On Classical dS Vacua in String Theory

Timm Wrase

C. Caviezel, TW, M. Zagermann 0912.3287 [hep-th]
R. Flauger, D. Robbins, S. Paban, TW 0812.3886 [hep-th]
C. Caviezel, P. Koerber, S. Körs, D. Lüst, TW, M. Zagermann 0812.3551 [hep-th]

Outline

- Motivation
- Type II flux compactifications
- Search for dS vacua and slow-roll inflation in concrete type II models
- Conclusion and Outlook

Motivation

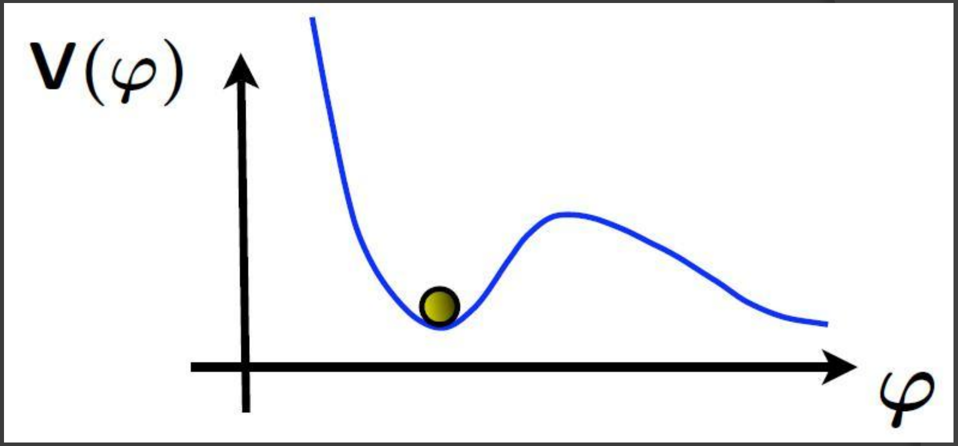
- Supersymmetric compactifications of supergravity/string theory generically lead to massless scalar fields $\Rightarrow$ moduli problem
- (NSNS and RR) Fluxes and/or (non-) perturbative corrections stabilize string moduli
- Interesting for cosmology: dS vacua? inflation?

Motivation

dS vacuum requires

$$\varepsilon \sim (V'/V)^2 = 0$$

$$\eta \sim V''/V > 0$$



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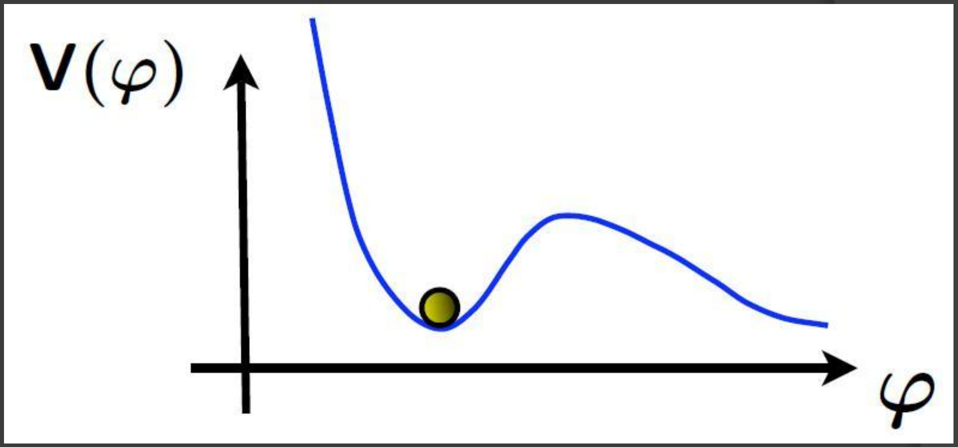
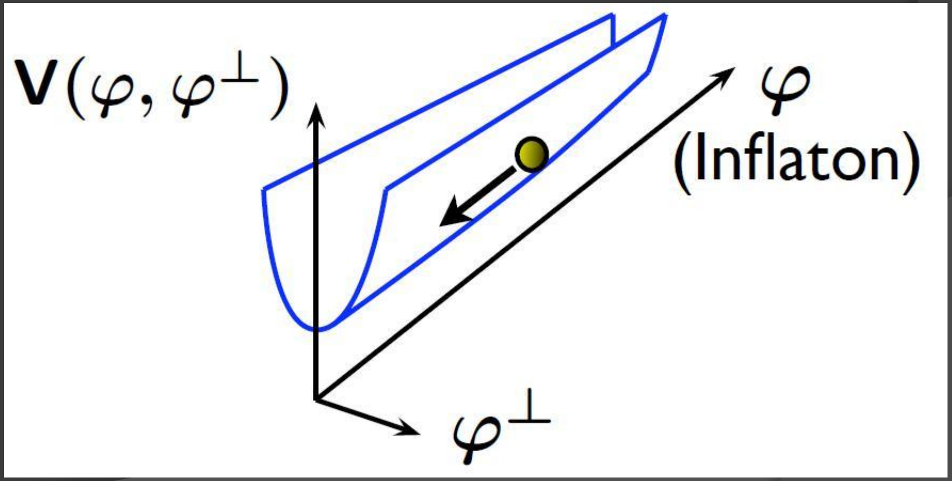


Inflation requires

$$\varepsilon \sim (V'/V)^2 << 1$$

$$|\eta| \sim |V''/V| << 1$$



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Can we find explicit compactifications that lead to fully stabilized dS vacua at tree-level?

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Need negative tension objects (O-planes)

Gibbons
deWit, Smit, Hari Dass
Maldacena, Nuñez

$\Rightarrow$ II string theory

Type II Flux Compactifications

Can we find explicit compactifications that lead to fully stabilized dS vacua at tree-level?

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$$\mathrm{IIA:}\ \ p \in \{0,2,4,6\},\ q \in \{4,6,8\}, \qquad \mathrm{IIB:}\ \ p \in \{1,3,5\},\ q \in \{3,5,7,9\}$$

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$$V = V_H + \sum_p V_{F_p} + \sum_q V_{Oq} + V_{R_6}, \qquad V_H, V_{F_p} \geq 0,\ V_{Oq} \leq 0$$

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no slow-roll: $\varepsilon = \frac{K^{i\bar{j}}\partial_i V \partial_{\bar{j}} V}{V^2} \geq \frac{c^2}{4a^2 + 3b^2} \approx O(1)$

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Can find a, b such that $(-a\tau\partial_\tau - b\rho\partial_\rho)V \geq cV, \quad c > 0,$

- whenever $p+q-6 \geq 0, \ \forall p,q,$ for $V_{R_6} \propto -R_6 \leq 0.$
- whenever $p+q-8 \geq 0, \ \forall p,q,$[1] for $V_{R_6} \propto -R_6 > 0.$

1) O3-planes with F_5-flux is also possible.

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Curvature	No-go if	No no-go IIA	No no-go IIB
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$V_{R_6} \propto -R_6 > 0$	$p+q-8 \geq 0,\ \forall p,q$	F_0, O4-planes	F_1, O3-planes
		F_2, O4-planes	F_3, O3-planes
		F_0, O6-planes	F_5, O3-planes
			F_1, O5-planes

Minimal ingredients needed to evade no-go theorem in the (ρ,τ)-plane.

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F_0 flux needs to be odd under O4 orientifold projection.

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		F_0, O6-planes	F_5, O3-planes
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$F_{1/5}$ flux needs to be even under O3 orientifold projection.

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Curvature and O3 orientifold projection:

$$de^i = -\frac{1}{2} f^i_{jk} e^j \wedge e^k, \quad \sigma_{O3} : e^i \to -e^i \quad \Rightarrow \quad f^i_{jk} = 0$$

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Full moduli stabilization in principle possible!

Type II Flux Compactifications

Can we find explicit compactifications that lead to fully stabilized classical dS vacua?

Assumptions:

- Restrict to bulk moduli and neglect blow-up sector
- Restrict to the closed string sector (no D-branes)
- Take O-planes to be smeared over transverse directions
- Consider only compactifications that give a 4d $\mathcal{N} = 1$ action

Type II Flux Compactifications

Flux compactifications that give a 4d $\mathcal{N}=1$ action

- CY3 with O6, O3/O7 or O5/O9

Grimm, Louis hep-th/0403067, hep-th/0412277
DeWolfe, Giryavets, Kachru, Taylor hep-th/0505160
Hertzberg, Kachru, Taylor, Tegmark 0711.2512 [hep-th]

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Danielsson, Haque, Shiu, Van Riet 0907.2041 [hep-th]
de Carlos, Guarino, Moreno 0907.5580, 0911.2876 [hep-th]

- SU(2)-structure with O5/O7 or O4/O6/O8

Louis, Triendl 0904.2993 [hep-th]
Danckaert, Louis 0911.5697 [hep-th]
C. Caviezel, TW, M. Zagermann 0912.3287 [hep-th]

SU(n)-structure manifolds, n=2,3

- Compactification on SU(n)-structure is difficult

Kashani-Poor, Minasian hep-th/0611106

Graña, Louis, Waldram hep-th/0612237

- Examples of SU(n)-structure manifolds include twisted tori and coset spaces G/H

Dabholkar, Hull, Reid-Edwards
Cvetic, Liu, Schulz
Robbins, Ihl, TW
Graña, Minasian, Petrini, Tomasiello
Caviezel, Koerber, Körs, Lüst, Tsimpis, Zagermann

- Natural expansion basis exists: G invariant forms
- Models expected to be consistent truncations ($\Rightarrow$ potential instability in other sector)

Cassani, Kashani-Poor 0901.4251 [hep-th]

Type IIA on SU(3)-structure

New no-go theorems using other directions in moduli space:

Applicable to models with:

Factorization of Kähler sector

$$vol_6 = \kappa_{abc} k^a k^b k^c = k^0 \tilde{\kappa}_{de} k^d k^e, \quad d, e \neq 0$$

and restrictions on curvature ("metric fluxes"), e.g. $J = k^0 w_0 + k^d w_d$

$$dw_0 = 0,\ dw_d \neq 0:\ -\tau \partial_\tau V - k^0 \partial_{k^0} V \geq 3V \ \Rightarrow\ \varepsilon \geq \frac{9}{5},$$

$$dw_0 \neq 0,\ dw_d = 0:\ -2\tau \partial_\tau V - k^d \partial_{k^d} V \geq 6V \ \Rightarrow\ \varepsilon \geq 2.$$

Flauger, Robbins, Paban, TW 0812.3886 [hep-th]
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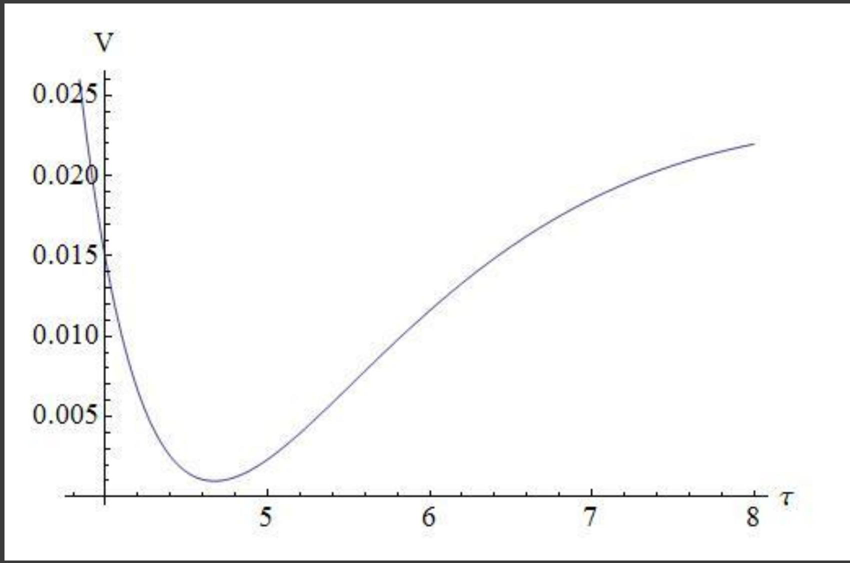
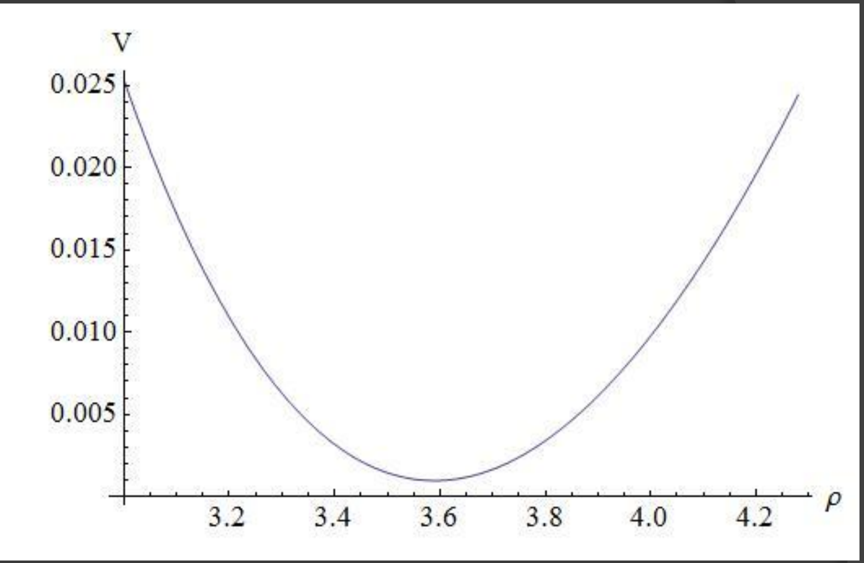
Type IIA on SU(3)-structure

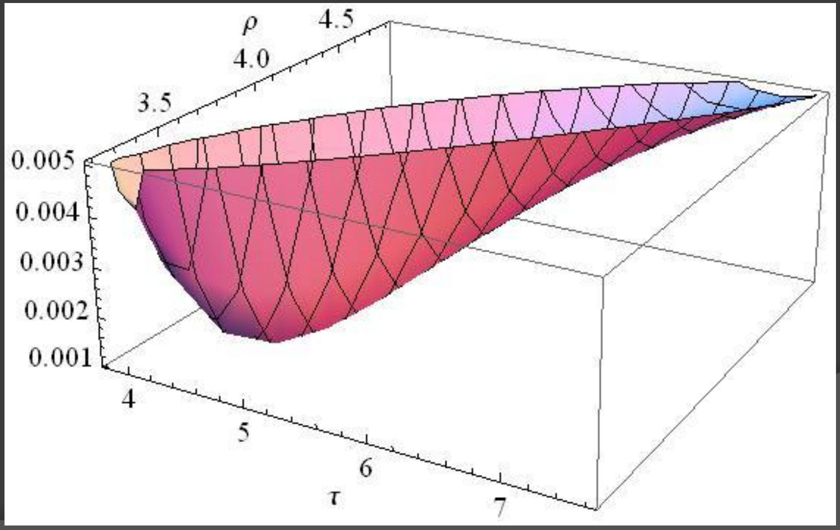
New no-go theorems using other directions in moduli space:

- Exclude almost all models (6 cosets, 10 twisted tori) that were studied
- $\check{T}^6/Z_2 x Z_2$ and $SU(2)xSU(2)/Z_2 x Z_2$ evade all known no-go theorems. Numerically we indeed find $\varepsilon \approx 0$!

Type IIA on SU(2)xSU(2)

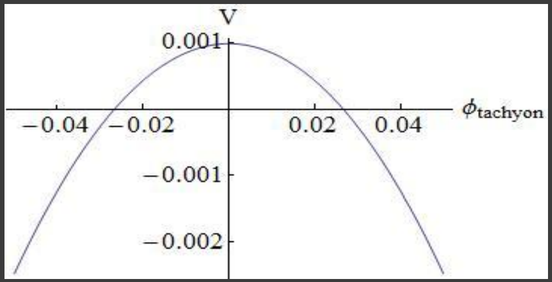






Type IIA on SU(3)-structure

- $\check{T}^6/Z_2 x Z_2$ and $SU(2)xSU(2)/Z_2 x Z_2$ evade all known no-go theorems. Numerically we indeed find $\varepsilon \approx 0$!
- But one tachyonic direction: $\eta \leq -1.5$



Flauger, Robbins, Paban, TW 0812.3886 [hep-th]
Caviezel, Koerber, Körs, Lüst, TW, Zagermann 0812.3551 [hep-th]

- Can stabilize13 directions, but one always unstable
- General no-go theorems for η parameter don't apply

Covi, Gomez-Reino, Gross, Louis, Palma, Scrucca 0804.1073 [hep-th]
Covi, Gomez-Reino, Gross, Louis, Palma, Scrucca 0805.3290 [hep-th]

Type IIB on SU(2)-structure

- SU(2)-structure compactifications with O5/O7 orientifold projections $\Rightarrow N = 1$ in 4d
- SU(2)-structure manifolds have 1- and 5-forms $\Rightarrow$ RR fluxes F_1, F_3, F_5 for IIB
- Can in principle stabilize all moduli at tree-level in a supersymmetric AdS vacuum with large volume and small string coupling

Caviezel, TW, Zagermann 0912.3287 [hep-th]

Type IIB on SU(2)-structure

Type IIA on $T^6/Z_2 x Z_2$ with

O6-planes

SU(3)-structure

O-plane	1	2	3	4	5	6
O6	X		X	X		
O6	X				X	X
O6		X	X		X	
O6		X		X		X

Type IIB on $T^2 x T^4/Z_2$ with

O5-planes and O7-planes

SU(2)-structure

O-plane	1	2	3	4	5	6
O5			X	X		
O5					X	X
O7	X	X	X		X	
O7	X	X		X		X

Type IIB on SU(2)-structure

T-dual to SU(3)-structure but might lead to new examples:

- SU(3)- and SU(2)-structure spaces have metric-flux
- T-duality might lead to non-geometric spaces

  $\Rightarrow$ supergravity applicable in T-dual description?

Wecht 0708.3984 [hep-th]

- SU(2)-structure compactifications not T-dual to geometric SU(3)-spaces are new

Type IIB on SU(2)-structure

- Natural split of Kähler and complex structure moduli:

$$vol_6 = V \wedge \bar{V} \wedge \omega_2 \wedge \omega_2, \quad \mathrm{Im}(\Omega_2),\ V \wedge \bar{V} \wedge \mathrm{Re}(\Omega_2)$$

- Only very few cosets and twisted $T^2 x T^4 / Z_2$
- Can derive no-go theorems to exclude dS vacua and slow-roll in several concrete examples
- SU(2)xSU(2) example not excluded by no-go theorems

Caviezel, TW, Zagermann 0912.3287 [hep-th]

Conclusions

- General no-go theorems against tree-level dS vacua and slow-roll inflation exists
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- General no-go theorems against tree-level dS vacua and slow-roll inflation exists
- Negative curvature spaces more promising
- Type IIA on SU(3)-structure with O6-planes and type IIB on SU(2)-structure with O5/O7-planes allow for stabilization of all closed string moduli
- Many no-go theorems for explicit examples
- Can find explicit numerical dS extrema but only with one tachyonic direction

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Villadoro, Zwirner hep-th/0602120
Palti, Tasinato, Ward 0804.1248 [hep-th]
Covi, Gomez-Reino, Gross, Palma, Scrucca 0812.3864 [hep-th]

  - NSNS source

Villadoro, Zwirner 0706.3049, 0710.2551 [hep-th]
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  Gomez-Reino, Louis, Scrucca 0812.0884 [hep-th]
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THANK YOU!