4D String Models, LARGE Volume Scenario and Cosmology

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PASCOS 2013,
Taipei November 2013.

Collaborations with:
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String Phenomenology:

Strategic (long term) Plan:

String theory scenario that satisfies all particle physics and cosmological observations and hopefully lead to measurable predictions

Challenges for String Models

- Gauge and matter structure of SM
- Hierarchy of scales + masses (including neutrinos)
- Flavor CKM, PMNS mixing, CP no FCNC
- Hierarchy of gauge couplings (unification?)
- 'Stable' proton + baryogenesis
- Inflation or alternative for CMB fluctuations
- Dark matter (+ avoid overclosing)
- Dark radiation ($N_{eff} \geq 3.04$)
- Dark energy

N.B. If ONE of them does not work, rule out the model!!!

Progress in several ways

- ‘Generic’ model independent results
- Explicit constructions of (classes) of models
- Extract scenarios that can lead to eventually ‘testable’ predictions.

‘Generic’ String Predictions

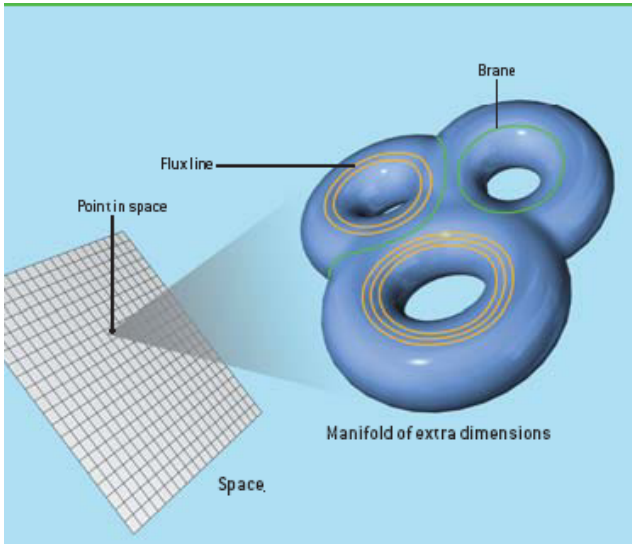
- Gravity + dilaton+antisymetric tensors+ gauge fields + matter
- SUSY (32,16, … supercharges, but breaking scale not fixed)
- Extra dimensions (6 or 7)
  (flat, small, large, warped?)
- No continuous spin representations in perturbative string theory (!)

A. Font, S. Theisen, FQ
1302.4771

Generic 4D String Predictions

- Moduli (s=0 'massless' fields)

- Antisymmetric tensors
  Branes (brane-world)
  Axions (not necessarily QCD axion)
  Quantised fluxes!

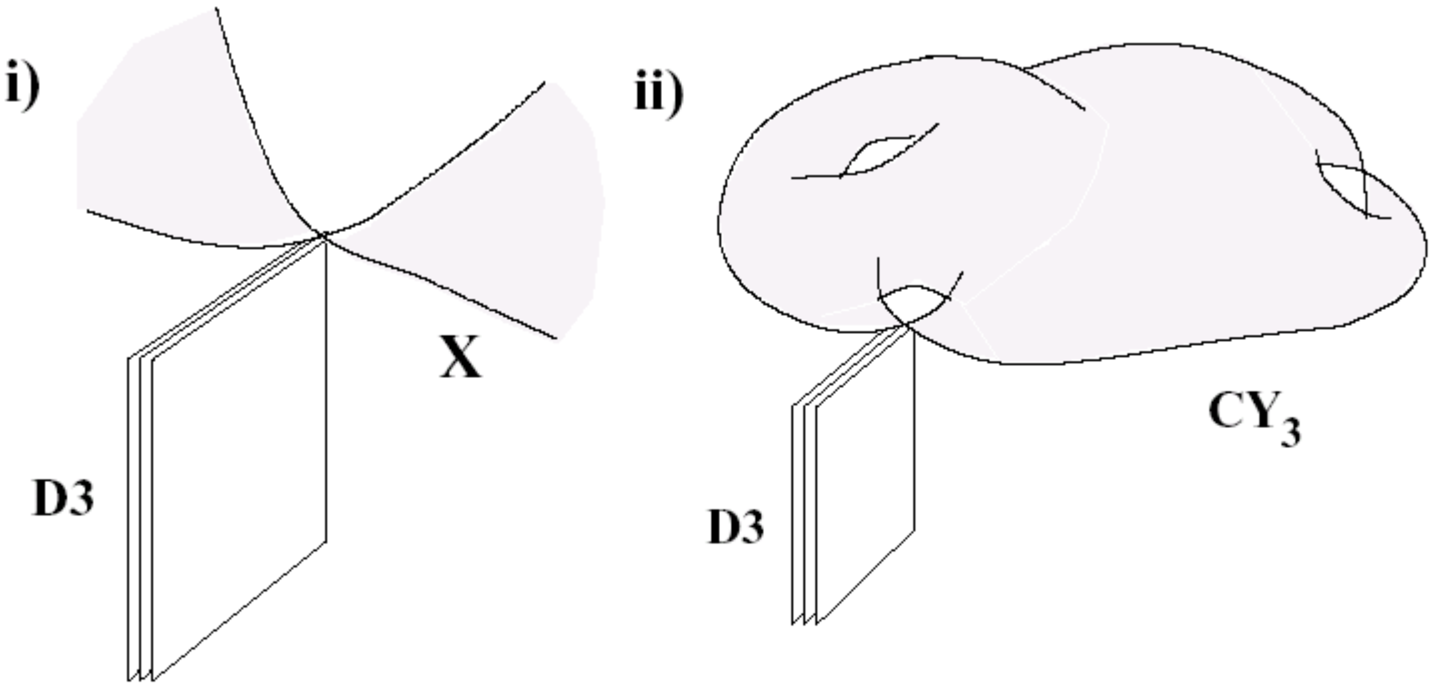


- Low dimensional Group representations:
  (bifundamentals, symmetric, antisymmetric, adjoints)

- If 4D N=1 TeV SUSY: Cosmological Moduli Problem!?
  (unless M_{moduli}>10 TeV)

String Model Building:

- **Global Models** (e.g. Heterotic)
- **Local Brane Models** (e.g. IIB) ⬅



Bottom-up Approach

Aldazabal,Ibanez, FQ, Uranga 2000

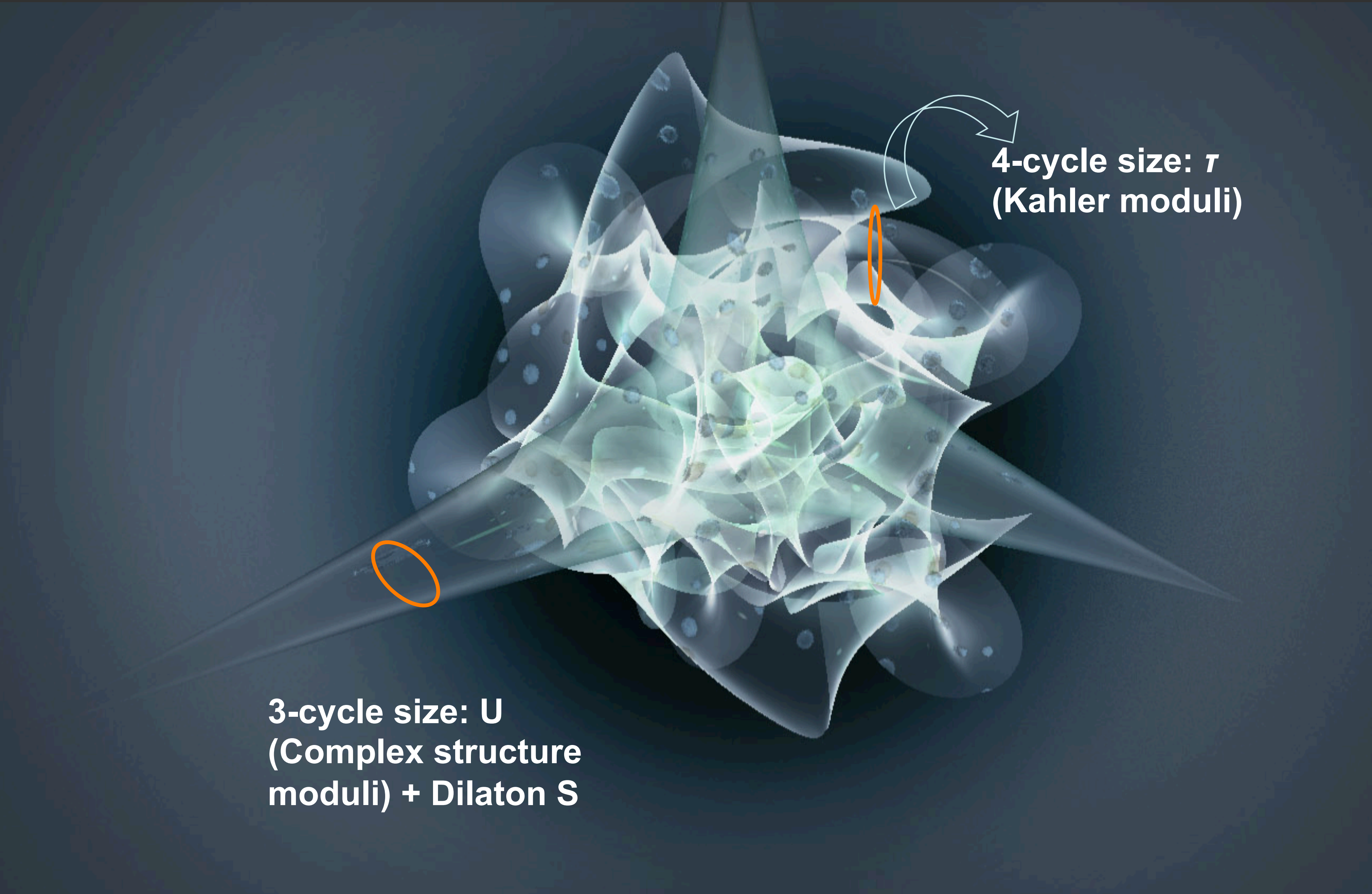
Local (brane) Properties

- Gauge group
- Chiral spectrum
- Yukawa couplings
- Gauge couplings
- Proton stability
- Flavour symmetries

Global (bulk) Properties

- Moduli Stabilisation
- Cosmological constant
- SUSY Breaking
- Scales (unification, axions,…)
- Inflation, Reheating
- Cosmological moduli problem

MODULI STABILISATION



LARGE Volume Scenario

IIB Moduli Stabilisation

…GKP, KKLT, …

Type IIB String on Calabi-Yau orientifold

Turn on Fluxes

$\int_a F_3 = n_a \qquad \int_b H_3 = m_b$

Size of cycle a = U_a

Superpotential $W = \int G_3 \wedge \Omega, \qquad G_3 = F_3 - iS H_3$

Scalar Potential: $$V_F = e^K \left(K^{I\bar{J}} D_I W D\overline{W}_{\bar{J}} - 3|W|^2 \right)$$

$V = e^K \ |D_a W|^2$

GKP

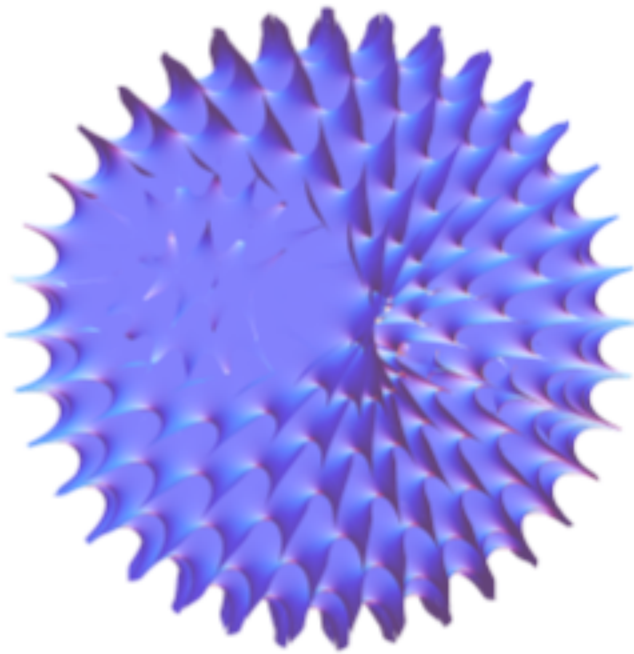
Minimum $D_a W = 0$ Fixes U_a and S

T moduli unfixed: No-Scale models

Kahler moduli?

Simple example:

P^4_{11169}



Exponentially Large Volumes

BBCQ, CQS (2005)

Example : $\mathbb{P}^4_{[1,1,1,6,9]}$,

Perturbative (alpha') corrections to K

$$\mathcal{K} = -2\ln\left(\frac{1}{9\sqrt{2}}\left(\tau_b^{3/2} - \tau_s^{3/2}\right) + \frac{\xi}{2g_s^{3/2}}\right)$$

Volume

$$W = W_0 + A_s e^{-a_s T_s}.$$

Fluxes

Nonperturbative corrections to W

$$V = \sum_{\Phi=S,U} \frac{\hat{K}^{\Phi\bar{\Phi}} D_\Phi W \bar{D}_{\bar{\Phi}} \bar{W}}{\mathcal{V}^2} + \frac{\lambda(a_s A_s)^2 \sqrt{\tau_s} e^{-2a_s\tau_s}}{\mathcal{V}} - \frac{\mu W_0 a_s A_s \tau_s e^{-a_s\tau_s}}{\mathcal{V}^2} + \frac{\nu\xi|W_0|^2}{g_s^{3/2}\mathcal{V}^3}$$

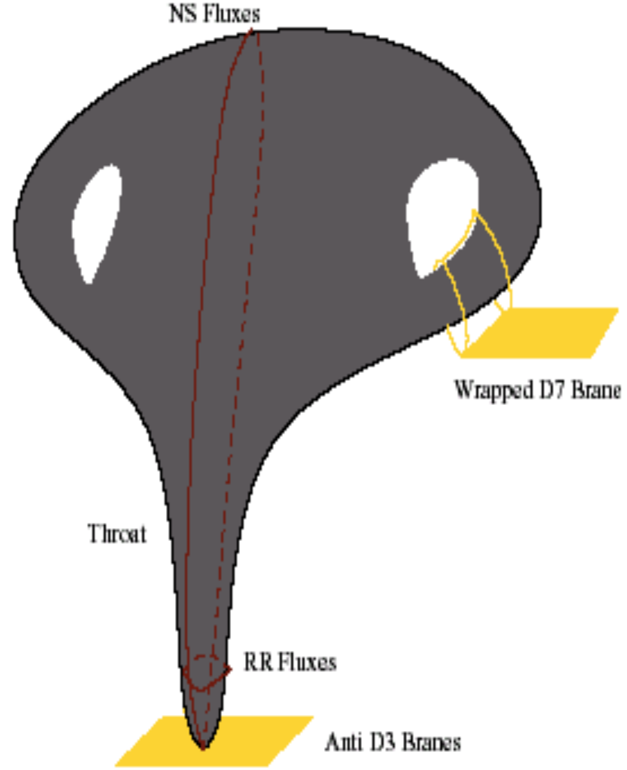
$$\mathcal{V} \sim e^{a_s\tau_s} \gg 1 \text{ with } \tau_s \sim \frac{\xi^{2/3}}{g_s}.$$

Exponentially large volumen, AdS + Broken SUSY!!!

De Sitter ‘Uplift’

- **‘Antibranes’ ?**

$$V_{\rm up} \sim \frac{e^{4A_0}}{\mathcal{V}^{\alpha-2/3}}\,,$$ **KKLT**



- **D-terms** **BKQ**

- **Non-perturbative effects (at singularities)**

$$V = V_{\rm LVS} + V_{\rm up}\,,$$

$$V_{\rm up} \propto h^2\,\frac{e^{-2b\langle s\rangle}}{\mathcal{V}}\,,$$

Cicoli et al arXiv:1203.1750

Relevant Scales

- **String scale** $M_s = M_P / \mathcal{V}^{1/2}$
- **Kaluza-Klein scale** $M_{KK} = M_P / \mathcal{V}^{2/3}$
- **Gravitino mass** $m_{3/2} = W_0 \, M_P / \mathcal{V}$
- **Volume modulus mass** $M_V = M_p / \mathcal{V}^{3/2}$
- **Lighter (fibre) moduli** $M_l = M_p / \mathcal{V}^{5/3}$

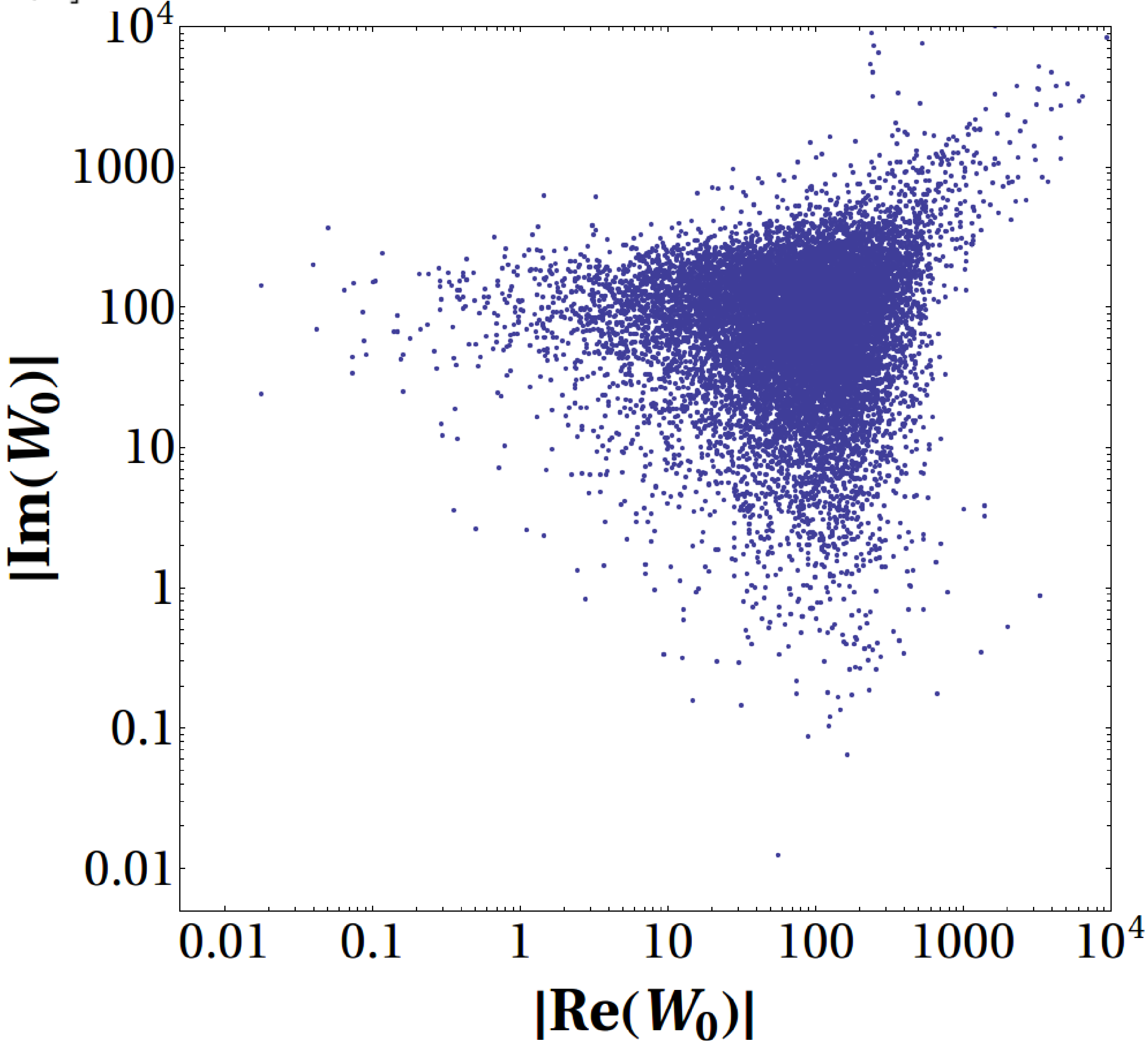
LVS vs KKLT

- W_0~0.1-100
- U,S,T stabilised one step
- AdS non SUSY
- Minimum: perturbative in big cycle vs non-perturb. in small cycle
- Uplift:anti D3 branes, D-terms...
- Small parameter = 1/V
- SUSY broken by fluxes
- Many moduli: need $h_{21}>h_{11}>1$ + one blow up, the rest by loop effects/ D-terms

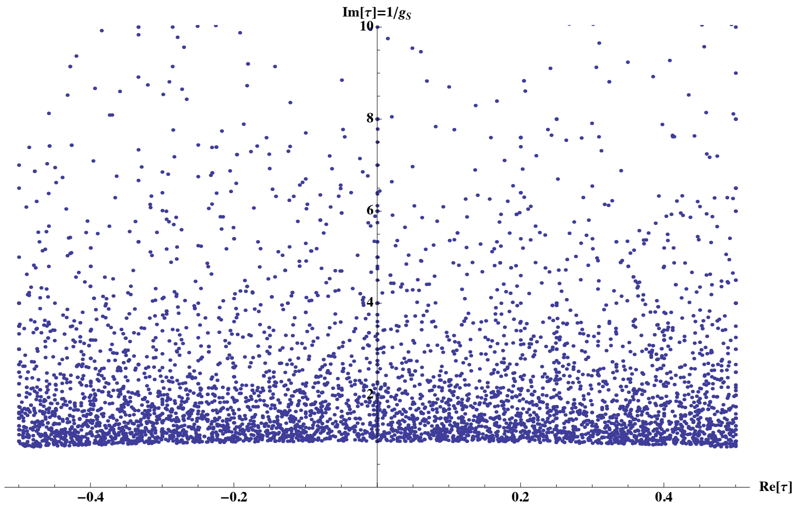
- $W_0<<1$
- U,S,T stabilised in 2 steps
- AdS SUSY
- Minimum: tree-level vs non-perturbative
- Uplift: anti D3 branes...(no D-terms)
- Small parameter W0
- SUSY broken by uplifting mechanism
- Many moduli: non-perturbative effects for each of them or ...

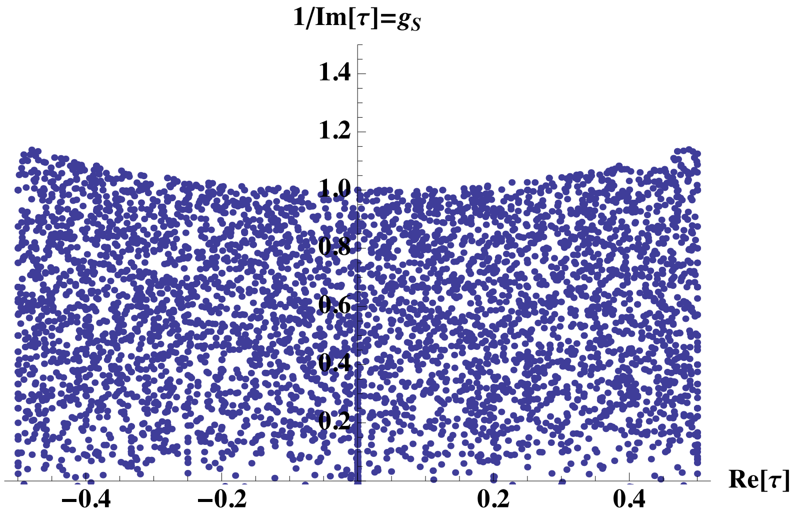
$\mathbb{P}^4_{[1,1,1,6,9]}$,

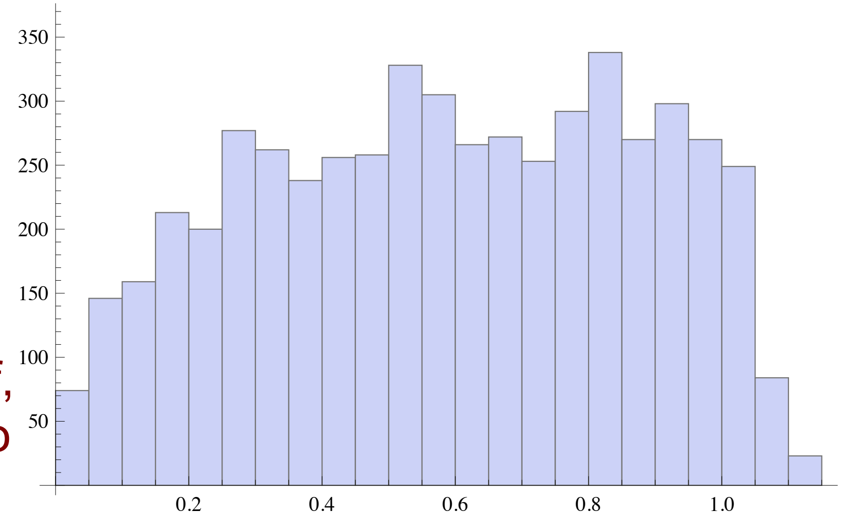
Martinez-Pedrera, Mehta, Rummel, Wesphal 1212.4530



Distribution of Vacua (~Uniform in W_0 and g_s)







Cicoli, Klevers, Krippendorf, Mayrhofer, FQ, Valandro, to appear

Stability of LVS minima

- Brown-Teitelboim (+CdL) D5/NS5 brane nucleation
- AdS: Brane tension>upper bound, so stable in EFT:
- dS: $P_{dS}/P_{AdS} \sim e^{-V}$ (The larger the volume, more stable!)

  $P_{dS}/P_{dec} \sim e^{V^2}$

(Also: no evidence for bubble of nothing decay)

S. de Alwis, R. Gupta, E. Hatefi, FQ arXiv:1308.1222

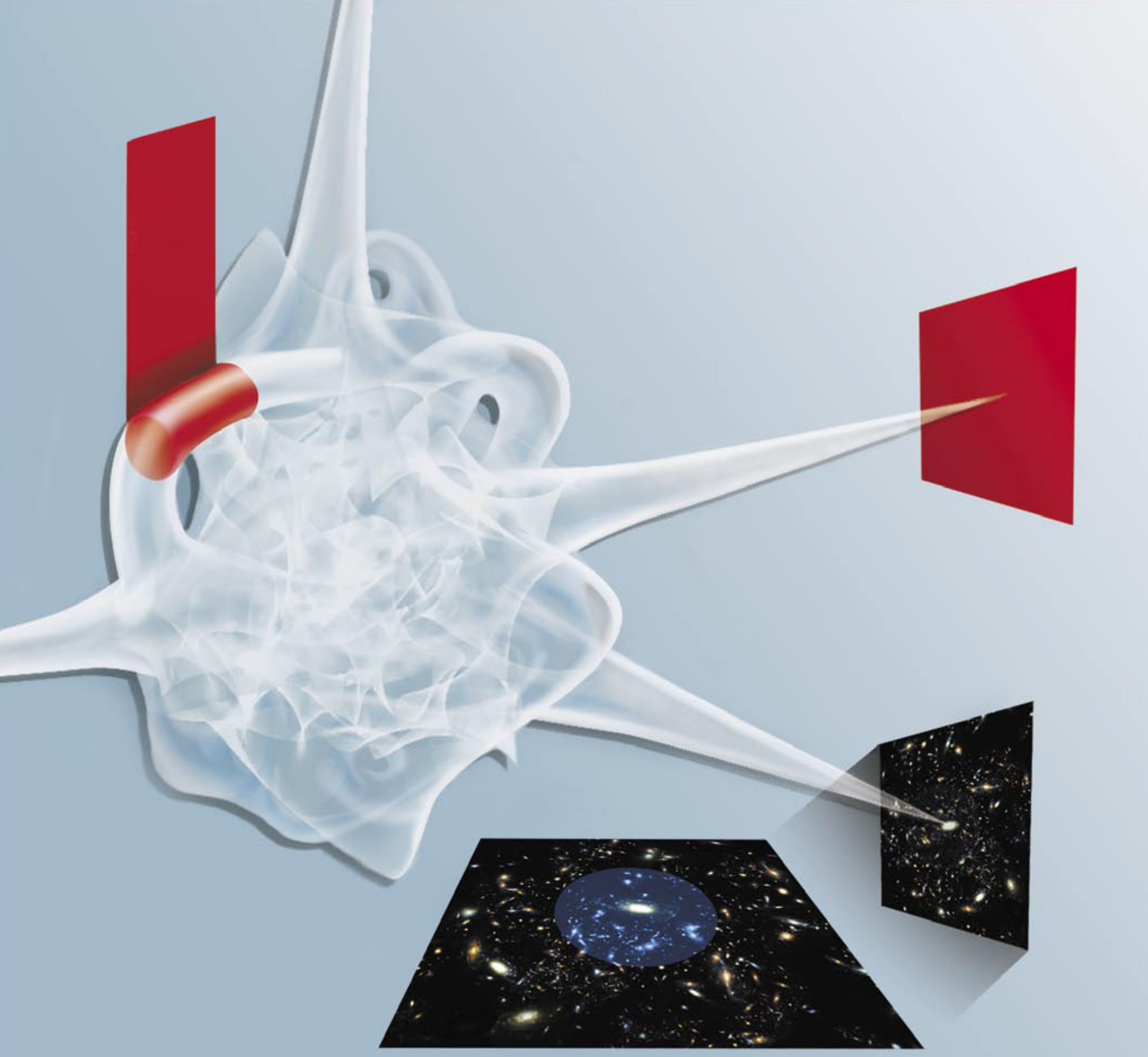
LVS and Particle Physics

LARGE Volume Implies

Standard Model is localised !

(SM D7 cannot wrap the exponentially large cycle since $g^2=1/\mathcal{V}^{2/3}$) ➡ 'Bottom-up'

- D3/D7 Branes at a singularity (collapsed cycle)
- Magnetised D7 - Brane wrapping a 'small' four-cycle
- Local F-Theory



Universe

D3 Brane

or

D7 Brane

But: Local/Global Mixing

- **Standard Model in small cycle**
- **SM cycle usually NOT fixed by non-perturbative effects:**

- **SM chiral implies:** $W_{np} = \left(\prod_i \Phi_{hidden,i}\right)\left(\prod_j \Phi_{MSSM,j}\right) e^{-aT_{MSSM}}.$

Blumenhagen et al.2007

$$D_a \sim \sum_i \left(|\Phi|^2 - \xi\right)^2, \quad \xi = (\partial_{V_a} K)|_{V_a=0} \sim T_{MSSM}$$

MSSM: $\langle\Phi\rangle=0$, **so** $W_{np}=0$, $\xi = 0.$

SM at Singularity ! (Or $\langle|\Phi|^2\rangle$: ξ)

SUSY Breaking

The Landscape

- **Good:** It allows for the first time to trust calculations for low-energy SUSY breaking.
- **Bad:** missed opportunity to have new physics at low energies from small Λ.
- **Ugly:** It allows not to use SUSY to address the hierarchy problem (Split SUSY, High-energy SUSY)

SUSY Breaking

- **Approximate Universality**

$$\Psi \Longleftrightarrow \text{Kähler moduli,}$$
$$\chi \Longleftrightarrow \text{Complex structure moduli.}$$

$$\Phi = \Psi_{\text{susy-breaking}} \oplus \chi_{\text{flavour}}.$$

CAQS, ConIon
(Mirror Mediation)

- **Two cases:** ♦ $F_{SM} \neq 0$ soft terms $\sim m_{3/2}$

  $M_s \sim 10^{12}$ GeV

  ♦ $F_{SM} = 0$ soft terms $\ll m_{3/2}$

  or $\sim m_{3/2}$

Different Scenarios

- $F_{SM} \neq 0$ (Magnetised D7s, D3/D7@singularities)

  $M_{soft} = \alpha M_{3/2} \sim \alpha W_0/V$

  $W_0 \sim 1$, $V \sim 10^{15}$, $Ms \sim 10^{11}$GeV **(TeV✓, GUT?, CMP?)**

  $W_0 \sim 10^{-11}$, $V \sim 10^5$, $Ms \sim M_{GUT}$ **(tuning?,CMP?)**

  $W_0 \sim 1$, $V \sim 10^5$, $Ms \sim M_{GUT}$ **(hierarchy?, CMP✓)**

- $F_{SM} = 0$ (D3@singularity): Sequestered !

  $M_{soft} \sim M_{3/2}/V$, $V \sim 10^{6-7}$, $Ms = M_{GUT}$ **(GUT✓,CMP✓)**

  $M_{1/2} = M_{3/2}/V$, $M_0 \sim M_{3/2}/V^{1/2}$ **(GUT✓,CMP✓, mini-split?)**

  $M_{soft} \sim M_{3/2}/V^{1/2}$ **(GUT✓,CMP✓, 1000TeV soft masses?)**

Sequestered Scenario

Blumenhagen et al 0906.3297

$$\begin{aligned} M_P &\equiv 2.4\times 10^{18}\,\mathrm{GeV}, \\ M_{string} &\sim M_P/\sqrt{\mathcal{V}}, \\ m_{\tau_{s,i}} \sim m_{a_{s,i}} &\sim M_P \ln\mathcal{V}/\mathcal{V}, \\ m_{3/2} \sim m_U \sim m_S &\sim M_P/\mathcal{V}, \\ m_{\tau_b} &\sim M_P/\mathcal{V}^{3/2}, \\ m_{a_b} &\lesssim M_P\, e^{-2\pi\mathcal{V}^{2/3}} \sim 0\,. \end{aligned}$$

Model independent !

$$M_{soft} \sim \frac{M_P}{\mathcal{V}^2} \ll m_{\tau_b} \sim \frac{M_P}{\mathcal{V}^{3/2}}\,.$$

$M_{soft} \sim 1\,\mathrm{TeV}$ $\quad$ $m_{\tau_b} \sim 3\times 10^6\,\mathrm{GeV}$

***No CMP,**
***No gravitino induced moduli problem,**
***Volume reheating**

LHC Phenomenology: Aparicio et al to appear

Cosmology

Inflation

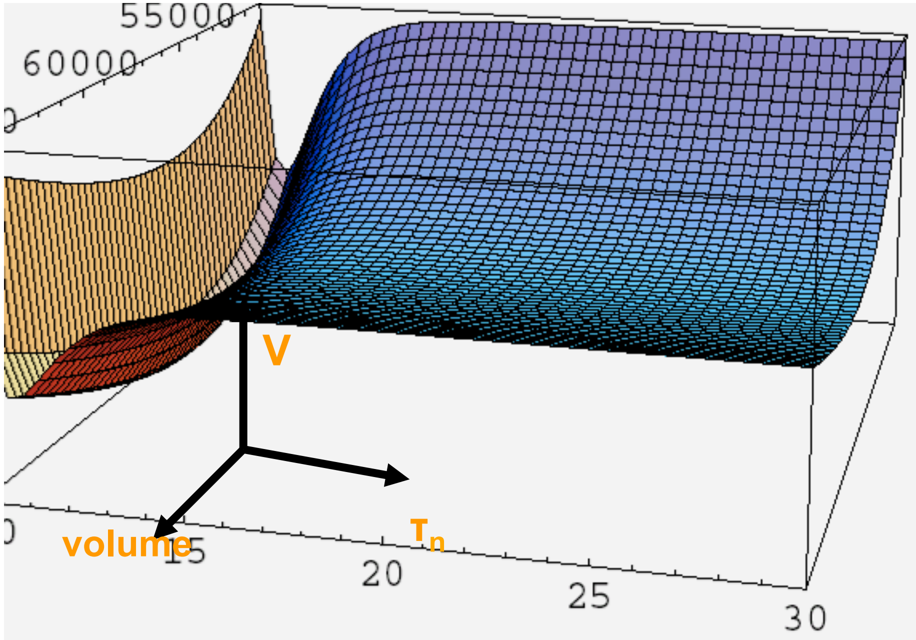
Kähler Moduli Inflation (Blow-up)

$$V=\sum_i \frac{8(a_iA_i)^2\sqrt{\tau_i}}{3\mathcal{V}\lambda_i\alpha}e^{-2a_i\tau_i}-\sum_i 4\frac{a_iA_i}{\mathcal{V}^2}W_0\tau_i e^{-a_i\tau_i}+\frac{3\xi W_0^2}{4\mathcal{V}^3}.$$

Conlon-FQ
Bond et al.
…

$$V\cong V_0-\frac{4W_0a_nA_n}{\mathcal{V}^2}\left(\frac{3\mathcal{V}}{4\lambda}\right)^{2/3}(\tau_n^c)^{4/3}\exp\left[-a_n\left(\frac{3\mathcal{V}}{4\lambda}\right)^{2/3}(\tau_n^c)^{4/3}\right].$$

Calabi-Yau: $h_{21}>h_{11}>2$

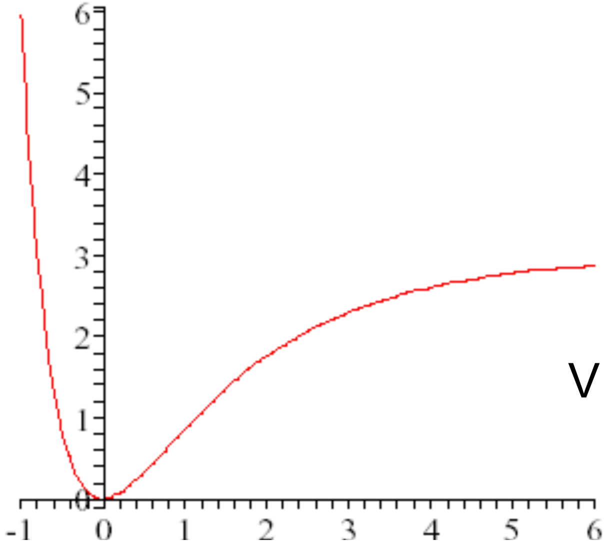


Small field inflation (r<<<1)
No fine-tuning!!
0.960<n<0.967
Loop corrections??

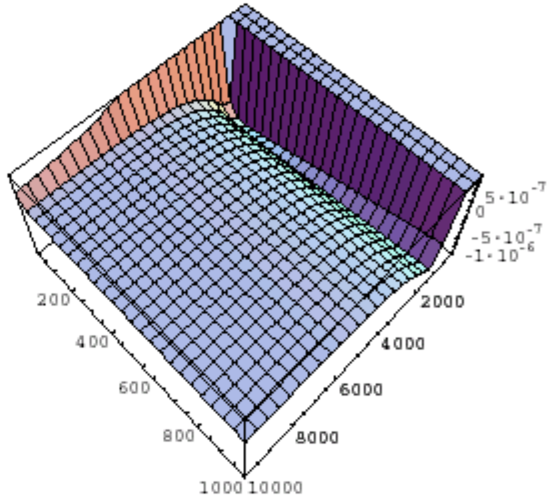
Fibre Inflatons

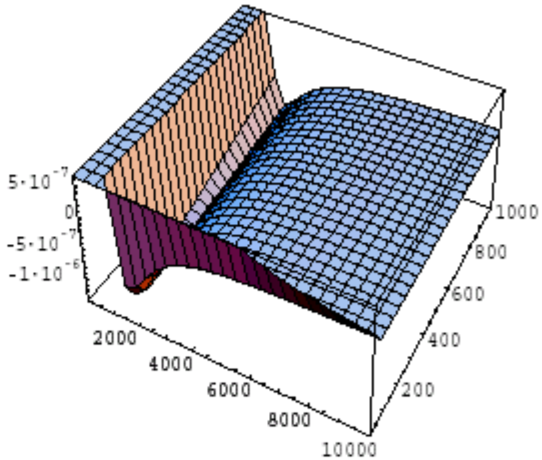
Burgess, Cicoli, FQ

$$\mathcal{V} = \alpha\left[\sqrt{\tau_1}(\tau_2 - \beta\tau_1) - \gamma\tau_3^{3/2}\right],$$



$$V = \frac{m_\varphi^2}{4}\left(3 - 4\,e^{-\kappa\hat{\varphi}/2} + e^{-2\kappa\hat{\varphi}}\right) \qquad \kappa = \frac{2}{\sqrt{3}}.$$

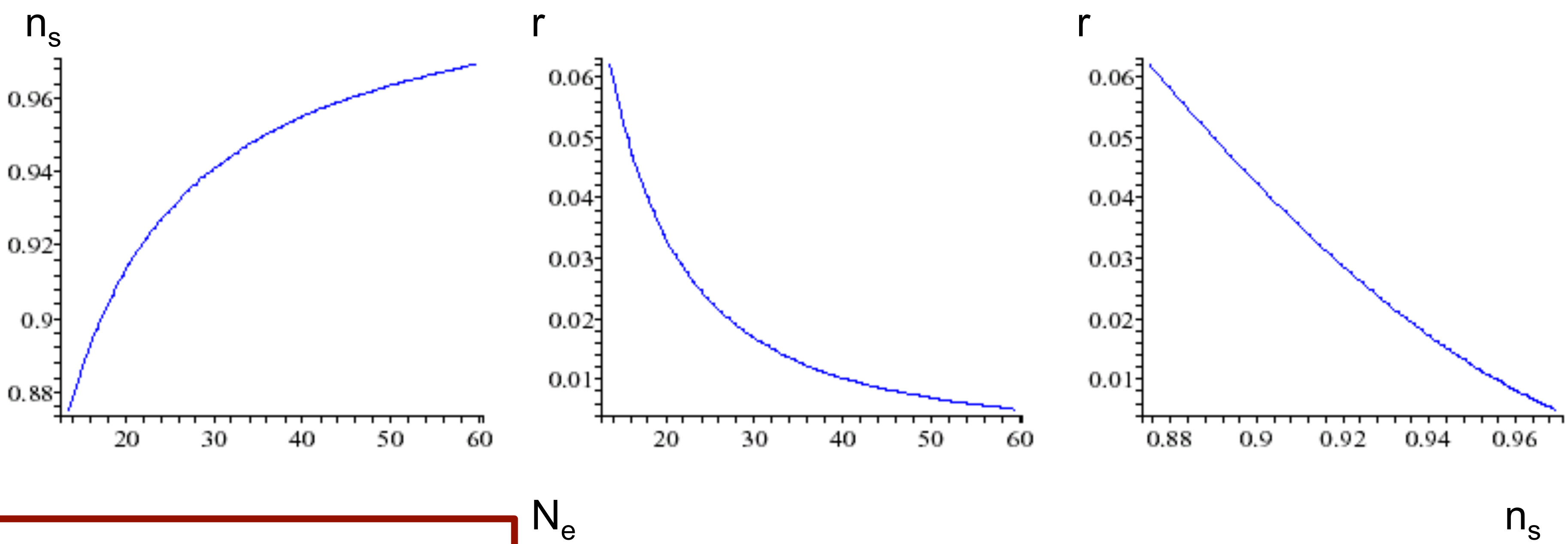




$$\varepsilon \simeq \frac{8}{3\left[3\,e^{\kappa\hat{\varphi}/2} - 4\right]^2},$$

$$\eta \simeq -\frac{4}{3\left[3\,e^{\kappa\hat{\varphi}/2} - 4\right]},$$

$$\varepsilon \simeq \frac{3\,\eta^2}{2}.$$



$$r \simeq 6(n_s - 1)^2\,,$$

$$n_s \simeq 0.970, \qquad r \simeq 4.6 \cdot 10^{-3}\,,$$

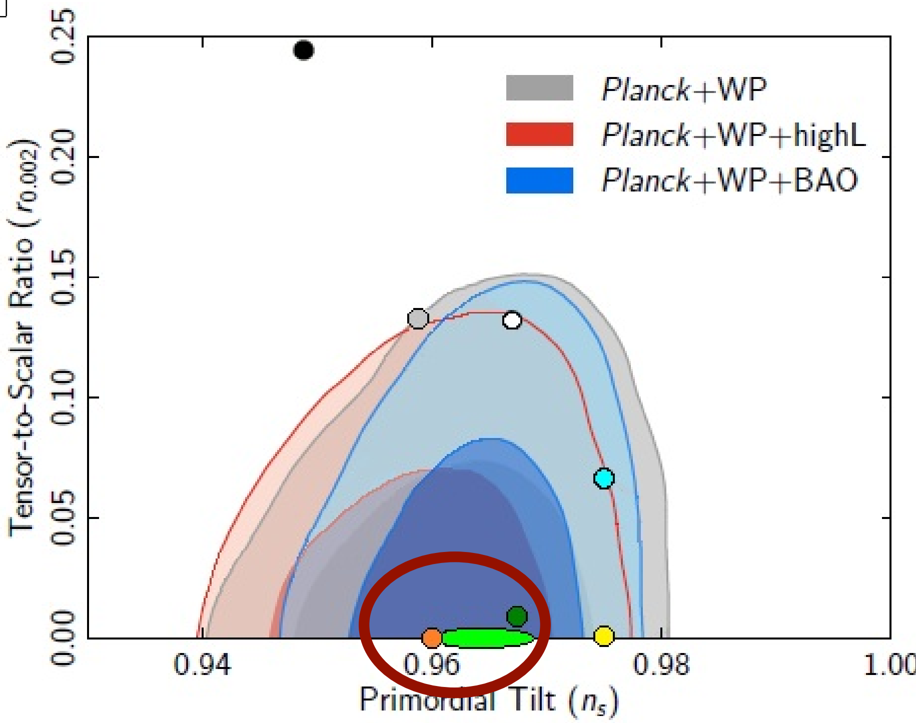
Volume ~ 10^4, tension with TeV SUSY?

Observable gravity waves !

(can be ruled out by Planck if they observe them and CMBpol… if they do not observe them)

String Scenario	n_s	r
D3/$\overline{\text{D3}}$ Inflation	$0.966 \leq n_s \leq 0.972$	$r \leq 10^{-5}$
Inflection Point Inflation	$0.92 \leq n_s \leq 0.93$	$r \leq 10^{-6}$
DBI Inflation	$0.93 \leq n_s \leq 0.93$	$r \leq 10^{-7}$
Wilson Line Inflation	$0.96 \leq n_s \leq 0.97$	$r \leq 10^{-10}$
D3/D7 Inflation	$0.95 \leq n_s \leq 0.97$	$10^{-12} \leq r \leq 10^{-5}$
Racetrack Inflation	$0.95 \leq n_s \leq 0.96$	$r \leq 10^{-8}$
N − flation	$0.93 \leq n_s \leq 0.95$	$r \leq 10^{-3}$
Axion Monodromy	$0.97 \leq n_s \leq 0.98$	$0.04 \leq r \leq 0.07$
Kahler Moduli Inflation	$0.96 \leq n_s \leq 0.967$	$r \leq 10^{-10}$
Fibre Inflation	$0.965 \leq n_s \leq 0.97$	$0.0057 \leq r \leq 0.007$
Poly − instanton Inflation	$0.95 \leq n_s \leq 0.97$	$r \leq 10^{-5}$

Overall, string inflation models in good shape after Planck 2013, waiting for further tests



C. Burgess, M. Cicoli, FQ arXiv:1306.3512

After Inflation

Volume Reheating*

*Sequestered scenarios

M.Cicoli, J.P. Conlon, FQ arXiv:1208.3562
T. Higaki, F.Takahashi arXiv:1208.3563

$$\Gamma_{\Phi\to a_b a_b} = \frac{1}{48\pi}\frac{m_\Phi^3}{M_P^2}.$$

Volume axion a_b

$$\Gamma_{\Phi\to H_u H_d} = \frac{2Z^2}{48\pi}\frac{m_\Phi^3}{M_P^2}.$$

Higgses

$$\Gamma_{\Phi\to BB} = \left(\frac{\lambda}{3/2}\right)^2 \frac{9}{16}\frac{1}{48\pi}\frac{m_\Phi^3}{M_P^2}$$

Closed string axions

$$\Gamma_{\Phi\to C\bar{C}} \sim \frac{m_0^2 m_\Phi}{M_P^2} \ll \frac{m_\Phi^3}{M_P^2}$$

Matter scalars C

$$T_{reheat} \sim \frac{m_\Phi^{3/2}}{M_{Pl}^{1/2}} \sim 0.6 \text{ GeV} \left(\frac{m_\Phi}{10^6 \text{GeV}}\right)^{3/2}.$$

Dark Radiation

Energy density:

$$\rho_{total} = \rho_\gamma \left(1 + \frac{7}{8}\left(\frac{4}{11}\right)^{4/3} N_{eff}\right).$$

Standard Model N_{eff}=3.04

At CMB: WMAP, ACT, SPT

$$N_{eff} = 4.34^{+0.86}_{-0.88}, 4.56\pm0.75, 3.86\pm0.42$$

$$3.12\,\kappa \leq \Delta N_{eff} \leq 3.48\,\kappa$$
$$\kappa = (1 + 9n_a/16)/n_H Z^2$$

Simplest Z=1:

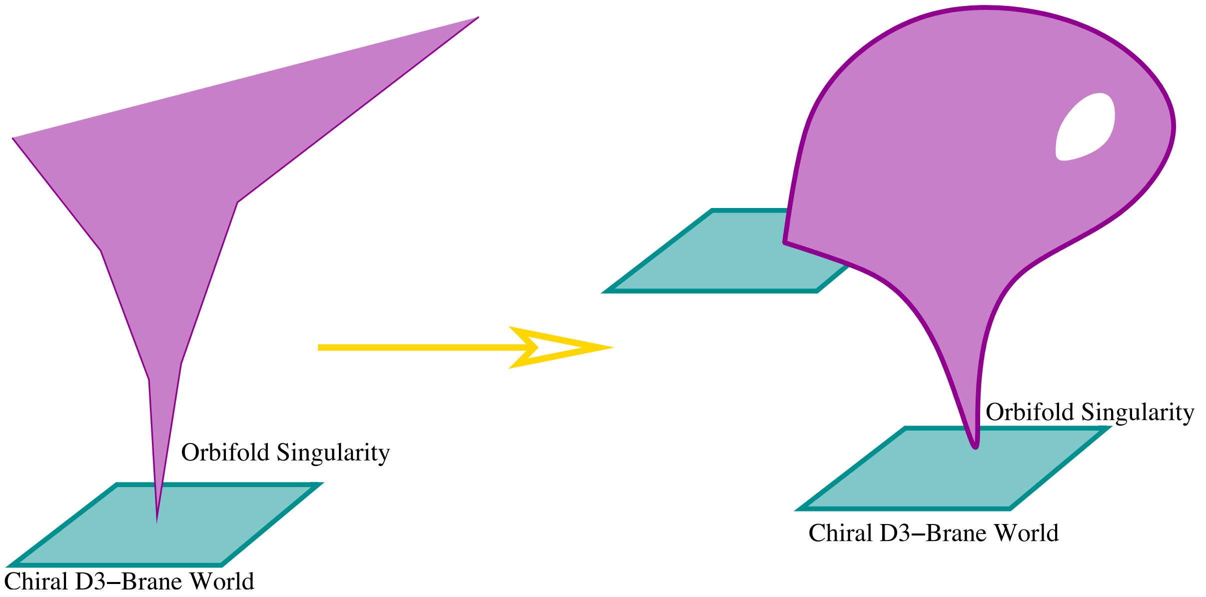
$$1.56 \leq \Delta N_{eff} \leq 1.74$$

General: Strong constraints on matter and couplings (even if not sign of DR)! Also CAB (Conlon+Marsh)

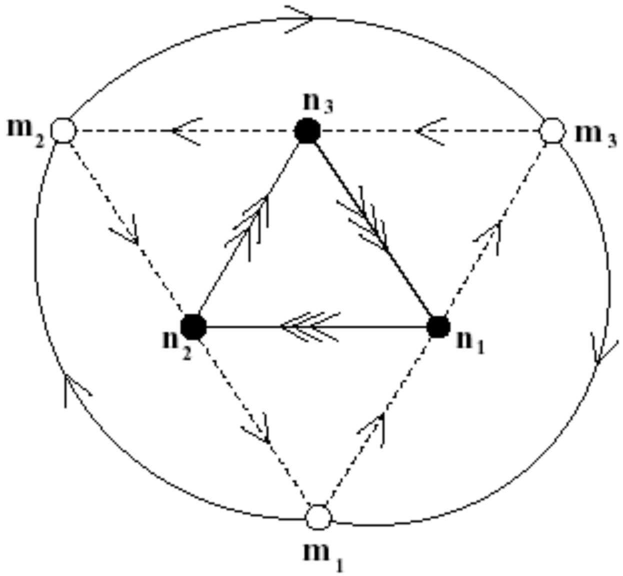
Global Embedding and Moduli Stabilisation

Cicoli, Krippendorf,Mayrhofer, FQ, Valandro
1206.5237, 1304.0022, 1304.2771
+ Klevers (to appear next week!)

Branes at Singularities



Del Pezzo Singularities/Quivers



e.g. del Pezzo 0 (C_3/Z_3)

n_i D3 Branes (group $\Pi U(n_i)$)

m_j D7 Branes (group $\Pi U(m_i)$)

Arrows=bi-fundamentals

$$3\left[(\mathbf{n_1},\bar{\mathbf{n}}_2,\mathbf{1})+(\mathbf{1},\mathbf{n_2},\bar{\mathbf{n}}_3)+(\bar{\mathbf{n}}_1,\mathbf{1},\mathbf{n_3})\right]+m_1\left[(\bar{\mathbf{n}}_1,\mathbf{1},\mathbf{1})+(\mathbf{1},\mathbf{n_2},\mathbf{1})\right]$$
$$+m_2\left[(\mathbf{1},\bar{\mathbf{n}}_2,\mathbf{1})+(\mathbf{1},\mathbf{1},\mathbf{n_3})\right]+m_3\left[(\mathbf{1},\mathbf{1},\bar{\mathbf{n}}_3)+(\mathbf{n_1},\mathbf{1},\mathbf{n_1})\right]$$

3 Families!

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

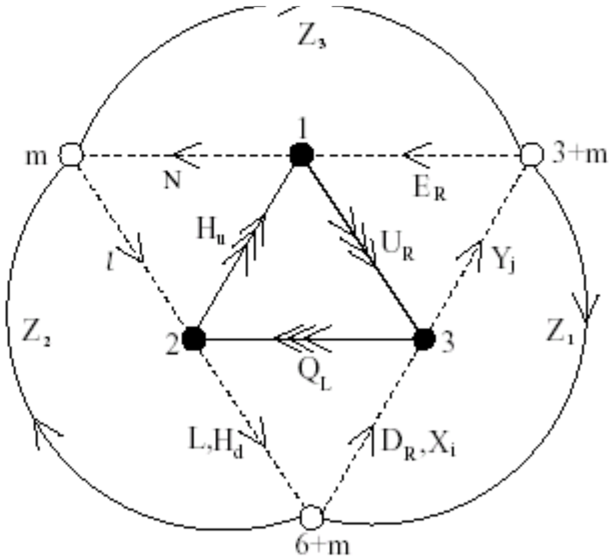
Anomaly/tadpole cancelation

$$Q_{anomaly-free} = -\sum_{i=1}^{3}\frac{Q_i}{n_i},$$

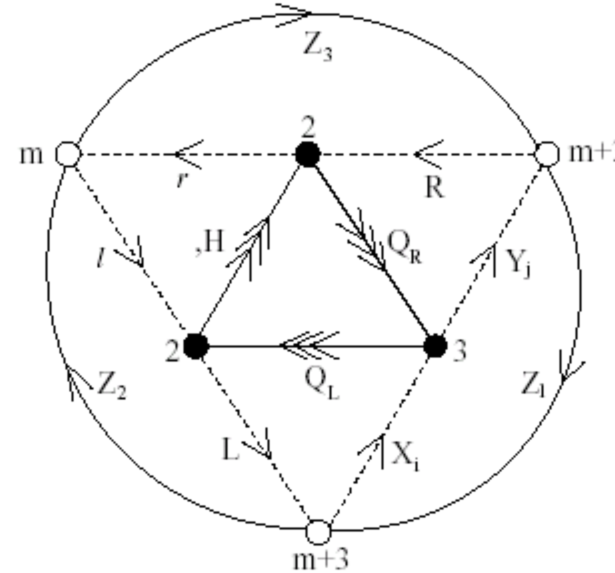
Hypercharge ($n_i \neq n_j$)

D7s:Franco-Uranga

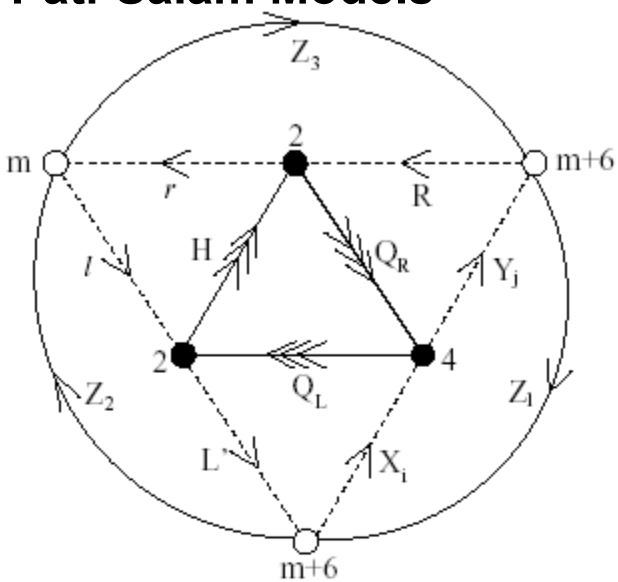
Standard Models



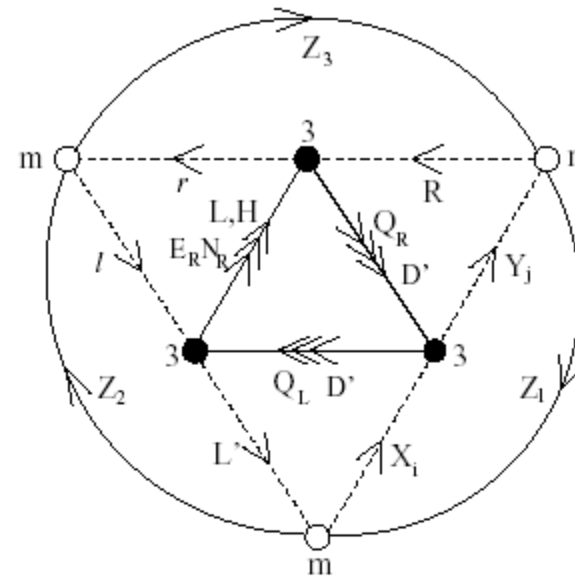
LR-Symmetric Models



Pati-Salam Models

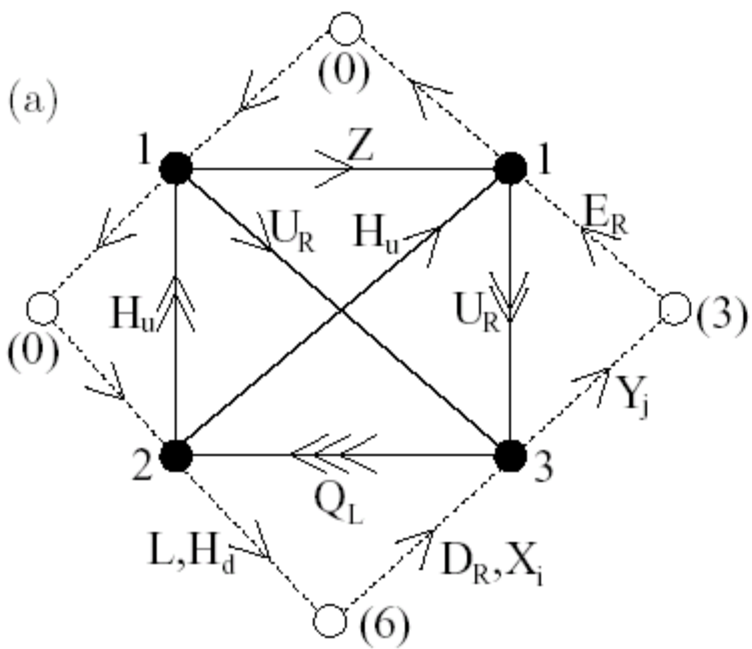


Trinification Models

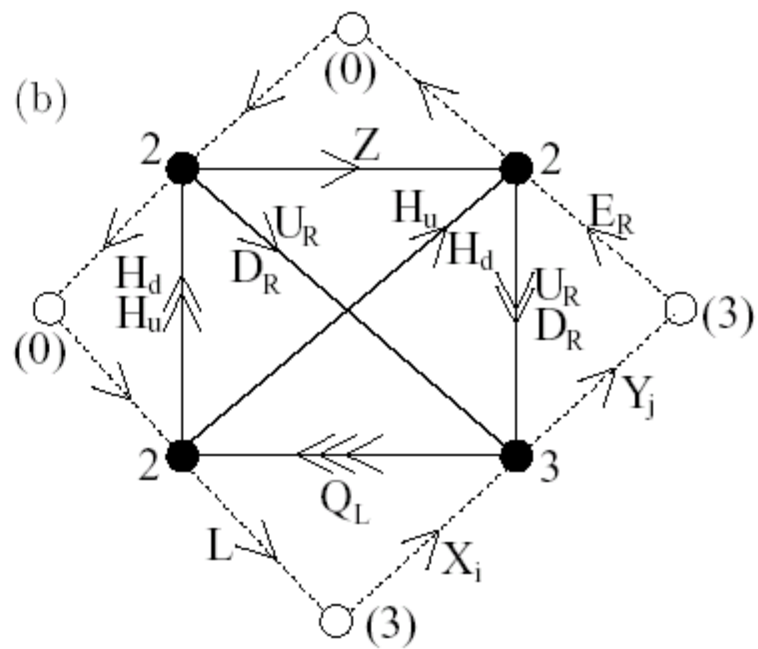


e.g. Realistic dP_1 Models

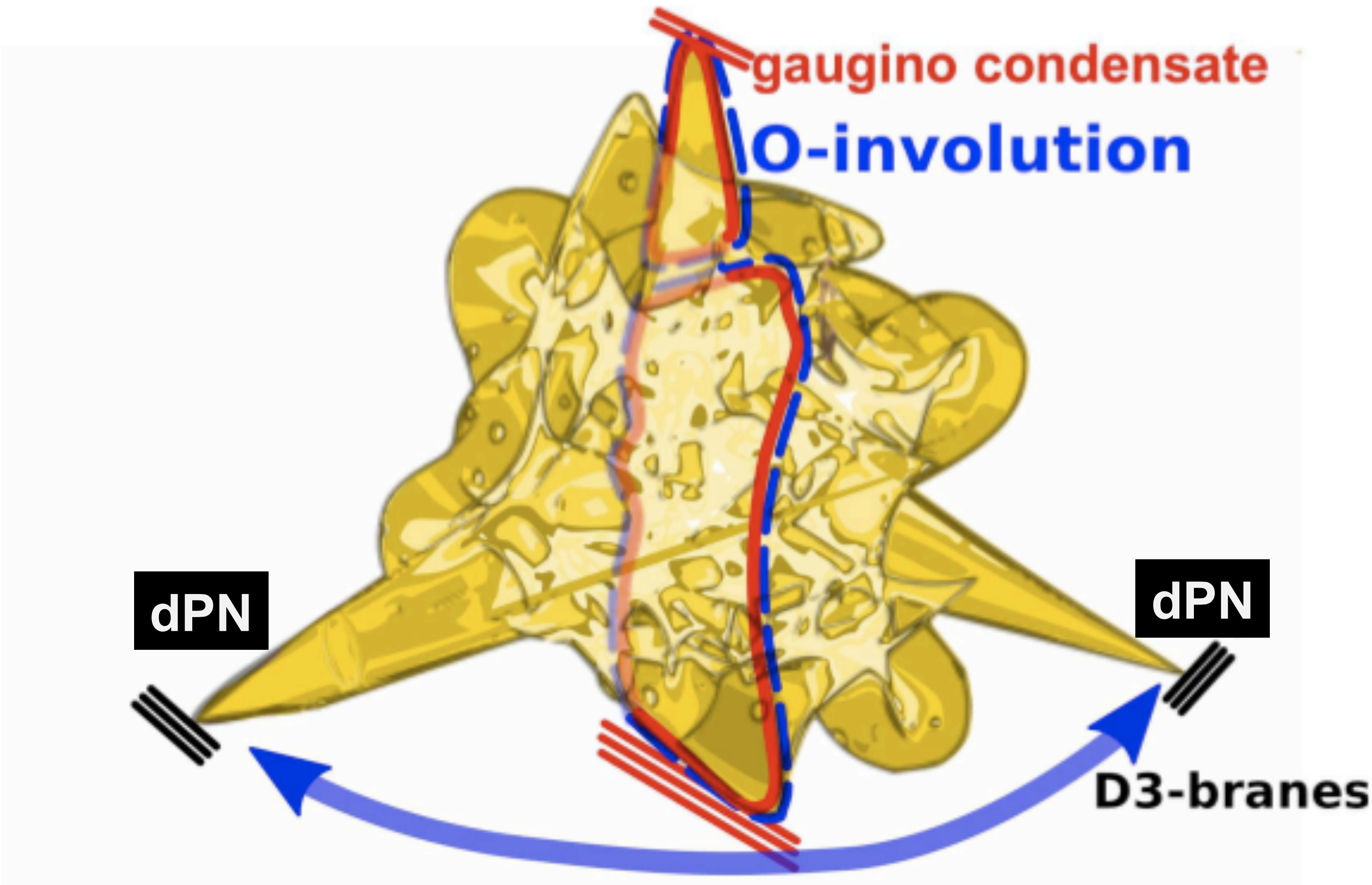
Standard Model



LR Symmetric Model



Global Picture



Classification from Toric Ambient Spaces

$h^{1,1} = 4 : 1197$ 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

Concrete (Compact) Calabi-Yau

z_1	z_2	z_3	z_4	z_5	z_6	z_7	z_8	D_{eq_X}
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

,

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

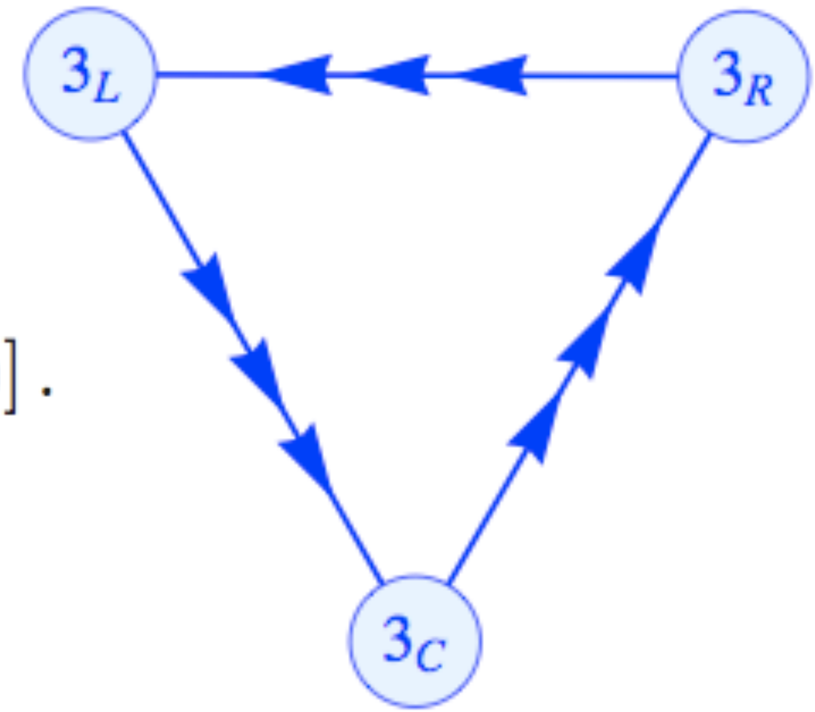
Orientifold $z_4 \leftrightarrow z_7$ and $z_5 \leftrightarrow z_6$

O7-planes	Locus in ambient space	Homology class in X_3
$O7_1$:	$y_6 = z_4 z_5 - z_6 z_7 = 0$	$D_{O7_1} = D_6 + D_7 = \mathcal{D}_b$
$O7_2$:	$y_5 = z_8 = 0$	$D_{O7_2} = D_8 = \mathcal{D}_s$

dP_0 with only D3 Branes

$$SU(3)_c \times SU(3)_L \times SU(3)_R$$

$$3[(\mathbf{3},\bar{\mathbf{3}},\mathbf{1}) + (\mathbf{1},\mathbf{3},\bar{\mathbf{3}}) + (\bar{\mathbf{3}},\mathbf{1},\mathbf{3})]\,.$$



$$\begin{aligned} SU(3)_c \times SU(3)_L \times SU(3)_R &\rightarrow SU(3)_c \times SU(2)_L \times SU(2)_R \times U(1)_{B-L} \\ &\rightarrow SU(3)_c \times SU(2)_L \times U(1)_Y\,. \end{aligned}$$

Consistency Constraints

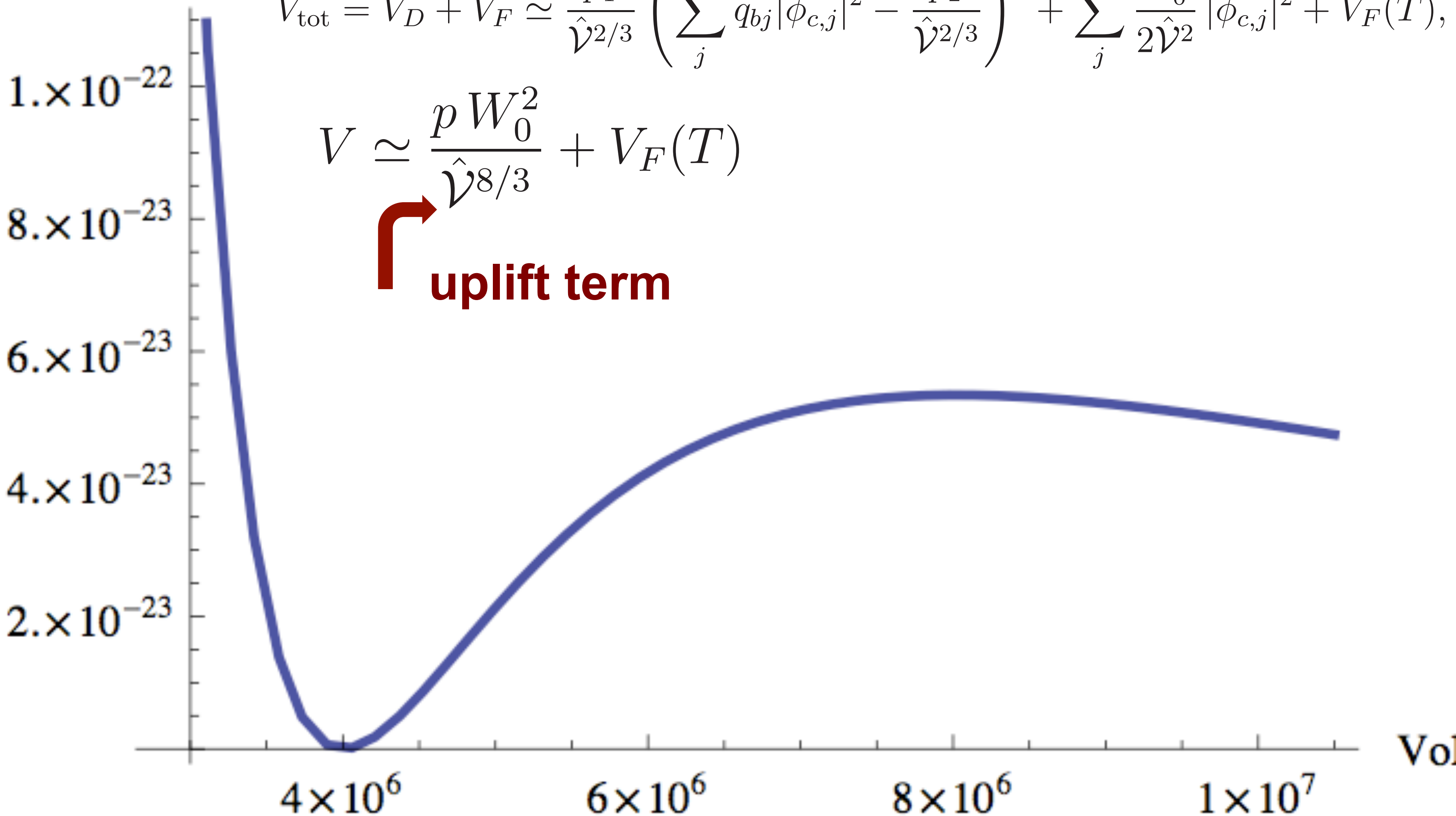
- Orientifolding induces orientifold planes with non zero 3-7 charges
- D7 tadpoles ✔
- D5 tadpoles ✔
- D3 tadpoles ✔
- Freed-Witten anomaly ✔
- K-theory charges ✔

Moduli Stabilisation

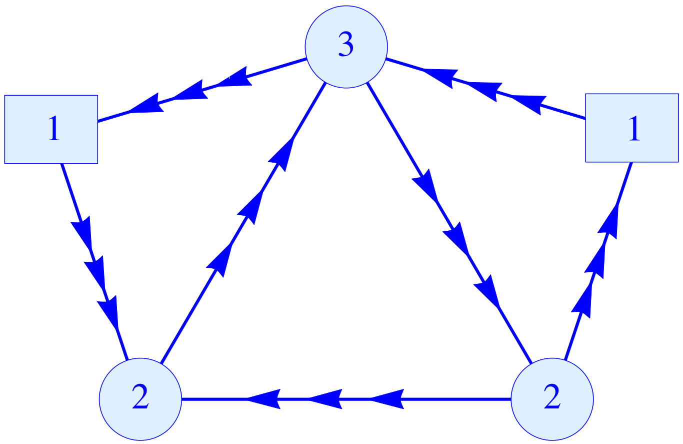
$$V_{\rm tot} = V_D + V_F \simeq \frac{p_1}{\hat{\mathcal{V}}^{2/3}} \left(\sum_j q_{bj} |\phi_{c,j}|^2 - \frac{p_2}{\hat{\mathcal{V}}^{2/3}} \right)^2 + \sum_j \frac{W_0^2}{2\hat{\mathcal{V}}^2} |\phi_{c,j}|^2 + V_F(T),$$

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

uplift term



dP_0 and Flavour D7 Branes

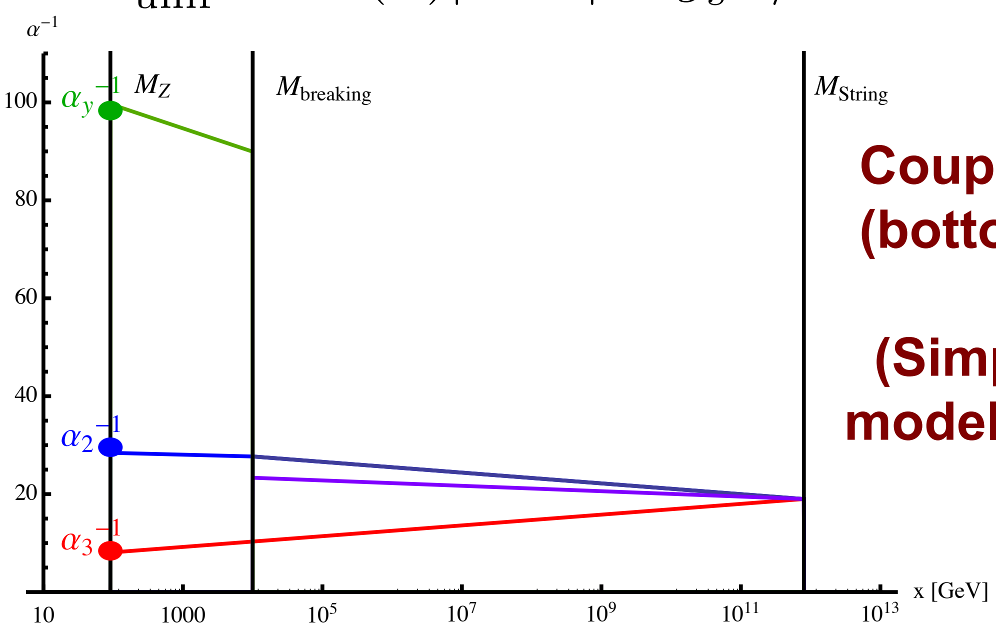


$SU(3)_c \times SU(2)_L \times SU(2)_R \times U(1)_{B-L}$

$$\mathcal{V}/W_0 \simeq 5 \cdot 10^{13}, \Lambda = 0 \Rightarrow W_0 \simeq 0.01, \mathcal{V} \simeq 5 \cdot 10^{11}$$

$$\zeta \simeq 0.522 \Rightarrow g_s \simeq 0.015 \simeq 1/65, M_s \simeq 10^{12}\text{GeV}$$

$$\alpha_{\text{unif}}^{-1} = \text{Re}(S)|Z_{\text{frac}}| = g_s^{-1}/3$$



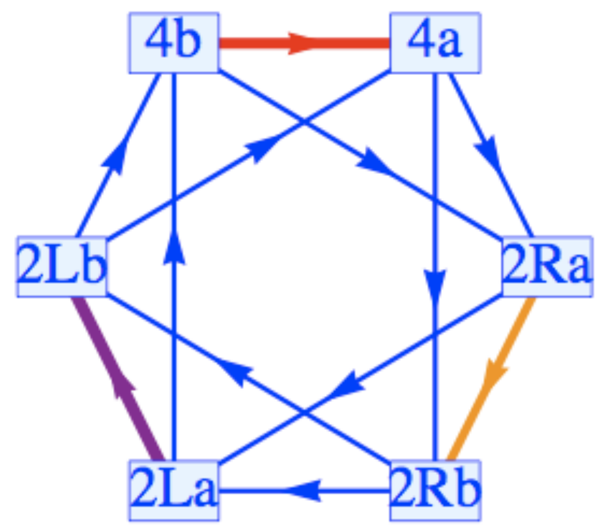
Couplings unified highly non-trivial! (bottom-up matching top-down)

(Simplest realistic global string model! But problem with Yukawas...)

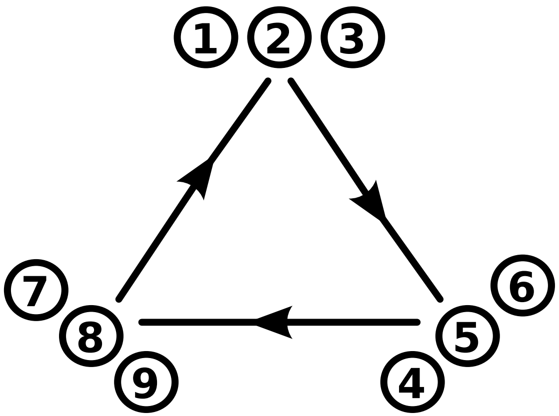
‘Realistic’ ‘Pati-Salam’ Model (dP3)

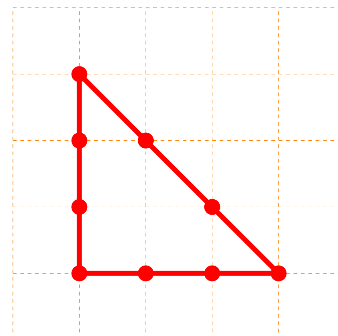
- Break symmetry to SM (+ U(1) or LR)
- Breaking U(1) to SM: RH sneutrino (R-parity broken)
- Quark+ lepton mass hierarchies
- See-saw neutrino masses
- Stable proton
- CKM, CP
- Controlled kinetic terms!!
- Gauge Unification

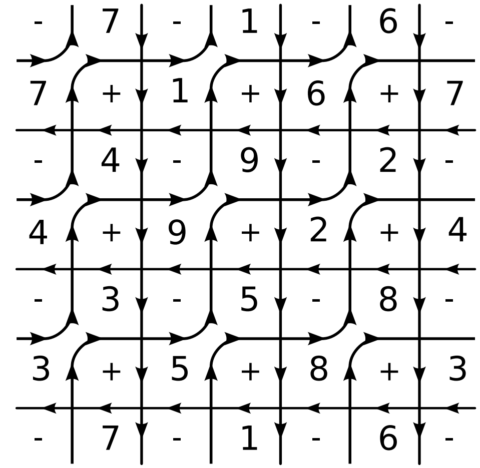
(But not Global realisation yet)



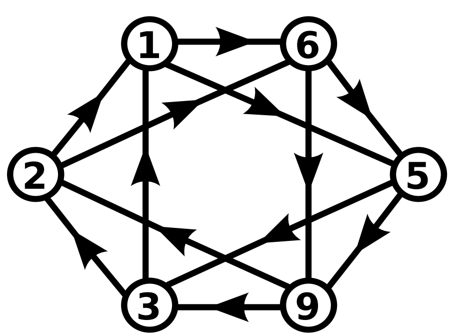
Global dP6 with D3 Branes

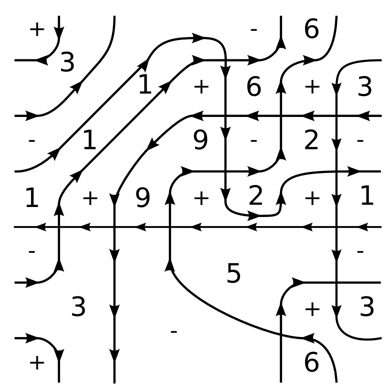


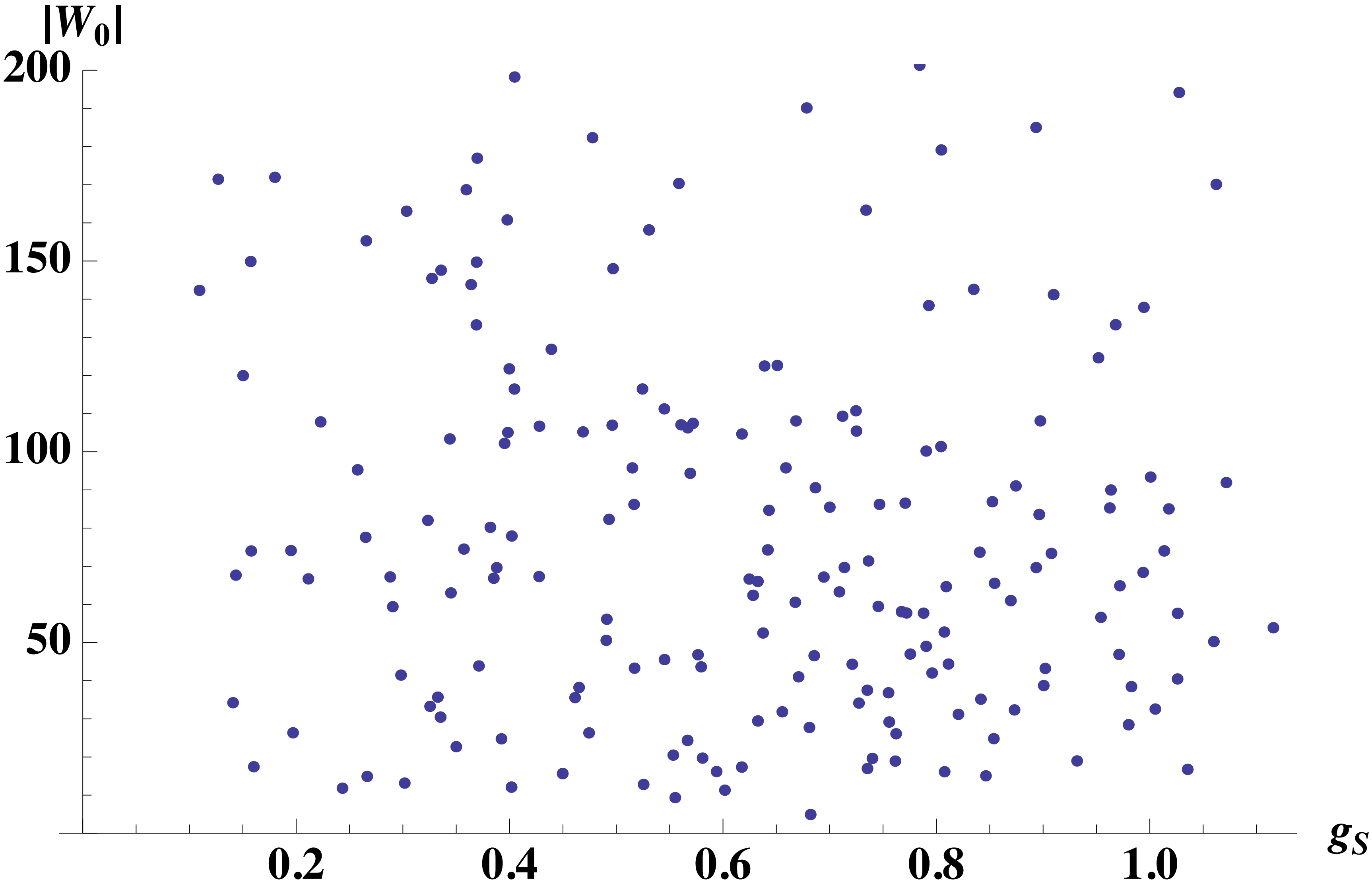




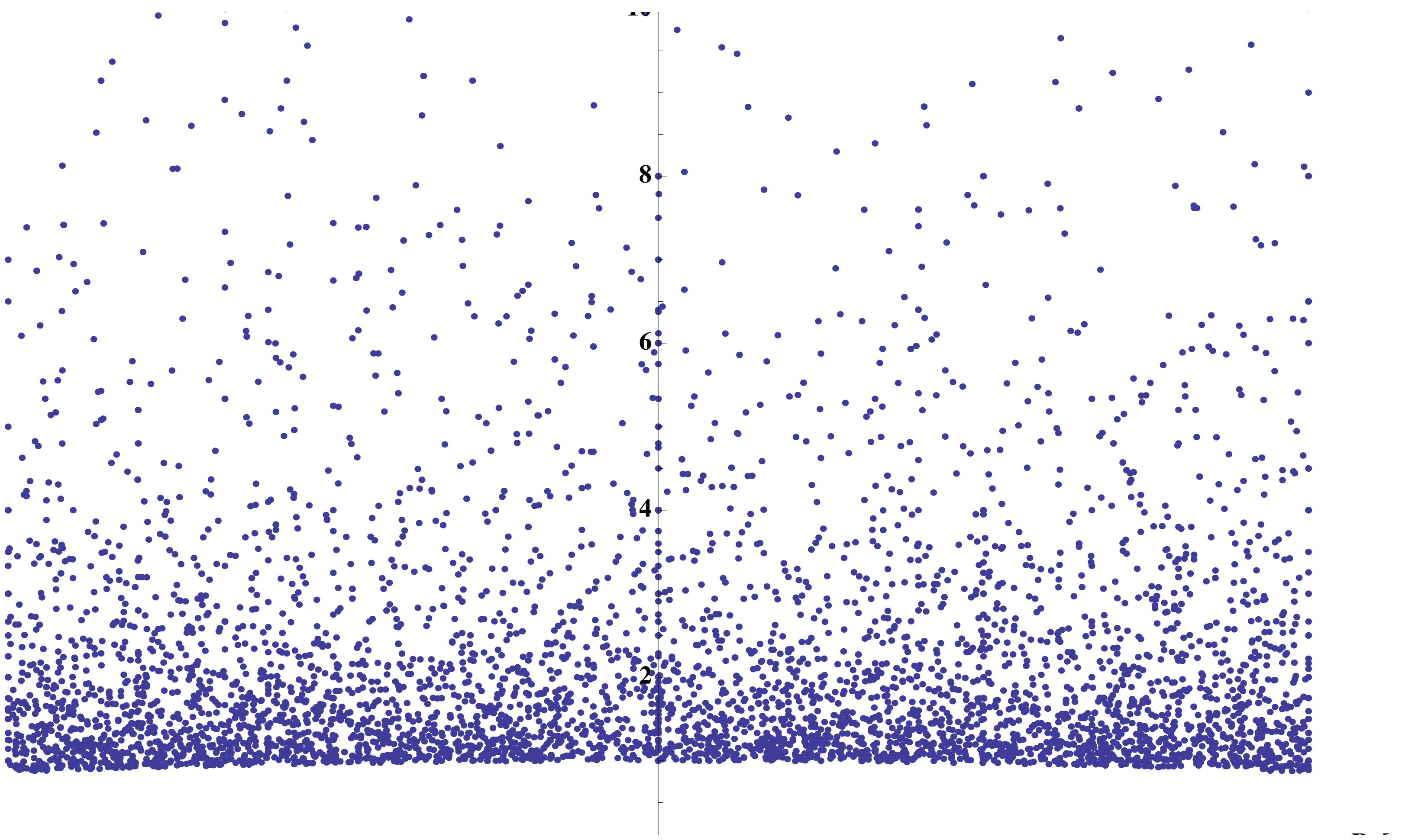
dP3

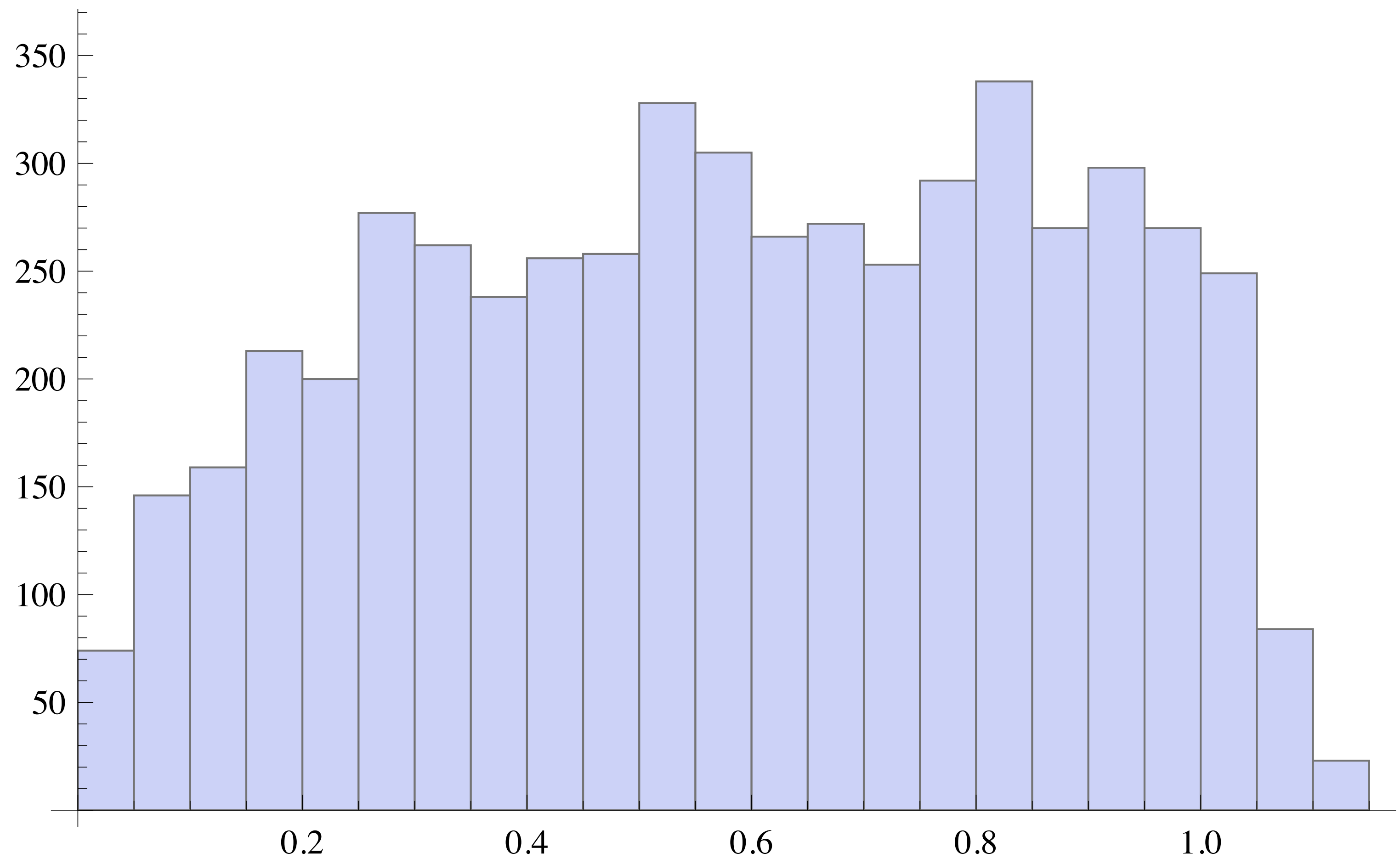






$|W_0|$
200
150
100
50
0.2
0.4
0.6
0.8
1.0
g_S


8
6
4
2


350
300
250
200
150
100
50
0.2
0.4
0.6
0.8
1.0

First Explicit String Model

- **Explicit Complex Structure + Dilaton stabilisation**
- **Explicit de Sitter after Kahler moduli stabilisation**
- **Chiral (realistic) spectrum**
- **Realistic scales** **(GUT, soft masses, no CMP, etc.)**
- **Detailed Phenomenology to be done**

CONCLUSIONS

- Continuous progress on local string models
- Several SUSY breaking scenarios
- Local models: Global embedding and dS Moduli Stabilisation!!!
  - ✓ Local models global embedding
- Most known ingredients used: geometry, fluxes, branes, perturbative, non-perturbative effects
- Relatively Complicated models

(Recall: SM is based on elegant principles but it is ugly !)

Open Questions

- **Single model with all moduli stabilised and realistic chiral matter (all cs)**
- **Stabilise 'flat' matter fields directions**
- **Complete phenomenological study of soft terms scenarios at low-energies**
- **Explicit realisation of dark radiation string models with excess of X-rays**
- **Extension to global F-theory models (α' corections to K)....**
- **K for matter fields, loop corrections, etc.**

ICTP The Abdus Salam International Centre for Theoretical Physics

To come:

PASCOS 2015 @ ICTP !!!