Local continuous luminosity of the mid-latitude night sky in thunderstorm periods

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Annotation

In order to search for the night-sky diffuse luminosity correlating with anomalous disturbances of secondary cosmic ray particles during thunderstorms remote video cameras viewed the sky above the experimental setup from the distance of 75 km. The BASA facility of the BNO (43.3°N 42.7° E) is used as a particle detector, and observations were made in the period 2013-2016. In total, more than 50 night thunderstorm events were detected, and in some cases the local diffuse luminosity was clearly seen with an intensity of 10^3-10^4 R. Accompanying geomagnetic and seismic activity were analyzed.

Introduction

The study of thunderstorm effects in cosmic rays on the The Baksan Air Shower Array (BASA) facility of the BNO of the Institute of Nuclear Research of the Russian Academy of Sciences has been conducted for more than 35 years. In the course of the analysis of the origin of the muon variations detected by the apparatus during thunderstorms, a hypothesis was proposed for the existence of a slow breakdown of the stratosphere on runaway electrons, analogous to a glow discharge. After that, it was decided to register this phenomenon with optical means, observing from the side in the distance of 75 and 1 km from the facility. Video points are placed on the border of residential areas, which was determined by the requirement of an infrastructure corresponding to the experiment. In the course of indirect nightly observations of thunderstorm activity, a local diffuse glow of clouds was observed. In some cases, it correlates with the variations of the secondary cosmic rays recorded by the facility. The description of the experiment and individual results are given in [1, 2]. In these works, the result of the detected luminescence is presented, but in relative subjective units. The observed connection of the luminescence with variations of the geomagnetic field in the vicinity of the facility was noted. In [3], an opinion was expressed on the registration of luminescence caused by precipitation of protons from the radiation belt associated with seismic activity in the region of the facility.

The aim of the paper is to expand the data presented earlier by defining the relationship between the relative units of brightness used and the objective characteristics. And also, the involvement of additional data demonstrating the role of seismic activity in luminescence generation 15.09.2013.

Calibration of the camera video signal

For calibration we used the method of quenching in which the brightness of a known source is attenuated by a known amount. As the source used LEDs with a known intensity and wavelength 405, 430, 525, 630, 940 (nm) with an accuracy of 30 nm. The sensitivity threshold determined, the noise of the photodetector (CMOS matrix). The lens performs focusing of the luminous flux on it. The calculation of the light source region of the matrix is made according to the laws of geometrical optics. This value corresponds to true, in the case of perfectly tuned image sharpness, which in practice is impossible to achieve. While maintaining the light flux variation of the sharpness of the image leads to "blurring" on the surface of the matrix, reducing the luminance, but increasing the area of the image. Mechanical procedure to adjust the sharpness Varifocal lens allows to apply the method of clearing. The attenuation coefficient of light at the same time increase the area of the source image relative to its "ideal" calculated theoretically. When the attenuation range was insufficient to reach the threshold, changing the exposure time. Results of calibration are the functional relation between the surface brightness of the source (different colors) illuminating the camera lens and the average brightness of pixels in its image in the picture. The minimum level of illumination at which statistical methods stands out against the background noise image with size of order square of the picture emitted in the experiment ~10^{-10} lux (stated in the passport camera 0.01 lux). Due to the internal settings of the camera, the dependence has an exponential character depending on the color that leads to the transformation of color depending on the amplitude. In addition, when the color of a certain wavelength is its RGB representation. That is, the decomposition of the colors into three components – red, green and blue. At small values of the video signal remains, only the main component. The performed calibration of the susceptibility of the chambers has the opportunity to quantify the color and brightness observed in the experiment of radiation.

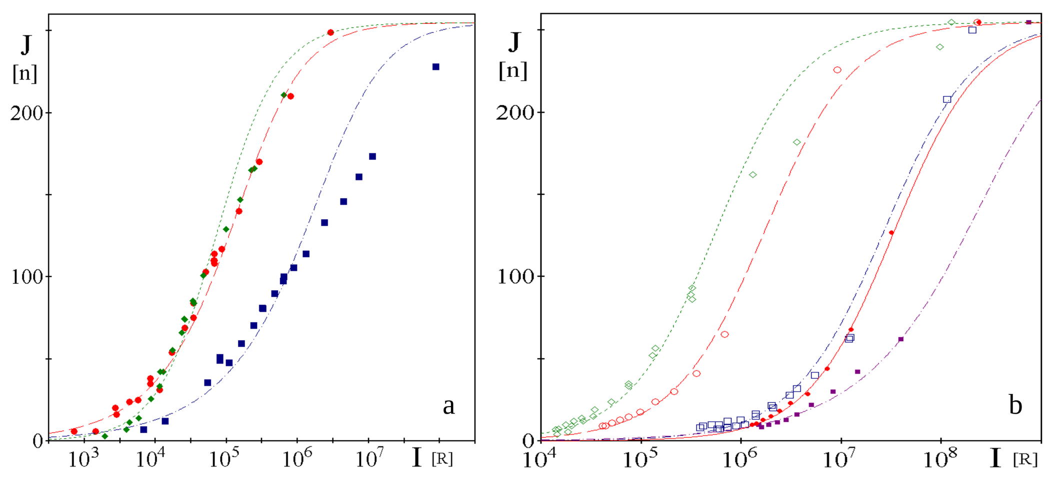

Fig.1. Calibration of the cameras. The brightness of the pixels (y-axis) the source image of the illumination in the picture, expressed in channels (0-255), depending on the intensity (brightness) of illumination of a surface, expressed in relays [R]. a) Camera calibration Cs280 in the color resolution. Red circles show the dependence of red (630 nm). Green rhombus – green (525 nm). The blue squares for the blue (430 nm). b) Camera calibration Cs265 used in black and white resolution at night mode with registration in the infrared range. Red hollow circles show the dependence of the response of the video signal to the lighting in red (630). Green rhombus – the response to green light (525 nm). Blue squares – blue light (430 nm). Purple filled circles – camera response to light violet (405 nm). Red filled circles show the response to the infrared light source (940 nm).

The result of calibration is shown in figure 1. From these data it follows that for events 10.06.2015 published in [3] a characteristic background glow region of the ionosphere above the storm of red color (R): 2.45 kR , green (G): 8.14 kR, blue (B): 23.51 kR. Or in photometric units, respectively R: $1.12 \cdot 10^{-4}$ cd/m^2, G: $1.32 \cdot 10^{-3}$ cd/m^2, B: $6.85 \cdot 10^{-5}$ cd/m^2. These estimates are comparable with the known brightness value of Cirrus clouds illuminated by the moon ~10 kR. The very amplitude of the luminescence, which correlates with the potential difference in the stratosphere: R: 0.42 kR , G: 1.58 kR B: 4.33 kR. Or in photometric units, respectively R: $1.92 \cdot 10^{-5}$ cd/m^2, G: $2.55 \cdot 10^{-4}$ cd/m^2, B: $1.26 \cdot 10^{-5}$ cd/m^2. This is comparable to the brightness of the milky way (1 kR). The data indicate that perceived eye should be green, although blue photons three times more. Typical measurement error of 2±1·is determined by the accuracy of placing the electronics of the camera in the standard surveillance mode after the "blinding" bright lightning flashes. An important result was the absence in the event of variations of the illumination in the infrared range. To determine this became possible after the procedure of exclusion of the contribution of the color video signal received by the registration chamber Cs280 from the result of observation of the camera Cs265 producing registration in all available for a sensor range of sensitivity of light, including infrared. The characteristic value of variations in brightness correlated with the disturbance intensity of energetic particles ~10^{-3} [cd/m^2], or 1 – 10 kR for the variation of photon intensity green.

Correlation with seismic activity

To determine the causes of recorded seismic vibrations in the facility area (43.3 N,42.7 E) during the illumination 15.09.2013 was attracted by the material (resource http://www.emsc-csem.org/Earthquake) of the registered earthquakes with a magnitude of more than 1 point across the Earth. Moments of all the earthquakes from a specified directory, in this period marked in the second panel of figure 2 by vertical lines. At the moment 2H 05M (LT) (14.09.2015 23:04:56.8(UT)) was recorded the earthquake at a depth of 55 km magnitude 1.9 in the area of 32.2 34.7 N E (Cyprus) at a distance of about 1300 km from the BASA. The next 4 earthquake was recorded in Turkey, Italy and Bulgaria, as well, in relative proximity. Noteworthy earthquake in Chile (time 1H 34m (LT) (14.09.2015 22:33:57(UT)), depth 96 km magnitude 2.6) pre-glow. In that moment, when longitudinal wave propagating in the depth of the Earth, with an average speed of 11 km/s reaches the centre (2H 43m) has been racing in the geomagnetic field recorded around the world. Such simultaneous perturbations in the geomagnetic field called "global Pc5 pulsations". Usually, their appearance is connected with the influence of perturbations of interplanetary field caused by solar activity. Figure 3 shows the data of the variations of the K-index (http://geodata.borok.ru) and Dst-index (http://wdc.kugi.kyoto-u.ac.jp/dstdir/index.html) in September, demonstrating the influence of solar activity on the geomagnetic field. During glow 14-15 September 2013 the activity of magnetic storms was very low, which is not conducive to the emergence of global Pc5 pulsations.

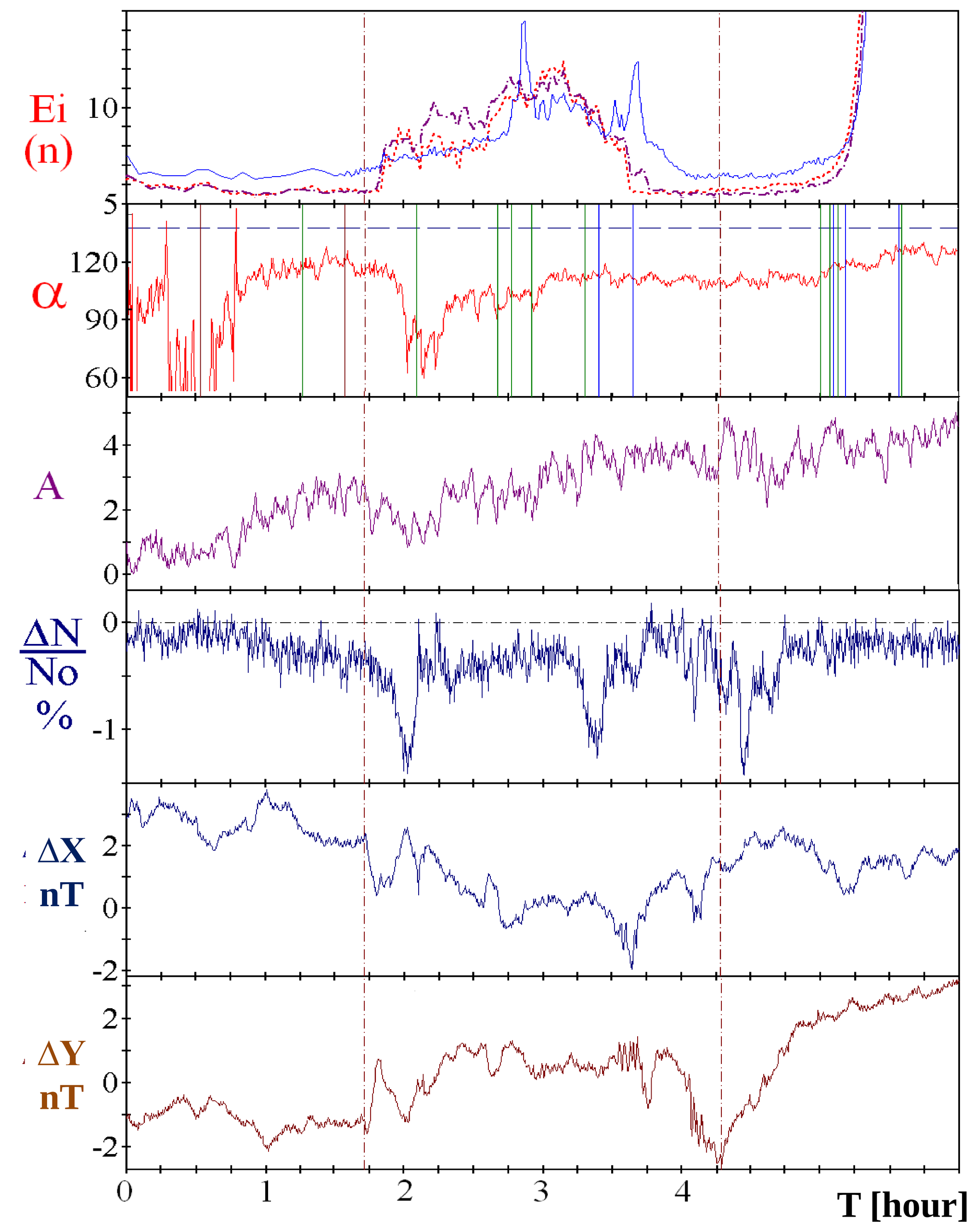

Fig.2. Storm event 15.09.2013. 0-6 h (averaging 20 seconds). Local time. A description of the data from top to bottom: 1) Brightness (Rel. units) the luminescence of the "ionosphere" (purple), of the "stratosphere" (red) and "troposphere" (blue). 2) Direction of variation of the tilt of the Earth's surface in the area of facility. Vertical lines mark the moments recorded earthquakes of a magnitude of more than 1 point in all the Earth (http://www.emsc-csem.org/Earthquake). 3) Amplitude of the variations of inclination. 4) Intensity of the muons. 5) Magnetic field, the direction of the North. 6) Magnetic field, the direction of the East.

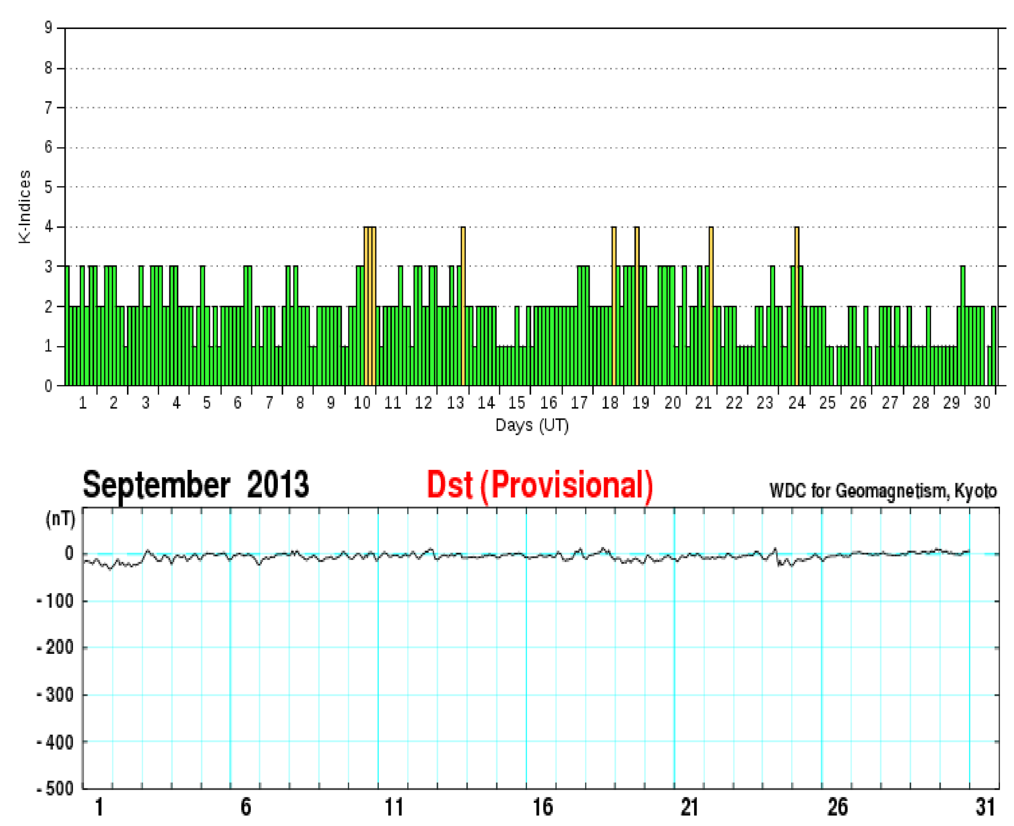

Fig.3. Disturbances of the geomagnetic field in September 2013. Top graph K-index (http://geodata.borok.ru). The bottom graph of Dst-index (http://wdc.kugi.kyoto-u.ac.jp/dstdir/index.html).

Conclusions

- The event was a continuous glow of the atmosphere above the storm clouds, correlating with anomalous perturbations of the secondary particles of cosmic rays that meet the conditions of electric breakdown in the stratosphere in near-treshold mode avalanche multiplication of runaway electrons. Colors glow – wideband. In visual perception dominates the green color. The intensity of the photons in the optical range, the maximum in blue. The infrared glow is not detected. The characteristic brightness of 10^{-4} – 10^{-3}) [cd/m^2], the intensity of photons 10^3 – 10^4 [R].
- Complex ground facility 15.09.2013 recorded the interaction of the thunderstorm with precipitation of protons into the atmosphere from the radiation belts of the Earth due to seismic activity.

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