Inflation from mater fields in supergravity

KRZYSZTOF TURZYŃSKI
IFT

work in progress, with J. Ellis, Z. Lalak & S. Pokorski

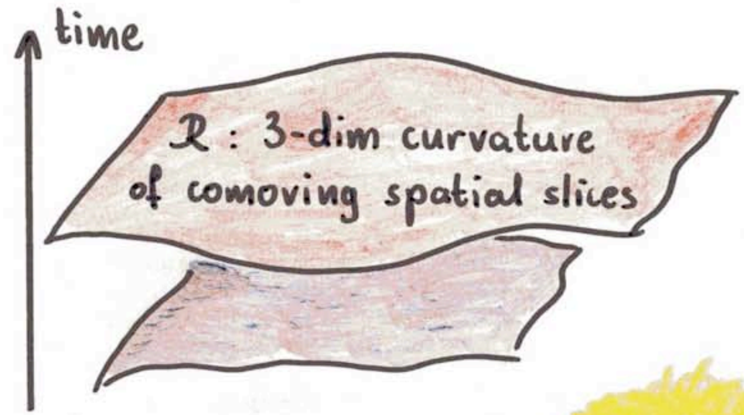
FACULTY OF PHYSICS
WARSAW UNIVERSITY

OUTLINE

1. INFLATION - - A SHORT INTRODUCTION
2. NO-SCALE SUPERGRAVITY (AND INFLATION)
3. NO-SCALE MODELS WITH T-MODULUS STABILISED THROUGH F-TERMS....
4. ... OR D-TERMS

INFLATION

- Quantum fluctuations of the scalar d.o.f. (gravity + scalar field) stretched to superhorizon sizes give rise to primordial density perturbations



$$\frac{V}{24\pi^2\varepsilon} \rightarrow \boxed{\mathcal{P}_{\mathcal{R}} = A\left(\frac{k}{k_0}\right)^{n_s-1}}$$

$$1-n_s = 6\varepsilon - 2\eta$$

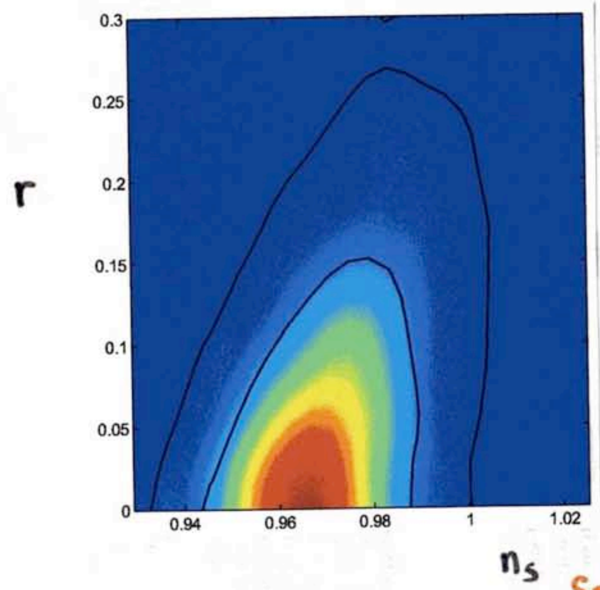
$$+$$

the same for tensor d.o.f.

$$16\varepsilon \rightarrow \boxed{r = \frac{\mathcal{P}_g}{\mathcal{P}_{\mathcal{R}}}}$$

$$\boxed{N \equiv \ln\frac{a_f}{a_i} \geqslant 47}$$

WMAP3



Seljak et al, 2006

η PROBLEM

In supergravity:

$$\mathcal{L}_{kin} = K^i{}_j \, (\partial_\mu \phi^j)(\partial^\mu \phi^*_i)$$

$$V = e^K \left(|K_j W + W_j|^2 - 3|W|^2 \right)$$

$K =$ Kähler potential

$W =$ superpotential

$K_j \equiv \frac{\partial K}{\partial \phi^j} \qquad K^i \equiv \frac{\partial K}{\partial \phi^*_i}$

Minimal kinetic terms for:

$$K = \phi^*_i \phi^i + \ldots$$

Typically:

$$V = e^{|\varphi|^2} (\ldots\ldots) \Longrightarrow \eta \sim \mathcal{O}(1)$$

no slow-roll

NO-SCALE MODELS

Arise in toroidal compactifications of string theories which mimic Calabi-Yau compactification

Witten 1985
Derendinger et al. 1985

SUPERGRAVITY

NO-SCALE MODELS

zero cosmological constant
global N=1 SUSY
gravitino mass not determined

} after local SUSY breaking

Ellis et al. 1984 abcd, 1985

NO-SCALE MODELS

$$\boxed{K = -3\ln\left(T + T^* - 2|\Phi|^2\right)}$$

Kinetic terms :

$$\mathcal{L}_{kin} = \frac{1}{(T+T^*-2|\Phi|^2)^2}\left(\partial_\mu T^*, \partial_\mu \Phi^*\right)\begin{pmatrix} 3 & -6\Phi^* \\ -6\Phi & 6(T+T^*)\end{pmatrix}\begin{pmatrix}\partial^\mu T \\ \partial^\mu \Phi\end{pmatrix} =$$

$$= \frac{1}{2}\left[\partial_\mu \sqrt{\frac{3}{2}}\ln 2(t-|\Phi|^2)\right]^2 + \frac{3}{4(t-|\Phi|^2)^2}\left[\partial_\mu t' + i(\Phi^*\partial_\mu\Phi - \Phi\partial_\mu\Phi^*)\right]^2 +$$

$$+ \frac{6}{(t-|\Phi|^2)}\partial_\mu\Phi^*\partial^\mu\Phi$$

$T = t + i t'$

Potential for $W = W(\Phi)$

$$V_F = \frac{|W_\Phi|^2}{6(T+T^*-2|\Phi|^2)^2} \geq 0$$

$$\boxed{\begin{aligned}\eta_T &\equiv \frac{1}{2}\frac{\partial}{\partial t}(K^{-1})_T{}^T\frac{\partial V}{\partial t} = \frac{4}{3}\\ \epsilon_T &\equiv \frac{1}{4}(K^{-1})_T{}^T\left(\frac{1}{V}\frac{\partial V}{\partial t}\right)^2 = \frac{4}{3}\end{aligned}}$$

No easy T- inflation.

NO-SCALE MODELS

$$\boxed{W = \frac{1}{2} M \Phi^2}$$

- T fixed

$$\mathcal{L}_\Phi = \frac{3t}{(t - |\Phi|^2)^2} \partial_\mu \Phi \partial^\mu \Phi^* - \frac{|W_\Phi|^2}{24\,(t - |\Phi|^2)^2}$$

with $|\Phi| \to \varphi$ canonically normalised

$$\mathcal{L}_\Phi = \frac{1}{2} \partial_\mu \varphi \partial^\mu \varphi - \frac{M^2}{96\,t} \sinh^2\left(\sqrt{\frac{2}{3}}\varphi\right)$$ No slow-roll

NO-SCALE MODELS

$$\boxed{W = \frac{1}{2} M \Phi^2}$$

- T fixed

$$\mathcal{L}_\Phi = \frac{3t}{(t-|\Phi|^2)^2}\,\partial_\mu \Phi\, \partial^\mu \Phi^* - \frac{|W_\Phi|^2}{24\,(t-|\Phi|^2)^2}$$

with $|\Phi| \to \varphi$ canonically normalised

$$\mathcal{L}_\Phi = \frac{1}{2}\,\partial_\mu \varphi\, \partial^\mu \varphi - \frac{M^2}{96\,t}\,\sinh^2\left(\sqrt{\frac{2}{3}}\,\varphi\right)$$

No slow-roll

- $T + T^* - 2|\Phi|^2$ fixed

$$\mathcal{L}_\Phi = \frac{6}{(t-|\Phi|^2)}\,\partial_\mu \Phi\, \partial^\mu \Phi^* - \frac{|W_\Phi|^2}{24\,(t-|\Phi|^2)^2}$$

with $|\Phi| \to \varphi$ canonically normalised

$$\mathcal{L}_\Phi = \frac{1}{2}\,\partial_\mu \varphi\, \partial^\mu \varphi - \frac{1}{2}\,\frac{M^2}{144\,(t-|\Phi|^2)}\,\varphi^2$$

★ Simple quadratic inflation

NO-SCALE MODELS

$$\boxed{W = \mu^2 \Phi + \frac{d}{3}\Phi^3}$$

T fixed

$$V_F = \frac{\mu^4}{24(t - |\Phi|^2)^2}\left[\left(1 - \frac{|\Phi|^2}{\Phi_0^2}\right)^2 + \frac{4|\Phi|^2}{\Phi_0^2}\cos^2(\arg\Phi)\right]$$

For $|\Phi|^2 \ll t$: $\rightarrow$ arg Φ quickly stabilises

$\rightarrow$ effectively

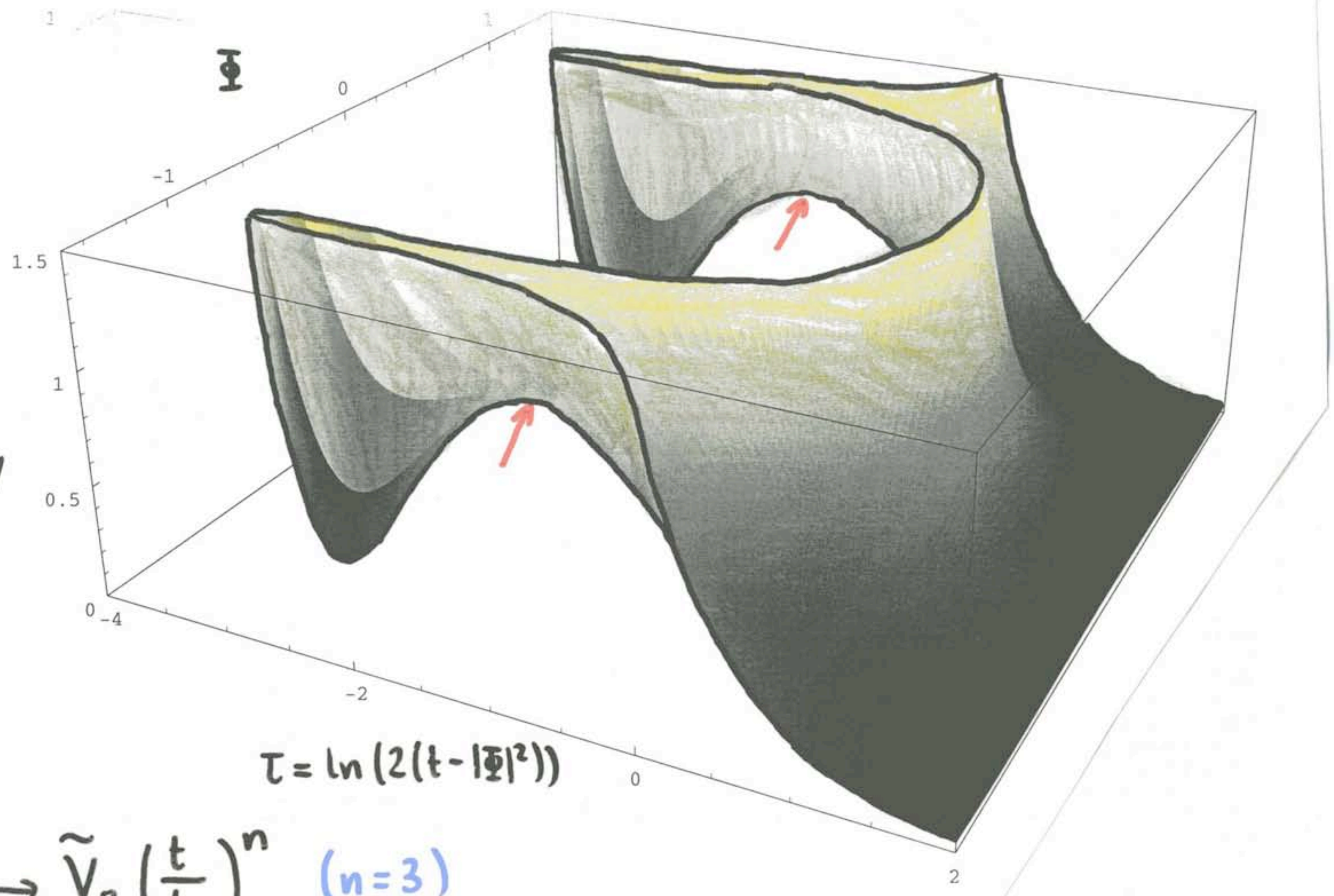
$$V_F \propto (1 - x'^2 \varphi^2)^2 \quad \star\star$$

φ canonically normalised

$$x'^2 = 1 - \frac{\Phi_0^2}{t} \ll 1$$

slow-roll inflation possible

T STABILISATION THROUGH F-TERMS

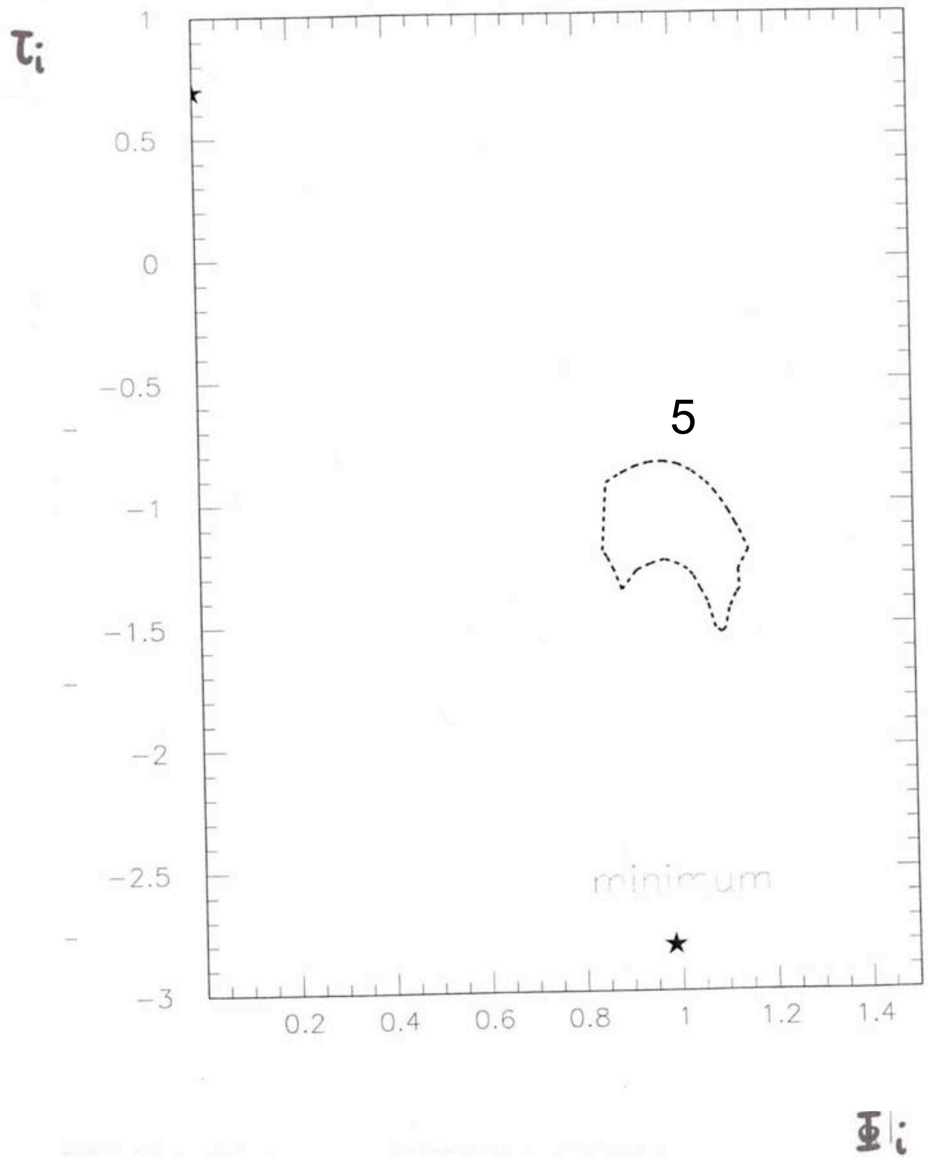


$$V_0 \to \tilde{V}_0 \left(\frac{t}{t_0}\right)^n \quad (n=3)$$

no inflation

η problem

T STABILISATION THROUGH F-TERMS



T STABILISATION THROUGH D-TERMS

$$\boxed{K = -3\ln\left(T+T^* - 2|\Phi|^2\right) + \sum_i \frac{|X_i|^2}{(T+T^*)^{n_i}}}$$

Symmetry U(1) :

$$T \longrightarrow T + i\frac{\delta}{2}\Lambda \qquad X_i \longrightarrow e^{iQ_{X_i}\Lambda} X_i$$

$$\downarrow$$

$$D = -\frac{\delta}{2}\frac{\partial K}{\partial T} - \sum_i Q_{X_i}\frac{\partial K}{\partial X_i} X_i$$

$$\downarrow$$

$$V_D = \frac{g^2}{2}\left(\frac{3\delta}{T+T^* - 2|\Phi|^2} + \sum_i Q_{X_i}\frac{|X_i|^2}{(T+T^*)^{n_i}}\right)^2$$

$$V_F = \frac{|W_\Phi|^2}{6\left(T+T^* - 2|\Phi|^2\right)^2}$$

T STABILISATION THROUGH D-TERMS

$$V_D = \frac{g^2}{2}\left(\frac{3\delta}{2(t-|\Phi|^2)} + \sum_{i=1}^{m} Q_{x_i} \frac{|x_i|^2}{(2t)^{n_i}} \right)^2$$

$$V_F = \frac{|W_\Phi|^2}{24(t-|\Phi|^2)^2}$$

Model A

$m = 1$

$Q_{x_1}\delta < 0$

$V_D \longrightarrow$ stabilises $t - |\Phi|^2$

$V_F \longrightarrow$ gives inflaton potential from $W = \frac{1}{2} M \Phi^2$

★

chaotic inflation

Model B

$m = 2 \qquad \delta = 0$

$Q_{x_1} Q_{x_2} < 0 \qquad n_1 > n_2$

$V_D \longrightarrow$ stabilises t

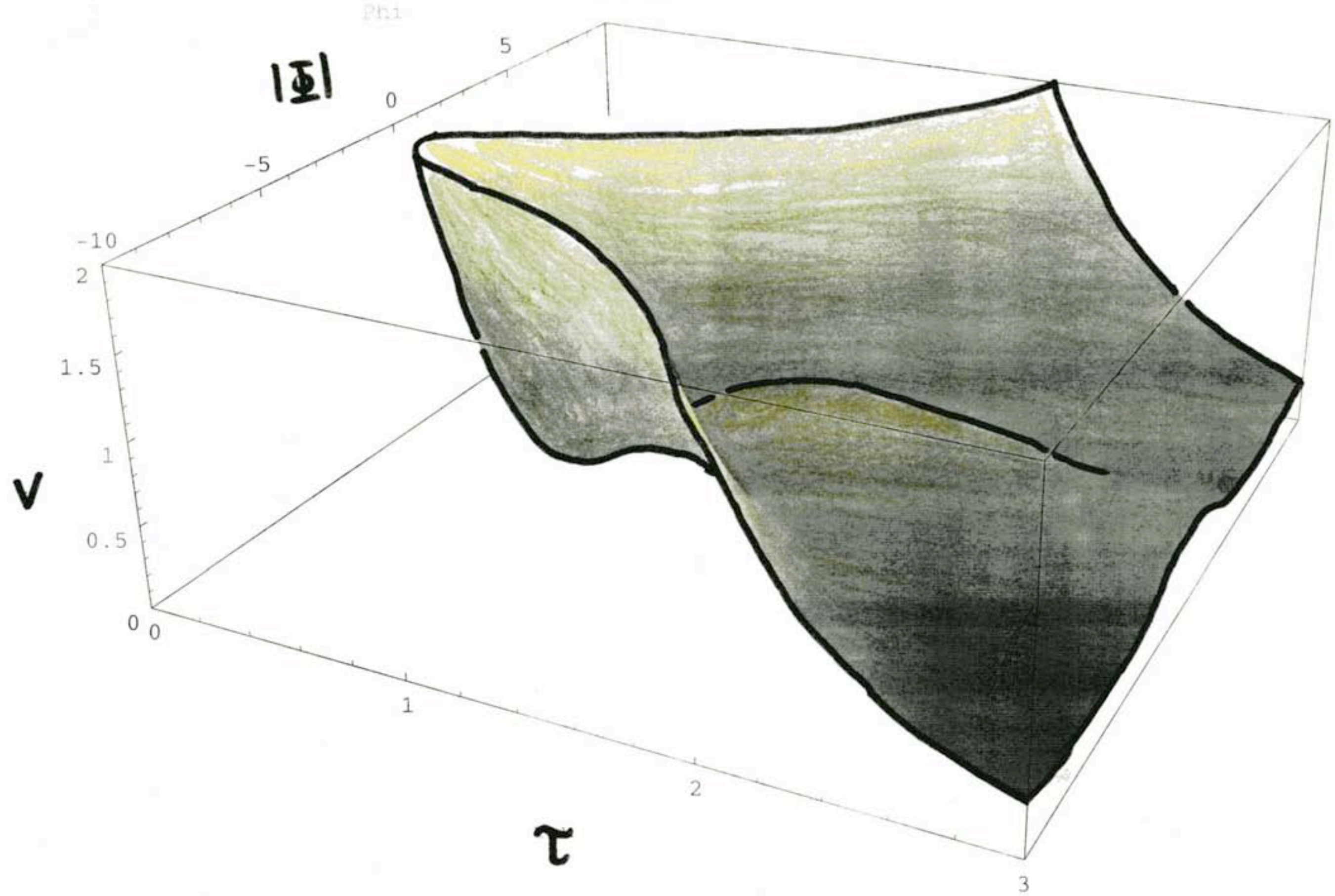
$V_F \longrightarrow$ gives inflaton potential from $W = \mu^2 \Phi + \frac{d}{3}\Phi^3$

★★

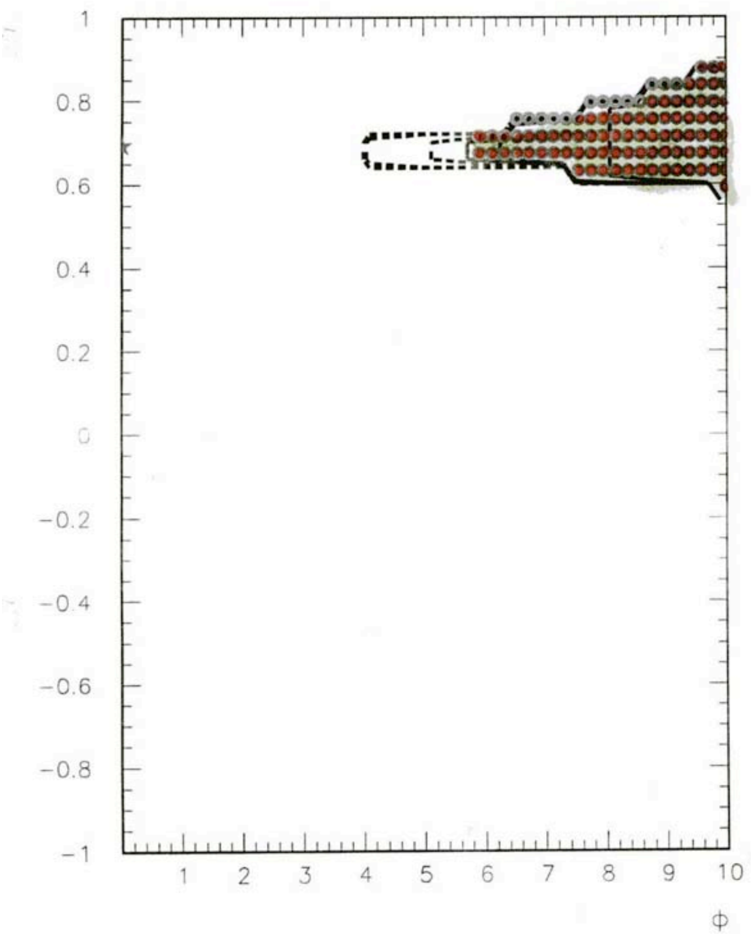
new inflation

T STABILISATION THROUGH D-TERMS

Model A



T STABILISATION THROUGH D-TERMS



$$V_D = \frac{g^2}{2}\left(\frac{3\delta}{2(t-|\Phi|^2)} + \sum_{i=1}^{m} Q_{X_i} \frac{|X_i|^2}{(2t)^{n_i}} \right)^2$$

$$V_F = \frac{|W_\Phi|^2}{24(t-|\Phi|^2)^2}$$

Model A

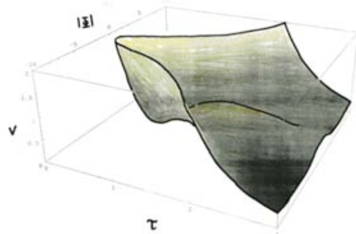
$m = 1$

$Q_{X_1}\delta < 0$

$V_D \longrightarrow$ stabilises $t - |\Phi|^2$

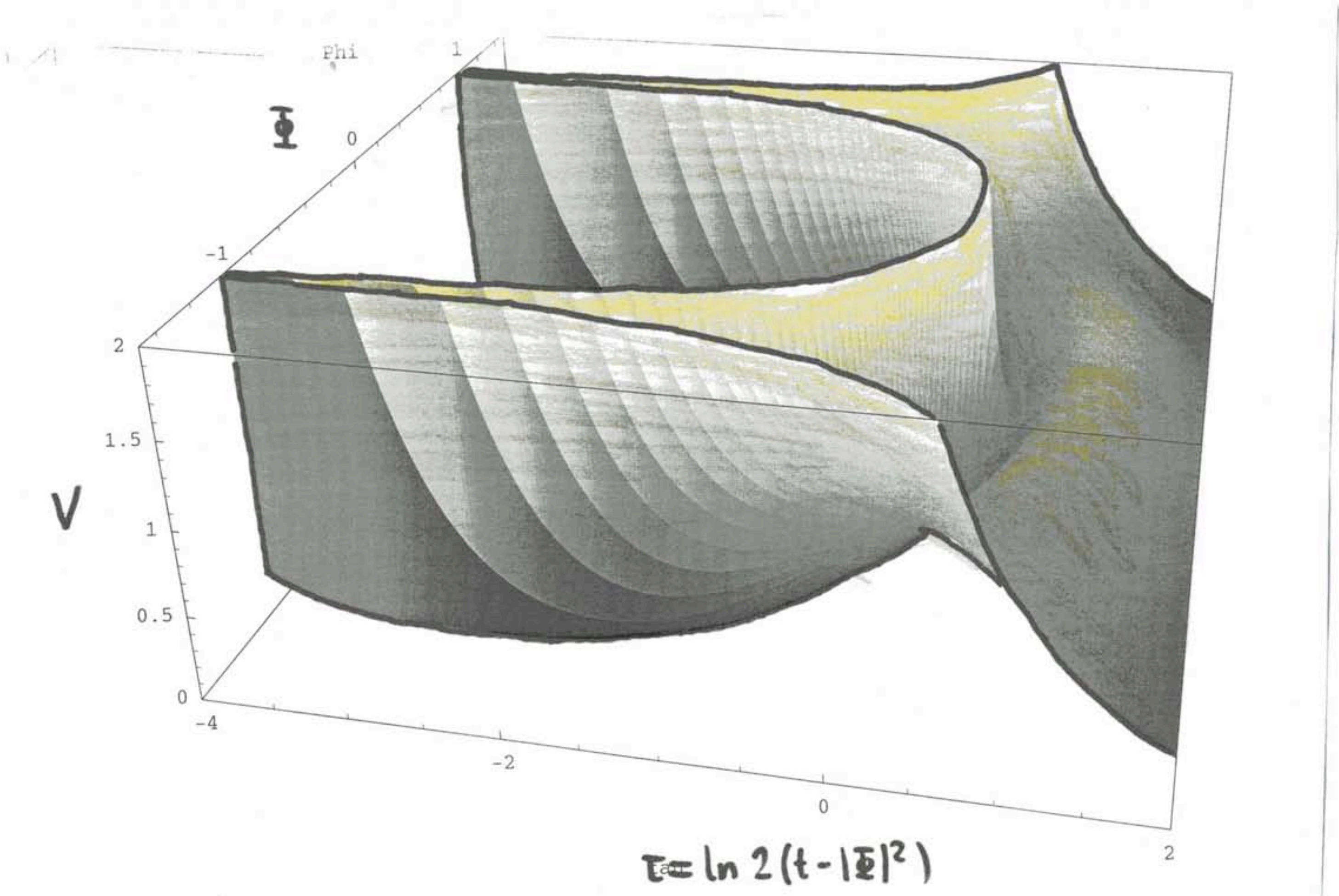
$V_F \longrightarrow$ gives inflaton potential from $W = \frac{1}{2} M \Phi^2$

★ chaotic inflation

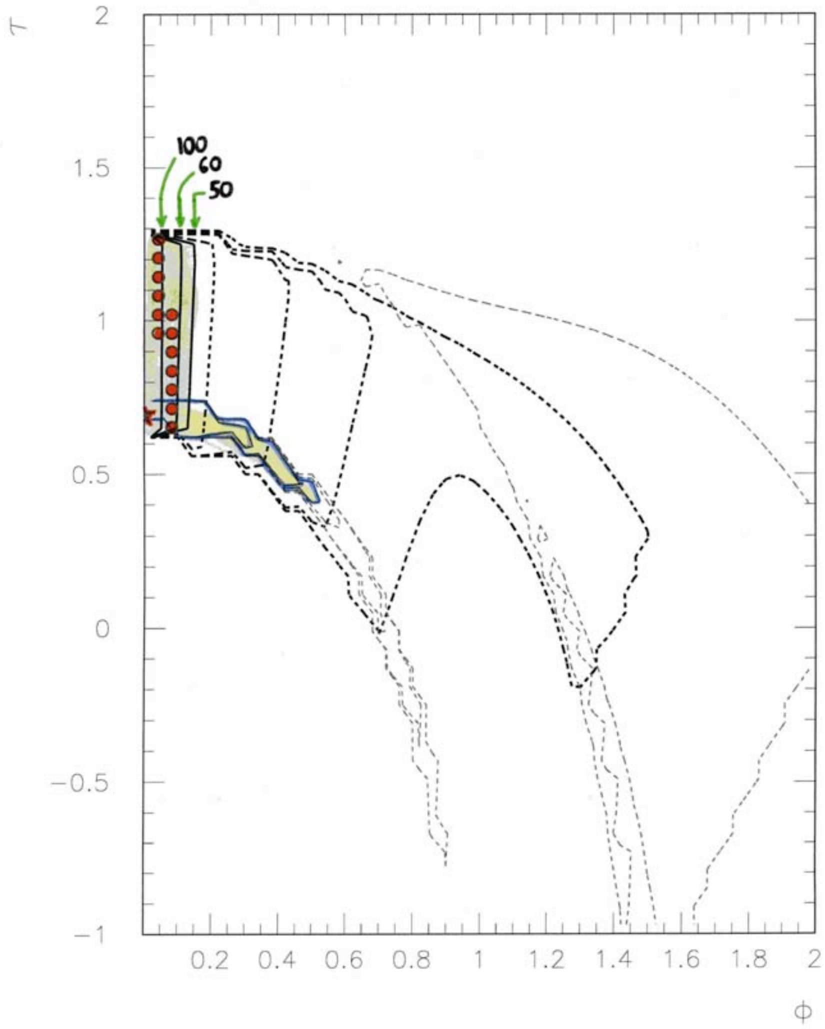


T STABILISATION THROUGH D-TERMS

Model B



T STABILISATION THROUGH D-TERMS



$$V_D = \frac{g^2}{2}\left(\frac{3\delta}{2(t-|\Phi|^2)} + \sum_{i=1}^{m} Q_{X_i} \frac{|X_i|^2}{(2t)^{n_i}} \right)^2$$

$$V_F = \frac{|W_\Phi|^2}{24(t-|\Phi|^2)^2}$$

Model B

$m = 2 \qquad \delta = 0$

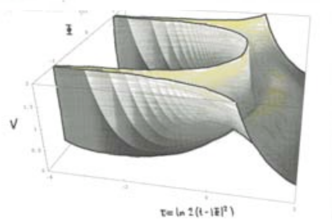
$Q_{X_1} Q_{X_2} < 0 \qquad n_1 > n_2$

$V_D \longrightarrow$ stabilises t

$V_F \longrightarrow$ gives inflaton potential from $W = \mu^2 \Phi + \frac{d}{3}\Phi^3$

★★

new inflation



CONCLUSION

YES! YES! YES! YES! YES! YES! YES! YES! YES! YES!

Simplest inflaton potentials

No-scale supergravity models

T modulus stabilised (separately)

fine-tuning between different sectors of the theory

YES! YES! YES! YES! YES! YES! YES! YES! YES! YES! YES!