DEPARTMENT OF THE AIR FORCE
NATIONAL AIR & SPACE INTELLIGENCE CENTER (AF ISR AGENCY)
WRIGHT-PATTERSON AFB OHIO

Colonel Mark E. Hess
Vice Commander
National Air and Space Intelligence Center (NASIC)
4180 Watson Way
Wright-Patterson AFB OH 45433-5648

SEP 21 2009

John Greenewald, Jr.
[redacted]

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Astrophysical Aspects of Cosmic-Ray Research (First 75 Years and Prospects for the Future)

FOREIGN TECHNOLOGY DIV WRIGHT-PATTERSON AFB OH

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ASTROPHYSICAL ASPECTS OF COSMIC-RAY RESEARCH

(First 75 Years and Prospects for the Future)

by

V.L. Ginzburg

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ASTROPHYSICAL ASPECTS OF COSMIC-RAY RESEARCH
(First 75 Years and Prospects for the Future)

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В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*<u>ye</u> initially, after vowels, and after ъ, ь; <u>e</u> elsewhere.
When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

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SUCCESSES IN PHYSICAL SCIENCES.

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ASTROPHYSICAL ASPECTS OF COSMIC-RAY RESEARCH (First 75 Years and Prospects for the Future)[1]).

FOOTNOTE[1]. Report prepared for the 20th international conference on cosmic rays (Moscow, 2-15 August of 1987). The changes virtually were not introduced in the text of report published in UFN. At the end there is placed, however, a supplement which, to a certain degree reflects the work of the conference. ENDFOOTNOTE.

V. L. Ginsburg.

TABLE OF CONTENTS.

1. Introduction.

Cosmic rays were not discovered in any one experiment. On the contrary, the existence of cosmic rays - the charged particles and by high energy - was established as a result of the prolonged investigations, which were begun in the first decade of our century. However, any doubts about the fact that to us from outer space comes the penetrating emission - cosmic rays, vanished only approximately in 1927-1928. Nevertheless, let it be somewhat conditionally, the date of the discovery of cosmic rays it is possible to consider on 7 August 1912, when Victor Hess completed his most successful flight on a balloon. In this case it was convincingly shown that the speed of the ionization of air in the hermetically sealed containers during the removal/distance from the earth's surface (above approximately two kilometers) it increases with the height/altitude. By achieved/reached on 7 August, 1912, to height/altitude of approximately 5 km the speed of ionization grew/rose already several times. Thus, it is possible to consider that the present conference is conducted exactly 75 years after the discovery of cosmic rays. This period, very large on the scales of human life, it proved to be insufficiently in order to thoroughly study cosmic rays - the rich program of conference testifies about this is completely eloquently. Of course cosmic rays are not in this respect some exception/elimination. For example, superconductivity was discovered in 1911, its study not only is continued, but also is expanded, so to speak, broadwise and in depth. It suffices to say that in 1986-1987 a notable event occurred - high-temperature superconductivity was discovered. (Incidentally, directly after the present conference on the cosmic rays in Japan it takes place so representative 18th international a conference on low-temperature physics - cosmic rays and low temperatures, can be said, contemporaries).

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Study of cosmic rays it is possible in rough approximation to divide into two directions, or section: astrophysical and nuclear physics. There was the period, when special importance had the second direction - cosmic-ray research for the solution of the problems of physics of elementary particles. It suffices to say that in the cosmic rays they were precisely the discovered positron, muons and $\pi^{\pm}$-mesons, and also some other particles. At present cosmic rays also by no means lost values for high-energy physics. Thus, for emitting interaction of particles with energies E of more than 10^{15} eV, also, up to 10^{16} eV, which are now unattainable on the accelerators, on Aragats mountain (USSR) there is constructed the installation ANI ("hadron-nucleon investigations"; it must begin to work in 1989). But nevertheless, beginning approximately from the 50's, increasing place occupies astrophysical aspect, or as I will speak, astrophysics of cosmic rays. Here is involved the study of primary cosmic-rays (observed in essence near Earth)[1]) and the problem of their origin (acceleration in the sources, cosmic-ray distribution in the galaxy, also, beyond its limits, solar cosmic rays, etc.).

FOOTNOTE[1]. By primary are understood the cosmic rays, which are located beyond the limits of the earth's atmosphere. Below discussion deals only with the primary cosmic-rays, but not about the products of their decomposition/decay and multiplication in the atmosphere. Therefore adjective "primary" will be usually omitted. ENDFOOTNOTE.

At present, as this clearly already from the program of the conference (see supplement), to astrophysics of cosmic rays is especially closely related also gamma-astronomy.

My report is planned as certain introduction, designed not only for basic participants in conference, but also to guests. Furthermore, even I will not attempt to enumerate all questions, which relate to astrophysics of cosmic rays (charged particles), also, one way or another of the connected with it radio-, by X-ray and to gamma-astronomy, or astronomy of high-energy neutrino. There is no possibility to dwell here, also, on the history of the study of the cosmic rays (see [1-3]). But it is nevertheless appropriate to mention some landmarks on this long path (we concern only astrophysical aspect).

1912. The discovery of cosmic rays (see above). During the first stage of their emission (about 15 years) there was no complete confidence in the nonterrestrial origin of the observed emission. Independent of it was assumed this that the discussion deals with the hard gamma-rays.

1927-1928. By this time doubts about the existence of well penetrating "emission coming from space" (cosmic rays) finally dropped out. Indications of the presence of latitude effect appeared (dependence of the speed of ionization on the geomagnetic latitude). Therefore it became clear that the primary cosmic-rays (particles which fall from space in the atmosphere) at least are partially the charged particles.

1936. It was approximately finally acknowledged at this time, that cosmic rays - these are charged particles.

1939-1941. It was explained that cosmic rays have positive charge and in essence are relativistic protons.

1948. In the composition of cosmic rays nuclei of series of elements are discovered. It was established In the same period (to 1951-1952) that the electron stream in the cosmic rays is less than approximately the percentage of their general/common flow. (Incidentally, electrons in the composition of primary cosmic-rays they were for the first time recorded only in 1961).

Thus, only 40 years after the discovery of cosmic rays it became, at least in the first approximation, was known their composition in Earth. But about the sources of cosmic rays and generally about the cosmic rays far from the Earth in effect there was nothing known prior to 1950-1953, when connection/communication between the electronic component of cosmic rays and nonthermal cosmic radio-frequency radiation was established/installed.

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Thus far the cosmic rays related, so to speak, to physics and were studied only by physicists. Therefore, it is presented as to me, it will not by exaggeration establish/install this historical landmark:

1950-1953. Generation of astrophysics of cosmic rays. Since the nonthermal cosmic radio-frequency radiation has in essence synchrotron nature - it is emitted by relativistic electrons (electronic component of cosmic rays), which move in the space magnetic fields, became clear two very important facts. First, electronic component is present in the intergalactic space, in the shells supernova, in other galaxies. Natural to assume that the same relates also to the basis - proton (and by generally nuclear) - to the component of cosmic rays. In the second place, estimations testify in favor of the fact that the cosmic rays are essential energy and dynamic factor in the mentioned regions (interstellar medium, the shell of supernovas, etc.). Thus, cosmic rays actually "entered" into astronomy together with its other objects - galaxies, stars, interstellar gas, etc.

1953. On the basis of radio- astronomical data obtained substantiation partially considered and previously representations about origin of cosmic rays, which are observed in Earth. Galactic model with the halo is proposed and developed. In this model galactic cosmic rays fill the large region, which surrounds the galactic disk (the "halo of cosmic rays"), and the supernova explosions stars (for greater detail, see '' and lower) are their basic sources.

Since then (since 1953) already 34 years have passed, and I consider the galactic model with halo (and, probably, many are considered) most probable and substantiated. Nevertheless not all lying/horizontal at its basis is reliably proved (insufficiently it is clear the size/dimension of the halo of cosmic rays, nevertheless there is no complete confidence in the dominant role of the supernova explosions as sources of cosmic rays). In such a manner as frequently it was and is in physics and astronomy, the problem of the origin of the cosmic rays (we specifically have here in mind the selection of model) proved to be "solid bean", to do completely reliable conclusions/outputs it impedes a whole series of difficulties. At the same time much is already explained and are sufficiently determined the paths, on which is feasible further progress. With this still will deal the discussion below. Now we refer to Tables I, to a certain degree, albeit schematically, that illuminates the region of investigations, which relates to astrophysics of cosmic rays.

Table I. Astrophysics of cosmic rays (objects, problem, connection/communication).

(1) *Первичные космические лучи у Земли:* (4) Химический (элементный) и изотопный состав (6) Энергетические спектры протонов и ядер (10) Электроны и позитроны ($e^{\pm}$) (11) Антипротоны ($\bar{p}$) (12) Анизотропия космических лучей (δ)	(2) Космические лучи в Галактике, в оболочках сверхновых звезд, в других галактиках и квазарах (7) Источники космических и гамма-лучей (в частности, проблема CygX-3)	(3) Радиоастрономия (5) Оптическая и рентгеновская астрономия (8) Гамма-астрономия (9) Нейтринная астрономия высоких энергий
(15) Солнечные космические лучи (17) Распространение космических лучей в солнечной системе, вариации космических лучей	(13) Происхождение космических лучей (14) Галактическая модель с гало (16) Распространение космических лучей в межзвездной среде (18) Механизмы ускорения космических лучей	

Key: (1). Primary cosmic-rays in the Earth: (2). Cosmic rays in the galaxy, in the shells supernova, in other galaxies and quasars. (3). Radio astronomy. (4). Chemical (element) and isotopic composition. (5). Optical and X-ray astronomy. (6). Energy spectra of protons and nuclei. (7). Sources of space and gamma- rays (in particular, problem Cyg X-3). (8). Gamma-astronomy. (9). Neutrino high-energy astronomy. (10). Electrons and positrons ($e^{\pm}$). (11). Antiprotons ($\bar{p}$). (12). Anisotropy of cosmic rays (δ). (13). Origin of cosmic rays. (14). Galactic model with halo. (15). Solar cosmic rays. (16). Cosmic-ray distribution in interstellar. (17). Cosmic-ray distribution in solar system, variation in cosmic rays. (18). Mechanisms of acceleration of cosmic rays.

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Table shows also some branches of astronomy, which directly adjoin astrophysics of cosmic rays. In this case is intended, of course, not entire/all radio astronomy, but only radio-astronomical investigations, which yield information about the cosmic rays in different regions of the universe. An analogous observation can be made in the application and to other enumerated in the table regions of astronomy. With respect to neutrino high-energy astronomy (is intended recording on the Earth neutrino with the energies, which exceed, let us say, 10^{12} eV, which are generated in space by cosmic rays) it is necessary to also note that there are no real measurements still, we thus far deal, unfortunately, only concerning the small installations and concerning the projects. The latter from already, so to speak, the born and acting branches of astronomy, which are of special interest for studying the cosmic rays, is gamma-astronomy.

Obviously, recording space gamma-rays yields information about cosmic rays when latter generate gamma-ray contracts during nuclear collisions and by other paths. The corresponding ideas appeared into 1952 more and 1958, and the first observations (balloons were utilized) were published in 1962. (references see in [4]). However, only on gamma-satellites SAS II (1972-1973) and COS-B (1975-1982) was obtained a considerable quantity of information about the space gamma-ray contracts with the energies 35 MeV $<E_\gamma<5$ GeV. Specifically, similar data are especially important for studying a proton-nuclear component of cosmic rays far from the solar system (topic, first of all, is about the gamma-ray contracts, which are formed from the decomposition/decay of π^0-mesons). But nevertheless the results obtained on these two satellites, these are only first steps, and it is not obtained in to some most important questions (for example, about the concentration gradient of cosmic rays in the galaxy) of precise responses/answers. Meanwhile in spite of entire obvious importance and prospect of gamma-astronomical investigations, thus already 5 years (since 1982) work not one gamma-satellite. Sad page in the history of physics and astronomy, especially taking into account the fact that it is necessary to attempt to examine thoroughly gamma-radiation from occured during February 1987 of the supernova explosion star in the large Magellan cloud.

Emergence of gamma-astronomy (it conditionally can be attributed to 1972) - latter/last important landmark in study of cosmic rays, which we can here fix.

Thus, it passed already 75 years from time of the discovery of cosmic rays. Done very much (see, in particular, '), but are visible and clear still many problems, which wait their solution. Will arise, of course, and new problems.

To throw light in present report already accumulated giant material, it goes without saying, is impossible. Later, in Section 2, we will attempt to give the basic information about the cosmic rays, observed in the Earth. In section 3 let us pause at some data about the cosmic rays in the universe, obtained by radio- and gamma-astronomical methods. Section 4 is dedicated to the origin of cosmic rays and concretely/specifically galactic model with the halo.

In section 5 let us attempt to enumerate the most important problems of further cosmic-ray research in the calculation approximately to 25 years, i.e. to the centenary anniversary from the time of the discovery of cosmic rays.

2. Primary cosmic-rays in the Earth.

Cosmic rays most fully can be described by differential intensity $I_{Z,A}(r, E, \theta, \varphi)\,dE$, measured by number of particles with energies in interval (E+dE, E) of those passing per unit time through single area/site, perpendicular to direction of observation; I is measured, let us say, in units: number of particles/(cm^2 s·sr·interval of energies).

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Higher than Z - the ordinal number (charge) of nucleus, A - its mass number r - observation point, $E = E_k + Mc^2$ - total energy ($M = AM_p$ - nuclear mass, M_p - the mass of proton) and θ, φ - angles which correspond to the direction of observation. If we do not concern solar cosmic rays and to consider the action of terrestrial magnetic field as that excluded, then primary cosmic-rays to a high degree are isotropic; therefore they usually disregard the dependence of θ on φ, but anisotropy they chara.. erize by the introduced below coefficient δ. Thus, in the Earth we deal concerning intensity $I_{ZA}(E)$ or for the electron-positron component with $I_{e\pm}(E)$. Is utilized also the integrated intensity

$$I_i(>E) = \int_{E_{min}}^{\infty} I_i(E)\, dE,$$

where, obviously, the role of index i play Z, A, $e^{\pm}$ and so forth. Finally, far from always is determined isotopic composition, but frequently, especially with the high energies, are not divided elements; therefore are utilized intensities $I_Z = \sum_A I_{Z,A}$ and $I = \sum_{Z,A} I_{Z,A}$. For the isotropic emission the particle flux from the hemisphere of directions,

$$F_i = \int I_i \cos\theta \cdot \sin\theta \, d\theta \, d\varphi = \pi I_i$$

(in the literature by flow frequently calls intensity I), and concentration of particles, which have speed v_i, is equal to $N_i = \frac{4\pi}{v_i} I_i$. Energy density of the cosmic rays

$$w_i = \int E_k N_i(E)\, dE$$

and "energy intensity"

$$J_i = \int E_k I_i(E)\, dE.$$

For the cosmic rays in the Earth (out of the action of terrestrial magnetic field) for the orientation it is possible to give such values, relating to all cosmic rays:

$$\begin{aligned}
I_{cr} &\sim 0{,}3 - 0{,}3 \overset{(1)}{\text{частиц/см}^2\text{с}\cdot\text{ср}}, \\
N_{cr} &\sim \frac{4\pi I_{cr}}{c} \sim 10^{-10} \overset{(2)}{\text{частиц/см}^3}, \\
w_{cr} &\sim 10^{-12} \overset{(3)}{\text{эрг/см}^3} \sim 1 \overset{(4)}{\text{эВ/см}^3}, \\
J_{cr} &\sim \frac{c w_{cr}}{4\pi} \sim 10^{-3} \overset{(5)}{\text{эрг/см}^2\text{с}\cdot\text{ср}}.
\end{aligned} \quad (1)$$

Key: (1). particles/cm²s·sr. (2). particles/cm³. (3). erg/cm³.

(4). eV/cm³. (5). erg/cm²s·sr.

In view of modulation effects in the solar system the cosmic-ray intensity in the region of energies $\mathscr{E}_к = E_к/A \leqslant 1$ GeV/nucleon changes depending on solar activity and, in particular, during the cycle of solar activity. Therefore the corrected above values, which correspond to energies $E_к \geqslant 100$ MeV, have the approximate value (maximum in the spectrum of protons it answers energy. $E_к \sim 250$ MeV and all integral values they converge). It is clear from (1) that to the Earth comes flow F~1 particles/cm² s. It consists (according to the number of particles) approximately to 90% of the protons (p). Nuclei ⁴He approximately 10 times less, ever more heavy elements introduce into the general/common flow of approximately 1%. Primary protons, to say nothing of nuclei, virtually do not reach the surface of the Earth (at the sea level).

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In the atmosphere (thickness of approximately 1000 g/cm²) secondary particles are formed; at the sea level their flow is approximately 10^{-2} particles/cm² sr·s (70% $\mu^{\pm}$-leptons, 30% $e^{\pm}$-leptons, i.e., electrons and positrons)[1]).

FOOTNOTE [1]. On the surface of the Earth is observed also the secondary neutron component of comic rays/beams; its drip composes approximately 1% of the flow of muon component. Neutron component is generated in essence by initial particles with the energy, considerably smaller than the energy of the reaching the Earth muons.

Furthermore, the flow of neutron component, in contrast to the flow of muons, virtually does not depend on the temperature distribution in the atmosphere. All this makes the emission of neutron component convenient for recording the time variations in the intensity of primary cosmic-rays with the energy into several GeV. The continuous recording of the intensity of the neutron component of cosmic rays is conducted by the network of the stations, located in many points/items of terrestial globe. ENDFOOTNOTE.

Emission of primary cosmic-rays - one of central problems of astrophysics of cosmic rays. Colossal efforts were already spent for its solution, this work is continued both on the high-altitude balloons and on the satellites. In order to describe the scale of the largest installations, let us point out that on space laboratories ("Spacelab-2") flown during July 1985. On the "Shuttle" there was located the installation of the University of Chicago (its name "The Egg" - egg) by weight about 2 t, intended for studying the nuclei with the energy from 50 GeV/nucleon to several TeV/nucleon. The results, which concern the composition and the spectrum of cosmic rays, are represented at all international conferences on cosmic rays (ICRC), including the present; to this are dedicated both original and reviews'. For the illustration let us exclusively give several graphs/curves. Thus, Fig. 1 presents' the energy spectra (so it is called usually differential intensity $I_i(E)$, named also flow) for nuclei H, He, C and Fe. The spectra relate to the period near the minimum of cycle of solar activity. The solid line for the spectrum of hydrogen (H) answers extrapolation to the interstellar space (i.e., beyond the limit of the solar system), of modulation in the solar system obtained by the exception/elimination of effect. Where is located maximum in the spectrum in the interstellar space - it is unknown, and therefore estimations (1) for the galaxy (near the Sun), possibly, must be increased several times. Fig. 2 shows' the element composition of cosmic rays in the Earth (line it answers cosmic rays, and "columns" - to the chemical composition of substance in the galaxy near the solar system according to astrophysical data).

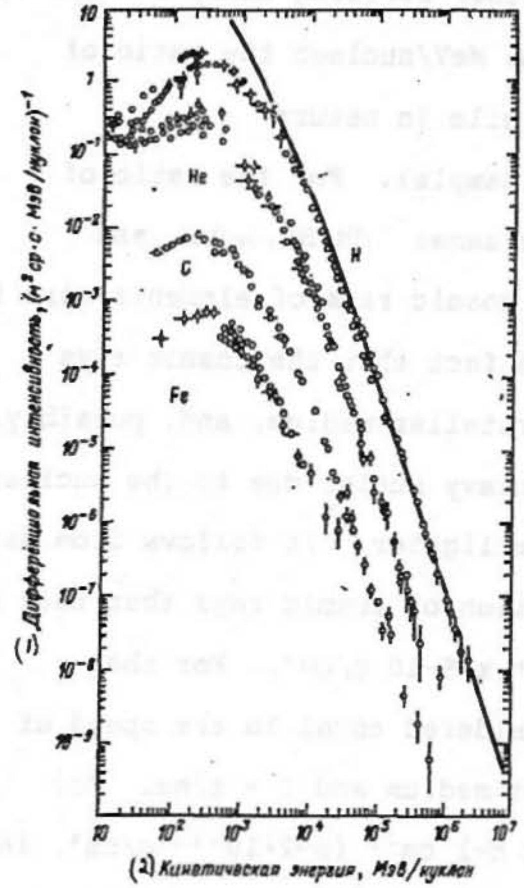

Fig. 1.

Key: (1). Differential intensity, $(m^2 sr \cdot s\ MeV/nucleon)^{-1}$. (2). Kinetic energy, MeV/nucleon.

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Attention is drawn to already long ago (from the very beginning of the study of the element composition of cosmic rays at the end of the 40's) the established/installed fact - in the cosmic rays there are sufficiently many nuclei, which are rare on the stars and in interstellar medium. The most typical examples - nuclei Li, Be and B.

Them in the cosmic rays it is approximately to 5 orders more (with respect to H), than in the galaxy. Another striking example - isotope ^3He. In the cosmic rays with $\mathcal{E}_K \approx 40-150$ MeV/nucleon the ratio of intensities $^3He/^4He \approx 7.5 \cdot 10^{-2}$ (see [1]), while in nature $^3He/^4He \sim 10^{-7}-10^{-4}$ depending on source (sample). For the ratio of deuterium to hydrogen approximately the same: $(^2H/^1H)_{cr} \approx 0{,}13$, and $(^2H/^1H)_{\text{в природе}} \approx 1{,}5 \cdot 10^{-4}$. An abundance in the cosmic rays of elements rare in nature and isotopes is explained by the fact that the cosmic rays arriving to us for long roamed in interstellar medium, and, possibly, and in their sources. Therefore more heavy nuclei due to the nuclear collisions had time partially to become lighter. It follows from data about the element and isotopic composition of cosmic rays that they on the average passed in the substance let $x \sim 5-10$ g/cm^2. For the relativistic nuclei speed v can be considered equal to the speed of light c and $x = c\rho T$, where ρ - density of medium and T - time. For interstellar medium with concentration $n \sim 1$ cm^{-3} ($\rho \sim 2 \cdot 10^{-24}$ g/cm^3, in essence it is present hydrogen) with $x \sim 5$ g/cm^2 time $T \sim 10^{14}$ s$\approx 3 \cdot 10^6$ years[1]).

FOOTNOTE[1]. The time T introduced here by specific relationship $T = x/c\rho$ makes physical sense only with the concrete definition of model. Thus, if nuclear disintegration occurs virtually only in the gas disk (i.e. the contribution of halo with this of view it is insignificant), then time T is the time, carried out by cosmic rays in the disk. ENDFOOTNOTE.

It is very important that the portion of product nuclei with an increase in the energy decreases (unfortunately, the data there are only for energy $\mathcal{E} \leqslant 100$ GeV/nucleon).

In cosmic rays heavy nuclei up to uranium are discovered. A relative quantity of heavy nuclei (them they usually name even superheavy nuclei) in the cosmic rays approximately is the same as in the solar system (see Fig. 3, undertaken from [10]). In the literature appeared the communications/reports about the recording in the meteoritic material of the traces of nuclei with Z~110; however, as far as we know, presence in the cosmic rays of such nuclei cannot still be considered established/installed.

Electronic component of cosmic rays is studied usually without separation into electrons (e^-) and positrons (e^+).

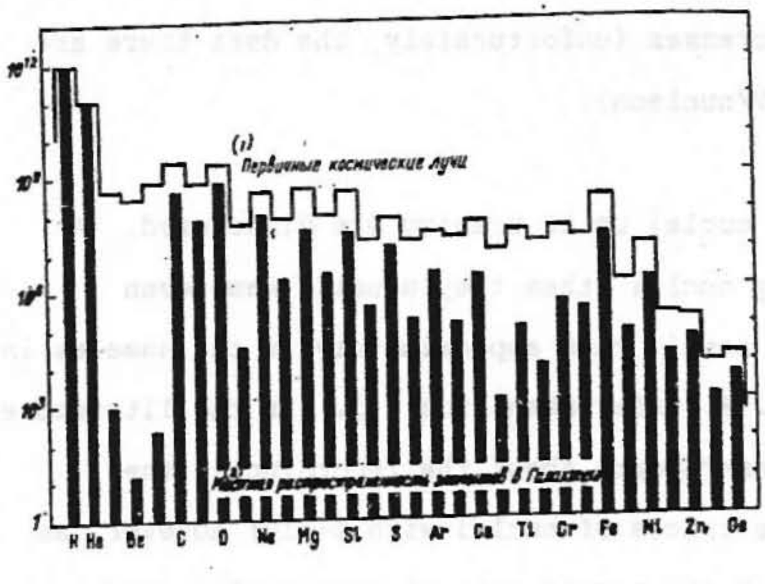

Fig. 2.

Key: (1). Primary cosmic-rays. (2). Local abundance of element in galaxy.

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With the assigned energy (let us say, E~1-3 GeV) the intensity of electronic component comprises order 1% of the intensity of protons. Thus, the energy density of electrons (see (1))

$$w_{\text{cr},e} \sim 10^{-2} w_{\text{cr}} \sim 10^{-14} \overset{(1)}{\text{эрг/см}^3}. \qquad (2)$$

Key: (1). erg/cm³.

The integrated spectrum of electrons in the interval of 5<E<100 GeV approximately takes the form

$$I_e(>E) = 1{,}5 \cdot 10^{-2} [E\,(\overset{(1)}{\text{ГэВ}})]^{-2} \overset{(2)}{\text{частиц/см}^2\text{с}\cdot\text{ср}}. \qquad (3)$$

Key: (1). GeV. (2). particles/cm²s·sr.

At the same time for all cosmic rays tentatively (with $10<E<3\cdot10^{4}$ GeV)

$$I_{cr}(>E)=[E\,(\text{ГэВ})]^{-1,7}\ \text{частиц/см}^2\text{с}\cdot\text{ср}, \quad (4)$$

Key: (1). GeV. (2). particles/cm²s·sr.

and with $E>3\cdot10^{4}$ GeV

$$I_{cr}(>E)=3\cdot10^{-10}\,[E\,(\text{ГэВ})\cdot10^{-6}]^{-2,1}\ \text{частиц/см}^2\text{с}\cdot\text{ср}. \quad (5)$$

Key: (1). GeV. (2). particles/cm²s·sr.

Wraparound ("fracture") of the spectrum of the cosmic rays with $E\sim10^{6}$ GeV they usually connect with the more rapid output from the galaxy of cosmic rays with the high energy.

Only more complete and precise are data about spectrum of electrons obtained in recent years; they are reflected in Fig. 4[11], in which is represented differential intensity, multiplied by E^3, i.e., value $E^3I(E)$ in ones (particles/m² s·sr) (GeV)². Obviously, index γ in power-law differential spectrum $I(E)=KE^{-\gamma}$ answers index γ-1 in integrated spectrum $I(>E)$. Thus, Fig. 4 is in the common agreement with spectrum (3), but the spectrum of electrons wrapped around with E>100 GeV. The intensity of positrons I_{e^+} in the composition of electronic component with E>1 GeV composes approximately 10% of entire intensity $I_{e^-+e^+}$. Unfortunately, available data are still insufficiently precise (Fig. 5[11]). Beginning with 1979 they appeared the data about antiprotons $\bar{p}$. With the energies of particles E~5-10 GeV relation $I_{\bar{p}}/I_p\sim5\cdot10^{-4}$ (see [12] and Fig. 6). With the smaller energies ($E_k\approx130-320$ MeV) the measured intensity of the antiprotons considerably higher than that, which it would be possible to expect under the natural assumption about their formation as secondary particles during the cosmic-ray distribution in interstellar medium (see lower curve in Fig. 6). The antinuclei (are heavier than $\overline{p}$) in the cosmic rays they are not discovered.

Long years went disputes about value of anisotropy of cosmic rays.

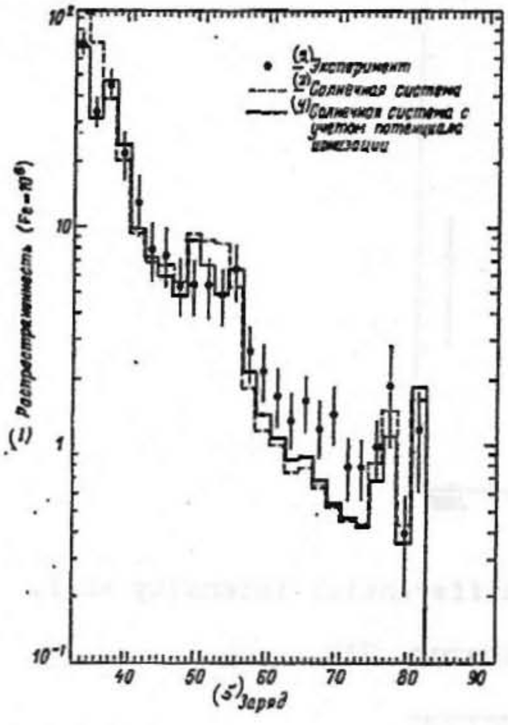

Fig. 3.

Key: (1). Prevalence. (2). Experiment. (3). Solar system. (4). Solar system taking into account ionization potential. (5). Charge.

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Since this anisotropy, at least with $E<10^5$ GeV, is very small, is usually characterized with the amplitude of the fundamental harmonic, i.e., by relation $\delta=I_1/I_0$. In this case the total intensity is considered depending on the angles according to the law of $I=I_0+I_1 \cos\theta$ ($I_1 \ll I_0$, angle θ it is counted off from the direction of maximum intensity). With $E \leqslant 10^5$ GeV amplitude $\delta \leqslant 10^{-3}$ grows/rises with the energy (see [13] and Fig. 7; in this figure λ - the latitude of place, in which the measurements were conducted).

Special, in a sense, is field of study of cosmic rays with superhigh energies $E \geqslant 10^{17}$ eV (see [8,13,14]).

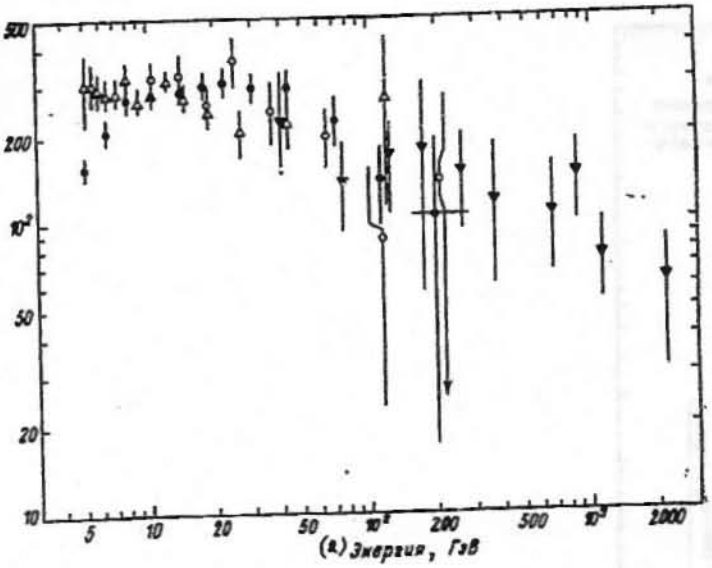

Fig. 4. (along axis of ordinates - differential intensity $\times E^3$).

Key: (1). $(m^2 sr \cdot s)^{-1}$ GeV^2. (2). Energy, GeV.

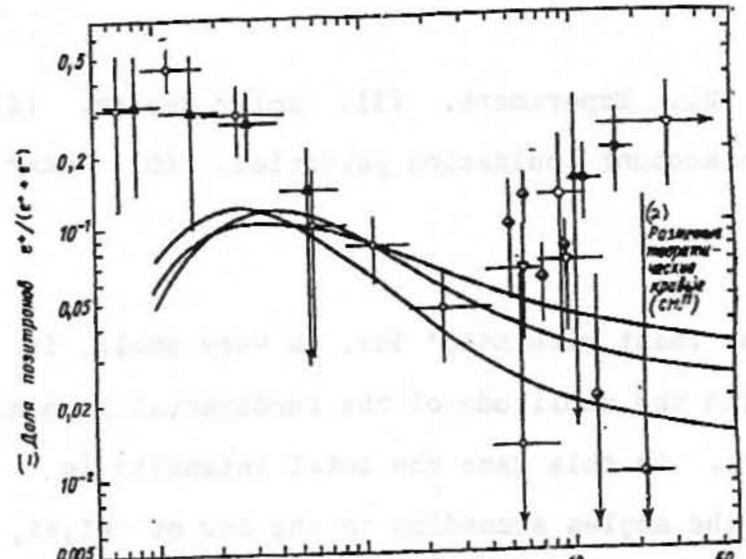

Fig. 5.

Key: (1). Portion of positrons. (2). Different theoretical curves (see [11]). (3). Energy, GeV.

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The extensive air showers, observed on the earth's surface, are the source of information in this region. Are observed particles with the energy, which reaches $E \sim 10^{20}$ eV. The character of the spectrum of all cosmic rays is clear from Fig. 8 (on the axis of ordinates it is deposited/postponed value $E^{2,5} I(E)$; see [14]). The element composition in this region is known badly/poorly, unclearly, and it does remain (especially with the highest energies $E \geqslant 10^{19}$ eV) the same as with the smaller energies. Is not clear a question about the possible "cutting" of the spectrum with $E \sim 3 \cdot 10^{19}$ eV (this cutting must occur, if the corresponding particles come to us from the metagalactic distances as a result of "braking" of particles during the collision with the photons of relict emission with the temperature of 2.7 K).

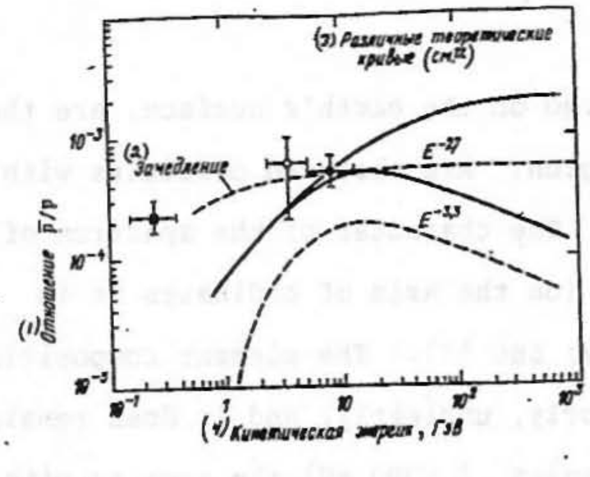

Fig. 6.

Key: (1). Relation. (2). Retarding/deceleration. (3). Different theoretical curves (see [12]). (4). Kinetic energy, GeV.

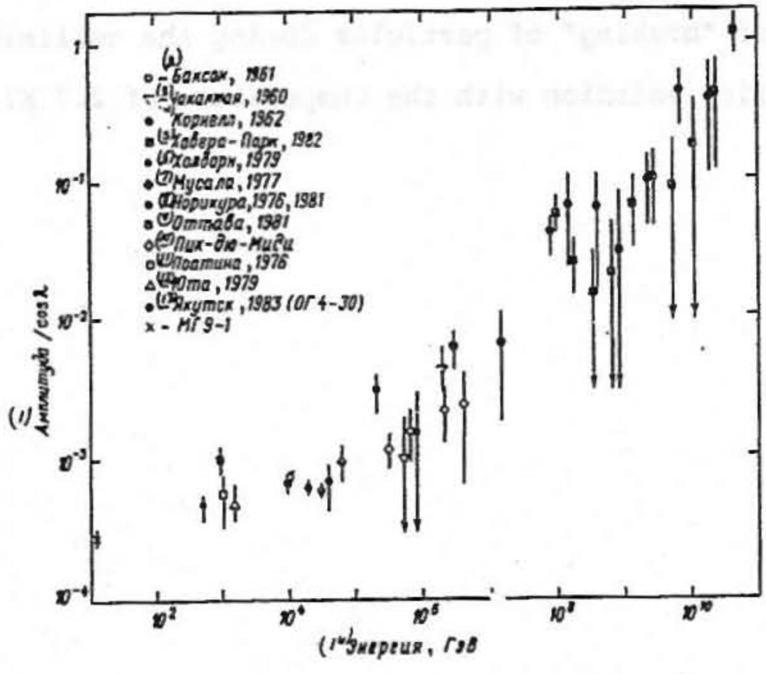

Fig. 7.

Key: (1). Amplitude. (2). Baksan. (3). Chakaltaya. (4). Cornell. (5). Haver Park. (6). Holdorn. (7). Musala. (8).

Norikura. (9). Ottawa. (10). Peak du midi. (11). Poatina. (12). Utah. (13). Yakutsk. (14). Energy, GeV.

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We must be bounded here by the given information. They cannot replace the detailed coverage (see [6-15]). Their goal is one - to demonstrate to a certain degree the contemporary state of a question (present state of art), to show, how much is done as a result of the many-year very heavy labor of the whole army of physicists - "cosmicists". It is at the same time clear that the picture is as yet far from complete, our data about the primary cosmic-rays in the Earth must be substantially supplemented. This concerns literally entire, but especially element composition with their high energies, isotopic composition, spectrum of positrons and antiprotons, cosmic rays of superhigh energy (element composition, the spectrum, anisotropy).

3. Cosmic rays in the universe.

Information about cosmic rays in universe, far from solar system, comes to us in all ranges of electromagnetic waves, but is especially important radio emission and gamma-radiation. The electronic component of cosmic rays is the basic source of nonthermal cosmic radio-frequency radiation. The mechanism of emission - synchrotron, i.e., speech goes about the emission of the charges, which move with the relativistic speeds in the magnetic role. As is known, particle with charge e and mass of m into uniform magnetic field H (discussion deals virtually with the vacuum so that magnetic field H we identify with the magnetic induction B) moves along the helix; moreover frequency of revolution is equal to

$$\omega_H^* = \omega_H \frac{mc^2}{E} = \frac{|e|H}{mc}\frac{mc^2}{E} = 1{,}76\cdot 10^7 H \frac{mc^2}{E}\, c^{-1}, \qquad (6)$$

where upon transfer to the numerical factor particle is considered electron (or positron) and field is measured in the oersteds. The ultrarelativistic particle ($E \gg mc^2$), which moves at a rate of v, which forms with field H angle $\chi \gg mc^2/E$, emits waves with many frequencies, multiple $\omega_H^*/\sin^2\chi$.

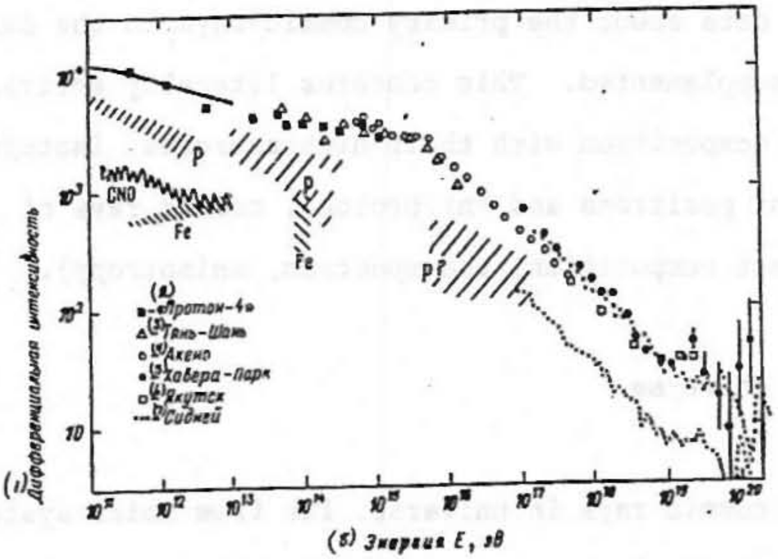

Fig. 8. (along the ordinate-units.$m^{-2}s^{-1}sr^{-1}$ $GeV^{1,5}$).
Key: (1). Differential intensity. (2). Proton - 4. (3). Tian-Shan. (4). Akeno. (5). Javiera Park. (6). Yakutsk. (7). Sidney. (8). Energy E, eV.

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Virtually the spectrum is continuous, and for the separate electron the maximum of the intensity of emission falls for the frequency ($H_\perp = H \sin \chi$ – field component perpendicular to speed v):

$$\nu_m = \frac{\omega_m}{2\pi} = 0{,}07 \frac{|e| H_\perp}{mc} \left(\frac{E}{mc^2}\right)^2 = 4{,}6 \cdot 10^{-6} H_\perp [E(\partial B)]^2 \; Гц. \qquad (7)$$

Key: (1). eV. (2). Hz.

In the typical interstellar field $H \sim 10^{-6}-10^{-5}$ E for the electrons with $E \sim 10^{9}$ eV frequency $\nu_m \approx 1{,}5 \cdot 10^{7}$ Hz (wavelength of $\lambda = \frac{c}{\nu_m} \approx 2$ m; for the certainty we they assumed $H_\perp \approx 3 \cdot 10^{-6}$ E). Thus, the electronic component of cosmic rays in the interstellar space emits exactly in the radio- frequency range. Of course in the regions with the strong magnetic field and (or) for the electrons with the sufficiently high energies synchrotron radiation can fall into the optical, the X-ray and even gamma-range. Thus, in the Crab Nebula, for example, with

H~10⁻³ E and E~10¹³ eV (electrons are injected by pulsar PSR 0531), according to (7), $\nu_m \sim 5\cdot 10^{17}$ and $\lambda_m \sim 10$ Å. The optical and X-radiation of crab with the continuous spectrum actually has synchrotron nature, about which especially clearly testifies the high degree of polarization of the emission (latter typically precisely for the synchrotron radiation, moreover electric field in the waves maximally in the direction, perpendicular to the projection of magnetic field to plane of figure). In the pulsars, for fields H~10¹² E, is especially the effectively allied to synchrotron bending emission (curvature radiation). Here not place, of course, in greater detail to stop on the theory of the synchrotron radiation (for example, see [4,5,2,6]). It suffices to note that the intensity of this emission along the line of sight for the monochromatic electrons at frequency ν_m (see (7)) it is equal to

$$J_{\nu,m} = 1{,}7\cdot 10^{-23} H_\perp \widetilde{N}_e \ \overset{(1)}{\text{эрг/см}^2\text{с}\cdot\text{ср}\cdot\text{Гц}}, \qquad (8)$$

Key: (1). erg/cm²s·sr·Hz.

where $\widetilde{N}_e = \int N_e(r)\,dr = N_e L -$ total number of isotropically distributed radiating electrons along the line of sight ($N_e -$ their mean concentration L - size/dimension of the radiating region). For the electrons with the isotropic directional distribution and power-law spectrum $N_e(E)\,dE = KE^{-\gamma_e}\,dE$ the intensity

$$J_\nu = 1{,}35\cdot 10^{-22} a(\gamma_e)\, LK_e H^{(\gamma_e+1)/2} \left(\frac{6{,}26\cdot 10^{18}}{\nu}\right)^{(\gamma_e-1)/2} \overset{(1)}{\text{эрг/см}^2\text{ср}\cdot\text{с}\cdot\text{Гц}} \quad (9)$$

Key: (1). erg/cm²sr·s·Hz.

(here with usual values $\gamma_e \sim 1{,}5-5$ coefficient $a(\gamma_e) \sim 0{,}1$ and value K_e

and $H^{(\gamma_e+1)/2}$ – some average values along the line of sight, field H it is considered in this case on the average isotropic).

Thus, spectrum of radio emission of also exponential:

$$J_\nu \propto \nu^{-\alpha}, \quad \alpha = \frac{1}{2}(\gamma_e - 1). \tag{10}$$

As it is clear of (8) and (9) and from the very essence of the matter, intensity measurement of radio emission J_ν makes it possible to find the electron concentration along the line of sight (let us say, from measurements α we obtain γ_e, and very value of intensity J_ν it makes it possible to find product LK_e).

In this case, however, it is necessary from independent considerations to determine field H. For this there is a number of methods[1]).

FOOTNOTE[1]. One such method, still rarely used, but promising, is such: the spectrum of electronic component can be determined along the spectrum of X- radiation, which it creates as a result of the so-called reverse Compton effect in the known radiation field, let us say during the relict emission with the temperature of 2.7 K. Then value LK_e is known in (9), and intensity measurement of radio emission J_ν from the same region will make it possible to find field H in this region from the same formula (9). ENDFOOTNOTE.

Here let us pause at one of them, although indirect, having high value in astrophysics of cosmic rays.

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In magnetohydrodynamics and physics of plasma in application to quasi-stationary conditions both of the theoretical considerations and from the experimental data is natural the exemplary/approximate equality to energy density of cosmic rays and energy density of the magnetic field:

$$w_{cr} \sim w_H = \frac{H^2}{8\pi}. \quad (11)$$

In the more general case it is possible to assume $w_H = \varkappa_H w_{cr}$. Unfortunately, from the wavelengths and callsigns density w_{cr} to us is unknown and, if we do not draw others given (first of all, gamma-astronomical, see below), then it is necessary to be based on connection/communication between densities $w_{cr,e}$ and $w_{cr} = \varkappa_e w_{cr,e}$. Near Earth $\varkappa_e \sim 10^2$ (see (1), (2)). If we assign values $\varkappa_H$ and $\varkappa_e$, then from the wavelengths and callsigns it is possible to find $w_{cr}, w_{cr,e}$ and $H^2/8\pi$ (or, are more precise, their average/mean values along the line of sight; for the discrete/digital sources, for example the shell of supernova, thus it is possible to determine energies $W_{cr}, W_{cr,e}$ and $W_H = \int (H^2/8\pi)\, dV$). Integral by the volume In this way of already 30 years ago (see [4] and there the literature indicated), assuming $\varkappa_H \sim 1$ and $\varkappa_e \sim 10^2$, were obtained the information about the cosmic rays in the galaxy, the shells of supernovas, in the radio galaxies, etc.

General conclusions are now well-known.

Cosmic rays - a universal phenomenon, are present in space plasma not as an exception, but as a rule. And this is completely understandable, since in the plasma the existence of a whole series of instabilities and processes is possible, including the motion of heterogeneities and shock waves. As a result occurs the particle acceleration of all types; the relativistic "tails" of the distribution of these particles on the energies they are cosmic rays. Acceleration occurs, generally speaking, until begins strongly to be manifested the reverse/inverse action of the accelerated particles on the nonrelativistic space plasma with the "frozen-in" in it magnetic fields. Therefore naturally we already noted the approximate equidistribution (11) between the energy of cosmic rays and magnetic field. Let us note, that also the density of internal energy of interstellar gas frequently of the same order as w_{cr} and w_H. For example, in the regions with concentration $n \sim 1$ cm^{-3} and $T \sim 10^4$ K energy density $w_g = (3/2) k_B n T \sim 10^{-12}$ erg/cm^3, i.e., the same, as density w_{cr} in the Earth (see (1)) and generally in the galactic disk.

In powerful/thick radio galaxies energy of cosmic rays W_{cr}, evaluated by method indicated, reaches 10^{60} ergs or even 10^{61} ergs $\sim 10^7 M_{\odot} c^2$. Our galaxy is "normal". Its gas disk has a thickness of $2h_g \sim 200$ $n_g \sim 6 \cdot 10^{20}$ cm, and its radius $R \sim 5 \cdot 10^{22}$ cm. In this volume $V \sim 5 \cdot 10^{66}$ cm^3 total energy of cosmic rays $W_{cr} \sim w_{cr} V \sim 5 \cdot 10^{54}$ ergs $\sim 3 M_{\odot} c^2$. There are no doubts, however, that the cosmic rays occupy considerably larger region, since they emerge from disk. As the minimum the discussion deals with the radio-disk with a thickness of

$2h_r \sim 5 \cdot 10^{21}$ cm. But at least a number of the authors, including myself[17], have considered since 1953 that the galaxy has sufficiently expressed radio-halo (it, of course, it is possible to call thick radio-disk, especially if halo is sealed). Volume of quasi-spherical halo $V_h \sim \frac{4\pi}{3} R^3 \sim 5 \cdot 10^{68}$ cm^3 and, even taking into account incidence/drop in density w_{cr} with the removal/distance from the galactic plane, in galaxy of $W_{crG} \sim 10^{56}$ ergs. The problem of the halo much was discussed, since it is difficult to determine its parameters at the observations from the Earth. This question sufficiently in detail concerned 10 years ago in its report on the 15th ICRC (see [4], and also [18]). Then news were observations "from the edge" of galaxies NGC4631 and NGC891. The radio-isophots of galaxy NGC4631 on the wave λ=49.2 cm (ν=610 MHz) are shown in Fig. 9 (white color - image of galaxy in the visible light; figure was kindly furnished by R. Sansizi). The fact that the radio-halo is considerably more than optical image, is obvious.

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Unfortunately, in recent years the study of the halo of galaxies did not move especially far. One of the reasons, it seems as me, is the absence of contemporary radiotelescopes with the sufficiently high angular resolution, which work on the waves of longer than 1 m. Meanwhile the longer the wave, the greater the radio-halo must be, since the energy of the electrons and intensity/strength of magnetic field, generally speaking, decrease during the removal/distance from the galactic plane (therefore, obviously, they are emitted ever longer waves). Here, by the way, it is necessary to stress that besides the radio- halo[4,5] it is possible to speak about the gas halo, the magnetic halo[1,9] and the halo of cosmic rays[5]. In the latter case the corresponding region of work is intended by cosmic rays. In this region, especially on its periphery, electrons with the sufficiently high energy it can be already little (in connection with energy loss) and magnetic field can strongly decrease. Therefore radio-halo can be unnoticeably, and energy density w_{cr} will be still considerable.

Radio-astronomical data attest to the fact that radio-halo in different galaxies, even close type, can be bright and weak. From this point of view an example of galaxies NGC4631 and NGC891, which possess the clearly expressed radio-halo, it is not possible to still consider the proof of the existence of radio-halo in the galaxy (for greater detail, see [15], p. 208). However, the analysis of galactic noise also leads to the conclusion about the presence in it of radio-halo with size/dimension of R~10 kps (see [5] the literature given there).

If in last decade radio astronomy it did not enrich astrophysics of cosmic rays by essential new information, then gamma-astronomy, on the contrary, brought important and sometimes unexpected information. True, it would like to learn more, but the already noted prolonged absence of gamma-satellites this it mixed. In spite of youth, gamma-astronomy had time already sufficiently widely to branch (Table II). Gamma-radiation with the continuous spectrum is created both by the electronic and proton-nuclear components of cosmic rays. The role of proton component is especially interesting, since relativistic electrons can be studied and are studied on their emission in the radio-, optical and X-ray ranges. Some contribution to the emission in these ranges they can give protons, but usually it is insignificant or even generally is absent (for example, in field H~10⁻⁵ E the synchrotron radiation of protons with energy of $E \lesssim 10^{-12}$ eV it falls for frequency $\nu_m \leqslant 10^4$ Hz; see (7) $m = M_p$). At the same time the protons and the nuclei, which form a part of the cosmic rays, during the collisions with the nuclei in the gas give rise to π°-meso, which very rapidly (mean life π°-meso $0.84 \cdot 10^{-16}$ s) decompose with the formation of gamma-rays. Decay of π°-meso with probability 98.8% occurs along the channel $\pi^\circ \rightarrow 2\gamma$, by virtue of which the gamma-rays with energy $E_\gamma = (1/2)\, m_{\pi^\circ} c^2 = 67{,}5$ eV are formed upon decay of quiescent π°-meso. Other reactions and decomposition/decays (for example, decomposition/decay of $\Sigma^\circ \rightarrow \Lambda + \gamma$) play considerably smaller role, and for the brevity we will mention only formation and decomposition/decay of π°-mesons. The intensity of the thus formed gamma-rays, naturally, is proportional to the concentration of nuclei in gas n and cosmic-ray intensity I_{cr}.

Fig. 9.

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It is concrete/specific, differential intensity according to the number of particles of the gamma-rays (gamma-ray spectrum) along the ray/beam of emission (coordinate r)

$$I_{\gamma}(E_{\gamma}) = \int \sigma(E_{\gamma}, E)\, n(r)\, I_{cr}(r, E)\, dE\, dr, \quad (12)$$

where $\sigma(E_{\gamma}, E)$ — corresponding cross section for the formation by cosmic rays with energy E of gamma-rays with energy E_{γ} (section must be, of course, averaged taking into account the element and isotopic composition of cosmic rays and nuclei in the gas). For the flow of gamma-rays from the discrete/digital source, on basis of (12), we have

$$F_{\gamma}(>E_{\gamma}) = \int_{\Omega} I_{\gamma}(>E_{\gamma})\, d\Omega \approx \frac{\overline{(\sigma I_{cr})}\, \tilde{n}(V)}{R^2}, \quad (13)$$

where Ω - solid angle at which is visible the source, $\overline{(\sigma I_{cr})}$ the averaged along the spectrum of cosmic rays section (see (12)) and $\tilde{n}(V)$

- quantity of nuclei of gas in the source with a volume V, which is located at a distance of R (for greater detail, see for example, [5,16]). From the aforesaid obviously (see (12), (13)), that the study of gamma-rays from the decomposition/decay of π^0-mesons makes it possible to find cosmic-ray intensity (their proton-nuclear component) far from the Earth. In this case it is necessary, of course, to know a quantity of gas (in essence of atomic and molecular hydrogen) in the appropriate regions (factors n and $\tilde{n}$ in (12) and (13)), but exactly are the concentration of interstellar gas (more precise, this it relates to atomic hydrogen) it is determined well by the radio-astronomical method (line λ=21 cm from hydrogen atoms).

Of this - in possibility to directly investigate basic, proton-nuclear component of cosmic rays in universe - consists most important role of gamma-astronomy for astrophysics of cosmic rays. In other words, gamma-astronomy with respect to the emission of a proton-nuclear component occupies the same place as radio astronomy with respect to electronic component.

Table II. Gamma-astronomy.

(1) Гамма-излучение с непрерывным спектром	(2) Источники и механизмы излучения
$E_\gamma < 30-50$ (3) МэВ (баллоны и спутники) $E_\gamma > 30-50$ (5) МэВ и до нескольких ГэВ (баллоны и спутники) $E_\gamma > 10^{11}-10^{12}$ (7) эВ (излучение Вавилова—Черенкова в атмосфере) $E_\gamma > 10^{14}$ эВ (9) и до 10^{16} эВ (широкие атмосферные ливни)	(4) Диффузионный фон (галактический и метагалактический) (6) Дискретные источники (пульсары, квазары, молекулярные облака, Cyg X-3) (8) Механизмы излучения (тормозное, синхротронное и изгибное излучения, комптоновское рассеяние, $\pi^0 \rightarrow \gamma+\gamma$ и т. п.)
(10) *Гамма-линии:* (11) Гамма-линии ядер, $E_\gamma \sim 1-10$ МэВ (линии от покоящихся ядер, «полосы» от ядер КЛ) (12) Аннигиляция $e^+ + e^- \rightarrow \gamma+\gamma$, $E_\gamma = 0{,}511$ МэВ (13) Циклотронное излучение в очень сильных магнитных полях ($\omega_H^* = (eH/mc)\, mc^2/E$; при $H = 10^{13}$ Э $\hbar\omega_H^* \sim 0{,}1$ МэВ)	
(14) *Гамма-всплески* (первые публикации 1973 г.): (15) Источники: вероятно, нейтронные звезды. Природа?	

Key: (1). Gamma-radiation with the continuous spectrum. (2). Sources and mechanisms of emission. (3). MeV (tanks/balloons and satellites). (4). Diffusion background (galactic and metagalactic). (5). MeV and to several GeV (balloons and satellites). (6). Discrete/digital sources (pulsars, quasars, molecular clouds, Cyg X-3). (7). eV (emission of Vavilov-Cerenkov in the atmosphere). (8). Mechanisms of emission (braking, synchrotron and bending emissions, Compton effect, $\pi^\circ \rightarrow \gamma+\gamma$ and the like). (9). eV and up to 10'' eV (extensive air showers). (10). Gamma peaks: (11). Gamma peaks of nuclei, ... MeV (line from the nuclei at rest, "band" from the nuclei C). (12). Annihilation:. MeV. (13). Cyclotron emission in very strong magnetic fields ... with ... MeV). (14). gamma-bursts (first publications of 1973): (15). The sources: probably, neutron stars. Nature?

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In particular, by a gamma-astronomical method as a result of the procedure of gamma-radiation Magellan clouds[20] and determination of the gradient of cosmic-ray intensity in the direction, let us say, in the anti-center of galaxy[21] it is possible, in the principle, to obtain the information about the cosmic rays in the metagalaxy (more specifically speech it goes about the method of the disproof of the metagalactic models of the origin of cosmic rays in the galaxy; see below).

Unfortunately, as already mentioned, gamma-astronomy is developed more slowly than it would like and, in principle, it would be completely possibly. Especially this relates exactly to the investigation of gamma-rays from the decomposition/decay of π^0-mesons, generated by basic part of a proton-nuclear component of cosmic rays. Entire/all hope now for the Soviet gamma-observatory "Gamma" and American GRO, which must begin within the next few years (there is a hope for the fact that the "Gamma" will be launched in 1988). Basic with the observatory "Gamma" telescope "Gamma-1" with a weight of 1500 kg must record gamma-radiation in the interval of 50-5000 MeV, its angular resolution of 2°, also, with the special "mask" 17', minimum recorded flow of $F_\gamma \sim 5 \cdot 10^{-8}$ photons/cm²s. In the future it is necessary always to have a gamma-observatory in orbit, and there is desirable not one, but several. Necessary is the complex "patrol" for emitting the flashing supernovas[22], so that the history with supernova 1987 A in the large Magellan cloud would not be repeated. It is not possible to disregard the possibilities of gamma-astronomy on the high-altitude balloons (let us point out, for example, to the work [23], in which were investigated the gamma-rays from the radio galaxy centaur A≡CenA in the range (0.7-20 MeV).

I will return, however, to that already done, since completely I am not accumulated to understate achievements of satellite SAS II and especially COS-B. As an example Fig. 10 gives some results COS-B [24] for the gamma-ray contracts with energy $E_\gamma = 70$ MeV $- 5$ GeV (shown in Fig. 10a is the map of intensity in the dependence on different galactic longitudes/lengths for galactic latitudes$|b| \leq 20°$; in Fig. 10b is indicated the distribution of intensity on the longitude/length, moreover is produced averaging in the interval of latitudes$|b| < 5°$). Unfortunately, the gradient of cosmic rays in the galaxy is not reliably yet established/installed, on this score the disputes (see latter/last known to us articles on this question [25], where there are corresponding references), go. It is important to note that the observations do not contradict the assumption that the energy density of cosmic rays drops in the direction of anti-center (and generally on the radius, calculated off the galactic center) according to the law of the type $w_{cr} \sim e^{-r/R}$, where R~10-15 kps (in this case as the distance from the center to the Sun selected distance of 10 kps, now accepted distance of 8 kps.). This conclusion/output (if, of course, gradient is realistic, that, strictly speaking, it is still necessary to demonstrate) completely answers galactic model with the halo; with this halo of cosmic rays must have the significant dimension of R~15 kps. The discussion in the following section of report still will deal with this.

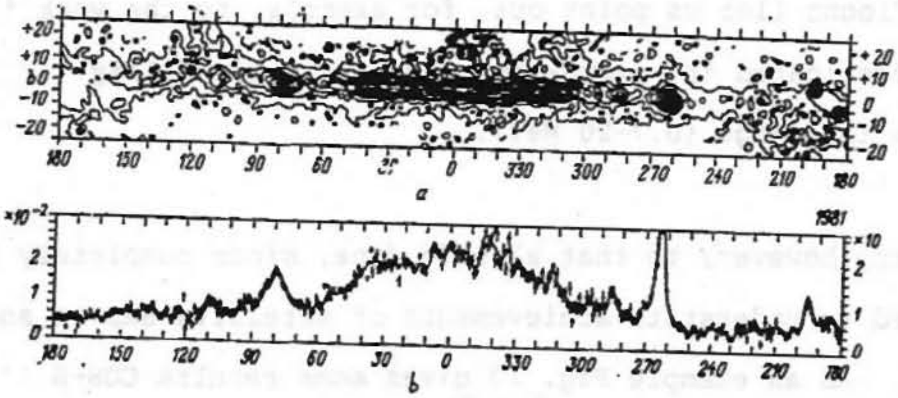

Fig. 10.

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On COS-B (with sensitivity $F_\gamma > 10^{-6}$ photons/cm²s) are recorded about 20 discrete/digital sources of gamma-rays. In their number pulsars PSR 0531 (Crab) and PSR 0833 (Vela), quasar 3S273 and the hydrogen cloud (molecular cloud) ρ-Serpent Bearer (ρ--Ophiuchi). Remaining sources are not yet identified, among them Geminga (Geminga≡2CG195+04), one of most powerful in the γ-range (flow from it $F_\gamma(>E_\gamma = 100$ MeV) $=4.8\cdot10^{-6}$ photons/cm² s). It is sufficiently probable that some of the non-identified sources are molecular clouds or pulsars. Besides the gamma ray sources, which were being studied COS-B, let us note already mentioned radio galaxy Cen-A, Seyfert galaxy NGC4151 and galactic X-ray source Cyg X-3 (Cygnus X-3). Typical luminous density of galactic gamma- sources $L_\gamma \sim 10^{34} - 10^{36}$ erg/s (for example, for spectrum $F_\gamma(E_\gamma) = K_\gamma E_\gamma^{-2}$ under the assumption about the isotropy of emission the luminous density

$$L_\gamma = 4\pi R^2 \int E_\gamma F_\gamma \, dE_\gamma = \frac{4\pi R^2 K_\gamma}{E_\gamma};$$

if $F_\gamma (>F_\gamma = 100$ MeV$) = 1/2 K_\gamma E_\gamma^{-1} \sim 5\cdot10^{-8}$ photons/cm² s, then with distance of 1000 ps $\approx 3\cdot10^{21}$ cm $L_\gamma \sim 10^{35}$ erg/s). For pulsar PSR 0531 (crab) L_γ (50 MeV $< E_\gamma < 10$ GeV) $=2\cdot10^{35}$ erg/s. The complete gamma-luminous density of galaxy $L_\gamma (>E_\gamma = 70$ MeV) $\sim10^{39}$ erg/s, which answers with the observed spectrum approximately $2\cdot10^{42}$ photons/s. By the way, the complete luminous density of galaxy in radio-frequency range $L_r \sim 3\cdot10^{38}$ erg/s.

For quasar 3S273 L_γ ($50 < E_\gamma < 500$ MeV) $=2\cdot10^{46}$ erg/s (accepted distance of 790 Mps; red shift z=0.158). The complete luminous density of this quasar, apparently, does not exceed $L=(2-5)\cdot10^{47}$ erg/s, but its X-ray luminous density L_X ($0{,}5 < E_X < 4{,}5$ keV) $=1.7\cdot10^{46}$ erg/s.

Especially strikes, perhaps, very high gamma-luminous density in region of energies $E_\gamma > (1-5)\cdot10^{11}$ eV (ground observations on emission of Vavilov-Cerenkov in the atmosphere) and in region $E_\gamma > 10^{14}$ eV (ground observations according to ShAL - to extensive air showers). The greatest attention in these regions draws source Cyg X-3, the youngest possible pulsar in the binary system with the orbital period of 4.8 hours[26]. For Cyg X-3 luminous density $L_\gamma (>E_\gamma = 40$ MeV) $\approx 3\cdot10^{38}$ erg/s, $L_\gamma (>E_\gamma = 2\cdot10^{12}) \approx 5\cdot10^{35}$ erg/s, $L_\gamma (>E_\gamma = 2\cdot10^{15}$ eV) $\approx 1\cdot10^{34}$ erg/s (according to other estimations, considering that distance to Cyg X-3 it composes R≈13 kps luminous density $L_\gamma (>E_\gamma = 10^{12}$ eV) $= 2-5\cdot10^{37}$ erg/s, and in interval of $3\cdot10^{15} < E_\gamma < 10^{16}$ eV luminous density $L_\gamma \approx 3\cdot10^{36}$

erg/s, and, as in other cases, emission is considered isotropic). For source Vela X-1 is given estimation $L_\gamma(>E_\gamma=3\cdot10^{15}$ eV) $\approx2\cdot10^{34}$ erg/s. True, luminous density is reduced $4\pi/\Omega$ times, if gamma-radiation has the directed character and is concentrated within the solid angle Ω. Such powerful/thick gamma-radiation can, probably, be generated only by the protons, for power (luminous density) of which in the case of Cyg X-3 we come to the estimations of the type $L_p(>E_p=10^9$ eV) ~10^{40} erg/s and $L_p(10^{16}<E_p<10^{17}$ eV) ~10^{39} erg/s (here as everywhere in the report, we we do not approach high accuracy and we do not specify all done during the estimations assumptions, see also supplement).

Unfortunately, we do not have now possibility in greater detail to stop at gamma-astronomy and its connection/communication with cosmic rays. It is possible to hope, however, that even the done sufficiently fragmentary observations clearly are shown, a gamma-astronomical method of emitting the cosmic rays in the universe is how powerful/thick and promising. This fact found, naturally, reflection in the program of present conference - gamma-astronomy will be on it devoted about 130 communications/reports, i.e., approximately 15% of all reports.

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4. Origin of cosmic rays. Galactic model with halo.

V. L. Ginsburg.

By the problem of origin of cosmic rays it is accepted to understand the complex of questions connected with the origin of primary cosmic-rays in Earth and generally in solar system. Certainly, it is possible to speak also about the origin of cosmic rays, let us say, in the radio galaxies. It is obvious, however, that the cosmic rays in the Earth are isolated in that sense, that only about them we have rich, so to say direct information. Thus, us it will interest only the origin of the cosmic rays, which reach the Earth.

For resolution of the problem it is necessary to indicate the "capture region" - the region from which cosmic rays, where they roam, come. It is necessary to indicate the sources of cosmic rays, the mechanisms of their acceleration, the character of propagation in the interstellar space. The set of all these information and their interpretation formulate the theory of the origin of cosmic rays. In this case the selection of model occupies a central place, for which it is necessary first of all to select the mentioned "capture region". Once it was considered, for example, solar model - in it the cosmic rays, which arrive to us (only about them and it will go speech without further stipulations), were considered accelerated in the Sun and seized into a certain circumsolar region (let us say, with size/dimension of $R \sim 10^{16}-10^{18}$ cm). But now we know that the cosmic rays in the same quantity approximately fill at least the region of galactic disk and essentially they come to us from the galaxy. It is another matter that as solar cosmic rays they are of interest and widely are investigated[4]. But to speak, of course, does not feel about the solar model of the origin of cosmic rays (in the sense indicated above). Another, it is possible to say, extremity - this the metagalactic models of the origin of cosmic rays. In these models it is assumed that the cosmic rays essentially flow into the galaxy from without - from the metagalactic space. Metagalactic models were criticized already long ago (see, in particular, [4,17]. After the discovery in 1965 of relict thermal radio emission with a temperature $T \approx 2.7$ K it became obvious that the electronic component of cosmic rays cannot have metagalactic origin and must be generated in galaxy itself. The fact is that the losses, caused (by the so-called inverse effect of Compton) of electron scatterings on the thermal photons, are so/such strong, that even from the nearest to us radio galaxy centaur A to us will not reach the electrons with the energy $E>10^{9}-10^{10}$ eV, exactly critical for the significant part of the synchrotron galactic radio emission. Probably, cannot, in connection with the nuclear losses, reach us from the metagalaxy and the heavy nuclei. However, as far as protons and light nuclei are concerned, of so direct and single-valued a disproof of metagalactic models there is no their origin still. Apparently, only gamma-astronomical observations - the investigation Magellan clouds [20] and gradient w_{cr} in the galaxy[21,25,27-29] is capable of introducing here complete clarity. In our opinion, however, of the set of all available data it is already sufficient for the failure of the metagalactic models (this does not relate to the particles with highest energy $E > 10^{17}$ eV or, faster, even at $E \geqslant 10^{19}$ eV, which, apparently, have metagalactic origin[13,14]).

They remain, thus, galactic models - in them cosmic rays (observed in Earth) are generated in galaxy and are seized in it, although in essence they emerge into metagalactic space. Galactic models can be divided into the disks and the models with the halo.

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In the disk models the cosmic rays are concentrated in a certain disk, even if thicker than the gas disk of galaxy (half-thickness of $h_g \sim 100$ ps), but nevertheless sufficiently flat/plane, let us say with the half-thickness of radio-disk of $h_r \sim 500-1000$ ps (see Fig. 11). In the models with the halo it is assumed that there is a halo (corona) of cosmic rays with significant dimension of $R \sim h_h \sim 10-15$ kps. Lake of the physical considerations (it is intended, how difficult to hold down/retain relativistic particles in the disk) and from the wavelengths and callsigns (then, true, unconvincing) I from the very beginning (since 1953;[11]) am the supporter of models with the halo (about this has already been mentioned in section 3). As it is presented to me, all data either confirm this model or, in any case, they do not contradict it. It is another matter that the size/dimension of the halo of cosmic rays is not yet established/installed. Furthermore, sometimes the halo of cosmic rays identify with the radio-halo, which, of course, is erroneous (see above section 3). In this connection appeared purely verbal/literary disagreements (for example, flattened radio-halo with half-thickness $h_h \sim 3$ кps it is possible to call thick disk, etc.).

Gamma - astronomical data, which testify about smallness of gradient of energy density w_{cr}, with existing low accuracy, albeit yet not completely, they disprove metagalactic models. But, in any case, if the discussion deals with the galactic models, then the smallness of gradient is consistent only with the large halo[24]. Incidentally, if in the work[27] there is made an attempt to somehow revive the possibility to utilize a metagalactic model, then in [23] on the basis of a more careful analysis of data the same COS-B metagalactic model is considered as already unlikely. Actually it is very unlikely on the series/row of other considerations (see [5] and the literature indicated there)[1]).

FOOTNOTE[1]. As so often is the case, positive and negative results do not lead to the directly opposite conclusions. Thus, the presence of the marked concentration gradient of cosmic rays in the galaxy (with the incidence/drop in this concentration with the removal/distance from the galactic center) would strongly attest about the galactic model and it contradicts metagalactic models. But if the gradient, let us say, is generally imperceptible, then this yet does not contradict galactic models under the assumption about the "closure/isolation" (closed nature) of this model (the presence of the strong reflection of cosmic rays on the boundaries is intended or, more precise, on the periphery of halo). Thus, for refining the model with the halo, undoubtedly, it is necessary to know the value of gradient. ENDFOOTNOTE.

Thus, let us pause at galactic model with halo. The characteristic parameters of this model (speech it goes only about an order of magnitudes) it is given in Table III.

Characteristic lifetime of cosmic rays T_{cr} is estimated from different considerations.

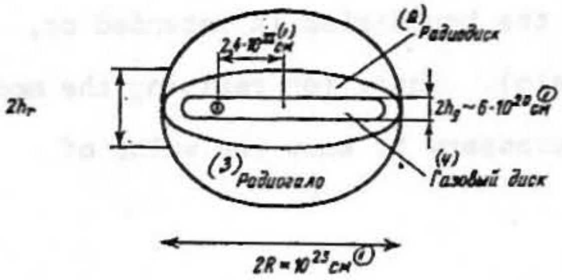

Fig. 11. $(2h_r \sim 5 \cdot 10^{21}$ cm).

Key: (1). cm. (2). Radio-disk. (3). Radio-halo. (4). Gas disk.

Table III. Galactic model with halo.

(1) Размеры гало космических лучей $R \sim 10$—15 кпс ~ 3—5.10^{22} см (радиогало несколько меньше, его размеры зависят от частоты и увеличиваются с уменьшением частоты)
(2) Объем $V_h \sim 10^{68}$ см^3
(3) Полная энергия космических лучей $W_{cr} \sim w_{cr}V_h \sim 10^{56}$ эрг $\sim 100\ M_{\odot}c^2$
(4) Полная энергия электронной компоненты $W_{cr,e} \sim w_{cr,e}V_h \sim 10^{54}$ эрг
(5) Характерное время жизни космических лучей $T_{cr} \sim (1$—$3) \cdot 10^8$ лет $\sim (3$—$10) \cdot 10^{15}$ с (протонов, легких ядер)
(6) Мощность (светимость) источников космических лучей $U_{cr} \equiv L_{cr} \sim W_{cr}/T_{cr} \sim (1$—$3) \times \times 10^{40}$ эрг/с
(7) Мощность источников электронной компоненты $U_{cr,e} \sim W_{cr,e}/T_{cr,e} \sim 10^{39}$ эрг/с

Key: (1). Dimensions of the halo of cosmic rays R~10-15 kps ~3-5·10^{22} cm (radio-halo somewhat less, its sizes/dimensions they depend on frequency they increase with the decrease of frequency). (2). Volume ... cm^3. (3). Total energy of cosmic rays ... ergs .... (4). Total energy of electronic component ... ergs. (5). Characteristic lifetime of cosmic rays ... years ~ (3-10) ·10^{15} s (protons, light nuclei). (6). Power (luminous density) of sources of cosmic rays ... erg/s. (7). Power of sources of electronic component ... erg/s.

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The simplest path is based on the expression for the passed thickness of substance $x = c\rho T_{cr}$ (see above), determined from the data about the chemical composition of cosmic rays. For interstellar medium $\rho \approx 2 \cdot 10^{-24} n$ g·cm^{-3}, where n - gas concentration. For the galaxy as a whole, taking into account the stay of cosmic rays in the halo, speaking in general terms, n~10^{-2} cm^{-3} and $T_{cr} \sim 10^{16}$ from ~$3 \cdot 10^{8}$ years (with x≈5-7 g·cm^{-2}). In connection with the unreliability of the value n accepted (gas concentration in the halo we we know badly/poorly) are somewhat more convincing the more detailed calculations, which are based on the analysis of cosmic-ray distribution in the galaxy[1]).

FOOTNOTE[1]. Let us note that this most important parameter, as the power of the generation of cosmic rays in galaxy $U_{cr} \equiv L_{cr} \sim (1-3) \cdot 10^{40}$ erg/s, only weakly depends on the selection of model. The fact is that

$$U_{cr} \sim \frac{W_{cr}}{T_{cr}} \sim \frac{w_{cr} V}{x}_{\bar{\rho}} \sim \frac{c w_{cr} M_g}{x} \sim 5 \cdot 10^{-3} M_g \sim 5 \cdot 10^{40} \text{ эрг/c.}^{(1)}$$

Key: (1). erg/s.

where $x = c\bar{\rho}T_{cr} \sim 5$ g·cm^{-2} - passed by cosmic rays thickness of gas, $\bar{\rho}$ - its average density and $M_g = \bar{\rho}V \sim 10^{43}$ g - total mass of gas in the galaxy (for the mass of atomic and molecular hydrogen in the literature figure respectively values of $M_H \sim 2 \cdot 10^{42}$ g and $M_{H_2} \sim 10^{42}$ g; taking into account other elements and especially ionized hydrogen, which prevails in the halo, the value of $M_g \sim 10^{43}$ g accepted it is completely reasonable). Let us note that the power of the generation of cosmic rays is called sometimes luminous density in the cosmic rays (hence the designation $L_{cr} = U_{cr}$). ENDFOOTNOTE.

Their sources are concentrated in the disk, whereas they wander not only in the disk, but they emerge in the halo, again they are returned to the disk, etc. Of course the motion of cosmic rays in the interstellar fields is not identical to the diffusion of neutral atoms in some inhomogeneous medium. However, diffusion approximation is widely used on a whole series of reasons in the examination of cosmic-ray distribution, moreover with a sufficient basis/base. Unfortunately, for the discussion of entire this vast series of questions here there is no place. We will be bounded to references to the surveys/coverage [4,5,14,19,20], in which is indicated a large quantity of other survey and original articles. As an example let us give also the sufficiently general/common diffusion equation for the concentration of particles of type i ($N_i(\mathbf{r}, t, E)\, d\mathbf{r}\, dE$ — a quantity of particles in the element of volume and energy dr dE):

$$\frac{\partial N_i}{\partial t} - \operatorname{div}(D_i \nabla N_i) + \frac{\partial}{\partial E}(b_i N_i) = Q_i - P_i N_i + \mathcal{P}_i; \quad (14)$$

here the coefficient of diffusion $D_i(\mathbf{r}, t, E)$ in even the more general case can be considered anisotropic; coefficient $b_i(\mathbf{r}, t, E)$ limits energy losses, Q_i — the "external" sources of the cosmic rays of type i, term $-P_i N_i$ considers "catastrophic" processes of the departure of particles of type i from the interval of dr dE in question and finally term $\mathcal{P}_i$ considers admission into this interval of particles also due to "catastrophic" losses of the particles of other types. For the nuclei the collisions with the nuclei of gas (concentration n) with the conversion into other nuclei or substantial change in the energy play the role catastrophic losses, i.e., $P_i = \sigma_i v_i n\_$ (σ_i — corresponding mean section and v_i — speed of the nucleus of type i). at the same time continuous losses for the nuclei - this in essence the ionizing losses, which in relativistic region for interstellar medium are very small; therefore $b_i = 0$. usually assume/set into (14) for the relativistic nuclei Are frequently possible other simplifications, but also upon their consideration equations of the type (14) are very rich in the content [2]).

FOOTNOTE [2]. On the other hand, in equation (14) is not taken into consideration the possibility of moving the medium (interstellar gas). Upon consideration of such motions into the left side of equation (14) it is necessary to supplement member div $(N_i u)$, where u - speed of the medium (necessary to supplement similar the term, which considers a change in the energy of particles with their motion in the nonuniform flow). In the galaxy there are different flows, in particular convective type. There is not excluded the existence of the "galactic wind" - the flow of gas, which exits from the galaxy or, let us say, that emerges into some directions and flowing in others (speech, thus, it goes about the large-scale convection or the circulation). ENDFOOTNOTE.

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In simplest diffusion approximation is introduced constant coefficient of diffusion $D_i = D$ and, if lifetime of cosmic rays T_{cr} is determined by output from system (from halo), then $T_{cr} \sim R^2/2D$. With $R\sim3\cdot10^{22}$ cm of time $T_{cr} \sim (1-3)\cdot10^8$ of years answers value of $D\sim10^{28}$-10^{29} $cm^2 s^{-1}$. The analysis of the data about the chemical composition of cosmic rays on the basis of diffusion model leads precisely to such coefficients of D, and thereby it justifies the estimation for T_{cr} used. As it is said, these are whole region - here and the account of the dependence of diffusion (and of the chemical composition) on the energy, and the examination of radioactive product nuclei (first of all of nuclei ^{10}Be), and much more. Another aspect of problem is the output beyond the limits of diffusion approximation, obtaining diffusion equations from the more general/more common kinetic equations, which describe the motion of the charged particles (in particular, cosmic rays) in electromagnetic fields and, is more concrete/more specific, in the galactic magnetic field taking into account regular and chaotic components of this field. This is also the whole direction (for example, see [5] of Chapter 8, [30] and the literature indicated there). It adjoins one additional vast region of investigations - analysis of mechanisms and processes of accelerating the charged particles.

Acceleration ci charged particles in space as almost in all known cases, has electromagnetic nature [1]).

FOOTNOTE [1]. As the important exception/elimination it is necessary to mention about the particle acceleration in the shock wave, which is spread in the absence of magnetic field in the direction of the decrease of substance density in the atmosphere of star. Under such conditions wave velocity can become relativistic and, consequently, also all particles behind the wave front acquire high energy[31]. Of course, at the microscopic level precisely electric field determines the transmission of pulse during the collisions of particles, but macroscopic electromagnetic field can be absent. ENDFOOTNOTE.

In other words, acceleration occurs under the action of electric fields, but the role of magnetic field usually is alsc not less essential, although energy of the charged particle this field by itself and does not change. Depending on situation and conditions distinguish the betatron action (it caused by the induction electric field, which appears with a change of the magnetic field with time), acceleration in the dual electrical layers, acceleration with reclosing of magnetic lines of force, set of energy during interaction of particles with the plasma waves (with plasma turbulence) and finally regular and statistical acceleration on the moving/driving magnetic heterogeneities, in particular at the shock wave fronts. Referring to the surveys/coverage (see [5], Chapter 9, [6,32,33]), let us make here only several observations.

Especially essential for analysis problem of acceleration of cosmic rays proved to be work of Fermi (1949, 1954, [34]). In this case at first the attention was concentrated in the statistical acceleration (acceleration of the second order). Specifically, collisions of the charged particle with the chaotically moving/driving magnetic heterogeneities ("clouds") were examined. Then the mean statistical acceleration is connected, in particular, with the larger probability of "contrary" collisions in comparison with the "overtaking" collisions. As a result of averaging over all collisions with the heterogeneities, distributed isotropically on the speeds, a change in the energy of particles is equal (see [4,5,32,34])

$$\frac{dE}{dt}=\alpha E, \quad \alpha=\xi\frac{u^2 v}{c^2 l}, \tag{15}$$

where u - the average speed of "clouds", v - speed of the accelerated particle, l - mean free path between the collisions and ξ - the numerical factor, depending on the configuration of magnetic fields and the like (in [5], Chapter 9 it is brought value ξ=4). The observed power-law spectra of cosmic rays can be explained under the assumption that the particles are accelerated independent of the energy for a while T. Then, without taking into account losses, from equation dN/dt=-αN-(N/T) we obtain spectrum $N(E)=KE^{-\gamma}$, $\gamma=1\div(1/\alpha T)$.

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As the time of acceleration T, in connection with the independence γ from the type of nuclei, it is necessary to take the time of the output of cosmic rays from the system. Assuming/setting γ~3 and $T=T_{cr}\sim10^8$ years, we obtain $\alpha\sim1/T_{cr}\sim3\cdot10^{-16}$ s^{-1}. But $\alpha\sim4u^2/Cl$ (see (15)), the rate of magnetic bumps ("clouds") in galaxy $u\sim10^6$ $cm\cdot s^{-1}$, and therefore is necessary that would be $l\sim4u^2/c\alpha\sim3\cdot10^{17}$ cm. Meanwhile for the large heterogeneities in the galaxy are faster l~3-10 ps ~ 1-3) $\cdot10^{19}$ cm. The same approximately value follows, if we take the coefficient of diffusion $D\sim cl/3\sim10^{29}$ cm^2 s^{-1}. The main thing, with the low values α particle for time T_{cr} will not have time substantially to be accelerated. From such considerations interstellar acceleration was in its time acknowledged deliberately ineffective [4]. Actually situation is considerably more complicated, since there is a whole spectrum of heterogeneities, and, in the principle, the role of interstellar acceleration could be essential. For an evaluation of this role it is necessary to connect particle acceleration with their diffusion, which occurs on the same heterogeneities, and to be based in the observational data, the portions of product nuclei in the cosmic rays (Li, Be, B, etc.) concerning dependence on their energy. If interstellar acceleration is substantial, then with an increase in the energy it is possible to expect[35] an increase in the relative quantity of product nuclei. Meanwhile the opposite dependence is observed. Furthermore, even taking into account acceleration at the shock wave fronts, with which will deal the discussion lower, interstellar acceleration is represented impossible with the energies $E \geqslant 10^{14}$ eV or even energies $E \geqslant 10^{12}$ eV[36].

At the same time from the essence of the matter and formally it is obvious from formula (15) that statistical mechanism (Fermi's mechanism) is especially effective in regions with small-scale (smallness l) and rapid motions of heterogeneities (high values of rate u). Acceleration in the shells supernova answers, generally speaking, specifically, such conditions. Therefore, and for other reasons, the shells supernova exactly were examined and are examined

[4-6,17,29] as the most probable sources of galactic cosmic rays. We still will return to this question.

Now let us mention about reaching/achievement in field of study of mechanism of acceleration of cosmic rays most important in last decade. The discussion deals with the acceleration by the shock waves, which are spread in the magnetoturbulent plasma (see [37]; surveys [32,33]). With the reflection of particles from the moving/driving "walls" (regions with the strong magnetic field) the energy of particle disregarding by the members of order u^2/c^2 changes according to the law

$$\frac{dE}{dt} = -2\,\frac{(\mathbf{uv})\,v}{c^2 l}\,E, \qquad (16)$$

where u - rate of wall. During one collision the acceleration is proportional u/c (acceleration or, to more rightly say, a change in the energy, first order), but with the averaging over the angle between u and v first-order acceleration in the isotropic case is absent and remains only the acceleration of second order (15). Of course, if particle "is closed" between two converging walls, then first-order acceleration occurs, but it is limited by the time, necessary for colliding the walls. Therefore previously first-order acceleration was considered in astrophysics having only the very limited value. Situation changes, if shock wave (wall) moves in the magnetoturbulent plasma. Then at the wave front there occurs first-order acceleration[1]).

FOOTNOTE[1]. The gas velocity u, along which runs the wave, changes at the shock wave front; moreover, the compression of gas at the front occurs. Therefore, in the region of the front (which upon consideration of the viscosity/ductility/toughness and other factors is somewhat washed away) div u<0, that it answers the acceleration (in more detail, for example, see [5], Chapter 9). ENDFOOTNOTE.

Then this particle as a result of scattering on the magnetic heterogeneities before or behind the shock wave front again falls on front, it again increases its energy, etc. As a result the accelerated particles with a certain power-law spectrum appear.

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In the interstellar space there are propagated shock waves, which appear as a result of the explosions of supernovas and for other reasons. Therefore acceleration in the interstellar space, in the principle, could prove to be very effective. But, as noted, actually this not so, if we do not speak about a certain "increased acceleration" of particles[31], accelerated in essence in the compact sources.

We have possibility, and this it is necessary, briefly to dwell within the framework of galactic model with halo only on one more very important question about are such basic sources of cosmic rays in galaxy. Beginning from the pioneer work of Baade and Zwicky (1934,[37]) as the sources of cosmic rays began to be examined the supernova explosions stars. Kinetic energy in shell ~10^{49}-10^{51} ergs is isolated in the supernova explosion, and bursts in the galaxy occur every 10-30 years. Therefore the average power of energy release for supernova is $L_{sn} > 10^{40}$ erg/s and, probably, $L_{sn} \sim 10^{41} - 10^{42}$ erg/s. However, for guaranteeing the quasi-steady-state with respect to cosmic rays in the galaxy it is necessary (see Table III) to inject cosmic rays with a power (luminous density) $U_{cr} \equiv L_{cr} \sim (1-3) \cdot 10^{40}$ erg/s. Thus, from an energy point of view supernovas can ensure the necessary acceleration of cosmic rays. Hypothesis about this role of supernovas obtained strong reinforcement in 1951-1953, when according to the data about the radio emission it became clear that in the shells of supernovas is a large quantity of relativistic electrons. Finally, soon after the discovery in 1967 of pulsars it was explained that some of them are located in the shells of supernovas. In particular, pulsar PSR0531 is undoubtedly the neutron star, which remained from the explosion of supernova into 1054, which led to the formation of the Crab Nebula. This pulsar is critical for the observing activity of the Crab Nebula.

Thus, undoubtedly, supernovas are powerful sources of cosmic rays. The stars of different types also generate cosmic rays, however, as a rule, with the incomparably smaller power. Thus, the average/mean power of the generation of cosmic rays by Sun $L_{cr,\odot} \sim 10^{23}$ erg/s. Consequently, even 10^{11} stars with this generation will ensure only power $L_{cr} \sim 10^{34}$ erg/s, which is 4-5 orders less than the required power $L_{cr} \sim (1-3) \cdot 10^{40}$ erg/s. Of course, some stars (star of the type O, etc.) are considerably more active than the Sun, but them not so there is much. On the whole, although this is strict and it is not proved, it seems very probable that the nonexploding stars, and also new stars cannot compete with the supernovas as the basic sources of cosmic rays.

Special position occupies problem of source Cygnus X-3 (Cyg X-3). As has already been mentioned, this source generates cosmic rays with a power of $L_{cr} \sim 10^{39} - 10^{40}$ erg/s[1]).

FOOTNOTE[1]. Apparently, the power of source Cyg X-3 strongly changes in time. With this fact, and also with a number of others there are associated doubts available with respect to the data about Cyg X-3 (see supplement). ENDFOOTNOTE.

Therefore one or several such sources are capable of ensuring the necessary power of generation for the entire galaxy. Since there are observed photons with an energy which reaches at least 10^{16} eV, it is clear from Cyg X-3 that their generating protons (this is most probable) have an energy which reaches to 10^{17}-10^{18} eV. This fact is also very important, since the acceleration in the galaxy of particles with the energy $E \geqslant 10^{15}$ eV even in the supernovas was always and, strictly, it remains problem. We do not know, however, how much exists sources of the type Cyg X-3 in this time (possibly, only one) and as for long they emit. It is necessary to stress that itself power $L_{cr} \sim 10^{40}$ erg/s, although it, of course, is enormous (let us recall that the complete luminous density of Sun $L_{\odot} = 3{,}86 \cdot 10^{33}$ erg/s) it is completely compared with the power of supernovas. In fact, upon transfer during the supernova explosion into the kinetic energy of 10^{49}-10^{52} ergs into the cosmic rays it can convert/transfer to 10^{51} ergs. If the process of acceleration lasts even 3000 years, then exactly we come to power $L_{cr} \sim 10^{40}$ erg/s.

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In the case of the Crab Nebula it is known that the generation of cosmic rays is continued already about 1000 years, occurs now with power $L_{cr} > 10^{38}$ erg/s (power of the electromagnetic radiation $L \sim 10^{38}$ erg/s) and is connected with the activity of pulsar PSR0531. Source Cyg X-3 is, apparently, young pulsar[1]), that is located in the binary system.

FOOTNOTE[1]. There are indications that this pulsar emits gamma-rays with $E_\gamma > 10^{12}$ eV with the period of 12.6 ms. ENDFOOTNOTE.

It is completely possible that this is the product of some supernova explosion. Thus, new, which introduces in this respect source Cyg X-3 it is of the indication of the possibility of the generation of protons pulsar with a power of up to 10^{40} erg/s and with energy $E \sim 10^{17}$-10^{18} eV. However, earlier it seemed that this power of the generation of cosmic rays was connected with the shell or, in any case, not with pulsar itself. However, a similar opinion does not meet objections and now, since sources of the type Cyg X-3 and generally dual sources with the pulsars are formed, apparently, only for the small portion of supernova explosions.

One way or another, study of supernovas, their evolution and emission is most intimately connected with astrophysics of cosmic rays and gamma-astronomy. Much here is not yet clear. For example, why does attenuate the luminous density of source? One of the explanations - decrease in the velocity of the rotation of the pulsar, which remained after flash/burst. However, for the supernova SN 1972E (galaxy NGC 5253) there is discovered the exponential incidence/drop in the luminous density, which is more natural to explain by radioactive decay of the products of explosion. These radioactive products must emit gamma peaks. For example, nuclei ^{56}Co via K-capture convert/transfer in ^{56}Fe with the emission of line with $E_\gamma = 0{,}847$ MeV. Recording such lines at future satellites can much explain (so, there is the design of the instrument, capable of recording gamma peaks from the supernovas, which flash in other galaxies up to distances of R~10 Mps).

In light of aforesaid is obvious special importance of study of flashes/bursts of close supernovas - in galaxy and in Magellan clouds. All the more worthy are regrets of the already noted unpreparedness for such investigations (appearing based on the example to that flared up on 23 February 1987 of supernova 1987 A) with respect to gamma-astronomical and neutrino measurements. As one well-known physicist noted in a conversation with me, observations SN 1987A were only "general rehearsal" and they will lead to the improvement of the entire observation system of flashes/bursts in the future. We will hope that so it will occur, but, unfortunately, the representatives of my generation to "premiers" completely can not at all live. Of course the probability of the flash/burst one additional supernova in the galaxy or in Magellan clouds in connection with flash of SN 1987A did not decrease, but it does not exceed one burst in 10 years, and, possibly, in 30 years. It is all the more important to attempt still something to obtain for SN 1987A, that is located in the large Magellan cloud[40]. The exploding star had large mass $M \sim 15M_{\odot}$, the mass of the shell of the same order, the rate of shell is also great - it reached (2-4) $\cdot 10^{9}$ cm/s (for the outer layers), kinetic energy of shell was (1-3) $\cdot 10^{51}$ erg. Cosmic rays in the shell can be accelerated due to three mechanisms: acceleration at the front of external shock wave, statistical acceleration on the turbulent motion within the shell and the acceleration by pulsar (if it was formed during the explosion, which is completely probable). By virtue of the sufficiently large mass of shell and its high rate it is possible to expect the large luminous density in the cosmic rays (in the protons), which reaches $L_{cr} \sim 10^{42} - 10^{43}$ erg/s. Not only with such, but also with to one-two orders of smaller power in the shell are formed many π^{0}-mesons and, therefore, gamma-ray contracts.

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The gamma-luminous density L_{γ} depends on L_{cr}, the spectrum of cosmic rays (natural to consider that it exponential, i.e., $N_{p}(E) = KE^{-\gamma}$, moreover has maximum, and, speaking in general terms, it is broken on certain energy E_{min}) and of some other factors[22,41]. Even with $L_{cr} = 10^{40}$ erg/s and $\gamma = 2,1-2.6$, $E_{min} \sim 1$ GeV the flow of gamma-ray contracts with $E_\gamma > 70$ MeV on the Earth can comprise $F_\gamma(>E_\gamma = 70$ MeV$) \sim (3-6)$ $\cdot 10^{-6}$ photons/cm^2$\cdot$s. At the same power L_{cr} the photons with $E_\gamma > 1000$ GeV, which can be recorded on the emission of Vavilov-Cerenkov, must have a flow $F_\gamma(>E_\gamma = 1000$ GeV$) \sim 10^{-11}-10^{-10}$ photons/cm^2$\cdot$s. Similar flows and even somewhat smaller can be recorded by the installations existing in the southern hemisphere. However, with respect to gamma-rays with $E_\gamma > 70$ MeV, perhaps, still it will be possible to launch instruments on the balloons. Time for all similar gamma-measurements is one-two years after the burst. As far as gamma-rays with $E_\gamma > 10^{15}$ eV are concerned, even with $L_{cr} \sim 10^{41}$ erg/s their flow on the Earth from SN 1987A would comprise order 10^{-14} photons/cm^{2}s (with γ=2.1) and 10^{-15} photons/cm^{2}s (with γ=2.3), but without taking into account absorption during the relict thermal emission. Absorption decreases the flow 10-30 times, yes even power $L_{cr} \sim 10^{41}$ erg/s it is difficult to expect for a prolonged time. Is small probability and recordings of neutrino with high energy $E_\nu \geqslant 10^{14}$ eV, generated in shell SN 1987A by cosmic rays. Referring to details in [41], we can note that most real is the recording from SN1987A gamma-rays with $E_\gamma > 1000$ GeV. We do not concern here recording gamma peaks. Thus, according to [40], the year after flash/burst from SN 1987A it is possible to expect from decomposition/decay of ^{56}Co of flow $F_\gamma(E_\gamma = 0,847$ MeV$) \geqslant 3 \cdot 10^{-3} f$ photons/cm^2 s. We will hope that the corresponding measurements will have time to carry out.

In future, undoubtedly, must work system (see, in particular, [22]), in which the following flash/burst it will be able to be in proper time studied in all ranges of electromagnetic waves, and also by neutrino telescopes (necessary to have in mind both the region low energies $E_\nu \sim 1-10$ MeV and neutrino with $E_\nu \geqslant 10^{12}$ eV) and gravitational antennas.

5. Some prospects for further investigations.

Study of cosmic rays as by direct methods (let us say, with use of tanks/balloons or satellites), so also indirect methods (for example, from radio-astronomical data) occurs sufficiently slowly in comparison with a whole series of investigations in physics. One way or another, long years it was impossible to obtain response/answer to many questions - this is clear from the historical introduction, done in the beginning of report, and the subsequent commentaries. For example, a question about the evaluation of the role of metagalactic cosmic rays by a gamma-astronomical method according to the observations Magellan clouds and from the measurements of the gradient of a gamma-luminous density in the galaxy was set respectively into 1972 and 1975 .[20,21]. However, an even simpler method of measuring the gradient yet did not give the completely specific results and it will be debated at the present conference. In this case the discussion cannot here solve problem - are necessary new measurements, and they already several years are not conducted due to the absence of gamma-satellites. It is necessary to wait another minimum several years before working/treatment of the given planned starting/launching of the observatories of the "Gamma" and GRO. For years and even decades await realizations and other projects (for example, the design of the neutrino telescope DUMAND).

In spite of similar difficulties, study of cosmic rays occurs by broad front. The present conference, to which are represented more than 800 reports is better to that evidence. International conferences on the cosmic rays (ICRC) are conducted every two years and last two weeks; constituting several volumes original reports previously (at the beginning of conference) are printed, after some time are published the "invited" and pattern repeat reports. All these transactions of conferences ICRC comprise the authentic annals of cosmic-ray research[4]. Of course to participants in conference ICRC-20 the aforesaid is well known. I mentioned this as an example for others.

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I do not know more fruitful and more effective conferences, although it is familiar with a number of the regions of physics and astrophysics.

What are the most important achievements in region of astrophysics of cosmic rays in last 10 years? This period I selected because the report, analogous to present, is made at the 15th conference in 1977 (ICRC-15, Plovdiv, Bulgaria[11]). Of course what results to relate to the important, and what - to the less essential, is usually disputable/debatable and subjective matter. I understand this and completely I do not claim to much and furthermore during the last decade I less deal with cosmic rays than earlier. And since it seems me it is possible to isolate such achievements.

1. A more detailed study of element and isotopic composition of primary cosmic-rays.

2. Detection and beginning of study of antiprotons.

3. gamma-astronomical observations to COS-B (1975-1982), which only now are in detail processed. The study of both the discrete sources and galactic background is intended.

4. Detection of photons with $E_\gamma > 10^{14}$ eV and up to $E_\gamma \sim 10^{16}$ eV from Cyg X-3 and, possibly, some other sources. The disputes are continued in regard to this. But indeed the same it is possible to say almost for each question.

5. Theoretical analysis of particle acceleration at shock wave fronts.

Undoubtedly, list can be widened, but then it can become enumeration of very many leading investigations.

What us does expect in future? I have in mind in the not very distant future (since, incidentally, is somehow indifferent to futurology), but plans prior to the beginning of the following century (formally until 1 January, 2001) or to the century from the time of the discovery of cosmic rays (on 7 August 2012). A similar extrapolation is not especially daring or purely speculative. We indeed are familiar with the history of the study of cosmic rays for 75 years. We know the plans/layouts of the creation of the series/row of the large installations, whose realization and operation occupy long years. It is difficult to doubt the fact that they await us and the unexpected contingency, possibly, even the essential discovery. Detection in 1983 of the extensive showers, which consider the generated gamma-ray contracts the energy to 10^{15} eV, emitted by source Cyg X-3, was the example to this unexpected contingency.

Let us enumerate some directions and problems, in sufficient measure clear and determined.

1. Further study of element and isotopic property of cosmic rays in Earth. In this direction always is conducted and is continued extensive work. It sufficiently fully is illuminated on ICRC, in particular at the present conference. Since I myself am somehow distant from this thematics, I will be bounded to the reference of the special urgency of the study of radioactive product nuclei (^{10}Be, ^{14}C, ^{26}Al, etc.), and also energy spectrum of different product nuclei. Projects "Advanced Composition Explorer" (ACE), "Astromag" and, probably, some others promise achievement of the essential progress in the considered region [12,42].

2. Study of electronic and positron components, in spite of successes, it remains completely actual.

3. Question about antiprotons is not clear. It is necessary to repeat the measurements of their spectrum. if actually much with low energies $E_{k} \sim 0,1$ GeV of antiprotons (considerably more than secondary antiprotons with $x=5\ g \cdot cm^{-2}$), then the problem of the formation of antiprotons it remains unresolved (for the state of the question on 1985 see[43]; as far as I know, since then there were no essential new results).

4. Entire region of superhigh energies $E>10^{17}$ eV and especially $E \gtrsim 10^{19}$ eV has already long ago been remained chosen: is here unclear spectrum (in particular, there is cutting spectrum with $E \gtrsim 3 \cdot 10^{19}$), chemical composition, anisotropy.

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Discovered, in fact, is the question about the origin of such particles, although the metagalactic version is most plausible with $E \gtrsim 10^{19}$ eV (for greater detail, see [8] of Chapter 5; [4,13,14]). For studying the cosmic rays with the energy at least to 10^{20} eV is expedient the creation of giant installations over the area, which reaches $10^{3}\ km^{2}$ [44].

5. About the value for astrophysics of cosmic rays of gamma-astronomy already much was said above. Besides the starting of the observatories of the "Gamma" and GRO, it is necessary to have new observatories approximately in the same range 30 MeV $< E_{\gamma} < 5$–30

GeV, and to also create instrument for the range of 5 GeV $< E_\gamma < 100-400$ GeV[45]. Only then will be filled existing now a "dip" in the investigated spectrum between the measurements on the satellites (COS-B, "Gamma-1", GRO) and with ground-based measurements on the brightness of Vavilov-Cerenkov ($E_\gamma > 10^{11} - 10^{12}$ eV). Moreover, ground-based measurements (on the brightness of the atmosphere) can fix/record only discrete/digital sources. The program of measurements on the observatories of the "Gamma" and GRO is known. In the large measure, and this is natural, the discussion deals with the repetition, the refinement and the expansion of the investigations, initiated on satellites SAS-11 and COS-B. I here wish to stress the need of conducting the measurements also on the high galactic latitudes for the purpose of the development/detection of gamma-halo galaxy, for which is critical in essence scattering relativistic electrons (the inverse effect of Compton) on the thermal photons in the halo (see [5] of Chapter 6 and [46]). Is obvious the urgency of the study of different discrete/digital gamma ray sources (molecular clouds, pulsars, etc.), explanation for them of spectrum and variations in the intensity. The same it is possible to speak about measurements in region $E_\gamma \geqslant 10^{11} - 10^{12}$ eV (Vavilov-Cerenkov brightness in the atmosphere) and in region $E_\gamma \geqslant 10^{14}$ eV (extensive showers)[1].

FOOTNOTE[1]. For this purpose necessary are the installations with the large area (S~1 km²), furnished with a sufficient quantity of detectors of the muons (latter is necessary for the isolation/liberation of showers lean in muons, which are generated by gamma-rays). ENDFOOTNOTE.

For source Cyg X-3, yes even for others, are justified the observations in all electromagnetic ranges, and also the underground observations, which are used for the development/detection of some nonphoton emission (its existence it is very doubtful, but it cannot be proceeded from the preconception, necessary to seek that seeming improbable).

6. If we have in mind and indirect effect, then almost all directions of astrophysics are interconnected. To be occupied here by detailed enumeration is senseless. From the fact that it is nearer to astrophysics of the cosmic rays (or even it composes its part), let us mention only the study of solar cosmic rays, modulation of cosmic rays in the solar system, radio- astronomical investigations by the halo of galaxies (especially on the long waves $\lambda \gtrsim 1$ m) and of shells of supernovas, some combined X-ray and radio observations of the galaxies (it is intended the measurement of magnetic field on the comparison of reverse/inverse Compton X-radiation and synchrotron radio emission).

7. The most important new direction of cosmic-ray research far from Earth is recording generatable cosmic rays neutrinos with very high energies $E_{\nu} \gtrsim 10^{12}$ EV. Unfortunately, although the corresponding project ДЮМАНД (DUMAND) is considered beginning with 1975, it, apparently, is still sufficiently far from realization. The same relates also to other known projects, except, possibly, installation

on the lake Baykal. The survey/coverage of situation on 1984 is contained in Chapter 7 monographs [*], data sequence was given also on all latter ICRC[4], present conference is not exception. Since I myself am the co-author only of one work in this region[47] and neutrino astrophysics as a whole not "my diocese", I can claim to the known objectivity. So thus, the study of neutrino with the high energies seems to me the exceptionally/exclusively interesting and important direction of astrophysics.

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And simply by blindness on the part of the organizers of science seems the fact that so many years it is impossible to obtain the sufficiently modest means, necessary for the actualization of project DUMAND or to it similar. It is difficult to doubt, however, the fact that even to the mentioned anniversary dates neutrino high-energy astronomy will begin to live not only on the paper, or, it is more precise, it will enter the phase of observations.

8. Astrophysics of cosmic rays as entire/all astrophysics, is not thought without theory. In this respect already of Fermi taught to us a good lesson[34]. In the region theory is done much, in particular, in the last decade. We have in mind the analysis of propagation and acceleration of relativistic particles in the turbulent magnetized plasma and much other. Insufficient completeness and accuracy of observational data is usually, however, are retarded. On the whole, here it suffices to note that astrophysics of cosmic

rays has reliable theoretical guarantee and, as a whole, not the theory retards its development.

Said in present section of report - this, of course, not program of work and even not project of this program. Some known problems were only enumerated. Our goal is to stress that astrophysics of cosmic rays and adjacent it directions are at present the widely branched and developed region of investigations. It is completely clear, at the same time that much still must be done and it is possible to do. But the advance forward requires large efforts/forces, and in this respect are important understanding and aid from the side of the association of physicists and astronomers, organizers of space investigations and, strictly, all, the development of science depends on whom. It would like so that the present conference and, in particular, my lead-in report would contribute to this understanding.

I use possibility to thank for observations and councils of V. S. Berezinskiy, V. A. Dogel and V. S. Ptuskin.

Supplement.

The goal of publication of the present report is to acquaint sufficiently wide circle of physicists and representatives of close specialties with development of astrophysics of cosmic rays and its contemporary state. This region of physics and astronomy so grew also as a whole just as rapidly it progresses, that, as in a number of other cases, to layman increasingly more difficult to be in the policy of matter, to see forest after the trees/wood. At the same time many (and, as me it seems, with good reason) they attempt to follow the remarkable successes of astronomy, including astrophysics of cosmic rays and gamma-astronomy.

In the report I attempted, without entering in part, to demonstrate how much is already done, as spectrum of considered problems was wide and prospects and problems of further investigations were such. But so there is much material, that the picture willy-nilly proved to be several impoverished. Therefore it seems advisable in the present supplement first at least to enumerate the sections, to which was decomposed the program of conference. This separation was reflected, naturally, in those six volumes of the materials, which were created to participants in the conference directly before its beginning. Then several observations, which concern the considered questions, will be done.

1. On the 20th international conference on the cosmic rays (20th ICRC).

Entire material was divided into three parts (this concerns both the published works of conference and its program).

Origin of cosmic rays and galactic phenomena (code OG; vols. 1

and 2):

1. Gamma-bursts.

2. Gamma-rays from point sources and diffuse emission with energy of $E_{\gamma} \leqslant 3 \cdot 10^{11}$ eV.

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3. Gamma-radiation with energy of $E_{\gamma} > 3 \cdot 10^{11}$ eV.

4. Nuclei in cosmic rays with energy $E \leq 10^{12}$ eV/nucleon (composition, spectra, anisotropy).

5. Nuclei in cosmic rays with energy, $E > 10^{12}$ eV/nucleon (composition, spectra, anisotropy).

6. Electrons, positrons, antiprotons.

7. Propagation in interstellar space and nuclear interactions.

8. Acceleration and sources of cosmic rays.

9. Technology and equipment.

10. Different.

Phenomena in Sun and in heliosphere (SN; Vols. 3 and 4):

1. Particle acceleration in the Sun.

2. Charged particles with high energy and neutral emission in solar flares.

3. Propagation of solar cosmic rays in corona and in interplanetary space.

4. Particle acceleration and their propagation in heliosphere.

5. Composition (element and isotopic composition, ionization) of particles of solar and heliospheric origin.

6. Lasting modulation of galactic cosmic rays and anomalous component.

7. Transient and atmospheric effects for primary and secondary cosmic rays.

8. Geomagnetic and atmospheric effects for primary and secondary

cosmic rays.

9. Nuclear cosmogony (cosmogenic nuclides).

10. Solar neutrinos.

11. Technology and equipment.

12. Different.

Processes at high energies (HE; Vols. 5 and 6):

1. Interactions at high energies.
2. Hadron and electromagnetic cascades/stages.
3. Extensive air showers.
4. Muons.
5. Neutrinos.
6. New particles and processes.
7. Technology and equipment.
8. Different.

Volume of each volume from 420 to 530 pages (total volume of 2890 pages), in all in these volumes are published 852 reports (in certain cases they are published only theses). At conference itself was reported a whole series of new data. On the contrary, the published reports, whose authors did not arrive, as a rule, were not considered. The recent three days of the conference (but in all it occupied 12, partially incomplete, workdays) were dedicated to the pattern repeat reports (all in all it was 19). Furthermore, took place the "invited" (invited) reports:

V. L. Ginsburg (placed above report);

M. M. Shapiro, "75 years of the study of cosmic rays";

D. N. Shramm, "Nucleosynthesis in the stars";

K. de Yager, "processes with the high energy in the solar flares";

Ya. B. Zeldovich, "The universe - yesterday and today;

L. B. Okun', "Fundamental interactions: from pions to wions";

Ye. S. Stone, "Interplanetary investigations out of the plane of ecliptic";

P. Povinets, "Cosmic-ray research with the use of "cosmogonic" radioactive nuclei".

G. Rubenstein, "State of quantum chromodynamics in a plan of study of cosmic rays";

G. Folk, "Particle acceleration in astrophysical shock waves",

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To number of such reports can be attributed also communications/reports of J. Simpson "Acceleration of cosmic rays in external heliosphere" and R. Z. Sagdeyeva "processes near Halley's comet as model of Fermi-acceleration by galactic shock waves", although they figured by the name "highlight" of reports. Furthermore, were carried out conferences, dedicated to the collisions of relativistic ions, gamma-astronomies of superhigh energies and neutrino from the supernova SN 1987A. Finally, took place different the so-called "workinng discussions" (workshops).

Invited and pattern repeat reports, and also some other communications/reports will be subsequently published - will comprise three additional volumes.

All these data are cited here both for information and for purpose to illustrate scale and latitude of considered circle of problems and that entire region, which dedicated conference. Such conferences occur approximately every two years (following conference ICRC-21, it must take place in Adelaide (Australia) during January 1990.

It is important to stress also following: to astrophysics of cosmic rays (or, it is more precise, that its part, which dedicated my report) answers only approximately one third of entire problems, considered at this and other similar conferences (ICRC). Of course all three parts (OG, SH and HE), with which dealt the discussion above, one way or another they were interconnected. The character of connections/communications is various in the different cases and it is not always immediately obvious. For example, repeatedly was assigned this question: why at the conference on the cosmic rays of so many attention it is given to the Sun and the heliosphere? It would seem, is by this more appropriate at the special conferences dedicated to physics of the Sun and to space investigations. The answer here is such. Solar cosmic rays as other "products" of solar activity and processes in the Sun and in the heliosphere, undoubtedly, it is characterized considerably less by energy release and energy of the emitted charged particles, and photons. But, on the other hand, the nearness of the Sun and heliosphere makes it possible to carry out such detailed observations and measurements, about which with respect to of interstellar medium, stars and shells of supernovas, to say nothing of quasars, galactic nuclei and radio galaxies, it is possible only to dream. Thus, the study of the Sun and heliosphere for galactic and metagalactic astrophysics of cosmic rays, radio astronomy and gamma-astronomy plays role, analogous to laboratory investigations for physics it is space of plasma or role of laboratory spectroscopy for optical astronomy. The study of shock waves in the heliosphere (and even, let us say, near Halley's comet) can serve as a more specific illustration of the aforesaid for the purpose of checking the theory of particle acceleration in the shock waves. But if we speak about connection/communication of astrophysics of cosmic rays (OG) with high-energy physics, studied in the cosmic rays (HE), then it is also sufficiently obvious. For example, the investigation of the extensive air showers (ShAL - EAS), on the one hand, serves for the determination of the series/row of the processes of interaction and their special features at high energies. On the other hand, the same ShAL are utilized for the compositional analysis, spectrum and anisotropy of primary cosmic-rays with the high and superhigh energy.

In short, complex approach, combined (to known limits) discussion of all problems, connected with cosmic rays, it is fruitful and it is completely justified. It is another matter that "it is not possible to fill immense", something is necessary to sacrifice, something to select/take. The bias/displacement of accents, which gradually occurs from one conference to the next, is therefore understandable. For example, already ten years ago, to 15 ICRC, special subsection was dedicated to X-ray astronomy, now there is no such subsection already. At ICRC conferences sufficiently widely are considered the designs of different new installations and instruments. In proportion to the actualization of these projects begin, naturally, to be considered the obtained results.

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As a whole international conferences on cosmic rays (ICRC) play enormous role for development of entire region. In this respect ICRC can serve as an example, also, for other directions of physics and astronomy.

2. Several observations on the results of conference with respect to astrophysics of cosmic rays.

At regularly conducted, previously prepared conferences in center of attention are located usually not hits, but a comparison of new data, the report and discussion of parts and designs of new installations. This occurred also at the present conference. At the same time, naturally, observations of SN 1987A were not forgotten. As far as gamma-astronomical observations of the shell of this supernova are concerned, they are not yet produced, but the disclosed possibilities are briefly illuminated in the text of my report. As regards the sensational observations of neutrino from SN 1987A, this is the special theme on which here we will not dwell, although at the conference it gave much attention (it is possible to think that in the UFN there will be published the corresponding survey/coverage).

Another most widely considered question - observation of gamma-rays with high ($E_\gamma > 3 \cdot 10^{11}$ eV) and superhigh ($E_\gamma > 10^{14} - 10^{15}$ eV) energy. Special attention attract the dual sources: Cyg X-3, Her X-1, Vela X-1, "candidate into the black holes" Cyg X-1 and some others. All this is a theme for the special survey (partially this problem it is proposed to solve in the prepared survey/coverage of V. A. Dogel and author). Now we will be limited by several observations, which concern Cyg X-3, i.e., considered type most known source. This is clearly unsteady, by virtue of which the comparison of the observations, which were being carried out in the different time, is very difficult or, it is better to say, little about which he speaks. In last year two level of gamma-radiation Cyg X-3 with $E_\gamma > 10^{14} - 10^{16}$ eV, apparently, was very low. This gave rise to even doubts about that, was observed generally this emission from Cyg X-3. However, In the opinion of the pattern repeat (R. Prozero), the comparison of different measurements, which were being conducted simultaneously for the number of years, makes it possible to consider emission Cyg X-3 with the superhigh energies completely real (although, we repeat this which occurs always). The fact that further observations are necessary, in particular on the large installations, does not cause doubts. In this case is especially important the isolation/liberation of the extensive showers (Shal), created precisely by gamma-rays. To do this they attempt, taking into account that the ShAL, generated by gamma-rays, they must be relatively lean in muons, and also to differ from ShAL of nuclear origin in some its parameters. Unfortunately, exactly in these directions of reliable data it is not yet obtained. Thus, if we approach the problem very strictly, then the existence of gamma-radiation of superhigh energies from Cyg X-3, and, possibly, from other sources, has not yet been proved. It is obvious that the subsequent observations of any it is far going affirmations cannot be done. But if we speak about the impressions and the opinions, then I share the opinion about the fact that sporadic gamma- radiation of some dual sources in the region of superhigh energy $(E_\gamma > 10^{14} - 10^{15}$ eV) occurs.

Continuous discussion of data COS-B makes very probable existence let and small, but noticeable concentration gradient of cosmic rays in galaxy. In any case, the affirmations about the explicit absence of gradient and even about the metagalactic origin of cosmic rays at the conference were not repeated. Only new observations can lead to the reliable measurement of gradient and, generally, distribution and spectrum of cosmic rays (in essence of protons) in the galaxy.

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New observations (Ye. A. Bogomolov et al., report OG 6.1-1) and calculations (V. Weber, report OG 6.1-5) make problem of antiprotons less acute - they attest to the fact that in region of energies $E_{\bar{p}} > 1$ GeV quantity of antiprotons, possibly, is not anomalously large (i.e. it can prove to be that coordinating with that expected with passage by cosmic rays of interstellar gas with thickness $x \approx 5-7$ g cm^{-2}). The anomalously large flow of the antiprotons in the region of energies $E_{\bar{p}} \sim 0{,}1 - 0.3$ GeV (speech goes, of course, about the kinetic energy) was reported only in one work (Buffington a. et al. Astrophysical Journal, 1981, V 248, P 1179) and cannot be considered established/installed before the independent checking (similar measurements, as far as is known, at present exactly they are carried out in the USA).

At conference there were reported first results of the processing of data obtained with the help of the installation "Egg", which flew for 191 hours on the "Shuttle" ("Spachelab-2") in 1985 (see text of my report and reports OG 4.1-5, OG 9.2-1). It is characteristic that even the most ideal contemporary installation made it possible to obtain, even then preliminary, the information about the spectrum with the energy, which reaches 10^3 GeV/nucleon, only two years after flight. Already hence it is clear as to what extent complicated the corresponding observations and their working/treatment is labor-consuming. For the production of a spectrum of nuclei up to energies on the order of 10^4-10^5 GeV/nucleon are necessary the even larger installations weighing tens of tons. This is the matter of the future (hardly such results they will be obtained earlier than the years through ten).

With respect to element and isotopic composition of cosmic rays with smaller energies (let us say, with $E \leqslant 10\,\mathrm{GeV/nucleon}$), and also spectrum of positrons at conference was reported and was considered series/row of results. However, in my report this important series of questions was only touched upon, and anything drama:ically new at the conference was not reported. Therefore it is here inexpedient to concern to concern both the problem of composition and spectrum of the cosmic rays and series/row others, reflected in the works of the conference (they, incidentally, are sufficiently available, since the conference occurred in the USSR, and all its numerous participants obtained the complete assembly of works).

Thus, I will be bounded in conclusion only by the observation that participation in conference did not give to me foundations for changing anything essential in text that placed higher than report. In the limits of the limited targets, which pursued this report (and, it goes without saying, my possibilities), it reflects the contemporary state of astrophysics of cosmic rays (besides the questions, connected with the solar cosmic rays and the processes in the heliosphere).

Physics Institute im. P. N. Lebedev of the AS of USSR.

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FOOTNOTE[1]. The literature cited not only does not claim to the completeness (this is obvious), but, moreover, is given only for the orientation (furthermore, there are indicated sources from which the author borrowed some figures). ENDFOOTNOTE.

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