TACHYON INFLATION WARPING AND FLUXES

· D. Cremades

· A. Sinha

· F. Q.

hep-th/0505252

Inflation

Scale factor $a \sim e^{Ht}$ $H \sim$ const.

- Slow roll:

$$\epsilon \equiv \frac{M_p^2}{2}\left(\frac{V'}{V}\right)^2 \ll 1$$

$$\eta \equiv M_p^2 \frac{V''}{V} \ll 1$$

- e-folds:

$$N \equiv \int H(t)dt = \frac{1}{M_p^2}\int \frac{V}{V'} d\phi \gtrsim 60$$

- density perturbations

$$\delta_H = \frac{1}{5\pi\sqrt{3}} \frac{V^{3/2}}{M_p V'} = 1.91 \times 10^{-5}$$

- spectral index:

$$n - 1 \approx 2\eta - 6\epsilon$$

Inflation from String Theory

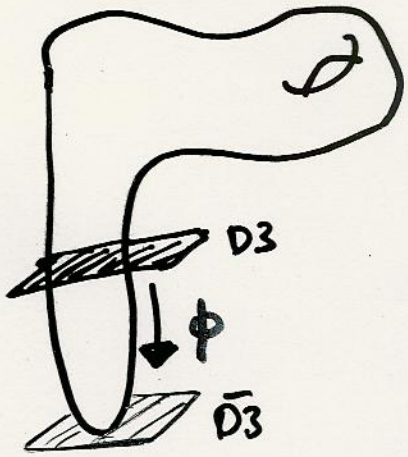
Progress:

* Candidate inflatons
  - Closed String Moduli BG
  - Open String Moduli DT
    (D-brane separation)

* Explicit computable potentials
  - Racetrack inflation
    BF, BCEGRKLQ
    (inflaton: axion partner of volume modulus)
  - Brane - Antibrane
    BMNQRZ DSS ... KKLMMT, ...
    (Also D3-D7) KP...

within KKLT scenario

e.g. Brane - Antibrane.



Potential $V(\rho, \phi)$

* η - problem. (... KKLMMT)

$V_F = e^K \{ \cdots \}$

$\Rightarrow \eta = \mathcal{O}(1) + \cdots \ll 1$

$\Rightarrow$ fine tuning

($\sim 1/100 - 1/1000$) BCSQ, BHK, ...

* Tachyon

. End inflation (hybrid) ! BMNQRT

. Topological defects (cosmic strings) JST, CMP, ...

. Universal for Sen. Non-BPS.

Tachyon as Inflaton ?

A, B--, MD, ... KL

Usually not:

$$V(T) = \frac{V_0}{\cosh(T)}$$

no small parameters
$\Rightarrow \epsilon, \eta \sim 1.$

But:

$$\mathcal{L}_T = A\,V(T)\sqrt{1 + B\,\partial_\mu T\,\partial^\mu T}$$

... R ...

with A, B "warp" constants

$$\epsilon = \frac{M_p^2}{2AB}\left(\frac{V'}{V^3}\right)$$

$$\eta = \frac{M_p^2}{AB}\left[\frac{V''}{V^2} - \frac{1}{2}\left(\frac{V'^2}{V^3}\right)\right]$$

$$N = \frac{AB}{M_p^2}\int \frac{V^2}{V'}\,dT$$

$\Rightarrow AB \gg 1 \Rightarrow$ slow roll inflation !

Also:

$$\delta_H^2 = \frac{A^2 B}{75\pi^2 M_p^6} \left(\frac{V^2}{V'}\right)^2 \sim 10^{-10}$$

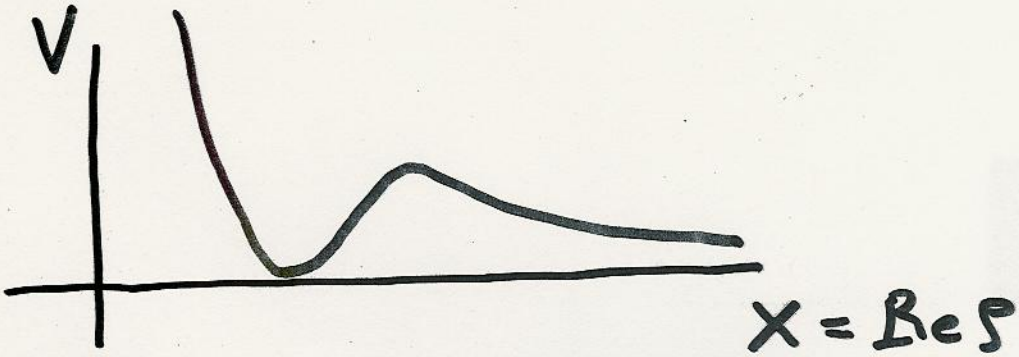
$\Rightarrow$ Choose $\gamma = \frac{m_s}{M_p}$, A, B

to get $N \sim 60$; $\delta_H \sim 10^{-5}$

But γ, A, B are calculable in concrete scenarios.

Q: Can A, B, γ for Non BPS D-branes in KKLT Scenario give rise to inflation?

KKLT:



KKLT + Non-BPS

$$V(x) \longrightarrow V(x) + V_{\text{Tachyon}}(X, T)$$

$$\mathcal{L}_{\text{Tachyon}} = A(x, \omega, \underline{F}) \sqrt{1 - B(\underline{\omega}) \dot{T}^2}$$

$\underline{\omega} \to X$

- $ds^2 = e^{2\omega - 6\omega + 6\omega_0} ds_4^2 + e^{-2\omega + 2\omega} ds_6^2$ $(e^{4\omega} \equiv X)$
- $F \to \underline{E}, \underline{B}$ fluxes on Dp

$$A \sim g_s^{-1} e^{(7-p)\omega_0} h_{p-3} X_0^3 X^{\frac{p-15}{4}} \sqrt{1+\underline{B}^2}\sqrt{1-\underline{E}^2}$$

$$B \sim e^{-2\omega} \left(\frac{X}{X_0}\right)^{3/2} (1-\underline{E}^2)^{-b\omega}$$

$$\gamma^2 \equiv \left(\frac{m_s}{m_p}\right)^2 \simeq \frac{g_s^2 (2\pi)^7}{2 X_0^{3/2}} \frac{e^{2\omega}}{C} \left(\frac{X}{X_0}\right)^{-3/2} (1-E^2)^{1/2}$$

$$h_{p-3} = \int d^6y \sqrt{\tilde{g}_6}$$

$$C = \int d^6y\, e^{-4\omega} \sqrt{\tilde{g}}$$

Warp factor $e^{-2\omega}$:

$$\nabla^2 e^{-4\omega} \simeq g_s G_{mnp}^2$$

↓

3-fluxes (K, M)

Effects of $V_{tachyon}$:

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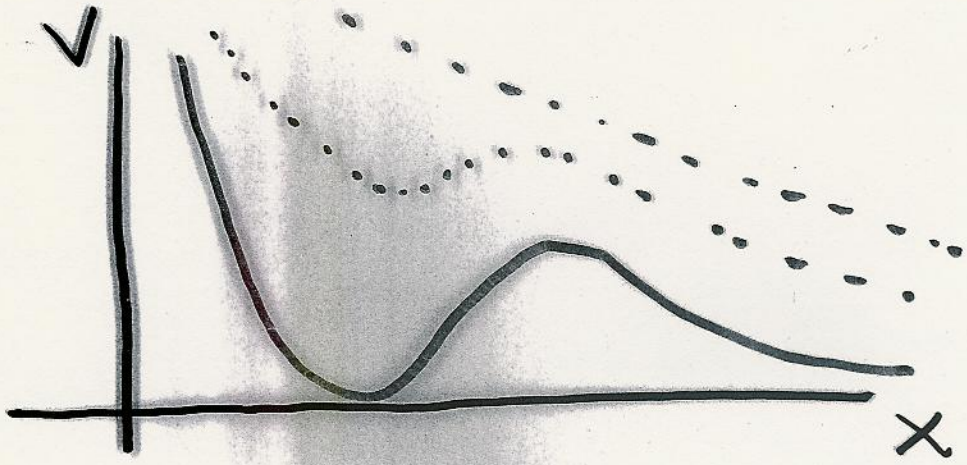


* Slow roll ?

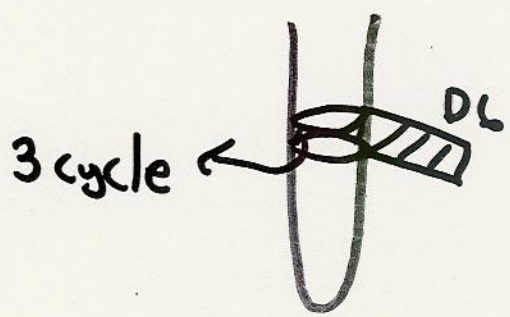
$(p, e^{\omega}, \underline{B}, \underline{E})$

↳ K, M + geometry

Examples:

(1) $p=6$ on Conifold throat

$E=B=0$



Tip :

$$ds_7^2 \simeq e^{2\omega} ds_4^2 + e^{\omega} R^2 ds_3^2$$

$$R \simeq g_s M$$

$$e^{2\omega} \sim e^{-2\pi K/g_s M}$$

(Thanks: Chen, Raegmakers, Trivedi)

$$N \sim \frac{X_0^{-3/4}}{C} e^{-\frac{2\pi K}{g_s M}} (g_s M)^{3/2}$$

If $K \sim g_s M \gg 1 \Rightarrow N \sim 10^2$

<u>but</u> Volume : $C \geq \left(\frac{2\pi}{3}\right)^3 R^6$ (dW, K, V)
constraint

(~ Giant inflaton case)

Improvements:

- $E \neq 0$ $\quad N \to N/\sqrt{1-E^2}$

  $\Rightarrow E \sim 1 \Rightarrow N \gg 1$

  (but fine tuning)

- $B \neq 0$ $\quad p=6$; D6 wrap throat
  (Need 2-cycles)

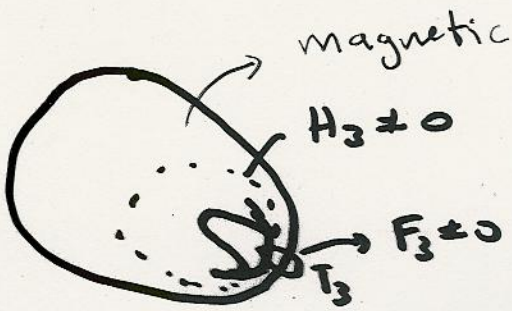
  $B \gg 1$.

- $p=8$; $B \neq 0$: "middle of throat"

(2.) T_3 fibrations

(SYZ)

$p=6$



$$\nabla^2 e^{-4\omega} \sim g_s \frac{F}{V_4} \cdot \frac{H}{V_x}$$

$$e^{-2\omega} \sim g_s^{1/2} \sqrt{\frac{FH}{V_x V_4}} \quad 1 \times 1$$

Constraints: ISD: $\frac{F}{V_4} = \frac{H}{V_x}$

Tadpole: $FH \lesssim 10^4$?

$N \sim 10^2$
$\delta_H^2 \sim 10^{-10}$ } $FH \sim 10^4$ ✓

$X_0 \sim 10^4$

$n \sim 10^8$

($p=8, \ldots$).

Time evolution + Sen's Conjecture

Open string completeness conjecture:

Non BPS D-brane → massive closed string modes.

⇒ back reaction ⇒ closed string description complicated.

Sen: OSFT describes fully decay of D-branes (w/o closed strings) + Classical results correctly describe evolution of quantum ev's (Ehrenfest).

Equations:

$$3H\left(\frac{AB\dot{V}\dot{T}}{\sqrt{1-B\dot{T}^2}}\right)+(\dot{\ })=-A\sqrt{1-B\dot{T}^2}\,V^3$$

$$6\left(\frac{\dot{X}}{X}\right)+18H\frac{\dot{X}}{X}+2X\hat{V}_x+2X\left(AV\sqrt{1-B\dot{T}^2}\right)_x=0$$

$$\frac{\ddot{a}}{a}=-\frac{1}{2}\left(\frac{\dot{X}}{X}\right)^2+\frac{\hat{V}}{6}+\frac{AV}{6}\frac{1-\frac{3}{2}B\dot{T}^2}{\sqrt{1-B\dot{T}^2}}$$

Sen's Conjecture:

$$T(t)=T(-t)$$
$$X(t)=X(-t)$$
$$a(t)=a(-t)$$

- Initial conditions:

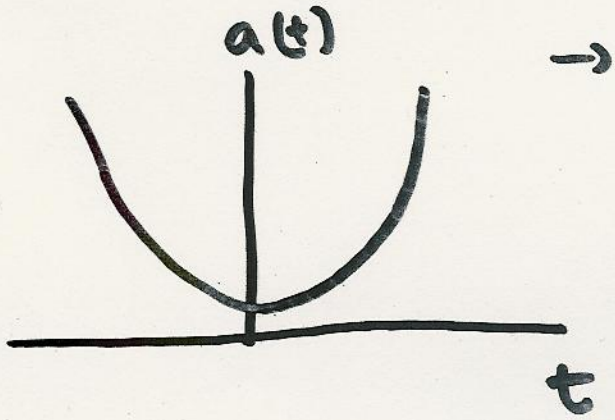
$$\dot{a}(0)=\dot{T}(0)=\dot{X}(0)=0$$

- Friedmann's: $H^2=\frac{1}{4}\left(\frac{\dot{X}}{X}\right)^2+\underbrace{\frac{1}{6}\hat{V}+\frac{1}{6}\frac{AV}{\sqrt{\ }}}_{=0 \text{ at } t=0}-\frac{k}{a^2}$!

$(k=1)$.

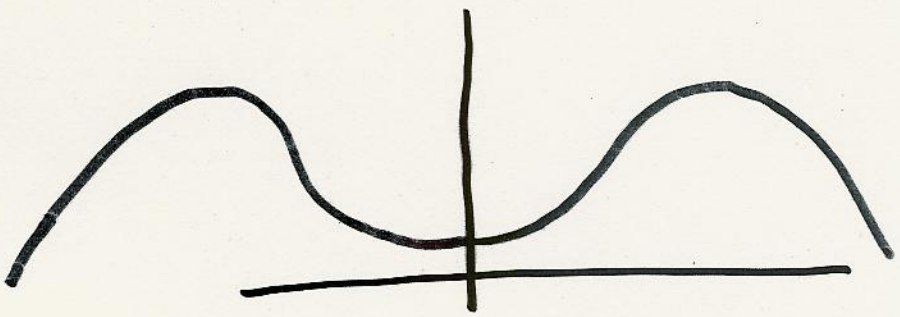
$\Rightarrow$ Free $T(0)$, $X(0)$.

Time evolution:



→ inflation + compactification + bounce ad.

or



big crunch + decompact.* + big-bang

$$\frac{\ddot{a}}{a} \sim -\left(\frac{\dot{X}}{4X}\right)^2$$

* Need fine-tuning to get inflation + decompactification.

Conclusions

* General scenario for inflation
  + moduli fixing

* 3 - Fluxes
  +
  magnetic (Wilson Line inflation (in progress))

* Initial conditions.
  (inflation + bounce ⇔ big crunch
  de compact.)