ANISOTROPY of the RELIC RADIATION in RELICT-1 EXPERIMENT and PARAMETERS of GRAND UNIFICATION

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1 Introduction

In January 1992 in the Sternberg Astronomical Institute, Moscow at the Astrophysical Seminar it was announced that after additional processing the RELIKT-1 data of the 1983-84 space survey the large scale anisotropy of the relic radiation has been detected. During 1992 the COBE group of observers announced the detection of the large scale anisotropy of the relic radiation too [1 -5].

Let us discuss scientific information which one can obtain from investigation anisotropy of the CMBR and specific goals of this observation. One can expand the large scale anisotropy of the CMBR as sum of spherical harmonics

$$T(\theta) = T_0 + T_1 \cdot cos(\theta) + T_2 \cdot (\frac{1}{3} - cos^2(\theta)) + \dots$$

the first term is monopole component of the CMBR or the CMBR itself. It was discovered by Penzias and Wilson at 1965. The observation of the CMBR allowed us to make choise between the cold and the hot model of our Universe. Now the hot model of our Universe is generally accepted. Next step in investigation of large anisotropy of our Universe was the observation of dipole anisotropy or the observation and determination of the second term of the sum . The value of dipole anisotropy $3mK$ indicates that our Galaxy moves with respect to relic frame of reference. This observation was a progenitor of the observation of peculiar galactic velocities.

Third term is quadrupole anisotropy. It allow us to make some conclusions about the early Universe.

The large scale perturbations which correspond to spherical harmonics with $2 < l < 30$ are one of the most powerful tool of investigation of the early Universe. They are now in the regime of linear growing. Their amplitude is not affected by late stage processes and are determined only by the parameters of the early Universe. The parameters of the early Universe are defined by super high energy physics namely the Grand Unification Theory (GUT). So,the amplitude of large scale perturbations are defined by the parameters of GUT. It was clarified when the theory of inflation was developed and the theory of perturbation in inflation was also developed [6-9].

The data of amplitude of low spherical harmonics define also a part of the initial spectrum perturbation. If the spectrum is Harrison - Zeldovich type the quadrupole component determines also the initial values of large scale structure of the Universe, as far as the H-Z spectrum is determined completely by one parameter (amplitude of the spectrum). In the case of a modified H-Z spectrum the connection between quadrupole component and parameters of large scale structure of the Universe is more complex.

Here we briefly discuss the results of additional data processing obtained from space experiment RELICT-1, compare it with the COBE quadrupole components and others data, and discuss some possible conclusions for the physics of the very early Universe (GUT parameters); and the nature of contributors of dark matter in the Universe is also discussed.

2 RELICT-1 data reprocessing

The RELICT-1 survey was carried out from the satellite board at the frequency range of 37 GHz with an angular resolution of 6°. Details about the experiment's configuration and data preparation were discussed in previous papers [2, 10-12]. New version of the data processing did not include any simplification in the model and as a result it shows the presence of an anisotropy of the microwave background.

We have corrected the initial data by removing the modelled contribution of the Earth's, Moon's and Sun's radiation. All the data in which this contribution was more than 15 μK (in the smoothed data) were excluded of analysis. Also, we excluded the data in which the difference between observed and modelled data was more then 10% (during fast motion of the satellite near the Moon and the Earth). After this correction, the dipole component [13] and the mean outside the Galactic plane were subtracted from the data. We have made an analysis and an estimation of the signal after the additional smoothing the data on the map.

3 RESULTS OF ANALYSIS

The method of estimation of the signal is to compare the measured value (the sum of the noise and the signal) with the amplitude of the apparatus noise, which is measured with high accuracy [1,2]. In order to estimate the amplitude of the signal we modelled the signal which is determined by the H-Z spectrum for primordial perturbation [14]

$$< \Delta T_l^2/T^2 >= \pi \varepsilon_H^2 (2l+1)/2l(l+1), \qquad (1)$$

where l is the number of spherical harmonics, and ε_H is the amplitude of the metric fluctuation.

The stochastic signal for the spectrum (1) is modelled onto the map. Then, the complete process of observations, and the data reduction is simulated in order to obtain survey transfer function, the mean value of the signal's dispersion and the variance's dispersion.

The measured values (corrected for effects of the apparatus and for the Sun's, Earth's and Moon's contributions) and the parameters of noise are listed in table 1 for different smoothing of experimental data. The data for a smoothing angle of 24° show that the signal is detected with a probability of 97%.

Table 1. Parameters of noise and measured value

Smoothing parameter angular degree	Measured variance on the map microK^2	Variance of the noise microK^2	Degrees of freedom of noise
6	127^2	124^2	106
12	67^2	56^2	19
24	34.5^2	23.7^2	9

An anomalous low value of temperature (we called it "blamb") is observed in the region which lies inside the ecliptic longitudes $65° \div 340°$ and ecliptic latitude $-20° \div -45°$.

Statistical simulation shows that the probability that this anomaly is a peak of Gaussian noise on the map is about 1%. With a confidence level of 90% we can estimate the mean value of the signal in this region ΔT_b inside the interval

$$-114\,\mu\text{K} < \Delta T_b < -27\,\mu\text{K}$$

or

$$-4 \cdot 10^{-5} < \Delta T_b/T < -1 \cdot 10^{-5}.$$

We have analyzed the following possible sources of the signal which have a noncosmological origin: apparatus effects, the Moon's, Earth's and Sun's radiation, and the contributions of Galactic sources.

Modelling the complete process of our survey including Moon, Earth and Sun shows that the observed signal could not be explained completely neither by the radiation of the known radio sources nor by the systematic errors of the survey. We expected the signal has the cosmological origin.

We use spectrum (1) to estimate the signal. The upper and lower limits of the mean quadrupole with a confidence level of 90% are:

$$17\,\mu\text{K} < \langle \Delta T_2 \rangle < 95\,\mu\text{K}.$$

$$6 \cdot 10^{-6} < \langle \Delta T_2/T \rangle < 3.3 \cdot 10^{-5}$$

and the amplitude of fluctuation ε_H in (1) is inside the interval

$$5.2 \cdot 10^{-6} < \varepsilon_H < 2.9 \cdot 10^{-5}.$$

The COBE data show [4]

$$2.9 \cdot 10^{-6} < \varepsilon_H < 5.5 \cdot 10^{-6}.$$

4 COMPARISON WITH THE COBE AND 19.2 GHz DATA

After the COBE group [3,4,5] declared its new results, it became possible to compare our data with the COBE data. Examining the *RMS* value of the cosmic quadrupole of the COBE data, one can see that the mean value of COBE quadrupole intensity $17 \pm 5\mu$K (for 68 % C.L) is less than RELICT one. Taking into account the experimental errors both amplitudes of quadrupoles correspond to one another. But, as one can see below there is significant disagreement in the location of quadrupoles. Unfortunately the COBE group has not yet published complete data, so we are forced to compare our map with COBE quadrupoles only and will analyze the COBE data and these disagreements. We will take into consideration only the declared sensitivity of the different radiometers of the COBE and the statistical arguments.

One can compare the RELICT and COBE quadrupole using cross correlation $r(R \cdot C)$

$$r(R \cdot C) = \frac{\sum Q_i(R) Q_i(C)}{\sqrt{\sum Q_i^2(R) \sum Q_i^2(C)}}$$

where $Q_i(R)$ are RELICT quadrupole components, $Q_i(C)$ are COBE quadrupole components and Q_1 is equal to the real quadrupole coefficient multiplyed by 3/4 the numerical coefficient. This direct comparison shows that RELICT and COBE quadrupoles do not correlate. For example,

$$r(R_{37} \cdot C_{53}) = -0.4$$

$$r(R_{37} \cdot C_{31}) = 0.2$$

where the lower index referees to the frequency of a map.

Therefore, there are two choices from this situation. The first is that the COBE quadrupole is correct and there are some systematical errors or unseparated galactic emission in the RELICT data. The second is that the RELICT quadrupole is correct and there are some systematical errors in the COBE data.

If one believes in the COBE results one should explain the discrepancy between the COBE proposed free-free emission [4] and optical data of [15, 16]. The interpretation of the COBE data requires at least 3 times more powerful free-free emission then follows from the Reynolds observations. We shall assume the Reynolds observations valid and analyze the second choices that the COBE data to some extend are affected by errors.

The COBE team shows a different quadrupole $Q_{(A-B)}$ [17]. In these data the cosmic signal should be reduced to zero as far as the transfer functions of two channels (A and B) are equal to one another. On the other hand, the $\chi^2 = 11$ for 31 GHz channel it indicates the presence of some signal with confidence level 95% . Only one explanation of this big value of χ^2 for 31 GHz channel is possible. It is the presence of a residual systematical error in the channel. To prove this claim one should calculate the correlation between the sum of the two channels and difference of its

$$r_{31}(Q_{(A+B)}, Q_{(A-B)}) = -0.48$$

The lower index 31 refers to the frequency. The correlation coefficient is significant and negative. From the other side, the cosmic signal is completely reduced from the difference map $A - B$. The significant correlation indicates that there exists some signal in the B channel. Seems to be that it is a error. If so, the variance of B channel must be more than the variance of A channel. One can use the variation of the sum of two channels and the variation of the difference to calculate the variation of B and A channels separately. One can obtain $\sigma_B^2 = 3 \cdot \sigma_A^2$, so our assumption on the presence of a systematical errors in B channel seems to be valid.

One can also find the correlation coefficients between A and B channels for different frequencies. The results are shown in Table 2. The data in this table is shown as follows. In the first column there is the list of maps including preliminary COBE map [18], the maps of two frequencies (53 and $90GHz$)., RELICT map and the difference map $(A - B)$ for $31GHz$ and the sum of two channels for $31GHz$. In the second column the correlation coefficients between A channel and the left hand maps are shown. In the next column the correlation coefficients between B channel and the first column are shown. The r of $(A-B)_{31}$ and B is equal to -0.85 instead of value 0.46 of $(A-B)_{31}$ and A. So, it supports again our assumption that B channel is contaminated by systematical errors.

Therefore, one should use only one channel A to analyze cosmological conclusion of COBE experiment. On the other hand, all data which are correlated with B_{31} channel should be rejected from consideration (or should be corrected).

The additional argument is that channel B_{31} is not correlate with RELICT quadrupole instead of A_{31} channel (see row 6). The correlation between A_{31} and RELICT data is 0.75 which is rather significant.

As far as $53GHz$ map is correlated with B_{31} (see row 4 of the table2) it are also contaminated by systematical errors.

It would be noticed that the direct comparison the COBE and RELICT quadrupole components is not correct due to the incomplete sky coverage in both surveys, low signal to noise ratio and different transfer and weighting functions of this two experiments. In this case the spherical harmonics lose its orthogonality and the power of the some harmonics transfers to others, moreover this transformation is different for COBE and RELICT radio maps.

Table 2. The correlation coefficients

Map	Channel $A(31GHz)$	Channel $B(31GHz)$
31 $\mathrm{GHz}_{20cut,(A+B)}$	0.55	0.87
31 $\mathrm{GHz}_{20cut,(A-B)}$	0.46	-0.85
53 GHz_{20cut}	0.22	0.66
53 GHz_{30cut}	-0.13	0.52
90 GHz_{20cut}	-0.31	0.47
90 GHz_{30cut}	-0.43	0.31
$RELICT$	0.75	-0.21
Channel $A(31GHz)$	1.00	0.07
Channel $B(31GHz)$	0.07	1.00

It would be very interesting to compare COBE and RELICT data with the 19.2 GHz survey [19] . COBE separation the Galactic and cosmic microwave emission [4] one can calculate quadrupole component at 19.2 GHz has to be 100 or 200 μK depends on the Galactic cut 10 or 20^0 correspondingly. Such value of the signal may be easy detected with the sensitivity declared for the 19.2 GHz survey. If our conclusion of the cosmological origin of RELICT signal is incorrect, the RELICT signal also has to be detected at 19.2 GHz at the same level.

5 COMPARISON with MODELS

Many authors have computed anisotropies of the relic radiation for different cosmological models. One can find the sum of these efforts in [20]. There are two main conclusion for cosmology which are the results of these detection. One is concerned to new physics and reveals the main parameters of interaction on the energy scale of the order of $10^{16}GeV$ and second is concerned to the present Universe and its contributors.

First of all we would like to concentrate on the parameters of Grand Unification. It is well known that the observational restrictions for $\delta T/T$ are the powerful test for modern theories of particle physics(see, for example, [21, 22] . Now there is hope that large scale anisotropy is discovered. Therefore, it is possible to estimate some main parameters of the elementary particle interaction, which determines the interaction at the energy scale near the Plank scale.

Although the standard minimal $SU(5)$ model with a Coleman - Weinberg potential with a large coupling constant is rejected by experimental data there is possibility that extended $SU(5)$ or supersymmetric $SU(5)$ work. We consider below some models which produce acceptable predictions. One is constructed by Shafi and Vilenkin [23] and second is constructed by Pi [24]. The authors add weakly interacting scalar singlet ϕ (it is real ϕ in Shafi and Vilenkin (SV) model and is complex ϕ in model of Pi). This field is coupled with other physical field with small coupling constant. In SV model the vacuum expectation value of ϕ induces $SU(5)$ symmetry breaking. In Pi model the real component of ϕ drives inflation and the imaginary component of ϕ is an axion field.

Potential which drives inflation can be represented in both models in standard form

$$V(\phi) = \frac{\lambda}{4} \cdot (\phi^2 - \phi_0^2)^2$$

Similar potential appears in supersymmetric models [25, 26].

Supersymmetry has some advantages from theoretical point of view. In cited paper of Ellis et al. analyzed consequences of supersymmetric model described by potential

$$V(\phi, T) = \alpha \cdot \phi^4 - \beta\phi^3 + (\gamma + c \cdot T^2)\phi^2 + \delta$$

where α, β, γ, c are parameters of the model, T is temperature of the plasma and δ is vacuum energy. The estimation which will be done below concerns to α in this model. It is necessary to mention that the difference of this potential from the standard form leads to some numerical coefficient of the order of unity.

Therefore, we can estimate the coupling constant in $\lambda\phi^4/4$ potential and it is approximately valid for more complicated models.

One can write [21] that $\varepsilon_H = 7.6 \cdot \sqrt{\lambda}$ and using the RELICT data we obtain the estimation of coupling constant in these models

$$5 \cdot 10^{-13} < \lambda < 1.5 \cdot 10^{-11}$$

The scale of $SU(5)$ symmetry breaking (in SV model for instance) is determined by $M_{Scale} \approx \lambda^{1/4} M_{pl} \approx 10^{16} GeV$. We choose arbitrary renormalization mass of the model to be M_{pl}. Similar estimation appears in other models of extended $SU(5)$ including supersymmetric models.

The second conclusion is connected with the contributors of our Universe (dark matter). There are authors who elaborated hybrid model in which there is dark matter of two types. One is stable and second is unstable type [27,28]. There is no main defect of standard models in it. It is possible to explaine the existence of the first objects at $z = 4 - 5$ (quasars) and the existence of large scale structure (LSS) at $z = 0$. LSS is evolving very fast in the standard models. In the hybrid model the main contributor consists from hot and unstable dark matter. At $10^{16-17} sec$ the hot particles decay and the rate of evolution decreases. Above mentioned data agree fairly well with the model in which the density perturbation in the moment of recombination is $\simeq 4 \cdot 10^{-3}$. The amplitude of

$\Delta T/T$ depends both on $\Delta\rho/\rho$ and on the content of these stable and unstable components. Our data show that the content of stable dark matter is $10\% - 20\%$ of the content of unstable type.

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