ENERGY SPECTRUM AND COSMIC RAY COMPOSITION IN THE REGION OF ENERGIES HIGHER THAN I TEV INVESTIGATED ONBOARD THE "COSMOS-I543" AND "COSMOS-I7I3" SATELLITES

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The results of measurements of the energy spectrum of protons, He nuclei and nuclei of the M, H and VH groups in the energy region $2 \cdot 10^{12}$-10^{14} eV are presented. The spectrum power indices and the charge composition are not a strong energy function significant for statistics.

Measurements onboard the satellites were made with the "Sokol" apparatus (Vernov et al I985, Grigorov et al I988) comprising Cerenkov charge detectors (DZ) and ionization calorimeter (IC) with thickness of ~ 5.5 nuclear path for protons, allowed to reconstruct the detected particle tracks with an accuracy of I cm at a DZ level. Events were selected within the apparatus working aperture with account for this uncertainty (Ivanenko et al I988). The effect of backscattered secondaries from IC proved to be inessential to separate protons from He nuclei (their "overlap" did not exceed several percent) and for charge resolution of nuclei with $Z \geq 6$, which represented ~ 0.4 of charge unit for the M group and $\sim$I for the VH one. A systematic error in a particle energy determination is valued at $\sim$(I2-I0)%, the mean value of energy release detected in IC being $\sim(0.74$-$0.80)E_0$ (for the first and second experiment, respectively) (Ivanen-ko et al I989). The threshold condition recording analysis has shown that the requirement for the energy release in IC to be above the threshold value of I.2 TeV and not less than 22 GeV in each of m any its rows, does not lead to the discrimination of both protons and He nuclei in the energy region of $E \geq 2.5$ TeV for m=5 (the second experiment) and in the range of $E \geq 4$ TeV for m=(7-8) (the first experiment; 27% of the second experiment time) provided that particles with the first interaction in the upper three IC rows (in the first experiment with that in the upper two rows) are selected. The threshold conditions do not lead to the discrimination of nuclei with $Z \geq 6$, beginning from the energy E = 2 TeV. The particle detection efficiency within the working aperture (2 50 cm^2ster) for the selection noted was 0.36-0.59 in the case of protons; 0.55-0.77 for the He nuclei and ~I for the nuclei with $Z \geq 6$ for the first and second experiments, respectively. The total effective time of the two experiments is 590 hrs, the first experiment contribution being $\sim$40%.

The differential and integral spectra of protons obtained with data of the two experiments are shown in Figs.I and 2 where they are compared with the results of other authors. The spectrum fits well the previous measurements in the region $E \leq$I TeV (Ryan et al I972, Grigorov et al I970) agrees with the results of (Burnett et al I983) and at E>I0 TeV it contradicts the data of (Varkovitskaya et al. I988). Our data do not confirm spectrum steepening from E~I-2 TeV reported in (Grigorov et al I970).

The spectrum of He nuclei (see Fig.3) fits well the results of (Burnett et al I987). The intensity differs from the extrapolation of data obtained earlier up to ~I TeV (Ryan et al I972, Grigorov et al I970). The ratio of proton to nucleus fluxes is I.4±0.2 by our present data, 2.3 ±0.2 by data of (Ryan et al I972), and I.8±0.3 by data of (Grigorov et al I97I).

Fig.4 shows the differential spectra for the M, H and VH nucleus groups compared with data of (Juliusson I974, Simon et al I980). The spectrum of all particles (see Fig.5) obtained by summing data for individual components extrapolates well the results of direct measurements at E≲I TeV (Ryan et al I972, Simon et al I980, Linsley I983) to EAS results. The obtained intensity values noticeably exceed the data of (Grigorov et al I970) in the region E≳I0 TeV. Approximation of the spectra by the power law yields the following integral indices γ for various components: in the energy region E> 2.5 TeV γ_p = I.67±0.I0; γ_{He} = I.7I±0.I0; $\gamma_{z\geq 6}$ = I.55±0.07; γ_{all} = I.63±0.05; in the energy region E> I0 TeV γ_p = 2.0I±0.35, γ_{He} = I.43±0.26, $\gamma_{z\geq 6}$ = I.48±0.I7, γ_{all} = I.56±0.I3.

The intensity of all-particles flux with energy E≥2.5 TeV is (3.26±0.II)·I0^{-2}m^{-2}ster^{-I}s^{-I} obtained in our experiment.

Data on the relative charge composition of particles are listed in Table I for two energy regions.

Table I

	The "Sokol" experiment (in percent)		Review (Linsley I983) (in percent)	
Energy range, TeV	> 2.5	> I0	> I	> I0
p	39±3	36±7	43	38
He	28 ±2	25±6	I9	I9
M	I3±I	I4±4	I3.9	I3
H	I0±I	I5±4	I5.I	I6
VH	I0±I	I0±3	9.6	I4

The joint analysis of readings of two charge detectors (DZ-I and DZ-2) usually used to attain better charge resolution (Juliusson I974, Simon et al I980, Grigorov I989) allowed both to separate nuclei in the range 6≤Z≤I4 more correctly than in (Grigorov I989) and to obtain quantitative data on the relative composition for each chemical element in this region. These data are listed in Table 2 where they are compared with the results of (Shapiro & Silberberg I975) for E> 4 GeV/nucleon (recalculated to energy per particle under assumption of γ =I.6). Fig.6 presents the ratio of the differential and integral proton spectrum to that of nuclei with Z≥2. It can be seen that in the region to ~20 TeV where sufficient statistics is available, the charge composition is close to the "normal" one with the proton fraction about 40%.

At high energies the proton fraction decreases that is due to both some deficiency of protons and abundance of nuclei. However to make definite conclusions in this region, the statistical material available is insufficient.

Table 2

Nuclei	C	O	Ne	Mg	Si
The "Sokol-2" experiment (in percent)	77±II	I00	46±8	39±7	38±7
Shapiro M. and Silberberg R. I975 (in percent)	63±3	I00	23±3	36±3	34±5

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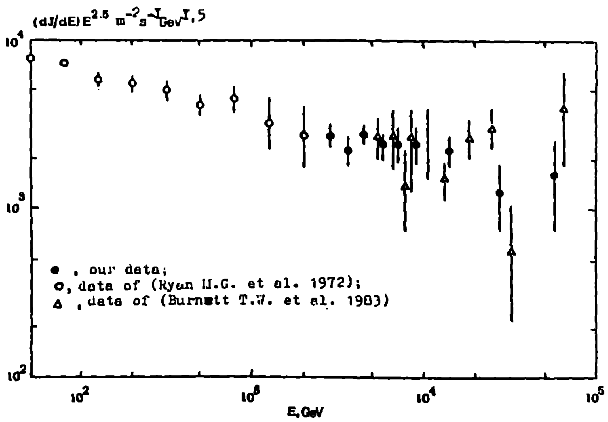

Fig.1. The differential energy spectrum of protons

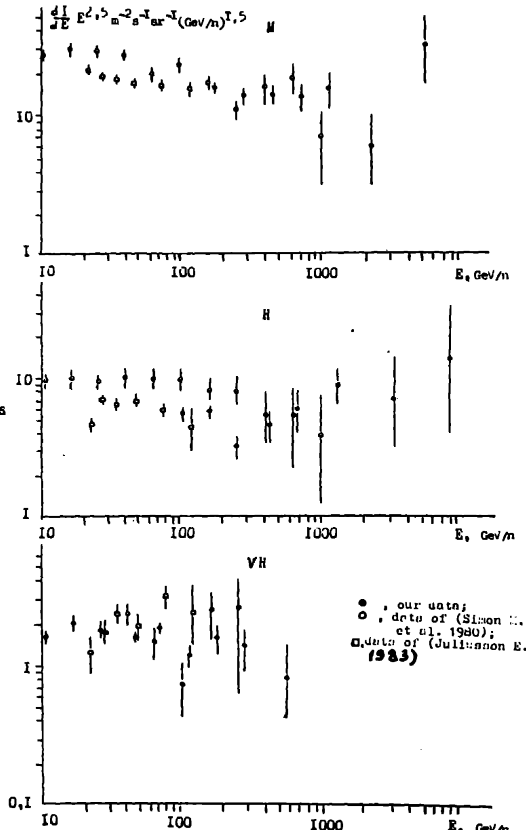

Fig.4. The differential energy spectrum of three groups of nuclei

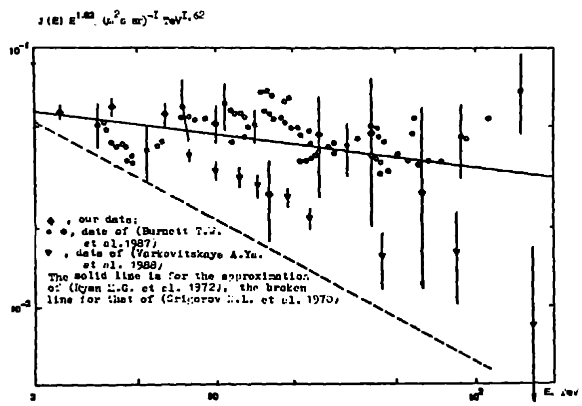

Fig.2. The integral energy spectrum of protons

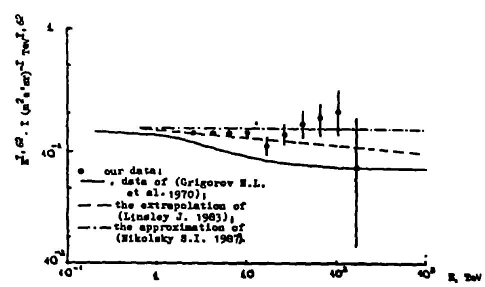

Fig.5. The integral energy spectrum of all particles

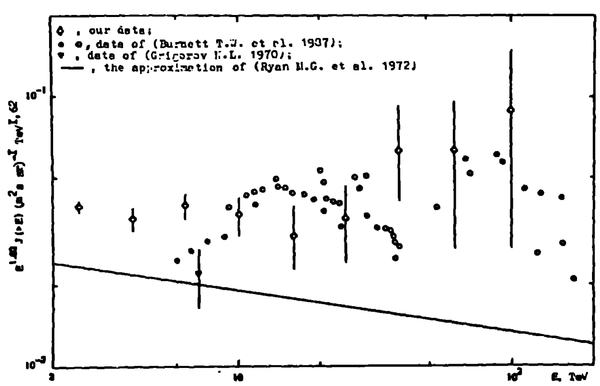

Fig.3. The integral energy spectrum of He nuclei

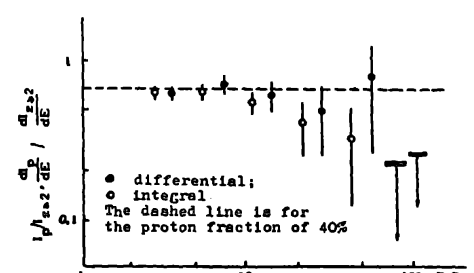

Fig.6. The ratio of proton intensity to intensity of nuclei with $z \geq 2$