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Phenomenological consequences of an interacting multicomponent dark sector

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We consider a dark sector with multiple dark fermions interacting under a dark U(1) gauge interaction, mediated by a massless dark photon, with no kinetic mixing. Apart from this self interaction, a portal interaction, mediated by scalar messengers, exists between dark fermions and SM fermions. The species which contribute to the total matter relic density of the Universe, are the stable dark fermions. To complement the existing limits on such a dark sector framework coming from precision physics, astrophysics, and collider physics, we assess the viability of this setup using cosmological observables and current direct detection limits. In studying the early Universe history under this scenario, we track both the number densities of the dark fermions, and the temperatures of the dark and visible sector reservoirs, by numerically solving a system of Boltzmann equations which account for number-changing processes and entropy exchanges between the reservoirs. We determine the couplings and masses in the dark sector framework which are consistent with the known matter relic density and CMB constraint on extra radiation components. Meanwhile, potential signals from direct detection searches are assumed to be mainly driven by dipole and charge radius interactions, between the dominant dark matter component and nuclei, mediated by long-range SM and dark photon mediators. We find that limits on these DM-nuclei effective interaction operators from null results on direct detection, are competitive with projected limits from the magnetic dipole moment of leptons and cooling of stellar systems.

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