THE DIFFERENCE IN THE ENERGY SPECTRA OF GALACTIC COSMIC RAYS AT THE MINIMA OF THE 19TH AND 20TH SOLAR ACTIVITY CYCLES

A.K. SVIRZHEVSKAYA, N.S. SVIRZHEVSKY, YU.I. STOZHKOV,

P.N.LEBEDEV Physical Institute of the Academy of Sciences of the USSR, Leninsky Prospect, 53, 117924, Moscow, USSR

T.N. CHARAKHCHYAN

Institute of Nuclear Physics, Moscow State University, 119899, Moscow, USSR

ABSTRACT

The absorption curves of the cosmic ray charged component for solar minima in 1965 and 1975-1977 are analysed on the basis of daily stratospheric measurements in Murmansk, Moscow, Alma-Ata and Mirny (Antarctic).

Two distinct features in the energy spectra of galactic cosmic rays are revealed during these periods.

1. At the 20th solar activity minimum there was the additional short range component of cosmic rays. Additional fluxes in the stratosphere at high latitudes (Murmansk, Mirny) caused by this component are probably protons and He nuclei with the energy 100-500 MeV/n. The fluxes are estimated as $\sim 300\ m^{-2}s^{-1}sr^{-1}$.

2. At the minimum in 1975-1977 the proton intensity in the energy range 1-15 GeV is 10-15% lower than that in the 1965 solar activity minimum.

Numerous experimental evidences are indicative of a significant role of the solar general magnetic field in the cosmic ray modulation effects /1,2/. The magnetic field direction in the polar regions of the Sun proves to be of importance for the formation of the energy spectra of galactic cosmic rays in the Earth's vicinity.

The differences in the primary cosmic ray energy spectra in the consecutive solar minima are pointed out in particular by the short range component detected in the stratosphere /3,4/. Although the nature of the particles of this component is not clear yet at middle latitudes (Moscow, Alma-Ata), at the same time the data obtained in /5/ suggest that the short range component at high latitudes (Murmansk, Mirny) should be associated probably with the protons and helium nuclei of energies below 500 MeV/n.

Information on the variations of the primary cosmic ray energy spectrum may be derived from the altitude dependence of the relative variations of the cosmic ray intensity $\Delta N/N$ in the stratosphere. In the case of the 11-year cosmic ray modulation the variation amplitude decreases with increasing the primary particle energy, and then the value of $\Delta N/N$ decreases with rising the atmospheric pressure X. Over Murmansk, for example, $\Delta N/N$ at X=10 g/cm^2 is two times as high as that at X=150 g/cm^2. However the shape of the dependence $\Delta N/N(X)$ in the years near the 20 solar activity minimum proved to be quite different.

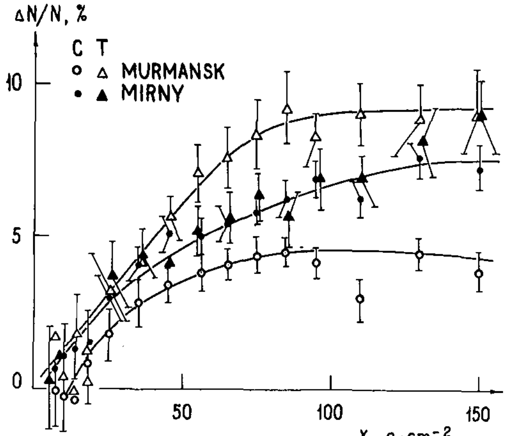


Fig.1. $\Delta N/N$ versus the atmospheric pressure in 1976 for a Geiger counter (C) and counter telescope (T) at Murmansk and Mirny.

Fig.1 shows the variations of the cosmic ray intensity $N_{76}(X)$ in 1976 relative to the intensity in 1965, $\Delta N/N=(N_{65}-N_{76})/N_{65}$, over Murmansk and Mirny. In a broad interval of pressures the cosmic ray intensity in the stratosphere and hence the primary particle intensity in 1976 was lower than that in 1965. The character of the dependence $\Delta N/N$ at $X > 70$ g/cm^2 indicates that the primary spectrum variation in a certain energy range is independent of the particle energy. The decrease of $\Delta N/N$ at $X < 70$ g/cm^2 may be explained by the existence of the cosmic ray short range component in 1976. The same situation took place also in 1975 and 1977.

The data presented in Fig.1 were used to obtain the absorption curves for the additional short range component of cosmic rays (see Fig.2). The absorption curves are actually identical at high latitudes in the nothern and southern hemispheres. The energy spectrum of the additional proton flux, which is also shown in Fig.2, was determined assuming that the additional component consists of protons. The value of the additional 100-400 MeV proton flux is ~ 300 m^{-2}s^{-1}sr^{-1}. Taking into account the fact that He nuclei make a definite contribution to the particles detected in the stratosphere, the flux obtained proves to be in a good agreement with the additional flux of protons and He nuclei in 1977 (compared with 1965) according to /5/. The short range particles at high latitudes in the stratosphere appeared in 1972 and disappeared practically after 1979 /4/, that is they existed during about the same period as the anomalous He component of cosmic rays detected by space probes /6/.

Another important conclusion can be drawn from the data presented in Fig.1, namely, the 1-12 GV rigidity cosmic ray fluxes were much lower in 1976 than in 1965. The same conclusion may be drawn from the analysis of the data of latitude stratospheric measurements in the years 1965, 1969 and 1975 /7/. Fig.3 shows the energy spectra of the variations of primary cosmic rays in 1969 and 1976 relative to 1965 inferred from the latitude measurements. From Fig.3 it seen that the primary cosmic ray intensity in the 4-12 GV was 10-15% lower in 1976 than that in 1965. In the examined energy range the cosmic ray intensity in 1976 was essentially the same as during the solar activity maximum of 1969. The dashed line in Fig.3 presents the spectrum of the variations $\Delta I/I(R)$

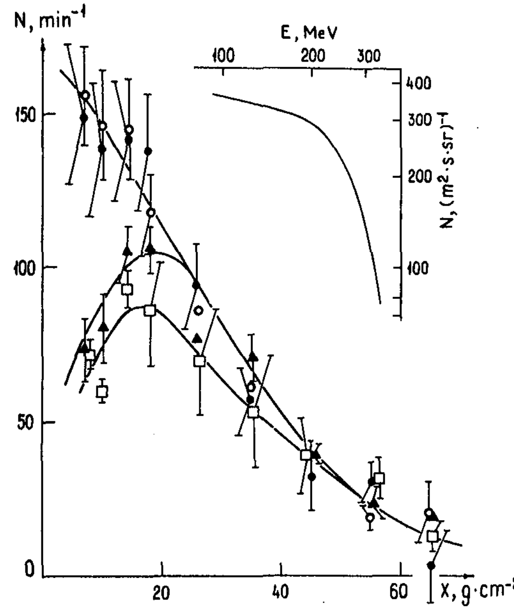


Fig.2. Additional fluxes of the cosmic ray short range component in the stratosphere over Murmansk (○), Mirny (●), Moscow (▲) and Alma-Ata (□). At the top right-hand corner the energy spectrum of the additional proton flux is shown.

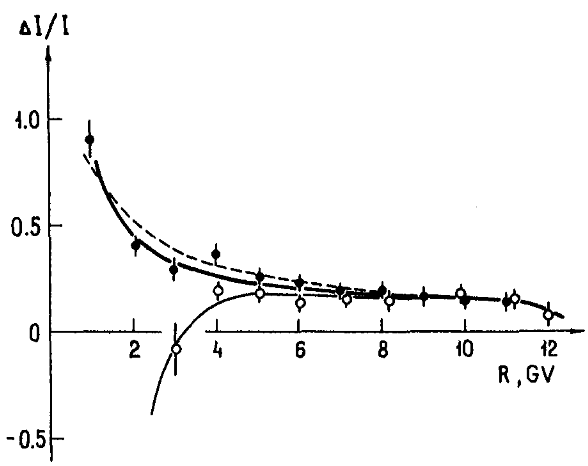
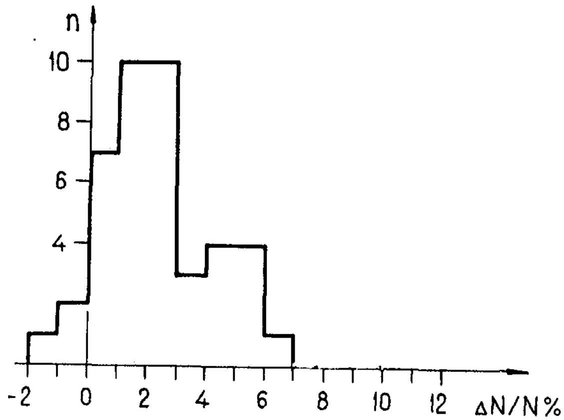


Fig.3. The spectra of the primary cosmic ray variations $\Delta I/I=(I_{65}-I_i)/I_{65}$ in 1969 and 1976 (the dark and light dots respectively). The dashed line shows the variation spectrum in 1969 calculated using the values of $\Delta N/N$ at high latitudes.

Fig.4. The distribution of $\Delta N/N$ for high latitude neutron monitors ($R \leq 2.3$ GV) in 1975-1977.



calculated for 1969 using $\Delta N/N$ at Murmansk and Mirny. The spectrum presented is in a good agreement with the spectrum inferred from the latitude measurements.

Fig.4 shows the distribution of $\Delta N/N=(N_{65}-N_i)/N_{65}$ for several neutron monitors located at high latitudes ($R \leq 2.3$ GV). The mean value of $\Delta N/N$ for neutron monitors is 2.3 ∓ 0.3 per cent, but $\Delta N/N$ appears to be 5-7 % for some of them (for example, Mt. Washington, Durham). The conclusion that the cosmic ray intensity was lower in 1976 than in 1965 is generally confirmed by the neutron monitor data. The broad distribution of $\Delta N/N$ inferred from the neutron monitor data and the difference in $\Delta N/N$ over Murmansk and Mirny together with the difference in $\Delta N/N$ from the data of a Geiger counter and counter telescope (Fig.1) seems to indicate that the modulation mechanism in the solar activity minima is different from the mechanism of the 11-year cosmic ray modulation.

References

1. Charakhchyan A.N. et al., (1973), Izv. Akad. Nauk SSSR, ser.fiz., v. 37, p. 1258.
2. Nagashima K. et al., (1977), Proc. 15th ICRC, v. 10, p.380.
3. Svirzhevskaya A.K. et al., (1981), Proc. 17th ICRC, v. 3, p. 187.
4. Svirzhevskaya A.K. et al., (1983), Proc. 18th ICRC, v. 3, p. 43.
5. Webber W.R. et al., (1983), Proc. 18th ICRC, v. 3, p. 35.
6. Garcia-Munoz M. et al., (1981), Proc. 17th ICRC, v. 3, p. 270.
7. Svirzhevsky N.S., (1983), Thesis, FIAN, Moscow.