State of the art in moduli stabilization

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"The Lotus and Swampland"

February 10th, 2025

McAllister, Quevedo 2407.167582310.20559 §1-5 and 9

Van Riet, Zoccarato 2305.01722

Outline

- Why moduli stabilization? Why $4d\ N = 1$?
- Flux compactifications of type IIA
- Flux compactifications of type IIB: KKLT and LVS

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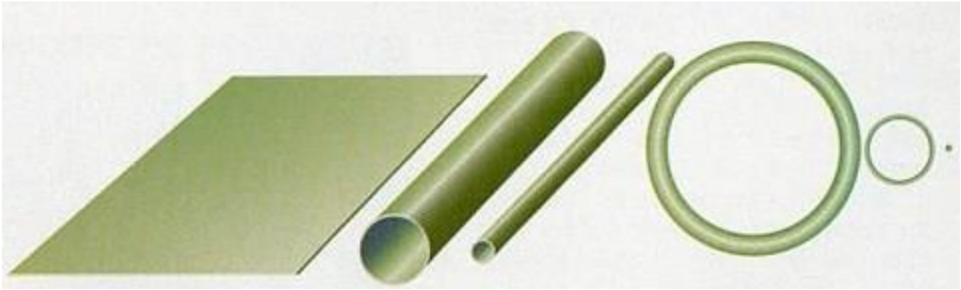
Moduli stabilization

String compactifications give rise to many scalar fields in the lower dimensional effective theory: The dilaton $g_s = e^{\Phi}$ and for a torus $T^2 = S^1 \times S^1$



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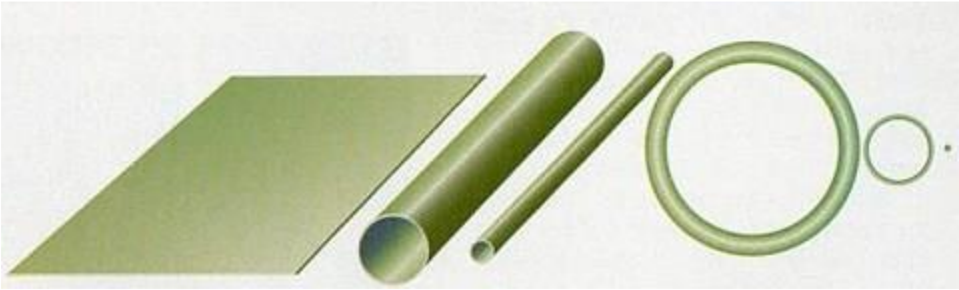
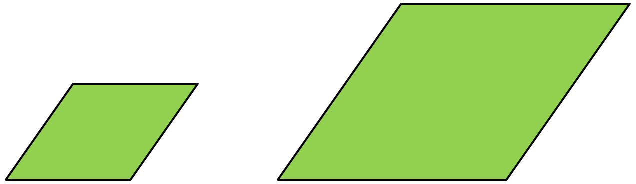
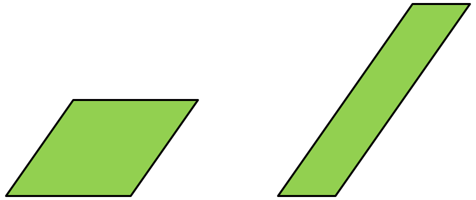


Two possible deformations lead to two massless scalar fields called moduli



volume deformation

= Kähler modulus



shape deformation

= complex structure modulus

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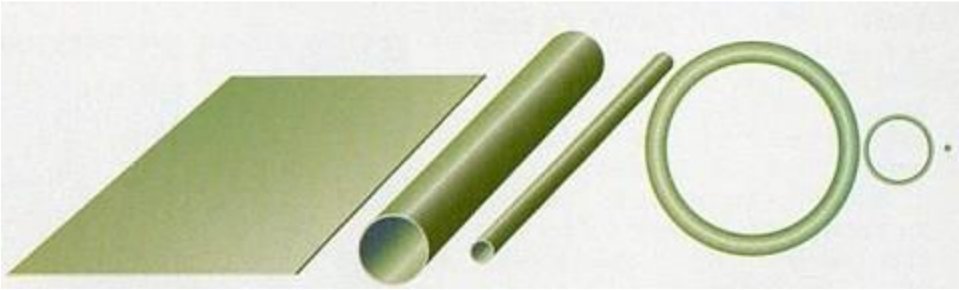

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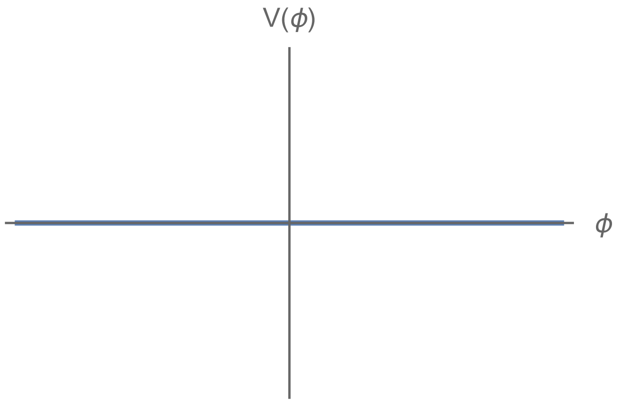
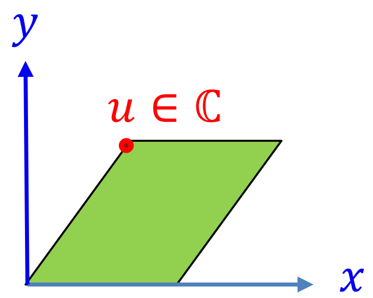
$$V(\phi) = 0 \quad \Rightarrow \quad m^2 = \frac{1}{2}\partial_\phi^2 V(\phi) = 0$$



Moduli stabilization

People mostly work with complex manifolds $dz = dx + u\, dy$



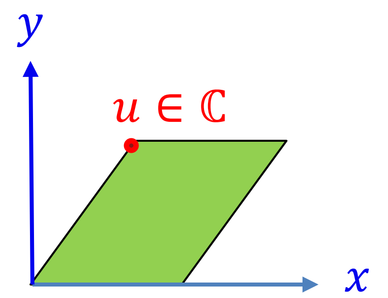
Line element $ds^2 = g\, dz d\bar{z}$

Kähler form $J = i\, g\, dz \wedge d\bar{z} \in H^{1,1}(T^2)$

Holomorphic 1-form $\Omega = dz = dx + u\, dy \in H^{1,0}(T^2)$

g is the Kähler modulus, u is the complex structure modulus

Moduli stabilization



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This generalizes to manifold M with n complex dimensions

Line element $ds^2 = g_{i\bar{j}}\, dz^i d\bar{z}^{\bar{j}}$

Kähler form $J = i\, g_{i\bar{j}}\, dz^i \wedge d\bar{z}^{\bar{j}} \in H^{1,1}(M)$

Holomorphic n-form $\Omega = dz^1 \wedge dz^2 \wedge \cdots \wedge dz^n \in H^{n,0}(M)$

Moduli stabilization

From 10d to 4d we could use $T^6 = T^2 \times T^2 \times T^2$ but too simple

Quotienting by discrete groups $\frac{T^6}{\mathbb{Z}_N}$ or $\frac{T^6}{\mathbb{Z}_N \times \mathbb{Z}_M}$ leads to many more moduli from blow-ups

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Mostly interested in Calabi-Yau manifolds (but one could study other spaces as well)

n complex dimensional Kähler manifold

$\exists$ metric $g_{i\bar{j}}$ that is Ricci-flat $R_{i\bar{j}} = 0$

Solves Einstein equations $R_{i\bar{j}} - \frac{1}{2} R g_{i\bar{j}} = 0$

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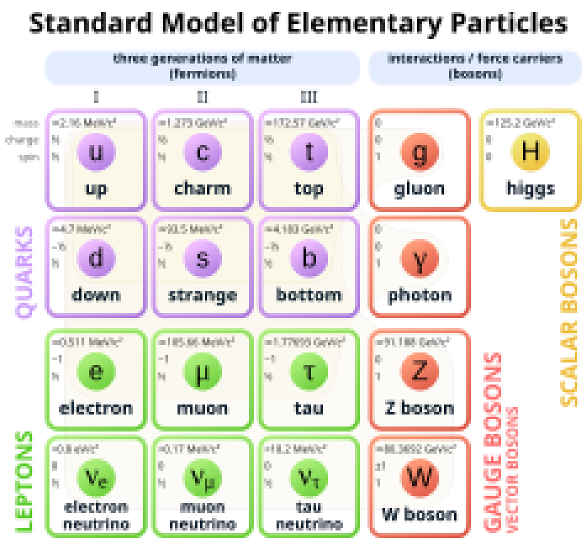
Here we are furthermore restricting to $n = 3$: 6 real dimensional and compact

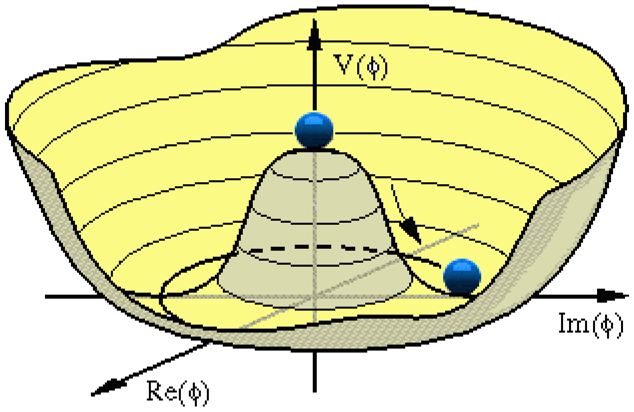
Moduli stabilization



- No massless scalar fields (= moduli) in our universe
- Scalar fields very abundant in string compactifications:

$$\mathcal{O}(1) \text{ to } \mathcal{O}(100) \text{ to } \mathcal{O}(10{,}000) \text{ ?}$$

- Need to find ways to give masses to scalar fields



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- No massless scalar fields (= moduli) in our universe
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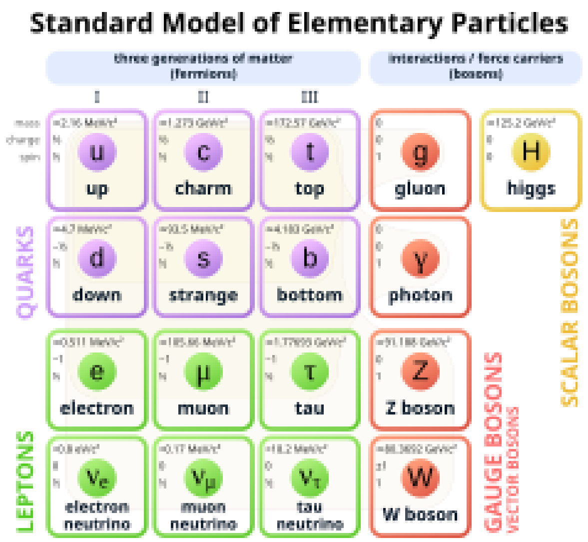
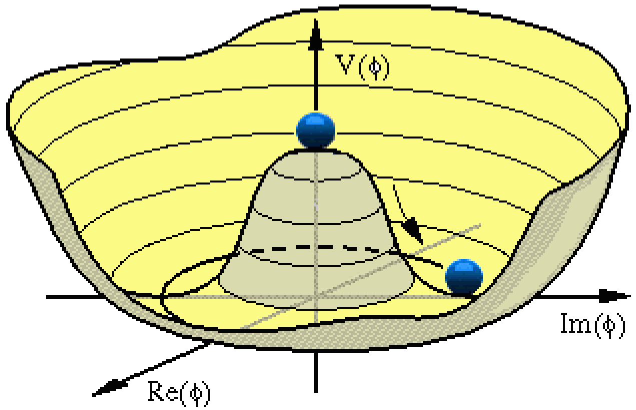
  $O(1)$ to $O(100)$ to $O(10{,}000)$?

- Need to find ways to give masses to scalar fields
- Lots of progress in the early 2000's

  KKLT, LVS, DGKT, …
  Recently reviewed McAllister, Quevedo 2310.20559

- The *swampland program* has called many (all?) of these into question





Moduli stabilization

- Why 4d? Because we live in spacetime with 3+1 large dimensions
- Why $N = 1$, i.e., four supercharges?

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1. Easier than no supersymmetry

The (real) scalar potential $V(\phi^I, \bar{\phi}^{\bar{I}})$ is fixed via

Superpotential $W(\phi^I)$ holomorphic

Kähler potential $K(\phi^I, \bar{\phi}^{\bar{I}})$ real function

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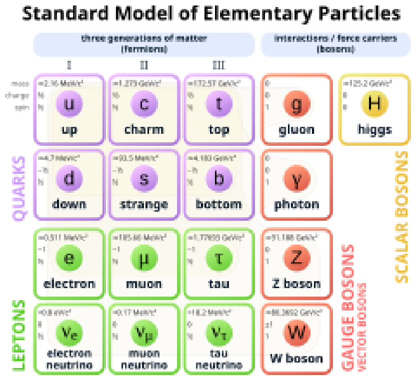
$$V(\phi^I, \bar{\phi}^{\bar{I}}) = e^K (K^{I\bar{J}} D_I W \, \overline{D_J W} - 3|W|^2)$$

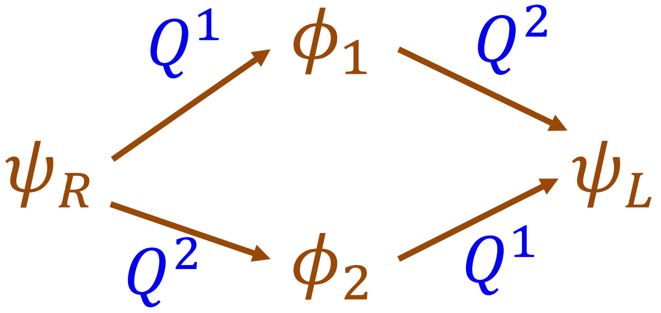
$K_{I\bar{J}} = \partial_I \partial_{\bar{J}} K(\phi^I, \bar{\phi}^{\bar{I}})$ Kähler metric, $D_I W = \partial_I W + W \, \partial_I K$

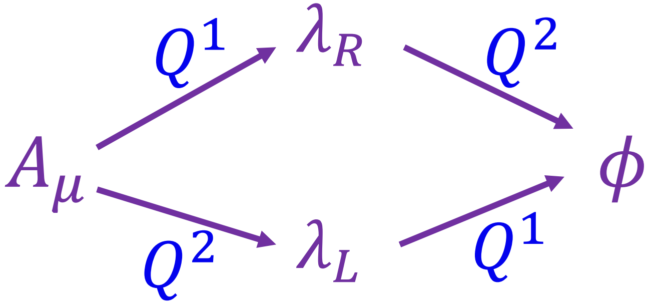
Moduli stabilization

- Why 4d? Because we live in spacetime with 3+1 large dimensions
- Why $N = 1$, i.e., four supercharges?

1. Easier than no supersymmetry
2. $N \geq 2$ does not allow for chiral matter
3. $N \geq 2$ massless vector multiplets contain massless scalars







$N = 2$ hypermultiplet

$N = 2$ vector multiplet

Moduli stabilization

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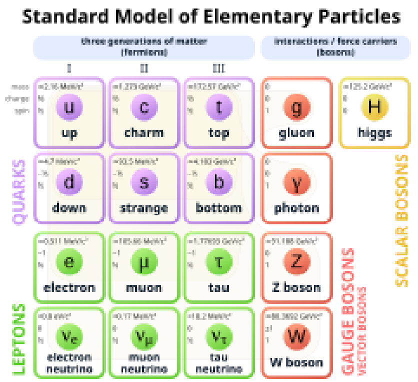
4. $N \geq 2$ compactifications much more constraint, no dS: $V > 0$?



Moduli stabilization

- Moduli stabilization mostly studied without including SM of particles
- Maybe we should include it? → Makes some things harder
  ↘ Maybe new ideas/approaches?

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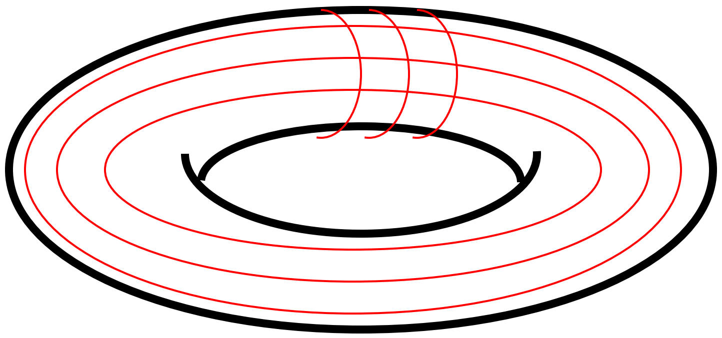
- Maybe we should include it? → Makes some things harder
  ↘ Maybe new ideas/approaches?
- Rest of this talk no Standard Model, no gauge groups but $4d, N = 1$

How do we give masses to scalar fields?

Moduli stabilization

- We turn on fluxes that thread the compact space.

$$\int_{T^2} F_{\mu\nu}\, dx^\mu \wedge dx^\nu = N$$



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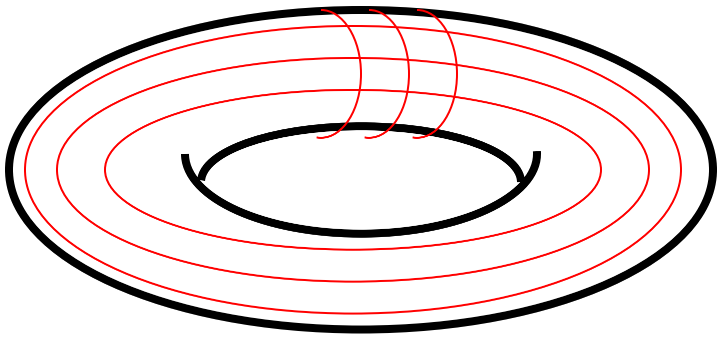
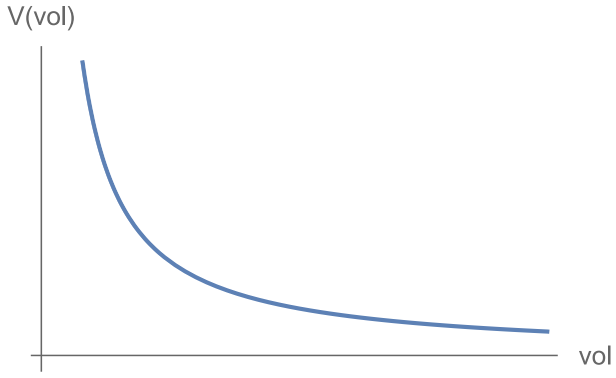


- This leads to a potential for the volume scalar

$$V = \int_{T^2} F^2 = \int_{T^2} \sqrt{g} g^{\mu\nu} g^{\alpha\beta} F_{\mu\nu} F_{\alpha\beta} \sim \frac{N^2}{vol} \xrightarrow{vol\to\infty} 0$$



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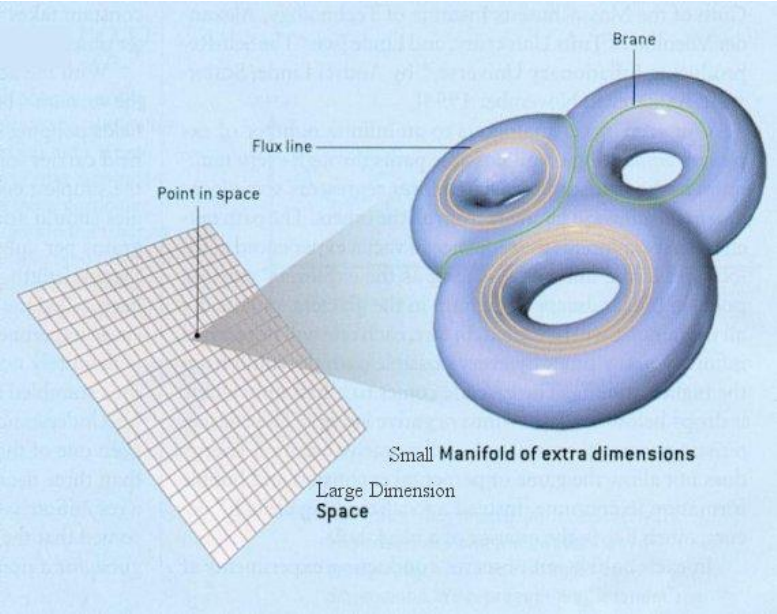
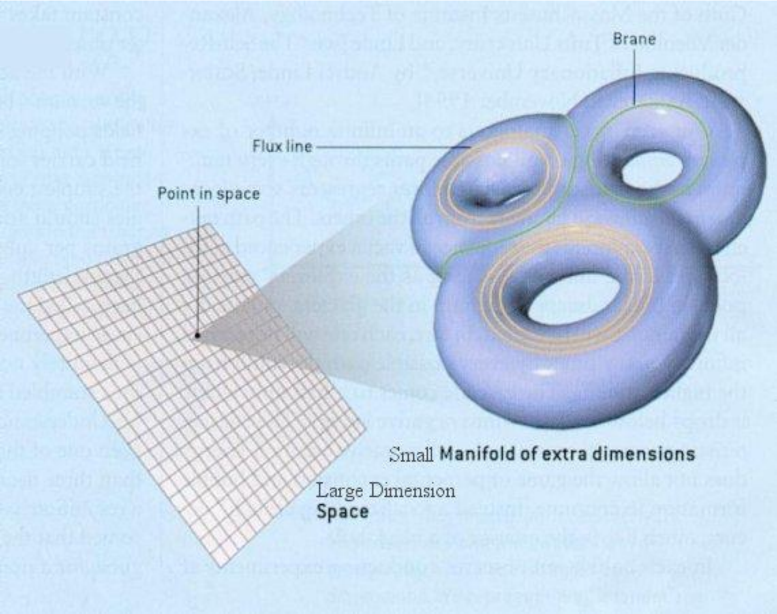


- This generalizes to 10d type II supergravity
- Fields: $g_{MN}, B_{MN}, e^{\phi}, C_p$
- Fluxes: $H = dB, F_{p+1} = dC_p$

Moduli stabilization



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- Lower dim. theory $S \sim \int d^D x (R_D - kinetic - V(\phi))$

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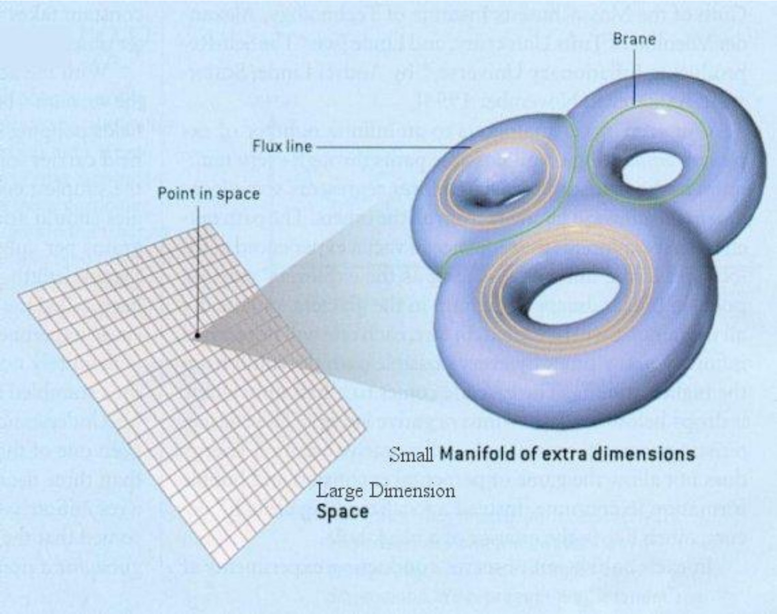

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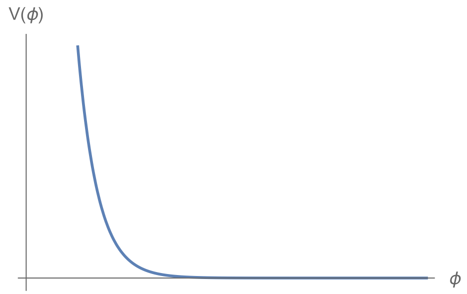
$$V \sim \int d^{10-D}x \sqrt{-g_{10-D}} \left(\frac{e^{-2\phi}}{2}|H|^2 + \frac{1}{4}\sum_n |F_n|^2 \right) \sim \frac{e^{-2\phi} N_H^2}{vol^{\#}} + \sum_n \frac{N_{F_n}^2}{vol^{\#_n}} \xrightarrow[e^{-2\phi} \to 0]{vol \to \infty} 0$$



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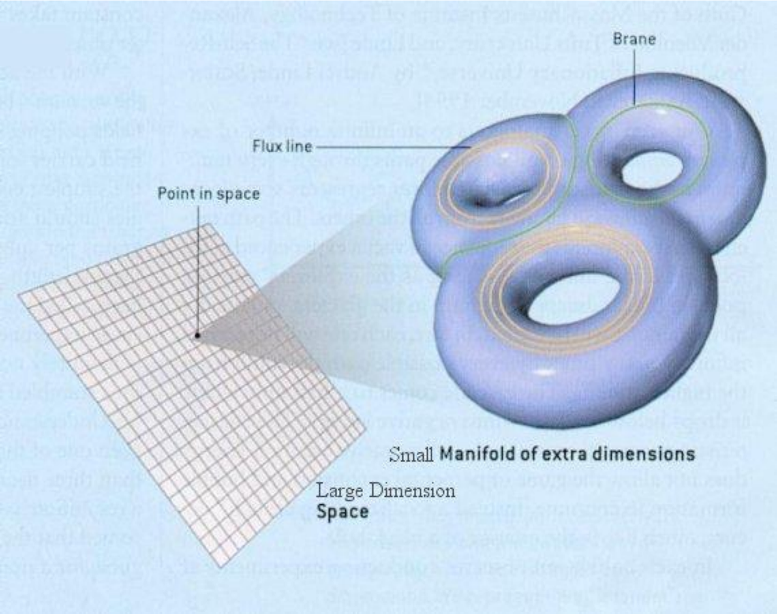

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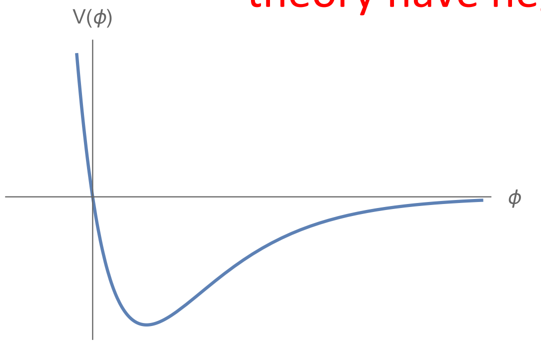
Need negative term in V! Orientifold planes in string theory have negative tension!

$$V \sim \frac{e^{-2\phi} N_H^2}{vol^{\#}} + \sum_n \frac{N_{F_n}^2}{vol^{\#}} - \frac{T_p e^{-\phi}}{vol^{\#}}$$



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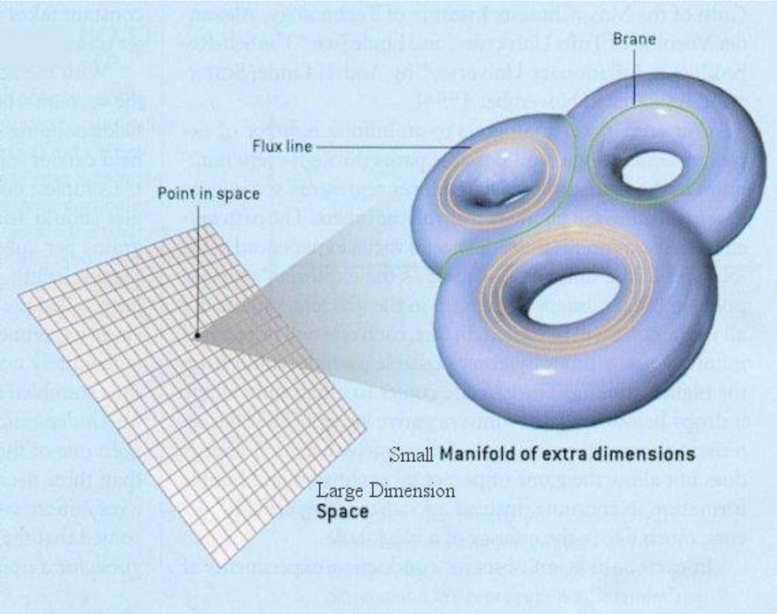

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<u>Goal:</u> Study SUGRA compactifications with fluxes and orientifold planes

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Type IIA Flux Compactifications

- Possible fluxes in type IIA are H_3, F_0, F_2, F_4
- 4d $N = 1$ arises from CY_3 manifold (with orientifold projection)
- CY_3 have no 1- or 5-cycles

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  $O4$-planes wraps 4+1 directions $\Rightarrow$ internal 1-cycle

  $O6$-planes wraps 6+1 directions $\Rightarrow$ internal 3-cycle

  $O8$-planes wraps 8+1 directions $\Rightarrow$ internal 5-cycle

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String worldsheet parity operator! Spacetime involution

- Include O6-planes via projection $\Omega_p \, I_6 \quad \Rightarrow \quad I_6\!: \; h^{p,q} \rightarrow \; h_+^{p,q} + h_-^{p,q}$
- Projects out some possible fluxes and scalar fields!

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- All fluxes allowed that satisfy

$$H_3 \in H_-^3(CY_3)$$

$$F_2 \in H_-^{1,1}(CY_3)$$

$$F_4 \in H_+^{2,2}(CY_3) \quad \text{also} \star F_4 = F_6 \in H_-^{3,3}(CY_3)$$

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- From above: $h_-^{1,1}$ real Kähler moduli in J

  $h^{2,1}$ real complex structure moduli in $\mathrm{Re}(\Omega)$
- Axions: $h_-^{1,1}$ real axions from $B_2 = \sum_a b_2^a\, Y_{-,a}^{1,1} \in H_-^{1,1}(CY_3)$

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Type IIA Flux Compactifications

- Do the integral over internal space explicitly to get V, K, W

Grimm, Louis hep-th/0412277

- The complex scalar fields in $4d, N = 1$ are

$$J_c \;= B_2 + i\,J = \sum_a t^a\, Y^{1,1}_{-,a}$$

$$\Omega_c = C_3 + i\,2\,e^{-\phi}\sqrt{vol_6}\,\mathrm{Re}(\Omega) = \sum_K U^K\, Y^3_{+,K}$$

$$vol_6 = \frac{1}{3!}\int J \wedge J \wedge J$$

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$$K = -4\log\left[e^{-\phi}\right] - 3\log[2vol_6]$$

Implicit function of Ω_c and moduli U^K

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Explicit function of $Im(J_c)$

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$$W = \int_{CY_3}\left(\Omega_c \wedge H_3 + F_6 + F_4 \wedge J_c + \frac{1}{2}F_2 \wedge J_c \wedge J_c + \frac{F_0}{3!}\,J_c \wedge J_c \wedge J_c\right)$$

Type IIA Flux Compactifications

- The vacua of $V = e^K(K^{I\bar{J}} D_I W \, \overline{D_J W} - 3|W|^2)$

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

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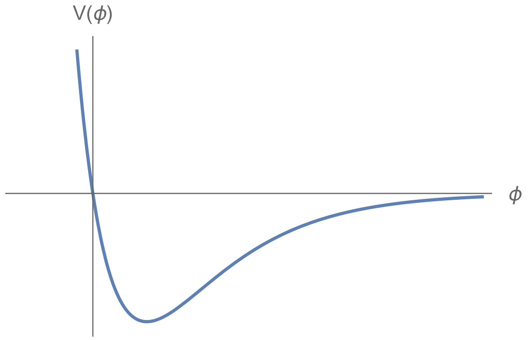

- Resulting isolated vacua are AdS, i.e. $V < 0$
- Solutions exist with and without SUSY
- No dS ($V > 0$) or Minkowski ($V = 0$) vacua with all moduli stabilized

Type IIA Flux Compactifications

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

- The O6-planes induces charge in internal compact space ↔ Gauss law

$$\int dF_2 = 0 = \int F_0 H_3 - 2N_{O6}$$

- Quantized F_0 and H_3 quanta must be $\pm 1, \pm 2$

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- F_2, F_4, F_6 must be closed and quantized, but otherwise unconstrained

Type IIA Flux Compactifications

- Type II SUGRA is not string theory
- SUGRA approximation ok for

1) Large volume $\frac{vol_6}{(\alpha')^3} \gg 1$ suppresses α' corrections

2) Weak coupling $e^{\Phi} \ll 1$ suppresses string loop corrections

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

$$\frac{vol_6}{(\alpha')^3} \sim N^{\frac{3}{2}} \gg 1$$

$$e^{\phi} \sim N^{-\frac{3}{4}} \ll 1$$

Type IIA Flux Compactifications

- AdS ($V < 0$) solutions usually not scale separated

  $\mathrm{AdS}_5 \times S^5$ has $L_{AdS_5} \sim L_{S^5}$

- No large gaps in operator dimensions in dual CFT

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- No large gaps in operator dimensions in dual CFT
- The type IIA AdS_4 flux vacua are scale separated

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

- Again, make F_4 flux quanta $N \gg 1$ large

$$L_{AdS} \sim N^{\frac{9}{4}} \gg L_{KK} \sim N^{\frac{7}{4}}$$

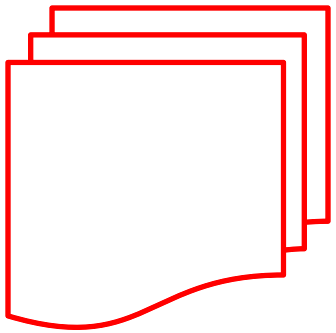
- Both grow $\Rightarrow$ decompactification limit

Type IIA Flux Compactifications - Issues

- Cannot solve 10d SUGRA equations of motion

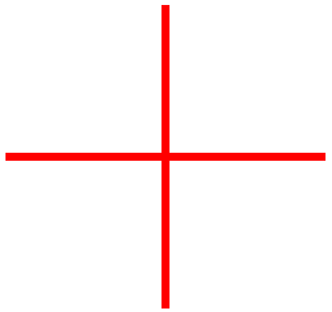
DeWolfe, Giryavets, Kachru, Taylor hep-th/0505160

- Stack of N Dp-branes in 10d flat space



$\Leftrightarrow$ higher dimensional BH

- No known solution exist for intersecting objects



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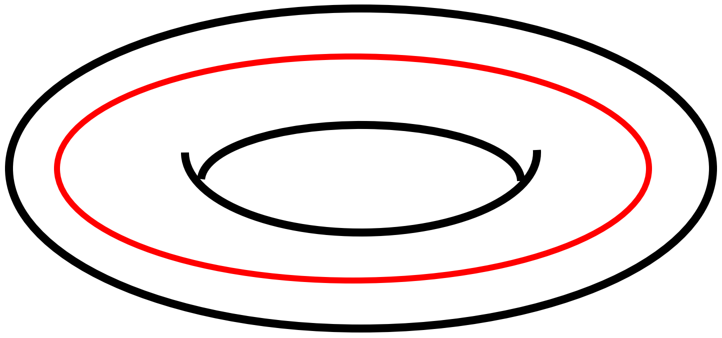
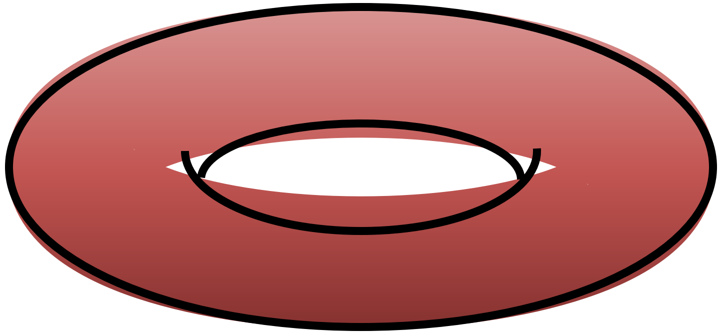
DeWolfe, Giryavets, Kachru, Taylor hep-th/0505160

- Solve equations with delta function sources replaced by constants

- Sometimes called smearing





Type IIA Flux Compactifications - Issues

- Cannot solve 10d SUGRA equations of motion

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

- Solve equations with delta function sources replaced by constants

- Sometimes called smearing , reasonable simplification?

- Solutions persist when doing 1^{st} order localization. What about 2^{nd}?

Junghans 2003.06274

Marchesano, Palti, Quirant, Tomasiello 2003.13578

…

Type IIA Flux Compactifications - Issues

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

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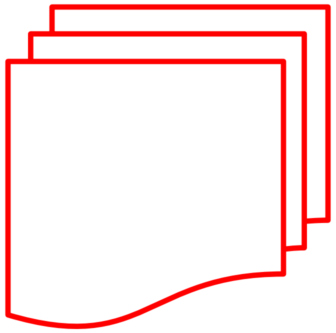


$\Leftrightarrow$ higher dimensional BH

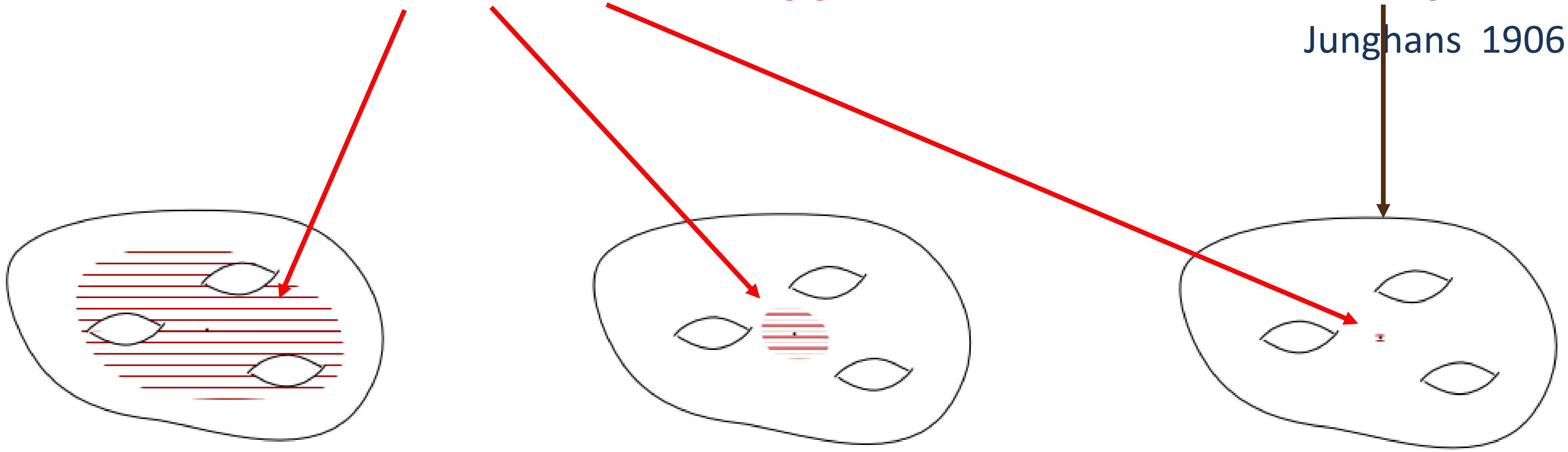
- Good SUGRA solution for large N not for single Dp-brane or Op-plane!

- Close to O6-planes SUGRA necessarily breaks down!

Type IIA Flux Compactifications - Issues

- How large is affected volume vol_{O6} compared to overall vol_6?

Junghans 1906.05225



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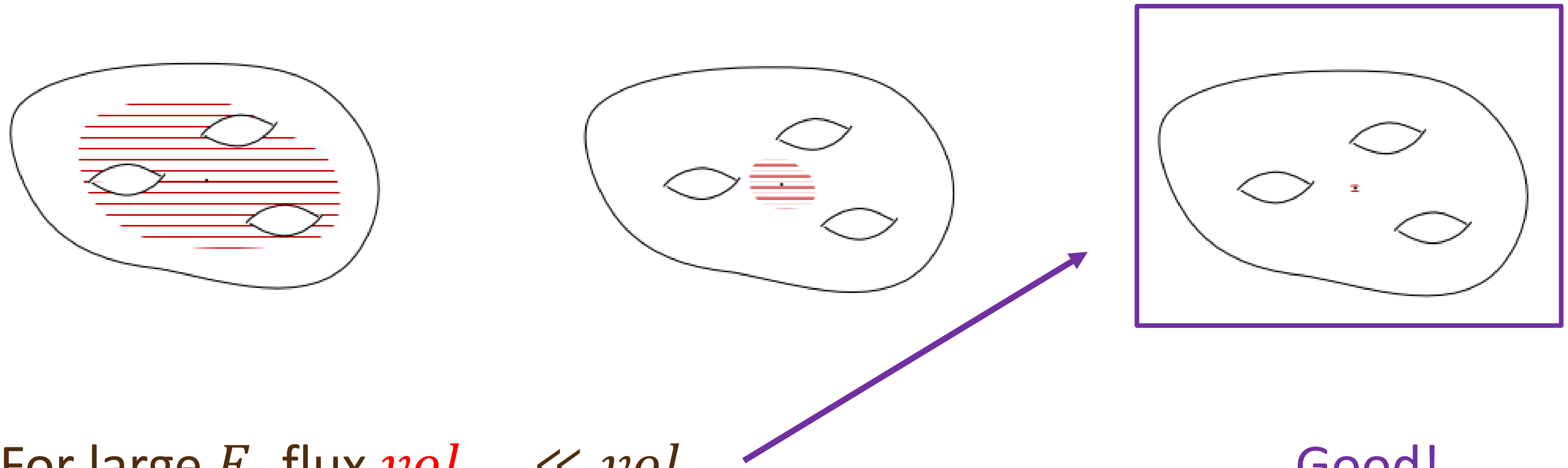

- For large F_4 flux $vol_{O6} \ll vol_6$

Good!

Type IIA Flux Compactifications - Issues

- $4d\ N = 1$ SUSY solutions have CFT_3 dual. What is it?

Banks, van den Broek hep-th/0611185

…

1) Set $F_2 = 0$
2) Do two T-dualities $F_2 \leftrightarrow F_0 = 0$
3) Lift solution to M-theory

} No sensible result

- Cannot lift smeared solutions, works for 1st order localized solutions

Cribiori, Junghans, Van Hemelryck, Van Riet, TW 2107.00019

…

More general swampland concerns

- <u>The AdS distance conjecture:</u>

D. Lüst, Palti, Vafa 1906.05225

$\exists$ an infinite tower of states with mass scale m which, as $\Lambda \sim \frac{-1}{L_{AdS}^2} \to 0$, behaves as $m \sim |\Lambda|^{\alpha}$, $\alpha > 0$ and $\alpha = O(1)$

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- The AdS distance conjecture: No counter example in string theory

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For KK-tower $\Rightarrow$ $L_{KK} \sim L_{AdS}$

$\Rightarrow$ Forbids DGKT type IIA SUSY AdS vacua

More general swampland concerns

- Conjectured universal properties for CFTs

Collins, Jafferis, Vafa, Xu, Yau 2201.03660

- Large number of holographic CFTs has universal bound on dimension of 1st non-trivial spin 2 operator

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Collins, Jafferis, Vafa, Xu, Yau 2201.03660

- Large number of holographic CFTs has universal bound on dimension of 1st non-trivial spin 2 operator

- Puts bounds on internal space to have minimal diameter in AdS units

- Conjecture makes scale separation impossible

Type IIA Flux Compactifications - Issues

- <u>Upshot:</u> $4d\ N = 1$ SUSY solutions break $N = 1$ to $N = 0$

Montero, Valenzuela 2412.00189

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Montero, Valenzuela 2412.00189

- Weak gravity conjecture (WGC) for membranes:

Arkani-Hamed, Motl, Nicolis, Vafa hep-th/0601001

Ooguri, Vafa 1610.01533

$$\exists \text{ membrane with } T \leq q$$

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Ooguri, Vafa 1610.01533

$$\exists \text{ membrane with } T \leq q$$

- Study this for DGKT type AdS vacua

Montero, Valenzuela 2412.00189

No such BPS brane with $T = q$ due to quantum corrections!

$\Leftrightarrow$ DGKT SUSY vacua violated WGC for membranes

Type IIA Flux Compactifications - Issues

- Upshot: $4d\ N = 1$ SUSY solutions break $N = 1$ to $N = 0$

Montero, Valenzuela 2412.00189

- <u>Non-SUSY AdS conjecture:</u>

Ooguri, Vafa 1610.01533

All non-SUSY vacua decay within AdS time (no dual CFT_3)

Outline

- Why moduli stabilization? Why $4d$ $N = 1$?
- Flux compactifications of type IIA
- Flux compactifications of type IIB: KKLT and LVS

Type IIB Flux Compactifications

- The two most famous scenarios:

  KKLT — Kachru, Kallosh, Linde, Trivedi hep-th/0301240

  LVS (Large Volume Scenario) — Balasubramanian, Berglund, Conlon, Quevedo hep-th/0502058

- Both use:
  - (warped) Calabi-Yau manifolds
  - O3/O7 orientifolds
  - Fluxes and non-pert. corrections

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- Both use a three-step procedure to get dS vacua with $V > 0$:

  1) Fluxes gives masses to τ and u^a

  2) Corrections lead to AdS vacua

  3) An anti-D3-branes leads to dS vacua

Type IIB Flux Compactifications

- Possible fluxes in type IIB are H_3, F_1, F_3, F_5
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- 4d $N = 1$ arises from CY_3 manifold (with orientifold projection)
- CY_3 have no 1- or 5-cycle: only fluxes H_3, F_3

$\Rightarrow\ G_3 = F_3 - \tau\, H_3$ with $\tau = C_0 + i\, e^{-\phi}$ the axio-dilaton

- Gukov-Vafa-Witten superpotential:

Gukov, Vafa, Witten hep-th/9906070

$W = \int G_3 \wedge \Omega$ with the holomorphic 3-form $\Omega(u^a)$, $a = 1,2, \dots, h^{2,1}$

Type IIB Flux Compactifications

- $G_3 = F_3 - \tau\, H_3$ induces a non-zero charge, requires sources

$$\int_{CY_3} \mathrm{d}F_5 = 0 = \int_{CY_3} F_3 \wedge \mathrm{H}_3 + N_{D3} - N_{\overline{D3}} - \frac{1}{2} N_{O3}$$

- Need to do an orientifold projection $\frac{\mathrm{CY}_3}{\Omega_p I}$

String worldsheet parity operator! Spacetime involution

- Fixed loci of spacetime involution I are O3/O7-planes

Type IIB Flux Compactifications

- Kähler moduli only appear in Kähler potential

$$
\begin{aligned}
K &= K_k + K_{cs} \\
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K_k &= -2\log\left[e^{-\frac{3}{2}\phi} vol_6\right] \\
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- No-scale conditions implies that volume only appears as overall factor

$\alpha, \beta = 0, 1, \dots, h^{2,1} \leftrightarrow \{\tau, u^a\}$

$$V = e^K\left(K^{I\bar{J}} D_I W \overline{D_J W} - 3|W|^2\right) = \frac{e^{K_{CS}}}{\left(e^{-\frac{3}{2}\phi} vol_6\right)^2} K_{cs}^{\alpha\bar{\beta}} D_\alpha W \overline{D_\beta W}$$

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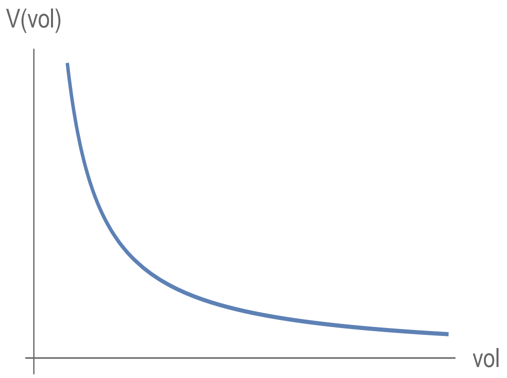

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Giddings, Kachru, Polchinski hep-th/0105097

- $1 + h^{2,1}$ complex equations $D_\alpha W = 0$ fix $1 + h^{2,1}$ complex scalars

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- What about Kähler moduli stabilization?

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Grimm, Louis hep-th/0403067

$$T^j = \int_{\Sigma^j_{2,2}} C_4 - \frac{i}{2} e^{-\phi} J \wedge J\,, \quad \Sigma^j_{2,2} \in H_{2,2} \quad \Rightarrow \quad j = 1,2,\ldots,h^{1,1}$$

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Kachru, Kallosh, Linde, Trivedi hep-th/0301240

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- Stack of D7-branes wrap internal 4-cycle: $a = 2\pi/N_c$

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Recently debated whether details works out $\Rightarrow$ Seems all ok

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- As before $D_\alpha W = 0$ fix τ and complex structure moduli u^a
- Now $D_T W = 0$ leads to $4d$ $N = 1$ supersymmetric AdS vacua

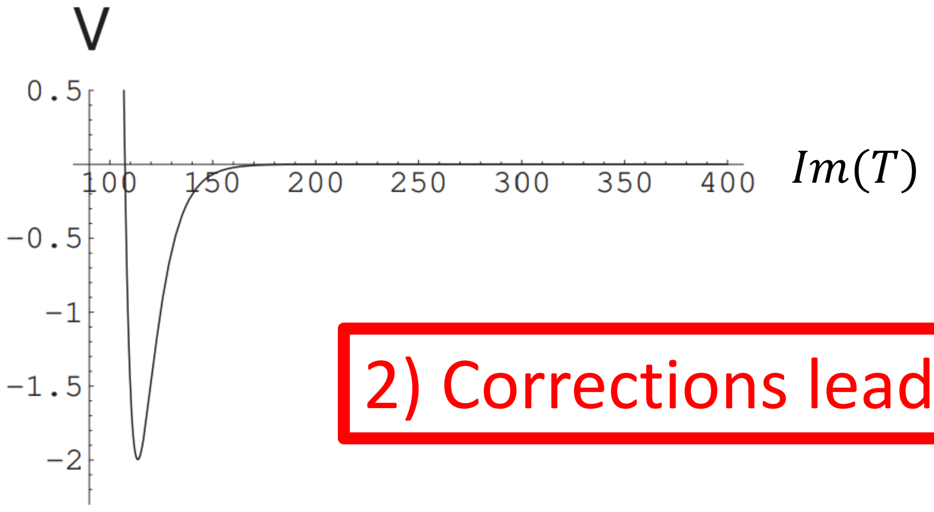

FIG. 1: Potential (multiplied by 10^{15}) for the case of exponential superpotential with $W_0 = -10^{-4}$, $A = 1$, $a = 0.1$. There is an AdS minimum.

2) Corrections lead to AdS vacua

Type IIB Flux Compactifications

$$W = \int G_3 \wedge \Omega + A(u^a)\, e^{-i\, a\, T}$$

- As before $D_\alpha W = 0$ fix τ and complex structure moduli u^a
- Now $D_T W = 0$ leads to $4d$ $N = 1$ supersymmetric AdS vacua

$$D_T W = 0 \quad \Leftrightarrow \quad W_0 = A e^{-a\, Im(T)} \left(1 + \frac{2}{3} a\, Im(T)\right)$$

- $a\, Im(T) \gg 1$ to control series $W = W_0 + A e^{-iaT} + A_2 e^{-2iaT} + \cdots$
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- Problem: $a\, Im(T) \gg 1 \quad \Leftrightarrow \quad W_0$ exp. small
- Many fluxes, u^a might give that

Denef, Douglas hep-th/0404116

- One can engineer this, leading to one light u modulus

Demirtas, Kim, McAllister, Moritz 1912.10047

Type IIB Flux Compactifications

- One can add an anti-D3-brane to uplift to $V > 0$ dS vacuum
- Orientifolds give negative term, anti-D3-brane $V_{D3} > 0, V + \frac{D}{Im(T)^3}$

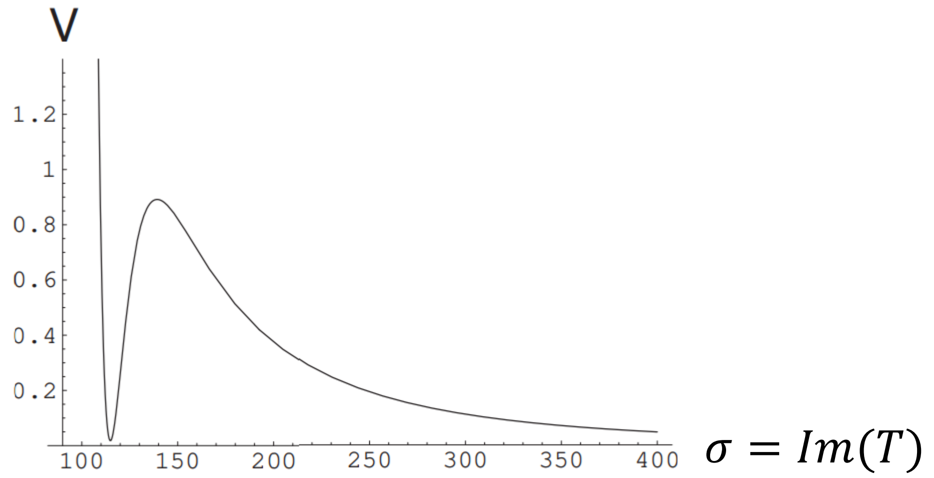

FIG. 2: Potential (multiplied by 10^{15}) for the case of exponential superpotential and including a $\frac{D}{\sigma^3}$ correction with $D = 3 \times 10^{-9}$ which uplifts the AdS minimum to a dS minimum.

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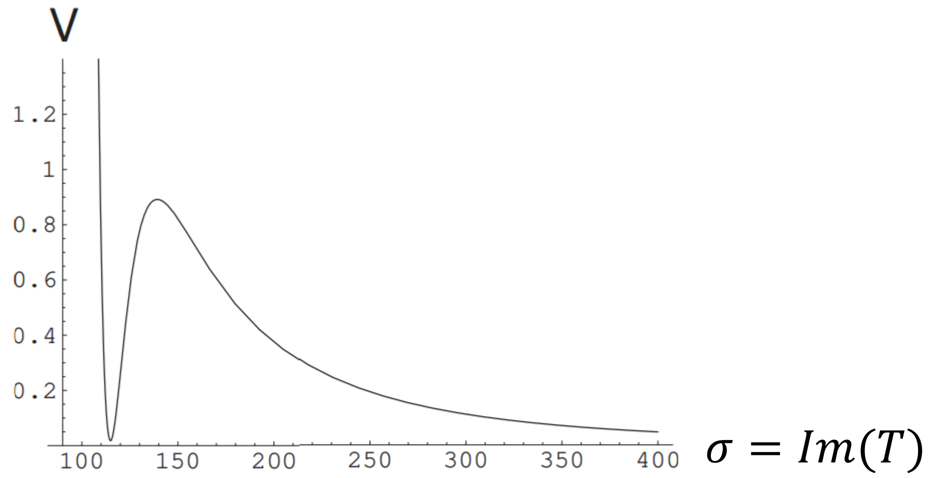

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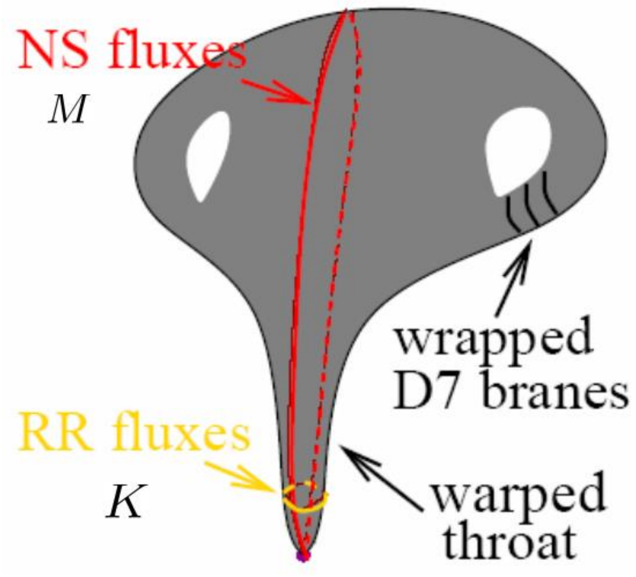
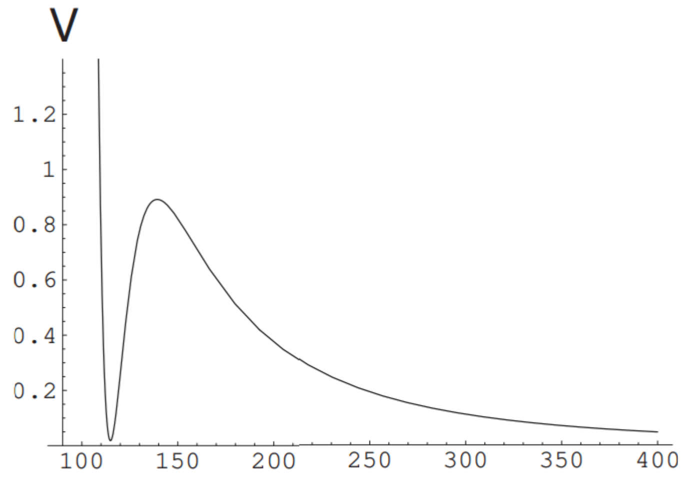


$\overline{D3}$-brane



$\sigma = Im(T)$

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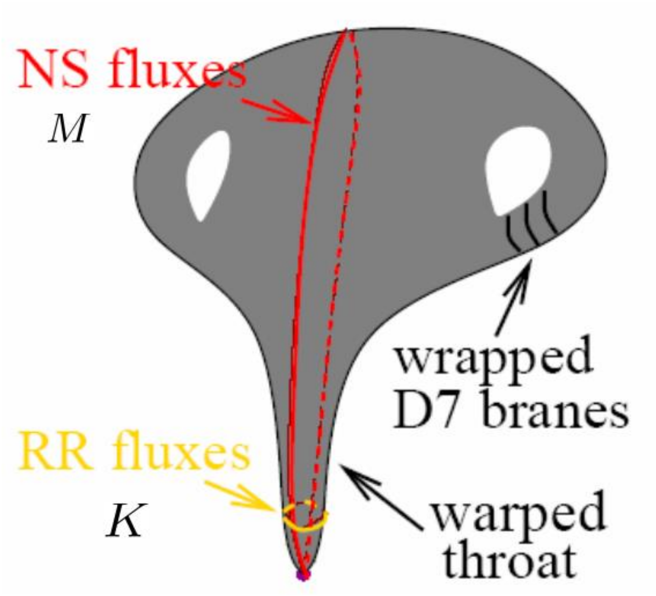

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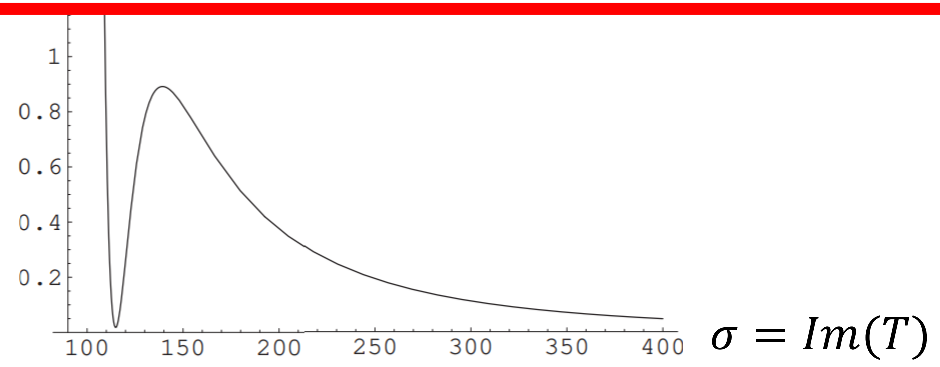
3) An anti-D3-branes leads to dS vacua



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Type IIB Flux Compactifications

- LVS (Large Volume Scenario)

Balasubramanian, Berglund, Conlon, Quevedo hep-th/0502058

- K does receive perturbative corrections, leading order α'

χ is Euler character

$$K_k = -2\log\left[e^{-\frac{3}{2}\phi} vol_6 - e^{-\frac{3}{2}\phi}\frac{\zeta(3)\chi(CY_3)}{2(2\pi)^3}\right]$$

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- Swiss cheese CY_3, e.g., $\mathbb{CP}_{1,1,1,6,9}$

$$vol_6 = \left(\frac{T_b+\overline{T_b}}{2}\right)^{\frac{3}{2}} - \left(\frac{T_s+\overline{T_s}}{2}\right)^{\frac{3}{2}}$$

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- Find vacua where α' corrections in K important and $W = W_{GVW} + A_s e^{-iaT_s}$
- No supersymmetric AdS solutions exist

Type IIB Flux Compactifications

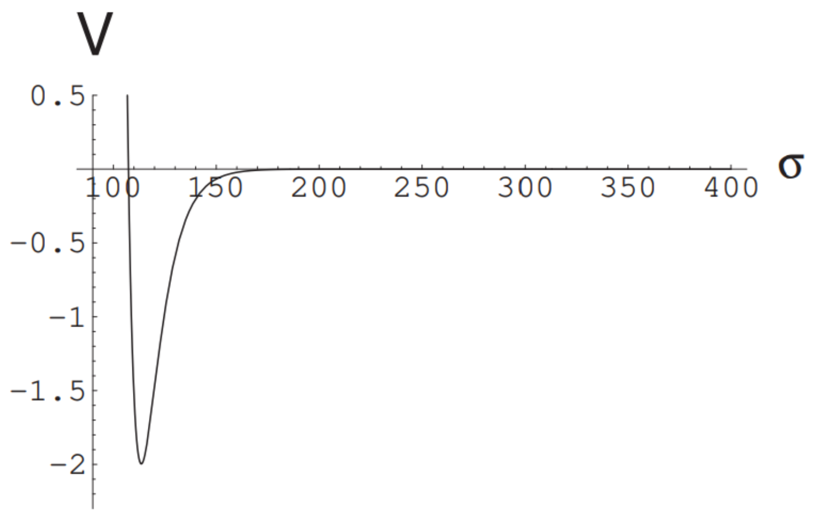
- LVS (Large Volume Scenario)

Balasubramanian, Berglund, Conlon, Quevedo hep-th/0502058

- Non-SUSY AdS vacua

$vol_6 \sim |W_0| e^{a\, Im(T_s)}$ exponentially large

$W_0 \sim O(1)$ is ok



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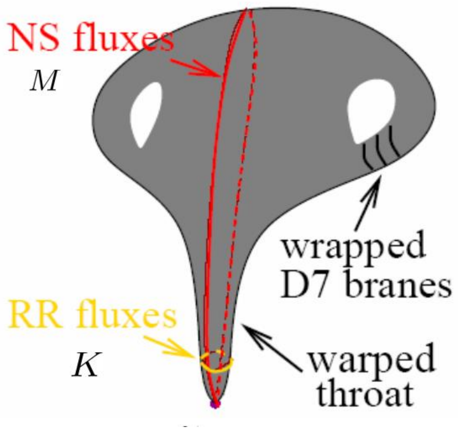
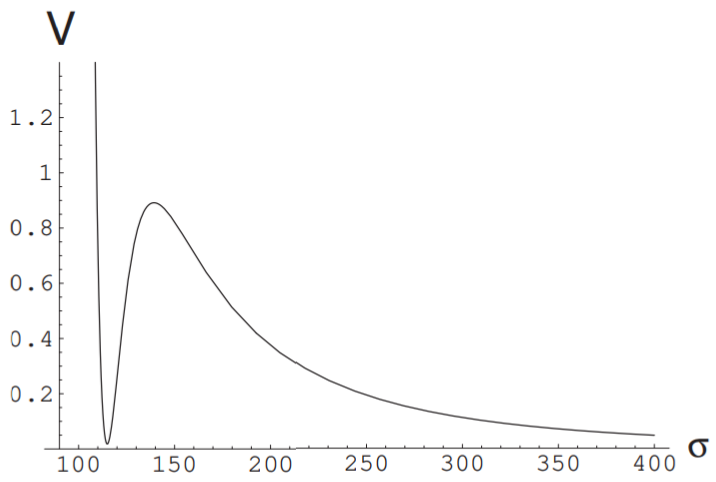
$vol_6 \sim |W_0| e^{a\, Im(T_s)}$ exponentially large

$W_0 \sim O(1)$ is ok

- Anti-D3-brane in throat

can again uplift this to dS





Type IIB Flux Compactifications - Issues

1) Fluxes gives masses to τ and u^a

- Interesting solutions $D_\alpha W = 0$ fix τ and complex structure moduli u^a

Giddings, Kachru, Polchinski hep-th/0105097

- Recall tadpole cancellation: $N_{flux} = \int F_3 \wedge H_3 + N_{D3} = \frac{1}{2} N_{O3}$
- PROBLEM: "Many massive fields require many fluxes ⇒ large tadpole"

Bena, Blåbäck, Graña, S. Lüst 2010.10519

…

See my talk on Thursday for more details

Summary for Mathematician in section 3.1 of arXiv:2210.03706

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  Bena, Blåbäck, Graña, S. Lüst 2010.10519

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- Solutions: 1) Can work with CY_3's with small $h^{2,1}$

  2) Go to special points in moduli space

Type IIB Flux Compactifications

2) Corrections lead to AdS vacua

- Few explicit models, some new recent constructions

Demirtas, Kim, McAllister, Moritz, Rios-Tascon 2107.09064

Type IIB Flux Compactifications - Issues

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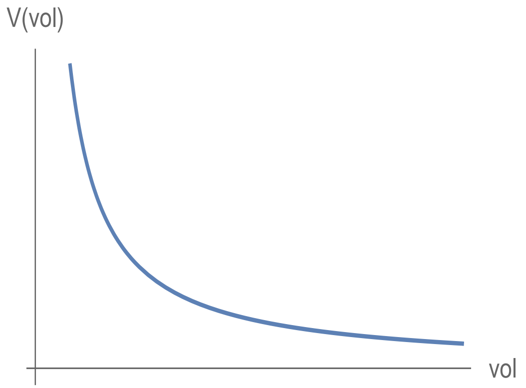
Demirtas, Kim, McAllister, Moritz, Rios-Tascon 2107.09064

- Due to corrections no Minkowski vacuum

$\Rightarrow$ Rolling volume modulus

$\Rightarrow$ Cannot calculate $W_{np} = Ae^{-iaT}$



Sethi 1709.03554

- Yes, you can calculate it

Kachru, Trivedi 1808.08971

Type IIB Flux Compactifications - Issues

2) Corrections lead to AdS vacua

- Few explicit models, some new recent constructions

Demirtas, Kim, McAllister, Moritz, Rios-Tascon 2107.09064

- Strong AdS distance conjecture: For SUSY AdS vacua $\alpha = \frac{1}{2}$

D. Lüst, Palti, Vafa 1906.05225

- Conjectured universal properties for CFTs

Collins, Jafferis, Vafa, Xu, Yau 2201.03660

$\Rightarrow$ Forbid KKLT type IIB SUSY AdS vacua

Type IIB Flux Compactifications - Issues

2) Corrections lead to AdS vacua

- Few explicit models, some new recent constructions

Demirtas, Kim, McAllister, Moritz, Rios-Tascon 2107.09064

- Brane configurations sourcing fluxes for AdS vacua incompatible scale separated, SUGRA controlled AdS solutions

S. Lüst, Vafa, Wiesner, Xu 2204.07171

Bena, Li, S. Lüst 2410.22400

See talk by Severin Lüst on Thursday

Type IIB Flux Compactifications - Issues

3) An anti-D3-branes leads to dS vacua

- Placing an anti-D3-brane at the bottom of a throat…

Bena, Grana, Halmagyi 0912.3519

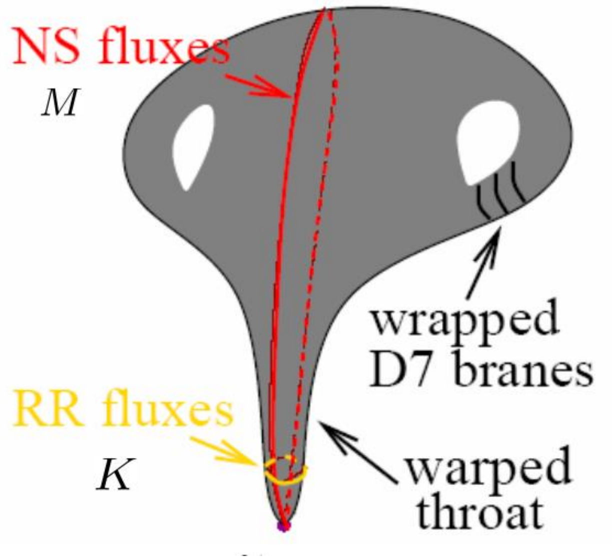
…

- Studied for more than 15 years:

  Saclay, Princeton, Cornell, UCSB, Stanford,…

- Upshot: 1) Cannot find exact solution

  2) No generically fatal issue found



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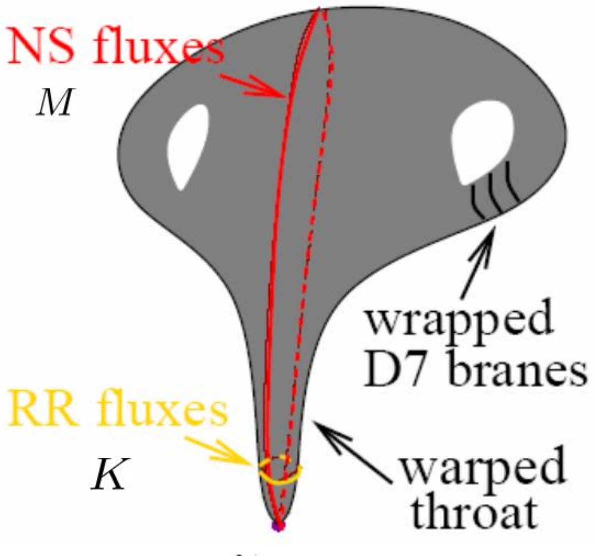

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Bena, Grana, Halmagyi 0912.3519

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- Singular bulk problem in KKLT and LVS

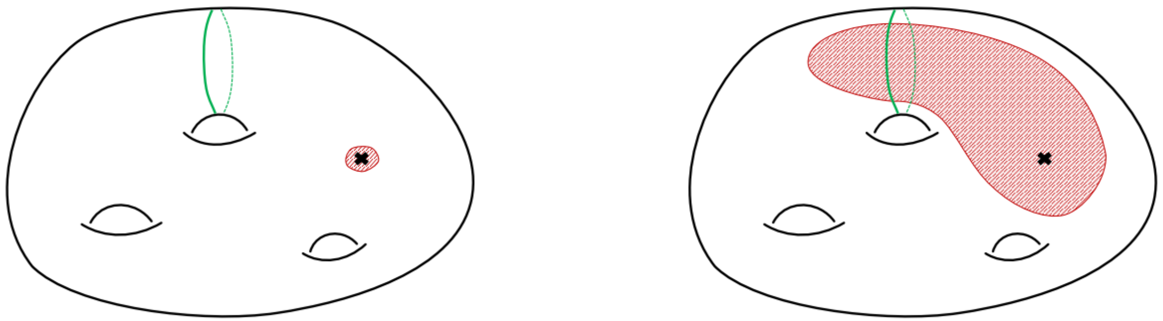

Figure 1: Sketch of a Calabi-Yau orientifold with a 4-cycle supporting a non-perturbative effect (green) and singular regions (red). The left-hand side shows the expected singularity in the vicinity of an O-plane (black cross). The right-hand side shows the large singular region that appears in a flux compactification compatible with a KKLT-like uplift.

Carta, Moritz, Westphal 1902.01412
Gao, Hebecker, Junghans 2009.03914
Blumenhagen, Gligovic, Kaddachi 2206.08400
Junghans 2201.03572
Gao, Hebecker, Schreyer, Venken 2202.04087
Junghans 2205.02856
Hebecker, Schreyer, Venken 2208.02826
Schreyer, Venken 2212.07437
Chakraborty, Parameswaran, Zavala 2306.07332

Type IIB Flux Compactifications - Issues

Upshot: 1) Extremely hard to control all moving parts!

2) No parameter that gives parametric control as in type IIA

3) Use pert. and/or non-pert. leading corrections

$\Rightarrow$ infinite number of other corrections neglected

4) Large regions of internal space not in SUGRA regime?

Summary

- Need to understand moduli stabilization in string theory
- $4d\ N = 1$ provides riches playground for semi-realistic models
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THANK YOU!