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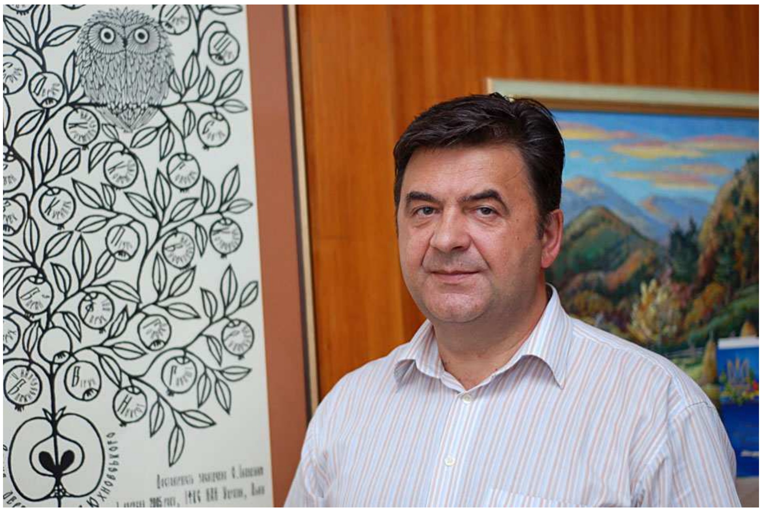
Foreword

From phase transitions to dynamics of liquids: on the 50-th anniversary of Ihor Mryglod



Theoretical physics in Lviv has always been associated with the famous names of Marian Smoluchowski, Stanislaw Ulam, Vasyl Milianchuk. In the 1960-1970-s a modern school of theoretical physics in Lviv was founded mainly by efforts of Professor Ihor Yukhnovskii and his pupils. One of the bright representatives of the modern school of theoretical physics in Lviv, Ihor Mryglod, became a successor of I.Yukhnovskii and since 2006 has headed a leading academic institution in Western Ukraine, the Institute for Condensed Matter Physics of National Academy of Sciences of Ukraine.

Ihor Mryglod graduated in 1982 from Department of Physics of the Lviv State University and was offered by Professor I. Yukhnovskii to join Lviv Division of statistical physics (LDSP) of the Institute for Theoretical Physics of Ukrainian Academy of Sciences. At that time the LDSP was known among the physicists first of all because of fundamental studies by I.Yukhnovskii on statistical theory of interacting many-particle systems. Being closely related to a famous mathematician and physicist Nikolai Bogolyubov, who was a founder of the Institute for Theoretical Physics in Kiev and later headed the Joint Institute for Nuclear Research in Dubna, Russia, Ihor Yukhnovskii during the 1970-1980-s accumulated in Lviv a group of young theoreticians, that organically became a part of Bogolyubov's school of theoretical physics. In the 1980-s the main focus of Yukhnovskii's research was on description of second order phase transitions within his original method of collective variables (CV) [1]. Within the framework of the CV method I.Yukhnovskii proposed a scheme of description of second order phase transitions in phase space of CVs suggesting a division of the reciprocal space into a set of shells and a successive integration out of the short-wavelength fluctuations in corresponding shells, which led to a transformation of renormalization group (RG).

Under I.Yukhnovskii's guidance Ihor Mryglod started his PhD work with a study of properties of an approximate RG transformation for large values of a shell parameter s for n-component isotropic model within the CV method. Solutions of the RG equations in the vicinity of a fixed point were obtained in the form of asymptotic expansions on $1/s$ parameter and critical indices were calculated. It was shown that in the region of intermediate values of s, the shell integration-out can be performed in Gaussian approximation and the corresponding differential recurrent relations were obtained.

Another problem focused on in I.Mryglod's PhD work was a study of mechanisms of formation of pre-transition clusters by approaching the second order phase transition using a method of Euler's equations. Some estimates of crossover temperature from high-temperature (effective mean-field or single-particle) behavior to pre-transition regime were obtained, where a cluster of a new low-temperature phase starts to play a leading role. In dynamics, this regime manifests as a formation of central peak in the corresponding dynamic structure factor. A temperature dependence of the crossover temperature on parameters of a generalized model of structural phase transition was studied.

For the first time I.Mryglod performed calculations of universal (critical indices and universal relations for critical amplitudes) and non-universal quantities (temperature of phase transition, heat capacity, order parameter, susceptibility etc.), that characterize the phase transition in n-component isotropic model using the method of approximate RG transformation. On this basis, the common features and differences in critical behavior of systems of displacement and order-disorder types were analyzed. The phase diagram was estimated for a generalized model of structural phase transition.

Solutions of the three abovementioned problems formed the body of PhD thesis entitled "Application of an approximate transformation of renormalization group to the study of critical behavior of the n-component model of structural phase transition", that was defended by Ihor Mryglod in 1988 at Kyiv University.

Big changes took place in the Soviet Union in 1989-1991-s, which also got reflected in academic life of Ukraine. The national Academy of Sciences became more independent in forming its structure and budget. In September 1990 in response to I.Yukhnovskii's request, that was supported by two famous physicists N.N.Bogoluybov and A.S.Davydov, the Academy set up an Institute for Condensed Matter Physics (ICMP) in Lviv on the basis of LDSP of the Institute for Theoretical Physics. The ICMP became the second academic institution of purely theoretical orientation in Ukraine. Ihor Mryglod got appointed a scientific secretary of ICMP.

At that time the Iron Curtain was down, which made it possible to establish direct scientific links between western and ukrainian researchers. In spring of 1992 I.Mryglod made a few-months visit as an ÖAD fellow to Professor R.Folk at Johann Kepler University of Linz, Austria. That visit to Linz initiated very fruitful and long-standing collaboration between ICMP and Professor Folk's group.

New directions of Ihor Mryglod's research in the 1990-s became non-equilibrium statistical mechanics and generalized hydrodynamics of liquids. Together with M.Tokarchuk he applied the Zubarev's method of non-equilibrium statistical operator to a consistent description of hydrodynamic and kinetic processes in condensed matter. A real breakthrough in theoretical description of collective dynamics in liquids turned out to be an approach of Generalized Collective Modes (GCM) elaborated in 1994–1995 [3]. By contrast to a kinetic approach, developed earlier by I. de Schepper and E.D.G. Cohen with coworkers [4], the GCM method was developed as an extension of hydrodynamics by including some short-time orthogonal dynamic variables into treatment, which permitted a systematic improvement of description of short-time behavior for time-dependent correlations in addition to the standard long-time hydrodynamic correlations. The most important feature of the GCM approach is in representation of all time correlation functions and the corresponding dynamic structure factors via a separable sum of contributions from generalized hydrodynamic and non-hydrodynamic eigenmodes, that can exist in liquids [5].

The concept of the existence of non-hydrodynamic modes, that cannot survive in liquids on macroscopic spatial and time scales, appeared to be very fruitful for a description of collective dynamics beyond hydrodynamic regime. The theory of non-hydrodynamic optic modes [6], heat waves [7] and structural relaxation [8] in liquids was constructed within the GCM approach. Over the last fifteen years the GCM approach has become one of the most powerful methods for the analysis of dynamic processes in liquids on macro- and microscopic spatial and time scales. The GCM approach permitted to establish the main microscopic mechanisms of formation of collective dynamics and transport processes in dense fluids and their mixtures [9], opened new possibilities for the analysis of time correlation functions and generalized transport coefficients [10] in complex disordered systems. The development of GCM approach was summarized in Habilitation thesis, defended by I.Mryglod in 2000 at Lviv University [11].

Success of the generalized hydrodynamic description of pure and many-component liquids has opened new perspectives for the exploration of dynamical processes in more complex systems, such as magnetic fluids. Analytical expressions for time-correlation functions of a Heisenberg model ferrofluid in homogeneous magnetic field were obtained in hydrodynamic limit and it was shown how the sound excitations contribute to the "spin density-spin density" time-correlation function, as well as the Landau-Placzek ratio for the dynamic structure factor of Heisenberg ferrofluid was obtained [12]. Pioneering studies were performed by computer simulations of ferromagnetic phase transition in a Heisenberg fluid [13] as well as new algorithms for molecular dynamics simulations of spin liquids were elaborated [14]. I.Mryglod together with Yu.Rudavskii and M.Tokarchuk received S.Pekar Award of the National Academy of Sciences of Ukraine in 2003 for the development of the theory for dynamic properties and phase transitions in magnetic liquids.

In 2002 a new department of quantum-statistical theory of catalytic processes was set up at ICMP, and I.Mryglod became the head of this department. Theoretical issues of catalytic processes, microscopic description of surface phenomena, ionic systems, prediction of phase diagrams became new topics in the spectrum of I.Mryglod's studies. Among the most interesting results obtained during the recent years were the studies on gas-liquid criticality in ionic fluids[15] and crossover behavior in fluids with long-range interactions [16].

The main idea of this Special issue of "Condensed Matter Physics" was to get together in one volume contributions from research fields that encompass I.Mryglod's interests over the last 25 years. The Editorial Board of "Condensed Matter Physics" expresses sincere gratitude to all I.Mryglod's colleagues from Ukraine and abroad who accepted the invitation to this Special issue in honor of the 50-th anniversary of Ihor Mryglod.

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