Dark matter mass from relic abundance, an extra $U(1)$ gauge boson, and active-sterile neutrino mixing

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In a model with an extra $U(1)$ gauge to SM gauge group, we have shown the allowed region of masses of the extra gauge boson and the dark matter which is the lightest one among other right-handed Majorana fermions present in the model. To obtain this region, we have used bounds coming from constraints on active-sterile neutrino masses and mixing from various oscillation experiments, constraint on dark matter relic density obtained by PLANCK together with the constraint on the extra gauge boson mass and its gauge coupling recently obtained by ATLAS Collaboration at LHC. From the allowed regions, it is possible to get some lower bounds on the masses of the extra gauge boson and the dark matter and considering those values it is possible to infer what could be the spontaneous symmetry breaking scale of an extra $U(1)$ gauge symmetry.

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I. INTRODUCTION

Although Standard Model (SM) has got tremendous success in describing various phenomena at the elementary particle level, but SM failed to account for two major experimental results, one related to the existence of dark matter (DM) [1] in the Universe and the other related to neutrino oscillation phenomena that require neutrinos to be massive and significant mixings among different flavors of neutrinos. To accommodate neutrino masses and a viable dark matter candidate something beyond SM is necessary. One such example is minimal extension of SM gauge group with an extra $U(1)_X$ gauge symmetry. Additional symmetries [2] either global or gauged are imposed which play the role in guaranteeing the stability of dark matter candidate. There are several $U(1)_X$ gauge extended models with minimal extension to the SM [3–5]. An important feature of these models is that in comparison to SM there is one extra neutral gauge boson. In general, there could be mixing of the extra gauge boson X with the SM Z boson, which results in the modification of neutral current phenomena. The Z pole data could be affected indirectly through such mixing and could shift the measured Z mass and its coupling to SM fermions. But nice agreement of the mass and coupling with SM predictions constrains such mixing to be lower than 1% [6].

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On the other hand, in cosmology to explain the rotational curves of the heavy massive body inside the galaxies, one need to propose the presence of dark matter [7,8]. Dark matter relic density has been constrained from PLANCK experiment [9].

$$\Omega_{\mathrm{DM}} h^2 = 0.1200 \pm 0.0012, \tag{1}$$

where Ω_{DM} is the density parameter for dark matter and $h = H_0/(100\ \mathrm{km\,s^{-1}\,Mpc^{-1}})$. Recently, CMS and ATLAS [10–12] Collaborations at LHC have obtained stringent bound on the mass and gauge coupling associated with the extra $U(1)$ gauge boson. In the light of recent neutrino oscillation phenomena [13,14], there is a proposition of the presence of sterile neutrino apart from three active neutrinos. There are recent indications in the Fermilab experiment [15] about some nonzero mixing among active and sterile neutrinos with sterile neutrino mass in the eV scale [16].

In connection with these observational results, we have considered here an $U(1)$ gauge extended model [17], which contains dark matter fields and also can accommodate active-sterile neutrino masses and mixing. In this model, right-handed Majorana fermion is found to be a suitable candidate for dark matter as discussed later. There are some studies on the constraints on model parameters of $U(1)$ gauge extended models based on collider phenomenology and cosmological constraints [18]. However, in this work, we have shown in detail the allowed region in the dark matter mass m_ψ and the extra $U(1)$ gauge boson mass M_X plane. For that, we have considered PLANCK constraint on dark matter relic abundance. Besides, we consider constraints coming from active and sterile neutrino masses