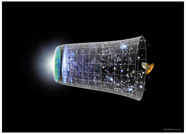
Observational signatures of Higgs inflation

Vera-Maria Enckell

University of Helsinki
Helsinki Institute of Physics

January 4th 2016

Background



- Higgs field an intriguing connection of cosmology and particle physics
- Non-minimal coupling to gravity as non-perturbative UV fixed point solution → Higgs a possible inflaton

- Correct interpolation of the Higgs potential from low SM energies to inflationary energies beyond today's theories

  → systematical studies of different outcomes of the model using combination of cosmological observations and particle physics data

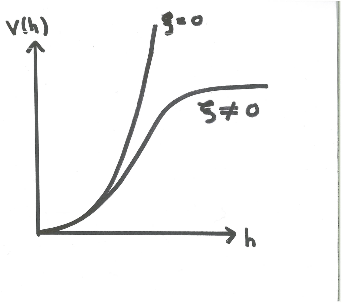
Inflation with SM Higgs

Pure SM Higgs pontetial too steep to inflate

The inclusion of non-minimal coupling [Bezrukov, Shaposhnikov 07]

$$\mathcal{L} = \frac{M_P^2}{2} R + \frac{\xi}{2} h^2 R + \mathcal{L}_{\mathrm{SM}}$$

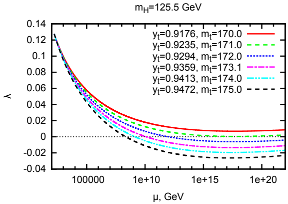
$$\to V \sim \frac{1}{4} \lambda \frac{h^4}{\left(1 + \xi \frac{h^2}{{M_P}^2}\right)^2}$$

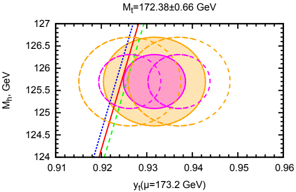


leads to flat potential below the Planck scale for $\xi \gg 1$

Effective Higgs potential: SM regime

SM vacuum metastable for the best fit values of m_h, m_t [see e.g. Degrassi et. al. 12]





- Higgs inflation needs either m_t 2-3 σ below the best fit or new physics?

Situation more complicated, the running $\lambda(\mu)$ affected by the gravitational interactions [Bezrukov, Rubio, Shaposhnikov 14]

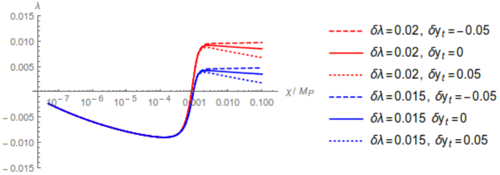
Effective Higgs potential: ambiguous extension to high energies

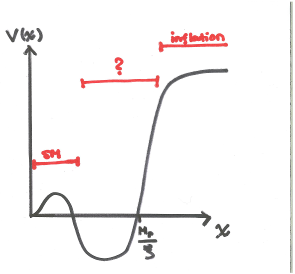
- Higgs inflation not renormalisable since gravity not renormalisable
- But becomes *effectively* renormalisable at low and high energy regimes

$$V(h) \simeq \frac{\lambda}{4} h^4 \, , \qquad h \ll M_P/\xi$$
$$V(h) \simeq \frac{\lambda}{4\xi^2} M_P^4 \, , \qquad h \gg M_P/\xi$$

- Interpolation between asymptotic regimes ambiguous, parameterised by jumps in coupling constants λ, y_t at scale M_p/ξ [Bezrukov, Rubio, Shaposhnikov 14]

Effective Higgs potential: ambiguous extension to high energies



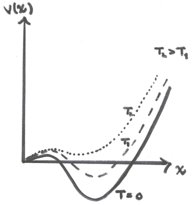


Aim:

> Find the parts of the parameter space $(m_h, m_t, \delta\lambda, \delta y_t, \xi)$ that lead to successful inflation according to both theoretical and observational constraints

Theoretical self-consistency and observational predictions

$$\lambda \rightarrow \lambda + \delta\lambda$$
$$y_t \rightarrow y_t + \delta y_t$$



1. Successful reheating

- The minimum should be lifted by thermal corrections, otherwise no reheating to the electroweak vacuum
- Problem of negative energy vacuum avoided by temperature corrections

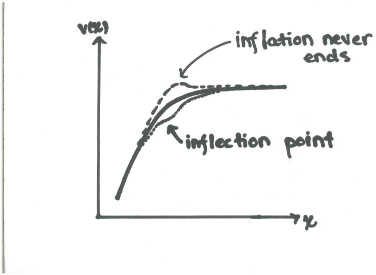
$$\Delta V_T = 1/24(m_W(\chi)^2 + m_Z(\chi)^2)T^2 - 1/48 m_t(\chi)^2)T^2 + ...$$

- Lower bound for $\delta\lambda$ from the requirement $\Delta V_T > |V_{\rm min}|$

Theoretical self-consistency and observational predictions

2. Successful inflation

- Inflation must end, $V' > 0 \Rightarrow \delta\lambda > \delta\lambda_{\text{min}}$
- Amplitude of scalar perturbations ($\mathcal{P}_\zeta \propto V^3/V'^2$) the observed one $2.2x10^{-9}$



Viable parameter space

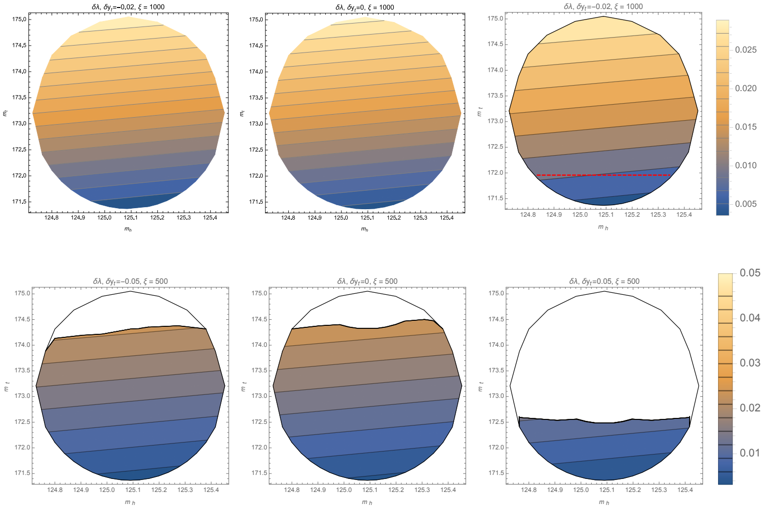


Figure : Values of $\delta\lambda$ which yield self-consistent reheating/inflation and the observed perturbation amplitude $\mathcal{P}_\zeta$. The white regions are ruled out either by reheating or never-ending inflation. The region under the dashed line allows for inflection points

Inflation at the inflection point

- For fine-tuned parameter values possible to have an inflection point $V' = V'' = 0$
- Predictions become completely dependent on $\delta\lambda$ and δy_t

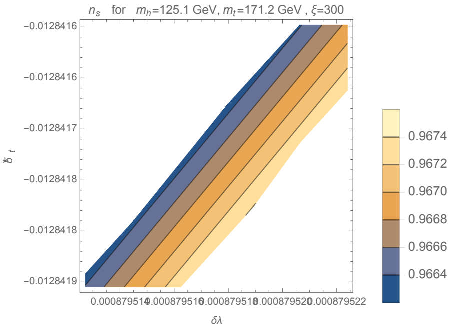


Figure : $n_s = 1 + 2\eta - 6\epsilon$, $\mathcal{P}_\zeta = \frac{1}{2\epsilon}\left(\frac{H/M_P}{2\pi}\right)^2$

Summary

- Predictions of the Higgs inflation not uniquely fixed by the measured SM parameters
- Low and high energy regimes not connected by renormalisable physics $\rightarrow$ inclusion of effective jumps in couplings $\delta\lambda, \delta y_t$
- Predictions of Higgs inflation generally robust but viable values of $\delta\lambda$ and δy_t non-trivially constrained by successfull reheating/inflation
- Inflection point inflation possible for fine-tuned parameter values, predictions completely dependent on $\delta\lambda$ and δy_t