Multi-Dimensional Starobinsky Influm in Maximal Gauged Supergavity

Hideo Kodama

Cosmophysics Group.Theory Center, KEK

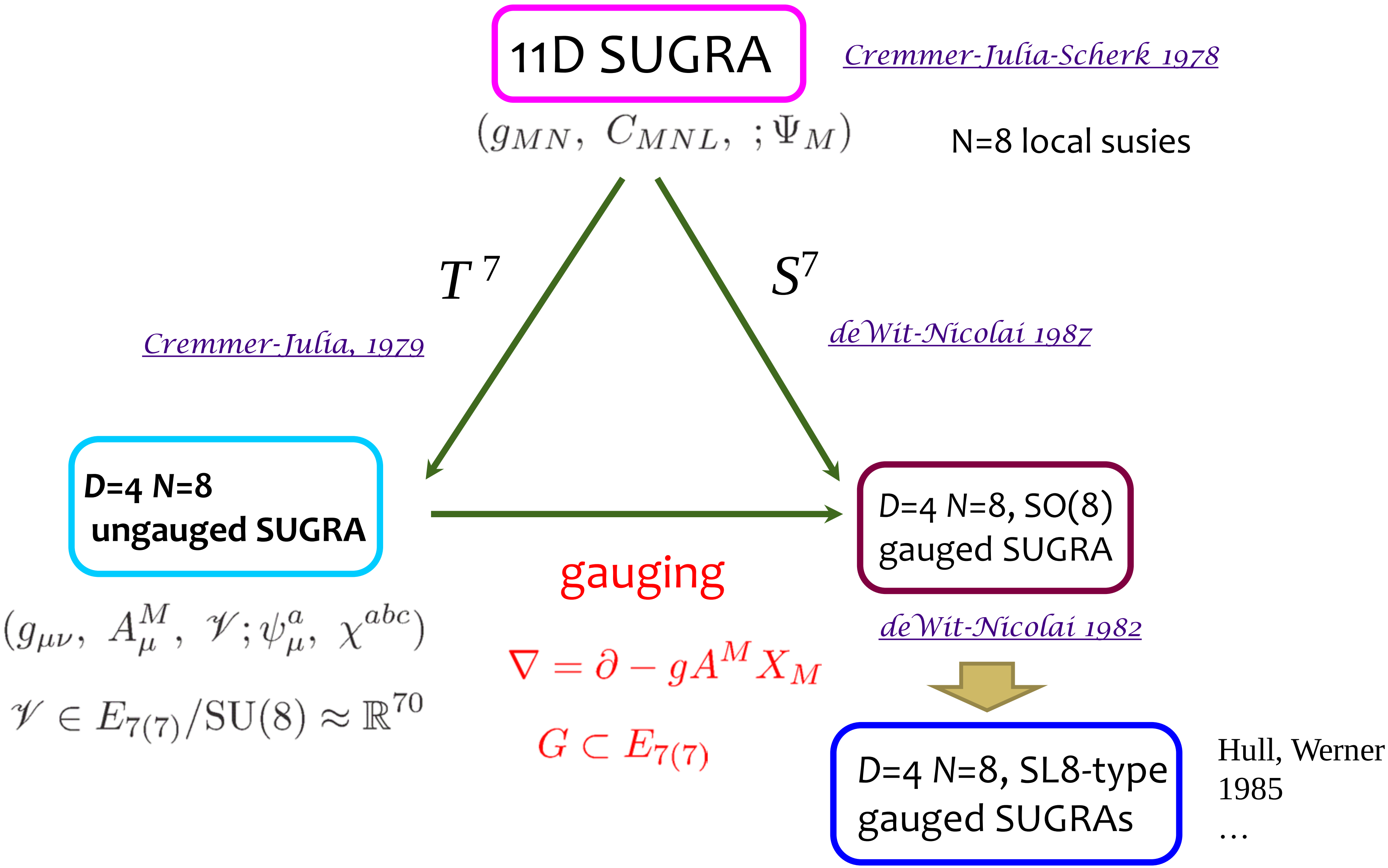
Based on the work in collaboration with Masato Nozawa

- HK, M Nozawa: arXiv: 1502.01378
- HK, M Nozawa: JHEP1301(2013)045 [arXiv:1210.4238]

2015/02/20 @ B-mode Cosmology

Introduction

4D Maximal Supergravity



SL8-type Vacua in Gauged Maximal Sugra

All special SL8-type dyonic gaugings are classified:

[HK, M Nozawa (2013); G Dall'Agata, G Inverso (2012)]

$$(A^M) = (A_e^{[ab]}, A_{m[cd]}) \mapsto A^M X_M = -\begin{pmatrix} (\theta A_e + A_m\xi)\wedge 1 & 0 \\ 0 & (A_e\theta + \xi A_m)\wedge 1 \end{pmatrix}$$

$$\theta, \xi \in \mathfrak{sl}_s(8,\mathbb{R}); \quad \theta\xi = cI_8$$

θξ=1 : $\mathrm{SO}(8), \quad \mathrm{SO}(7,1), \quad \mathrm{SO}(6,2), \quad \mathrm{SO}(5,3), \quad \mathrm{SO}(4,4)$

θξ=0 : $\mathrm{SO}(4)\times\mathrm{SO}(2,2)\ltimes\mathbb{R}^{16}, \quad \mathrm{SO}(6)\times\mathrm{SO}(1,1)\ltimes\mathbb{R}^{12},$
$\mathrm{SO}(2)^2\ltimes\mathbb{R}^{20}, \quad \mathrm{SO}(7)\ltimes\mathbb{R}^{7}$

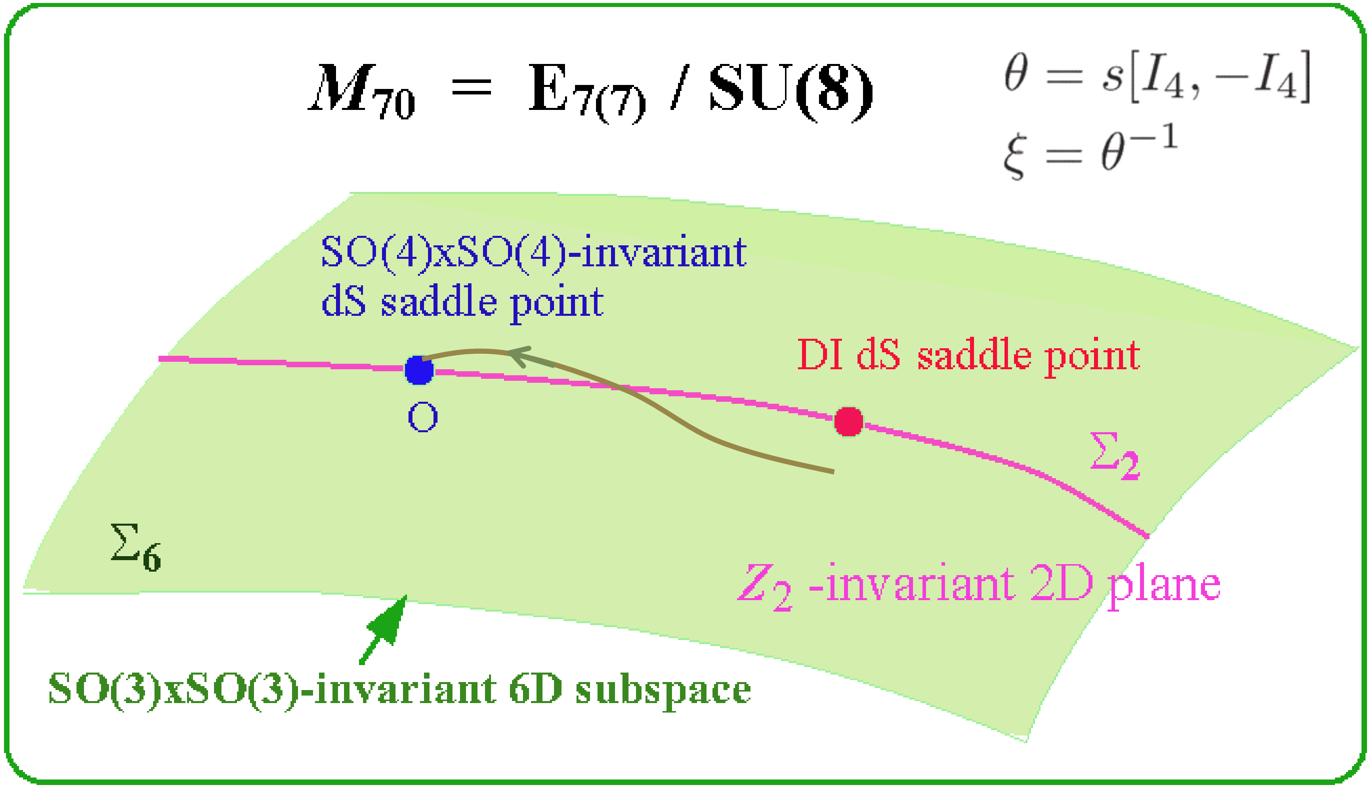
- ◆(unstable) dS vacua at the origin only for SO(4,4) and SO(5,3) .
- ◆There exists a new deformation parameter s for all semi-simple gaugings in addition to the gauge coupling constant g.

[cf. SO(8) gauging: G Dall'Agata, G Inverso, M Trigiante (2012)]

dS vacua in the SO(4,4) and SO(5,3) gaugings.

- New vacua in SO(4,4) gaugings avoiding the η-problem.

  [G Dall'Agata, G Inverso (2013)]



Can realistic inflation be realised around the new DI saddle point in the SO(4,4) gauging ?

The full potential in the SO(3)xSO(3)-invariant 6D sector for SO(4,4) &SO(5,3) gaugings. No new vacuum. [HK, M Nozawa (2015)]

Note: The potential has no lower bound in gauged maximal supergravities. So, we cannot discuss reheating and the post-inflation evolution of the universe in this framework.

Cosmology in the 6D sector

System Description

- Fundamental variables
  - spacetime metric: $a(t) = \exp(\alpha(t))$:

$$ds^2 = -dt^2 + a(t)^2 d\boldsymbol{x}^2$$

  - scalar fields: $(x, y, z, \theta_1, \theta_2, \theta_3) \leftarrow (x_1, y_1, x_2, y_2, w_1, w_2)$

$$x = x_2(t), \quad y = \frac{1}{2}(\mu_2(t) - \mu_3(t)), \quad z = \frac{1}{2}(\mu_2(t) + \mu_3(t))$$

  - SO(3) Gauge fields: $\psi_1(t)$, $\psi_2(t)$

$$A^{(1)I} = a(t)\psi_1(t)dx^I, \quad A^{(2)I} = a(t)\psi_2(t)dx^I$$

$$F^{(\epsilon)I} = a(t)\left(\dot{\psi}_\epsilon + \dot{\alpha}\psi_\epsilon\right) dt \wedge dx^I + \frac{g}{2}a(t)^2\psi_\epsilon(t)^2\epsilon_{IJK}dx^J \wedge dx^K$$

Basic Equations

- Action

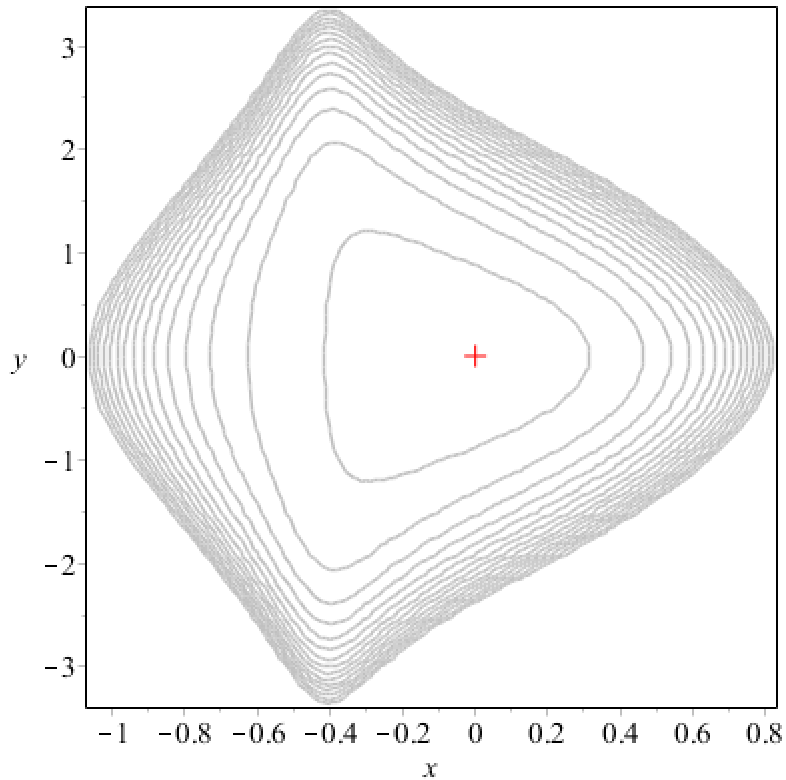
$$
\begin{aligned}
L &= L_G + L_K - a^3 N V + L_G; \\
\kappa^2 L_G &= -\frac{3a^3}{N}\dot{\alpha}^2, \\
\kappa^2 L_K &= \frac{3a^3}{N}\Big[3\dot{x}_2^2 + \frac{1}{2}\sum_i \dot{\mu}_i^2 \\
&\quad + \sinh^2(\mu_2-\mu_3)\dot{\chi}_1^2 + \sinh^2(\mu_1-\mu_3)\dot{\chi}_2^2 + \sinh^2(\mu_1-\mu_2)\dot{\chi}_3^2\Big]. \\
\kappa^2 L_F &= a^3 \sum_\epsilon \left[\frac{3}{2}\mathrm{Im}\left(-\mathcal{N}_\epsilon\right)\left\{\frac{1}{N}\left(\dot{\psi}_\epsilon + \dot{\alpha}\psi_\epsilon\right)^2 - g^2 N \psi_\epsilon^4\right\}\right. \\
&\qquad \left. + \frac{3g}{2} N \mathrm{Re}\left(\mathcal{N}_\epsilon\right)\psi_\epsilon^2(\dot{\psi}_\epsilon + \dot{\alpha}\epsilon)\right].
\end{aligned}
$$

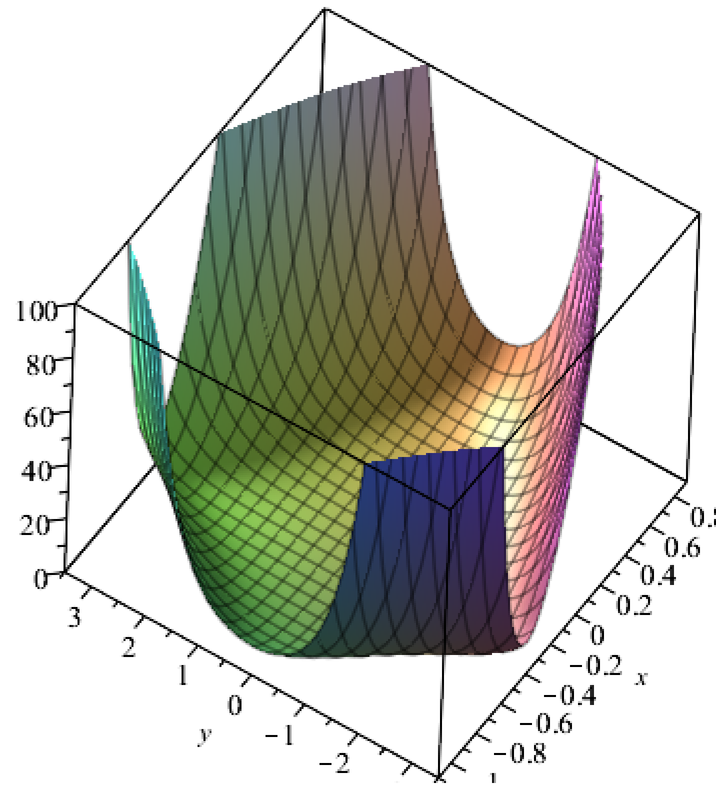
$(\mu_1 + \mu_2 + \mu_3 = 0)$

Z_2-invariant 2D sector : (x_2, y_2)

- **Subcritical case:** $(\sqrt{2}-1)^{1/2} < s < (\sqrt{2}+1)^{1/2}.$

  Unique dS vacuum at (x,y)=(0,0)

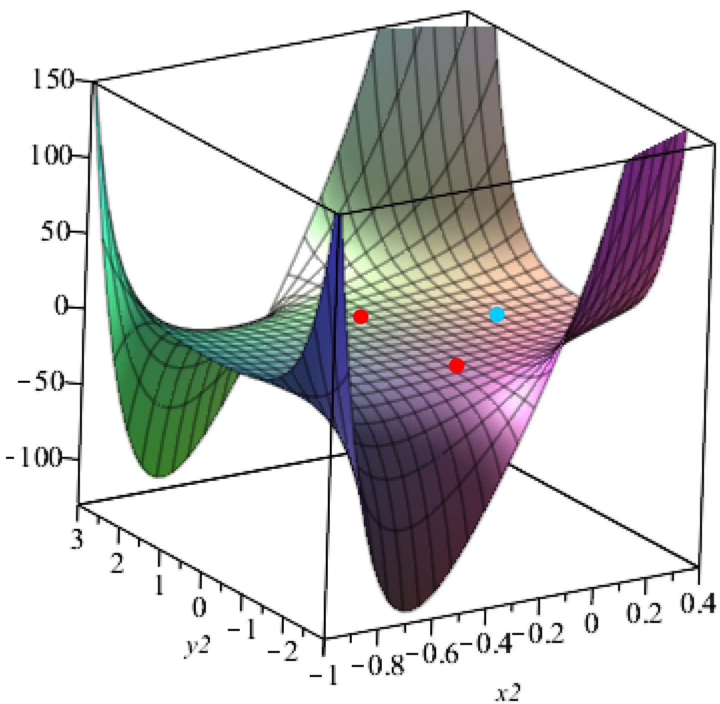


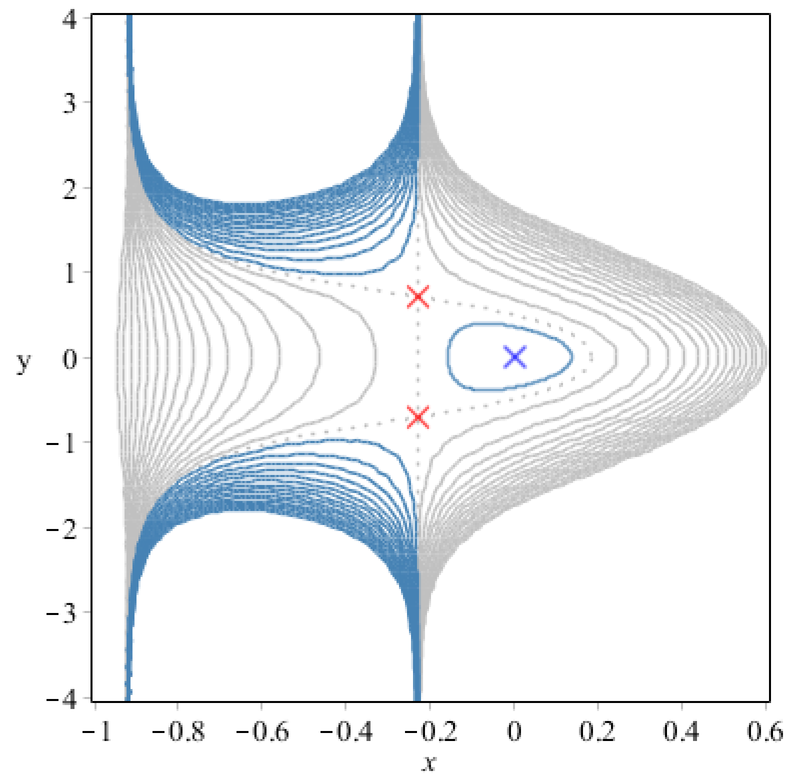


s=1.5

- Supercritial case: $s < (\sqrt{2}-1)^{1/2}, \quad \text{or} \quad s > (\sqrt{2}+1)^{1/2}.$

Two new dS vacua at $(x_*, +y_*)$ and $(x_*, -y_*)$

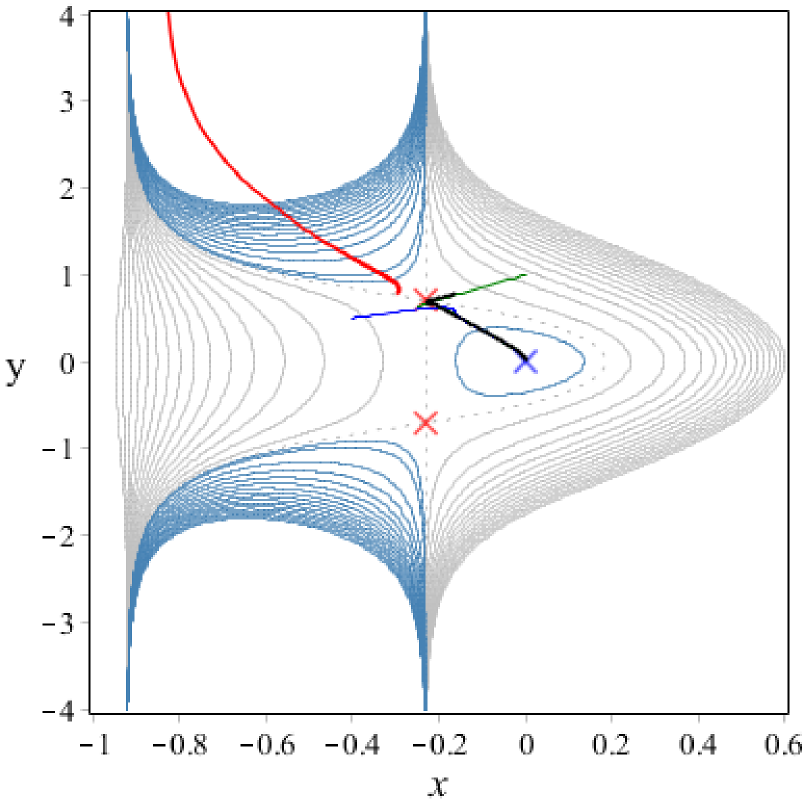


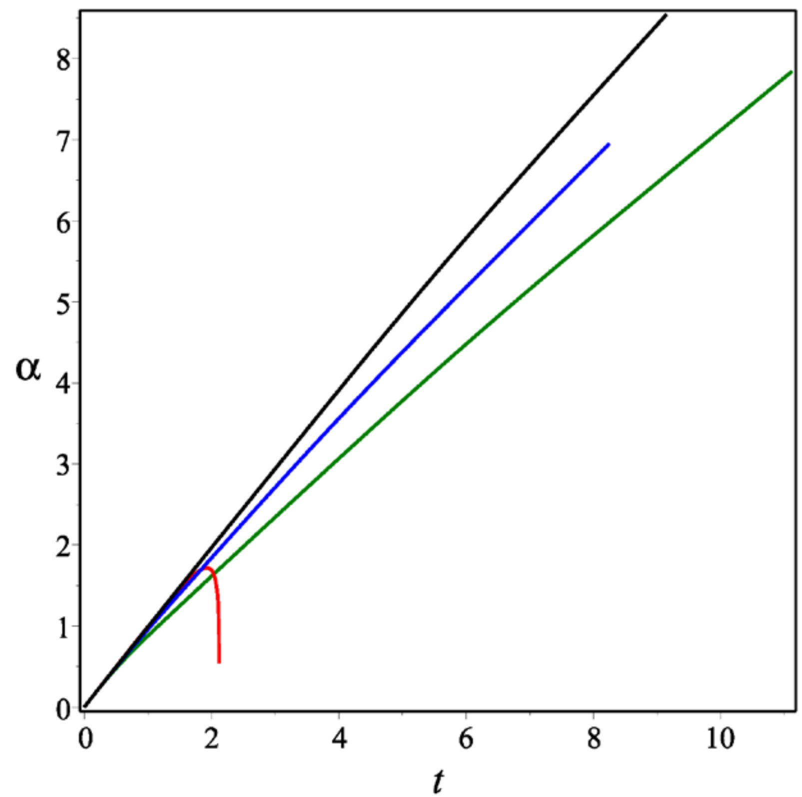


s=2

Trajectories on the Z2-inv plane

s=2

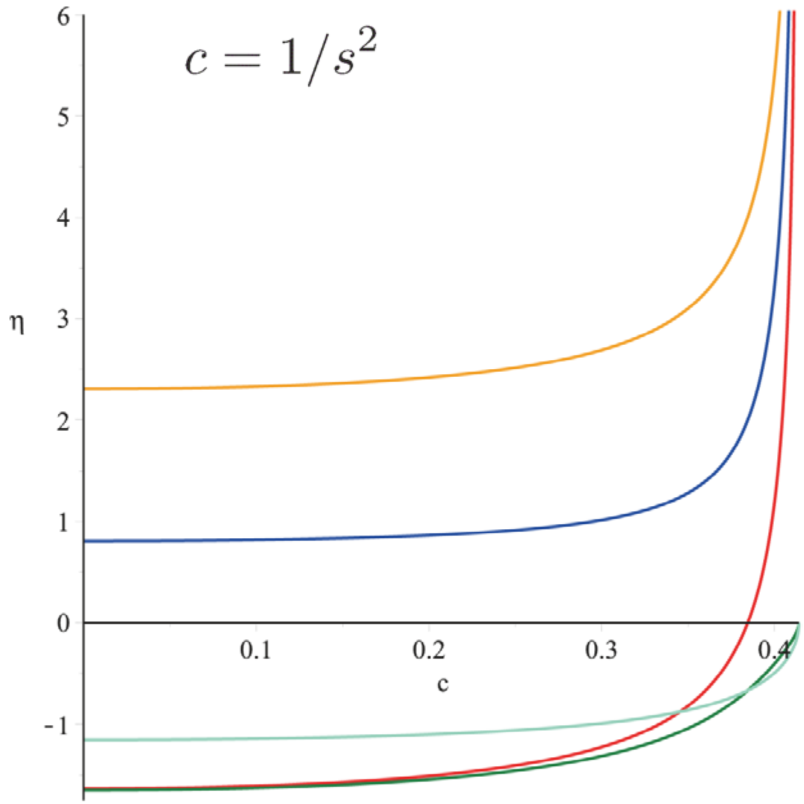


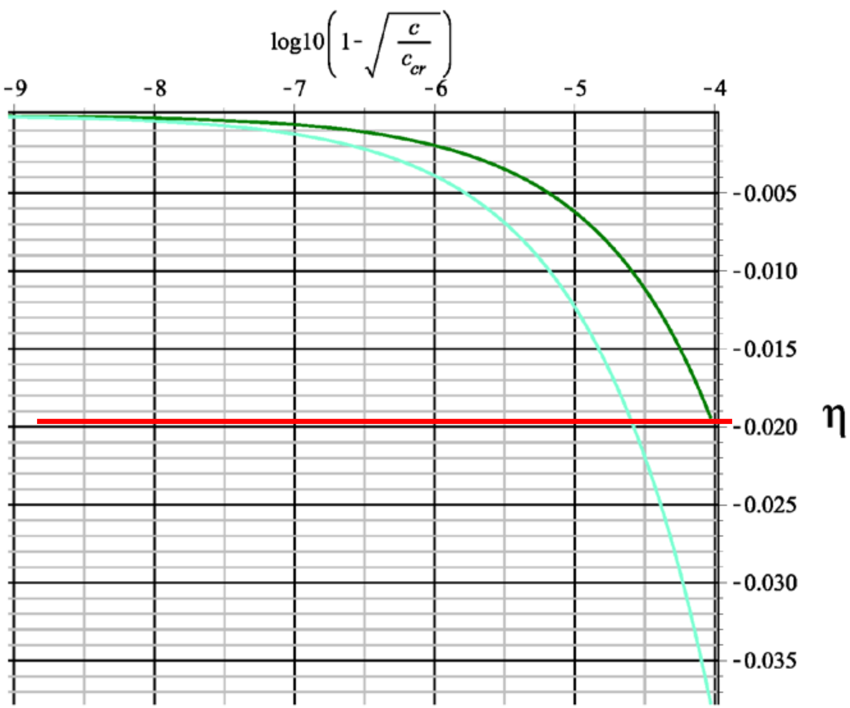


The η matrix and η parameter

The minimum eigenvalue of the eta matrix determines the slow-roll trajectory.

$$\boldsymbol{\eta} = (\eta_{ab}) : \quad \eta_{ab} = \frac{1}{V} e_a^\alpha e_b^\beta D_\alpha D_\beta V$$



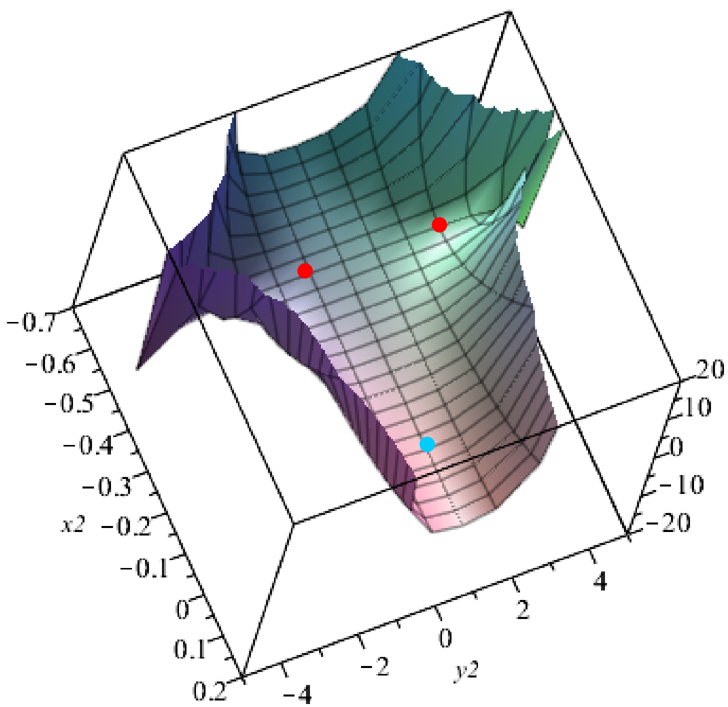


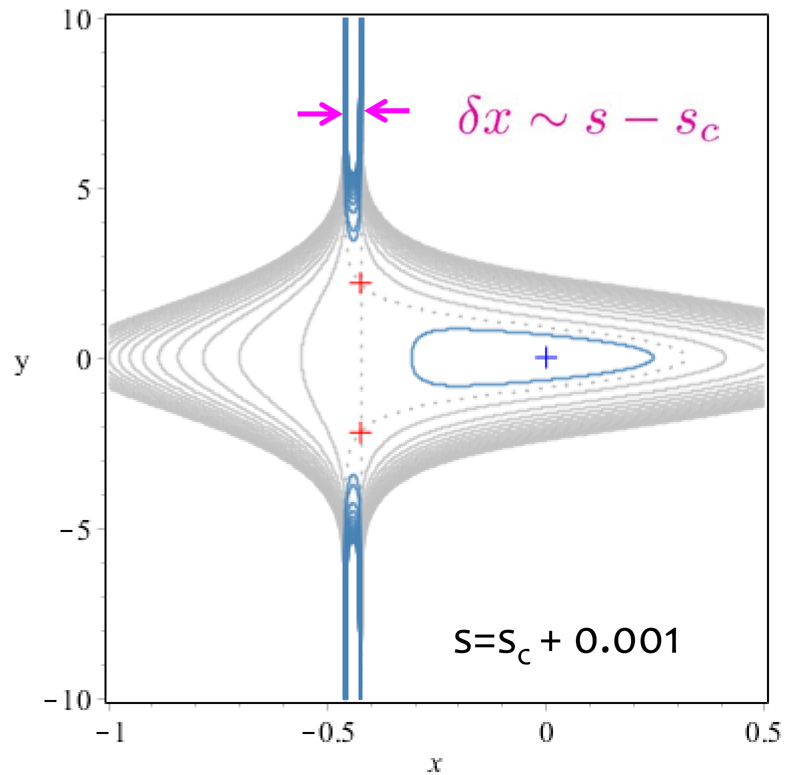
Critical Limit

- As s approaches the critical value, the DI saddle point runs away to infinity keeping the potential height finite.

$$s \to \sqrt{1+\sqrt{2}}: \quad (x_*, y_*) \to (-\tfrac{1}{2}\log(1+\sqrt{2}), \infty), \quad V_* \to 3g^2/2$$

- At the same time, the waterfall region becomes narrower and narrower.



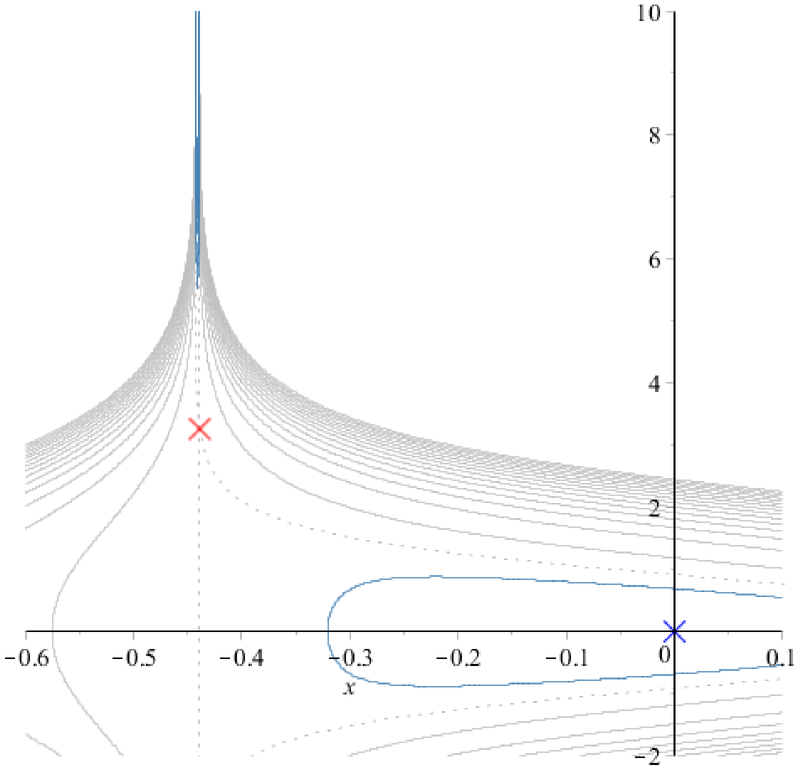


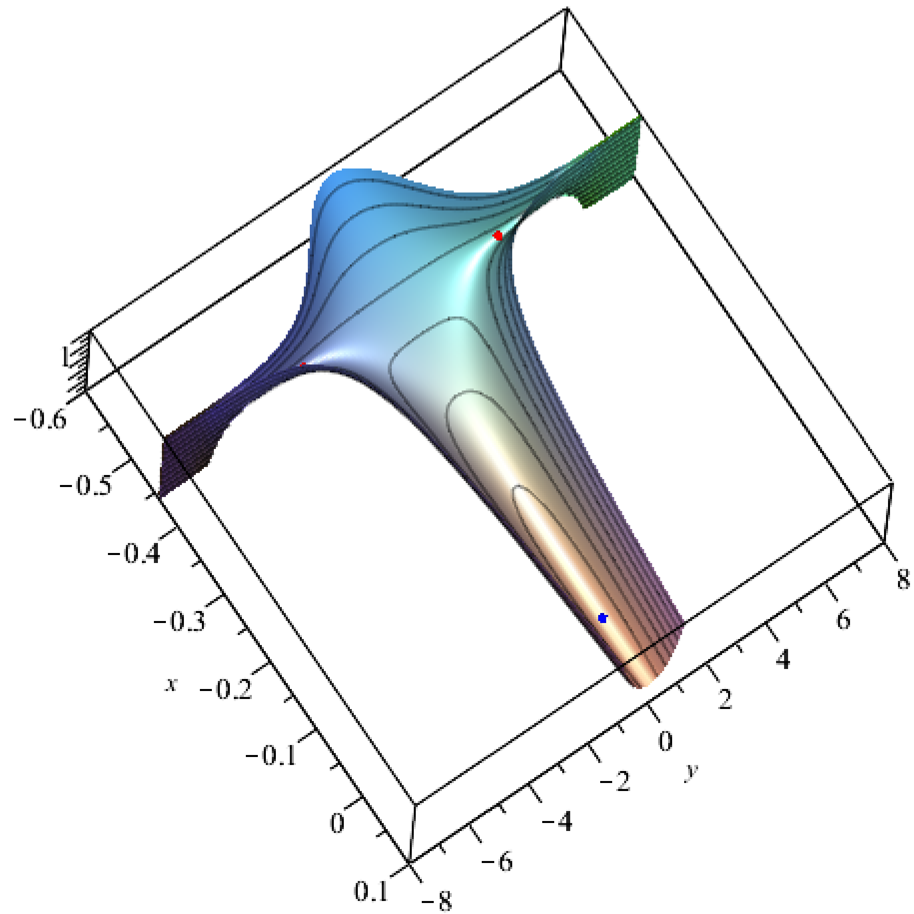
$s = s_c + 1.4e\text{-}5$: On Σ_2

DI Saddle Point:

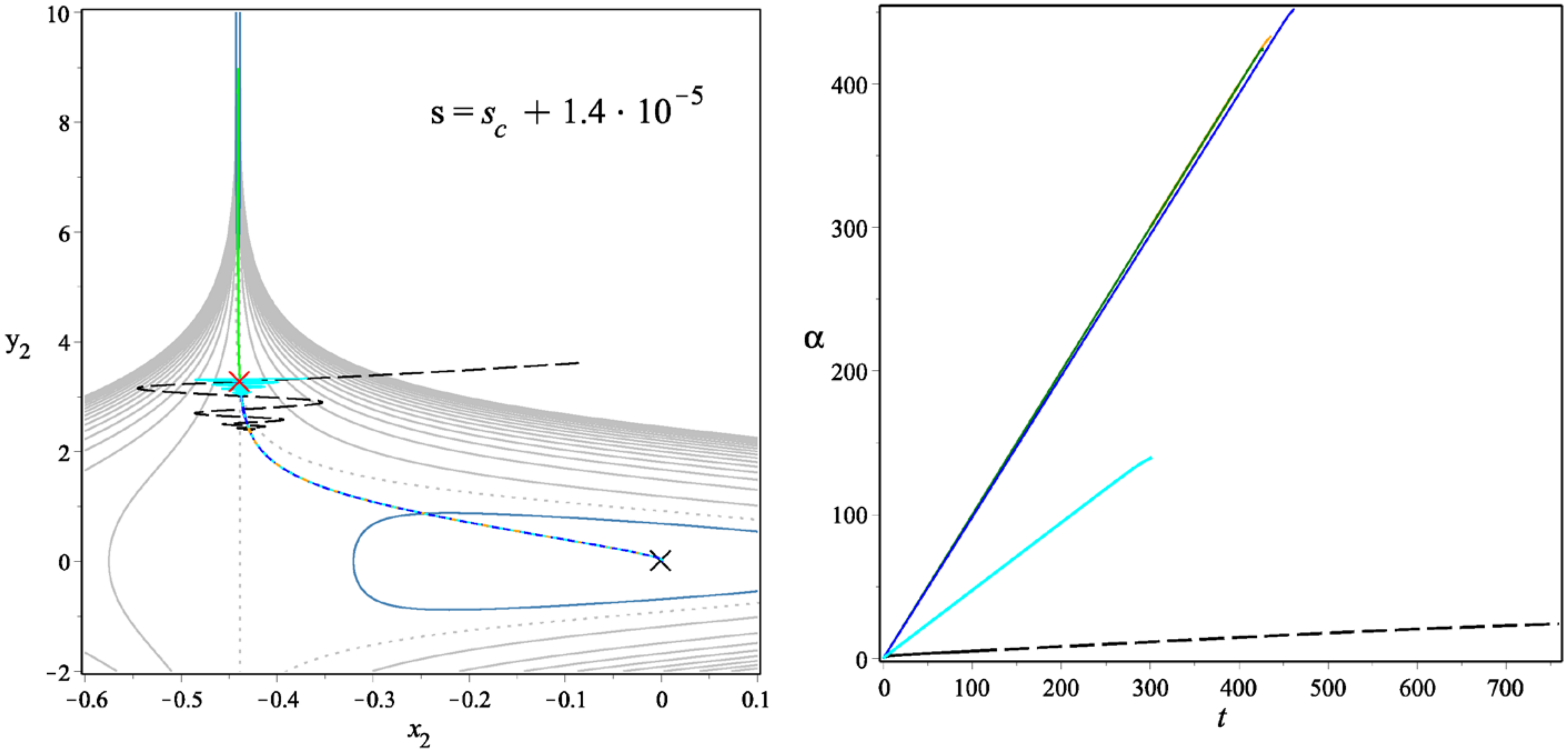
$$(x_*, y_*) = (-0.44, \pm 3.26.), \quad H_* = 0.705g$$

$$\text{The } \eta \text{ parameter} : \eta_* = [\mathbf{-0.01168}, 228; \; -0.005891, 226; \; 168; \; 0]$$





- For any initial condition, after initial oscillations, all trajectories settle down to one of the two attractor slow roll trajectories.
- If the initial point is within $O(m_{pl})$ from the DI saddle point, sufficient inflation is realised.

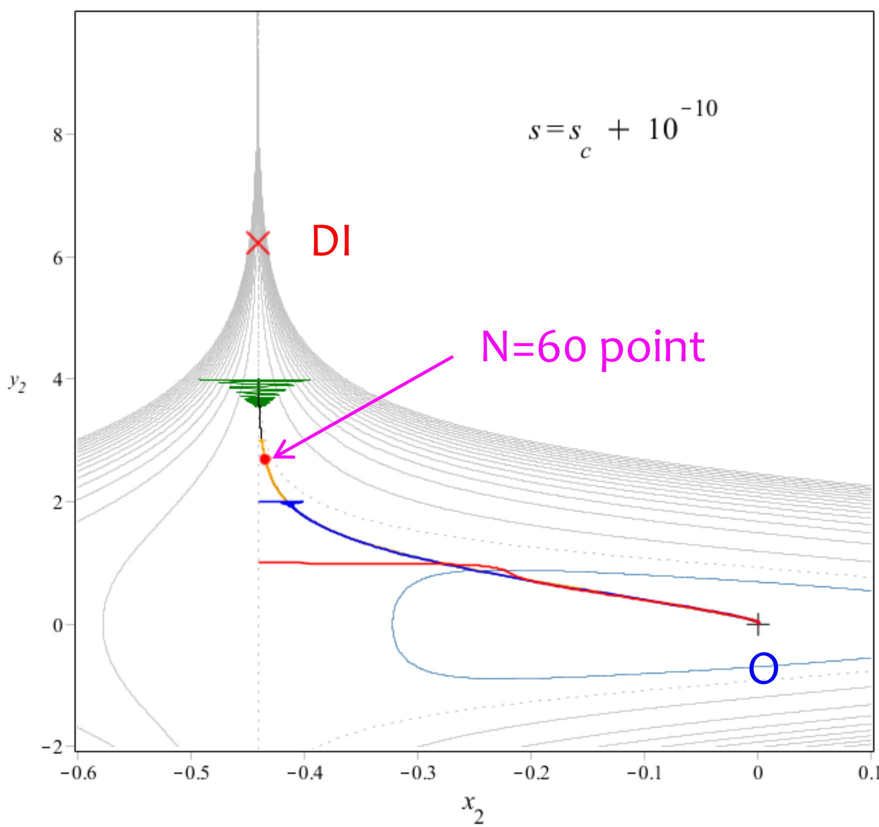


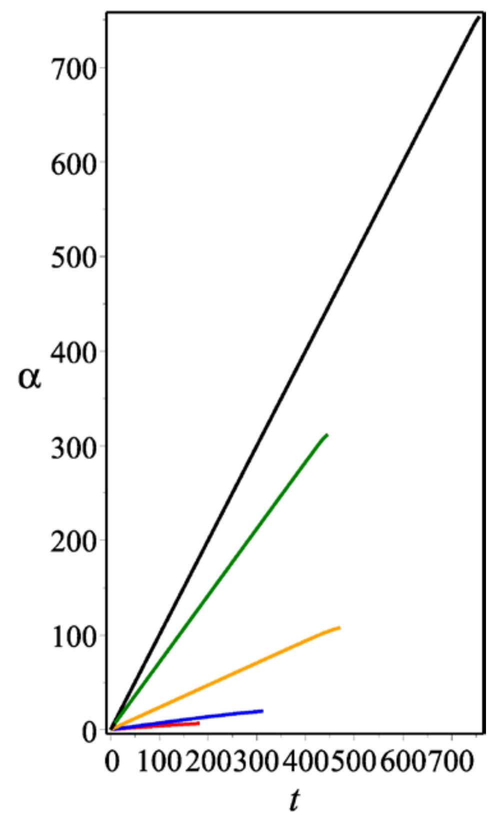
$s=s_c$ +1e-10: On Σ_2

DI Saddle Point: $(x_*, y_*) = (-0.440, \pm 6.22), \quad H_* = 0.707g$

The η parameter : $\eta_* = [\mathbf{-3.115 \cdot 10^{-5}}, 8.44 \cdot 10^4; \cdots]$

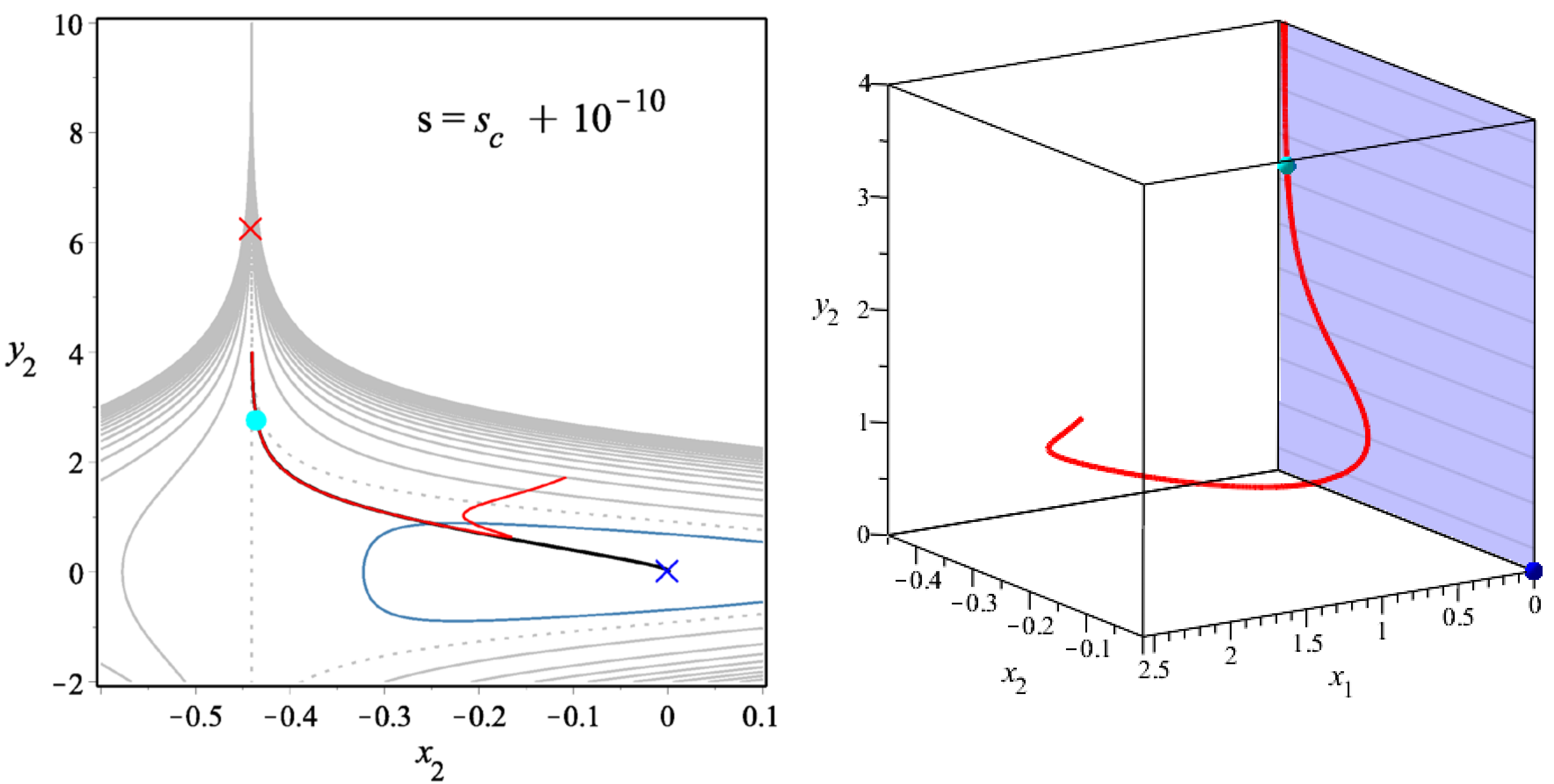
- If $y_2 > 3$ and V =O(V_*) initially, sufficient inflation is realised.





Off Σ_2 Trajectories

- If the initial offset from Σ_2 is less than $10^4\, H_*(g=4\times 10^{-6})$, sufficient inflation is realised, although the final stage of inflation is sensitive to the offset.



Observational predictions

- Spectral index of the scalar perturbation:

When a sufficient inflation is realised and s is close to s_c, n_s is miraculously within the 1 σ range of Planck result:

$$n_s = 0.958 \sim 0.967 \qquad \text{Cf. Planck2015: } n_s = 0.9645 \pm 0.0049$$

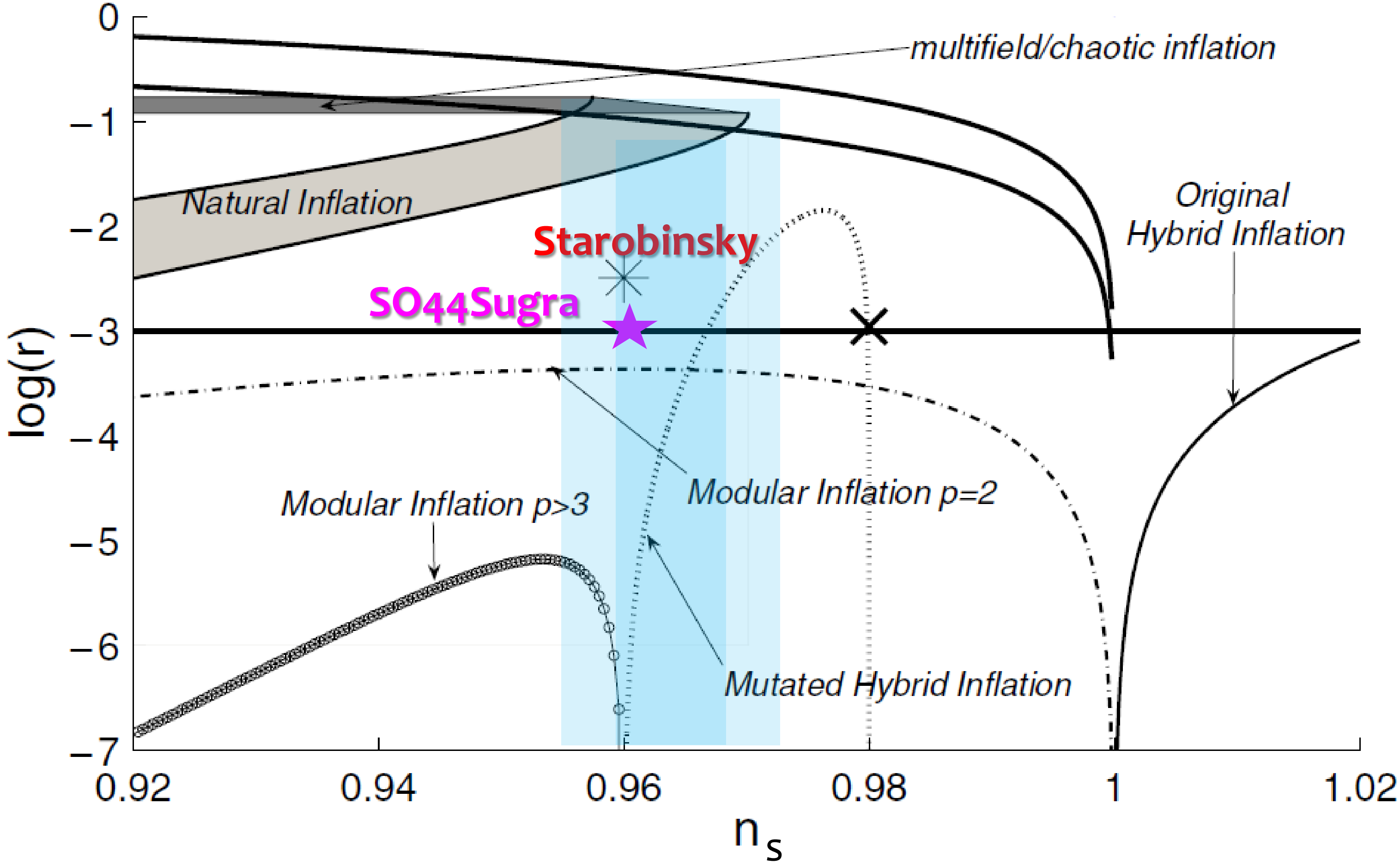
- Tensor-scalar ratio:

Inflation in our theory is the intermediate scale type and similar to that in the Starobinsky model:

$$0.96 \times 10^{-3} \lesssim r = 16\epsilon \lesssim 1.37 \times 10^{-3}$$

- Scalar perturbation amplitudes:

$$\mathscr{P}_\zeta = \frac{1}{2\epsilon}\left(\frac{H}{2\pi m_{\rm pl}}\right)^2 \simeq 2 \times 10^{-9} \Rightarrow \quad g \simeq 4 \times 10^{-6}$$



Alabidi L, Lyth D: JCAP 0605 (2006) 016

Conclusion

Summary

- Cosmology of a multi-component inflaton system corresponding to the SO(3)xSO(3) –invariant sector in the SO(4,4) gauging.

  When the deformation parameter s is very close to the critical value,

  – a multi-dimensional version of the Starobinsky-type inflation is realised;

  – n_s is miraculously consistent with the Planck result;

  – $r \sim 10^{-3}$;

  – No chromonatural-type inflation or anisotropic inflation occurs.

- Next task is to find a string uplifting of this theory.