

Constraining General Light Massive Relics with the CMB

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Cosmic light massive relics (LiMRs) exhibit unique redshifting behavior, contributing to the radiation content of the early universe while relativistic but to the matter content of the late universe when non-relativistic. While these asymptotic abundances of a LiMR species, parametrized by its radiation contribution ΔN_{eff} and its non-relativistic transition redshift z_{NR} , should source the predominant constraints on that species, they provide no insight into the shape of its distribution function. Specifically, non-thermal relics can always recover the same asymptotic abundances as their thermal counterparts via a simple mapping between mass, typical present momentum scale, and the first two moments of the distribution function. With the asymptotic abundances fixed in this way, we point out that the largest remaining physical difference between different relic distributions is the LiMR energy density during its non-relativistic transition. Identifying that the width of the distribution most directly controls this observable, we constrain the features of general LiMRs described by a phenomenological distribution of adjustable width. Finding that even a future CMB experiment would have no sensitivity to the shape of a monomodal LiMR distribution beyond ΔN_{eff} and z_{NR} , we emphasize that our constraints apply to any non-thermal LiMR production scenario characterized by a single momentum scale and thus are as model-independent as constraints on ΔN_{eff} .

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