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Topic: Some Astro-Particle Physics Aspects of Early Universe

Abstract

This thesis addresses two main questions related to Early Universe. One of them is concerning the baryon asymmetry of the Universe. Second is the question of a viable model to explain the plausible candidate for Dark Matter along with the astrophysical process which could happen due to it.

For the baryon asymmetry we have considered Soft-leptogenesis which is a mechanism that generates the matter-antimatter asymmetry of the Universe in presence of sphaleron transitions via the out-of-equilibrium decays of heavy sneutrinos in which soft supersymmetry breaking terms play two important roles: they provide the required CP violation and give rise to the mass splitting between otherwise degenerate sneutrino mass eigenstates within a single generation. This mechanism is interesting because it can be successful at lower temperature regime $T \lesssim 10^9$ GeV in which the conflict with the overproduction of gravitinos can possibly be avoided. In earlier works the leading CP violation is found to be nonzero only if finite temperature effects are included. By considering generic soft trilinear couplings, we find two interesting consequences: 1) the leading CP violation can be nonzero even at zero temperature realizing nonthermal CP violation and 2) the CP violation is sufficient even far away from the resonant regime allowing soft supersymmetry breaking parameters to assume natural values at around the TeV scale. We discuss phenomenological constraints on such scenarios and conclude that the contributions to charged lepton flavor violating processes are close to the sensitivities of present and future experiments.

In this thesis we have tried to constrain the lepton number violating couplings responsible for Leptogenesis through Charged Lepton Flavor Violating (CLFV) processes like $\mu \to e\gamma$ and Neutrino Oscillation. In neutrino oscillation such couplings are parametrized as Non-Standard Interaction (NSI) and are constrained in a model independent way by considering the recent results from T2K and Daya Bay neutrino oscillations experiments. Using perturbation method we present generic formulas (suitable for T2K baseline and for large θ_{13} as evident from Daya Bay) for the probability of oscillation for $\nu_\mu \to \nu_e$, taking into account NSIs at source (ϵ^s), detector (ϵ^d) and during propagation (ϵ^m) of neutrinos through matter. Two separate cases of perturbation with small (slightly large) NSI ($\epsilon^m_{\alpha\beta} \sim 0.03(0.18)$) are discussed in detail. Using various possible presently allowed NSI values we reanalyze numerically the θ_{13}–δ allowed region given by recent T2K experimental data. We obtain model independent constraints on NSIs in the δ–$\epsilon^m_{\alpha\beta}$ plane using the θ_{13} value as measured by Daya Bay, where δ is the CP violating phase. Depending on δ values significant constraints on $\epsilon_{e\tau}$ and $\epsilon_{\tau\tau}$, in particular, are possible for both hierarchies of neutrino masses. Corresponding to T2K's 66% confidence level result, the constraints on $\epsilon_{\tau\tau}$ is shown to be independent of any δ value. There are other constraints on ϵ_{ij} also from LSND, NuTev , CHARM, CHARM II and LEP II. Considering various experiments we have considered stringent constraints on ϵ_{ij} and have obtained experimental bounds on lepton number violating couplings. We have compared such experimental constraints with the required value of lepton number violating coupling for successful leptogenesis.

Lastly in this thesis, by considering dark matter, we have made an attempt to simultaneously explain the recently observed 3.55 keV X-ray line in the analysis of XMM-Newton telescope data and the galactic center gamma ray excess observed by the Fermi gamma ray space telescope. For dark matter candidate we have considered an abelian gauge extension of standard model. We consider a two component dark matter scenario with a mass difference 3.55 keV such that the heavier one can decay into the lighter one and a photon with energy 3.55 keV. The lighter dark matter candidate is protected from decaying into the standard model particles by a remnant Z_2 symmetry into which the abelian gauge symmetry gets spontaneously broken. If the mass of the dark matter particle is chosen to be within 31–40 GeV, then this model can also explain the galactic center gamma ray excess if the dark matter annihilation into $b\bar{b}$ pairs has a cross section of $\langle\sigma v\rangle \simeq (1.4 - 2.0) \times 10^{-26}$ cm^3/s. We constrain the model from the requirement of producing correct dark matter relic density, 3.55 keV X-ray line flux and galactic center gamma ray excess. We also impose the bounds coming from dark matter direct detection experiments as well as collider limits on additional gauge boson mass and coupling. We also briefly discuss how this model can give rise to sub-eV neutrino masses at tree level as well as one loop level while keeping the dark matter mass at few tens of GeV.