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DISTORSION OF THE CMBR SPECTRUM: A TENTATIVE EXPLANATION

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Abstract. The purpose of this note is to present a possible explanation of the spectral distortions that could be measured in the Cosmic Microwave Background Radiation (CMBR) spectrum. We propose that distorsions of the order of $y \sim 10^{-6}$ can be interpreted as a consequence of the radiative decay of massive tau neutrinos. We have also obtained a constraint on the value of the decaying neutrino mass.

1. INTRODUCTION

The CMBR represents perhaps the most important clue for understanding of the universe as we know it today. It has a well established blackbody spectrum of temperature $T_0 = 2.728 \pm 0.004$ (95 % CL) (Fixsen *et al.* 1996). However, CMBR is not perfectly isotropic leading thus to very important conclusions concerning the evolution and development of the Universe. We here try to present the possible influence of decaying massive neutrinos on the distorsions of the CMBR profile.

It is well known that the decay of stable particles, for example, massive neutrinos decaying with a small branching ratio, distorts the CMBR spectrum (e.g., Smoot 1995). We assume that a massive neutrino ν_1 of mass m_{ν_1} and lifetime τ decays into:

$$\nu_1 \to \nu_2 + X \tag{1}$$

or

$$\nu_1 \to \gamma + \nu_2 \tag{2}$$

(e.g., Bernstein and Dodelson, 1990).

The following relation holds:

$$\frac{m_{\nu_2}}{m_{\nu_1}} \ll 1. \tag{3}$$

2. CALCULATIONS

In the decaying dark matter (DDM) theory (Sciama 1993, for modifications see Sciama 1997) we assume that the mass of the τ neutrino is:

$$m_{\nu_\tau} = 27.4 \pm 0.2\,\mathrm{eV}.$$

As one can see this is a heavy constraint, leading thus to constraints of some important cosmological parameters such as the density parameter Ω, Hubble constant H_0 and the age of the Universe (see Sciama 1997)). One important characteristic of these decaying neutrinos is their lifetime. According to some latest estimates it is:

$$\tau \sim 1 \times 10^{23}\,\mathrm{s} \tag{4}$$

(Sciama 1995, Sciama 1997).

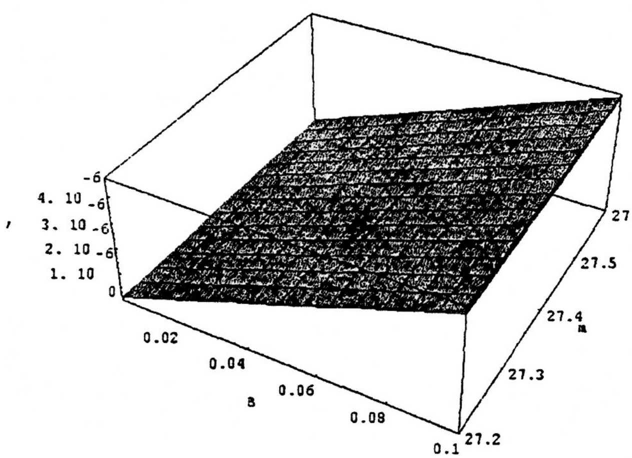

Fig. 1. Dependence of y, deviation of the CMBR spectrum from a blackbody function, on the branching ratio B and the mass of the tau neutrino m.

Apart from being important for the structure of spiral galaxies (see e.g., Samurović and Čelebonović 1996) these neutrinos could have important influence on the ionization in the Universe (Sciama 1993). One of the possible tests for their detection, besides the direct search for the decay line originating from the emission of the line with energy $E_\gamma \approx \frac{m_{\nu_\tau}}{2} \approx 13.7$ eV (enough to ionize hydrogen) that has recently started (mission EURD, April 21, 1997)* could also be transfer of the decay photon

* URL: http://www.laeff.esa.es/eng/laeff/activity/eurd.html.

energy to the CMBR photons in a two step process: decay photons heat the electrons through the inverse Compton scattering and hot electrons through inverse Compton scattering, give energy to the CMBR (Sunyaev-Zel'dovich effect). In the limit of small energy transfer from decay photons to electrons, the deviations of the CMBR spectrum from a blackbody spectrum $y \sim \frac{\delta u}{4u} \leq 1.5 \times 10^{-5}$ is:

$$y \simeq 6 \times 10^{-8} B(\frac{m_\nu}{\mathrm{eV}})^2 \tag{5}$$

(Sethi 1997). As one can from the Figure 1 the possibly observable region of y ($y \lesssim 4 \times 10^{-6}$) requires that the branching ratio is equal to 0.1. The mass of the tau neutrino $m_{\nu_\tau} = 27.4 \pm 0.2$ is assumed. If these parameters B and m_{ν_τ} are really in this range then the evidence for the existence of these massive neutrinos will come in the next decade when the new high-resolution CMBR experiments are planned. One can hope that the evidence will come much earlier – after the results of the EURD mission are obtained.

According to Sethi (1997) (and references therein) the following equation holds:

$$y \simeq 5 \times 10^{-5} B m_\nu{}^{\frac{4}{3}} t_\nu^{-\frac{1}{3}}. \tag{6}$$

where m_ν is expressed in eV and $t_\nu = \tau_\nu B$ is expressed in seconds.

Imposing $y = 4 \times 10^{-6}$ and $\tau_\nu \sim 10^{23}$ from Fig. 1 it follows from the equation (6) that:

$$B \simeq \frac{7.1 \times 10^9}{m_\nu^2}. \tag{7}$$

Obviously B must be $B \leq 1$ thus giving from eq. (7):

$$m_\nu \leq 8.4 \times 10^4 \mathrm{eV}. \tag{8}$$

A strange coincidence is that according to recent experiments $m_{\nu_\mu} \leq 170$ keV (Brunner 1997)! The current experimental upper limit (Brunner 1997) for the mass for the mass of the tau neutrino is:

$$\mathrm{ALEPH}: \; m_{\nu_\tau} < 23.1\mathrm{MeV}\ 95\%\ \mathrm{C.L.}$$

$$\mathrm{OPAL}: \; m_{\nu_\tau} < 29.9\mathrm{MeV}\ 95\%\ \mathrm{C.L.}$$

Taking the mean value and inserting it into eq. (7) one gets that

$$B \simeq 10^{-5}.$$

3. DDM AND THE REIONIZATION

The only other astrophysical method in search for the DDM is direct observing of the decay line. Gunn-Peterson (GP) test suggests that this radiation is absorbed in ambiental intergalactic medium (IGM) or Lyman α forest clouds. Fluorescence will cause transfer of energy from original narrow line to optical recombination line of hydrogen. Unfortunately, contribution of DDM to Lyman α and Hα lines is indistinguishable from fluorescence due to other photoionization sources. If baryonic content of the Universe is near the lower bound from primordial nucleosynthesis (Walker *et al.* 1991), but much clumpier then usually supposed, internal photoionization sources (like star formation in galaxies) will dominate over the weak background. In any case, weakness of recombination signal from gas clouds free of internal ionization may be used to constrain lifetime and branching ratio of decaying neutrinos. Failure to detect any recombination emission at high and medium redshift will probably be remedied soon, as sensitivity of deep space narrow-band imaging increases (Bland-Hawthorn 1997; Ćirković and Samurović 1997).

The exact picture of energy transport processes depends on (1) abundance of baryons in the Universe, and (2) clustering properties of IGM. The second issue remains basic problem for both optical and CMBR methods. In addition optical searches suffer from big uncertainty in value of metagalactic ionizing flux, $J(HI)$. "Classical" proximity effect value of $\sim 10^{-21}$ erg s^{-1} Hz^{-1} cm^{-2} sr^{-1} (Bajtlik *et al.* 1988) is an overestimate, probably for a whole order of magnitude. This circumstance is another advantage of looking for DDM signature in the microwave anisotropies.

4. CONCLUSION

We have shown that attempting to explain the distortions of the CMBR of the order of $\sim 10^{-6}$ as a consequence of the radiative decay of massive neutrinos is physically acceptable. Another conclusion is the upper limit for the mass of the neutrinos. The value we have obtained is in agreement with recent laboratory work and Sciama's theory. The continuation of this work aiming at predicting the values of observable parameters, such as angular scale and correlation length, for a given set of cosmological parameters is in preparation.

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