INFLATION FROM A TACHYON FLUID

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plan

1. D-brane decay
2. Tachyon cosmology
3. Tachyon inflation
4. Problems

based on work with Michel Tytgat

(hep-th/0204070)

Inflation difficult in string theory

supergravity theories

$\Downarrow$

strong energy condition ($3P > -\rho$)

$\Downarrow$

no accelerated expansion

see e.g. Maldacena & Nuñez (hep-th/0007018)

Tachyonic Decay of D3-brane

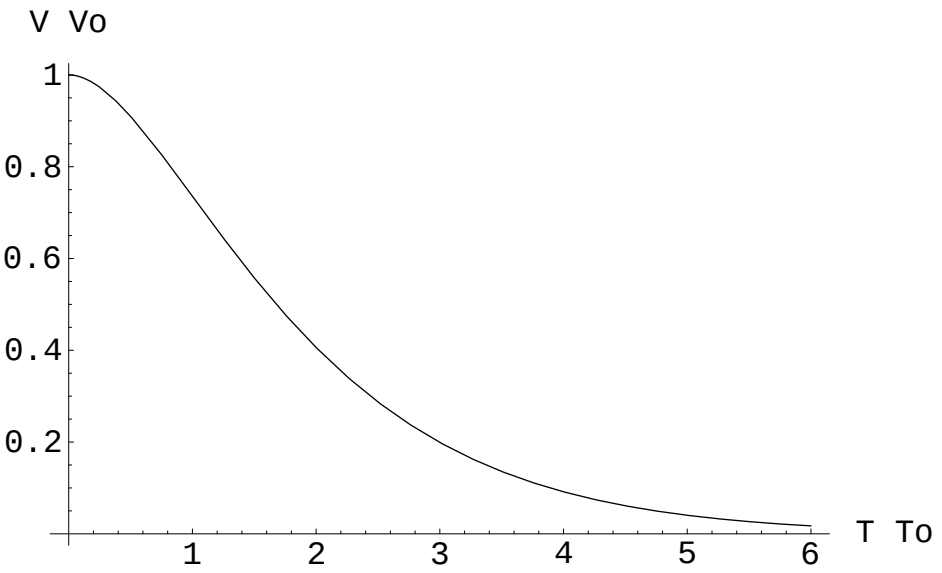
effective action for tachyon field T during decay of D3-brane (Sen hep-th/0203265)

$$S_{eff} = -\int d^4x V(T)\sqrt{-det(\eta_{\mu\nu} + \partial_\mu T \partial_\nu T)}$$

D-brane tension $= V_0$

$$V \to 0 \qquad \text{as} \qquad \mathrm{T} \to \infty$$

$$V(T) = V_0(1 + T/T_0)exp(-T/T_0)$$



Gerasimov and Shatashvili hep-th/0009103

Kutasov, Marino and Moore hep-th/0009148

Equation of state

for spatially homogeneous field configuration

$$\mathcal{L} = -V(T)\sqrt{1-\dot{T}^2}$$

$$\Downarrow$$

$$\rho = \frac{V(T)}{\sqrt{1-\dot{T}^2}}$$

&

$$p = -V(T)\sqrt{1-\dot{T}^2} \equiv -\rho(T)(1-\dot{T}^2)$$

tachyon matter therefore interpolates smoothly between

$$p = -\rho \iff w = -1$$

for $\dot{T} = 0$

$$p = 0 \iff w = 0$$

for $\dot{T} = 1$

$\dot{T}$ asymptotes to 1 at late times: dark matter? (although see Frolov, Kofman and Starobinsky hep-th/0204187)

Scalar field⇔tachyon field dictionary

Gibbons hep-th/0204008 and also our paper

1 equation of motion

scalar field $\ddot{\phi} + 3H\dot{\phi} + V'(\phi) = 0$

tachyon field $\dfrac{\ddot{T}}{1-\dot{T}^2} + 3H\dot{T} + \dfrac{V'(T)}{V(T)} = 0$

2 expansion (friction) term dominates

scalar field $\dot{\phi} \simeq -\dfrac{1}{3H}V'(\phi)$

tachyon field $\dot{T} \simeq -\dfrac{1}{3H}\dfrac{V'(T)}{V(T)}$

Scalar field⇔tachyon field dictionary

3 accelerated expansion

scalar field $V(\phi) > \dot{\phi}^2$

tachyon field $\dot{T}^2 < \frac{2}{3}$

4 slow-roll parameters

$(\kappa^2 = 8\pi/M_{pl}^2)$

scalar field

$$\epsilon = \frac{4\pi}{\kappa^2}\left(\frac{V'(\phi)}{V(\phi)}\right)^2$$

$$\eta = \frac{8\pi}{\kappa^2}\frac{V''(\phi)}{V(\phi)}$$

tachyon field

$$\epsilon \sim \frac{1}{\kappa^2}\frac{V'(T)^2}{V(T)^3}$$

$$\eta \sim \epsilon - \frac{1}{\kappa^2}\frac{V''(T)}{V(T)^2}$$

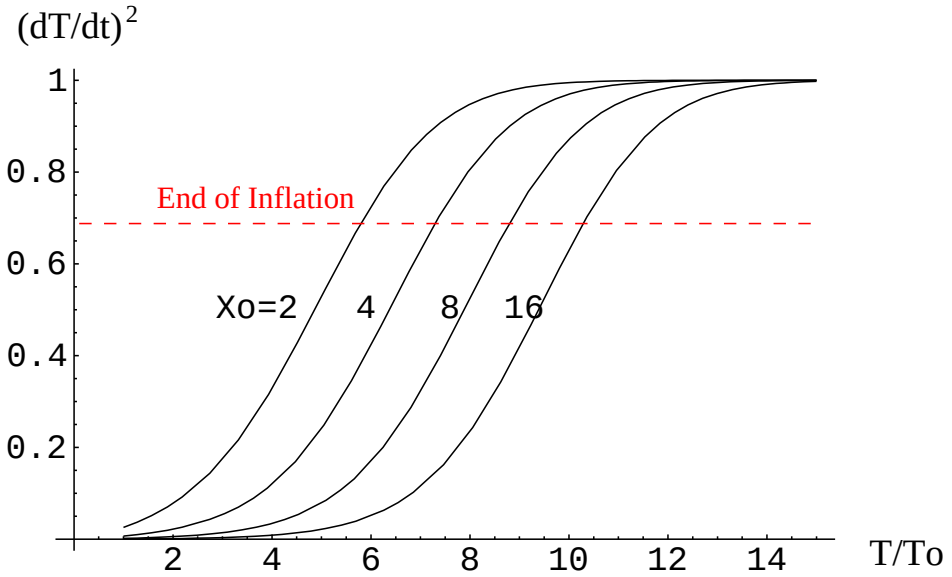
Can we get inflation from this set-up?

Introduce new parameter X_0

$$X_0^2 = \kappa^2 T_0^2 V_0$$

initial conditions:-

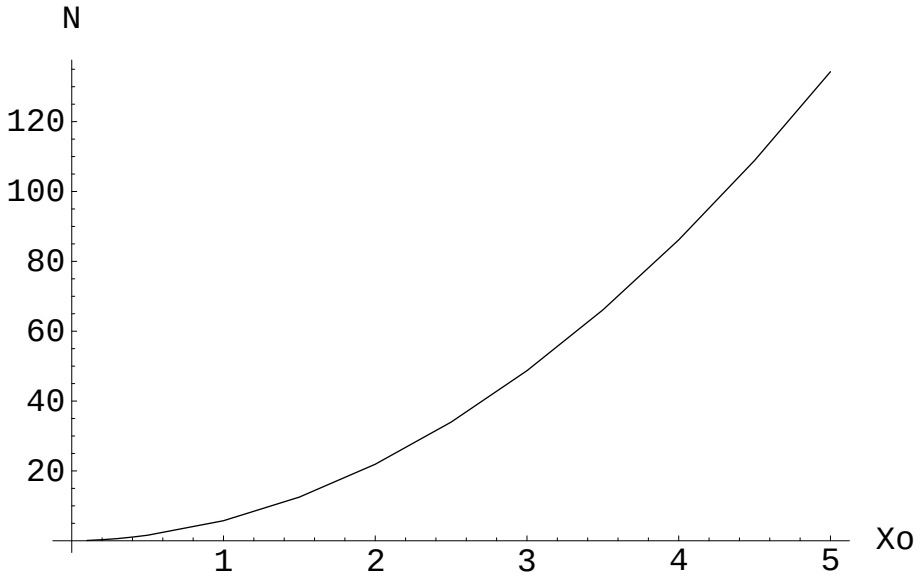
T very close to 0, $\dot{T} = 0$



behaviour of $\dot{T}$ for different X_0

efolds

Number of efolds for different X_0



perturbations

Near the top of the potential

$$\left|\frac{\delta\rho}{\rho}\right| \approx \frac{H}{\dot{\phi}}\delta\phi \approx \frac{H}{\dot{T}}\delta T$$

$$\approx \frac{1}{3^{3/2}2\pi}\frac{X_0^3}{\sqrt{V_0}T_0^2}$$

(∼60 efolds before end of inflation for $5 \leq X_0 \leq 7$)

gravitational waves

we require

$$\frac{H_{end}}{M_p l} \leq 3.6 \times 10^{-5}$$

Do these parameters fit with string theory?

$$V_0 = \frac{v_0}{g_s l_s^4 (2\pi)^3} \quad \text{(D-brane tension)}$$

$$T_0 = \tau_0 l_s \quad \text{(tachyon mass)}$$

$$\kappa^2 = \pi g_s^2 l_s^2 \left(\frac{l_s}{R}\right)^6 \quad \text{(gravitational coupling)}$$

where R is the size of the compact space and g_s, l_s are string coupling and length

$$\left(\frac{l_s}{R}\right)^{12} v_0 g_s^3 \lesssim 1.4 \times 10^{-6} \quad \text{(no grav. waves)}$$

$$\left(\frac{l_s}{R}\right)^{9} v_0 \tau_0 g_s^2 \sim 2.7 \times 10^{-2} \quad \text{(COBE normalization)}$$

$$\left(\frac{l_s}{R}\right)^{6} v_0 \tau_0^2 g_s \gtrsim 7.1 \times 10^{2} \quad \text{(inflationary cond.)}$$

NOT POSSIBLE for $v_0 = \tau_0 = 1$ and any $R \gtrsim l_s$

Solution 1

we can reduce the tachyon mass $T_0 \gtrsim 10^2 l_s$,

$g_s \sim 10^{-2}$

(possible theoretical motivation Kim hep-th/0204191)

Solution 2

we can increase the number of branes

(in the spirit of Mazumdar, Panda and Perez-Lorenzana hep-ph/0107058)

need $R \sim 10 l_s$, $g_s \sim 10^{-2}$ and about 10^{11} branes.

Similar conclusion to dS/CFT authors

(Larsen, Van der Schaar and Leigh hep-th/0202127

Halyo hep-th/0203235)

Reheating

classical potential $V(T)$ has no finite minimum

$\Downarrow$

no oscillations in T (Kofman and Linde hep-th/0205121)

however field does behave like MASSIVE "partons"

may decay to massive string modes

$$\Gamma \sim \frac{g_s^n}{l_s} \sim \left(\frac{l_s}{R}\right)^3 g_s^{n+1} M_{pl}$$

reheat temperature then

$$T_{RH} \sim \sqrt{M_{pl}\Gamma} \sim \left(\frac{l_s}{R}\right)^{\frac{3}{2}} g_s^{\frac{n+1}{2}} M_{pl}$$

easily high enough for cosmology

Possible theory motivation - Okuda and Sugimoto

hep-th/0208196

(also see Cline et al hep-th/0207156

and Shiu et al hep-th/0207119)

unanswered questions

Q. if potential symmetric how do we get rid of domain walls?

A. we use some eternal inflation hypothesis

⇓

Q. how do we get this inflation?

A. we assume a large number of branes

⇓

Q. why are the quantum fluctuations of all these branes correlated?

A. hmmmm.....

Conclusions

1. decay of D-brane leads to cosmological acceleration
2. may give rise to inflation if you cook the parameters
3. need to find out if/how reheating occurs
4. there may be an initial condition problem depending on which parameters you cook