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Gamma-Radiation of the Earth's Atmosphere from the CORONAS-I Data

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Abstract

Results of the statistical study of gamma-ray fluxes in the energy intervals 0.12-0.32, 3.0-8.3 MeV measured by the SONG-instrument on board the low altitude (500 km), high inclination (83°) satellite CORONAS-I are presented. The geographic maps based on sets of data in March-June 1994 are constructed. There are regions of enhanced 0.12-0.32 MeV gamma-flux on L about 1.3, 1.6 and 2.3 and longitudes from 50° to -80° where it is determined by the quasi-trapped electron bremsstrahlung. Variations of the fluxes of gamma-rays with the energies 3.0-8.3 MeV with the latitude, longitude and local time are studied. Comparison of our data with that of OSSE/CGRO experiment show what induced radioactivity determines about 75% and 72% of total measured flux in the 0.32-1 MeV and 1-3 MeV energy ranges accordingly.

1 Introduction:

Although there exist several earlier measurements of gamma-ray flux under the Earth's radiation belts there are not numerous extensive statistical studies revealing the features of gamma-flux distribution, its composition in satellite experiments, contribution of albedo fluxes. Here we analyzing data received by SONG- instrument in the experiment onboard CORONAS-I satellite (nearly circular polar orbit with height ≈500 km). Gamma-rays with energies 0.12-0.32 MeV, 0.32-1 MeV, 1-3 MeV and 3-8.3 MeV were detected by a CsI(Tl) crystal with diameter 200 mm and height 100 mm in active 4π anti-coincidence shielding of plastic scintillator with thickness 20 mm (Balaz, et al., 1993). CORONAS-I satellite was oriented with its longitudinal axis directed toward the Sun. SONG- instrument was installed on the platform for the scientific instruments near the side of it. The platform was moved away on about 1 m from the top of the satellite. SONG-instrument longitudinal axis was also directed to the Sun. It observed the Sun in the day side of the orbit and the Earth on the night side. Data used in this report were obtained in March-June 1994.

2 Results:

Figure 1 displays geographical maps of 0.12-0.32 MeV (a) and 3-8.3 MeV (b) gamma-ray fluxes on CORONAS-I orbit. In both figures data from 5 March to 14 June were used. The extent of the set is 1.4×10^6 data points with time resolution 2.5 sec. Data were divided into pixels according to the geographic coordinates with the step of 1° in latitude and of 2° in longitude. The average number of points of measurements covering one individual pixel is 47. For each of these pixels the estimation of the mean has been evaluated assuming normal distribution of the measurement points. In energy range 0.12-0.32 MeV the values obtained from measurement have been corrected for the induced background (Bucik, et al., 1998). The reason is what in our primary data there are observed the different latitudinal profiles for low and high gamma-ray energies. This is most probably due to the fact that the significant contribution for gamma-rays below 2.1 MeV is caused by the decay of the long living radioisotopes induced due to the interactions of protons of inner radiation belt and of cosmic rays with the detector material (Johnson, et al., 1993). In both energy ranges a correction of the flux of gamma rays on time dependence of primary cosmic rays was done on daily basis adjusting its absolute value to the ratio of average primary cosmic rays measured by a high cut-off rigidity neutron monitor station Haleakala.

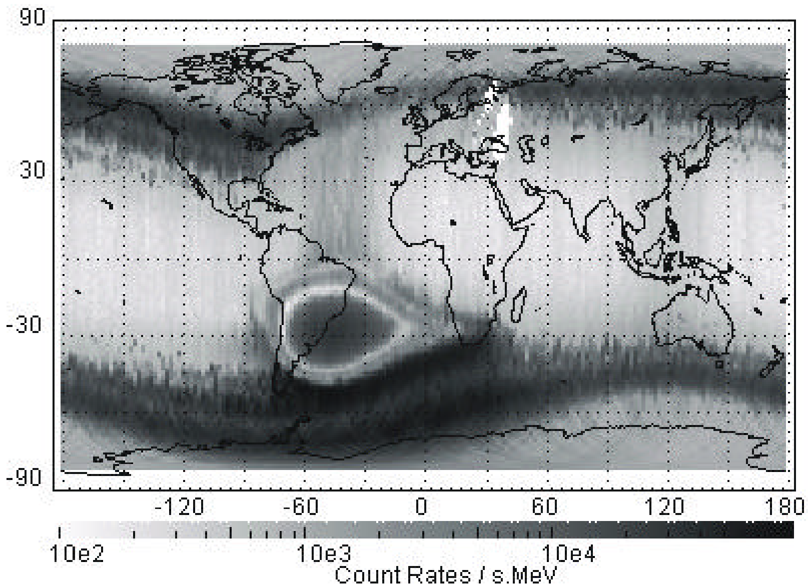

Fig. 1a. Geographycal map of gamma ray flux of 0.12-0.32 MeV

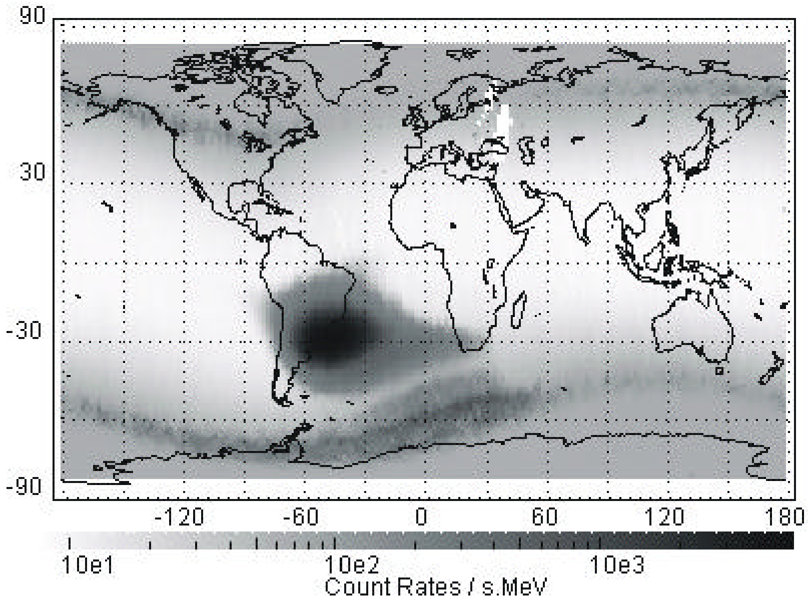

Fig. 1b. Geographycal map of gamma ray flux of 3.0-8.3 MeV

Regions of precipitation of electrons from the outer radiation belt and of South Atlantic Anomaly (SAA) are clearly seen on fig.1b. Out of this zones flux of 3-8.3 MeV gamma's is monotonously increases with geomagnetic latitude increase. More complicated is fig.1a. Besides regions which is influenced by outer radiation belt near it toward the equator zones of high intensity of 0.12-0.32 MeV gamma's are exist. These zones are localized on latitudes 30°÷60° and -30°÷-60° and longitudes from 50° to -80° and are very similar to that observed by Kuznetsov, \& Myagkova (1998) on the same CORONAS-I satellite for quasi-trapped electrons with the energies >0.5 MeV on L about 1.3, 1.6 and 2.3. In the region of SAA instrument electronics is overloaded by a very large particle flux what leads to appearing of more light zones toward the center of it. To North of SAA on longitudes -30°÷-60° up to the outer radiation belt flux is increased due to the short living radioisotopes produced in the detector matter by protons of the inner radiation belt.

To receive more detailed distributions we search for dependencies of gamma-ray fluxes on longitude, on latitude and on local time. As conditions of atmospheric gamma-ray observations on night side of CORONAS-I orbit due to its solar orientation are significantly better, than on day side, we study longitude and latitude dependencies separately for local times 10^h-14^h and 22^h-02^h. Only 3-8.3 MeV data were used for the analysis because in the energy interval 0.12-0.32 MeV significant part of detected flux is due to induced radioactivity and studied effect is small. Longitudinal dependence we search for on L=1.9-2.1 where flux of charged particles of cosmic rays according to Kuznetsov, \& Myagkova (1998) is dependent on longitude in a maximal degree. We obtained that gamma's longitudinal dependence can be approximated by a law $A+B\sin\varphi+C\cos\varphi+D\sin2\varphi+ +E\cos2\varphi$, where φ is longitude and coefficients A,B,C,D,E are equal to 133.31±0.19, 3.78±0.26, -4.80±0.27, 2.30±0.26, -6.64±0.26 for day and 156.79±0.21, 2.42±0.27, -4.75±0.32, 1.61±0.29, -7.18±0.30 for night accordingly. Values of χ^2 are equal to 3.47 for day and to 2.44 for night. This dependence is very similar to that obtained by Kuznetsov, \& Myagkova (1998) but for charged particles coefficients B,C,D,E are 1.5-2.5 times as large. As for charged particles this dependence is significantly weaker near the equator.

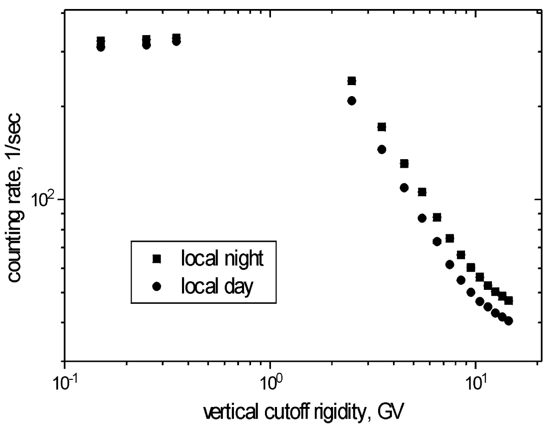

Fig. 2. Latitude dependence of 3-8.3 MeV gamma-ray flux.

Figure 2 depicts latitudinal dependencies for local day and local night. In order to exclude trapped radiation minimal altitude of mirror points was chosen to be H_{min} <100km. The vertical cutoff rigidity is computed as R(GV)=14.9/L^2 (Shea, Smart, \& Gentile, 1987). Shown on Fig.2 data in the rigidity interval 2-15 GV can be fitted with power law. For local night the spectral index is 0.936±0.001 and for local day - 0.924±0.001. For equal latitudes on night side measured flux is larger.

Since from the obtained by Kuznetsov, \& Myagkova (1998) longitudinal dependence it follows that in the 90° - 180° range variation of cosmic-ray flux near the equator is minimal, it is this range which we used to study dependence of gamma-ray flux on local time for L 1.06 -1.10. Data from 21 March to 31 May 1994 were used. As a longitude one the dependence can be approximated by a law A+Bsinx+Ccosx+ +Dsin2x+Ecos2x, where x is (Local Time, hours)*15°. Values of fitted parameters are: A=45.81±0.05, B=0.48±0.09, C=3.89±0.05, D=0.75±0.07, E=-0.93±0.07; χ^2=4.58.

Detailed spectra of gamma-rays, detected by SONG-instrument were measured by ABC-instrument (Belousova, et al., 1996). We used this data, background gamma-ray spectra, detected by OSSE-instrument on CGRO (Johnson, et al., 1993), which are mainly due to the induced radioactivity, and results of Truscott et al (1996) calculations of spectra of produced in CsI and NaI crystals in near-Earth space radioactive isotopes emission to estimate albedo gamma-ray flux for the energies 0.32-3 MeV. Induced radioactivity determine about 75% and 72% of total measured flux in the 0.32-1 MeV and 1-3 MeV energy ranges accordingly. Since the latitudinal dependence of the induced gamma-ray flux is practically absent (Dean, et al, 1993), the induced contribution was subtracted as a constant simply. Obtained values in $(cm^2 s*sr*MeV)^{-1}$ are as following: equator 0.32-1 MeV - 0.079±0.059, equator 1-3 MeV - 0.022±0.014, polar cap 0.32-1MeV - 0.174±0.059, polar cap 1-3 MeV - 0.095±0.014.

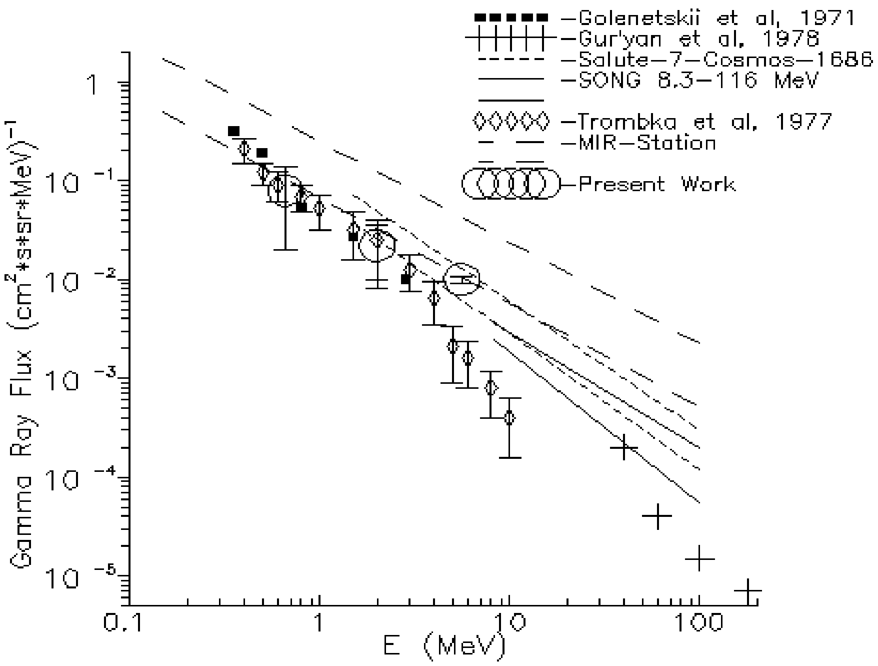

Fig. 3. Gamma-ray spectra near the geomagnetic equator.

Obtained values of albedo gamma-ray flux in the energy range 0.32-8.3 MeV for L=1.06-1.10 and data of other experiments about albedo gamma-rays near the geomagnetic equator (Golenetskii, et al., 1971, Gur‘yan, et al., 1978, Trombka, et al., 1977) are shown on Fig.3. Also shown are our results about gamma-ray flux detected by SONG-instrument in the 8.3-116 MeV range and about gamma-ray flux on Salute-7 - Cosmos-1686 orbital complex and on MIR - station (Bogomolov, et al., 1999). It is clearly seen from Fig.3 that as against from flux on massive MIR-station on CORONAS-I satellite at least for the energies 0.32-3 MeV gamma-ray flux is nearly the same as that of albedo.

3 Conclusions:

Geographical maps of 0.12-0.32 MeV and 3-8.3 MeV gamma-ray fluxes on CORONAS-I orbit and analytical approximations of its latitudinal dependence, longitudinal dependence for L=2 and dependence on local time near the equator are obtained. From the dependence on local time in the equator region night-day fluxes ratio is equal to 1.21; difference of this fluxes is significantly larger than experimental deviations. Fluxes on 06^h and 18^h in the limits of experimental deviations are the same. There are two effects which can cause obtained dependence on local time: i) variation of SONG-instrument screening from Earth, that is from albedo gamma’s, by satellite body, and ii) the fact that in a some degree energetic secondary particles are collimated along the primary particle direction. Because of it detected by SONG-instrument fluxes of gamma's, born in the interactions of primary cosmic rays in the satellite matter (local gamma-rays) can vary with the changes of CORONAS-I orientation. Unfortunately we have not information about orientation of CORONAS-I axes, normal to its longitudinal axis and can not use obtained results to estimate fluxes of gamma-ray albedo and local gamma's. Comparing our data with that of OSSE/CGRO experiment we obtained what induced radioactivity determine about 75% and 72% of total measured flux in the 0.32-1 MeV and 1-3 MeV energy ranges accordingly. Based on these results estimations of spectrum of albedo gamma-rays in the whole energy range 0.32- 8.3 MeV is obtained. It is consistent with the results of earlier experiments.

4 Acknowledgment:

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References

Balaz, J., et al. 1993, IAU Proc. 144th colloquium, ed. J.Rusin, P.Heinzel, J.-C. Vial, Veda Pub., Slovakia, 635.
Belousova, I.V., et al. 1996, Journal of Moscow Physical Society 6, 415.
Bogomolov, A. V., et al. 1999, to be published in Advances in Space Research.
Bucik, R., et al. 1998, WDS’98 Proceedings of contributed papers, matfizpress, vydavatelstvi Matematicko-fyzikalny fakulty Univerzity Karlovy, Prague, Czech Republic, ed. Safrankova, J., p. II, 216
Dean, A.J., Lei, F., \& Knight, P.J. 1991, Space Science Reviews 57, 109.
Golenetskii, S. V., et al. 1971, Astrophysical Letters 9, 69.
Gur'yan, Yu. A., Mazets, E. P., \& Proskura, M. P. 1978, Preprint of Ioffe Physics-Technical Institute, Academy of Science, No 570, Leningrad, USSR.
Johnson, W.N., et al. 1993, ApJS 86, 693.
Kuznetsov, S.N., \& Myagkova, I.N. 1998, WDS’98 Proceedings of contributed papers, matfizpress, vydavatelstvi Matematicko-fyzikalny fakulty Univerzity Karlovy, Prague, Czech Republic, ed. Safrankova, J., p. II, 220
Shea, M.A., Smart, D.F., \& L.C. Gentile. 1987, Phys. of the Earth and Planet. Interirors 48, 200.
Truscott, P.R., et al. 1995, IEEE Trans. Nucl. Sci. 42, 946
Trombka, J. I., Dyer, C. S, \& Evans, L. G. 1977, ApJ. 212, 925.