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

String Pheno 2022

Muthusamy Rajaguru

LEHIGH UNIVERSITY

Based on : Bardzell, Gonzalo, MR, Smith, Wrase 2203.15818

Outline

- Motivation
- Review of the setup
- A closer look at the vacua
  1. AdS vacua
  2. dS vacua
- Summary and Outlook

Outline

- Motivation
- Review of the setup
- A closer look at the vacua
  1. AdS vacua
  2. dS vacua
- Summary and Outlook

Motivation

- Swampland program has given rise to many promising conjectures with implications for string pheno.
- Evidence for the conjectures typically arises from black hole arguments or explicit string theory compactifications.
- We focus on exploring new string theory compactifications to further test and understand interconnections between conjectures.

Outline

- Motivation
- Review of the setup
- A closer look at the vacua
  1. AdS vacua
  2. dS vacua
- Summary and Outlook

Review of the Setup

- We focus on type IIB Landau-Ginzburg orientifolds with background fluxes (H_3 and F_3) turned on.

Review of the Setup

- We focus on type IIB Landau-Ginzburg orientifolds with background fluxes (H_3 and F_3) turned on.
- Landau-Ginzburg models are useful to –

Review of the Setup

- We focus on type IIB Landau-Ginzburg orientifolds with background fluxes (H_3 and F_3) turned on.
- Landau-Ginzburg models are useful to –
    1. Analytically continue Calabi-Yau compactifications to small volume

Review of the Setup

- We focus on type IIB Landau-Ginzburg orientifolds with background fluxes (H_3 and F_3) turned on.
- Landau-Ginzburg models are useful to –
  1. Analytically continue Calabi-Yau compactifications to small volume
  2. Find mirror duals of Calabi-Yau compactifications (with no fluxes)

Review of the Setup

- We focus on type IIB Landau-Ginzburg orientifolds with background fluxes (H_3 and F_3) turned on.
- Landau-Ginzburg models are useful to –
  1. Analytically continue Calabi-Yau compactifications to small volume
  2. Find mirror duals of Calabi-Yau compactifications (with no fluxes)
- The machinery to compute the effective action has already been developed. *Becker, Becker, Vafa, Walcher hep-th/0611001*

Review of the Setup

- Of the two LG models $(1^9, 2^6)$ discussed by Becker, Becker, Vafa, Walcher, we focus on the 1^9 model for most of this talk.

Review of the Setup

- Of the two LG models $(1^9, 2^6)$ discussed by Becker, Becker, Vafa, Walcher, we focus on the 1^9 model for most of this talk.
- We restrict our discussion to the simplest case where we do not consider the blow-up modes and set the three bulk complex structure moduli equal.

Review of the Setup

- Of the two LG models $(1^9, 2^6)$ discussed by Becker, Becker, Vafa, Walcher, we focus on the 1^9 model for most of this talk.
- We restrict our discussion to the simplest case where we do not consider the blow-up modes and set the three bulk complex structure moduli equal.
- The 4d effective action is determined entirely in terms of the Kähler potential and superpotential,

Review of the Setup

- Of the two LG models $(1^9, 2^6)$ discussed by Becker, Becker, Vafa, Walcher, we focus on the 1^9 model for most of this talk.
- We restrict our discussion to the simplest case where we do not consider the blow-up modes and set the three bulk complex structure moduli equal.
- The 4d effective action is determined entirely in terms of the Kähler potential and superpotential,

$$K = -4\log[i(\bar{\tau} - \tau)] - 3\log[i(\bar{U} - U)]$$

Review of the Setup

- Of the two LG models $(1^9, 2^6)$ discussed by Becker, Becker, Vafa, Walcher, we focus on the 1^9 model for most of this talk.
- We restrict out discussion to the simplest case where we do not consider the blow-up modes and set the three bulk complex structure moduli equal.
- The 4d effective action is determined entirely in terms of the Kähler potential and superpotential,

$$K = -4\log[i(\bar{\tau} - \tau)] - 3\log[i(\bar{U} - U)]$$

$$W = W_{RR} - \tau W_{NS}$$

$$W_{RR} = f_0 + 3f_1 U + 3f^2 U^2 + f^0 U^3, W_{NS} = h_0 + 3h_1 U + 3h^1 U^2 + h^0 U^3$$

Review of the Setup

- The net charge of the O_3 planes, fluxes and D_3 branes have to cancel.

$$\int F_3 \wedge H_3 + N_{D3} = \frac{1}{2} N_{O3}$$

Review of the Setup

- The net charge of the O_3 planes, fluxes and D_3 branes have to cancel.

$$\int F_3 \wedge H_3 + N_{D3} = \frac{1}{2} N_{O3}$$

- The Orientifold projection for the 1^9 model leads to $N_{O3} = 24$, whereas for the 2^6 model $N_{O3} = 80$.

Review of the Setup

- The net charge of the O_3 planes, fluxes and D_3 branes have to cancel.

$$\int F_3 \wedge H_3 + N_{D3} = \frac{1}{2} N_{O3}$$

- The Orientifold projection for the 1^9 model leads to $N_{O3} = 24$, whereas for the 2^6 model $N_{O3} = 80$.
- This setup with only one component of H_3 flux turned on is dual to DGKT.

DeWolfe, Girvayets, Kachru, Taylor hep-th/0505260

Review of the Setup

- The net charge of the O_3 planes, fluxes and D_3 branes have to cancel.

$$\int F_3 \wedge H_3 + N_{D3} = \frac{1}{2} N_{O3}$$

- The Orientifold projection for the 1^9 model leads to $N_{O3} = 24$, whereas for the 2^6 model $N_{O3} = 80$.
- This setup with only one component of H_3 flux turned on is dual to DGKT.

DeWolfe, Girvayets, Kachru, Taylor hep-th/0505260

- When more than one component of the H_3 flux is turned on the type IIB side, the mirror dual IIA set up has geometric and non-geometric fluxes.

Review of the Setup

- The net charge of the O_3 planes, fluxes and D_3 branes have to cancel.

$$\int F_3 \wedge H_3 + N_{D3} = \frac{1}{2} N_{O3}$$

- The Orientifold projection for the 1^9 model leads to $N_{O3} = 24$, whereas for the 2^6 model $N_{O3} = 80$.
- This setup with only one component of H_3 flux turned on is dual to DGKT.

DeWolfe, Girvayets, Kachru, Taylor hep-th/0505260

- When more than one component of the H_3 flux is turned on in the type IIB side, the mirror dual IIA set up has geometric and non-geometric fluxes. For more details, see Timm's talk on Friday!

Outline

- Motivation
- Review of the setup
- A closer look at the vacua (See Timm's talk for discussion on Minkowski vacua!)
  1. AdS vacua
  2. dS vacua
- Summary and Outlook

$\mathcal{N}$=1,D=4 AdS Vacua

- AdS Distance Conjecture –

AdS vacua cannot be continuously connected to Minkowski (i.e) a tower of states become light as $\Lambda \to 0$. Specifically, the mass scale of the tower goes as,

$$m \sim |\Lambda|^{\alpha}$$

Where $\alpha > 0$ and is *O(1)*.

D.Lüst, Palti, Vafa 1906.05225

$\mathcal{N} = 1, \mathrm{D} = 4$ AdS Vacua

- AdS Distance Conjecture –

AdS vacua cannot be continuously connected to Minkowski (i.e) a tower of states become light as $\Lambda \to 0$. Specifically, the mass scale of the tower goes as,

$$m \sim |\Lambda|^{\alpha}$$

Where $\alpha > 0$ and is *O(1)*.

- AdS Distance Conjecture (strong version) -

For SUSY AdS vacua, $\alpha = \frac{1}{2}$.

D.Lüst, Palti, Vafa 1906.05225

$\mathcal{N}$=1,D=4 AdS Vacua

DGKT Dual -

- In terms of the non-zero flux components the moduli are then stabilized at,

$$f_0 = f^1 = h^1 = h^0 = h_1 = 0$$

$$Re(\tau) = 0, Im(\tau) = 2\sqrt{\frac{5}{3}\frac{\sqrt{f^0}f_1^{\frac{3}{2}}}{9}}$$

$$Re(U) = 0, Im(U) = \sqrt{\frac{5f_1}{3f^0}}$$

$\mathcal{N}$=1,D=4 AdS Vacua

DGKT Dual -

- In terms of the non-zero flux components the moduli are then stabilized at,

$$f_0 = f^1 = h^1 = h^0 = h_1 = 0$$

$$Re(\tau) = 0, Im(\tau) = 2\sqrt{\frac{5}{3}\frac{\sqrt{f^0}f_1^{\frac{3}{2}}}{9}}$$

$$Re(U) = 0, Im(U) = \sqrt{\frac{5f_1}{3f^0}}$$

- The tadpole cancellation implies, $\mathrm{h}_0 = \frac{12}{f^0}$.

Becker, Becker, Walcher 0706.0514

$\mathcal{N}$=1,D=4 AdS Vacua

DGKT Dual -

- The potential at the minima is given by,

$$V_{AdS} = \frac{-19683\sqrt{\frac{3}{5}}}{3200\,(f^0)^{\frac{3}{2}}}\frac{1}{f_1^{\frac{9}{2}}}$$

$\mathcal{N}$=1,D=4 AdS Vacua

DGKT Dual -

- The potential at the minima is given by,

$$V_{AdS} = \frac{-19683\sqrt{\frac{3}{5}}}{3200\,(f^0)^{\frac{3}{2}}}\frac{1}{f_1^{\frac{9}{2}}}$$

- In the limit where f_1 becomes large, the potential goes to 0 and a tower of states becomes light. The mass scale of the tower goes as,

$$m_{tower}\sim \frac{1}{f_1^{\frac{7}{4}}}\sim |V_{AdS}|^{\frac{7}{18}} \qquad \left(\text{from } m_{tower}^2\sim\frac{1}{Im(\tau)^2 Im(U)}\right)$$

$\mathcal{N}$=1,D=4 AdS Vacua

DGKT Dual -

- Whilst this seems to be in tension with the strong version of the ADC, we expect that it satisfies the refined version of the ADC much like the type IIA DGKT vacua. *Buratti, Calderon, Mininno,Uranga 2003.07940*

$\mathcal{N}$=1, D=4 AdS Vacua

DGKT Dual -

- Whilst this seems to be in tension with the strong version of the ADC, we expect that it satisfies the refined version of the ADC much like the type IIA DGKT vacua. *Buratti, Calderon, Mininno, Uranga 2003.07940*
- The masses squared for these solutions are,

$$m^2 = \left\{\frac{10}{3}, 6, \frac{70}{3}, \frac{88}{3}\right\} |V_{AdS}|$$

$\mathcal{N}$=1,D=4 AdS Vacua

DGKT Dual -

- Whilst this seems to be in tension with the strong version of the ADC, we expect that it satisfies the refined version of the ADC much like the type IIA DGKT vacua. *Buratti, Calderon, Mininno,Uranga 2003.07940*
- The masses squared for these solutions are,

$$m^2 = \left\{\frac{10}{3}, 6, \frac{70}{3}, \frac{88}{3}\right\} |V_{AdS}|$$

- The operator scaling dimension of the corresponding CFT are integers just as in the DGKT solutions.

Conlon, Ning, Revello 2110.06245

Apers, Montero, Van Riet, Wrase 2202.00682

Apers, Conlon, Ning, Revello 2202.09330

Quiriant 2204.00014

$\mathcal{N}$=1,D=4 AdS Vacua

Infinite SUSY families with $\alpha = \frac{1}{2}$:

$$f^0 = f_1 = 0, h^0 = -3, f^1 = h_0 = 0$$

$\mathcal{N}$=1,D=4 AdS Vacua

Infinite SUSY families with $\alpha = \frac{1}{2}$:

$$f^0 = f_1 = 0, h^0 = -3, g^1 = h_0 = 0$$

$$f_0 = 4 - f^1 h_1 \; (tadpole\ cancellation)$$

$\mathcal{N}$=1,D=4 AdS Vacua

Infinite SUSY families with $\alpha = \frac{1}{2}$:

$$f^0 = f_1 = 0, h^0 = -3, g^1 = h_0 = 0$$

$$f_0 = 4 - f^1 h_1 \; (tadpole\ cancellation)$$

$$Re(U) = 0, Im(U) = \frac{\sqrt{\frac{9f^1h_1 + 2\left(-9+\sqrt{81+24\, f^1h_1}\right)}{f^1}}}{\sqrt{15}}$$

$$Re(\tau) = 0, Im(\tau) = \frac{\left(-16f^1h_1 + 3\left(9+\sqrt{81+24f^1h_1(-4+f^1h_1)}\right)\right)}{2h_1^2} Im(U)$$

$\mathcal{N}$=1,D=4 AdS Vacua

Infinite SUSY families with $\alpha = \frac{1}{2}$:

- In the large f^1 limit (for $h_1 < 0$),

$$Im(\tau) \approx \frac{\sqrt{6+8\sqrt{\frac{2}{3}}f^1}}{\sqrt{-h_1}}, Im(U) \approx \frac{\sqrt{(9-4\sqrt{6})h_1}}{15}$$

$$V_{Ads} \approx -\frac{27(-h_1)^{\frac{5}{2}}}{32\sqrt{1329+544\sqrt{6}}}\frac{1}{(f^1)^2}$$

$\mathcal{N}$=1,D=4 AdS Vacua

Infinite SUSY family with $\alpha = \frac{1}{2}$ and $N_{D3} \to \infty$:

$$f^1 = f_0 = h^0 = h_1 = 0, h^1 = f^0 = 1$$

$\mathcal{N}$=1,D=4 AdS Vacua

Infinite SUSY family with $\alpha = \frac{1}{2}$ and $N_{D3} \to \infty$:

$$f^1 = f_0 = h^0 = h_1 = 0, h^1 = f^0 = 1$$

$$-3f_1 + h_0 + N_{D3} = 12 \ (tadpole\ cancellation)$$

$\mathcal{N}$=1,D=4 AdS Vacua

Infinite SUSY family with $\alpha = \frac{1}{2}$ and $N_{D3} \to \infty$:

$$f^1 = f_0 = h^0 = h_1 = 0, h^1 = f^0 = 1$$

$$-3f_1 + h_0 + N_{D3} = 12 \ (tadpole\ cancellation)$$

In the large f_1 limit,

$$Im(U) \approx \frac{\sqrt{5\ h_0}}{3}, Im(\tau) \approx \frac{3\sqrt{5} f_1}{4\sqrt{h_0}}$$

$$V_{AdS} \approx -\frac{2\ (h_0)^\wedge\frac{3}{2}}{25\sqrt{5} f_1^2}$$

$\mathcal{N}$=1,D=4 AdS Vacua

Infinite SUSY family with $\alpha = \frac{1}{2}$ and $N_{D3} \to \infty$:

$$f^1 = f_0 = h^0 = h_1 = 0, h^1 = f^0 = 1$$

$$-3f_1 + h_0 + N_{D3} = 12 \; (tadpole\ cancellation)$$

In the large f_1 limit,

$$Im(U) \approx \frac{\sqrt{5\, h_0}}{3}, Im(\tau) \approx \frac{3\sqrt{5} f_1}{4\sqrt{h_0}}$$

$$V_{AdS} \approx -\frac{2\,(h_0)^{\wedge}\frac{3}{2}}{25\sqrt{5} f_1^2}$$

$$m_{tower} \sim |V_{AdS}|^{\frac{1}{2}}$$

$\mathcal{N}$=1,D=4 AdS Vacua

Infinite SUSY family with $\alpha = \frac{3}{2}$ and $N_{D3} \to \infty$:

$$f^1 = f_0 = f^0 = 1, h^0 = h_1 = 0, h^1 = h_0 = -1$$

$\mathcal{N}$=1,D=4 AdS Vacua

Infinite SUSY family with $\alpha = \frac{3}{2}$ and $N_{D3} \to \infty$:

$$f^1 = f_0 = f^0 = 1, h^0 = h_1 = 0, h^1 = h_0 = -1$$

$$3f_1 + N_{D3} = 13 \ (tadpole\ cancellation)$$

$\mathcal{N}$=1,D=4 AdS Vacua

Infinite SUSY family with $\alpha = \frac{3}{2}$ and $N_{D3} \to \infty$:

$$f^1 = f_0 = f^0 = 1, h^0 = h_1 = 0, h^1 = h_0 = -1$$

$$3f_1 + N_{D3} = 13 \; (tadpole\ cancellation)$$

In the limt $f_1 \to -\infty$,

$$Im(U) \approx 3\sqrt{-f_1}, Im(\tau) \approx \frac{8\sqrt{-f_1}}{3}$$

$$V_{AdS} \approx -\frac{729}{32768\sqrt{-f_1}}$$

$\mathcal{N}$=1,D=4 AdS Vacua

Infinite SUSY family with $\alpha = \frac{3}{2}$ and $N_{D3} \to \infty$:

$$f^1 = f_0 = f^0 = 1, h^0 = h_1 = 0, h^1 = h_0 = -1$$

$$3f_1 + N_{D3} = 13 \; (tadpole\ cancellation)$$

In the limt $f_1 \to -\infty$,

$$Im(U) \approx 3\sqrt{-f_1}, Im(\tau) \approx \frac{8\sqrt{-f_1}}{3}$$

$$V_{AdS} \approx -\frac{729}{32768\sqrt{-f_1}}$$

$$m_{tower} \sim |V_{AdS}|^{\frac{3}{2}}$$

Outline

- Motivation
- Review of the setup
- A closer look at the vacua
    1. AdS vacua
    2. dS vacua
- Summary and Outlook

dS Vacua

- A search for dS vacua was initiated by Ishiguro, Otsuka.

Ishiguro, Otsuka 2104.15030

dS Vacua

- A search for dS vacua was initiated by Ishiguro, Otsuka. *Ishiguro, Otsuka 2104.15030*
- Meta-stable dS vacua are possible to find without violating tadpole cancellation.

$$f^1 = f_0 = h^0 = h_1 = 0, f^0 = 33, f_1 = -1, h^1 = -1, h_0 = 1$$

dS Vacua

- A search for dS vacua was initiated by Ishiguro, Otsuka. *Ishiguro, Otsuka 2104.15030*
- Meta-stable dS vacua are possible to find without violating tadpole cancellation.

$$f^1 = f_0 = h^0 = h_1 = 0, f^0 = 33, f_1 = -1, h^1 = -1, h_0 = 1$$

$$Re(U) = 0, Im(U) \approx 0.299$$

$$Re(\tau) = 0, Im(\tau) \approx 1.32$$

dS Vacua

- A search for dS vacua was initiated by Ishiguro, Otsuka. *Ishiguro, Otsuka 2104.15030*
- Meta-stable dS vacua are possible to find without violating tadpole cancellation.

$$f^1 = f_0 = h^0 = h_1 = 0, f^0 = 33, f_1 = -1, h^1 = -1, h_0 = 1$$

$$Re(U) = 0, Im(U) \approx 0.299$$

$$Re(\tau) = 0, Im(\tau) \approx 1.32$$

$$N_{flux} = 30$$

dS Vacua

- A search for dS vacua was initiated by Ishiguro, Otsuka. *Ishiguro, Otsuka 2104.15030*
- Meta-stable dS vacua are possible to find without violating tadpole cancellation.

$$f^1 = f_0 = h^0 = h_1 = 0, f^0 = 33, f_1 = -1, h^1 = -1, h_0 = 1$$

$$Re(U) = 0, Im(U) \approx 0.299$$

$$Re(\tau) = 0, Im(\tau) \approx 1.32$$

$$N_{flux} = 30$$

- They are not immune to corrections as they are not SUSY vacua.

Outline

- Motivation

- Review of the setup

- A closer look at the vacua
    1. AdS vacua
    2. dS vacua

- Summary and Outlook

Summary and Outlook

- We have studied a non-geometric type IIB flux compactification setup and used it to test swampland conjectures.
- There is still much to explore here,
    1. Are there more AdS vacua which exhibit properties of the DGKT dual
    2. Can we find reliable metastable dS vacua?
    3. Are the Minkowski vacua fully stabilized (see Timm's talk)

Thank you!

Non-Renormalization Theorems

- There are no perturbative and non-perturbative corrections to the superpotential.
- The Kähler potential can receive corrections. We have shown in our paper that this will not change anything for the Minkowski vacua and also will not alter the presence of SUSY AdS vacua.
- The masses of the SUSY vacua might get corrections.
- The LG model takes into account all α' corrections.

Mass Scale

- On the type IIA side the mass scale of the KK tower is given by,

$$m_{KK}^2 \sim \frac{1}{Im(\tau)^2 Im(T)}$$

- Using mirror symmetry we find,

$$m_{tower}^2 \sim \frac{1}{Im(\tau)^2 Im(U)}$$