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Limits on Non-Relativistic Matter During Big-Bang Nucleosynthesis

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Big-bang nucleosynthesis (BBN) probes the cosmic mass-energy density at temperatures ~ 10 MeV to ~ 100 keV. Here, we consider the effect of a cosmic matter-like species that is non-relativistic and pressureless during BBN. Such a component must decay; doing so during BBN can alter the baryon-to-photon ratio, η, and the effective number of neutrino species. We use light element abundances and the cosmic microwave background (CMB) constraints on η and N_ν to place constraints on such a matter component. We find that electromagnetic decays heat the photons relative to neutrinos, and thus dilute the effective number of relativistic species to $N_{\rm eff} < 3$ for the case of three Standard Model neutrino species. Intriguingly, likelihood results based on *Planck* CMB data alone find $N_\nu = 2.800 \pm 0.294$, and when combined with standard BBN and the observations of D and ^{4}He give $N_\nu = 2.898 \pm 0.141$. While both results are consistent with the Standard Model, we find that a nonzero abundance of electromagnetically decaying matter gives a better fit to these results. Our best-fit results are for a matter species that decays entirely electromagnetically with a lifetime $\tau_X = 0.89$ sec and pre-decay density that is a fraction $\xi = (\rho_X/\rho_{\rm rad})|_{10\ {\rm MeV}} = 0.0026$ of the radiation energy density at 10 MeV; similarly good fits are found over a range where $\xi\tau_X^{1/2}$ is constant. On the other hand, decaying matter often spoils the BBN+CMB concordance, and we present limits in the (τ_X, ξ) plane for both electromagnetic and invisible decays. For dark (invisible) decays, standard BBN (i.e. $\xi = 0$) supplies the best fit. We end with a brief discussion of the impact of future measurements including CMB-S4.

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Keyword-3

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Author: Dr YEH, Tsung-Han (TRIUMF)

Co-authors: Prof. OLIVE, Keith (University of Minnesota); Prof. FIELDS, Brian (University of Illinois Urbana-Champaign)

Presenter: Dr YEH, Tsung-Han (TRIUMF)

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