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Signatures of Light Massive Relics on nonlinear structure formation

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Cosmologies with Light Massive Relics (LiMRs) as a subdominant component of the dark sector are well-motivated from a particle physics perspective, and can also have implications for the σ_8 tension between early and late time probes of clustering. The effects of LiMRs on the Cosmic Microwave Background (CMB) and structure formation on large (linear) scales have been investigated extensively. In this paper, we initiate a systematic study of the effects of LiMRs on smaller, nonlinear scales using cosmological N-body simulations; focusing on quantities relevant for photometric galaxy surveys. For most of our study, we use a particular model of nonthermal LiMRs but the methods developed generalize to a large class of LiMR models — we explicitly demonstrate this by considering the Dodelson-Widrow velocity distribution. We find that, in general, the effects of LiMR on small scales are distinct from those of a ΛCDM universe, even when the value of σ_8 is matched between the models. We show that weak lensing measurements around massive clusters, between ~ 0.1
$hmpc$ and ~ 10
$hmpc$, should have sufficient signal-to-noise in future surveys to distinguish between ΛCDM and LiMR models that are tuned to fit both CMB data and linear scale clustering data at late times. Furthermore, we find that different
LiMR cosmologies indistinguishable by conventional linear probes can be distinguished by nonlinear probes if their velocity distributions are sufficiently different. LiMR models can, therefore, be best tested by jointly analyzing the CMB and late-time structure formation on both large \textit{and} small scales.

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