

Cosmological constraint
on the mass of Higgs boson
in the Standard Model
minimally coupled to the gravity

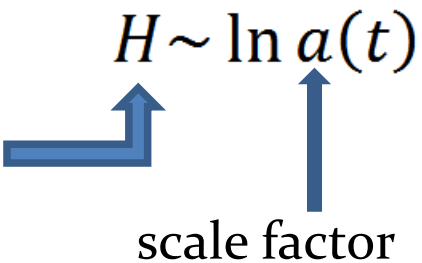
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Introduction

- Scalar fields: inflation

Hubble constant $H \sim \ln a(t)$
scale factor



(zero curvature of space, homogeneity, ...)

- Fluctuations of scalar field:
 1. Non-homogeneity of matter,
Large scale structure of Universe (LSS)
 2. Anisotropy of cosmic microwave background radiation
(CMBR)

- Inflaton:

$$m \sim 10^{13} \text{ GeV}, \quad \lambda \leq 10^{-13}, \quad v \geq 10 M_{Pl}$$

- Higgs boson:

$$114 \text{ GeV} < m_H < 185 \text{ GeV}, \quad v \approx 246 \text{ GeV},$$

The Higgs boson is not successful for the generation of observed inflation

Question:

Why does the Higgs boson not generate the inflation?
(problem of the preference for the inflaton)

Answer: ***if the mass of Higgs boson exceeds a threshold value, the Higgs scalar is not able to cause the inflation***

Inflation (Higgs scalar)

- Potential $V = \lambda(\phi^2 - \cancel{v^2})^2/4$

- Scaling variables $\kappa^2 = 8\pi G$

$$x = \frac{\kappa}{\sqrt{6}} \frac{\dot{\phi}}{H}, \quad y = \sqrt[4]{\frac{\lambda}{12}} \frac{\kappa \phi}{\sqrt{\kappa H}},$$

- Parameter $z = \frac{\sqrt[4]{3\lambda}}{\sqrt{\kappa H}},$

Method:

L. A. Urena-Lopez and M. J. Reyes-Ibarra,
Int. J. Mod. Phys. D **18**, 621 (2009)
[arXiv:0709.3996 [astro-ph]]

- Equations of motion

$$N = \ln a_{\text{end}} - \ln a$$

$$x' = -3x^3 + 3x + 2y^3 z, \quad y' = -\frac{3}{2} x^2 y - xz,$$

- Parametric attractor $x'=y'=0$ $x(z), y(z)$

- Driftage $z' = -\frac{3}{2} x^2 z$

- Criteria of stability (the end of inflation)

$$2\pi G H^2 = \lambda.$$

- $\lambda \sim 1 \Rightarrow H \sim M_{Pl}$ (inflation is not possible) **Linde(1982)**

Quantum gravity fluctuations in cosmology

- *What is the curvature of de Sitter space, when quantum effects of gravity become essential?*

- *Action*
$$S = \frac{1}{6GH^2} \qquad \delta S = 2\pi$$

- *Number of waves*
$$\frac{S}{2\pi} = 1 \implies \lambda = \frac{1}{6}$$

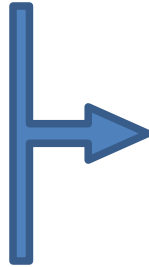
- *Confidence level*
$$\chi^2 = 2n$$

Cosmological constraint: tree approximation

$$m^2 = 2\lambda v^2$$

$$m > \frac{v}{\sqrt{3}} = 142.3 \text{ GeV}$$

Renormalization group (2 loops)

- Scale $\lambda(\mu), \mu = ?$
 1. Field $\mu = \varphi$
 2. Energy density $\rho = \mu^4$
 3. Virtuality $\mu^2 = m^2 - p^2$

$3 \times 10^{18} \text{ GeV}$
- *Initial data of evolution*
 - $m_Z = 91.1873 \pm 0.0021 \text{ GeV},$
 - $m_t = 170.9 \pm 1.9 \text{ GeV},$
 - $\alpha_{\text{em}}^{-1}(m_Z) = 127.906 \pm 0.019,$
 - $\alpha_s(m_Z) = 0.1187 \pm 0.0020,$
 - $\sin^2 \theta_W = 0.2312 \pm 0.002,$

- mass

$$\lambda(m_t) = \frac{m_H^2}{2v^2} (1 + \Delta_H),$$

$$h_t(m_t) = \frac{\sqrt{2}}{v} m_t (1 + \Delta_t),$$

← corrections

- Result**

$$m_H^{min} = 150 + 0.28 \cdot \ln \frac{10^{18}}{\mu} - 0.19 \cdot \frac{\alpha_s - 0.1187}{0.002} + 2 \cdot \frac{m_t - 171}{2} \pm 2 \text{ GeV}$$

↑
loops

Conclusion

- *The Higgs scalar (min.SM)*
is not able to produce any inflation of Universe,
if it is heavier than

$$m_H^{\min} = 150 \pm 3 \text{ GeV}$$

- *Parametric attractor in the inflation*
- *Border of quantum gravity fluctuations in cosmology*
- *Renormalization group*