Starobinsky-Type Inflation from α'-Corrections

Based on 1509.00024 (and 1411.6010)

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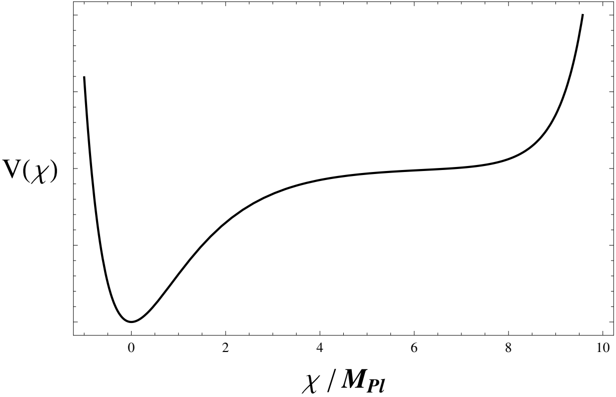
String-Pheno-Cosmo 2015, Florence

with D. Ciupke, F. Pedro, and A. Westphal

Take home message [1509.00024]



Possible to obtain above (large-field) potential from recently computed higher derivative $(\alpha')^3$-corrections in combination with string loop effects.
Caveat: Terms and Conditions may apply (ie. tuning)

LVS in a nutshell

Cicoli, Conlon, Burgess, Quevedo

IIB Flux compactifications with K3-fibred $\mathcal{V}(\tau_1, \tau_2, \tau_3)$, where $\tau_1, \tau_2 \gg \tau_3$

$$K = -2\log\left(\mathcal{V} + \frac{\hat{\xi}}{2}\right) \quad \text{and} \quad W = W_0 + Ae^{-a\tau_3},$$

F-term scalar potential gets generated for the Kähler moduli:

$$V^{LVS}(\mathcal{V}, \tau_3) = g_s\left[\frac{8a_3^2A_3^2}{3\alpha\gamma}\frac{\sqrt{\tau_3}}{\mathcal{V}}\mathrm{e}^{-2a_3\tau_3} - 4W_0a_3A_3\frac{\tau_3}{\mathcal{V}^2}\mathrm{e}^{-a_3\tau_3} + \frac{3\hat{\xi}W_0^2}{4\mathcal{V}^3}\right]$$

Potential does not depend on τ_1, τ_2. V^{LVS} has minima to stabilise

$$\langle\tau_3\rangle = \left(\frac{\hat{\xi}}{2\alpha\gamma}\right)^{2/3}, \quad \langle\mathcal{V}\rangle = \frac{3\alpha\gamma}{4a_3A_3}W_0\sqrt{\langle\tau_3\rangle}\mathrm{e}^{a_3\langle\tau_3\rangle}$$

Four-Superspace-Derivative Correction [1505.03092]

Ciupke, Louis, Westphal

$$\boldsymbol{V_{(1)} = -g_s^2 \hat{\lambda} \frac{|W_0|^4}{\mathcal{V}^4} \Pi_i t^i} \quad \Rightarrow \quad V_{eff} = V^{LVS} + V_{(1)}$$

Recall

$$\mathcal{V} \sim k_{ijk} t^i t^j t^k \,, \quad \tau_i = \frac{\partial \mathcal{V}}{\partial t^i}$$

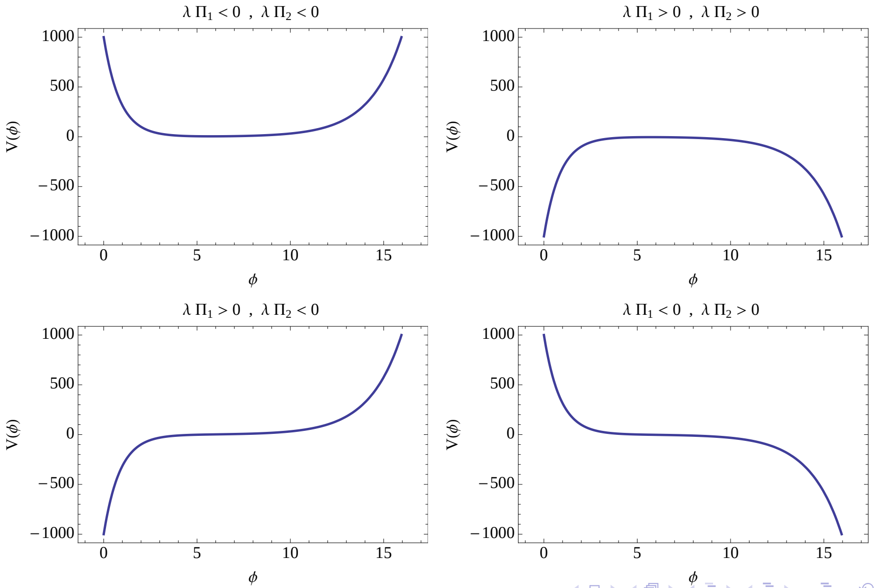
Non-trivial to find t^i as function of τ_i. Choose a geometry

$$\mathcal{V} = \alpha \left(\sqrt{\tau_1} \tau_2 - \gamma \tau_3^{3/2} \right)$$

$$V_{(1)} \simeq -g_s^2 \hat{\lambda} \frac{|W_0|^4}{\mathcal{V}^4} \left(\Pi_1 \frac{\mathcal{V}}{\tau_1} + \Pi_2 \lambda_1^{-1/2} \sqrt{\tau_1} \right)$$

$$V_{eff} = V^{LVS} - g_s^2 \hat{\lambda} \frac{|W_0|^4}{\langle \mathcal{V} \rangle^4} \left(\Pi_1 \langle \mathcal{V} \rangle e^{-2/\sqrt{3}\varphi} + \Pi_2 \lambda_1^{-1/2} e^{\varphi/\sqrt{3}} \right)$$

Possible Inflationary Potentials



String Loop Corrections

$$V_{eff} + \delta V_{(g_s)} \simeq V^{LVS} + V_{(1)} + \frac{g_s |W_0|^2}{\mathcal{V}^2} \left(g_s^2 \frac{(C_1^{KK})^2}{\tau_1^2} + 2 g_s^2 (\alpha C_2^{KK})^2 \frac{\tau_1}{\mathcal{V}^2} \right)$$

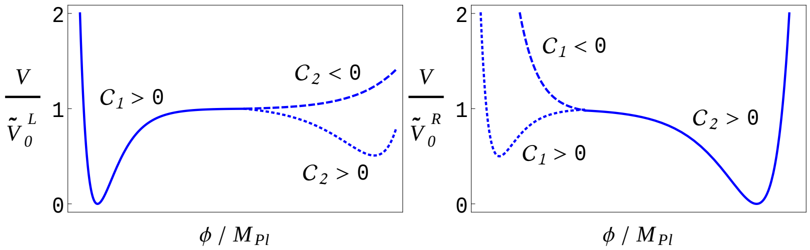
$$V = V_{\delta_{up}}^{LVS} + V_0 \left(-\mathcal{C}_1 e^{-2/\sqrt{3}\varphi} - \mathcal{C}_2 e^{\varphi/\sqrt{3}} + \mathcal{C}_1^{loop} e^{-4/\sqrt{3}\varphi} + \mathcal{C}_2^{loop} e^{2\sqrt{3}\varphi} \right)$$

where we have defined

$$V_0 = g_s^2 \frac{|W_0|^4}{\mathcal{V}^4}\,, \quad \mathcal{C}_1 = \hat{\lambda}\,\Pi_1 \mathcal{V}\,, \quad \mathcal{C}_2 = \hat{\lambda}\,\Pi_2 \lambda_1^{-1/2}\,,$$

$$\mathcal{C}_1^{loop} = \frac{\mathcal{V}^2}{|W_0|^2} g_s (C_1^{KK})^2 > 0\,, \quad \mathcal{C}_2^{loop} = \frac{2 g_s}{|W_0|^2} (\alpha C_2^{KK})^2 > 0$$

Inflationary Potentials & Observables



$$V_{inf}^L \sim V_0 \left(-\frac{\mathcal{C}_1}{\tau_1} + \frac{\mathcal{C}_1^{loop}}{\tau_1^2} \right) \qquad V_{inf}^R \sim V_0 \left(-\mathcal{C}_2 \sqrt{\tau_1} + \mathcal{C}_2^{loop} \tau_1 \right)$$

$$V_{inf}^L = \tilde{V}_0^L \left(1 - e^{-\kappa\phi} \right)^2 \qquad V_{inf}^R = \tilde{V}_0^R \left(1 - e^{\frac{\kappa}{2}\phi} \right)^2$$

	$n_s(50)$	$n_s(60)$	$r(50)$	$r(60)$
right	0.960	0.967	0.0077	0.0055
left	0.960	0.967	0.0043	0.0016

Second Order Observables

Inflation to the Right

$$V_{inf}^{R} \sim V_0 \left(-\frac{\mathcal{C}_1}{\tau_1} - \mathcal{C}_2 \sqrt{\tau_1} + \mathcal{C}_2^{loop} \tau_1 \right) \quad \Rightarrow \quad V_0^R \left(1 - 2 e^{\frac{\kappa}{2}\phi} + \varepsilon^2 e^{-\kappa\phi} \right)$$

$$n_s = 1 - \frac{2}{N} - 3\,\varepsilon^2 \kappa^4 N + \frac{\varepsilon^2 \kappa^6}{2} N^2 + \dots$$

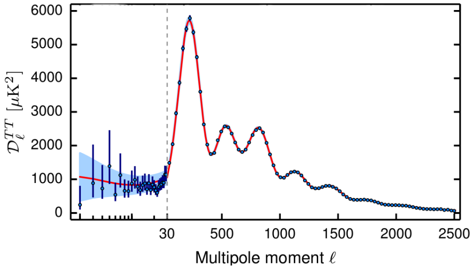
$$\varepsilon^2 \sim \lambda^{-3}\, \mathcal{V}\, g_s^{15/2}\, \Pi_1\, \Pi_2^{-4} (C_2^{KK})^6 \lesssim 2.4 \times 10^{-6}$$

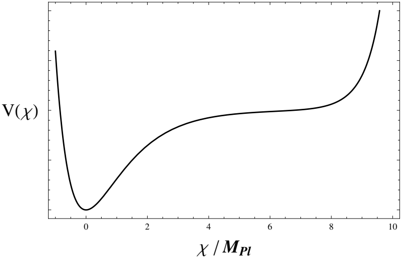
Power-loss: $n_s = d \ln P / d \ln k = P^{-1} dP/dN$ and hence

$$\left. \frac{\Delta P(\delta n_s)}{P} \right|_{N+\Delta N}^{N} \sim \delta n_s \, \Delta N \quad \rightarrow \quad \mathbf{4\%}$$

Hints for power suppression at low ℓ

$$\Delta_s^2(k) \sim (k/k^*)^{n_s-1}$$





$$V_{inf} = V_0 \left(1 - e^{-\sqrt{\frac{2}{3}}\chi}\right)^2 + \varepsilon\, e^{\sqrt{\frac{2}{3}}\chi} \quad \Longleftrightarrow \quad f(R) = R + \alpha R^2 + \ldots ?$$

An exact $f(R)$ - Toy Model [1411.6010]

Pedro, Westphal, BJB

JCAP03 (2015) 029

Consider

$$V(\chi) = V_0 \left[\left(1 - e^{-\sqrt{2/3}\chi} \right)^2 + \varepsilon\, e^{\sqrt{2/3}\chi} \right] - \varepsilon\, V_0$$

to obtain exact

$$f(R) = \frac{\varepsilon - 1}{3\varepsilon} R + 4\varepsilon V_0 \left[\frac{(1-\varepsilon)^2}{9\varepsilon^2} + \frac{2}{3\varepsilon} + \frac{R}{6\varepsilon V_0} \right]^{3/2} + K(\varepsilon, V_0)$$

Taylor expanding for $\varepsilon \to 0$ recovers Starobinsky coefficients, i.e.

$$\lim_{\varepsilon \to 0} c_2 = \frac{1}{8\, V_0}$$

$\varepsilon \lesssim \mathcal{O}\left(10^{-4}\right)$ for $n_s \sim 0.97$

A non-zero Λ for free?

It is easy to show that when $\boldsymbol{V(0) = 0}$

$$f(R|_{\boldsymbol{\chi=0}}) \; = \; R|_{\boldsymbol{\chi=0}} \; = \; 2\,\varepsilon\,V_0$$

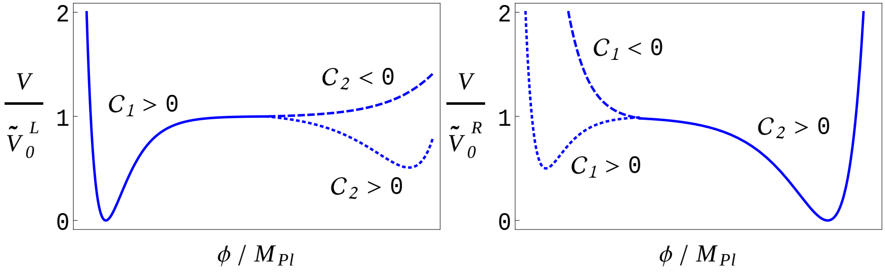
Checklist for $f(R)$

$$f(0) = 0\,, \quad f(R)\,,\, f'(R) > 0 \quad \forall\, R > 0$$

At first attempt, **not possible** to have both

$$f(R|_{\boldsymbol{\chi=0}})\,,\; f(0) = 0$$

Conclusions



Possible to obtain above potentials from recently computed higher derivative $(\alpha')^3$-corrections in combination with string loop effects.

Corresponding $f(R)$ - dual is to leading order R^n with $1 < n < 2$.

Thank you very much for your attention!