Fluxbrane inflation
(moduli stabilization, D7-brane Kähler potential)

Arthur Hebecker (Heidelberg)

AH, Kraus, Lüst, Steinfurt, Weigand (1104.5016)
. . . , **Küntzler** (1207.2766)
. . . , **Arends, Heimpel, Mayrhofer, Schick** (12...)

Outline

- Inflation, brane inflation, fluxbrane inflation
- Moduli stabilization
- Flat direction from shift symmetry

Also: Application to Higgs physics...

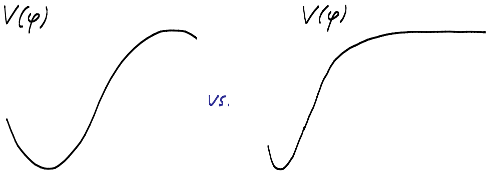
Inflation

- Inflation does not arise from generic, natural potentials:

$$V(\varphi) \sim \sum_n a_n \varphi^n \qquad \Longrightarrow \qquad \eta \equiv \frac{V''}{V} \sim \frac{1}{\varphi^2}$$

- Field-theoretic approaches include

  - Using large φ
  - Tuning
  - Symmetries ($\varphi \to \varphi + c$) in part of the field space.



Brane inflation

- We focus on the last option and attempt a realization in brane inflation

- However:
  The simplest brane-antibrane scenario is well known to fail

  Burgess et al., '01

$$V \sim 1 - \frac{g_s}{r^{d_\perp - 2}}$$

....set $M_P = 1$, identify canonically normalized inflaton....

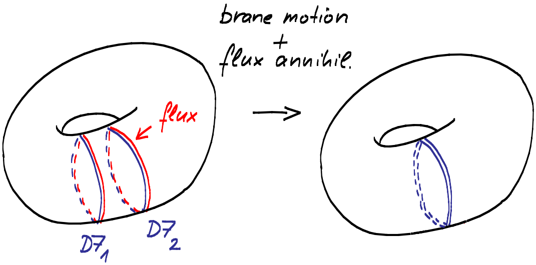
$$\eta \equiv \frac{V''}{V} \sim \left(\frac{L_\perp}{r}\right)^{d_\perp}$$

Hence: $\eta \geq 1$

- This can be overcome e.g. by warping. However, moduli stabilization and lack of shift-symmetry eventually lead to fine-tuning.

KKLMMT, '03
Baumann et al.
...

- We propose to let brane-flux annihilate instead of brane-antibrane



Fluxbrane inflation

- Crucial fact: At large volume (i.e. weak flux F), the potential becomes very flat:

$$V \sim 1 - \frac{g_s}{r^{d_\perp - 2}} \quad \rightarrow \quad V \sim F^2 - F^4 \frac{g_s}{r^{d_\perp - 2}}$$

Hence: $\eta \sim F^2 \ll 1$

- Note: This is conceptually similar to D3/D7 inflation

Dasgupta, Herdeiro, Hirano, Kallosh, '02

and T-dual to inflation from branes at angles and Wilson lines

Garcia-Bellido, Rabadan, Zamora, '01
Avgoustidis, Cremades, Quevedo, '06

Fluxbrane inflation on CYs

- In type IIB on CY-orientifolds with D7 branes, one can be rather explicit:

building e.g. on Jockers, Louis '05

$$V(\varphi) = \frac{1}{2} g_{\rm YM}^2 \xi^2 \left[1 + \frac{g_{\rm YM}^2}{16\pi^2} c \ln(\varphi/\varphi_0) \right] ,$$

where

$$\frac{1}{g_{\rm YM}^2} \sim \int j \wedge j \qquad , \qquad \xi \sim \frac{1}{\mathcal{V}} \int j \wedge \mathcal{F} .$$

- This is standard D term inflation, but with an adjustable parameter c.
- Phenomenologically $c \ll 1$ is advantageous.

- The explicit calculation proceeds by standard methods.

  Marino, Minasian, Moore, Strominger '99

  . . .

  Haack et al. '06

- Since

$$c = -2\int \mathcal{F}^2 + \left(\int j\wedge\mathcal{F}\right)^2 \Big/ \left(\tfrac{1}{2}\int j\wedge j\right) ,$$

  it is possible to realise $c \ll 1$ if there is no D3 tadpole and $j|_{\mathrm{D7}}$ is 'almost' orthogonal to $\mathcal{F}$.

- We show that: CMB normalisation, spectral index & cosmic string constraint can be satisfied in appropriate regions of Kähler moduli space.

Moduli stabilization

- More specifically: $10^{-5} \sim \Delta T/T \sim \mathcal{V}^{-2/3}$.

  demands large $\mathcal{V}$. $\Rightarrow$ Large Volume Scenario.

  Balasubramanian, Berglund, Conlon, Quevedo '05
  Cicoli, Conlon, Quevedo '07
  Cremades, Garcia del Moral, Quevedo, Suruliz '07
  cf. also talks by M. Grana and R. Valandro

- The crucial ingredients are (anisotropic version):

$$W = W_0 + e^{-\tau_s} \qquad , \qquad K = -2\ln(\mathcal{V} + \xi) + \delta K_{\rm loop}$$

  where

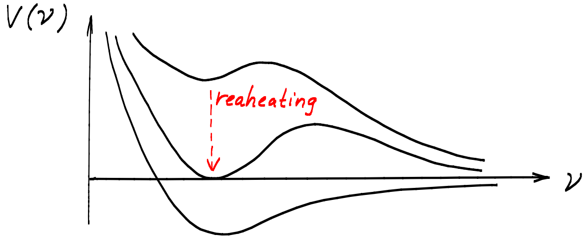
$$\mathcal{V} \sim f(t_1, t_2, \ldots) - t_s^3 \qquad , \qquad \delta K_{\rm loop} \sim \frac{g(t_1, t_2, \ldots)}{\mathcal{V}} + \cdots .$$

- τ_s stabilized as in basic Large Volume Scenario
- Ratios t_i/t_j stabilized by interplay of $V_{\rm loop}$ and V_D.

$$\Longrightarrow \qquad V(\mathcal{V}) \sim \frac{1}{\mathcal{V}^3}\left(1 + \ln(\mathcal{V})^{3/2} + \mathcal{V}^{5/9}\right) .$$

- The result is a version of D term uplifting from AdS to Minkowski to dS. Parametric control is realized using

  $(\int j \wedge F)^2/(\int j \wedge j) \ll 1.$



Flat direction / shift symmetry

- Chose brane/bulk fluxes such that W_0 does not depend on φ.

- Of course, since $W_0 \not\equiv 0$, the usual 'η-problem of supergravity' is still present:

$$K = -\ln(S + \overline{S} + \kappa(\varphi, \overline{\varphi})) + \cdots \qquad \Longrightarrow \qquad \eta \simeq 1 \text{ from } V_F$$

  [Here κ is the Kähler potential on the D7-brane moduli space; similar to situation in KKLMMT.]

- Fact: F-theory on K3×K3 has $\kappa = \kappa(\varphi + \overline{\varphi})$

- We expect this shift-symmetric structure to arise more generally in the large complex structure limit.

Grimm, Ha, Klemm, Klevers, ... '09-'11
Alim, Hecht, Jockers, Mayr, Mertens, ...

Shift symmetry in LCS limit

- Think of the type IIB orientifold in SYZ language, i.e. T^3 over B^3.
- The D7-brane fills 2 dimensions in T^3 and B^3 respectively.
- The D6-brane in the type IIA-mirror fills 1 dimension in T^3 and 2 dimensions in B^3.
- Hence, the brane modulus φ contains the corresponding Wilson line
- At large IIA-volume (corresponding to LCS on the IIB side), this enforces the shift-symmetric structure $\kappa = \kappa(\varphi + \overline{\varphi})$

  (up to exponentially small instanton corrections).

Conclusions / Summary

- Fluxbrane inflation offers a novel way to avoid the no-go theorem for (unwarped) brane-antibrane inflation.
- It is a stringy version of D-term inflation (with stabilization by interplay of D and F terms).
- The flatness depends on detailed features of D7-brane moduli space (especially shift-symmetry, related to Wilson-lines of mirror CY).
- Another interesting application of this shift-symmetry:
  High-scale SUSY-breaking with $\kappa = \kappa(H_u + \overline{H}_d)$
  $\Leftrightarrow \quad \lambda = 0$ at high scale
  $\Leftrightarrow$ 125 GeV Higgs mass.

AH, Knochel, Weigand (1204.2551)
Ibanez, Marchesano, Regalado, Valenzuela (1206.2655)