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PENETRATION OF SOLAR PROTONS INTO THE EARTH'S MAGNETOSPHERE ON NOVEMBER 22,1977

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ABSTRACT

The low polar-orbiting Cosmos-900 satellite carried a large geometric factor (~0.9 m^2sr) Cerenkov counter which may be used to study the particle anisotropy and spectrum near the proton increase peak in solar cosmic rays. The data obtained supplement the information from the ground-based cosmic ray stations and help understand different temporal behaviour of the increases detected at the stations because the whole set of data has shown that the angular distribution of solar cosmic ray particles in interplanetary space was narrow throughout the observation time, thereby resulting, particularly, in a rapid variation of particle intensity near the poles. The power-law index of the solar cosmic ray integral spectrum varied from -2.4 to -5.2 in the 1-4 GV rigidity range from 10.31 to 11.25 UT on November 22, 1977. The flare-time data from all orbits are indicative of an increased radiation intensity on L=3.5-4.0.

1. Introduction. The solar flare responsible for the Nov.22, 1977 event began at 9.45 UT and reached a maximum at 10.07 UT. The cosmic ray intensity enhancement was detected by the neutron monitors with the cut-off rigidity less than 5 GV and also by the satellite instruments /1-3/. The onset of the cosmic ray intensity enhancement was detected by the neutron monitors at 10.10-10.15 UT and the maximum intensity of the enhancement at 10.35-10.50 UT.

2. Results. The data from three channels of the Cerenkov detector on Cosmos-900 for the interval 8.45-11.50 UT, 22. 11, 1977 are presented in fig.1. Up to 10.30 UT the counting rate corresponds to the latitude behaviour of the cosmic-ray intensity during the quiet period. During the interval 10.30-11.50 UT, while Cosmoc-900 was outside the equatorial region, the intensity enhancement associated with the penetration of cosmic ray into the Earth's magnetosphere was observed. (The peak at 9.35 and 11.12 UT is detected during the passage of the satellite through the Brazil magnetic anomaly). The intensity enhancement was, mainly, due to protons of the solar cosmic rays since the electron contribution for our instrument according to ref. /4/, could not be $>$ 4%. According to the 11th channel detected only particles with $Z \geq 2$, the intensity of these particles during the flare was smaller, at least, by a factor of 200 than the proton intensity. The maximum intensity

of >400 MeV protons was higher by 600 % then the pre-flare level, being equal to (2.3 ± 0.5) 10^4 $m^{-2}s^{-1}sr^{-1}$.

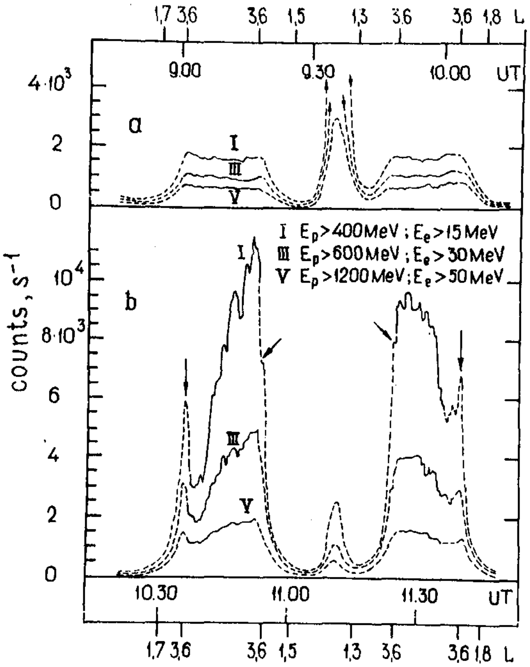

Fig.1. The cosmic ray count rates for three channels:
a) in the quiet time (prior to the flare),
b) during the flare.
The broken curves refer to the satellit passage through the region of action of geomagnetic cut-off.

The intensity distributions are characterized by the peaks and irregularities in the count rates marked by arrows in fig.1b. Note that all these cases were detected on L = 3.6 which proves the spatial behaviour of these variations. Accord to the neutron monitors the latitude distribution is also characterised by irregularities /5/.

It must be noted that this phenomenon is observed on the magnetic shells where the energy of the geomagnetic cut-off is compared with the energy threshold of the instrument.

3. **Discussion.** The peaks and irregularities in the count rates cannot be attributed to the radiation belts and to the particle precipitation from them /2/. Hence, the peaks on L = 3.6 are connected with the propagation of cosmic rays into the magnetosphere and, possibly, with the albedo particles and, also the quasi-trapping effects.

In our case the flux anisotropy and the longitudinal distribution of the receipt cones are, seemingly, the simplest explanation of the count-rate peculiarities.

On L = 3.6 the receipt cones have a wide longitude distribution and the instrument detects an averaged intensity. In the region adjoining L = 3.6 from the side of high latitudes the longitude distribution of the cones is always narrow and in the case of peaks the sunward particles /6/ are, mainly, detected whose intensity is known to be less then the mean intensity.

From our data it is possible to determine the flux anisotropy during the flare. The angles θ between the axis of the solar proton flux in the interplanetary space and the axis of the asymptotic receipt cone for two points of the satellite trajectory (fig.2) in the high-latitude region of the Northen hemisphere, have been determined from the calculations /6/ including the outer magnetosphere currents. The difference in the intensities detected in these regions can be accounted for by the presence of a positive cosmic-ray flux anisotropy. If the time behaviour of the intensity in the interval 10.38-10.51 UT is neglected (according to the high-latitude neutron monitors the changes in intensity were small in the interval) the antisun-to-sunward ratio of particle fluxes for the above pitch-angles is estimated from our data to be ~6. During the interval 10.15-10.35 UT this ratio is close to 4 according to the neutron-monitor data /7/.

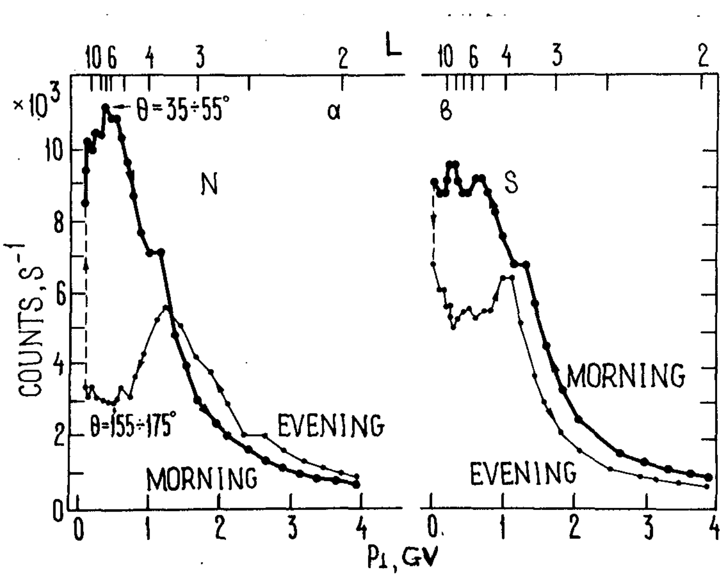

Fig.2a. Counting rate of the first channel versus the vertical rigidity of the geom. cut-off in the flight through the Northern hemisphere during the flare. The arrows mark the time flow. The thin and thick lines correspond to the satellite flight in the evening and morning sides of the Earth.
Fig.2b. the same in the Southern hemisphere.

Assuming that in the South hemisphere in the high-latitude region the outer magnetosphere currents exert the same influence upon the asymptotic directions as they do in the Northern hemisphere, we may conclude that the solar cosmic-ray anisotropy decreases with time and maintains a positive sign (at least for high-latitude regions).

The spectra of observed particles within the rigidities 1-4 GV were obtained using the movement of the satellite in space. The calculations shown that in the interval 10.31-10.35 UT the index of the integral spectrum γ was 2.4 and in the intervals (10.54-10.58, 11.21-11.25, 11.40-11.44 UT) γ was on the average 4.1, 4.3 and 4.2, respectively. The slope of the spectra was not always the same, the index γ increased with rigidity, reaching the value 5.2. It follows that at 10.35 UT bulk of 400 MeV protons did not reach the observing point, and during the next interval the spectrum was equilibrium.

In conclusion we note one more feature of the intensity distribution of the solar cosmic rays, namely the regular small peaks of intensity observed in the first channel every 2 minits throughout the flare observation period. We have failed to connect these variations with the peculiarities of the instrument operation and tentatively attribute them either to the solar or magnetospheric pulsations or to the propagation of particles in the interplanetary space. In the latter case these variations may be connected with the value of free path of particles.

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