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## S N Vernov and space physics: Apatity–Leningrad, 1968–1983

V A Dergachev

### 1. From the biography of S N Vernov (Leningrad period)

Sergei Nikolaevich Vernov (11.07.1910–26.09.1982), an outstanding Soviet physicist, was the first to initiate programs for studying cosmic rays and cosmic radiation with the aid of the first Soviet satellites.

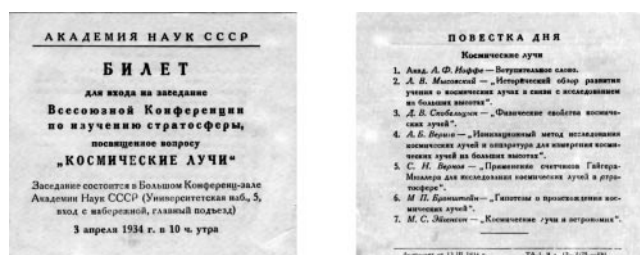
Sergei Nikolaevich was born in the city of Sestroretsk near St. Petersburg. His father was a post office employee and his mother was a mathematics teacher. After graduating from a unified labor high school in 1926, as ‘the best graduate of the class’ he joined a mechanical technical school and already after one year became a student in the Physicomechanical Department of the Leningrad Polytechnical Institute (LPI) (at present, the St. Petersburg State Polytechnical University), from which he graduated in 1931 with a diploma in engineering physics. The Physicomechanical Department at the LPI, which was founded in 1919 on the initiative of A F Ioffe, was for a long time an incubator for engineers–physicists. Beginning from 1930, being a fourth classman at the LPI, S N Vernov started to work as a temporal researcher at the Radium Institute and then became a postgraduate at this institute. Sergei Nikolaevich recalls that he chose the theme of his doctoral thesis after meeting D V Skobel'syn at the LPI, whom he considered his teacher and who discovered charged particles in cosmic rays as early as 1927. His choice was naturally related to the study of cosmic rays which became the main field of his research till the end of his life.

Sergei Nikolaevich worked at the Radium Institute from 1930 to 1936. His doctoral thesis was devoted to the study of cosmic rays using Geiger–Müller counters. He wrote an abstract, “Newest data in the study of cosmic rays,” where he showed that small-volume gas-discharge counters can be successfully used for both terrestrial and balloon investigations of cosmic rays. Already in 1934, S N Vernov presented a report at the All-Union Conference on Stratosphere Studies, devoted to the issue of cosmic rays.

During the same period, S N Vernov was sent to the Main Geophysical Observatory (Leningrad) to study cosmic rays in

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Ticket for a session of the All-Union Conference on Cosmic Rays and the agenda with the S N Vernov report (Leningrad, 1934).

the stratosphere. In 1934, he was included in the crew of the Osoviakhim stratostat, but came down with tonsillitis and could not take part in the flight. He was replaced by his peer Il'ya Usyskin who tragically perished in this flight. Fate saved the life of Sergei Nikolaevich to give him the opportunity to accomplish many scientific cosmic feats in the future.

In 1935, S N Vernov was accepted into the doctoral program at the Lebedev Physical Institute, USSR Academy of Sciences (FIAN in *Russ. abbr.*) and, supervised by S I Vavilov and D V Skobeltsyn, finally formed his scientific style combining adventurous experiments with deep theoretical analysis. However, the connection between Sergei Nikolaevich and the Radium Institute continued for many years.

The maximum creative and scientific-organizational activity of S N Vernov was manifested in the 1950–70s. The scope of his scientific interests in the field of cosmic rays had considerably expanded. He used cosmic rays as a tool for studying the interplanetary medium, solar activity, and other objects.

A memorial tablet mounted on a wall of the first building of the Radium Institute on Roentgen Street, 1 in St. Petersburg names academicians and corresponding members of the USSR Academy of Sciences, who worked at the institute in different years, Academician Sergei Nikolaevich Vernov being among them.

In the year of the 100th anniversary of Sergei Nikolaevich's birthday, we cannot help remembering those brilliant pages that he wrote on the history of studying cosmic rays and of space exploration.

## 2. How fate brought Sergei Nikolaevich and me together

I have had the luck to meet many brilliant people in my life, but Sergei Nikolaevich Vernov occupies a special place among them. I was fortunate to associate with him beginning from 1968 almost until his death.

In 1964, when I was in my fifth year at the Physicomechanical Department of the LPI, where Sergei Nikolaevich had studied earlier, I was lucky, along with a few of the students, to take part in the IV-th Conference on Cosmic Rays, which was held in the small town Apatity, Murmansk region, from 24 to 29 August. On the beautiful day of 22 August 1964, I flew for the first time in my life to a scientific conference together with scientists of the Ioffe Physical-Technical Institute (PTI), USSR Academy of Sciences. (This episode and my further contacts with S N Vernov are described in more detail in my paper, "Sergei Nikolaevich Vernov, as I remember him" [1]).

The conference was set up by the Scientific Council of the USSR Academy of Sciences within the framework of the complex issue of Cosmic Rays chaired by S N Vernov.

Being a third-year student at the Physicomechanical Department of the Chair of Experimental Nuclear Physics at the Kalinin LPI, I joined G E Kocharov's group at the PTI. Early in 1968, G E Kocharov asked me to help in organizing the Fifth All-Union School on Cosmophysics in Apatity, Murmansk region. At the request of Sergei Nikolaevich he went to Apatity and met Sergei Ivanovich Isaev, the Director of the Polar Geophysical Institute, and after meetings with E K Kozlov, the Chairman of the Kol'sk Branch of the USSR Academy of Sciences, and the Secretary of the CPSU town Committee of Apatity, the question about the organization of a Winter School on Cosmophysics in Apatity, which had already become traditional at the Academy of Sciences, was resolved. We began to make trips to Sergei Nikolaevich in Moscow to coordinate the organizing committee of the school and its program, the list of participants, and other organizational questions. After that, being the scientific secretary of schools, a number of seminars, symposia, and conferences on cosmic rays, and the scientific secretary of the Scientific Council on Cosmic Rays, for many years I often visited Sergei Nikolaevich at the Research Institute for Nuclear Physics (RINP) of Moscow State University, who was Director of this institute, and at the Nuclear Physics Division of the Presidium of the USSR Academy of Sciences, where Sergei Nikolaevich was the Deputy Academician-Secretary of the Division.

## 3. Apatity stage of cosmophysics schools (1968–1969)

I would like to emphasize at once the special role of S N Vernov in the development of cosmic ray science and the organization of many scientific meetings on cosmic rays. He continuously organized these meetings, not only in Moscow, but also in Apatity, Irkutsk, Yakutsk, Alma-Ata, Erevan, and other places. This undoubtedly facilitated the advancement of science in these cities and attracted the attention to cosmic rays of not only young scientists but also the local administration on which the development of the infrastructure of scientific studies considerably depended.

Cosmophysics schools held in our country had a specific feature distinguishing them from meetings, conferences and symposia. The main task of these schools was to give new knowledge on different lines of investigation in cosmic ray physics to participants working in different fields of physics, to present a clear picture of the general state and prospects of cosmic physics, and to establish interrelations between different natural processes. Sergei Nikolaevich believed that the participants in the school should discuss the state of the art and prospects of the main avenues in cosmic physics and receive information on advances in related scientific fields covering neutrino astrophysics, cosmological objects, the role of relict radiation in the evolution of the Universe, and solar physics, etc. This required the invitation of well-known scientists as lecturers at the school. Sergei Nikolaevich paid close attention to the choice of reports and review lectures of interest for a wide circle of participants. Of course, the duration of such schools was quite long and their regulation differed from that accepted in the Academy of Sciences for meetings and seminars.

By the time I was included on the committee for organizing and carrying out the Winter Cosmophysics School in Apatity in 1968, already four such schools supported by the resolution of the Section of Cosmic Rays and Radiation Belts had been held in previous years in different cities. Thus, we could use the

experience of these schools for organizing the V-th Winter Cosmophysics School.

The V-th and VI-th Winter Cosmophysics Schools chaired by S N Vernov were supported by the resolution of the Presidium of the USSR Academy of Sciences and were held at the Polar Geophysical Institute (PGI) in Apatity from 21 March to 5 April 1968 (the V-th school) and from 18 March to 1 April 1969 (the VI-th school). 150 scientists presenting 57 reports attended the fifth school, and 300 scientists presenting 116 reports attended the sixth school. The PGI had well-equipped laboratories in which the ionosphere, aurora, Earth's magnetic field, and cosmic rays were investigated. I was lucky to collaborate with Sergei Nikolaevich and his colleagues for a long time after these schools during the organization of other meetings on cosmic physics.

The organizing committees of the V-th and VI-th Schools usually prepared the program of sessions at least 3–4 months prior to their beginning, and asked well-known scientists to give lectures. For example, the organizing committee of the



During a lecture: (from right to left) E K Kozlov, S N Vernov, L L Lazutin (PGI), and A E Chudakov (Apatity, PGI, 1969).



Opening of the Sixth Cosmophysics School: (from left to right) Yu A Volkov, Scientific Secretary of the Polar Geophysical Institute, S I Isaev, Director of the Polar Geophysical Institute, S N Vernov, Chair of the School's Organizing Committee, E K Kozlov, Chairman of the Kol'sk Branch of the USSR Academy of Sciences, G E Kocharov, Deputy Chair of the School's Organizing Committee, P V Prokoshin, Secretary of the CPSU town Committee, and V A Dergachev, Scientific Secretary of the School's Organizing Committee (Apatity, Murmansk region, 1969).



S N Vernov during a break between sessions among participants in the school. V A Dergachev is instructed about changes in the program of the Sixth Cosmophysics School (Apatity, PGI, 1969).



Visit to the I A Kuz'min laboratory: (from left to right) L I Miroshnichenko (Pushkov Institute of Earth Magnetism, the Ionosphere and Propagation of Radiowaves, RAS (IZMIRAN in *Russ. abbr.*), G E Kocharov, S N Vernov, and I A Kuz'min (Apatity, PGI, 1969).

V-th School invited our leading scientists V L Ginzburg, Ya B Zel'dovich, B M Pontecorvo, E P Mustel', E L Feinberg, L E Gurevich, A Z Dolginov, G T Zatsepin, L I Dorman, S I Syrovatskii, and some others.

The task of organizing the V-th and VI-th Cosmophysics Schools was mainly performed by researchers of the PTI, and, of course, Sergei Nikolaevich, with me and G E Kocharov, considered all the questions, including the accommodations of the participants (which was rather difficult to do in a small town). In addition, Sergei Nikolaevich emphasized the importance of publishing the proceedings of the school and proposed attempting to publish them (the proceedings of previous schools were not published). Because the next school was to be held the next year, it was necessary to publish the proceedings as fast as possible. We took on this task not understanding on the whole all the problems that awaited us. We accepted papers till the end of May 1968 and then carefully edited them by enlisting the services of scientific and style editors, and finally printed them on an offset duplicator. As a result, I had to be in Apatity for more than three summer months in 1968. Eventually, the proceedings of the V-th school were published within four months after the end of the school. Sergei Nikolaevich was very glad and

emphasized the importance of this work, showing a copy of proceedings at each convenient opportunity.

However, this wide publicity of the school played a malicious jest on us when we organized the next school, the VI-th one. The number of proposed reports and lectures was so large that all of them could not be accepted. And the number of researchers willing to attend the school was too large (300 people). I will not describe here the problems concerning the accommodations of participants in the school and how Sergei Nikolaevich organized a visit to a Secretary of a CPSU town Committee, who understood our situation and asked local inhabitants who had already received apartments in a new building not to occupy flats in one part of one of the building for two weeks during the work of the School. Such was the authority of science at that time!

By the time of the VI-th Cosmophysics School, we had become friendly with the scientific community in Apatity and regularly discussed with Sergei Nikolaevich many questions at the Kol'sk Branch of the USSR Academy of Sciences with A N Voronkov, the Deputy Chairman of the Presidium of the Kol'sk Branch of the Academy of Sciences and Yu A Shashmurin, the Scientific Secretary of the Branch, who significantly helped us to organize the printing of the proceedings on an offset duplicator. S I Isaev, the Director of the PGI, and Yu A Volkov, the Scientific Secretary, helped us to solve all the problems encountered during the work of the school and organized leisure hours. We visited some laboratories at the PGI. Yu A Volkov, L L Lazutin, I N Kapustin, and others invited us to their homes and we appreciated their northern hospitality.

One day during a break between sessions we walked about the lobby and discussed the possibility of including an additional report in the evening session. Sergei Nikolaevich saw one of the participants standing stock-still near the stand displaying the program and said: "Pay attention to this young man, he will go far." This young man was Mikhail Igorevich Panasyuk, who was then only a postgraduate student. And Sergei Nikolaevich was not mistaken!

Due to the huge number of reports, the Organizing Committee of the Sixth School decided to publish mainly

lectures of invited scientists and review papers of interest to a wide circle of researchers. During the session of the Scientific Council on the complex problem of cosmic rays on the last day of the school, Sergei Nikolaevich highly praised the activity of the school organizers. Of course, it was necessary to publish the proceedings of the Sixth School, like those of the Fifth School, in a short time, which was accomplished (the proceedings were published in two volumes).

Unfortunately, this was the end of the Apatity stage of these schools. One of the reasons, as pointed out in the discussion of the next schools, was that we could not maintain the high level of conducting the schools and could not provide the rapid publishing of proceedings. Nevertheless, these cosmophysics schools were exceptional in a certain sense, and they considerably expressed and even determined in some aspects the development of the cosmophysics community. However, another format for these schools was required.

#### 4. Leningrad stage of cosmophysics at international seminars, conferences on cosmic rays, the European symposium (1969–1983).

Sergei Nikolaevich loved Leningrad and cosmic ray physics very much. This love led to the resolution of the Nuclear Physics Division of the Presidium of the USSR Academy of Sciences to organize annual international seminars in Leningrad, beginning from 1969. These seminars were devoted to the discussion of separate problems of cosmic physics, with the participation of foreign scientists.

The First Leningrad International Seminar on the Physics of Interplanetary Space was held at the Ioffe PTI in Leningrad from 3 to 7 June 1969. One should not forget about the difficulties of organizing scientific meetings during the white nights period in Leningrad, when the number of unoccupied apartments in hotels is lacking. All the problems encountered in the organization of seminars had to be agreed with the local administration at the highest level. Reports were mainly presented by invited scientists. Reports by foreign participants were synchronously translated and discussed in detail.



Conversation with S N Vernov near the Ioffe PTI building in Leningrad during a meeting on 3–7 June 1969. From left to right: G E Kocharov, V I Chesnokov (PTI), K I Gringauz (Space Research Institute, RAS (IKI in *Russ. abbr.*)), J R Winkler (USA), I M Podgorny (IKI), D J Williams (USA), S N Vernov, S M Krimiges (USA), K G McCracken (Australia) (photograph from the S M Krimiges paper, "Decades of great accomplishments" in book [2]) (Leningrad, 1969).

In opening the seminar, B P Konstantinov, Vice President of the USSR Academy of Sciences (Director of the PTI for a long time) highly valued the idea of organizing such seminars and considered some of the urgent problems of modern physics. In conclusion, he thanked foreign colleagues who took part in the seminar: H Alfvén (Sweden), D J Williams, J R Winkler, and S M Krimiges (USA), W R Webber (England), A Somogyi (Hungary), K G McCracken (Australia), P Velinov (Bulgaria), and Knut (German Democratic Republic).

It was natural to publish seminar proceedings in the current year. And here Sergei Nikolaevich had our support. Of course, the organization of these meetings took much time. The publishing of proceedings on the offset duplicator required a lot of routine work, which was performed by our small group. Nevertheless, the seminar proceedings were published at the PTI in 1969.

As a whole, the year 1969 was very arduous, and we in fact had no time for research.

Sergei Nikolaevich saw this and proposed that the proceedings of the next seminars be published at the Research Institute for Nuclear Physics of Moscow State University, because they had better equipment and could use a greater number of staff members for this work. So, the proceedings of the second and third Leningrad seminars were published at the MSU RINP, although they failed to do it in the same year as the seminar.

Sergei Nikolaevich believed that seminar proceedings should be published as fast as possible and asked G E Kocharov to estimate the possibilities. I remember that Grant Egorovich said that everything depended on V A Dergachev. Of course, I could not refuse Sergei Nikolaevich! And I toiled at this generous task in fact until the last seminar which was headed by Sergei Nikolaevich. And while Sergei Nikolaevich was alive, 12 Leningrad seminars were held in which scientists from other countries participated with pleasure and presented review papers containing the newest information. Seminars were devoted each year to different problems of cosmophysics, which was rapidly developing in the 1970s–1980s.

S M Krimiges, a leading researcher in several NASA's projects in the USA and a participant in the first Leningrad seminar, visited Russia in 2007 in connection with the 50th

anniversary of the launching of the first sputnik in the USSR and pointed out in his talk: “*I remember well my first visit to the USSR in 1969 at the invitation of Academician S N Vernov to participate in the conference at the Ioffe Physical-Technical Institute in the then Leningrad. Several Western scientists (H Alfvén, K G McCracken, W R Webber, J R Winkler, D J Williams) also took part in the conference and we had a magnificent series of discussions and compared for the first time the data on solar high-energy particles obtained by means of satellites in the USA and USSR*” [2].

The topics of the next seminars were as follows.

The Second International Seminar on the problem ‘Generation of Cosmic Rays in the Sun’ (Leningrad, 8–12 December 1970). In opening the seminar, S N Vernov pointed out the importance of studying solar cosmic rays and indicated the main areas of these studies. He said that the accumulated experimental data and theoretical hypotheses could be used to analyze in detail the physical processes governing the generation of cosmic rays in the Sun and their acceleration in outer space, and to work out recommendations for further theoretical and experimental investigations in this field. The seminar proceedings were published at the MSU RINP in 1971 [3].

The Third International Seminar on the problem ‘Acceleration of Particles in Space (Circumterrestrial and Interplanetary Space), the Galaxy and the Metagalaxy’ (Leningrad, 13–15 July 1971) [4].

The Fourth Leningrad International Seminar on ‘The Uniformity of the Particle Acceleration on Different Space Scales’ (Leningrad, 16–18 August, 1972) [5].

The Fifth Leningrad International Seminar on ‘Solar Cosmic Rays and Their Penetration into Earth’s Magnetosphere’ (Leningrad, 26–29 June 1973) [6].

The Sixth Leningrad International Seminar on ‘Particle Acceleration and Nuclear Reactions in Space’ (Leningrad, 19–21 August 1974) [7].

The Seventh Leningrad International Seminar on ‘Corpuscular Solar Fluxes and Earth and Jupiter Radiation Belts’ (Leningrad, 25–28 May 1975) [8].

The Eighth Leningrad International Seminar on ‘Active Processes in the Sun and the Problem of Solar Neutrinos’ (Leningrad, 25–27 September 1976) [9].

The Ninth Leningrad Cosmophysics Seminar on ‘Solar Cosmic Rays: Their Generation and Interaction with Matter from the Source to Earth’ (Leningrad, 23–25 December 1977) [10].

The Tenth Leningrad Cosmophysics Seminar on ‘Nuclear Cosmic Physics’ (Leningrad, 6–8 October 1978) [11].

The Eleventh Leningrad Cosmophysics Seminar on ‘The Interaction of Cosmic Rays with a Medium’ (Leningrad, 30 November–2 December 1979) [12].

The Seventh European Cosmic Ray Symposium (Leningrad, 15–19 September 1980) [13].

The Twelfth Leningrad Cosmophysics Seminar on ‘Complex Studies of the Sun’ (Leningrad, 6–8 February 1982) [14].

The Thirteenth Leningrad Cosmophysics Seminar on ‘The Intensity of Cosmic Rays and Cosmogenic Isotopes’ (Leningrad, 19–21 November 1982) [15].

The world’s best-known scientists in cosmophysics felt-honored to be invited to participate in the Leningrad seminars. These seminars attracted great attention of outstanding foreign and Russian scientists because they could discuss here in detail the most urgent scientific problems.



The Sixth Leningrad International Cosmophysics Seminar: during a lecture. First row (from left to right): S N Vernov, G E Kocharov, A Somogyi (Hungary), A Z Dolginov (Ioffe PTI), V A Krat (Pulkovo Observatory); second row (from right to left): S I Syrovatskii (FIAN), V A Dergachev (Leningrad, 1974).



Seminar opening: A Somogyi (Hungary) addresses the meeting. Seated are (from left to right): V Kuchovich (Poland), S N Vernov, G E Kocharov, J Simpson (USA), V A Dergachev, E Bagge (FRG), P Povinec (Czechoslovakia) (Leningrad, 1976).



During a banquet after seminar's closing (from right to left): S N Vernov with his wife, I M Podgorny (IKI) with his wife, G E Kocharov, V A Dergachev, T N Charakhch'yan (FIAN) (Leningrad, 1976).

As an example, we can consider the Eighth Leningrad International Seminar on 'Active Processes in the Sun and the Problem of Solar Neutrinos', which was held at the Ioffe PTI from 25 to 27 September 1976. S N Vernov opened the seminar. Many known scientists presented reports. Among them were: G E Kocharov, G V Domogatskii, N N Stepanyan, B V Somov, B I Luchkov, M I Pudovkin, V A Krat, T N Charakhch'yan, A Z Dolginov, A K Lavrukhina, L I Dorman, I M Podgorny, B M Vladimirkii, and some others (USSR); A Somogyi, D Benko, G Erdesz (Hungary); Z Kobylinsky, V Kuchovich (Poland); J Vorpál and J Simpson (USA); K Kudela, S Pinter, P Povinec (Czechoslovakia), and E Bagge (Federal Republic of Germany). L E Gurevich and B M Pontecorvo also actively participated in discussions.

The seminar opened with a speech by S N Vernov, the Chair of the Organizing Committee, who said that the Leningrad seminars had already been of much benefit, especially concerning cosmophysics. S N Vernov demonstrated in his talk that he knew in detail many problems of current interest in cosmophysics. He presented a number of problems related to processes proceeding in the Sun, which had to be studied theoretically. A A Somogyi (Chair of the Commission on Cosmic Rays of the International Union of Pure and Applied Physics) pointed out that interest in the

seminar arose not only due to scientific problems, but also due to the beauty of Leningrad and the warm friendly atmosphere at the seminar. John A Simpson, Director of the Enrico Fermi Institute, University of Chicago and a world-renowned scientist, said that the seminar was important due to representative scientific discussions and reports concerning the latest studies and the opportunity of visiting the USSR to meet many Soviet scientists, especially young scientists, studying cosmic rays. He also pointed out that the Leningrad seminars actively facilitated collaboration between the two countries and exchange programs developed by the Academy of Sciences in the USA and USSR. The seminar closed with speeches by E Bagge, Director of the Institute for Nuclear Physics, Kiel University, S Pinter, Director of the Geophysical Observatory (Hurbanovo, Czechoslovakia), and G E Kocharov, Deputy Chair of the Organizing Committee.

The jubilee seminar, the tenth, opened with a speech by S N Vernov, who pointed out that the idea of such international seminars devoted to some problems of cosmophysics belonged to Moisei Aleksandrovich Markov, Academician-Secretary of the Nuclear Physics Division of the USSR AS.

S N Vernov said that the different aspects of cosmophysics in space and time were discussed at previous seminars: *"And we have managed to relate the different aspects of these complex and interconnected phenomena by bridging them. And we expanded the topic from seminar to seminar, increasing the number of organizations and the number of researchers who more and more became the enthusiasts of our seminars. And in the meantime, our science developed very successfully. We worked and are still working in the field where the flights of satellites and cosmic rockets provide a great amount of new information. Therefore, it is natural that our seminars are always of current interest. They are devoted to very new and very interesting questions that appeared only recently and require active discussions of different aspects and rapid solution"* [11].

Along with seminars, we also organized together Conferences on Cosmic Rays in Leningrad and the Seventh European Cosmic Ray Symposium (ECRS).

I would like to emphasize how deeply S N Vernov understood the scale of cosmic ray physics. He said: *"In fact we are divided into two parts, some of us gravitating to astronomy, having practically no relation to nuclear physics, while others gravitate to nuclear physics and are clearly far from astronomy. However, there are people among us who can be cut in half because one part of them belongs to nuclear physics, while the other to astronomy"* [13].

D N Skobeltsyn called the astronomical aspect of cosmic rays cosmophysical. From this point on, cosmic ray physics was divided into the cosmophysical and nuclear-physical fields, and cosmic ray conferences were held and are being held in these two fields. It is pertinent here to cite S N Vernov again: *"What will we have if we break cosmic ray physics into cosmic ray physics studying astronomical problems, and cosmic ray physics investigating nuclear problems? This will lead to a parcel of rubbish, comrades"* [13]. Such conferences were held in Leningrad: in 1969, the cosmic ray conference was chaired by Sergei Nikolaevich, and the 30th Jubilee Conference was held in 2008 without him, and we remembered him again.

During the conference opening in 1969, K P Seleznev, Rector of the Leningrad Polytechnical Institute, gave Sergei Nikolaevich a memorial medal in connection with the 50th anniversary of the Physicomechanical Department where Sergei Nikolaevich had studied.



A speech by S N Vernov during the opening of the Seventh European Cosmic Ray Symposium at the LPI on 15 September 1980 was very profound. He talked with feeling about Dmitrii Vladimirovich Skobeltsyn, his teacher, whom he met at the LPI in 1932 and to whom, according to S N Vernov's words, we were indebted not only because of cosmic ray physics but also due to high-energy physics. Although D V Skobeltsyn was 88 in 1980, he was the leader of the Cosmic-Ray Physics School in the Soviet Union.

The Seventh European Cosmic Ray Symposium opened with greeting speeches by A Wolfendale (England), Secretary and future Chair of the IUPAP Cosmic Ray Commission, A Somogyi (Hungary), ex-Chair of this Commission, and G N Aleksandrov, prorector of the LPI.

S N Vernov emphasized in his talk at the Symposium that many cosmophysical problems had been considered at Leningrad seminars (by this time, 11 seminars had already been held) and, giving these seminars credit, he said: *"I even misspoke, calling the symposium a seminar because we have already simply become accustomed to meet together each year at traditional Leningrad seminars"* [13].

At the end of his talk, S N Vernov called on participants not to stop at the achieved results. He said: *"What do we need now from cosmic rays? The Academician M A Markov, Head of the Nuclear Physics Division, thinks that we work poorly because we have not followed the way of researchers in the field of accelerators and have not created industrialization in cosmic rays. We should build boldly large facilities, use computers instead of manual calculations and we should not be afraid of large scales, as are researchers who are now building giant accelerators that cost hundreds of millions of rubles"* [13]. How this is also relevant now!

On the behalf of the LPI staff, G N Aleksandrov extended his best wishes to S N Vernov on his 70th birthday and on awarding the high rank of Hero of Socialist Labor for outstanding merits in scientific, pedagogical, and communal activities.

In his concluding speech, S N Vernov highly praised the Symposium in which more than 300 scientists had participated. The total number of reports, including plenary talks, amounted to 445; 22 invited speakers presented lectures. S N Vernov pointed out that, unlike the proceedings of the previous symposia, the proceedings of this symposium would be published. And they were published in 1980.

S N Vernov also said: *"I think that the field of studying cosmic rays is so diversified and our science is developing so quickly that we should meet together each year, i.e., international conferences should be held every two years and European symposia in the year between them; one year is a large enough time period"* [13]. As a whole, the symposia changed the structure of Leningrad International Seminars.

Cosmic physics suffered an irrecoverable loss after the death of Sergei Nikolaevich. He lived a very meaningful life, did much for people, and left the memory of himself in the hearts of his numerous pupils, collaborators, and all those who were lucky enough to associate with him, listening to his interesting reports. We will always remember Sergei Nikolaevich and will try to ensure that his living image influences our deeds.

## 5. S N Vernov as a man

I have met in my life two brilliant scientists and organizers of science, Academicians B P Konstantinov and S N Vernov. The 100th anniversary of their births is celebrated in this year.

They greatly influenced me in the choice of my scientific path and, which may be even more important, in the wish to be and remain a man in any situation.

I worked with Sergei Nikolaevich for more than 12 years as a scientific secretary of his seminars, all-union conferences, and schools. He was distinguished among others by his great talent in physics, exceptional creativity, and extraordinary capacity for work.

I often visited the MSU RINP at that time and saw how he cared about his collaborators and how he was easily accessible to them all, from the heads of departments to simple staff members. Sergei Nikolaevich never pretended, never was didactic, but, I would say, rather preferred to teach. And all the staff members of the Institute had the greatest and warmest respect for him. Sergei Ivanovich treated everyone equally and respectfully. Overall, he appreciated in people good manners and the ability to behave properly.

Sergei Nikolaevich was a rather mild-tempered man. But in the cause of science, his mildness could instantly evaporate. And I saw it two times.

I still remember the special, elated, and even joyful mood that I experienced during each visit to Sergei Nikolaevich at the MSU RINP or at the Nuclear Physics Division of the Academy of Sciences or in Leningrad at the home of his daughter on Grazhdanskii prospect. Now, after almost 40 years, it is very difficult to recall in detail the content of our conversations. Because I also lived on Grazhdanskii prospect at that time, Sergei Nikolaevich called me almost every time he came to Leningrad and asked which questions remained unsolved and which help was required. Of course, we always discussed both the preliminary and final programs of planned meetings. I remember how I sometimes visited Sergei Nikolaevich on Grazhdanskii prospect when he had a cold. He said that he cured himself by a simple down-to-earth method and asked me about my attitude to a small glass of Zubrovka vodka, whose healing properties were not appreciated by his relatives. Here, I was on the side of Sergei Nikolaevich.

Usually, when I was going to leave, Sergei Nikolaevich said: "Let's walk and I will escort you to your home." I understood that Sergei Nikolaevich needed a walk and we went first to my home and then back. I felt that Sergei



The 70th birthday of S N Vernov (from right to left): S N Vernov, V A Dergachev (PTI), G B Khristiansen (MSU RINP), G V Kulikov (MSU RINP), G E Kocharov (PTI), and G Ya Goryacheva (FIAN) (Moscow, 1980).

Nikolaevich wanted to share his thoughts about his successors who would continue his work. Thus, we discussed candidates for the position of the deputy director of the MSU RINP and the head of the Baikal neutrino experiment to which Sergei Nikolaevich paid great attention. I remember how acutely he understood this situation. He said that it was very difficult to find a head who would have high moral values and at the same time could deal with Party bodies which could provide the help, otherwise everything could be spoiled. It was necessary not only to have talent, staying power, and the capacity for work, but to be able to orientate in the political life of the country under those conditions in order to obtain the many excellent results which were achieved due to the efforts of S N Vernov himself. When we separated after each walk, Sergei Nikolaevich used to say: "Well, we have discussed not only scientific but also political problems."

During one of my visits to the MSU RINP for discussing the program of the next Leningrad seminar, I entered the office of Sergei Nikolaevich and he said that he had to go home then because his wife, Mariya Sergeevna, was ill and needed continuous care, and nobody was near her at this moment. He apologized for involving me, a stranger, in his family affairs and invited me to discuss our problems at his home during dinner. The dinner resembled a simple student dormitory meal: there was cheese, sausage, and a bottle of dry wine on a table covered with a cloth. When Sergei Nikolaevich told me about the grave illness of Mariya Sergeevna, I understood how much strength this constant pain took from him. He lovingly cared for his wife.

Fate gives everybody his own life span to accomplish all that he can do. And Sergei Nikolaevich showed what one can do if he is devoted to his work. He was a unique person and all his life was given up to science. Let us admit that now there is no other scientist in the field of cosmic ray physics who is capable of combining equally the cosmophysical and nuclear-physical aspects of cosmic rays. Really, of no little significance was to gather around himself at the MSU RINP creative people capable of developing space science and due to their activity promoting the formation of a first-class research institute widely known not only in this country.

I felt his special attitude towards experimental studies. He believed that cosmic ray physics could not be completely understood without experiments. "Never abandon experiments," Sergei Nikolaevich used to say to me. And I follow his 'experimental' testament, heading a cosmic ray laboratory at which we are now performing two cosmic experiments: the study of the charge and energy spectra of cosmic rays with solid-state track detectors mounted aboard the International Space Station, and the polarization study of solar radiation with a satellite-borne Compton polarimeter.

100 years is a serious jubilee, and different thoughts about the future, present, and past come to mind. And they are interrelated because nothing vanishes into thin air. Sergei Nikolaevich long ago left us, but now we are peering into the short life of this unique man with undying interest and it seems that he is near and you will meet him now. And you are waiting to see what new things Sergei Nikolaevich will propose for us to do. We still remember him and will remember in the future.

The creative life of Sergei Nikolaevich took place in the Soviet Union in tortuous times. However, it should be emphasized that Soviet rule created more favorable conditions for the work of scientists than the present conditions in our science. But we must maintain the high level of

cosmophysics created by Sergei Nikolaevich and attract young talent into this field of science. How can we help many curious youngsters to choose the right way in their life? To do this, we should write a book about S N Vernov in a series 'The Life of Remarkable People'. The biography of S N Vernov described in this book can encompass the entire history of cosmic physics and tell about our contemporaries who have made noticeable contributions to cosmic science. A young reader, especially a gifted one, cannot help but pay attention to the scientific aspect of the S N Vernov biography, which can initiate their contemplations about their own life ideals.

## 6. In lieu of a conclusion

The time when Sergei Nikolaevich Vernov lived was truly grandiose and was related to the realization of the dream of a human to escape from Earth's limits. And this was accomplished. And Sergei Nikolaevich was among those who realized this dream. I would rather conclude my recollections by the most objective estimate of that time and the contributions of those who realized this dream of humankind. I will cite part of the concluding remarks from the paper "Decades of great accomplishments" by S M Krimiges, a participant in the First Leningrad Cosmophysics Seminar (1969) in book [2]: "*By contemplating the beginning of the cosmic era, I am amazed by the fact that a key role was played by the 'cold war'. It is difficult to imagine that high-carrying capacity missiles, which were used to launch satellites and space probes, would be developed in the absence of the arms race caused by the competition of superpowers. It is possible that such missiles would also have been built without the 'cold war', but this would have taken much more time, so that the beginning of the space age would be delayed. So, the cosmic science benefited by the 'cold war' in this strange way. It is undoubtedly, however, that the space age was an inevitable next step in the development of our civilization and it was of much benefit to all of humankind. Thus, we should thank the prophets and pioneers of this era: Korolev, von Brown, Van Allen, Vernov, and all their colleagues following their dream and acting it out by their imagination and skills.*"

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## S N Vernov and cosmic ray research in the Earth atmosphere

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### 1. Introduction

Sergei Nikolaevich Vernov (1910–1982) devoted all his scientific life to the investigation of cosmic rays (CRs). The energy spectrum of CRs occupies a huge energy range from  $\sim 10^8$  to  $\sim 10^{20}$  eV, and S N made important contributions to studying the properties of cosmic particles in practically all this range. In the present report, we discuss the range of energies from  $\sim 10^8$  to  $\sim 2 \times 10^{10}$  eV. The energies of more than 95% of the cosmic particles crossing the atmospheric boundary fall into this range. Almost all the particles and their energy are absorbed by Earth’s atmosphere.

Cosmic rays—the radiation that enhances with altitude in the atmosphere—were discovered by V F Hess in 1912, and it was clear by the early 1930s that this radiation comes from outer space. S N Vernov understood that, because of the absorption of particles in Earth’s atmosphere, observations in upper atmospheric layers have significant advantages over ground-based measurements.

Active studies of the properties of CRs were initiated by S N in the 1930s, when he was a postgraduate student at the Radium Institute in Leningrad and developed the first radio probe aimed at studying CRs at different altitudes in the Earth atmosphere (Fig. 1) [1, 2]. As a prototype of this probe, he had chosen a meteorological probe developed by Professor P A Molchanov, who advised the young scientist. Data on CR fluxes were transmitted to the ground by radio. This device was launched for the first time on-board meteorological balloons in 1935. From this point on, studies of CR properties in the Earth atmosphere have been performed.

### 2. Early studies of cosmic rays in Earth’s atmosphere (from 1935 to 1957, the launch of the International Geophysical Year project)

In the middle of the 1930s, the origin and main properties of CRs were unknown. At that time, the key question was whether these enigmatic space particles have a charge. If they have a charge, Earth’s magnetic field will act on these particles in such a way that their fluxes in the equatorial and mid-latitude atmosphere will be different: the CR fluxes near the equator should be smaller than those at middle latitudes. To solve this fundamental problem, S N Vernov organized in 1935–1938 the performance of experiments at the middle and equatorial latitudes. Radio probes were launched into the atmosphere both from the ground and from a ship; the ship was going from the Black Sea to the far east [3–6]. Latitudinal variations of CR fluxes were observed, confirming the existence of the electric charge for cosmic particles.

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