S N Vernov was one of those who stood at the origins of space physics. His name is inseparable from the breakthroughs and important achievements of space research in the USSR. His work started with cosmic ray physics. The physics of cosmic rays is the field having organic links to other fields of science. The origin of cosmic rays and the processes in which they acquire enormous energies are questions whose solutions can only be found in close contact with astrophysics, radio astronomy, and cosmology. The energy spectrum of cosmic rays extends from 0.1 to 10^{11} GeV, i.e., there exist particles whose energies exceed that of particles generated in modern accelerators by a factor of several tens and hundreds of millions. The study of the interaction between such particles and nuclei led to the creation of elementary particle physics and high-energy physics, with whom the cosmic ray physics continues to maintain a very close link. Cosmic rays throw a bridge between the space and the microcosm.

S N Vernov's span of interests in science was very broad. He carried out a number of fundamental studies in cosmic ray physics and in fields related to them, like elementary particle physics, plasma phenomena, astrophysics, and geophysics, and he was one of the founding fathers who established the foothold in space studies and exploration. Sergei Nikolaevich was the first in the world to develop the methodology of high-altitude automatic studies of cosmic rays using stratospheric radiosondes. With this technique, he measured the flux of cosmic rays in the stratosphere as a function of geomagnetic latitude and proved that most of the energy of cosmic rays is associated with charged particles. Sergei Nikolaevich studied in detail the electron–photon, muon, and nuclear-active components of cosmic rays in the stratosphere, measured the east–west asymmetry in the fluxes of primary cosmic rays, proved that the primary component consists mainly of protons, established the mechanism of production of secondary particles, and obtained indications that the π meson existed. In the 1950s, a unique facility was built under S N Vernov's guidance at MSU for studying ultrahigh-energy cosmic rays, and the energy spectrum of cosmic rays with energies up to 10^{17} eV was obtained. An inflection point was found experimentally at about 10^{15} eV in the energy spectrum of cosmic rays. The establishment of this phenomenon was recorded as a discovery. Its authors were S N Vernov, G B Khristiansen, G V Kulikov, V I Solov'eva, A T Abrosimov, and B A Khrenov.

Many important experiments, first on geophysical rockets and then on artificial Earth satellites and interplanetary probes, were conducted since the late 1940s under S N Vernov's leadership. Using instruments on the first artificial Earth satellites, S N Vernov, A E Chudakov, Yu I Logachev, E V Gorchakov, and P V Vakulov discovered Earth's outer radiation belt and found an explanation for the nature of the inner belt. Detailed studies performed under the guidance of S N Vernov on the sputniks (the Elektron and Kosmos series) led to understanding the structure and dynamics of the Earth radiation belts and to the development of the theory of the belts' origin. Further progress in these studies under S N Vernov's scientific leadership resulted in establishing a number of fundamental laws of solar physics, physics of interplanetary medium, and Earth's magnetosphere and ionosphere. S N Vernov was one of the creators of space materials science and of the study of problems related to radiation safety in the course of piloted space flights.

S N Vernov was an outstanding science administrator. Our ancestors used to say: "For obtaining a good result it is necessary to find the right person at the right time." Sergei Nikolaevich possessed this gift. Owing to his leadership, various research avenues created in space physics continue to produce valuable results.

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A tribute to S N Vernov

V A Matveev

1. Introduction

We have gathered here today to give credit to the memory of an outstanding Soviet scientist, a science and physics education organizer, and Full Member of the USSR Academy of Sciences, Sergei Nikolaevich Vernov.

S N Vernov's name is inseparable from the era of the inception and maturation of the physics of cosmic rays, nuclear physics, and space research.

We pay tribute to the memory of a Russian scientist who built a world-famous scientific school, whose students and followers work actively in many areas of modern fundamental and applied physics, both in this country and abroad.

Sergei Nikolaevich chose which direction to pursue in his research at the beginning of the 1930s when, as a postgraduate at the Radium Institute, he began to study cosmic rays. Only very few people could have foreseen that the study of cosmic rays would become fundamentally important for science and turn new pages in elementary particle physics, as well as in the physics of interplanetary space and interstellar-matter physics. From the very first years of S N Vernov's life in science he was guided in his work by Academician D V Skobeltsyn and worked in close contact with him; time showed that S N Vernov was one of D V Skobeltsyn's most talented disciples.

2. Study of cosmic rays in the stratosphere

The area that S N Vernov started to attack with all his energy was the study of cosmic rays at high altitudes. This meant that experiments inevitably excluded human presence and hence any active participation of the experimentalist in the operation of the equipment. In 1935, S N Vernov realized for the first time in world practice the transmission of information on cosmic rays by radio from balloon probes. This opened a future full of promise for stratospheric, and later for still higher altitude rocket studies [1].

In 1935, S N Vernov went to work for a Doctor's degree at the P N Lebedev Physical Institute (FIAN in *Russ. abbr.*), where his style of research was much influenced by S I Vavilov and D V Skobeltsyn: a combination of daring experiment and profound theoretical analysis.

In 1945 and later S N Vernov launched large-scale stratospheric studies, having set up FIAN's stratospheric station and a special research team at Moscow State

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University. This project was aimed at clarifying the nature of cosmic rays and the mechanism of their interaction with matter. New instruments — unique and having no analogs at the time were then designed — which made it possible to draw the conclusion that protons constituted the main component of primary cosmic rays. Many years of devoted work by S N Vernov and his students led to successfully uncovering the nature and mechanism of the generation of secondary components. The results received wide international recognition and numerous confirmations.

Sergei Nikolaevich Vernov's extraordinary success in studying cosmic rays in the stratosphere brought him in 1949 the First-Class State Prize, and in 1953 he was elected Corresponding Member of the USSR Academy of Sciences.

S N Vernov took an active part in building in the USSR a network of stations for continuously monitoring cosmic rays, thus performing an extensive research program. Beginning in 1958, regular daily releases of balloon probes were carried out in a number of locations in the USSR, and after 1963 also in Antarctica. Unique data collected in this way made it possible to identify giant spikes of cosmic ray intensity in the stratosphere caused by solar flares and to form a detailed picture of the effect of the 11- and 22-year cycles of solar activity on galactic cosmic rays [2–4]. In 1976, a group of S N Vernov's collaborators were awarded the Lenin Prize for a series of papers and results on cosmic rays in the stratosphere.

3. Building facilities for studying extensive air showers

S N Vernov was not only an outstanding scientist with a broad outlook, but also an important science organizer who knew how to form a closely knit research team and point it to solving problems in the principal fields of cosmic ray physics.

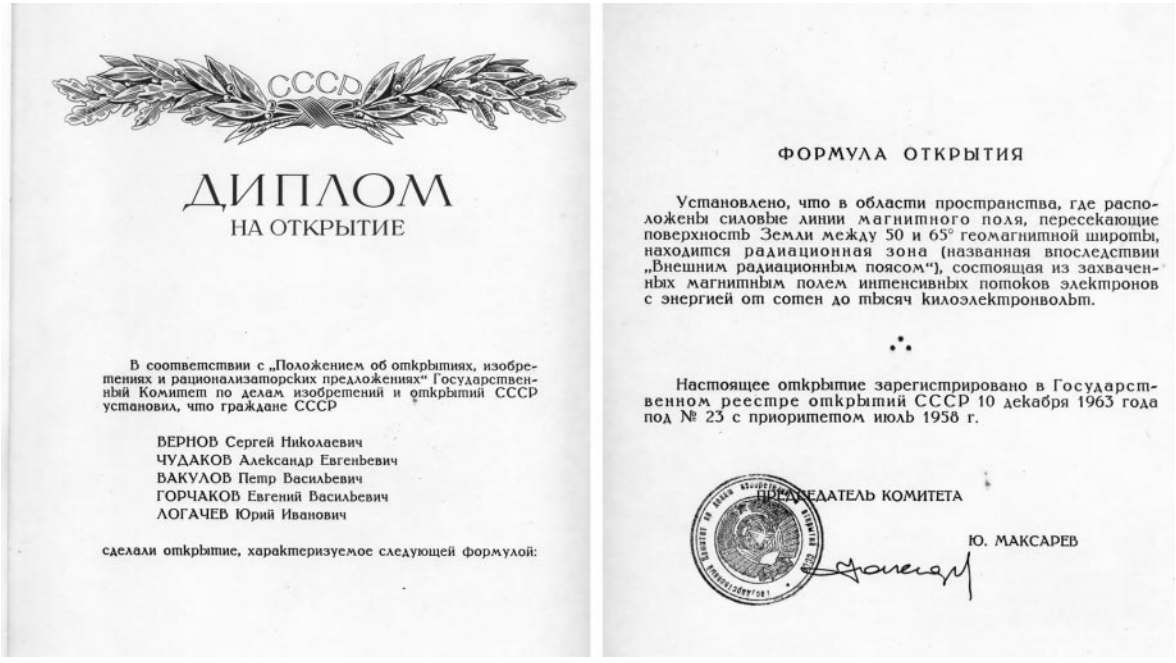
In the late 1950s, a special laboratory building equipped with unique apparatus was erected at MSU under S N Vernov's supervision, designed to study the interaction of particles at ultrahigh energies ($10^{14}-10^{17}$ eV) with matter. The most fundamental observation was the change in the slope of the energy spectrum of cosmic rays in the range of $10^{15}-10^{16}$ eV [5]. This result was certified as a discovery; its significance for profound understanding of astrophysical processes proceeding in the deep space remains great.

In the 1970s, S N Vernov supervised the creation in Yakutia of a new giant facility (covering an area of about 20 km^2) for recording the data on extensive air showers, which makes it possible to study particles with ultimately high energies ($10^{17}-10^{20}$ eV) [6]. In 1982, a group of researchers closely collaborating with Vernov was awarded the Lenin Prize for their investigation of primary ultrahigh-energy cosmic radiation.

4. Study of cosmic rays using Soviet sputniks and interplanetary probes

S N Vernov's talents as an extraordinary scientist and organizer manifested themselves especially in the work on cosmic rays using Soviet artificial satellites and interplanetary probes. A discovery of momentous significance was made already with the first Soviet sputniks — the discovery of Earth's outer radiation belt [7]. The investigation of Earth's radiation belts is of major significance not only for studying the physical properties of interplanetary space but equally for a number of theoretical and practical issues of modern geophysics. In 1960, S N Vernov was awarded the Lenin Prize for the discovery of Earth's outer radiation belt and the investigation of its properties.

In subsequent years S N Vernov headed the program of implementation of detailed studies of Earth's radiation belts and magnetosphere on Soviet satellites of the Elektron series. Already by 1968 this project allowed the team of researchers to clarify the complete structure and dynamics of radiation belts and to develop the theory of their origin. The study of Earth's radiation belts, supervised by S N Vernov, became an outstanding achievement of Soviet science. In 1968, S N Vernov was elected Full Member of the USSR Academy of Sciences.



СССР

ДИПЛОМ
НА ОТКРЫТИЕ

В соответствии с „Положением об открытиях, изобретениях и рационализаторских предложениях" Государственный Комитет по делам изобретений и открытий СССР установил, что граждане СССР

ВЕРНОВ Сергей Николаевич
ЧУДАКОВ Александр Евгеньевич
ВАКУЛОВ Петр Васильевич
ГОРЧАКОВ Евгений Васильевич
ЛОГАЧЕВ Юрий Иванович

сделали открытие, характеризуемое следующей формулой:

ФОРМУЛА ОТКРЫТИЯ

Установлено, что в области пространства, где расположены силовые линии магнитного поля, пересекающие поверхность Земли между 50 и 65° геомагнитной широты, находится радиационная зона (названная впоследствии „Внешним радиационным поясом"), состоящая из захваченных магнитным полем интенсивных потоков электронов с энергией от сотен до тысяч килоэлектронвольт.

∴

Настоящее открытие зарегистрировано в Государственном реестре открытий СССР 10 декабря 1963 года под № 23 с приоритетом июль 1958 г.

ПРЕДСЕДАТЕЛЬ КОМИТЕТА

Ю. МАКСАРЕВ

Certificate for the discovery of Earth's outer radiation belt.

5. Progress in high-energy physics

S N Vernov possessed an amazing feel for new physics.

In the late 1970s, M A Markov and A A Logunov supported the project of construction of a new building for the MSU Research Institute for Nuclear Physics (RINP) — the High Energy building. S N Vernov felt certain that this new stage in the advancement of physics demanded the creation of new accelerators and large-scale machines, and that these would lead to fundamental results at particle energies above 10^{15} eV. The processing of these results called for special equipment and highly skilled personnel. S N Vernov proved his ability to bring a project to life, and currently we have at the MSU RINP a team of researchers, experimentalists and theoreticians — around 150 people — who take active part in experiments on the biggest accelerators in the world, including the Large Hadron Collider at CERN [8].

6. Conclusion

S N Vernov devoted much energy and effort to science management and social functions. He served as MSU RINP Director, Chair of the Cosmic Ray Division at the MSU Department of Physics, Deputy Academician-Secretary of the Nuclear Physics Division of the USSR Academy of Sciences, Chair of the Scientific Council on the Problem of Cosmic Rays, Head of the Commission on Nuclear Physics and Cosmic Rays of the Research and Technology Council of the USSR Ministry of Higher and Medium Special Education, Chair of the Moscow Peace Defense Committee, etc.

Celebrating now the centenary since the day Sergei Nikolaevich was born, we recall the illustrious pages of our history, the history of academic science and its close links to university science: this is precisely the collaboration that resulted in rich output — outstanding scientific results. These close links survive today in the latest experimental projects in which the personnel of MSU and RAS work side by side.

S N Vernov enjoyed the highest reputation both among his research fellows and among his colleagues in the USSR Academy of Sciences. His standing was based not only on his impeccable professionalism, but also on his human qualities. Many outstanding scientists were among his friends: S N Vavilov, D V Skobeltsyn, M A Markov, N I Bogoliubov, M V Keldysh, B M Pontecorvo, A A Logunov, N A Dobrotin, A E Chudakov, and G T Zatsepin.

I happened to be present when S N Vernov met N N Bogoliubov, M A Markov, A M Baldin, D I Blokhintsev, and others. I was profoundly impressed by their deepest mutual respect, and at the same time their warm friendly relations. They all belonged to the same era — the era of great scientific discoveries against the background of the hard and multifaceted, at times tragic, history of the country and its people and the trials and tribulations that fate brought to them. At the same time, they belonged to that category of people for whom serving their science was inseparable from serving their country.

S N Vernov's work at each phase of his creative activities was of primary importance for the progress of cosmic ray physics and space physics. It is not surprising that his name is widely known not only in this country, but also beyond its borders, and that it everywhere enjoys a well-deserved high reputation. In the 50 years of S N Vernov's life in science, he built a large and actively working scientific school of several dozen PhD and DSc physicists in every section of cosmic ray physics. At the conclusion of each stage in his research career, teams of researchers would spring up whose subsequent work would open a number of new avenues of inquiry and solve many important problems. The achievements of the scientists of this school have twice been rewarded with the Lenin Prize, four times with the USSR State Prize. As for Sergei Nikolaevich Vernov himself, he was awarded the high distinction of Hero of Socialist Labor.

S N Vernov (left) with Academician A A Logunov (MSU chancellor) and Professor I M Ternov (1980).

S N Vernov (right) with Academicians N N Bogoliubov, A N Tavkhelidze, and V G Kadyshevskii.

S N Vernov (right) with Academician M A Markov.

S N Vernov (left) with Academician G B Khristiansen.

S N Vernov (left) with Academician B M Pontecorvo.

S N Vernov's name belongs to the pantheon of scientists who symbolize the pride and glory of the physical science in this country and of the Russian Academy of Sciences and its Physical Sciences Division.

Studying the heritage of the research work of S N Vernov and his students is a good school for young generations of scientists who seek to leave their mark on modern science as it strives to achieve understanding of the fundamental laws of the Universe.

Included in this article are photographs taken by Yu A Tumanov, D V Bobkov, and A T Abrosimov, and also photographs received from the family archive of E S Vernova.

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S N Vernov as a Moscow University scientist

V A Sadovnichy

The date 11 July 2010 marks the 100th anniversary of the birth of Academician Sergei Nikolaevich Vernov — the scientist of world renown, Hero of Socialist Labor, recipient of the USSR Lenin and State Prizes, one of the founders of the Research Institute for Nuclear Physics (RINP) [now renamed as D V Skobeltsyn Institute of Nuclear Physics (SINP)] of Moscow State University and then its Director from 1960 till 1982, and Head of the Nuclear Physics Division at the Department of Physics of the M V Lomonosov Moscow State University. The name of S N Vernov marks grandiose achievements of this country in the implementation of the Soviet Atomic project, in space exploration, in gaining knowledge of the fundamental properties of matter.

In the second half of the 20th century, nuclear physics, space physics, and high-energy physics took a giant jump to an enormously higher qualitative level. This was reflected in the birth of many other scientific and technological fields. It was a renaissance of fundamental and applied research throughout the world, especially in this country. Sergei Nikolaevich Vernov proved to be just the person that the State and Moscow State University needed at that very moment. To quote a metaphoric comparison made by Georgii Borisovich Khristiansen, he acted for more than 25 years as an outstanding conductor of research on the structure of matter and space physics. It was to a large extent owing to S N Vernov that Moscow State University continues to show great achievements in these fields of science.

S N Vernov, in his capacity of RINP Deputy Director from 1946 till 1960, and RINP Director from 1960 till 1982, made a huge contribution, alongside D V Skobeltsyn, to the creation and further evolution of this Institute and of the Nuclear Physics Division at the MSU Department of Physics and to training the personnel for the Soviet Atomic project and for space research.

It was in the years of S N Vernov's work at Moscow State University that space research using artificial satellites (sputniks) and space rockets was born and then grew in volume and stature. Direct contacts between S N Vernov

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