Sneutrino Hybrid Inflation and Nonthermal Leptogenesis

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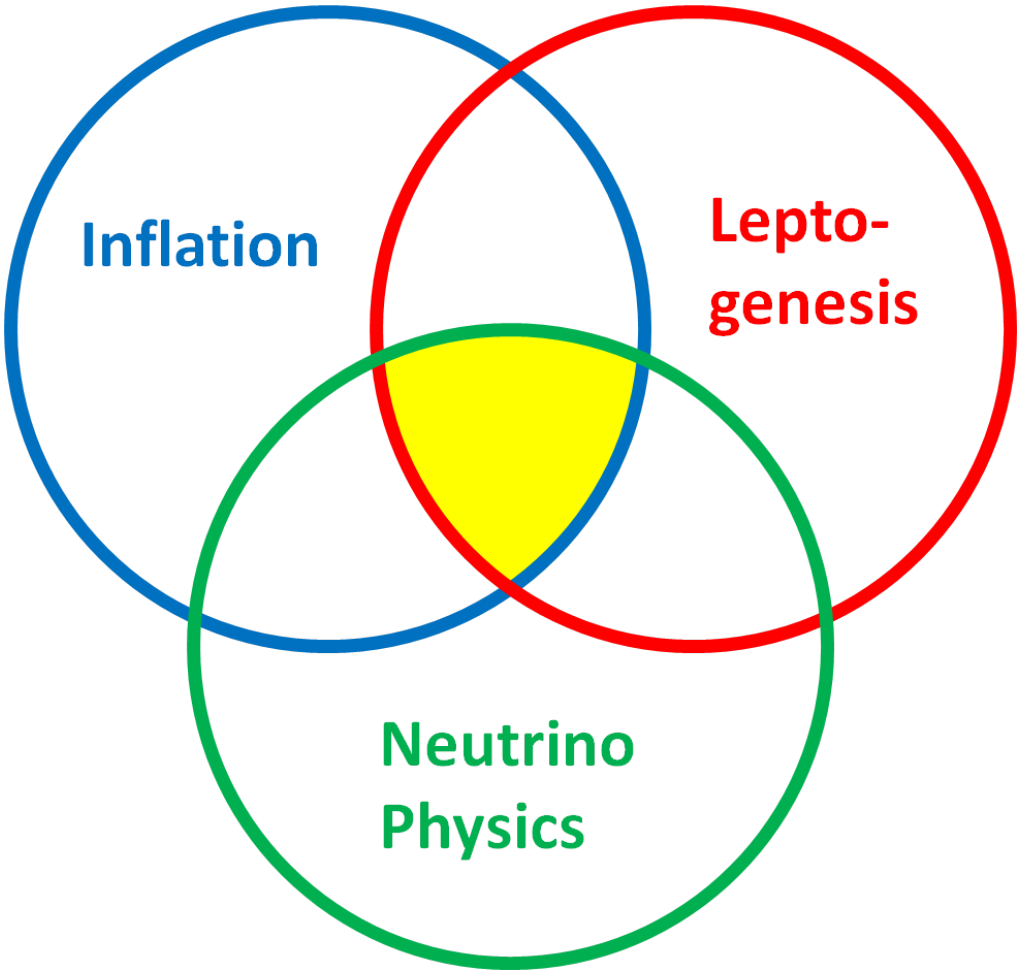
Based on a collaboration with S. Antusch, J.P. Baumann and P.M. Kostka

See also arxiv: 1007.0708

SUSY 2010, 26.8.2010

Motivation



Outline

Inflation in a Nutshell

- Slowly rolling classical scalar field:
  $\rightarrow$ exponential expansion of the universe.

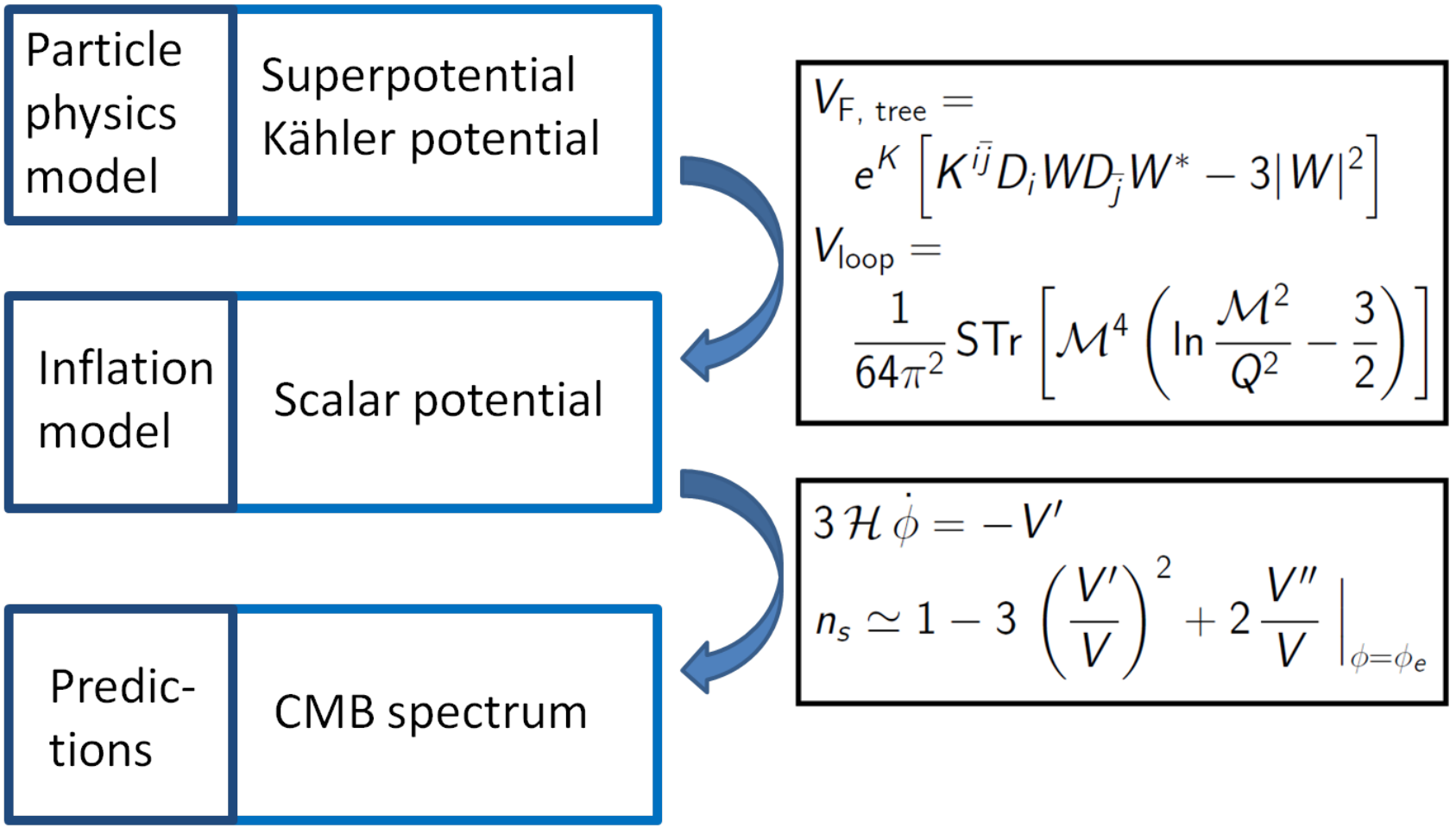
$$R(t) \propto \exp(\mathcal{H}\, t)\,, \qquad \mathcal{H} \sim const.$$

- 'Stretched' quantum fluctuations
  $\rightarrow$ spectrum of CMB inhomogeneities, e.g. spectral index n_s.

$$P_{\mathcal{R}}(k) \sim P_{\mathcal{R}}(k_0) \left(\frac{k}{k_0}\right)^{n_s - 1}$$

- End of inflation:
  $\rightarrow$ scalar fields oszillate around the minimum of the potential
  $\rightarrow$ decay into ultrarelativistic degrees of freedom (reheating)

From the Model to CMB Predictions



A Specific Model

$$W = W_{\mathrm{MSSM}} + (y_\nu)_{ij} \hat{N}^i \hat{h} \cdot \hat{L}^j + \frac{\lambda_{ii}}{M_P} (\hat{N}^i)^2 \hat{H}^2 + \kappa \hat{S} (\hat{H}^2 - M^2) + \ldots$$

- MSSM
- Seesaw mechanism
- Heavy neutrino mass
  $m_N \sim \langle H \rangle$

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- Hybrid inflation potential
- Inflaton = Sneutrino

[S. Antusch, M. Bastero-Gil, S. King, Q. Shafi '04]

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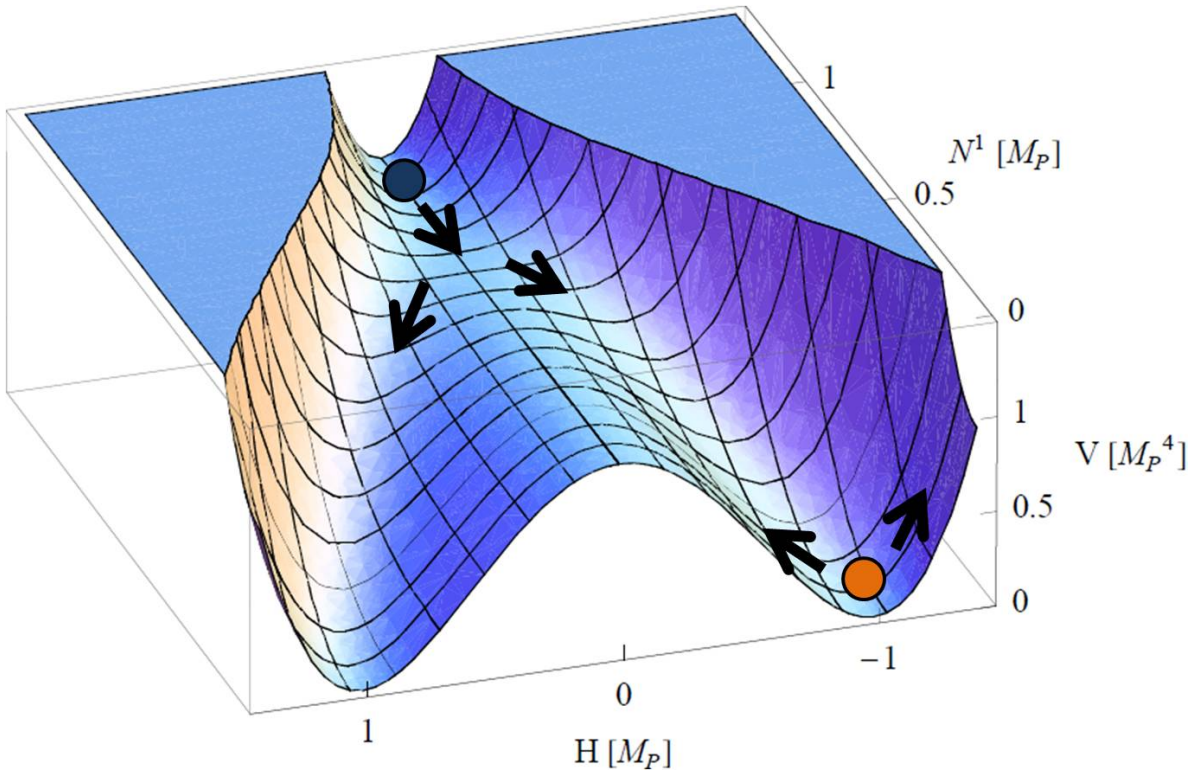
$$K = |\hat{S}|^2 + |\hat{H}|^2 + |\hat{h}|^2 + \sum_i \frac{1}{2}(\hat{N}^i + (\hat{N}^i)^\dagger)^2 + \sum_j |\hat{L}^j|^2 + \frac{\kappa SH}{M_P^2}|\hat{S}|^2|\hat{H}|^2 + \ldots.$$

- η - problem resolved by shift symmetry

[S. Antusch, K. Dutta and P. Kostka '09]

The Scalar Potential

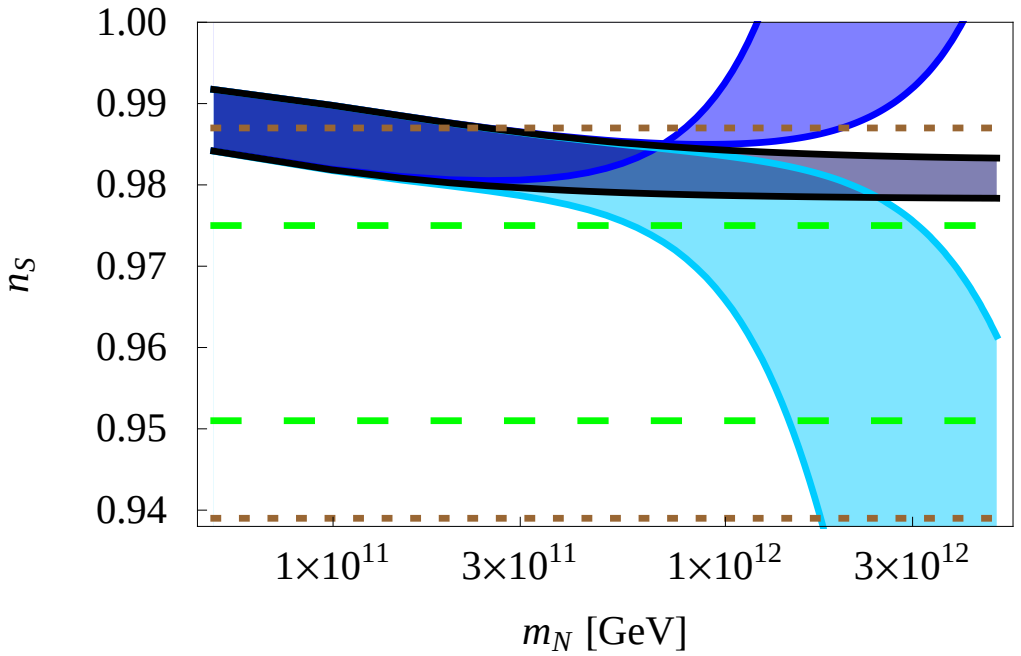


N^1 = Inflaton field

H = Waterfall field

Predictions

The spectral index n_s and the (s)neutrino mass m_N:



\- 0 + } SUGRA corrections

95% CL

68% CL

[WMAP '09]

Dynamics at the End of Inflation (I)

Massive scalar fields

$$\ddot{\phi} + 3\mathcal{H}\dot{\phi} + \frac{\partial V}{\partial \phi} + \Gamma_\phi \dot{\phi} = 0$$

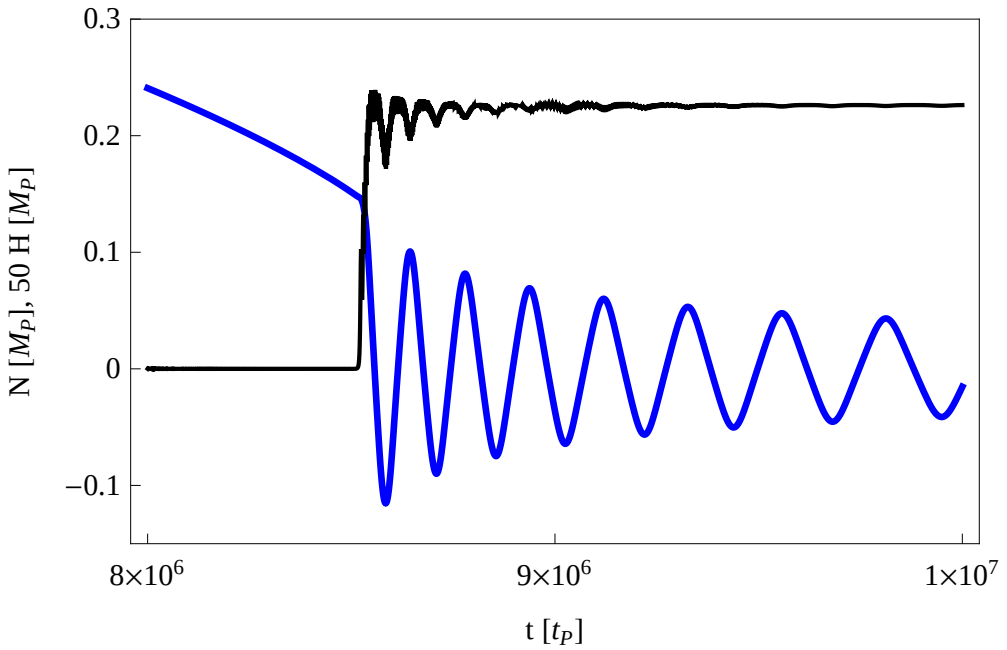
Boltzmann equation for light particles

$$\dot{\rho_R} + 4\mathcal{H}\rho_R - \sum_\phi \Gamma_\phi \rho_\phi = 0$$

Friedmann equation

$$\frac{1}{3}\left(\sum_\phi \rho_\phi + \rho_R\right) = \mathcal{H}^2$$

Dynamics at the End of Inflation (II)

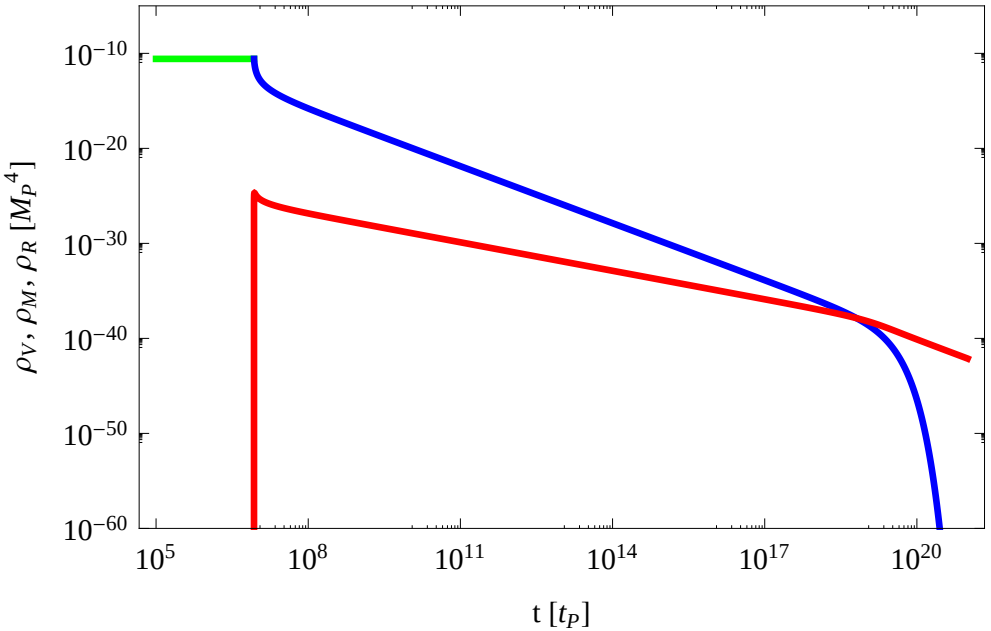


Waterfall field
Inflaton field

Sneutrino dominated universe → nonthermal leptogenesis

$$\dot{n}_{L-\bar{L}} + 3\,\mathcal{H}\,n_{L-\bar{L}} = \epsilon_N\,\Gamma_N\,n_N$$

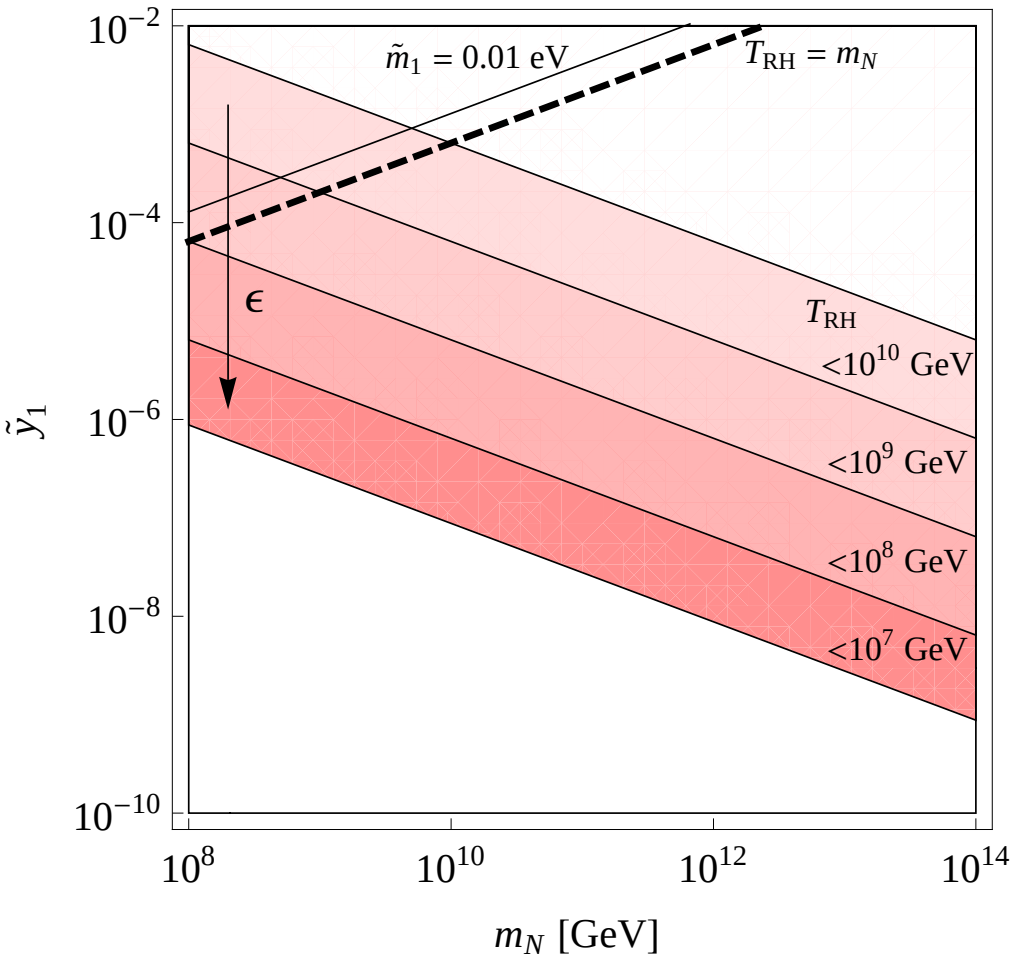
Dynamics at the End of Inflation (III)



Vacuum
Matter
Radiation
} energy density

- Reheat temperature: $T_{RH} \sim \rho_R^{1/4}\big|_{\rho_R=\rho_M}$ ($\rightarrow$ gravitino problem)

Predictions



- Reheating + Leptogenesis

$$\widetilde{y}_1 \equiv \sqrt{(y_\nu y_\nu^\dagger)_{11}}$$

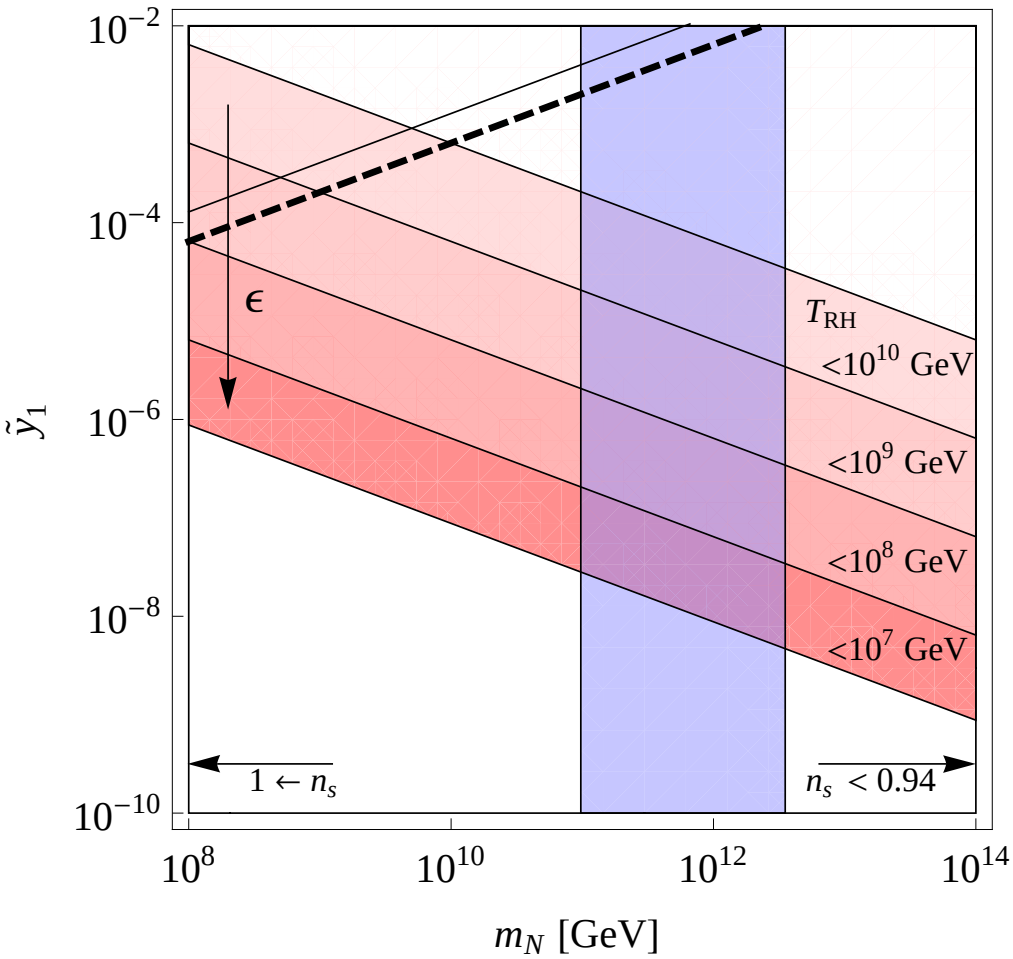
$$m_N = \text{(s)neutrino mass}$$

$$\widetilde{m}_1 = \tilde{y}_1^2 \langle v \rangle^2 / m_N$$

$$\epsilon < \frac{3}{8\pi} \frac{\sqrt{\Delta m^2_{\rm atm}}\, m_N}{\langle v \rangle^2}$$

[S. Davidson, A. Ibarra '02]

Combining Inflation and Leptogenesis



- Reheating + Leptogenesis
- Inflation

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[S. Davidson, A. Ibarra '02]

Implications for Neutrino Physics

Mass of lightest right handed (s)neutrino

$$m_N = \mathcal{O}(10^{10} - 10^{12}) \text{ GeV}$$

Mass of lightest left handed neutrino

$$m_{\nu_1} \lesssim \mathcal{O}(10^{-4}) \text{ eV}$$

Effective first generation neutrino Yukawa coupling

$$\widetilde{y}_1 = \mathcal{O}(10^{-9} - 10^{-4})$$

Conclusions

General Picture

Particle physics framework $\Rightarrow$ [Inflation $\rightarrow$ CMB spectrum; Leptogenesis $\rightarrow$ reheat temperature; matter asymmetry] $\Leftarrow$ Exp.

Specific case

Sneutrino hybrid inflation

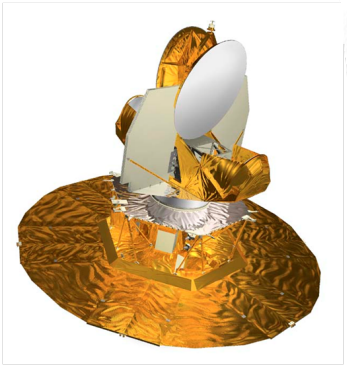
$+$

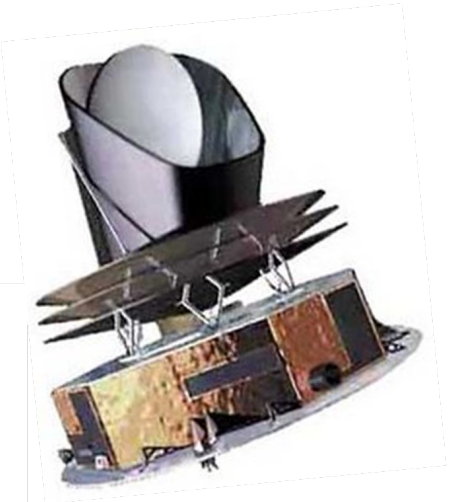
Nonthermal leptogenesis

$\Downarrow$

Constraints on

neutrino physics parameters



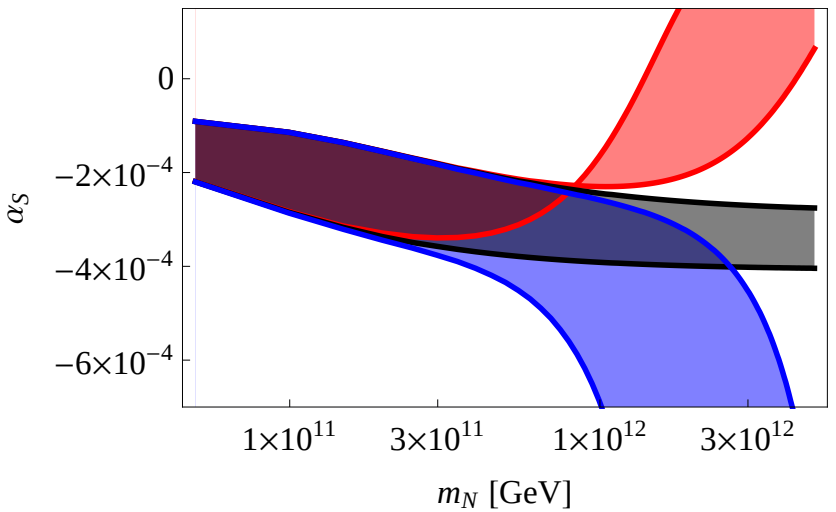


The End

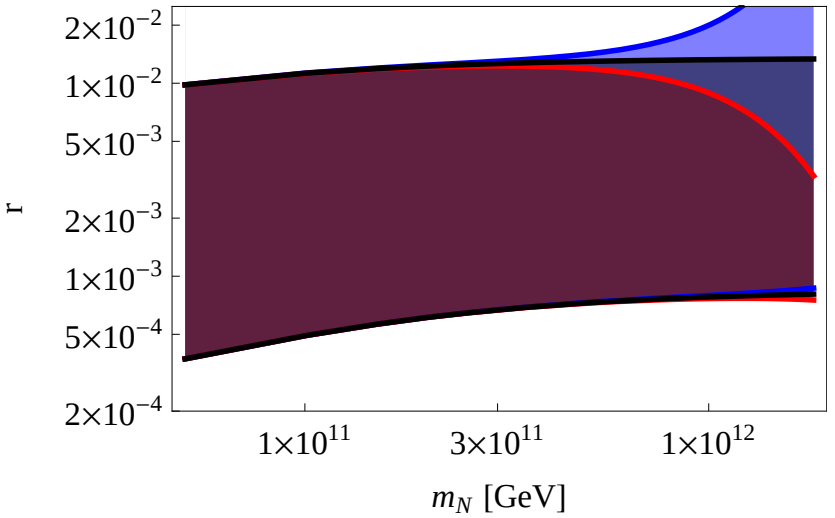
Thank You

Results from Inflation II

Running of spectral index α_s



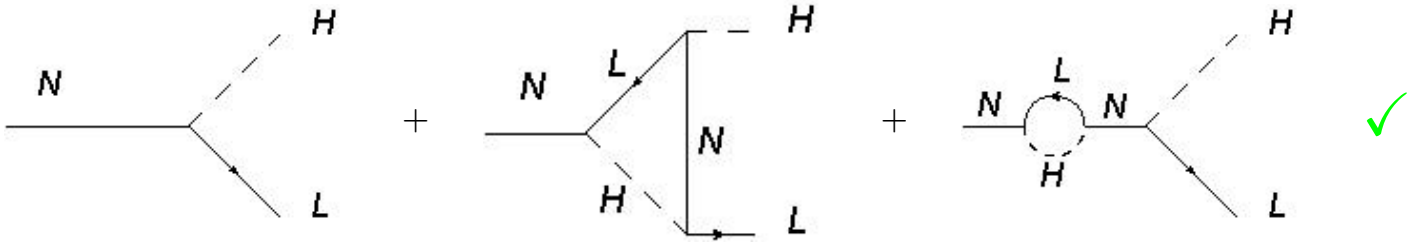
Tensor-to-scalar ratio r



Sakharov Conditions

$N \to H\,L,\ N \to \bar{H}\,\bar{L}$

1. ~~B~~: ~~L~~ (N is Majorana) + Sphalerons ✓
2. ~~C~~, ~~CP~~:



✓

3. ~~thermal equilibrium~~: if $m_N \gg T_{\text{universe}}$ ✓