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Reconciliation of Secluded dark sector and muon $g-2$ in light of fast expanding Universe

The lack of information before Big Bang Neucleosynthesis (BBN) allow us to assume the presence of a new species ϕ whose energy density redshifts as $a^{-(4+n)}$ where $n > 0$ and a is the scale factor. In this non-standard cosmological setup, we have considered $U(1)_{L_\mu - L_\tau} \otimes U(1)_X$ gauge extension of the Standard Model (SM) and studied different phases of the cosmological evolution of a thermally decoupled dark sector such as leak-in, freeze-in, reannihilation, and late-time annihilation. This non-standard cosmological setup facilitates a larger portal coupling (ϵ) between the dark and the visible sectors even when the two sectors are not in thermal equilibrium. The dark sector couples with the μ and τ flavored leptons of the SM due to the tree level kinetic mixing between $U(1)_X$ and $U(1)_{L_\mu - L_\tau}$ gauge bosons. We show that in our scenario it is possible to reconcile the dark matter relic density and muon $(g-2)$ anomaly. In particular, we show that for $3 \times 10^{-4} < \epsilon < 10^{-3}$, 30 MeV $< m_{Z'} <$ 300 MeV, $n = 4$, and 1 TeV $< m_\chi <$ 10 TeV relic density constraint of dark matter, constraint from muon $(g-2)$ anomaly, and other cosmological, astrophysical constraints are satisfied.

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