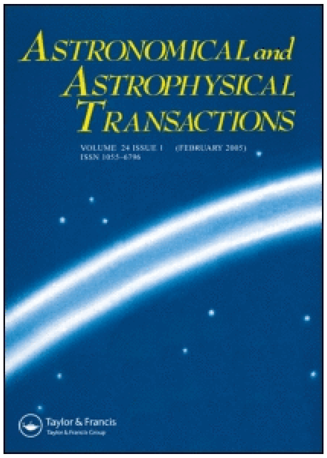

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MICROWAVE BACKGROUND RADIATION AND COSMOLOGICAL LARGE NUMBERS

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The possible interpretations of the cosmic microwave background radiation (CMBR) in different cosmological models are reviewed. It is shown that the wavelength of the maximum in microwave background spectrum is expressed as a geometrical mean of the Planck and Hubble length: $\lambda_{\rm MB} \sim \sqrt{l_{\rm pl} \cdot R_H}$. This is not a coincidence but a direct consequence of physical laws in an extreme selfgravitating object, "Hubbloid", with an upper limit of equilibrium radiation temperature about 30 K.

KEY WORDS Cosmological models, cosmic microwave background radiation, temperature

1 INTRODUCTION

For a long time since discovery of the microwave background radiation by Penzias and Wilson (1965), its Gamov's "hot Big-Bang" interpretation (Gamov, 1953) has been prevailing. But growing amount of observational data and corresponding problems stimulated other approaches to this problem dealing with "non-primordial" nature of the CMBR (Lyser and Hively, 1973; Rees, 1978; Hoyle *et al.*, 1993). It appeared that CMBR phenomenon could, in principle, be understood in "hot Big-Bang" cosmological models, providing, in general, the energy release and thermalization mechanisms. At the same time the expression for characteristic temperature of the CMBR could be obtained using physical constants only (without any reference to observable parameters) aggregated in the so-called "Cosmological Large Numbers".

In Section 2 we analyze known estimates of the CMBR temperature. In Section 3 we suggest a new way for getting its upper limit under very broad and general conditions. In Section 4 observational tests concerning the nature of the CMBR are briefly discussed.

2 PREVIOUS ESTIMATES OF THE CMBR TEMPERATURE (BT)

Gamov (1953) calculated the background temperature (BT) in "three steps" according to Chernin (1994), (1) equating matter ρ_m to radiation ρ_r densities at some epoch $t_* = 2.2 \times 10^{15}$ s:

$$\rho_r = \rho_m = 9.4 \times 10^{-26}\ \mathrm{g\ cm^{-3}}; \tag{1}$$

(2) from the Stefan-Boltzmann law $\rho_r c^2 = aT^4$, temperature T at the same epoch is

$$T(t_*) = \left(\frac{p_r c^2}{a}\right)^{1/4} = 320\ \mathrm{K}; \tag{2}$$

(3) the BT at present epoch $t_0 = 10^{17}$ s with allowance for the Universe expansion is

$$T(t_0) = T(t_*)\left(\frac{t_*}{t_0}\right) = 7\ \mathrm{K}. \tag{3}$$

So to get a BT estimate, Gamov used two observed quantities, ρ_m and t_0 and three steps, (1), (2) and (3).

Within non-primordial CMBR interpretations, Lyser and Hively (1973) proposed that CMBR was generated by ordinary astrophysical processes (thermonuclear reactions in stars or gravitational collapse of primordial objects) and subsequently thermalized by interaction with dust grains.

Rees (1978) discussed the contributions to the opacity associated with dust, molecules and the ionized component of the medium. His BT estimation based on "two observed parameters", ρ_m and z_*, the redshift of primary massive stars formation, and "three steps":

(1) $\rho_r = \varepsilon \rho_m$ at $z_* = 100$,

(2) $T(z_*) = (\rho c^2/a)^{1/4} \approx 300$ K,

(3) $T(0) = T(z_*)/(z_* + 1) \approx 3$ K.

The suggestion about equality of some part of matter ρ_m and radiation ρ_r densities among these steps is most important. It gives clue to the order of magnitude of the BT as was shown by Hoyle at the late sixties, after the CMBR discovery (Hoyle, 1992). Hoyle obtained the CMBR temperature in "two steps": (1) it is accepted that the He abundance observed at present time is about 1/4 of the total mass density of luminous matter in the Universe, $\rho_{\mathrm{lum}} = 3 \times 10^{-31}$ g cm^{-3}, as a result of thermonuclear reactions in previous generations of stars, which is equivalent of the 0.0018 fraction of mass having been transformed into radiation:

$$\rho_r = 0.0018 \rho_{\mathrm{lum}} = 5 \times 10^{-34}\ \mathrm{g\ cm^{-3}}; \tag{4}$$

(2) The Stefan-Boltzmann law then gives the BT:

$$T = (\rho_r c^2/a)^{1/4} = 3\ \mathrm{K}. \tag{5}$$

Thus the central point in Hoyle's arguments is the suggestion of the equality of the CMBR energy density to the fixed portion of the baryonic matter. He used "one observed parameter" $\rho_{\rm lum}$ and "two steps" (4), (5).

This estimation (5) is a stable one because of the fourth power root of the radiative energy density. As was emphasized by Harrison (1981), even in the case when all observable matter were transformed to background radiation its temperature would not exceed 20 K.

3 BT UPPER LIMIT FOR THE EXTREME COSMOLOGICAL OBJECT

Now we show that there is an upper limit on the CMBR temperature which can be derived from very general physical principles and does not depend on observed cosmological parameters. Let us consider two Large Cosmological Numbers, $Q_1 = \frac{e^2}{Gm_em_p}$ and $Q_2 = \frac{R_H}{r_e}$, where e is the electron's electric charge, m_e, m_p are the electron and proton masses, respectively, R_H is the Hubble radius and r_e is the classical electron radius.

Following Baryshev and Raikov (1988) and Baryshev *et al.* (1994), consider the extreme self-gravitating object ("Hubbloid") for which the Eddington luminousity is equal to the Planck one:

$$L_{\rm Edd} \sim \frac{GMm_pc}{\sigma_T} \sim L_{\rm pl} \sim \frac{c^5}{G}. \qquad (6)$$

It follows from (6) that the "Hubbloid" mass is given by

$$M_H \sim m_pQ_1^2 \sim 10^{56}\ {\rm g}, \qquad (7)$$

and its radius is $R_H = R_g = \frac{2GM}{c^2} \sim r_eQ_1 \sim 10^{28}$ cm, which leads to $Q_1 \sim Q_2 = Q$.

The characteristic radiation density within the "Hubbloid" is

$$\rho_rc^2 \sim \frac{L_{\rm pl}}{\pi R_H^2C} \sim \frac{c^8}{4\pi G^3m_p^2Q^4} \sim 10^{-7}\ {\rm g\ cm^{-1}\ s^{-2}}, \qquad (8)$$

which, according to the Stefan-Boltzmann law gives

$$T_H = \left(\frac{\rho_rc^2}{a}\right)^{1/4} \sim 30\ {\rm K}. \qquad (9)$$

This temperature corresponds to the so-called Planck temperature $T_{\rm pl} \sim h^{1/2}$ divided by the Large Number to the power 3/4:

$$T_H \sim T_{\rm pl}/Q^{3/4}. \qquad (10)$$

Equation (10) can be written in the form

$$\lambda_{\rm MB} \sim \sqrt{l_{\rm pl} \cdot R_H}, \qquad (11)$$

where λ_{MB} is the characteristic wavelength of the CMBR, l_{pl} is the Planck length and R_H is the Hubble length.

The above calculations obviously give only an upper limit on the BT. It is very important that it does not depend on specific cosmological model, thermalization mechanisms and observed cosmological parameters.

4 OBSERVATIONAL TEST ON THE CMBR NATURE

The standard "Big-Bang" model gives a linear dependence of the BT on redshift:

$$T_0 = T_1/(1+z_1),$$

which suggest experimental testing of its nature because in other models there could be other dependencies.

There are at least two tests of this kind: observations of CI exitations in remote absorbing clouds with large redshifts and observations of the Sunyaev–Zel'dovich effect, namely the behavior of a flux excess with the redshift (see e.g. Baryshev, 1992). So the question about the nature of the cosmic microwave background should be solved by observations.

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