Warm Inflation and TCC

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Outline

1. Introduction
   - Horizon Problem

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   - Horizon Problem
2. Standard Inflation
3. Early time cosmology
   - Slow-roll
   - Energy Density Evolution
   - Reheating
   - Thermalization

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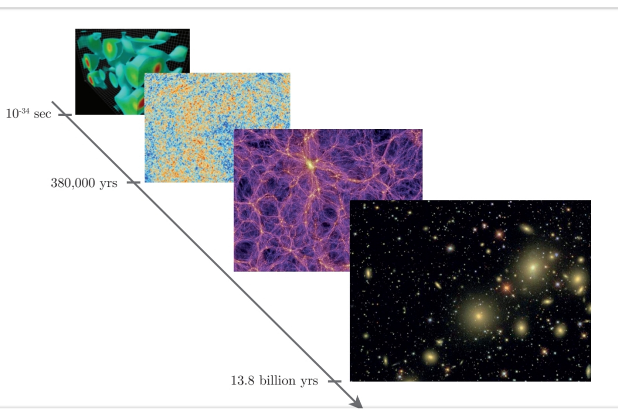
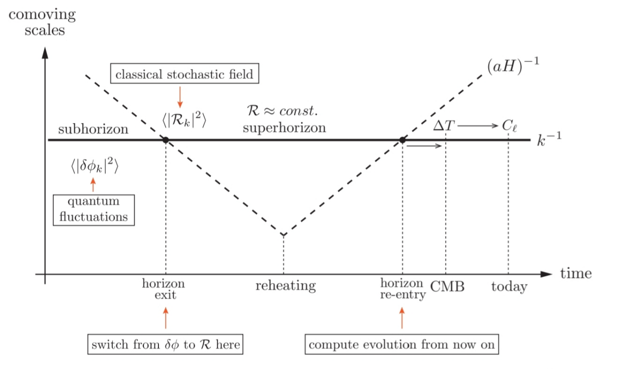
Observation

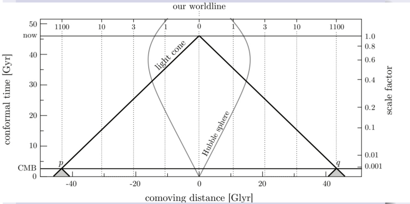


Horizon Problem



Horizon Problem

CMB Map



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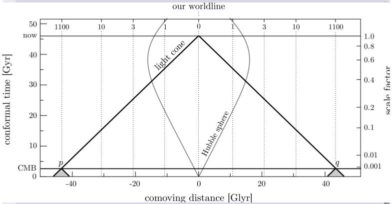

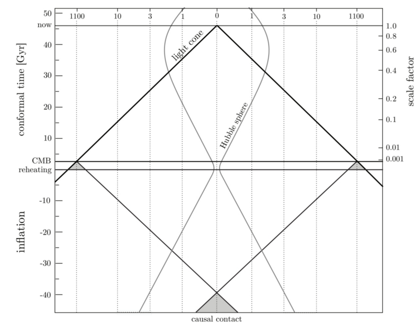

Cold inflation

Two separated epochs

Cold inflation

Two separated epochs

- Slow-roll

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Two separated epochs

- Slow-roll
- Reheating

Standard cosmology

Expanding universe

- Expanding homogeneous and isotropic universe

$$ds^2 = -dt^2 + a(t)^2(dx^2 + dy^2 + dz^2) \tag{1}$$

- General Relativity

$$G_{\mu\nu} = 8\pi G T_{\mu\nu} \tag{2}$$

- Friedmann equations

$$\frac{\ddot{a}}{a} = -\frac{4\pi G}{3}(\rho + 3P) \tag{3}$$

- Early and late time accelerated expansions
- Inflation, Dark energy

$$\rho = \frac{1}{2}\dot{\phi}^2 + V(\phi) \quad P = \frac{1}{2}\dot{\phi}^2 - V(\phi) \tag{4}$$

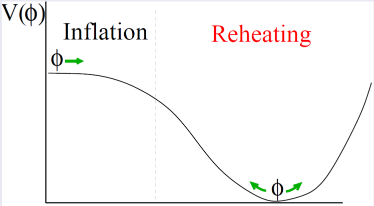
Standard Inflation

Condition

We know from G.R in order to realize inflation, it requires an equation of state $P < -\rho/3$, thus a substance with negative pressure that scalar fields can provide such an equation of state.

$$\rho(\phi) = \frac{1}{2}\dot{\phi}^2 + V(\phi) \qquad P(\phi) = \frac{1}{2}\dot{\phi}^2 - V(\phi) \tag{5}$$

Evolution of the Inflaton



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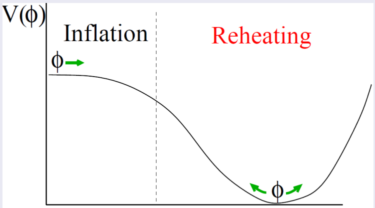
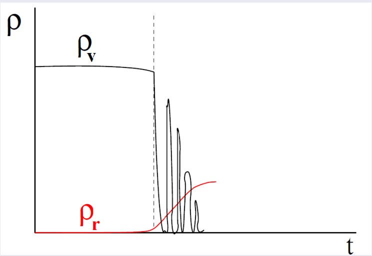


Evolution of Energy Density



Evolution of the Scalar Field

Related Equations

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- Energy Density Conservation

$$\dot{\rho} + 3H(\rho + P) = 0 \;, \tag{6}$$

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- Equations Describing the Evolution of Scalar Field

$$\ddot{\phi} + 3H\dot{\phi} + \frac{dV}{d\phi} = 0 \ , \ \epsilon = \frac{1}{2}M_p^2(\frac{V'}{V})^2,$$

where H is Hubble parameter

Reheating

Interacting Potential

Reheating

Interacting Potential

- Non-thermal phase

$$V(\phi,\chi) = \frac{\lambda}{4}(\phi^2 - \phi_0^2)^2 + \frac{1}{2}g^2\phi^2\chi^2 \tag{7}$$

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$$V(\phi,\chi) = \frac{1}{2}m_\phi^2\phi^2 + \frac{1}{2}m_\chi^2\chi^2 + \sigma\phi\chi^2 + h^2\phi^2\chi^2 + k\chi^4 \tag{8}$$

where σ, h, k are coupling constants

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- Thermalization

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The main contradiction between the conjecture and effective field theory of early time cosmology is not slow-roll part of inflation but is reheating (thermalization part) which can be solved in the context of warm inflation model

Swampland

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- Field excursion (Distance conjecture)
- de Sitter conjecture
- Refined de Sitter conjecture

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$$\frac{|V'(\phi)|}{V} > \frac{c_2}{M_p}$$
$$\frac{V''(\phi)}{V} \leq -\frac{c_3}{M_p^2}, \tag{10}$$

Robert. Brandenberger, V.K, Rudnei.O.Ramos; JHEP08(2020)127

TCC

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- Trans-Planckian Censorship Conjecture (TCC) is a constraint on cosmological models coming from demanding that physics on scales larger than the cosmological horizon be shielded from the non-unitarity of the effective field theory description of the cosmological model, and can be viewed as a generalization of Penrose's Cosmic Censorship Conjecture to the case of cosmology

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  1. Duration of inflation

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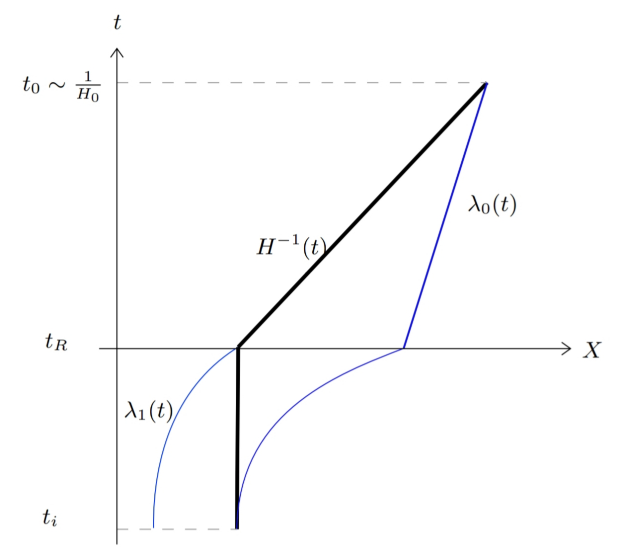
$$V^{\frac{1}{4}} < 10^8 Gev \tag{12}$$

$$r < 10^{-30}$$

$V.K, Robert.Brandenbeger; Eur.Phys.J.C80(2020)4, 339$


t
$t_0 \sim \frac{1}{H_0}$
$\lambda_0(t)$
$H^{-1}(t)$
t_R
X
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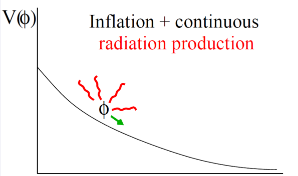

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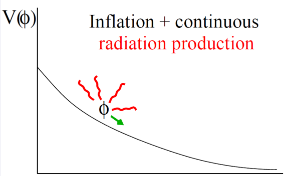

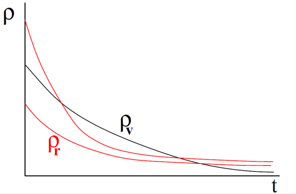

Condition of Warm inflation

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- Conservation equation

$$\dot{\rho}_\phi + 3H(\rho_\phi + P_\phi) = -\Gamma\dot{\phi}^2 \qquad (13)$$

$$\dot{\rho}_\gamma + 4H\rho_\gamma = \Gamma\dot{\phi}^2;$$

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$$\delta\phi_{warm} \sim \sqrt{HT} \qquad \delta\phi_{cold} \sim H; \qquad (15)$$
$$V.K;\ Phys.Rev.D99\ (2019)\ 6,\ 063513$$

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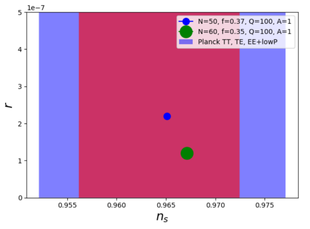

- 1σ and 2σ confidence regions which borrowed from Planck [?], $r - n_s$ trajectories of the present model in high dissipative regime. The solid red, dashed orange and dot-ashed green lines correspond to Γ_0 values: 3.14×10^{-3}, 6.28×10^{-3} and 1.25×10^{-2}.

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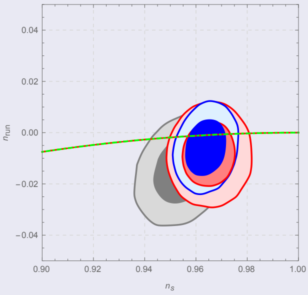

- The area corresponds to Planck data and $n_s - n_{run}$ trajectories relate to our model.The solid red, dashed orange and dot-ashed green lines correspond to Γ_0 values: 3.14×10^{-3}, 6.28×10^{-3} and 1.25×10^{-2}.

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Thanks for your attention