Cosmological implications of Higgs field fluctuations during inflation

A.V. Grobov
R.V. Konoplich
S.G. Rubin

National Research Nuclear University MEPhI

Moscow, 2015

Introduction

- In the Standard model the renormalisation group improved effective potential develops an instability (an additional minimum and maximum) at energies $\gtrsim 10^{10}$ GeV.
- The vacuum instability can become relevant at the inflationary stage when large fluctuations can drag to the false vacuum.
- We consider the standard model of chaotic inflation with the inflaton ϕ and quadratic potential $V_{inf}(\phi)$, and Hubble parameter

$$H \approx 1.1 \cdot 10^{14} \sqrt{r/0.2}\ \text{GeV} \qquad (1)$$

Introduction

- In the Standard model the renormalisation group improved effective potential develops an instability (an additional minimum and maximum) at energies $\gtrsim 10^{10}$ GeV.
- The vacuum instability can become relevant at the inflationary stage when large fluctuations can drag to the false vacuum.
- We consider the standard model of chaotic inflation with the inflaton ϕ and quadratic potential $V_{inf}(\phi)$, and Hubble parameter

$$H \approx 1.1 \cdot 10^{14} \sqrt{r/0.2}\ \text{GeV} \tag{1}$$

Introduction

- In the Standard model the renormalisation group improved effective potential develops an instability (an additional minimum and maximum) at energies $\gtrsim 10^{10}$ GeV.
- The vacuum instability can become relevant at the inflationary stage when large fluctuations can drag to the false vacuum.
- We consider the standard model of chaotic inflation with the inflaton ϕ and quadratic potential $V_{inf}(\phi)$, and Hubble parameter

$$H \approx 1.1 \cdot 10^{14} \sqrt{r/0.2}\ \text{GeV} \tag{1}$$

Instability scale

The effective Higgs field potential is

$$V(h) = \frac{1}{4}\lambda(h)h^4 \tag{2}$$

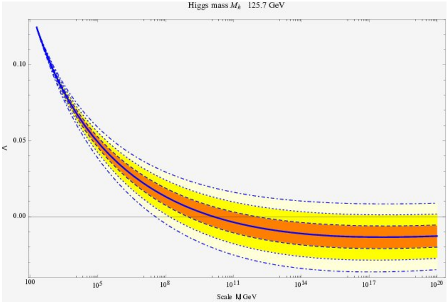

Рис. : Higgs self-coupling λ, obtained in the framework of $\overline{MS}$ renormalization scheme for central values $M_h = 125.7$ GeV and $m_t = 173.34 \pm 0.82$ GeV. Deviations for $m_t \pm 1\sigma$, $m_t \pm 2\sigma$, $m_t \pm 3\sigma$ are shown.

The instability scale Λ_I, defined as the zero point of the running coupling λ

Fluctuations during inflation

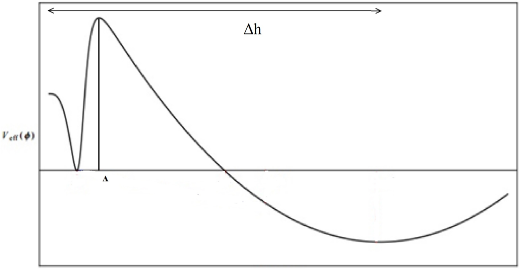

Рис. : Sketch of potential

In a time $t \sim H^{-1}$ the field fluctuates by $\delta h \sim H/2\pi$ (1 e-fold). For the number of e-folds $N_V = 60$ the average deviation of the Higgs field from its initial value during the time of inflation is about $\Delta h = \sqrt{N_V} H/2\pi \sim H \simeq 10^{14}$ GeV

Fluctuations during inflation

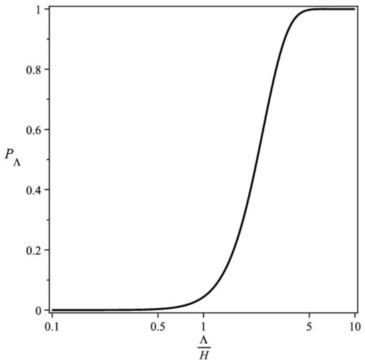

Рис. : Probability of landing in the electroweak vacuum at the end of inflation.

The probability at the time $t_{end} = H^{-1} N_V$ with $N_V = 60$, when inflation has just finished.

$$P_\Lambda(t_{end}) = \left(1 - e^{-\frac{2\pi^2\Lambda^2}{H^2 N_V}} - \frac{2\pi^2\Lambda^2}{H^2 N_V} e^{-\frac{2\pi^2\Lambda^2}{H^2 N_V}}\right). \qquad (3)$$

Case $\Lambda > H$

The presence of regions with vacuum v_2 can lead to observable effects such as

- De Sitter stage continuing in these regions even after the end of inflation.
- Elementary particle masses being proportional to the vacuum expectation v_2.
- These regions shrink rapidly releasing energy. This could result in local inhomogeneities of the cosmic microwave background radiation be observed as hot objects with non-standard chemical composition.

Case $\Lambda > H$

The presence of regions with vacuum v_2 can lead to observable effects such as

- De Sitter stage continuing in these regions even after the end of inflation.
- Elementary particle masses being proportional to the vacuum expectation v_2.
- These regions shrink rapidly releasing energy. This could result in local inhomogeneities of the cosmic microwave background radiation be observed as hot objects with non-standard chemical composition.

Case $\Lambda > H$

The presence of regions with vacuum v_2 can lead to observable effects such as

- De Sitter stage continuing in these regions even after the end of inflation.
- Elementary particle masses being proportional to the vacuum expectation v_2.
- These regions shrink rapidly releasing energy. This could result in local inhomogeneities of the cosmic microwave background radiation be observed as hot objects with non-standard chemical composition.

Conclusion

- In the case of $\Lambda < H$ the universe lands in vacuum state which differs from the electroweak one.
- The probability of tunneling to the electroweak vacuum is suppressed by the width of the potential barrier.
- additional maximum of the Higgs potential should be located at an energy scale above 10^{14} GeV; otherwise a universe like ours is extremely unlikely.

- Thank you!

Conclusion

- In the case of $\Lambda < H$ the universe lands in vacuum state which differs from the electroweak one.
- The probability of tunneling to the electroweak vacuum is suppressed by the width of the potential barrier.
- additional maximum of the Higgs potential should be located at an energy scale above 10^{14} GeV; otherwise a universe like ours is extremely unlikely.

- Thank you!

Conclusion

- In the case of $\Lambda < H$ the universe lands in vacuum state which differs from the electroweak one.
- The probability of tunneling to the electroweak vacuum is suppressed by the width of the potential barrier.
- additional maximum of the Higgs potential should be located at an energy scale above 10^{14} GeV; otherwise a universe like ours is extremely unlikely.
- Thank you!

Conclusion

- In the case of $\Lambda < H$ the universe lands in vacuum state which differs from the electroweak one.
- The probability of tunneling to the electroweak vacuum is suppressed by the width of the potential barrier.
- additional maximum of the Higgs potential should be located at an energy scale above 10^{14} GeV; otherwise a universe like ours is extremely unlikely.

  - Thank you!