Higgs Inflation, Quantum Smearing, and the Tensor to Scalar Ratio

Mansoor Ur Rehman

Mansoor Ur Rehman and Qaisar Shafi [arXiv:1003.5915 [astro-ph.CO]

Bartol Research Institute
Department of Physics and Astronomy
University of Delaware

Phenomenology 2010 Symposium
University of Wisconsin, Madison, Wisconsin
May 10, 2010

Outline

- Motivation
- Non-Supersymmetric Higgs Inflation
- Supersymmetric Higgs (Hybrid) Inflation
- Conclusions

Motivation

Higgs inflation can be interesting for a number of reasons:

- SM Higgs as inflation? I will not discuss this because of lack of time. In any case the subject is rather controversial.
- ϕ^2 and ϕ^4 inflationary potentials are limiting cases of non-supersymmetric Higgs potential.
- Supersymmetric version of the Higgs potential leads to very different predictions for the tensor to scalar ratio r (measure of primordial gravity waves).
- Last but not least PLANCK, as I will show, will test Higgs inflation models through measurement of the tensor to scalar ratio r.

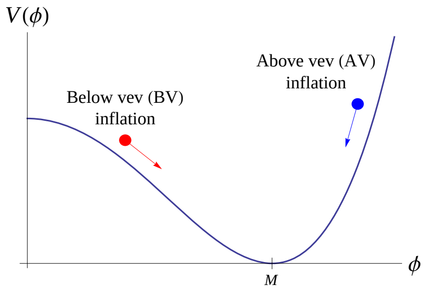
Tree Level Higgs Inflation

[Kallosh and Linde, 07; Rehman, Shafi and Wickman, 08]

- Consider the following Higgs Potential:

$$V(\phi) = V_0 \left[1 - \left(\frac{\phi}{M} \right)^2 \right]^2 \quad \longleftarrow \text{(tree level)}$$

Here ϕ is a gauge singlet field.

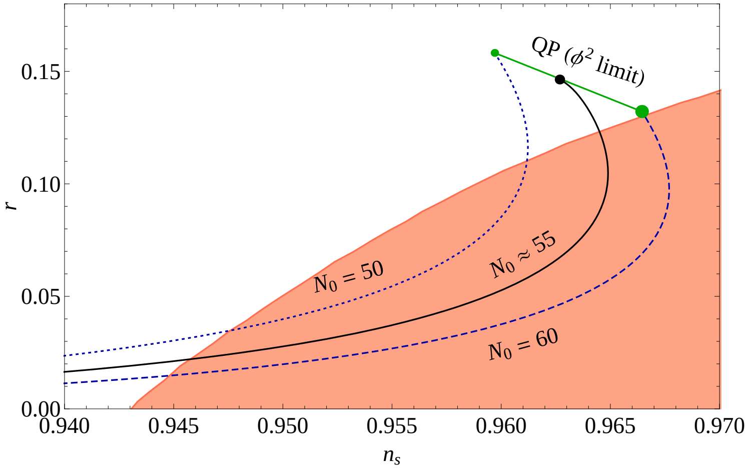


- WMAP data favors BV inflation.

Limiting Behavior of the Higgs Model

limit	$\phi \longrightarrow M$	$\phi \gg M$	$\phi \ll M$
model	quadratic inflation	quartic inflation	new inflation
V	$\frac{1}{2}m_\phi^2(\Delta\phi)^2$	$\left(\frac{V_0}{M^4}\right)\phi^4$	$V_0\left(1-2\left(\frac{\phi}{M}\right)^2\right)$
n_s	$1-\frac{2}{N_0}$	$1-\frac{3}{N_0}$	$1-\frac{2}{N_0}\ln\left(\frac{M}{\sqrt{2}\phi_0}\right)$
r	$4(1-n_s)$	$\frac{16}{3}(1-n_s)$	$8(1-n_s)e^{-N_0(1-n_s)}$

Tree Level Higgs Inflation



Radiative Corrections in Higgs Inflation

- Consider the following interaction of inflaton ϕ with some GUT symmetry breaking scalar boson Φ:

$$\mathcal{L}_{int} = \frac{\lambda_\Phi^2}{2}\,\phi^2\,\Phi^2$$

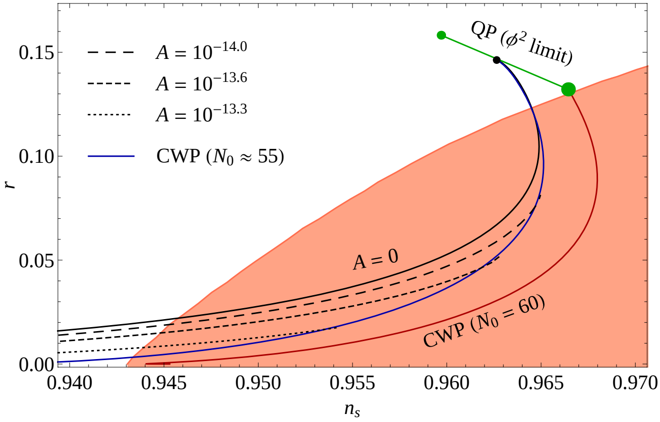
- Include Radiative Corrections (Quantum Smearing):

$$V = \left(\frac{m^2\,M^2}{4}\right)\,\left[1 - \left(\frac{\phi}{M}\right)^2\right]^2 + A\,\phi^4\,\left[\ln\left(\frac{\phi}{M}\right) - \frac{1}{4}\right] + \frac{A\,M^4}{4},$$

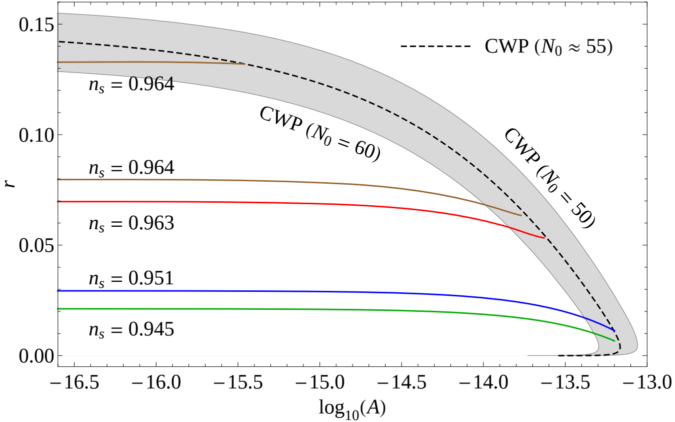
where $V(\phi = 0) \equiv V_0 = \frac{m^2\,M^2}{4} + \frac{A\,M^4}{4}$ and $A = \frac{\mathcal{N}\lambda_\Phi^4}{32\,\pi^2}$.

- Note that we can use 'Minkowski space' CW corrections provided the propagating fields have masses $\gg H$ (Hubble constant).

[Rehman and Shafi, 2010]

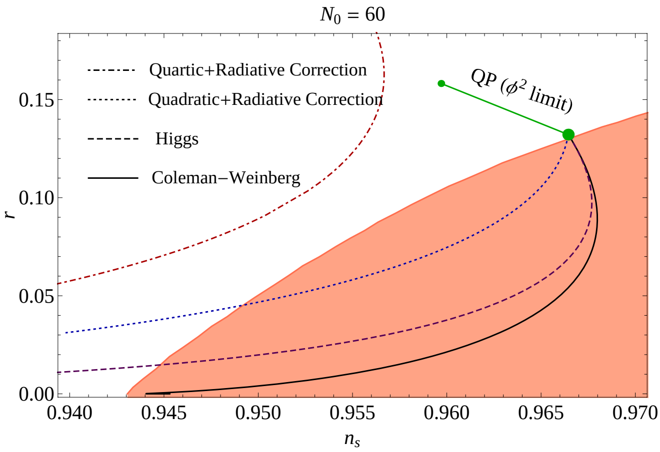


Note that $r \gtrsim 0.02$ if $n_s \gtrsim 0.96$. Thus, Planck will test Higgs inflation soon!

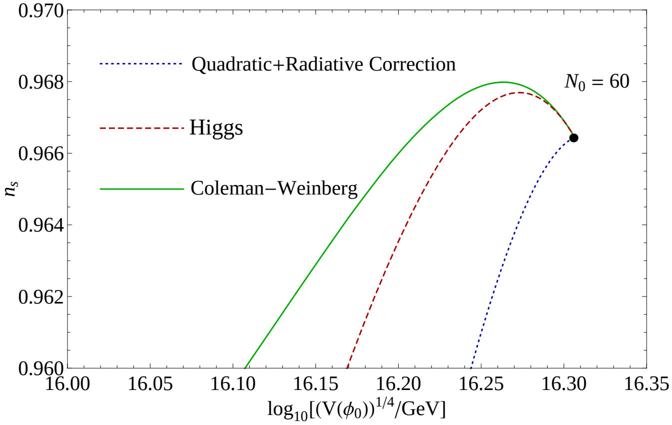


$$n_s \geq 0.96 \;\; \Rightarrow \;\; A \lesssim 10^{-13.5} \;\; \left(\lambda_\Phi \lesssim \frac{0.002}{\mathcal{N}^{1/4}}\right)$$

Quantum Smearing



Quantum Smearing



The vacuum energy scale during observable inflation is well below m_P. This implies that the quantum gravity effects are relatively unimportant here.

Supersymmetric Higgs (Hybrid) Inflation

[Dvali, Shafi, Schaefer; Copeland, Liddle, Lyth, Stewart, Wands '94]

[Senoguz, Shafi '04; Linde, Riotto '97]

- Attractive scenario in which inflation can be associated with symmetry breaking $G \longrightarrow H$.
- Simplest inflation model is based on the superpotential

$$W = \kappa\, S\, (\Phi\, \overline{\Phi} - M^2)$$

$S =$ gauge singlet superfield, $(\Phi\,, \overline{\Phi})$ belong to suitable representation of G

- Need $\Phi\,, \overline{\Phi}$ pair in order to preserve susy while breaking $G \longrightarrow H$ at scale $M \gg$ TeV, susy breaking scale.
- R-symmetry

$$\Phi\,\overline{\Phi} \to \Phi\,\overline{\Phi}, \;\; S \to e^{i\alpha}\, S, \;\; W \to e^{i\alpha}\, W$$

$\Rightarrow \quad W$ is a unique renormalizable superpotential

Susy Higgs (Hybrid) Inflation

- Some examples of gauge groups:

$$G = U(1)_{B-L}, \text{ (Supersymmetric superconductor)}$$

$$G = SU(5) \times U(1), \quad (\Phi = 10), \quad \text{(Flipped } SU(5))$$

$$G = 3_c \times 2_L \times 2_R \times 1_{B-L}, \; (\Phi = (1, 1, 2, +1))$$

$$G = 4_c \times 2_L \times 2_R, \; (\Phi = (\overline{4}, 1, 2)),$$

$$G = SO(10), \; (\Phi = 16)$$

Susy Higgs (Hybrid) Inflation

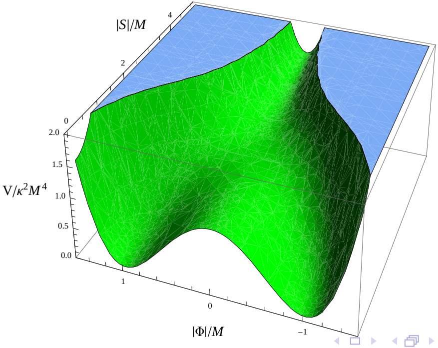
- Tree Level Potential

$$V_F = \kappa^2 \left(M^2 - |\Phi^2|\right)^2 + 2\kappa^2 |S|^2 |\Phi|^2$$

This is similar to a superconductor with S playing the role of temperature, and $\langle\overline{\Phi}\rangle$, $\langle\Phi\rangle$ are Cooper pairs.

- Susy vacua

$$|\langle\overline{\Phi}\rangle| = |\langle\Phi\rangle| = M, \ \langle S\rangle = 0$$



Susy Higgs (Hybrid) Inflation

Take into account radiative corrections (because during inflation $V \neq 0$ and susy is broken by $F_S = -\kappa\, M^2$)

- Mass splitting in $\Phi - \overline{\Phi}$

$$m_{\pm}^2 = \kappa^2\, S^2 \pm \kappa^2\, M^2, \quad m_F^2 = \kappa^2\, S^2$$

- One-loop radiative corrections

$$\Delta V_{\text{1loop}} = \frac{1}{64\pi^2} \text{Str}[\mathcal{M}^4(S)(\ln \frac{\mathcal{M}^2(S)}{Q^2} - \frac{3}{2})]$$

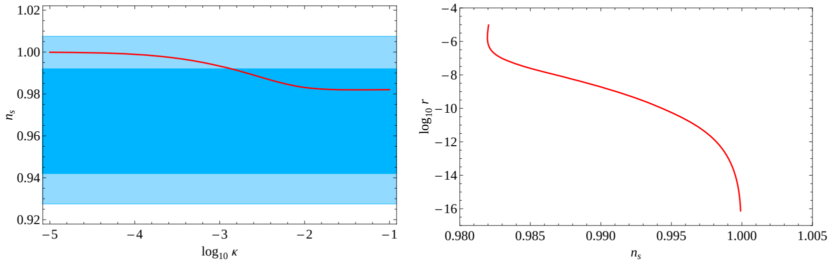
- In the inflationary valley $(\Phi = 0)$ with $|S| \gg M$

$$V \approx \kappa^2\, M^4 \left(1 + \frac{\kappa^2 \mathcal{N}}{8\pi^2} \ln(|S/M|)\right)$$

Susy Higgs (Hybrid) Inflation

[Dvali, Shafi, Schaefer '94]

Tree Level plus radiative corrections:



$$n_s \approx 1 - \frac{1}{N_0} \approx 0.98$$

$\delta T/T \propto (M/M_P)^2 \sim 10^{-5} \longrightarrow$ attractive scenario $(M \sim M_G)$

Full Story

[Senoguz, Shafi '04]

- Take into account sugra corrections, radiative corrections and soft susy breaking terms:

$$V \simeq \kappa^2 M^4 \left(1 + \left(\frac{M}{m_p}\right)^4 \frac{x^4}{2} + \frac{\kappa^2 \mathcal{N}}{8\pi^2} F(x) + a\left(\frac{m_{3/2} x}{\kappa M}\right) + \left(\frac{M_S x}{\kappa M}\right)^2\right),$$

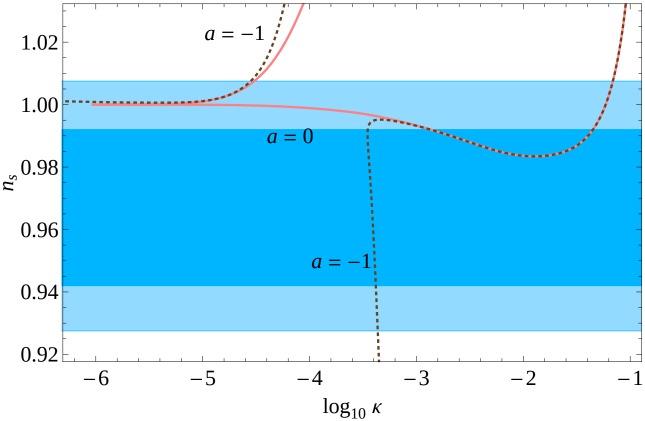
where $a = 2\,|2 - A|\cos[\arg S + \arg(2 - A)]$, $x = |S|/M$ and

$$F(x) = \frac{1}{4}\left(\left(x^4 + 1\right)\ln\frac{(x^4 - 1)}{x^4} + 2x^2 \ln\frac{x^2 + 1}{x^2 - 1} + 2\ln\frac{\kappa^2 M^2 x^2}{Q^2} - 3\right).$$

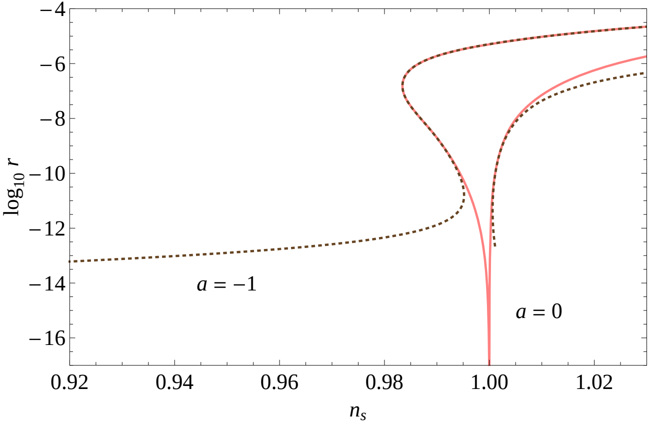
Note: No 'η problem' with minimal (canonical) Kähler potential !

Results

[Rehman, Shafi, Wickman, 2009]



Results



$r \lesssim 10^{-4}$ within 2-σ bounds of WMAP data

Conclusions

- One of the most important challenges is to find a “Standard Model of Inflationary Cosmology”.
- Radiative corrections are important in the context of precision cosmology.
- Non-supersymmetric GUT inflation models typically predict an ‘observable’ value for the tensor to scalar ratio r (≥ 0.02, for $n_s \geq 0.96$)
- Supersymmetric Higgs (hybrid) models by comparison predict ‘tiny’ values of r ($\lesssim 10^{-4}$).
- Results from PLANCK are eagerly awaited!