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Compensated Isocurvature Perturbations and the Cosmic Microwave Background

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Measurements of cosmic microwave background (CMB) anisotropies constrain isocurvature fluctuations between photons and non-relativistic particles to be sub-dominant to adiabatic fluctuations. Perturbations in the relative number densities of baryons and dark matter, however, are surprisingly poorly constrained. In fact, baryon-density perturbations of fairly large amplitude may exist if they are compensated by dark-matter perturbations, so that the total density remains unchanged. These compensated isocurvature perturbations (CIPs) leave no imprint on the CMB at observable scales, at linear order in their amplitude. B modes in the CMB polarization are generated at reionization through the modulation of the optical depth by CIPs, but this induced polarization is small. The strongest known constraint $\lesssim 10%$ to the CIP amplitude comes from galaxy cluster baryon fractions. Here it is shown that modulation of the baryon density by the CIP at and before the decoupling of Thomson scattering at $z\sim 1100$ gives rise to CMB effects several orders of magnitude larger than those considered before. Polarization B modes are induced, as are correlations between temperature/polarization spherical-harmonic coefficients of different lm. It is shown that the CIP field at the surface of last scatter can be measured with these higher-order correlations. The sensitivity of ongoing and future experiments to these fluctuations is estimated. Data from the WMAP, ACT, SPT, and Spider experiments will be sensitive to fluctuations with amplitude $\sim 5-10%$. The Planck satellite and Polarbear experiment will be sensitive to fluctuations with amplitude $\sim 3%$. SPTPol, ACTPol, and future space-based polarization methods will probe amplitudes as low as $\sim 0.4%-0.6%$. In the cosmic variance limit, the lowest amplitude CIPs that could be detected with the CMB are of amplitude $\sim 0.05%$.

Comments: 22 pages, 10 figures. Replaced with version published in Phys. Rev. D. Results unchanged, added Fig. 1 and corresponding discussion to explain physical origin of induced CMB correlations. Short discussion added on how to distinguish compensated isocurvature perturbations from gravitational lensing of the CMB

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