Instanton effects in chiral large volume scenarios

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MPI für Physik

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- R. Blumenhagen, E. Plauschinn, S. Moster: *to appear soon*

Motivation

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- Motivation: discuss these models in view of the recent progress in instanton calculus.
- Especially: is the "*modular approach*" in model building really consistent?

Outline

Large volume models

- Balasubramanian, Berglund, Conlon, Quevedo: *"Systematics of Moduli Stabilisation in Calabi-Yau Flux Compactifications"*
- Conlon, Kom, Suruliz, Allanach, Quevedo: *"Sparticle Spectra and LHC Signatures for Large Volume String Compactifications"*
- Many other by the Cambridge group
- Berg, Haack, Pajer: *Jumping Through Loops: On Soft Terms from Large Volume Compactifications*

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- No-scale structure for Kähler moduli T_I is broken by α' corrections to the Kähler potential

$$K = -2\ln(\mathcal{V} + \frac{\xi}{2g_s^{3/2}}) - \ln(S + \overline{S}) - \ln(-i\int_X \Omega \wedge \overline{\Omega})$$

  as well as non-perturbative corrections to the superpotential, generated by instantons

$$W_{np} = A(S, U)e^{-S_{inst}} = A(S, U)e^{-i\sum a_n T_n}$$

Large volume models - swiss cheese structure

- If the volume of X is given in form $\mathcal{V} = \tau_b^{3/2} - \sum \tau_i^{3/2}$ there exists a non-susy minimum in the F-term potential with

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$$V_F \sim \frac{\lambda \sqrt{\tau_s} e^{-2a_s\tau_s}}{\mathcal{V}} - \frac{\mu \tau_s e^{-a_s\tau_s}}{\mathcal{V}^2} + \frac{\nu}{\mathcal{V}^3}$$

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- D7-branes supporting the MSSM wrap also the “small” cycle.

Instantons and chirality

E3-brane instantons

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$$Z = N \int_{D_{\rm D7} \cap D_{\rm E3}} c_1(\mathcal{L}) = N \int_X c_1(\mathcal{L}) \wedge [D_{\rm D7}] \wedge [D_{\rm E3}]$$

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- If D7 supports the MSSM, we demand $\langle \Phi_{\mathrm{SM}} \rangle = 0$, avoiding a contribution to W of the form above.

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- If E3 lies on top of D7, one gets a ADS like contribution to W:

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  assuming that we are on the Higgs branch.
- If D7 supports the MSSM, this would break the flavour gauge group completely

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- Consequence: we cannot generate a contribution to W of the form

$$W \sim A e^{-T_{\mathrm{SM}}}$$

$\Rightarrow$ V_F is independent of T_{SM}, and thus cannot be fixed!

D-Terms

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- Such chiral D-brane models generically contain anomalous $U(1)$'s.
- These are cancelled by gauging the axionic shift symmetry leading to D-term potential

$$V_D = \sum_{a=1}^{K} \frac{1}{T_{\mathrm{SM}}} \left(\sum_i Q_i^{(a)} |\Phi_i|^2 - \xi_a \right)^2$$

with FI-terms

$$\xi_a = \frac{1}{\mathcal{V}} \int_X c_1(\mathcal{L}_a) \wedge [D_{\mathrm{SM}}] \wedge J$$

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- In order not to destabilise the large volume vacuum found at order $\mathcal{V}^{-3}$, require $V_D = 0$
- Remember: $\xi \sim \int_X c_1(\mathcal{L}_a) \wedge [D_{\mathrm{SM}}] \wedge J$
  Hope: since J depends implicitly on all Kähler moduli, the condition $V_D = 0$ fixes the so far unconstrained modulus T_{SM} at $\mathcal{O}(\mathrm{Vol}(D_{\mathrm{Inst}}))$.

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6. Minimize $V_F + V_D$ and analyse, if the Kähler moduli are stabilised inside the Kähler cone.

An example

The manifold

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- The "swiss-cheese"-structure can best be seen in a "diagonal basis"

$$\mathcal{V} = \sqrt{\frac{2}{45}}\left(\tau_a^{3/2} - \tfrac{1}{3}\tau_b^{3/2} - \tfrac{\sqrt{5}}{3}\tau_c^{3/2}\right)$$

Rigid cycles

In order to contribute to W, the E3-instantons should be rigid, i.e.

$$H^0(D,\mathcal{O}_D)=1, \quad H^1(D,\mathcal{O}_D)=H^2(D,\mathcal{O}_D)=0$$

- A necessary condition for this is $\chi(D,\mathcal{O}_D)=1$. We found five candidate cycles with wrapping numbers

$$(m,n,l)=\{(1,0,0),(1,1,0),(2,1,0),(2,2,0),(12,11,0)\}$$

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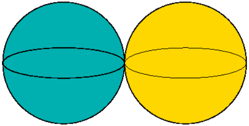
- The first four four-cycles have really $H^*(D,\mathcal{O}_D) = (1,0,0)$.
- The cycles $\{(1,1,0),(2,1,0),(2,2,0)\}$ are singular, but we allow E3-instantons to wrap also those



Branes and instantons

- We choose two stacks of D7-branes wrapping the rigid four-cycles

$$D_{D7_A} = D_5 + D_6 = \frac{1}{3}(D_b - 2D_c), \quad D_{D7_B} = D_5 = D_c$$

with line bundles

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- No *chiral* zero modes on D7-E3 intersections.
- Possible *vector-like* bosonic and fermionic zero modes could be removed by discrete Wilson lines or discrete replacement of D7 or E3

Scalar potential

- for the F-term potential, we find:

$$V_F \simeq \frac{\lambda}{\mathcal{V}}(\sqrt{5\tau_b} + \sqrt{\tau_c})e^{-\frac{4\pi}{3}(\tau_b+\tau_c)} - \frac{\mu}{\mathcal{V}^2}(\tau_b + \tau_c)e^{-\frac{2\pi}{3}(\tau_b+\tau_c)} + \frac{\nu}{\mathcal{V}^3}$$

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- Example with plausible values for $\lambda, \mu, \nu, \sigma$:

$$\tau_b \approx 1.64, \quad \tau_c \approx 0.33, \quad \mathcal{V} \approx \tau_a^{3/2} \approx 2.15 \times 10^{16}$$

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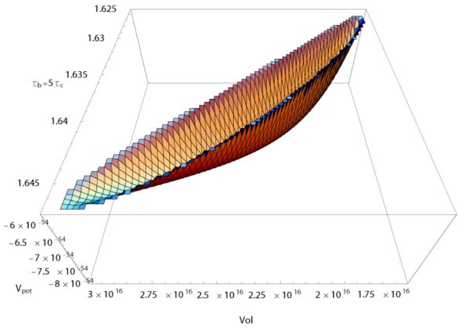

$V(\mathcal{V}, \tau_b)$ for $\tau_c = 0.33$.

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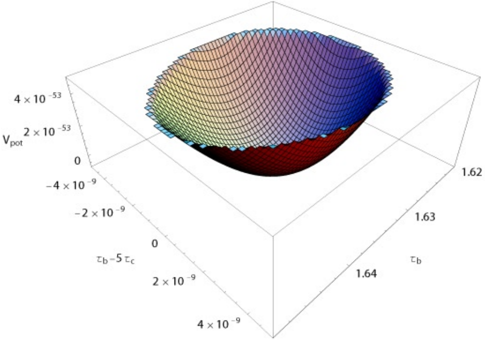

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- Taking into account F- *and* D-terms allows to fix all Kähler moduli.
- As a proof of concept, we presented a toy model on the CY $\mathbb{P}^4_{[1,3,3,3,5]}[15]$.