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Energetic charged particle fluxes under the radiation belts

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Abstract. We analyzed data of the detector with the large CsI(Tl) crystal corresponding to the energy deposit >60 MeV onboard the CORONAS-I satellite. This detector measured the mixture of proton fluxes with energy >80 MeV and electron fluxes with energy >65 MeV. We assume that this mixed flux consists of GCR, atmospheric albedo and satellite local particles. We analyzed the distribution of fluxes in 12 geomagnetic longitudinal intervals in the Northern and Southern hemispheres and obtained, that the maximum of albedo deposit relatively to the GCR fluxes was observed near the geomagnetic equator and minimum was observed at high geomagnetic latitudes. For *L*-shells <2 we found a strong longitude dependence of particle fluxes. Such flux dependence is connected with the longitudinal variation of the geomagnetic field. Comparison of CORONAS-I data with other satellite data shows that the albedo flux consists of electron fluxes with E_e >65 MeV and proton fluxes with E_p >500 MeV.

1 Introduction

Only detectors with a large geometric factor are suitable for measuring energetic charged particle fluxes below the Earth's radiation belts with sufficient accuracy. Such detectors were installed onboard some satellites (Explorer-7, Cosmos-17, Cosmos -53, Proton-4, Cosmos-426, Cosmos-721, Intercosmos-17, Cosmos-1870, CORONAS-I). Gas-discharge, semiconductor and scintillator detectors were used. They showed that the measured particle fluxes exceed the galactic cosmic ray (GCR) ones at all L-shells. For example, the charged particle flux near the equator exceeds the GCR flux several times. The "additional" flux consists of atmospheric albedo and secondary particle fluxes produced in interactions of GCR with the satellite and detector matter. The different components of additional particle fluxes were discovered in space experiments. Analysis of the experimental results permits to achieve understanding of the composition of these fluxes.

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2 Latitude distribution of energetic particles

We used data of the SONG detector onboard the CORONAS-I satellite (Balaz et al., 1994). This satellite was launched on March 2, 1994 into a near-circular orbit with altitude ~520 km and inclination ~83°. The data obtained during March, 19-31, 1994 were used. The analyzed channel corresponds to the energy deposit >60 MeV in the CsI crystal with a diameter 20 cm and thickness 10 cm. This channel measured proton (E_p >80 MeV) and electron (E_e >65 MeV) fluxes with the geometric factor of ~2100 cm^2·sr.

Experimental data were separated into bins corresponding to 30° intervals of magnetic longitude and *L*-range with the following boundaries: 1.03, 1.1, 1.2, 1.3, 1.4, 1.6, 1.8, 2.0, 2.2, 2.4, 3.0, 4.0, 5.0. The radiation belt region was excluded. The intensity measured by the SONG detector is shown in Fig.1 (upper panel, curve 1).

The GCR fluxes and spectra were calculated according to Beliaev et al. (1996). If rigidity spectrum of GCR is J_{GCR}~$R^{-1.7}$, the GCR flux dependence upon *L*-shell must be J_{GCR} ~$L^{3.4}$. The GCR flux is shown in the same panel by curve 2. We observe similar *L*-dependences for curves 1 and 2 in the 1.2<*L*<1.8 range. The difference between them (J_a - albedo and local particle flux) is shown by curve 3 in both panels. An albedo flux is proportional to the GCR one in this *L*-interval.

2 Composition of energetic particle fluxes under radiation belts

Data on the proton flux (E_p >500 MeV) from the western and eastern directions were obtained during the experiment onboard the Intercosmos-17 satellite (Efimov et al., 1985). These fluxes were similar to the GCR flux with the same cut-off rigidity *R* at 10>*R*>3 GV. The difference between the measured flux and GCR proton flux is the proton albedo flux. This flux (E_p >500 MeV) is shown in the bottom of Fig.1 by curve 5.

Note that the measured eastern flux in the range 16<*R*<60 GV is equal to ~0.006-0.007(cm^2 ·s·sr)$^{-1}$ and exceeds essentially the GCR flux. After subtraction we

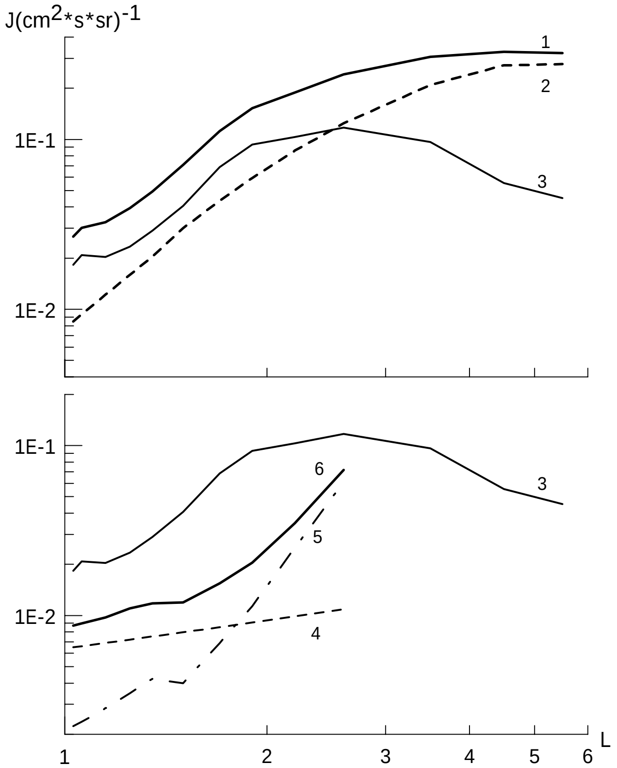

Fig.1. *L*- dependences of particle fluxes

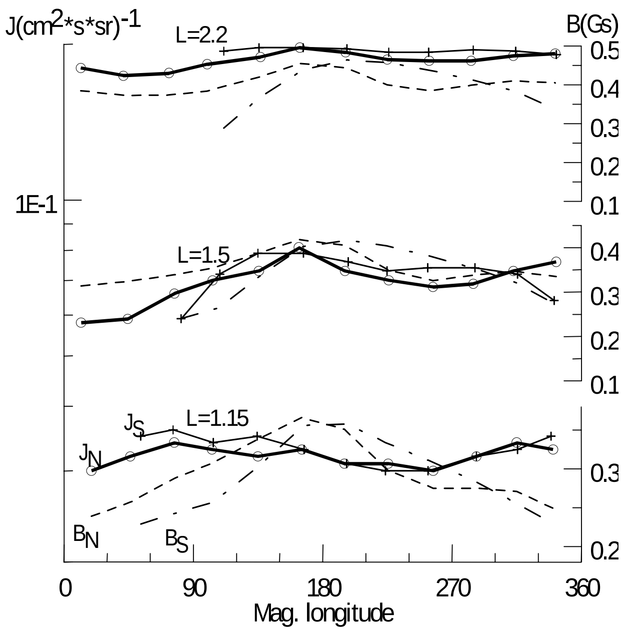

Fig.2. The longitudinal variations of particle fluxes and magnetic field *B* at the certain *L*-shells

received at L=1.0 ~0.002(cm^{2}s*sr)$^{-1}$ that is less than the albedo flux from eastern direction (Efimov et al., 1985). The Larmor radius of protons with E_p~500MeV is equal to ~100km, therefore we can propose that this flux is omnidirectional.

Now we will analyze data on electron fluxes, obtained also onboard "Intercosmos-17" (Efimov et al., 1985). The western flux of electron with E_e>130 MeV was equal to the eastern one. This flux has a weak latitude dependence and increases by a factor <2 during *R* changes from 10 to 5 GV. The flux of electron with E_e >300 MeV changes by factor of 1.2 in this *R* range. Besides electrons with E_e >1.4 GeV were measured in this experiment, all data were received with 30% error. We assume that the electron spectrum is exponential and can be described as E_0 (MeV) =267·$L^{-0.35}$.

According to Cosmos-1870 data (Abramenko et al., 1990), the energy spectrum of electrons in the 8-30 MeV is J_e(>E)=0.1·E^{-1}(cm^2·s·sr)$^{-1}$ .The electron spectrum for the E_e >8 MeV range can be connected with the spectrum for E_e >130 MeV at E_e =35 MeV. Unfortunately we have no latitude dependence of this electron flux. We assume that the electron energy spectrum for E_e >65 MeV is exponential at all *L*-shells and then we received J_e (E_e >65 MeV) = 0.0064·$L^{0.56}$ at *L*<2.6. The calculated in this way electron albedo flux in the bottom panel of Fig.1 by curve 4**.** Note that the sum of electron and proton albedo fluxes (curve 6) is less than the measured albedo flux (curve 3).

A certain contribution to the detector count rates can be due to the local gamma-quanta (Bucik et al., 1999).

4 The longitude dependence of particle fluxes

The longitudinal variation of particle flux at *L*=const can be obtained from Cosmos-426 satellite data (Aleksandrov et al., 1977). This effect is connected with the longitudinal dependence of the albedo particle flux. The amplitude of such variation of the albedo electron fluxes (E_e >130 MeV) at *L*~1.6 evaluated from Intercosmos-17 data (Gusev and Pugacheva, 1987) is equal to ~4±2. The proton flux (E_p >500MeV) has no longitudinal variation at *L*~1.6.

The variations of the energetic particle flux measured by the CORONAS-I in the Northern and Southern hemispheres at *L*-shells 1.15, 1.5, 2.2 are shown in Fig 2 versus the geomagnetic longitude. The longitudinal dependence of the magnetic field *B* is also presented. Data corresponding to the Northern hemisphere are marked by solid line (particle fluxes) and thin dashed line (*B*), to the Southern hemisphere – by thin line (fluxes) and thin dashed-dotted line (*B*). Significant longitudinal variations of the particle flux can be seen. Maximum variations are observed at *L*=1.6, here they correlate with the change of *B*.

For every magnetic longitudinal 30°-interval we received the albedo flux $J_{a.lon}$=J_{lon}-J_{GCR}, where subscript "*lon*" marks values in the certain intervals. Then we analyzed the relative variation of the albedo flux ($J_{a.lon}$-J_a)/J_a. Results are presented in Fig. 3 in the geographic coordinates. The regoins of the decreased J_a are shaded. Isolines *L*=1.1 and 1.6 are marked by dashed-dotted lines.

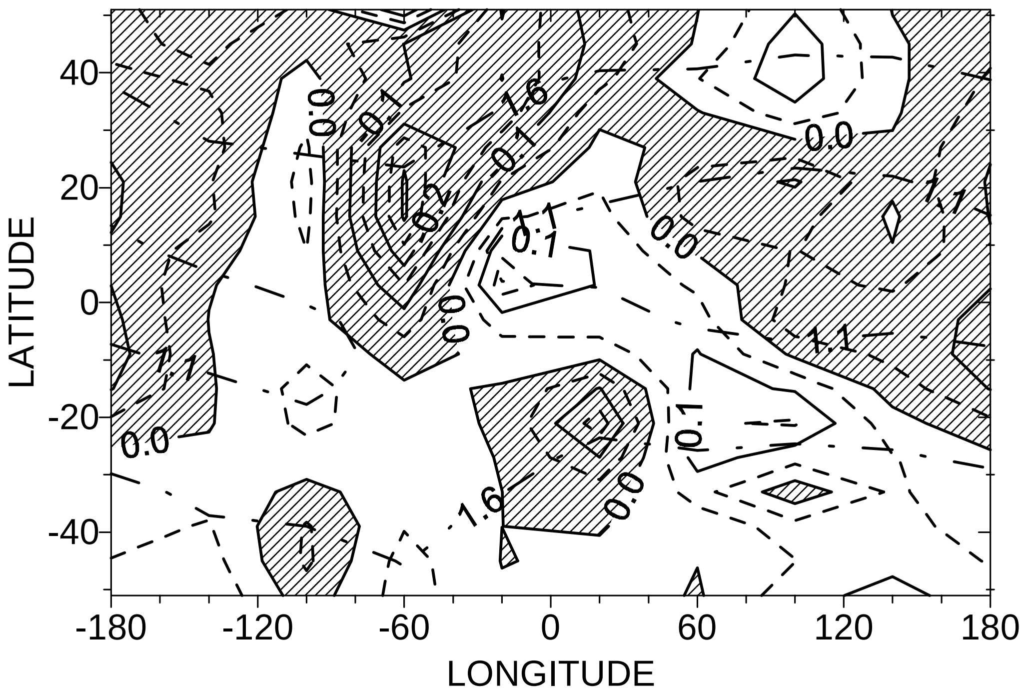

Fig.3. The distribution of the albedo flux at the certain *L*-shells

The increase of the albedo flux reaches to 0.15, its decrease reaches to 0.3. The region of geographic latitudes -10°÷ -40° and longitudes -20°÷ +40° is the radiation belts region. Variations of the albedo flux are observed at all latitudes. Maximum amplitudes of this variations are observed near *L*=1.6.

5 Conclusions

Contribution of albedo particles to detector count rate depends on the latitude (or the L-shell number).

1. The GCR flux is ~0.28(cm^2·s·sr)$^{-1}$ and the electron flux is 0.01 (cm^2·s·sr)$^{-1}$ at the high latitude region.

2. The GCR flux at the equator is ~ 0.01(cm^2·s·sr)$^{-1}$, the albedo proton flux with E_p >500 MeV is ~0.006(cm^2·s·sr)$^{-1}$ .The flux of albedo electrons with E_e >65 MeV is ~0.006 (cm^2·s·sr)$^{-1}$.

3. The flux of charged particles at the equator exceeds the GCR flux in 3-4 times.

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