RATAN-600 AND CMB ANISOTROPY: NEW RATAN-600 LIMITS

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ABSTRACT

We present new limits on the small scale 3 K emission anisotropy. At scales of 1°-3.3° all seven harmonics have amplitudes below 10^{-5} in $\Delta T/T$ at our wavelength of 7.6 cm. At the 6.1×10^3 to 17.5×10^3 (rad^{-1}) scale, this limit is about 2.8×10^{-4} (at 2.7 cm wavelength) and the observations may be fully explained by contributions from discrete sources. The low baryonic content of the Universe and present limit on the $\Delta T/T$ at the horizon scale suggest that $(\Delta M/M)_{\mathrm{gravitating}} \ll (\Delta M/M)_{\mathrm{baryonic}}$. We speculate that the 3 K anisotropy measurements prove a) the existence of the dark matter, b) the nonbaryonic nature of this dark matter and c) that the space distribution of this matter is much more homogeneous than that of the visible one.

1. INTRODUCTION

All our attempts (from 1968) to observe theoretically predicted 3 K emission anisotropy are summarized in Parijskij et al., 1986. In this paper we present new attempts, using specially developed multi-frequency cryogenic receivers and data acquisition system at the RATAN-600 radio telescope.

2. STRATEGY

We tried to decrease problems we've had in the COLD-80 experiment (Parijskij et al., 1986) with the confusion effect. The main wavelength in the present COLD-90 experiment was chosen to be 2.7 cm instead of 7.6 cm as used earlier. This change decreased the confusion noise by a factor of about 20. To get the appropriate level of thermal sensitivity we chose a circumpolar region (instead of the equatorial one in the COLD-80 experiment) for transit mode of observation.

3. RECEIVERS

In the COLD-80 experiment we used 31 cm, 8.3 cm, 7.6 cm, 3.9 cm, 2.1 cm and 1.38 cm receivers, having 7.6 cm as the main

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wavelength. In the present COLD-90 experiment we improved the 31 cm receiver's sensitivity by a factor of 2, improved the stability of the 7.6 cm receiver, developed a new cryogenic receiver at 2.7 cm with sensitivity 5 mK/s$^{\frac{1}{2}}$, improved the 1.38 cm receiver's sensitivity by a factor of 3 and installed a new three-frequency receiver block at 6 cm, 2.7 cm and 1.0 cm wavelengths with sensitivities of 5, 7, and 12 mK/s$^{\frac{1}{2}}$, respectively. At 31 cm and 7.6 cm only single beam observations were possible; at the others, a beam switching mode might be used with some freedom in positions of the beams on the sky.

4. DATA REDUCTION

R.m.s. fluctuations on the average scan (we had about 60 daily scans) were about 0.4 mK without any cleaning except for background subtraction with a smoothing window of 200 sec width. We divided all the scans into two independent groups, averaged over all the scans in each group, convolved both results with main beam cross section and looked for the r.m.s. amplitude of the coherent signal which existed in both groups after cleaning them at some fixed level (to find weak coherence signal we used the "Jackknifing" method, Miller, 1968). Then the result was averaged over different scan groupings. This was done for different cleaning levels down to 3-sigma level (about 1.1 mK). If the coherent signal does not depend on the cutoff level, it might be 3 K-anisotropy noise well below the receiver noise. In the opposite case it may be the confusion noise.

To estimate confusion noise we used source counts collected by Franceschini et al. (1989) extrapolated to 2.7 cm with the source population model presented in the same paper. The computer simulation included generation of two scans with different levels of noise added in, evaluation of the above described algorithm and averaging the results over different signal realizations.

5. RESULTS

Here only preliminary results will be discussed, involving the smallest beam spacing at 2.7 cm and the new data reduction of 7.6 cm COLD-80 data.

5.1 7.6 cm Observations

Using COLD-80 data (see Parijskij, Korolkov, 1986 for the details) in the 0.5°-5° scale interval, we calculated a Fourier spectrum of the coldest part of the strip centered at the declination of SS433, after subtraction of the correlated noise at 31 cm and at 2.1 cm (Galaxy, standard spectrum sources and water vapor emission). The result is shown in Table I.

TABLE I

Scale, degrees	1.1	1.25	1.43	1.67	2.0	2.5	3.3
Amplitude, $\Delta T/T\times 10^6$	4	2	7	6	4	8	7

5.2 2.7 cm Observations

At this wavelength the resolution of RATAN-600 is limited by the proper interval 7.5 arcsec with FWHP = 18 arcsec in right ascension and by FWHP = 12 arcmin in declination. Separation between two beams in the observations discussed here was 40 arcsec. The resulting data discreteness interval was 10 arcsec. We subtracted the background using 200 arcsec window to reduce large-scale interferences and then convolved data with the central beam cross section. All this affected the spectral sensitivity. It results in the fact that only the information at the scales between $\ell = 6.1\times 10^3$ and $\ell = 17.5\times 10^3$ was left (the limits correspond to half-maximum spectral sensitivity).

We accumulated data in the transit mode with fixed position of the beam at DEC 86°14′ (1950) and at $2^h <$ R.A. $< 22^h$ during two months in the spring of 1990. At this declination transit time of 1 arcsec is about 1 sec of time.

We shall summarize the results of 2.7 cm experiment at the present stage of data reduction:

1. The presence of coherent signal in two independent groups of observations was established.

2. The amplitude of this signal depends on the cleaning level, being smaller at lower cleaning level.

Table II illustrates these statements.

TABLE II Coherent signal and cleaning level

Cleaning	Experiment		Computer simulation	
level mK	signal mK	sigma-error mK	signal mK	sigma-error mK
3.500	0.171	0.027	0.143	0.017
1.600	0.127	0.011	0.115	0.009
1.100	0.088	0.017	0.098	0.012

We see that the experiment shows practically the same level of the coherent signal as was expected from the simple LogN-LogS curve model.

Our observations do not contradict the zero level of small scale anisotropy in the resulting spectral window. After careful analysis we estimate an extra noise no more than about 20 microK in antenna temperature (one sigma error), that is 7×10^{-6} in $\Delta T_a/T_{bb}$ where T_a = antenna temperature and T_{bb} = Blackbody temperature = 2.78 K. This difference between the experiment and the expected contribution from discrete sources may be due just to uncertainties in the source counts. To convert 20 microK in ΔT into the brightness temperature fluctuations we should take into account the spectral sensitivity function affected by the mentioned factors. After this correction we found that our 20 microK in T_a corresponds to 2.8×10^{-4} in $\Delta T_{bb}/T_{bb}$ when ℓ is between 6.1×10^3 and 17.5×10^3. This limit is close to the best earlier estimate at these scales (Hogan et al., 1989).

The main new result of the first step of realization of our program is the direct check of the validity of Franceschini et al., 1989 model of LogN-LogS curve at low flux densities and short wavelengths.

6. DISCUSSION

We believe that there is no positive detection of anisotropy of the 3 K emission at the level about 10^{-5} at the few degrees scale, the upper limit being close to 10^{-5}. For the CDM models with standard flat Harrison-Zel'dovich initial spectrum, it follows from Table I that the biasing parameter, $b > 0.5$ at 2-σ level (this corresponds to $e < 4\times10^{-5}$ where $e^2c^4 = dP/d\ln(k)^P$, see Starobinsky (1987) for details). Inflation suggests $\Omega = 1$. Visible matter gives $\Omega = 0.1$. Nuclear synthesis suggests Ω less or equal to $0.035\times h^{-2}$ ($h = H_0/100$ km/s/Mps); small scale anisotropy measurements suggest even smaller value, $\Omega = 0.008$ for the baryonic content of the Universe (Fukugita et al., 1989). Visible matter shows the void structure with $\Delta M/M$ about 0.5 at the scales under consideration. The Sachs-Wolf effect predicts $\Delta T/T$ approximately equal to $\Delta M/M$. To be below 10^{-5} in $\Delta T/T$ gravitating matter has to be distributed much more homogeneously than the visible one. Anisotropy measurements have already demonstrated that all models with the Universe filled by visible matter alone contradict the observations. Here we stress that anisotropy measurements show that the invisible matter should have nonbaryonic nature (at least, if reionization is absent) and that it cannot be distributed in the same way as the halos of the visible galaxies (or clusters).

Very small scale anisotropy can tell us about the second ionization epoch and velocity dispersion of the protogalactic objects.

With the present sensitivity we were able to use our results only to check the behavior of the source counts at unexplored level of flux densities at 2.7 cm. Good agreement with the model of Franceschini et al. (1989) suggests that the new flat spectrum population of blue galaxies plays definite role at short cm-wavelengths in 0.1 mJy--few mJy region.

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