The LARGE Volume Scenario: a status report

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Stockholm, June 6th 2011

Talk Structure

- Moduli Stabilisation and Scales
- Supersymmetry Breaking
- Model Building
- Variations
- Future Directions

The LARGE Volume Scenario

The LARGE Volume Scenario (LVS) comes from considering alpha' corrections to IIB flux compactifications.

Balasubramanian-Berglund-Conlon-Quevedo, Conlon-Quevedo-Suruliz

$$
\begin{aligned}
K &= -2\ln\left(\mathcal{V}+\frac{\xi}{g_s^{3/2}}\right)-\ln\left(i\int\Omega\wedge\bar{\Omega}\right)-\ln\left(S+\bar{S}\right),\\
W &= \int G_3\wedge\Omega+\sum_i A_i e^{-a_i T_i}.
\end{aligned}
$$

Dilaton and complex structure moduli stabilised by fluxes, Kähler moduli stabilised non-perturbatively.

The LARGE Volume Scenario

The classic model is $\mathbb{P}^4_{[1,1,1,6,9]}$ which has two Kähler moduli.

$$\mathcal{V} = \left(\left(\frac{T_b + \bar{T}_b}{2} \right)^{3/2} - \left(\frac{T_s + \bar{T}_s}{2} \right)^{3/2} \right) \equiv \left(\tau_b^{3/2} - \tau_s^{3/2} \right).$$

At $\mathcal{V} \gg 1$ the potential for the Kähler moduli is

$$V = \frac{\sqrt{\tau_s} a_s^2 |A_s|^2 e^{-2a_s\tau_s}}{\mathcal{V}} - \frac{a_s |A_s W_0| \tau_s e^{-a_s\tau_s}}{\mathcal{V}^2} + \frac{\xi |W_0|^2}{\mathcal{V}^3}.$$

Non-perturbative instanton corrections balance against perturbative α' corrections.

The locus of the minimum satisfies

$$\mathcal{V} \sim |W_0| e^{c/g_s}, \qquad \tau_s \sim \ln \mathcal{V}.$$

The minimum is non-supersymmetric AdS and at exponentially large volume.

The large volume lowers the string scale and gravitino mass through

$$m_s = \frac{M_P}{\sqrt{\mathcal{V}}}, \qquad m_{3/2} = \frac{M_P}{\mathcal{V}}.$$

Basic Scales

Planck scale: M_P

String scale: $m_s \sim \frac{M_P}{\sqrt{\mathcal{V}}}$.

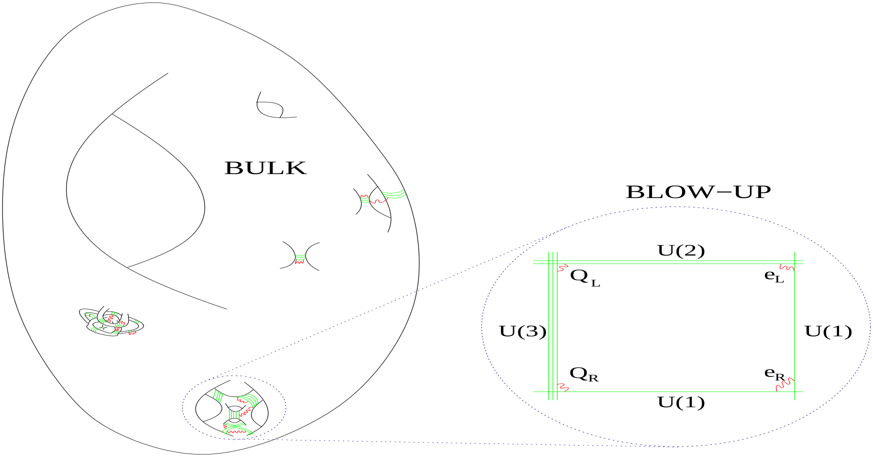
KK scale: $m_{KK} \sim \frac{M_P}{\mathcal{V}^{4/3}}$.

Gravitino mass: $m_{3/2} \sim \frac{M_P}{\mathcal{V}}$.

Complex structure moduli: $m_U \sim \frac{M_P}{\mathcal{V}}$

'Small' Kähler moduli: $m_{\tau_s} \sim \frac{(\ln \mathcal{V}) M_P}{\mathcal{V}}$.

Volume modulus: $m_{\tau_b} \sim \frac{M_P}{\mathcal{V}^{3/2}}$.


BULK
BLOW−UP
U(2)
Q_L
e_L
U(3)
U(1)
Q_R
e_R
U(1)

Stabilisation Questions

The LVS relies critically on the effect of α'^3 corrections to the scalar potential which are $\mathcal{V}^{-1}$ suppressed.

$$\delta K = -2 \ln \mathcal{V} + \frac{\xi}{\mathcal{V}} + \dots$$

Other known corrections do not destabilise these effects.

- Other bulk 10D α' corrections $(G_3^2 \mathcal{R}^3, F_5^2 \mathcal{R}^3, \dots)$ are higher order in $\mathcal{V}$
- Brane α' corrections are incorporated into GKP already.
- Open string loops dominate in the Kähler potential but are subdominant in the scalar potential (Berg-Haack-Kors/Pajer, Cicoli-JC-Quevedo)

$$\delta K = -2 \ln \mathcal{V} + \frac{\epsilon}{\mathcal{V}^{2/3}} + \frac{\xi}{\mathcal{V}} + \dots \rightarrow \delta V = 0 + \frac{\xi}{\mathcal{V}^3} + \frac{\epsilon^2}{\mathcal{V}^{10/3}} + \dots$$

Stabilisation Questions

The stabilisation proceeds via a 2-step procedure: first stabilise U, S, fix these, and then stabilise T.

However S, U are not significantly heavier (and in some cases are lighter) than the T moduli. Is it justified to 'integrate out' these moduli?

Answer is yes - essentially because Kähler potential factorises,

$$K = -2\ln \mathcal{V}(T) - \ln(\int \Omega \wedge \bar{\Omega})(U) - \ln(S + \bar{S})$$

and couplings between dilaton/CS moduli and Kähler moduli are volume-suppressed.

Studied by JC-Quevedo-Suruliz, Achucarro et al, Serone et al, Gallego...

Multiple Moduli

Can extend the number of moduli:

1. More blow-ups:

$$\mathcal{V} = \tau_b^{3/2} - \tau_{s,1}^{3/2} - \tau_{s,2}^{3/2} - \tau_{s,3}^{3/2} - \dots$$

   Small cycles are stabilised by instantons / D-terms.

2. More big moduli:

$$\mathcal{V} = \tau_1 \sqrt{\tau_2} - \tau_{s,1}^{3/2} - \tau_{s,2}^{3/2}$$

   Residual flat direction $\tau_1 \sqrt{\tau_2} =$ const is fixed by additional perturbative corrections (e.g. loop corrections)

   This gives an additional light fibre modulus, $m_{fibre} < m_{volume}$.

SUSY Breaking and Soft Terms

The MSSM is specified by its matter content (that of the supersymmetric Standard Model) plus soft breaking terms. These are

- Soft scalar masses, $m_i^2 \phi_i^2$
- Gaugino masses, $M_a \lambda^a \lambda^a$,
- Trilinear scalar A-terms, $A_{\alpha\beta\gamma} \phi^\alpha \phi^\beta \phi^\gamma$
- B-terms, $B H_1 H_2$.

The soft terms break supersymmetry explicitly, but do not reintroduce quadratic divergences into the Lagrangian.

We want to compute these soft terms for the large volume models.

SUSY Breaking and Soft Terms

- The computation of soft terms starts by expanding the supergravity K and W in terms of the matter fields C^α and moduli Φ,

$$\begin{aligned} W &= \hat{W}(\Phi) + \mu(\Phi) H_1 H_2 + \frac{1}{6} Y_{\alpha\beta\gamma}(\Phi) C^\alpha C^\beta C^\gamma + \ldots, \\ K &= \hat{K}(\Phi, \bar{\Phi}) + \tilde{K}_{\alpha\bar{\beta}}(\Phi, \bar{\Phi}) C^\alpha C^{\bar{\beta}} + [Z H_1 H_2 + h.c.] + \ldots, \\ f_a &= f_a(\Phi). \end{aligned}$$

- The matter kinetic function $\tilde{K}_{\alpha\bar{\beta}}(\Phi)$ is crucial in computing soft terms.

SUSY Breaking and Soft Terms

- Gaugino masses M_a, soft scalar masses $m^2_{\bar{i}j}$ and trilinears $A_{\alpha\beta\gamma}$ are given by

$$\begin{aligned}
M_a &= \frac{F^m \partial_m f_a}{\mathrm{Re} f_a}, \\
\tilde{m}^2_{\alpha\bar{\beta}} &= (m^2_{3/2} + V_0)\tilde{K}_{\alpha\bar{\beta}} \\
&\quad -\bar{F}^{\bar{m}} F^n \left(\partial_{\bar{m}} \partial_n \tilde{K}_{\alpha\bar{\beta}} - (\partial_{\bar{m}} \tilde{K}_{\alpha\bar{\gamma}}) \tilde{K}^{\bar{\gamma}\delta} (\partial_n \tilde{K}_{\delta\bar{\beta}}) \right) \\
A'_{\alpha\beta\gamma} &= e^{\hat{K}/2} F^m \Big[\hat{K}_m Y_{\alpha\beta\gamma} + \partial_m Y_{\alpha\beta\gamma} \\
&\quad - \Big((\partial_m \tilde{K}_{\alpha\bar{\rho}}) \tilde{K}^{\bar{\rho}\delta} Y_{\delta\beta\gamma} + (\alpha \leftrightarrow \beta) + (\alpha \leftrightarrow \gamma) \Big) \Big].
\end{aligned}$$

SUSY Breaking and Soft Terms

The LVS naturally involves gravity mediation.

The expected scales are then

- Tree level contributions -

$$m_{soft} \approx M_{3/2} \sim \frac{M_P}{\mathcal{V}}$$

- Loop level contributions ('anomaly mediation')

$$m_{soft} \approx \frac{\alpha_i}{4\pi} M_{3/2} \sim \frac{\alpha_i}{4\pi} \frac{M_P}{\mathcal{V}}$$

One of the most interesting features of LVS is the way it violates these expectations.

Basics of LVS Susy Breaking

Dilaton and complex structure moduli are flux-stabilised in a supersymmetric fashion,

$$D_S W = 0, \qquad D_U W = 0.$$

Kähler moduli break supersymmetry through the structure of the LVS supergravity potential.

Structure of susy breaking is dominantly (up to $\mathcal{O}(V^{-1})$) no-scale structure.

$$\begin{aligned} K &= -2 \ln \mathcal{V} \qquad (\sim -3 \ln(T + \bar{T})) \\ W &= W_0. \end{aligned}$$

Leading F-term is overall volume modulus, $|F^b|^2 = 3m_{3/2}^2$.

SUSY Breaking and Soft Terms

Original analyses of soft terms in LVS considered matter metric

$$\tilde{K}_{\alpha\beta} \sim \frac{\tau_s^{\lambda}}{\mathcal{V}^{\mu}}$$

For $\mu \neq 2/3$, soft terms are $\mathcal{O}(m_{3/2})$.

However locality of physical Yukawa couplings

$$\hat{Y}_{\alpha\beta\gamma} = e^{\hat{K}/2} \frac{Y_{\alpha\beta\gamma}}{(\tilde{K}_{\alpha}\tilde{K}_{\beta}\tilde{K}_{\gamma})^{\frac{1}{2}}}.$$

requires (0609180 JC, Cremades, Quevedo)

$$\tilde{K} \sim \frac{1}{\mathcal{V}^{2/3}}$$

$\mathcal{O}(m_{3/2})$ tree-level soft terms then cancel.

SUSY Breaking and Soft Terms

So consider

$$\tilde{K}_{\alpha\beta} \sim \frac{\tau_s^{\lambda}}{\mathcal{V}^{2/3}}$$

For $\lambda \neq 0$ soft terms are $\mathcal{O}\left(\frac{m_{3/2}}{\ln(M_P/m_{3/2})}\right)$.

However BMP instanton/SM chirality arguments say that instanton and SM cycles are different, giving $\lambda = 0$.

This suppresses classical supergravity contributions to soft masses of order $\mathcal{O}(m_{3/2})$.

SUSY Breaking and Soft Terms

The gauge kinetic function is

$$f_a = T_{SM} + \epsilon S$$

Instanton/chirality tensions implies no F-term for Standard Model cycle.

Flux stabilisation implies $F^S = 0$.

Vanishing F-terms for T_{SM}, S then imply that classical gaugino masses vanish.

SUSY Breaking and Soft Terms

If classical contributions vanish what about quantum ones?

Loop level gaugino masses are given by (Kaplunovsky-Louis, Randall-Sundrum, Giudice-Luty-Murayama-Rattazzi, Bagger-Moroi-Poppitz, JC-Goodsell-Palti)

$$
\begin{aligned}
m_{1/2} &= -\frac{g^2}{16\pi^2}\Big[(3T_G - T_R)\, m_{3/2} - (T_G - T_R)\, K_i F^i \\
&\quad - \frac{2T_R}{d_R} F^i \partial_i \left(\ln \det Z\right) + 2T_G F^I \partial_I \ln\left(\frac{1}{g_0^2}\right)\Big].
\end{aligned}
$$

However for no-scale susy breaking these terms also conspire to cancel and contributions of order $\mathcal{O}\left(\frac{\alpha}{4\pi} m_{3/2}\right)$ vanish.

SUSY Breaking and Soft Terms

The upshot is that all contributions to soft terms of $\mathcal{O}(m_{3/2})$ appear to vanish.

A possible and not yet understood exception is if 1-loop field redefinitions occur on the Standard Model cycle taking $T_{SM} \to T_{SM} + \ln \mathcal{V}$ JC-Palti, JC-Pedro, Choi-Nilles. Depending on how the field redefinitions affect the action soft terms may then be generated at $\mathcal{O}(m_{3/2})$ and suppressed only by a loop factor.

We then need to consider terms subleading in the volume.

Non-vanishing soft terms will be generated at some order in the inverse volume expansion, of size

$$M_{soft} = \frac{M_{3/2}}{\mathcal{V}^{\lambda}}.$$

SUSY Breaking and Soft Terms

Cross couplings between the dilaton and Kähler modulus ensure that soft terms will be unavoidably generated at $\lambda = 1$.

$$M_{soft} = \frac{M_{3/2}}{\mathcal{V}}.$$

For $M_{soft} \sim 1\text{TeV}$ this scenario requires $\mathcal{V} \sim 10^7$ and gives $M_b \sim 10^7\text{GeV}$.

A possible solution of the cosmological moduli problem....?

Contributions at order $\lambda = 1/2$ may be generated by the α'^3 correction but a consistent analysis also requires the α'^3 corrections to the matter metrics.

Scenarios

1. $M_{soft} \sim M_{3/2}, \quad \mathcal{V} \sim 10^{15}$ - original, not viable, ignores necessity of SM to be local
2. $M_{soft} \sim (\text{loop}) M_{3/2}, \quad \mathcal{V} \sim 10^{13} \to 10^{14}$ - only possible with field redefinitions of SM cycle and associated corrections to Kähler potential
3. $M_{soft} \sim \frac{M_{3/2}}{\sqrt{\mathcal{V}}}, \mathcal{V} \sim 10^{10}$ - soft terms come from α'^3 correction to K
4. $M_{soft} \sim \frac{M_{3/2}}{\mathcal{V}}, \mathcal{V} \sim 10^{7}$ - guaranteed soft terms from dilaton-Kähler mixing

Soft Terms: Flavour Structure

One of the most interesting stringy features is the total failure of a field theory flavour argument.

1. No symmetry prevents the presence of the following operator:

$$\int d^4 x d^4 \theta c_{ij} \frac{X^\dagger X}{M_P^2} Q_i Q_j^\dagger$$

2. Planck scale physics does not respect flavour symmetries and so c_{ij} is arbitrary.
3. For $F^X \neq 0$, this leads to anarchic soft masses and the gravity flavour problem.

This argument (has always) failed badly in string theory

Soft Terms: Flavour Structure

In contrast to naive EFT, in string theory, we have Kähler (T) and complex structure (U) moduli.

These are decoupled at leading order with no kinetic mixing

$$\mathcal{K} = -2\ln\left(\mathcal{V}(T)\right) - \ln\left(i\int \Omega \wedge \bar{\Omega}(U)\right) - \ln(S + \bar{S}).$$

The T-moduli break supersymmetry,

$$D_T W \neq 0, F^T \neq 0, \qquad D_U W = 0, F^U = 0.$$

The U-moduli appear in the superpotential

$$W = \ldots + \frac{1}{6} Y_{\alpha\beta\gamma}(U) C^\alpha C^\beta C^\gamma + \ldots.$$

Soft Terms: Flavour Structure

The matter metrics have a leading universal dependence on the Kähler moduli,

$$\tilde{K}_{\alpha\beta} \sim \frac{1}{\mathcal{V}^{2/3}}$$

'In a local model, different generations see the bulk volume in the same way'

The no-scale vanishing of $\mathcal{O}(m_{3/2})$ contributions to soft terms is a consequence of this universal dependence.

This shows the inadequacy of EFT arguments on flavour. However it does not establish flavour universality, as soft term generation occurs at a higher order in the inverse volume expansion.

The calculational structure of subleading contributions to matter metrics and soft terms is not well established.

Soft Terms: Flavour Structure

Soft terms can come from

1. Subleading corrections to moduli Kähler potnetial
2. Subleading corrections to matter Kähler metric (Blumenhagen et al)
3. Dilaton and complex structure F-terms induced by mixing of Kähler and complex structure moduli.
4. Non-perturbative appearances of T in superpotential

   Berg-Marsh-McAllister-Pajer

Soft Terms: Flavour Structure

One source of subleading soft terms recently considered

Berg-Marsh-McAllister-Pajer

$$\delta W = \delta Y_{ijk} \Phi^i \Phi^j \Phi^k e^{-a_s T_s}$$

These are non-perturbative contributions to SM Yukawa couplings coupled to hidden moduli instantons.

For generic $\mathcal{O}(1)$ values of δY_{ijk} with no flavour structure dangerous contributions to soft terms can be generated.

These can be large enough to rule out scenario for cases of highly suppressed soft terms, $m_{soft} \sim M_{3/2}/\mathcal{V}$.

Soft Terms: Flavour Structure

One source of subleading soft terms recently considered

Berg-Marsh-McAllister-Pajer

$$\delta W = \delta Y_{ijk} \Phi^i \Phi^j \Phi^k e^{-a_s T_s}$$

Not clear whether such terms are present or not, and hard to calculate explicitly.

To make constraints, a key assumption is that δY_{ijk} is 'generic' with $\mathcal{O}(1)$ values.

Genericity expectations are often violated in string theory: tree level SM Yukawas Y_{ijk} are known to be non-generic and so generic δY_{ijk} is not well justified.

Important but hard to make more explicit.

Model Building

How can we realise the Standard Model? For chirality must use (possibly collapsed) D7 branes rather than D3 branes.

Gauge couplings are

$$\alpha_i^{-1} = \frac{T_i}{2\pi}$$

However

$$\langle T_b \rangle \sim \mathcal{V}^{2/3} \gg 1, \qquad \langle T_s \rangle \gtrsim \mathcal{O}(1)$$

Observed gauge couplings imply SM cannot be realised on large cycle T_b.

Necessity: a local model with SM on a small cycles with sizes close to string scale.

Model Building

There are *a priori* two options for the realisation of the Standard Model

1. Geometric limit with cycle size $\langle T \rangle > l_s^4$

$$f_a = T + \epsilon_a S$$

   Intersecting fluxed D7-branes/F-theory

2. Collapsed limit with cycle size $\langle T \rangle \approx 0$

$$f_a = S + \epsilon_a T_a$$

   D3/D7 branes at del Pezzo singularities

Model Building

Original analyses of 0505076, 0610129 assumed SM could be realised on cycle T_s of moduli stabilisation model.

T_s is stabilised by instanton $e^{-a_s T_s}$ and has non-zero F-term

$$F^s \sim 2\tau_s m_{3/2}$$

Branes wrapping T_s collect soft terms of order $\mathcal{O}\left(\frac{m_{3/2}}{\ln(M_P/m_{3/2})}\right)$.

However there is a tension (Blumenhagen-Moster-Plauschinn) between the chirality of the SM and a bare instanton e^{-aT} in the superpotential (extra chiral zero modes can require instanton to be dressed with SM fields).

Stabilisation of SM cycle should *not* be performed by instantons (cf KKLT/mirage)

However see Grimm-Palti-Weigand recently

Model Building

For branes at singularities, Kähler moduli appears as FI term for gauge theory.

Scalar potential is

$$V_D = g^2 \left(\sum q|\Phi|^2 + \langle T \rangle\right)^2$$

Combining with a soft mass term

$$V_{soft} = m^2 |\Phi|^2$$

can fix $\langle T \rangle = 0$ at the singularity.

Model Building

Models can be constructed as D3/D7 quivers at del Pezzo singularities.

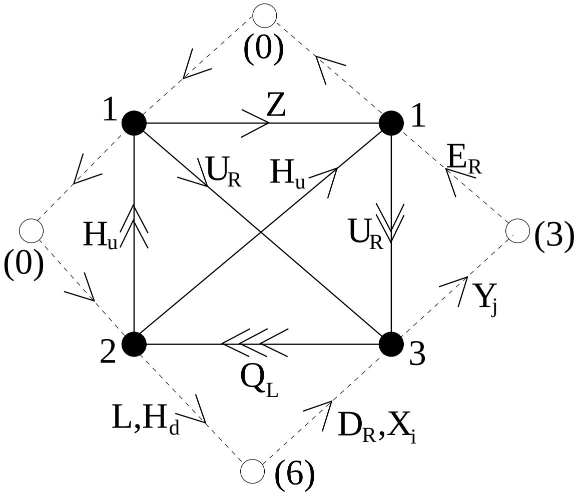
del Pezzo quivers and superpotentials have global symmetries that give non-trivial flavour textures.

Semi-realistic models have been proposed by Aldazabal-Ibanez-Quevedo-Uranag, JC-Maharana-Quevedo, Burgess-Krippendorf-Maharana-Quevedo

Promising textures can be obtained, although having to give vevs to various field along flat directions without a microscopic justification

An example quiver is....

Model Building



Model Building

The power of LVS is often the ability to suppress quantities by powers of $\mathcal{V}$

One would like to be able to do this also for some dimensionless properties of local models (e.g. Yukawa couplings).

Ideas in this direction Burgess-JC-Maharana-Quevedo are that local models have isometries/ global symmetries that are broken by the bulk, and so should be volume-suppressed.

No really convincing examples yet though.

Cosmology I

There are several proposals for inflationary models using LVS.

1. Kähler moduli inflation JC-Quevedo

Take

$$\mathcal{V} = \tau_1^{3/2} - \tau_2^{3/2} - \tau_3^{3/2} - \ldots$$

and move one small modulus out, $\tau_{INF} >> 1$. Flat potential is lifted only by non-perturbative effects and can generate inflation.

Principal danger is loop corrections to Kähler potential lifting the flatness.

Cosmology II

2. Fiber modulus inflation Burgess-Cicoli-Quevedo

Take

$$\mathcal{V} = \tau_1 \sqrt{\tau_2} - \tau_3^{3/2} - \tau_4^{3/2} - \ldots$$

The direction $\tau_1 \sqrt{\tau_2}$ is flat up to subleading corrections to the Kähler potential.

These corrections are volume-suppressed, and so the potential can be flat enough for inflation.

Possible to achieve close-to-Planckian field ranges.

Cosmology III

The light volume modulus $m_b \sim \frac{M_{3/2}}{\sqrt{\mathcal{V}}}$ has important cosmological implications.

As it is much emphlighter than the gravitino mass the cosmological moduli problem is more severe in LVS than in other frameworks.

The light volume modulus may be a potential dark matter candidate through a non-thermal history, although it is unclear how to fix the abundance.

This problem may be alleviated if $m_{soft} \ll m_{3/2}$ when the volume modulus may have a mass $m \gg 1\text{TeV}$.

TeV Strings

- How large is LARGE in LARGE volume?
  Is it LARGE or LARGE or LARGE or LARGE?
- $$\text{Recall: } M_s = \frac{M_P}{\sqrt{\mathcal{V}/l_s^6}}$$
- Is it possible to realise strings at the TeV scale? This requires $\mathcal{V} = 10^{30} l_s^6$?

  What about the large extra dimensions scenario with 2 dimensions large and 4 small?

TeV Strings

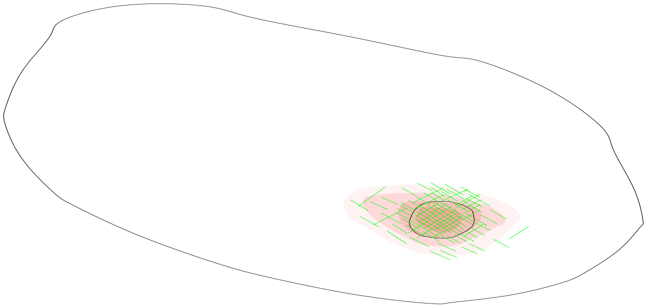
- Recently there is a proposal to achieve this by Cicoli, Burgess and Quevedo using fibration CYs.

$$\mathcal{V} = \tau_1 \sqrt{\tau_2} - \tau_3^{3/2} - \tau_4^{3/2} - \ldots$$

- Ordinary LARGE volume mechanism stabilises $\mathcal{V} \sim \tau_1 \sqrt{\tau_2} \gg 1$ and leaves a residual flat direction in the (τ_1, τ_2) plane.
- Polyinstanton corrections (becoming strong for $\tau_1 \sim \mathcal{O}(1)$ lift the residual flat direction and give $\tau_2 \gg \tau_1$.
- Issues: light moduli and fifth forces, absence of perturbative lifting of flat direction

Axions

- A QCD axion with a decay constant $10^9\text{GeV} < f_a < 10^{12}\text{GeV}$ may solve the strong CP problem.
- The axion is the RR 4-form reduced on the SM 4-cycle.
- f_a measures the axion-matter coupling.



Axions

- The coupling of the axion to matter is a local coupling and does not see the overall volume.
- This coupling can only see the string scale, and so

$$f_a \sim m_s \sim \frac{M_P}{\sqrt{\mathcal{V}}}.$$

- The largeness of the volume (for $\mathcal{V} \sim 10^{15}$) may then explain the smallness of the axion decay constant relative to the Planck scale,

$$f_a \sim \frac{M_P}{\sqrt{\mathcal{V}}} \sim 10^{11}\text{GeV}.$$

Weak gauge groups

One distinctive feature of LVS is the presence of a large cycle with $T \gg 1$, implying $g^2 \ll 1$.

This gives two possibilities:

1. The presence of hyper-weakly coupled gauge groups with $g^2 \lll 1$.

   A very distinctive feature of LARGE volume/low string scale.

2. Possible kinetic mixing involving the weakly coupled bulk gauge group and light U(1)s Goodsell, Jaeckel, Ringwald...

IIA Models

A mirror IIA construction can be described Palti-Tasinato-Ward using intersecting D6-branes

The idea is to exactly mirror the IIB construction in IIA.

The dual of large volume is an extremely weak string coupling.

Finite gauge couplings come from small g_s mutliplied by a large volume.

The space is highly anisotropic and the easy Swiss-cheese IIB geometric picture is harder to see.

Summary

The LVS remains one of the most promising approaches to moduli stabilisation and supersymmetry breaking in string theory.

Its key advantages are:

1. Stabilisation deep in the controlled, weakly coupled regime of moduli space (cf KKLT).
2. Automatic generation of hierarchically small supersymmetry breaking without fine-tuning
3. (A practical advantage:) by forcing a restriction to local model building, it eliminates some of the complexities required for globally consistent constructions.

Open Problems

The biggest open issue in the LVS (also other IIB models) is the structure of supersymmetry breaking.

At what order in volume are the soft terms generated? Where are the soft terms generated?

What is the structure of the resulting soft terms? Do they have a distinct phenomenology?

What other applications of the large volume are there?

What are the distinctive signatures of the many hierarchical scales generated by a volume $\mathcal{V} \gg 1$?