Curvature Perturbations from Supersymmetric Flat Directions

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A. Riotto and F.R., PLB, [arXiv:0806.3382]

Curvature Perturbations from Supersymmetric Flat Directions

Fluctuations

Dynamics

Decay

## Outline

Fluctuations During Inflation

Dynamics after inflation

Decay and Production of Perturbations

Curvature Perturbations from Supersymmetric Flat Directions

Fluctuations

Dynamics

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Remarks and Conclusions II

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## Fluctuations

**During Inflation:** 

Recall FD potential for Flat Direction *QQQL* or *uude* 

$$V(\phi) = -c_I H_I^2 |\phi|^2 + \left(\lambda \frac{\frac{\partial I}{\partial M_P}}{4M_P} \phi^4 + \text{h.c.}\right) + |\lambda|^2 \frac{|\phi|^6}{M^2},$$

FD VEV amplitude becomes large

$$\phi_I = |\phi_I| e^{i\theta_I}$$

• Mass of  $\theta$ 

$$m_\theta^2 \approx 4 a_I H_I^2 \ll H_I^2$$

 $\Rightarrow$  Flat Direction phase  $\theta_l$  fluctuates during inflation

$$|\delta\theta(k)|^2 \approx \frac{H_I^2}{2k^3|\phi_I|^2}$$

⇒ Different patches have different initial conditions

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# FD Potential During Inflation



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### Fluctuations in the FD Phase



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# AFTER Inflation



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# FD Dynamics

#### After (hybrid) Inflation:

- Energy transferred from  $\psi_1$  to  $\psi_2$ , inflation ends
- $\psi_1$  and  $\psi_2$  have different couplings to FD
- FD potential V"(0) changes sign

$$V = +\frac{1}{2}H_{I}^{2}|\phi|^{2} + \left(\frac{a_{\rm osc}H_{I}}{M_{p}}\phi^{4} + h.c\right) + \lambda^{2}\frac{|\phi|^{6}}{M^{2}},$$

⇒ FD starts oscillations around  $\phi = 0$ ⇒ Frequency of oscillations ~  $H_I$ 

For small a<sub>osc</sub> ≠ 0 potential is phase-dependent
 ⇒ Different initial conditions θ<sub>l</sub> have different dynamics

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# FD Potetnial During Inflation



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# FD Potential After Inflation



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**Different Trajectories** 

 $\Rightarrow$  FD passes at different distances from origin:

$$|\phi_*| \approx \frac{2\pi}{3} a_{\rm osc} |\phi_I| \sin(4\theta_I)$$



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**Different Trajectories** 

 $\Rightarrow$  Different speed at origin:

$$|\dot{\phi}_*| pprox \mathcal{H}_I |\phi_I| \sqrt{1 + 4(a_{
m osc}/4)\cos(4 heta_I)}.$$



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...Different Distance and speed at origin:

 $\Rightarrow$  Different decay (preheat) efficiency into light fields

$$n_{\text{light}} = \frac{(h|\dot{\phi}_{*}|)^{3/2}}{8\pi^{3}} \exp\left[-\frac{\pi h|\phi_{*}|^{2}}{|\dot{\phi}_{*}|}\right] \quad \text{with} \quad \phi_{*} = \phi_{*}(\theta_{I})$$

⇒ Curvature perturbation

$$\zeta = rac{\dot{
ho}_{ ext{light}}}{\dot{
ho}_{ ext{tot}}} \, \zeta_{ ext{light}} \simeq -rac{1}{3} rac{
ho_{ ext{light}}}{
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 $\Rightarrow$  Maximum spectrum for  $\lambda = 0.01$ 

$$\mathscr{P}_{\zeta}^{1/2}(k) \simeq rac{\operatorname{cot}(4\theta_l)}{2\pi} \left(rac{H_l^3}{\lambda M_p^{(3)}}\right)^{1/2} \sim 2.5 \times 10^{-5},$$

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 $\Rightarrow$  Curvature perturbation

$$\zeta = \frac{\dot{\rho}_{\text{light}}}{\dot{\rho}_{\text{tot}}} \zeta_{\text{light}} \simeq -\frac{1}{3} \frac{\rho_{\text{light}}}{\rho_{\text{tot}}} \frac{\delta n_{\text{light}}}{n_{\text{light}}},$$

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# Remarks and Conclusions II

- Large and possibly dominating curvature perturbation can be produced by the non-perturbative decay of Flat Directions
- FD QQQL and uude don't produce baryon isocurvature perturbation

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Large Non-Gaussianities are expected

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