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COSMIC RAY VARIATIONS FROM "METEOR" OBSERVATIONS IN 1969—1981[1])

ВАРИАЦИИ КОСМИЧЕСКИХ ЛУЧЕЙ НА ОСНОВЕ НАБЛЮДЕНИЙ В 1969–81 гг. ПРИ ПОМОЩИ СПУТНИКА «МЕТЕОР»

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Solar and galactic cosmic rays are the main source of radiation hazard during space flights.

Since 1969 we have been studying morphological characteristics of cosmic rays: their temporal, spectral and spatial distributions. So far we have acquired a continuous series of data on solar cosmic ray characteristics from observations by "Meteor" — a satellite that has a circular orbit and inclination angle of ~82° [1—4].

While developing methods of forecasting the radiation situation in the near-Earth space, the whole complex of heliogeophysical events accompanying the solar proton flare was investigated. Correlations between solar cosmic ray characteristics and some events that accompany the flare were studied [4].

It has been established that temporal, spatial and spectral characteristics of solar cosmic rays vary considerably, which is attributed to proton flare characteristics, the solar coronal magnetic field structure, interplanetary medium disturbances, as well as the solar activity cyclicity [5]. Data on changes of the main radiation parameters, some solar and geomagnetic activity indices are shown in Fig. 1. The diagram presents the average monthly values of the Wolf numbers R_z, F — the 10.7 cm radio emission flux, D_{st} — variations, and A_p — the index for the period of 1965—1981, i.e. covering the whole 20, and the growth period, and the maximum epoch of the 21 solar cycle. The total values for the corresponding month are given for the following parameters: number of proton flares on the Sun, N; satellite-detected total proton flux for the whole solar cosmic ray event — I; the number of flares with importance $1F$—$4B$; the γ parameter — spectrum hardness index during the event maximum — is presented for each registered event.

Radiation characteristics were studied of solar cosmic ray events with proton fluxes with an energy $E_p > 10$ MeV, an intensity in the maximum $J_p > 1$ cm^{-2}s^{-2}sr^{-1} [1—7, 18]. The integral spectrum of the proton fluxes was approximated by the power function $J_p \sim E^{-\gamma}$, where γ is the spectral index. The presented indices and parameters show substantial variations over the considered period related to solar activity cyclicity. It is seen that in cycle 21 large-amplitude variations during the growth period and the maximum epoch are observed for the F and the R_z indices. Based on these indices 21 cycle is more powerful than the 20 cycle. Based on flare activity the new cycle manifests itself somewhat differently, than the 20 cycle. The total number of flares is probably less, and that of the proton flares greater than during the previous cycle. Full proton fluxes — I on the growth branch and during the maximum epoch of the 21 cycle are higher, the variation range of γ is wider. The largest values of full proton fluxes were

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registered during solar cosmic ray events of August 2, 4 and 7, 1972 [8]. During the minimum epoch of the 20 and 21 solar cycles — in 1965 and 1976 — soft-spectrum solar cosmic ray events ($\gamma<2.5$) were not observed. A considerable nonuniformity in the radiation parameter distribution among the solar cycle phases is also worth noting. Magnetic activity is higher during the 21 cycle by A_p and D_{st}-indices.

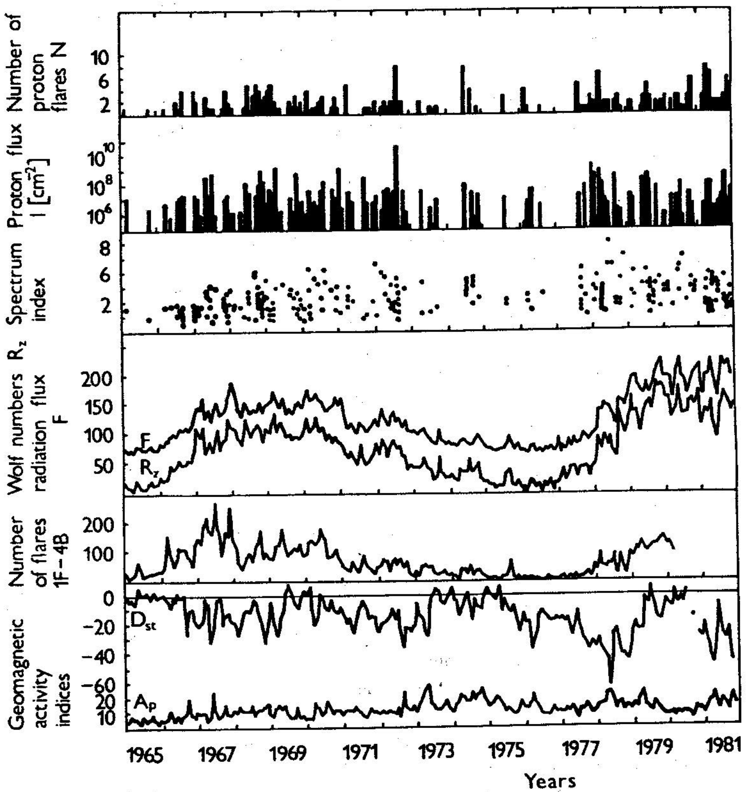

Fig. 1. Temporal variations of the main radiation parameters; indices of solar and geomagnetic activity.

Probabilities of the solar cosmic ray distribution by the flux magnitude and the spectrum index during the event maximum were studied. Events with $I<J_{max}<10^2\ s^{-1}sr^{-1}$ are most probable, events with $J_{max}>10^4\ cm^{-2}s^{-1}sr^{-1}$ are seldom observed, and, as a rule, occur over the growth and the decay periods of the 11-year solar cycle (August, 1972, September, 1978; October, 1981). Very hard ($\gamma<1$) and very soft ($\gamma>5$) spectra are seldom registered; events with the spectrum index γ equal to 1—4 (energetic range under consideration $5<E_p<90$ MeV) are generally observed. Fig. 2 presents heliolongitudinal variations of the spectrum index γ, for the 20 and the 21 cycles, separately. In the 21 cycle a considerable spectrum softening occurs during the events related to flare in the solar western hemisphere.

During initial stage of the flare flux registration, in most cases flux anisotropy is observed resulting in an asymmetry of the flux distribution over the polar caps. Both the north-southern and the south-northern asymmetries are observed. As a rule, during the flux growth period the asymmetry amplitude ($A=(J_N-J_S)/(J_N+J_S)\times 100$ %) is maximal. Sometimes the asymmetry is evident through-

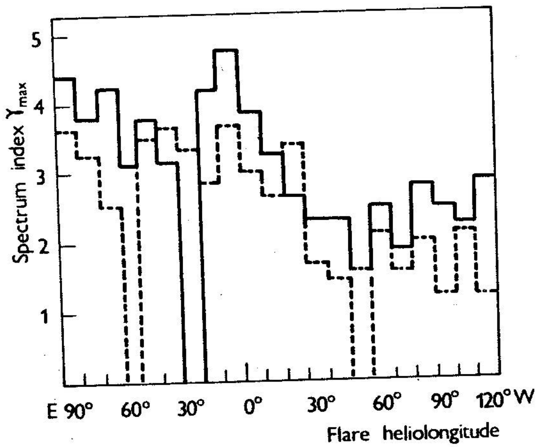

Fig. 2. Relationshipetween the spectrum hardness index during the solar cosmic ray event maximum and flare heliolongitude; dotted line — data averaged for 1969—1976, firm line — averaging period 1977—1981

out the whole solar cosmic ray event, as, for example, on September 23, 1978 [6]. In case of a considerable spatial asymmetry, inhomogeneities in proton flux distribution over a polar cap are observed. During the solar cosmic ray event in October, 1981 complex spatial distribution profiles occurred: polar cusp and auroral peaks were observed. The peak intensity differs by a factor of 1.5—2. The observed distribution profiles vary quickly with time. The solar cosmic ray event in October, 1981 (Fig. 3) is distinguished for its proton flux intensity, spectrum hardness and the dynamics of the heliogeophysical disturbance development. It is evident that in this case the proton flare activity manifested itself prominently: several powerful proton flares of a 3B—1B importance took place one by one, generating hard spectrum proton fluxes; the flares resulted in a geomagnetic activity increase; shock-generated substorms and storms with SC were observed in the magnetosphere and on the Earth. As indicated above, proton fluxes characterized by a hard spectrum and a high intensity level are seldom observed, therefore according to its radiation characteristics, the event can be considered as an extreme one.

Fig. 4a presents the mean-monthly variations of cosmic rays with $E_p>90$ MeV in the absence of solar proton fluxes for the period of 1969—1981 (curve 1), and Alert monitor data ($\Phi=86°$) [9]. Experimental results have shown that the greatest cosmic ray variations are caused by the solar activity cyclicity. The 11-year variation amplitude amounts to 180—220 %, that is to significantly more than according to the neutron monitor data (Deep River, Alert: 16—17.5 %).

The observed (1972—1974) quasiperiodic variations are related to the solar wind modulation of cosmic rays. The variation amplitude increases and amounts to 11 %, 18 %, and 26 % in 1972, 1973, and 1974, respectively. It is also seen that during the solar minimum epoch the spectrum is enriched with softer energy particles.

Solar ray asymmetry was studied from the northern and the southern polar cap observations. The asymmetry amplitude was determined in the same way as in the case of the solar cosmic rays. A constant south-northern asymmetry in cosmic ray fluxes with $E_p > 65$ MeV and 90 MeV is established for 1969—1982 (Fig. 4b). The asymmetry amplitude varies within the range of 0.1—3.2 % [10]. During the

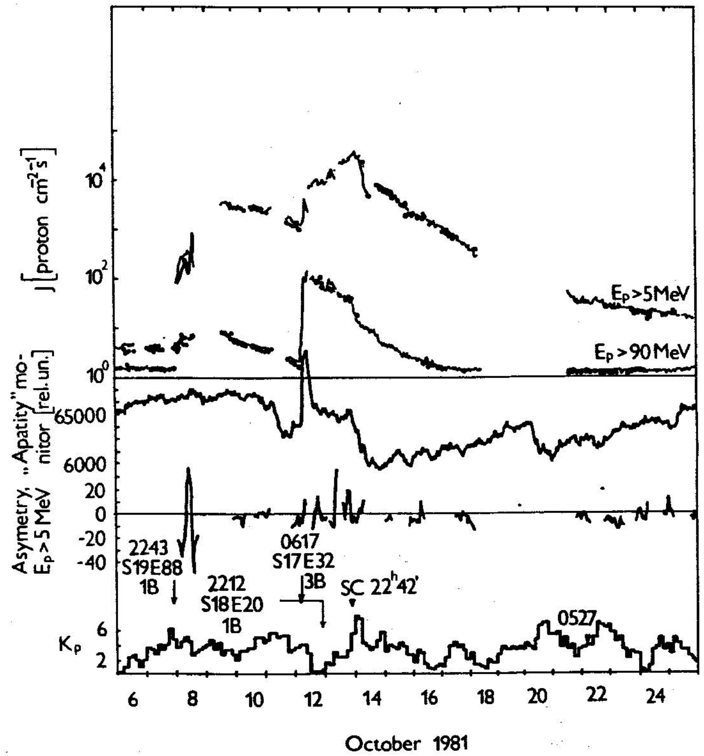

Fig. 3. Proton flare and geomagnetic activity in October 1981.

polarity reversals of the total solar magnetic field maximum values of asymmetry, amplitude occur. From Fig. 4b (curve 1) we can see cyclic variations related to the 11-year solar cycle, as well as semi-year variations pronounced in the period of the solar activity minimum. Fig. 4b (curve 2) presents a variation of the "knee" in the latitudinal effect of cosmic rays with $E_p > 90$ MeV during the period from 1975 to 1982, i.e. from the 21 cycle minimum epoch to the decay branch. Substantial variations in the cosmic ray "knee" (L_{crk}, where L — McIlwain coordinate) position are observed. From the minimum to the maximum epoch of the cycle the "knee" has shifted from $L_{crk} = 3.84$ to $L_{crk} = 2.67$, i.e. by 30 %. Since May 1981 L_{crk} has been growing.

Experimental data on cosmic rays and their relationship with solar activity show that variations of both radiation and heliogeophysical parameters are governed by the solar activity cyclicity, depend on the cycle phase and vary with the cycle.

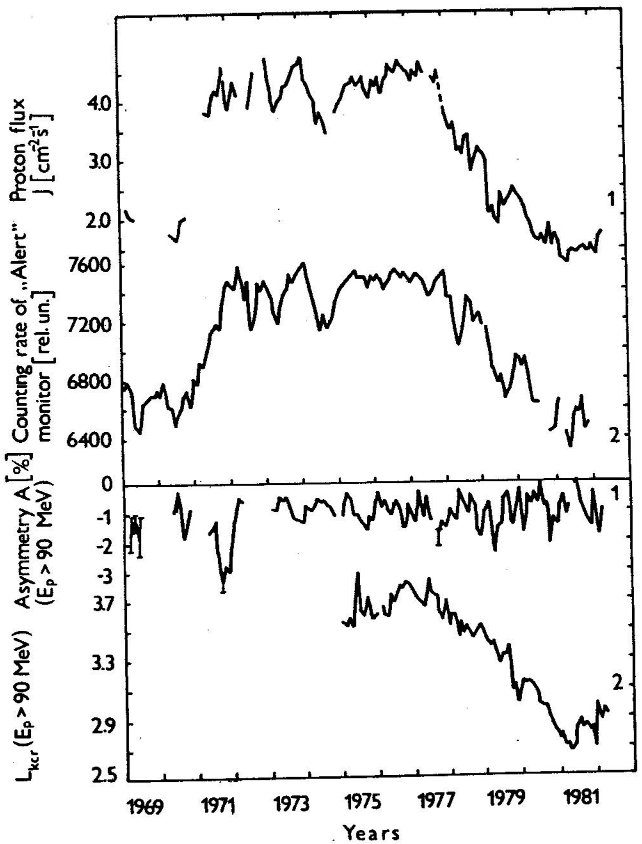

Fig. 4. Cosmic ray variations in 20 and 21 solar cycles: cosmic ray flux with $E_p > 65$ MeV, and cosmic ray flux with $E_p > 90$ MeV.

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