Type IIB flux compactifications with $h^{1,1} = 0$

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J. Bardzell, E. Gonzalo, M. Rajaguru, D. Smith in progress
Becker, Becker, Vafa, Walcher hep-th/0611001
Becker, Becker, Walcher 0706.0514

NSF

FWF Der Wissenschaftsfonds.

Outline

- Review of flux compactifications in type IIA and IIB
- The cool results in type IIB for $h^{1,1} = 0$
- Non-renormalization theorems and control issues
- Conclusion

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Type II Flux Compactifications

- In massive type IIA we have NSNS and RR fluxes

$$H_3 \text{ and } F_0, F_2, F_4, F_6$$

- The moduli are encoded in

Grimm, Louis hep-th/0412277

$$J_c = B_2 + i\,J \in H_-^{1,1}(M_6) \qquad \text{and}$$
$$\Omega_c = C_3 + i\,e^{-\phi} Re(\Omega) \in H_+^{3,0}(M_6) + H_+^{2,1}(M_6)$$

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- With (smeared) O6-planes and the above fluxes we can stabilize *all geometric* moduli but only *one* of the C_3-axion ($W \supset \int H_3 \wedge \Omega_c$)

DeWolfe, Giryavets, Kachru, Taylor hep-th/0505160

- Only for $h_+^{2,1} = 0$, i.e. $h^{2,1} = 0$, are all moduli stabilized

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H_3 and F_3

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$\tau = C_0 + i\, e^{-\phi}$ $\qquad$ $T_4 = C_4 + i\, J \wedge J \in H_+^{2,2}(M_6)$

$G_2 = C_2 + i\, B_2 \in H_-^{1,1}(M_6)$ $\qquad$ $\Omega \in H_+^{3,0}(M_6) + H_+^{2,1}(M_6)$

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- With O3/O7-planes and the above fluxes we can only stabilize *the complex structure and axio-dilaton* using the GVW superpotential ($W = \int (F_3 - \tau H_3) \wedge \Omega$)

Giddings, Kachru, Polchinski hep-th/0105097

- Only for $h_-^{1,1} = 0$ and $h_+^{2,2} = 0$ are all moduli stabilized

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Type II Flux Compactifications

Type IIA

All moduli stabilized: $h^{2,1} = 0$

Type IIB

All moduli stabilized: $h^{1,1} = 0$

- Type IIA and type IIB on CY_3 are related by mirror symmetry
- This should extend to spaces with $h^{2,1} = 0$ that are dual to *spaces* with $h^{1,1} = 0$

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- Type IIA and type IIB on CY_3 are related by mirror symmetry
- This should extend to spaces with $h^{2,1} = 0$ that are dual to *spaces* with $h^{1,1} = 0$
- In principle $h^{1,1} = 0$ seems to imply absence of an underlying geometry (which is fine for string theory)
- Actually the volume is fixed by an orbifold to small value and cannot fluctuate

Type IIB Flux Compactifications

- Flux compactifications with $h^{1,1} = 0$ where originally studied in 2006 and 2007

Becker, Becker, Vafa, Walcher hep-th/0611001

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- Recently revisited in the swampland context

Ishiguro, Otsuka 2104.15030

- Given the plethora of recent swampland conjectures a further and closer look is warranted

Bardzell, Gonzalo, Rajaguru, Smith, TW work in progress

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- The authors were guided by trying to find the dual of a $\frac{T^6}{\mathbb{Z}_3 \times \mathbb{Z}_3}$ type IIA flux compactification with $h^{2,1} = 0$

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- They study Landau-Ginzburg models that are dual to rigid Calabi-Yau manifolds
- At particular points in moduli space these can be described by Gepner models

Type IIB Flux Compactifications

- Focus on $1^9/\mathbb{Z}_3$ model, where $\mathbb{Z}_3$ is a 'quantum symmetry' (not geometric and fixes Kähler moduli, $h^{1,1} = 0$)

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- Model is mirror dual of geometric $T^6/\mathbb{Z}_3 \times \mathbb{Z}_3$ with $h^{2,1} = 0$
- They work out/discuss how to include D3-branes, O3-planes and fluxes that give the usual K and W
- Find SUSY and AdS Minkowski vacua (see below)
- Discuss also 2^6 model which allows for larger O3 charge

Type IIB Flux Compactifications

- The ‘quantum orbifold’ does not remove the volume moduli but rather fixes their values

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$$K \supset -\log[-i(\tau - \bar{\tau})] - 2\log(vol_6)$$

$$\supset -\log[-i(\tau - \bar{\tau})] - 2\log\left(\frac{1}{6}\kappa_{abc}v^a v^b v^c\right)$$

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$$\supset -\log[-i(\tau-\bar{\tau})] - 2\log\left(e^{-\frac{3}{2}\phi}\frac{1}{6}\kappa_{abc}v_s^a v_s^b v_s^c\right)$$

$$\supset -4\log[-i(\tau-\bar{\tau})] - const.$$

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The effective 4d SUGRA action

- Type IIB compactifications with $h^{1,1} = 0$ one has

$$K = -4\log(\tau - \bar{\tau}) - \log(-i \int \Omega \wedge \overline{\Omega})$$

$$W = \int (H_{RR} - \tau H_{NS}) \wedge \Omega$$

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- Restricting to the bulk moduli of the underlying torus for simplicity and setting the three bulk complex structure moduli equal, $U = U_1 = U_2 = U_3$ we are left with

$$K = -4 \log(\tau - \bar{\tau}) - 3 \log[-i\,(U - \bar{U})]$$
$$W = W_{RR}(U) - \tau\, W_{NS}(U)$$
$$W_{RR}(U) = f_0 + 3f_1 U + 3f_2 U^2 + f_3 U^3$$
$$W_{NS}(U) = h_0 + 3h_1 U + 3h_2 U^2 + h_3 U^3$$

Supersymmetric AdS vacua

- All moduli are fixed in SUSY AdS vacua

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- There are infinite families with parametrically large complex structure and parametrically weak coupling

(as expected from mirror dual type IIA DGKT analysis)

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- How is that possible?
- For ISD fluxes $0 \leq \int H_3 \wedge F_3 \leq N_{O3}/2$

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$D_T W = K_T W = 0$ equation is not there

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$$\int H_3 \wedge F_3 \leq N_{O3}/2$$

- Tadpole: $N_{D3} + \int H_3 \wedge F_3 = N_{O3}/2,\ N_{D3} = 0,1,2,3, \ldots$

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- Tadpole: $N_{D3} + \int H_3 \wedge F_3 = N_{O3}/2, \; N_{D3} = 0,1,2,3, \ldots$
- Also cancellation $\int H_3 \wedge F_3 = f_0 h_3 + 3 f_1 h_2 + 3 f_2 h_1 + h_0 f_3$

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$$M \sim \Lambda_{AdS}^{\frac{1}{2}}$$

DeWolfe, Giryavets, Kachru, Taylor hep-th/0505160

Lüst, Palti, Vafa 1906.05225

Supersymmetric Minkowski vacua

- There are fully stable Minkowski vacua

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- Appear in simple as well as full fledged models where all moduli are taken into account

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- Connection to AdS moduli conjecture

Gautason, Hemelryck, Van Riet 1810.08518

- SUSY protection in the swampland?

Palti, Vafa, Weigand 2003.10452

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- Appear in simple as well as full fledged models where all moduli are taken into account
- Argued to be trustworthy at small complex structure and strong coupling due to non-renormalization theorems (see next section)
- Caveat is that masses get renormalized at strong coupling $\Rightarrow$ the calculated masses are not to be trusted

String coupling in Minkowski vacua

- It was stated that all Minkowski solutions are necessarily at strong coupling

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4.1 Minkowski space solutions

In the following we will see that supersymmetric Minkowski space solutions do not emerge for large complex structure but are confined to finite value of the complex structure and strong coupling. These are the solutions presented in [5]. Groundstates

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- We find obstruction to infinitely weak coupling but solutions with $Im(\tau) = e^{-\phi} = 2\sqrt{3} \approx 3.5$
- Note that this implies $\frac{e^{2\phi}}{4\pi} = \frac{1}{48\pi} \approx \frac{1}{150} < \frac{1}{137} \approx \frac{e^2}{4\pi} = \alpha$

dS vacua

- There are unstable dS vacua and stable dS vacua when the tadpole or flux quantization is violated

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- No systematic study exist

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- Simplest model has $\int H_3 \wedge F_3 \leq 12$ and for dS we need net O3-planes so $0 \leq \int H_3 \wedge F_3 \leq 12$

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- Metastable dS vacua exist if some fluxes are roughly 10 times larger than others. Flux quantization gives dominant term $\int H_3 \wedge F_3 \approx\ 10 \cdot 10 = O(100)$
- What is the lowest value? Is this model dependent?

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Non-renormalization theorems

- Let us first look at the superpotential W

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- W does not receive string loop correction (neither perturbative nor non-perturbative). Variety or reasons presented and analogue to geometric case:

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- W does not receive string loop correction (neither perturbative nor non-perturbative). Variety or reasons presented and analogue to geometric case:
  - Domain wall argument for D5/NS5-branes and non-renormalization of BPS brane tension
  - Checked explicitly in holographic settings
  - Underlying $\mathcal{N} = 2$ ensures no non-perturbative corr.

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- W does not receive string loop correction (neither perturbative nor non-perturbative). Variety or reasons presented and analogue to geometric case.
- In the dual type IIA model this means that for $h^{2,1} = 0$ there are likewise no perturbative or non-perturbative corrections to W. This follows from there being only one 3-cycle that is threaded with H-flux

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- W does not receive string loop correction (neither perturbative nor non-perturbative). Variety or reasons presented and analogue to geometric case.

- Non-renormalization of W means that the fully stable $\mathcal{N} = 1$ Minkowski vacua are trustworthy

Non-renormalization theorems

- The above no-go theorems do not apply to K

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- For SUSY AdS vacua we solve

$$D_i W = \partial_i W + W\, \partial_i K = 0$$

so we need to understand corrections to K

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- Expand solution around minimum at $U_i = 0$

$$K = U_i \bar{U}_i + a_{ij} U_i \bar{U}_j \, f(U_i, \bar{U}_i)$$

- Quantum corrections around $U = 0$ are of the form

$$\delta K = c_0 + c(U) + \bar{c}(\bar{U}) + U\bar{U} d(U, \bar{U})$$

- For K_i (and $\bar{K}_i$) only $\delta K = c(U) + \bar{c}(\bar{U})$ relevant

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This is a Kähler transformation!

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- For SUSY AdS vacua we solve

$$D_i W = \partial_i W + W\, \partial_i K = 0$$

so we need to understand corrections to K

- Corrections to K_i are Kähler transformation that do not change the equations $D_i W = 0$
- However, for example masses could receive corrections

Summary

- Type IIB with $h^{1,1} = 0$ provides a new class of string compactifications to check swampland conjectures
- These compactifications have been argued to be provide trustworthy result even at strong coupling

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- Unstable dS vacua exist and maybe even metastable ones as well

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- These compactifications have been argued to be provide trustworthy result even at strong coupling
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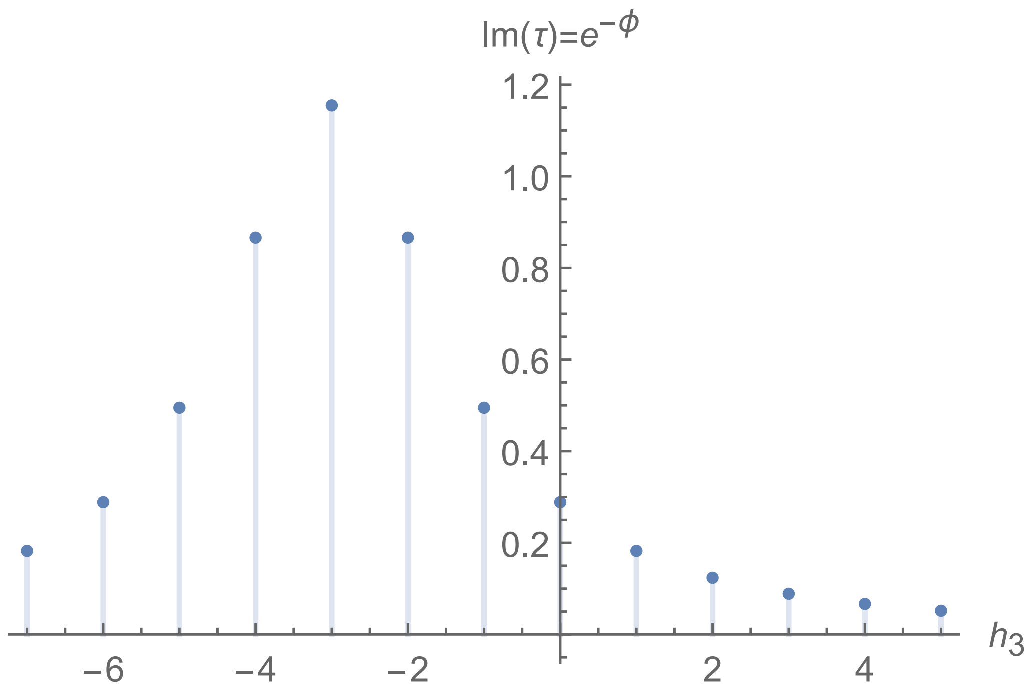
THANK YOU!

String coupling in Minkowski vacua

- Infinite families of Minkowski vacua with no D3-branes and tadpole cancelled by fluxes only:

$$\int H_3 \wedge F_3 = f_0 h_3 + 3 f_1 h_2 + 3 f_2 h_1 + h_0 f_3 = 12$$



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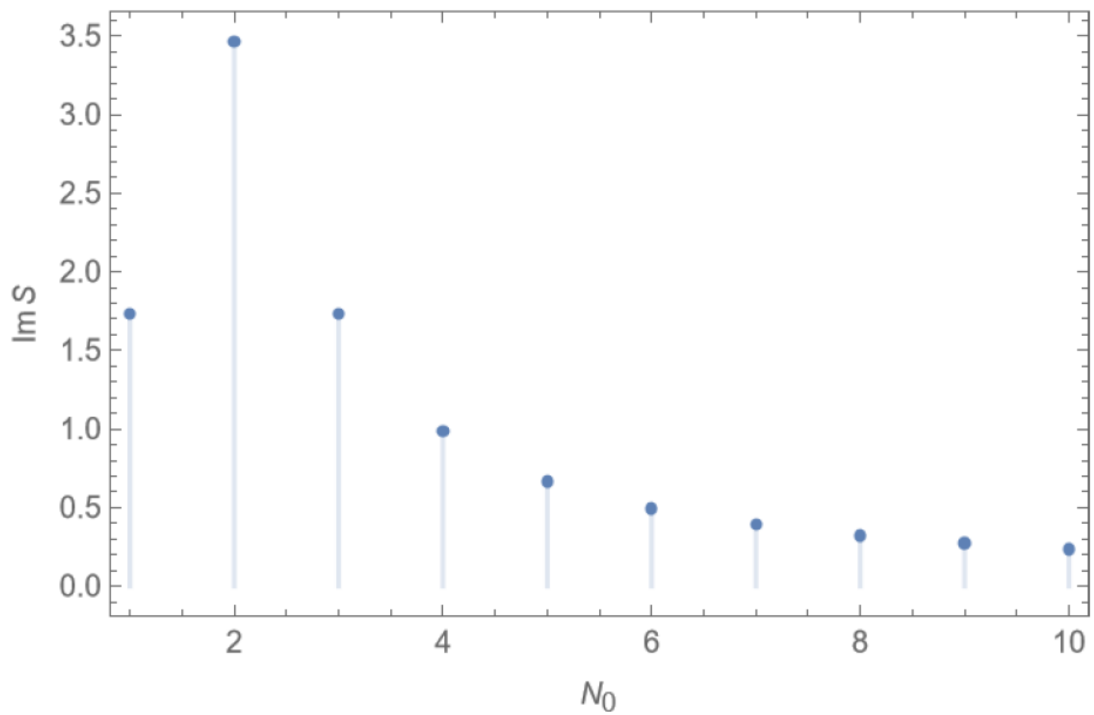

Non-renormalization theorems

- What about the standard ED3-brane e^{-aT} terms?
- Given that the volume is essentially fixed to a particular small value these could appear
- $W_{np} = \sum_n A_n(U_i) e^{-a_n T}$ would, at fixed T, be a complex structure dependent function
- Should be forbidden by above no-go theorem