

Preheating and inflation in supergravity - the role of flat directions

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Flat direction

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- general feature of supersymmetric models

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Preheating

very efficient non-perturbative particle production during inflaton oscillations

Preheating and flat directions

Toy model

$$V \supset \frac{1}{2}m^2\varphi^2 + A\varphi^2\chi^2 + Bm\varphi\chi^2 \quad (1)$$

φ - inflaton field, χ - represents the inflaton decay products

$$\omega_{\chi k}^2 = k^2 + 2A\langle\varphi\rangle^2 + 2Bm\langle\varphi\rangle \quad (2)$$

$$|\tau| \equiv \left| \frac{\dot{\omega}}{\omega^2} \right| > 1 \leftrightarrow \textit{preheating} \quad (3)$$

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Toy model with a flat direction

(Allahverdi, Mazumdar '07)

$$V \supset \frac{1}{2}m^2\varphi^2 + A\varphi^2\chi^2 + Bm\varphi\chi^2 + C\alpha^2\chi^2 \quad (4)$$

α - parameterizes the flat direction

$$\omega_{\chi k}^2 = k^2 + 2A\langle\varphi\rangle^2 + 2Bm\langle\varphi\rangle + 2C\langle\alpha\rangle^2 \quad (5)$$

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 - consider excitations around VEVs
 - study the evolution of the mass matrix
 - determine if preheating from the inflaton is possible

The model

Inflaton sector

M. Kawasaki, M. Yamaguchi, T. Yanagida "Natural Chaotic Inflation in Supergravity"

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- shift symmetry in the inflaton superfield in order to avoid the eta problem

$$K \supset \frac{1}{2}(\Phi + \Phi^\dagger)^2 + X^\dagger X, \quad \Phi = (\eta + i\varphi)/\sqrt{2} \quad (6)$$

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- auxiliary field X used to obtain chaotic inflation potential during inflaton domination

$$W \supset mX\Phi \quad (7)$$

$$V \xrightarrow{\text{inflaton domination}} \frac{1}{2}m^2\varphi^2 \quad (8)$$

The model

Observable sector

- MSSM superpotential

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$$W \supset 2hXH_uH_d \quad (10)$$

$$H_d = \frac{1}{\sqrt{2}} \begin{pmatrix} \chi \\ 0 \end{pmatrix}, \quad H_u = \frac{1}{\sqrt{2}} \begin{pmatrix} 0 \\ \chi \end{pmatrix}, \quad \chi = ce^{i\kappa} \quad (11)$$

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- representative flat direction udd

$$u_i^\beta = d_j^\gamma = d_k^\delta = \frac{1}{\sqrt{3}}\alpha, \quad \alpha = \rho e^{i\sigma} \quad (12)$$

Observable sector

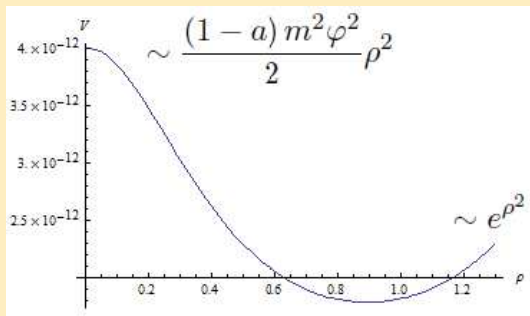
- non-minimal Kähler

$$K \supset \left(1 + \frac{a}{M_4^2} X^\dagger X \right) \left(H_u^\dagger H_u + H_d^\dagger H_d + u_i^\dagger u_i + d_j^\dagger d_j + d_k^\dagger d_k \right) \quad (13)$$

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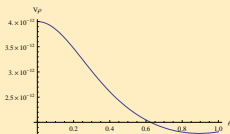
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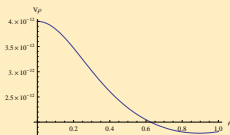
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- non-renormalisable terms

$$W \supset \frac{\lambda_\chi}{M_{Pl}} (H_u \cdot H_d)^2 + \frac{3\sqrt{3}\lambda_\alpha}{M_{Pl}} (u_i d_j d_k \nu_R) \quad (14)$$



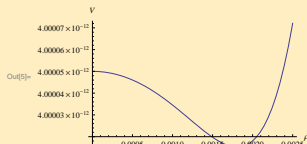
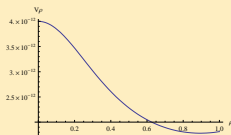
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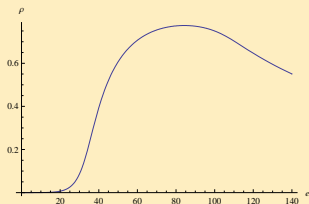


Classical evolution during inflation

Flat directions, $\lambda_\alpha \ll \lambda_\chi \sim 1$

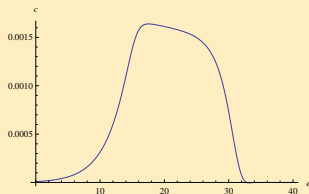
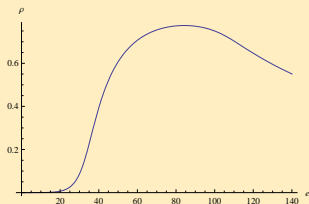
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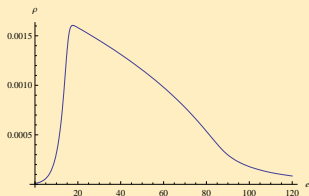


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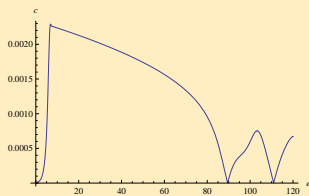
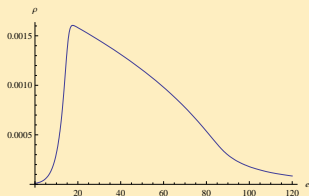
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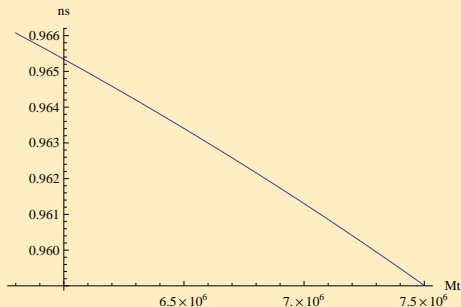
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Classical evolution during inflation

Spectral index

values of the spectral index 50-60 e-folds before the end of inflation in the slow-roll approximation



$$\text{WMAP5: } n_s = 0.960^{+0.014}_{-0.013}$$

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- consider excitations around fields belonging to H_u , H_d , u_i , d_j and d_k multiplets

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$$VEV = 0 \longrightarrow field \sim \delta_a + i\delta_b \quad (16)$$

Analyzing the mass matrix evolution, $\lambda_\alpha \ll \lambda_\chi \sim 1$

heavy eigenvalues

$$m_{udd}^2 \approx \frac{g^2}{3} \rho^2 + \underbrace{-\frac{m^2 \varphi^2}{2} (a-1)}_{\text{SUGRA}} + \dots \quad (17)$$

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Toy model analogy

$$m_\chi^2 = 2A \langle \varphi \rangle^2 + 2Bm \langle \varphi \rangle + 2C \langle \alpha \rangle^2 \quad (19)$$

Preheating

Analyzing the mass matrix evolution, $\lambda_\alpha \ll \lambda_\chi \sim 1$

naturally light eigenvalues corresponding to

$$\left(\xi_{u_i} + \xi_{d_j} + \xi_{d_k} \right) / \sqrt{3}$$

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and the excitation around the phase of the flat direction VEV

$$m_{phase}^2 \approx \underbrace{(1-a) \frac{m^2 \varphi^2}{2} + g(a) \frac{m^2 \varphi^2}{2} \rho^2}_{SUGRA} + \dots \quad (21)$$

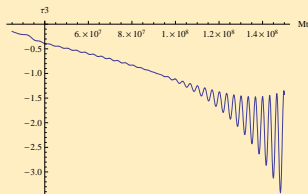
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the time evolution of both m_{abs}^2 and m_{phase}^2 leads to non-perturbative particle production

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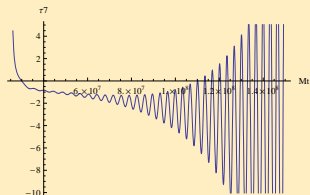
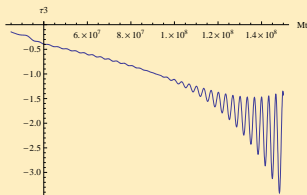
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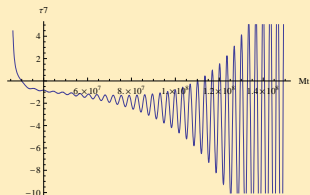
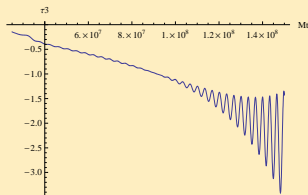
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→ melting of flat direction VEV and unblocking all other channels of preheating

Analyzing the mass matrix evolution, $\lambda_\alpha \sim \lambda_\chi \sim 1$

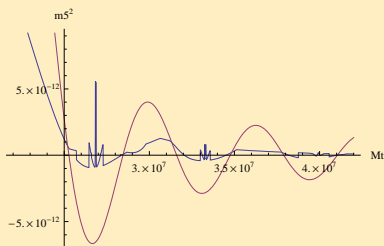
$$SU(3) \times SU(2) \times U(1) \rightarrow U(1)$$

Preheating

Analyzing the mass matrix evolution, $\lambda_\alpha \sim \lambda_\chi \sim 1$

$SU(3) \times SU(2) \times U(1) \rightarrow U(1)$

an example of a **naturally light eigenvalue** corresponding to a combination of excitations around VEVs of complex fields α and χ parameterizing the (quasi) flat directions

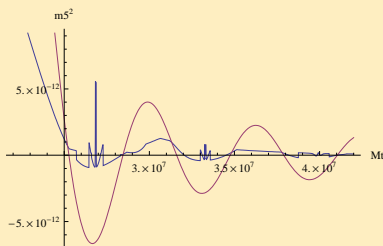


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→ very efficient preheating into Higgs particles allowed from the beginning of inflaton oscillations

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- Non-perturbative particle production from the inflaton is likely to remain the source of preheating even in the initial presence of large flat direction VEVs.