M.M. BOGOLYUBOV AS I SAW AND UNDERSTOOD HIM

A. SVIDZINSKYI

Lesya Ukrainka Volynskyi National University
(13, Volya Ave., Lutsk 43000, Ukraine)

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I came to know about M.M. Bogolyubov as a physicist-theorist, when I was a fourth-year student at the Faculty of Physics and Mathematics of the Ivan Franko Lviv State University. It occurred in 1951, but earlier I heard about M.M.'s outstanding works in pure and applied mathematics, as well as in nonlinear mechanics, the founder of which he was together with M.M. Krylov. Our known lecturer, a senior lecturer at that time – later on, professor – A.Yu. Glauberman announced that he would lecture a special course connected with new works of M.M. devoted to fundamental problems in statistical physics. These were "Problems of Dynamical Theory in Statistical Physics" (published in 1946 in Russian) and "Lectures on Quantum Statistics" (published in 1948 in Ukrainian). We, students-theorists, were amazed by the novelty of ideas, their basic value for the development of science, and by a precise clear description of quite non-trivial issues.

In the former of those books, a chain of equations for partial distribution functions – one-, two-particle, and so on to infinity (in the thermodynamic limit) – was introduced. Those partial functions were sufficient to calculate the average statistical values of the additive, binary, and higher types, respectively. However, the equations in that system hooked one another, so that it contained information equivalent to the Gibbs distribution or – in the nonequilibrium case – to the Liouville equation. However, the new mathematical formulation of the theory opened various opportunities for the construction of approximate solutions, and – as was demonstrated by M.M. himself and, later on, became a subject of researches for numerous authors – turned out extremely productive for physics.

Being applied to the description of systems in equilibrium, the new approach allowed not only the theory of rarefied gases, but also a quite acceptable theory of liquids to be developed, which was considered impossible earlier.

The fundamental result obtained by Bogolyubov in the nonequilibrium theory became a substantiation of the Boltzmann kinetic equation.

In "Lectures on Quantum Statistics", the greatest admiration was invoked by the microscopic theory of super-fluidity in a weakly nonideal Bose gas, which explained a mysterious earlier phenomenon of superfluidity from the microscopic point of view. In particular, the new theory inserted principal corrections to the Landau phenomenological theory. For me, it became clear that the time of phenomenological theories was coming to its end, and a new consistently microscopic approach, which enabled suitable models for the description of phenomena in nonideal systems to be constructed from the first principles, was asserting itself in theoretical physics. In particular, it concerned the superfluidity of helium-4 below its λ-point. For this phenomenon, M.M. Bogolyubov, proceeding from the principles of quantum mechanics and using an original mathematical method for a canonical transformation of secondary quantization operators, constructed a microscopic theory. In the due time, this method, properly modified, has been used to develop the microscopic theory of superconductivity.

Being the fifth-year student, I was fascinated by quantum electrodynamics. In particular, I tried to overcome known difficulties with divergences in the perturbation theory series by modifying the theory, namely, by introducing the equations with higher-order derivatives. My attempts led me to a conclusion about the lack of any prospect for such an approach, because it not only failed in solving basic difficulties, but generated new ones (an indefinite metrics). Therefore, having entered the postgraduate study, I was very interested by messages that M.M. had begun researches of the basic aspects of the quantum field theory. I decided to go on a long-term mission trip to Moscow, in order to be engaged, at place, into new researches – first of all, the researches of Bogolyubov's school. Having overcome an unexpected formal barrier (the Moscow University was severely guarded, so that it was impossible to get into without a pass), I obtained at last a pass to the physical block, where Bogolyubov's seminars on theoretical physics occurred weekly.

My first conversation with Bogolyubov was not encouraged. M.M. inquired at once what books in quantum electrodynamics I had read. I could cite, as an example, the known books by Wentzel and Heitler, which I had read being still in Lviv. M.M. replied, "Well, but

today, we have the collection of works 'The newest developments in quantum electrodynamics', as well as the newest course by Akhiezer and Berestetskii. In addition, we already have in circulation the sections of the book by Shirkov and me on the quantum field theory. You may get them. After studying them, come to me". Certainly, to study all that within a year was difficult. Therefore, I interpreted first such a reply as a polite refusal. However, it could not be otherwise. Hence, with all my persistence, I started studying not only those books, but also journals, a good many of which were at the capital's university. I made a list of about 25 foreign journals, which I decided to look through by all means. In addition, I got interested in a series of articles by L.D. Landau, A.A. Abrikosov, and I.M. Khalatnikov which invoked a considerable interest of some participants of the Bogolyubov seminar and, first of all, of the scientist O.S. Parasiuk, whom I knew from Lviv (he lectured the course on theoretical mechanics at the Lviv State University). Today, I am surprised myself at the enthusiasm and obtrusiveness, which I had revealed in the work. In particular, I kept accounts of my time spending, aiming at allotting not less than 14 hours per day for science. Apparently, O.S., who cooperated with Bogolyubov (their researches resulted in the theory of R-operation), told something about my efforts to M.M. Anyway, one day, M.M., walking along the corridor near the lecture hall, where his seminar should begin, stopped before me and said, "I have heard that you are moving ahead well in the field theory. I could offer you a topic for your dissertational research. Which would you like: a more computational or a more theoretical one?" I answered, "A more theoretical one" and felt that it was an answer that M.M. expected of me. "In this case, I could propose you the problem of application of the functional averaging method in the quantum field theory. Recently, we have discussed the fundamental work by Feynman at the seminar. His method must be rather effective." I answered that I liked the functional integral very much. Approvingly, M.M. nodded his head and said, "Call me up tomorrow at 10 o'clock. I shall prepare some materials for you and appoint a meeting at home." At this moment, I asked him with all my directness, "What is your phone number?" M.M. replied immediately with an ironical smile, "You know, I do not call up to myself; therefore, unfortunately, I do not know it". I understood that I had asked something silly, because young men from M.M.'s chair, which stood not far away, smiled ironically too, whereas M.M. passed through the door to the lecture hall. Nevertheless, one of those young men came up to me with a smile, which em-

phasized and, simultaneously, excused my provinciality, and said, "Write down M.M.'s phone, I shall dictate it to you". So, the problem was resolved, and I, going to my place at the table, thought: "It is quite right. The time of a great person should not be wasted for superfluous questions".

Exactly at the appointed time, to within a second, I rang a doorbell at the Moscow apartment of M.M. in sector[1] L of the Moscow State University building (I did not know at that time but intuitively felt that M.M. liked high accuracy very much). Our conversation lasted only twelve minutes. Bogolyubov gave me his notes containing only formulas, without any words (among theorists, such notes are coined as "formular" (interpreter's note: a slang word, which means "sheets of paper with formulas"), written down very pronounced, but without any logic spaces, on large pink sheets of paper (it was the favorite paper of M.M.). M.M. also recommended me some journal articles devoted to the mathematical substantiation of the functional integration method. In particular, among them, there was an article by – as he said – "the fair lady Cecile Morette". He gave me a week term for studying all the materials, and I was happy that a new meeting did not take place, because M.M. was sent for in connection with a *very* important issue, which should not be spoken of.

But having taken those sheets of paper and leaving the M.M. apartment, I noticed that I walked very quickly, almost running, because I awfully wanted to learn them in detail as soon as possible. Some later, I got convinced that everyone who finished the conversation with M.M., behaved in the same manner. All his disciples evidently obtained a huge charge of inspiration from such conversations.

Bogolyubov's papers concerned the solution of the well-known Schwinger equations for Green's functions in quantum electrodynamics in terms of functional integral. His solution was exact, unlike the Peierls one, in which the author could not take electron-positron loops into account. In this connection, I faced a problem – to understand the Schwinger equations themselves. Due to a Japanese work, I knew that its authors had formulated more than ten unclear items concerning the Schwinger equations. But soon, I learned that M.M.'s disciple Mykhailo Polivanov would report at the M.Sci. conference. I had heard this report, but had not understood anything from it, because even the basic terms

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[1] Usually, the word "zone" rather than "sector" was used. But, owing to known reasons (interpreter's note: an allusion with "criminal zone"), M.M. strongly disliked the former.

were absolutely unknown for me. Therefore, I came up to Polivanov and asked him to give me his work. It only asked, "For how long?" I answered, "For three months", meaning that holidays were approaching and, implicitly, that the time required for the study of the work, bearing various difficulties in mind, should be comparable. But in three days, I could give him the work back. It was based on rather an effective method of incomplete Wick expansion, which had been suggested by M.M. and used by Polivanov. The method was completely transparent: I understood it quite well and even made an additional simplification in one item. Thus, I had easily entered into the most challenging, at that time, problematic of quantum electrodynamics. Before my departure, I managed to meet once more with Bogolyubov at his seminar and informed him about my departure. He wished me to have a good relaxation and noticed that, for the recreation to be the best, he recommended to calculate, by regularizing in the framework of the Pauli–Villars method, three diagrams: for radiation corrections of the lowest order to the electron characteristic energy and to the vertex part.

After the vacation, I came to Moscow again and, having met with M.M. before the seminar, shortly reported about my activity. M.M. approvingly nodded and quietly said to somewhere in space, "Give me a piece of paper". Immediately, somebody of the chair young members, who were regularly within the audible region around M.M., offered him a piece of paper and a pen; another young man, from the other side, gave him a note-book with a hard wrapper, which it was convenient to write upon. Bogolyubov wrote the following note:

> "To the scientific department
>
> This is to inform you about my agreement to advise comrade Svidzynskyi. He was given the dissertational topic 'On the functional averaging method in the Green's function theory'
>
> 19.X.1954 N. Bogolyubov"

In such a way, which looked very simple and free of various bureaucratic formalities, I was accepted to the Bogolyubov school, and the young men congratulated me.

Before the next seminar, M.M. noticed me and asked, "Why are you looking so yellow?" I answered, smiling, that I had camped out with old people in the Taganka district, and I slept little because of fleas. M.M. interpreted all that, however, very seriously and said, "You must immediately move to a dormitory" and, as usual, quietly added into space, "Bazarov – to me". I do not

know how many seconds have passed, but here comes I.P. Bazarov (it turned out that he was not only the author of the textbook on thermodynamics, but also the chairman of the trade-union committee), standing before M.M. and expecting for his orders. M.M. said, "Here, my disciple arrived to me. Settle him in the dormitory for the whole academic year". The order was fulfilled, though with considerable difficulties. I stood behind the door of the trade-union committee office, as Bazarov ordered, and heard a discussion between him and the committee members, all of which being against my settlement. Bazarov listened to their objections in silence, and, after every objection, repeated only one phrase, "*Nikolai Nikolaevich has ordered*". Only when his patience gave way, he cried at the top of his voice, "*Nikolai Nikolaevich has ordered!!!*" Standing behind the door, I heard that a water carafe fell down and broke; then, silence fell; then, I heard Bazarov's steps and his words: "Here is the order for you".

By the way, the trade-union committee had put forward no reasons against my settlement in the dormitory. The corresponding reluctance was based on absolutely different reasons, which had nothing in common with business ones.

This example demonstrates how Bogolyubov cared about his disciples, and how great his authority was. At that time, such young scientists from the faculty of statistical physics as B.I. Sadovnikov and I.A. Kvasnikov worked with Bogolyubov in the field of theoretical physics. His oldest disciples were S.V. Tyablikov, D.M. Zubarev, B.V. Medvedev. A group of theorists – Bogolyubov's disciples – emerged, because M.M. had been engaged into the fulfillment of a classified government research program in Arzamas. B.V. Medvedev, D.V. Shirkov, D.M. Zubarev, and V.M. Klimov – the latter, unfortunately, was lost in the Caucasus mountains – were also involved. At the time of my appearance in Moscow, M.M. had already accepted a job (since 1949) at the V.A. Steklov Mathematical institute of the Academy of Sciences of the USSR and – later on, since 1953 – at the Faculty of Physics of the M.V. Lomonosov Moscow University. The number of his disciples grew annually. Among them, in Moscow, I met A.O. Logunov, Yu.O. Tserkovnikov, A. Tavkhelidze, V.Z. Blank (he was also lost in mountains), M.K. Polivanov, V.G. Solovyov.

Very interesting was the inclusion of I.R. Yukhnovskyi to Bogolyubov's school. I.R. Yukhnovskyi studied M.M. Bogolyubov's "Problems of Dynamical Theory in Statistical Physics" in Lviv. He independently carried out researches of the system of particles with the Coulomb interaction on the basis of Bogolyubov's

method, having overcome serious difficulties. Afterwards, he invited Bogolyubov to be an opponent of his thesis for a doctoral degree on this topic. Bogolyubov suggested to transfer him the dissertation for consideration and, having convinced that the research was correct, agreed to be opponent. In such a way, I.R. Yukhnovskyi became the Doctor of science and headed the secondary M.M. Bogolyubov school in Lviv. First, it was organized on the basis of Lviv University. Then, I.R. Yukhnovskyi, progressively increasing the staff, created the present-day Institute for Condensed Matter Physics of the National Academy of Sciences of Ukraine.

A new branch of Bogolyubov's school started its formation also at the JINR in Dubna, where M.M. first headed the Laboratory of Theoretical Physics (since 1956) and, in 1965, became the Director of the whole institute. It is difficult to point to somebody, who would not largely affected by M.M. Being in the position of the Director of this international institute, Bogolyubov revealed himself as an extremely active and skilful organizer.

As a patriot of Ukraine, who worked at the AS of the UkrSSR for a long time, Bogolyubov initiated the creation of the Institute for Theoretical Physics (ITP) in Kiev and had been its director since 1966. His above-mentioned disciple O.S. Parasiuk headed a department at this institute. For a long time, the ITP had been the work-place for the outstanding expert in the branch of theoretical and mathematical physics D.Ya. Petrina, the disciple of O.S. Parasiuk and the co-author of M.M. Bogolyubov in some fundamental works (during his last years, Petrina worked at the Institute of Mathematics).

Now, the Institute for Theoretical Physics of the NAS of Ukraine is named after M.M. Bogolyubov, being the leading physical institute in the branch of theoretical physics in our country (now, it is headed by Academician of the NAS of Ukraine A.G. Zagorodny).

I would like to emphasize the love that M.M. had with respect to his disciples, his solicitude about and, at the same time, high demands to them. He always cared of their scientific growth, gave various powerful stimuli, cared about their life, even if his disciple was not a member of the group headed by him.

I intend to give a number of examples, which evidently illustrate how M.M. taught us, his disciples.

When I started to solve the Bloch–Nordsick model, making use of the Green's function representation for an electron with radiation corrections in the form of functional integral, I needed, for this purpose, an expression for Green's function in an arbitrary given,

non-quantized, 4-vector field: the functional averaging should be carried out over this field. However, I could not solve the corresponding equation. It was a partial differential equation with respect to four time-space coordinates. I began to tackle the problem by constructing the general solution of the equation following the standard technique. But this way led to an emergence of arbitrary functions of those variables, and it was not clear how those functions were to be fixed. At this moment, rather difficult for me, Bonch-Bruevich came up and asked how my scientific affairs were. I answered, "Badly". We discussed this problem, and Bonch-Bruevich said that, in his opinion, I did everything correctly, and that he would try to understand himself what was wrong. However, in two days he informed me that he, as well as those colleagues, whom he consulted with, failed. They decided that it was worth addressing Bogolyubov. First, M.M. was surprised that nobody succeeded. But, in a minute, he laughed and said, "You all do not read classics – here is the matter. Reading classics is necessary. Get together, I shall explain".

When we gathered, he reproached us once more that we did not read classics. In that case, M.M. meant V.O. Fock, who proposed the fifth parameter method, and this method had to be known. It turned out that the matter was about using the parametrization

$$H^{-1} = \frac{1}{i} \int_0^\infty \exp(iH\nu - \varepsilon\nu)d\nu \equiv i \int_0^\infty U(\nu)d\nu, \varepsilon \to +0,$$

which gives rise to the equation for $U(\nu)$, $-i\frac{\partial U(\nu)}{\partial \nu} = HU(\nu)$, with the initial condition $U(0) = 1$. If rewritten in the x-representation ($x = (x_0, x_1, x_2, x_3)$), it can be simply solved by making use of the Fourier transformation.

After that lesson, things went better, although a lot of obstacles had to be overcome in this way, but I did not address M.M. anymore. And for me, I got in love forever with parametrization as an effective method, which often revealed unexpected capabilities. Here is an example. Having the Poisson integral $\int_{-\infty}^\infty \exp(-u^2)du = \sqrt{\pi}$, it is possible, by shifting the integration variable, to obtain the representation for $\exp(a^2)$ as an integral over the parameter u,

$$\exp(a^2) = \frac{1}{\sqrt{\pi}} \int_{-\infty}^\infty \exp(-u^2 + 2au)du.$$

Whence, for the functions of an operator, we obtain the

formula

$$\exp\left(t\frac{d^2}{dx^2}\right)f(x) = \frac{1}{\sqrt{\pi}}\int\limits_{-\infty}^{\infty}\exp(-u^2)f(x+2u\sqrt{t})du.$$

It is the fundamental solution of the one-dimensional heat equation with the initial condition being given by the function $f(x)$. Generalizing this representation on the multidimensional case and, in the limit, the case with a continuum of dimensions, I even obtained – later on – the representation of the superconductor partition function in the functional integral form!

Another interesting episode occurred after a seminar, when M.M. told us, post-graduate students, not to leave, because he had to make a postgraduate entrance examination, and pointed to a young man. "By the way", he added, "what questions would you suggest for him?" Someone answered, "The second law of thermodynamics. The theorem about the growth of entropy in an adiabatically closed system". M.M. denied, "He either knows it or does not. If he knows, he will rattle off all that. If not, I do not think that, within 40 minutes of his preparation, he could rediscover what the best minds of the mankind have spent more than a decade for. Hence, a question should be given, which would not demonstrate what he has learnt, but how he understands familiar things, for instance, an integral". Nevertheless, someone said, "Nevertheless, what if he discovered the second principle of thermodynamics here, before our eyes?" "Then", said M.M., "any postgraduate study would be unnecessary for him".

M.M. suggested the young man to evaluate the integral $I(\lambda) = \int_0^\infty \frac{\exp(-\lambda x)}{1+x}dx$ with $\lambda > 0$ at $\lambda \approx 0$ and $\lambda \to \infty$. The young the man did it at last, though, as M.M. said, in a barbarian way. Therefore, he showed us an irreproachable method for the corresponding asymptotics to be obtained. Of course, after that case, we took a great interest in asymptotics, which became very useful in the work to follow. The first – introductory – section in my book "Mathematical Methods of Theoretical Physics" is devoted to integrals and their asymptotics[2].

The belief in his disciples was characteristic of M.M. One day, he suggested me to obtain the transformation law for the Schwinger Green's function of an electron at gradient transformations and said that, to his

knowledge, this issue was also a matter of interest for L.D. Landau and I.M. Khalatnikov. I was shocked by the perspective to compete with Landau himself and, in this connection, revealed a corresponding uncertainty. M.M. laughed and said, "But you will surely use your favorite method of functional integration, and it will be the best way". Afterwards, he said very seriously, "You must aspire to do everything independently. Certainly, you could avoid it and address someone, and ask him to tell you how all that is done. I suppose that you will be shown and explained everything, and you will understand. However, will it be your result? By no means! I do not mean priority problems. Remember, what is made by you independently, using the method that you appreciate, remains with you forever. Only such things will be really yours"[3].

By the way, I.M. Gelfand gave me a similar advice. Feeling that my mathematical education is rather weak, he, when saying goodbye to me before his departure, said the following: "You are amazingly ignorant in mathematics. But do not take into your head to study it. Mathematics is not for studying, it is for creating".

A year had passed since I obtained a theme from M.M. I had already presented my dissertation to the academic council of the Lviv University. On the eve of the thesis defence day, I met M.M. at the railroad station. Bogolyubov, having appeared in the carriage door, immediately exclaimed, "Shirkov comes at the limit". D.V. Shirkov was my opponent, and M.M. used this exclamation to calm me: the opponent would be in time. J.Z. Shtokalo also came up to the carriage, and M.M said him proudly, "This is my disciple, comrade Svidzinskyi. I recommend him to you". In a minute, when Shtokalo went forward, he addressed me, "Tell me your first and patronymic names". I named myself, and, in the future, M.M. addressed me only in such a way. It was a lovely feature of an intellectual of old school: the disciple had to feel the importance of the formal career procedures.

The defence took place, followed by what I euphemistically call "its second part". I already knew that, in such cases, M.M. drank exactly one bottle of good cognac, previously warming it in the pocket of his jacket. By no mean could such a dose affect his working capability, but I observed with alarm that he did not refuse those, who would like to have an opportunity to tell one day about a unique occasion of having a drink of good wine with a genius. Alas, there were too many such in-

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[2] In standard textbooks on mathematical physics, physicists are not taught, as a rule, asymptotics. One day, the known mathematician Ya. Sinai told in my presence – as about a curious – that he rang up to his colleagues physicists and asked them whether they knew the accurate and the asymptotic value of the integral $I_{\pm}(\lambda) = \int_0^\infty \exp(-t^4 \pm 2\lambda t^2)dt$. He found nobody who knew it. All that is in my book.

[3] M.M. pronounced it in Russian, but the words "By no means!" in Ukrainian ("Azh niyak!"). He liked to use them instead of their Russian equivalent ("nikoim obrazom ne"), considering the Ukrainian expression to be geniusly expressive.

terested persons... Moreover, next day, exactly at eight in the morning, there was appointed a departure by a car to Liblin Velykyi – a resort district near Lviv. In the morning, I appeared near the door of M.M.' room in the "Intourist" hotel precisely at the appointed time. Against the habitude, I pressed the button even with a few-second delay, being afraid that M.M. was still sleeping. But I heard vigorous steps, the door opened, and I saw a lighting lamp and traditional sheets of pink paper on a small bureau. Bogolyubov worked! "One minute", he said, "I shall finish with the formula". We went out, and Shirkov joined us. During the trip and the walk, M.M. was imbedded in reflections, he quietly hummed something, but, nevertheless, he heard us, and, from time to time, he neatly replied to our conversation with Shirkov. When we came back, it occurred that M.M. had finished the proving of the basic lemma, which was necessary for the construction of dispersion relations. It was done in the head, without any sheet of paper. Later on, only the formulation of this lemma in the book required about a page!

After the defence, I obtained an appointment to the Kharkiv Polytechnical Institute. (Today, it – as well as many other higher educational institutions in Kharkiv – is classed as a university, similarly to the institution founded by Karazin; but all this mess is a tribute to a present fashion.) My arrival coincided in time with the date of the known Khrushchev's speech; however, the KGB continued its activity. Therefore, when I required a so-called "form" in order to go to Dubna, where M.M. worked at that time, I was refused. It was the more so that, when being interviewed, I behaved in the spirit of the brave soldier Schwejk, i.e., as it is called in Lviv, I played a crazy, rejecting dangerous propositions. All that resulted in my disappearance from the vision range of M.M., and he said with dissatisfactory about it to O.S. Parasiuk. I had to explain the situation by engaging a reliable person, and M.M. made a nice step: he invited me to a conference, the participants of which could pass to the JINR without permission – "on a list"– during the conference, of course. In such a way, our contact was ultimately restored.

Usually, I came to M.M. to Dubna to the administrative building, because the entrance into it was free, and M.M. could be caught in his director's office. One day, his secretary told me to wait in the reception room, because Bogolyubov held a large meeting of the administration staff and the communist party committee, but might be released soon. Having waited a little, I saw that the door opened, and plenty of people quitted the room. When everybody had gone, I came inside and,

through dense cigarette smoke, saw M.M. in the room depth, sitting and quickly writing something. As I approached closely to him, he lifted his head, and I saw that he wrote formulas. The question "So, you engage in theoretical physics under such conditions too?" escaped my lips. M.M. replied, "Now, it is necessary to catch every minute". "Now" meant his new director's life. M.M. took two articles that I brought to him, quickly looked through, and not only proposed a final part for one of them, but actually dictated it. I was pleased that he liked the articles, but, having left the room, I thought where I could find a typist to type all that was said. With this issue, I addressed the secretary. She immediately led me to a typing pool, and, while I apologized that the page was to be retyped in order to add the text proposed by Bogolyubov, but I had no paper, one of the typists had already inserted a sheet of paper into the typewriter and started to retype the written fragment. In such a way, very quickly and without any bureaucratic excuses, the last page of the article was changed. Later, I repeatedly received evidence that there were no bureaucratic pretexts at the JINR.

At the Kharkiv Polytechnical Institute, I organized a seminar, where we studied the book by M.M. Bogolyubov and D.V. Shirkov on the quantum field theory in detail. Nevertheless, my interests shifted towards the low temperature physics, because a scientific research institute with such a profile had been organized in Kharkiv. Soon, I transferred there. It was the more so because the work at the KhPI seemed to have no prospects due to senseless experiments in education that were started in 1957. However, the main reason of my transfer consisted in that the theory of superconductivity, having a fine formulation developed by Bogolyubov, created a fertile field for new interesting theoretical researches in this branch. In addition, I obtained – at last – a security clearance at the Institute for Low Temperature Physics and Engineering. In essence, I would not ever need it, because I avoided to be engaged in closed subject matters. However, this piece of paper provided me necessary passes.

In the book "N.N. Bogolyubov" (Dubna, 1994), which contains the reports made at the International Bogolyubov Conference in Dubna in 1993, as well as in the accompanying book "Bogolyubov Conference" (Dubna, 1994) (the former book is more memoiristic, the later more scientific), a considerable body of materials concerning the life and activity of M.M. was gathered, together with a number of scientific problems associated with his activity. Unfortunately, those books were re-

leased after his death that occurred on February 13, 1992.

Certainly, the material contained in those books is far from being exhausting. In the former book, there is also my article, in which, along with scientific fragments, there are my impressions inspired by the contacts with M.M., when I dealt with the superconductivity theory. I shall not repeat here what I told in it. I shall dwell on those features of this great scientist and human being, which were not evident at once, but were the essence of his person.

Bogolyubov was an extremely kind person, but, at the same time, a very exigent one – first of all to himself, but also to people, whom he worked with. Here, however, his kindness conflicted with his exigency, because nobody could satisfy all those criteria that he had established for himself. Evidently, a crucial importance for the formation of Bogolyubov' character had the labor upbringing in his family. His father Nikolai Mikhailovich Bogolyubov transferred his three sons a strong Christian belief, the knowledge of ancient and modern European languages, the skill to work diligently – and all that from the very early age. The M.M. brother Alexei recounted well about that in the book just mentioned.

Of course, I was interested in M.M.'s political views. However, no statements did I hear on this topic, but about the hetman Pavlo Skoropadskyi, whom M.M. estimated as an outstanding statesman. This allowed me to draw certain conclusions. Really, let us pay attention to such an estimation of Bolshevism and, at the same time, the vision of the future of Ukraine made by P. Skoropadskyi: "There is no socialism among our people; therefore, if it does exist, it exists among a small group of intellectuals, which are separated from people, have no ground, and are spiritually unhealthy. I have no doubt, as I had not before, that various socialistic experiments, provided that we had the socialistic government, would have immediately resulted in that the whole country would have become the prey of the all-devouring Moloch of Bolshevism within six weeks. The Bolshevism, having destroyed any culture, would have transformed our remarkable country into a dried-up plain, where the capitalism would have settle in due course; but what capitalism would it have been!.. It would not be a weak and feeble capitalism that has been gleaming inside us till now, but an omnipotent god, at the feet of which the same people will roll and grovel."

Certainly, M.M., being a committed Christian, could not sympathize with the aggressively atheistic Bolshevist authority. Moreover, in 1930, this authority arrested M.M.'s father – an outstanding theologian, the author of important works on the religion theory – having presented no charges to him, and held him, already sick, in prison. In this situation, Nikolai Nikolaevich made a courageous step: he addressed the requirement to release his father from prison to the State Political Directorate (GPU) header Menzhinskii, though authoritative people warned him that he subjected himself to the danger of death. But Nikolai Nikolaevich achieved the goal: his father was freed; however, his life after discharge was short.

Therefore, it is quite clear why M.M. was not a member of the party, although, according to the nomenclature rules, the occupation of such high posts, which he held, demanded the party membership. As we see, for the genius, an exception was made.

Bogolyubov's attitude to the Russian and, the more so, the Soviet bureaucracy was surely negative. He liked Shchedrin very much, knew his works well, and often quoted, for instance, the following sarcastic sentence: "Education should be introduced with modesty and avoiding bloodshed, if possible".

With all that, M.M. Bogolyubov worked in pure science and in military projects as a loyal citizen of the USSR. This fact sometimes provokes ambiguous estimations. I think that, for the comprehension to be correct, the following circumstance has to be taken into account. The development of scientific basis for the hydrogen bomb creation was completely justified, taking into account the necessity to reach the parity between two mutually conflicting global systems. This parity constrained both forces from a military attack, resulting in the "cold" war only. Certainly, Bogolyubov used his cooperation with the Soviet system in full in order to create a powerful scientific school in theoretical and mathematical physics, which was beneficial not so much for the system – which collapsed later on – as for the country and the mankind.

I would like to emphasize different – actually, opposite – attitudes of various scientists in the Soviet Union to their activity in science and education in those years. Some scientists and teachers followed the principle "the worse the better", especially, when it concerned the disorder in the Soviet education system. That is, when the matter concerned a reduction of requirements to students and an introduction of ostentation instead of real knowledge, the people of this category believed that it must be done, because it favored the disorder of the whole system, which was cutting the branch it was sitting on. They also did not struggle against prosecutions of scientific directions that were undesirable to the authority – on the basis of the same principle. Another

category of scientists had no sympathies to the regime too. However, they adhered to the opposite opinion: they condemned ignorant actions of the governing body as those, which destroy the culture, the latter being an absolute value. The scientists of the former category tried to leave the motherland, whereas those of the latter one considered it necessary to remain – they understood their work as a service to the people rather than the regime. It is evident that Bogolyubov belonged just to the latter category of scientists.

The fact that M.M. joined the condemnation of A.D. Sakharov excited ambiguous estimations. In this connection, the following information published by G. Gorelik ("The power of knowledge and the impetus of faith" in Notes on Jewish history, 2002, No. 22) is worth attention. This author found, in the USA, the former citizen of the USSR Mattes Agrest, a talented self-educated person, who became an outstanding mathematicians and was involved into carrying out the secret developments at Arzamas. Agrest was a faithful Jew, and he was also interested in the theoretical aspects of religion. On this ground, he established friendly relations with Bogolyubov, who was deeply interested in the philosophy of religion, not only Christian, and they even organized a secret seminar on theological problems in Judaism and Christianity (in the course of those seminars, Agrest came to know that Bogolyubov knows Hebrew). However, it happened (most probably, because Agrest made the circumcision of his newborn son, which was revealed at the medical examination of the child) that the KGB accused Agrest that he had relatives in Israel and demanded to quit the "object" within 24 hours. Only M.M. Bogolyubov and I.E. Tamm stood up for him. They managed to delay the exile term to 7 days. Concerning A.D. Sakharov, Bogolyubov did not dare stand up. But he helped Agrest, giving him the keys of the Moscow apartment, which was free at that time. Agrest told Gorelik that M.M. and he hid their religious occupations from both Sakharov and Tamm, considering the both – not without reason – to be atheists and pro-Soviet inclined. As to Bogolyubov, Agrest spoke of him with a large cordiality.

The aforesaid makes it clear that, actually, M.M. had also a life hidden from extraneous sights, and his religious and political convictions gave him a basis to consider Sakharov's ideas critically, in particular, the idea of the possibility for the socialist and capitalist systems to converge. It was all the more justified with respect to Sakharov's atheism. (For the sake of justice, it is necessary to say that Sakharov departed from the extreme

atheism at the evening of his life, though he did not become a believer.)

Every Soviet scientist, even among the greatest ones, could not help adhering to the regime with a certain degree of loyalty, if he wished to be active in science, to create science, and – the more so – to organize scientific schools. This circumstance was not associated with a lack of courage. For instance, P.L. Kapitsa was an extremely courageous person. He could get Landau and Fock out of the NKVD clutches and saved their lives, by addressing – resolutely and persistently – on this occasion both to Stalin and Beriya. The scientific and technical activity of Kapitsa was objectively directed at strengthening and protection of the socialist, at that time, state. In the same manner, in order to fulfill his vital task, Bogolyubov, a person with a large courage and willpower, had to reveal a certain level of loyalty to the regime, which he was fated to live with, to execute his most priority duty before his scientific school, his numerous disciples, at last, before the whole people, science, and culture. In my opinion, he irreproachably found this vital line.

Returning back to M.M. Bogolyubov's scientific activity, I should note that it would be difficult to make even the list of his basic results, because of their huge number. When I spoke above about his first works in theoretical physics (1940s–1950s), I did not mention the monograph "On Some Statistical Methods in Mathematical Physics" (Kyiv, 1945, in Russian) and the theorem (together with B.I. Khatset) on the condition for the free energy per unit volume to exist in the thermodynamic limit. Both works appeared considerably ahead of their time. When the problem, which was formulated and resolved in that paper, started to be recognized by scientific community with a more than 20-year delay, M.M. together with B.I. Khatset and D.Ya. Petrina gave its updated formulation. Talking about the theory of superfluidity, besides the paper on weakly nonideal Bose gas, it is also worth mentioning the first microscopic derivation of the equations for two-liquid hydrodynamics; the technique applied in this case was used further in a good many works. Concerning the theory of superconductivity, M.M. tirelessly studied the mathematical structure of the theory, until he brought it – in the well-known preprint on quasiaverages (1963) – to such a level of ideological perfection that met his highest requirements put before himself. Note that, in this work, very important inequalities were established for the Fourier transforms of two-time Green's functions (introduced by M.M. Bogolyubov and S.V. Tyablikov in 1959), which allowed various authors to prove rigor-

ously that the long-range order is impossible in a wide class of low-dimensional systems with phase transition. One could not also help mentioning M.M.'s work executed together with D.M. Zubarev on the wave function of the ground state of the system of interacting Bose particles (1955), which, in the hands of I.R. Yukhnovskyi, grew later on into a powerful method of collective variables. I.R. so improved and developed the method that he managed to find the solution of the three-dimensional Ising model, which was the aim of futile efforts of a huge number of researchers. I.R.'s school in Lviv successfully applied this method to the description of many other systems with the phase transition of the second kind.

As if to sum up, in short, the achievements of M.M. in the branch of the condensed system theory, it can be asserted that his activity has cardinally changed the exterior of this theory, substantially extended its problematics, and introduced essentially new methods of solution for the problems, which could not even be tackled earlier.

However, in the 1950s, M.M. turned to the problematics of the quantized field theory. He began from the revision of its fundamentals and formulated its axiomatics. In parallel, a capital monography was created together with D.V. Shirkov (the first edition was published in 1957; afterwards, new, updated editions, as well as their translations into various languages of the civilized world, were released). On the basis of the developed axiomatics and extremely powerful mathematical methods (in so doing, M.M. had founded new branches in the theory of functions of many complex variables and generalized functions), the dispersion relations were proved rigorously – it turned out an insurmountable problem for other researchers. At the same time, the renormalization group method was being developed together with Shirkov, which made it possible to resolve the known paradoxes in quantum electrodynamics and to find the asymptotics of Green's functions for an electron and a photon at large and small momenta. Note that the renormalization group methods were applied later on to plenty of problems in theoretical physics, in particular, to the theory of phase transitions. In 1957, together with O.S. Parasiuk, M.M. formulated and proved the well-known R-operation. Its theory was based on the determination of products of generalized functions belonging to the causal-type class. This work remains among the most cited in the quantum field theory till now. In 1966, in the work carried out together with A. Tavkhelidze and B.V. Struminskii, a new quantum number for quarks was introduced, which eliminated the paradox with the violation of the Pauli principle for quarks and opened a way to the construction of quantum chromodynamics.

I would like to emphasize once more that the given list of M.M.' works is not complete. But it is important to notice that the fundamental researches of M.M. on the plasma theory, which were forbidden for publication earlier, have been published recently (in 2008).

To summarize, I emphasize that the 20-th century was exclusively rich in great researchers in theoretical physics. However, M.M. Bogolyubov distinguishes among them by an extreme wealth of the results obtained, which have a fundamental value. After his unprecedented activity, theoretical physics got an absolutely different form.

Translated from Ukrainian by O.I. Voitenko