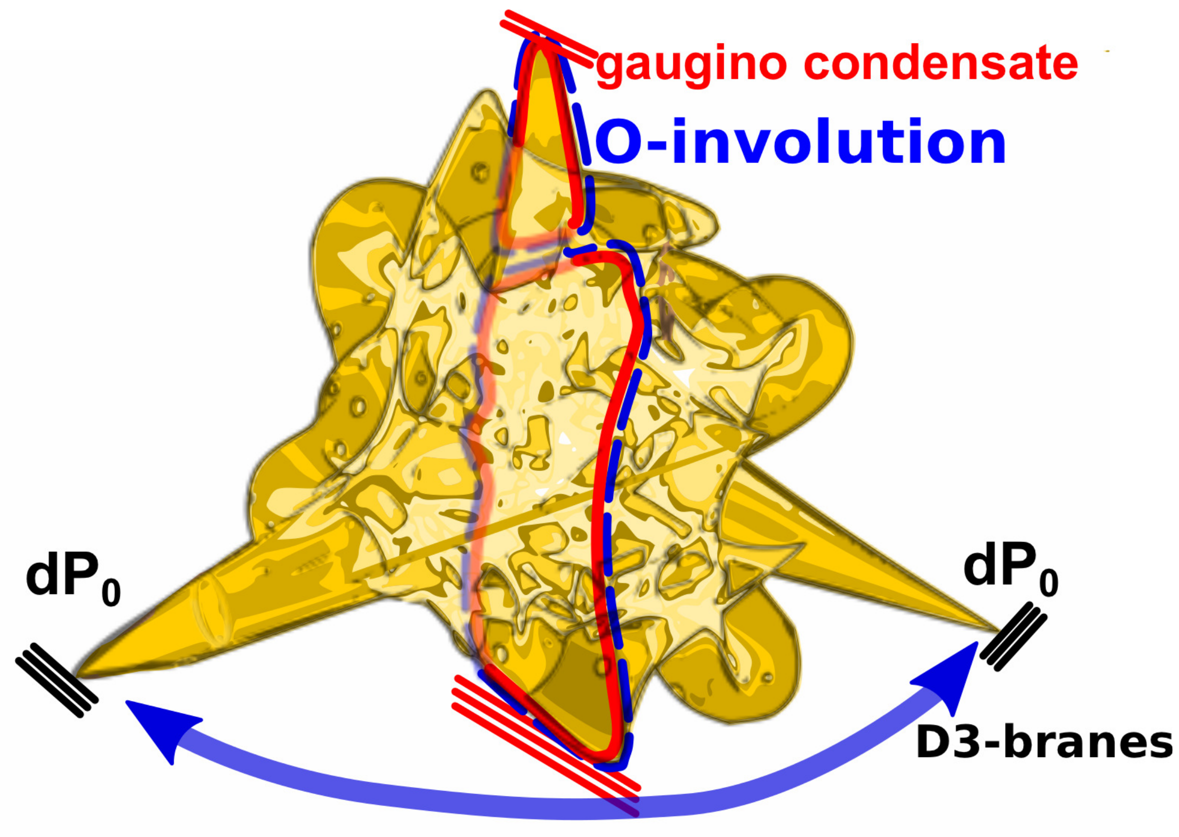
- We take an O-involution exchanging two (shrinking) dP0s:

  $z_4 \leftrightarrow z_7$ and $z_5 \leftrightarrow z_6$ $\quad$ ($h^{1,1-}=1$ and $h^{1,1+}=3$)

- This exchanges the two dP0s: $D_{q1}=D_4$ and $D_{q2}=D_7$

- There are no O3-planes and 2 O7-planes:
  $O7_1$: $z_4z_5 - z_6z_7 = 0 \rightarrow [O7_1]=D_b$. $\quad$ $O7_2$: $z_8 = 0 \rightarrow [O7_2]=D_s$.

- O7-planes do not intersect the shrinking dP0s and each other



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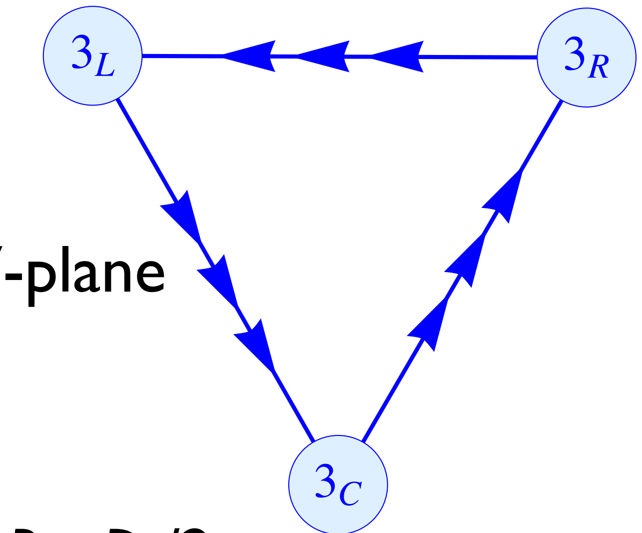
Model without flavour branes



- dP0 trinification model (N=3 D3-branes)
- to cancel D7 tadpole: 4 D7s (+images) on top of each O7-plane
- hidden sector: SO(8)xSO(8)
- FW flux (non-spin cycles): F_s=-D_s/2 cancelled by choosing B=-D_s/2
  ➛ $\mathcal{F}$s=Fs-B=0 → pure SO(8) SYM on Ds (gaugino condensate)
- FW flux: F_b=-D_b/2 also cancelled by choosing B=-D_b/2 -D_s/2
  ➛ adjoint scalars; can be lifted by flux but SO(8)→SU(4)xU(1)
  (special! no intersection of Γ_s & $\Gamma_{b,}$ so cancellation on both possible)
- Non-perturbative superpotential

$$W = W_0 + A_s e^{-a_s T_s} (+A_b e^{-a_b T_b}) \qquad a_s = \frac{\pi}{3} \qquad a_b = \frac{\pi}{2}$$

- D5 tadpole cancelled as $\mathcal{F}$ = -$\mathcal{F}$'.
- Q_{D3} = -60 + 2N_{D3} = -54 (Whitney brane: Q_{D3}=-432, no g.c. on Γ_b)
  freedom to turn on three-form fluxes H_3 & F_3.

Moduli Stabilisation

- complex structure assumed to be stabilised with 3-form fluxes (D3 tadpole allows to turn on fluxes.)
- EFT: $$K = -2\ln\left(\mathcal{V} + \frac{\zeta}{g_s^{3/2}}\right) + \frac{(T_+ + \bar{T}_+ + q_1 V_1)^2}{\mathcal{V}} + \frac{(G + \bar{G} + q_2 V_2)^2}{\mathcal{V}} + \frac{C^i \bar{C}^i}{\mathcal{V}^{2/3}}\,,$$

$$W = W_{\rm local} + W_{\rm bulk} = W_0 + y_{ijk}\, C^i C^j C^k + A_s\, e^{-\frac{\pi}{3}\, T_s} + A_b\, e^{-\frac{\pi}{2}\, T_b}$$

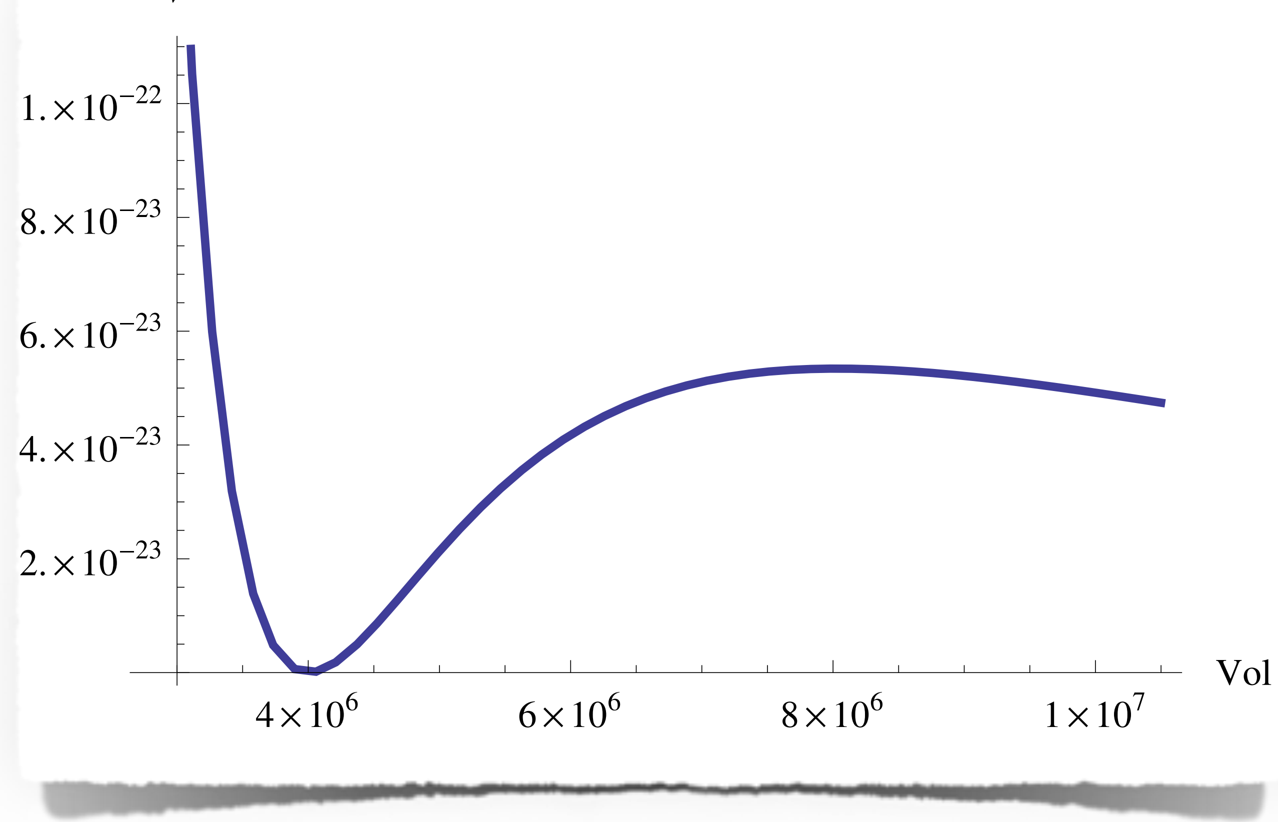
$$\mathcal{V} = \frac{1}{9}\sqrt{\frac{2}{3}}\left(\tau_b^{3/2} - \sqrt{3}\tau_s^{3/2}\right)$$

- singularity stabilisation: D-term minimum at ξ_i=0 and C_i=0 (soft-masses), F-terms sub-leading

$$V_D = \frac{1}{\mathrm{Re}(f_1)}\left(\sum_i q_{1i} K_i C_i - \xi_1\right)^2 + \frac{1}{\mathrm{Re}(f_2)}\left(\sum_i q_{2i} K_i C_i - \xi_2\right)^2,$$

$$\xi_1 = -4 q_1 \frac{\tau_+}{\mathcal{V}} \qquad \xi_2 = -4 q_2 \frac{b}{\mathcal{V}}$$

Moduli Stabilisation



- F-term potential

$$V_F \simeq \frac{8}{3}(a_s A_s)^2 \sqrt{\tau_s}\, \frac{e^{-2\,a_s\tau_s}}{\mathcal{V}} - 4\,a_s A_s W_0 \tau_s \frac{e^{-a_s\tau_s}}{\mathcal{V}^2} + \frac{3}{4}\frac{\zeta W_0^2}{g_s^{3/2}\mathcal{V}^3}$$

$$\langle\mathcal{V}\rangle \simeq \frac{3W_0\sqrt{\tau_s}}{4a_s A_s}\, e^{a_s\langle\tau_s\rangle} \qquad \langle\tau_s\rangle \simeq \left(\frac{3\zeta}{2}\right)^{2/3}\frac{1}{g_s}$$

$$\zeta \simeq 0.522$$
$$W_0 \simeq 0.2$$
$$g_s \simeq 0.03$$
$$A_s \simeq 1$$

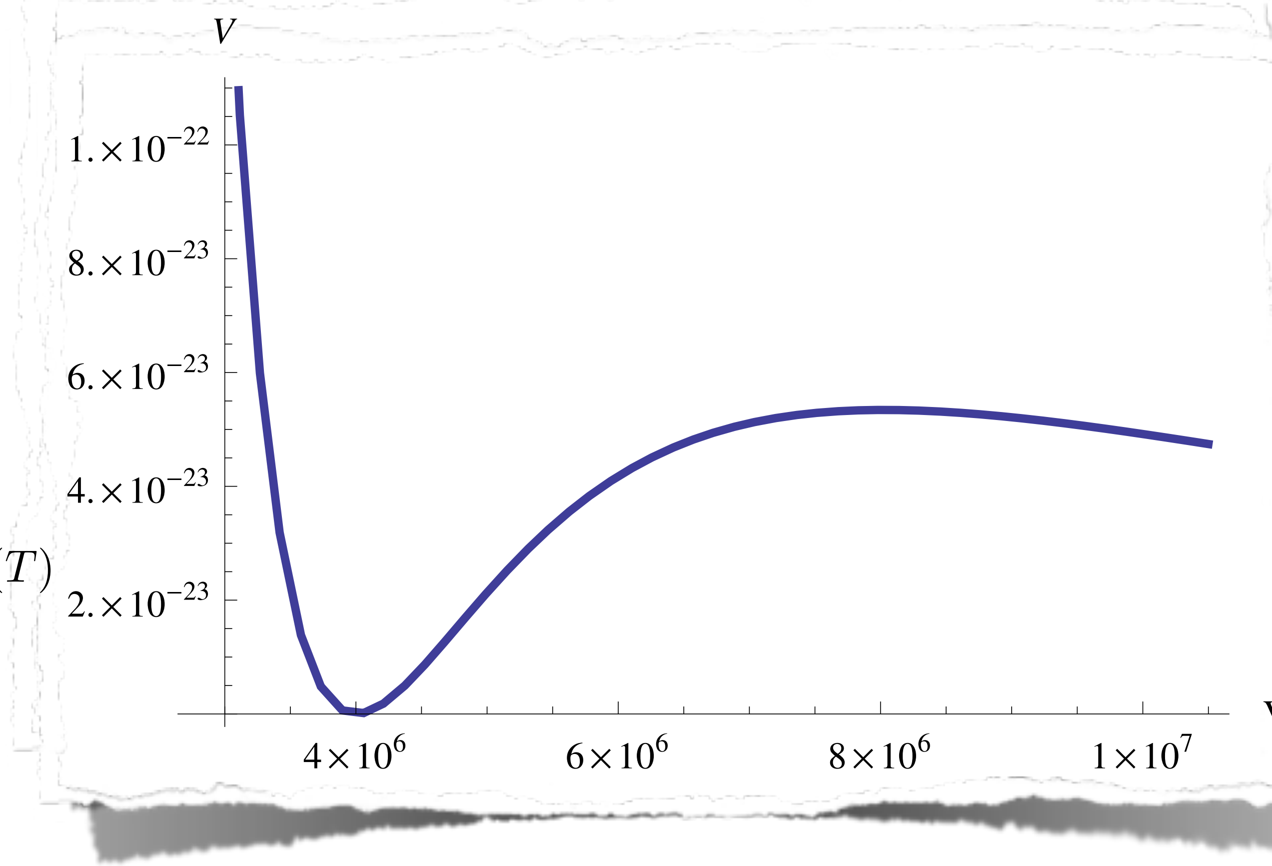
- FW flux on large four-cycle (matter fields), D-term potential

$$V_{\rm tot} = V_D + V_F \simeq \frac{p_1}{\mathcal{V}^{2/3}}\left(\sum_j q_{bj}|\phi_{c,j}|^2 - \frac{p_2}{\mathcal{V}^{2/3}}\right)^2 + \sum_j \frac{W_0^2}{2\mathcal{V}^2}\,|\phi_{c,j}|^2 + V_F(T)$$

- can account for dS/Minkowski minima...

dS minima

$$V_{\rm tot} = V_D + V_F \simeq \frac{p_1}{\mathcal{V}^{2/3}}\left(\sum_j q_{bj}|\phi_{c,j}|^2 - \frac{p_2}{\mathcal{V}^{2/3}}\right)^2 + \sum_j \frac{W_0^2}{2\mathcal{V}^2}|\phi_{c,j}|^2 + V_F(T)$$



- Specialise to one matter field
- Minimise with respect to matter fields

$$\langle|\phi_c|^2\rangle \simeq \frac{p_2}{q_b\mathcal{V}^{2/3}}$$

$$\zeta \simeq 0.522$$

$$W_0 \simeq 0.2$$
$$g_s \simeq 0.03$$
$$A_s \simeq 1$$
$$q_b = 2$$

- Plugging back this condition into potential leads to uplifting term

$$V \simeq \frac{p\,W_0^2}{\mathcal{V}^{8/3}} + V_F(T)$$

- After minimisation leads to following vacuum energy

$$\langle V\rangle = \frac{W_0^2}{\langle\mathcal{V}\rangle^3}\left\{-\frac{3}{4\,a_s^{3/2}}\sqrt{\ln\left(\frac{\langle\mathcal{V}\rangle}{W_0}\right)} + \frac{p}{9}\langle\mathcal{V}\rangle^{1/3}\right\}$$

$$p = \frac{p_2}{2q_b}$$
$$p_1 = \pi\alpha^{2/3}$$
$$p_2 = 3q_{bb}\alpha^{2/3}/4\pi$$
$$\mathcal{V} = \alpha\tau_b^{3/2}$$

Gravity/moduli mediated SUSY breaking

0906.3297
1409.1931

- no flavour branes ➔ no redefinitions of moduli
- $F^{TSM}=0$ ➔ sequestered soft-masses
- gravitino mass:

$$m_{3/2} = e^{K/2}|W| \sim \frac{M_P|W_0|}{\mathcal{V}}$$

- remaining soft-masses receive contributions from F^{tb}, F^s, gauge kinetic function f=Re(S), after many no-scale cancellations

M_{gaugino}	$\frac{m_{3/2}}{\mathcal{V}}$
m_{scalar}	$\frac{m_{3/2}}{\sqrt{\mathcal{V}}}$ or $\frac{m_{3/2}}{\mathcal{V}}$
M_{string}	$\frac{M_P}{\sqrt{\mathcal{V}}}$
$\mathcal{V}$	10^{6-7}

- Assumption: no D-term contribution [soft scalar masses after gauge breaking will need further study]
- Note: lightest modulus (m_{Tb}~$M_p/V^{3/2}$) heavier than TeV soft-masses [➔cosmological moduli problem]
- Pheno: particular slice of CMSSM, resp. Mini Split-SUSY

... being explicit about fluxes

Flux stabilisation 1312.0014

- Immediate use: calculate g_s, W_0 explicitly
- Long term use: flux landscape, distribution of vacua (CC)
- typical problem: many cs-moduli, O(100), computationally unfeasible to determine prepotential and then to find minima is computationally also non-trivial
- However, CY can have discrete symmetries in cs-moduli space reducing the effective number of cs-moduli
- Look for CYs with such discrete symmetries that reduce the CS moduli space. Further simplification focus on CYs where the mirror is given by the Greene-Plesser construction
- GP orbifold group reduces the number of CS moduli to number of Kähler moduli. Invariant periods are identical on mirror and original manifold.

$\mathbb{P}_{1,1,1,6,9}$

Giryavets, Kachru, Tripathy, Trivedi; Denef, Douglas, Florea
Martinez-Pedrera, Louis, Mehta, Rummel, Westphal, Valandro

Example: h^{11}=4, h^{21}=70, 2xdP6

- Prepotential:

$$F = -\frac{3}{2}(u^1)^2u^4 - 3u^1u^2u^4 - 3u^1u^3u^4 - 3u^2u^3u^4 - \frac{9}{2}u^1(u^4)^2 - 3u^2(u^4)^2 - 3u^3(u^4)^2$$
$$\frac{5}{2}(u^4)^3 + 3u^1u^4 + \frac{3}{2}u^2u^4 + \frac{3}{2}u^3u^4 + \frac{15}{4}(u^4)^2 + \frac{3}{2}u^1 + u^2 + u^3 + \frac{33}{12}u^4 - i\zeta(3)\frac{33}{4\pi^3}$$
$$+\sum_\beta n^0_\beta \,\mathrm{Li}_3(q^\beta) \qquad q^\beta = e^{2\pi i d_i t^i} \qquad n^0_\beta \text{ genus 0 Gopakumar-Vafa invariants}$$

- Period vector:

$$\Pi = \begin{pmatrix} 1 \\ u^i \\ 2F - u^i\partial_i F \\ \partial_i F \end{pmatrix} \qquad W = \int G_3 \wedge \Omega = (F - \tau H).\Pi$$
$$K = -\log\left(-i\Pi^\dagger.\Sigma.\Pi\right) - \log\left(-i(\tau - \bar{\tau})\right)$$

- All moduli not appearing, minima at zero. Other cs+dilaton stabilised by turning on fluxes

Flux stabilisation

- Use fluxes of the following type (ISD-condition)

$$\begin{pmatrix} \tilde{M}_K \\ \tilde{N}^K \end{pmatrix} = \begin{pmatrix} N^K \\ -M_K \end{pmatrix} \qquad Q_{D3} = \sum_K (\tilde{M}_K^2 + \tilde{N}_K^2) \qquad \begin{matrix} F_3 : \ (M, N) \\ H_3 : \ (\tilde{M}, \tilde{N}) \end{matrix}$$

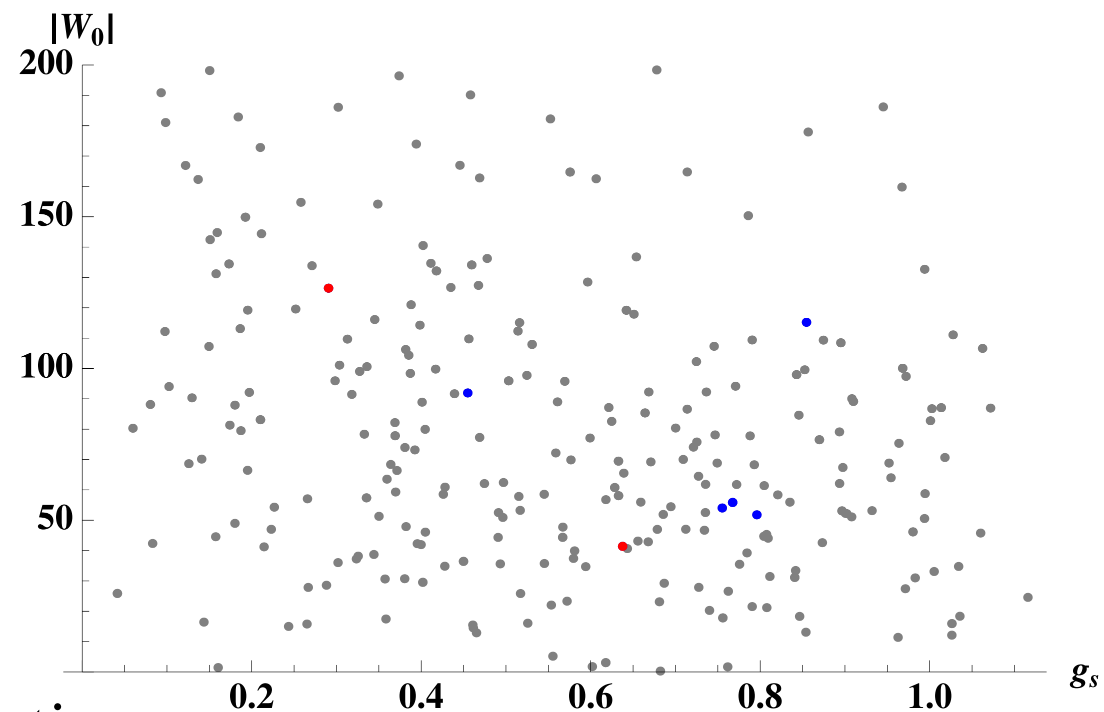
- For SL(2,Z) invariant flux choices, look for minima of $D_i W=0$, not including instanton corrections and then check that instanton contributions to prepotential are small:

$$\frac{|F_{\text{inst}}|}{|F|} < \epsilon \, , \ \ \frac{\max_i |F^i_{\text{inst}}|}{|F|} < \epsilon$$

- Numerically, we use Paramotopy and Bertini (finds isolated minima, might miss some minima)

Results

- Search for 1000 random flux choices with Q_{D3}=10,...,20; utilising additional symmetry between u_2 and u_3 in prepotential

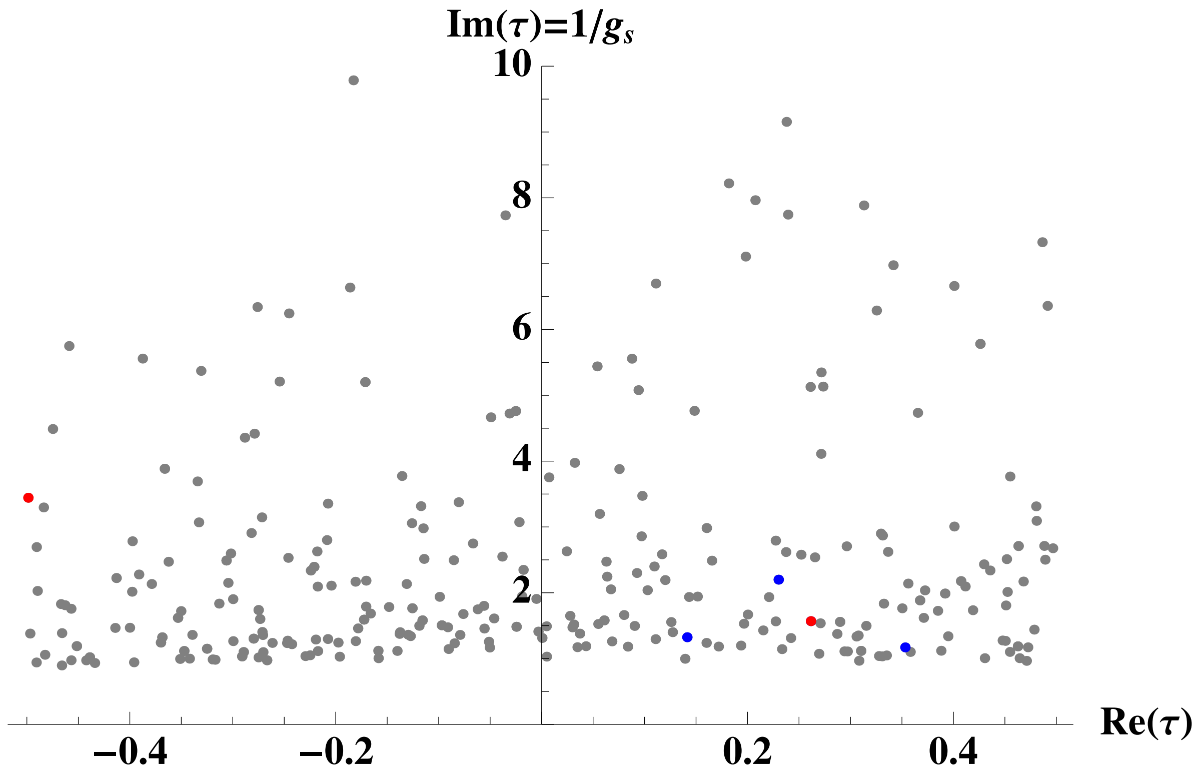


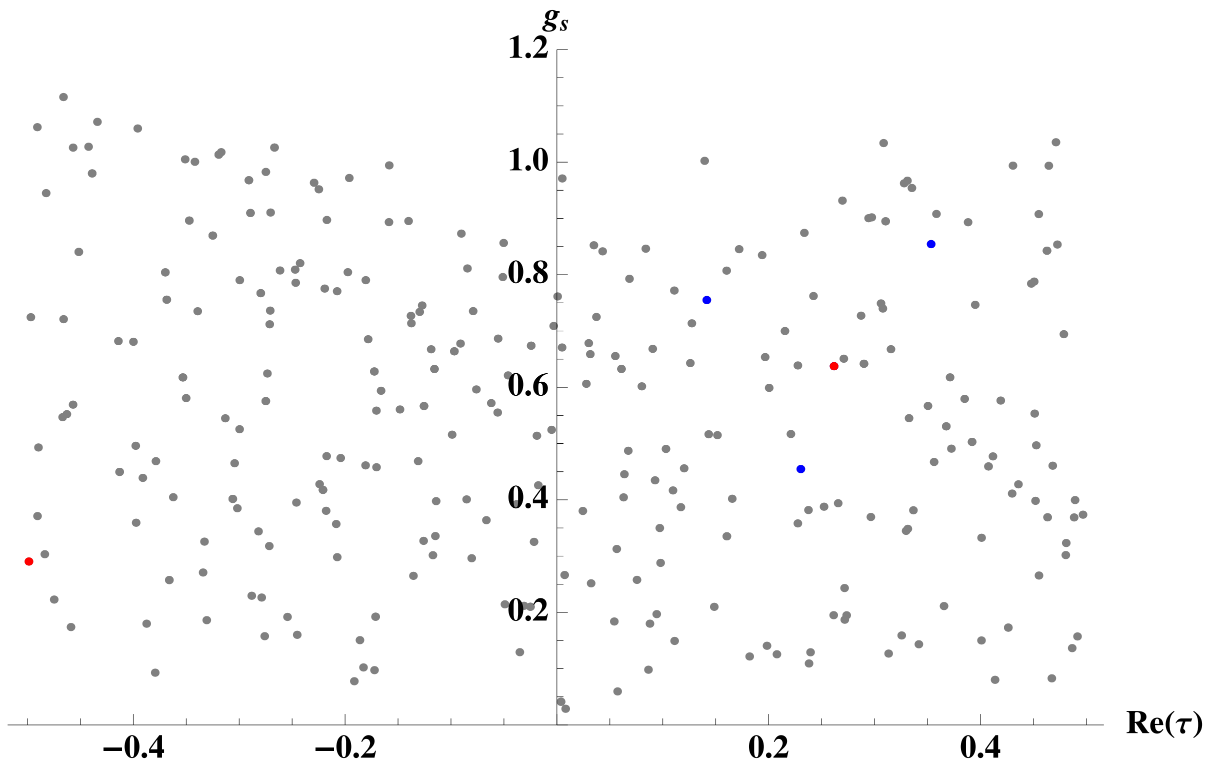
- Example solutions:

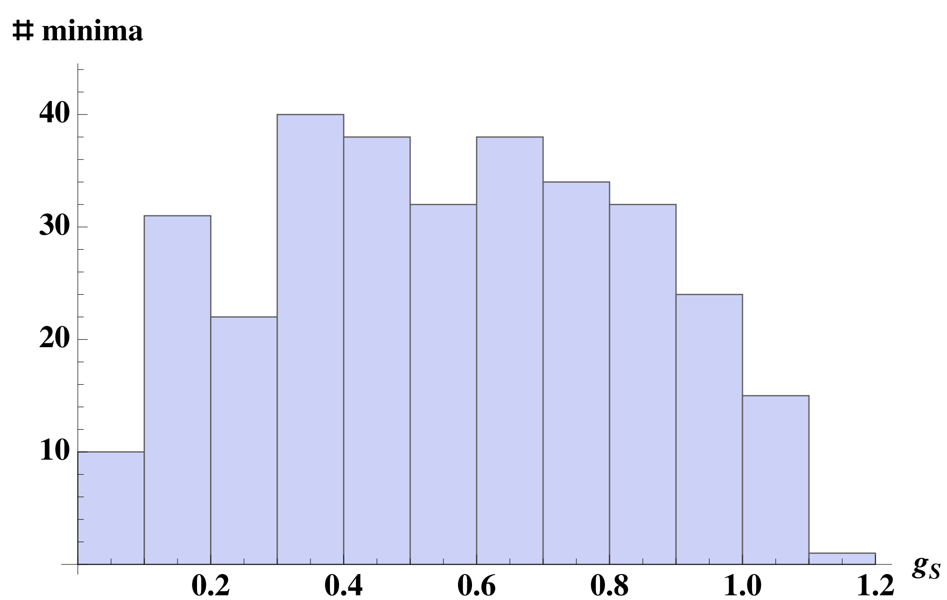
Q_{D3}	$(\tilde{N}_i, \tilde{M}_i)$	u_1	$u_{2,3}$	u_4	τ	g_s	$\lvert W_0\rvert$
19	(1,-3,0,0,0,0,2,-1)	$4.39 - 1.22i$	$19.3 + 0.971i$	$-21.6 + 1.18i$	$2.21 + 2.58i$	0.39	954.4
14	(1,1,1,1,3,0,0,0)	$-5.99 + 2.69i$	$4.09 + 1.59i$	$-0.115 - 0.0581i$	$-2.76 + 1.24i$	0.8	82.66
14	(1,0,0,1,1,-3,1,0)	$4.72 + 2.7i$	$-3.92 + 1.94i$	$0.176 - 0.0468i$	$4.14 + 1.32i$	0.75	54.03
15	(2,0,2,1,0,0,-1,0)	$28. + 3.3i$	$-11.4 + 2.62i$	$0.331 - 0.0291i$	$6.72 + 1.3i$	0.77	55.85
15	(1,2,1,1,1,2,-1,0)	$1.49 + 0.861i$	$-1.22 + 1.77i$	$-0.201 - 0.0276i$	$-2.41 + 2.22i$	0.45	36.44
18	(1,2,0,2,2,2,0,-1)	$1.13 + 0.473i$	$-0.327 + 2.02i$	$-0.583 + 0.103i$	$-1.5 + 3.44i$	0.29	126.5

- Consistency conditions satisfied as before. Kähler moduli stabilisation can proceed as before. Explicit example of dS moduli stabilisation with all closed string moduli stabilised. Chiral matter on dP6.

Distribution in fundamental domain







Note: gray points have no small instanton contributions

Conclusions

- successful mechanisms for dS moduli stabilisation (LVS) and D-brane model building with D-branes at singularities (extensions of MSSM) in type IIB string theory
- bottom-up mechanisms can be combined in global consistent string compactification (explicit examples), tension between chirality and moduli stabilisation can be avoided
- explicit flux stabilisation of cs moduli + dilaton
- first model explicitly realising closed string m.s. and chiral (realistic) D-brane configuration
- realistic scales (M_{GUT}, M_{SOFT}, no CMP)

Thank you!