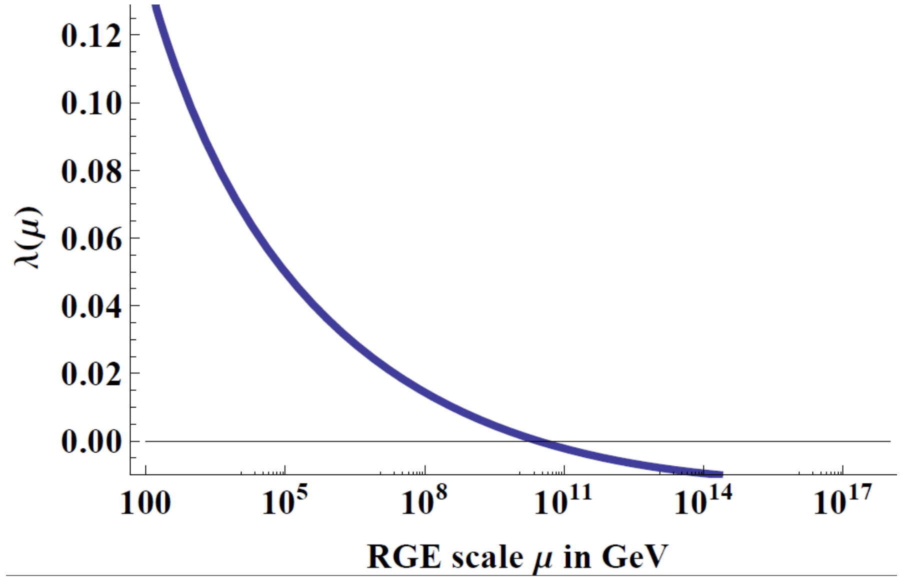
Higgs Inflation in Light of BICEP2

Jessica Cook

Arizona State University

SM as in has an instability around 10^(11) GeV.

Higgs potential becomes negative, develops minimum much deeper than electroweak minimum.



And before BICEP this was considered metastable. Because if you calculate the tunneling rate into the higher scale vacuum, you get time scale larger than age of the universe.

- If BICEP2's result is correct, picture changes
- Higgs field would have had vacuum fluctuations of order H (Hubble parameter during inflation)
- BICEP2 predicts H ≈ 10^{14} GeV
- This is both order of magnitudes larger than the instability scale (10^{11} GeV), and the max height of the Higgs potential (5×10^{10}GeV).
- Multiple papers recently have talked about how unlikely if no new physics in SM, that we would have ended up in electroweak minimum
- So some amount of new physics missing from Higgs potential, and need something that has a sizable effect, and must kick in before the instability scale 10^{11}GeV

Since need to modify Higgs potential anyway

Worth asking if we can modify it in such a way to make the Higgs the inflaton.

Most models of Higgs inflation used a non-minimal gravitational coupling $\mathcal{L} \to -\xi R H^\dagger H$ to flatten out the potential enough at high scales to get inflation.

But almost always leads to very small tensor production

Considering BICEP2, still possible to get non-minimal Higgs inflation, but forced into region of parameter space, highly sensitive to changes in Higgs and top mass => favors a top mass = 171.6 GeV

- Alternatives...
- One of the things known to be missing is a method of generating neutrino masses
- Want to ask if the type II seesaw model could modify the Higgs potential enough to solve the instability, and allow the Higgs to work as the inflaton.

- Add a new complex Higgs triplet, Δ charged under SU(2)xU(1)
- Gives neutrinos a mass through

$$\frac{1}{\sqrt{2}} Y_{\Delta,ij} \bar{l}^c_{Li} i\sigma_2 \Delta l_{Lj} + h.c.$$

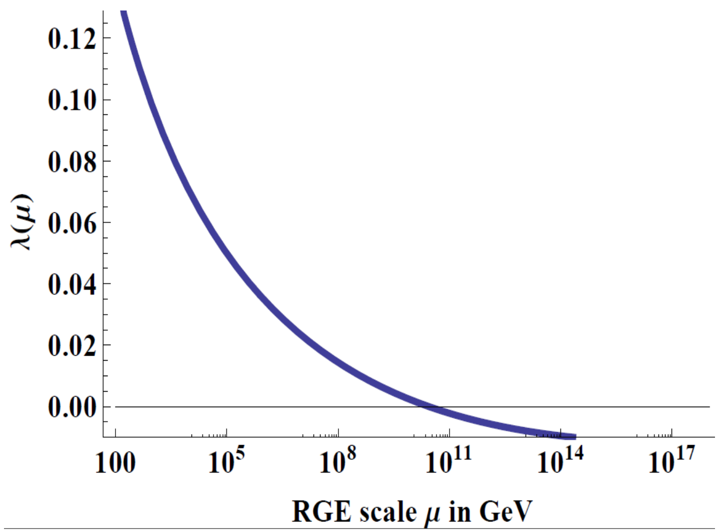
- When Δ gets a vev, neutrinos pick up a mass, but not the charged leptons.
- Assume $\langle \Delta_0 \rangle \ll v$ so neutrinos are light.
- Neutrinos get a Majorana mass term this way.

- Δ couples to SM Higgs, adds terms which are always positive to β_λ so helps Higgs vacuum stability
- Three renormalizable terms that couple delta to Higgs at tree level:

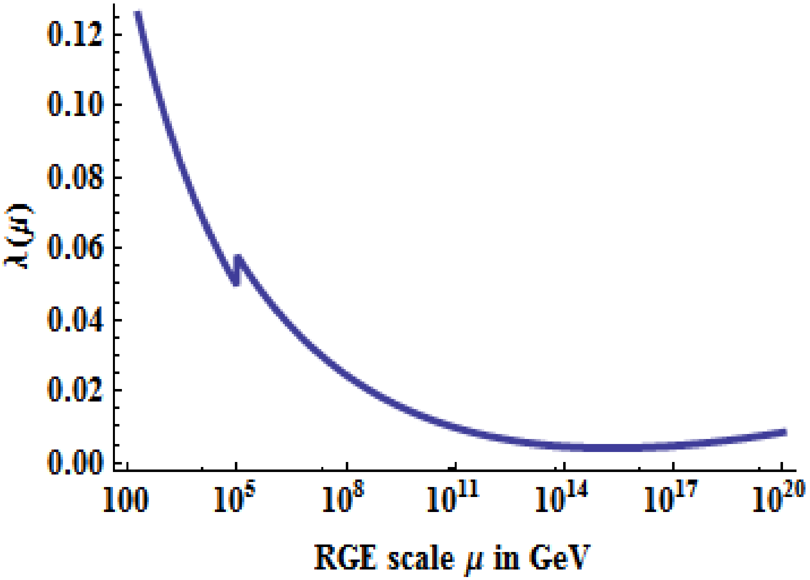
$$-\lambda_4(\phi^\dagger\phi)tr(\Delta^\dagger\Delta)-\lambda_5\phi^\dagger[\Delta^\dagger,\Delta]\phi-[\frac{\lambda_6}{\sqrt{2}}\phi^T i\sigma_2\Delta^\dagger\phi+h.c.]$$

- Each one of these couplings aides Higgs stability

Shown by [Archil Kobakhidze and Alexander Spencer-Smith] that you can tune the seesaw parameters to get absolute stability of the Higgs vacuum.



SM



Seesaw

$M_\Delta = 10^5$ GeV

$\lambda_6(M_\Delta) = .13\ M_\Delta$

$\lambda_4(M_\Delta) = \lambda_5(M_\Delta) = \lambda(M_\Delta)$

SM Higgs potential has large negative values at inflationary scales, adding seesaw couplings can make it positive =>

question of tuning things to make the potential positive but flat enough to get inflation.

Generally φ^4 potentials are too steep to inflaton on, but with renormalization group corrections, not exactly a φ^4 potential.

Inflate on V_{eff}

$$V_{eff} = \frac{\lambda_{eff}(h)}{4} h^4$$

To get inflation to work, BICEP2 tells us the scale of inflation, $V_{in} \approx 2 \times 10^{16}$ GeV so for φ^4 need $\lambda \approx 10^{-13}$ at the end of inflation.

Also need the potential to not be too steep. Know φ^4 generally too steep for inflaton, so need λ larger at the beginning of inflation than the end, to flatten out the potential