

NEW HIGGS INFLATION

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Lowering the
curvature during
Inflation

New Higgs
Inflation

Uniqueness

Unitarity

New Natural
Inflation

Conclusions

Lowering the curvature during Inflation

In Standard GR Higgs inflation fails because of Quantum Gravity:

Lowering the curvature during Inflation

New Higgs Inflation

Uniqueness

Unitarity

New Natural Inflation

Conclusions

Lowering the curvature during Inflation

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$$R \sim H^2 \propto V(\Phi) \propto \Phi^4$$

Lowering the curvature during Inflation

New Higgs Inflation

Uniqueness

Unitarity

New Natural Inflation

Conclusions

Lowering the curvature during Inflation

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Lowering the curvature during Inflation

New Higgs Inflation

Uniqueness

Unitarity

New Natural Inflation

Conclusions

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$$\epsilon = -\frac{\dot{H}}{H^2} \propto \frac{\dot{\Phi}^2}{H^2 M_p^2} \sim \frac{M_p^2}{\Phi^2} \ll 1$$



$$R \gg M_p^2$$

Lowering the curvature during Inflation

New Higgs Inflation

Uniqueness

Unitarity

New Natural Inflation

Conclusions

Lowering the curvature during Inflation

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Solution: **Increase the friction!**

Lowering the curvature during Inflation

New Higgs Inflation

Uniqueness

Unitarity

New Natural Inflation

Conclusions

New Higgs Inflation

How to increase the friction:

Lowering the curvature during Inflation

New Higgs Inflation

Uniqueness

Unitarity

New Natural Inflation

Conclusions

New Higgs Inflation

How to increase the friction:

if $\dot{\phi} \rightarrow \Omega^2 \dot{\phi}$ with $\Omega \gg 1$

Lowering the
curvature during
Inflation

New Higgs
Inflation

Uniqueness

Unitarity

New Natural
Inflation

Conclusions

New Higgs Inflation

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Lowering the
curvature during
Inflation

New Higgs
Inflation

Uniqueness

Unitarity

New Natural
Inflation

Conclusions

New Higgs Inflation

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Lowering the curvature during Inflation

New Higgs Inflation

Uniqueness

Unitarity

New Natural Inflation

Conclusions

New Higgs Inflation

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Quantum Gravity regime is avoided during Inflation!

Lowering the curvature during Inflation

New Higgs Inflation

Uniqueness

Unitarity

New Natural Inflation

Conclusions

During Inflation H is “large” so we may construct

$$\Omega^2 = \omega^2 H^2 \sim \omega^2 G^{tt}$$

(where $G^{\alpha\beta}$ is the Einstein tensor)

Lowering the
curvature during
Inflation

New Higgs
Inflation

Uniqueness

Unitarity

New Natural
Inflation

Conclusions

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$$g^{\alpha\beta} \partial_\alpha \Phi \partial_\beta \Phi \rightarrow (g^{\alpha\beta} - \omega^2 G^{\alpha\beta}) \partial_\alpha \Phi \partial_\beta \Phi$$

Lowering the curvature during Inflation

New Higgs Inflation

Uniqueness

Unitarity

New Natural Inflation

Conclusions

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This defines the “New Higgs Inflation” Lagrangian:

$$S = \int d^4x \sqrt{-g} \left[\frac{R}{2\kappa^2} - \frac{1}{2} (g^{\alpha\beta} - \omega^2 G^{\alpha\beta}) \partial_\alpha \Phi \partial_\beta \Phi - \frac{\lambda}{4} \Phi^4 \right]$$

Lowering the curvature during Inflation

New Higgs Inflation

Uniqueness

Unitarity

New Natural Inflation

Conclusions

Uniqueness

We found a realization of the "New Higgs Inflation" idea
Is this unique?

Lowering the
curvature during
Inflation

New Higgs
Inflation

Uniqueness

Unitarity

New Natural
Inflation

Conclusions

Uniqueness

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The unique action is the **New Higgs Inflation** action!!!

Unitarity

Does the non-renormalizable operator

$$I = \omega^2 G^{\alpha\beta} \partial_\alpha \Phi \partial_\beta \Phi$$

violates unitarity during Inflation since $\omega^2 H^2 \gg 1$?

Lowering the
curvature during
Inflation

New Higgs
Inflation

Uniqueness

Unitarity

New Natural
Inflation

Conclusions

Unitarity

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Lowering the
curvature during
Inflation

New Higgs
Inflation

Uniqueness

Unitarity

New Natural
Inflation

Conclusions

Unitarity

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Lowering the
curvature during
Inflation

New Higgs
Inflation

Uniqueness

Unitarity

New Natural
Inflation

Conclusions

Unitarity

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- Expand the fields at linear level
- Canonically normalize the Higgs: $\Phi = \Phi_0 + \frac{1}{\sqrt{3}\omega H} \phi$
(the non-standard normalization comes from $\omega^2 G^{tt} \dot{\phi}^2$)

Lowering the curvature during Inflation

New Higgs Inflation

Uniqueness

Unitarity

New Natural Inflation

Conclusions

Unitarity

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Lowering the curvature during Inflation

New Higgs Inflation

Uniqueness

Unitarity

New Natural Inflation

Conclusions

Unitarity

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- Canonically Normalize the metric: $g_{\mu\nu} = g_{\mu\nu}^0 + \frac{1}{M_p} h_{\mu\nu}$
- Read out the scale (Λ) in which $I \sim \mathcal{O}(1)$:
 $\Lambda(H) \sim (M_p H^2)^{1/3} \gg R \sim H^2$ because $H \ll M_p$

Lowering the curvature during Inflation

New Higgs Inflation

Uniqueness

Unitarity

New Natural Inflation

Conclusions

Unitarity

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Unitarity is not violated up to the Quantum Gravity scales!!!!

Lowering the curvature during Inflation

New Higgs Inflation

Uniqueness

Unitarity

New Natural Inflation

Conclusions

Natural Inflation

- In large field Inflation $\Phi \gg M_p \Rightarrow$ we cannot trust the tree-level potential
- Suppose some global symmetry is broken at energies $f > \text{TeV}$ (like in the QCD axion case)

Lowering the curvature during Inflation

New Higgs Inflation

Uniqueness

Unitarity

New Natural Inflation

Conclusions

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- Suppose some global symmetry is broken at energies $f > \text{TeV}$ (like in the QCD axion case)
- a Pseudo Nambu-Goldston Boson Φ is produced

$$V(\Phi) = 2\Lambda^4 \sin^2\left(\frac{\Phi}{f}\right) \simeq 2\Lambda^4 \left(1 - \frac{\Phi^2}{4f^2}\right)$$

protected by global shift symmetry $\Phi \rightarrow \Phi + c$ at $\Lambda \rightarrow 0$

Lowering the curvature during Inflation

New Higgs Inflation

Uniqueness

Unitarity

New Natural Inflation

Conclusions

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- If $\Lambda \sim 10^{16}$ GeV (GUT scale), Inflation is produced with

$$n_s - 1 \propto \epsilon \simeq -\frac{M_p^2}{8\pi f^2}$$

Lowering the curvature during Inflation

New Higgs Inflation

Uniqueness

Unitarity

New Natural Inflation

Conclusions

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- so $n_s \leq 1 \rightarrow f > M_p \Rightarrow$ the model cannot be trusted!

Lowering the curvature during Inflation

New Higgs Inflation

Uniqueness

Unitarity

New Natural Inflation

Conclusions

Resolution

Once again we can increase the friction so that

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Lowering the curvature during Inflation

New Higgs Inflation

Uniqueness

Unitarity

New Natural Inflation

Conclusions

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Then for large enough Ω , $f \ll M_p$!!!!

The model is Natural!!!

(i.e. no UV modifications of the potential)

Lowering the
curvature during
Inflation

New Higgs
Inflation

Uniqueness

Unitarity

New Natural
Inflation

Conclusions

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Lowering the curvature during Inflation

New Higgs Inflation

Uniqueness

Unitarity

New Natural Inflation

Conclusions

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Lowering the curvature during Inflation

New Higgs Inflation

Uniqueness

Unitarity

New Natural Inflation

Conclusions

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- *Is invariant* under the global unbroken symmetry
 $\Phi \rightarrow \Phi + c$

Lowering the curvature during Inflation

New Higgs Inflation

Uniqueness

Unitarity

New Natural Inflation

Conclusions

Conclusions

Lowering the
curvature during
Inflation

New Higgs
Inflation

Uniqueness

Unitarity

New Natural
Inflation

Conclusions

Conclusions

- By increasing the friction **Inflation** can be obtained with the Standard Model Higgs Boson without unitarity violation

Lowering the curvature during Inflation

New Higgs Inflation

Uniqueness

Unitarity

New Natural Inflation

Conclusions

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Lowering the curvature during Inflation

New Higgs Inflation

Uniqueness

Unitarity

New Natural Inflation

Conclusions

Conclusions

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Lowering the curvature during Inflation

New Higgs Inflation

Uniqueness

Unitarity

New Natural Inflation

Conclusions

Conclusions

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Lowering the curvature during Inflation

New Higgs Inflation

Uniqueness

Unitarity

New Natural Inflation

Conclusions

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- New proposal: small field inflation with Nambu-Goldston Boson → New Natural Inflation

Lowering the curvature during Inflation

New Higgs Inflation

Uniqueness

Unitarity

New Natural Inflation

Conclusions