Stability of Inflationary Dynamics in $F(\mathcal{R})$ Supergravity

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Based on arXiv:1309.7494 [version 2 will appear]

with Sergei V. Ketov (University of Oslo, Tokyo Metropolitan University, Kavli IPMU)

Supergravity Actions

Minimal action of Supergravity

$$S = -\int d^4x\, d^2\Theta\, \mathcal{E}\, 3\mathcal{R} + \text{h. c.}$$

Holomorphic action of Supergravity

$$S = \int d^4x\, d^2\Theta\, \mathcal{E}\, F(\mathcal{R}) + \text{h. c.}$$

Generic action of Supergravity

$$S = \int d^4x\, d^4\Theta\, E\, N(\mathcal{R}, \bar{\mathcal{R}}) + \int d^4x\, d^2\Theta\, \mathcal{E}\, F(\mathcal{R}) + \text{h. c.}$$

No R^2 inflation in $F(\mathcal{R})$ supergravity

- Correct bosonic Lagrangian

  S. V. Ketov and T. Terada, JHEP 1307 (2013) 127, arXiv:1304.4319 [hep-th]

  S. Ferrara, R. Kallosh, and A. V. Proeyen, arXiv:1309.4052 [hep-th]

- Argument using scale invariance in the equivalent no-scale supergravity

  J. Ellis, D. V. Nanopoulos, and K. A. Olive, JCAP 1310 (2013) 009 , arXiv:1307.3537 [hep-th]

- Argument using scale invariance in the original $F(\mathcal{R})$ theory

  S. V. Ketov and T. Terada, arXiv:1309.7494 [hep-th]

- Investigation of the scalar potential for $F(\mathcal{R})\sim\mathcal{R}+\mathcal{R}^n$

  S. Ferrara, A. Kehagias, and M. Porrati, arXiv:1310.0399 [hep-th]

Generic Supergravity Actions and R^2 Inflation

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Planck collaboration, arXiv:1303.5082

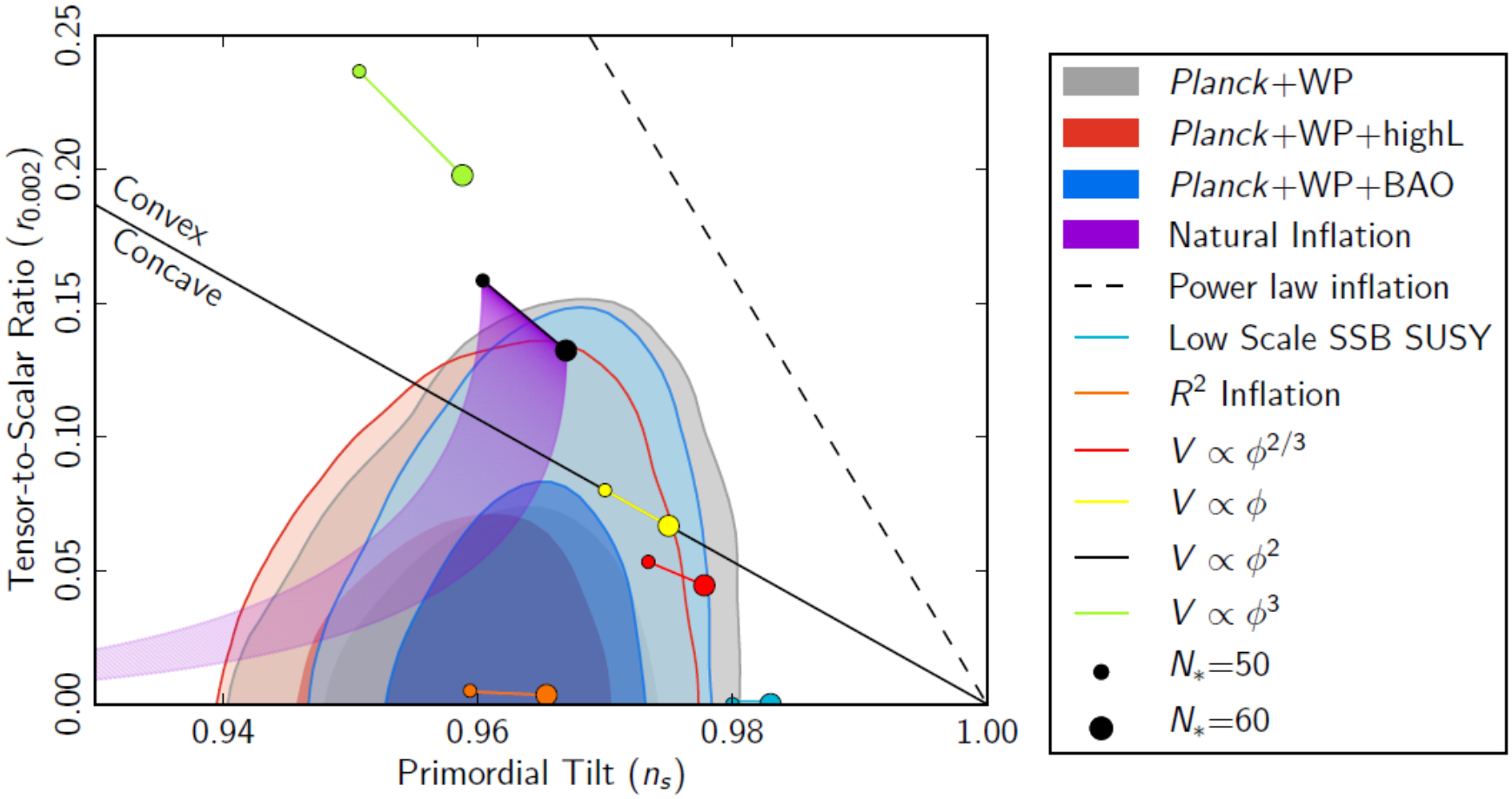


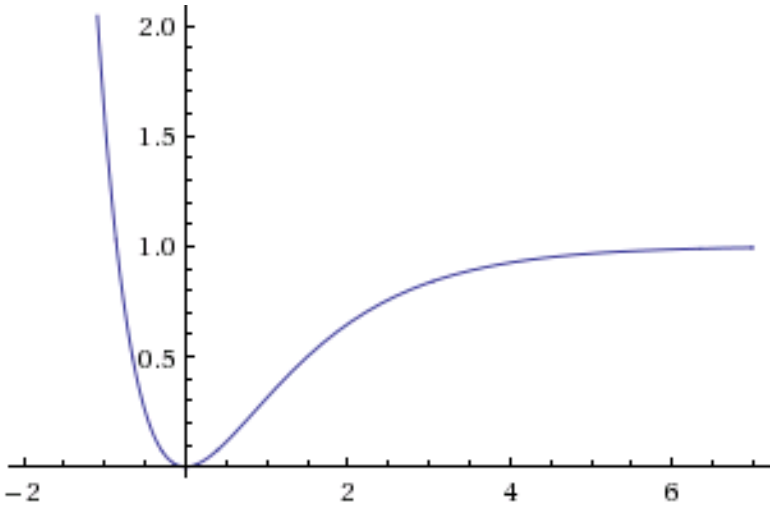
Fig. 1. Marginalized joint 68% and 95% CL regions for n_s and $r_{0.002}$ from *Planck* in combination with other data sets compared to the theoretical predictions of selected inflationary models.

Starobinsky inflation

$f(R)$ gravity ⟺ Classically Equivalent ⟺ Scalar-tensor theory

$$e^{-1}\mathcal{L} = -\frac{1}{2}R + \frac{R^2}{12M^2}$$

$$e^{-1}\mathcal{L} = -\frac{1}{2}R - \frac{1}{2}\partial^\mu\phi\partial_\mu\phi - \frac{3M^2}{4}\left(1 - e^{-\sqrt{2/3}\phi}\right)^2$$



Supergravity multiplet

Old-minimal multiplet

graviton $e_m{}^a$, gravitino $\psi_m{}^\alpha$, complex scalar X, real vector b^a.

	On-Shell Degrees Of Freedom
Minimal Action of Supergravity $S = -\int d^4x\, d^2\Theta\, \mathcal{E}\, 3\mathcal{R} + \text{h. c.}$	**2** bosons **+2** fermions
Holomorphic Action of Supergravity $S = \int d^4x\, d^2\Theta\, \mathcal{E}\, F(\mathcal{R}) + \text{h. c.}$	**4** bosons **+4** fermions
Generic Action of Supergravity $S = \int d^4x\, d^4\Theta\, E\, N(\mathcal{R}, \bar{\mathcal{R}}) + \int d^4x\, d^2\Theta\, \mathcal{E}\, F(\mathcal{R}) + \text{h. c.}$	**6** bosons **+6** fermions

Bosonic Lagrangian

$$
\begin{aligned}
e^{-1}\mathcal{L} = {} & \frac{1}{12}\left(2N + 2N_X X + 2N_{\bar{X}} X^* + F_X + \bar{F}_{\bar{X}} - 8N_{X\bar{X}} X^* X - \frac{1}{9} N_{X\bar{X}} b^a b_a\right) R \\
& + \frac{1}{144} N_{X\bar{X}} R^2 - N_{X\bar{X}} \partial_m X^* \partial^m X + \frac{1}{36} N_{X\bar{X}} \left(\mathscr{D}_m b^m\right)^2 \\
& - \frac{i}{3} b^m \left(N_X \partial_m X - N_{\bar{X}} \partial_m X^*\right) + \frac{i}{6} \mathscr{D}_m b^m \left(2N_X X - 2N_{\bar{X}} X^* + F_X - \bar{F}_{\bar{X}}\right) \\
& - \frac{1}{18}\left(2N + 2N_X X + 2N_{\bar{X}} X^* + F_X + \bar{F}_{\bar{X}} - 8N_{X\bar{X}} X^* X - \frac{1}{18} N_{X\bar{X}} b^b b_b\right) b^a b_a \\
& + 16 N_{X\bar{X}} (X^* X)^2 + 6F X^* + 6\bar{F} X - 4X^* X \left(-N + 2N_X X + 2N_{\bar{X}} X^* + F_X + \bar{F}_{\bar{X}}\right)
\end{aligned}
$$

$$
S = \int d^4x \, d^4\Theta \, E \, N(\mathcal{R}, \bar{\mathcal{R}}) + \int d^4x \, d^2\Theta \, \mathcal{E} \, F(\mathcal{R}) + \text{h. c.}
$$

Non-minimal Couplings

$-R + R^2$ Starobinsky inflation

$$e^{-1}\mathcal{L} = \frac{1}{12}\left(2N + 2N_X X + 2N_{\bar{X}} X^* + F_X + \bar{F}_{\bar{X}} - 8N_{X\bar{X}} X^* X - \frac{1}{9} N_{X\bar{X}} b^a b_a\right) R$$
$$+ \frac{1}{144} N_{X\bar{X}} R^2 - N_{X\bar{X}} \partial_m X^* \partial^m X + \frac{1}{36} N_{X\bar{X}} \left(\mathscr{D}_m b^m\right)^2$$
$$- \frac{i}{3} b^m \left(N_X \partial_m X - N_{\bar{X}} \partial_m X^*\right) + \frac{i}{6} \mathscr{D}_m b^m \left(2N_X X - 2N_{\bar{X}} X^* + F_X - \bar{F}_{\bar{X}}\right)$$
$$- \frac{1}{18}\left(2N + 2N_X X + 2N_{\bar{X}} X^* + F_X + \bar{F}_{\bar{X}} - 8N_{X\bar{X}} X^* X - \frac{1}{18} N_{X\bar{X}} b^b b_b\right) b^a b_a$$
$$+ 16 N_{X\bar{X}} (X^* X)^2 + 6F X^* + 6\bar{F} X - 4X^* X \left(-N + 2N_X X + 2N_{\bar{X}} X^* + F_X + \bar{F}_{\bar{X}}\right)$$

Higgs inflation $-\xi H^2 R - \lambda H^4$

Vacuum conditions

M : inflaton mass

$$e^{-1}\mathcal{L} = \frac{1}{12}\left(2N + 2N_X X + 2N_{\bar{X}} X^* + F_X + \bar{F}_{\bar{X}} - 8N_{X\bar{X}} X^* X - \frac{1}{9} N_{X\bar{X}} b^a b_a\right) R$$

$$\frac{1}{12M^2} = + \frac{1}{144} N_{X\bar{X}} R^2 - N_{X\bar{X}} \partial_m X^* \partial^m X + \frac{1}{36} N_{X\bar{X}} \left(\mathscr{D}_m b^m\right)^2$$
$$- \frac{i}{3} b^m \left(N_X \partial_m X - N_{\bar{X}} \partial_m X^*\right) + \frac{i}{6} \mathscr{D}_m b^m \left(2N_X X - 2N_{\bar{X}} X^* + F_X - \bar{F}_{\bar{X}}\right)$$
$$- \frac{1}{18}\left(2N + 2N_X X + 2N_{\bar{X}} X^* + F_X + \bar{F}_{\bar{X}} - 8N_{X\bar{X}} X^* X - \frac{1}{18} N_{X\bar{X}} b^b b_b\right) b^a b_a$$
$$+ 16 N_{X\bar{X}} (X^* X)^2 + 6FX^* + 6\bar{F}X - 4X^* X \left(-N + 2N_X X + 2N_{\bar{X}} X^* + F_X + \bar{F}_{\bar{X}}\right)$$

$= -6$

$= 0$

Stabilizing the scalar potential

$$N \sim n_p (\mathcal{R}\bar{\mathcal{R}})^p$$

$$\Delta \mathcal{L}_{kin} = -n_p p^2 (X^* X)^{p-1} \partial^m X^* \partial_m X$$

$$\Delta V = -4 n_p (2p-1)^2 (X^* X)^{p+1}$$

The potential UNBOUNDED BELOW or the WRONG SIGN of the kinetic term.

Conclusion & Prospects

There are

Rich structures

in Generic Higher-order Supergravity.

- Hybrid of Starobinsky and Higgs inflation?
- To incorporate inflation and dark energy?

- Matter-coupling and reheating of the Universe?

Conclusion & Prospects

There are Rich structures in General Higher-order Supergravity.

Thank you!

謝謝

For more information, see **arXiv:1309.7494**.
(version 2 will appear soon.)

- Hybrid of Starobinsky and Higgs inflation?
- To incorporate inflation and dark energy?

- Matter-coupling and reheating of the Universe?