Hybrid Inflation with a U(1) Gauge Symmetry

A Toy Model.

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Hybrid Inflation

Superpotential

$$W = \lambda \Phi \left(M_G^2 - \Sigma^2 \right)$$

Φ, Σ	:	Chiral superfields
λ	:	Coupling constant
M_G	:	Mass parameter $\mathcal{O}(10^{16})$ GeV

Scalar Potential

$$V_F = \lambda^2 \left(M_G^2 - \sigma^2 \right)^2 + \lambda^2 \phi^2 \sigma^2 + \ldots$$

ϕ, σ	:	Real part of the scalar component of Φ, Σ

Hybrid Inflation

Superpotential (+ Polonyi-Term)

[Buchmüller, Covi, Delépine '00], [Asaka, Buchmüller, Covi '01]

$$W = \lambda\Phi\left(M_G^2 - \Sigma^2\right) + M_S^2\left(\beta + S\right)$$

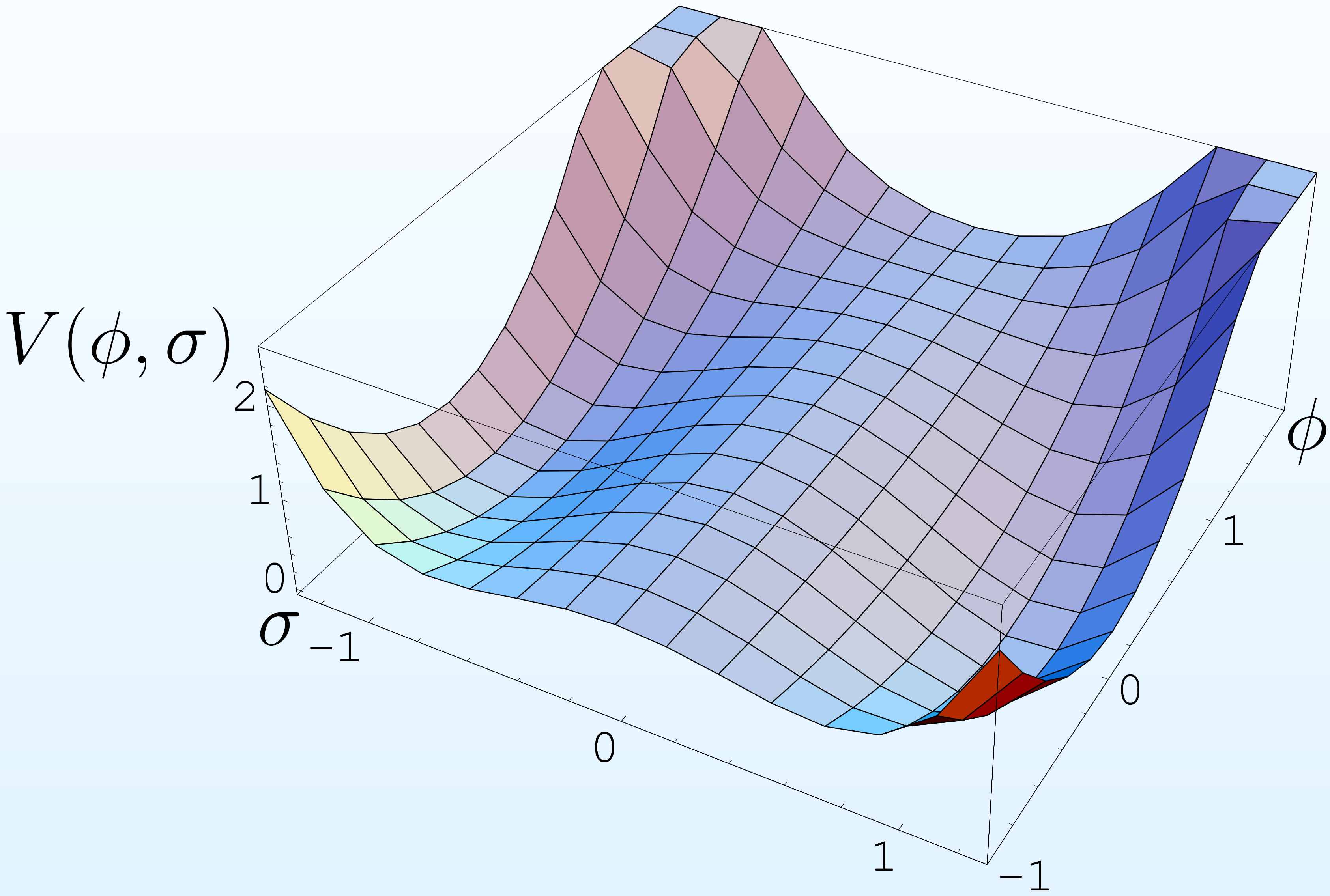
Φ, Σ, S	:	Chiral superfields
λ	:	Coupling constant
M_G	:	Mass parameter $\mathcal{O}(10^{16})$ GeV
M_S	:	Susy breaking scale
β	:	Mass parameter

Scalar Potential

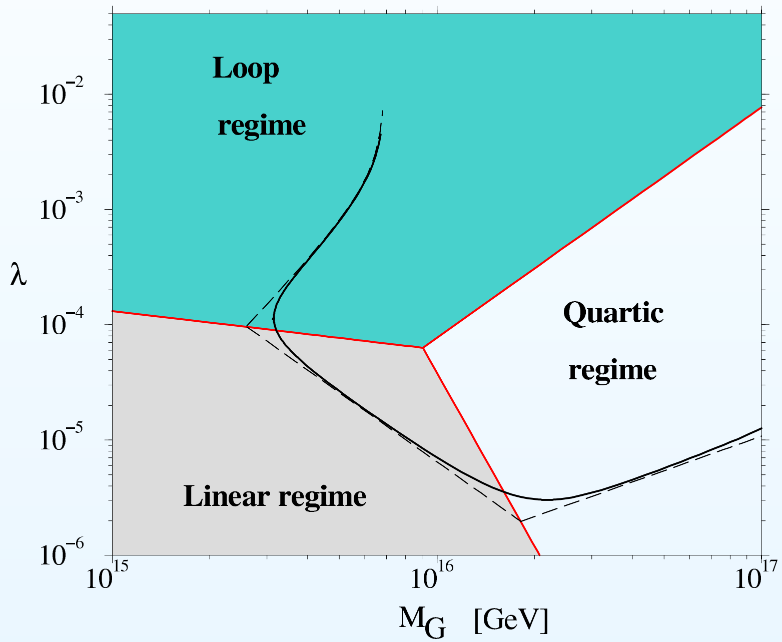
$$V_F = \lambda^2\left(M_G^2 - \sigma^2\right)^2 + \lambda^2\phi^2\sigma^2 + \ldots$$

ϕ, σ : Real part of the scalar component of Φ, Σ

Hybrid Inflation Scalar Potential



Parameter Space



Slope dominated by either

- Linear Sugra correction
- Quartic Sugra corrections
- Coleman-Weinberg loop corrections

[Buchmüller, Covi, Delépine ’00]

Constrained by WMAP normalisation

Symmetries

$$W = \lambda\Phi\left(M_G^2 - \Sigma^2\right) + M_S^2\,(\beta + S)$$

is symmetric under $\Sigma \to -\Sigma$ $\Rightarrow$ Domain wall problem!

Solution:
Use continuous instead of discrete symmetry, e. g.

$$W = \lambda\Phi\left(M_G^2 - \Sigma_+\Sigma_-\right) + M_S^2\,(\beta + S)$$

$\Sigma_\pm$ have opposite charges under a U(1) symmetry

$$\Sigma_\pm \longrightarrow e^{\pm\,\mathrm{i}g\Lambda}\,\Sigma_\pm$$

Symmetries

Spontaneous breaking of global symmetry
$\longrightarrow$ Goldstone boson

Goals:

- Analyse dynamics of the phase transition in the globally symmetric case
- Compare semi-analytical (Hartree) approximation to lattice simulation with LatticeEasy [Felder, Tkachev '01]
- Estimate the effect of the gauge field in the locally symmetric case

Global U(1) Symmetry

Redefine the fields: $\Theta_{\pm} = \frac{1}{\sqrt{2}}\left(\Sigma_{+} \pm \Sigma_{-}^{*}\right)$

Scalar potential

$$
\begin{aligned}
V =& \lambda^2 \Big[M_G^4 + |\Theta_+|^2 \left(\phi^2 - M_G^2\right) + |\Theta_-|^2 \left(\phi^2 + M_G^2\right) \\
&+ \frac{1}{4}\left|\Theta_+^2 - \Theta_-^2\right|^2 \Big] + \ldots
\end{aligned}
$$

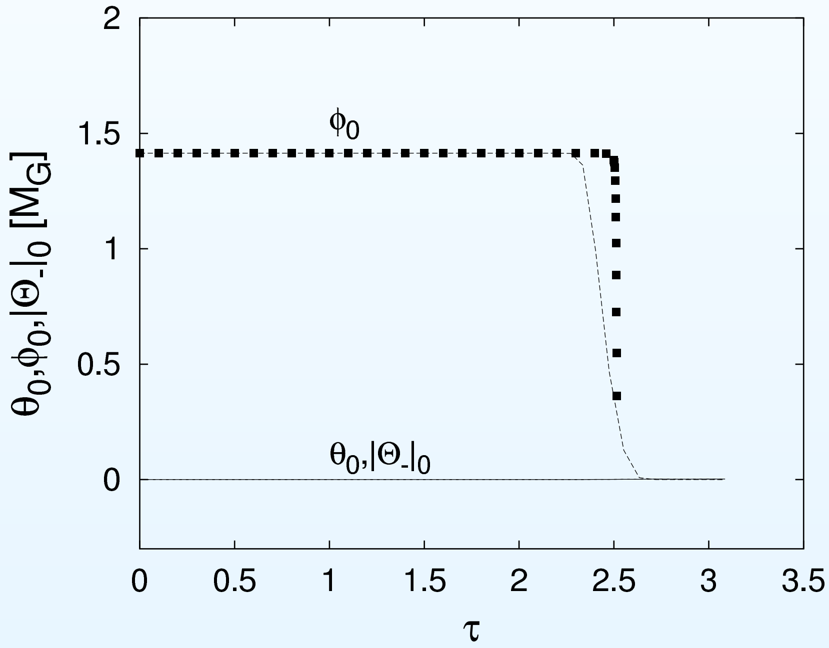
Neglecting fields with positive mass leads to

$$
V \simeq \lambda^2 \left[M_G^4 + \frac{1}{4}\left(\phi^2 - 2M_G^2\right)\theta^2 + \frac{1}{16}\,\theta^4 \right] + \ldots
$$

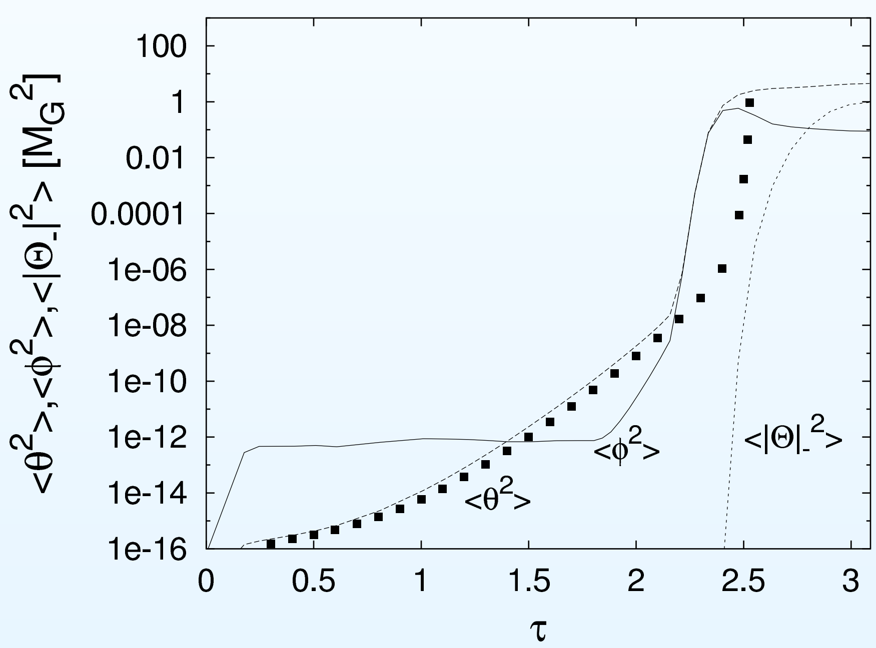
with $\Theta_+ = \frac{1}{\sqrt{2}}\,\theta\, e^{-\mathrm{i}\gamma/2M_G}$ $\qquad\gamma$: Goldstone boson

Dynamics of the Phase Transition

Homogeneous part



Fluctuations



[Covi, JH, Janutta (in preparation)]

Local U(1) Symmetry

What's different in the local case?

- Gauge field A_μ
  Induces effective mass term for θ field:

$$\Delta\mathcal{L}_g = -g^2\theta^2 A_\mu A^\mu \simeq -g^2\theta^2 \langle A_\mu A^\mu \rangle$$

- D-Term

$$V_D = \frac{g^2}{2}\left(\Theta_+^*\Theta_- + \Theta_+\Theta_-^*\right)^2$$

- Unitary gauge $\quad \rightarrow \quad \gamma = 0$

The Gauge Field

Split A_μ into components and Fourier transform:

- $\hat{A}_0$ - Not an independent d.o.f., depends on $\hat{A}_{||}$
- $\hat{A}_{||} \equiv \frac{1}{k}\vec{k}.\vec{\hat{A}}$ - Longitudinal component

$$\ddot{\hat{A}}_{||} + \left(H \frac{3k^2 + a^2 g^2 \langle\theta^2\rangle}{k^2 + a^2 g^2 \langle\theta^2\rangle} + \frac{\langle\theta\dot{\theta}\rangle}{\langle\theta^2\rangle} \frac{2k^2}{k^2 + a^2 g^2 \langle\theta^2\rangle} \right) \dot{\hat{A}}_{||} + \left(\frac{k^2}{a^2} + g^2 \langle\theta^2\rangle \right) \hat{A}_{||} = 0$$

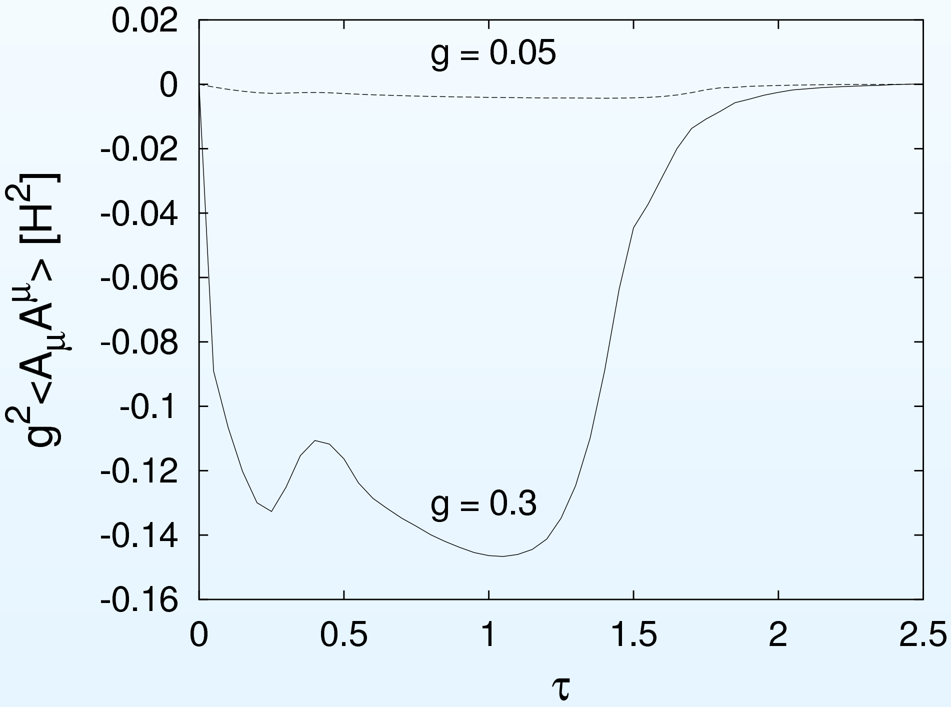
- $\hat{A}_\perp \equiv \frac{1}{k}\epsilon_{lmn} k_m \hat{A}_n$ - Transverse component

$$\ddot{\hat{A}}_\perp + H \dot{\hat{A}}_\perp + \left(\frac{k^2}{a^2} + g^2 \langle\theta^2\rangle \right) \hat{A}_\perp = 0$$

[Massive scalar field X: $(\Box + m^2) X + 3H\dot{X} = 0 \;\Rightarrow\; \ddot{\hat{X}} + 3H\dot{\hat{X}} + \left(\frac{k^2}{a^2} + m^2 \right) \hat{X} = 0$]

Gauge field

Transverse and longitudinal component become massive after symmetry breaking
$\Rightarrow$ Higgs mechanism



$|\frac{g^2}{H^2}\langle A_\mu A^\mu \rangle| \ll 1$
$\Rightarrow$ Effect on dynamics negligible

$$\left[\ddot{\theta}_k + \left(\frac{k^2}{a^2} + \lambda^2(\langle\phi^2\rangle - M_G^2) + 3\lambda^2\langle\theta^2\rangle - g^2\langle A_\mu A^\mu\rangle - \frac{9}{4}H^2\right)\theta_k = 0\right]$$

Summary

- Constructed a (toy) model in Sugra theory
- Analysed dynamics in globally and locally symmetric cases
- Find that contribution of gauge field can be neglected during phase transition

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Thank you :-)