Cosmological perturbations in the UV-protected inflation

Yuki Watanabe

Ludwig-Maximilians-University, Munich, Germany

Based on: Cristiano Germani, Gerasimos Rigopoulos, & Y. W.
in preparation

PONT Avignon, 18th April 2011

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Q: Do we know any scalar field?

Higgs Boson!

The failure of Higgs boson in Inflation:

$$V(\Phi) \simeq \lambda \Phi^4$$
$$H = \dot{a}/a \simeq const \text{ (almost de Sitter)}$$
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$R \gg M_p^2$ for the Standard Model value of $\lambda \sim 10^{-1}$

Inflation happens during the Quantum Gravity regime!!

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$$\frac{M_p^2}{\mu^4} \ll R \ll M_p^2$$

Solution: $3\mu H \dot{\Phi} \simeq -V'$ Increase the friction!

New Higgs Inflation

[Germani & Kehagias 2010]

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$$\boxed{\text{Quantum Gravity regime is avoided during Inflation!}}$$

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To form eventually Galaxies, the friction should only be efficient at high energies:

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If $H \gg M$ the scalar field clock is frozen w.r.t. the observer and friction is enhanced.

Gravitationally Enhanced Friction: Realization

In order to realize covariantly the enhanced friction, we promote the rescaling to all coords.

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The enhanced friction is covariantly realized by shifting the kinetic action

$$g^{\mu\nu}\partial_\mu\Phi\partial_\nu\Phi \to \left(g^{\mu\nu} - \frac{G^{\mu\nu}}{M^2}\right)\partial_\mu\Phi\partial_\nu\Phi$$

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- Makes harder for the scalar field to roll down the potential!

UV Protected Inflation

[Germani & Kehagias 2011]

In large field scenarios

$\Phi \gg \Lambda_{cut-off} \leftarrow$ not only M_p!

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In small field scenarios ($\Phi \ll \Lambda_{cut-off}$) there is no problem!

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- a Pseudo Nambu-Goldstone Boson Φ is produced with a potential at one loop (chiral anomaly)

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

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- so $n_s - 1 \simeq -0.04 \to f > M_p$
  $\Rightarrow$ the model may not be trusted!

Resolution

Once again we can increase the friction so that

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- *Does not* introduce new degrees of freedom
- *Is invariant* under the global unbroken symmetry $\Phi \to \Phi + c$

What about the “eta” problem?

QG does not like global symmetries so that

$$V \to V \times (1 + c\frac{\phi^2}{M_p^2} + \ldots)$$

Then

$$\eta_{qg} = \frac{V''}{3V} M_p^2 \simeq \eta + c\frac{2}{3} \geq 1 \text{ , if } c \sim \mathcal{O}(1)!$$

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Again the increment of friction solves the problem as

$$\boxed{\eta \rightarrow \frac{\eta}{\mu} \Rightarrow c_{eff} = \frac{c}{\mu} \ll 1}$$

Cosmological perturbations in GEF

ADM form

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- $N = \frac{\Gamma}{H}\dot{\zeta}$, $N^i = -\frac{\Gamma}{H}\partial_i\zeta + \frac{\Sigma}{H^2}\partial_i\partial^{-2}\dot{\zeta}$
- $\Gamma(\dot{\Phi}, H, M) \simeq 1 + \epsilon$, $\Sigma(\dot{\Phi}, H, M) \simeq \mathcal{O}(\epsilon)$ for $H \gg M$

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Matching with the best fit WMAP 7-years

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Since the new non-linear interaction and $c_s^2 < 1$, any Non-Gaussianity?

Red tilt in UV Protected Inflation

- $n_s - 1 \simeq -6\epsilon + \frac{2}{3}\frac{M_p^2 V''}{V}\frac{M^2}{H^2} < 0 \Rightarrow$ Red spectrum!

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$$\boxed{\frac{\Lambda^2}{M_p^2} \sim 10^{-4}\frac{\Phi_0}{f}, \; \frac{M^2}{H^2} \sim 10\frac{f^2}{M_p^2} \; \text{(pNGB)}}$$

- Consistent with the theoretical hierarchy of scales: $M_p^4 \gg \Lambda^4 \gg M^2 M_p^2, \; \frac{M M_p}{\Lambda^2} \ll \frac{f}{M_p} \ll 1$

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- Additional data to fix?

Preliminary: Non-Gaussianity in GEF

$$L_3 = \epsilon^2 [a C_1 M_p^2 \zeta (\partial_i \zeta)^2 + a C_2 M_p \dot{\zeta} (\partial_i \zeta)^2 + a^3 C_3 M_p^2 \zeta \dot{\zeta}^2 + a^3 C_4 M_p \dot{\zeta}^3 + a C_5 \dot{\zeta}^2 \partial_i^2 \zeta] + \mathcal{O}(\epsilon^3)$$

- Use the gauge $\zeta = 0$ since L_3 in the ADM form is too complicated.

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