

PERSONALIA

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In memory of Evgenii Grigorievich Maksimov

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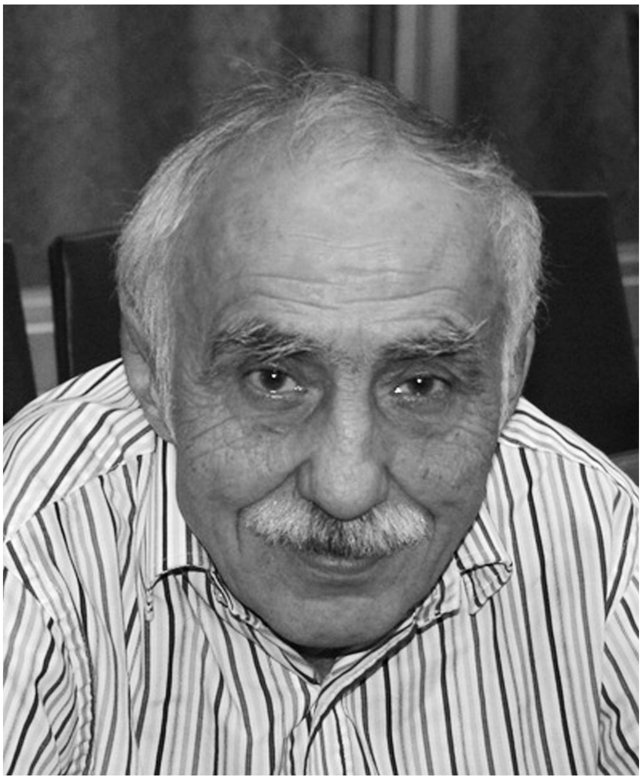
E G Maksimov, a corresponding member of the Russian Academy of Sciences (RAS), the Head of the Theory of Superconductivity Section at the I E Tamm Theoretical Physics Department of the P N Lebedev Physical Institute of the Russian Academy of Sciences, passed away on April 30, 2011. Evgenii ('Zhenya') Maksimov belonged to a generation of physicists that started their career in the golden age of physics, the 1960s. As a contemporary poet observed, "Looks as if physicists are in, looks as if lyricists are out...." [1] Those were years of enthusiasm in social life, which inspired a generation of people socially active and of broad interests. This is very true of E G Maksimov, who was a top expert in the theory of superconductivity, lattice dynamics, electron-phonon coupling, *ab initio* calculations of materials properties, and ferroelectricity. He made invaluable contributions in all these areas. Many physicists recall his smart and witty speeches, never leaving listeners indifferent.

Evgenii Grigorievich Maksimov was born on October 27, 1938, in the town of Aprelevka near Moscow, well known in the USSR for its vinyl records plant. His father, Grigorii Vasil'evich Maksimov, had worked at this plant before he became a soldier in the WWII, and perished in battle in 1943. His mother, Anna Gavrilovna Kuleshova, then became the sole breadwinner for the family. Zhenya was an honors student in high school and graduated with a Gold Medal (*summa cum laude*). He was known among the students for his poetry writing and his photographic memory: he could read a page of German text in one minute, and then reproduce it exactly, by heart. In 1955 Evgenii was accepted to the Physics Department of M V Lomonosov Moscow State University (MSU). At that time, the Physics Department at MSU employed such outstanding scientists as I K Kikoin, L D Landau, and M A Leontovich. In 1963 Maksimov was accepted as a Ph.D. student at the Theoretical Physics Department (TPD) of the Lebedev Institute, and his subsequent scientific career was inseparable from this Department. His adviser was David Abramovich Kirzhnits, a universal theorist successfully working on nuclear physics, astrophysics, quantum field theory, and condensed matter. He helped Evgenii to master the methods of theoretical physics, learn to analyze rigorously the results, and be an objective judge of his own work and the work of others.

During that time at TPD, V L Ginzburg initiated exploratory research on the problem of high temperature superconductivity (HTSC). All contemporary superconductors then had a critical temperature $T_c \leqslant 23$ K. It was well established that superconductivity in these materials was driven by electron-phonon (EP) coupling. The main thrust of HTSC research was the quest for superconductors where phonons would be supplanted by electronic excitations. Having higher energy, they would have provided a higher T_c. The initial idea was to utilize thin films, embedded in highly polarizable media. However, it was shown by Maksimov and Kirzhnits, in some of Maksimov's first papers (1965–1966), that in such sandwiches T_c is defined by the coupling constant averaged over all film layers, including deep inside, so the effect of the surface contact with another medium should be small.



Evgenii Grigorievich Maksimov
(27.10.1938 – 30.04.2011)

Important progress in the HTSC theory was brought about by a new formulation of the theory of superconductivity, in terms of the dielectric function (DF), proposed in 1970 by D A Kirzhnits, E G Maksimov, and D I Khomskii. In a way, it reduced the issue of HTSC to the physically more transparent problem of screening. In this framework, they derived a universal expression for T_c, applicable for both phonon and electronic mechanisms of superconductivity. They found that an electronic mechanism can only be efficient if the static (nonlocal) DF changes sign, becoming negative. This finding, in turn, allows one to analyze some crucial issues in a general framework, without relying on particular models. Maksimov further showed that a negative DF, while softening some phonons, does not necessarily trigger lattice instability. In doing that, he elucidated the

[1] Initial lines of Boris Slutsky's poem "Physicists and Lyricists," which were widely used in the 1960s to describe public discussions on the role of art and science in Soviet society. Translated by V M Zubok.

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decisive role of the local field effects and the relation between HTSC and the stability with respect to spontaneous spin polarization. Somewhat later, O V Dolgov, D A Kirzhnits, and E G Maksimov demonstrated that a negative DF is consistent with causality and Kramers–Kronig dispersion relations. However, despite such progress, superconductivity with $T_c \sim 100-300$ K remained elusive, even in theoretical calculations. In ensuing heated discussions Evgenii used to compare static attraction among electrons, mediated by excitations themselves of electronic origin, with Baron Münchhausen's feat when he pulled himself by his hair out of a swamp.

A ramification of this research was the realization that one cannot predict HTSC without quantitative calculations, based upon first-principles and addressing all properties of the material in question. In the early 1980s E G Maksimov advocated inception of a dedicated workgroup at TPD charged with first-principles calculations of materials' using the Density Functional Theory (DFT). While many of the groups involved in similar projects concentrated on advancing computational methods, Maksimov and his group concentrated on studying physical processes in complex systems that could not be described by simple models. Within a few years, they obtained new results on optical, magneto-optical, and plasmon spectroscopy of transition metals, investigated one of the most burning problems of the DFT, namely, the dielectric gap problem, established its intimate relation to the non-locality of the screened exchange interaction in insulators, and derived a simple correction to the DFT gap. A few years later, in the early 1990s, a principally new, efficient method for calculating phonon spectra and EP interaction *ab initio* was developed in Maksimov's group. Using this method, numerous phononic superconductors have been investigated, and their superconducting gaps, critical temperatures, and temperature-dependent resistivities and thermal conductivities computed, with excellent agreement with the experiment.

The discovery in 1986 of high-temperature superconductors, first $La_{2-x}Sr_xCuO_4$, and then $YBa_2Cu_3O_7$, triggered a barrage of experimental and theoretical studies. Maksimov's group was among the first to study their electronic structure, X-ray emission spectra, and nuclear magnetic resonance. Particularly worth mentioning are calculations of the optical spectra, which reproduced rather accurately the experiment in a broad frequency range, and in many cases actually predicted the experimental results. Of special interest was the low-frequency range, $\hbar\omega \leqslant 0.2$ eV, where the optical conductivity is strongly affected by interaction of electrons with bosonic excitations (phonons, spin waves) and defects. The theoretical foundation for theses studies had been laid out in Maksimov's papers of the late 1970s — early 1980s, where he investigated materials with strong electron–phonon coupling, the isotope effect, nonmagnetic impurities effects, and anharmonicity. In the 1990s this study was extended to include vertex corrections to the susceptibility, which are responsible for the difference between the superconducting and transport coupling constants (λ and $\lambda_{\rm tr}$r), and for the fulfillment of the optical sum rule. It turned out that EP interaction affects optical spectra far beyond the phonon frequency range, up to kT and $\hbar\omega \sim 0.2$ eV. Calculations reproduced the reflectivity spectra and linear temperature dependence of the resistivity in HTSC at $T > T_c$ and rendered an estimate of the EP coupling constant. Using the same methodology, Maksimov and his collaborators in 2008 found a novel resonance-like effect in superconductors close to a magnetic instability (such as $MgCNi_3$), namely, that spin excitations in such systems enhance the isotope effect, while suppressing T_c.

The most challenging and controversial issue in HTSC is the pairing mechanism. Most theorists believe that the strong same-site Coulomb repulsion between electrons is a leading, if not *the* leading, source of electron pairing. Over time, this point of view has stimulated research on magnetic, electronic, and other unconventional mechanisms of superconductivity. However, Evgenii, using his experience accumulated during the early years of HTSC research, was more inclined toward a conventional strong EP coupling mechanism. At the same time, he was closely monitoring the new works in the field, especially experimental ones. His point of view was presented in detail in a review, written in 2010 with M L Kulic and O V Dolgov. In that review numerous experimental data were analyzed, and it was deduced that in the optimally doped cuprates the EP coupling constant λ exceeds 1. A theoretical analysis presented in the review identifies the key features of HTSC cuprates: weak screening, renormalization of the electron dispersion compared to DFT, strong interaction with out-of-plane phonons, and a maximum of the electron–phonon spectral function for the forward scattering. In this framework, one can qualitatively rationalize such facts as the d-wave symmetry of the superconducting state, large disparity of λ and $\lambda_{\rm tr}$, as well as other unusual properties of HTSC cuprates.

A profound understanding of the electronic structure, lattice stability, and lattice dynamics let Maksimov contribute substantially to the theory of highly compressed matter, and to the theory of ferroelectricity, as well. His first-principles calculations covered both ground state and temperature-dependent properties. They included development of a polarizable and deformable ion method, temperature-induced changes in the crystal structure of perovskites above and below a ferroelectric transition, justification of the soft-mode model for the same materials, and $P-T$ phase diagrams of metals under high pressure.

As a theorist, Maksimov always kept close contact with reality. This was ensured by careful formulation of problems, close collaboration with many experimental groups, regular discussions with experimentalists regarding the physics of the problem at hand and attention to detail and to experimental techniques. Quite often such discussions bore fruit not only in the form of new theoretical ideas, but also in the form of new directions of experimental research. Evgenii always strove to recognize, behind rigorous and often rather sophisticated theoretical constructions, a clear physical picture, accessible also on an intuitive level. His broad knowledge and harmonious approach to physical problems were something he strove to pass on to his students and postdocs. He mentored many world-class theorists, working now in various subfields of condensed matter physics.

A distinguished scientist, Maksimov was not indifferent to the problems of Russian science, always stressed its important role, and defended, when needed, the priority of Russian scientists. He served on numerous Ph.D. committees and proposal evaluation panels of the Russian Foundation for Basic Research, was a member of the RAS Scientific Council on Condensed Matter Physics, and was an active member of the *Physics–Uspekhi* Editorial Board. His presentations and comments were always distinguished by their sharp wit and outside-the-box approach to scientific and organizational issues. Many recall his speech at the General

Assembly of the Physical Sciences Division of RAS in 2010, where he spoke about the Russian Academy's role in the development of basic science and higher education in the present difficult situation in this country. His speech triggered a heated discussion and resulted in a memorandum of the Physical Sciences Division, addressed to the General Assembly of the whole Academy.

When speaking at conferences and seminars, Evgenii was in his element. There he revealed in their entirety his broad knowledge, his nature as a fighter, his sharp wit, and his swift reactions. When facing a particularly challenging presentation, he was always dressed in a red shirt (no jacket), symbolizing readiness to fight and to challenge his opponents to a discussion. Maksimov was one of the most active participants in the famed Theoretical Physics Seminar moderated by Vitalii Lazarevich Ginzburg. Ginzburg valued highly Maksimov's scientific integrity and independence of his scientific views. He often sought Evgenii's opinion and used his expertise in condensed matter theory. The two shared many things in common: many personality traits, dedication to superconducting science, and similar views on many issues. Ginzburg treated Evgenii as his favorite student: he often discussed with him various problems and plans for joint publications, or solicited a review for *Physics–Uspekhi*.

E G Maksimov was a very lively, easygoing person, addressed often just by his nickname, Zhenya. When he, on his way in the Department's hallway, would stop to chat with a passerby, immediately a circle of listeners would gather around them. Often the conversation would start with contemporary events, but expand into the recent past. Evgenii took pleasure in recalling his encounters with many interesting characters, not necessarily physicists. His narrations had a folkloric flair; some details would fade away with time, while other would enter the story, but the essence of the account would remain unaltered, while the form would grow more colorful and captivating. Evgenii loved poetry and was a skillful poet himself:

The images still lack their power,
Their final forms are not in sight,
Yet as a bud reveals its flower,
So nascent words will come to light.

And while the sounds are being nurtured
And words are ordered in their place,
You feel as if you're being tortured,
And losing something in this chase.

And when you come to the grand finale
Of words and sounds, powerful and great,
Stubborn as a rower on a galley,
You don't just labor, you create. [2]

These stanzas perfectly well convey that feeling of bursting creativity that accompanied Evgenii Maksimov his entire life, in science, in literature, and in all other endeavors.

V A Alekseev, P I Arseev, M A Vasiliev,
A V Gurevich, O V Dolgov, Yu M Kagan,
L V Keldysh, Yu V Kopaev, Yu E Lozovik,
M V Sadovskii, Yu A Uspenskii, V E Fortov

[2] Translated by I I Mazin.