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Growth of primeval molecular fluctuations during the dark age

Denis Puy, Daniel Pfenniger

Observatory of Geneva, 1290 Sauverny, Switzerland

Abstract. During the post Big Bang recombination epoch and subsequent dark age the first molecules are thought to be form from the first neutral (He) and charged atomic species in the growing matter inhomogeneities. The knowledge of the precise molecular abundances given by solving the chemical kinetic equations in the post recombination nucleo-synthesis matter is crucial in order to determine the non-linear growth of small scale structure because some molecules such H_2 and HD do strongly determine the gas cooling.

In a Universe made of nonbaryonic dark matter and baryons, we need to discuss each component separately. Because the dark matter is affected only by gravity and is collisionless, there is no effective pressure terms in the equation of evolution for dark matter. Thus from the linearized continuity equation in the pure Fourier modes, the dark matter-baryon fluid is governed by two second-order differential equations which are coupled with the chemical and baryons evolution equations of temperature and of density.

In this talk we present calculations in the linear approximation about primordial molecule formation in a uniform medium perturbed by small inhomogeneities of various wavelengths. We analyse the differential abundances of primordial molecules H_2, HD and LiH. As Universe expands, baryonic fluctuations increase and induce strong contrasts of primordial molecules. We compare the amplitude of the molecular fluctuations with the baryonic fluctuations.

The main results is that the chemical conditions at the transition between the linear and non-linear regimes (such as in collapsing structures) are non trivial and scale dependent. Compared with the baryonic fluctuations, we find that the molecular abundance fluctuations are up to several times larger for H_2, HD and LiH. These results indicate that pronounced inhomogeneous chemical abundances are present already during the dark age. This has direct implications for the spectrum of the first bound objects since gas cooling depends then mainly on the molecules H_2 and HD.

Keywords. cosmology: early universe, cosmology: theory

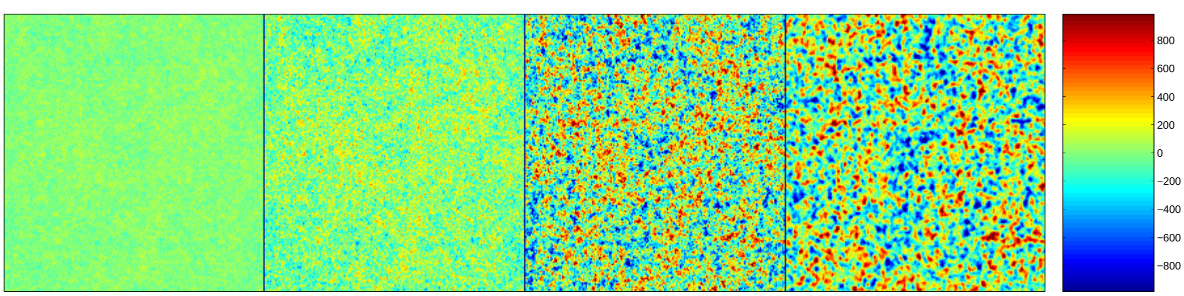

Figure 1. H_2 number density in slices cut through the simulation box (comoving size 8.85 Mpc) at redshifts $z = 1425$, $z = 1200$, $z = 600$, $z = 10$ from left to right. The scale of the pixel values are indicated at right (from -1000×10^{-6} to 1000×10^{-6}).

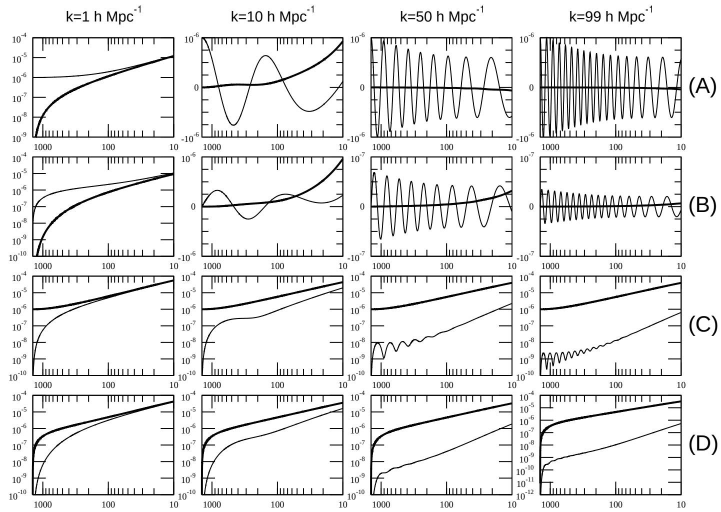

Figure 2. Evolution of the density fluctuations, in pure Fourier modes, versus the redshift z for different comoving wavenumber and elementary initial conditions. The bold lines are the dark matter density fluctuations, the thin lines are relative to baryons density fluctuation. Each column defines a particular scale ($k = 1$, $k = 10$, $k = 50$ and $k = 99$ h Mpc^{-1}), each row is relative to a particular initial condition such as (A): $\delta_{\mathrm{b,s}} = 10^{-6}/\sqrt{k}$ and $\delta_{\mathrm{d,s}} = \dot{\delta}_{\mathrm{b,s}} = \dot{\delta}_{\mathrm{d,s}} = 0$, (B): $\dot{\delta}_{\mathrm{b,s}} = 10^{-6}H/\sqrt{k}$ and $\delta_{\mathrm{b,s}} = \delta_{\mathrm{d,s}} = \dot{\delta}_{\mathrm{d,s}} = 0$, (C): $\delta_{\mathrm{d,s}} = 10^{-6}H/\sqrt{k}$ and $\delta_{\mathrm{b,s}} = \dot{\delta}_{\mathrm{b,s}} = \dot{\delta}_{\mathrm{d,s}} = 0$, (D): $\dot{\delta}_{\mathrm{d,s}} = 10^{-6}H/\sqrt{k}$ and $\delta_{\mathrm{b,s}} = \dot{\delta}_{\mathrm{b,s}} = \dot{\delta}_{\mathrm{b,s}} = 0$.

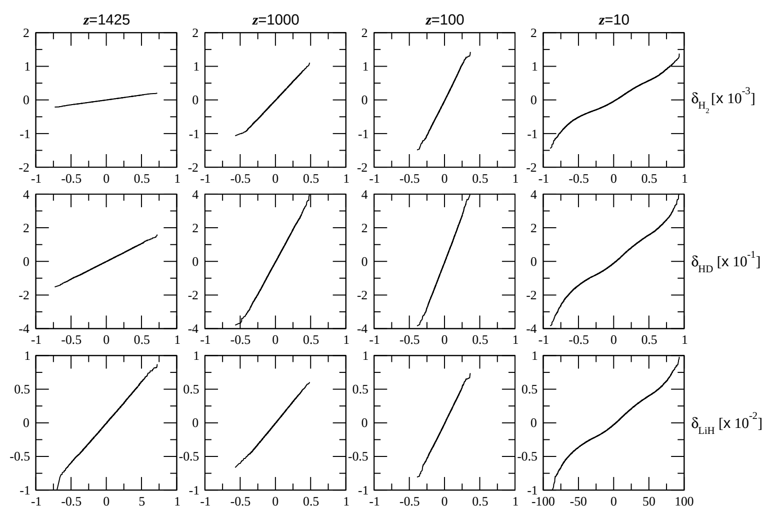

Figure 3. Comparison of amplitude between molecular fluctuations and baryonic fluctuations at the same pixel of the mapping of the physical space. Columns corresponds to some particular redshifts (from left to right): z=1425, z=1200, z=600 and z=10). Vertical axis of the top row is relative to $\delta_{\mathrm{H_2}}$ (in 10^{-3} unit), vertical axis of the middle row to δ_{HD} (in 10^{-1} unit) and vertical axis of the lower row to δ_{LiH} (in 10^{-2} unit). Horizontal axis correspond to δ_{b} (in 10^{-4} unit).