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The Formation of the united metagalactic energy spectrum of the cosmic rays

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Abstract. The investigation of the extensive air showers is revealed the absent of the breaks in the spectrum of the showers, generated by the primary protons at the atmosphere depths more than 200 g/cm^2, and in the spectrum of the showers produced by the primary nuclei. It is equivalent to the absent of any knee in the energy spectrum of the primary cosmic rays in the region 10^{15}-10^{18} eV. The united galactic and meta galaxy spectrum $\sim E_0^{-2.7} dE$ extends from 10^{12} eV until 10^{19} eV. One discusses the process formation of the united meta galaxy energy spectrum of the cosmic rays.

1 Introduction

A discovery of the relic cut-off for the extensive air shower (EAS), produced by the primary nuclei with the energy $\geq 10^9$ GeV instead $> 3 \cdot 10^{10}$ GeV (D.J.Bird, 1993; M.N.Dyakonov, 1990) allowed to determine the real primary energy of the EAS with the electron number $N_e > 10^8$. This correction of the primary energy of the observed EAS restores the real energy spectrum in the interval $10^8 - 3 \cdot 10^{10}$ GeV and conforms the less popular explanation of the knee in the EAS spectrum, as the change in the inelassity collisions primary cosmic rays with the air nuclei. It has reveals the unity of the primary cosmic ray energy spectrum in the wide interval from 10^2 GeV up to $3 \cdot 10^{10}$ GeV as $f(E_0)dE_0 \sim E_0^{-2.72 \pm 0.02}$ (S.I.Nikolsky, 2000). The analysis of the EAS in detail allowed to put up, that neither the spectrum of EAS, which produced by the primary protons in the depth of atmosphere, nor the showers, produced by the primary nuclei have not the knee in its spectrum in the interval of the primary energies $10^6 - 10^8$ GeV (Fig. 1).

It is necessary to remark, that the installations with the wide apart detectors of the electron stream (> 40 m) do not allow to determine the age parameter of the EAS. The absence of the information about the age parameter S and as a rule, about the electron stream in the vicinity the shower core do not allow to estimate the altitude of the shower origin and the energies of the primary particles. The systematic underestimation of the electron number in the proton generated showers and, as a result, to the loss of this EASs. For instance, one can cite the discovery of the returning knee (G.B.Khristiansen, 1973) and its loss up to the new discovery later on twenty five years (L.I.Vil'danova, 1994). The lost primary protons remind about oneself anew and anew in the young showers, in the returning knee, in the hockey club at $3 \cdot 10^{18}$ eV (Fig. 2) Generally the cosmic ray energy spectrum is underestimated in the five-eight times at the primary energies $\sim 10^{20}$ eV.

The unity of the primary cosmic ray energy spectrum aggravated the problem of the galactic or metagalactic origin of the cosmic ray. Usually the galactic origin of the cosmic rays one connectes with the supernova remnants, but the systematically searches and observations of the gamma-ray sources with the energies more 1 TeV compel to renounce from the early established conceptions both about the essential role our Galaxy in the acceleration of the cosmic rays and about the process of a formation of the united cosmic ray spectrum in the total interval of the relativistic primary energies. Fig. 3 and 4 present the spectra of the gamma-quanta from the supernova remnant Crab Nebula in our Galaxy and from extragalactic source Markarian 501. The observed intensities of the sources are distinguished a little (Tabl. 1). It connected with the confined time of observations of the revealed sources. In order to compare the galactic gamma-sources with the extragalactic sources, it is necessary to recount the observed intensity of the TeV γ-rays extragalactic sources, which are very far from our Galaxy to the distance between the sun system and Crab Nebula. We have seen that the power of the non-Galaxy TeV γ-sources from the Tabl. 1 incomparable tremendous in the comparison with Crab Nebula. Such powers of the extragalactic gamma-sources, a number of which certainly exceeds the number of gamma-sources in our Galaxy, have to change the very widespread opinion about the place of the cosmic ray origin from our Galaxy to the all space of the universe.

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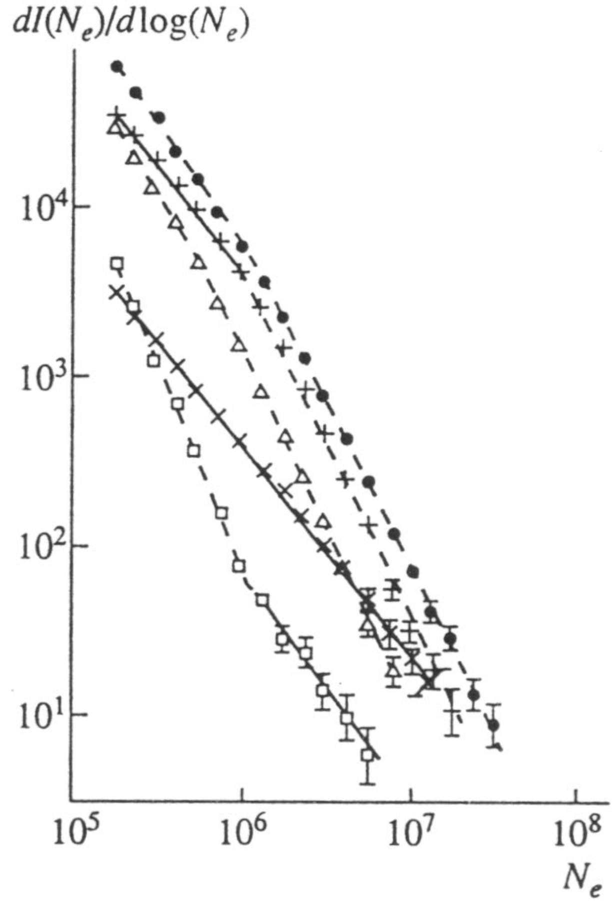

Fig. 1. (•) Total spectrum of EAS containing $N_e = 2 \cdot 10^5 - 3 \cdot 10^7$ electrons at the atmosphere depth of 760 g/cm^2 and four components of the spectrum that correspond to S values falling within the ranges (×) 0.35-0.75; (+) 0.75-1.05; (△) 1.05-1.35 and (⊓) 1.35-1.95.

The second difference of the protons and nuclei accelerated in the galactic sources and the cosmic rays is a discrepancy between the energy spectrum of the accelerated in the source particles, that is reflected by the spectrum of the gamma-quanta from the sources: $f(E_\gamma)dE_\gamma \sim E_\gamma^{-2.3\pm0.15}dE_\gamma$ the cosmic ray energy spectrum $f(E_0)dE_0 \sim E_0^{2.72\pm0.02}dE_0$ in the all energy interval $3 \cdot 10^2 - 5 \cdot 10^{10}$ GeV. At present, only the gamma-spectrum from the most far sources can be conformed with the energy spectrum of cosmic rays. Perhaps one can to take into account of a space, where the cosmic rays are located the most part of the their time and to discern what happens with the protons and the nuclei of the cosmic rays in this space. The distances between galaxies in 10–20 times exceed the galactic sizes. It determines the extragalactic spaces to as the exceptional huge spaces, which more than in thousand times exceed the summary volume of the extragalactic spaces. The cosmic rays are the most energy capacious from the scattered component of the universe and the main energy losses of the cosmic rays in the extragalactic space are connected with the elastic collisions with the relic photons and inelastic collisions with the nuclei of the ionized gas. It is essential, that the gravitation field of the surrounding galaxies has to clear the extragalactic space from the gas, but this process can not touch the central part of the extragalactic space.

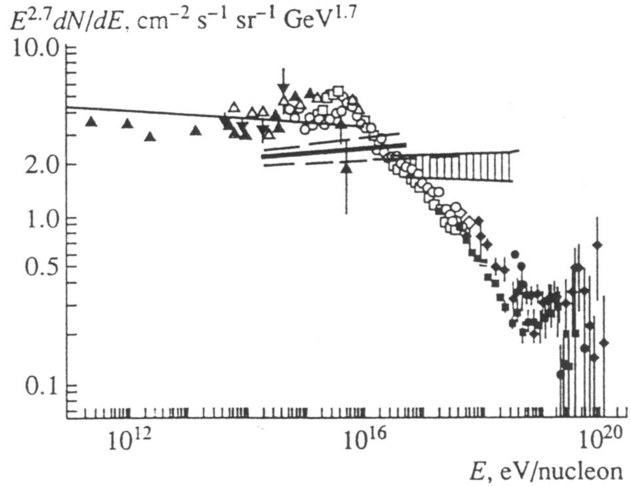

Fig. 2. Energy spectrum of primary cosmic rays from the review article of Gaisser and Stanev. The straight line in the interval $10^{11} - 10^{16}$ eV represents a generalization of experimental data on the energy spectrum of cosmic rays according to the studies beyond the atmosphere. The energy spectra of primary protons according to data on $S < 0.75$ EASs and to observations of the inverse knee in the spectrum are shown within the error corridors.

The main losses of the energy by the cosmic rays in the extragalactic space are connected with the elastic collisions. On the whole more rare catastrophic collisions with the nuclei and in succession of the minuend losses of energy by the elastic collisions with relic protons are similar to the succession, which comes to the Neper number $e = 2.718....$ It coincides with the cosmic ray energy spectrum 2.72 ± 0.02.

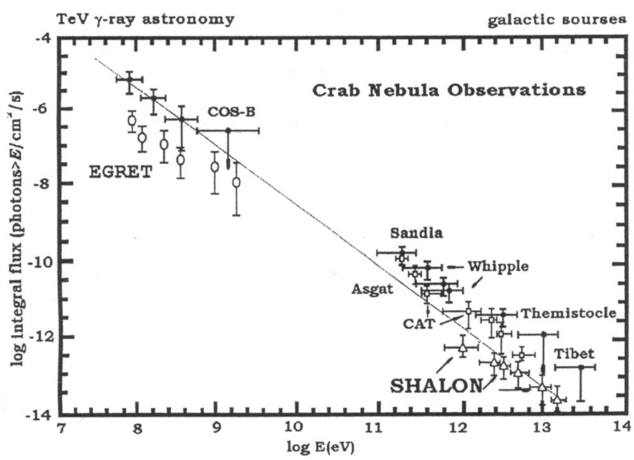

Fig. 3.

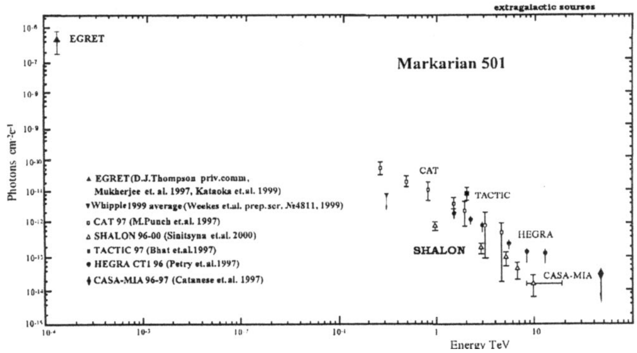

Fig. 4.

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Source $E_\gamma \geq 0.8$ eV	Flux, cm^{-2}s^{-1}	Distance	Power in relation to Crab
Galactic		Kpc	
Crab Nebula	$(1.10 \pm 0.30) \cdot 10^{-12}$	2.0	1
Cygnus X-3	$(0.42 \pm 0.07) \cdot 10^{-12}$	1.1	0.12
Geminga	$(0.48 \pm 0.17) \cdot 10^{-12}$	0.25	0.007
Tycho Brahe	$(0.19 \pm 0.09) \cdot 10^{-12}$	2.0-5.1	1.08
Extragalactic		Mpc	
Mkn 421	$(0.63 \pm 0.14) \cdot 10^{-12}$	124	$2.2 \cdot 10^{9}$
Mkn 501	$(0.86 \pm 0.13) \cdot 10^{-12}$	135	$3.56 \cdot 10^{9}$
NGC 1275	$(0.78 \pm 0.13) \cdot 10^{-12}$	71	$8.9 \cdot 10^{8}$
3c454.3	$(0.43 \pm 0.17) \cdot 10^{-12}$	4685	$2.1 \cdot 10^{12}$
1739+522	$(0.47 \pm 0.18) \cdot 10^{-12}$	7500	$6 \cdot 10^{12}$