Combining D-term inflation with moduli stabilization

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[in progress]

Overview

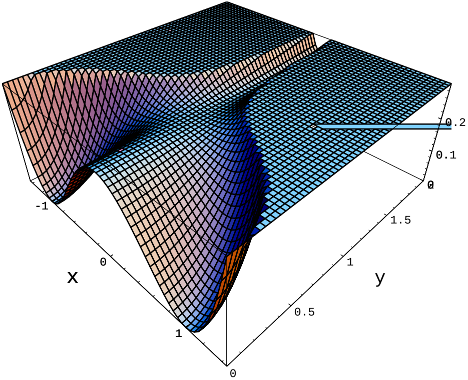
- Introduction
  - D-term inflation
  - Moduli stabilization
- Combining D-term inflation with moduli stabilization
  - Problems
- Inflation
  - Predictions
- Conclusions

BINETRUY & DVALI '98

$W = \lambda \phi \phi_+ \phi_-$

$V_D = \frac{g^2}{2}(|\phi_+|^2 - |\phi_-|^2 - \xi)^2$

minimal Kähler



inflation:

$\phi_\pm = 0, \quad V = \frac{g^2}{2}\xi^2$

$m_-^2 = \lambda^2 \phi^2 - g^2 \xi$

vacuum:

$\phi_- = \phi = 0 \;\&\; \phi_+ = \sqrt{\xi}, \quad V = 0$

SUGRA D-term inflation

FI-term in sugra invariant under R-symmetry $\Rightarrow$ W charged

BINETRUY, DVALI, KALLOSH, VAN PROEYEN '04

- Charge all other sectors

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- Effective FI-term from VEVs of other fields

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Nice features:

- String motivated (brane inflation, $D3/D7$ system)
- Free of η-problem ($m_\phi^2 \ll H^2$)

Moduli stabilization

KKLT set-up with uplifting D-term [anomalous U(1)] instead of D-brane

- fluxes to fix all moduli except for the breathing mode T:
- non-perturbative effects fix T:

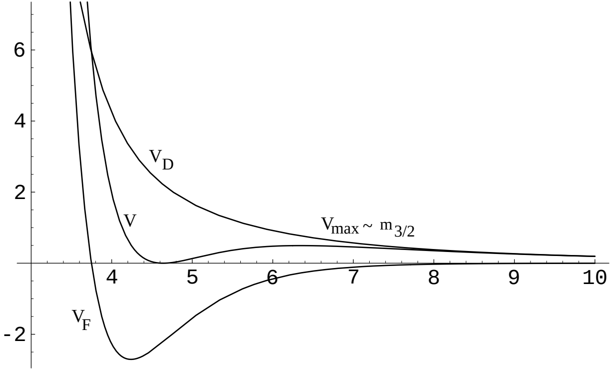
$$W = W_0 + A\chi^{-b} \mathrm{e}^{-aT}$$
$$K = -3 \log(T + \bar{T} + \delta_{\mathrm{GS}} V - |\chi|^2)$$

- lift SUSY AdS solution to non-SUSY dS:

$$V_D = \frac{E\left(1 + \frac{a}{b}|\chi|^2\right)^2}{T_R(2T_R - |\chi|^2)} \quad \xrightarrow{|\chi| \ll 1} \quad \frac{E}{T_R^3}$$

BURGESS, KALLOSH, QUEVEDO '03

ACHUCARO, DE CARLOS, CASAS, DOPLICHER '06



Combining moduli and inflaton sector

- moduli fixed during inflation: $m_{3/2}^2 \gtrsim V_0 = g^2\xi^2/2$
- moduli corrections to inflation

Combining the moduli and inflaton sector

The Model:

symmetry: $U(1)_{[\phi_\pm, T, \chi]} \times U(1)_{[T,\chi]}$

superpotential: $W = W_{\text{inf}}(\phi, \phi_\pm) + W_{\text{mod}}(T, \chi)$

$$\Rightarrow \quad V = e^K \left(K^{I\bar{J}} D_I W D_{\bar{J}} \overline{W} - 3|W|^2\right) + \frac{1}{2} Re(f_a) D^a D^a$$

Kähler potential?

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1) $K = -3 \ln(T + \bar{T} - |\chi|^2) + |\phi|^2 + |\phi_+|^2 + |\phi_-|^2$

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η-problem:

$$V(\text{inflation}) = V_D + {\rm e}^{|\phi|^2} (V^F_{\rm mod} + m^2_{3/2} |\phi|^2)$$

Combining the moduli and inflaton sector

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exit problem:

$$m_\pm^2 = \lambda^2\phi^2 + m_{3/2}^2 + V_{\rm mod}^F \pm g^2\xi\sqrt{1+\ldots} > 0 \text{ always}$$

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3) $K = -3\ln(T + \bar{T} - |\chi|^2 + \frac{1}{2}|\phi - \bar{\phi}|^2 + |\phi_+|^2 + |\phi_-|^2)$ V

End of inflation

Masses waterfall fields

$$m_\pm^2 = g^2\xi\left(x^2 + \frac{\xi}{3} \pm g^2\xi\sqrt{1+\frac{2}{3}\alpha\xi x^2}\right)$$
$$\tilde{m}^2 = g^2\xi x^2$$

$$x^2 = \frac{g^2\xi}{2\lambda^2}\phi^2$$
$$\alpha \sim \frac{m_{3/2}^2}{g^2\xi^2} > 1$$

$$\Rightarrow \quad x_c^2 = \left(\sqrt{1+(\xi\alpha/3)^2} + (\xi\alpha/3)\right)$$

$\alpha\xi \ll 1$

Loop potential

$$V_{\rm loop} = \frac{1}{32\pi^2}{\rm Str}M^2\Lambda^2 + \frac{1}{64\pi^2}{\rm Str}M^4\ln M^2/\Lambda^2$$
$$= \frac{1}{2}g^2\xi^2\left[1+\frac{g^2}{4\pi^2}\left(\ln x + \frac{2}{3}\xi\alpha x^2(\ln x + \ln\frac{g\sqrt{\xi}}{\Lambda})\right)\right] \qquad (x \gg 1)$$

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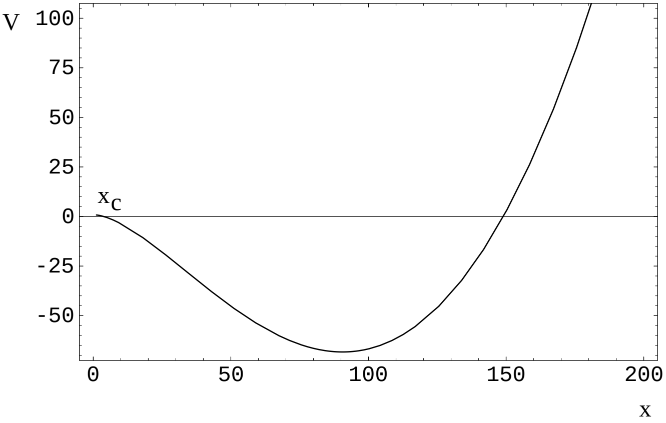
$\alpha\xi > 1$

no good!



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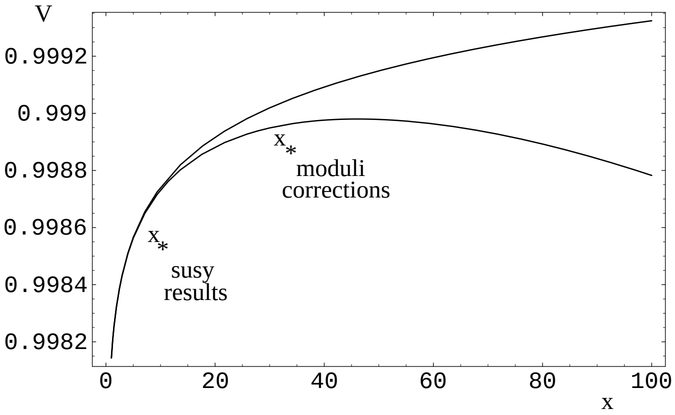
$\alpha\xi < 1$

OK!



Inflationary predictions

	SUSY results	moduli corrections
large field ($x_* \gg x_c$)	$10^{-3} \lesssim \lambda \lesssim 1/\sqrt{\alpha}$ $\xi \approx 10^{-5}$ $n_s \approx 0.98$	(cutoff dep.) $\xi < 10^{-5}$ $n_s < 0.98$
small field ($x_* \sim x_c$)	$\lambda \lesssim \min[10^{-3}, 1/\sqrt{\alpha}]$ $\xi \approx 10^{-3}\lambda^{2/3}$ $n_s \approx 1$	—

Results n_s

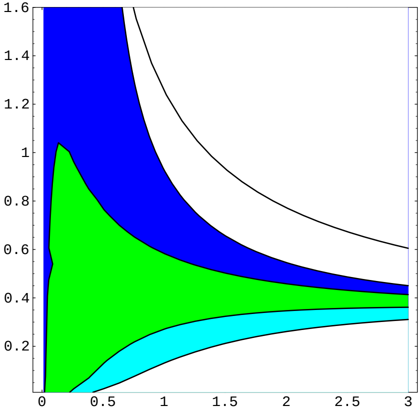


Figure: Contour plot of n_s for $u \approx \alpha\lambda^2$ vs $B \approx 50g^2/\alpha$. Contours are $n_s = 0.92, 0.95.0.98, 1$. The line corresponds to $\varphi_* = \varphi_\Lambda$.

Moduli variation during inflation

Moduli variation wrecks F-term inflation: $\delta T, \delta\chi$ small, but $\delta V'$ appreciable BRAX, VAN DE BRUCK, DAVIS, DAVIS '06

Perturb around min of $V_{\rm mod}$ (ignore χ)

$$\delta V \approx \frac{1}{2}(\delta T)^2 \partial_T^2 V_{\rm mod}(T) + (\delta T)\partial_T V_{\rm loop}(T,\phi)$$

minimize V wrt δT:

$$\approx -\frac{1}{2}\frac{(\partial_T V_{\rm loop})^2}{\partial_T^2 V_{\rm mod}}$$

$$\delta V \sim V_{\rm loop} g^2/\alpha \ll V_{\rm loop}$$

using $(\partial_T V_{\rm loop}) \sim V_{\rm loop}/T,\ \partial_T^2 V_{\rm mod} \sim m_{3/2}^2/T^2$

Conclusions

Combining hybrid inflation with moduli stabilization:

- F-term does not work — Brax, van de Bruck, Davis, Davis '06

- D-term works for $\alpha\xi < 1$

- inflaton shift symmetry to solve η-problem
- no-scale Kähler for gracefull exit
- perturbations SUSY + moduli variations
- ...