A flux-scaling scenario for axion inflation in string theory

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LMU Munich

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This talk is based on ::

- *The challenge of realizing F-term axion monodromy inflation in string theory*

  Blumenhagen, Herschmann, EP

  [arXiv:1409.7075]

- *A flux-scaling scenario for high-scale moduli stabilization in string theory*

  Blumenhagen, Font, Fuchs, Herschmann, EP,
  Sekiguchi, Wolf

  [arXiv:1503.07634]

aim of this talk

The aim of this talk is to ::

1) elaborate on some aspects of R. Blumenhagen's talk,

2) provide introduction to M. Fuchs's talk.

outline

1. scenario & objective
2. moduli stabilization
3. fluxes
4. summary

Scenario ::

- Study single- and large-field inflation in type IIB orientifolds.
- The inflaton originates from a closed-string modulus.
- The shift symmetry is broken by fluxes.

Objective ::

- Combine inflation with moduli stabilization.

[Marchesano, Shiu, Uranga - 2014]
[Blumenhagen, EP - 2014]
[Hebecker, Kraus, Witkowski - 2014]
[Dudas, Wieck - 2015]

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moduli stabilization :: type IIb

Recall :: moduli stabilization for type IIB orientifolds via KKLT/LVS.

complex-structure moduli U^i axio-dilaton S	Kähler moduli T_a

- Choose constant fluxes $\mathfrak{F}$ and H in

$$W_{\text{flux}} = \int \big(\mathfrak{F} - i\,S\,H\big) \wedge \Omega_3\,,$$

- and solve

$$D_{\mathcal{U}^i} W_{\text{flux}} = 0\,, \qquad D_S W_{\text{flux}} = 0\,.$$

- Generically, all U^i and S are stabilized.

- Non-perturbative effects of the form

$$W_{\text{np}} = \mathcal{A}\, e^{m^a T_a}\,,$$

- can stabilize Kähler moduli T_a.

- Generically, one finds $M_{U,S} \gg M_T\,.$

To combine moduli stabilization and inflation, a mass hierarchy has to be realized ::

$$M_{\mathsf{Pl}} \;>\; M_{\mathsf{string}} \;>\; M_{\mathsf{KK}} \;>\; M_{\mathsf{moduli}} \;>\; H_{\mathsf{inflation}} \;>\; M_{\mathsf{inflaton}}\,.$$

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moduli stabilization :: mass hierarchy

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In type IIB moduli stabilization via KKLT/LVS,

- background fluxes F and H break the shift symmetry of U^i and S.

→ In the present setting, the inflaton is a combination of U^i and S.

This is in conflict with the above mass hierarchy

$$M_{U,S} \gg M_T > M_{\mathsf{inflaton}} .$$

moduli stabilization :: fine tuning

The conflict can be resolved by fine-tuning the inflaton mass M_{inflaton}.

[Hebecker, Mangat, Rompineve, Witkowski - 2014]

A different approach is a flux-scaling scenario ::

1) Fix all moduli at tree-level by fluxes → $M_U \sim M_S \sim M_T$.

2) Leave one axion ϕ massless → non-susy minimum.

[Conlon - 2006]

3) Scale existing fluxes $\gg 1$ → $M_{U,S,T}$ increase.

4) Potential for ϕ via additional flux → $M_{\text{moduli}} > M_{\text{inflaton}}$.

[Blumenhagen, Herschmann, EP - 2014]
[Blumenhagen, Font, Fuchs, Herschmann, EP, Sekiguchi, Wolf - 2015]

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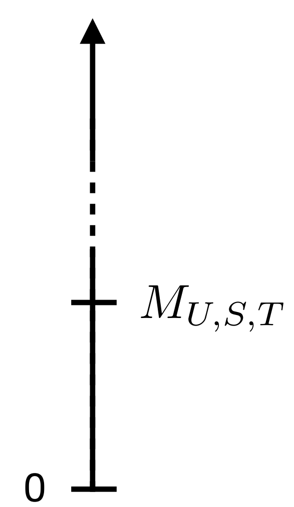
[Conlon - 2006]



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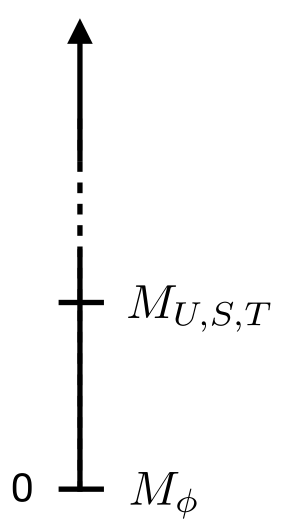

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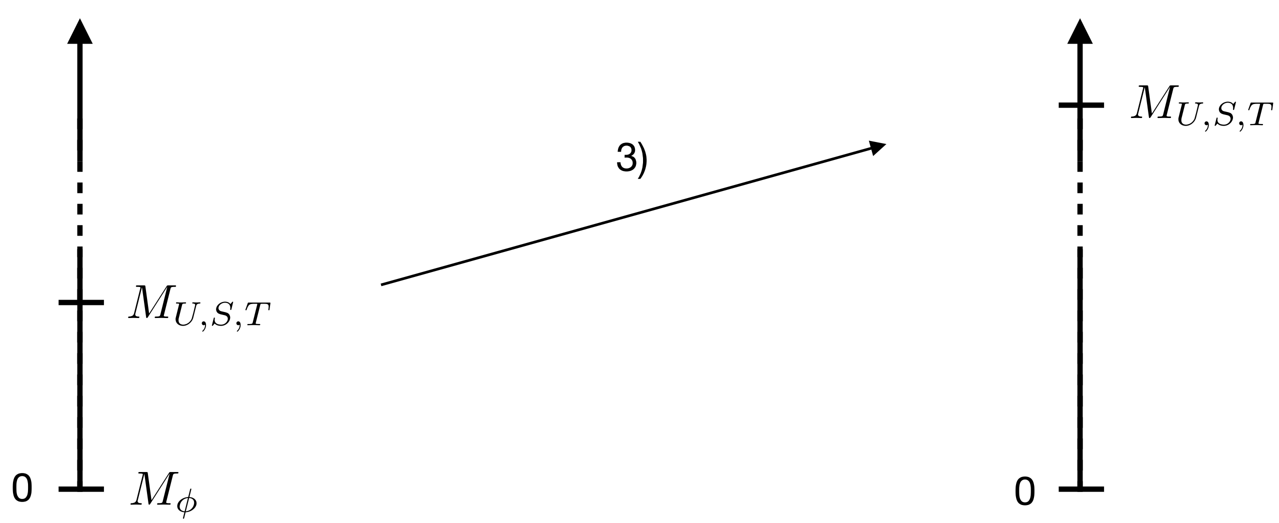

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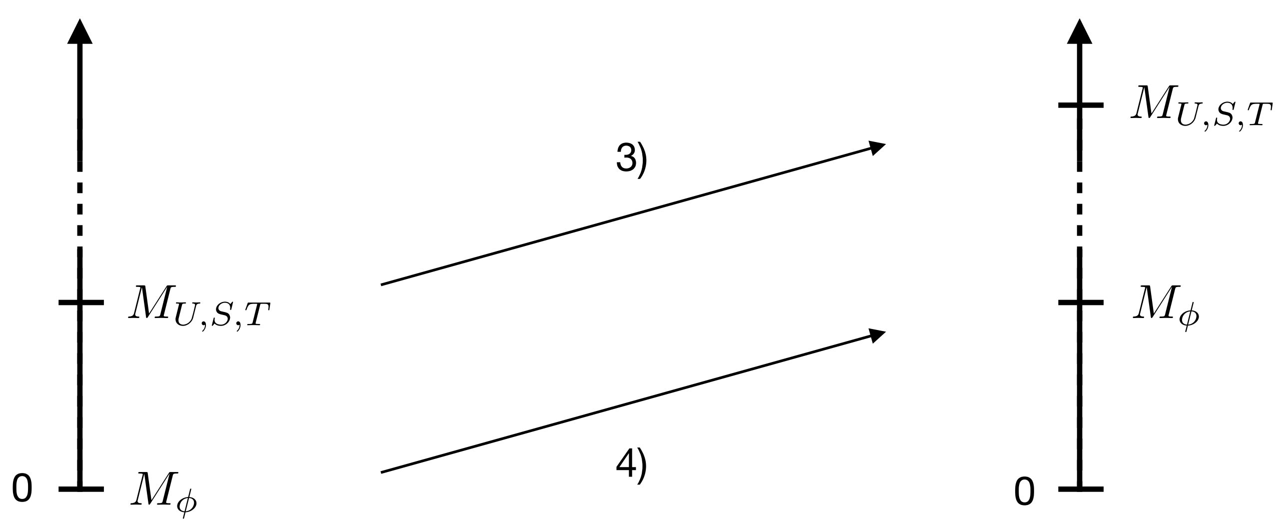

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Question :: How can all (but one) moduli be stabilized at tree-level by fluxes?

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Notation :: consider a Calabi-Yau three-fold $\mathcal{M}$ and denote

- a symplectic basis for the third cohomology by

$$\{\alpha_\Lambda, \beta^\Lambda\} \in H^3(\mathcal{M})\,, \qquad \Lambda = 0, \ldots, h^{2,1}\,.$$

- Bases for the *(1,1)*- and *(2,2)*-cohomology of $\mathcal{M}$ are

$$\begin{aligned} \{\omega_\mathsf{A}\} &\in H^{1,1}(\mathcal{M})\,, \\ \{\tilde{\omega}^\mathsf{A}\} &\in H^{2,2}(\mathcal{M})\,, \end{aligned} \qquad \mathsf{A} = 1, \ldots, \mathsf{h}^{1,1}\,,$$

and combine $\{\omega_A\} = \{1, \omega_\mathsf{A}\}$ and $\{\tilde{\omega}^A\} = \{d\mathrm{vol}_6, \tilde{\omega}^\mathsf{A}\}$.

- The holomorphic three-form depends on U^i and reads

$$\Omega_3 = X^\lambda \alpha_\lambda - F_\lambda \beta^\lambda\,.$$

The flux superpotential for type IIB orientifolds is given by

$$W = \int \big(\mathfrak{F} - i\,S\,H\big) \wedge \Omega_3\,.$$

[Gukov, Vafa, Witten - 1999]

This can be expressed in terms of

- a complex multi-form $\Phi_c^{\text{ev}} = i\,S - i\,G^a \omega_a - i\,T_\alpha \tilde{\omega}^\alpha\,,$
- and a H-twisted differential $d_H = d - H\wedge$
- in the following way :: $$W = \int \big(\mathfrak{F} + d_H \Phi_c^{\text{ev}}\big) \wedge \Omega_3\,.$$

[Grana, Louis, Waldram - 2005]
[Benmachiche, Grimm - 2006]

Non-geometric fluxes can be introduced via a twisted differential

$$\mathcal{D} = d - H\wedge \; - F\circ \; - Q\bullet \; - R\llcorner \, .$$

[Shelton, Taylor, Wecht - 2005]
[Grana, Louis, Waldram - 2006]
[Micu, Palti, Tasinato - 2007]

The fluxes are operators implementing the mapping

$$\begin{array}{lcl} H\wedge & : & p\text{-form} \;\rightarrow\; (p+3)\text{-form}\,, \\ F\circ & : & p\text{-form} \;\rightarrow\; (p+1)\text{-form}\,, \\ Q\bullet & : & p\text{-form} \;\rightarrow\; (p-1)\text{-form}\,, \\ R\llcorner & : & p\text{-form} \;\rightarrow\; (p-3)\text{-form}\,. \end{array}$$

On the cohomology of a Calabi-Yau three-fold $\mathcal{D}$ acts as

$$\begin{aligned} \mathcal{D}\alpha_\Lambda &= q_\Lambda{}^A\omega_A + f_{\Lambda\,A}\tilde{\omega}^A\,, & \mathcal{D}\beta^\Lambda &= \tilde{q}^{\Lambda\,A}\omega_A + \tilde{f}^\Lambda{}_A\tilde{\omega}^A\,, \\ \mathcal{D}\omega_A &= \tilde{f}^\Lambda{}_A\alpha_\Lambda - f_{\Lambda A}\beta^\Lambda\,, & \mathcal{D}\tilde{\omega}^A &= -\tilde{q}^{\Lambda\,A}\alpha_\Lambda + q_\Lambda{}^A\beta^\Lambda\,. \end{aligned}$$

[Grana, Louis, Waldram - 2006]

fluxes :: superpotential II

The superpotential for non-geometric fluxes is obtained by substituting

$$d_H \to \mathcal{D}\,.$$

This leads to an expression linear in the moduli S, G and T ::

$$W = \int \big(\mathfrak{F} + \mathcal{D}\,\Phi_c^{\text{ev}}\big) \wedge \Omega_3$$

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$$\begin{aligned} W = \int \big(\mathfrak{F} + \mathcal{D}\,\Phi_c^{\text{ev}} \big) \wedge \Omega_3 = \; & - \qquad \big(\, \mathfrak{f}_\lambda \; X^\lambda \; - \; \tilde{\mathfrak{f}}^\lambda \; F_\lambda \big) \\ & + \, i\,S \; \big(\, h_\lambda \; X^\lambda \; - \; \tilde{h}^\lambda \; F_\lambda \big) \\ & - \, i\,G^a \big(f_{\lambda a}\, X^\lambda \; - \; \tilde{f}^\lambda{}_a \, F_\lambda \big) \\ & + \, i\,T_\alpha \big(q_\lambda{}^\alpha \, X^\lambda \; - \; \tilde{q}^{\lambda\alpha} \, F_\lambda \big)\,. \end{aligned}$$

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The fluxes are constrained by Bianchi identities originating from

$$\mathcal{D}^2 = 0\,.$$

[Grana, Louis, Waldram - 2006]

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Summary ::

- A flux-scaling scenario allows to realize $M_{\mathsf{moduli}} > M_{\mathsf{inflaton}}$ (for closed-string axion inflation in type IIB orientifolds).
- Moduli are stabilized by non-geometric fluxes at tree-level.

Next steps ::

- See M. Fuchs's talk …