WEAK-coupling IIA Compactifications

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IIA and IIB Geometric Flux Compactifications

Compactifications on explicit manifolds with all moduli stabilised

Theory	10D Understanding	Chiral Spectrum	SUSY Breaking	deSitter/inflation
IIA	✓	✓ (D6)	✗	✗ (no-go)
IIB	✗ (non-pertubative)	✓ (D7/3)	✓ (Warping/LARGE -volume)	✓

Key reason: Mirror symmetry interchanges H-flux and geometry.

Study IIA at its 'geometric intersection' with IIB – H-flux with no-legs along the T-duality directions.

IIA orientifolds: complex-structure moduli

Lesson from IIB: corrections away from large complex-structure limit are important (mirrors to IIB alpha' corrections).

Balasubramanian et al. '05

Start from N=2 CY prepotential and impose orientifold constraints.

$$F = \frac{1}{6} d_{abc} \frac{Z^a Z^b Z^c}{Z^0} + d^{(1)}_{ab} Z^a Z^b - \frac{1}{2} d^{(2)}_a Z^a Z^0 - i (Z^0)^2 \xi + \mathcal{O}\left(e^{iZ}\right) .$$

$$\mathrm{Im}\,(CZ_{\hat{k}}) = \mathrm{Re}\,(CF_{\hat{k}}) = \mathrm{Re}\,(CZ_\lambda) = \mathrm{Im}\,(CF_\lambda) = 0 .$$

Candelas et al. '91

Grimm and Louis '04

We get the Kahler potential

$$K^Q = -\ln\left[S + \bar{S}\right] - 2\ln\left[\mathcal{V}' + \frac{\xi'}{2}\right]$$

$$\frac{1}{6} d_{\lambda\rho\sigma} q^\lambda q^\rho q^\sigma + s^{3/2} \frac{\xi}{2} \equiv \mathcal{V}' + \frac{\xi'}{2} ,$$

$$q^\lambda = -2 s^{-\frac{1}{2}} \mathrm{Im}\,(CZ^\lambda) .$$

The superfields are

$$S = 2\mathrm{Re}\,(CZ^0) - i\xi^0 \equiv s + i\sigma \qquad U_\lambda = -2\mathrm{Re}\,(CF_\lambda) + i\xi_\lambda \equiv u_\lambda + i\nu_\lambda .$$

This is the mirror to the alpha' corrected IIB Kahler potential.

The Kahler moduli superpotential

From now on we work in the large complex-structure (no-scale) regime

We turn on the full RR fluxes but only one component of H-flux

$$H = -h_0 \beta^0 \,, \quad F_0 = -f_0 \,, \quad F_2 = -\tilde{f}^i \omega_i \,, \quad F_4 = -f_i \tilde{\omega}^i \,, \quad F_6 = -\tilde{f}_0 \epsilon \,.$$

The superpotential reads

$$W = W^T(T) + W^Q(S) = \frac{f_0}{6} K_{ijk} T^i T^j T^k + \frac{1}{2} K_{ijk} \tilde{f}^i T^j T^k - f_i T^i + \tilde{f}_0 - i h_0 S \,.$$

Dilaton F-term $-i h_0 \bar{S} = W^T$.

When satisfied the Kahler F-terms read

$$b^i = -\frac{\tilde{f}^i}{f_0} \,. \qquad \kappa \left[\kappa_{ijk} \tilde{f}_j \tilde{f}_k + 2 f_0 f_i \right] = 0 \,. \qquad \mathcal{V} \equiv \frac{1}{6} K_{ijk} \tau^i \tau^j \tau^k \equiv \frac{1}{6} \kappa$$

This means that either we pick the fluxes and the Kahler moduli are flat directions, or they are driven to a non-physical regime.

Adding alpha' corrections

To stabilise the Kahler moduli in a physical regime we add the effects of alpha' corrections.

This is done as in the IIB literature: we use the correction calculated due to the induced dilaton gradient

$$\mathcal{V}R_4 \to \left(\mathcal{V} + \frac{\epsilon}{2}\right) R_4 \,,$$

Becker et al. '02

and fit this into a truncated prepotential framework, matching the mirror symmetry predictions

$$F = -\frac{1}{6}\frac{K_{ijk}T^iT^jT^k}{T^0} + K^{(1)}_{ij}T^iT^j + K^{(2)}_iT^iT^0 - i\epsilon(T^0)^2 \,.$$

$$K^T = -\ln 8\left(\mathcal{V} + \frac{1}{2}\epsilon\right) \,.$$

$$W^T = f_0F_0 - \tilde{f}^iF_i - f_iT^i + \tilde{f}_0 = \frac{f_0}{6}K_{ijk}T^iT^jT^k + \frac{1}{2}K_{ijk}\tilde{f}^iT^jT^k - \bar{f}_iT^i + \bar{f}_0 - 2if_0\epsilon$$

$$\bar{f}_i = f_i - f_0K^{(2)}_i + 2\tilde{f}^jK^{(1)}_{ij} \,, \quad \bar{f}_0 = \tilde{f}_0 - \tilde{f}^iK^{(2)}_i \,.$$

Fixing the Kahler moduli

This fixes the Kahler moduli as

$$9\epsilon f_0^2 \kappa_i = (3\epsilon - 2\kappa)\left(K_{ijk}\tilde{f}^j\tilde{f}^k + 2f_0\bar{f}_i\right) \, .$$

Or schematically

$$\tau \simeq \frac{-9\epsilon f_0^2}{2K\left(\tilde{f}^2 + 2f_0\bar{f}\right)} \, , \qquad s \simeq \frac{f_0 K\tau^3}{6h_0} \, ,$$

If want to pick the fluxes so flat directions at tree-level then Moduli stabilised at unphysical points again.

For general fluxes tree-level potential is not flat but drives towards zero volume. To move away require competition between alpha' corrections and tree-level terms.

Alpha' expansion breakdown? Not so simple with fluxes.

Taking F_0 large means can still expand in terms of the Kahler vevs.

Fixing the Kahler moduli

Schematically the scalar potential reads

$$V \sim \frac{f_0^2}{\tau^3} + \frac{h_0^2}{\tau^6} + \frac{f_0 h_0}{\tau^{\frac{9}{2}}} + \frac{f_0^2 \epsilon}{\tau^6} + \frac{\left(f_i + f_0 K_i^{(2)}\right)^2}{\tau^7} + \frac{\left(f_i + f_0 K_i^{(2)}\right) f_0 \epsilon}{\tau^8} + \frac{f_0^2 \epsilon^2}{\tau^9} + \ldots$$

Tree-level in F_4 more supressed than higher orders in F_0 .

Can show that first four terms vanish at minimum for dilaton.

The moduli are stabilised by a competition between a tree level term in F_4 and a higher order term in F_0 .

Other corrections?

It can be shown that these are equivalent to the IIB ISD conditions away from the large complex-structure limit.

String-loop corrections highly supressed at minimum where coupling exponentially small.

Including the complex-structure moduli

Having fixed the Kahler moduli and dilaton we can fix the complex-structure moduli using D6-brane gaugino condensation or E2-instantons. This is the mirror to KKLT or LARGE-volume.

$$W = W_0(S,T) + \sum A_{\tilde{\lambda}} e^{-a_{\tilde{\lambda}} U_{\tilde{\lambda}}} \, .$$

$$V = \frac{1}{32 s \mathcal{V}} \left[\frac{8 u_{\tilde{\lambda}}^{\frac{1}{2}}}{3 \mathcal{V}' \alpha h^{\tilde{\lambda}}} \left| A_{\tilde{\lambda}} a_{\tilde{\lambda}} \right|^2 e^{-2 a_{\tilde{\lambda}} u_{\tilde{\lambda}}} - \frac{4 u_{\tilde{\lambda}}}{\mathcal{V}'^2} \left| A_{\tilde{\lambda}} a_{\tilde{\lambda}} \right| |W_0| e^{-a_{\tilde{\lambda}} u_{\tilde{\lambda}}} + \frac{3 \xi' |W_0|^2}{4 \mathcal{V}'^3} \right] ,$$

This has an AdS minimum with exponentially large $\mathcal{V}'$.

Look at 10D dilaton = string coupling

$$g_s^{-1} = e^{-\hat{\phi}} \simeq \sqrt{2} s^{\frac{1}{4}} \mathcal{V}^{-\frac{1}{2}} \mathcal{V}'^{\frac{1}{2}} \, .$$

Hence we are at WEAK (or maybe weak) coupling.

Consequence of T-duality mixing dilaton and metric components.

Uplifting with D6 branes at angles

No go: No inflation/deSitter vacua with moduli stabilised in IIA on CY

(at tree level in alpha'). Hertzberg et al. '08

We consider a D6 brane calibrated with a different phase to the calibration of the orientifold wrapping the cycle

$$\pi = e_0 \alpha_0 + m_\lambda \alpha_\lambda + e^\lambda \beta^\lambda \ ,$$

Reducing the DBI action gives

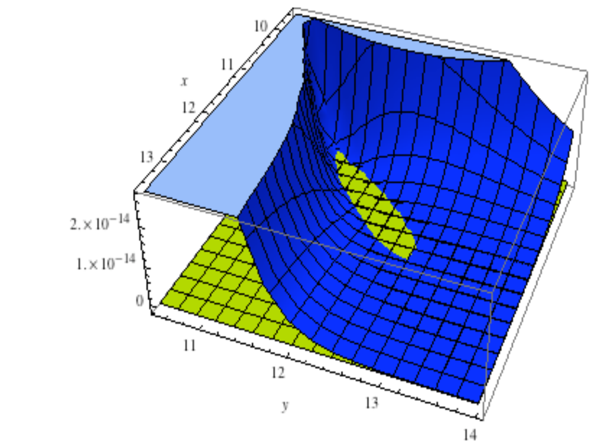
$$V_D = \frac{\left(m_\lambda q^\lambda\right)^2}{4\left(\mathcal{V}' + \frac{1}{2}\xi'\right)^2 \left(e_0 s + e^\lambda u_\lambda\right)}$$

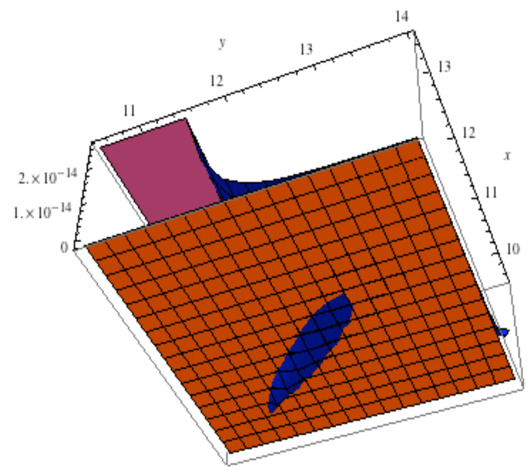
Taking two modulus toy model and picking typical values for the many parameters gives

$$V = \frac{\sqrt{u_s} e^{-2u_s}}{\mathcal{V}'} - \frac{2u_s e^{-u_s}}{\mathcal{V}'^2} + \frac{10^{\frac{3}{2}}}{\mathcal{V}'^3} + \frac{10^3 \mathcal{V}_0}{s_0^2 \mathcal{V}'^2} \frac{u_s}{e_0 s_0 + e^b u_b + e^s u_s} \ .$$

deSitter minima

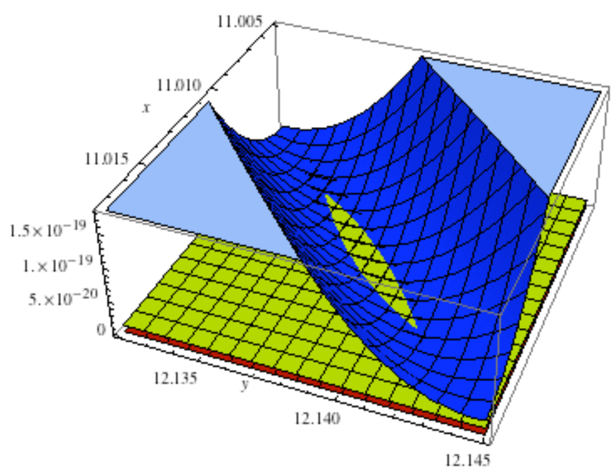
No uplift AdS minimum:

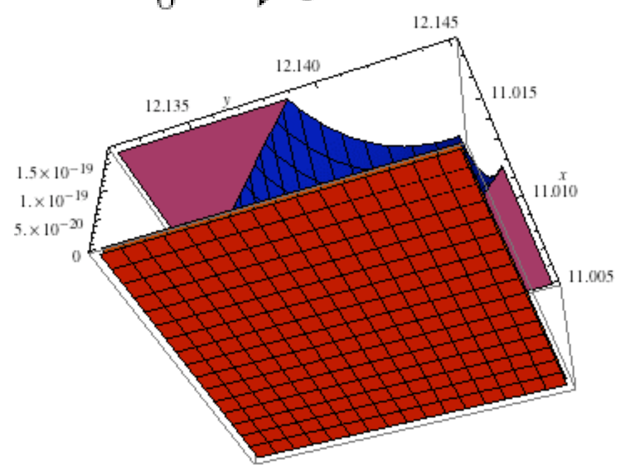




Example deSitter minimum

$$V_1 = \frac{10^3 \mathcal{V}_0}{s_0^2 e^b} \frac{u_s}{\mathcal{V}'^{\frac{8}{3}}} \equiv 1.0323 \times 10^{-2} \frac{u_s}{\mathcal{V}'^{\frac{8}{3}}} \ .$$





String and SUSY scale + inflation

We have

$$m_s \sim \frac{g_s}{\sqrt{\mathcal{V}}} M_p \,, \quad m_{\frac{3}{2}} \sim \frac{g_s^2}{\mathcal{V}} M_p$$

Require $g_s \sim 10^{-7}$.

Can recreate the IIB Kahler moduli inflation model.

Conlon Quevedo ‘05

Summary

Can recreate some of the IIB phenomenological success in IIA.

Alpha' corrections play a crucial role in fixing the Kahler moduli and avoiding the no-go theorem for D6 uplifting.

The IIA mirrors to IIB LARGE-volume models are at WEAK-coupling

Can study LARGE-volume/KKLT phenomenology from both sides of the mirror

Perhaps some things easier to calculate in the IIA side:

- Matter sector related to CY complex-structure instead of Kahler.
- Exponentially weak string coupling