The analysis of frequency-independent jumps of CMB according to the Planck data

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The analysis of frequency-independent jumps of CMB according to the Planck data

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Abstract. The temporal analysis of the changes of temperature anisotropy of CMB revealed in the Planck database at frequencies of 30, 44 and 70 GHz is submitted. Existence of jumps of temperature anisotropy which not depend on the frequency of the accepted radiation is established. It is shown that the found number of such jumps significantly exceeds their number which could be caused by statistical probability in a case imposing of random changes of temperature anisotropy. The assumption that emergence of such jumps can be caused by a gravitational lensing of CMB is made.

1. Introduction
In the present time experiments on detection of a gravitational lensing of CMB which, in particular, are executed by the joint groups “Planck” and “BICEP2” [1] are known. Search of the directions of the celestial sphere in which lensing events are implemented is based on the analysis of “cold” and “hot” spots on allocation maps of anisotropy of temperature of CMB.

The experimental studies of a gravitational lensing are implemented by search of couples of images of the same object possessing identical frequency spectrum. If couples of images do not manage to be separated by means of instruments, then about an event of a lensing draw conclusion by compliance of observed time diagrams of brightness of tight couples of images to theoretical dependences. One of the main differences of the phenomenon of a gravitational microlensing of starlike objects from the phenomenon of variability of stars is that the changes of luminosity of stars happen out synchronously at different frequencies of the accepted radiation. The achromatism of change of brightness can be used also for search of the phenomena of a gravitational lensing of CMB.

So far the longest researches of CMB are satellite experiments with use of the probes “WMAP” (USA) [2–3] and “Planck” (EU) [4–6]. Measurements of anisotropy of temperature of CMB by means of the first of probes continued for nine years. Measurements by means of the second probe lasted four years. The published results are integrated on nine cycles of measurements by year duration by means of the probe “WMAP” and also on eight cycles of measurements by means of the probe “Planck” duration on half a year.

The considerable duration of measuring cycles of accumulation of data and rather short general operating time of satellites do not allow to research in details temporal dependences of anisotropy of temperature of radiation in the directions of the celestial sphere for the purpose of detection of compliance of their look to the form of standard theoretical curves of a gravitational microlensing.

However the available data allow to find the most significant amplitudes of jumps of temperature of CMB between adjacent cycles of measurements and to check them for existence in different frequency
domains, i.e. for independence of appearance of the jumps on frequency of the accepted radiation. The similar achromatism can be put in a basis for a conclusion about possible existence in corresponding direction of the phenomenon of a gravitational lensing of CMB.

The purpose of this research is detection and a research of properties of frequency-independent jumps of anisotropy of temperature of CMB.

2. Identification of temporary jumps of anisotropy of temperature of CMB

Multi-channel measurements of temperature anisotropy of CMB were executed by the probe “Planck” on two frequency ranges. The lower range had frequencies 30, 44 and also 70 GHz. The high range had frequencies 100, 143, 217, 35, 545 and also 857 GHz. For timing analysis of jumps $\Delta T_{CMB}$ of temperature anisotropy $T_{CMB}$ of CMB were used the data of multi-channel measurements in the low-frequency range as these data are fully submitted. At the same time the anisotropy of temperature $T$ of radiations which coincides with temperature of absolutely black body of $T_0$ value ($T_0=2,72548\pm0,00057 \ K [7]$) was exposed to measurements. Deviations $T_{CMB}$ of temperature $T$ of radiations from $T_0$ value on an absolute value reached of the several tenth shares of millikelvin.

The values $T_{CMB}$ were measured in the lower frequencies range for more than twelve million directions of the celestial sphere. It corresponds to the linear angular permission of measurements approximately in 8 angular minutes. Distributions of $T_{CMB}$ on the celestial sphere for the listed above frequencies according to the first and second measuring accumulation cycles of data contain of Figure 1. Change $\Delta T_{CMB}$ of temperature anisotropy TCMB as the differences of these second and first measuring cycles are postponed in various directions of the celestial sphere are presented of Figure 1.

In Figure 2 the frequencies distributions of temperature anisotropy of CMB for cycles of the measurements which are available in Figure 1 are represented. The analysis of Figure 2 shows that the measured values of temperature anisotropy for the first of measuring cycles belong to ranges from the lower $T_{min}$ to the high $T_{max}$ borders. These borders form intervals from $-0,0156\cdot10^{-1}$ to $2,1498\cdot10^{-1} \ mK$ at a frequency of 30 GHz, from $-0,0148\cdot10^{-1}$ to $1,2320\cdot10^{-1} \ mK$ at a frequency of 44 GHz and from $-0,0209\cdot10^{-1}$ to $1,5229\cdot10^{-1} \ mK$ at a frequency of 70 GHz. At the same time the difference of $T_{min}$ from zero arises owing to a deviation of limit of sensibility of gages from zero value at a smallness of gaged value.

Similarly, the measured values $T_{CMB}$ for the second of measuring cycles have borders of $T_{min}$ and $T_{max}$. These borders form intervals from $-0,0176\cdot10^{-1}$ to $2,1506\cdot10^{-1} \ mK$ at a frequency of 30 GHz, from $-0,0148\cdot10^{-1}$ to $1,2323\cdot10^{-1} \ mK$ at a frequency of 44 GHz and from $-0,0209\cdot10^{-1}$ to $1,5229\cdot10^{-1} \ mK$ at a frequency of 70 GHz.

Thus, temperature anisotropy $T_{CMB}$ of CMB on average in all three frequencies of reception in the first of measuring cycles was characterized by boundary values of range from 0 to $T_{max0}$, and $T_{max}$ value is equal to $1,64\cdot10^{-1} \ mK$. Similarly, in the second measuring cycle the $T_{max0}$ value is equal to $1,62\cdot10^{-1} \ mK$. At the same time changes $\Delta T_{CMB}$ of temperature anisotropy cannot exceed the received $T_{CMB}$ values. The distribution of changes of temperature anisotropy on the celestial sphere presented of fragments (a), (b) and (c) of Figure 1, is characterized by statistical distributions $\Delta T_{CMB}$, represented in Figure 3.

Axes of ordinates of schedules of this drawing are represented in logarithmic scale for the purpose of identification of features of tails of these distributions which overstep the bounds $\pm3\sigma$ from the corresponding mean values. The analysis of the received distributions shows that their central part which is in borders $\pm3\sigma$ for frequencies 30, 44 and also 70 GHz, are characterized by values $\Delta T_{CMB}$ respectively from $-0,7291\cdot10^{-3}$ to $0,7287\cdot10^{-3} \ mK$, from $-0,8116\cdot10^{-3}$ to $0,8101\cdot10^{-3} \ mK$ and also from $-0,7038\cdot3$ to $0,7044\cdot10^{-3} \ mK$. 

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Figure 1. Distributions on the celestial sphere of data of the first (left row) and the second (right row) cycles of measurement of temperature anisotropy $T_{\text{CMB}}$ and also changes $\Delta T_{\text{CMB}}$ of anisotropy (average row) at frequencies of 30 GHz (a), 44 GHz (b) and 70 GHz (c).
Figure 2. A statistical distribution of temperature anisotropy of $T_{CMB}$ at frequencies 30 GHz, 44 GHz and also 70 GHz and also 70 GHz for the first (a) and second (b) measuring cycles.
Figure 3. Histograms of distributions of changes $\Delta T_{CMB}$ of temperature anisotropy $T_{CMB}$ between the second and first measuring cycles at frequencies 30 GHz (a), 44 GHz (b) and also 70 GHz (c).

Thus, these changes of temperature anisotropy do not exceed 0.5% of $T_{max}$ value. The tails of the analyzed distribution which are going beyond $\pm 3\sigma$ from mean value for frequencies 30, 44 and also 70 GHz, are characterized by absolute values $\Delta T_{CMB}$ which are equal respectively $14.03 \times 10^{-3}$, $9.74 \times 10^{-4}$ and also $6.03 \times 10^{-3} \mu K$ for the left tails of distributions and $14.32 \times 10^{-3}$, $11.456 \times 10^{-3}$ and also $6.65 \times 10^{-3} \mu K$ for the right tails of distributions. Thus, at tails of series of satellite there is changes $\Delta T_{CMB}$ temperature anisotropy of $T_{CMB}$ which can reach 7% of the range of $T_{max}$ value of temperature anisotropy of CMB.
The analysis of results of satellite measurements shows that the conclusions received for the first pair of cycles of satellite measurements are fair also for all other pair of measuring cycles. At the same time changes of temperature anisotropy can reach value of 9% of $T_{\text{max}}$. Further it is necessary to consider a question of that in how many times the temperature anisotropy $T_{\text{CMB}}$ of CMB can change during realization of the revealed jumps.

3. Statistical analysis of multiplication (decrease) coefficient of temperature anisotropy of CMB

Value of change of temperature anisotropy $T_{\text{CMB}}$ of CMB can be described by means of multiplication (decrease) coefficient $K$. This coefficient is equal to the module of the relation of the greatest and the least values of temperature anisotropy $\Delta T_{\text{CMB}}$ implemented during its change in some direction of the celestial sphere, between two neighboring measuring cycles, for example, the second and the first. The frequencies distributions of coefficient of $K$ between the second and first measuring cycles for frequencies 30, 44 and also 70 GHz are represented in Figure 4. Axes of ordinates of schedules of this drawing are represented in logarithmic scale for the purpose of identification of features of these distributions.

It is established that the maximal $K_{\text{max}}$ values of coefficient of $K$ which were implemented between the first and second measuring cycles for frequencies 30, 44 and also 70 GHz are equal respectively $4.7 \times 10^5, 0.34 \times 10^5$ and also $15 \times 10^5$ times. The analysis of distributions demonstrates that the maximal values of size $K$ can be casual leaps. They are caused by the fact that the minimum values of temperature anisotropy of a CMB which were realized in the course of its changes can be in value of limit of sensibility of a satellite gage, i.e. near zero. Using of the maximal value of temperature anisotropy to such value can cause essential uprating of result of division.

Thereof it is more expedient to characterize of change of anisotropy not by maximal value $K_{\text{max}}$, but $K_0$ averages values of coefficient of $K$. The $K_0$ values which were realized between the first and second measuring cycles for frequencies 30, 44 and also 70 GHz are equal respectively 25, 10 and also 37 times. Thus, the realized change of temperature anisotropy can correspond to multiplication (decrease) coefficient of temperature anisotropy on average to forty times. The analysis of results of satellite measurements shows that the conclusions received for the first couple of cycles of satellite measurements are fair also for all other couples of measuring cycles. It is established that on all set of the available observed data the average value $K_0$ of multiplication (decrease) coefficient $K$ of temperature anisotropy of $T_{\text{CMB}}$ during change can reach of value 45 times.

Further it is necessary to establish repeatability of change of temperature anisotropy of CMB at various frequencies of its measurement.

4. Analysis of the frequencies independence of temporary jumps of temperature anisotropy of CMB

The relation of number of changes $\Delta T_{\text{CMB}}$ temperature anisotropy of $T_{\text{CMB}}$ which are in tails of statistical distributions of these changes of Figure 3 to total change for each of measuring cycles and on each of frequencies of measurement corresponds to probability $p$ of emergence of the change in a tail of the corresponding distribution.

Such probability for changes of temperature anisotropy which in various directions of the celestial sphere between the second and first measuring cycles for frequencies of the radiation 30, 44 and also 70 GHz are equal respectively to $p_1=4.72 \times 10^{-3}, p_2=4.90 \times 10^{-3}$ and also $p_3=4.83 \times 10^{-3}$.
The probability of identification of changes at two frequencies in the same direction of the celestial sphere corresponds to the multiplication of probabilities of their identification at each frequency separately. This theoretical probability in a case with changes, revealed between the second and first measuring cycles, for a combination of the considered higher than the frequencies of radiation of 30 and 44 GHz, 30 and 70 GHz and also 44 and 70 GHz are equal respectively to $p_{1,2}=2,31\cdot10^{-5}$, $p_{1,3}=2,28\cdot10^{-5}$ and also $p_{2,3}=2,37\cdot10^{-5}$.

However use of the “Planck” database showed that the changes revealed by results to experiments are characterized by higher probabilities of their paired emergence of $p_{1,2}=15,9\cdot10^{-5}$, $p_{1,3}=10,1\cdot10^{-5}$ and equal $p_{2,3}=7,86\cdot10^{-5}$. The established excess of values of the probabilities received on the basis of the experimental data over theoretical values of the corresponding probabilities confirms possible existence of frequency-independent physical processes which do a part of changes $\Delta T_{CMB}$ to temperature anisotropy of $T_{CMB}$ in a number of the directions of the celestial sphere. The assumption of existence of similar processes can be checked by calculation of probability of detection of jumps in various directions of the celestial sphere between the second and first measuring cycles for all three frequencies of low-frequency range of measurement of the probe. It demands the subsequent comparison of this probability with the probability established experimentally.

**Figure 4.** Histograms of distributions of the coefficient of $K$ between the second and the first measuring cycles at frequencies of 30 GHz (a), 44 GHz (b) and also 70 GHz (c).
Figure 5. Diagrams of the theoretical $p_1; p_2; p_3$ (a); $p_{1,2}; p_{1,3}; p_{2,3}$ (b) and the experimental $p_1; p_2; p_3$ (a) probabilities illustrating the frequencies independence of jumps of temperature anisotropy of CMB.
Figure 6. Diagrams of the theoretical $p_{1,2,3}$ (d) and the experimental $p_{1,2}$; $p_{1,3}$; $p_{2,3}$ (c); $p_{1,2,3}$ (e) probabilities illustrating the frequencies independence of jumps of temperature anisotropy of CMB.

The probability of identification of jumps at three frequencies in the same directions on the celestial sphere corresponds to the multiplication of probabilities of their identification on each of three frequencies separately. This probability was equal $p_{1,2,3}=1.12 \times 10^{-7}$. However the analysis of the experimental data gave an assessment to this probability, more than by 400 times exceeding theoretical
and equal \( p_{1,2,3}=4.47 \cdot 10^{-5} \). The received experimental probability corresponds to identification of several hundred frequency-independent jumps of temperature anisotropy within half a year.

In Figure 5 - 6 diagrams of theoretical and experimental probabilities are shown. They demonstrate that the established excess of the probability of \( p_{1,2,3} \) received experimentally over similar theoretical probability for seven neighboring pair of measuring cycles in eight years of functioning of the probe “Planck” is in limits from 130 up to 490 times. It confirms the received conclusion about existence of the physical processes causing frequency-independent jumps of anisotropy of temperature of CMB.

5. Conclusions
The made analysis allows making a conclusion on a possibility of searching of candidates for events of a gravitational lensing of CMB by the analysis of jumps \( \Delta T_{CMB} \) its temperature anisotropy \( T_{CMB} \) of within neighboring pair of satellite measuring cycles of anisotropy.

The method of identification of similar candidates consists of the sequence of actions including four stages.
At the first stage it is necessary to calculate of changes \( \Delta T_{CMB} \), i.e. differences of values of temperature anisotropy \( T_{CMB} \) between neighboring cycles of satellite measurements.
At the second stage it is necessary to establish a statistical distribution of changes of temperature anisotropy and also to execute selection of the tails of this distribution remote from mean value, for example, more than on \( \pm 3\sigma \).
At the third stage it is necessary to reveal jumps which are present at all frequencies of reception of CMB between the analyzed cycles of satellite measurements among the selected changes of temperature anisotropy.
At the fourth stage among frequency-independent jumps it is necessary to select set of those from them which amplitudes are the most close on values.

In relation to the corresponding directions on the celestial sphere it is possible to draw a conclusion on realization in them frequency-independent processes which can be considered candidates for a gravitational lensing of CMB.

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