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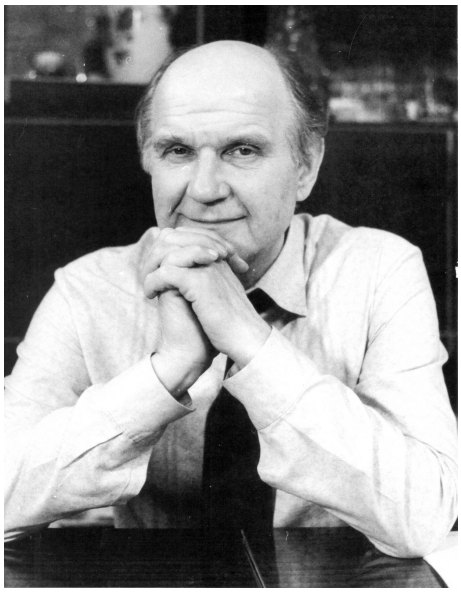
CONDENSED MATTER PHYSICS

Foreword

Founder of the Lviv School of Statistical Physics and Builder of Ukrainian Statehood. To the Centenary of Ihor Yukhnovskii' Birth (01.09.1925–26.03.2024)



September 1, 2025 marks the 100th anniversary of the birth of one of the Founding Fathers of the renewed Ukrainian state, a prominent Ukrainian scientist, theoretical physicist, founder of the modern Lviv school of statistical physics, Professor, full member of the National Academy of Sciences of Ukraine, full and honorary member of the Shevchenko Scientific Society, Hero of Ukraine, Ihor Yukhnovskii. He completed his earthly journey on March 26, 2024, in his 99th year of life. At the end of his eventful life, he pondered: "And now I no longer know what was most important to me in life — physics or politics?" Let us reflect on this issue as well.

Ihor Yukhnovskii was born in the historical region of Volyn in the family of a civil servant. Both of his parents came from old priestly families. He studied at the renowned Lyceum in Kremenets, where the language of teaching changed with each change in political power. His education was interrupted by the war, which, in fact, began in Western Ukraine in 1939. In 1944, he was recruited into the Soviet Army, fought on the fronts of World War II, and witnessed its end on the territory of Austria. In 1946, he became a student of the Department of Physics and Mathematics at the Ivan Franko State University of Lviv graduating with honors in 1951. He continued his study as a postgraduate student at the Chair of Theoretical Physics under the supervision of Abba Glauberman. At this time, Ihor Yukhnovskii got acquainted with the works of Nikolai Bogolyubov. Inspired by Bogolyubov's ideas, he conducted a series of original studies related to the development of the Bogolyubov method of plasma parameter expansion and its applications to the systems of charged particles. These results formed the basis for his Ph. D. thesis "The Binary Distribution Function for the Systems of Interacting Particles" (1954), and turned to be far ahead of the similar research results by foreign scientists. His thesis opponent was N. Bogolyubov himself.

In the late 1950s, I. Yukhnovskii formulated a new method for the study of many-particle systems

the method of collective variables. This approach opened up new prospects to describe various classical many-particle systems using the formalism of functional integration. The method was developed about the same time the Stratonovich-Hubbard transformation began to be widely used, but its range of applications proved to be much broader. Later, Yukhnovskii extended the method of collective variables to quantum many-particle systems. Thus, there emerged a method of displacements and collective variables, which turned out to be quite favourable for the study of quantum Fermi and Bose systems. The obtained results formed the basis for Ihor Yukhnovskii's D. Sc. (habilitation) thesis "Statistical Theory of Equilibrium Systems of Charged Particles" that was defended in 1965 at the Taras Shevchenko State University of Kyiv. Two years later, he was granted the title of professor. By that time, I. Yukhnovskii had already been heading the Chair of Theoretical Physics at Lviv University for several years.

Having defended his D. Sc. thesis, I. Yukhnovskii focused his primary efforts on working with young scientists. Under his supervision, there worked about a dozen young scientists. In May 1969, with the support of academician N. Bogolyubov, Ihor Yukhnovskii initiated the establishment of the Department of Statistical Theory of Condensed Systems (STCS) of the Institute for Theoretical Physics (ITP) of the Academy of Sciences of the Ukrainian SSR, based in Lviv. He became the head of this new department. This marked the beginning of a new stage in his scientific career — a period of work in the Academy of Sciences. The newly founded department became the first academic physics unit in Western Ukraine. The methods developed by I. Yukhnovskii laid the foundation for the study of a wide range of important problems in condensed matter physics. This department opened up new opportunities for Ihor Yukhnovskii to realize his dream of creating a strong research group on statistical physics in Lviv. Thus, the groundwork was laid for the future scientific school.

In science, perhaps the most important component of success is competitiveness and the ability to see the horizons, because any form of isolation leads to a transformation into pseudoscience and creates closed subsystems that exhibit certain features of science but are not truly scientific. Yukhnovskii understood this clearly. In the late 1960th Ihor Yuknovskii started a close collaboration with the University of Rostock in Germany. He presented there lectures, initiated an agreement about collaboration, and invited several colleagues from Rostock as G. Kelbg, W. Ebeling and H. Krienke to visits his group in Lviv. During the Soviet period, he did also everything possible to align the work of physicists in Lviv with that of researchers from the largest scientific centers of the USSR. Already in the 1970s, with the support of N. Bogolyubov, he initiated the All-Union Conferences on Statistical Physics, which attracted enthusiastic participants from all over the Soviet Union. Between the 1970s and 1980s, about ten such conferences were organized, including the International School on the Physics of Ionic Solvation (1983), the Second Soviet-Italian Symposium on Mathematical Problems of Statistical Physics (1985), and several others. Thanks to I. Yukhnovskii and his students, Lviv gradually became a leading center for statistical physics. Regular international conferences are now held there, and the next one is scheduled for August 2025. From the experience of such exchanges, Ihor Yukhnovskii formulated one of his key principles for setting new research problems. He said that, since scientists in Moscow had the advantage of better access to information from Western countries, we should focus on problems that are hard to solve and have a historical background because this is our main niche for competing with the "metropolitan" physicists. At the same time, every effort was made to strengthen our communication and raise our awareness of global scientific achievements. Naturally, these principles remain relevant up till now.

Many more examples could be given regarding the initiatives aimed at focusing on the most relevant fields. To begin with, even the name of the STCS department was quite innovative at that time. The term "condensed matter" began to appear in scientific literature only in 1963, when the journal "Physics of Condensed Matter" started to be published by Springer-Verlag. In 1967, Philip Warren Anderson, the Nobel laureate in physics (1977), was the first to use this term to entitle a scientific unit, renaming his group at the Cavendish Laboratory of the University of Cambridge from "Solid State Theory" to "Condensed Matter Theory". Shortly, the Department of Statistical Theory of Condensed Systems was established in the spring of 1969. In a similar way, Ihor Yukhnovskii quickly responded to the emergence and growing use of new computer technologies in science. In the mid-1980s, following his contacts with Karl Heinzinger, one of the pioneers of computer simulation in Western Germany, he supported the idea of expanding the use of computer simulation methods in physical research. Today, this has become one of the core directions of the Yukhnovskii scientific school. In 1993, with his strong support, the "Ukrainian Academic and Research Network" project was launched. Since then, this initiative has

developed from a small laboratory within the Institute into a fully independent and self-sufficient state enterprise, "UARNet". Over time, UARNet has become the main internet provider not only for the National Academy of Sciences of Ukraine but also for a large number of universities, government and commercial institutions, and private users.

In 1972, I. Yukhnovskii was elected a corresponding member of the Academy of Sciences of the Ukrainian SSR, which was a significant achievement and confirmation of the prospects of both the scientist himself and the scientific unit he headed. The achievements of the researchers in the STCS department and the availability of sufficient human resources made it possible to establish the Lviv Division of Statistical Physics of the Institute for Theoretical Physics of the Academy of Sciences of the Ukrainian SSR in 1980. This division included three scientific departments: the already existing STCS department, and two new ones — the Department of Solution Theory and the Department of Quantum Statistics, headed by Yukhnovskii's students Myroslav Holovko and Ivan Vakarchuk, respectively. In 1982, I. Yukhnovskii was elected a full member of the Academy of Sciences of the Ukrainian SSR.

In 1980, the monograph "Statistical Theory of Classical Equilibrium Systems" by I. Yukhnovskii and M. Holovko was published (Kyiv, Naukova Dumka). It became one of the first works in the world scientific literature devoted to the microscopic theory of the liquid state. Within the framework of the ion-molecular approach to the theory of electrolyte solutions, the authors demonstrated a fundamental difference in how electrostatic interactions are screened by ions versus solvent molecules: ionic screening leads to an exponential decay of electrostatic interactions, while screening by polar molecules determines the dielectric properties of the solution. Together with his disciples, I. Yukhnovskii investigated the fundamental role of the molecular subsystem of the solvent and the nature of ionic solvation phenomena, studied the mechanisms of formation and the specificity of short-range order in solutions.

The theory of electrolyte solution was then extended to the case of spatially bounded systems (films and membranes). It was shown that due to the presence of electrostatic image forces in semi-confined systems, leading to adsorption effects at the electrolyte surface, the screening effects in spatially inhomogeneous and bulk systems are qualitatively different. These studies were carried out in collaboration with M. Holovko, V. Vysochansky, I. Kurylyak, O. Pizio, A. Popov, Ye. Sovyak, A. Kovalenko, and others.

To study quantum systems, a method of displacements and collective variables was formulated, enabling Yukhnovskii and his students to calculate the average and free energy, heat capacity, and binding energy for non-transition metals. Furthermore, they derived equation of state of a degenerate electron gas, binary distribution functions of electrons in a regime of strong nonideality. For the first time, the correct asymptotic behavior of the binary function at short distances was obtained for electron densities typical of metals. These studies were conducted in collaboration with M. Vavrukh, H. Bihun, R. Petrashko, P. Kostrobij, and others. The application of the method of displacements and collective variables to the theory of high-temperature plasma was explored in joint research with L. Blazhiyevskii. The calculation of the pseudopotential and the study of the properties of quasiclassical plasma were carried out in collaboration with H. Hetzheim from the University of Rostock. Research on the electron gas in alkali metals using the method of displacements and collective variables was conducted jointly with N. Albehrendt and G. Kelbg from the same university. More details about I. Yukhnovskii's collaboration with the University of Rostock can be found in the article by W. Ebeling in the current issue of the journal.

Another area of research where the method of displacements and collective variables proved to be effective was the theory of interacting Bose particles. In this context, wave functions for the ground and weakly excited states were obtained, the ground state energy and spectrum of elementary excitations were calculated, structural functions were determined, and the problem of Bose-Einstein condensation was analyzed. This led to the development of a microscopic theory of liquid He^4, which demonstrated a quantitative agreement with experimental results. These works were conducted in collaboration with I. Vakarchuk. In solid state theory, Yukhnovskii's approach, which considers short-range interactions as a basis for describing the systems with competing short- and long-range potentials, was developed in collaboration with R. Levitskii. This approach was extended to quantum systems exhibiting order-disorder behavior, described using pseudospin models (such as ferroelectrics, magnets, etc.). In this framework, short-range interactions were taken into account using the cluster approximation.

Next area of Yukhnovskii's research concerns the theory of phase transitions and critical phenomena, an interest that emerged in the early 1970s and the one he continued to pursue until his final days. The starting point of this research was a collaborative work with Yu. Rudavskii, establishing the form

of the basic distribution near the second-order phase transition point. It was determined that to accurately describe critical phenomena, one must consider higher (non-Gaussian) distributions that take into account fluctuations in the collective variable associated with the order parameter. Using the method of collective variables, recursive relations for the coefficients of the basic density measure were derived. Analysis of these relations revealed a unique critical regime near the critical point, indicating the manifestation of a new type of symmetry, namely, the symmetry of the renormalization group. This symmetry leads to a universal behaviour of different systems, characterized by shared fundamental features such as spatial dimensionality, the number of order parameter components, and the type of interaction. These investigations were carried out in collaboration with M. Kozlovskii, I. Vakarchuk, Yu. Rudavskii, V. Kolomiets, Yu. Holovatch, I. Mryglod and others. The principal concepts of this theory were published in Yukhnovskii's monograph "Phase Transitions of the Second Order: The Collective Variables Method" (Kyiv: Naukova Dumka, 1985), which was later translated into English and published by World Scientific (Singapore). It was found that solely considering the critical regime is insufficient for calculating the thermodynamic characteristics near a phase transition. Using the Ising model as an example, Ihor Yukhnovskii and collaborators proposed a scheme that enabled calculations of both universal (critical exponents) and non-universal (transition temperature, heat capacity, susceptibility, etc.) quantities in the vicinity of the transition point. This approach, tested on the Ising model, became fundamental in developing a general theory of critical phenomena in three-dimensional systems. Yukhnovskii's disciples applied this approach to describe critical behavior in various condensed matter models, including: Stanley model (with I. Vakarchuk, Yu. Rudavskii, Yu. Holovatch), binary substitution alloys (with Z. Gurskii), structural phase transition models (with I. Mryglod), Ising-like systems with anisotropic interactions (with M. Korynevskii), hierarchical models (with Yu. Kozitsky), a gas-liquid critical point (with I. Idzyk and V. Kolomiyets), classical multicomponent mixtures (with O. Patsahan).

Due to the emergence of powerful sources of electromagnetic radiation, the study of the properties of the atomic system, a part of which are in an excited electronic state, has become increasingly relevant. The unique features of such systems are determined by a new type of interaction - resonant interactions. A detailed study of resonant interactions in groups of atoms, and the identification of their essentially many-particle nature, became the focus of research initiated by I. Yukhnovskii in the early 1970s in collaboration with R. Kadobyansky. Later, R. Levitskii and O. Derzhko joined them. With the support and encouragement of Ihor Yukhnovskii, the study of non-equilibrium statistical physics began in the 1980s. This work was initiated by D. Zubarev and M. Tokarchuk. The development of the collective variables method as applied to problems in non-equilibrium statistical physics enabled the disciples of I. Yukhnovskii to achieve fundamentally new results in the dynamics of dense fluids and liquid systems (M. Tokarchuk, I. Mryglod, T. Bryk, I. Omelyan).

In 1986, I. Yukhnovskii, together with N. Bogolyubov (Jr.) and S. Peletminskyi, was awarded the M. Krylov Prize by the Academy of Sciences of Ukraine for their series of works on "Mathematical Methods for the Study of Systems with Spontaneously Broken Symmetry".

In the late 1980s, Ihor Yukhnovskii's life became closely intertwined with significant societal events during the formation of the modern Ukraine state. As he recalled: "My entry into political activities did not happen immediately — it began with the objective realization of the inevitable collapse of the USSR and the emergence of independent states. This conviction that the USSR would fall apart was for me only natural and logical, without anguish. ...The people rose up, oppressed both nationally and socially by the Soviet system. This uprising was powerful". At that time, I. Yukhnovskii was already a renowned scientist and active public figure. He founded the Junior Academy of Sciences for secondary school children in Lviv, the first of this kind in Ukraine; contributed to the revival and development of the Plast (the Ukrainian equivalent of the Scout movement); organized and co-chaired the Lviv regional Memorial society, a historical-educational and human rights organization dedicated to preserving the memory of political repressions during the Soviet period; and was among the founders of the People's Movement (Narodnyi Ruch) of Ukraine, the first opposition public organization officially registered by the Council of Ministers of the Ukrainian SSR in February 1990. With his calm and persuasive manner of communication, Ihor Yukhnovskii was able to convince thousands at rallies or his opponents in the quiet of their offices. Consequently, in March 1990, he was elected a member of the Ukrainian parliament, Verkhovna Rada of the Ukrainian SSR (later the first democratic convocation of the Verkhovna Rada of Ukraine). At the age of 65, the academician began a new and exceptionally productive period of

state-building activities.

After his election as a member of the Verkhovna Rada of Ukraine, Ihor Yukhnovskyi moved to Kyiv, marking the start of a period that lasted over twenty years. During this time, he played a pivotal role in the formation of the modern Ukrainian state. As the leader of the opposition in the first convocation of the Verkhovna Rada, he headed the People's Council (Narodna Rada) and was an active participant in the adoption of the Declaration of State Sovereignty of Ukraine. He was also one of the authors of the Law "On the Economic Independence of Ukraine" and initiated the All-Ukrainian referendum on confirming Ukraine's independence, which took place on December 1, 1991. At the same time, Yukhnovskii continued to take an interest in the life of the physics team he had essentially established in Lviv whenever he had a free moment.

In September 1990, based on the Lviv Division of Statistical Physics of the Institute for Theoretical Physics of the Academy of Sciences of the Ukrainian SSR, the Institute for Condensed Matter Physics of the National Academy of Sciences of Ukraine was established — the first academic institute devoted to fundamental research in physics in Western Ukraine. Ihor Yukhnovskii became its first director and headed it for 16 years. From 2006 until the end of his life, he served as honorary director of the Institute, envisaging its activities and supporting all veritable initiatives and undertakings.

While working in Kyiv at the Verkhovna Rada, I. Yukhnovskii set new tasks for the Institute for Condensed Matter Physics, related to the development of the young Ukrainian state. Among these were the problem of interaction of nuclear magma with water in "Shelter" site in the Chornobyl nuclear power plant, issues of self-destruction of fuel-containing materials under radiation exposure and the spread of radioactive dust, as well as problems of catalysis and fuel cells.

In 1993, the ICMP launched the journal Condensed Matter Physics, which has become one of Ukraine's premier scientific publications in the field. Ihor Yukhnovskii served as the editor-in-chief of this journal for 29 years. During that time, the publication evolved from an interdepartmental collection to an internationally recognized open-access journal indexed in the scientometric databases Scopus and the Web of Science Core Collection since 2005.

From 1990 to 1993, Ihor Yukhnovskii headed the Verkhovna Rada Commission on Science and Education and was a member of the Presidium of the Verkhovna Rada. In 1992, he worked as a State Advisor of Ukraine and chaired the Collegium on Scientific and Technical Policy of the State Duma of Ukraine. From 1992 to 1993, he was the First Deputy Prime Minister of Ukraine in the government of L. Kuchma. In 1994, he was re-elected a member of the Verkhovna Rada of Ukraine, heading the parliamentary group "Statehood" ("Derzhavnist"). He was one of the key authors and drivers behind the adoption of the Constitution of Ukraine in 1996. During this period, he initiated the creation of the Interdepartmental Analytical Advisory Council under the Cabinet of Ministers of Ukraine. In 1998, Yukhnovskii was elected a member of the Verhovna Rada for the third time and again became head of the Committee on Science and Education. In 2002, he became a member of the Verkhovna Rada of Ukraine for the fourth time, joining the "Our Ukraine" fraction, chairing the Committee on Science and Education, and leading the Special Temporary Commission on Future Issues. I. Yukhnovskii was the organizer and the first Head of the Ukrainian Institute of National Memory, a newly established (2006) central executive body with a special status, which he led until 2010. During his tenure, the Law of Ukraine "On the Holodomor (Purposeful famine) of 1932–1933 in Ukraine" was adopted, the National Book of Memory of Holodomor Victims was created, the first phase of the Memorial to the Victims of Holodomor was built, and the Museum of the Ukrainian Revolution of 1917–1921 was established in the historic Teachers' House in Kyiv. In addition to his work in parliament and government structures, Ihor Yukhnovskii actively works in Ukrainian public organizations. He became the organizer and first chairman of the All-Ukrainian Veterans' Association (1996–2009), organizer and president of the International Charitable Foundation of National Memory of Ukraine (2006–2024), and a founding member of the "First of December" Initiative Group (2011–2024).

Ihor Yukhnovskii returned to Lviv in 2010 at the age of 85. Here, he returned to the problem of describing from first principles the behavior of a system of interacting particles at the critical point and at lower temperatures. For the collection of his recent scientific works titled "Asymptotic Methods of Nonlinear Mechanics and Statistical Physics," in 2017 he was awarded the Bogolyubov Prize of the National Academy of Sciences of Ukraine (together with M. Perestyuk), and his latest article, co-authored with R. Romanik, was published in 2024 in the Ukrainian Physical Journal. Ihor Yukhnovskii's

scientific contribution includes over 500 research articles, 7 monographs and textbooks. Among his direct students there are 37 candidates and 18 doctors of science. The Institute for Condensed Matter Physics he founded became one of the leading scientific centers in Ukraine and Eastern Europe in the field of statistical physics of condensed matter and computer simulations of many-particle systems. He was elected an honorary doctor of the Bogolyubov Institute for Theoretical Physics of the National Academy of Sciences of Ukraine and at a number of the National Universities: Ivan Franko National University of Lviv, Lviv Polytechnic National University, Lesya Ukrainka Volyn National University, Vasyl Stefanyk Precarpathian National University, and Uzhhorod National University. He was awarded the Order of Merit of the 1st degree, Orders of Prince Yaroslav the Wise of the 5th, 4th, and 3rd degrees, the Order of Freedom, and he was also recognized as a Hero of Ukraine and a recipient of the Order of the State.

The ascent of Hoverla, the highest peak of the Ukrainian Carpathians, dedicated to the 90th birthday of Ihor Yukhnovskii and led by the hero of day himself(!), will remain unforgettable for those who participated in it. And on September 1, 2023, on his 98th birthday, Ihor Yukhnovskii spoke at a seminar of the Institute for Condensed Matter Physics of the National Academy of Sciences of Ukraine, which he founded, with a report titled "A New Perspective on First-Order Phase Transitions". His presentation lasted almost an hour and was followed by a half-hour discussion. Ihor Yukhnovskii was tired, but his face showed the emotions of satisfaction and joy of a physicist after a job well done. This is how he will remain in the memory of his students, his students' students, and many who were lucky enough to know him personally. *Vivat Academia! Vivant professores!*

On June 4, 2025, the Presidium of the National Academy of Sciences of Ukraine supported the proposal of the staff of the Institute for Condensed Matter Physics of the National Academy of Sciences of Ukraine to name the Institute after Ihor Yuhnovskii.

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