# Last Interview with D.V.Volkov

by Yu.N. Ranyuk (KFTI, Kharkov)

My conversation today is with the renowned scientist and academician Dmitrij Vasilievich Volkov, head of the theoretical laboratory of the Kharkov Physical-Technical Institute (KhFTI).

QUESTION: Dmitrij Vasilievich, could you tell me, please, what was your path into theoretical science, how did you become a theoretician, and was this accidental or was there any specific cause.

ANSWER: I was born in Leningrad. When I was 16 years old and when I was studying in the 8th class, the Great Patriotic War began. I was evacuated from Leningrad. These were very difficult years for young people. In this period I came to work on a collective farm and in a military factory. After that I was drafted into the army and took part as a soldier in the war on the Karelian front, above the polar circle. When the war began with Japan, I participated in military action on the Far Eastern front. I want to say that the war had a considerable influence on my attitude to life. In my generation the war created a feeling of responsibility for the country. After the war we carried over the same ideology into civilian life. When the question of a choice of profession arose, many of us thought about how we might be useful to our country. During all the war years I dreamed about going into science, because already in school I was attracted especially to the exact sciences: mathematics and physics. After the demobilisation I entered Leningrad State University, in the faculty of physics. At that time prominent scientists such as V.A. Fok and T.P. Kravets were teaching there. The lectures of T.P. Kravets were distinguished by his ability to link the study material with personal moments. He taught us that physics is created by living people and he spoke much about his teacher Lebedev. From the first days Kravets infected us with a deep love for science, and for physics in particular. Aside from that, I listened to the lectures of V.I. Smirnov, whose widely known multi-volume works were specially intended for theoretical physicists , and, in fact, formed the basis of our whole education. We learned a lot from other mathematicians of his school: O.A. Ladyzhenskaya, M.I. Petrashen. In the final year I received a profound training in the specialisation of theoretical physics thanks to the excellent teacher L.E. Gurevitch. There were also other teachers, which I remember to this time with thankfulness.

Unfortunately, a great tragedy happened in Leningrad when I was studying there, and this had an impact on my further destiny. It is now commonly known that at the end of the forties took place the so-called Leningrad trial, as a result of which prominent party leaders and representatives of the scientific and cultural community of the city were repressed, and among their number were leading scientists of Leningrad University. Therefore, the group in which I was studying was dissolved and the scientific line on which I was working ceased to exist there. Here one should give credit to the Kharkov scientists. From the very beginning, the Kharkov scientists had close contacts with their colleagues in Leningrad. In particular, it is known, that our Institute, KhFTI, was organised thanks to the arrival in Kharkov of the group of scientists headed by the well-known physicists Kirill Dmitrievitch Sinelnikov, Anton Karlovitch Walter and others. One of the major concerns at the foundation of the Institute was how to attract young people so that in the future the Institute would be staffed by highly qualified scientists. Therefore a special representative came to Leningrad and our students were offered the possibility to move to Kharkov and to continue their studies there. I agreed. Together with me came the already well-known scientists E.V. Inopin, K.N. Stepanov, V.F. Alexin and some other students.

QUESTION: Dmitrij Vasilievich, in which year of your studies did this happen?

ANSWER: This was after the fourth year. I finished the fourth year in Leningrad, and in the fifth year I was already studying at Kharkov University. Education here was also carried out on a high level. Lectures were given by outstanding lecturers and popularisers of science, such as, e.g. Alexander Iljitch Akhiezer. The lectures of L.N. Rosenzweig made a special impression upon me. He was a man of sparkling wit, and, besides that, he was aware of the latest developments, which were taking place in physics. And at this time, physics was receiving an extremely interesting boost connected with the discovery of new elementary particles, and, in fact, the physics of elementary particles was going through its birth period. This was a very interesting period. Lipa Natanovitch was fascinated by this new physics and imagine that while we were still students, he came to a lecture, and, instead of reading to us material according to the programme, took a fresh article from the "Physical Review" and summarised it to us. Aside from that, he would even give these articles to us young students to learn from and to discuss in seminars.

QUESTION: Dmitrij Vasilievich, when did you move to Kharkov, and how did your further scientific interests develop?

ANSWER: I moved to Kharkov in 1951. Now, about my scientific interests and their development. During my student years, the mathematical aspects of science attracted me even more than the physical ones. At that time I had already developed a deep feeling for the general theory of relativity. Quantum field theory was just beginning. Just at this same time the development of physics received some sharp impacts. On the one hand, quantum electrodynamics was effectively reborn thanks to the theory of renormalization, and, on the other hand, the physics of new particles arose. At this time the pi-meson was observed and the neutral pi-0-meson was discovered and discussions on the definition of spin and parity were going on. This was a real revolution in science. Later on, after graduation from university, I began my graduate training. My advisor was A.I. Akhiezer. He organised a small group of graduate students, including R. Polovin, P. Fomin, V. Alexin and me. All of us actively studied quantum electrodynamics. This was especially important for me, because I continued to work in this area and quantum electrodynamics became for me a sort of initial example of the theories that I work on now.

I would like to discuss in some more detail the directions of science that interested me most and on which I worked later. I don't know why - somehow intuitively - but already in my years of study my favourite subject was connected with the theory of symmetry groups. At that time, the theory of symmetry groups was already being adopted in physics, but not widely enough. Later on, the application of this theory came into a full flowering, especially when many new elementary particles were discovered and the question of systematising them on the basis of symmetry groups became very important. When I started to work, there were no powerful group-theoretical methods. The first pieces of work that I consider to be somehow connected to what I am doing now were concerned with the properties of particles with high spin. I would like to emphasise that questions that were also related to supersymmetry interested me already at the earliest stage of my activity. How do particles with different spin differ one from another? Why are there bosons; why are there fermions? I remember, in part, that just when I learned about the group SU(3), it amazed me that the multiplets of this group contained simultaneously particles with integral and with half-integral isospin. I was already trying to do something in this direction, replacing isotopic spin with ordinary spin, that is, actually, the idea that now lies at the basis of supersymmetry. An important role in the conception of the idea of supersymmetry was played by work on phenomenological Lagrangians, in which the interactions of Goldstone particles in the presence of spontaneous symmetry breaking are practically uniquely described by geometrical group-theoretical methods. I actively participated in the development of this line; it fascinated me very much. At the same time, the ideology of gauge fields started to penetrate actively into physics and I returned to the old questions. It amazed me that all these particles, the Goldstone particles and the gauge fields, were bosons, but the fermions somehow were not involved at all. Here, a kind of inequality appeared: why were some particles - bosons - selected, but others - fermions - not included in this group? This was a key moment, because the very thought that fermions can also be Goldstone particles or gauge fields contained in itself somehow the answer: if it were clear how to build a general scheme of Goldstone particles with integral spin, then upon making the transition to fermions one should replace the corresponding operators with operators firstly carrying spin one-half and secondly being anticommuting, in accordance with their fermionic nature; and in fact I did this. After that, when this was done, I, together with my co-authors V. Akulov and V. Soroka, considered first the global properties of supersymmetric theories and their local properties.

I would like to say that I worked not only on the theory of symmetry groups, but I also had pieces of work on nuclear physics and even on the theory of accelerators, but, nevertheless, the theory of symmetry groups has always been my favourite subject. And certainly, my main work was connected with the application of this theory to the physics of elementary particles.

By main, I mean my work on the establishment of parastatistics, work on the discovery of the conspiracy of Regge poles, and on the application of symmetry groups to the classification of hadronic resonances, that is, to baryonic and mesonic resonances. But my most important result, which is the most widely-known one now in the world, is certainly the discovery of a new symmetry group - supersymmetry - and the extension of this to aspects of the general theory of relativity, the so-called supergravity. I can speak about this in some more detail. First, a couple of words about how I came to the discovery of supersymmetry and supergravity. The starting point was the idea of W. Heisenberg. Let me tell you what this idea was. At the end of the 60's, Heisenberg proposed the idea that all elementary particles can be described by a uniform theory on the basis of the nonlinear equation formulated by him. He started this work together with W. Pauli, but sometime later Pauli dissociated himself from this theory and even sharply criticised Heisenberg for his assumptions. But, nevertheless what did Heisenberg contribute to the discovery of supersymmetry? Heisenberg tried to explain the spectrum of all elementary particles on the basis of his theory. And thanks to his great intuition, he guessed the places of the particles and predicted how the photon should appear in this theory. Moreover, he found a place for the neutrino within his theory and assumed that the neutrino emerges as a result of spontaneous symmetry breaking. This was a very unusual assumption, because all known Goldstone particles emerging as a result of spontaneous symmetry breaking had spin zero in all theories known at that time. This idea of Heisenberg was revolutionary, because he was the first to formulate that the thought that there might exist Goldstone particles in nature with spin one-half. To tell the truth, he found this particle by an incorrect method, but nonetheless it was an idea that had a strong impact on me and from that time I often although not constantly would think about whether this idea could be realised. And when I started to consider how such a particle might appear in the theory, I understood that this requires an extension of the usual physical groups, which is the basis for all relativistic processes. That means an extension of the Lorentz group and an extension of the Poincare group so that new operators would be present, which would correspond to a quantum number of the neutrino. Thus, the main result that we obtained was that we managed to create such an extension of the Poincare group, which is now called the Poincare supergroup.

Later on, we encountered certain difficulties and, if one speaks about the direct application to the neutrino, this idea nonetheless did not work. Why? Because the group that we were considering contained the Poincare group and it is known that the Poincare group leads eventually to the general theory of relativity, if one considers the local transformations of this group. That means that the same local transformations of the supergroup would lead to the emergence of certain superpartners of the ordinary gravity field, and these superpartners would totally absorb the Goldstone particles. And thus, when I understood such ideas, I, together with my collaborators, proposed an extension even of Einstein's general theory of relativity, which would include just what we call supersymmetry. So, in fact, certain superpartners would emerge. Moreover, in the extension of this theory arose not only superpartners - particles with spin 3/2 - but also particles with spin 1, with spin 1/2 and with spin zero. That is, there arose the idea that all elementary particles might be included into the system of supergravity. Now, many scientists all over the world are working on it. Different variants of supergravity are being considered and also different variants of superstring theory, which are based on a certain extension of supergravity that takes into account the fact that elementary particles can be not simply point objects but also extended objects. This direction is now the main direction in theoretical physics and proposes that there is a unified theory of all elementary particles, based on one common principle - namely on local supersymmetry.

Heisenberg's idea was, if one can say so, a physical idea, but in order to give this idea shape in a new precise mathematical theory, a certain mathematical formalism was required. And here I am very thankful to J. Schwinger, whom I personally knew, and who in a number of cases could have discovered supersymmetry. Moreover, I have recently seen an article by Schwinger, in which he writes why he didn't discover supersymmetry in spite of the fact that he was completely ready for it.

Why did I think that Schwinger could have discovered supersymmetry? Firstly, he introduced the concept of certain anticommuting variables, which played the roles of physical variables in field theory. He was the first to do this. Secondly, when I was saying that in supergravity the superpartner of the gravity field appears, well, these superpartners are particles of spin 3/2, and the theory of such spin 3/2 particles was first developed by Schwinger. It is even called the Rarita-Schwinger theory.

Recently, I received this article by Schwinger in which he writes about the reasons why he did not discover supersymmetry. Schwinger also says that he was very close to the discovery of supersymmetry and explains why. At the same time, in response to a general question as to why he didn't do it, which he received from the audience in an auditorium, he answered that this is a philosophical question and that this philosophy of discoveries is discussed in a number of monographs and that he could give only a general answer to the question.

The next moment that played an immense role in the mathematical formulation of supersymmetry, this was the work of the greatest French mathematician Elie Cartan. He created a special formalism of differential geometry, which seems to be specially appropriate for the system that I was considering. This particular circumstance, that I knew this work very well, helped me to create the mathematical formalism of supersymmetry. So, I think that there were actually three sources that helped me to develop the theory of supersymmetry and the theory of supergravity: the idea of Heisenberg, the idea of Schwinger and the mathematical idea of the great mathematician Elie Cartan.

QUESTION: Dmitrij Vasilievich, I am not a theoretician, and it is very difficult for me to assess your accomplishments. Could you tell me in popular terms how your work is recognised and about its place in theoretical science.

ANSWER: It's very easy to answer this question, mostly because there are many references to our work. The number of references is more than a thousand. This is a very large indicator for scientific works. Besides that, testimony to the fact that this work is recognised in the world is the fact that in 1994 I gave a talk at a very important conference where the results of scientific development for the past 50 years were summarised and where the speakers were authors who had made fundamental contributions to the development both of theoretical ideas and in the acquisition of new experimental data.

QUESTION: Where was this conference?

ANSWER: It was in Erice, in Italy. It was called the "International Conference on the History of Original Ideas and Basic Discoveries in Particle Physics." I was invited to speak on supergravity, and it was a great honour for me. And so I gave my talk at this conference.

QUESTION: Dmitrij Vasilievich, who else was studying the same problems that you were working on at that time?

ANSWER: At that time, in fact there was one more work that was done at the same time as ours. This was the work by Yu. Gol'fand and Lichtman, who introduced formulations of the theory of supersymmetry, but for completely different reasons. They tried to explain on the basis of supersymmetry the breaking of parity that exists in nature. Unfortunately, Gol'fand passed away in 1994. There was no further work. If one talks about supergravity, our first work was done in 1973. The next work in this field appeared in the west only in 1976.

QUESTION: Dmitrij Vasilievich, I know that you have worked at CERN for some time. Could you say something about your work at CERN, and its influence on your scientific activity and, if possible, about your own influence on the theoreticians at CERN?

ANSWER: CERN has a very close importance for me. I was at CERN five times: three times for conferences and two times for work - once for three months and one time for a month. Certainly, the work at CERN stimulated my scientific activity. CERN in general plays an important role in the development of world science, and this is not only my opinion. I have talked to Americans and to other scientists. They consider that CERN is the most ideal place both for theoreticians and for experimentalists. It is the biggest centre, uniting mostly European physicists but also scientists from America continually working there as visitors. I was lucky, for instance, to work together with M. Gell-Mann, a famous Nobel-Prize laureate, and had the possibility to discuss many idea with Eitiro Nambu and other no-less-famous physicists. Therefore, of course, the fact that I was at CERN and had the chance to be in contact with outstanding scientists from Europe and America was very important for me.

QUESTION: Dmitrij Vasilievich, could you please tell us about your scientific contacts with your colleagues from the countries of the CIS and with the scientists of KhFTI?

ANSWER: At KhFTI, when I was starting my work, there was a group studying quantum electrodynamics. Later on, I worked practically alone. But I had very good contacts with physicists from Moscow and Leningrad. I would like in particular to stress the role of Isaac Yakovlevich Pomeranchuk, who was working at that time in Moscow.

QUESTION: Did you know him personally?

ANSWER: I knew him personally. Every time I came to Moscow, I always visited Pomeranchuk. We had lengthy discussions together and it was interesting that we had the same way of thinking, because we usually discussed the conceptual part of work without going into formulas. We didn't even write formulas, but clarified what connections are possible between phenomena. I would like to tell about the following episode as an interesting example. It was in 1962 and I had been sent as a member of a delegation from the Soviet Union to CERN. I was lucky to share a hotel room with Isaac Yakovlevich Pomeranchuk. This was a stressful time for me, because just then I had finished some work together with V.N. Gribov about the conspiracy of Regge poles, which I spoke about earlier. This was the most important subject for me at that time. So, I remember lying on a hotel bed and that I couldn't fall asleep. It was already two o'clock in the morning and a certain idea came to me. I shook Isaac Yakovlevich awake, he awoke and said "What!" and I told him about this idea. After that, we discussed this idea for a couple of hours without turning on the light and we fell asleep only at dawn. This certainly characterises a person, if he can discuss a topic that interests him at any time of day or night. Such a person was Isaac Yakovlevich Pomeranchuk. I was also very impressed by meetings with D.I. Blokhintsev. We often spoke about science too, but he always amazed me mostly by the firmness of his conviction, which had a very high philosophical level. He was a man of multiple interests: he studied art and many questions of philosophy. He also had his own views on different fields of science and culture. His character seemed very integral to me. I learned many things about him only after his death from conversations with his students, and I regretted very much that I did not profit more from the possibilities of having contact with him.

Now, about Kharkov. At first I worked in relative solitude. Then I managed to form a small group of young capable scientists. The personnel of my laboratory consist of about 8 people, and I continue working with them.

QUESTION: Dmitrij Vasilievich, could you tell us please what you and your laboratory are working on now?

ANSWER: Now, I am working on a problem that I consider very interesting. Up until recent times, if we take, for example, the textbooks by L.D. Landau, it has been stated that the requirements of relativistic invariance lead to the fact that elementary particles can only be point objects. Now, a new theory has been created which shows that elementary particles can also be extended. They can look like strings or membranes. At the present time, this line is developing very actively. It is interesting, for example, that when speaking about extended objects it has been proved that such extended objects can exist and the theory can be consistently formulated only in the case when supersymmetry is required. Without this requirement, these theories become senseless. Therefore I and my collaborators continue working in this area. I consider that we have found some quite interesting results, which I will include in a talk at an upcoming international conference.

QUESTION: Dmitrij Vasilievich, I would like to remind you that the record of our conversation will be kept in the American Institute of Physics' Niels Bohr Library for the history of physics. I think that it will be interesting to historians of physics to learn about the contribution of our institute to the development of science, and in particular the contribution of our theoreticians. And of course, my conversation with you will useful to them. I thank you for agreeing to this interview.

ANSWER: I thank you too, for the interesting questions that you asked and which I have tried to answer as best I could.

Translated by K. Stelle