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SOME NEW RESULTS FROM THE DETAILED INFORMATION IN THE REGULAR BALLOON MONITORING OF COSMIC RAYS IN APATITY AND DOLGOPRUDNY

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Abstract. We consider the data collected in the course of the regular balloon monitoring of cosmic rays in Apatity and Dolgoprudny in November 2005 – May 2007. The main properties of the abrupt periodical drops in the cosmic ray detectors' count rates, which could be got only using the recorded detailed information, are discussed.

1. Introduction

The long-term experiment of the regular balloon monitoring (RBM) of cosmic ray in the Earth's atmosphere has been carried out by Lebedev Physical Institute, RAS, for more than 50 years (since July 1957) , (see [1]). In spite of the difficulties, especially during the last two decades, the RBM experiment still provides useful data on both galactic and solar cosmic rays. However, there are some flaws in the standard method of data registration which hinder getting good data, [2]. To overcome some of these shortcomings we suggested to record during the flight besides the standard information (the count rate for each minute of the flight) a so called detailed information (DI; the form and characteristics of every pulse received), [3, 4].

In [5] we demonstrated that the advantages of DI can be successively used for correcting the count rate of the RBM cosmic ray detectors by rejecting on sound statistical grounds the seconds when too few or too many pulses were recorded. In principle, the phenomenon of abrupt changes in the count rate of the RBM detectors is wellknown. The data for a lot of minutes during many flights have been rejected in the course of the processing the RBM standard information, because for such (*i*-th) minute the count rate as a function of the atmospheric depth (or pressure) x, $N_i(x)$, deviates widely from the normal absorption curve $N(x)$. As using only standard information one cannot study the structure of the data within the rejected minute, it has been implicitly accepted that an unusually high count rate is due to the burst of the noise pulses while a very low count rate is due to the oscillation of the probe about the vertical, when its antenna points to the receiver and the amplitude of the pulses emitted is very small.

However, the detailed information allows one to study the fine structure of the rejected data and not only saves the data for the most part of the previously rejected minutes, but also makes it possible to try to unravel the mechanisms of the underlying phenomena. In this paper we shall discuss some features of the phenomenon (we call it the abrupt periodical drops (APD) of the count rate of the RBM detectors) basing on the DI recorded in Dolgoprudny (Moscow region) and Apatity (Murmansk region) in November 2005 – May 2007.

2. Example and formulation of APD

In the course of the RBM experiment the radio-pulses emitted by the probe's transmitter after passing the ionizing particles through the Geiger counters are counted by the ground-based recorder for each minute of the flight. In [3, 4] we suggested to record a much more comprehensive information coming from the RBM probe. We fed the output voltage from the receiver to the analogue-to-digital converter that yielded the value of voltage at regular small intervals (~25 μs). If this value exceeds some small threshold (~160 mV), it is stored into the memory. The continuous set of the stored voltage values is a digital analogue of the pulse. However up to now we have not registered the amplification coefficient of the receiver, which would allow us to get the pulses incoming to the input of the receiver. That is why we call the above digital pulses recorded during the RBM flight the restricted detailed information (RDI), while by the full-scale detailed information (DI) we mean RDI plus the amplification coefficient. Like in [5] here we shall discuss only some results of the analysis of the Level-1 of RDI - the time of the beginning T of each pulse, its length L and maximum voltage U.

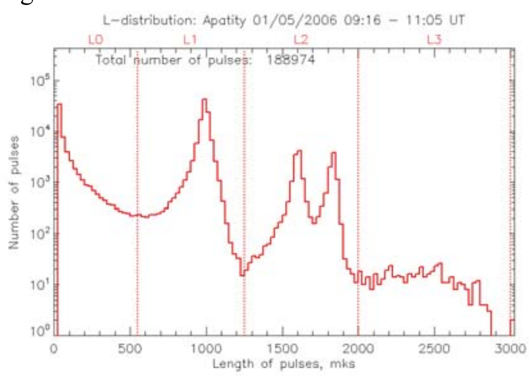

Figure 1

In Fig. 1 the length distribution of all pulses for an ordinary RBM flight in Apatity (May 1, 2006) is shown as a hystogram. The length ranges L0-L3 are shown by the dashed vertical boundaries (those separating L0, L1 and L2 ranges are the standard thresholds for the pulses belonging to the count rates of the omnidiractional counter (L_{01}) and telescope (L_{12}), respectively). So the standard information on the count rate of the omnidirectional RBM cosmic ray detector consists of the sum

$$N1 = \sum_{L>L_{01}} N(L) \qquad (1)$$

for each minute of the flight. The expression for the count rate of the telescope is similar to (1) but with the length threshold L_{12} instead of L_{01}.

The range L0 below the lower threshold of the pulses emitted by the RBM transmitter presumably consists of the background (or noise) pulses. Using DI one can easily construct the sum

$$N0 = \sum_{L<L_{01}} N(L), \qquad (2)$$

the number of noise pulses for each minute of the flight.

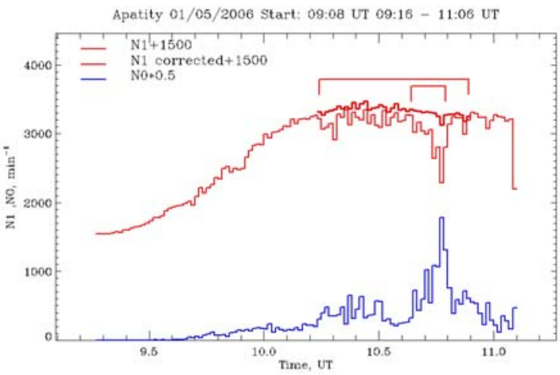

Figure 2

In Fig. 2 the time behavior of both N1 and N0 is shown by the thin hystogram-like curves for the same flight as in Fig. 1. Note that the noise count rate is divided by 2 and the curve for the count rate of the omnidirectional counter is shifted by 1500 min^{-1} to not interfere in the figure. It is easily seen that 1) there is some lack of N1 in the region where the curve N1(t) attains its maximum and 2) N1 and N0 count rates vary in antiphase.

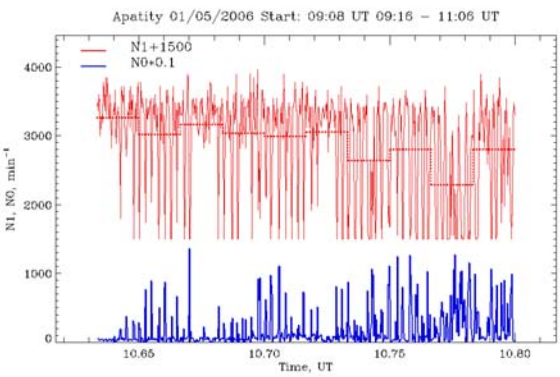

Figure 3

As DI allows one to construct the sums (1-2) for any arbitrarily small time intervals we can compare in Fig. 3 the time behavior of N0 and N1 for each second of the period shown by the shorter horizontal bracket in Fig. 2. One can see that the fine structure of the count rate N1 at the top of the N1(t) curve consists of the narrow (about 1 second wide) periodical gaps when it falls almost to zero (remember the vertical shift in Figs. 2 and 3). The period between these gaps is about 5-7 seconds and during this period the count rate changes according to the Poisson's law. It is easily seen that for each gap in N1 there is a corresponding peak in N0. So the general anticorrelation between N0 and N1 seen in Fig. 2 is just the result of the mentioned peaks and gaps.

It is clear that the above gaps in N1 are not relevant to the real time variations of the cosmic ray intensity in the atmosphere. So if we reject the seconds with the gap through some statistically justified procedure we shall have the N1(t) corrected for this effect. In Fig. 2 we show by the thicker curve the corrected omnidirectional count rate calculated using for the rejection condition $N < N_{th}$ with the same threshold for the whole period backetted by the wider horizontal bracket in Fig. 2 ($N_{th} = N_{av}-3\sigma$, where N_{av} and σ are the average and root meen square of the 1 second count rates). However, in [5] we applied for correction more strict statistical approach and carried it out for wider period of time (the period of "good statistics", N1 > 16 pulses/sec). One can see in [5] the brief discussion with illustration for the same flight in Apatity, May 1, 2006, as in Figs. 1-3.

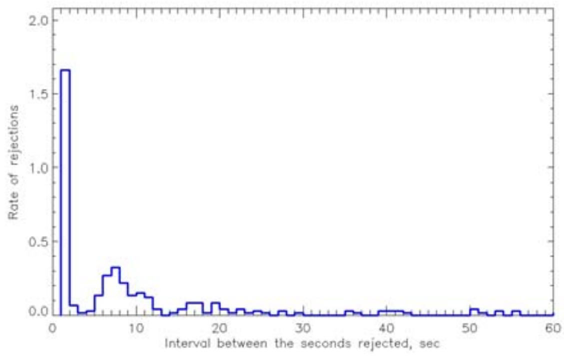

Figure 4

One can judge about the periodicity of the drops from the number of rejections as function of intervals between the seconds for which the data were rejected because of too low count rate. In Fig. 4 the hystogram of this characteristic divided by the period of "good statistics" (we call it the rate of rejections) is shown for the same flight as in Figs. 1-3. One can see that there are two significant peaks in the hystogram, corresponding to the number of rejections with 1 second between the periods of too low count rate ([1, 1]-range) and 5-8 seconds ([5, 8]-range), respectively.

So by the abrupt periodical gaps (APD) in the RBM experiment we mean the periodical drops in the counting rates of the RBM detectors with periods 1 second and 5-8 seconds, accompanied by the short peaks in the number of the noise pulses.

3. APD in November 2005 – May 2007

As the detailed information has been recorded in the RBM flights since October 2005 both in Apatity and in Dolgoprudny, we can make some inferrance on what the average properties are of the phenomenon under study and how it changes with location and time.

First we consider the average periodicity of the drops. In Fig. 5 the hystograms of the rate of rejections summed over all flights are shown as functions of intervals between the seconds for which the data were rejected because of too low count rate for Apatity (the red solid line) and Dolgoprudny (the blue dotted line). To make the comparison for different locations meaningful both hystogams refer to the average rate of rejections. That is, the total number of rejections was divided by the total period when the data were checked for rejection (the period of “good statistics”) for each location.

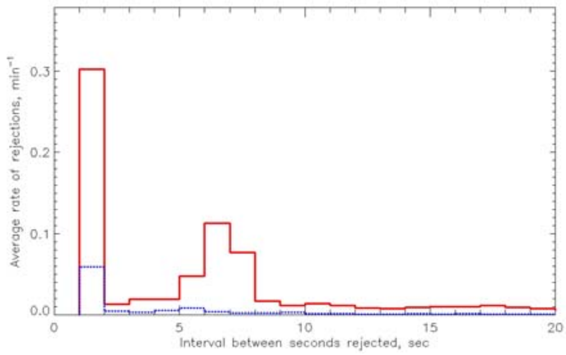

Figure 5

The first inference from Fig. 5 is that the total rate of rejections is much higher in Apatity than in Dolgoprudny. Second, in Apatity there are two significant peaks in the hystogram, corresponding to the number of rejections with 1 second between them ([1, 1]-range) and 5-8 seconds ([5, 8]-range), respectively, both ranges being of approximately equal total rate of rejections. In Dolgoprudny only the first of these peaks is significant, although the second one is also present (and shifted to [4, 6]-range).

Now we can consider the time variations of the rates of rejections corresponding to these two peaks. In Figs. 6 and 7 these rates are shown for [1, 1]- and [5, 8]-ranges, respectively, by the vertical bars with different symbols at the top (the red triangles for Apatity and blue squares for Dolgoprudny). We can infer from these figures that in Apatity during the period under consideration the rate of drops in the RBM count rate is rather inhomogeneous, being concentrated in two periods each 3-4 months long. In Dolgoprudny for [5, 8]-range the total rate of drops is due to a few flights randomly distributed, while for [1, 1]-range the rate of drops also looks more homogeneous than in Apatity.

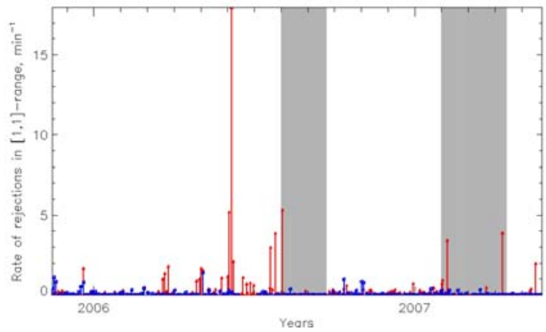

Figure 6

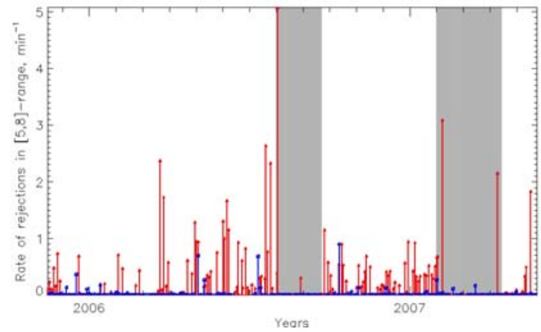

Figure 7

We should also consider the possibility that the mentioned inhomogeneity in the time distribution of the APD in Apatity could (at least in part) be the manifestation in APD of some changes in the method of preparation and launch of the RBM probes in Apatity during the period considered. As an indirect indication that the “human factor” can be of importance we consider the fact that two periods seen in Figs. 6, 7 when there were no flights with the pronounced APD practically coincide with the periods (shaded in Figs. 6, 7) when the RBM probes were prepared and launched by the operator (Operator-2), different from that usually attending the experiment (Operator-1).

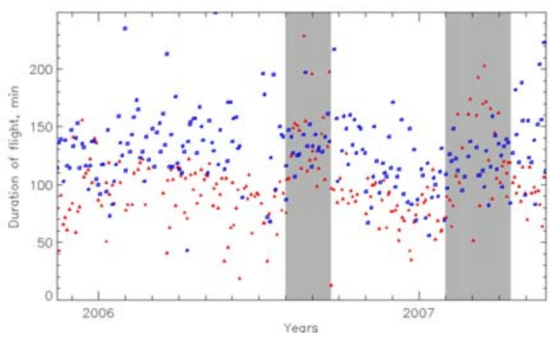

Figure 8

In Fig. 8 the duration of the flight is shown by trianges for Apatity and squares for Dolgoprudny for the whole period under consideration. The periods when the flights were attendant by Operator-2 are also shaded. One can see that usually the flights in

Apatity are shorter (i. e., the velocity of their rise is higher) then in Dolgoprudny while in the shaded period they are of equal duration or even longer.

4. Discussion

The phenomenon under consideration (the abrupt periodical drop of the RBM detector's count rate) is very important (at least for Apatity), as it requires a significant correction to the count rate to be made. So we should discuss its possible causes and if it is due to some factors which could be controlled, the efforts should be taken to illiminate this cause.

The first feature that attracts attention is the coincidence of the main APD period (6-7 sec) with the period of the free oscillation of the probe on the strip of average length $l \approx 10$ m ($T = 2\pi\sqrt{l/g} \approx$ 6.3 sec, where g is the free-fall acceleration). So the main hypothesis to consider is that APD is connected with free oscillation of the probe, namely, the drop of the RBM count rate occurs each second when the axis of the transmitter's antenna points to the ground-based receiver.

In this context the dependence of the level of APD on the velocity of the balloon's rise means that the amplitude of the free oscillations depends on this velocity and one should control it to avoid the strong drop of the count rate. Besides, the APD component with 1-sec period could imply that the period when the RBM count rate drops because of small angle between the axis of the antenna and the straight line probe-receiver is longer than 1 second, e. g., it lasts 2 seconds. It can be also assumed (as suggested by N.S. Svirzhevsky) that the presence of the abrupt peaks in the number of the noise pulses coinciding with the drops of the RBM ones means that, when the amplitude of the RBM pulse with length $L > L_{01}$ becomes low (only slightly above the threshold of the DI recording, U_{th} = 160 mV), this pulse is splitted into a few (k) shorter pulses with $L_i < L_{01}$, $i = 1,\dots,k$. Both of these assumptions, in principle, can be checked using DI. Further still, the whole oscillation hypothesis of the APD's origin can be checked simply launching a lot of balloons with the strip's length strongly different from the normal one.

However, it is rather difficult to fit in the above hypothesis some other APD features, revealed in the previous section, e. g., the strong 1-sec and weak 5-8-sec components of APD in Dolgoprudny. So we should also consider the assumption that the cause of the periodical drops of the RBM detectors' count rate can be some independent of the RBM pulses periodical peaks in the noise, somehow suppressing the RBM pulses. Such periodical component of the radio background can be revealed receving the pulses in the same frequency, amplification, and local time ranges as during the RBM flight, but in the days between the flights. Such recordings have been made both in Apatity and in Dolgoprudny (during ≈ 3-5 hours in each location) and they have not revealed any significant 1- or 5-8-sec components. However, to make the final conclusion more detailed study of the RBM radio background should be carried out.

5. Conclusions

1. The detailed information that has been registered during the regular balloon monitoring (RBM) of cosmic rays in Apatity and Dolgoprudny in November 2005 – May 2007 revealed some important properties of the phenomenon of the abrupt periodic drop (APD) of the RBM detectors' count rate:
   1) The APD frequently coincides with abrupt periodic peaks in the number of the pulses with length shorter than the threshold of the RBM pulses;
   2) The rate of occurence of APD in Apatity is much greater than in Dolgoprudny;
   3) In Apatity two main components of APD are those with periods 5-8 seconds and 1 second;
   4) In Dolgoprudny the main component of APD is the 1-sec one, while the 5-8-sec component is rather weak.
2. The coincidence of the main period of the APD in Apatity with that of the free oscillation of the probe about the zenith forces us to consider as the main hypothesis on the origin of APD the above oscillation, namely, that the APD occurs in the periods when the axis of the transmitter's antenna points to the ground-based receiver. However, it is not quite clear how to fit in this hypothesis some of the APD features, listed in the previous conclusion. So the further study of other possible causes of APD, e. g., the suppression of the RBM pulses by the abrupt periodical peaks in the noise, should also be considered.

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