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SERGEĬ NIKOLAEVICH VERNOV (on his sixtieth birthday)

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ON July 10, 1970 Academician Sergeĭ Nikolaevich Vernov, the distinguished Soviet physicist, widely known for his work on cosmic rays, will be sixty years old.

Vernov was born in the town Sestroretska to a family of a postal employee. In 1926 he completed a trade school in Leningrad and in 1931—the Leningrad Polytechnic Institute. The direction of his scientific activity was determined at the beginning of the Thirties when, as a graduate student of the Radium Institute, he began to study cosmic rays. At that time few could predict that the investigation of cosmic rays would be of fundamental significance to science and would open up new chapters of elementary particle physics, interplanetary and cosmic space physics, etc. The elucidation of the problem of the nature of even the principal part of the cosmic radiation in the atmosphere and of the nature of the primary radiation originating from cosmic space presented at that time a problem of immense difficulty and required the creation of new principles in the methods of investigation and new instrumentation.

The field that Vernov started to develop intensively was the study of cosmic rays at high altitudes; this required the setting up of experiments excluding the presence of man and his active intervention in the operation of the instrumentation. In 1935, using Professor P. A. Molchanov's radiosonde, Vernov for the first time achieved the transfer of information about cosmic rays from a sonde balloon by means of radio; this opened up extensive prospects for stratospheric and also future rocket investigations. In 1936 Vernov defended his candidate's dissertation on the subject "The Study of Cosmic Rays in the Atmosphere by Means of Radiosondes."

In 1936 Vernov entered as a doctoral candidate into the P. N. Lebedev Physics Institute, where D. V. Skobel'tsyn became his supervisor. Vernov's scientific style, combining bold experiment with profound theoretical analysis, was formed at that time, to a large extent under the influence of Skobel'tsyn. Vernov's doctoral dissertation "The Latitudinal Effect of Cosmic Rays in the Stratosphere and a Test of Cascade Theory" was based on a fundamental investigation of the latitudinal effect carried out during the equatorial expedition of the U.S.S.R. Academy of Sciences during the years 1937–1938. In this work it was first established that at least a large portion of the cosmic-ray energy is due to charged particles deflected by the terrestrial magnetic field. In the analysis of the altitude dependence of cosmic-ray intensity at various latitudes Vernov applied the method of determining the energy from the area under the cascade curve which enabled him to determine the energy spectrum of the primary particles without direct data on their intensity.

A similar method of energy measurement is at present widely utilized.

In 1945 Vernov organized extensive stratospheric investigations, creating a special group at the Moscow State University and a stratosphere station at the P. N. Lebedev Physics Institute of the U.S.S.R. Academy of Sciences.

The main direction of the work of these two groups was the elucidation of the composition of the cosmic radiation in the stratosphere. At first they used for this purpose a method worked out by Vernov for separating electrons and photons by means of the so-called transition effect. Even during the prewar period Vernov devoted a number of papers to an investigation of this effect consisting of an intensity increase during the transition of electron-photon cascades from a material with a low atomic number to one with a higher atomic number. In these it was discovered that the Bhabha-Heitler-Arley cascade theory is only a crude approximation and the correct energy spectrum of the electrons in the electromagnetic cascades was first

obtained; this stimulated considerably the further development of cascade theory and made it possible to interpret the experimental data on the transition effect. Measurements of the transition effect at various altitudes showed that electrons constitute the bulk of cosmic-ray particles in the stratosphere. At the same time, the magnitude of the transition effect at the highest altitudes did not change with altitude as was to be expected if the primary particles were electrons. Another method of investigating the nature of the primary particles, requiring more complicated apparatus and first used by M. Schein in the U.S.A. and then improved by Vernov, consisted of observing showers produced when primary particles passed through lead absorbers of various thicknesses. Because of the large difference in the cross sections of the electromagnetic and nuclear interactions for targets of large atomic number, this method made it possible to separate efficiently electrons and protons and led to the assertion that the primary particles are protons. According to the theory of geomagnetic effects, for positively charged primary particles the intensity of the flux of primary particles at the equator coming from the west should be several times as large as from the east. For a long time it proved impossible to observe the expected asymmetry experimentally. Vernov and his co-workers were the first to overcome successfully the considerable technical difficulties of this experiment and to measure in 1949 the azimuthal asymmetry in the stratosphere; this turned out to correspond to a positive charge of the primary particles, a fact which finally confirmed the proton nature of the cosmic radiation incident on the atmosphere. Even before the discovery of neutral π^0 mesons Vernov showed that the electron-photon component generated in the atmosphere cannot be ascribed to the $\pi^{\pm} \rightarrow \mu \rightarrow e$ decay process and the lifetimes of the particles responsible for its appearance are less than 10^{-10} sec. Using the results of stratospheric investigations, Vernov explained a series of characteristics of proton interactions with light atomic nuclei at an energy of $\sim 10^{10}$ eV, including the multiple-act nature of the process of absorption of the nucleon component due to the smallness of the coefficient of inelastic collision. Measurements at various latitudes were used to explain the fact that in the $3 \times 10^9 - 3 \times 10^{10}$ eV region, to a first approximation, the characteristics of the interaction do not depend on the energy. In 1949 Vernov was awarded a Government Prize of the U.S.S.R. of the First Class for his investigations of cosmic rays in the stratosphere.

In order to obtain data about $10^{14}-10^{16}$ eV particles a unique installation for investigating extensive air showers was constructed under Vernov's direction at Moscow University in the Fifties. In this experiment it became possible for the first time to record simultaneously with great accuracy various characteristics of the shower: the spatial distribution of electrons and μ mesons and the energy flux of the electron-photon and nuclear components. In this installation detailed data were obtained for the first time on the structure of the extensive air shower core and on the μ mesons, and studies were carried out of the relative fluctuations of the various components. However, the change in the energy spectrum of cosmic rays in the region of $10^{15}-10^{16}$ eV observed in this experiment was possibly of the most fundamental significance. The considerable increase in the exponent of the spectrum in this energy interval apparently reflects a change in the nature of the propagation of particles in the galaxy and is of great significance for the theory of the origin of cosmic rays.

Since 1949 Vernov has been increasingly attracted by the astrophysical aspect of the study of cosmic rays. A network of stations for the study of cosmic-ray intensity variations was created in this country on his initiative, increasing considerably the effectiveness of the world-wide network of such stations. The study of intensity variations of low-energy cosmic rays makes it possible to obtain data on magnetic fields in interplanetary space and on large-scale variations of these fields. An important supplement to the general working program of ground stations was the study of variations in the stratosphere started at Vernov's suggestion by his co-workers at the stratospheric station of the Physics Institute of the Academy of Sciences in 1958. Since then daily soundings of the stratosphere have been carried out at several latitudes; this makes it possible to follow the intensity of particles, including those of relatively low energies to which ground stations are insensitive. In the course of this work it became possible for the first time to record numerous cases of generation of particles with energies of several hundred megaelectron-volt on the sun, to determine their energy spectrum, study the nature of their motion in interplanetary space, etc. This program is also of great significance for investigating the modulation of cosmic rays arriving from the galaxy.

The study of cosmic rays by utilizing rocket technology occupies an important place in Vernov's scientific work. At present this is for him the principal direction of investigation. Vernov's constant striving to study cosmic rays as high as possible above the earth's surface was reflected by his carrying out intensity measurements of charged particles outside the limits of the atmosphere even during the first rocket launchings in this country. After the launching of the first artificial earth satellites in 1957 new possibilities appeared for experiments, and phenomena which had not been expected were observed. Immediately after the publication of the unexpectedly high radiation intensity observed at altitudes exceeding 1000 km, Vernov interpreted this phenomenon as the capture of particles in a magnetic trap and proposed a possible injection mechanism of charged particles by the decay of neutrons emitted by the atmosphere. The experiment carried out in the third Soviet artificial satellite confirmed the discovery of the high-intensity zone and also led to the conclusion that there are two belts of charged particles differing both in the particle composition and in their spatial distribution. In subsequent detailed investigations of the radiation belts carried out during the flights of rockets to the moon, of the artificial satellites "Élektron" and "Kosmos" and of the cosmic ships, Vernov measured the energy spectra of electrons in various regions of the outer belt, studied the dynamics of the belts, their topography at low altitudes, etc. In 1960 Vernov was awarded the Lenin

prize for the discovery and investigation of the outer radiation belt of the earth.

During the flights of rockets to the moon and to Venus Vernov's group obtained important data on the spatial gradient of the cosmic-ray intensity in the solar system, on the modulation of galactic cosmic rays and on the flux of low-energy protons generated on the sun. Flares of 1—10 MeV protons whose study has been undertaken during the past few years attract Vernov's special attention. It has turned out that during a period of maximum solar activity they occur very frequently. It has been possible to observe the anisotropy of these particles during the initial phase of the flare up, which attests to their orderly motion from the sun, in contradiction to the generally accepted diffusion model of the propagation of particles in interplanetary space. It is hoped that a study of this new phenomenon will yield important information about the acceleration process of particles during solar flares and the properties of the interplanetary medium.

The investigations of radiation in interplanetary space and in the magneto-sphere of the earth carried out by Vernov are not only of purely scientific but also of great practical significance in connection with the problem of the safety of man's sojurn in cosmic space and the stability of various materials under the conditions in space.

At all stages of his creative activity Vernov's work was of first-class importance for the development of the physics of cosmic rays and cosmic space. It is no wonder that his name is widely known not only in this country but also outside its borders and enjoys everywhere a well-earned authority. Vernov created a large and actively working school of physicists specializing in all branches of cosmic-ray science. During his many years as director of the Section of Nuclear Physics of the Physics Faculty of MSU he made a large contribution to the training of nuclear physics specialists.

Vernov has contributed much effort and energy to the organization of scientific work and to public activity. He is the director of the Scientific Research Institute for Nuclear Physics of MSU, holds the chair of cosmic physics of the Physics Faculty of MSU, is the deputy academic secretary of the Nuclear Physics Section of the U.S.S.R. Academy of Sciences, chairman of the Scientific Council on the Problem of Cosmic Rays, chairman of the Commission for Nuclear Physics and Cosmic Rays of the Scientific-technical Council of the Ministry of Higher and Intermediate Special Education of the U.S.S.R., chairman of the Moscow Committee for the Defense of Peace, etc. He has been a member of the communist party of the Soviet Union since 1952. His versatile scientific, organizational, and pedagogic activity has been recognized and highly valued. He has been awarded the Order of Lenin, two Orders of the Red Banner of Work and one Badge of Honor. For many years he has generously contributed his entire ability and enormous energy to the development of science in this country. We wish him many years of health and successful continuation of his fruitful activity.

Translated by Z. Barnea