

# QUANTUM-FIELD AND GROUP APPROACHES IN THEORETICAL PHYSICS

WORKSHOP IN MEMORY OF PETR IVANOVICH FOMIN

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## TO THE MEMORY OF PETR IVANOVICH FOMIN

Petr Ivanovich Fomin, Doctor of Sciences, Professor in theoretical physics, Corresponding Member of the National Academy of Sciences of Ukraine, Head of the Theoretical Physics Department at the Institute of Applied Physics of the National Academy of Sciences of Ukraine (Sumy), and leading researcher of the Bogolyubov Institute for Theoretical Physics of the National Academy of Sciences of Ukraine (Kyiv) had passed away on the 5<sup>th</sup> of October, 2011.

P.I. Fomin was one of the brilliant theoretical physicists whose scientific investigations greatly contributed to the world-wide recognition of the Soviet, and later on, after the SU disintegration, the Ukrainian School of Physics.

P.I. Fomin was born in the village of Zhykharevo, Orel Region, on June 20, 1930. When a school-boy, he was distinguished by a lively mind and curiosity to know how the world works, which eventually prompted him to choose his way in life. So, it was not by chance that after finishing a secondary school P.I. Fomin went to study physics at the Leningrad State University, but in 1951 he moved to Kharkov where he completed his course at the Kharkov State University, and was offered a post-graduate studentship under A.I. Akhiezer, the well-known theorist.

Since 1957 P.I. Fomin worked at the Kharkov Institute of Physics and Technology, where he obtained his Ph.D. and, afterwards, Doctor of Sciences Degree. In 1972 P.I. Fomin left Kharkov and moved to the Bogolyubov Institute for Theoretical Physics in Kyiv, where two years later (in 1974) he was appointed Head of the Department of Astrophysics and Elementary Particles. In 1981 P.I. Fomin obtained the rank of Professor, in 1982 the title of Honoured Scientist, and in 1990 he was elected the Corresponding Member of the National Academy of Sciences of Ukraine. In 1989 P.I. Fomin became a winner of the N.P. Barabashov Prize of the National Academy of Sciences of Ukraine.



Petr Ivanovich Fomin  
(20.06.1930 – 05.10.2011)



The investigations of P.I. Fomin (over 150 publications) are devoted to the problems of current interest in the quantum field theory and particle theory, gravitation, astrophysics and cosmology, theory of superfluidity and superconductivity. Many original ideas and interesting results in these areas are due to P.I. Fomin. Among his most distinguished results which are widely known and recognized by the physics community is the idea of the quantum birth of expanding Universe based on the effect of gravitation instability of the physical vacuum, also discovered by P.I. Fomin. This theory, providing the basis for a new area of research, namely, quantum cosmology, eliminates most of the principal difficulties encountered in the classical Friedmann cosmology.

Predictions concerning the spatial closeness of the Universe and the existence of dark matter in space were subsequently confirmed by the astronomical ob-

servations. According to Fomin's theory, dark energy and dark matter have the same nature. This is the vacuum condensate having the property of superfluidity. In particular, it leads to the value of the mass ratio of dark matter and dark energy of the order of one-third.

In the field of particle physics and quantum field theory P.I. Fomin investigated the structure of the physical vacuum and its manifestation in various physical phenomena. In quantum electrodynamics, he obtained significant results concerning the radiation effects in high-energy scattering processes studied in high orders of perturbation theory. For the first time the problem of "superconducting type" was solved for the fermion spectrum in quantum electrodynamics, permitting the dynamical origin of fermion masses to be explained. The ideas and results obtained in quantum electrodynamics were further developed in quantum chromodynamics - the field theory of strong interactions. P.I. Fomin with his pupils (V.A. Miransky, V.A. Gusynin and Yu.A. Sitenko) were the first to propose a mechanism for the dynamical origin of the quark and hadron masses which is related to the production of a quark-antiquark vacuum condensate as a relativistic analog of the Cooper pairing in the strong quark-gluon interaction.

The work on the coherence effects in bremsstrahlung observed in single crystals which P.I. Fomin performed together with A.I. Akhiezer and N.F. Shul'ga, initiated a new approach to the description of coherence phenomena at high energies which was successfully developed in the subsequent years.

In modern astrophysics, P.I. Fomin proposed an elegant solution for the problem of the physical nature of the high-energy activity of quasars, radiogalaxies, and active galactic nuclei, in particular, the nature of their characteristic activity in the form of relativistic jets. To solve this problem, he made use of a concept, adopted in modern particle physics, of the existence of quantum field condensates in the vacuum similar to the quantum condensates in the superfluid. This approach has led to a quantitative theory that gave a clear description of the whole power range of the jet activity of the observed cosmic objects.

Under the guidance of P.I. Fomin an explanation was found for the phenomenon of superpowerful radio-frequency radiation from the Jupiter-Io system, which for a long time was a puzzle to astrophysicists. This phenomenon turned out to be a version of the so-called superradiation, a collective coherent spontaneous radiation occurring in the system of electrons on high Landau levels in the Jupiter's magnetic field.

P.I. Fomin is the author of a new approach to the development of a microscopic theory for superfluid helium-II as a quantum fluid with a lattice-like arrangement of atoms. As a result, a simple analytic formula for the Landau dispersion curve was derived which was in good agreement with the known neutron-graphical data over a wide range of momenta.

Two interesting papers of P.I. Fomin that attracted attention of geophysicists are devoted to the solution of two problems related to the interior dynamics of the Earth: the problem of geomagnetic field inversion and the problem of the existence of the so-called macrodrop mode of the mantle convection.

In his last years P.I. Fomin was preoccupied with the problem of the wave function reduction in quantum mechanics and a quantum field vacuum model of dark energy and dark matter.

In 1994 P.I. Fomin accepted the proposition of Academician V.E. Storizhko, Director of the Institute of Applied Physics of the National Academy of Sciences of Ukraine (IAP NASU), and moved to Sumy to take up the position of Head of the Theoretical Physics Department, which he held until his death. Although his principal interest was focused on fundamental problems of theoretical physics, he recognized the important role of applied research and was always ready to support it in every possible way. That is why in his department, together with a team studying quantum electrodynamics, there were researchers who developed theoretical models for various analytical techniques or the theory of phase transitions in ferromagnets.

The most significant results obtained by the IAP theorists led by P.I. Fomin in last several years include:

- the effects of the dynamical chiral symmetry breaking with the vacuum condensate formation in quantum chromodynamics and in the theory of electroweak interactions are shown to explain the nature of inertia, i.e., the left-hand side of Newton's equations, as a purely vacuum quantum-field effect, namely, as a manifestation of the "vacuum wind", arising in the bodies accelerated relative to the vacuum condensates. In contrast to the hypothetical classical "ether wind" of the XIX century, the "vacuum wind" is proportional to acceleration rather than to velocity (2006);
- in the framework of the quantum-vortex model of the relativistic jet activity of quasars the time evolution and typical activity times of these objects were studied. The typical times predicted by the theory were found to range from 50 to 100 million years, which agrees by the order of magnitude with the observations. The formula for the typical time of the quasar evolution includes only three universal constants and the dynamical quark mass known from hadron physics (2007);
- based on the integrated scheme - the physics of vacuum condensates in quantum chromodynamics, relativistic superfluidity theory, and physics of rotating Kerr black holes - the quantum-vortex theory was developed for the relativistic jets in quasars, radiogalaxies and active galactic nuclei. The law was found govern-

ing the evolution of the jet energy in time as well as the dependence of the jet length on the average density of the interstellar gas encountered by the jets (2008);

- theoretical investigations were performed into the production of an electron-positron pair by an electron in an external magnetic field near the threshold. The kinematics of the process was studied and threshold values were determined for the particle momenta. It was shown that a dominant role belongs to the process with the initial electron spin oriented along the magnetic field. The estimated probability of the process per unit time is  $10^{13}\text{s}^{-1}$ . The production of an electron-positron pair by an electron of ultrarelativistic energy was observed in the field of an intense laser wave in the SLAC accelerator and still needs an adequate theoretical description. As is known, the external electromagnetic field configuration is not significant at relativistic energies, therefore the process in the magnetic field is expected to have similar characteristics (2010, in collaboration with R.I. Kholodov and O.P. Novak);
- a solution was proposed for the fundamental "problem of reduction" in quantum mechanics, namely, the problem of the abrupt change of the quantum state (wave function) of an object occurring in the measurements. The internal dynamics of the wave packet is shown to be considerably nonlinear, being described by

equations of hydrodynamical type of which the first is the continuity equation and the second has the form of the dynamical equation for superfluids, which under certain conditions leads to the reduction of the wave function (2011).

P.I. Fomin was always kind and friendly with his associates, his friends, his colleagues, and his disciples. Of virtues he valued most and followed himself were the devotion to Physics and incessant aspiration to self-education.

His kindness, his generosity, his ability to love are especially manifest in his attitude to his family. Once he said: "My family, my wife, particularly, my children make me the happiest man. My sons and my daughter are nice people, they are open-hearted, honest, with a sense of humour. I enjoy their company. I am happy to have the time of my life." His willingness and readiness to help, encyclopedic erudition, scientific intuition and adherence to principles, optimism and love for life, ability to be natural and well-disposed in all circumstances, tact and refinement are only some of the qualities that make up the character of P.I. Fomin, the outstanding scientist and striking personality. There was not science alone - there were brilliant issues of wall-papers edited by P.I. Fomin during many years, breath-taking philosophical discussions, lectures for freshmen, and many other things...

The death of P.I. Fomin is a great loss for physicists and for many other people. We all feel keen sorrow. The memory of P.I. Fomin will encourage and help us in our life and work.

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