Journal of Molecular Liquids
Volume 93, Issue 1-3, September 2001
Special Problems in Physics of Liquids International Conference dedicated to the memory of Professor I.Z. Fisher
Odessa, Ukraine, 31 May - 4 June 1999
Edited by Leonid A. Bulavin and Nikolay P. Malomuzh

Professor I. Z. Fisher's scientific legacy

This article does not claim to be a thorough review of all works by Prof. I.Z. Fisher. Only have those papers been selected for the survey – in retrospect – which have contributed significantly to gaining insight into the nature of liquid state and introducing new relevant qualitative concepts.

At the very beginning of his carrier, Prof. I.Z. Fisher was concerned about specific topics in cosmology and general theory of relativity, elementary particles and gravity [1,2]. Later, his scientific interests had shifted to a broad range of theoretical problems in condensed matters, such as simple liquids, solutions, electrolytes, critical phenomena, etc.

When dealing with the theory of gravity, Prof. Fisher discovered a new relativistic effect caused by the self-rotation of a gravitational mass [3]. Then he offered a new equation for the gravitational field [4] which differed from Einstein's one by taking into account gravitational field fluctuations by means of a space-time averaging procedure. In contrast to Friedman’s theory, the solution of that equation had no singular point, with infinite mass density at the initial time. That paper first reflected Prof. Fisher's interest to averaging procedures of different types, playing so important a role in the kinetics of molecular motions in liquids.

Prof. Fisher’s main works, however, were devoted to the theory of classical and quantum liquids. Prof. Fisher was the first to apply the correlation functions method to the study of equilibrium properties of simple liquids. His earlier findings were summarized in his book *Statistical Theory of Liquids*, 1961, translated later into English and published in the USA and India [5]. The book has undoubtely played a crucial role in the development of our understanding of the nature of liquid state matter.

Prof. Fisher's scientific and pedagogical activities became especially fruitful after his move in 1963 to Odessa, where he was invited to run the Department of Theoretical Physics at Odessa State University, named after I.I.Mechnikov. He initiated there numerous modern courses in theoretical physics taught to the undergraduate students and also a systematic seminar involving the graduate students and researchers. Those activities profoundly revealed Prof. Fisher's bright scientific and pedagogical talents and resulted in forming a wide circle of students and colleagues around him.

After his arrival to Odessa State University, Prof. Fisher started researching into various problems of the critical state, such as fluctuations, kinetics of diffusion processes, hydrostatic effect, viscosity, sound velocity, etc. [6 - 11]. He revived an old idea by M.Leontovich about a nonlocal coupling between the density and concentration fluctuations and developed a phenomenological theory of fluctuations in multicomponent solutions near their critical states. As a result, all concentration – concentration correlation functions were proved to be long-ranging and asymptotically expessable in terms of a single and the same function. The diffusion processes near the critical point were shown to be very slow and the corresponding equation nonlinear. The equation revealed an oscillatory-like concentration distribution, quite different from the classical behavior. Problems of statistical theory of equilibrium liquids always remained in the center of Prof. Fisher’s scientific activity. This is evidenced by both his reviews [12-16] and original works [17-23].

A series of Prof. Fisher's works were devoted to the structure of liquids [20, 23], the structure factor *S(k)* being one of their major characteristics. Earlier, *S(k)* had been shown [24] to be a non-analytic function, with its third derivative discontinious. Such a peculiarity resulted from the long-distance behavior of the interparticle potential $\Phi(r) \sim r^{-6}$. Prof. Fisher noticed that, in reality, $\Phi(r) \sim r^{-7}$, which corresponds to the fact that the speed of light is finite. In such a case, the radial distribution function *g(r),* related to *S(k)* through the Fourier transformation, behaves asymptotically as $g(r) \sim r^{-7}$ and, therefore, the behavior of *S(k)* is significantly different from the result [24].

It is also worth mentioning Prof. Fisher's works on the behavior of many-particle distribution functions F_n near the critical point [21, 22]. Prof. Fisher pointed out that their analysis is important because many thermodynamic derivatives are expressed in terms of F_n, with $n = 2,3,4,\ldots$. In collaboration with his coworkers, Prof. Fisher showed that in the vicinity of the critical point the three-particle distribution function F_3 can be asymptotically expressed in terms of F_2 and its derivatives. Similar expressions were obtained for F_4 as well. Those results can be considered as additional sum rules for F_n.

During many years, Prof. Fisher investigated equilibrium and kinetic properties of water [25-28] and hydrated ions solutions [29-31], having obtained here some interesting results, too. It is also worth mentioning a graceful work on the statistical thermodynamics of incompletely defined systems, with the model potential depending on the density and temperature [32].

While performing his research on liquid ^4He, ^3He and their solutions, Prof. Fisher obtained some new results [33, 34]. It had been known that at low temperatures dilute solutions ^3He in ^4He were in the superfluid state and quantum vorteces might develop in there. Prof. Fisher and his co-workers found that the quasiparticles which correspond to the normal component and the vorteces effectively attract one another, causing absorption of the normal component by the vorteces. The most interesting consequence of this picture is a possibility of forming a linear fermi-liquid system along the vortex. Other interesting results were obtained in the works on the mobility of positive ions in a dilute solution of ^3He in liquid ^4He, those on the roton shells of negative ions in liquid helium, and those dealing with the effect of the finite-time excitations on thermodynamic properties of $HeII$ [35-37].

The year 1957 signified the beginning of a new era in the study of liquids – computers started to be used for modeling statistical properties of liquids. Prof. Fisher was the first to draw attention to computer "experiments" as a powerful tool for investigation of disordered systems [38, 13]. In 1971, Prof. Fisher published an article on the autocorrelation velocity function of a molecule in classical fluid [40]. It explained some "unusual" results of the early computer experiments and also promoted a new qualitative understanding of the nature of molecular motions in liquids. In fact, it was Prof. Fisher and his post-graduate student Sokolovskaya who in the late 1960s first found the $t^{-3/2}$-asymptotic behavior of autocorrelation velocity function (unpublished result). In 1971, Prof. Fisher developed a theory of thermal hydrodynamic fluctuations within the Lagrange formulation. He regarded the low-frequency part of the molecular thermal velocity in equilibrium liquid as the velocity of its "drift" in the hydrodynamic fluctuation field. His simplest model of uncompressed liquid further developed the classical jump model. Some other developments of Prof. Fisher's model were given in [40, 41].

We would like to point out to the work by Prof. Fisher and Komarov [42], too. They generalized the time correlation functions method to explain light scattering experiments. That work stimulated a number of theoretical and experimental studies.

One of the last Prof. Fisher's work [43] was devoted to the study of the exponential asymptotic in the spectra of molecular light scattering in gases and simple liquids. According to Prof. Fisher, the phenomenon reflects the time dynamics of the initial phase of intermolecular collisions within the scattering system.

A comprehensive list of Prof. Fisher's publications can be found in [44].

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N. P. Kovalenko, A. V. Zatovsky