Preheating and inflation in supergravity - the role of flat directions

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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

$$\omega^2_{\chi_k} = k^2 + 2A\langle\varphi\rangle^2 + 2Bm\langle\varphi\rangle \quad (2)$$

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

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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

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

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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"’

Φ - inflaton superfield, X - auxiliary superfield

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

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

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

$$W \supset mX\Phi \tag{7}$$

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

The model

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$$W \supset 2hXH_uH_d \tag{10}$$

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- representative flat direction *udd*

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

The model

Observable sector

- non-minimal Kähler

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

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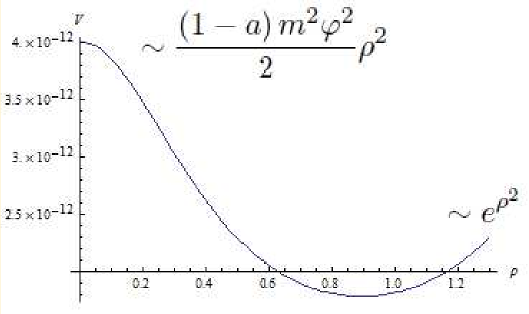

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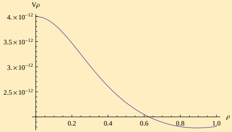

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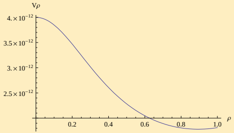

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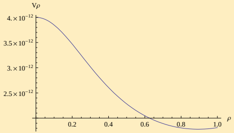

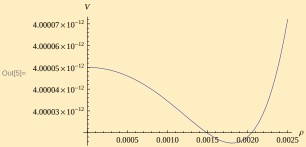

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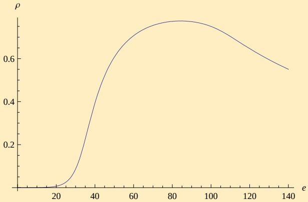

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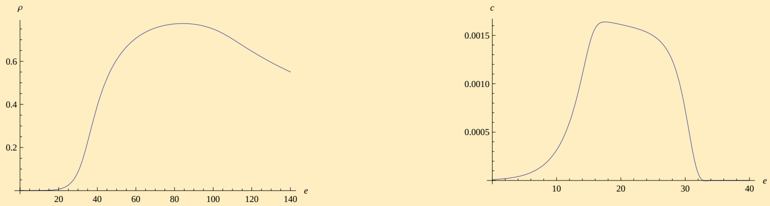

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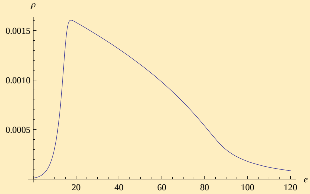

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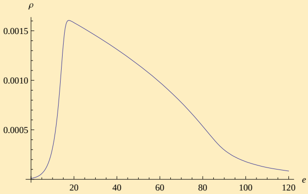
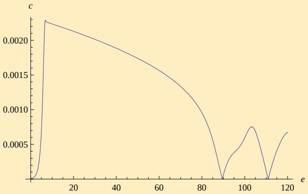
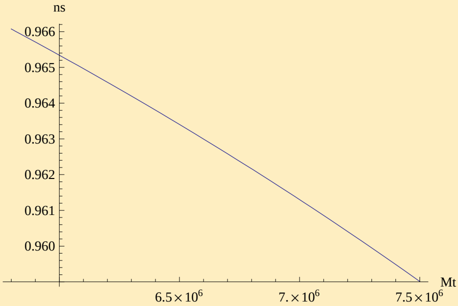




Classical evolution during inflation

Spectral index

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



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

Preheating

Parameterization of excitations

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

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

heavy eigenvalues

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

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Toy model analogy

$$m_\chi^2 = 2A\langle\varphi\rangle^2 + 2Bm\langle\varphi\rangle + 2C\langle\alpha\rangle^2 \tag{19}$$

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and the excitation around the phase of the flat direction VEV

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

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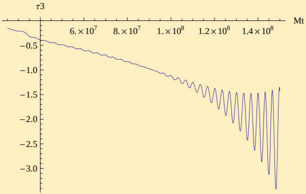

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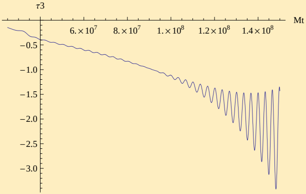

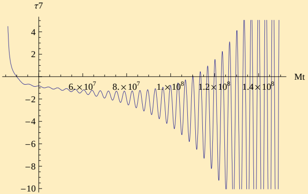

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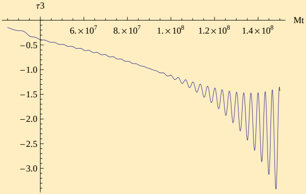

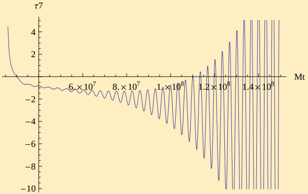

$\longrightarrow$ melting of flat direction VEV and unblocking all other channels of preheating

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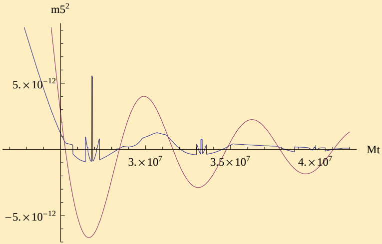
an example of a naturally light eigenvalue corresponding to a combination of excitations around VEVs of complex fields α and χ parameterizing the (quasi) flat directions



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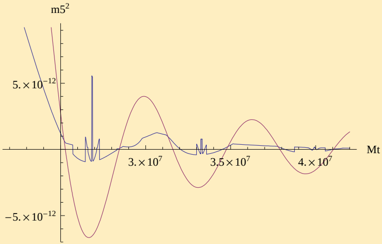

$\longrightarrow$ very efficient preheating into Higgs particles allowed from the beginning of inflaton oscillations

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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.