Particle Physics Models of Inflation in SUGRA: New Developments

Stefan Antusch

based on collaborations with: K. Dutta, M. Bastero-Gil, J.P. Baumann, S.F. King, and P.M. Kostka

Talk at Planck 2010,
CERN, Geneva, Switzerland

Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

Outline

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- New possible solution to the η-problem in SUGRA inflation: Heisenberg symmetry with stabilised modulus

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- New class of models, very suitable for applying symmetry solutions to the η-problem: Tribrid Inflation
- New possibile connection to particle physics: Gauge Non-Singlet (Tribrid) Inflaton in SUSY GUTs

Inflationary epoch in the early universe

- Requirements for “slow roll“ inflation
  - → “Slow roll parameters” small: ε, |*η*|, *ξ* << 1, V ~ V_0 dominates

$$\epsilon = \frac{M_P^2}{2}\left(\frac{V'}{V}\right)^2 , \quad \eta = M_P^2\left(\frac{V''}{V}\right) , \quad \xi = M_P^4\left(\frac{V'V'''}{V^2}\right)$$

“slope of V”

“inflaton mass”

The η-problem

- Challenge for realising inflation: Flat enough potential, $m_\phi << \mathcal{H}$

$$\mathcal{H} = \frac{\sqrt{V}}{\sqrt{3}M_P}$$

E.J Copeland, A.R. Liddle, D.H. Lyth, E.D. Stewart, D. Wands ('94)

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$$V \subset V_0 \frac{\phi^\dagger \phi}{M_P^2} \Rightarrow m_\phi \sim \mathcal{H} \leftrightarrow \eta \sim 1$$

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  - In supergravity (with K = $\phi^* \phi$ and V_0 from F-term)

$$V_F = e^{K/M_P^2} \left(K^{i\bar{j}} D_i W \, D_{\bar{j}} W^* - \frac{3|W|^2}{M_P^2} \right)$$

with $D_i W := W_i + K_i W$

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$$V_F \sim \left(1 + \frac{\phi^\dagger \phi}{M_P^2} + \ldots\right) V_0$$

with $D_i W := W_i + K_i \, W$

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Approaches to solve the η-problem: 3 strategies

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- Expansion of K in fields/M_P:

requires tuning of parameters!
(at 1%-level)

$$K = |\phi|^2 + \frac{\lambda_\phi}{M_P^2}|\phi|^4 + \frac{\lambda_{\phi i}}{M_P^2}|\phi|^2|X_i|^2 + \ldots$$

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- 'Shift' symmetry:

$$\boxed{\phi \rightarrow \phi + i\alpha}$$

$$K = f(\phi + \phi^*)$$

protects Im[ϕ] from obtaining a SUGRA mass by symmetry!

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- Heisenberg symmetry:

solves the η-problem for |ϕ| by symmetry!

$$\boxed{T \rightarrow T + \mathrm{i}\,\beta\,, \quad T \rightarrow T + \alpha^*\phi + |\alpha|^2/2\,, \quad \phi \rightarrow \phi + \alpha}$$

$$K = f(\rho)\,, \text{ with } \quad \rho = T + T^* - |\phi|^2$$

Gaillard, Murayama, Olive ('95),
S.A., Bastero-Gil, Dutta, King, Kostka ('08,'09)

T: 'modulus field' → has to be stabilised

Approaches to solve the η-problem: 3 strategies

- Expansion of K in fields/M_P:

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- Heisenberg symmetry:

Remark:
Symmetries have to be broken to allow for slope of $V(\phi)$!
→ approximate symmetries

Heisenberg symmetry solution to the η-problem

S.A., M. Bastero-Gil, K. Dutta,
S. F. King, P. M. Kostka ('08)

Heisenberg symmetry solution to the η-problem

- Example for K:

$$K = \underbrace{-3 \ln \rho}_{\text{Example: No-scale form}} + |X|^2 + \kappa_\rho \frac{\rho\,|X|^2}{M_P} + \ldots\,, \text{ with } \quad \rho = T + T^* - |\phi|^2$$

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→ Consider suitable W with (i) $W_{inf} = 0$, $W_\phi = 0$ during inflation and (ii) which yields a tree-level ϕ-flat potential in global SUSY limit

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→ Parameter κ_ρ: Couples ρ to V_0

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Heisenberg symmetry solution to the η-problem

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✓ In the the (ϕ,ρ)-basis: no kinetic mixing between ϕ and ρ

$$\mathcal{L}_{\text{kin}} = \frac{f''(\rho)}{4}\left(\partial_\mu \rho\right)^2 - \frac{f'(\rho)}{2}\left(\partial_\mu \phi\right)^2$$

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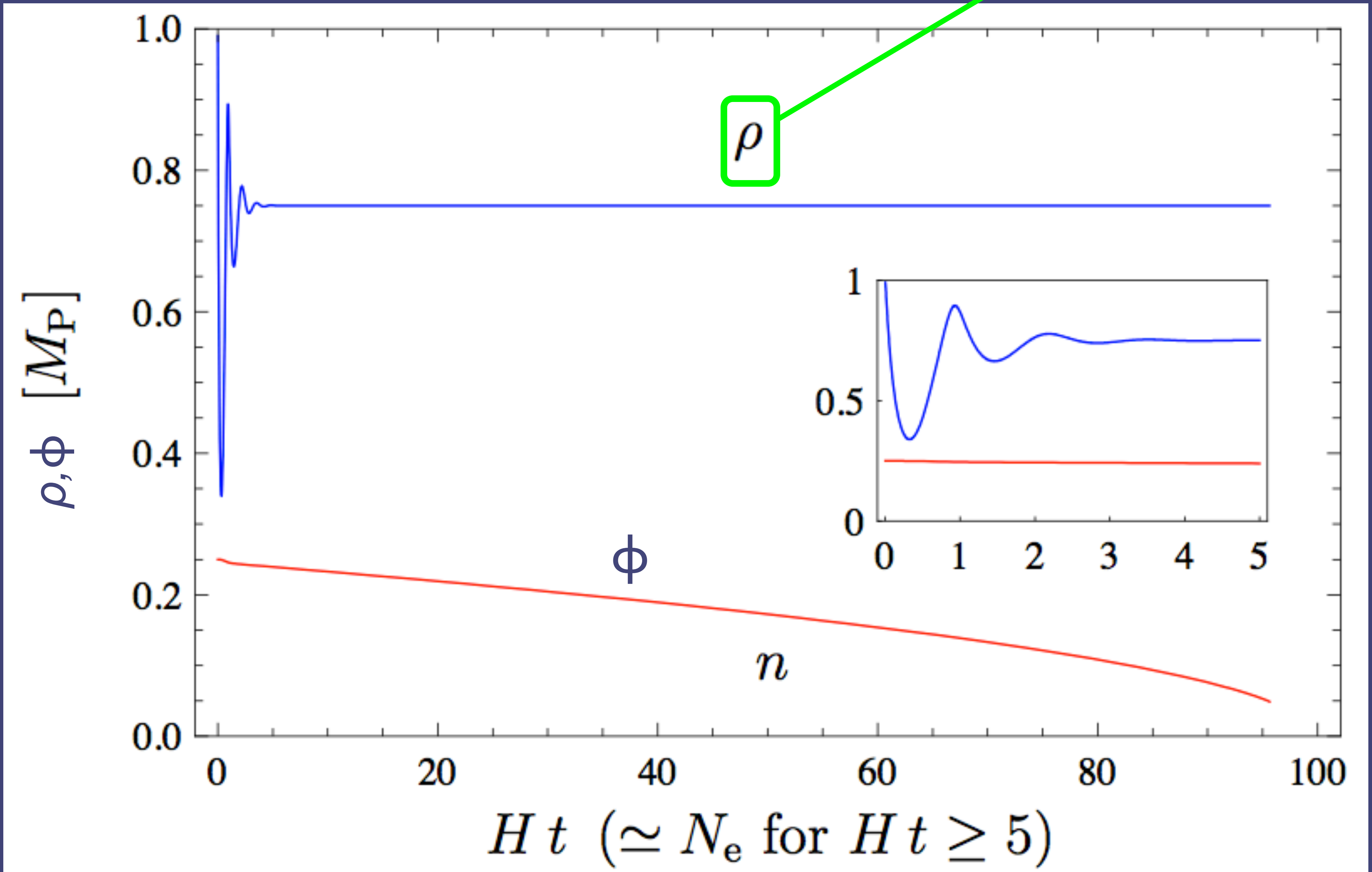
→ ρ can be stabilsed by large V_0

With $V = V_{tree} + V_{loop}$

Modulus field ρ gets stabilized quickly and allows for >> 60 e-folds of inflation!



S.A., M. Bastero-Gil, K. Dutta,
S. F. King, P. M. Kostka ('08)

A new class of inflation models: Tribrid Inflation

- Simple example (singlet fields, global SUSY to start with):

$$W = X(H^2 - M^2) + \frac{1}{\Lambda} H^2 \Phi^2$$

Driving superfield

Waterfall superfield

Inflaton superfield

First model of this class in: S.A., Bastero-Gil, King, Shafi ('04)
"Tribrid Inflation" in SUGRA: S.A., Dutta, Kostka ('09);
S.A., M. Bastero-Gil, K. Dutta, S. F. King, P. M. Kostka ('08)

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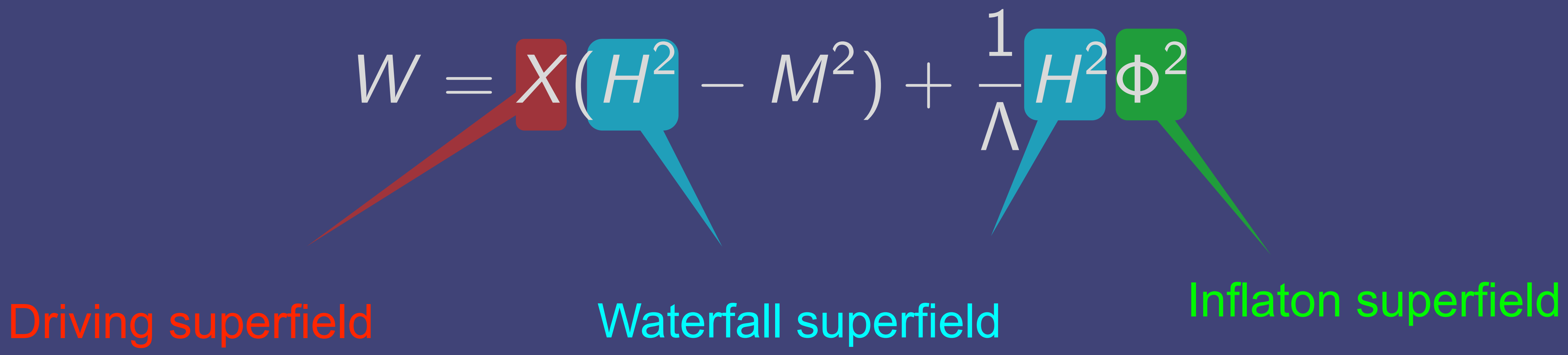

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  - Three fields, X, H and Φ relevant for the model → "Tribrid Inflation"

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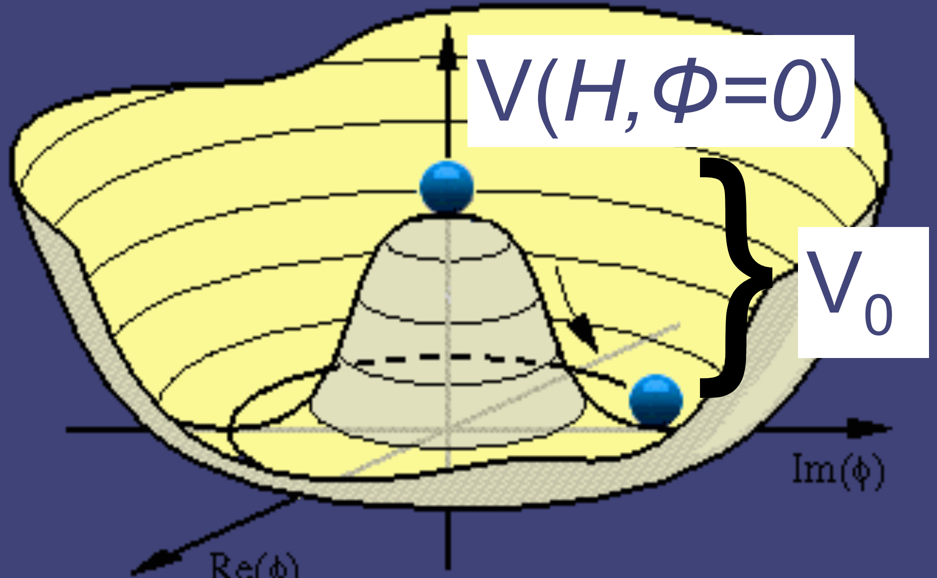
(its F-term generates the potential for H and provides the vacuum energy V_0;
During and after inflation: $\langle X \rangle = 0$.)

$|F_X|^2 \Rightarrow$



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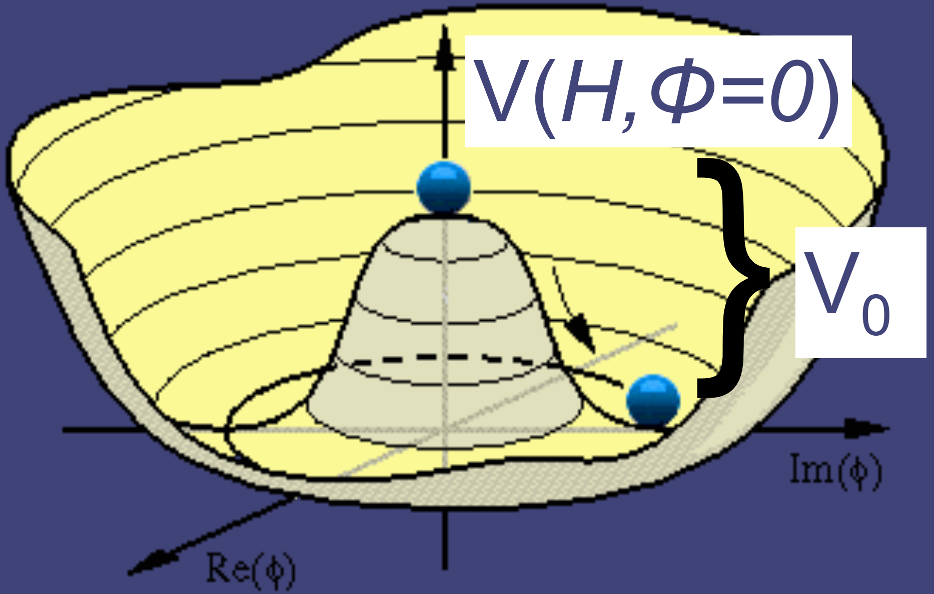
Waterfall superfield
(contains the “waterfall field” (e.g. GUT- or Flavour-Higgs field) that ends inflation by a 2nd order phase transition and gives mass to ϕ after inflation)



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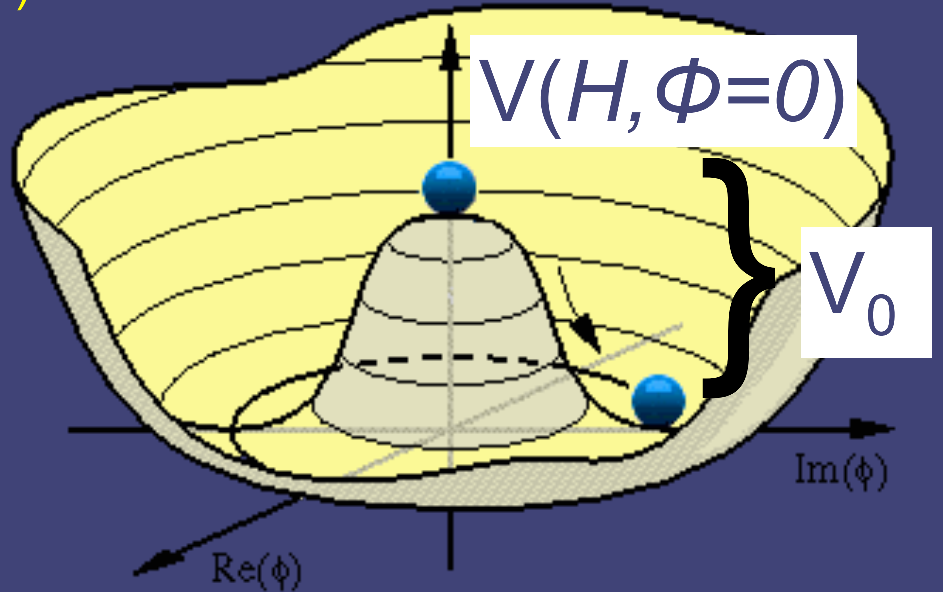
→ Possible candidate for the inflaton is the RH sneutrino

"Sneutrino Hybrid Inflation":
S.A., Bastero-Gil, King, Shafi ('04)

Inflaton superfield
(contains the inflaton field as scalar component;
For $\langle\phi\rangle > \phi_{crit}$ it stabilises H at $\langle H\rangle = 0$)



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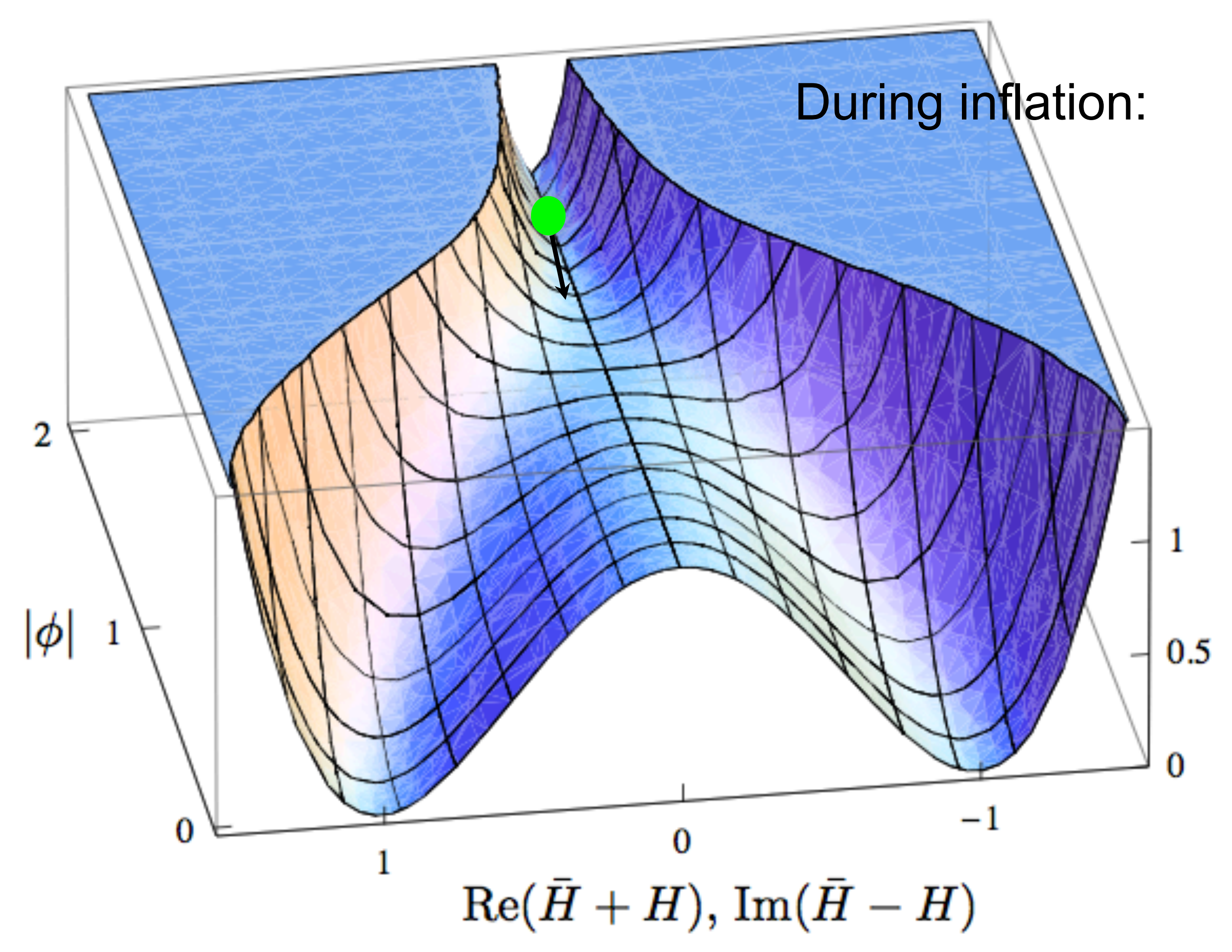
During inflation:

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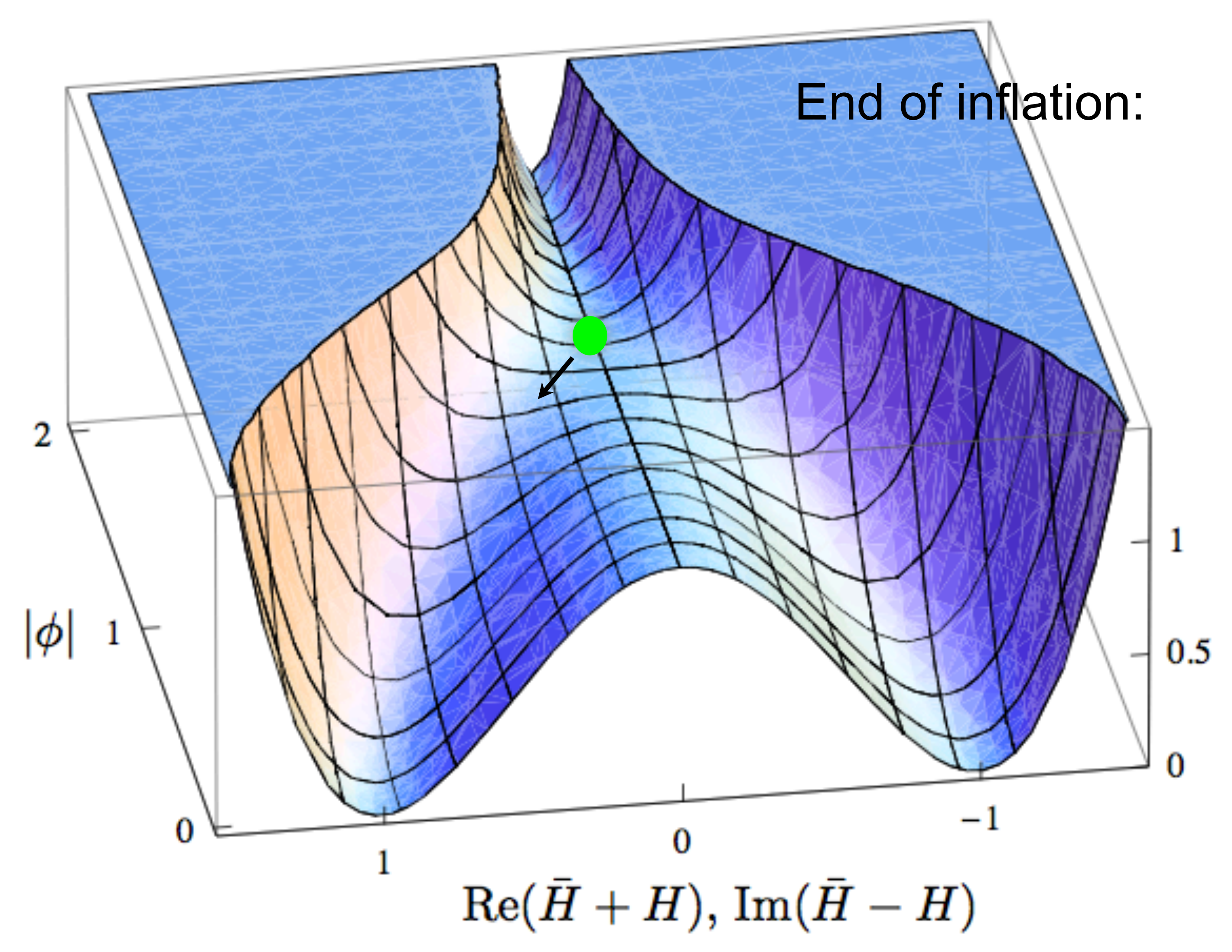

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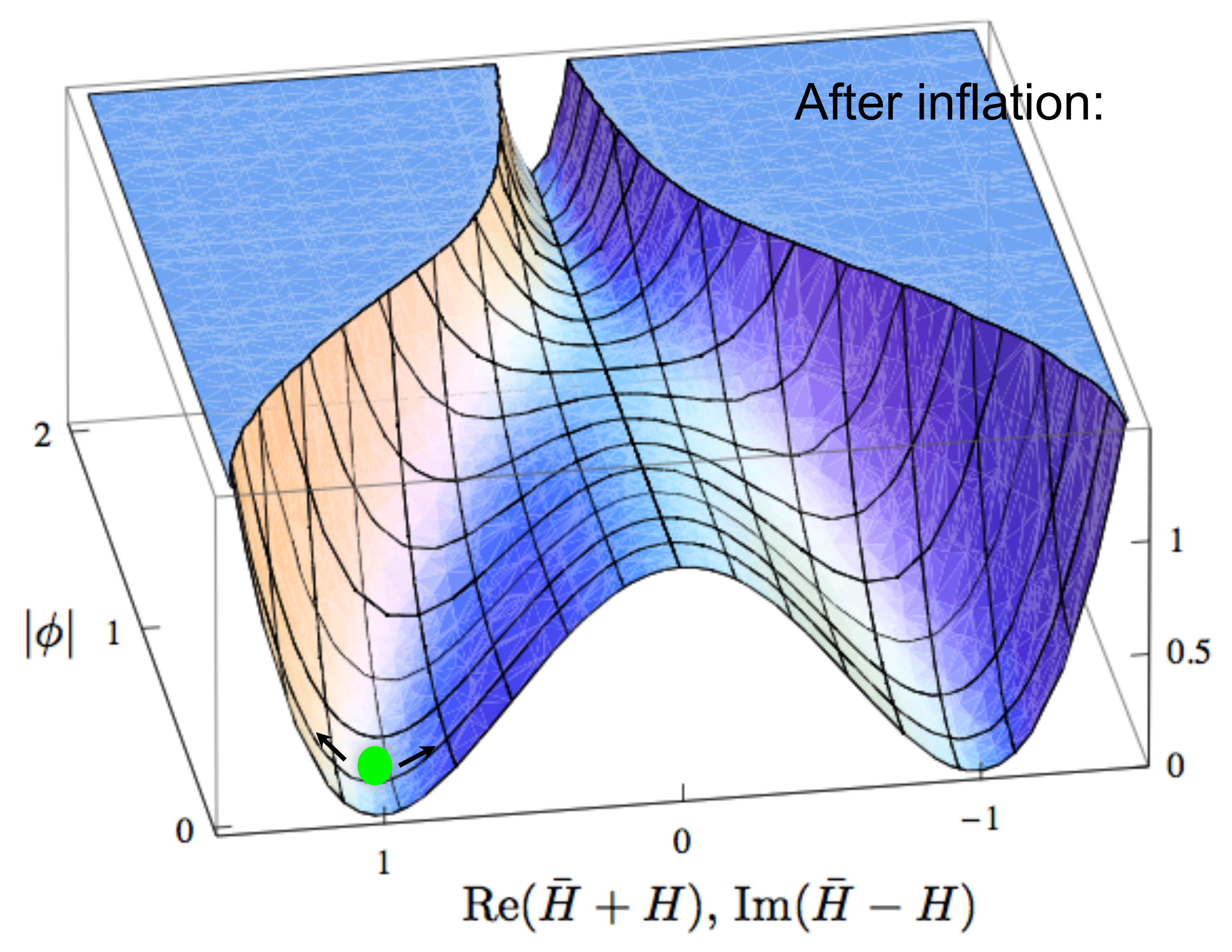

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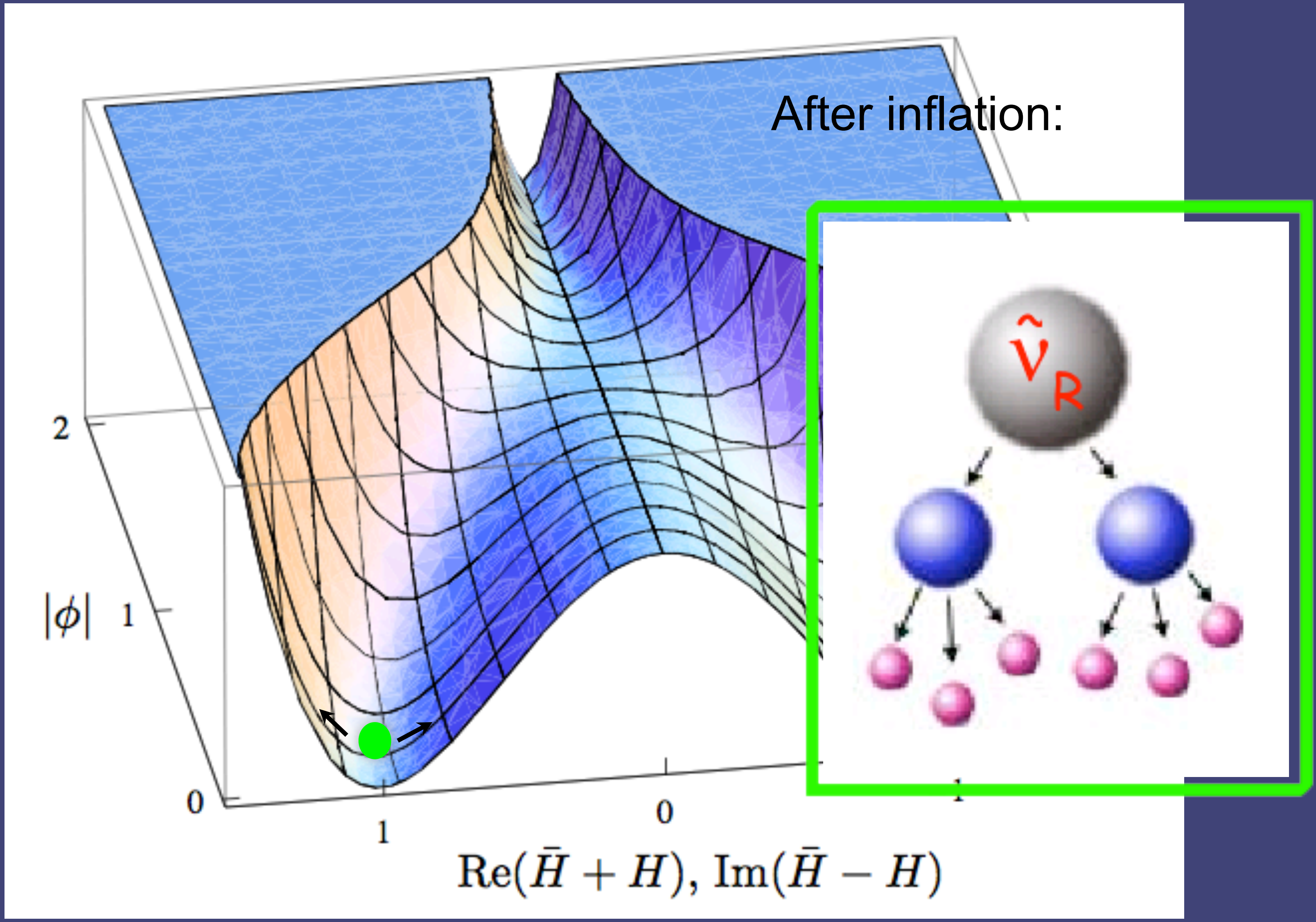

Non-thermal leptogenesis after sneutrino inflation: very efficient way of generating the observed baryon asymmetry!

Tribrid inflation in Supergravity

S.A., M. Bastero-Gil, K. Dutta,
S. F. King, P. M. Kostka ('08)

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K invariant under Heisenberg symmetry

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→ η-problem solved:

✓ Flat potential for ϕ at tree-level

✓ Slope from $V_{\text{1-loop}}$

S.A., M. Bastero-Gil, K. Dutta,
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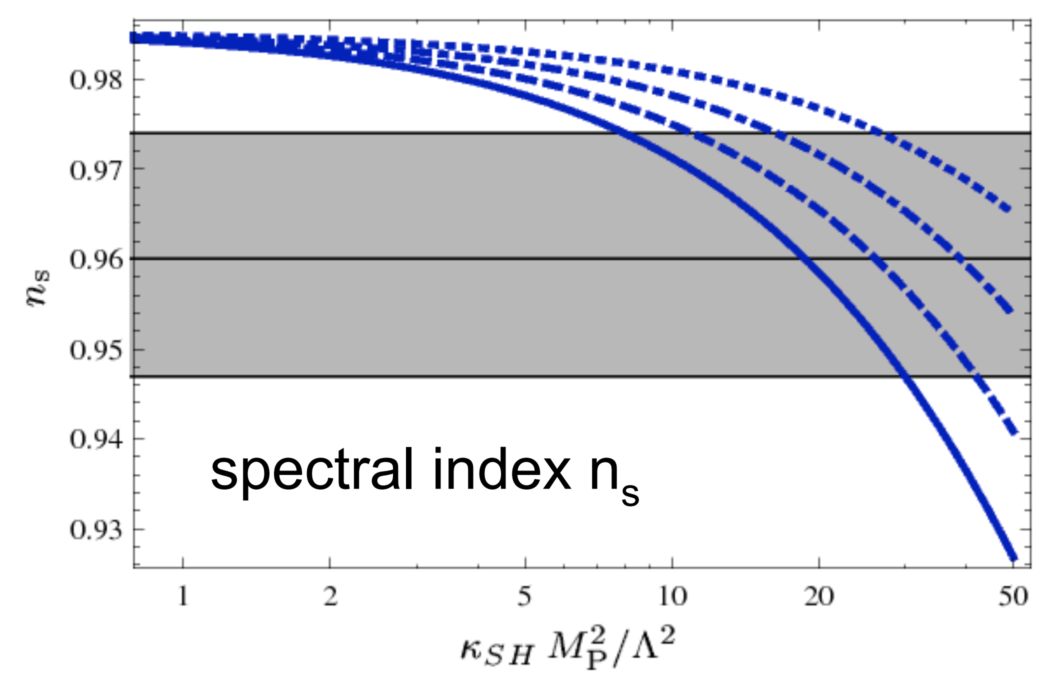
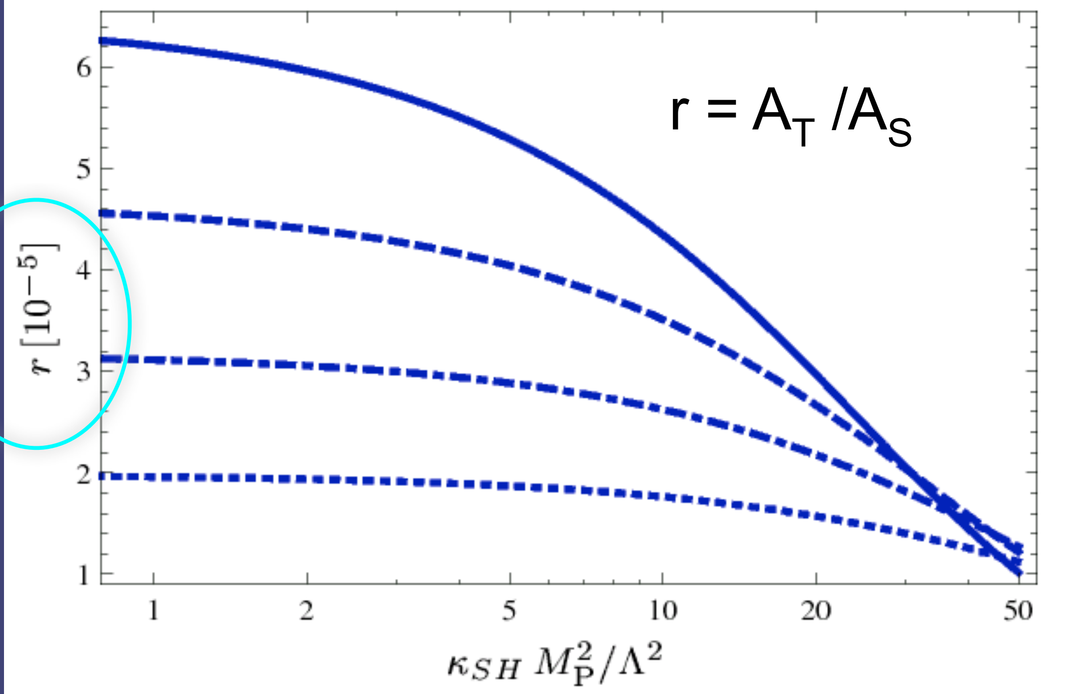
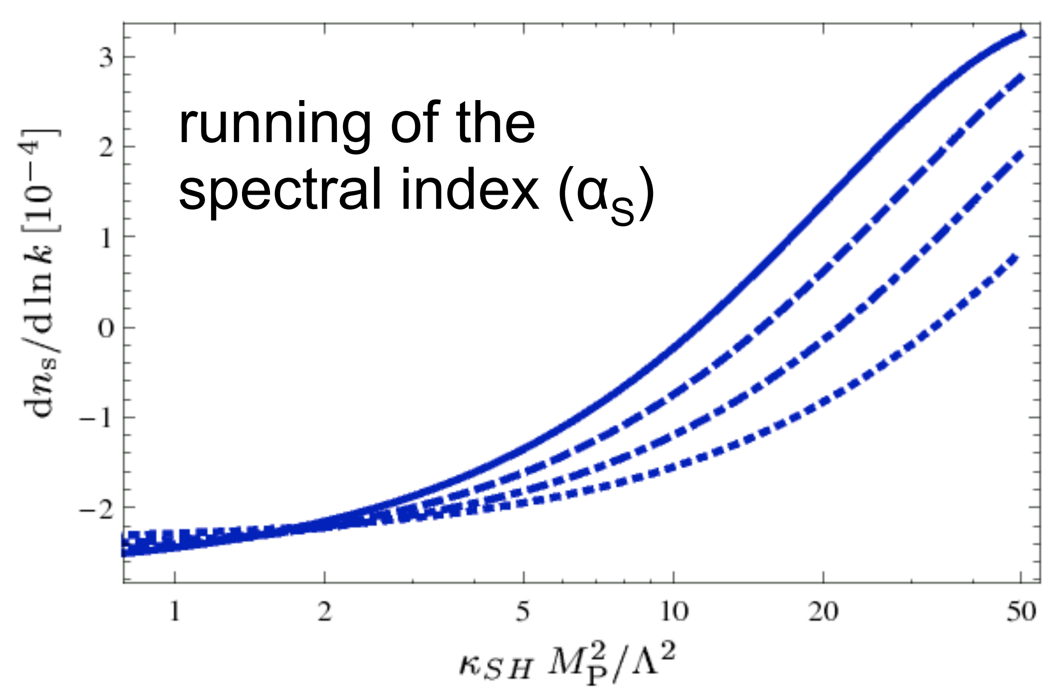
S.A., K. Dutta, P. M. Kostka ('09)

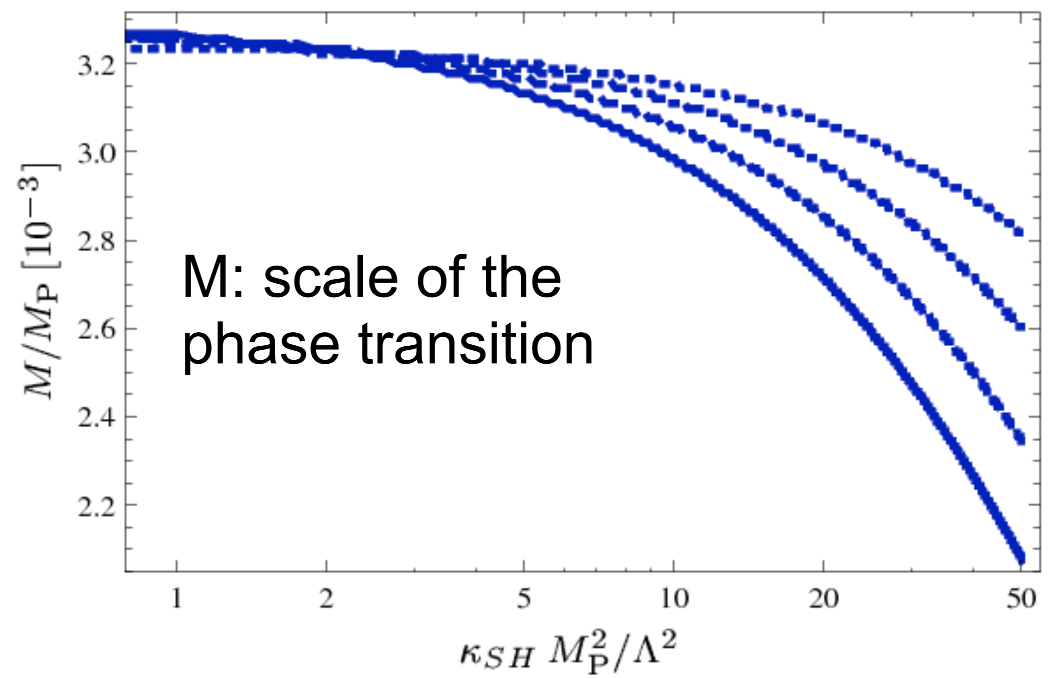

spectral index n_s


$r = A_T / A_S$

very small

(as typical for Hybrid-type models)


running of the spectral index (α_S)


M: scale of the phase transition

Example: Predictions in a toy model ...

Can the inflaton be a Gauge Non-Singlet?

S.A., Bastero-Gil, Baumann, Dutta, King, Kostka (‘10)

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Example: SO(10) GUTs

F_i in representation 16 of SO(10)

$\bar{F}$ in representation $\overline{16}$ of SO(10)

i = (1,...,4)

$$\mathbf{16}_i = \left(q_L \quad u_R^c \quad e_R^c \quad d_R^c \quad \ell_L \quad \nu_R^c\right)_i$$

S.A., Bastero-Gil, Baumann, Dutta, King, Kostka (‘10)

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✓ Many additional challenges for GNS inflation ... all resolved!

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- We discussed three recent developments ...

  - ✓ Heisenberg symmetry with stabilised modulus: New possible solution to the η-problem in SUGRA inflation
  - ✓ Tribrid Inflation: New class of models, very suitable for applying symmetry solutions to the η-problem
  - ✓ GNS (Tribrid) Inflaton in SUSY GUTs: Novel possibility that the inflaton field can be in a GUT matter rep., e.g. in 16 of SO(10)