Inhomogeneity Primordial Magnetic Field, non Maxwell-Boltzmann Distribution of Ions, and their Effect on Big Bang Nucleosynthesis

Y. Luo[a], T. Kajino[b], G. Mathews[c], M. Kusakabe[d] and J. He[e]

[a]The University of Tokyo, [b]National Astronomical Observatory of Japan, The University of Tokyo, [c]University of Notre Dame, [d]IRCBBC, School of Physics and Nuclear Energy Engineering, Beihang University, [e]National Astronomical Observatories, Chinese Academy of Sciences

Cosmological theory of Big Bang nucleosynthesis (BBN) predicts the right amount of production of the light elements 2H, 3He, 4He, and 7Li in the early universe to constrain several cosmological parameters. We find that the abundance of these elements can be affected strongly by a stochastic primordial magnetic field (PMF) whose strength is spatially inhomogeneous. We assume a large-scale stochastic PMF with a power law (PL) correlation function and strength that follows a Gaussian distribution, while the total energy density is uniform. We show that the distribution function of particles deviates from the Maxwell-Boltzmann (MB) distribution with the stochastic PMF fluctuations being taken into account. This deviation is related to $\rho\lambda$ and σ which are scale invariant (SI) strength of PMF energy density and fluctuation parameter. We perform a BBN network calculation by taking account of non-MB distribution generated by PMF strength distribution, and show the elemental abundances as a function of baryon to photon ratio η, $\rho\lambda$, and σ. We then concluded that the fluctuation of PMF strength reduces 7Be production and enhances 2H production. We analyze thermonuclear reaction rates compared with classical MB framework, find that the charged particles reaction rates are very different from each other due to the Coulomb penetration effects. On the other hand, neutron induced reaction rates almost maintain the same amplitudes as those in the MB distribution. We also show that the distribution function in our PMF model indicates a linear drift with a relatively steeper sloop than the MB distribution in terms of Fokker-Plank equation. Finally, we constrain the parameters $\rho\lambda$ and σ for our fluctuated PMF model from observed abundances of 4He and 2H. In this model, 7Li abundance is significantly reduced within an allowed region from observational constraints.