Constraints on the neutrino mass and the primordial magnetic field

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Recently cosmological observations and ground experiments constrain the neutrino-mass of order < 0.1–1 eV. If the velocities of such finite-mass neutrinos with the finite-mass are enough large, the time evolution of density fluctuations in the neutrinos free-streaming scale will be impeded. Therefore it is very important to limit the neutrino mass. At the same time, magnetic fields have been observed in clusters of galaxies with a strength of 0.1–1.0 μG. One possible explanation for such magnetic fields in galactic clusters is the existence of a primordial magnetic field (PMF) of order 1 nG whose field lines collapsed as the cluster formed. The PMF could have influenced a variety of phenomena in the early universe such as the cosmic microwave background (CMB)[1], and the formation of the large scale structure (LSS)[2].

In this regard, the alternative normalization parameter σ_8 is of particular interest as a measure of large-scale structure effects. It is defined as the root-mean-square of the matter density fluctuations in a comoving sphere of radius $8h^{-1}$ Mpc. It is determined by a weighted integral of the matter power spectrum. Observations which determine σ_8 provide information about the physical processes affecting the evolution of density-field fluctuations and the formation of structure on cosmological scales.

In this article, We consider the effect of a PMF on σ_8 and compare theoretically deduced values for σ_8 with the observed range. In this way we show that the degeneracy between the effects of a PMF and that of a finite neutrino mass on the matter density fluctuations can be effectively broken by combining the analysis with the CMB data at higher multipoles. We thus obtain not only insight into the underlying physical processes of density field fluctuations in the presence of a PMF, but also place new constraints on the amplitude and spectral index of the PMF and the sum of neutrino mass[3].

Figure 1 shows the constraints on the PMF parameter B_λ and the sum of neutrino masses Σm_ν for various fixed values of n_B and ranges of σ_8 as the caption. The expected parameters of the PMF from the combined analysis of the CMB and observed magnetic fields in galactic clusters is $B_\lambda < 2.0$ nG(1σ) and < 3.0 nG(2σ), while the expected value of σ_8 based upon observations is $0.75 < \sigma_8 < 0.85$. For this range of σ_8, the sum of the neutrino masses is constrained to be $\sum_{N_\nu} m_\nu < 0.11$ eV without the PMF. On the other hand, considering the PMF, from Fig. 1, the sum of the neutrino masses is constrained to be $\sum_{N_\nu} m_\nu < 0.24$ eV on $n_B = -1.5$ and < 0.6 eV on $n_B = -2.5$ for $N_\nu = 3$. This is a larger upper limit than that deduced previously because the effect of the PMF cancels the effect of neutrinos on the density fluctuations.

We confirm that the upper limit on the neutrino mass from σ_8 in the presence of a PMF is heavier than without a PMF even if we consider the matter contributions. We also have shown that the prior limited range on the sum of neutrino masses and PMF parameters is within the expected range for σ_8 from observations of the LSS. In principle, by applying our method to future observations it will be possible to obtain not only the upper but also the lower limits to the neutrino mass from cosmology in the presence of a PMF.

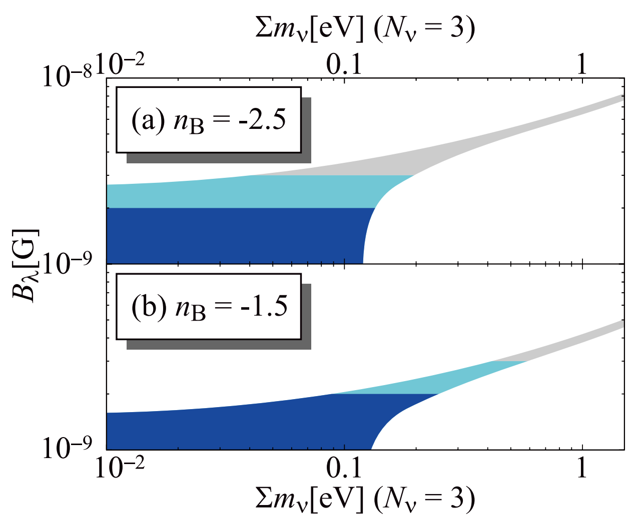

Figure 1: Excluded and allowed regions of ranges for σ_8 in the parameter plane of PMF amplitude B_λ vs. mass of neutrinos $\sum_{N_\nu=3} m_\nu$. n_B is the power-law spectral index of the PMF. All painted Regions indicate ranges of σ_8 as $0.75 < \sigma_8 < 0.85$ and gray, sky blue and blue ragions show $B_\lambda > 3.0$ nG, 2.0 nG $< B_\lambda < 3.0$ nG and $B_\lambda < 2.0$ nG, respectively.

References

[1] Yamazaki, D. G., et al.: 2010, *Phys. Rev. D*, **81**, 023008.
[2] Yamazaki, D. G., et al.: 2008, *Phys. Rev. D*, **78**, 123001.
[3] Yamazaki, D. G., et al.: 2010, *Phys. Rev. D*, **81**, 103519.