The primordial baryonic clouds and their contribution to the CMB anisotropy and polarization formation.

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A B S T R A C T

We discuss possible distortions of the ionization history of the Universe in the model with small scale baryonic clouds. The corresponding scales of the clouds are much smaller than the typical galactic mass scales. These clouds are considered in a framework of the cosmological model with the isocurvature and adiabatic perturbations. In this model the baryonic clouds do not influence the cosmic microwave background anisotropy formation directly as additional sources of perturbations, but due to change of the kinetics of the hydrogen recombination. We also study the corresponding distortions of the anisotropy and polarization power spectra in connection with the launched MAP and future PLANCK missions.

Key words: cosmology; cosmic microwave background

1 INTRODUCTION.

One of the important problems of the modern cosmology is the determination of the density and spatial distribution of the baryonic fraction of the matter.

There are several sources of information about \( \rho_b h^2 = c_b \rho_0 \) parameter, where \( \rho_b \) and \( c_b \) are the present values of the baryonic and critical densities and \( h \) is the Hubble constant normalized to 100 km s\(^{-1}\) Mpc\(^{-1}\). Firstly, the baryonic fraction of the matter manifests itself in the well-known mass-luminosity relation for galaxies and cluster of galaxies which leads to the following value of the \( \rho_b h^2 \) parameter: \( \rho_b h^2 \sim 0.028 \pm 0.009 \) (see for the review by Freedman et al. 2001). Another one comes from the confrontation of the standard Big Bang nucleosynthesis (SBBN) theory and observational data (see for the review by Fukugita, Hogan & Peebles 1998). The corresponding value of the baryonic density from this method is \( \rho_b h^2 = 0.019 \pm 0.001 \). An additional empirical relation between baryonic and dark matter fractions \( F_{\rho_m} = \rho_b / \rho_0 = 0.1 \) at \( h = 0.65 \) com es from the X-ray data on clusters of galaxies (Canenberg et al. 1996; Ettori & Fabian 1999). For the most popular CDM cosmological model with \( \Omega_b h^2 = 0.03 \) and \( \Omega_m = 0.7 \), the corresponding value of the \( \rho_b h^2 \) parameter is \( 0.02 \) in agreement with the SBBN predictions.

An independent in postant information about the baryonic fraction of the matter in the Universe comes from the recent CMB experiments such as BOOMERANG (de Bernardis et al. 2000) and MAXIMA-1 (Hanany et al. 2000). Fitting the CMB anisotropy power spectrum to the above-mentioned observational data (Tegmark & Zaldarriaga 2000; White et al. 2000 and Leagoureus &Floso 2000) indicates that a baryon fraction parameter should be significantly larger than the SBBN expected value, namely \( \rho_b h^2 \sim 0.03 \). However, recently Bond & Crittenden (2001) show that new BOOMERANG, MAXIMA-1 and DASI data do not contradict to \( \rho_b h^2 = 0.022 \pm 0.004 \).

It is worth noting that the above mentioned methods of the baryonic fraction density estimation from the CMB and SBBN predictions are based on the simple idea that the distribution of matter (including dark matter particles and baryons) is practically homogeneous for all scales, except some fluctuations leading to the galaxy and large-scale structure formation. Typically, they are assumed to be adiabatic. One can ask, how sensitive are the CMB data to the presence of the small scale baryonic (non-linear) clouds before cosmological recombination and how can they transform the standard schemes of the cosmological parameter extraction from the CMB data? Definitely, this possibility is related to the isocurvature perturbations of the com position which contains baryons, CDM particles, photons and neutrinos at very high redshift \( z \sim 10^3 \). There are a lot of modes of perturbations in the com position which is discussed by Riazuelo & Langlois (2000), Bartolo, Matarrese & Riotto (2001), Polarski & Starobinsky
el d per tur bat i ons and some kind of the CDM particles. Note, that exactly the same mode was described by Abram o & Finelli (2001), Bucher, M. oodley & Tumik (2000) and others. The general idea about classification of modes of perturbations is based on a very simple definition of the isocurvature modes. They do not perturb the gravitational potential. This means that the fluctuations of the total matter density $\delta$ are zero (see Bums 2001),

$$\delta \equiv \frac{\rho'}{\rho},$$

where $\rho'$ denotes the density of each massive species including baryons and different kinds of the CDM particles, $\rho = \rho_\text{baryon} + \rho_\text{CDM}$ is the density contrast for each massive component, $\rho'$ is the density ratio between neutrinos and black body radiation, and $T = T'$ is the CMB temperature perturbations.

We would like to point out that in the definition of the isocurvature perturbations in Eq. (1), one can nd sme peculiar mode (or modes) which compensates the baryonic perturbations potential, i.e., it corresponds to the condition $b = b'$ for some x component of the CDM particles mixture. We called this mode as a compensating isocurvature mode (CIM) for the x-component of the dark matter particles. If several components of the dark matter particles take part in the CMB formation, we will continue to call them as $\times$-components.

In principle, for the CIM perturbations it is possible to assume that the amplitudes $b$ and $b'$ are less than unity or $|b| < 1$ and $|b'| < 1$. This means that some patches of the cosmological matter do not contain the CDM $\times$-particles, but at the same patches there are non-linear clouds of the baryonic matter which compensate the perturbations of the gravitational potential. Below we will assume that a typical small scale of the CIM perturbations is smaller than the typical galactic mass scale. This means that CIM perturbations do not influence on the CMB anisotropy formation as the additional sources of perturbations, but they can transform the kinetics of the hydrogen recombination. This leads to the transformation of the corresponding CMB power spectrum of the CMB for the adiabatic fluctuations at the scales above a few Mpc.

It is necessary to note that the idea about non-homogeneous distribution of the baryonic matter at small scales is not new. The importance of the entropic perturbations in the history of the cosmological expansion was already commented by D. ozhelievich, Zeidovich and Novikov (1967) and Peebles (1967,1994) and recently was generalized taking into account multi-species structure of the cosmological plasma by Gnedin & Ostriker (1992), Hogan (1993) & Loeb (1993), Peebles & Juszkiewicz (1998). The possible inhomogeneities of the baryon fraction distribution in the epoch of the nucleosynthesis (Inhomogeneous Big Bang Nucleosynthesis -BBN) was widely discussed in the literature (see for the review by Jedam zik & Rehm 2001) in connection with quark-hadron phase transition. But the typical scales of such kind of peculiarities are extremely small compared to the typical mass scale $M = 10^{12} - 10^{13}$ for the isocurvature perturbations. Other events or processes have been suggested as possible sources of the isocurvature perturbations partially connected with the baryon re-distribution in the space. For example, cosmic strings and corresponding currents and magnetic fields could generate specific features in the baryonic matter (Malaney & Butler 1989). Yokoyama a & Sato (1991), Dolgov & Silk (1993), Polarsky & Stambinsky (1994), Novikov, Schmid & Mukhanov (2000) have shown a few different ways for the generation of the isocurvature perturbation in the framework of the inflation theory.

In connection with the above mentioned problem of the baryon fraction determination from the cosmological nucleosynthesis and the CMB anisotropy we dedicate our paper to the re-examination of the models with non-linear sub-horizon-scale (at the epoch of the hydrogen recombination) baryonic clouds with $b < 1$. Such inhomogeneities do not manifest in the CMB anisotropy (because of the extremely small scales) but manifest themselves by the transformation of the ionization history of the primordial hydrogen-helium plasma at redshift $z > 10$. All these factors should be taken into account in the reconstruction of the ionization history of the Universe especially at the period of the cosmological hydrogen recombination. The reason for importance of the possible very small scale entropy perturbations at the epoch of recombination is connected with the very small mean free path of the Ly- photons at $z > 10$. The recombination of the hydrogen-helium plasma at redshift $z = 10$ is not the hydrogen-helium recombination but it is the hydrogen-helium recombination inside and outside clouds goes independently. Due to non-linear dependency of the electronic ionization fraction $x_e$ on the baryon density the hydrogen-helium inside the clouds recombine faster than outside them. Thus the dynamical value of the electronic ionization fraction $x_e$, which plays a crucial role in the CMB anisotropy and polarization formation decreases slower than, for example, in the uniform model with the mean value of the baryonic fraction of the matter. We will show that in the cloudy baryonic plasma the kinetics of the hydrogen-helium recombination is closer to the delayed recombination model by Peebles et al. (2000) with concrete relation between and $\delta$-parametrization of their model and amplitudes of perturbations and the $\delta$-parametrization of the baryonic clouds. We will show how sensitive the CMB power spectrum of the CMB anisotropy is for the mentioned above parametrization of the baryonic clouds. We will discuss possible manifestation of the small scale perturbations in the MAP and upcoming PLANCK observational data.

\footnote{As one can see this mode corresponds to $T = T' = 0$. This means that the CMB are equivalent to an isocurvature perturbations. Note, that the same mode was described by Abram o & Finelli (2001), but for compensation between quasinormal scalar ell perturbations and some kind of the CDM particles.
2 BASIC DEFINITIONS AND MODIFICATIONS OF THE HYDROGEN-HELIUM IONIZATION HISTORY.

We consider a model with non-linear baryonic perturbations at the small scales \( M = 10^{-3} M \). In the analysis of the kinetics of recombination we will take into account electrons, protons, ionized and neutral hydrogen and helium. For simplicity we suppose that all baryonic clouds have the same characteristic sizes \( R_{c} \), which are much smaller than the size of the horizon \( R_{rec} \). Close to the period of recombination \( z \approx 10^{-3} \), \( R_{c} \approx R_{rec} \). We denote \( b_{in}, b_{out} \) and \( b_{mean} \) the baryon density inside the clouds, outside of them and the mean density at the scales much greater than \( R_{c} \) and distances between them, respectively. We have the following relations

\[
b_{mean} = b_{in} f + b_{out}(1-f),
\]

where \( f \) is the volume fraction of the clouds. We denote

\[
e = \frac{b_{in}}{b_{out}}.
\]

We can write down the following relations between the mean value of the baryon density and inner and outer values

\[
b_{in} = \frac{b_{mean}}{1 + f(1/e)},
\]

and

\[
b_{out} = \frac{b_{mean}}{1 + f(1/e)}.
\]

As mentioned in Introduction the presence of the baryonic clouds in the primordial hydrogen-helium plasma at redshift \( z \approx 10^{-3} \) changes the dynamics of the recombination due to non-linear dependence \( x_{h} \) on the baryon density. Below we will describe the kinetics of the recombination in a cloudy baryonic fraction of the Universe taking into account that the dissipation damping is not important for the clouds with \( M > M_{c} \). As it was shown by Liu et al. (2001), during the period of recombination dissipation of baryons from inner to outer regions of the clouds can suppress any small scale irregularities inside the clumps. The natural length of this process is close to the Jeans length \( R_{J} \), where \( x_{h} \) is the baryonic speed of sound and \( R_{J} \) is the corresponding time when the plasma became transparent for the CMB radiation. Note that our aim is to predict some possible observational features in the CMB anisotropy and polarization power spectrum connected with possible non-uniform distribution of baryons on very small scales much smaller than \( R_{rec} \), but greater than the Jeans scale \( R_{J} \). That means that for all adiabatic perturbations at the scales \( M = 10^{-3} M \) (which are the source of the Doppler peaks in the CMB anisotropy and polarization power spectra) the evolution during the period of recombination depends not on the ionization fraction inside or outside the clouds but rather on the mean value of ionization fraction over the scales of adiabatic perturbations. As mentioned above this mean ionization fraction does not correspond to the ionization fraction for the mean value of the baryon density due to non-linear effects. For our analysis we use two basic software packages, RECFAST (Seager et al. 2000) and CM BFAST (Seljak & Zaldarriaga 1996) with modification for the cloudy baryonic model. Let us start from CM BFAST modification because the calculation of the CMB anisotropy and polarization power spectra depends on the number density of free electrons.

For the cloudy baryonic model we introduce the mean value of the electron density

\[
n_{e;in} = n_{e;in} f + n_{e;out}(1-f),
\]

where \( f \) is the fraction of volume with clouds from Eq. (2). For the baryonic clouds with scales \( R > R_{c} \) we can neglect diffusion of baryons and Ly \( \alpha \) photons and describe the recombination process inside and outside the clouds separately. In such a case we can write down

\[
n_{e;in} = n_{e;in} \frac{1}{2} \frac{Y_{e;in} x_{h}}{x_{h}} n_{b;in};
\]

\[
n_{e;out} = n_{e;out} \frac{1}{2} \frac{Y_{e;out} x_{h}}{x_{h}} n_{b;out};
\]

where \( x_{e;in}, x_{e;out}, Y_{e;in} \) and \( Y_{e;out} \) are the ionization fraction and helium mass fractions for inner and outer regions. Note that by definition \( x_{h} = n_{e;in} / n_{b;in} \), where \( n_{h} \) is the number density of neutral and ionized hydrogen. Let us introduce the mean value of the ionization fraction \( h_{x;in} \)

\[
h_{x;in} = \frac{m_{e;in}}{m_{e;in} + m_{h;in} + 1} \frac{1}{2} Y_{e;in} x_{h};
\]

then

\[
h_{x;in} = x_{e;in} G_{in} + x_{e;out} G_{out};
\]

where

\[
G_{in} = \frac{f}{1 + f(1/e)} \frac{1}{1} \frac{Y_{e;in} x_{h} = 2}{1} Y_{e;in} \frac{1}{2};
\]

\[
G_{out} = \frac{f}{1 + f(1/e)} \frac{1}{1} \frac{Y_{e;out} x_{h} = 2}{1} Y_{e;out} \frac{1}{2};
\]

and \( Y_{e;in} \) denotes the mean mass fraction of helium.

The second remark is related with the modification of the CM BFAST code, particularly with the characteristic time of friction \( \tau_{fr} \) between electron and radiation scales before and at the period of the recombination. Let us consider the hydrodynamic equations for baryon-electron and radiation using the Newtonian approximation. Following Liu et al. (2001), we have

\[
b + 3H_{b} + r_{i} (b V_{ib}) = 0;
\]

\[
V_{ib} + H V_{ib} + V_{ib} (r_{i} V_{ib}) + r_{i} P_{b} = b + r_{i}
\]

where \( H = a \omega_{a} \), \( a \) is the scale factor of the Universe, \( \omega_{a} \) is the gravitational potential, \( r_{i} \) denotes the derivative with respect to time \( d = dw_{a} / c \), the speed of light \( c = 1 \), \( m_{b} \) is the density of the CMB, \( n_{e} \) is the local concentration of electrons, \( V_{ib} \) is hydrodynamic velocity of radiation (doppler moment) and \( \gamma \) is the Thompsen cross-section. In our cloudy baryonic model we can denote the large scale adiabatic tail of the perturbations of the matter and the small scale CMB tail as follows

\[
b = b_{in} (\tau t) + b_{out} (\tau t);
\]

\[
V_{ib} = \frac{V_{ib}^{(a)} (\tau t)}{V_{ib}^{(a)} (\tau t)} + V_{ib}^{(i)} (\tau t);
\]

\[
= \gamma (\tau t) + i (\tau t);
\]

(12)
where

\[
\begin{align*}
\h_{\beta i} &= \h_{\beta i} (\tau; t) + \h_{i} (\tau; t), \\
\h_{\beta i} (\tau; t) &= \h_{\beta i} (\tau; t) (1 + \h_{i} (\tau; t)), \\
\h_{i} (\tau; t) &= \h_{i} (\tau; t) + V_{i b}^{(i)} (\tau; t), \\
\h_{i} (\tau; t) &= \h_{i} (\tau; t) + V_{i b}^{(i)} (\tau; t) + V_{i b}^{(1)} (\tau; t), \\
\h_{i} (\tau; t) &= \h_{i} (\tau; t) + V_{i b}^{(i)} (\tau; t) + V_{i b}^{(1)} (\tau; t) + V_{i b}^{(2)} (\tau; t), \\
\end{align*}
\]

and \(\tau; t\), \(V_{i b}^{(i)} (\tau; t)\) and \(V_{i b}^{(1)} (\tau; t)\) are the linear adiabatic perturbation of the hydrodynamic quantities. By the definition \(\h_{\beta i} (\tau; t)\) means average over the scales \(\h_{\beta i} (\tau; t)\) but \(\h_{\beta i} (\tau; t)\) for all \(k\) Fourier harmonics of the adiabatic perturbations. Using Eq. (12) and (13) we can describe the evolution of the velocity perturbations for the adiabatic modes

\[
\frac{\partial V_{i b}^{(i)} (\tau; t)}{\partial \tau} + H \frac{\partial V_{i b}^{(i)} (\tau; t)}{\partial \tau} + \frac{V_{i b}^{(i)} (\tau; t)}{3} = 3 \frac{\partial n_{h} (\tau; t)}{\partial \tau},
\]

where \(n_{h} (\tau; t)\) is the mass density of the baryon-photon fluid and \(3 \frac{\partial h_{i} (\tau; t)}{\partial \tau}\) means the adiabatic part of the perturbations. As one can see from Eq. (14) in the cloudy baryonic matter the characteristic time of baryon-radiation friction is

\[
\frac{1}{3} = \frac{4 \frac{\partial n_{h} (\tau; t)}{\partial \tau}}{3 \frac{\partial n_{h} (\tau; t)}{\partial \tau}} = \frac{4 \h_{i} (\tau; t)}{3 \frac{\partial n_{h} (\tau; t)}{\partial \tau}},
\]

where \(\h_{i} (\tau; t)\) is the standard equation depends on \(n_{h} (\tau; t)\). Thus Eq. (15) and Eq. (16) generalize the standard homogeneous model of the CMB anisotropy and polarization formation on the cloudy baryonic model of the Universe. Note the difference between Eq. (15) and the standard kinetic equation for the CMB anisotropy formation. Whereas Eq. (15) depends on \(\h_{i} (\tau; t)\), the standard equation depends on \(\f_{i} (\tau; t)\) (see Eq. (8) and (9)). The corresponding modification of the CMBFAST program which calculates the kinetics of recombination inside and outside the small scale baryonic clouds as a function of cosmological parameter \(\h_{i} (\tau; t) = \beta m i = \h_{i} (\tau; t)\) density contrast and volume element \(dV\). In Fig. 1 and Fig. 2 we plot the functions \(n_{h} (\tau; t)\) and \(m_{h} (\tau; t)\) for different mean values of the baryonic density \(\h_{i} (\tau; t)\) and \(\h_{i} (\tau; t) = 1\) and \(\h_{i} (\tau; t) = 1\). As one can see from these figures the functions of ionization \(\h_{i} (\tau; t)\) and \(m_{h} (\tau; t)\) have different shapes and different asymptotic behavior at low redshifts.

In the next section we describe the results of the corresponding number of computer simulations. However, some preliminary discussions could be very useful for understanding of the most important peculiarities connected with two characteristic functions of ionization \(\h_{i} (\tau; t)\) and \(m_{h} (\tau; t)\). Firstly we would like to point out that in the case when the volume fraction \(f = 1\), but \(f = 0.1\) the function \(\f_{i} (\tau; t)\) should be very close to \(n_{h} (\tau; t)\), which practically does not change. From Eq. (15) and Eq. (16) we can immediately find the asymptotic behavior of the function \(\f_{i} (\tau; t)\) at low redshifts:

\[
\f_{i} (\tau; t) \rightarrow h_{i} (\tau; t) = (1 + f (\tau; t)) < h_{i} (\tau; t).
\]

This means that the Silk damping scale is very sensitive on the parameter \(\f_{i} (\tau; t)\), which is proportional to \(h_{i} (\tau; t)\), should increase due to the increasing of the effective inertial mass \(h_{i} (\tau; t)\). Thus we can conclude that in cloudy baryonic model the position and amplitudes of the CMB peaks in the CMB power spectrum differ from the same values in the standard non-cloudy model with the same mean value of the baryonic density \(\h_{i} (\tau; t)\).

Secondly it is well known that the so-called "viscosity function" \(g(\tau) = \exp(-\tau)\), where is the Thomp-
son optical depth, depends on the function \( \bar{h} \). Because \( \bar{h}_\text{i} \) and \( \bar{h}_\text{out} \) we can conclude that in our model the kinetics of recombination is similar (in general) to the models with additional sources of the ionization.

One additional moment is related with the delayed recombination model by Peebles et al. (2000) mentioned in Introduction. We would like to note, that the physical basis of their model and our cloudy baryonic model are completely different, but the mean eral data for the corresponding function \( x_\text{a} \) in the model by Peebles et al. (2000) and \( \bar{h}_\text{i} \) in our model are close to each other. If we compare the solid lines with the shaded lines in Fig. 1, we can conclude that change of the ionization fraction \( \bar{h}_\text{i} \) plays a role in the corresponding delay of the recombination with respect to the recombination inside the clouds. To understand the change of the CMB anisotropy and polarization power spectra we need to compare the ionization fraction for outer regions and \( \bar{h}_\text{i} \). From Fig. 1 it is clearly seen that in such a case we can introduce the term "accelerated recombination" because the mean ionization \( \bar{h}_\text{i} \) faster then \( x_\text{a} \) for the outer regions at the same values of the \( \bar{h} \) parameter. In both cases, following Peebles et al. (2000), we can describe the number of additional resonance quanta produced at the epoch of the hydrogen recombination by the sources of ionization

\[
\frac{dn_{\text{res}}}{dt} = \bar{h} (t) n_\text{b} \quad (18)
\]

where \( \bar{h} \) is the efficiency of the \( \text{Ly} \alpha \) quanta production, \( n_\text{b} \) is the Hubble parameter and \( n_\text{b} \) is the number density of baryons. According to Peebles et al. (2000), \( \bar{h} > 0 \) describes the productivity of the sources of additional resonance quanta, which leads to the delay of the hydrogen recombination. Formally, if \( \bar{h} < 0 \) then recombination goes faster and we have "accelerated recombination" regime. Thus, the difference between these two situations is related to the definition of the background state (inner or outer parts of the clouds). Note that for the CMB power spectrum calculations the term "accelerated recombination" is preferable because it depends mainly on the characteristics of the outer zones.

3 ANISOTROPY AND POLARIZATION POWER SPECTRA IN A CLOUDY BARYONIC UNIVERSE.

For numerical calculations of the CMB anisotropy and polarization power spectra we will use the model of CMBFAST code taking into account the above-mentioned peculiarities of the ionization history of the plasma. We take into account the difference in the hydrogen mass fractions \( Y_\text{b} \) for inner and outer zones into account, using well-calibrated dependence of \( Y_\text{b} \) on \( \bar{h} \) (parametric dependence of \( Y_\text{b} \) on \( \bar{h} \) is 0.117 Steigman & Walker 2000). For illustration of the importance of the cloudy structure at small scales on the CMB anisotropy signal in Fig. 3 we plot the function \( \bar{h} \) for various values of the mass fractions \( Y_\text{b} \) for inner and outer zones into account, using well-calibrated dependence of \( Y_\text{b} \) on \( \bar{h} \) (parametric dependence of \( Y_\text{b} \) on \( \bar{h} \) is 0.117 Steigman & Walker 2000).

As one can see from Fig. 3, the presence of the clouds before and during the period of the hydrogen and helium recombination significantly perturbs the corresponding \( \bar{h} \) function. The same conclusion follows from Fig. 4 for the polarization of the CMB in the cloudy baryonic model.

As it is seen from Fig. 4 the more complicated ionization history of the plasma in the cloudy model leads to the decreasing of the corresponding power spectrum of the polarization at \( l \sim 900 \) due to the increasing of the effective dissipation scale. It is worth noting that in our cloudy model we do not take into account the possible reionization of the hydrogen at low redshift (\( z < 20 \)) due to the influence of...
As was mentioned in Introduction, the baryonic fraction of the matter is one of the most important cosmological parameters, which determines the mass of observable objects in the Universe. Two crucial parameters of the theory are now under discussion, i.e., the light chemical elements abundance, which is related directly to the SBBN predictions, and the $b$ parameter, which can be determined from the current and future CMB observations. Both cases the detection fraction depends on the hypothesis about the spatial distribution of the baryonic fraction of the matter and can be tested by the CMB experiments such as the launched MAP and the future PLANCK missions.

In our paper we have shown how important it is the possible baryonization at small scales ($M \sim 10^{13} M_\odot$) in the CMB anisotropy and polarization formation through distortions of the cosmological background. The extreme case, when the density contrast $\delta > 10$, shows that the clumps in the baryon fraction of the matter can significantly change the anisotropies and positions of the Doppell peak in the CMB anisotropy and polarization power spectrum. For example, in the above mentioned $\delta > 10$ model the differences between $C_2$ for the anisotropy and for the polarization in the models with $\delta h = 0.02$ (no clouds) and $\delta h = 0.02$ (with clouds) are presented in Fig. 5 in a form of the following relations. For the anisotropy

$$D_2(l) = 2(C_{2,l} \pm C_{2,l} + C_{2,l} + C_{2,l}),$$

(19)

where $C_{2,l}$ (solid line) and $C_{2,l}$ (dashed line) denote the non-cloudy and cloudy models, respectively, and the index $l$ corresponds to the anisotropy spectrum. The analogous definition of the $D_2(l)$ function is used in Fig. 5 for the CMB polarization. As one can see from Fig. 5, practically for all ranges of multipoles the differences between cloudy and non-cloudy models are observable for the PLANCK mission. Moreover, if the parameter $\delta > 1$, then we need to include the possible cloudy baryonic cloud in the scheme of the cosmological parameter extraction from the current and future CMB anisotropy and polarization data. As one can see from Eq.(4) and Eq.(5), if $f(1) > 1$, then the difference between $b_{\text{planck}}$ and mean baryon density is $f(1)$, where $f(1)$ corresponds to the Planck mission. According to the prediction of the cosmological parameter extraction from the Planck mission, the corresponding uncertainties for the baryonic fraction of the matter $\delta = \delta_{\text{b}}$ must be less than a few percent. Taking conservative limits $f = 0.01$ and $f = 1.0$ we can obtain that the corresponding fraction should be detectable by the Planck satellite, $f(1) > 10^{-2}$.

We would like to point out that our simple model of the baryonic clouds is based on the one possible mode of the anisotropy perturbations at all scales. It would be interesting to investigate the more complicated models of the initial perturbations. This program is in progress.

4 CONCLUSION.

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Figure 5. The functions $D(l)$ for the anisotropy (solid line) and polarization (dashed line) as functions of the multipole number $l$ for $b = b_0$, $f = 0$ in a model.
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