Curvature Perturbations from Supersymmetric Flat Directions

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

Outline

Fluctuations

During Inflation:

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

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

- FD VEV amplitude becomes large

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

- Mass of θ

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

$\Rightarrow$ Flat Direction phase θ_I fluctuates during inflation

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

$\Rightarrow$ Different patches have different initial conditions

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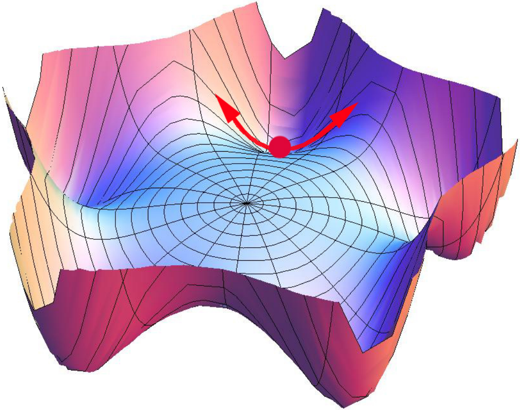
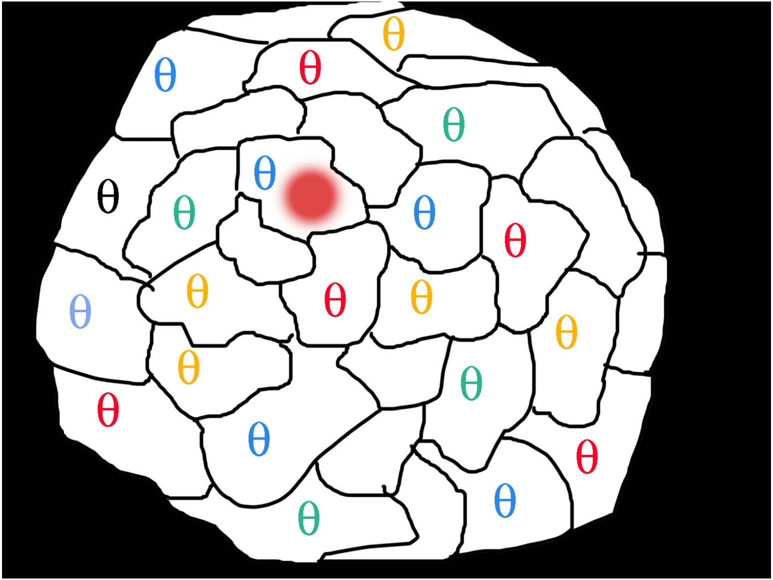
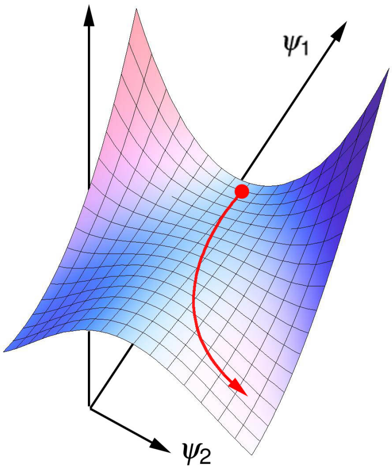
FD Potential During Inflation



Fluctuations in the FD Phase



AFTER Inflation



FD Dynamics

After (hybrid) Inflation:

- Energy transferred from ψ_1 to ψ_2, inflation ends
- ψ_1 and ψ_2 have different couplings to FD
- FD potential $V''(0)$ changes sign

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

$\Rightarrow$ FD starts oscillations around $\phi = 0$
$\Rightarrow$ Frequency of oscillations $\sim H_I$

- For small $a_{\rm osc} \neq 0$ potential is phase-dependent
  $\Rightarrow$ Different initial conditions θ_I have different dynamics

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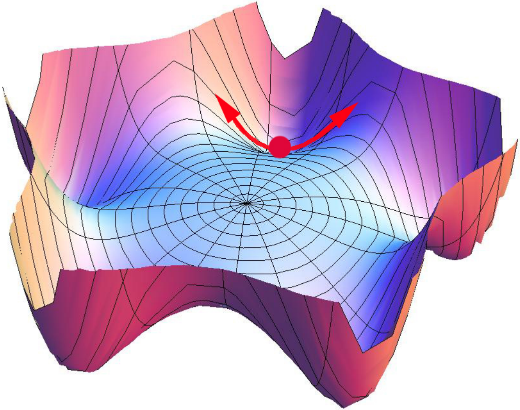
FD Potetnial During Inflation



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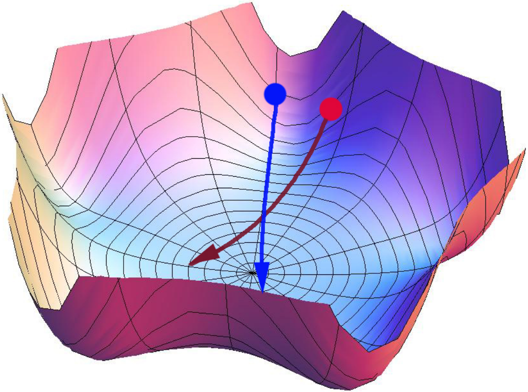
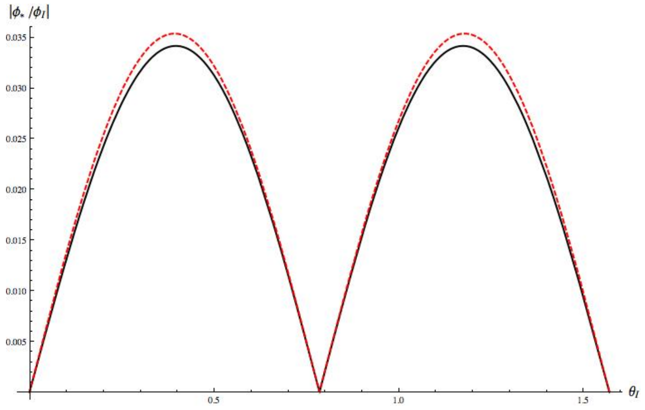


Preheating

Different Trajectories

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

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

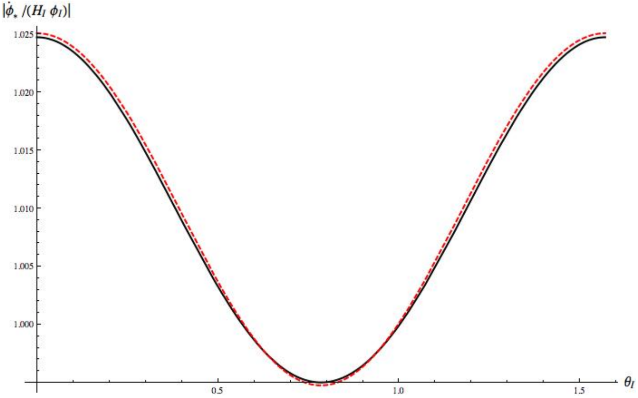


Preheating

Different Trajectories

$\Rightarrow$ Different speed at origin:

$$|\dot{\phi}_*| \approx H_I\,|\phi_I|\,\sqrt{1+4(a_{\rm osc}/4)\cos(4\theta_I)}.$$



Preheating

...Different Distance and speed at origin:

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

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

$\Rightarrow$ Curvature perturbation

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

$\Rightarrow$ Maximum spectrum for $\lambda = 0.01$

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

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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
- Large Non-Gaussianities are expected