Title: D3/D7-Brane Inflation and Semilocal Cosmic Strings

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Abstract:

D3/D7 - Inflation

and

Semilocal Cosmic Strings

Marco Zagermann
(Stanford)

[Dasgupta, Hsu, Kallosh, Linde, M.Z. : hep-th/0405247
Chen, Dasgupta, K. Narayan, Shmakova, M.Z. :
hep-th/0501185]

Outline

1. Introduction
2. D3/D7 - brane inflation
   - ⇒ Hybrid D-term inflation in 4D
   - ⇒ Cosmic string problem
     ("local" cosmic strings
     $U(1)_{local} \longrightarrow 1$)
3. Generalized D-term inflation
   - ⇒ Double Higgs content
     - → $SU(2)_{global} \times U(1)_{local} \longrightarrow U(1)_{global}$
   - ⇒ "semilocal" cosmic strings
   - ⇒ O.K. for CMB
4. Implementation in D3/D7-system
5. Conclusion

① Introduction

Inflation in string theory?

A popular approach:

> Inflaton = a modulus

(i) **Closed string modulus**

E.g., "racetrack" inflation (BPBCEGRKLQ) 2004
(Inflaton = volume modulus)

(ii) **open string modulus**

↳ e.g. brane position/orientation
↳ "brane inflation" (Dvali, Tye 1998)

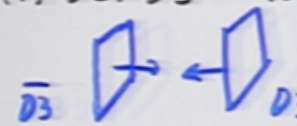
⋮

A very intuitive and minimalistic setup:

Movable D3-branes in IIB string theory

Two popular models:

(i) $D3/\overline{D3}$ - inflation (2001 Alexander, Burgess, Majumdar, Molto, Quevedo, Rajesh, Zhang)



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(ii) D3/D7 - inflation (Dasgupta, Herdeiro, ...)

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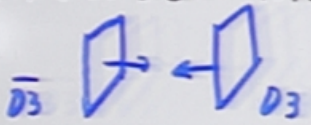
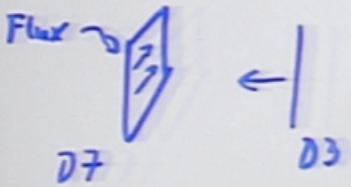


⋮

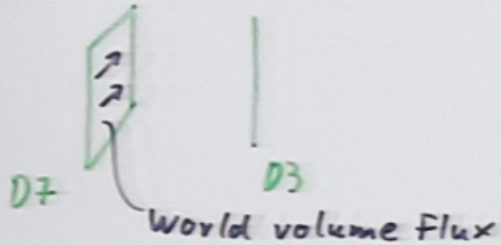
(ii) D3/D7 - inflation (Dasgupta, Herdeiro, Hirano, Kallosh, 2002)



(2) D3/D7-brane inflation

Basic configuration:

(i) An "isolated" D3/D7-system:



(ii) A compactification:

$M^{(1,3)} \times K^{(6)}$

D3: $M^{(1,3)}$

D7: $M^{(1,3)} \times$ (4-cycle of $K^{(6)}$)

(4-cycle of $K^{(6)}$): world volume flux

⇒ Anomaly cancellation requires care.

⇒ A well-understood example: (Dasgupta, Herdeiro, Hirano, Kallosh, 2002)

$M^{(1,3)} \times K3 \times T^2/Z_2$

⇒ 4 O7 + 16 D7 (+ n D3 + flux)

D3 . . .

D7 :111, . .

$F = dA^{07} - B^{NS\,45}$

} isolate ⇒ F-theory (well-understood

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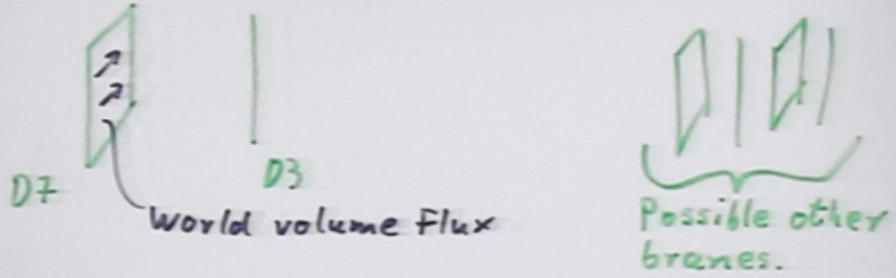

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D3 . . .

D7 ⋮ ↑↑↑ $\mathcal{F} = dA^{D7} - B^{NS\,NS}$

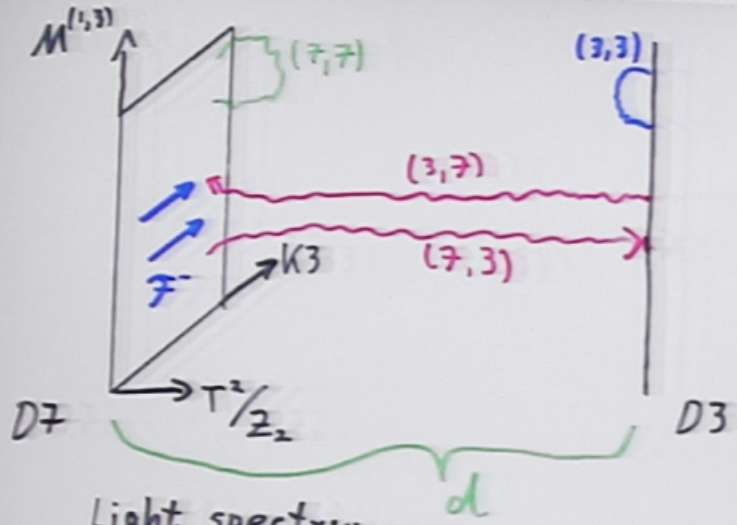
} isolate ⇒ F-theory (well-understood in this example)

D7 ⋮

O7 ⋮

$\hat{\mathcal{F}}^- := \mathcal{F} - *^{K3}\mathcal{F}$

$\langle \hat{\mathcal{F}}^- \rangle \neq 0 \Rightarrow$ SUSY



Light spectrum:

K3 large $\Rightarrow$ decouples

$(7,7)$-strings $\Rightarrow$ $N=2$ vector multiplet $\Rightarrow$ $U(1)_{D7}$

$(3,3)$-strings $\Rightarrow$ $N=2$ vector multiplet $\Rightarrow$ $U(1)_{D3}$

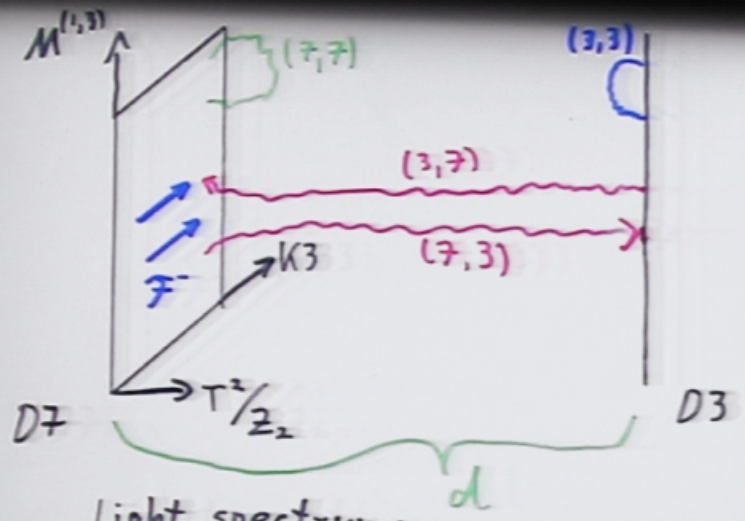
$\ni$ S $\Longleftrightarrow$ D3-position on T^2/Z_2 $\cong$ inflaton

$(3,7)$-strings, $(7,3)$-strings $\Rightarrow$ $N=2$ hypermultiplet $\ni$ ϕ_+, ϕ_-

$U(1)_{D3}$: $(+1)$, (-1)

$\langle \mathcal{F}^- \rangle \neq 0 \Rightarrow$ Susy spontaneously broken

$\Rightarrow$ mass splitting in hypermultiplet: $m^2_{\phi_\pm} = d^2 \pm f(\mathcal{F}^-)$



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⇒ $S \Longleftrightarrow$ D3-position on T^2/Z_2 ≅ inflaton

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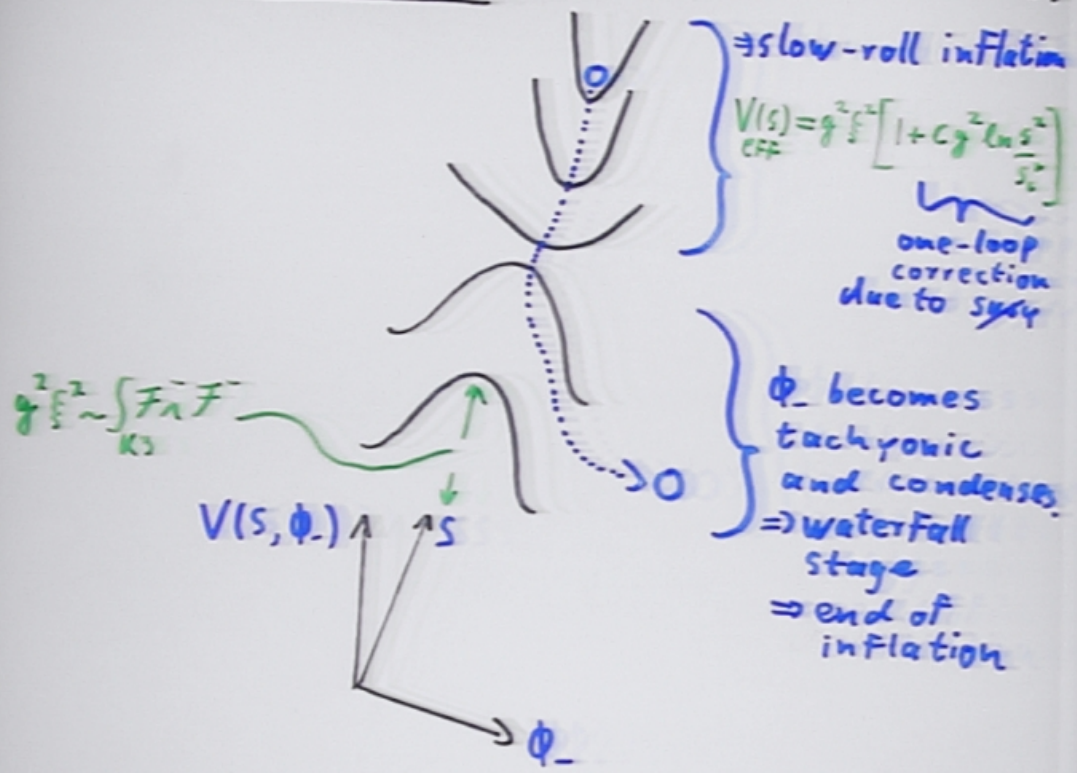
⇒ mass splitting in hypermultiplet: $m^2_{\phi_\pm} = \frac{d^2}{(\pi\alpha')^2} \pm \frac{f(\mathcal{F}^-)}{2\pi\alpha'}$

$(\mathrm{Str}(M^2)=0)$ $m^2_{\mathcal{F}^-} = d^2$

The scalar potential:

D3 → D7 ⇒ S decreases



≙ **Hybrid D-term inflation**

- η-problem, volume stabilization, shift symmetry, loop corrections...
  - → M. Haack's talk tomorrow

Unfortunately: This model has a cosmic string problem.

- ϕ_- is charged under $U(1)_{D3}^{\text{Local}}$
- ϕ_- condenses $\Rightarrow U(1)_{D3}^{\text{Local}} \longrightarrow \mathbb{1}$
- $\Rightarrow$ "local" cosmic strings form ("gauge strings") ("Nielsen-Olesen" strings)

  Thin magnetic flux tubes supported by a topologically non-trivial Higgs configuration.

[see also H. Tye's talk tomorrow]

$\Rightarrow$ spoil CMB predictions!

Solutions!

- In $D3/\overline{D3}$ inflation: (KKLMMT 2003)
  Put $\overline{D3}$ at tip of warped throat
  $\rightarrow$ c. string tension is red-shifted to acceptable values.
  But not for D3/D7.
- Assume $g^2_{U(1)_{D3}} \leq 10^{-10}$ (or 10^{-7}) (Kallosh, Linde 2003)

  But: Unnaturally small.

③ Generalized D-term inflation

Urrestilla, Achúcarro, D[illegible]is (2004):
"Double the Higgs [illegible]tent"

one hypermultiplet ⟶ two [illegible]lets

$(\phi_+, \phi_-) \rightarrow$ $SU(2)_{global}$ (ϕ_+^1, ϕ_-^1), (ϕ_+^2, ϕ_-^2)

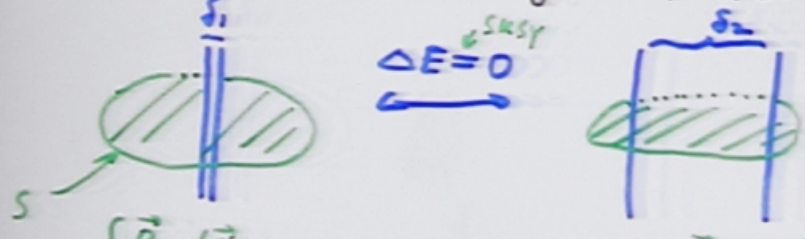
$\Rightarrow G = SU(2)_{global} \times U(1)_{local} \rightarrow U(1)_{global}$

$\Rightarrow$ **"semilocal" strings.**

$U(1)_{local} \rightarrow \mathbb{1} \Rightarrow$ Still topologically conserved fluxes.

⇝ cosmic strings can still exist.

But: The "width" of the flux tube is no longer fixed:



③ Generalized D-term inflation

Urrestilla, Achúcarro, Davis (2004):
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one hypermultiplet ⟶ two hypermultiplets

$(\phi_+, \phi_-) \rightarrow$ $SU(2)_{global}$ $\begin{cases} (\phi_+^1, \phi_-^1) \\ (\phi_+^2, \phi_-^2) \end{cases}$

$\Rightarrow G = SU(2)_{global} \times U(1)_{local} \rightarrow U(1)_{global}$

$\Rightarrow$ "semilocal" strings.

$U(1)_{local} \rightarrow$ 1 $\Rightarrow$ Still topologically conserved fluxes.

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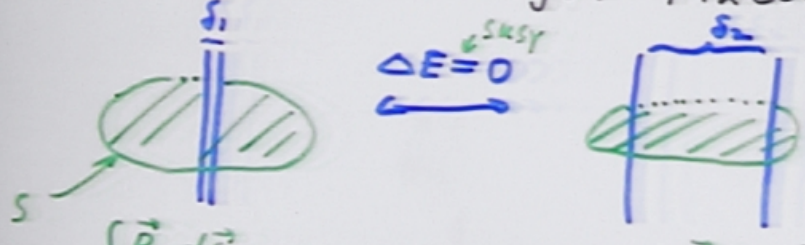
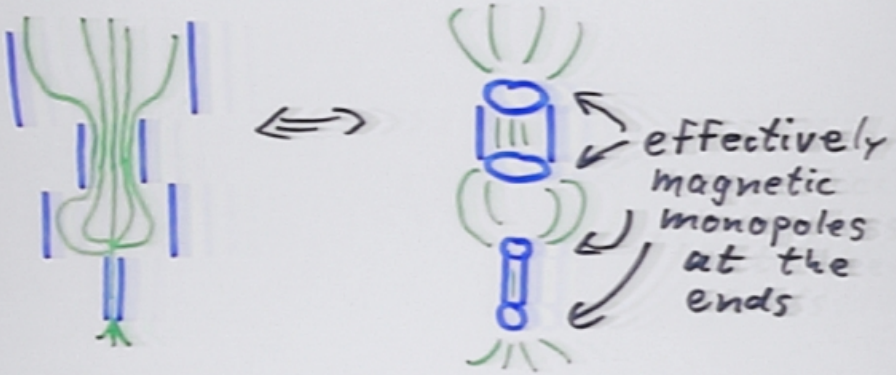
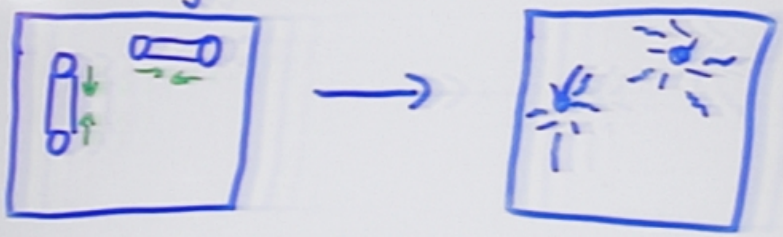


Consequences for cosmic string formation:

After the phase transition: string segments of different thicknesses:



⇒ Most segments will shrink instead of combining with other segments:



Semilocal string segments disappear soon after their formation.

Achúcarro, Borrill, Liddle (1999)
Urrestilla, Achúcarro, Borrill, Liddle (2008)

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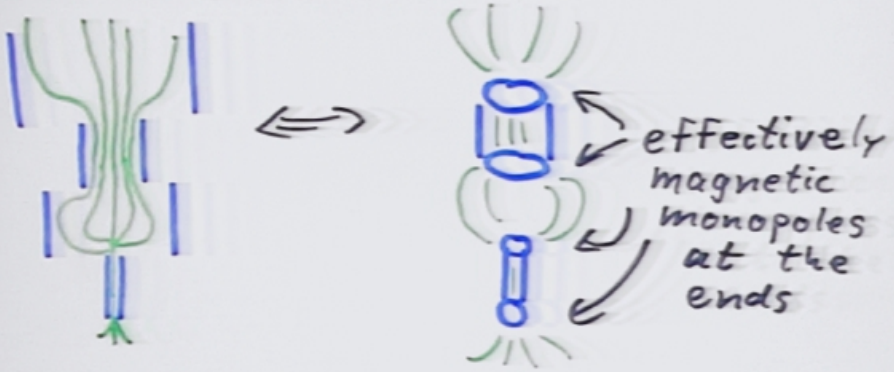

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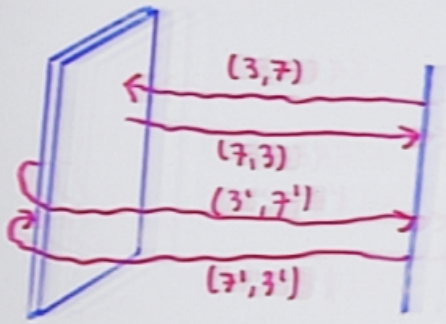
⇒ ok for CMB + all good properties of D-term inflation preserved.

④ Implementation in D3/D7 system

(Dasgupta, Hsu, Kallosh, Linde, M.Z.) 2004



⇒ 2 Hypermultiplets

Two D7's ‖ D3

⇓

$SU(2)_{local} \xrightarrow{K3\ big} SU(2)_{global}$

⇒ Effectively realizes Urrestilla, Achúcarro, Davis mechanism.

F-theory analysis o.k.

⑤ Conclusions

- D3/D7 inflation: An alternative to $D3/\overline{D3}$ in IIB string theory.
- ⇒ Hybrid D-term inFlation in 4D
- ⇒ Has a cosmic string problem
- A possible solution: Two coincident D7's
  - ⇒ Doubles the Higgs content
  - ⇒ semilocal cosmic strings
    - ↳ stable solutions, but degenerate w.r.t. flux tube thickness.
  - ⇒ Disappear soon after their formation.
    - ↳ ok for CMB.
  - + preserves all the good properties of hybrid D-term inflation.

Some open problems:

- Construct more realistic models
  - → moduli stabilization, quantum corrections, replace $K3 \times T^2/\mathbb{Z}_2$) & ...
  - ⇒ still consistent?
- Stringy description of semilocal strings?

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  → moduli stabilization, quantum corrections, replace $K3 \times T^2/\mathbb{Z}_2$ & ...
  ⇒ still consistent?
- Stringy description of semilocal strings? (Hanany, Tong, 2003)
- Other semilocal defects? (Preskill, 1992; Hindmarsh, Holman, Kephart, Vachaspati, 1992 ...)