Condensed Matter Physics, 2024, Vol. 27, No. 2, 20001: 1–5
DOI: 10.5488/CMP.27.20001
http://www.icmp.lviv.ua/journal

CONDENSED MATTER PHYSICS

Editorial

In memory of Ihor Yukhnovskii, the founder and editor-in-chief of the journal "Condensed Matter Physics" (1925–2024)

On March 26, 2024, the prominent Ukrainian scholar, theoretical physicist, and founder of the Lviv school of statistical physics, professor, academician of the National Academy of Sciences of Ukraine Ihor Yukhnovskii, passed away. He lived almost 99 years and his life was filled with many events. He was a soldier during World War II, a scientist and educator, and a public and state figure of the highest level. But above all, he was a scientist. He approached any task as a researcher, from formulating the problem to finding its optimal solution. Analytical thinking and mathematical logic dominated all his activities. At the same time, he remarkably combined scientific pragmatism with unexpected imaginative ideas, which ensured his outstanding achievements both in science and in politics.

Ihor Yukhnovskii was born on September 1, 1925, in the region of Volyn, in Northwestern Ukraine. His lineage came from old priestly families. He graduated from the renowned Kremenets Lyceum. In 1944, he was recruited into the Soviet army, and the end of World War II found him in Austria. In 1946, he enrolled in 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 A. Yu. Glauberman. The scientific works and ideas of N. N. Bogolyubov had a significant impact on his development as a scientist. In the 1960s, he conducted a series of original studies related to the development of the Bogolyubov method of plasma parameter expansion and its application to the description of binary distribution functions for a system of charged particles. He obtained general expressions that included screened potentials of Coulomb interactions, thus allowing for the correct consideration of long-range effects. These results formed the basis of his Ph.D. thesis, "Binary distribution function of systems of interacting particles" (1954), and turned to be more than a decade ahead of similar studies by foreign scientists, now known in the literature as the γ-ordering technique.

At the end of the 1950s, Ihor Yukhnovskii's efforts to generalize and formalize the results obtained for systems of charged particles led him to formulate a new and powerful method for studying many-particle

systems — the method of collective variables. The method became the basis of most of the works of Yukhnovskii and his disciples. He proposed an original calculation scheme of the transition function from the Cartesian coordinates of particles to the variables describing collective movements in the system. This allowed for a mathematically correct functional representation of the partition function in the phase space of collective variables, enabling the consideration of correlations among fluctuation waves.

The definition of collective variables and the developed mathematical apparatus for them enabled the resolution of another important problem in the statistical theory of interacting particles — a simultaneous consideration of long-range and short-range interactions. In the formalism proposed by I. R. Yukhnovskii, known now as the reference approach, the description of a system of interacting particles is carried out in an extended phase space. This space includes both the individual coordinates of particles (a reference system) and the collective variables that describe density fluctuation waves. Depending on the specificity of the problem, these could be the densities of the number of particles, charge, dipole moment, magnetization, and so on. Individual and collective variables describe the effects caused by short- and long-range interactions, respectively. The transition to the extended phase space is performed using the Jacobian of the transition, for which an explicit expression was found, and properties of completeness and orthonormality were proven. The expressions obtained in this formalism for the thermodynamic and structural functions of systems of interacting particles take the form of cluster expansions, allowing for the consistent consideration of many-particle correlation effects. A characteristic feature of these expansions is the screening of long-range interactions.

The method of the reference system to the description of short-range interactions developed by I. R. Yukhnovskii proved to be effective for the quantitative description of various condensed matter systems. Notably, the application of this method to the description of ion-dipole systems paved the way for the development of a microscopic theory of electrolyte solutions. This theory is based on the equivalent consideration of all possible interactions between electrolyte ions and solvent molecules.

In the mid-1960s, I. R. Yukhnovskii generalized the formalism of collective variables to quantum many-particle systems. The idea of the proposed approach was to sequentially extract from the quantum statistical operator, defined on the set of Cartesian coordinates of particles, the component that describes the interaction of particle wave packets and can be expressed in terms of collective variables. In this way, an equivalent representation of the partition function of a quantum system was found, which formally corresponded to a classical system with many-particle interactions. This approach became known as the method of displacements and collective variables and proved to be quite successful in describing Fermi and Bose systems. Using this method, it was possible to construct a quantitative microscopic theory of liquid helium and obtain a number of original results in the electronic theory of metals. The original results from the studies of charged particle systems formed the basis of I. R. Yukhnovskii's D.Sc. (habilitation) thesis, "Statistical theory of systems of charged particles" (1965), which he defended at the Taras Shevchenko State University in Kyiv. In 1967, he was granted the title of professor.

After habilitation, Yukhnovskii's scientific work reached a qualitatively different level and scale, both in terms of research topics and the number of his disciples. Under his supervision, about a dozen young scientists were already working. Wishing to focus entirely on scientific activities, Ihor Yukhnovskii turned his attention to the Academy of Sciences. In May 1969, at his initiative, the Department of Statistical Theory of Condensed Systems (STCS) of the Institute of Theoretical Physics (ITP) of the Academy of Sciences of the Ukrainian SSR was founded in Lviv. Yukhnovskii became its head. This marked the beginning of a new, academic period in his scientific career. The idea of creating the department was a natural continuation of Yukhnovskii's collaboration with academician N. N. Bogolyubov and representatives of his scientific school. The STCS department became the first academic unit in the field of physics in Western Ukraine. The original and powerful methods developed by Yukhnovskii laid the foundation for studying a wide range of problems in condensed matter physics. Yukhnovskii was highly motivated to create a strong research group in Lviv, capable of effectively solving such problems. His main focus was on working with talented youth, laying the foundations for a future scientific school.

In 1972, I. R. Yukhnovskii was elected a corresponding member of the Academy of Sciences of the Ukrainian SSR in the field of theoretical physics, which was a significant achievement and a confirmation of both his scientist's prospects and the research unit he headed. Immediately after the establishment of the STCS department, under Yukhnovskii's leadership and with the support of N. N. Bogolyubov, Lviv became a location for organizing conferences on statistical physics. From 1970 till 1990, a dozen

conferences on statistical physics were organized and held in Lviv, including the International School on Ion Solvation Physics (1983), the Second Soviet-Italian Symposium on Mathematical Problems of Statistical Physics (1985), and several others. Thanks to Yukhnovskii and his disciples, Lviv established itself as a leading center for statistical physics. In 1982, I. R. Yukhnovskii was elected an academician of the Academy of Sciences of the Ukrainian SSR in the field of theoretical physics.

In 1980, the monograph by I. R. Yukhnovskii and M. F. Holovko, "Statistical Theory of Classical Equilibrium Systems" (Kyiv, Naukova Dumka), was published. This work became one of the first in the world literature and eventually a classic textbook on the microscopic theory of the liquid state. Within the framework of the ion-molecular approach in the theory of electrolyte solutions, it was demonstrated that the nature of screening of electrostatic interactions by ions and solvent molecules is fundamentally different: ion screening leads to an exponential decay of all electrostatic interactions, while screening by polar molecules determines the dielectric properties of the solution. Together with his disciples, I. R. Yukhnovskii investigated the fundamental role of the molecular subsystem of the solvent and the nature of ion solvation phenomena, examined the mechanisms of formation and specificity of short-range order in solutions.

Subsequently, the theory of electrolyte solutions was generalized to spatially confined systems (electrolyte films and membranes). It was shown that due to the presence of electrostatic image forces in semi-confined systems, which cause adsorption effects on the electrolyte surface, the screening effects in spatially inhomogeneous and bulk systems are qualitatively different. Research in this direction was conducted jointly with M. F. Holovko, V. S. Vysochanskii, I. Y. Kurylyak, O. O. Pizio, Y. M. Sovyak, A. F. Kovalenko, and others.

With the formulation of the method of displacements and collective variables, intensive studies of quantum systems of interacting particles began. I. R. Yukhnovsky, together with his disciples, conducted calculations of the mean and free energy, heat capacity, and binding energy for transition metals, as well as derived the equation of state for a degenerate electron gas and investigated the properties of the binary distribution function of electrons under conditions of strong nonideality. For the first time, the correct asymptotics of the binary distribution function at small distances for electron densities typical of metals were obtained. These works were carried out together with M. V. Vavrukh, H. I. Bigun, R. M. Petrashko, and P. P. Kostrobij. The application of the method of displacements and collective variables to the problems of high-temperature plasma theory was conducted jointly with L. F. Blazhiyevskii.

Another area of research where the method of displacements and collective variables proved effective was the theory of interacting Bose particles. In this field, wave functions for the ground and slightly excited states were found, the ground state energy and the spectrum of elementary excitations were calculated, structural functions were determined, and the problem of Bose-Einstein condensation was analyzed. This allowed for the development of a microscopic theory of liquid helium-4, which demonstrated a quantitative agreement between the calculated results and experimental data. These studies were conducted jointly with I. O. Vakarchuk.

The idea of the reference system method for describing systems with short-range and long-range interactions, together with R. R. Levitskii, was extended to quantum systems of the order–disorder type, which are described by pseudospin models (such as ferroelectrics and Ising magnets). A new approach was formulated in which short-range interactions are taken into account in a cluster approximation.

Phase transitions and critical phenomena became a focus of interest of I. R. Yukhnovskii in the early 1970s, a topic he continued to work on until the end of his life. The starting point for these studies was the work on justifying the form of the basic distribution near the second-order phase transition point, performed jointly with Yu. K. Rudavskii. It was established that to successfully describe the critical phenomena, one should start with higher-order (non-Gaussian) distributions that describe the fluctuations of the collective variable associated with the order parameter. Here, recursive relations for the coefficients of the basic density measure were obtained. It was found that near the critical point, a unique critical regime is observed in which a new type of symmetry—renormalization group symmetry—emerges, leading to universality in the behavior of different systems that share general characteristics (space dimensionality, symmetry and number of components of the order parameter, type of interactions, etc.). These studies were conducted jointly with M. P. Kozlovskii, I. O. Vakarchuk, Yu. K. Rudavskii, V. O. Kolomiyets, Yu. V. Holovatch, and I. M. Mryglod. The main principles of this theory were published in Yukhnovskii's monograph "Phase transitions of the second order. Collective variables method" (Kyiv,

Naukova Dumka, 1985), which was later translated into English and published by World Scientific (Singapore), 1987.

At the same time, it was shown that to consider only the critical regime is insufficient for the calculation of the thermodynamic characteristics of a system near a phase transition. I. R. Yukhnovskii, together with M. P. Kozlovskii, proposed a scheme of systematic calculations of both universal (critical exponents) and non-universal (phase transition temperature, heat capacity, susceptibility, etc.) quantities in the vicinity of the phase transition. This approach, tested on the Ising model, became the key to developing a general theory of critical phenomena in three-dimensional systems. It was later applied by Yukhnovskii's disciples to study the critical behavior in various models of statistical physics and condensed matter theory: a n-component Stanley spin model (in collaboration with I. O. Vakarchuk, Yu. K. Rudavskii, Yu. V. Holovatch), binary substitutional alloys (with Z. O. Gurskii), a n-component model of structural phase transitions (with I. M. Mryglod), Ising systems with anisotropic interactions (with M. A. Korynevskii), hierarchical models (with Y. V. Kozitsky), a liquid-gas critical point (with I. M. Idzyk and V. O. Kolomiyets), and classical multicomponent mixtures (with O. V. Patsahan).

In 1986, I. R. Yukhnovsky, along with N. N. Bogolubov, Jr. and S. V. Peletminsky, was awarded the N. 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 September 1990, based on the Lviv Branch of Statistical Physics at 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 (NASU) was established—the first academic institute devoted to fundamental research in physics in Western Ukraine. I. R. 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, actively overseeing its activities and supporting all initiatives and undertakings.

In 1993, the Institute for Condensed Matter Physics of NASU founded a new journal, Condensed Matter Physics. Ihor Yukhnovskii was the editor-in-chief of this journal for 29 years (until 2022), elevating it to one of the top scientific journals in Ukraine and integrating it into the global information field. Since 2005, the journal has been included in scientometric databases such as Scopus and the Web of Science Core Collection, as well as other databases like Chemical Abstract Service, EBSCO Academic Search Premier, IET Inspec (UK), PubScience (USA), and "Dzherelo" (Ukraine).

At the same time, in 1990, a new period began in the life of Ihor Yukhnovskii—the state formation of Ukraine. Having been elected a member of the Ukrainian parliament, Verkhovna Rada, he moved from Lviv to Kyiv. This period lasted for more than twenty years. In the first convocation of the Verkhovna Rada, Ihor Yukhnovskii led the opposition as the head of the People's Council (Narodna Rada), was an active participant in the adoption of the Declaration of State Sovereignty of Ukraine, and was one of the authors of the Law "On the Economic Independence of Ukraine". He was an initiator of the All-Ukrainian referendum on confirming Ukraine's independence, which took place on December 1, 1991. From 1990 to 1993, he chaired the Verkhovna Rada's Commission on Science and Education and was a member of the Presidium of the Verkhovna Rada. In 1992, he served as the State Advisor of Ukraine and headed the Collegium on Scientific and Technological 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, Ihor Yukhnovskii was re-elected a member of the Verkhovna Rada of Ukraine, heading the "Statehood" (Derzhavnist') parliamentary group. 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, he was elected as a member of parliament of Ukraine for the third time, belonging to the faction of the Ukrainian People's Movement and chaired 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" faction, chairing the Committee on Science and Education, and leading the Special Temporary Commission on Future Issues.

He was the organizer and first Head of the Ukrainian Institute of National Memory, a newly established (2006) central executive body with a special status, which he headed until 2010. During his tenure, the Law of Ukraine was adopted "On the Holodomor (Great Purposeful Famine) of 1932–1933 in Ukraine", the National Book of Memory of the Victims of the Holodomor was created, the first stage of the Holodomor Memorial was built, and the Museum of the Ukrainian Revolution of 1917-1921 was established in the

historic Teacher's House in Kyiv.

I. R. Yukhnovskii was the organizer and first president of the Junior Academy of Sciences for schoolchildren in Lviv (1978–1990), the organizer and first chairman of the All-Ukrainian Association of Veterans (1996–2009), the organizer and president of the International Charitable Foundation of National Memory of Ukraine (2006–2024), and a founding member of the Initiative Group "The First of December" (2011–2024).

In 2010, at the age of 85, Ihor Yukhnovskii returned from Kyiv to Lviv and continued to actively engage in a topic that was of great interest to him — the description of the behavior of interacting particles system from first principles at and below the critical point. For his series of recent scientific works entitled "Asymptotic Methods in Nonlinear Mechanics and Statistical Physics" in 2017, he was awarded the N. N. Bogolyubov Prize by the National Academy of Sciences of Ukraine (together with M. O. Perestyuk), and his latest article, co-authored with R. V. Romanik, was published in the Journal of Physical Studies in 2024.

Overall, I. R. Yukhnovskii is the author of over 500 scientific papers, 7 monographs and textbooks. He supervised 37 candidates and 18 doctoral candidates. The Institute for Condensed Matter Physics, founded by him, became one of the leading scientific centers in Ukraine and Eastern Europe in the field of statistical physics of condensed matter and computer modelling of multiparticle systems. He was a honorary doctor of the Bogolyubov Institute of 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 was recognized as a Hero of Ukraine and a recipient of the Order of the State.

Despite his advanced age, Ihor Yukhnovskii passed away suddenly while being in good physical shape, full of new ideas and plans. On his 98th birthday, he gave a talk entitled "A New Perspective on First-Order Phase Transitions" at a seminar at the Institute of Condensed Matter Physics of the National Academy of Sciences of Ukraine, which sparked a lively discussion and debate. The disciples and collaborators of Ihor Yukhnovskii deeply mourn the loss of their teacher and colleague and are ready to continue his work and contribute to the achievements and glory of the modern Lviv school of statistical physics.