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CP violating vacuum transition and Big Bang Nucleosynthesis

H. L. Duorah

Gauhati University, Guwahati 781014, India

R. K. Das

SBMS College, Sualkuchi, Assam, India

Abstract. An analysis of primordial nucleosynthesis is made in the perspective of transition in the early universe from quark gluon to a hadronic phase in a CP violating vacuum. The universe opaque to color, quarks and anti quarks binds into globally colorless hadrons. u, d and s quarks are considered in a sea of degenerate neutrinos for the case of $\mu_{\nu_e} = \mu_{\nu_\mu} = \mu_{\nu_\tau}$. The n_n/n_p ratio is calculated for a transition temperature $\sim 100 - 200 MeV$ for various values of neutrino degeneracy $\xi_{\nu_e} = \mu_{\nu_e}/T, \mu_{\nu_e}$ being the chemical potential of electron type neutrino. The limiting value of ξ_{ν_e} is found to be 2.38, if the upper bound of fractional helium abundance Y_p is 0.26.

1. Introduction

The theory of QCD predicts (Cleymans et al. 1986) that ordinary matter consisting of protons and neutrons dissolves into a quark gluon plasma (qgp) at a critical temperature $\sim 150 MeV$. Applying this idea to the *Standard Big Bang (SSB)* model, it is traced back to the early quark gluon phase that subsequently cooled down at the critical the temperature T_c to form the hadronic phase in a sea of three types degenerate neutrinos. The admittance of neutrino degeneracy ($\mid \xi_{\nu_e} \mid \gg 1$) requires the lepton asymmetry to be large (Langacker 1983). The natural units have been followed.

2. Calculations

We calculate the ratio of number density of neutrons (n_n) to that of protons (n_p) in qgp to be

$$\left(\frac{n_n}{n_p}\right)^{qgp} = \left[\frac{9\pi^2 T^2 \mu_n + \mu_n^3 + 6\mu_n \mu_{\nu_e}^2 + 2\mu_{\nu_e}^3}{9\pi^2 T^2 \mu_p + \mu_p^3 + 6\mu_p \mu_{\nu_e}^2 - 2\mu_{\nu_e}^3}\right] \tag{1}$$

In the hadon phase this ratio becomes

$$(n_n/n_p)^h = \left(\frac{n_n}{n_p}\right)^{qgp} (m_n/m_p)^{3/2} \exp\left(\frac{m_p - m_n}{T_c}\right), \tag{2}$$

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Due to adiabatic expansion, the temperature drops down to the freeze out temperature T_f at which the charge current weak interaction rate (Wagoner et al. 1967) just balances the expansion rate. This gives

$$T_f = \left[\frac{(8\pi/3)^{1/2}(E_{q-g} - E_v)^{1/2} \times 10^{50}}{0.0083\left((2/3)\pi^2 {\xi_{\nu_e}}^3 + (7/15)\pi^4 \xi_{\nu_e}\right)} \right]^{1/5}, \quad (3)$$

where E_{q-g} is the qgp energy density (Cleymans et al. 1986) and $E_v = \frac{\Lambda_0 T^4}{8\pi T_0^4}$ is vacuum energy density, $\Lambda_0 < 10^{-56}\,\mathrm{cm}^{-2}$ (Hawking et al. 1984) being the cosmological constant at present epoch.

3. Calculation of Y_p

With a case study of $\Lambda_0 \sim 10^{-58}\,\mathrm{cm}^{-2}$ at $T_c = 100MeV$, we have calculated a Y_p that comes out between 0.21 and 0.32 for various values of ξ_{ν_e} ranging from 1 to 4. For an upper bound 0.26 of Y_p, ξ_{ν_e} is found to be 2.38, for which consistent value of neutrino lepton asymmetry is 2.5.

4. Conclusion

The quark gluon phase transition in the early Universe in a sea of degenerate electron neutrinos can provide the answer for helium production at the SBB stage. An anisotropic model can be considered easily in this set-up as well. CP violating vacuum transition is inherently built into the system. Attempt is being made to synthesize the other elements such as ^{2}D, ^{3}H, ^{3}He, ^7Li during this expansion phase of the universe.

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