On the Cosmology of Type II Flux Compactifications

Timm Wrase

MPI for Physics, Munich

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]
D. Robbins, TW	0709.2186 [hep-th]
D. Robbins, M. Ihl, TW	0705.3410 [hep-th]
M. Ihl, TW	hep-th/0604087

Outline

- Motivation
- Type IIA flux compactifications
- Slow-roll inflation and dS vacua in type IIA
- “T-dual” type IIB compactifications
- Conclusion and Outlook

Motivation

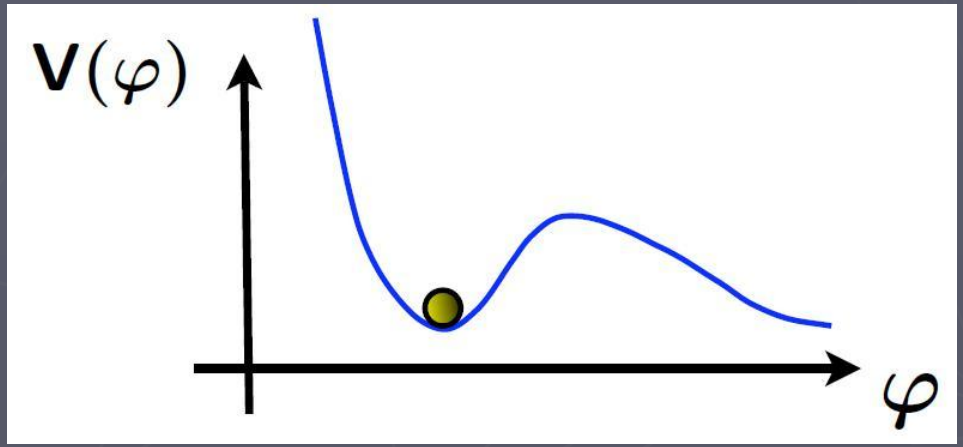
- Flux compactifications lead to a scalar potential $V(\varphi)$
- Stabilizes closed string moduli
- Interesting for cosmology: dS vacua and inflation

Motivation

dS vacuum requires

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

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



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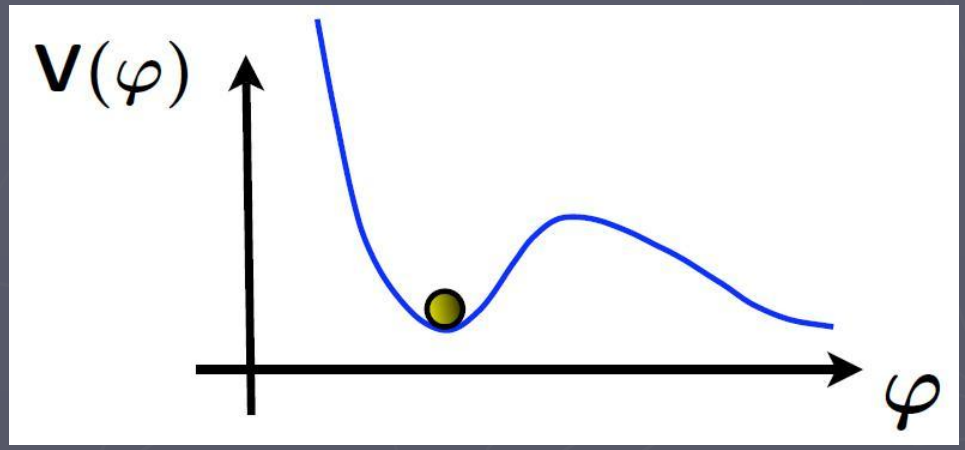
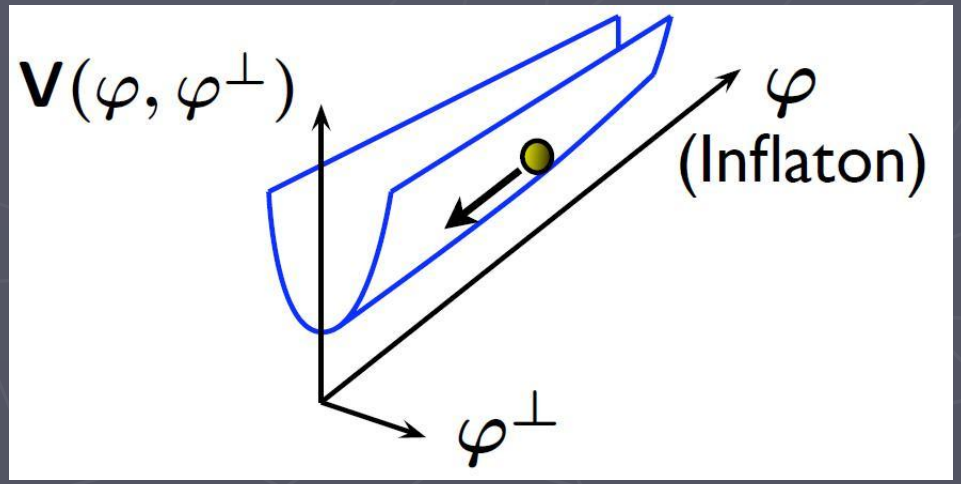


Inflation requires

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

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



Type II Flux Compactifications

Type II on a CY_3-manifold with orientifold projection

<u>Type IIB intensively studied:</u>

$$V(\varphi) = V_{classical} + V_{quantum}$$

- Can stabilize all moduli in certain cases
- Quantum corrections hard to compute precisely
- Interesting for cosmology

Kachru, Kallosh, Linde, Maldacena, McAllister, Trivedi
Burgess, Kallosh, Quevedo
Conlon, Quevedo
many, many others

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Type IIA:

$$V(\varphi) = V_{classical}$$

- Can stabilize all moduli in certain cases
- Classical contributions sufficient
- Controlled regime in which corrections can be neglected
- No-go theorems against dS and inflation under mild assumptions

Type IIA Flux Compactifications

IIA on CY_3 with fluxes:

- Can stabilize all moduli (except some RR axions) in an AdS vacuum
- Controlled regime
- No quantum corrections needed

Grimm, Louis hep-th/0412277
DeWolfe, Giryavets, Kachru, Taylor hep-th/0505160

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Grimm, Louis hep-th/0412277
DeWolfe, Giryavets, Kachru, Taylor hep-th/0505160

IIA on (non Ricci flat) SU(3)-structure with fluxes:

- Can stabilize all moduli (except some RR axions) in an AdS vacuum
- Curvature leads to new F-term and D-term contributions
- No quantum corrections needed

Villadoro, Zwirner hep-th/0503169
Camara, Font, Ibanez hep-th/0506066
D. Robbins, M. Ihl, TW 0705.3410 [hep-th]

Cosmological aspects in type IIA

CY_3 with fluxes: only AdS vacua, no slow-roll inflation:

Identify scaling with respect to

$$\rho = (vol_6)^{1/3}, \quad \tau = e^{-\phi}\sqrt{vol_6}$$

$$V_H \propto \rho^{-3}\tau^{-2}, \; V_{F_p} \propto \rho^{3-p}\tau^{-4}, \; V_{O6} \propto \tau^{-3},$$

$$-\rho\partial_\rho V - 3\tau\partial_\tau V = 9V + \sum_p pV_{F_p} \geq 9V \Rightarrow \varepsilon \sim \left(\frac{V'}{V}\right)^2 \geq \frac{27}{13}$$

Hertzberg, Kachru, Taylor, Tegmark 0711.2512 [hep-th]

$\Rightarrow$ Need more ingredients to get a richer potential!

Cosmological aspects in type IIA

SU(3)-structure manifolds: lead to new terms in the scalar potential that evades the no-go theorem

$$\rho = (vol_6)^{1/3}, \quad \tau = e^{-\phi}\sqrt{vol_6}$$

$$V_H \propto \rho^{-3}\tau^{-2}, \; V_{F_p} \propto \rho^{3-p}\tau^{-4}, \; V_{O6} \propto \tau^{-3}, \; \boxed{V_R \propto \rho^{-1}\tau^{-2}}$$

$$-\rho\partial_\rho V - 3\tau\partial_\tau V = 9V + \sum_p pV_{F_p} \boxed{-2V_R} \quad \Rightarrow \quad \varepsilon \geq ?$$

$V_R \propto -R_6$ Need manifolds with negative curvature.

Silverstein 0712.1196 [hep-th]
Caviezel, Koerber, Körs, Lüst, Tsimpis, Zagermann 0806.3458 [hep-th]
Haque, Shiu, Underwood, Van Riet 0810.5328 [hep-th]
Danielsson, Haque, Shiu, Van Riet 0907.2041 [hep-th]

Cosmological aspects in type IIA

- Examples of SU(3)-structure manifolds include coset spaces G/H and twisted tori

Dabholkar, Hull hep-th/0210209
Hull, Reid-Edwards hep-th/0503114
D. Robbins, M. Ihl, TW 0705.3410 [hep-th]
Koerber, Lust, Tsimpis 0804.0614 [hep-th]
Caviezel, Koerber, Körs, Lüst, Zagermann 0806.3458 [hep-th]

- Natural expansion basis exists: G invariant forms
- Models expected to be consistent truncations

Cassani, Kashani-Poor 0901.4251 [hep-th]

Cosmological aspects in type IIA

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/or factorization of complex structure sector $Z^I = \int_{\Gamma^I} \Omega, \; I = 1,\ldots,h^{2,1}+1$

$$1 = p(Z) = p_1(Z_{(1)}) \cdot p_2(Z_{(2)}), \quad \{Z_{(1)}\} \cap \{Z_{(2)}\} = 0$$

and restrictions on curvature ("metric fluxes").

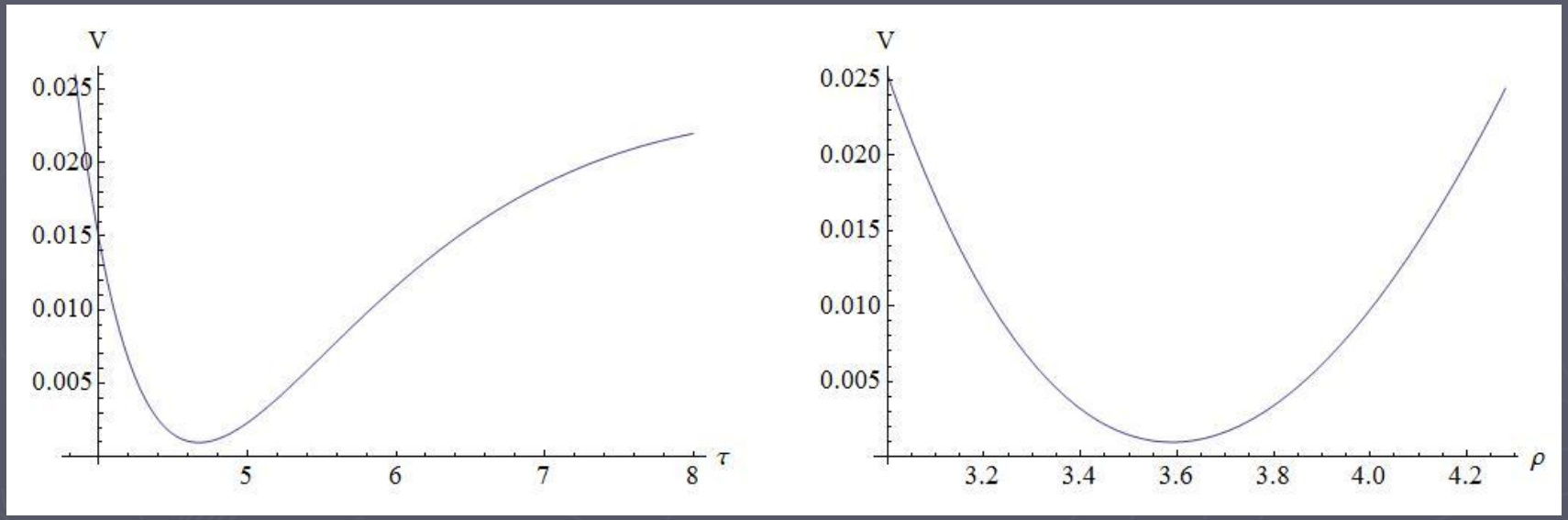
Flauger, Robbins, Paban, TW 0812.3886 [hep-th]
Caviezel, Koerber, Körs, Lüst, TW, Zagermann 0812.3551 [hep-th]

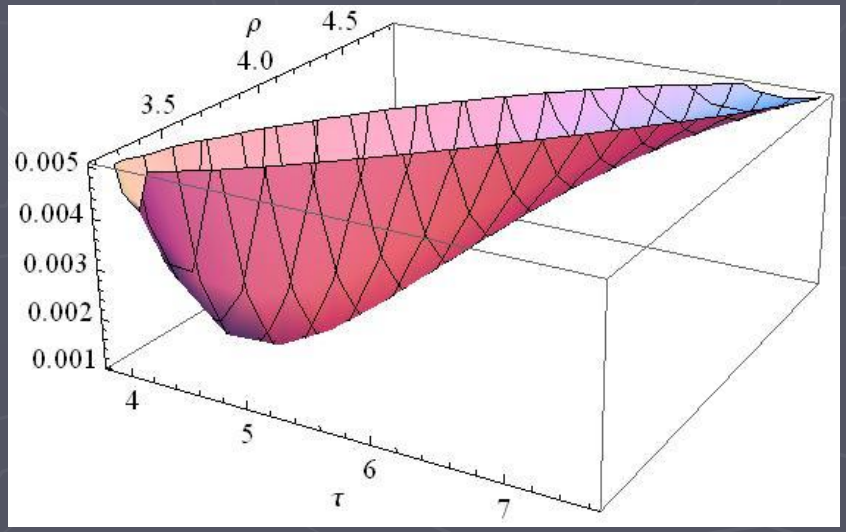
Cosmological aspects in type IIA

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

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

Type IIA on SU(2)xSU(2)





Cosmological aspects in type IIA

- $\check{T}^6/Z_2 x Z_2$ and SU(2)xSU(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]

- Out of 14 directions, along one we have a maximum
- Do no-go theorems for η parameter apply?

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

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

Cosmological aspects in type IIA/IIB

- Type IIB O3/O7 or O5/O9 on SU(3)-structure, without corrections insufficient moduli stabilization

  Benmachiche, Grimm hep-th/0602241

  Robbins, TW 0709.2186 [hep-th]

- SU(2)-structure compactifications with two orientifold projections $\Rightarrow N=1$ in 4d

  TW, Zagermann,… to appear

Cosmological aspects in type IIA/IIB

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

Cosmological aspects in type IIA/IIB

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 i.e. supergravity not applicable in T-dual description

Shelton, Taylor, Wecht hep-th/0508133

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

Cosmological aspects in type IIA/IIB

- Can in principle stabilize (almost) all moduli in type IIA and type IIB
- Only very few cosets and twisted T^2xT^4/Z_2
- Concrete examples only interesting in type IIB
- Can derive new no-go theorems to exclude dS vacua and slow-roll in concrete examples
- Again no general no-go theorem exists

Conclusion – type IIA on SU(3)

- Type IIA flux compactifications give scalar potentials that depend on (almost) all moduli
- No-go theorem against slow-roll inflation and dS vacua exist for CY_3 with fluxes
- Can evade previous no-go theorem in compactifications on SU(3)-structure manifolds
- Many new no-go theorems exclude most examples
- Few numerical extrema but only with η-problem

Conclusion – type IIB on SU(2)

- Type IIB flux compactifications give scalar potentials that depend on (almost) all moduli
- Only very few concrete examples
- Can derive new no-go theorems against slow-roll inflation and dS vacua for specific cases

Outlook / Future research

- Try to study more models and understand whether the η-problem is model specific or generic
- Include more ingredients like (non-) susy D6-branes, co-isotropic D8-branes and NSNS sources
- Include α' and string loop corrections

  Palti, Tasinato, Ward 0804.1248 [hep-th]
- Study non-geometric compactifications spaces

  de Carlos, Guarino, Moreno 0907.5580v1 [hep-th]
- Study models that preserve more SUSY

  Fre, Trigiante, Van Proeyen hep-th/0205119
  Fre, Trigiante, Van Proeyen hep-th/0301024
  Ogetbil 0809.0544 [hep-th]
  THIS AFTERNOON Diederik Roest 0902.0479 [hep-th]
  Dall'Agata, Villadoro, Zwirner 0906.0370 [hep-th]

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THANK YOU!