Strong coupling in the Galilean Genesis?

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Yulia Ageeva
based on work in progress by YA, O.Evseev, O.Melichev, V.Rubakov

Chair of Particle Physics and Cosmology
Department of Physics
Moscow State University/ INR RAS

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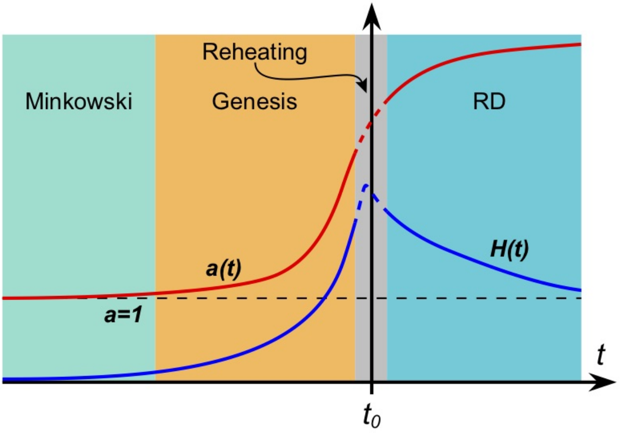
Outline

Motivation

- Inflation is now the strongest candidate of the early universe scenario that explains current cosmological observations consistently.
  Starobinsky'80, Guth'81, Steinhardt'82, Linde'83
- Non-singular stages in the early universe cannot only be something that replaces inflation, but also early-time completion of inflation just to get rid of the initial singularity.
  Vilenkin'92, Vilenkin, Borde'93
- We address whether healthy non-singular cosmologies can be implemented in the framework of general scalar-tensor theories.

Genesis



The Horndeski theory

- Non-singular → VIOLATE Null Energy Condition (NEC) within Galileon theory:

$$T_{\mu\nu} k^{\mu} k^{\nu} \geq 0,$$

$$\rho + p \leq 0 \text{ violated},$$

$$d\rho/dt = -3H(\rho + p).$$

The Lagrangian of our theory is:

$$\mathcal{L}_H = G_2(\phi, X) - G_3(\phi, X)\Box\phi + G_4(\phi)R,$$

$$X = -\frac{1}{2} g^{\mu\nu} \partial_{\mu}\phi \partial_{\nu}\phi, \ \Box\phi = g^{\mu\nu} \nabla_{\mu} \nabla_{\nu} \phi.$$

Stable solutions and Strong coupling?

The only possibility to avoid No-Go (Kobayashi'16)

$\mathcal{F}_T \to 0$ as $t \to -\infty$ where $\mathcal{F}_T := 2G_4$.

The perturbed metric is written in ADM 3+1 splitting:

$$ds^2 = -N^2(\alpha)dt^2 + \gamma_{ij}(\zeta)(dx^i + N^i(\beta)dt)(dx^j + N^j(\beta)dt),$$

$$S_h^{(2)} = \frac{1}{8}\int dtd^3x\, a^3 \left[\mathcal{G}_T \dot{h}_{ij}^2 - \frac{\mathcal{F}_T}{a^2}(\partial h_{ij})^2\right],$$

But now we obtain strong coupling (SC):

$$\mathcal{L}_H = G_2(\phi, X) - G_3(\phi, X)\Box\phi$$
$$+ \mathbf{G_4}(\phi)\mathbf{R}.$$

No SC condition:

$$\mathbb{A}_i \gg \Lambda_{cutoff} \gg \frac{\dot{H}}{H}.$$

Strong coupling...or not?

Cubic action for any perturbation (scalar or tensor one):

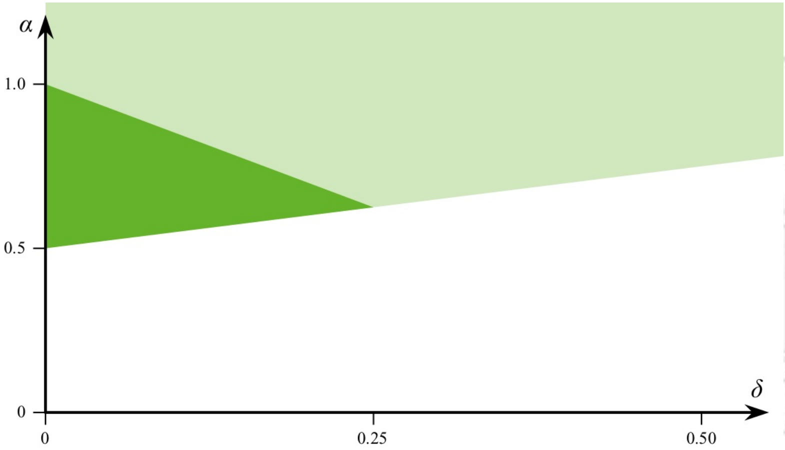
$$S_{\psi}^{(3)} \sim \frac{\Lambda_i}{\mathcal{F}_{(S,T)}^{3/2}} \left(\psi^3(')^a(\partial)^b\right), \; \mathbb{A}_i \;\gg\; \Lambda_{cutoff} \;\gg\; \frac{\dot{H}}{H}.$$

$$\begin{aligned}
\mathcal{L} =& A_2(t,N) + A_3(t,N)K + A_4(K^2 - K_{ij}^2) + B_4(t,N)R^{(3)},\\
& A_2 = M_{Pl}^4 f^{-2(\alpha+1)-\delta} a_2(N),\\
& A_3 = M_{PL}^3 f^{-2\alpha-1-\delta} a_3(N),\\
& A_4 = -B_4 = -M_{Pl} f^{-2\alpha},\\
& f \approx c(-t) \text{ for } t \to -\infty.
\end{aligned}$$

No strong coupling condition then:

$$\alpha < 1 - \frac{3}{2}\delta \text{ and } 2\alpha > 1 + \delta > 0.$$

Strong coupling...or not?



Conclusion

- It was shown that due to NEC-violation one can build new early stage as an alternative or completion to inflation, e.g. genesis stage.
- If one violate NEC and use theories with higher order derivatives $\rightarrow$ be sure that all no-go theorems are avoided and solutions are stable for all times!
- Now one should also test their theory with "strong coupling"!
- OUTLOOK 1: We need to test tensor-scalar-scalar and tensor-tensor-scalar sectors.
- OUTLOOK 2: Try to sew our Genesis stage with next stages in a healthy way.

THANK YOU FOR YOUR ATTENTION!