Wilson Line Inflation

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Based on:

Gen.Rel.Grav.39:1203-1234,2007

Inflation

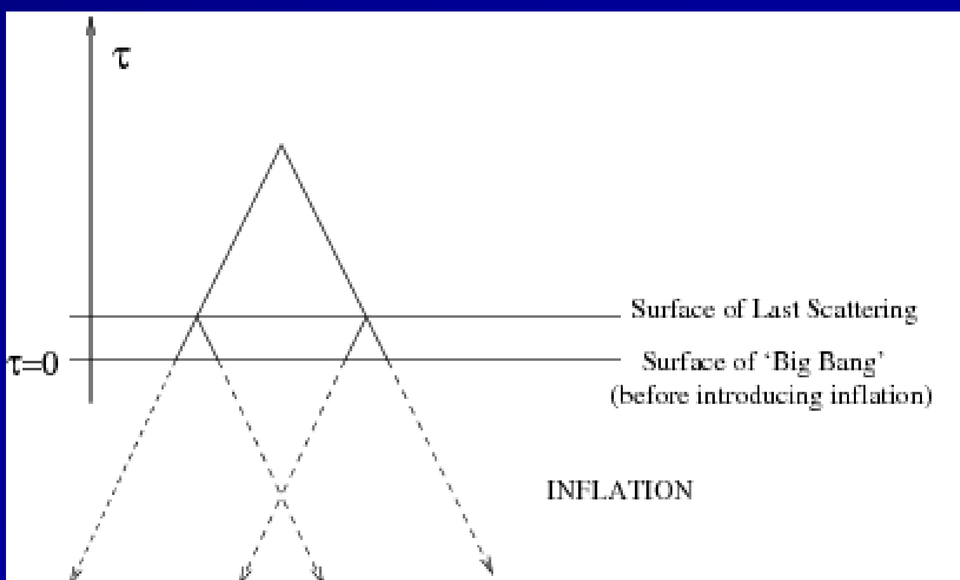
- Horizon, Flatness, Monopole problems, …

$$\tau = \int_0^t a(t)^{-1}\,dt \qquad |\Omega - 1| = |k| \big/ a^2 H^2 \qquad \pi_2(G/SM) \supset \pi_1(U(1)) \neq I$$

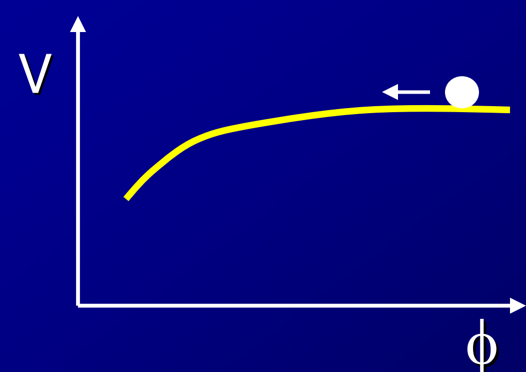
- Exponential expansion with H~const

Comoving horizon decreases

Expansion dilutes curvature and monopoles



owly rolling down a flat



Stringy Inflation

- String Theory Moduli as inflatons
- Break SUSY to lift potential
- Inflaton candidates
  - Closed String: dilaton, Kahler, cx structrure
  - Open String: Brane positions, tachyon, Wilson lines
- Models: Racetrack, Kahler (Kahler)

  DDbar, Branes @ angles, D3-D7, DBI (brane separation)

  Warped tachyonic (open string tachyon)

SUGRA η problem

- Potential is of the form: $V = V_0 + V_{\text{int}}(\varphi)$

where typically $V_0 = \frac{X}{r^{\alpha}}$

- Sugra variable is T, where: $2r = T + T^* + \varphi\varphi^*$

- After stabilisation: $V_0 = V_0(\varphi)$

- Fine tuning!

(KKLMMT 03, BDKMS 07)

Wilson Lines

- Consider gauge field: $F = dA, \quad A \to A + d\chi$
- Wilson Line: $U_\gamma = P\exp \oint_\gamma A$
- If γ contractible, then: $U_\gamma = P\exp \int_C F, \quad \gamma = \partial C$
  and $F = 0 \Rightarrow U = 1$
- However, if $\pi_1(C) \neq I$ one can have: $F = 0, \quad U \neq 1$
- Abuse of terminology $U_\gamma \leftrightarrow A$
- In particular: $A \to A + \lambda, \quad \lambda = const$

Wilson Line Inflation: Setup

- Parallel D7 branes wrapping a 4-torus $T^4 = T^2 \times T^2$

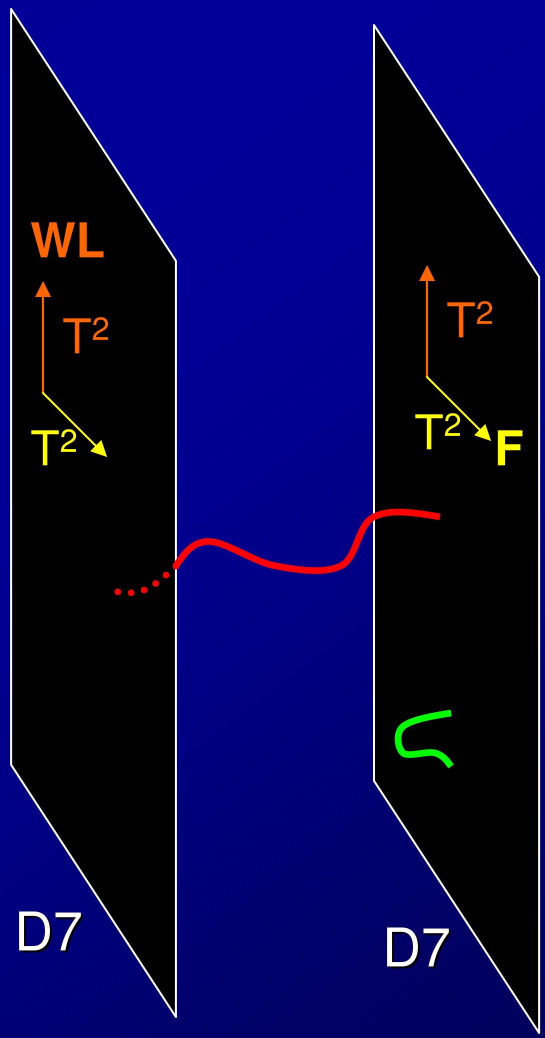
- Brane1: Turn on a **WL** in one T^2

$$A = \frac{\lambda}{2\pi R_1} dx^1$$

- Brane2: Turn on **F** in the other T^2

$$F = \frac{m}{2\pi R_3 R_4} dx^3 \wedge dx^4$$

- Open Strings: BCs, mode expansion, Virasoro operators, **MASS**



Wilson Line Inflation: Potential

- BCs lead to twisted mode expansions (cf Branes @ angles)
- Mass op: $$\alpha' M^2 = \sum_{i=1}^{2} \frac{(y_i + 2\pi w_i)^2 \tilde{R}_i^2}{4\pi^2 \alpha'} + \frac{(\lambda + 2\pi n)^2 \alpha'}{4\pi^2 R_1^2} + N_\nu + \nu(\theta - 1)$$
- Interaction Energy given by Coleman-Weinberg formula:

$$V_{\text{int}} = 2\int \frac{d^4 k}{(2\pi)^4} \int_0^\infty \frac{dt}{t} Tr \exp[-2\pi\alpha' t(k^2 + M^2)]$$

- Leads to: $$V_{\text{int}}(\lambda, y) = -\frac{\sin^2(\theta/2)\tan(\theta/2)}{8\pi^3 \alpha'^2 \|Y, \Lambda\|^2}$$ (cf G-BRZ,2003)

where $$\|Y, \Lambda\|^2 = \sum_{i=1}^{2} \frac{y_i^2 \tilde{R}_i^2}{\alpha'} + \frac{\lambda^2 \alpha'}{R_1^2} \equiv Y^2 + \Lambda^2$$

Wilson Line Inflation: Results

- Total potential: $$V = V_0 + V_{\text{int}}(\lambda) = \frac{Vol(T^4)}{8\pi^3 \alpha'^4 g_s}\frac{\tan^2(\theta)}{4} - \frac{\sin^2(\theta/2)\tan(\theta/2)}{8\pi^3\alpha'^2(Y^2+\Lambda^2)}$$
- Slow Roll Parameters: $$\varepsilon = 4(8\pi)^2 g_s \frac{\tilde{R}_1\tilde{R}_2\alpha'^4}{R_1^4 R_2^2 R_3^2 R_4^2}\frac{\sin^4(\theta/2)\tan^2(\theta/2)}{\tan^4(\theta)}\frac{\lambda^2}{\|Y,\Lambda\|^8}$$ $$\eta = (8\pi)^2 \frac{\tilde{R}_1\tilde{R}_2\alpha'}{R_1R_2R_3R_4}\frac{\sin^2(\theta/2)\tan(\theta/2)}{\tan^2(\theta)}\frac{1}{\|Y,\Lambda\|^4}\left(1-\frac{4\alpha'\lambda^2}{R_1^2\|Y,\Lambda\|^2}\right)$$
- Two cases
  - $\Lambda \ll Y$, $V_{\text{int}}(\phi) \sim \phi^2$, ε, η +ve $\quad \varepsilon \approx 10^{-13}, \eta \approx 3\times 10^{-3}$
  - $\Lambda \gg Y$, $-V_{\text{int}}(\phi) \sim \phi^{-2}$, η -ve $\quad \varepsilon \approx 10^{-13}, \eta \approx -1.5\times 10^{-2}$
- Hybrid-like exit: $$M^2 = \sum_{i=1}^{2}\frac{y_i^2\tilde{R}_i^2}{4\pi^2\alpha'^2} + \frac{\lambda}{4\pi^2 R_1^2} - \frac{|\theta|}{2\pi}$$ strings
- Fine tuning: 1/1000

Realistic Compactifications

- Work in type IIB, KKLT-like setup
- Kahler moduli stabilised by non-pert W
- Turn on $G_3 = F_3 + \phi H_3$ to stabilise brane positions

  (GMM, 2005)
- WLs appear in Kahler potential as positions

$$K = -3\log(T + T^* - \varphi\varphi^*)$$

- Results of previous setup apply to this case

SUGRA η problem

- Consider the IIB toroidal model ($T^6 = T^2 \times T^2 \times T^2$)
- Superpotential stabilisation fixes $\mathrm{Re}\,T_1, \mathrm{Re}\,T_2, \mathrm{Re}\,T_3$

where:

$$A_1 = \sqrt{\frac{2e^{\phi}\,\mathrm{Re}\,T_3}{\mathrm{Re}\,T_1}\left(\mathrm{Re}\,T_2 - \frac{1}{2}|\varphi|^2\right)}$$

$$A_2 = \sqrt{\frac{2e^{\phi}\,\mathrm{Re}\,T_1\,\mathrm{Re}\,T_3}{\mathrm{Re}\,T_2 - \frac{1}{2}|\varphi|^2}}$$

$$A_3 = \sqrt{\frac{2e^{\phi}\,\mathrm{Re}\,T_1}{\mathrm{Re}\,T_3}\left(\mathrm{Re}\,T_2 - \frac{1}{2}|\varphi|^2\right)}$$

- Compute V_0 in the 4D Einstein frame:

$$V_0 = \frac{(2\pi)^{-3} m^2 \alpha'^{-2} g_s^3}{4 A_1^2 A_2^3 A_3}$$

- Independent of ϕ !

Summary

- Model of inflation using WLs as inflatons
- Similar to Branes @ angles (T-duality)
- But: provides more tuning parameters
- Predictions: small ε (no gravitational waves)

  HZ or slightly red scalar spectrum

  Cosmic strings with $G\mu<10^{-7}$
- No SUGRA η problem!
- Heterotic?