[redacted]

STAT

OFFICIAL USE ONLY

LITERATURE SURVEY

COSMIC RAY RESEARCH IN THE SOVIET UNION

Air Information Division
Library of Congress
March 1960

[redacted]

STAT

LITERATURE SURVEY OF COSMIC RAY RESEARCH IN THE SOVIET UNION

Air Information Division
Library of Congress
March 1960

TABLE OF CONTENTS

INTRODUCTION

Since the end of World War II, remarkable progress has been made in cosmic-ray research. The hundreds of studies that have been written during this period attest both a practical and a purely scientific interest in this form of radiation. In addition to the danger it represents in connection with space flight, cosmic radiation has an appreciable effect on the earth's atmosphere, possibly even influencing the weather according to E. P. Ney of the University of Minnesota and the Russian scientists Eygenson and Rakipova. The intimate relationship between cosmic radiation and certain astrophysical processes is now being studied by astronomers and cosmic-ray physicists to increase our knowledge of the galaxy and the universe. Radioactive tracers produced by cosmic-ray collisions are being used by scientists to investigate exchanges of matter in the atmosphere, biosphere and hydrosphere. These are just a few of the problems which are stimulating cosmic-ray research.

The purpose of this report is to provide a literature survey of Soviet research in this field. By way of comparison and illustration, non-Russian sources have frequently been cited. A complementary report deals with the closely related problem of Van Allen radiation belts.

In July 1959, the International Conference on Cosmic Rays was held in Moscow. According to the New York Times of July 14, 1959, Rossi and other Western representatives reported that Russian scientists are making some substantial contributions. Rossi referred specifically to the discovery of anomalies in the earth's magnetic field as a major development. Detection equipment shown at the Moscow University was reported to be of the best and latest types. A review of this conference by Dobrotin [55] points up the problems which have most interested Russian scientists in the past few years and which are likely to constitute a future trend, namely, the origin of cosmic rays, high-energy nuclear interactions, and the high-altitude composition and variations of cosmic radiation.

It may be useful here to associate the names of the leading Russian scientists with their main areas of research. Ginzburg and Shklovskiy have won wide recognition for their work on the theory of the origin of cosmic rays and the application of radio astronomy to the problem. Important contributions to the theory of high-energy interactions have been made by Landau, Feynberg, Grigorov, Takibayev, and Rapoport. Original work on extensive air showers and the intensity of cosmic rays at different altitudes and latitudes has been done by Zatsepin, Vernov, Rozental', and Khristiansen. Chudakov is known for his investigations of Cherenkov radiation of showers.

Finally, the work done by Dorman ranks him as a world authority on variations in cosmic-ray intensity. These scientists may be expected to continue their research on these important problems.

Aided by great progress in rocketry, Russian scientists are in a position to carry out more extensive high-altitude investigations. In the area of machine physics, plans for a giant 50 BeV accelerator are being drawn up. If built, this machine will be twice as powerful as the synchrotron installed at the European Center of Nuclear Research, now the largest in the world. It is also likely that much of the work initiated during the International Geophysical Year will give further impetus to Russian activity in the field of cosmic rays.

Part I of this report consists of eight sections corresponding in the main to a conventional breakdown of the subject. A given paper or study, however, does not always pertain solely to one section and may be cited in more than one. Bracketed numbers in the text refer to the bibliography which consists entirely of Russian materials available in the Library of Congress. Western sources are identified only by a publication date in parentheses. Part II of the report contains abstracts, summaries and translations of the more significant material arranged to correspond to the sections of Part I. It may be useful to note that many Russian studies on cosmic radiation are available in translation. Finally, information on the leading Russian cosmic-ray physicists and on cosmic-ray facilities and equipment is presented in three appendixes.

PART I.

PROBLEMS IN COSMIC RADIATION

A. THEORY OF THE ORIGIN OF COSMIC RAYS

From the beginning of cosmic-ray studies, theories of the origin of the radiation have been in a state of flux both in the West and in the U.S.S.R. This is due to a constant revision of views resulting from an increased knowledge of the galaxy and the rapid accumulation of basic data, especially during the last decade. For this reason a complete, generally accepted theory does not yet exist. Nevertheless, Russian contributions to this problem have been substantial. A general description of theories of cosmic-ray origin is to be found in a book on cosmic radiation by Zhdanov [271].

Dobrotin [53, p. 297] states that any acceptable theory of cosmic-ray origin must explain the following: (1) the power-law energy spectrum $N(E)\,dE=AE^{(\gamma+1)}\,dE$, where E = energy, $N(E)$ = number of particles, γ =a constant varying between 1 and 1.8, and A = a constant; (2) the absolute magnitude of energy carried by cosmic rays; (3) the composition of primary radiation, that is, the presence of protons, α-particles, and the nuclei of heavy particles; (4) the constancy of the intensity of cosmic radiation; and (5) the isotropy of cosmic radiation in space.

All modern theories on the origin of cosmic-radiation can be essentially reduced to the dynamics of ionized gas in a magnetic field and the creation of electromagnetic fields. It is assumed that a sufficient number of relativistic particles is created when the displacement of large masses of ionized gas takes place at high velocities (of the order of 1,000 km/sec). According to most theories, initial acceleration of particles occurs in the vicinity of stars. It has also been suggested that electromagnetic induction is caused by great changes in magnetic fields, such as occur during and between sun spots. This hypothesis is supported by observed changes in cosmic-ray intensity which can be related to solar activity (Dorman[61, Ch.8]).

It has been stated (Ginzburg [83]) that the main problem in explaining the origin of cosmic rays is that of the acceleration mechanism linked with actual astrophysical conditions and real bodies such as the sun and certain stars. Efforts in this direction began with Swann (1930) who pointed out that a change in the magnetic fields in sun spots (and probably in stars) with respect to time might lead to particle acceleration up to energies of 10^9 to 10^{10}eV.

In 1939 and again in 1952, Alfvén and his school of magnetohydrodynamicists presented a model of a "celestial cyclotron" based on assumed magnetic moments of double stars. This school maintains that solar particles as well as cosmic rays are accelerated magnetic and electric fields in space and considers erroneous the view of S. Chapman and V. A. Ferraro that during a flare the sun ejects a powerful stream of electrons and protons. Riddiford and Butler (1952) studied the acceleration of particles on the sun and in the atmospheres of stars. Terletskiy [227,228] and Kolpakov and Terletskiy [132] derived a detailed acceleration mechanism based on the noncoincidence of the magnetic moment of a star and its axis of rotation.

Many Soviet scientists have published significant studies on the origin of cosmic rays based on the work of Fermi (1949). Among these are Logunov and Terletskiy [157], Shklovskiy [209], Ginzburg [87,89], Pikel'ner [183,184], and Shayn and Gaze [207].

Logunov and Terletskiy [157] added to Fermi's theory by evaluating the motion of charged particles through interstellar "clouds" in a state of turbulent motion.

Pikel'ner [183], in his study of the motion of interstellar "clouds", found that such motion, in relation to the sun, equals on the average several tens of kilometers per second. In an article on the interstellar polarization of light (Pikel'ner [184]), he shows that (1) gaseous masses in interstellar space have a high conductivity, and (2) magnetic lines of force may be considered "frozen" to matter in interstellar space.

In studying the shape and motion of several gaseous "clouds" within the galaxy, Shayn, Gaze, and Pikel'ner [208] found that the shapes and motions observed can best be explained by assuming a state of turbulence and the existence of magnetic fields in the interstellar "clouds".

In a paper published in 1953, V. L. Ginzburg [83] reviews the work of Swann (1933), Alfvén (1950,1952), Richtmeyer and Teller (1949), Kiepenheuer (1953), McMillan (1950), Fermi (1949), Terletskiy [227], and Terletskiy and Logunov [229]. He arrives at the conclusion that the theory of the origin of cosmic rays should be based on radio-astronomical findings, particularly on radio emission due to the bremsstrahlung of electrons moving through magnetic fields. He also applies a rigorous mathematical analysis to the motion of charged particles through interstellar space and the envelopes of stars and draws the following conclusions:

1. Cosmic electrons with energies of 10^8 to 10^9 eV (where $1 \text{ eV} = 1.6 \times 10^{-12}$ ergs) are disseminated through galactic space in the same manner as rarefied intergalactic gas.

2. Energy density of cosmic particles in galactic space is about 1 eV/cm^3, and the volume and total energy of the particles are respectively 10^{68} cm^3 and 10^{68} eV.

3. There are no valid arguments for the hypothesis that the sun is the source of cosmic rays nor for the galactic origin of cosmic rays suggested by Terletskiy and Logunov [229].

Zwicky (1934) and ter Haar (1950) suggested that cosmic rays may be produced by supernovae explosions. Shklovskiy [209, 211] and Ginzburg [84] developed ter Haar's hypothesis as follows: (1) radio-astronomical data indicate that in explosions of supernovae the expanding envelopes generate a considerable number of relativistic electrons, cosmic protons, and nuclei; (2) in our galactic system new supernovae flare up, on the average, once every 300 years, giving off from 10^{39} to 10^{40} ergs of energy per second which is sufficient to supply the cosmic-ray energy reaching the earth; (3) assuming that in our galaxy about 100 novae occur each year, releasing 10^{39} to 10^{40} ergs per second, it is probable that the supply of cosmic rays from novae is greater than that from supernovae; (4) the birth of a supernova does not increase the intensity of cosmic radiation on earth because cosmic particles require considerable time to be accelerated, much longer than the period of birth of a supernova; (5) all the stars of the same class as the sun combined cannot account for more than a small fraction of the intensity of cosmic radiation.

Writing in 1956, Ginzburg [88] re-evaluates his earlier studies on the theory of the origin of cosmic rays taking into account theoretical and experimental data from Getmantsev and Ginzburg [82], Pikel'ner [83], Shklovskiy [209, 210], and Vladimirskiy [252], as well as studies by Baldwin, ter Haar, Morrison, Olbert, Rossi, and other non-Russian scientists. He states that the magnetic bremsstrahlung hypothesis, which links nonthermal cosmic radio emission with waves radiated by relativistic electrons moving in the interstellar magnetic field, not only yields values in agreement with the probable values of interstellar fields and the concentration of relativistic electrons, but is, in general, a very fruitful concept in the theory of radio astronomy and the theory of the origin of cosmic rays. The hypothesis explains the fact that at the earth not more than 1% of primary cosmic rays of energy greater or equal to 10^9 eV consists of electrons. This is due to the loss of energy by electrons in magnetic bremsstrahlung which is negligible for protons and nuclei.

In one of his most comprehensive papers, Ginzburg [90,91] further develops his ideas on the origin of cosmic rays and compares the hypotheses of other scientists. His concluding remarks point up the progress and problems in the theory of cosmic-ray origin and are included in translation in Part II of this report.

In 1958, the magazine Nuovo Cimento devoted a large supplement to cosmic radiation. In the section on the theory of the origin of cosmic rays there are twelve articles, three of which are from the U.S.S.R. In one of these, Ginzburg [92] reexamines the concepts and experimental data bearing on the problem as given previously by Ginzburg [84,86,88,91], Ginzburg and Fradkin [93], Pikel'ner [185], Pikel'ner and Shklovskiy [186], Shklovskiy [209,212], and a number of Western scientists. In this paper he states that:

1. Nonthermal cosmic radio emission is the emission of relativistic electrons moving in weak magnetic fields.
2. In determining the spectra of the radiation, it is assumed that the galactic corona includes irregular magnetic fields (H/r) of 10^{-5} oersteds.
3. The average energy density of unidirectional isotropic cosmic electrons with energies greater than 10^8 eV is about 10^{-2} eV/cm^3.
4. The lifetime of protons (T_p) and electrons (T_e) in the galaxy, where average gas concentration n varies from 0.01 to 0.1, is from 4 x 10^8 to 4 x 10^9 years.
5. Secondary electrons and protons resulting from nuclear collisions and subsequent decay ($\pi \rightarrow \mu \rightarrow$ electron) carry away approximately 1/10 of the total electronic energy of the electrons with energies greater than 1 - 3 x 10^8 eV.
6. The following energy is transferred to relativistic electrons and protons in the galaxy in a steady state:

   a. U_e = power = $\frac{\text{energy}}{\text{second}}$ = 10^{39} to 10^{40} ergs,
   where U_e = power transferred to the electronic component as a result of cosmic-ray proton-nuclei collisions;

b. U_{cr} — main power transferred to cosmic rays = 10^{39} to 10^{40} ergs approximately.

7. The major part of the power U_{cr} transferred to cosmic rays is supplied by primary sources including (according to Fermi) the moving interstellar gas cloud.

8. In accordance with recent radio-astronomical data and numerical values computed for U_e and U_{cr}, it is assumed that cosmic rays are formed as a result of the explosion of supernovae and probably also novae.

9. Relativistic particle generation takes place in the envelopes of supernovae and novae in accordance with Fermi's statistical acceleration mechanism.

10. The hypothesis of the solar origin of the major part of cosmic rays is not supported by present cosmic-ray data.

11. Energy considerations, radio-astronomical data, and other factors preclude the acceptance of the metagalactic origin of cosmic rays.

12. The galactic theory based on interstellar acceleration as the source of cosmic rays is not sufficiently supported by radio-astronomical observations.

13. The assumption of cosmic-ray acceleration due only to supernovae and novae explosions is plausible and sufficient to explain all the known facts.

Shklovskiy [212], in his comprehensive book on radio emission, devotes only a few pages to the theory of the origin of cosmic rays. In a later study, Shklovskiy [213] analyzes the work of Dombrovskiy [58], Ginzburg [83,84,85], Pikel'ner and Shklovskiy [186], Landau and Rumer [155], Shklovskiy [209, 210] and some Western scientists. His analysis leads him to the acceptance of a theory of the origin of cosmic rays similar to that postulated by Ginzburg [92].

There is now wide agreement that part of the low-energy cosmic radiation originates on the sun. It is believed that the ejection process is related to gas turbulence on the sun and to corresponding changes in the magnetic fields. The small but periodic variations connected with the sun-spot cycle is well known and sudden increases in the rate of arrival of cosmic rays have been observed at the time of solar flares accompanied by unusual ultraviolet and corpuscular radiation (Dorman [62]).

Mustel' [172,p.69] includes cosmic rays in solar corpuscular radiation. In an earlier work (Mustel' [171]), he concludes that corpuscular emission arises in photospheric faculae and overlying flocculi and is influenced by magnetic fields of sun spots. Vsekhsvyatskiy et al. [253], on the other hand, believe with some Western scientists that the corpuscular radiation issues from the corona (coronal rays). A recent paper by Kolpakov [131] complements the Mustel' hypothesis. In another recent study, Severnyy [205] deals with the problem of corpuscular emission during solar flares.

In 1958, two other leading astrophysicists published papers pertaining to specific aspects of the theory of the origin of cosmic radiation. Gordon [96] finds nonstationary stars to be a source of cosmic rays. The mechanism is one of nonthermal (synchrotron) radiation of relativistic electrons. Veksler [233] suggests a new mechanism for the generation of relativistic electrons based essentially on the law of the conservation of energy. According to this hypothesis totally ionized clusters of plasma moving through a heterogeneous magnetic field should give rise to the generation of fast electrons. Such electrons have become significant in the investigation of cosmic radio emission as it relates to the origin of cosmic rays.

Recently, Van Allen in the United States and Vernov et al. [244] have investigated the distribution of "cosmic" radiation up to 100,000 kilometers above the earth, and have presented theoretical considerations for its distribution in space. Vernov and his associates state that:

1. Under the action of cosmic rays the earth becomes a source of neutrons.
2. The neutrons, as uncharged particles, diffuse freely through the magnetic field of the earth, reaching great altitudes.

3. Decaying neutrons generate charged particles which move along the magnetic force lines of the earth.

4. Eventually a particle reaches high magnetic latitudes where the velocity vector of the particle gradually rotates in respect to vector H of the magnetic field of the earth until a 90° position is reached and the motion of the particle is or may be reversed.

5. Electrons and protons resulting from neutron decay are considered corpuscular emission of the earth and are subject to a certain law of distribution in time and space.

6. At considerable distances from the earth's surface the intensity of corpuscular emission diminishes in proportion to $1/R^2$ and later to $1/R^3$, where R is the distance, and the loss of the particles escaping from the magnetic trap is due to the nonconservation of magnetic moment.

For a more detailed presentation of the problem of radiation around the earth the reader is referred to the Report on Van Allen Radiation Belts prepared by the Air Information Division.

As has been shown, the basic questions in the problems of cosmic-ray origins concern the mechanisms of cosmic-ray injection and acceleration. Even though inconclusive, the postulates of Ginzburg and Shklovskiy, based on radio-astronomical data and Fermi's theory of acceleration, are now widely accepted outside as well as inside the Soviet Union.

B. BREMSSTRAHLUNG OF CHARGED PARTICLES AND THE ABSORPTION OF HIGH-ENERGY PROTONS

Most general works on cosmic radiation include a brief explanation of bremsstrahlung and pair production. A detailed theoretical treatment of the problem is to be found in Belen'kiy [33] and Heitler (Quantum Theory of Radiation, 1940, 1954). An example of the importance of bremsstrahlung has been given by Chudakov [46]. Writing on the investigation of the photon component by means of the third artificial satellite, he points out that the study of bremsstrahlung can be used to obtain useful information on the nature and intensity of corpuscular flux in the atmosphere.

Dobrotin [53, Ch.3] devotes several pages to these processes and lists the following basic phenomena that take place during the passage of charged particles and high-energy photons though material media:

1. A charged particle is slowed as it dissipates its energy in atomic excitation and in tearing off electrons from atoms (ionization and generation of high-energy electrons).
2. A photon can eject an atomic electron by giving all its energy to the electron (photoelectric effect).
3. In the field of an atomic nucleus a high-energy photon generates an electron-positron pair, giving up all its energy.
4. Scattering of photons takes place through the interaction of a photon and an electron as a result of the transfer of a part of the photon energy to the electron (Compton effect).
5. Interaction between a nucleus and a charged particle can produce a high braking effect accompanied by bremsstrahlung which is the emission of a photon of energy comparable to that of the incident particle.

In his treatment of the above phenomena, Dobrotin [53,Ch.3] takes into account theoretical and experimental contributions by Bethe (1929), Fermi (1940), Klein and Nishina (1929), Kharitonov [122], Kharitonov and Barskiy [123], Yeliseyev, Kosmachevskiy, and Lyubimov [255], Landau [148], Podgoretskiy [187], and Meshkovskiy and Shebanov [164].

On bremsstrahlung and photon absorption in particular, the same author states that:

1. The intensity of bremsstrahlung is proportional to the square of the acceleration and inversely proportional to the square of the mass of a particle.
2. Cosmic-ray meson and proton bremsstrahlung losses are insignificant.
3. Radiation loss of energy by an electron is greater in air than in lead.
4. Under certain conditions quanta of gamma rays produce electron-positron pairs.
5. The theory of the production of electron-positron pairs is based on Dirac's relativistic wave equation.
6. The production of electron-positron pairs cannot take place unless the energy of quanta is more than $2M_o c^2$, where M_o is the rest mass of a particle, and $c = 3 \times 10^{10}$ cm/sec.

Benisz, Chylinski, and Wolter (1959) investigated four high-energy electron-photon cascades and found that the experimental energy spectrum of first generation electron pairs shows a statistically significant deviation from the Bethe-Heitler energy spectrum curve and good agreement with the energy spectrum of Landau and Pomeranchuk [153,154] and Ter-Mikaelyan [230]. Migdal [168] has also contributed to the study of bremsstrahlung and pair production at high energies.

Several recent Soviet studies treat of polarization effects and spin in bremsstrahlung and pair formation. Nadzhafov [173,174] has investigated the elliptical polarization of a bremsstrahlung photon in addition to linear polarization. He also presents an analysis of the reversal of spin in bremsstrahlung. Kerimov and Nadzhafov [118] have investigated the case of bremsstrahlung of an electron with oriented spin, and in a later paper [119] derive a formula for the effective cross section for bremsstrahlung which is a generalization of the

Bethe-Heitler formula, with account taken of the longitudinal polarization of the electron and photon spin. Bremsstrahlung of particles with a spin of 2 has been studied by Bedritskiy [32].

Bremsstrahlung of other particles interacting with nuclei is at present receiving some attention. Dyatlov [70] and Lomanov et al. [159] discuss interaction of pi-mesons and various nuclei, taking into account the form of nuclei and the cross section for bremsstrahlung. Cross sections have also been investigated in a recent paper by Patarya [183].

The question of photonuclear reactions, or the interaction of nuclei and gamma bremsstrahlung, is the subject of papers by Chuvilo and Shevchenko [49] and Agranovich and Stavinskiy [6].

C. SOFT COMPONENT OF COSMIC RADIATION

The soft component of cosmic radiation comprises secondary electrons, positrons, photons, low-energy mesons and protons. These are produced in the earth's atmosphere and are designated "soft" because they are easily absorbed and, conversely, weakly penetrating.

Birger et al.[39], Vernov [238], and Carlson, Hooper and King (1950) showed that photons and electron-positron pairs are due to neutral pi-meson decay. Hooper and Scharff (1958) specify the decay of neutral pi-mesons as the most important source of this component. At low altitudes and at sea level, the soft component may be divided into three parts: (1) decay electrons, i.e. electrons resulting from the decay of mu-mesons; (2) knock-on electrons, which are knocked on by collisions with mu-mesons or other fast charged particles; and (3) the "nonequilibrium" soft component, i.e. photons and electrons not resulting from meson decay. Once created, these particles multiply in accordance with the cascade shower theory.

At sea level the soft component equals about 40 percent of the hard component. Azimov [23] found that at an altitude of 900 meters this percentage increases to 44 ± 5 percent, while at 3,860 meters it is 111 ± 5 percent. At a few kilometers above sea level the number of knock-on electrons grows proportionally with the intensity of the hard component while the number of decay electrons is proportional to the intensity of the hard component and inversely proportional to air pressure. Experimental evaluation of the number of decay electrons by Azimov, Vishevskiy, and Ryzhkova [28] gave results which do not deviate significantly from results obtained by using cascade theory formulas.

During the last few years many more data have been obtained on the soft component, thanks largely to the three Soviet artificial earth satellites. At the same time, additional problems have been revealed. Al'pert [17] reports data obtained by the first artificial satellite on electron concentration up to 650 kilometers, and tabulates the estimated concentration up to 3,100 kilometers. Use of the third artificial satellite for the detection and study of particles in the upper atmosphere and beyond has been reported by several researchers. Krasovskiy [141] presents evidence of high-intensity electron bands presumably of nonsolar origin. Vernov et al. [250] and Chudakov [46] report that luminescence counters recorded ten times as many counts as were expected from primaries. This is attributed to photons. The electronic component was also measured. Data obtained by this satellite have not been completely analyzed.

Significant studies of the soft component in the stratosphere at different latitudes and depths have been made by Vernov et al. [240], Ageshin, Charakhch'yan and Charakhch'yan [5], Rapoport [196], Azimov and Karimov [25], and Tulinov [231].

The cascade shower theory is based on the application of quantum electrodynamics. Integrodifferential equations to evaluate changes in the number of high-energy electrons and photons during their passage through matter are based on the pioneering work of Bethe and Heitler (1937) and Carlson and Oppenheimer (1937). This quantum approach was later modified by Landau and Rumer [155], Belen'kiy [33], Belen'kiy and Maksimov [36], and Janossy (1952,1954). It may be noted that Landau and Rumer [155] used Laplace and Mellin transforms in their work.

Vernov [237], Vavilov [232], Faynberg [77], and many Western scientists have investigated transition effects, that is, those effects which radiation displays in passing from one medium to a denser medium.

Guzhavin and Ivanenko [108] report that the problem of the one-dimensional development of an electron-photon cascade shower may be considered completely solved, but that the problem of a three-dimensional development of a cascade shower cannot be considered solved. Using the method of functional transformation (Belen'kiy [33]) and the method of moments (Ivanenko [113]), the authors were able to arrive at a fairly complete solution to the problem of the behavior of showers in light and heavy substances and to derive formulas for evaluating the angular and lateral distribution of particles in a cascade shower. Pomeranchuk [190] and Migdal [167,168] have also studied this problem. More extensive coverage of the question of showers will be found in section G of this report.

D. HARD COMPONENT OF COSMIC RADIATION

The penetrating, or hard, component contains all the high-energy nucleons and mesons, and is further defined as those rays which penetrate certain thicknesses of matter, usually taken as 10, 15, or 18 centimeters of lead. At sea level it accounts for 75 to 80 percent of registered radiation and is primarily composed of mu-mesons in the 5 - 6 x 10^8 eV range. The mass of mu-mesons is approximately 200 m_e. It has been said that apart from its decay process, the mu-meson is in all important respects a heavy electron (Fowler and Wolfendale, 1958). mu-mesons can be detected hundreds of meters underground. Nonionizing particles are also present in the hard component. In the atmosphere, the intensity of this component increases with altitude as does the ratio of protons to mu-mesons. Investigations of these mesons in the stratosphere have been carried out by Ageshin and Charakhch'yan [4], and Kocharyan et al. [130]. The ratio of positive mu-mesons to negative mu-mesons $\frac{N_{\mu+}}{N_{\mu-}}$ is found to vary from 1.25 at sea level to 1.5 at an altitude of 10 kilometers.

It may be recalled that Yukawa (1935) predicted the existence of a particle with a mass between that of electrons and protons. After the discovery of the mu-meson by Anderson and Neddermeyer (1938), research was carried out to identify it with Yukawa's particle. The theoretical difficulties in this research were resolved by the discovery of the pi-meson by Powell et al. (1947). Among others, the following scientists made theoretical and experimental contributions to the study of mu-mesons and the mass of charged particles: Conversi (1950), Wilson (1946), Alikhan'yan et al. [10], Kocharyan et al.[130], Alikhanov and Yeliseyev [8], Nikitin [175], Kharitonov [121], and Rozental' [201].

In a paper published in 1956, Grigorov [102] presents formulas for evaluating the number and intensity of nucleons, mesons, and particles producing stars in photographic emulsions. The formulas are applied to data for different altitudes and geomagnetic latitudes. His work is partially based on papers by Garibyan and Gol'dman [81] and Grigorov [101].

According to data supplied by Dobrotin [53, p.84], mu-mesons have a mean lifetime of several microseconds. This mean lifetime for a meson with an energy of 10^9 eV is ten times greater than that of a slow mu-meson. Instead of using the mean life, the "decay length" L may be used to denote mu-meson decay, with $L = \frac{z_1 - z_2}{\ln \frac{N_1}{N_2}}$, where z_1, z_2 = altitudes, and N_1 and N_2 = the number of mesons at altitudes 1 and 2. The constant of mu-meson decay is independent of the substance traversed, which indicates that the decay is spontaneous. It is concluded that the decay scheme is $\mu \rightarrow e^{\pm} + v + \overline{v}$.

Baradzey, Vernov and Smorodin [30] investigated the decay of mu-mesons in connection with the Fermi effect and atmospheric density. The effect of air pressure and temperature was studied by Feynberg [78]. Zhdanov and Naumov [273] found that the differential spectrum of paths up to 100 g/cm^2 of air is only slightly altitude-dependent. The latter investigators and Zhdanov and Khaydarov [272] have carried out work with delayed coincidences to study the decay mechanism and the products of decay. The passage of high-energy mu-mesons through matter is the subject of a recent paper by Rozental' and Strel'tsov [203].

mu-mesons moving in a compact medium expend their energy in the process of ionization. Stopped positive mu-mesons are subjected to Coulomb repulsion and decay. Negative low-velocity mu-mesons, after capture in the electric field of nuclei, begin moving along certain quantum orbits and may be captured by one of the protons of a nucleus. These negative mu-mesons may also decay.

Western cosmic-ray physicists helped formulate the theory that positively charged mu-mesons decaying in a filtering medium generate positrons, whereas negatively charged mu-mesons, in filters of light elements, produce electrons. Work in the West and by Podgoretskiy [88] has led to the conclusion that the capture of negative mu-mesons at sea level does not create high-energy charged particles and photons, that the capture of mesons leads to the disappearance of an equal number of protons and neutrons, and that in the process some energy is released in the form of a neutrino.

Shapiro [206] has investigated beta decay, a weak interaction typical of meson and hyperon decay. He postulates the following:

1. Parity is not conserved in β-decay of nuclei.

2. The angular distribution of decay electrons is anisotropic.

3. Space should be considered anisotropic, oriented for large distances and disoriented for small distances.

Shapiro's paper contains references to Zel'dovich [269], Landau [151,152], and Ioffe, Rudik, and Okun' [111]. A more recent discussion of this problem is to be found in Michel (1957) and Fowler and Wolfendale (1958).

E. HEAVILY-IONIZING PARTICLES, NUCLEAR DISINTEGRATIONS AND THEIR PRODUCTS

A particle moving with a velocity much lower than the velocity of light will ionize more heavily than a relativistic particle, that is, one moving with a speed close to that of light. In a nuclear emulsion the tracks of slow or high-charge particles will appear gray or black because of their greater density relative to those of fast particles. It has been established that the slow heavily-ionizing cosmic-ray particles consist of protons, α-particles, deuterons, tritons, mesons, and some heavier nuclei. The path length in which a charged particle is more heavily ionizing than a relativistic particle is proportional to the mass of the particle. Therefore, heavy charged particles are heavily-ionizing over a comparatively large path. This characteristic makes it possible to distinguish them from other particles.

Skobel'tsyn [215], and Razorenov and Knyazev [197], using a modified Wilson chamber in conjunction with proportional counters, were able to differentiate ionization bursts due to heavy particles from those due to showers. Skobel'tsyn showed that most bursts in an unshielded chamber at sea level are produced by showers, but that at heights of only a few thousand meters the relationship is reversed. Using a thin-walled chamber, Rossi and Williams (1947) found, in opposition to Skobel'tsyn's data, that 98 percent of ionization bursts at 3,000 - 4,000 meters are caused by strongly-ionizing heavy particles.

At the Third All-Union Conference on the Physics of Cosmic Rays in 1954, Chudakov [44] and Rapoport [195] presented papers on ionization of cosmic-ray particles in the stratosphere. The latter paper shows that there is an appreciable flux of strongly-ionizing particles accounting for over one-third of the total ionization.

Other Soviet contributions to the theory of heavily-ionizing particles and the recording of particles by means of chambers, counters and nuclear emulsions include Kharitonov [123], Landau [148], Gorbunov [95], Alikhan'yan and Marikyan [16], Takibayev [223], and Grigorov, Yevreynova and Sokolov [106].

Experiments conducted by Blau and Wambacher (1937) established that cosmic-ray particles cause nuclear disintegrations. These are due to the various possibilities of interaction between nucleons, nuclei, and the nuclear-active pi-mesons. The star, which is formed by the emerging, strongly-ionizing particles, is typical of such interaction. An excited nucleus radiates protons and neutrons by "evaporation". It has been found that in light nuclei the ratio of neutrons to protons is equal while in heavy nuclei the ratio is approximately 3/2. In studying high-energy interactions, nuclear emulsions and Wilson chambers in a magnetic field have proved reasonably effective despite the limitations of each.

Alikhan'yan and Marikyan [16] and Marikyan [161] found that the energies of secondary deuterons are in many cases as high as 10^8 eV. The reason for the appearance of a large number of particles with energies considerably exceeding their binding energy is still not clear. Using a magnetic mass spectrometer developed by Alikhan'yan and Alikhanov, Asatiani and Khrimyan [22] have determined the momentum spectrum of negative pi-mesons from stars and the ratio of negative pi-mesons to positive pi-mesons. Recently, two similar studies at mountain altitude were made by Alikhanov et al.[8] and Khrimyan [124] to determine the nature and momentum spectrum of protons, deuterons and K-mesons generated by charged and neutral particles of high energies.

In a recent study on the multiple production of particles in jets, Chernavskiy [42] says: "Jet showers in photoemulsions are due to the interaction of high-energy nucleons ($>10^{10}$ eV) with a substance. The following events are possible: (1) interaction of a nucleon with the internal parts of a heavy nucleus; (2) direct collision of a nucleon with a heavy nucleus; (3) direct collision of a nucleon with one of the surface nucleons of the nucleus or with a hydrogen nucleus; (4) peripheral interaction of a nucleon with a nucleon when the incident nucleon passes within a certain minimum distance of the edge of the nucleus". The first two cases have been investigated by Ivanovskaya and Chernavskiy [115], Landau [150], Maksimenko and Rozental' [160], and peripheral collisions have been studied by Feynberg and Chernavskiy [79], and Rozental' and Chernavskiy [202].

According to Zatsepin [260], it is ordinarily assumed that in a collision of nucleons a certain coupled system is formed which takes up the entire energy of the incident nucleon and that the break-up of this system leads to the production of particles. However, when the energy of the colliding nucleons is high, there is another possible mechanism of multiple production of particles as follows: (1) the interacting nucleons exchange a small portion of their momenta and energy; (2) one or both nucleons become excited; (3) the excited state of the nucleons leads to the production of particles. It is quite possible that stars may also be produced simultaneously by both types of interaction.

In 1956, two survey papers were published (Grigorov [102] and Saakyan [204]) on the passage of the nucleonic component through the atmosphere, high-energy collisions and the generation of pi-mesons. The study of high-energy particles and interactions with the aid of a synchrocyclotron built in 1949 is the subject of a detailed paper by Dzhelepov and Pontecorvo [71].

The question of star-producing particles, stars and related processes has been examined in several papers by Takibayev. He has investigated the transition effect for stars at altitudes up to 30 kilometers (Takibayev [224,225]. More recently, the spatial distribution of stars and the possibility of a genetic connection between near stars were investigated by Loktionov, Stafeyev, and Takibayev [158]. No experimental evidence of a genetic relationship was obtained, but the possibility is not excluded in theory.

Detailed investigation of proton-proton and neutron-proton collisions has shown that nuclear forces are independent of the electric charge of the interacting nucleons. To explain this, the theory assumes that these forces are the result of the emission and absorption of particles by nucleons and that in addition to charged particles, there are neutral particles which are agents of nuclear interaction. It follows that the mass of such neutral particles should not deviate greatly from that of the charged particles, that is, the charged pi-mesons.

Bjorklund,. Grandall, Moyer and York (1950) first demonstrated the existence of neutral pi-mesons by bombarding a target with high-energy protons. Steinberger,,Panofsky, Steller (1950) obtained further evidence of neutral pi-mesons by bombarding a beryllium target with high-energy gamma rays. A more accurate determination of the mass of neutral pi-mesons was supplied by Panofsky et al. (1951). Landau [149] showed that the pi-meson has a spin 0 and a very short lifetime. In 1957, Barkov and Nikol'skiy [31] published a critical review of pi-meson studies in the U.S.S.R. and in the West.

Dobrotin [53,Ch.7] ascribes the first systematic investigations of the composition of cosmic rays to Alikhan'yan, Alikhanov, and their coworkers. The existence of heavy particles of mass between that of light mesons and protons was demonstrated by Alikhan'yan and Alikhanov [9], Alikhan'yan and Kharitonov [13,14], Alikhan'yan, Dadayan, and Shostakovich [12], Vernov, Dobrotin, and Zatsepin [239], and Alikhanov and Yeliseyev [7]. By improving the design of their mass-spectrometer, Alikhan'yan et al. [15] were able to detect a heavy particle with a mass of 2230 ± 150. From photographic plates flown to an altitude of 3,500 meters, Powell et al. (1949) detected a heavy particle, the tau-meson, later found to decay into three pi-mesons. Friedlander (1954) obtained evidence from photographic plates indicating the existence of a charged particle with a mass greater than that of a nucleon.

All these investigations relate to the heavy unstable particles, sometimes called the "strange" particles, which are divided into two major classes, the K-mesons or heavy mesons, and the Y-particles or hyperons. They may be positive, negative, or neutral. A recent, extensive monograph on these particles has been written by Markov [162]. In the study of their properties, the work of Gell-Mann and Pais (1953,1955) has been very significant. Table 1 shows the properties of these and other elementary particles.

Using a combination of two nuclear-emulsion plates in a strong magnetic field at 3,500 meters, Franzinetti (1950) observed over 300 stopped particles. According to his estimates, the maximum number of K-mesons could not be more than 2 percent of the total number of heavy particles. Similar conclusions were reached by Brown et al. (1949) and Fowler (1950) from data obtained at an altitude of 40 kilometers. τ-mesons found in an emulsion stack were investigated by Gramenitskiy et al. [97] who found evidence to support the hypothesis that τ-mesons and κ-mesons are different particles.

In other more recent studies of K-mesons, Zel'dovich [268] investigates neutral K-mesons and cross sections for their interaction with electrons. Investigating the properties of K-mesons, Granovskiy [99] concludes that the mass, parity and spin of these particles may be determined according to the Heisenberg theory.

The track of a V-particle was first observed by Rochester and Butler (1947) using a Wilson chamber at sea level. These authors suggested that the observed forked track was formed by a charged pi-meson and a charged mu-meson resulting from the decay of a neutral V-particle. Seriff et al. (1950) were able to show that V-particles constitute approximately 3 percent of the charged particles generated by high-energy interactions. Dobrotin [53], assuming two forms of neutral V-particles, suggests the following decay scheme:

$$\Lambda^{\circ} \longrightarrow p + \pi^{-} + Q, \text{ and}$$
$$\theta^{\circ} \longrightarrow \pi^{+} + \pi^{-} + Q,$$

Table 1.

Fundamental Particles

Symbol	Charge	Name	Mass		Decay Products	Q MeV
			m_e	MeV		
γ	0	Photon	0	0	Stable	0
ν	0	Neutrino	<0.0005	<250 eV	stable	0
$\tilde{\nu}$	0	Anti-neutrino	<0.0005	<250 eV	stable	0
e-	-	Electron	1	0.510976	stable $e^+ + e^- \to k\gamma$	0
e+	+	Positron	$m_{e+} = m_e$ - 1)		stable $k = 1,2,3\ldots$	0
$\mu+$	+	μ^+ -meson	~206.7	105.70±0.06	$e^+ + \nu + \tilde{\nu}$	105.1
$\mu-$	-	μ^- -meson	~206.7	105.70±0.06	$e- + \nu + \tilde{\nu}$	105.1
$\pi+$	+	π^+ -meson	~273.3	139.63±0.06	$\mu^+ + \nu$	~34
$\pi-$	-	π^- -meson	~272.8	139.63±0.06	$\mu- + \tilde{\nu}$	~34
π°	0	π° -meson	~264.3	135.04±0.16	$\gamma + \gamma$	~135
$K^\pm$	+-	K -mesons 2)	~966	494.0±0.14	$K+ \to \pi^+ + \pi- + \pi^+$	~ 75
					$\pi^+ + \pi^\circ + \pi^\circ$	~ 83
					$\mu^+ + \nu$	~389
					$\mu^+ + \nu + \pi^\circ$	~250
					$e^+ + \nu + \pi^\circ$	~358
Θ_1°	0	Θ°-meson	965±10	493±5	$\pi^\circ + \pi^\circ$	~ 223
					$\pi^+ + \pi-$	
Θ_2°	0	Long-lived Θ°-meson	$\Theta_2^\circ \sim \Theta_1^\circ$			~ 214
P	+	Proton	1836.12	938.213±0.01	$p^+ + e^- + \tilde{\nu}$	0
n	0	Neutron	1838.65	939.506±0.01		0.7830
$\tilde{p}$	-	Anti-proton	$m_{\tilde{p}} \sim m_p$			
$\tilde{n}$	0	Anti-neutron	$m_n \sim m_{\tilde{n}}$			
Λ°	0	Λ°-hyperon	~ 2181	1115±0.016	$p^+ + \pi^-$	~36.9
					$(n + \pi^\circ)$?	
Σ^+	+	Σ^+-hyperon	~ 2327	1189.3±0.3	$p^+ + \pi^\circ$	~ 116.1
					$n + \pi^+$	~ 110
$\Sigma-$	−	Σ^--hyperon	~ 2340	1196.5±0.5	$n + \pi-$	~ 118
Σ°	0	Σ°-hyperon	~ $m_\Sigma \pm$ 4)	1188.5±3	$\Lambda^\circ + \gamma$	~ 70
$\Xi-$	-	Cascade hyperon	~2585	1321±3.5	$\Lambda^\circ + \pi-$	~ 65
Ξ° 5)	0	Cascade hyperon	~$m_{\Xi-}$		$\Lambda^\circ + \pi^\circ$	

Phenomenological Classification:
"V -events" - decays of hyperons and K-mesons in flight;
"S -events" - decays of stopped hyperons and K-mesons.

Table 1. (continued)

Symbols	Lifetime (sec.)	Spin	Parity	Isotopic Spin		Strange-ness	Class	Comments
				I	I_z			
γ	∞	1						
ν	∞	1/2					Leptons	1)Equal within a margin of 0.007%
$\tilde{\nu}$	∞	1/2						
e^-	∞	1/2						
e^+	∞	1/2						
μ^+	$(2.22\pm0.02)\cdot10^{-6}$	1/2						
μ^-	$(2.22\pm0.02)\cdot10^{-6}$	1/2						
π^+	$(2.56\pm0.05)\cdot10^{-8}$	0	-	1	+1	0	L-mesons	
π^-	$(2.56\pm0.05)\cdot10^{-8}$	0	-	1	-1	0		
π°	$(1\div4)\cdot10^{-16}$	0	-	1	0	0		
$K^\pm$	$(1.224\pm0.013\cdot10^{-8}$ 3)	0?		1/2?	1/2?	1	K-mesons	2)K-mesons is the general name for particles of similar mass and lifetime, but with different decay modes. 3)According to Lee $t_{K}=(1.19\pm0.95)10^{-8}$ sec.
θ°_1	$(0.95\pm0.08)\cdot10^{-10}$	0?	?	1/2?	-1/2?	1		
θ°_2	$(0.3< t <10)\cdot10^{-7}$	0?	?	1/2?				
p	∞	1/2		1/2	1/2	0	Nucleons	
n	$(1.04\pm0.13)\cdot10^{3}$	1/2		1/2	1/2	0		
$\tilde{p}$							Anti-Nucleons	
$\tilde{n}$								
Λ°	$(2.77\pm0.15)\cdot10^{-10}$	?		0?	0?	-1	Hyperons	4)Preliminary data: $m_{\Sigma^+} < m_{\Sigma^\circ} < m_{\Sigma^-}$.
Σ^+	$(0.78\pm0.074)\cdot10^{-10}$	?		1?	1?	-1		
Σ^-	$(1.58\pm0.17)\cdot10^{-10}$	?		1?	-1?	-1		
Σ°	$\tau_{\Sigma^\circ} << \tau_{\Sigma^+}$	?		1?	0?	-1		
Ξ^-	$(4.6< t <200)\cdot10^{-10}$	?		1/2?	-1/2?	-2	Cascade hyperons	5)Predicted on the basis of the hypothesis of isotopic invariance.
Ξ° 5)		?		1/2?	+1/2?	-2		

where the mass of Λ° is taken as $2200m_e$, the mass of Θ° is taken as $800m_e$, and Q equals the kinetic energy of the decay products. Other modes are indicated. However, more recent data are furnished by Markov [162] and Thompson (1956).

Fowler et al. (1953) were successful in producing neutral V-particles artificially by bombarding carbon targets with neutrons of 2.2×10^9eV and with high-energy negative pi-mesons. Similar experiments were made by Tidman et al. (1953), Danysz and Pniewski (1953), Zhdanov and Lukirskiy [270], and Danysz, Lock, and Yekutieli (1952). The creation of neutral V-particles in complex nuclei has been investigated recently by Azimov, Masagutov, and Yunusov [26], and the emission of neutral V-particles during nuclear capture of K-mesons is the subject of a paper by Bunyatov et al. [41].

Application of the theory of dispersion relations to the study of the production of strange particles has been suggested by Polivanov [189]. A paper by Bannik et al. [29] presents new data on the identification of hyperfragments.

The nature of interactions involving heavy mesons and hyperons is exceedingly complex. Worthy of note in this connection are three recent papers by Okun', Pomeranchuk, and Shmushkevich [181], Hu Ning [110], and Matinyan [163].

The research problems set out here are among the most complex in cosmic-ray physics. They also constitute a focal point of interest of Russian scientists. More discoveries can be anticipated with the increasing use of rockets and satellites to investigate ionization and interaction of fast and heavy particles at the top of the atmosphere. To complement this research, a new 50 BeV accelerator is being planned. If carried out, this will give access to the high-energy range under controlled conditions and new data on the behavior of particles at high energies will doubtless be obtained.

F. PRIMARY COSMIC RAYS AND GEOMAGNETIC EFFECTS

The study of high-energy particles entering the atmosphere is an important aspect of nuclear physics since the energy of most primaries greatly exceeds the energies that can be attained in accelerators.

Charged particles follow a helical trajectory around magnetic lines of force. The fact that most primaries are charged is indicated by their deflection in the earth's magnetic field. From an elementary consideration of the earth's magnetic field, approximated by a dipole field, it is clear that positively charged particles approaching vertically in the equatorial plane will be deflected to the east while negatively charged particles will be deflected to the west. Lemaître and Vallarta (1933,1936), and Vallarta (1935,1948) developed Störmer's theory to explain the trajectories of cosmic-ray particles in a magnetic field. Assuming isotropic distribution of cosmic rays in space, this theory indicates that there are certain directions in which the number of particles reaching the earth is independent of the earth's magnetic field provided the energy of the primary particles exceeds a certain minimum magnitude. In other words, for each point on the earth's surface there are permissible directions (Störmer's cones) from which cosmic particles are able to reach the earth. The theory of allowed and forbidden cones becomes much more complicated when the effects of the solid earth and the penumbra are taken into account.

Near the equator, primaries with energies less than 10 BeV cannot penetrate the atmosphere. The intensity of the radiation increases with latitude to $\lambda = 45°$, the latitude cutoff. Beyond this, increased intensity is not appreciable. Störmer (1931) expressed the relationship between the necessary minimum momentum of a particle reaching the earth and the magnetic latitude of the point of observation as follows:

$p = 14.9 \times \mathrm{Cos}^4 \lambda$, where p = momentum in eV/c, and λ = angle of magnetic latitude.

Experimental data show that the primary radiation is predominantly positively charged. This results in somewhat greater intensity from the west. This east-west asymmetry has been studied by Vernov and Kulikov [246], Vernov et al. [243], Vernov, Kulikov, and Charakhch'yan [247], Winckler et al. (1950), and Biehl and Neher (1950).

It is now generally accepted that protons and stable nuclei stripped of orbital electrons constitute the primary radiation. Critchfield, Nay, and Oleksa (1950) concluded on the basis of experiments at altitudes of 5 - 25 kilometers that electrons and photons comprise less than 1 percent of the total number of primary particles. The presence of negative antiprotons has been postulated by Vernov and Kulikov [246].

Bradt and Peters (1950) discovered that at an altitude of 36 kilometers primary cosmic rays contain the nuclei of relatively heavy elements with Z as high as 26 (Fe). Later, Skobel'tsyn [218] detected the nuclei of oxygen among the primaries. Kaplon et al. (1952) found that the flux of particles with $Z > 2$ is considerably smaller than that of α-particles. Dividing these particles into groups I (B,Be,Li), II (C,N,O,F,), and III (nuclei with $Z > 16$), the authors found the relative intensities to be 15.0, 12,0, and 1.2 respectively. Ginzburg [91] offers the following table showing the relative abundance of the primaries.

TABLE I

Relative Abundance of Nuclei in the Primary Cosmic Radiation Compared With Their Universal Abundance

Nuclei	Primary cosmic radiation			Universal abundance per 10^5 hydrogen atoms
	Number per 10^5 protons	As a % of primary particles	% of primary nucleons carried	
Protons (p)	100 000	91.5	69	100 000
α-particles (Z=2)	10 000 (8 000)	7.8	23	7 700
L-group (Li, Be, B; Z = 3 - 5)	$\lesssim$ 50 (?)	-	-	3.6×10^{-4}
M-group (C, N, O,F; Z = 6 - 9)	520 (400)	0.4	4.5	80
H-group ($Z \geqslant 10$)	160	0.15	3.5	30
Iron (Fe; Z = 26)	30	-	-	1.5
All nuclei $Z > 30$	< 1	< 0.001	-	10^{-3}

(After Ginzburg, Uspekhi fizicheskikh nauk, v. 62, no. 2, 1957)

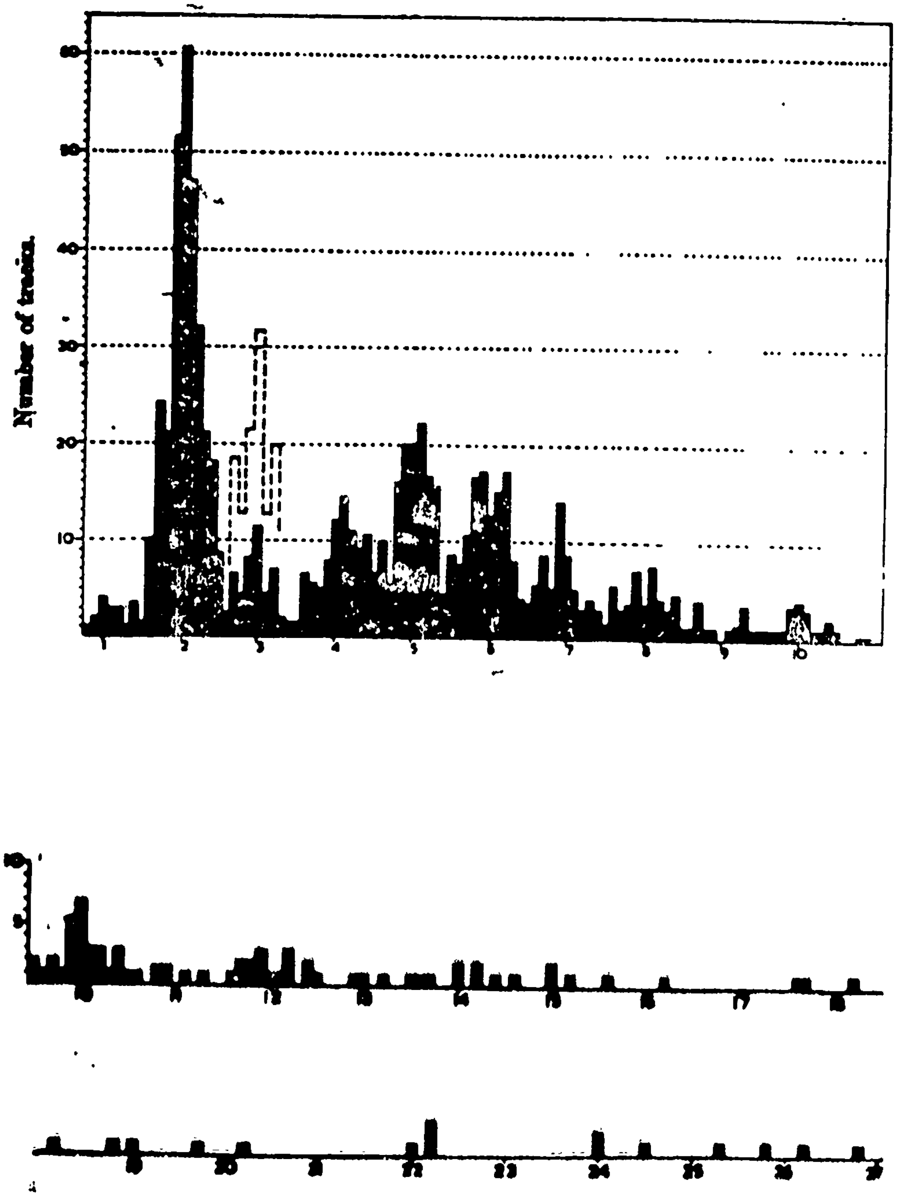
Quite recent work on the composition of primaries has been done by Kurnosova, Razorenov, and Fradkin [144] who investigate evidence for nuclei with Z > 30, and by Korchak and Syrovatskiy [134], investigating the prevalence and selective acceleration of heavy nuclei. Figure 1 below shows the charge distribution for particles with Z > 2, the α-particles being included only for charge calibration.

In 1948, Vallarta investigated the energy of incident protons as a function of magnetic latitudes. Similarly, Vernov [236] and Kocharyan et al. [129] studied the energy spectrum of charged particles as a function of magnetic latitude and altitude. Vernov, Kulikov, and Charakhch'yan [247,248] studied the energy distribution with respect to geographical latitude. Also based on the latitude variations of the ionizing and neutron components is the coupling function treated by Dorman [60, 61: Ch. 4]. This concept, which expresses the relationship between primary changes and secondary changes, is also called the yield function and the relative intensity spectrum.

Vernov [237], and Millikan, Bowen, and Neher (1938) computed the intensities of primary cosmic rays in the stratosphere. Study of cosmic-ray intensity with the aid of satellites is discussed by Kurnosova [142].

Finally, the possible effect of cosmic radiation on the earth's magnetic field has been studied by several Soviet scientists. Berishvili [38], Katsiashvili [117] and Khvedelidze [127] correlate variations in solar corpuscular radiation with magnetic storms. Shuleykin [214] suggests a complex relationship between cosmic rays and the earth's magnetic field, but finds no conclusive evidence for the relationship.

Figure 1.



(From Dainton et al. Philosophical Magazine, v. 43, 1952)

G. COSMIC-RAY SHOWERS

The investigation of extensive air showers has proved to be one of the most effective means of gathering information on primary cosmic rays and the interaction of high-energy particles. The energy of the initiating primary, for example, can be approximated from the total number of secondaries at a given depth in the atmosphere. The number and distribution of the secondaries also give some indication of the interactions which take place higher in the atmosphere.

Using electronic counters placed relatively far apart, Auger, Maze, and Robley (1938) established the existence of extensive air showers. Later, at Skobel'tsyn's suggestion, Zatsepin and Miller [262] used several groups of counters to evaluate the spread of extensive air showers. Their observations confirmed the existence of showers covering areas of several hundred acres. It was also shown that shower particles do not cover the area uniformly, particle density being greatest along the core of the shower.

Intensive investigation followed the discovery of air showers. The electron-photon cascade was found to be a secondary phenomenon, the primary one being a nucleon cascade. Dobrotin [53] points out that the electromagnetic cascade theory is inadequate to explain all the processes occurring in showers, especially high-energy nuclear interactions. Landau and Pomeranchuk [153,154] found that the formulas for the probability of pair production and the emission of quanta by bremsstrahlung are not valid for electrons and photons of extremely high energies.

A comprehensive method for the investigation of extensive air showers is described by Dobrotin et al. [56]. The most thorough and up-to-date account of research on extensive air showers, including Russian contributions, is contained in a monograph by Galbraith (1958).

On the basis of research done by Grigorov and Murzin [103], Grigorov, Yevreynova, and Sokolov [106], and Vernov, Kulikov, and Charakhch'yan [248], Dobrotin [53,Ch. 10] makes the following points concerning the generation of the soft component in showers:

1. The number of knock-on electrons increases much more slowly with altitude than electron-nuclear showers, and in the stratosphere, the number of knock-on electrons generated in filters between and above counters is negligible compared with electrons and photons from electron-nuclear showers:

2. Primary protons with an average energy of 3×10^9 eV transmit through neutral pi-mesons about 0.3×10^9 eV to photons and electrons in their first collision with the nuclei of hydrogen and oxygen;

3. Primary protons with energies over 7×10^9 eV transfer on the average 2.1×10^9 eV to neutral pi-mesons as a result of the first collision with a nucleus;

4. Protons of extremely high energies generate neutral pi-mesons in more than three successive acts;

5. The formation of showers with the participation of secondary mesons becomes substantial at primary energies near 5×10^9 eV; at lower energies most of the energy goes into other processes, particularly the generation of stars;

6. The energy flux of the soft component resulting from the decay of mu-mesons is 15 percent of the total energy flux of the soft component, which shows that the greater part of this component originates in electron-nuclear showers.

Janossy (1944), Veksler, Kurnosova, and Lyubimov [234], Birger et al. [39] studied the properties of showers with counters and Wilson chambers in a magnetic field. They established the fact that in addition to electrons and photons, penetrating particles and nuclear-active particles are present in showers of a special kind. The Russians call these showers electron-nuclear showers.

The penetrating component of air showers consists primarily of mu-mesons, nucleons, pi-mesons, and neutrons. The latter three are often called the N-component.

Eydus et al. [72] have shown that (1) in extensive air showers, penetrating particles constitute about 2 percent in the core and up to 50 percent on the periphery and (2) the total number of penetrating particles over the total area of an extensive air shower is about 10 percent of the total number of particles at sea level. The average energy of penetrating particles is given as 10^9 eV by Dobrotin [53].

Additional theoretical and experimental data on electron-nuclear showers are to be found in Zatsepin [258], Korablev, Lyubimov, and Nevrayev [133], Kurnosova and Tikhonova [143], Vernov, Kulikov, and Charakhch'yan [248], and Azimov and Vishnevskiy [27].

The discovery of mu-meson decay made it clear that mu-mesons are not extra-atmospheric in origin but rather one of the products of the absorption of protons in the upper layers of the earth's atmosphere. Penetrating mu-mesons reach the earth's surface in relatively large numbers and penetrate to considerable depths before being absorbed.

In their study of air showers at an altitude of 3,860 meters, Zatsepin and Sarycheva [266], Birger et al. [39], and Anishchenko et al. [20] found that around the core of a shower nuclear-passive mu-mesons constitute 75 percent and nuclear-active particles 25 percent of the penetrating component. A very recent investigation by Vernov, Khrenov, and Khristiansen [245] also deals with the flux of mu-mesons in extensive air showers. The mechanism of multiple mu-meson generation is examined in one of the latest papers by Rozental' [201].

In experiments up to 4,300 meters, Tongiorgi (1949) found that the number of neutrons in extensive air showers is proportional to the number of electrons and is equal to 1 to 2 percent of the number of charged particles in a shower. According to Dobrotin [53,p.237], the large number of neutrons in showers in lead indicates that a number of successive nuclear disintegrations take place in the lead.

Azimov et al. [24], using a Wilson chamber in a strong magnetic field at 3,860 meters, were able to separate protons from mesons. It was established that protons with energies from $0.5 — 2 \times 10^9$eV comprise 30 percent of the penetrating particles in electron-nuclear showers. Verkhovskiy et al. [235] studied nucleon interactions at high energies and found that free protons as well as nucleus-bound protons and neutrons are equally capable of generating electron-nuclear showers.

The discovery of electron-nuclear showers helped to clarify the phenomenon of extensive air showers as due to both electromagnetic and nuclear processes. The reaction of primary particles of very high energies, i.e., over 10^{11}eV, with atmospheric nuclei gives rise to the shower process which is continued by secondary nuclear-active particles. In each reaction a certain amount of energy is transferred from neutral pi-mesons to photons and electrons.

Dmitriyev, Khristiansen, and Kulikov [52] made a statistical sea-level investigation of electron-nuclear cascades in extensive air showers with high-energy particles ranging from 10^{11} to 10^{12}eV. Some of their findings are as follows:

1. The role of electron-photon cascades in the creation of bursts is insignificant;
2. Nuclear disintegrations may be produced by low-energy nuclear-active particles;
3. Large bursts are produced by high-energy nuclear-active particles;
4. The basic energy carried by a nuclear cascade is concentrated in a core less than 3 meters in radius.

Related studies have been made by Abrosimov et al. [3] and Andronikashvili and Bibilashvili [19].

Much theoretical work on the nuclear cascade model has been done by Rozental' [198,199]. In Table 1 below, taken from the first of these papers, v is a variable parameter, and the parameter b represents the fraction of nucleons present in the secondary particles.

A similar investigation, under somewhat different conditions, was carried out by Guzhavin and Zatsepin [109]. Their findings differed from those of Rozental' in several respects, particularly in the slope of altitude dependence.

The passage of nuclear cascades and the nucleonic component through the atmosphere has been surveyed by Saakyan [204] and solution of equations describing the process has been treated in recent papers by Ivanenko et al. [114], and Zatsepin, Nikol'skiy and Pomanskiy [264]. Dobrotin [54], in a paper presented at a conference in Budapest in 1956, reviews the research on high-energy nuclear processes in the U.S.S.R. and abroad, especially as related to extensive air showers.

High-energy nuclear and nucleonic interactions were investigated by Pomeranchuk and Feynberg [191], Grigorov and Murzin [103], and Camerini (1951). One of Dobrotin's conclusions from these studies is that protons with an average energy of 10^{10}eV lose about one-third of their energy in each collision with a nucleus of the air. The transmission of a large portion of energy to secondary particles has been observed by many researchers.

Table 1. Values of the Ratio of Particles in Showers

	Experimental data		Computed values												
	H=3-4 km	Sea level	v=1/4; b=3/4		v=1/4;b=1/4		v=1/3;b=1/4		b= 1/4 v=1/3;$E_1 > 100$ v= 1/4;$E_1 < 100$		b=1/2 v=1/3;Ei >100 v=1/4;Ei <100		v=1/2;b= 3/4	
			H=3km	Sea level	H=3km	Sea level	H=3km	Sea level	H=3km	Sea level	H=3km	Sea level	H=3km	Sea level
$\frac{N_N + N_\pi + N_\mu}{\text{All particles}}$ N - component	0.01-0.015	0.1	0.02	0.1	0.01	0.08	0.04	0.4	0.03	0.3	0.04	0.3	0.3	0.9
Penetrating component	0.3-05	-	0.4	0.1	0.1	0.02	0.04	0.005	0.06	0.008	0.1	0.02	0.06	0.005
$\frac{N(\pi) + N(\text{proton})}{N(\text{neutron})}$	1	-	1	1	2.5	2.0	2.0	1.5	2.0	2.0	1.5	1.5	1	1

Theoretical studies of this phenomenon have been made by Fermi (1950,1951). He based his work on a postulated statistical distribution of energy during collisions and on the degree of freedom in the volume in which the collision takes place. Landau [150] and Belen'kiy and Landau [35] extended Fermi's concepts by applying relativistic hydrodynamics to high-energy interactions.

Gramenitskiy et al. [98] investigated a high-energy interaction in a photoemulsion. By averaging data obtained by three observers, the authors plotted both the experimental and the theoretical curves after Landau and Belen'kiy. Similar investigations of high-energy interactions in photographic emulsions were made by Zhdanov et al. [274] and Milekhin and Rozental' [169].

Milekhin and Rozental' also studied the application of the hydrodynamic theory to particle interaction at high energies. Rozental' and Chernavskiy [202] found that the hydrodynamic theory satisfactorily describes many multiple process characteristics. Khalatnikov [120] applied the hydrodynamic theory to one-dimensional problems, and Rozental' [200] applied his method of successive approximations to three-dimensional problems.

From investigations conducted by Debenedetti et al. (1956), and Belen'kiy [34], the following conclusions may be drawn:

1. The one-dimensional variant of the hydrodynamic theory adequately describes the nature of the distribution of the transverse component;

2. The best agreement of both distributions

   is at $T = Pi \times C^2/K$, where T = final temperature, Pi = mass of pi-meson, K = Boltzmann constant, and C = velocity of light.

Gurevich et al. [107] investigated explosive showers produced by high-energy cosmic-ray particles. After making certain assumptions and accepting Belen'kiy and Landau's hydrodynamical model [35], the authors found that the results of an analysis of 43 showers caused by nucleons and 20 showers caused by alpha particles and heavier nuclei to some extent contradict the conclusions reached on the basis of the hydrodynamic theory.

In their study of the penetrating component at 3,860 meters, Azimov et al. [24] found that most of the mesons registered were pi-mesons. This was in fair agreement with data obtained by Powell et al. (1950) and Powell (1951) showing that 80 percent of high-energy shower particles with a specific ionization 1.5 times greater than that of a relativistic particle are mesons.

Nikol'skiy [177] presented a report at the Budapest Conference in 1956 on his investigation of nuclear-active components in air showers, likewise at 3,860 meters. He found that the number of such particles in the region of primary particles of energies below 10^{15}eV is proportional to E_o0.18, where E_o is the energy of the shower-producing particle. For primaries with energies above 10^{15}eV the number of nuclear-active particles is proportional to E_o.

Chudakov et al. [47] analyzed extensive air showers on the basis of interactions at high energies. They found that (1) the cross section P of the interaction is equal to a constant divided by R, where R is the interaction length; (2) the greater part of the energy of a primary is transferred to a secondary particle, probably a nucleon. Moreover, they determined that these characteristics vary with the energy of the primary particle.

Grigorov et al. [105] investigated the interaction of high-energy particles with light nuclei at an altitude of 3,200 meters above sea level. They found that the interactions between particles with energies from 10^{12} to 10^{13}eV and light nuclei can be divided into two classes: a relatively weak interaction in which the nuclear-active particle loses only a small amount of energy and a strong interaction in which most of the energy of the primary is lost.

The lateral distribution of the penetrating component has been studied by Nikol'skiy Vavilov, and Batov [180], Andronikashvili and Bibilashvili [18], and Abrosimov et al. [1].

Recent studies of nuclear-active particles at sea level have been made by Ivanovskaya, Sarycheva, and Chikin [JETP v.34, no.1, '58:45], and Abrosimov et al. [16]. In the first of these two studies, nuclear-active particles were found to be about equally divided between charged and neutral particles. This led to the conclusion that at sea level nuclear-active particles in the energy range 10^{9} to 10^{10}eV are primarily nucleons.

The development of the nuclear-active component and the dependence of this component on the elementary interaction has been recently examined by Vernov et al. [241]. The importance of the nuclear-active component in the development of air showers has been minimized in a recent study by Grigorov and Shestoperov [104].

Early theoretical and experimental work on the lateral distribution of shower particles was done by Pomeranchuk [190], Skobel'tsyn [216,217], Eydus et al. [72,73], and Molière (1943).

In a report on the lateral distribution of electrons in air showers, Nikol'skiy and Khristiansen [178] found that (1) the lateral distribution is in accord with Nishimura and Kamata's computations; (2) the electron-photon component of air showers is in equilibrium with nuclear-active particles with energies 10^{11} to 10^{12}eV in the lower layers of the atmosphere; (3) high-energy nuclear-active particles are concentrated in a narrow core with a radius of approximately 1 meter.

Khristiansen [125] investigated the distribution of electrons and mu-mesons in showers up to several hundred meters from the shower axis. The author's curves are based on theoretical and experimental data provided by Antonov et al. [21], Andronikashvili and Bibilashvili [18], Abrosimov et al. [2], and others. Similar research on density distribution up to 1,000 meters from the shower axis at mountain altitudes has been done by Antonov et al. [21] and Nikol'skiy and Seleznev [179]

There have also been recent investigations of the distribution of the soft component and other components near the axis of showers by Danilova et al. [51], Yemel'yanov [256], Vernov et al. [249], and Granovskiy and Chasnikov [100].

The longitudinal development is another major aspect of the study of showers. In this connection, the absorption of showers has been investigated by Zatsepin, Kuchay, and Rozental' [261]. Among others, Zakharova and Eydus [257], Zatsepin and Sarycheva [267], with their method of successive generations, Zatsepin and Rozental' [265], and Kurnosova and Tikhonova [143] have studied the altitude dependence of showers.

Density and number spectra have been studied by Khristiansen and Kulikov [126] in order to obtain more information on primary particles. They recorded 3,700 showers, 270 of which were found to have a number of particles greater than 2×10^5. Primary energies have been investigated in relation to the size of showers by Vernov et al. [242] and Dovzhenko et al. [69]. Dobrotin et al. [57] showed that contrary to the postulates of the cascade theory, increase in shower intensity with altitude is independent of particle density. Earlier, Migdal [166], Alikhan'yan and Asatiani [11], and Zatsepin et al. [263] investigated the particle density distribution in extensive showers and found that particle density is related to the energy spectrum of primary particles.

On the basis of work by Cherenkov, Vavilov, and Tamm, Frank [80] developed basic formulas for Cherenkov radiation, which is caused by charged particles passing through a dielectric medium with a velocity greater than the velocity of light in that medium. In such a case, the particles emit light. Gol'danskiy and Zhdanov [94], and Galbraith and Jelley (1953, 1955) investigated the presence of flashes of Cherenkov radiation in the atmosphere due to extensive air showers and susceptible to detection with suitable equipment.

Using eight light receivers, Chudakov and Nesterova [48] studied Cherenkov radiation in extensive air showers at an altitude of 3,860 meters in the Pamir Mountains. During 80 hours of observation they registered 230 showers and plotted distribution curves for light intensity and the number of shower particles relative to the axis of the showers. From his observations in the fall of 1955, Chudakov [45] found that the registration of a flash depends on the location of the shower axis and that the intensity of the light flux decreases monotonically with increasing distance from the shower. A statistical maximum at a distance of 70 meters from the shower axis was observed with the number of particles equal to 10^6.

From the foregoing survey it may be seen that cosmic-ray showers are one of the most comprehensive aspects of the study of cosmic radiation. Russian scientists have made many experimental and theoretical contributions to the unanswered questions in this field. Some of the most significant work includes the development of the Fermi and Heisenberg theories of the nuclear cascade by Landau and Belen'kiy, the description and measurement of the penetrating and nuclear-active components in showers by Zatsepin, Nikol'skiy, and Grigorov, and the detection and measurement of Cherenkov radiation in showers by Chudakov. These and other studies will undoubtedly be intensively pursued if the trend of the past ten years holds in the years to come.

H. COSMIC-RAY VARIATIONS AND ATMOSPHERIC CONDITIONS

In the issue of "Nature" for February 14, 1959, Dr. Ney of the University of Minnesota postulates a relationship between cosmic radiation and weather. He demonstrates his hypothesis by the following chain of events, the first two links of which rest on experimental verification:

Increased solar activity $\xrightarrow[(1)]{}$ Decreased cosmic-ray flux $\xrightarrow[(2)]{}$ Decreased atmospheric ionization $\xrightarrow[(3)]{?}$ Increased storminess $\xrightarrow[(4)]{?}$ Lower atmospheric temperature

This is one of the more interesting facets of research on cosmic radiation and the earth's atmosphere. Others include the problem of radio fadeout, auroras, night-sky light, and time variations in cosmic radiation. All these areas of investigation are at present receiving more and more attention in the Soviet Union, largely due to recent successes in rocketry.

In the more detailed survey of these questions below, solar activity, as in Ney's paper, and especially solar corpuscular emission or beams of ionized matter will be taken into account. In some papers, solar corpuscular emission and cosmic radiation are not clearly distinguished. According to Mustel' [172,p.69] and most Soviet researchers, cosmic rays from the sun are only those particles of the corpuscular radiation traveling with nearly the speed of light. However, the two forms of corpuscular radiation are intimately related and together have a significant effect on atmospheric conditions.

In addition to the above-cited book by Mustel', excerpts from which appear in Part II, much useful information is contained in Eygenson's book [74] on solar activity and the atmosphere, Ben'kova's booklet [37] on atmospheric research during the International Geophysical Year, and Dorman's book [61] on cosmic-ray variations.

At the time of preparation of this report there is no evidence of Soviet research to test or develop Ney's hypothesis. Nevertheless, it is clear from a survey of recent literature that Russian scientists are keenly interested in the possibility of such a relationship. The Moscow conference in 1955 on the effect of solar corpuscular radiation on the upper atmosphere serves as an example of this interest. Another example is the suggested use of satellites as a permanent source of data on solar corpuscular radiation for the purpose of forecasting conditions in the upper atmosphere.

One of the most important of these conditions is ionization, especially in the ionosphere. Ben'kova [37, pp. 17-18] shows that there is an obvious but complex correlation between solar activity and ionospheric ionization. The greater the intensity of radiation from the sun the greater the ionization in all levels of the ionosphere. She also points out latitudinal anomalies and variations in the ionosphere. Mogilevskiy [170], in a quantitative study of the ionizing role of solar corpuscular beams, develops a method for obtaining characteristics of beam parameters from ionospheric data.

According to Istomin [112], a general theory of the atmosphere is impossible without a knowledge of the composition of the atmosphere. The mass-spectrometer is the sole existing means of obtaining data on the mass spectra of ions from which the chemical composition of the ionosphere may be derived. Istomin's paper is devoted to a variant of the radio-frequency mass-spectrometer of the type described by Bennett (1950).

Ionization spectra of cosmic rays at mountain altitudes have been determined by Meshkovskiy and Sokolov [165] and Kotenko [135]. A similar study of particles in the stratosphere has been made by Rapoport [195].

Corpuscular beams from the sun are also an important factor in interrupting radio communication, especially shortwave transmissions. Parker (1957) has attributed radio fadeout and other ionospheric disturbances primarily to solar flares. Chestnov [43] describes the basic aspects of the interdependence of ionospheric conditions and radio-wave propagation. In this relationship, the degree of ionization is one of the most important elements. The higher the degree of ionization, the greater the absorption of radio waves. The impairment of radio communication resulting from ionospheric disturbances leads Ben'kova [37,p.17] to the conclusion that forecasts of the state of the ionosphere should be one of the primary tasks in the field of ionospheric physics.

The question of forecasts is also raised by Eygenson [76]. He speaks of successful long-range meteorological forecasts in the U.S.S.R. based on reasonably accurate forecasts of solar activity during the 11-year and secular cycles.

In 1951, Rakipova suggested a model of vertical circulation taking into account solar activity. In more recent papers (Rakipova [192, 194]) she has restated and developed her original thesis according to which deviations in the normal state of an atmospheric layer may be transmitted to the top or bottom of the atmosphere by means of superposed cyclones and anticyclones separated by a temperature inversion layer. By this mechanism, solar activity may exert a direct or indirect effect on the troposphere. Eygenson [76] concludes that a direct radiative effect is possible.

The most extensive research on the relationship between solar activity and atmospheric circulation has been done by Eygenson [74,75]. Quite recent studies on this problem have also been published by Spitsyna [222], Vitel's [251], and Yegorova [254].

Related to the foregoing is the involved problem of the thermal regime of the atmosphere. Here again Rakipova [192] has attached considerable importance to solar corpuscular streams as additional external sources of thermal effects. In a later paper (Rakipova [194]), the heating produced by these effects is related to the author's mechanism of vertical circulation. A broader treatment is given in a book by the same author (Rakipova [193]). New information on this problem obtained by means of rockets is discussed by Krasovskiy [140] and Danilin [50]. At altitudes above 100 kilometers the atmosphere was found to be hotter than was previously supposed.

Turning now to the question of variations in cosmic-ray intensity, the complementary aspect of meteorology and cosmic-ray research should be pointed out. Dorman [61,p.5], whose book is the most recent and complete treatment of the subject, states that meteorology and geophysics are sciences which make use of data on cosmic-ray variations to find out more about conditions in the earth's atmosphere. Conversely, other studies correlate changes in atmospheric conditions with variations in cosmic-ray intensity. The amplitude of variations in cosmic-ray intensity is generally very slight, but exceptionally, as when associated with solar flares, the intensity can increase enormously (cf. Table 1). Variations are usually classed as periodic and nonperiodic. Although much remains to be learned about them, enough is known to afford considerable insight into the nature of the primary beam, interstellar matter, and solar physics. In the remaining paragraphs, attention will be limited to a survey of atmospheric effects and the effect of solar corpuscular beams on cosmic rays.

The most important meteorological factors are the barometric effect, which is increased absorption of mesons with increased mass of absorber above the recording apparatus, and the temperature effect, which means the shift of the height of meson production with a change in the temperature of the atmosphere (Dorman et al. [68]).

Variations of Cosmic Rays (amplitude in %) Table 1

Type of variation	λ = 50°				λ = 0°		Origin	Mechanism (nature of variation
	Hard comp. at sea level	Neutron comp. at sea or mountain level	Ionization at high altitudes	Hard comp. underground 60 m.w.e.	Hard comp. at sea level	Neutron comp. at sea or mountain level		
Seasonal	2-4	-	-	-	-	-	Atmospheric	Instability of π and μ mesons and absorption in the atmosphere (separated with the aid of the theory of meteorological effects).
Diurnal (masking effect of extra-atmospheric origin)	~ 0.15	-	-	-	~ 0.15	-		
11-year	~ 2	-	-	-	~ 2	-	Extra-atmospheric	Class 1 (acceleration, deceleration and scattering of solar corpuscular beams with magnetic fields "frozen" into them). Class 2 (generation of cosmic rays of several Bev energy on the sun, apparently by a statistical acceleration mechanism). Class 3 (possible nonuniform distribution of sources; diffusion from the galaxy, etc.).
Annual	0.5-1	-	-	-	0.5-1	-		
27-day	~ 0.3	~ 1	-	-	~ 0.35	-		
Solar day	~ 0.3	~ 0.6	$\lesssim 1$-2	0.05	~ 0.35	~ 0.43		
Semidiurnal	~ 0.03	-	-	$\lesssim 0.02$	~ 0.03	-		
Decrease during magnetic storms	$\lesssim 10$	-	~ 22	< 0.5	$\lesssim 10$	-		
Increase during large solar flares	10-40	~ 550	-	< 0.5	< 0.5	-		
Increase during small solar flares	~ 0.3	~ 0.6	$\lesssim 10$	-	-	-		
Sidereal day (existence open to question)	$\lesssim 0.02$	-	-	$\lesssim 0.02$	< 0.02	-		

(From Dorman, Izvestiya Akademii nauk, seriya fizicheskaya, v. 20, no. 1, 1956)

A number of Soviet researchers have studied these meteorological effects and their relationship to diurnal, seasonal, and other periods of variations in meson intensity. Dorman et al. [68], Dorman and Feynberg [65], Sokolov and Shafer [221], Sokolov [219], and Koval'skaya [136] have investigated the seasonal effect of intensity variations in the hard component. They conclude that these variations are almost entirely due to meteorological factors.

Diurnal variations have been studied by Dorman and Feynberg [65] and Kuz'min [145]. Evidence of meteorological effects is apparent but experimental verification has not been completed. The semidiurnal variations as a function of barometric pressure have been investigated by Kuz'min and Skripin [146]. Here again, experimental data on meteorological fluctuations in the atmosphere are incomplete, but the authors find a strong probability for correlation with the semidiurnal fluctuation of the hard component intensity.

Similar results were obtained on the 27-day variations by Sokolov [220] and Kuz'min and Skripin [147]. These were summed up in the latter paper as follows:

1. Periodic effects in the monthly variations in cosmic rays are almost entirely due to corresponding periodic fluctuations of barometric pressure;
2. Monthly cyclic variations in the hard component intensity show no noticeable periodic effect of extra-atmospheric origin.

The most recent work on the relationship between meteorological effects and intensity variations in the neutron, soft, and ionizing components of cosmic rays has been done by Dorman [63,64]. Correlations are shown and certain errors in the work of Simpson, Fonger, and Treiman (1951) and Duperier (1951) are pointed out. Temperature and barometric effects on extensive air showers have been investigated by Koval'skaya, Krasil'nikov, and Nikol'skiy [137].

Minor meteorological factors include the passage of air masses or fronts, humidity, cloud cover, and precipitation. Of these, the effect of air masses, first noted by Loughridge and Gast (1940), has received the most attention. Among the Soviet contributions to this problem are papers by Krasil'nikov [138] and Krasil'nikov and Shafer [139].

All Soviet cosmic-ray recording stations now use a method for eliminating atmospheric effects in determining true primary variations. This method, which leads to results differing from those obtained by Western researchers, is described by Dorman and Feynberg [65,66].

The final point to be surveyed here is the relationship between cosmic-ray variations and solar activity. One of the most significant factors in this relationship is solar corpuscular radiation. Among Russian scientists, Dorman [59,61] has most thoroughly studied this factor.

Solar corpuscular streams have their origin in chromospheric flares and are believed to carry away, "frozen-in", that part of the solar magnetic field associated with their point of origin. Very significant work on the theory of these streams has been done in the West by Alfvén and his school, Nagashima (1955), and others. Soviet scientists, however, have for the most part accepted only certain aspects of these beam theories. In his works cited above, Dorman describes two types of corpuscular beams, differentiated primarily by the intensity of their magnetic fields and their particle density. A simple representation of the modulating effect of these beams on primary cosmic rays is given in Figures 2 and 3.

Solar corpuscular radiation is also associated with magnetic storms which in turn frequently have a considerable effect, such as Forbush decreases, on cosmic rays in the atmosphere. Information on this relationship is contained in Dorman [60], Dorman and Feynberg [65], Lashkhi and Gugunava [156], Bryunelli [40], and Nikol'skiy [176]. Solar flares, particularly that of February 23, 1956, are discussed in detail by Dorman [61, Ch. 11], Dorman and Freydman [67], and Severnyy [205].

In conclusion, it may be said that despite the complexity of the reciprocal effects of cosmic rays and atmospheric conditions, Russian scientists are doing much to explain and measure these effects. Although much attention has been given to ionospheric ionization, no follow-up on Ney's hypothesis has yet been reported in Soviet literature. It seems safe to assume, however, that this and other possible relationships will be investigated in the Soviet Union, probably by Dorman or other scientists cited in this section.

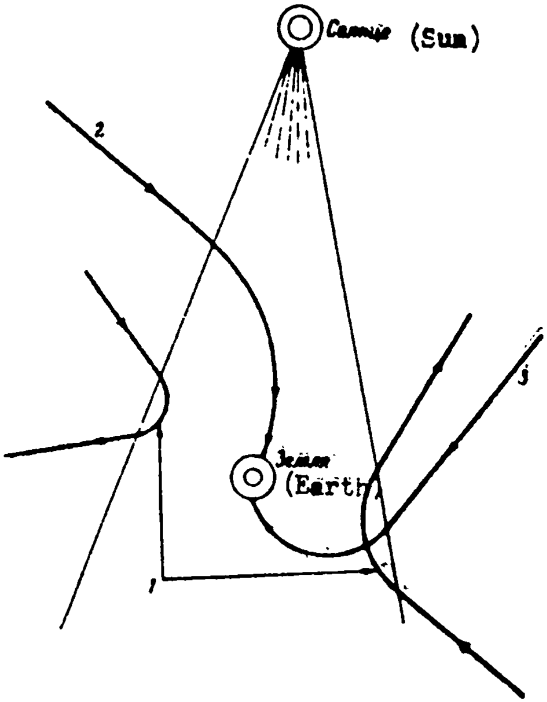


Figure 2. Diurnal variations in cosmic rays due to beams with magnetic fields frozen in (beam does not fall on the earth). 1. Two types of offsetting scattering of low-energy particles, leaving their intensity unchanged; 2. High-energy particles are accelerated and their flux increases; 3. High-energy particles are slowed down and their flux decreases.

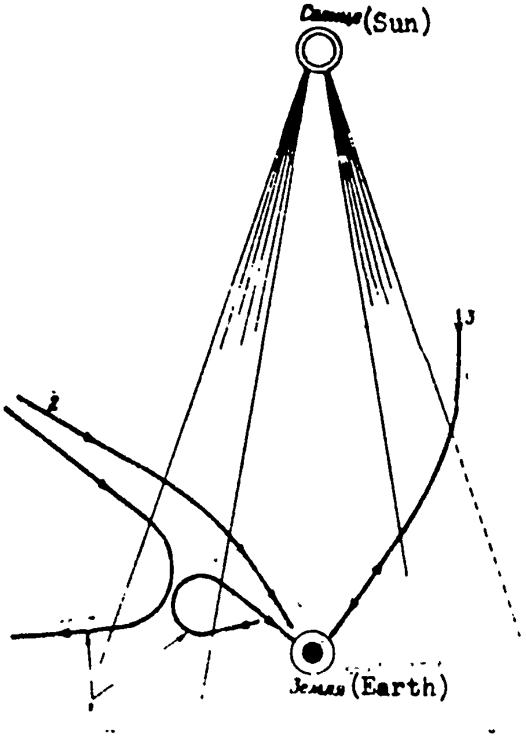


Figure 3. Variations in cosmic-ray intensity when corpuscular beams fall on the earth. 1. Relatively low-energy particles are scattered and their intensity decreases; 2. High-energy particles are accelerated (changes are detected in the morning hours); 3. High-energy particles are slowed down (changes are detected in the evening and at night).

PART II.

ABSTRACTS, SUMMARIES, AND TRANSLATIONS

A. THEORY OF THE ORIGIN OF COSMIC RAYS

1.

Ginzburg, V. L. (Institute of Physics imeni Lebedev). The origin of cosmic radiation. Uspekhi fizicheskikh nauk, v. 62,no. 2, 1957: 37-98. (Excerpt)

Concluding Remarks

In conclusion we would like to set out some problems for further research leading to a clearer picture of the origin of cosmic rays.

The following problems, most of which are well known and have long been the subject of study, should be clarified by the methods of cosmic-ray physics.

1. The determination of the abundance of Li, Be and B nuclei in the flux of the primary radiation near the earth. More precise information on the other components of the primary radiation would be interesting, particularly the detection of nuclei substantially heavier than the iron nucleus.

2. The determination of the composition of cosmic rays at very high energies. Here, it would be especially interesting to know whether protons remain dominant at energies of $E \geqslant 10^{18}$ eV.

3. The more accurate determination of the energy spectrum of cosmic rays, primarily to discover whether it is continuous in the range $E \sim 10^9$ to $E \sim 10^{18}$ eV. The presence of any break would be highly significant for the reasons given in section 3. It would be very interesting to determine the spectrum at kinetic energies $E_K < 5 \times 10^8$ eV/nucleon. The question of the similarity of the spectra of different groups of protons and nuclei is likewise important.

4. The determination of the highest degree of anisotropy, δ, of cosmic rays, especially at the highest energies, $E \geqslant 10^{18}$eV (here it is evidently a question of variations in intensity with sidereal time).

5. The investigation of the electron and positron spectra near

the earth. Even an improvement of one order of magnitude would be promising. The relative abundance of electrons and positrons should also be determined. At the time of minimum solar activity it should be possible to detect soft electrons ($E<10^9$eV), which should be much more prevalent than hard electrons.

6. The more accurate determination of the cross sections for the interaction and absorption of fast protons and nuclei in hydrogen and helium in cosmic-ray and, especially, accelerator experiments; also the determination of the energy resulting from collisions of secondary electrons and the transformation coefficients of nuclei, P_{ij}.

The following investigations may be carried out by radio-astronomical methods:

1. The redetermination of the spectrum of cosmic radio emission in the widest possible range of wavelengths and in relation to galactic coordinates. This should be done for other galaxies, particularly M 31.

2. The determination of more accurate spectra for the greatest possible number of galactic discrete sources and especially residues of supernovae and novae. In certain cases these investigations might be supported by determining the spectrum of continuous (magnetic bremsstrahlung) radiation at infrared and optical wavelengths.

3. The measurement of weak polarization of cosmic radio emission would apparently make possible some important conclusions on the configuration of the magnetic field in the galactic "corona". The importance of determining the polarization of optical emission from the Crab nebula and perhaps other objects is obvious.

There is also reason to believe that much valuable data on the origin of cosmic radiation may be obtained by astronomical and astrophysical means. Very important here is the density of interstellar gas in the galaxy and particularly the corona, as its value enters into a number of considerations. Further, the configuration and intensity of the magnetic field must be investigated, and in this connection, also the effective free path of cosmic particles which determines the rate of diffusion. Finally, more accurate determination of the data on the velocity of motion in the interstellar medium, in conjunction with the effective length in which changes in field direction take place, is necessary for evaluating the interstellar acceleration of particles. Investigation of the evolution, peculiarities and chemical composition of the envelopes of novae and supernovae should also be noted in particular.

In the realm of theory, let us indicate the necessity of studying the problem of reflection from the galactic boundary and the limits of application of the diffusion approximation in the analysis of the motion of cosmic particles in an interstellar medium carrying magnetic fields. To this must be added the explanation of the diffusion of electrons in the galaxy taking into account magnetic bremsstrahlung and other losses, and a thorough analysis of the problem of injection and acceleration of particles in the envelopes of supernovae and novae.

The above list, which could be made a little longer, indicates that there are still many unexplained or inadequately explained problems. Naturally, therefore, the theory of the origin of cosmic rays will become wider and more accurate. In conclusion, however, the writer is confident that the theory set out in this paper will not undergo substantial changes in principle, and therefore that it will not share the fate of all previous treatments of this problem.

2.

Gordon, I. M. Physical nature of nonthermal ultraviolet emission in the spectra of T Taurus stars and the origin of cosmic rays. Astronomicheskiy zhurnal, v. 35, no. 3, 1958: 458-468.

High polarization and rapid variations of light were discovered by K. Hunger and G. Cron in the peculiar ultraviolet emission of NX Monoceros. Spectrophotometric investigations by K. H. Böhm fully confirmed the conclusion made independently by V. Ambartsumyan and the author about the nonthermal nature of this radiation. In the present investigation it is shown that all the peculiar features of the radiation in question can be interpreted by the theory of the excitation of emission lines in the atmospheres of nonstationary stars by synchrotron radiation of relativistic electrons. This theory was proposed by the author in his previous papers.

1. Ultraviolet emission in the region $\lambda < 3,800$ Å is a confluence of higher members of the Balmer series which merge into a Balmer continuum, as was first suggested by K. H. Böhm.

2. Emission arises in a small part of the atmosphere of the star (active zone).

3. The great density of nonthermal radiation leads to the predominance of induced transitions and to the broadening and merging of the higher members of the Balmer series.

4. Polarization of the Balmer lines and the Balmer continuum is due to the linear polarization of synchrotron radiation which evokes induced transitions. The polarization of such emission lines in the spectra of nonstationary stars was theoretically predicted by the author. This prediction has been confirmed by the observations of K. Hunger and G. Cron. It was estimated that the area of the active zone $= 2.5 \cdot 10^{-4}$ $S \approx 1.5 \cdot 10^{19}$ cm^2, $H \approx 10^4$ oersted, $N_e \approx 10^{13}$ cm^{-3}. The spectrum of synchrotron radiation in a broad interval from $\lambda = 10^{-3}$ cm to $\lambda = 5.10^{-6}$ cm, was found to satify $I(\nu) = \nu^{-1}$, which corresponds to the energy of relativistic particles $N(E) = KE^{-3}$. The total energy of relativistic electrons generated in the active zone is $\approx 3.10^{33}$ ergs/sec. This is more than all the energy radiated by the star in the form of thermal radiation.

3.

Kolpakov, P. Ye. On the generation of corpuscular streams by the magnetic fields of sun spots. Astronomicheskiy zhurnal, v. 36, no. 1, 1959: 65-72.

The possibility of generation of corpuscular streams in a temporally increasing nonuniform magnetic field of a unipolar group of sun spots is considered. The most rapid particles of the coronal-chromospheric plasma belonging to the "wing" of the Maxwell distribution, for which the condition $eE_{\perp} \geq F_{dec}$ is fulfilled, will acquire energy from the action of the induced electric field according to $W_{\perp} = W_0 \frac{H}{H_0} \sim 6.10^3 - 4.10^5$ eV. Because of the nonuniformity of the magnetic field these particles will rise upward and their energy $W_{\perp}$ will be transformed into the energy $W_{\parallel}$ of motion along the magnetic lines of force of the spot. Particles with energy $W_{\parallel} \sim 6 \cdot 10^3 - 4 \cdot 10^5$ eV in the region of the corona can escape from the sun and from corpuscular streams.

4.

Krasovskiy, V. I., and I. S. Shklovskiy (State Astronomical

Institute imeni Shternberg). Variations of the intensity of cosmic radiation during the earth's geological history and their possible influence on life's evolution. Nuovo cimento. Supplemento, v. 8, series 10, no. 2, 1958: 440-443.

It has been shown that both the Crab Nebula's radio and optical emissions are caused by relativistic electrons that move in magnetic fields. As a consequence this nebula contains a great number of relativistic particles, i.e., primary cosmic rays. Recently it was found that nebulae in Cygnus, a remnant of a supernova explosion which took place several thousand years ago, are also sources of radio emissions. When, owing to the Crab Nebula expansion, its radius will be ~ 5 parsecs, the concentration of relativistic particles will still be 30 times larger than the concentration of primary cosmic rays in the neighborhood of the earth. The sun with its planetary system at times gets into regions of cosmic radiation tens or even hundreds of times higher than at present. This took place when the supernova exploded in the immediate proximity of the sun. During the last 1000 years, at least 5 explosions of supernovae took place in our galaxy. Their distances did not exceed 2000 to 2500 parsecs. Once in 200 million years a supernova explodes at a distance less than 8 parsecs. The biological and genetic consequences of such cosmic-ray increases are discussed. (Nuclear Science Abstracts, v. 13, no. 9, 1959, 8001)

5.

Logunov, A. A., and Ya. P. Terletskiy. The acceleration of charged particles moving in a magnetized medium. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 26, no. 2, 1954: 129-138.

The mechanism of the acceleration of a charged particle entering a region of uniform magnetic field is analysed, and formulae for the rate of gain of energy are derived when the radius of curvature is either smaller or greater than the dimensions L of the region. The resulting spectrum of primary cosmic-ray nuclei should be effectively cut off at a critical energy varying as (mass number) 2/3. For protons this would be $\sim 10^{17}$-10^{18} eV, if $L \gtrsim 10^{20}$ cm and the velocities of the magnetic clouds are $\sim$ 70 km/sec. (Physics Abstracts, v. 57, no. 679, 1954, 10300)

6.

Severnyy, A.B. On the production of high-energy particles and hard radiation in solar flares. Doklady Akademii nauk SSSR, v. 121, no. 5, 1958: 819-822.

Cinematography of typical flare emissions provides valuable evidence of the transient character of these explosive outbursts. Main results from this study are as follows: (1) Bright wavefronts moving at supersonic velocities sometimes occur, and indicate shock-wave development. When the waves approach a sunspot region they brighten, and commence to spread with diminished velocity along the lines of force of the sunspot magnetic field. (2) The non-stationary continuous emission originates in optically thin grains at various depths in the sun's atmosphere. The spectral distribution of this radiation, and its low polarization, both point to a non-thermal origin. (3) The observed strengthening of the Dα-line in flares (and in non-flare wideline emission) shows that neutrons may be produced in these disturbed regions. (4) Both cosmic-ray particles (of energy 10^9-10^{11} eV) and X-radiation (but not Lα-radiation as previously thought) are produced in flare outbursts. (5) Flares originate at the neutral points of the solar magnetic field, and lead to a breakdown of the field near the neutral point. (6) The discharge hypothesis is inadequate to explain the origin of flares since the current density is insufficient to provide for the required energy liberation via the Joule effect. (Physics Abstracts, v. 62, no. 741, 1959, 9153)

7.

Shklovskiy, I. S. (State Astronomical Institute imeni Shternberg). Some problems of radioastronomical theory of the origin of cosmic rays. Nuovo cimento. Supplemento, v. 8, series 10, no. 2, 1958: 421-429.

In 1950 Alfvén and Herlfson as well as Kiepenheuer showed that nonthermal cosmic radiation may be explained by relativistic electrons moving in interstellar magnetic fields. Since the nonthermal radio emission of the galaxy is caused by relativistic electrons that move in interstellar magnetic fields, it becomes possible to observe the electron component of the primary cosmic rays in the universe. From the analysis of the nature of nonthermal radio emission and of the physical conditions of discrete sources it was concluded that only relativistic electrons moving in magnetic fields can be responsible for their radiation. From the observed flux of radio emission of the Crab Nebula, the quantity of relativistic electrons and their energy were evaluated. These calculations showed that an explosion of a supernova results in the formation of a large number of relativistic particles. It has been shown that taking into account the frequency of outbursts of supernovae in our galaxy and the "duration of life" of cosmic rays in interstellar media, the quantity of relativistic particles actually formed during these outbursts was quite enough to provide the observed concentration of primary cosmic rays. Thus it was shown that supernovae explosions may be the injectors of primary cosmic rays in our stellar system. (Nuclear Science Abstracts, v. 13, no. 9, 1959, 7999)

8.

Terletskiy, Ya. P. Origin of cosmic rays. Uspekhi fizicheskikh nauk, v. 44, 1951: 46-69.

In a synthetic view on recent hypotheses of the origin of cosmic rays, the primary source of energy of this radiation is sought in interstellar nuclear transformations which furnish the energy (1) to grand-scale eruptions by the stars of ionized matter of high electric conductivity and, thus, (2) to magnetic fields both around the star itself and around interstellar clouds that form from the erupted material; these fields act as inductive accelerators on some ofthe particles of the ejected matter, first while the particles are still within the rotating or pulsating magnetic field of the parent star, then during multiple collision with wandering interstellar clouds. The primary component of the cosmic radiation is thus formed in a two-step acceleration process. The main accumulation of energy takes place during the first, stellar, phase, whereas the second (Fermi's) mechanism serves chiefly for the spatial homogenization of the radiation and for its redistribution according to the final energy spectrum. The author was among the first to point to stellar magnetic fields as probable accelerators of cosmic particles (Doklady Akademii nauk SSSR, v. 47, 1945: 104); (Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 16, 1946: 463); he also foresaw the presence of heavy ions in the primary component (Vestnik Moskovskogo universiteta, 1948: 75). (Nuclear Science Abstracts, v. 5, no. 13, 1951, 5708)

9.

Veksler, V. I. New mechanism of relativistic electron production in space. Doklady Akademii nauk SSSR, v. 118, 1958: 263-265.

It is shown that the motion of quasi-neutral bunches of totally ionized plasma in a heterogeneous magnetic field should be followed (under certain general conditions) by production of relativistic electrons. Analysis is made of a limited bunch of quasi-neutral plasma composed of equal numbers of positive ions and electrons with a total transition velocity v_0 and initial velocity $v_0 < c$. The case considered corresponds to the quasi-neutral bunch reflection in a magnetic field at 180°. However, the qualitative analysis convincingly demonstrates the mechanism by which any motion of the quasi-neutral bunch in a heterogeneous magnetic field (in addition to other processes) will result in the energy transition from the heavy fraction of the bunch to the light one. (Nuclear Science Abstracts, v. 12, no. 13, 1958, 9891)

B. BREMSSTRAHLUNG OF CHARGED PARTICLES AND THE ABSORPTION OF HIGH-ENERGY PHOTONS

1.

Dyatlov, I. T. (Leningrad Applied Physics Institute). Bremsstrahlung of π-mesons and production of π-meson pairs by γ-quanta in collisions with nonspherical nuclei. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 34, no. 1, 1958: 80-86.

Effective cross sections are computed for a number of radiative processes arising in the interaction of high-energy π-mesons with nonspherical nuclei. Nonsphericity of the nuclei modifies the angular distributions and leads to the appearance in the cross sections of factors which are dependent only on the geometrical shape of the nucleus. (Author's abstract)

2.

Ivanenko, I. P. (Moscow State University). Cascade curves for electrons and photons from lead. Doklady Akademii nauk SSSR, v. 107, 1956:819-822.

A "method of moments" offered by S. Z. Belen'kiy Zhur. Eksptl. Tekh. Fiz. 22, 102(1952) has been used in developing cascade curves for electrons and protons from lead. Equations were derived considering the relation of the photon absorption coefficient $\sigma(E)$ to the energy and Coulomb scattering of charged particles. Recurring expressions based on the function of "equilibrium" (integrated on the depth of spectra, which is the zero moment) permit the calculation of all the succeeding moments of t^{-n}. The radiation t-unit in lead was taken as equal to 5.9 g/cm^2. Results of calculations are tabulated. (Nuclear Science Abstracts, v. 10, no. 21, 1956, 11262)

3.

Lomanov, M. F., A. G. Meshkovsky, Ya. Ya. Shalamov, V. V. Shebanov, and A. F. Grashin. Bremsstrahlung of π^+-mesons interacting with nuclei. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 35, no. 4, 1958: 887-893.

Nuclear force bremsstrahlung of π^+-mesons was observed in a freon bubble chamber during the interaction between 80-300 MeV π^+-mesons with carbon, fluorine and chlorine nuclei. The bremsstrahlung cross section in inelastic and elastic scattering of π^+-mesons deduced from 20 observed events was $(4.5^{+1.2}_{-2.0})\cdot 10^{-27}$ cm^2 per fluorine nucleus in the indicated energy region. Three events of bremsstrahlung have been detected in the absorption of π^+-mesons by a nucleus and 2 cases can be ascribed to bremsstrahlung in charge-exchange scattering of π^+-mesons on the nucleus. The bremsstrahlung cross section for various nuclear processes has been computed in the quasi-classical approximation. The values of the cross sections computed from these formulas are in good agreement with the experimental results. (Authors' abstract)

4.

Migdal, A. B. Bremsstrahlung and pair production at high energies in condensed media. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 32, no. 4, 1957: 633-646.

The effect of multiple scattering on bremsstrahlung and pair production is considered. The probability of these processes decreases appreciably at energies $\sim 10^{13}$ eV. The computation is carried out with the aid of the density matrix. Equations are derived for the probability of pair production and bremsstrahlung per unit path for electrons and quanta of arbitrary energy. (Author's abstract)

5.

Ryazanov, M. I. (Moscow Institute of Engineering Physics). Radiative corrections to Compton scattering taking into account the polarization of the medium. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 34, no. 5, 1958:1258-1266.

A general procedure is developed which permits one to take into account the polarization of the medium in calculating radiative corrections in phenomenological quantum electrodynamics. The effect of a nonconducting medium on radiative corrections to Compton scattering is taken into account for an arbitrary dependence of the dielectric permeability of the medium on frequency. It is shown that in some cases account of the medium significantly changes the cross section in the region of small scattering angles. (Author's abstract)

6.

Ter-Mikaelyan, M. L. Spectrum of bremsstrahlung in the atmosphere. Doklady Akademii nauk SSSR, v. 94, 1954: 1033-1036.

It is shown that the Bethe-Heitler equation is applicable for the bremsstrahlung spectrum in cases where the frequency $\omega \gg \frac{4\ ne^2}{m}\frac{E}{mc^2}$, but for cases where $\sqrt{\frac{4\pi Ne^2}{m}} < \omega < \sqrt{\frac{4\pi Ne^2}{m}\frac{E}{mc^2}}$, the formula describing the atmospheric bremsstrahlung spectrum is $dI = \frac{E^2}{12\pi^2}\frac{m}{LN}\quad\frac{\omega^2 d\omega}{E^2}$, where L is the length of the radiation unit in cm, E_s is 21 Mev, and N is the number of electrons per unit volume. (Nuclear Science Abstracts, v. 8, no. 13, 1954, 4122)

C. SOFT COMPONENT OF COSMIC RADIATION

1.

Ageshin, P. N., A. N. Charakhch'yan, and T. N. Charakhch'yan (Moscow State University). Investigation of the origin of cosmic-ray components in the stratosphere at geomagnetic latitude 51° N. Izvestiya Akademii nauk SSSR, seriya fizicheskaya, v. 19, 1955: 533-536.

The available data for π^0 and π^+ meson spectra generation in the stratosphere and their decay scheme make it possible to calculate the electron-photon component transmissions through the atmosphere and to determine the electron energy spectra at various elevations. Experimental study to determine the relation of the number of soft component particles to the elevation, in transmission interval, of 0.4 to 0.9, 1.2 to 2.0, 2.0 to 6.6, on 6.6 to 11.3 g/cm^{-2} glass or aluminum, was made with the counter telescope at 51°N latitude. The measurements of the particle numbers in the indicated intervals were made simultaneously with four telescopes in a single exposure of the equipment in the stratosphere. Two series of measurements gave results which coincided within the limits of statistical error. The presence of a large number of low-energy electrons at shallow depth, the continuous softening of electron transmission spectra with reducing depths, and the great effect of latitudes on low-energy electrons call for new assumptions about the existence of a special mechanism for generating electron-photon components of low energies in the stratosphere. (Nuclear Science Abstracts, v. 10, July-October, 1956,4727)

2.

Charakhch'yan, A. N., and T. N. Charakhch'yan. Measurement of the cosmic-ray intensity in the stratosphere at various heights and latitudes. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 35, no. 5, 1958: 1088-1102.

Results of measurements of the altitude dependence of particles of the cosmic-ray soft component having different ranges are presented for latitudes of 51° and 31°. The altitude dependence of electrons of a given energy is computed on the basis of the energy spectrum of μ-meson production in the atmosphere. The results of the calculations are in good agreement with the results of measurements performed at a latitude of 31° which indicates that the overwhelming majority of particles of the soft component are electrons generated by π-mesons at the indicated latitude.

An analysis of the experimental and calculated values for a latitude of 51° indicates the existence of an excess of electrons possessing ranges below 2-3 g/cm^2. This phenomenon, which is most pronounced at 51°, is most probably caused by γ-quanta emitted in the atmosphere in reactions involving neutron evaporation. The energy flux carried away by these surplus short-range electrons comprises ~10% of the total energy flux of the electron component at this latitude. The magnitude of the cosmic-ray energy fluxes at latitudes of 2°, 31° and 51° has been determined. On the basis of these data and also data on the intensity of cosmic-ray particles at the top of the atmosphere at latitudes 51° and 31°, an expression has been obtained for the primary particle energy spectrum. The primary cosmic-ray particle flux ($N_p + N_\alpha$) at the equator (2°) has been found to equal 0.48 ± 0.04 particles/min·cm$^{2-1}$sterad.

3.

Krasovskiy, V. I., Yu, M. Kushnir, G.A. Bordovskiy, G. F. Zakharov, and Ye. M. Svetlitskiy (Academy of Sciences, USSR). Detection of corpuscles by means of the third artificial satellite. Iskusstvennyye sputniki Zemli, no. 2, 1958:59-60.

An arrangement of two fluorescent screens covered with aluminum foil and connected for telemetering data to earth revealed the presence of intense signals which began and ended suddenly. These were assumed to be due to electrons as the possibility of proton or x-ray beams seemed excluded according to known parameters. These electrons, with energies from several KeV to several hundred KeV, are not considered to be of solar origin. Accounting for their origin near the earth likewise presents considerable difficulties. The flux is more intense during the daytime, possibly due to greater ionization at the exospheric limit. X-radiation created by these electrons would present a danger for persons exposed to it for long periods in the upper atmosphere.

4.

Rapoport, I. D. Some sources of the low-energy electron-photon component of cosmic radiation in the stratosphere. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 34, no. 5, 1958: 1306-1309.

Ionization at altitudes of 10-17 kilometers indicates a considerable flux of heavily ionizing particles. The contribution of these particles to total ionization, or I excess = $I - k_p N$, where k_p is the mean ionizing capacity of relativistic particles. After comparing the results of other investigations, it was concluded that about one third of the excess ionization cannot be attributed to protons and heavier particles produced by nuclear disintegration. A flux of low-energy electrons with range $R < 1.7$ g/cm^2 accounts for approximately 20% of the total flux of charged particles at a height of 19 kilometers. This component is highly altitude-dependent. It creates roughly 10% of the total excess ionization and is shown to be genetically related to disintegration products. The remaining part of the electron flux, accounting for 20% of the excess ionization, is attributed to electron-photon cascades in the atmosphere.

5.

Vernov, S.N., P.V. Vakulov, Ye.V. Gorchakov, Yu. I. Logachev, and A. Ye. Chudakov (Academy of Sciences, USSR). Iskusstvennyye sputniki Zemli, no. 2, 1958: 61-69.

A luminescence counter with a cylindrical sodium iodide crystal 40 X 39 mm was used to measure several quantities which were recorded on magnetic tape by a radio transmitter. Data collected by the apparatus during more than a month in flight have not yet been completely analyzed. The counts were ten times higher than expected for primaries, a fact which is attributed to photons. Measured ionization was several times greater than that due to cosmic rays, and the "excess ionization" is partially explained by the luminescence of the crystal irradiated in another portion of the flight. It was verified that in the photon spectrum energies near the threshold of 35 KeV are characteristic of only a small part. The electron component and its ionization effect were measured in the polar region. It is not excluded that the electrons are accelerated near the earth by electric fields, nor that they may come from the sun and penetrate the earth's magnetic field despite their low energy. Incompletely analyzed data on high radiation belts are presented as well as an account of unsuccessful efforts to detect weak gamma radiation from the sun and other celestial bodies.

D. HARD COMPONENT OF COSMIC RADIATION

1.

Baradzey, L. T., S.N. Vernov, and Yu. A. Smorodin. On disintegrating particles in the cosmic rays of the stratosphere. Doklady Akademii nauk SSSR, v. 63, 1948: 233-234.

Stratospheric measurements of the intensity of the penetrating component of cosmic radiation were made, the angles α, formed by the rays and the vertical, being equal to 0° and 60°. The intensities for these two angles, and the differences of the two intensities, were plotted against $p/\cos\alpha$ g/cm^2, i.e., against the thickness of the layer of matter traversed by the radiation. The difference curve has a maximum at 120 g/cm^2. This curve represents the differences between the numbers of mesons disintegrating above the observation point. At the altitude corresponding to the maximum, this quantity is about 30% of the intensity of the penetrating radiation. Below this point, mesons probably form a considerable fraction of the penetrating component. (Nuclear Science Abstracts, v. 3, no. 4, 1949, 977)

2.

Dovzhenko, O. I., B. A. Nelepo and S. I. Nikol'skiy. Energy spectrum of μ -mesons in extensive atmospheric cosmic-ray showers. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 32, no. 3, 1957: 463-466.

The energy spectrum of μ -mesons in extensive atmospheric showers of varying primary energy was studied in the energy range from 0.3 to 3.5 BeV. The measurements were carried out at mountain altitudes. It was found that in the aforementioned energy range the energy spectrum of μ -mesons is independent of the energy of the primary particle which initiated the shower. The mean μ -meson energy decreases with the distance from the shower axis. (Authors' abstract)

3.

Kocharyan, N. M., M. T. Ayvazyan, Z. A. Kirakosyan, and A. S. Aleksanyan, Meson component of cosmic radiation at 3200 m. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 30, no. 2, 1956: 243-249.

The μ-meson momentum spectrum in the momentum range $0.4 \leq p \leq 14$ BeV/c has been measured at an altitude of 3200 m above sea level. The ratio between the numbers of protons and μ-mesons at this height has been determined. The momentum dependence of the ratio between the numbers of positive and negative μ-mesons has also been determined. (Physics Abstracts, v. 59, July-December, 1956, 5194)

4.

Kocharyan, N. M., G. S. Saakyan, M. T. Ayvazyan, Z. A. Kirakosyan, and S. D. Kaytmazov. A study of the composition of cosmic rays at a height of 1000 m above sea level. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 23, no. 5, 1952: 532-542.

Using a large magnet (useful space 80 x 20 x 10 cm) with horizontal sets of double trays of crossed counters to define the co-ordinates of 3 points on the path of a particle, and sets of Cu absorbers (22, 6.3, 7.8, 8.4, 10.1 g.cm^{-2}) interspersed with trays of counters to delimit the energy, a study was made of the mass spectrum of mesons and the momentum spectrum of protons. The $\mu+$, μ^--meson peaks give masses $(211 \pm 3)\ m_e$ respectively. The number of π's is $< 5\%$ of the μ flux. The ratio of positive to negative particles decreases from 1.24 for momenta $(11\text{-}35) \times 10^8$ eV/c to 0.9 for $(2\text{-}3.6) \times 10^8$ eV/c. The proton spectrum shows a tail on the high-energy side. A theoretical estimate shows that this can be understood in terms of the non-ionizing nuclear collisions which become important at higher energies. A similar estimate is made for π-mesons. (Physics Abstracts, v. 56, no. 667, 1953, 5550)

5.

Meshkovskiy, A. G., and V. A. Shebanov. The ionization spectrum of the hard component of cosmic radiation at sea level. Doklady Akademii nauk SSSR, v. 82, no. 2, 1952: 233-236.

This was measured for mesons in two energy ranges (23-66 cm Pb and 66 cm) using a stilbene scintillation counter. Comparison of ionizations in the two ranges shows that the "density effect" due to the polarization of the medium by the mesons is present. Qualitative agreement of the spectrum with Landau's theory is obtained but fluctuations about the mean are still 50% greater than calculated. (Physics Abstracts, v. 55, no. 656, 1952, 8290).

E. HEAVILY-IONIZING PARTICLES AND NUCLEAR DISINTEGRATION UNDER THE ACTION OF COSMIC RAYS

1.

Belen'kiy, S.Z. On the theory of multiple production of particles at higher energies. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 28, no. 1, 1955: 111-113.

The relative numbers and energies (E) of nucleons, antinucleons and pions (N_π) in Fermi's theory of multiple production are calculated as functions of the initial numbers of nucleons (N_0) involved in the collision ($N_0 \gtrsim 2$) and the temperature T at which the statistical system disintegrates into separate particles. If $T = 1\cdot 2\ m_\pi c^2$, then for $N_0/N_\pi = 0.15$, E (nucleons + antinucleons)/$E_\pi = 0.42$ and for $N_0/N_\pi = 1$, E(n. + a.)/$E_\pi = 2.3$. The results are generalized to the case when Λ -mesons of mass $2200 m_e$ are also created. (Physics Abstracts, v. 58, no. 693, 1955, 7390).

2.

Chernavskiy,D. S. (Institute of Physics imeni Lebedev). Multiple production of particles in jets. Nuovo cimento. Supplemento, v. 8, series 10, no. 2, 1958:775-785.

Jets observed in photoemulsions are due to interaction of nucleons of high energy ($> 10^{10}$ ev). The following cases are possible: (1) interaction of a nucleon with internal parts of a heavy nucleus; (2) head-on interaction of a nucleon with one of the surface nucleons of the nucleus; and (3) peripheric interaction of a nucleon with a nucleon. When a collision of a nucleon with a nucleon occurs, the nucleon cuts a tunnel in the nucleus and interacts only with that nucleon. It is shown that the classical treatment of peripheric interactions of two nucleons is not adequate and that it is necessary to take into account the quantum structure of the field. The problem of peripheric interaction of two nucleons is reduced to the problem of head-on interaction of a nucleon with a meson. The nucleons flying past each other exchange mesons. The energies (and meson momenta) which are exchanged by the nucleons may vary within the limits of the spectrum which is determined by the development of Ψ (r) in a Fourier series. (Nuclear Science Abstracts, v. 13, no. 9, 1959, 8047)

3.

Feynberg, Ye. L., and I. Pomeranchuk (Academy of Sciences, USSR). High-energy inelastic diffraction phenomena. Nuovo cimento. Supplemento, v. 3, series 10, no. 4, 1956: 652-671.

A survey is made of recent theoretical papers on processes arising in the course of collisions of high-energy particles. Consideration is given to the electromagnetic phenomena accompanying nuclear collisions, purely electromagnetic processes such as bremsstrahlung, and nuclear phenomena such as meson emission, deuteron splitting, and nucleon-nucleus collisions. (Nuclear Science Abstracts, v. 11, no. 1, 1957, 743).

4.

Granovskiy, Ya. I. (Institute of Nuclear Physics, Academy of Sciences, Kazakh SSR). On the problem of ρ^0-meson. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 36, no. 2, 1959: 623-624.

In the compound elementary particle model of Fermi-Jung, the π-meson is represented as a system of strongly interacting nucleons with antinucleons. However, along with the π-meson triplet it is possible to form an isotopic singlet from the same bare particles. It is observed that due to the difference in isotopic spins, the force binding nucleons with antinucleons in π^0 and ρ^0 mesons would also be different. In this event the π-mesons eliminate the ρ^0 meson. An addition of an item into the potential independent of T does not change the inference because such forces are weak. (Nuclear Science Abstracts, v. 13, no. 11, 1959, 10366)

5.

Grigorov, N. L. Interactions of primary cosmic particles of various energies (2 to 1000 Bev) with light atomic nuclei. Uspekhi fizicheskikh nauk, v. 58, no. 4, 1956: 599-666.

Analyses of studies show that with cosmic particles of several Bev, the primary particle is absorbed in the process of π-meson formation and in nuclear fissions. The loss of energy and complete absorption depend upon the energy of the primary particles; $E_0 = 3$ Bev lose 53 ± 5% of their energy on formation of heavy particles in nuclear fission; $E_0 = 200$ Bev lose only

15 ± 2%. The energy losses in π-meson formation are for primary particles of 3 Bev = 45 ± 3% and for 20 Bev = 84 ± 2%. The process of π-meson formation is multiple. In the first collision with the light nucleus the primary particle transmits to the π-meson only a small part of its energy (3 Bev = 21%; 20 to 40 Bev = 28 to 30%; 100 to 1000 Bev = 30% or less than 50%). The remaining energy is absorbed by a nucleon. For particles of 10^{11} to 10^{12} ev the retained energy (of 70% of primary energy) also is absorbed by nucleons. During fission of light nuclei the particles of high energies (3 to 40 Bev) use $\varepsilon = 440 \pm 160$ Mev. These energies remain independent of the energy of the incoming nucleon. Approximately 200 Mev are transmitted to the charged heavy particle and the remaining energy of ~ 200 Mev is absorbed by an average 2.8 ± 0.4 neutrons. Experimental observations of the characteristics of the interaction processes of light nuclei with particles of high energy may be used to describe quantitatively the path of cosmic-ray nucleon components through the atmosphere. (Nuclear Science Abstracts, v. 10, no. 17, 1956, 6795)

6.

Ivanenko, I. R. On the theory of passage of nuclear cascades through the atmosphere. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 37,no. 4, 1959: 1046-1049.

A method for solution of the equations describing the passage of nuclear cascades through the atmosphere is proposed. The boundary conditions can be prescribed at an arbitrary depth. The proposed method permits one to obtain the solution in a form similar to that obtained by the usual method of successive generations with boundary conditions prescribed at the top of the atmosphere. The form of the solutions for various types of boundary conditions is considered. (Author's abstract)

7.

Kotenko, L. P. (Institute of Physics imeni Lebedev). Investigation of ionizing properties of cosmic radiation at 3200 m by means of scintillation proportional counters. Izvestiya Akademii nauk SSSR, seriya fizicheskaya, v. 19, no. 5, 1955: 525-532.

Stilbene and napthalene crystals of 17 x 24 x 24 mm and 14 x 11 x 21 mm were used in the investigation of ionizing properties of cosmic radiation. The evaluation based on three series of measurements gave the number of protons in the soft component as 4.8% of the total hard component, a percentage obviously too high. A certain number of electrons and mesons could have been added to the number of strongly ionizing particles (protons). By subtracting the number of electrons and mesons from the number of ionizing particles (based on the electron and meson distribution), a value for the number of protons of 3.5% was obtained. Finally, the number of strongly ionizing particles or protons stopped by ionization losses in 7.5 cm of lead at 3200 m under 30 g. cm^{-2} layer of light matter was 3.5± 1% of the hard component, which corresponds to a vertical proton beam with 0.8 Bev/c impulses, and which equals impulses, and which equals to $(2.1 \pm 0.6) \times 10^{-3}$ $(Bev/c)^{-1}$ cm^{-2} sec^{-1} $ster^{-1}$. Determination of the most probable ionization losses are given in an appendix. (Nuclear Science Abstracts, v. 10, July-October 1956, 4726)

8.

Loktionov, A. A., V. I. Stafeyev, and Zh. S. Takibayev. Study of the spatial distribution of nuclear disintegrations in thick nuclear emulsions. Vestnik Akademii nauk Kazakhskoy SSR, no. 10, 1958:49-59.

The statistical method was used to study the formation and distribution of close stars. The authors draw the following conclusions:

1. The statistical investigation of experimental data shows that the distribution of stars at small distances (up to 1mm) differs from the Poissonian distribution.

2. The occurrence of multiprong stars increases with altitude and is practically independent of the atomic number of the absorber.

3. Investigation of the simultaneous formation of close stars leads to the conclusion that fewer of them are genetically related than is indicated by the statistical approach.

4. The hypothesis that "related stars" are formed by collimated showers is not borne out by experiment.

5. In a number of cases, the reciprocal disposition of stars and the orientation of their prongs give qualitative evidence of a genetic bond.

9.

Matinyan, S. G. On nonconservation of parity in strong interactions between strange particles. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 37, no. 4, 1959: 1035-1040.

A modification of Lee and Yang's theory of strange particle parity doublets is considered in which parity conjugation invariance is extended to weak interactions. As a result, nonconservation of parity in weak interactions is found to be closely related to a change in strangeness.

Results of the analysis pertaining to the "forward-backward" asymmetry of the hyperon decay products are compared with the corresponding consequences due to nonconservation of parity in strange particle creation and interaction processes. Both interpretations are found to yield the same results as long as particles with odd strangeness are concerned. The two approaches can be distinguished by studying processes involving Σ -hyperons. (Author's abstract)

10.

Pontecorvo, B. M., and G. I. Selivanov. The formation of π^0-mesons by neutrons. Doklady Akademii nauk SSSR, v. 102, no. 2, 1955: 253-256.

This paper is based on work done in 1951-2 at the Institute of Nuclear Problems. Neutrons of about 400 MeV were collimated and directed at specimens of seven elements ranging from beryllium to lead, and γ-quanta produced by the decay of π^0-mesons were recorded by a counter arrangement. The total cross-section for π^0-meson formation by neutrons at carbon was found to be 3 ± 1.5 millibarn. The total cross-section for other elements, expressed as a ratio to that for carbon, varies from 0.8 ± 0.1 (Be) to 5.0 ± 1.7 (Pb). It is shown that this cross-section is proportional, within the limits of error, to $ZA^{-1/3}$. This is in agreement with the theoretical relation, derived on the hypothesis that the π^0-meson absorption mean free path in nuclear matter is less than the diameter of the nucleus, supposed spherical. A further paper is to give the corresponding results for π^0-meson formation by neutrons at hydrogen and deuterium. (Physics Abstracts, v. 58, no. 693, 1955, 7393)

11.

Rapoport, I. D. (Moscow State University). Ionization spectra of particles of cosmic radiation in the stratosphere. Izvestiya Akademii nauk SSSR, seriya fizicheskaya, v. 19, 1955: 519-524.

Measurements of cosmic ray intensities according to the number of charged particles and study of the ionization created by these particles in the stratosphere indicated the presence of a well defined beam of ionized particles which contribute one-third to the total ionization. Experiments were made (for finding the origin of these strongly ionizing particles) to determine the spectrum of cosmic-ray particles according to the ionization created by them. These works were carried out during the years of 1951 to 1953 in Moscow at the local latitude. Two variations of experiments were used; in the first the investigation of vertical particle beams with range larger or equal to 1.7 g/cm^{-2}, and in the second, ionization impulses were registered independently from the range or direction of the particle motion with the minimum registration limit of 0.4 order and mean impulse created by a relativistic particle. Both experiments were carried out simultaneously at the same installation with a small, spherical, thin-walled aluminum ionization chamber with gas volume (spectrochemically pure argon) of 8:1 and with an impulse collecting time of $\sim 5 \times 10^{-5}$ sec for the electronic component. (Nuclear Science Abstracts, v. 10, July-October, 1956, 4725)

12.

Takibayev, Zh. S. (Physical and Engineering Institute, Academy of Sciences, Kazakh SSR). Transition effect for stars and its relation to cascade multiplication of particles of the nucleonic component. Izvestiya Akademii nauk SSSR, seriya fizicheskaya, v. 19, no. 6, 1955:687-696.

Data obtained from balloon ascents to an altitude of 30 km and the exposure of various arrangements of absorbers and emulsions are analyzed to explain transition effects for stars. It was found that primarily low-energy (50-500 MeV) star-producing particles are generated in absorber, which, in the case of lead, results in an increase of 30% in star-producing particles under the absorber. For graphite and paraffin absorbers the increase is much less, especially below 20 km. Transition effects for stars in both heavy and light absorbers are primarily associated with stars of 3 to 6 prongs, indicating generation of relatively low-energy particles in the absorbers. Altitude dependence was determined for the number of stars in the interval from 20 to 29 kilometers. Slow mesons were also determined and found to increase appreciably when even a thin absorber is placed above the plates. Transition curve maxima were not clearly established in the experiments.

F. PRIMARY COSMIC RAYS AND GEOMAGNETIC EFFECTS

1.

Kurnosova, L. V., L. A. Razorenov, and M.I. Fradkin (Academy of Sciences, USSR). Heavy nuclei in primary cosmic radiation. Iskusstvennyye sputniki Zemli, no. 2, 1958:70-74.

This paper describes a Soviet study made in connection with the International Geophysical Year. A detector based on the Cherenkov-Vavilov effect was mounted in the third artificial satellite and calibrated to record omnidirectional nuclei with $Z > 15$ and $Z > 30$ and energies greater than $3 \cdot 10^8$ eV/nucleon. A general view and block diagram of the instrument are shown. Preliminary analysis of data covering nine days of operation **shows** that the average number of nuclei of $Z > 15$-20 was 1.22 ± 0.08 per minute. Only one case of output voltage corresponding to the recording of a nucleus of $Z > 30$ was observed. The calculated ratio of fluxes for these groups was found not to conflict with the present-day notions of the acceleration and motion of cosmic rays in interstellar space.

2.

Shuleykin, V. V. (Naval Hydrophysical Institute, Academy of Sciences, USSR). Terrestrial magnetic field and the world ocean. Doklady Akademii nauk SSSR, v. 76, no. 1, 1951: 57-60.

In an effort to explain additional elements of the earth's magnetic field, the author notes the continuous temperature difference in the stratosphere over oceans and continents. This gives rise to stratospheric cyclonic air movement which is most intense parallel to coast lines. Citing the work of D. B. Skobel'tsyn (1950) and S. N. Vernov et al. (1950), the author suggests that another factor contributing to the geomagnetic field might be cosmic radiation in the stratosphere. It is assumed that protons have little significance below 5 kilometers above sea level, but that their importance rises steadily above this level to 20 kilometers and higher. The quantity of protons stopped in the stratosphere can be evaluated. The electric conductivity of the air and the turbulent movement of air masses equalize the density of the "protonic gas" in the atmosphere. This "protonic gas" is caught up in both the zonal circulation around the earth and in the system arising from the temperature differential over oceans and continents. It is found that the predicted quantity of positive charges creating a convective electric current is too high, and therefore, that the origin of such currents is more complex in nature. Noting the difference in the behavior of positive and negative particles, the author states that the positively charged particles are caught in air currents and become an admixture in the neutral gas of the stratosphere. Carried along in the general circulation of the air they could create the electric currents of the necessary density without giving rise to an excessively high intensity of the electric field in the atmosphere. It is concluded that it is still not possible to judge the importance of these currents in the basic magnetic field of the earth.

3.

Vernov, S. N., and A. M. Kulikov. Angular distribution of cosmic particles in the stratosphere. Doklady Akademii nauk, v. 61, 1948: 1013-1015.

The angular distribution of cosmic rays in the stratosphere was studied in a series of balloon experiments using a three-counter telescope whose axis performed periodic rotations varying its angles with the vertical between 0° and 90°. It follows from the analysis of the curves plotted for various altitudes that the number of particles moving in a direction which forms an angle α with the vertical at an altitude corresponding to a pressure p is equal to the number of particles moving in a vertical direction at an altitude corresponding to a pressure $p/\cos\alpha$. The important fraction of almost horizontal paths at altitudes exceeding 20 km is explained by the long range of particles moving at about 75° in the rarefied air. These conditions favor the formation of a large number of horizontally moving particles. It is thus shown that the primary particles maintain their original direction in the atmosphere, and that the angular dispersion of the secondary radiation is small. By tying in these facts with the known large latitude effect in the stratosphere, and with the absence of the azimuthal asymmetry effect, the conclusion is reached, that, besides protons, the primary cosmic rays must contain negative anti-protons. (Nuclear Science Abstracts, v. 2, 1949, 1349)

G. COSMIC-RAY SHOWERS

1.

Abrosimov, A. T., V. A. Dmitriyev, G. V. Kulikov, Ye. I. Massal'skiy, K. I. Solov'yev, and G. B. Khristiansen. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 36, no. 3, 1959: 751-761.

Data presented on the number of high-energy nuclear-active particles in showers containing a total number of particles between 1.10^4 and 2.10^6 and also on the lateral distribution of the energy flux of the nuclear-active component. It is noted that the energy of the nuclear-active component in individual showers with an equal number of particles may differ widely. On the basis of the shape of the spectrum of the nuclear-active particles and the shape of the lateral distribution of the energy flux of the nuclear-active component, some conclusions are drawn regarding the nature of the elementary act underlying the nuclear-cascade process. (Authors' abstract)

2.

Antonov, Yu. N., Yu. N. Vavilov, G. T. Zatsepin, A. A. Kutuzov, Yu. V. Skvortsov, and G. B. Khristiansen (Academy of Sciences, USSR). Structure of the periphery of extensive atmospheric cosmic-ray showers. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 32, no. 2, 1957:227-240.

An investigation of the lateral distribution of various components of extensive showers at their periphery (200 to 800 m from the axis) has been carried out. The data on the lateral distribution indicate that the contribution of the shower periphery to the total shower particle flux is significant. The lateral distribution of the electron component at the periphery can be explained by means of the theory of multiple Coulomb scattering. Coulomb scattering also plays an important role in the divergence of the penetrating particles (μ-mesons); however, the angles of emission in the elementary events of nuclear cascade processes of $\pi^{\pm}$-mesons which give rise to μ -mesons can apparently also lead to this type of divergence of μ -mesons. An investigation of the intensity of the primary cosmic radiation at very high energies (10^{16} to 10^{17} ev) was also carried out. (Authors' abstract)

3.

Belen'kiy, S. Z., and B. I. Maksimov. The scattering of cascade particles in heavy elements. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 22, no. 1, 1952: 102-111.

A recurrence formula is derived for the nth moment of the distribution-in-depth function of an electron-photon cascade including scattering. The angular distribution, averaged over depth, is calculated without assuming small angles and including ionization losses (which are found to be unimportant for energies $\gtrsim$15 MeV). In the case of a 10^8 eV cascade in Pb the first 2 moments of the cascade curve are changed by a few % due to scattering. (Physics Abstracts, v. 56, no. 667, 1953, 5553).

4.

Chudakov, A. Ye., and N. M. Nesterova (Institute of Physics imeni Lebedev). Cherenkov radiation of extensive air showers. Nuovo cimento. Supplemento, v. 8, series 10, no 2, 1958:606-611.

Short light flashes superimposed on the background of the night sky glow, correlated with the passage of cosmic rays in the atmosphere, were first detected in 1952. It was established that at least some of these flashes were caused by Cherenkov radiation of extensive air showers. Further experiments were conducted in the Pamir Mountains (altitude 3860 m)in the autumn of 1955. The purpose of this investigation was to study the lateral distribution of the light flux relative to the core of the showers and also to determine the relation between the intensity of the light flashes and the size of the shower. The experimental arrangement included an optical receiver that registered the light flashes and a Geiger counter hodoscope. Two series of measurements were made. The sensitivity of the light receivers was adjusted so that about 100 pulses per hour were registered. On an average, each flash was accompanied by triggering of 20 hodoscope counters, while the number of cases when no counter was triggered was 4%. Thus it was established that practically all light flashes of a given intensity were produced by extensive air showers. (Nuclear Science Abstracts, v. 13, no. 9, 1959, 8025)

5.

Dobrotin, N., O. Dovzhenko, V. Zatsepin, E. Murzina, S. I. Nikol'skiy, I. Rakobol'skaya, and Ye. Tukish (Institute of Physics imeni Lebedev). Combined method of investigation of extensive air showers. Nuovo cimento. Supplemento, v. 8, series 10, no. 2, 1958:612-622.

In order to reconstruct the picture of an elementary act of nuclear interaction at extremely high energies based on data of extensive air showers, it is necessary to make a detailed and comprehensive study of all the characteristics of the showers. Therefore, the investigation should be carried out with the use of a combined arrangement that will enable the investigators to determine (for an individual shower) not only the position of its axis and the total number of particles but to obtain all the characteristics of its different components. Tentative data are given concerning partial results of measurements carried out during the autumn of 1955 at an altitude of 3860 m (the Pamir Mountains, Central Asia) by workers of the Academy of Sciences of the USSR. The electronic arrangement used allowed the measurement of bursts in one chamber within the ionization interval (from 6×10^3 to 1×10^8 ion pairs), which corresponded to the ionization by the passage of 1 to 1.5×10^4 relativistic particles along its diameter and perpendicular to its axis. The master group of counters produced 60 master pulses per hour; 4×10^4 showers were recorded. The arrangement permitted the study of showers caused by primary particles with energies of 3×10^{13} to 2×10^{15} ev. (Nuclear Science Abstracts, v. 13, no. 9, 1959, 8026)

6.

Gol'danskiy, V. I., and G. B. Zhdanov. On Cherenkov radiation of cosmic ray particles in the atmosphere. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 26, no. 4, 1954: 405-416.

The contribution of this radiation to the continuous spectrum of the luminosity at night is calculated and found to contribute less than 10%, in agreement with previous estimates. It is shown however, that a single burst of radiation could be observed by a registering device (e.g., photomultiplier) provided the radius of the collector is large and the resolution short, $\sim 10^{-8}$ sec. The observation of Cherenkov radiation from wide air showers is shown to afford a sensitive means of detecting these showers where the density of particles is so low as to make detection by counters difficult. The amplitude of radiation in this case is given as a function of distance from the axis of the shower. (Physics Abstracts, v. 58, no. 685, 1955, 377).

7.

Gurevich, I. I., A. P. Mishakova, B. A. Nikol'skiy, and L. V. Surkova (Academy of Sciences, USSR). Explosion showers produced by high energy cosmic ray particles. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 34, no. 2, 1958: 265-279.

Experimental results are presented which pertain to 43 shower events induced by 10^{10} to 10^{14} ev nucleons and to 20 showers produced by particles with $Z \geqslant 2$. Asymmetry in the angular distribution of shower particles with respect to the angle $\pi/2$ in the center-of-mass system has been observed in showers produced by nucleons possessing an energy $> 10^{11}$ ev. This fact is not consistent with the concept of shower production in nuclei in nucleon-nucleon collisions or with the predictions of the hydrodynamical theory of multiple production of particles proposed by Belen'kiy and Landau. (Authors' abstract)

8.

Khristiansen, G. B. (Moscow State University). On the lateral distribution of electrons and μ-mesons in extensive air showers. Nuovo cimento. Supplemento, v. 8, series 10, no. 2, 1958:598-605.

A graphical comparison of experimental lateral distribution of electrons in extensive air showers with theoretical distribution shows a good fit. The coincidence of the experimental curve with the theoretical curve with one definite value of S in such a wide range of distances is not accidental, and it is natural to assume that this is due to the fact that the energy spectrum of the electron-proton cascade of age S and the divergence of electrons, is entirely determined by Coulomb scattering. The lateral distribution of μ-mesons was considered. μ-mesons arise from the decay of π- and K-mesons in the upper layers of the atmosphere. According to experimental data the generation of μ-mesons takes place in the altitude range from the point of generation to the level of observation without any interactions involving energy losses and [these mesons] lose their energy slowly on ionization of the air. (Nuclear Science Abstracts, v. 13, no. 9, 1959, 8024)

9.

Khristiansen, G. B., and G. V. Kulikov (Moscow State University). On the number-of-particles spectrum of extensive air showers. Nuovo cimento. Supplemento, v. 8, series 10, no. 2, 1958:742-745

Up to the present, mainly measurements of density spectra of extensive air showers were carried out. The number-of-particles spectrum of showers was obtained by recalculation from the obtained density spectrum. This method has serious disadvantages. In this investigation a direct study was made of the number-of-particles spectrum of showers. The measurements were carried out by means of the method of correlated hodoscopes. Using the hodoscope installation, it was possible to determine the position of the axis and the number of particles in showers with a total number from 2 x 10^4 to 2 x 10^6. The hodoscope system made it possible to determine the number of triggered counters in different groups of counters during the recording of each shower. Knowing the distribution of the counters that trigger in the plane of observation, it is possible, under certain assumptions, to find the number of particles and the coordinates of the axis in the plane of observations. (Nuclear Science Abstracts, v. 13, no. 9, 1959, 8042)

10.

Milekhin, G. A., and I. L. Rozental' (Institute of Physics imeni Lebedev). On some interaction characteristics of very high-energy particles and their interpretation from the viewpoint of the hydrodynamical theory of multiple particle production. Nuovo cimento. Supplemento, v. 8, series 10, no. 2, 1958: 770-774.

Landau, using the idea stated by Fermi, employed relativistic hydrodynamics in describing very high energy particle collision. The first attempts to compare the conclusions of hydrodynamical theory with experimental data on the multiplicity and angular and energy distributions of secondary particles already showed that the hydrodynamical theory satisfactorily described many multiple process characteristics. By comparison of the theory with experimental data taken from the analysis of showers recorded in a photographic emulsion, a number of essential additional assumptions were made. These assumptions caused a certain obscurity of the conclusions. For example, it was assumed that the collision of nucleons with heavy nuclei took place in the coordinate system in which notion of substance was symmetrical. Extensive shower analysis carried out on the assumption that the nuclear interaction cross section is independent of energy shows that the formal part of the hydrodynamical theory is incomplete. (Nuclear Science Abstracts, v. 13, no. 9, 1959, 8046)

11.

Nikol'skiy, S. I., Yu. N. Vavilov, and V. V. Batov (Institute of Physics imeni Lebedev). Investigations of nuclear-active components of extensive air showers. Doklady Akademii nauk SSSR, 111, 1956: 71-73.

Experiments were made to determine the spatial distribution and the number of nuclear-active particles with energy $\gtrsim 10^{-9}$ ev. The measurements were taken at 3860 m above sea level (Pamir) in the summer and autumn of 1954. The total number of charged particles in each recorded shower was calculated (with the relative error of $\lesssim 10\%$) by measuring the stream density of shower particles at various distances from the shower axis. The possibility of δ formation and the recording of showers induced by nuclear-passive particles (μ-mesons) were also determined in the same experiments. All showers recorded during the period of observation were divided into groups according to the total number of particles. The functions of spatial distribution of nuclear-active particles for each group were analyzed in the intervals from 1 to 40 m from the axis of the showers. (Nuclear Science Abstracts, v. 11, no. 7, 1957, 3892).

12.

Rozental', I. L. Cascade processes in extensive atmospheric showers of cosmic rays. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 23, no. 4, 1952: 440-455.

A phenomenological study of the cascade produced by a high-energy nucleon ($E_0 \sim 10^7$ BeV) supposed to consist of nucleons and π-mesons interacting with air nuclei with geometrical cross-sections. Charged π's decay, producing a μ-meson component, neutral π's give two γ's which initiate an electron-photon cascade. The "nuclear" cascade (i.e., nucleons + π) is assumed to cease with energies $<$ 10 BeV. The general features of the individual collisions are taken according to **Fermi's** statistical theory. The number of secondaries is assumed to be E^{ν} (E = energy of primary, ν = const.), of which a fraction b are nucleons. The equations describing the development of the cascade are used to evaluate (as functions of the depth) the mean square radii of the various components of the cascade (including electrons), their density distribution and the ratios (nucl. + π + μ)/(nucl. + π + μ + e) and (π + prot.)/(neutr.). Comparison with experiments suggests $\nu = 1/4$, $b = 3/4$. This case is studied in more detail and graphical results are given. (Physics Abstracts, v. 56, no. 667, 1953, 5555).

13.

Rozental', I. L. A quasi-unidimensional interpretation of the hydrodynamical theory of multiple particle production. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 31, no. 2, 1956: 278-287.

The hydrodynamical theory of multiple formation of particles developed by Landau is based on the introduction of two stages of separation of the liquid: a unidimensional motion and a conical separation whose limits of validity are difficult to estimate. The hydrodynamical theory version in which only the unidimensional stage is involved is investigated in the present paper. It is shown that this variant yields a very satisfactory approximation for the values of the final temperatures $T_k \sim 1.5\text{-}2\mu$. For $T_k = \mu$ the unidimensional approximation yields (especially for slow secondary particles) a result which is correct only in order of magnitude. The dependence of the energy of the fastest particle on $T_k = \mu$ was also investigated. It is found that in order for the calculated value of the velocity to agree with the experiment value the condition $T_k \sim< \mu$ must be satisfied. A preliminary conclusion can be drawn that the interaction cross-section of the secondary particles (apparently π mesons) for $T_k \sim \mu$ is of the order of the geometrical value. (Author's abstract)

H. COSMIC RAYS AND ATMOSPHERIC EFFECTS

1.

Dorman, L. I., A. I. Kuz'min, G. V. Tyanutova, E. L. Feynberg, and Yu. G. Shafer. The variation of the intensity of cosmic rays and the role of meteorological factors. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 26, no. 5, 1954: 537-544.

In discussing the temperature and barometric effects on the variation of the intensity I of the hard component of cosmic rays, one must allow for (a) the dependence of the meson lifetime on its energy and (b) the temperature distribution of the entire atmosphere over the point of observation. (Seasonal variations in the temperature may have the opposite sign at sea level and in the stratosphere.) Several erroneous conclusions in the literature concerning the seasonal variation of intensity can be ascribed to the disregard of these effects. (e.g. Dolbear and Elliot, Abstr. 6306, 1951; Duperier, Abstr. 2814, 1952). By taking them into account it is possible to deduce a formula for the effect of meteorological factors on I (Dorman, L. I., Doklady Akademii nauk SSSR, v. 94, 1954: 433) which agrees to within 0.1-0.2% with the observed annual variation of some 2%. This is illustrated with reference to 3 stations in the USSR and one (Cheltenham) in the USA. Recent precision measurements have made it possible to detect also a daily variation in I with an amplitude 0.2%, partly masked by meteorological factors. (Physics Abstracts, v. 58, January-June 1955, 1030)

2.

Dorman, L. I. Data on solar corpuscular beams obtained by means of studying variations in cosmic radiation. <u>In</u> Fizika solnechnykh korpuskulyarnykh potokov i ikh vozdeystviye na verkhnyuyu atmosferu zemli; Trudy konferentsii Komissii po issledovaniyu solntsa, 22-24 noyabrya 1955 g [Physics of solar corpuscular beams and their effect on the upper atmosphere of the earth; proceedings of the Conference of the Commission on Solar Research, November 22-24, 1955]. Moscow, Izd-vo AN SSSR, 1957, pp. 112-128.

This paper demonstrates the effectiveness of studying astrophysical and interplanetary conditions by starting from a knowledge of cosmic-ray variations. Two methods, the so-called "consecutive" method and the method of "coupling coefficients" are used. These exclude distortions of observed variations due to the earth's atmosphere and magnetic field and make it possible to determine and understand the properties and nature of causes of cosmic-ray variations. It is shown that most of the types of variations are subject to a single mechanism of accelerating, decelerating and braking due to solar corpuscular beams with magnetic fields "frozen" into them. This leads the author to the conclusion that there are two rather sharply differentiated types of corpuscular beams: (1) those with comparatively weak magnetic fields ($\sim 10^{-5}$ gauss near the earth), related to high-latitude events on the sun and possessing relatively low density, and (2) those with magnetic fields of considerable intensity ($1\text{-}2 \times 10^{-4}$ gauss near the earth) principally related to low-latitude events on the sun and having relatively high density (of the order of 10^3 corpuscles per cm^3). The number of the latter type of beam is in good correlation with Wolf's sun-spot numbers and varies sharply during the cycle of solar activity. It is found that cosmic rays can be effectively used to determine the interaction of solar corpuscular beams with the earth's magnetic field and upper layers of the atmosphere.

3.

Dorman, L. I. (Scientific Research Institute for Terrestrial Magnetism, the Ionosphere, and the Propagation of Radio Waves). The generation and propagation of solar cosmic rays. Nuovo cimento.. Supplemento, v. 8, series 10, no. 2, 1958:291-302.

The mechanisms of generation and propagation of solar cosmic particles in the solar system during the outburst of February 23, 1956, are discussed. In the initial period of the outburst, there was a well impressed impact zone which showed the anisotropy of the additional cosmic flow. Calculations showed this flow came from the sun. The particles arrived in the impact zone and in the background zone almost simultaneously, but there was a tendency towards earlier arrival by as much as two or three minutes at lower latitudes. On the rest of the earth's surface the particles arrived as much as ten minutes late. The existence and location of impact zones at the initial stage of the outburst were in agreement with expectations due to the influence of the earth's magnetic field on the trajectories of solar particles. This proved that a regular, uniform magnetic field does not exist between the earth and the sun. A model was proposed to explain the variations of intensity during the outburst. From energy relations it was shown that the generation of solar cosmic rays took place in an enormous chromospheric outburst. (Nuclear Science Abstracts, v. 13, no. 9, 1959, 7997)

4.

Dorman, L. I., and Ye. L. Feynberg (Scientific Research Institute for Terrestrial Magnetism, the Ionosphere, and the Propagation of Radio Waves; Institute of Physics imeni Lebedev). True primary energy spectrum variations and solar activity. Nuovo cimento. Supplemento, v. 8, series 10, no. 2, 1958:358-378.

In order to obtain true primary variations, meteorological variations must be eliminated. A method of eliminating atmospheric effects has been developed, tested, and applied. The method was applied to the deduction of true variations, essential in connection with solar activity, namely, of long-term seasonal changes of diurnal variations and for the determination of the direction of the source of diurnal variations. The results differ in many points from those of other investigators. This method of elimination is now limited only by the accuracy of temperature data. It is used systematically at all Soviet stations for permanent recording of cosmic rays. (Nuclear Science Abstracts, v. 13, no. 9, 1959, 7995)

5.

Glokova, Ye. S. (Research Institute of Earth Magnetism). Izvestiya Akademii nauk SSSR, seriya fizicheskaya, v. 20, no. 1, 1956: 47-54.

The Feynberg-Dorman theory of temperature effects is useful for obtaining correct evaluations of variations caused by temperature. The accuracy of the method is determined by the accuracy of the available aerological data. All variations in the universe (except the flashes) were observed as variations in meson component intensity, and all belonged to the same type of variations. Processes which cause the variations are related to corpuscular currents which cause magnetic storms and turbulences. To variations of this type belong the cyclic, long-lasting, yearly variations in the magnetic storms, the irregular day-to-day oscillations of the universe, and the 27-day variations. According to experimental data, the daily variations of the space components are caused by the processes which also cause the magnetic variations in the general intensity of cosmic rays. (Nuclear Science Abstracts,v. 10, July-October 1956, 9403)

6.

Kuz'min, A. I.,G. V. Skripin, G. V. Tyanutova, and Yu. G. Shafer (Yakutsk Branch , Academy of Sciences). Unique flash of cosmic rays of great intensity. Doklady Akademii nauk SSSR, v.108, no. 5, 1956: 66-68.

On Feb. 23, 1956 at 3:45 Greenwich time, in the town of Yakutsk, three instruments of the Cosmic Radiation Laboratory recorded a flash of cosmic rays of great intensity. The ionization chambers recorded a 200% increase from the mean value. Crossed counter telescopes recorded an increase of the same magnitude. The earth remained quiet and only rare pulsations of H compound were observed. Atmospheric pressure remained unchanged but there was a sudden 10° temperature increase. At 4:00 o'clock Greenwich time, the ionization station in Yakutsk recorded complete radiowave absorption in the 2- and 7-megacycle bands. During the flash all radio communications were interrupted in Yakutsk territory. This ionospheric disturbance was due to an unprecedented chromospheric explosion on the sun. Previously recorded flashes were much weaker. A 200% increase in intensity of cosmic rays along the vertical and the considerable influx of cosmic radiation from the south, as well as the analysis of other data indicated that the intensity flash was induced by particles of 10^9 to 10^{10} ev, which originated on the sun. (Nuclear Science Abstracts, v. 10, no. 21, November 1956, 11263.)

7.

Mogilevskiy, E. I. Equation of quasi-stationary ionization equilibrium in the F_2 layer, and solar corpuscular radiation. In Fizika solnechnykh korpuskulyarnykh potokov i ikh vozdeystviye na verkhnyuyu atmosferu zemli; Trudy konferentsii Komissii po issledovaniyu solntsa, 22-24 noyabrya 1955 g [Physics of solar corpuscular-beams and their effect on the upper atmosphere of the earth; proceedings of the Conference of the Commission on Solar Research, November 22-24, 1955]. Moscow, Izd-vo AN SSSR, 1957, pp. 261-268.

The author points to experimental evidence of the effects of corpuscular ionization in the ionosphere such as daily and seasonal variations, variations in the F_2 layer, especially at high latitudes, during a solar cycle, and ionospheric disturbances. The purpose of the paper is to provide a method for the quantitative evaluation of the ionization of corpuscular emission according to ionospheric data and from this to determine some parameters of solar corpuscular beams. The author begins with the equation for ionospheric ionization, derives the equation for quasi-stationary ionization equilibrium, and applies this to the determination of some parameters of solar corpuscular beams. Statistical ionospheric data on the relative stability of the ionosphere in disturbed periods are found to confirm the correctness of this approach.

8.

Mustel', E. R. Solntse i atmosfera Zemli [The sun and the atmosphere of the earth]. Moscow, Gos. izd-vo tekhniko-teoret. lit-ry, 1957. 103 p. [Excerpts]

...The question of the effect of solar activity on the troposphere is to a considerable degree one of the effect of solar activity on climate and weather. It is extremely interesting but at the same time extremely complex. We have seen that the question whether solar activity has an effect on the upper atmosphere must be answered in the affirmative and is not, strictly speaking, a problem. Rather, it is primarily a question of more exhaustive study of the mechanisms of the effect of solar ultraviolet and corpuscular radiation on the ionosphere, etc.

On the other hand, the question of the effect of solar activity on the troposphere, and therefore on weather and climate, is still quite moot...

...Existing data indicate that the total amount of solar energy radiated per unit of time is practically constant, in any case independent of the phase of solar activity. From this it would seem that the thermal conditions of the atmosphere, the lower atmosphere, and consequently climate and weather should not vary in relation to the state of solar activity. However, the actual situation is much more complicated. This much can be said. In many countries, including the Soviet Union, there has been to date a tremendous amount of research in which every possible relationship between tropospheric phenomena and solar activity has been examined. Moreover, in a large number of cases, positive correlations were postulated. For example, in a number of papers it was found that in periods of maximum solar activity the temperature in the tropical zone is approximately 0.5° lower than in periods of minimum activity. Other researchers have repeatedly found a correlation between solar activity and storminess. In the period 1902-1922 there was a fairly close correlation between the level of Lake Victoria in Africa and solar activity. For the period 1900-1939 according to the Soviet scientist L. A. Vitel's, there was a relationship between solar activity and the number of days with deep cyclones over seas washing northern and northwestern Europe. Many authors have found a relationship between solar activity and the thickness of growth rings in the trunks of the giant sequoias growing in the United States. A similar result was obtained from the trunk of red spruce in southern Sweden and elsewhere.

Of course, the establishment of such relationships is rather difficult and linked with many uncertainties... This has led to the fact that many leading meteorologists have denied any effect of solar activity on the lower layers of the earth's atmosphere. However, it is not easy to agree with such an extreme view. There are many grounds for the belief that certain definite correlations do exist between solar activity and tropospheric phenomena, but that they are masked by those complex internal processes peculiar to the troposphere...

...All present-day data based on the study of the ionosphere and auroras either indirectly or by means of rockets show that neither far ultraviolet rays, X-rays, nor corpuscular radiation can penetrate deep into the atmosphere...

...Therefore, all the energy of the far ultraviolet, roentgen and corpuscular radiation from the sun is absorbed at an altitude considerably higher than the upper limit of the troposphere. Consequently, a direct effect of these forms of radiation on the troposphere is excluded...

...Inasmuch as a direct effect of solar activity on the troposphere is excluded, we must consider other possible mechanisms. The most plausible of them is the following. In sections 4 and 5 we have seen that the upper layers of the earth's atmosphere are extremely dependent on the state of solar activity. Especially great changes take place in these layers during the influx of corpuscular radiation...

...Another possibility is the presence of rather intense circulation between the upper and lower layers of the atmosphere. In such a case, the energy absorbed in the upper layers of the atmosphere could be carried (perhaps in modified form) to the lower layers of the atmosphere, thereby bringing about an indirect effect of solar activity on the troposphere.

It is still difficult to assess the degree of correctness of this model of the effect of solar activity on the troposphere. At any rate, the theoretical calculations of L. A. Rakipova indicate the possibility of such circulation. It is expected that rocket investigations will make it possible to clarify this question...

9.

Rakipova, L. R. Effect of solar corpuscular beams on dynamic disturbances in the upper atmosphere. In Fizika solnechnykh korpuskulyarnykh potokov i ikh vozdeystviye na verkhnyuyu atmosferu zemli; Trudy konferentsii Komissii po issledovaniyu solntsa, 22-24 noyabrya 1955 g [Physics of solar corpuscular beams and their effect on the upper atmosphere of the earth; proceedings of the Conference of the Commission on Solar Research, Nobember 22-24, 1955]. Moscow, Izd-vo AN SSSR, 1957, pp. 273-276.

The author restates a hypothesis presented earlier demonstrating that the effect of cyclones and anticyclones in the troposphere can extend to the upper atmosphere and back to the lower atmosphere. The mechanism is one of alternating vortical disturbances in which the temperature in the lower part of cyclones falls while in the upper part of cyclones and the lower part of anticyclones it rises. Such effects in the troposphere cause additional heating in the ionosphere. An external factor contributing to additional thermal effects can be ultraviolet and corpuscular radiation from the sun. Corpuscular beams produce anomalous ionization in the F layer and auroras in the E layer of the ionosphere. If these beams cause thermal effects in the upper ionosphere, then, according to this hydrodynamic mechanism, a lowering of pressure and temperature at the earth's surface should be found. A number of experimental facts have borne this out. Further, on the basis of the spread of tropospheric disturbances to the ionosphere, the author presents a plausible explanation of the decrease of critical frequency and ionization in the ionosphere due to corpuscular radiation from the sun.

10.

Rakipova, L. R. Effect of solar activity on general atmospheric circulation. Trudy Glavnoy geofizicheskoy observatorii, no. 87, 1959:40-45.

During high solar activity cyclonic activity in the atmosphere increases due to increased baric gradients between cyclones and anticyclones. Increased solar activity increases the general circulation in the atmosphere, particularly in interlatitudinal exchange of air masses. This leads to a lower temperature differential between the pole and the equator and to the development of thermal anomalies of different sign relative to higher and lower latitudes. Data are cited to show that high solar activity intensifies meridional circulation.

11.

Shafer, Yu. G. (Yakutsk Branch, Academy of Sciences, USSR). Cosmic-ray research in the International Geophysical Year. Izvestiya Sibirskogo otdeleniya Akademii Nauk SSSR, no. 8, 1958: 3-17.

The author gives an up-to-date account of cosmic-ray studies in the Soviet Union, especially those carried out at the Cosmic-Ray Laboratory of the Yakutsk Branch of the USSR Academy of Sciences. It is stated that there is a considerable correlation between cosmic-ray time variations and meteorological processes, terrestrial magnetic phenomena, auroras, and the state of the ionosphere. The author notes that solar activity was at a maximum during the IGY, and adds that such activity is an important factor in the primary cosmic radiation. The finding of a pronounced latitude effect of neutron intensity is mentioned and other discoveries are claimed. Emphasis is placed on the mesonic component and variations in cosmic-ray intensity.

12.

Vernov, S. N., Yu. I. Logachev, A. Ye. Chudakov, and Yu. G. Shafer. Investigation of the variations of cosmic radiation. Uspekhi fizicheskikh nauk, v. 63, no. 1b, 1957: 149-162.

The present paper reports on the problem of the use of an artificial satellite for the study of the variations of cosmic radiation. By means of a comparatively simple apparatus consisting of a counter and ionization chamber the following phenomena can be studied: (a) the variations of the primary cosmic radiation; (b) the variations of the multiply charged component of the primary cosmic radiation which consists of helium nuclei and heavier atoms; (c) the geomagnetic field at great distances from the earth; (d) the albedo of the earth for cosmic radiation; (e) the structure of currents emitted by the sun.

I. Possibilities offered by the artificial earth satellites for the investigation of the variations. The variations of the secondary cosmic radiation differ essentially from the variations of the primary radiation. It is just for that reason that the study of the variations of the primary radiation is desirable. The variations recorded at sea level are usually much smaller than the variations of primary radiation. The measurements obtained by means of rockets are very inaccurate because of the short stay of the rockets in high altitudes, but artificial earth satellites offer great possibilities in this respect. Simultaneous measurements by counters and ionization chambers make possible a comparison of the variation of intensity of the primary protons with the variation of the intensity of the heavier primary nuclei. The variations have to be determined in the various regions of the energy spectrum of cosmic radiation. This is possible only by using satellites with suitably selected orbits. The measurements of the intensity above the polar regions are of special interest.

II. The various phenomena which can be studied by an apparatus fixed in the satellite. The authors here consider the case in which the satellite passes over the poles and is in the earth's shadow half of the time. Further, the measurement data can be transmitted during the entire time of the satellite's existence. The experimental material thus obtained in a single day by far surpasses the material hitherto existing in this field. By a comparison of the material obtained from various revolutions and on various days the variations of intensity of the cosmic radiation can be determined. If data for the intensity and ionization capacity of cosmic radiation over the entire surface of the globe are available, interesting conclusions concerning the following phenomena may be drawn: (1) the alteration of intensity in time; great irregularities of intensity in connection with eruptions of the solar chromosphere, reduction of intensity during magnetic storms, the one-and-one-half-hour variation connected with the revolution of the satellite round the earth, the variations of intensity of the heavy nuclei of primary cosmic radiation, the longtime periodic variations, the experimental verification of the connection between primary and secondary variations; (2) the earth's magnetic field and the interplanetary magnetic field; (3) the alteration of the earth's albedo for cosmic radiation; (4) the search for electrons and photons in the primary radiation.

III. The apparatus for the study of the variations of cosmic radiation outside the earth's atmosphere can determine these variations by measuring the variations of the ionization or the variations of particles passing through a counter. The influence of a possible revolution of the satellite is pointed out, but this variation can at least partially be compensated by installing two counters in the satellite. For the radio equipment, semiconductor triodes and thyratrons with a cold cathode are used. The counters of the charged particles and the method of counting by means of semiconductor triodes are discussed in detail.

APPENDIX I. BIOGRAPHICAL INFORMATION ON LEADING SCIENTISTS IN THE FIELD

APPENDIX I. BIOGRAPHICAL INFORMATION ON LEADING SCIENTISTS IN IN THE FIELD

Information contained in the following biographical sketches was taken entirely from source material available in the Library of Congress.

ALIKHANOV, Abram Isaakovich (1904-), Academician.

In 1943 Alikhanov became a member of the Academy of Sciences of the U.S.S.R. He has also been associated with the Aragats (Alagez) Cosmic Ray Station since its creation. More recently he has been named director of the Institute of Theoretical and Experimental Physics and head of the Commission on Cosmic Rays of the Academy of Sciences of the U.S.S.R. His first scientific work was in the field of X-ray diffraction analysis and the physics of X rays. In 1934 he began doing research on radioactivity and radioactive radiation. Subsequent work has been done in close association with his brother, A. I. Alikhan'yan. In 1934, Alikhanov, Kozodayev, and Alikhan'yan discovered the phenomenon of pair emission by excited nuclei and formulated the basic laws of pair production. In 1936, Alikhanov, Alikan'yan, and Artsimovich demonstrated the correctness of the laws of momentum conservation in the dematerialization of positrons and electrons. With Alikhan'yan and Nikitin, he began research in 1939 which led to the discovery of "varitrons". He has also done much work on air showers. In 1941, Alikhanov and Alikhan'yan were awarded a Stalin Prize for their work in the field of nuclear physics. A second Stalin Prize was awarded to them in 1948 for their work in connection with the discovery of varitrons.

ALIKHAN'YAN, Artemiy Isaakovich (1908-), Academician, Armenian Academy of Sciences, Corresponding Member of the Academy of Sciences, U.S.S.R.

Alikhan'yan has been a member of the Armenian Academy of Sciences since 1943. In the same year, the Institute of Physics of the Armenian Academy of Sciences was organized in Yerevan with Alikhan'yan as director. In 1945 he set up the Aragats (Alagez) Cosmic Ray Station. He became a corresponding member of the Academy of Sciences of the U.S.S.R. in 1946. Alikhan'yan's first work was in the field of X-ray physics and in the diffraction of fast electrons. Later his work centered around atomic nuclei and elementary particles. In 1936 Alikhan'yan, Alikhanov, and Artsimovich proved that the laws of the conservation of momentum and energy apply during the annihilation of positrons, and in 1939, Alikhan'yan and Alikhanov contributed substantially to the theory of pair production. With his brother, A. I. Alikhanov, he established the relationship between β-spectra and the atomic number of elements. They also developed the Alikhan'yan-Alikhanov mass-spectrometer and succeeded in separating cosmic-ray particles with a mass of approximately 200 m_e, and in obtaining evidence for the existence of particles with masses of approximately 600 m_e and 950 m_e. Alikhan'yan has published upwards of 100 papers on nuclear physics and cosmic rays. He and his brother were awarded a Stalin Prize in 1941 for their work in nuclear physics, and again in 1948 for their work in connection with the discovery of "varitrons".

AMBARTSUMYAN, Viktor Amazaspovich (1908-   ), Academician, Professor. Doctor of Physical and Mathematical Sciences.

Ambartsumyan was twenty-three years old when he finished his postgraduate studies at the Pulkovo Observatory and delivered in Leningrad the first course on the theory of astrophysics to be presented in the U.S.S.R. He was a deputy to the Third Supreme Soviet. Construction of the Byurakan Observatory was begun in 1945 under his supervision. He is now director of the observatory. Ambartsumyan is a professor at the Yerevan State University and head of the Astrophysics Department there. A full member of the Academy of Sciences of the U.S.S.R., he is also president of the Armenian Branch of the Academy of Sciences, U.S.S.R., and president of the Armenian Academy of Sciences. He is a member of the Permanent Commission for Interplanetary Communication of the Astronomical Council, Academy of Sciences, U.S.S.R. This commission was set up for the coordination and direction of all work connected with the study of outer space. In 1948, Ambartsumyan was elected vice-president of the International Astronomical Union and held that post for a number of years. He is also a member of a number of scientific academies and societies outside the Soviet Union. His main interest has been in theoretical astrophysics. He has also discovered and studied star associations and new star clusters, worked out a new theory of the radial equilibrium of planetary nebulae, and explained the physical composition of the atmosphere and the shells of meteorites. He has written more than 120 papers on these and related problems. He has received the Stalin Prize twice, the Red Banner of Labor twice, and the Order of Lenin.

ARTSIMOVICH, Lev Andreyevich (1909-   ), Academician, Professor.

Artsimovich is a full member of the Acedemy of Sciences of the U.S.S.R. and a member of the Institute of Nuclear Energy of the same academy. He is also a professor of atomic and nuclear physics at the Moscow State University. In addition, he is on the editorial boards of the journals "Vestnik Akademii nauk SSSR" and "Doklady Akademii nauk SSSR". Artsimovich has done valuable research on the properties of fast electrons and on theoretical electron optics. The precise experimental data obtained by him in 1935-1940 on the processes of bremsstrahlung and the angular distribution of scattered electrons have proved the validity of the present quantum-mechanical theory of fast electrons. In the period 1943-1945 Artsimovich completed a series of important experiments in the field of electron optics and worked out the theory of chromatic aberration of electron-optical systems. At the same time he made a theoretical study of the mechanism of emission in electron accelerators. Artsimovich and eleven other scientists were awarded the Lenin Prize for research on powerful gas discharges which produce high-temperature plasma. This has helped to open the way to controlled thermonuclear reactions. He has also received a Stalin Prize and three Orders of the Red Banner of Labor.

BLINOVA, Yekaterina Nikitichna (1906-), Corresponding Member of the Academy of Sciences, U.S.S.R.

Ye. N. Blinova became a corresponding member of the Academy of Sciences in 1953. She has also been associated with the Main Geophysical Observatory and the Central Forecasting Institute. Her most important work has been on problems of the stability of atmospheric fronts, general atmospheric circulation, and centers of atmospheric activity. She has presented a theory of radiative equilibrium in the atmosphere, as well as a method of long-range forecasting based on integration of the vortex equation. This method is useful in computer forecasts and the solution of problems of atmospheric dynamics.

CHUDAKOV, Aleksandr Ye., Candidate of Physical and Mathematical Sciences.

From 1949 to 1955 Chudakov was a member of the Physics Institute imeni Lebedev of the Academy of Sciences, U.S.S.R. He participated in the Tenth International Astronomical Congress, August 12-21, 1958, in Moscow. He is also a member of the group doing research on cosmic rays in the Pamirs at an elevation of 3,860 meters. Chudakov's investigations have been concerned chiefly with the composition of cosmic radiation, especially at mountain altitudes, and with Cherenkov radiation in extensive air showers. He has recently been associated with studies carried out with the aid of rockets and satellites.

DOLGINOV, S. Sh.

Dolginov is a member of the Institute for Research on Terrestrial Magnetism, the Ionosphere, and Radio-wave Propagation. Recently, he and N. V. Pushkov discovered anomalies in the earth's magnetic field at the point of highest intensity in the outer radiation belt. This was made possible by a magnetometer installed in a Soviet space vehicle.

DORMAN, Leib Isaakovich, Candidate of Physical and Mathematical Sciences.

Dorman is a member of the Physics Institute imeni Lebedev of the Academy of Sciences, U.S.S.R. and the Institute for Research on Terrestrial Magnetism, the Ionosphere, and Radio-wave Propagation. He has also been a member of the Commission on Cosmic Rays and the National Committee of the International Geophysical Year. His most significant work has been done on variations in cosmic-ray intensity, especially as influenced by meteorological factors and solar activity.

EYGENSON, Moris Semenovich (1906-), Professor.

Eygenson is the director of the Astronomical Observatory of the L'vov State University imeni Franko. He has done considerable research on the atmosphere and the effect of the sun on geophysical processes. He presented a paper on this subject at the International Astronomical Congress in Moscow in August 1958.

FEDOROV, Yevgeniy Konstantinovich (1910-), Corresponding Member of the Academy of Sciences, U.S.S.R., Doctor of Geographical Sciences, Hero of the Soviet Union.

Upon graduating from Leningrad University in 1932, Fedorov joined the Arctic Institute. He spent the winter of 1932-1933 as scientific director and assistant chief of the Polar Station on Franz Josef Land where he studied terrestrial magnetism. Upon his return he was put in charge of a group working on the magnetic data gathered at the Polar Station during the Second

International Polar Year. In 1934 Fedorov organized a magnetic observatory on Cape Chelyuskin. In 1938 he was accepted for membership in the Communist Party and was elected deputy to the Supreme Soviet. He was elected corresponding member of the Academy of Sciences, U.S.S.R., in 1939. In April of the same year, Fedorov was named director of the Arctic Institute and in December 1939 became chief of the Hydrometeorological Service of the U.S.S.R. He also worked as geophysicist-astronomer on the first Soviet drifting station "North Pole 1". From 1947 to 1955 he worked at the Institute of Geophysics of the Academy of Sciences, U.S.S.R. In 1954 he was a member of the I. Cherevichnyy detachment of the polar expedition for the study of the relief of the Lomonosov underwater range. He is also a deputy senior scientific secretary of the Presideium of the Academy of Sciences, U.S.S.R. Fedorov was one of the Soviet delegates to the Geneva conference of experts on the detection of nuclear tests. He is best known for basic research on geomagnetism, meteorology, and applied astronomy. The Order of Lenin has twice been awarded to him.

FEYNBERG, Yevgeniy L'vovich, Doctor of Physical and Mathematical Sciences.

Feynberg has been a member of the Physics Institute imeni Lebedev of the Academy of Sciences, U.S.S.R., since 1939. In 1945 he became a member of the Laboratory of Theoretical Physics. For the past ten years he has served on the editorial board of the magazine "Zhurnal eksperimental'noy i teoreticheskoy fiziki". He is also a member of the Commission on Cosmic Rays and the National Committee for the International Geophysical Year. Some of his studies include the relationship between atomic lattices, the Thomas-Fermi theory and metallic cohesion, the electric moment of the nucleus, ionization of the atom due to beta decay, interaction of mesons with ~~nuclei~~; propagation of radio waves, barometric and temperature effects on cosmic rays, electromagnetic radiation in proton-neutron collisions, interaction cross sections for extremely fast nucleons, high-energy proton showers, and nonrelativistic nucleon interactions. He has also designed instruments for computing values of the coefficient of correlation of stochastic stationary processes, renormalization and dispersion relationships.

FESENKOV, Vasiliy Grigor'yevich (1889-   ), Academician.

Fesenkov became a corresponding member of the Academy of Sciences, U.S.S.R. in 1927 and a full member in 1935. In 1946 he was made a member of the Kazakh Academy of Sciences. He is also a member of various commissions of the International Astronomical Union. Fesenkov has done scientific work on the physical properties of planets, meteoric material, the physics of the sun and stars, the structure of gas-dust clouds, the structure of the galaxy, celestial mechanics, and atmospheric optics. He has been a pioneer in the photometric study of zodiacal light and has developed a dynamic theory of this phenomenon. He also originated the corpuscular hypothesis of stellar radiation and the hypothesis of the formation of stars from interstellar gas and dust particles.

FRANK, Il'ya Mikhaylovich (1908-), Corresponding Member of the Academy of Sciences, U.S.S.R., Doctor of Physical and Mathematical Sciences, Professor.

From 1930 to 1934 Frank was associated with the Optics Institute in Leningrad, and afterwards with the Physics Institute imeni Lebedev of the Academy of Sciences, U.S.S.R. He now heads its Laboratory of Atomic Nuclei. His work is concentrated in the fields of physical optics and nuclear physics. In particular, he has investigated the movement of charged particles through a refracting medium (Cherenkov effect, Doppler effect, and intermediate radiation). Frank and Groshev were able to produce the conversion of gamma quanta into electron-positron pairs. A number of his studies have been on neutrons.

GINZBURG, Vitaliy Lazarevich (1916-), Corresponding Member of the Academy of Sciences, U.S.S.R.

After graduating from Moscow University, Ginzburg began working in 1940 at the Physics Institute imeni Lebedev of the Academy of Sciences , U.S.S.R. In 1945 he became a professor at the Gor'kiy University. He entered the Academy of Sciences as a corresponding member in 1953. He has been most active in the fields of radio-wave propagation in the ionosphere, photoelectrical phenomena, superconductivity, radioastronomy, and the origin of cosmic rays. Ginzburg and Frank analyzed Cherenkov radiation during the motion of particles along the axis of a dense medium. Their findings formed the basis for the method of generating radio waves by means of the Cherenkov effect.

KRASOVSKIY, Valeryan Ivanovich, Doctor of Physical and Mathematical Sciences, Professor.

Krasovskiy is head of the Department of Upper Atmospheric Physics of the Institute of Atmospheric Physics, Academy of Sciences, U.S.S.R. In 1958, at the Moscow conference of the I.G.Y. governing committee, Krasovskiy read a paper on the results of ionospheric research conducted in the U.S.S.R. between 1954 and 1958. Data for this research was obtained by high-altitude rockets. Krasovskiy has also played an active part in more recent investigations of the upper atmosphere and cosmic radiation by means of satellites. In 1959 he attended a conference of the American Rocket Society.

LEBEDINSKIY, Aleksandr Ignat'yevich, Professor.

Lebedinskiy was formerly associated with the Leningrad State Pedagogical Institute imeni Gertsen. Now he is at the Moscow State University imeni Lomonosov. In July 1959, he participated in the International Conference on Cosmic Rays. His principal studies are concerned with astrophysics, cosmogony, magnetic fields of sun spots, and nuclear reactions on stars.

LEONTOVICH, Mikhail Aleksandrovich (1903-), Academician.

In 1929 Leontovich joined the faculty of the Institute of Physics of Moscow University, and in 1934 he became associated with the Physics Institute imeni Lebedev. Since 1946 he has been a full member of the Academy of Sciences, U.S.S.R. Leontovich is well known for his research in the fields of electrodynamics, optics, physics and radio physics. He is the author of a series of studies on the theory of molecular light scattering, on the theory of fluctuations and on various problems of radio physics. His work on the thin-wire antenna has served as a basis for the development of antenna theory. He has also solved several practical problems in radio engineering. He is one of twelve scientists awarded the Lenin Prize for research on powerful gas discharges. Other awards include the Order of Lenin, the Order of the Red Banner of Labor, and the Popov Gold Medal.

PUSHKOV, Nikolai Vasil'yevich, Candidate of Physical and Mathematical Sciences.

Pushkov is the head of the Institute for Research on Terrestrial Magnetism, the Ionosphere, and Radio-wave Propagation. He specializes in ionospheric physics and terrestrial magnetism. By means of magnetic instruments installed in Lunik I, Pushkov and Dolginov discovered anomalies in the earth's magnetic field in the region of highest intensity of the outer radiation belt.

SEVERNYY, Andrey Borisovich (1913-), Corresponding Member of the Academy of Sciences, U.S.S.R.

In 1956 Severnyy began working at the Crimean Astrophysical Observatory of the Academy of Sciences, U.S.S.R., and has been director of this observatory since 1952. His membership in the Communist Party dates from 1941. In 1958 he was made a corresponding member of the Academy of Sciences, U.S.S.R. His principal scientific work has been in the fields of theoretical astrophysics and the physics of the sun. He has investigated the amount of heavy hydrogen in the atmosphere. In 1952 he was awarded a Stalin Prize for his study of solar flares.

SHAFER, Yuriy Georgiyevich, Candidate of Physical and Mathematical Sciences.

Since 1947 Shafer has headed the Cosmic Ray Laboratory of the Yakut Branch of the Academy of Sciences, U.S.S.R. He is also associated with the Physics Institute of the same branch of the Academy of Sciences. He is a member of the Commission on Cosmic Rays and in 1955 served on the National Committee for the International Geophysical Year. His work bears primarily on variations in the intensity of cosmic radiation, especially those due to to meteorological effects. He has designed equipment for studying cosmic rays and has received a Stalin Prize.

SHKLOVSKIY, Iosif Samoylovich (1916-)

Shklovskiy has been associated with the State Astronomical Institute imeni Shternberg since 1944. He has developed a theory of the ionization of the solar corona, carried out a quantitative separation of galactic radiation into thermal and nonthermal radiation, and has sought to ascertain the origin of cosmic rays in the envelopes of novae and supernovae. He has also written on the aurora borealis and the infrared radiation of night glow.

SKOBEL'TSYN, Dmitriy Vladimirovich (1892-), Academician, Doctor of Physical and Mathematical Sciences, Professor.

A corresponding member of the Academy of Sciences, U.S.S.R., Since 1939, Skobel'tsyn became a full member in 1946. He was a deputy to the Fourth Supreme Soviet. In 1951 he became director of the Physics Institute of the Academy of Sciences, U.S.S.R. He has also served on the Soviet Foreign Affairs

Committee. One of the first cosmic-ray physicists in the Soviet Union, Skobel'tsyn discovered one of the most remarkable features of cosmic radiation, the formation of groups of genetically related particles, or showers. Some of his work determined the course of future studies in the field. This is especially true with respect to the phenomena of electron-nuclear and nuclear-cascade showers. Skobel'tsyn was awarded a Stalin Prize in 1951, the Vavilov Gold Medal in 1952, and has twice been awarded the Order of Lenin.

TAMM, Igor Yevgen'yevich (1895-), Academician, Doctor of Physical and Mathematical Sciences, Hero of Socialist Labor.

From 1924 to 1941 Tamm taught in different institutions of higher education. He is the head of the Department of Theoretical Physics of the Moscow State University and a full member of the Academy of Sciences, U.S.S.R. His work has been devoted primarily to quantum mechanics and its application, theories of radiation and the interaction of relativistic particles. In 1930 he formulated the quantum theory of light dispersion in solids. In 1932 he established the theoretical possibility of special conditions of electrons on crystal surfaces, and in 1937 elaborated the theory of the radiation of electrons moving at high speeds in the atmosphere. Recently he won the Nobel Prize and participated in the Geneva conference of experts on the detection of nuclear explosions.

VEKSLER, Vladimir Iosifovich (1907-), Academician, Doctor of Physical and Mathematical Sciences, Professor.

In his third year at the Moscow Technical University, Veksler invented a circuit for doubling the voltage of a three-phase current. In the period 1930 to 1936 he worked at the All-Union Electrical Engineering Institute. From 1936 to 1956 he was associated with the Institute of Physics of the Academy of Sciences, U.S.S.R. His membership in the Communist Party of the Soviet Union dates from 1937. While in the Institute of Physics he studied the structure of the atom and participated in expeditions to the Pamirs and the Caucasus for investigation of the nature of cosmic rays. In 1944-1945 his significant work on the automatic phasing of particles marked a turning point in the design of particle accelerators. He became a corresponding member of the Academy of Sciences in 1946, and in 1958 a full member. In 1956 Veksler was named director of the Joint Institute of Nuclear Research in Dubna. He is also a member of the editorial board of two magazines: "Uspekhi fizicheskikh nauk" and "Atomnaya energiya". Veksler is a recipient of the Lenin Prize.

VERNOV, Sergey Nikolayevich (1910-), Corresponding Member of the Academy of Sciences, U.S.S.R., Professor.

After graduating from the Leningrad Polytechnic Institute in 1931, Vernov began working at the Radium Institute of the Academy of Sciences, U.S.S.R. He has been working at the Institute of Physics of the Academy of Sciences since 1936, and in 1944 became a professor at the Moscow State University. He was made a corresponding member of the Academy of Sciences in 1953. He heads a group studying cosmic rays under the Soviet Committee for the International Geophysical Year. He is also on the editorial board of the magazine "Vestnik Moskovskogo universiteta, seriya matematiki, mekhaniki, astronomii, fiziki, khimii". Vernov's principal work has been in the field of high-altitude cosmic-ray research. He developed a method for studying cosmic rays by means of automatic equipment carried to high altitudes by balloons. He and his coworkers demonstrated conclusively that protons are the basic component of primary cosmic radiation. They also helped to explain the nature of the soft component of cosmic radiation, the transition effect, the latitude effect, and Van Allen radiation belts. Vernov and Khristiansen have been using special equipment installed at the Moscow State University for the study of high-energy cosmic rays. A Stalin Prize was awarded to Vernov in 1949.

ZATSEPIN, Georgiy Timofeyevich, Candidate of Physical and Mathematical Sciences.

Zatsepin is associated with the Institute of Physics imeni Lebedev, Academy of Sciences, U.S.S.R. In 1951 he was awarded a Stalin Prize for research which led to the discovery of electron-nuclear showers and nuclear cascade processes in cosmic radiation. At the International Conference on Cosmic Rays in Moscow in July 1959, he presented a paper on the theoretical development of showers.

ZAVOYSKIY, Yevgeniy Konstantinovich (1907-), Corresponding Member of the Academy of Sciences, U.S.S.R., Professor.

Zavoyskiy began teaching at the Kazan University in 1933, and became a professor there in 1945. He has worked in various institutions of the Academy of Sciences, U.S.S.R., since 1947. In 1953, he was made a corresponding member of the Academy of Sciences. Zavoyskiy discovered the phenomenon of electronic paramagnetic resonance in 1944. Later, Zavoyskiy, Al'tshuller, and Kozyrev discovered a series of laws relating to the form of resonance lines. Since 1947 he has been working on different problems in the field of physics. He helped develop a luminescence camera using electron-optic converters. He has also used electron-optic converters for the study of phenomena occurring in very short periods of time. In 1957 Zavoyskiy was awarded a Lenin Prize.

APPENDIX II. INSTITUTES, STATIONS, AND OBSERVATORIES

APPENDIX II. INSTITUTES, STATIONS, AND OBSERVATORIES

A. Institutes.

1. Physics Institute imeni Lebedev of the Academy of Sciences, U.S.S.R. The institute is located in Moscow. The major work of the institute at present includes the construction of particle accelerators and the study of the properties of cosmic rays and fast particles. Achievements of the past twenty years include the discovery of Cherenkov radiation, new accelerators, findings on the primary cosmic radiation, and the development of the methods of radio astronomy. Much research is carried out by expeditions.

2. State Astronomical Institute imeni Shternberg. This institute, including the Moscow Astronomical Observatory, is a part of the Moscow State University. Much research done at the institute has been related to the study of cosmic radiation. The institute published its "Trudy" [Transactions] and "Soobshcheniya" [Reports].

3. Physics Research Institute of the Moscow State University. Work of the institute is published in Vestnik Moskovskogo universiteta, seriya matematiki, mekhaniki, astronomii, fiziki, khimii.

4. Commission on Cosmic Rays, Department of Physics and Mathematics, Academy of Sciences, U.S.S.R. The commission was created in 1944 and is headed by A. I. Alikhanov. The principal function of the commission is organizing and coordinating research on cosmic radiation.

5. Institute of Research on Terrestrial Magnetism, the Ionosphere, and Radio-wave Propagation. The institute is located in Leningrad. Research on variations in cosmic radiation, auroras and ionospheric physics has been done by its members.

6. Physics Institute of the Academy of Sciences of the Armenian S.S.R. This institute is located in Yerevan. Much research on the composition of cosmic radiation has been done by its members.

7. Physical-Engineering Institute of the Academy of Sciences of the Uzbek S.S.R. The institute is located in Tashkent.

B. Cosmic-ray stations participating in the International Geophysical Year.

Name	Geographic coordinates	Equipment
Alma-Ata	43° 14' N 76° 56' E	Neutron monitor
Cape Schmidt	68° 52' N 179° 30' E	Shielded ionization chamber
Krasnaya Pakhra (or Moscow)	55° 28' N 37° 19' E	Standard cubic counter telescope; shielded ionization chamber; neutron monitor; underground counter telescope; balloons; air-shower instruments
Mirnyy	66° 33' S 93° 00' E	Shielded ionization chamber; neutron monitor
Murmansk	68° 55' N 33° 10' E	Standard cubic counter telescope; neutron monitor; balloons
Partizanskaya	44° 50' N 34° 04' E	
Simferopol	44° 50' N 34° 04' E	
Sverdlovsk	56° 14' N 61° 04' E	Standard cubic counter telescope; shielded ionization chamber
Tbilisi	41° 43' N 44° 49' E	Standard cubic counter telescope; shielded ionization chamber
Tikhaya Bay (or Heiss Island)	80° 20' N 52° 48' E	Shielded ionization chamber; Neutron monitor
Tiksi Bay	71° 40' N 128° 54' E	Shielded ionization chamber
Yakutsk	62° 01' N 129° 43' E	Standard cubic counter telescope; shielded ionization chamber; air-shower instruments; underground counter telescope; neutron monitor

C. Other Stations and Observatories.

1. The Central Astronomical Observatory, better known as the Pulkovo Observatory, was built in 1839 in Pulkovo, about twelve miles south of Leningrad. It has been rebuilt since World War II. Since the turn of the century, its work has centered on the sun and astrophysics.

2. Mountain Station of the Pulkovo Observatory. This station, located near Kislovodsk (coordinates: 43° 44' N 42° 30' E), is one of the two Solar Service Centers in the Soviet Union. It is equipped with an occulting coronagraph.

3. The Alma-Ata Astrophysical Observatory of the Academy of Sciences of the Kazakh S.S.R. Situated near Alma-Ata at an elevation of 1450 meters, this observatory is used mainly for studying the sun, the earth's upper atmosphere, and meteoric matter in the solar system.

4. The Gor'kiy Scientific Research Institute of Radio Physics.

5. The Crimean Astrophysical Observatory of the Academy of Sciences of the U.S.S.R. was established in 1908 as a branch of the Pulkovo Observatory. Most of the equipment, as well as the building of the observatory, was destroyed during World War II. In 1945 the observatory was restored and made an independent institution. It is now one of two Solar Service Centers in the Soviet Union. The work of the observatory is devoted to the study of the physics of solar and stellar atmospheres, the structure of the stellar system, and dispersed gaseous and dust-like matter in interstellar space.

6. The Crimean Scientific Station of the Institute of Physics imeni Lebedev. This station, located in Simeiz, is part of the Crimean Astrophysical Observatory.

7. The Aragats Cosmic Ray Station on Mount Aragats in Armenia was established in 1942 for the purpose of studying the composition of cosmic radiation. This station, formerly and occasionally still called the Alagez Cosmic Ray Station, is situated at an altitude of 3,250 meters. It is administered by the Institute of the Armenian S.S.R. One of the main laboratories at the station is the Large Magnet Laboratory where elementary particles of cosmic rays are investigated. The laboratory has some complex radio and electrical equipment and a system of high-sensitivity counters which are used for the study of high-energy particles. A powerful new electromagnet is now being installed. The director of the station is A. L. Khrimyan.

8. The Byurakan Astrophysical Observatory near Yerevan is one of the newest in the U.S.S.R. Organized in 1933 as a branch of Yerevan State University, it was later brought under the Academy of Sciences of the Armenian S.S.R. The observatory is situated on Mount Aragats at an elevation of 1500 meters. The principal fields of activity are the study of galaxies, the origin and life of stars, nebulae, radio astrophysics and astronomy beyond the galactic system. The largest Soviet interference radiotelescope has been erected here making it possible to study radio emission from distant heavenly bodies. The director of the observatory is V. A. Ambartsumyan.

9. The Abastumani Astrophysical Observatory of the Academy of Sciences of the Georgian S.S.R. was established in 1932. It is situated at an altitude of 1700 meters on Kanobili Mountain. Its basic work is the study of radio emission from the sun and light absorption in interstellar space and the earth's atmosphere.

10. The Ashkhabad Astrophysical Observatory was established in 1945 under the Academy of Sciences of the Turkmen S.S.R. It is situated at an elevation of 232 meters.

11. Loparskaya Station. Also called the Northern Scientific Station of the Academy of Sciences of the U.S.S.R. Geographical coordinates: 68° 15' N 33° 05' E.

12. Dolgoprudnaya Station. Also called the Scientific Station of the Institute of Physics of the U.S.S.R. Geographical coordinates: 55° 56' N 37° 31' E.

13. Chechekty in the Pamirs is situated at an altitude of 3,860 meters, between Ostra and Khorog. It is a base for the Pamir Expedition of the Institute of Physics of the Academy of Sciences, U.S.S.R. There are reports that a well-equipped scientific center is being built there.

14. The Cosmic-Ray Laboratory of the Yakut Branch of the Academy of Sciences, U.S.S.R., was established in Yakutsk because of the favorable temperature regime and geophysical location of that city. The laboratory has equipment for the measurement of variations in cosmic-ray intensity in a wide interval of the energy spectrum. Measurements are made at various altitudes in the atmosphere, on the surface of the earth, and underground. The low-energy components are being studied to establish correlations between intensity variations and solar and geomagnetic effects.

15. The Zarya, a nonmagnetic ship of the Institute for Research on Terrestrial Magnetism, the Ionosphere, and Radio-wave

Propagation, sailed from Odessa on April 26, 1959 on a new scientific voyage. For the first time, instruments for ionospheric investigations and the study of cosmic radiation have been placed on board.

APPENDIX III. INSTRUMENTS AND EQUIPMENT

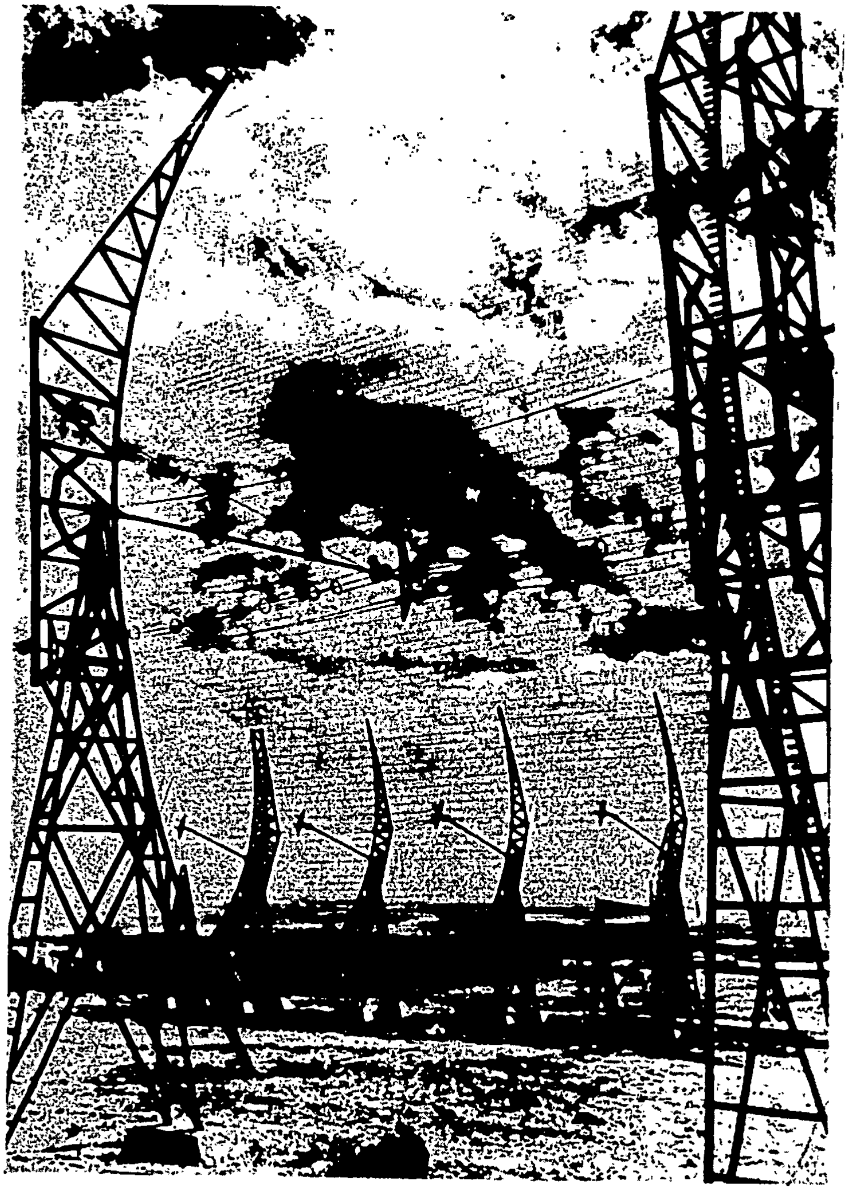


Figure 1. Soviet Radio Telescope in Armenia

Photograph shows part of what appears to be a large linear array which is one portion of the largest radio telescope known to exist in the Soviet Union. Telescope is located near Burakan, in Soviet Armenia. Fixed radio telescopes such as this utilize the earth's rotation to scan a section of sky along the equatorial plane, and can employ interferometer techniques to improve resolution. (From Aviation Week, December 7, 1959, p. 72)

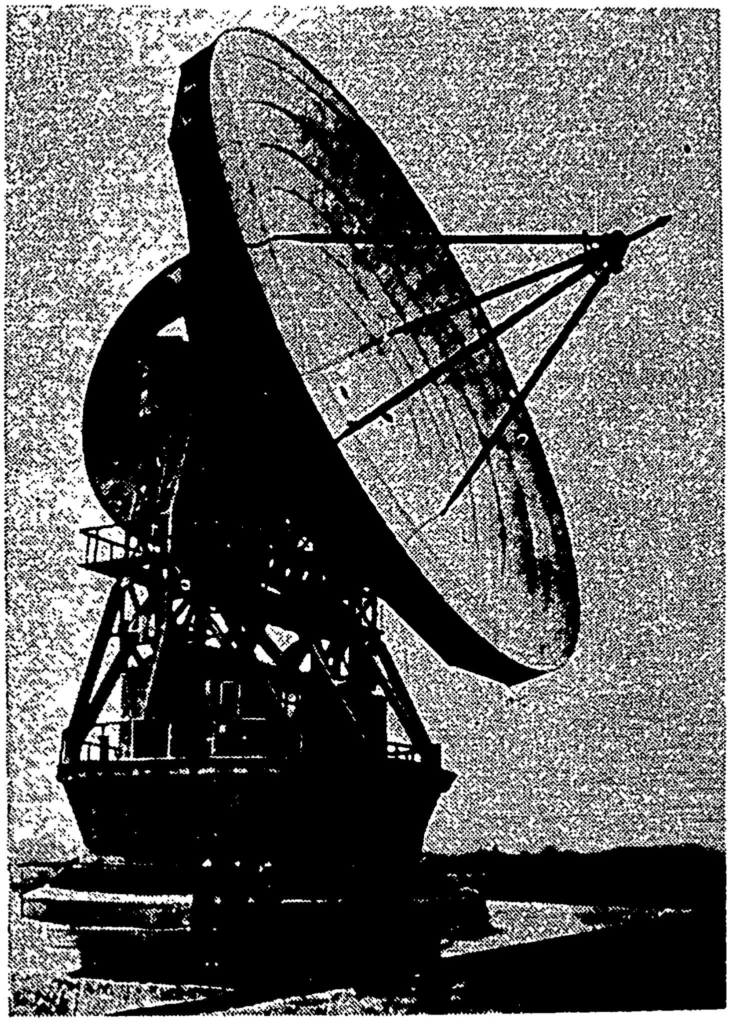


Figure 2. New radio telescope of the Radio-Astronomy Station of the Physics Institute imeni Lebedev, Academy of Sciences, USSR. The parabolic reflector has a diameter of 22 meters, a focal length of 9.5 meters, and a weight of 65 tons. The overall weight of the telescope is 380 tons. This telescope is claimed to have the highest resolving power of any steerable telescope in the world. A much larger radio telescope, in the shape of a cross, is being built at the same site. (Izvestiya, October 30, 1959, p. 12)

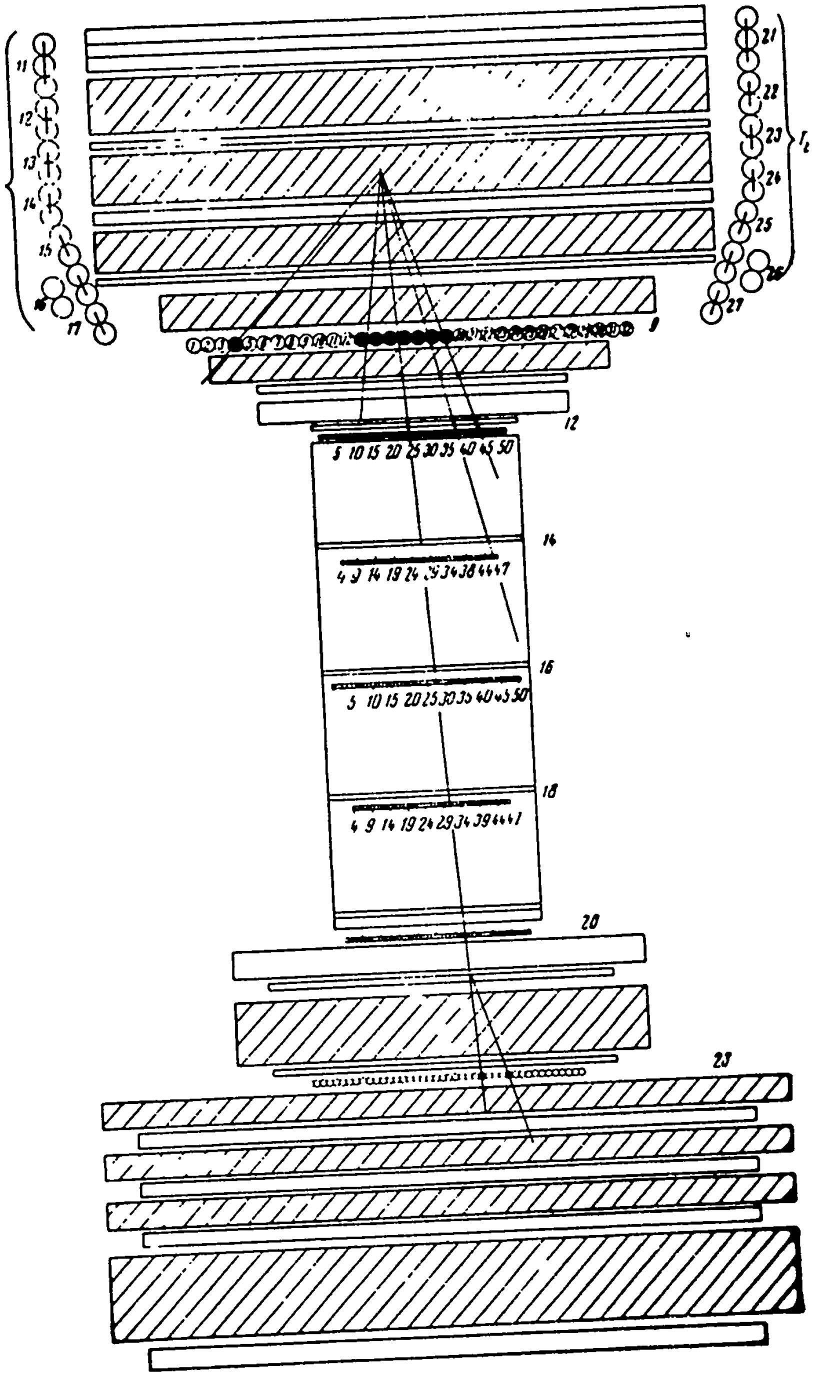


Figure 3. Perpendicular cross section of the Alikhan'yan-Alikhanov magnetic mass spectrometer. Lead blocks above the spectrometer and graphite filters below. Numbered circles and rows represent counters. Magnetic field value 6,850 oersted. (From Asatiani and Khrimyan, Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 33, no. 3, 1957: 561-566)

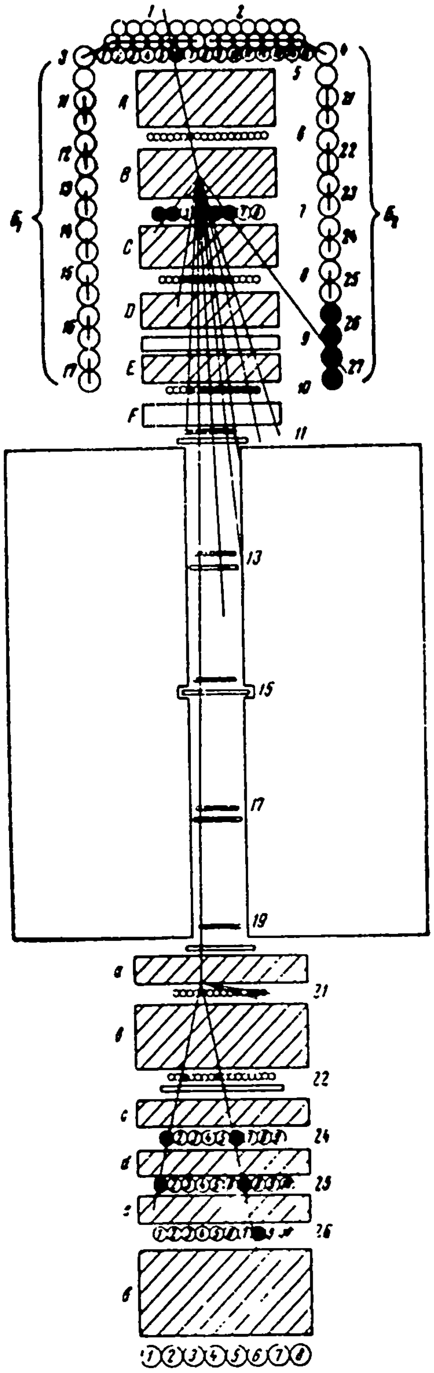


Figure 4. Perpendicular cross section of the Alikhan'yan-Alikhanov magnetic mass spectrometer. Hodoscopic arrangement above the spectrometer is shown. Lead blocks represented by A, B, C, D, E, F, separate rows of counters., Graphite filters a, b, c, e, f are located below the mass spectrometer. Numbered circles and rows represent counters. Magnetic field value 6,850 oersted. (From Asatiani and Khrimyan, Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 33, no. 3, 1957: 561-566)

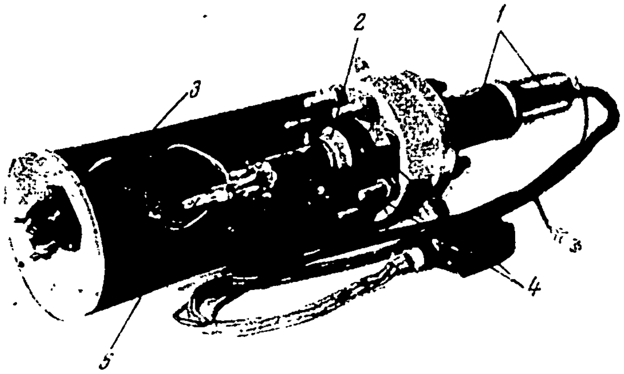


Figure 5. Mass-spectrometer tube. 1. Analyzer with preamplifier. 2. Ion source. 3. Cover (cut-away view). 4. Tie bolts. 5. Projection with sputtered gas absorber.

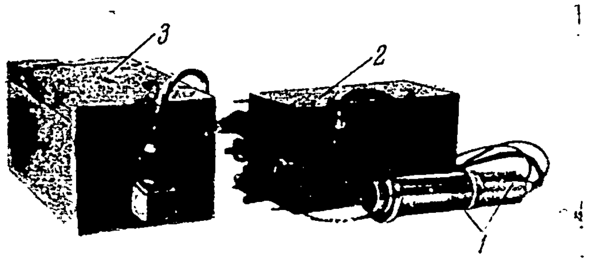


Figure 6. RMS-1 radio-frequency mass-spectrometer. 1. Mass-spectrometer tube with preamplifier. 2. Electronic unit. 3. Power pack (sputnik type).

(Both figures from Istomin, Iskusstvennyye sputniki Zemli, no.3, 1959: 98-112)

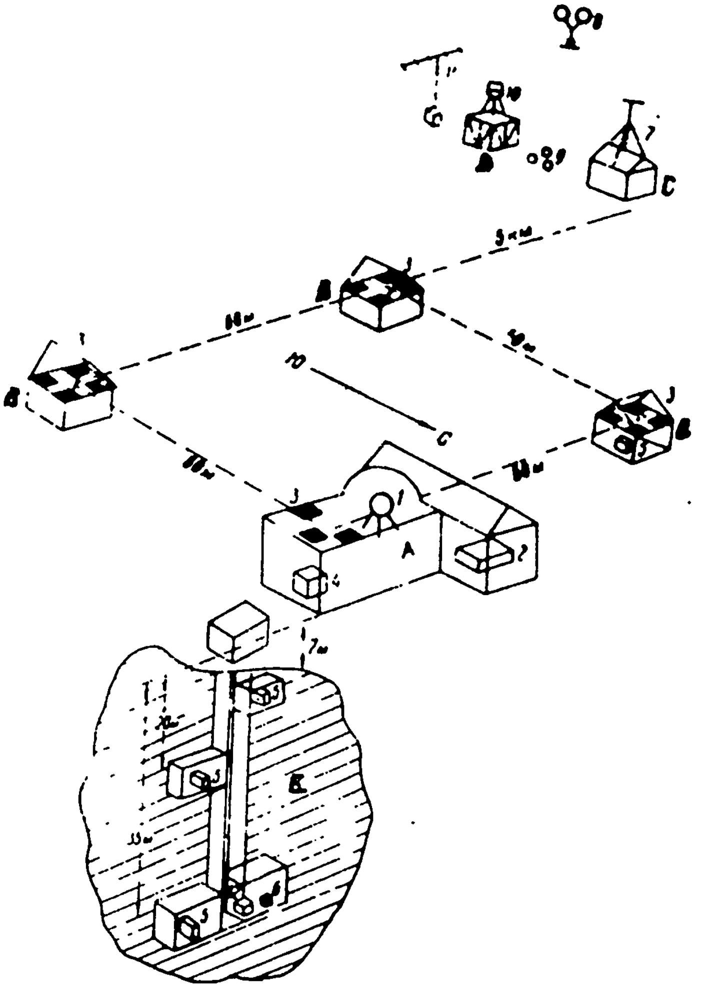


Figure 7. Arrangement of equipment of the Cosmic-Ray Laboratory of the Yakut Branch of the Academy of Sciences of the USSR in Yakutsk at the beginning of the International Geophysical Year.

A. Main building. B. Stations for extensive air showers. C. Stratospheric station. D. Aurora station. E. Underground installation.

1. ASK-1 ionization chamber. 2. Neutron monitor. 3. Air-shower equipment. 4. Inclined azimuthally-opposed counter telescope. 5. Underground inclined azimuthally-opposed counter telescope. 6. Semicubic telescope. 7. Ultrashortwave receiving station. 8. Stratospheric balloons. 9. SP-48, SP-49, and SP-50 spectrographs. 10. S-180 automatic motion-picture camera. 11. P-3 radar. 12. Seismic station. (From Shafer, Izvestiya Sibirskogo otdeleniya Akademii nauk SSSR, no. 8, 1958: 3-17)

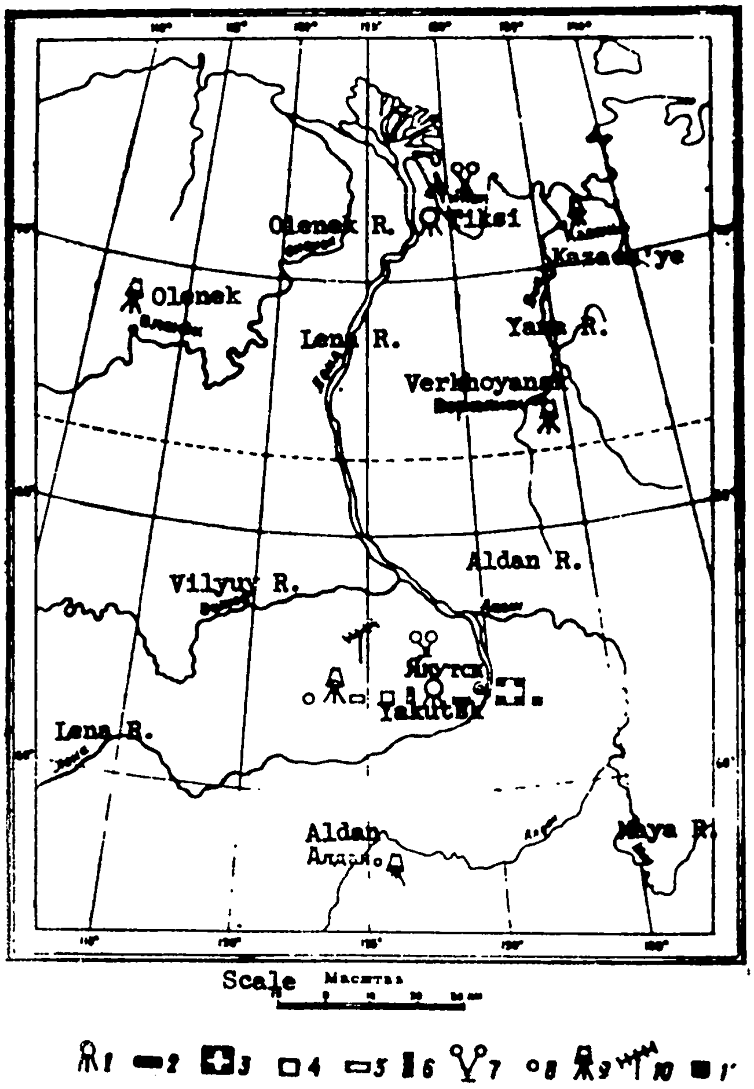


Figure 8. Location of equipment for recording cosmic rays and auroras in the Yakut ASSR. 1. ASK-1 ionization chamber. 2. Neutron monitor. 3. Equipment for extensive air showers. 4. Inclined azimuthally-opposed counter telescope. 5. Underground inclined azimuthally-opposed counter telescope. 6. Semicubic telescope. 7. Balloons. 8. SP-48, SP-49, and SP-50 spectrographs. 9. S-180 automatic motion-picture camera. 10. P-3 radar. 11. Seismic station. (From Shafer, Izvestiya Sibirskogo otdeleniya Akademii nauk SSSR, no. 8, 1958: 3-17)

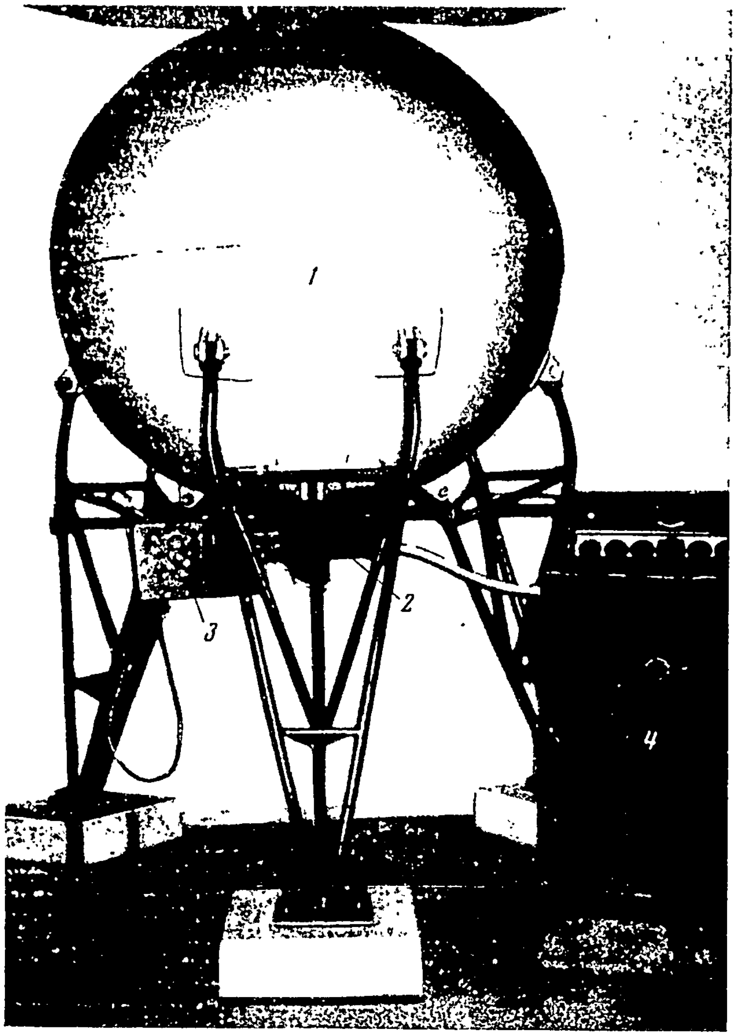


Figure 9. ASK-1 chamber for measuring cosmic-ray intensity. 1. Spherical steel shell surrounding lead-lined chamber with a volume of 950 liters. 2. Frame with electrometer installed inside. 3. Photorecorder. 4. Power unit. (From Shafer, Trudy Yakutskogo filiala Akademii nauk SSSR, seriya fizicheskaya, no. 2, 1958: 7-22)

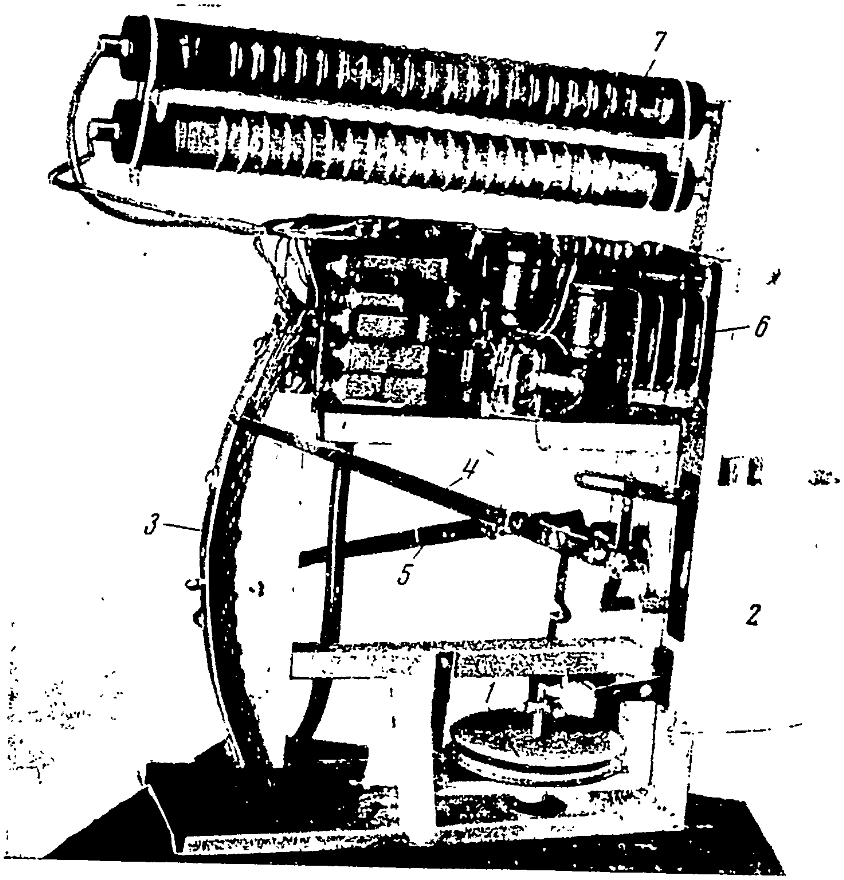


Figure 10. Radiosonde for cosmic rays. 1. Aneroid capsules. 2. Temperature-sensing element. 3. Contact ridges. 4. Slider of thermometer. 5. Slider of barometer. 6. Radio circuit. 7. Counter telescope. (From Belomestnykh and Shafer, Trudy Yakutskogo filiala Akademii nauk SSSR, seriya fizicheskaya, no. 2, 1958: 47-56)

BIBLIOGRAPHY

1. Abrosimov, A. T., V. A. Dmitriyev, G. V. Kulikov, Ye. I. Massal'skiy, K. I. Solov'yev, and G. B. Khristiansen. High-energy nuclear-active component in extensive air showers above sea level. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 36, no. 3, 1959: 751-761.

2. Abrosimov, A. T., N. N. Goryunov, V. A. Dmitriyev, V. I. Solov'yeva, B. A. Khrenov, and G. B. Khristiansen. Structure of extensive air showers at sea level. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 34, no. 5, 1958: 1077-1089.

3. Abrosimov, A. T., V. I. Zatsepin, V. I. Solov'yeva, G. B. Khristiansen, and P. S. Chikin. Structure of extensive air showers at sea level. Izvestiya Akademii nauk SSSR, seriya fizicheskaya, v. 19, no. 6, 1955: 677-680.

4. Ageshin, P. N., and T. N. Charakhch'yan. Investigation of μ-mesons in the stratosphere. Vestnik Moskovskogo universiteta, seriya matematiki, mekhaniki, astronomii, fiziki, khimii, v. 11, no. 2, 1956: 77-88.

5. Ageshin, P. N., A. N. Charakhch'yan, and T. N. Charakhch'yan. Study of the origin of the soft component of cosmic rays in the stratosphere at 51° North geomagnetic latitude. Izvestiya Akademii nauk SSSR, seriya fizicheskaya, v. 19, no. 5, 1955: 533-536

6. Agranovich, V. M., and V. S. Stavinskiy. Theory of photonuclear reactions. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 34, no. 3, 1958: 700-706.

7. Alikhanov, A. I., and G. P. Yeliseyev. Investigation of the mass spectrum of particles of cosmic rays at sea level. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 21, no. 9, 1951: 1009 1022.

8. Alikhanov, A. I., G. P. Yeliseyev, V. Sh. Kamalyan, V. A. Lyubimov, B. N. Moiseyev, and A. V. Khrimyan. Investigation of the nature and spectra of particles produced by high-energy nucleons. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 36, no. 2, 1959: 404-410.

9. Alikhan'yan, A. I., and A. I. Alikhanov. Varitrons. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 21, no. 9, 1951: 1023-1044.

10. Alikhan'yan, A. I., A. Alikhanov, V. Morozov, G. Muskhelishvili, and A. Khrimyan. Mass spectrum of varitrons. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 18, no. 8, 1948: 673-702.

11. Alikhan'yan, A. I., and T. A. Asatiani. Investigation of Auger showers. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 15, no. 6, 1945: 225-234.

12. Alikhan'yan, A. I., A. Dadayan, and N. Shostakovich. Cosmic-ray particles with a mass of 600-1000 m_e. Doklady Akademii nauk SSSR, v. 82, no. 5, 1952: 693-696

13. Alikhan'yan, A. I., and V. Kharitonov. Particles with mass intermediate between that of mesons and protons. Doklady Akademii nauk SSSR, v. 85, no. 2, 1952: 295-298.

14. Alikhan'yan, A. I., and V. Kharitonov. Determination of the mass of cosmic-ray particles by their ionization capacity. Doklady Akademii nauk SSSR, v. 92, no. 6, 1953: 1125-1128.

15. Alikhan'yan, A. I., V. Kirillov-Ugryumov, N. Shostakovich, V. Fedorov, and G. Merzon. About the existence of unstable charged particles with mass exceeding that of protons. Doklady Akademii nauk SSSR, v. 92, no. 4, 1953: 719-721.

16. Alikhan'yan, A. I., and G. A. Marikyan. Generation of fast deuterons in cosmic rays. Doklady Akademii nauk SSSR, v. 87, no. 2, 1952: 191-194.

17. Al'pert, Ya. L. State of the outer ionosphere. Priroda, no. 6, 1958: 86-89.

18. Andronikashvili, Ye. L., and M. F. Bibilashvili. Investigation of the lateral distribution of penetrating particles of extensive air showers. In Mezhdunarodnaya konferentsiya po kosmicheskim lucham organizovana Vengerskoy Akademiyey nauk v gor. Budapesht, ot 28-ogo do 31-ogo avgusta 1956 g

[Conference on Cosmic Radiation organized by the Hungarian Academy of Sciences, August 28-31, 1956]. Budapest, 1957, pp. 63-72.

19. Andronikashvili, Ye. L., and M. F. Bibilashvili. Space distribution of the penetrating component of extensive air showers. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 32, no. 2, 1957: 403-405.

20. Anishchenko, Yu. V., G. T. Zatsepin, I. L. Rozental', and L. I. Sarycheva. Electron-nuclear and extensive air showers of cosmic rays. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 22, no. 2, 1952: 143-151.

21. Antonov, Yu. N., Yu. N. Vavilov, G. T. Zatsepin, A. A. Kutuzov, Yu. V. Skvortsov, and G. B. Khristiansen. Structure of the periphery of extensive air showers of cosmic rays. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 32, no. 2, 1957: 227-240.

22. Asatiani, T. L., and G. V. Khrimyan. Study of nuclear disintegrations produced by charged component of cosmic radiation. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 33, no. 3, 1957: 561-566.

23. Azimov, S. A. Investigation of cosmic rays by means of a "circular arrangement." Trudy Fizicheskogo instituta Akademii nauk SSSR, v. 4, 1949: 315-363.

24. Azimov, S. A., N. G. Birger, V. N. Polynov, and S. A. Slavatinskiy. Nature of the penetrating particles of electron-nuclear showers. Doklady Akademii nauk SSSR, v. 85, no. 2, 1952: 287-289.

25. Azimov, S. A., and R. Karimov. Nonequilibrium soft component at mountain altitudes. Doklady Akademii nauk Uzbekskoy SSR, no. 3, 1959: 9-12.

26. Azimov, S. A., V. S. Masagutov, and M. Yunusov. Generation of V^0 - particles in complex nuclei. Izvestiya Akademii nauk Uzbekskoy SSR, seriya fiziko-matematicheskikh nauk, no. 4, 1958: 13-22.

27. Azimov, S. A., and V. F. Vishnevskiy. Decay of particles generating electron-nuclear showers. Izvestiya Akademii nauk SSSR, seriya fizicheskaya, v. 17, no. 1, 1953: 88-91.

28. Azimov, S. A., V. F. Vishnevskiy, and K. P. Ryzhkova. On electrons produced in the decay of fast mesons. Doklady Akademii nauk SSSR, v. 83, no. 1, 1952: 55-58.

29. Bannik, B. P., V. G. Gudyamov, D. K. Kopylova, A. A. Nomofilov, M. I. Podgoretskiy, B. G. Rakhimbayev, and M. Usmanova. Hyperfragments in nuclear emulsions. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 34, no. 2, 1958: 286-297.

30. Baradzey, L. T., S. N. Vernov, and Yu. Smorodin. Decaying particles in the composition of cosmic rays in the stratosphere. Doklady Akademii nauk SSSR, v. 63, no. 3, 1948: 233-234.

31. Barkov, L. M., and B. A. Nikol'skiy. Pi-mesons. Uspekhi fizicheskikh nauk, v. 61, no. 3, 1957: 341-398.

32. Bedritskiy, A. I. Bremsstrahlung of a particle of spin 2. Uchenyye zapiski Belorusskogo gosudarstvennogo universiteta, no. 41, 1958: 139-158.

33. Belen'kiy, S. Z. Lavinnyye protsessy v kosmicheskikh luchakh [Cascade processes in cosmic rays]. Moscow, Gos. izd-vo tekhniko-teoret. lit-ry, 1948. 243 p.

34. Belen'kiy, S. Z. Formation of heavy particles in collisions. Doklady Akademii nauk SSSR, v. 99, no. 4, 1954: 523-526.

35. Belen'kiy, S. Z., and L. D. Landau. Hydrodynamic theory of multiple particle formation. Uspekhi fizicheskikh nauk, v. 56, no. 3, 1955: 309-348.

36. Belen'kiy, S. Z., and B. I. Maksimov. Scattering of cascade particles in heavy elements. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 22, no. 1, 1952: 102-111.

37. Ben'kova, N. P. Mezhdunarodnyy geofizicheskiy god i issledovaniya verknikh sloyev atmosfery [International Geophysical Year and investigations of the upper atmosphere]. Moscow, Gos. izd-vo lit-ry po voprosam svyazi i radio, 1958. 47 p.

38. Berishvili, G. P. Study of the principal characteristics of sudden geomagnetic storms. Trudy Akademii nauk Gruzinskoy SSR, v. 16, 1957: 39-51.

39. Birger, N. G., V. I. Veksler, N. A. Dobrotin, G. T. Zatsepin, L. V. Kurnosova, A. L. Lyubimov, I. L. Rozental', and L. Kh. Eydus. Electron-nuclear showers of cosmic rays and nuclear-cascade processes. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 19, no. 9, 1949: 826-850.

40. Bryunelli, B. Ye. Interpretation of research data on geomagnetic disturbances of a corpuscular nature. <u>In</u> Fizika solnechnykh korpuskulyarnykh potokov i ikh vozdeystviye na verkhnyuyu atmosferu zemli; Trudy konferentsii Komissii po issledovanyu solntsa, 22-24 noyabrya 1955 g [Physics of solar corpuscular beams and their effect on the upper atmosphere of the earth; proceedings of the Conference of the Commission on Solar Research, November 22-24, 1955]. Moscow, Izd-vo AN SSSR, 1957, pp. 131-143.

41. Bunyatov, S. A., A. Vrublevskiy, D. K. Kopylova, Yu. B. Korolevich, N. I. Petukhova, V. M. Sidorov, E. Skzhipchak, and A. Filipkovskiy. Emission of π-particles during capture of K-mesons by nuclei in a photoemulsion. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 34, no. 4, 1958: 1028-1030.

42. Chernavskiy, D. S. Multiple production of particles in jets. Nuovo cimento. Supplemento, v. 8, series 10, no. 2, 1958: 775-785.

43. Chestnov, F. I. Zagadka ionosfery [Secrets of the ionosphere]. Gos. tekhniko-teoret. lit-ry, 1956. 64 p.

44. Chudakov, A. Ye. Ionization effect related to the observation of electron-positron pairs at very high energies. Izvestiya Akademii nauk, SSSR, seriya fizicheskaya, v. 19, no. 6, 1955: 651-656.

45. Chudakov, A. Ye. Cherenkov radiation of extensive air showers. In Mezhdunarodnaya konferentsiya po kosmicheskim lucham organizovana Vengerskoy Akademiyey nauk v gor. Budapesht, ot 28-ogo do 31-ogo avgusta 1956 g [Conference on Cosmic Radiation organized by the Hungarian Academy of Sciences, August 28-31, 1956]. Budapest, 1957, pp. 57-62.

46. Chudakov, A. Ye. Investigation of photons by means of the third artificial earth satellite. Priroda, v. 47, no. 12, 1958: 88-90.

47. Chudakov, A. Ye., N. A. Dobrotin, N. L. Grigorov, G. N. Vernov and G. T. Zatsepin. Investigation of interaction at extremely high energies using the analysis of extensive air showers. Nuovo cimento. Supplemento, v. 8, series 10, no. 2, 1958: 737-741.

48. Chudakov, A. Ye., and N. M. Nesterova. Cherenkov radiation of extensive air showers. Nuovo cimento. Supplemento, v. 8, series 10, no. 2, 1958: 606-611.

49. Chuvilo, I. V., and V. G. Shevchenko. Photodisintegration of Be^9 and C^{12} by gamma bremsstrahlung of 44 MeV maximum energy. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 34, no. 3, 1958: 593-598.

50. Danilin, B. S. Model of the upper atmosphere. Nauka i zhizn', no. 5, 1959: 20.

51. Danilova, T. V., O. I. Dovzhenko, S. I. Nikol'skiy, and I. V. Rakobol'skaya. Study of the electron-photon component of extensive air showers near the axis of a shower at an altitude of 3860 meters using a Wilson chamber. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 34, no 3, 1958: 541-547.

52. Dmitriyev, V. A., G. B. Khristiansen, and G. V. Kulikov. High-energy nuclear-active component of extensive air showers. Nuovo cimento. Supplemento, v. 8, series 10, no. 2, 1958: 587-597.

53. Dobrotin, N. A. Kosmicheskiye luchi [Cosmic rays]. Moscow, Gos. izd-vo tekhniko-teoret. lit-ry, 1954. 320 p.

54. Dobrotin, N. A. Investigation of nuclear processes at very high energies. In Mezhdunarodnaya konferentsiya po kosmicheskim lucham organizovana Vengerskoy Akademiyey nauk v gor. Budapesht, ot 28-ogo do 31-ogo avgusta 1956 g [Conference on Cosmic Radiation organized by the Hungarian Academy of Sciences, August 28-31, 1956]. Budapest, 1957, pp. 24-39.

55. Dobrotin, N. A. International Conference on Cosmic Rays. Uspekhi fizicheskikh nauk, v. 59, no. 4, 1959: 679-691.

56. Dobrotin, N., O. Dovzhenko, V. Zatsepin, E. Murzina, S. I. Nikol'skiy, I. Rakobol'skaya, and Ye. Tukish. Combined method of investigation of extensive air showers. Nuovo cimento. Supplemento, v. 8, series 10, no. 2, 1958: 612-622.

57. Dobrotin, N. A., G. T. Zatsepin, S. I. Nikol'skiy, and G. B. Khristiansen. Interaction of ultra-high-energy particles with nucleons and atomic nuclei. Nuovo cimento. Supplemento, v. 3, series 10, no. 4, 1956: 635-651.

58. Dombrovskiy, V. A. The nature of the emission of the Crab nebula. Doklady Akademii nauk SSSR, v. 94, no. 6, 1954: 1021-1024.

59. Dorman, L. I. Data on solar corpuscular beams obtained by means of studying variations in cosmic radiation. In Fizika solnechnykh korpuskulyarnykh potokov i ikh vozdeystviye na verkhnyuyu atmosferu zemli; Trudy konferentsii Komissii po issledovanyu solntsa, 22-24 noyabrya 1955 g [Physics of solar corpuscular beams and their effect on the upper atmosphere of the earth; proceedings of the Conference of the Commission on Solar Research, November 22-24, 1955]. Moscow, Izd-vo AN SSSR, 1957, pp. 112-128.

60. Dorman, L. I. Nature of variations in cosmic rays. Izvestiya Akademii nauk SSSR, seriya fizicheskaya, v. 20, no. 1, 1956: 24-46.

61. Dorman, L. I. Variatsii kosmicheskikh luchey [Variations in cosmic rays]. Moscow, 1957. 492 p.

62. Dorman, L. I. Generation and propagation of solar cosmic rays. Nuovo cimento. Supplemento, v. 8, series 10, no. 2, 1958: 391-402.

63. Dorman, L. I. Meteorological effects of the soft and total ionizing components of cosmic rays. Trudy Yakutskogo filiala Akademii nauk SSSR, seriya fizicheskaya, no. 2, 1958: 59-67.

64. Dorman, L. I. Temperature effect of the neutron component of cosmic rays. Trudy Yakutskogo filiala Akademii nauk SSSR, seriya fizicheskaya, no. 2, 1958: 68-72.

65. Dorman, L. I., and Ye. L. Feynberg. Variations of cosmic rays. Uspekhi fizicheskikh nauk, v. 59, no. 2, 1956: 189-228.

66. Dorman, L. I., and Ye. L. Feynberg. True primary energy spectrum variations and solar activity. Nuovo cimento. Supplemento, v. 8, series 10, no. 2, 1958: 358-378.

67. Dorman, L. I., and G. I. Freydman. Cosmic-ray intensity burst on February 23, 1956, and its interpretation. Trudy Yakutskogo filiala Akademii nauk SSSR, seriya fizicheskaya, no. 2, 1958: 129-169.

68. Dorman, L. I., A. I. Kuz'min, G. V. Tyanutova, Ye. L. Feynberg, and Yu. G. Shafer. Cosmic-ray variations and the role of meteorological effects. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 26, no. 5, 1954: 537-544.

69. Dovzhenko, O., G. Zatsepin, Ye. Murzina, S. Nikol'skiy, I. Rakobol'skaya, and Ye. Tukish. Research on extensive air showers. Doklady Akademii nauk SSSR, v. 118, no. 5, 1958: 899-902.

70. Dyatlov, I. T. Bremsstrahlung of gamma quanta induced by π -mesons and the production of π -mesons pairs by gamma quanta in collisions with nonspherical nuclei. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 34, no. 1, 1958: 80-86.

71. Dzhelepov, V. P., and B. M. Pontecorvo. Investigations of high-energy particles with the synchrocyclotron of the nuclear laboratory of the Joint Institute for Nuclear Research. Uspekhi fizicheskikh nauk, v. 64, no. 1, 1958: 15-54.

72. Eydus, L. Kh., M. I. Adamovich, I. A. Ivanovskaya, V. S. Nikolayev, and M. S. Tulyankina. Lateral distribution of penetrating particles in air showers of cosmic rays. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 22, no. 4, 1952: 440-447.

73. Eydus, L. Kh., N. M. Blinova, V. G. Videnskiy, and L. D. Suvorova. Investigation of the width of cosmic-particle showers at sea level. Doklady Akademii nauk SSSR, v. 74, no. 3, 1950: 477-480.

74. Eygenson, M. S. Ocherki fiziko-geograficheskikh proyavleniy solnechnoy aktivnosti [Studies on the geophysical effects of solar activity]. L'vov, Izdatel'stvo L'vovskogo universiteta, 1957. 230 p.

75. Eygenson, M. S. Probable solar origin for the great anomaly in the general circulation in the troposphere of the Northern Hemisphere in the winter and spring of 1956. Dopovidi ta povidomlennya L'vivs'kogo universitety, no. 7, part 3, 1957: 222-224.

76. Eygenson, M. S. Sun, weather and climate. Priroda, v. 48, no. 4, 1959: 83-85.

77. Faynberg, V. Ya. Cascade curve in heavy elements. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 22, no. 1, 1952: 112-119.

78. Feynberg, Ye. L. Nature of barometric and temperature effects on cosmic rays. Doklady Akademii nauk SSSR, v. 53, no. 5, 1946: 421-424.

79. Feynberg, Ye. L., and D. S. Chernavskiy. Cross section for the interaction of extremely fast nucleons. Doklady Akademii nauk SSSR, v. 91, no. 3, 1953: 511-513.

80. Frank, I. M. Radiation of electrons moving in a substance with a speed greater than that of light. Uspekhi fizicheskikh nauk, v. 30, no. 3-4, 1946: 149-183.

81. Garibyan, G. M., and I. I. Gol'dman. Spectra of π - and μ -mesons of the cosmic radiation. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 26, no. 3, 1954: 257-263.

82. Getmantsev, G. G., and V. L. Ginzburg. Possible mechanism of sporadic solar radio emission. Doklady Akademii nauk SSSR, v. 87, no. 2, 1952: 187-190.

83. Ginzburg, V. L. Origin of cosmic rays and radio astronomy. Uspekhi fizicheskikh nauk, v. 51, no. 3, 1953: 343-392.

84. Ginzburg, V. L. Supernovae and novae as sources of cosmic and radio emissions. Doklady Akademii nauk SSSR, v. 92, no. 6, 1953: 1133-1136.

85. Ginzburg, V. L. Statistical mechanism of the acceleration of particles on the Sun and in star envelopes. Doklady Akademii nauk SSSR, v. 92, no. 4, 1953: 727-730.

86. Ginzburg, V. L. Origin of cosmic rays. Doklady Akademii nauk SSSR, v. 99, no. 5, 1954: 703-706.

87. Ginzburg, V. L. The origin of cosmic radiation and radio astronomy. Fortschritte der Physik, v. 1, no. 12, 1954: 659-706.

88. Ginzburg, V. L. The nature of cosmic-ray emission and the origin of cosmic rays. Nuovo cimento. Supplemento, v. 3, series 10, no. 1, 1956: 38-49.

89. Ginzburg, V. L. The origin of cosmic rays. Izvestiya Akademii nauk SSSR, seriya fizicheskaya, v. 20, no. 1, 1956: 5-15.

90. Ginzburg, V. L. The origin of cosmic rays. In Progress in elementary and cosmic ray physics. New York, Interscience Publishers Inc., 1958, pp. 337-421.

91. Ginzburg, V. L. Origin of cosmic rays and radio astronomy. Uspekhi fizicheskikh nauk, v. 62, no. 2, 1957: 37-98.

92. Ginzburg, V. L. The origin of cosmic rays. Nuovo cimento. Supplemento, v. 8, series 10, no. 2, 1958: 430-439.

93. Ginzburg, V. L., and M. I. Fradkin. The origin of cosmic rays. Priroda, no. 8, 1958: 3-12.

94. Gol'danskiy, V. I., and G. B. Zhdanov. On Cherenkov radiation of cosmic particles in the atmosphere. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 26, no. 4, 1954: 405-416.

95. Gorbunov, A.N. Nuclear disintegrations and electron-nuclear showers in cosmic rays. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 19, no. 12, 1949: 1076-1097.

96. Gordon, I. M. Physical nature of the nonthermal emission in spectra of T Taurus stars and the origin of cosmic rays. Astronomicheskiy zhurnal, v. 35, no. 3, 1958: 458-468.

97. Gramenitskiy, I. M., Ye. A. Zamchalova, M. I. Podgoretskiy, M. I. Tret'yakova, and M. N. Shcherbakova. Two-τ-mesons found in a photographic emulsion. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 30, no. 5, 1956: 967-969.

98. Gramenitskiy, I. M., G. B. Zhdanov, Ye. A. Zamchalova, M. I. Tretyakova, and M. N. Shcherbakova. One case of nuclear interaction in a photoemulsion at the energy of $\sim 5.10^{13}$ eV/nucleon. Nuovo cimento. Supplemento, v. 8, series 10, no. 2, 1958: 714-721.

99. Granovskiy, Ya. I. Properties of K-mesons. Doklady Akademii nauk SSSR, v. 125, no. 6, 1959: 1225-1226.

100. Granovskiy, Ya. I., and I. Ya. Chasnikov. Analysis of high-energy showers. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 36, no. 4, 1959: 1119-1122.

101. Grigorov, N. L. Mechanism of collisions of high-energy nucleons with light nuclei. Doklady Akademii nauk SSSR, v. 94, no. 5, 1954: 835-838.

102. Grigorov, N. L. Mean characteristics of the interaction of primary cosmic particles of various energies (2 to 1000 BeV) with light nuclei. Uspekhi fizicheskikh nauk, v. 58, no. 4, 1956: 599-666.

103. Grigorov, N. L., and V. S. Murzin. Interaction of primary cosmic particles of different energies with substances. Izvestiya Akademiya nauk SSSR, seriya fizicheskaya, v. 17, no. 1, 1953: 21-38.

104. Grigorov, N. L., and V. Ya. Shestoperov. Possible mode of development of extensive air showers. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 34, no. 6, 1958: 1539-1547.

105. Grigorov, N. L., V. Ya. Shestoperov, V. A. Sobinyakov, and A. V. Podgurskaya. Large bursts and high-energy particle (10^{12} to 10^{13} eV) interactions with light nuclei. Nuovo cimento. Supplemento, v. 8, series 10, no. 2, 1958: 730-732.

106. Grigorov, N. L., I. M. Yevreynova, and S. P. Sokolov. On the ionization in the stratosphere produced by various components of cosmic radiation. Doklady Akademii nauk SSSR, v. 81, no. 3, 1951: 379-382.

107. Gurevich, I. I., A. P. Mishakova, B. A. Nikol'skiy, and L. V. Surkova. Explosive showers produced by high-energy cosmic-ray particles. Nuovo cimento. Supplemento, v. 8, series 10, no. 2, 1958: 786-792.

108. Guzhavin, V. V., and I. P. Ivanenko. On three-dimensional development of an electron-photon cascade shower. Nuovo cimento. Supplemento, v. 8, series 10, no. 2, 1958: 749-760.

109. Guzhavin, V. V., and G. T. Zatsepin. Altitude dependence of air showers according to different models of elementary nuclear collisions. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 32, no. 2, 1957: 365-366.

110. Hu Ning. Strong and weak interactions involving hyperons. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 34, no. 3, 1958: 646-650.

111. Ioffe, B. L., L. B. Okun', and A. P. Rudik. The problem of nonconservation of parity in weak interactions. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 32, no. 2, 1957: 396-397.

112. Istomin, V. G. Radio-frequency mass-spectrometer for investigating the ion composition of the upper atmosphere. Iskusstvennyye sputniki Zemli, no. 3, 1959: 99-112.

113. Ivanenko, I. P. Cascade curves for electrons and photons in lead. Doklady Akademii nauk SSSR, v. 107, no. 6, 1956: 819-822.

114. Ivanenko, I. P., G. T. Zatsepin, S. I. Nikol'skiy, and A. A. Pomanskiy. Theory of the passage of nuclear cascade through the atmosphere. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 37, no. 4, 1959: 1046-1049.

115. Ivanovskaya, I. A., and D. S. Chernavskiy. Interpretation of cosmic-ray jets observed in photographic emulsions. Nuclear Physics, v. 4, August-November 1957: 29-38.

116. Ivanovskaya, I. A., L. I. Sarycheva, and P. S. Chikin. Cloud-chamber investigation of the nuclear-active component of air showers. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 34, no. 1, 1958: 45-57.

117. Katsiashvili, N. A. Some characteristics of Sq-variations H in Tbilisi. Trudy Akademii nauk Gruzinskoy SSR, v. 16, 1957: 53-61.

118. Kerimov, B. K., and I. M. Nadzhafov. Bremsstrahlung of an electron with oriented spin. Nauchnyye doklady vysshey shkoly; fiziko-matematicheskiye nauki, no. 1, 1958: 95-100.

119. Kerimov, B. K., and I. M. Nadzhafov. Bremsstrahlung of longitudinally polarized electrons. Izvestiya Akademii nauk SSSR, seriya fizicheskaya, v. 22, no. 7, 1958: 886-892.

120. Khalatnikov, I. M. Some problems of relativistic hydrodynamics. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 27, no. 5, 1954: 529-541.

121. Kharitonov, V. Measurement of the ionizing capacity of particles using a new magnetic spectrometer. Doklady Akademii nauk SSSR, v. 85, no. 1, 1952: 71-74.

122. Kharitonov, V. Ionization losses of relativistic particles in gas. Doklady Akademii nauk SSSR, v. 86, no. 2, 1952: 285-287.

123. Kharitonov, V., and A. Barskiy. Ionization created by fast particles in gas. Doklady Akademii nauk SSSR, v. 93, no. 4, 1953: 645-646.

124. Khrimyan, G. V. Study of nuclear disintegration produced by the charged component of cosmic radiation. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 35, no. 5. 1958: 1076-1082.

125. Khristiansen, G. B. On the lateral distribution of electrons and mu-mesons in extensive air showers. Nuovo cimento. Supplemento, v. 8, series 10, no. 2, 1958: 598-605.

126. Khristiansen, G. B., and G. V. Kulikov. On the spectrum of extensive air showers. Nuovo cimento. Supplemento, v. 8, series 10, no. 2, 1958: 742-745.

127. Khvedelidze, N. S. One aspect of irregular variations. Trudy Akademii nauk Gruzinskoy SSR, v. 16, 1957: 63-76.

128. Kocharyan, N. M., G. S. Saakyan, M. T. Ayvazyan, Z. A. Kirakosyan, and S. D. Kaytmazov. Investigation of cosmic-ray composition at an altitude of 1000 m above sea level. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 23, no. 5, 1952: 532-542.

129. Kocharyan, N. M., M. T. Ayvazyan, S. D. Kaytmazov, and Z. A. Kirakosyan. East-west asymmetry and angular distribution of protons and mesons. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 25, 1953: 364-367.

130. Kocharyan, N. M., M. T. Ayvazyan, Z. A. Kirakosyan, and A. S. Aleksanyan. Meson component of cosmic radiation at 3200 m. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 30, no. 2, 1956: 243-249.

131. Kolpakov, P. Ye. Generation of corpuscular beams by magnetic fields of sun spots. Astronomicheskiy zhurnal, v. 36, no. 1, 1959: 65-72.

132. Kolpakov, P. Ye., and Ya. P. Terletskiy. The question of the electromagnetic field of spots in the sun's atmosphere. Doklady Akademii nauk SSSR, v. 76, 1951: 185-188.

133. Korablyev, L. N., A. L. Lyubimov, and A. T. Nevrayev. Study of "singular showers" of cosmic rays with a hodoscope. Doklady Akademii nauk SSSR, v. 68, 1949: 273-276.

134. Korchak, A. A., and S. I. Syrovatskiy. Possibility of the predominant acceleration of heavy elements in cosmic-ray sources. Doklady Akademii nauk SSSR, v. 122, no. 5, 1958: 792-794.

135. Kotenko, L. P. Investigation of the ionizing power of cosmic radiation at 3,200 meters by means of proportional scintillation counters. Izvestiya Akademii nauk SSSR, seriya fizicheskaya, v. 19, no. 5, 1955:525-532.

136. Koval'skaya, A. I. Seasonal variation of the barometric coefficient of the hard component of cosmic rays. Trudy Yakutskogo filiala Akademii nauk SSSR, seriya fizicheskaya, no. 2, 1958: 85-87.

137. Koval'skaya, A. I., D. D. Krasil'nikov, and S. I. Nikol'skiy. Preliminary results of determining the temperature and barometric effects of extensive air showers near sea level. Trudy Yakutskogo filiala Akademii nauk SSSR, seriya fizicheskaya, no. 2, 1958: 88-92.

138. Krasil'nikov, D. D. Diurnal variation in the hard component of cosmic rays during overcast and clear days. Trudy Yakutskogo filiala Akademii nauk SSSR, seriya fizicheskaya, no. 1, 1955: 19-22.

139. Krasil'nikov, D. D., and Yu. G. Shafer. Intensity variations in the hard component of cosmic rays during the passage of fronts. Trudy Yakutskogo filiala Akademii nauk SSSR, no. 1, 1955: 33-41.

140. Krasovskiy, V. I. Study of the atmosphere with the help of the third artificial satellite. Priroda, v. 47, no. 12, 1958: 71-78.

141. Krasovskiy, V. I., Yu. M. Kushnir, G. A. Bordovskiy, G. F. Zakharov, and Yu. M. Svetlitskiy. Detection of corpuscles by means of the third artificial earth satellite. Iskusstvennyye sputniki Zemli, no. 2, 1958: 59-60.

142. Kurnosova, L. V. Intensity of cosmic radiation. Priroda, no. 6, 1958: 85-86.

143. Kurnosova, L. V., and N. Tikhonova. Measurement of the altitude dependence of electron-nuclear showers. Doklady Akademii nauk SSSR, v. 69, no. 4, 1949: 535-537.

144. Kurnosova, L. V., L. A. Razorenov, and M. I. Fradkin. Heavy nuclei in primary cosmic radiation. Iskusstvenyye sputniki Zemli, no. 2, 1958: 70-74.

145. Kuz'min, A. I. Daily variations in the total intensity of the hard component according to the data of the Yakutsk station. Trudy Yakutskogo filiala Akademii nauk SSSR, seriya fizicheskaya, no. 1, 1955: 11-18.

146. Kuz'min, A. I., and G. V. Skripin. Correlation of the semidiurnal intensity variations in the cosmic-ray hard component with semidiurnal fluctuations in barometric pressure in the earth's atmosphere. Trudy Yakutskogo filiala Akademii nauk SSSR, seriya fizicheskaya, no. 1, 1955: 23-26.

147. Kuz'min, A. I., and G. V. Skripin. Monthly and semimonthly variations in cosmic-ray intensity. Trudy Yakutskogo filiala Akademii nauk SSSR, seriya fizicheskaya, no. 1, 1955: 27-32.

148. Landau, L. D. On the energy loss of fast particles by ionization. Journal of Physics, v. 8, no. 4, 1944: 201-205.

149. Landau, L. D. Momentum of a two-photon system. Doklady Akademii nauk SSSR, v. 60, no. 2, 1948: 207-209.

150. Landau, L. D. Multiple formation of particles by collision of fast particles. Izvestiya Akademii nauk SSSR, seriya fizicheskaya, v. 17, no. 1, 1953: 51-64.

151. Landau, L. D. Conservation laws in weak interactions. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 32, no. 2, 1957: 405-406.

152. Landau, L. D. Possible explanation of the polarization properties of the neutrino. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 32, no. 2, 1957: 407-408.

153. Landau, L. D., and I. Pomeranchuk. Limits of application of the theory of bremsstrahlung of electrons and of formation of pairs at high energies. Doklady Akademii nauk SSSR, v. 92, no. 3, 1953: 535-536.

154. Landau, L. D., and I. Pomeranchuk. Electronic cascade processes at superhigh energies. Doklady Akademii nauk SSSR, v. 92, no. 4, 1953: 735-738.

155. Landau, L. D., and G. Rumer. The cascade theory of electronic showers. Proceedings of the Royal Society of London, v. 166, series A, 1938: [illegible]-228.

156. Lashkhi, A. S., and G. Ye. Gugunava. Problems of the relationship between variations in cosmic-ray intensity and terrestrial electrical disturbances. Soobshcheniya Akademii nauk Gruzinskoy SSR, v. 21, no. 4, 1958: 413-416.

157. Logunov, A. A., and Ya. P. Terletskiy. Distribution of particles of primary cosmic radiation according to energy. Izvestiya Akademii nauk SSSR, seriya fizicheskaya, v. 17, no. 1, 1953: 119-135.

158. Loktionov, A. A., V. I. Stafeyev, and Zh. S. Takibayev, Study of the spatial distribution of nuclear disintegrations on thick nuclear emulsions. Vestnik Akademii nauk Kazakhskoy SSR, v. 14, no. 10, 1958: 49-59.

159. Lomanov, M. F., A. G. Meshkovskiy, Ya. Ya. Shalemov, V.A. Shebanov, and A. F. Grashin. Bremsstrahlung of -mesons interacting with nuclei. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 35, no. 4, 1958: 887-893.

160. Maksimenko, V. M., and I. L. Rozental'. Some problems of the statistical theory of multiple production of particles. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 32, no. 4, 1957: 658-666.

161. Marikyan, G. A. Problem of the existence of high-energy deuterons in cosmic rays. Doklady Akademii nauk SSSR, v. 85, no. 2, 1952: 305-307.

162. Markov, M. A. Giperony i K-mezony [Hyperons and K-mesons]. Moscow, Gos. izd-vo fiziko-matematicheskoy lit-ry, 1958. 343 p.

163. Matinyan, S. G. Question of parity nonconservation in strong interactions between strange particles. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 37, no. 4, 1959: 1034-1040.

164. Meshkovskiy, A. G., and V. A. Shebanov. Spectrum of ionization of the hard component of the cosmic radiation at sea level. Doklady Akademii nauk SSSR, v. 82, no. 2, 1952: 233-236.

165. Meshkovskiy, A. G., and L. I. Sokolov. Study of the ionization spectrum of cosmic-ray particles at an altitude of 3,250 meters above sea level. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 31, no. 5, 1956: 752-755.

166. Migdal, A. B. Analysis of experimental data on Auger showers and ionization bursts. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 15, no. 7, 1945: 313-329.

167. Migdal, A. B. Quantum-kinetic equation for mutiple scattering. Doklady Akademii nauk SSSR, v. 105, no. 1, 1955: 77-79.

168. Migdal, A. B. Bremsstrahlung and pair production at high energies in a condensation medium. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 32, no. 4, 1957: 633-646.

169. Milekhin, G. A., and I. L. Rozental'. Hydrodynamic interpretation of a characteristic of large showers recorded in photographic emulsions. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 35, no. 1, 1957: 197-199.

170. Mogilevskiy, E. I. Equation of quasi-stationary ionization equilibrium in the F_2 layer, and solar corpuscular radiation. In Fizika solnechnykh korpuskulyarnykh potokov i ikh vozdeystviye na verkhnyuyu atmosferu zemli; Trudy konferentsii Komissii po issledovanyu solntsa, 22-24 noyabrya 1955 g [Physics of solar corpuscular beams and their effect on the upper atmosphere of the earth; proceedings of the Conference of the Commission on Solar Research, November 22-24, 1955]. Moscow, Izd-vo AN SSSR, 1957, pp. 261-268.

171. Mustel', E. R. Consideration of possible sources of geoactive corpuscles in the envelope of the sun. In Fizika solnechnykh korpuskulyarnykh potokov i ikh vozdeystviye na verkhnyuyu atmosferu zemli; Trudy konferentsii Komissii po issledovanyu solntsa, 22-24 noyabrya 1955 g [Physics of solar corpuscular beams and their effect on the upper atmosphere of the earth; proceedings of the Conference of the Commission on Solar Research, November 22-24, 1955]. Moscow, Izd-vo AN SSSR, 1957, pp. 8-39.

172. Mustel', E. R. Solntse i atmosfera Zemli [The sun and the atmosphere of the earth]. Moscow, Gos. izd-vo tekhniko-teoret. lit-ry, 1957. 103 p.

173. Nadzhafov, I. M. Polarization effects during bremsstrahlung and pair production. Vestnik Moskovskogo universiteta, seriya matematiki, mekhaniki, astronomii, fiziki, khimii, v. 13, no. 5, 1958: 209-211.

174. Nadzhafov, I. M. Polarization effects during the bremsstrahlung of a photon by an electron. Vestnik Moskovskogo universiteta, seriya matematiki, mekhaniki, astronomii, fiziki, khimii, v. 13, no. 3, 1958: 139-150.

175. Nikitin, S. Ya. Existence of particles with a mass larger than that of mesons. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 18, no. 7, 1948: 577-602.

176. Nikol'skiy, A. P. Magnetic disturbances in the polar region and the existence of another zone in which these disturbances have a high intensity. In Fizika solnechnykh korpuskulyarnykh potokov i ikh vozdeystviye na verkhnyuyu atmosferu zemli; Trudy konferentsii Komissii po issledovanyu solntsa, 22-24 noyabrya 1955 g [Physics of solar corpuscular beams and their effect on the upper atmosphere of the earth: proceedings of the Conference of the Commission on Solar Research, November 22-24, 1955]. Moscow, Izd-vo AN SSSR, 1957, pp. 144-158.

177. Nikol'skiy S. I. Investigation of nuclear-active components of extensive air showers. In Mezhdunarodnaya konferentsiya po kosmicheskim lucham organizovana Vengerskoy Akademiyey nauk v gor. Budapesht, ot 28-ogo do 31-ogo avgusta 1956 g [Conference on Cosmic Radiation organized by the Hungarian Academy of Sciences, August 28-31, 1956]. Budapest, 1957, pp. 40-49.

178. Nikol'skiy, S. I., and G. B. Khristiansen. Lateral distribution of electrons in extensive air showers generated by primary cosmic rays of various energies. In Mezhdunarodnaya konferentsiya po kosmicheskim lucham organizovana Vengerskoy Akademiyey nauk v gor. Budapesht, ot 28-ogo do 31-ogo avgusta 1956 g [Conference on Cosmic Radiation organized by the Hungarian Academy of Sciences, August 28-31, 1956]. Budapest, 1957, pp. 40-49.

179. Nikol'skiy, S. I., and V. M. Seleznev. Distribution of the electron-proton component on the periphery of extensive cosmic-ray air showers. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 32, no. 5, 1957: 1250-1252.

180. Nikol'skiy, S. I., Yu. N. Vavilov, and V. V. Batov. Investigations of nuclear-active components of extensive air showers in cosmic radiation. Doklady Akademii nauk SSSR, v. 111, 1956: 71-73.

181. Okun', L. B., I. Ya. Pomeranchuk, and I. M. Shmushkevich. Interaction of Ξ^--hyperons with nucleons and light nuclei. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 34, no. 5, 1958: 1246-1249.

182. Pataraya, A. D. Calculating the effective cross section for bremsstrahlung taking into account terms Z^2 and Z^3. Soobshcheniya Akademii nauk Gruzinskoy SSR, v. 21, no. 1, 1958: 19-24.

183. Pikel'ner, S. B. Kinematic properties of interstellar gases as related to the isotropy of cosmic rays. Doklady Akademii nauk SSSR, v. 88, no. 2, 1953: 229-232.

184. Pikel'ner, S. B. Interstellar polarization of light. Uspekhi fizicheskikh nauk, v. 58, no. 2, 1956: 285-310.

185. Pikel'ner, S. B. The magnetic field of the Crab nebula and the central star. Astronomicheskiy zhurnal, v. 33, no. 6, 1956: 785-799.

186. Pikel'ner, S. B., and I. S. Shklovskiy. Investigation of the properties and energy dissipation of the galactic halo. Astronomicheskiy zhurnal, v. 34, no. 2, 1957: 145-158.

187. Podgoretskiy, M. I. Fluctuation of the ionization effect. Doklady Akademii nauk SSSR, v. 67, no. 5, 1949: 823-826.

188. Podgoretskiy, M. I. On the mechanism of negative mu-mesons capture. Uspekhi fizicheskikh nauk, v. 46, no. 1, 1952: 107-108.

189. Polivanov, M. K. Processes involved in the production of heavy mesons and hyperons considered from the standpoint of dispersion relations. Doklady Akademii nauk SSSR, v. 118, no. 4, 1958: 679-682.

190. Pomeranchuk, I. Ya. Interpretation of experimental data on large cascade showers. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 14, no. 7-8, 1944: 252-268.

191. Pomeranchuk, I. Ya., and Ye. L. Feynberg. External diffraction generation of particles by nuclear collision. Doklady Akademii nauk SSSR, v. 93, no. 3, 1953: 439-441.

192. Rakipova, L. R. Effect of solar corpuscular beams on dynamic disturbances in the upper atmosphere. In Fizika solnechnykh korpuskulyarnykh potokov i ikh vozdeystviye na verkhnyuyu atmosferu zemli; Trudy konferentsii Komissii po issledovanyu solntsa, 22-24 noyabrya 1955 g [Physics of solar corpuscular beams and their effect on the upper atmosphere of the earth; proceedings of the Conference of the Commission on Solar Research, November 22-24, 1955]. Moscow, Izd-vo AN SSSR, 1957, pp. 273-276.

193. Rakipova, L. R. Teplovoy rezhim atmosfery [Thermal conditions in the atmosphere]. Leningrad, Gidro-meteorologicheskoye izdatel'stvo, 1957. 184 p.

194. Rakipova, L. R. Effect of solar activity on general atmospheric circulation. Trudy Glavnoy geofizicheskoy observatorii, no. 87, 1959: 40-45.

195. Rapoport, I. D. Ionization spectra of cosmic-ray particles in the stratosphere. Izvestiya Akademii nauk SSSR, seriya fizicheskaya, v. 19, no. 5, 1955: 519-524.

196. Rapoport, I. D. Source of low-energy electron-photon component of cosmic rays in stratosphere. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 34, no. 5, 1958: 1306-1309.

197. Razorenov, L. A., and A. K. Knyazev. Bursts in two ionization chambers produced by extensive air showers at an altitude of 3860 meters. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 19, no. 4, 1949: 283-291.

198. Rozental', I. L. Cascade processes in extensive air showers of cosmic rays. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 23, no. 4, 1952: 440-455.

199. Rozental', I. L. Theory of the nuclear-cascade process in extensive air showers. Izvestiya Akademii nauk SSSR, seriya fizicheskaya, v. 17, no. 1, 1953: 65-71.

200. Rozental', I. L. A quasi-unidimensional interpretation of the hydrodynamic theory of multiple particle production. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 31, no. 2, 1956: 278-287.

201. Rozental', I. L. Possible multiple production of mu-mesons. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 36, no. 3, 1959: 943-945.

202. Rozental', I. L., and D. S. Chernavskiy. Theoretical and experimental data on particle formation at high energies. Uspekhi fizicheskikh nauk, v. 52, no. 2, 1954: 185-238.

203. Rozental', I. L., and V. N. Strel'tsov. Passage of high-energy mu-mesons through matter. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 35, no. 6, 1958: 1440-1446.

204. Saakyan, G. S. Passage of the nucleonic compound through the atmosphere. Izvestiya Akademii nauk Armyanskoy SSR, seriya FMET, v. 9, no. 7, 1956: 79-99.

205. Severnyy, A. B. Formation of high-energy particles and hard radiation in solar flares. Doklady Akademii nauk SSSR, v. 121, no. 5, 1958: 819-821.

206. Shapiro, I. Nonconservation of parity in beta disintegration. Uspekhi fizicheskikh nauk, v. 61, no. 3, 1957: 313-330.

207. Shayn, G. A., and V. F. Gaze. A peculiarity of certain gases of nebulae which is possibly connected with the magnetic field. Izvestiya Akademii nauk SSSR, seriya fizicheskaya, v. 17, no. 1, 1953: 114-118.

208. Shayn, G. A., V. F. Gaze, and S. B. Pikel'ner. Some results of the investigation of the presence of dust and gas in diffuse nebulae. Astronomicheskiy zhurnal, v. 31, no. 2, 1954: 105-111.

209. Shklovskiy, I. S. The origin of cosmic rays. Doklady Akademii nauk SSSR, v. 91, no. 3, 1953: 475-478.

210. Shklovskiy, I. S. Problem of cosmic radiation. Astronomicheskiy zhurnal, v. 30, no. 1, 1953: 15-36.

211. Shklovskiy, I. S. Nature of the luminescence of the Crab nebula. Doklady Akademii nauk SSSR, v. 90, no. 6, 1953: 983-986.

212. Shklovskiy, I. S. Kosmicheskoye radioizlucheniye [Cosmic radio emission]. Moscow, Gos. izd-vo tekhniko-teoret. lit-ry, 1957. 492 p.

213. Shklovskiy, I. S. Some problems of the radio astronomy theory of the origin of cosmic rays. Nuovo cimento. Supplemento, v. 8, series 10, no. 2, 1958: 421-429.

214. Shuleykin, V. V. Terrestrial magnetic field and the world ocean. Doklady Akademii nauk SSSR, v. 76, no. 1, 1951: 57-60.

215. Skobel'tsyn, D. V. Altitude dependence of ionization bursts and Auger showers. Doklady Akademii nauk SSSR, v. 44, no. 4, 1944: 154-158.

216. Skobel'tsyn, D. V. On the maximum extent of air showers of cosmic rays. Doklady Akademii nauk SSSR, v. 67, no. 1, 1949: 45-48.

217. Skobel'tsyn, D. V. Variation of the "correlation curve" of Auger showers at great distances from the axis. Doklady Akademii nauk SSSR, v. 67, no. 2, 1949: 255-258.

218. Skobel'tsyn, D. V. The nature of cosmic radiation. Uspekhi fizicheskikh nauk, v. 41, no. 3, 1950: 331-349.

219. Sokolov, V. D. Method for making temperature corrections in the results of measurements of the hard component of cosmic rays according to data on temperature at an altitude of 5 to 6 kilometers. Trudy Yakutskogo filiala Akademii nauk SSSR, seriya fizicheskaya, no. 2, 1958: 78-80.

220. Sokolov, V. D. Nature of the 27-day variations in cosmic-ray intensity. Trudy Yakutskogo filiala Akademii nauk SSSR, seriya fizicheskaya, no. 2, 1958: 123-128.

221. Sokolov, V. D., and Yu. G. Shafer. Seasonal effect on the intensity of the hard component of cosmic rays. Trudy Yakutskogo filiala Akademii nauk SSSR, seriya fizicheskaya, no. 1, 1955: 5-10.

222. Spitsyna, N. L. One concrete example of the effect of recurrent sunspots on atmospheric circulation. Trudy Glavnoy geofizicheskoy observatorii, no. 87, 1959:46-55.

223. Takibayev, Zh. S. Generation of star-forming particles in a dense substance at an altitude of 25 km. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 23, no. 5, 1952: 543-551.

224. Takibayev, Zh. S. Transition effect for stars and its relation to cascade multiplication of particles of the nucleonic component. Izvestiya Akademii nauk SSSR, seriya fizicheskaya, v. 19, no. 6, 1955: 687-698.

225. Takibayev, Zh. S. Explanation of transition effect for "stars" in the stratosphere. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 30, no. 4, 1956: 713-718.

226. Tamm, I., and S. Z. Belen'kiy. On the soft component of cosmic rays at sea level. Journal of Physics, v. 1, no. 3, 1939: 177-198.

227. Terletskiy, Ya. P. The induction of a flux of fast charged particles by rotating magnetized cosmic rays. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 16, no. 5, 1946: 403-409.

228. Terletskiy, Ya. P. Origin of cosmic rays. Uspekhi fizicheskikh nauk, v. 44, no. 1, 1951: 46-69.

229. Terletskiy, Ya. P., and A. A. Logunov. Function of the distribution of cosmic particles of the primary component. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 23, no. 6, 1952: 682-685

230. Ter-Mikaelyan, M. L. Spectrum of bremsstrahlung in a medium. Doklady Akademii nauk SSSR, v. 94, no. 6, 1954: 1033-1036.

231. Tulinov, V. F. Study of slow mu-mesons in the stratosphere by means of delayed coincidences. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 33, no. 5, 1957: 1163-1165.

232. Vavilov, O. N. Transition effect of cosmic rays and gamma rays. Trudy Fizicheskogo instituta Akademii nauk SSSR, v. 4, 1949: 7-102.

233. Veksler, V. I. New mechanism of relativistic electron production in cosmic space. Doklady Akademii nauk SSSR, v. 118, no. 2, 1958: 263-265.

234. Veksler, V. I., L. V. Kurnosova, and A. L. Lyubimov. Formation of cosmic-ray showers in thick layers of lead at different altitudes. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 17, no. 11, 1947: 1026-1033.

235. Verkhovskiy, B. I., N. A. Dobrotin, I. I. Levintov, and G. N. Khodakov. Comparison of the absorption of particles generating electron-nuclear showers in hydrogen and carbon. Doklady Akademii nauk SSSR, v. 77, no. 6, 1951: 1007-1009.

236. Vernov, S. N. On the study of cosmic rays at great altitudes. Physical Review, v. 46, no. 9, 1934: 822.

237. Vernov, S. N. The latitude effect of cosmic rays in the stratosphere and the verification of the cascade theory. Trudy Fizicheskogo instituta Akademii nauk SSSR, v. 3, no. 1, 1945: 25-114.

238. Vernov, S. N. Investigation of the interaction of the primary component of cosmic rays with matter in the stratosphere. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 19, no. 7, 1949: 621-626.

239. Vernov, S. N., N. A. Dobrotin, and G. T. Zatsepin. Existence of varitrons. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 21, no. 9, 1951: 1045-1061.

240. Vernov, S. N., V. A. Gladyshev, V. M. Filatov, A. N. Charakhch'yan, and T. N. Charakhch'yan. The nature of the absorption of cosmic particles at different altitudes in the atmosphere. Doklady Akademii nauk SSSR, v. 94, no. 3, 1954: 425-427.

241. Vernov, S. N., Ye. V. Gorchakov, I. P. Ivanenko, and G. B. Khristiansen. Development of the nuclear-active component of extensive air showers. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 36, no. 4, 1959: 1233-1239.

242. Vernov, S. N., N. N. Goryunov, G. T. Zatsepin, G. V. Kulikov, Yu. A. Nechin, Z. S. Strugal'skiy, and G. B. Khristiansen. Investigation of the core of air showers. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 36, no. 3, 1959: 669-681.

243. Vernov, S. N., N. L. Grigorov, N. A. Dobrotin, S. P. Sokolov, F. D. Savin, and A. I. Kurakin. Determination of the charge sign of primary cosmic rays by measuring the azimuthal asymmetry in the stratosphere in the equatorial region. Doklady Akademii nauk SSSR, v. 68, no. 2, 1949: 253-255.

244. Vernov, S. N., N. L. Grigorov, I. P. Ivanenko, I. I. Lebedinskiy, V. S. Murzin, and A. Ye. Chudakov. Possible mechanism for the generation of corpuscular emission under the action of cosmic rays. Doklady Akademii nauk SSSR, v. 124, no. 5, 1959: 1022-1025.

245. Vernov, S. N., B. A. Khrenov, and G. B. Khristiansen. Study of the flux of high-energy mu-mesons in extensive air showers. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 37, no. 5, 1959: 1252-1265.

246. Vernov, S. N., and A. M. Kulikov. Angular distribution of cosmic particles in the stratosphere. Doklady Akademii nauk SSSR, v. 61, no. 6, 1948: 1013-1015.

247. Vernov, S. N., A. M. Kulikov, and A. N. Charakhch'yan. Azimuthal asymmetry of cosmic rays in the stratosphere at the equator. Doklady Akademii nauk SSSR, v. 85, no. 3, 1952: 525-528.

248. Vernov, S. N., A. M. Kulikov, and A. N. Charakhch'yan. Nature and properties of primary cosmic radiation. Izvestiya Akademii nauk SSSR, seriya fizicheskaya, v. 17, no. 1, 1953: 13-20.

249. Vernov, S. N., G. V. Kulikov, Z. S. Strugal'skiy, and G. B. Khristiansen. Microstructure of the core of extensive air showers. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 37, no. 5, 1959: 1193-1196.

250. Vernov, S. N., P. V. Vakulov, Ye. V. Gorchakov, Yu. Logachev, and A. Ye. Chudakov. Investigation of soft component of cosmic radiation above the atmosphere. Iskusstvennyye sputniki Zemli, no. 2, 1958: 61-69.

251. Vitel's, L. A. Solar activity, changes of forms of atmospheric circulation, and temperature fluctuations within separate months. Trudy Glavnoy geofizicheskoy observatorii, no. 87, 1959: 56-65.

252. Vladimirskiy, V. V. Effect of the earth's magnetic field on Auger showers. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 18, no. 4, 1948: 392-401.

253. Vsekhsvyatskiy, S. K., Ye. A. Ponomarev, G. M. Nikol'skiy, and V. I. Cherednichenko. Solar corpuscular radiation. In Fizika solnechnykh korpuskulyarnykh potokov i ikh vozdeystviye na verkhnyuyu atmosferu zemli; Trudy konferentsii Komissii po issledovanyu solntsa, 22-24 noyabrya 1955 g [Physics of solar corpuscular beams and their effect on the upper atmosphere of the earth; proceedings of the Conference of the Commission on Solar Research, November 22-24, 1955]. Moscow, Izd-vo AN SSSR; 1957, pp. 51-58.

254. Yegorova, V. I. Cycle of the principal forms of atmospheric circulation. Trudy Glavnoy geofizicheskoy observatorii, no. 87, 1959: 66-85.

255. Yeliseyev, G. P., V. K. Kosmachevskiy and V. A. Lyubimov. Energy dependence of relative primary and total ionization of μ -mesons. Doklady Akademii nauk SSSR, v. 90, no. 6, 1953: 995-998.

256. Yemel'yanov, A. A. Lateral distribution of photons near the axis of extensive air showers. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 34, no. 2, 1958: 516-518.

257. Zakharova, V. P., and L. Kh. Eydus. Study of the density spectrum of extensive air showers of high density. Doklady Akademii nauk SSSR, v. 65, no. 4, 1949: 477-479.

258. Zatsepin, G. T. Nuclear-cascade process and its role in the development of extensive air showers. Doklady Akademii nauk SSSR, v. 67, no. 6, 1949: 993-996.

259. Zatsepin, G. T. Observations of cosmic-ray air showers exceeding 1000 m in width. Doklady Akademii nauk SSSR, v. 74, no. 1, 1950: 29-32.

260. Zatsepin, G. T. On the multiple production of particles in weak interaction of nucleons by means of their excitation. Nuovo cimento. Supplemento, v. 8, series 10, no. 2, 1958: 746-748.

261. Zatsepin, G. T., S. A. Kuchay, and I. L. Rozental'. Penetrating particles in extensive air showers. Doklady Akademii nauk SSSR, v. 61, no. 1, 1948: 47-49.

262. Zatsepin, G. T., and V. V. Miller. Width of Auger showers. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 17, no. 10, 1947: 939-940.

263. Zatsepin, G. T., V. V. Miller, I. L. Rozental', and L. Kh. Eydus. Study of flux density in Auger showers. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 17, no. 12, 1947: 1125-1127.

264. Zatsepin, G. T., S. I. Nikol'skiy, and A. A. Pomanskiy. Decay processes in the development of nuclear cascades in the atmosphere. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 37, no. 1, 1959: 197-201.

265. Zatsepin, G. T., and I. L. Rozental', General theory of the nuclear-cascade process. Doklady Akademii nauk SSSR, v. 99, no. 3, 1954: 369-372.

266. Zatsepin, G. T., and L. I. Sarycheva. Nuclear-active particles in extensive air showers. Doklady Akademii nauk SSSR, v. 69, no. 5, 1949: 635-638.

267. Zatsepin, G. T., and L. I. Sarycheva. Altitude dependence of extensive air showers. Doklady Akademii nauk SSSR, v. 92, no. 6, 1954: 951-954.

268. Zel'dovich, Ya. B. $K_2^{\circ} \rightarrow K_1^{\circ}$ transformation on electrons. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 36, no. 5, 1959: 1381-1386.

269. Zel'dovich, Ya. B. Present state of the theory of beta disintegration. Uspekhi fizicheskikh nauk, v. 56, no. 2, 1955: 165-200.

270. Zhdanov, A. P., and P. I. Lukirskiy. Observation of mesotron pair production. Doklady Akademii nauk SSSR, v. 69, no. 6, 1949: 785-786.

271. Zhdanov, G. B. Luchi iz mirovykh glubin [Rays from cosmic space]. Moscow, Gos. izd-vo tekhniko-teoret. lit-ry, 1955. 135 p.

272. Zhdanov, G. B., and A. A. Khaydarov. Electron spectrum of meson decay. Doklady Akademii nauk SSSR, v. 65, no. 3, 1949: 287-289.

273. Zhdanov, G. B., and A. A. Naumov. Slow mesons at an altitude of 900-4700 meters. Doklady Akademii nauk SSSR, v. 60, no. 9, 1948: 1519-1521.

274. Zhdanov, G. B., Ye. A. Zamchalova, M. I. Tretyakova, and M. N. Shcherbakova. Two interesting cases of secondary high-energy interactions in photographic emulsions. Nuovo cimento. Supplemento, v. 8, series 10, no. 2, 1958: 726-729.