

PERSONALIA

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Vladimir Evgen'evich Zakharov (on his 70th birthday)

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Vladimir Evgen'evich Zakharov, an outstanding theoretical physicist and full member of the Russian Academy of Sciences, turned 70 on August 1, 2009. He is credited with co-founding and fostering modern nonlinear physics. Zakharov's diverse contributions to his chosen field have brought him world-wide renown: the extremely high impact of his publications is confirmed by a citation index of more than 17000, which is the fourth highest among Russian scientists.

V E Zakharov belongs to the remarkable cohort of the first graduates of the Physics Department of Novosibirsk State University and the school of academician R Z Sagdeev. His scientific career began at the famous Budker Institute: the Nuclear Physics Institute of the Siberian Branch of the USSR Academy of Sciences. In 1974 he joined the L D Landau Institute for Theoretical Physics, where he became director in 1992, a post that he held for more than ten years. In 2004 he moved to the P N Lebedev Institute of Physics, where he has been heading the section of mathematical physics ever since.

Dr. Zakharov's research interests span the whole spectrum of modern physics. He made fundamental contributions to the nonlinear theory of plasmas, fluid dynamics, solid state physics, nonlinear optics, oceanography, general relativity, field theory, and mathematical physics. His pioneering results in the theory of integrable systems and the development of the inverse scattering method — a gem of 20th-century mathematical physics — have brought him recognition by theoretical physicists and mathematicians alike.

Dr. Zakharov's main contributions are part of the research community's efforts in the development of three major areas of nonlinear physics: the theories of wave collapse, solitons, and wave turbulence.

In the theory of wave collapse, Zakharov's fundamental achievement is the prediction of the Langmuir-wave collapse, published in a 1972 paper. The earlier theory of Langmuir turbulence, based on the random phase approximation, had predicted the formation of condensate at $k = 0$ and had failed to explain many existing experimental facts. It turned out that this scenario of plasma-turbulence evolution is unfeasible due to the instability of the condensate. The collapse of Langmuir waves, which is the nonlinear phase of that instability, leads to the compression of the Langmuir wave packets down to the size of several Debye radii, in the course of which fast electrons are produced. The theory of Langmuir collapse is based on what is now called Zakharov equations, derived by the method of averaging and capable of describing the interaction of Langmuir and ion-acoustic waves in plasma, in particular the interaction between high and low acoustic type frequency waves. This work has dramatically changed the understanding of plasma turbulence and of the dissipation mechanisms of high-frequency wave turbulence in situations

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of collective heating, for example, by electron beams or a high-frequency electromagnetic field.

The creation of the theory of wave collapse begins with Zakharov's work on the theory of Langmuir collapse and the self-focusing of light in two- and three-dimensional geometries. It culminates in the studies of the interaction between collapses and weak turbulence and of the impact of plasma collapses on particle spectra. This theory is Zakharov's fundamental contribution to the physics of nonlinear wave processes. According to the papers by Zakharov and his students, the existence of a wave collapse or solitons in a wave system depends on whether or not the Hamiltonian of the system is bounded from below. If it is, its minimum corresponds to stable solitons. Precisely in this way, i.e. as solutions to the Zakharov – Kuznetsov equation, stable three-dimensional ion-acoustic solitons have been found in a magnetized plasma.

The development of the theory for Kolmogorov spectra of wave turbulence, now often referred to as Kolmogorov – Zakharov spectra, is one of Zakharov's major achievements in the theory of turbulence. Kolmogorov – Zakharov spectra are power-law spectra corresponding to constant spectral fluxes of energy or quasiparticles. They represent exact solutions of the kinetic wave equation which are derived

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with the help of a special conformal transform, dubbed the Zakharov transform. The spectra describe downscale (direct) and upscale (inverse) wave cascades. Zakharov's theory of the Kolmogorov spectra of wave turbulence is relevant to the turbulence of rough seas, acoustic turbulence, and the excitation of plasma oscillations. It has had a significant impact on oceanography and plasma physics, shaping as it did to a large extent their state of the art. In recognition of his outstanding contribution to the turbulence theory, and in particular to the prediction of the inverse cascade, V E Zakharov was awarded the International Dirac Medal in 2003.

Dr. Zakharov is a co-founder of a soliton theory based on elaborate mathematical methods of integrating nonlinear partial differential equations using the formalism of inverse scattering transform. Together with A B Shabat, he integrated the nonlinear Shrödinger equation that describes the self-focusing and self-modulation of light in nonlinear dielectrics. The mathematical side of this boils down to solving the inverse problem for the Zakharov – Shabat operator with a time-independent spectrum. All soliton parameters depend solely on the discrete spectrum of the operator. That is the reason why, despite being nonlinear coherent localized structures, solitons prove to be structurally stable: their shape remains unchanged after scattering on both solitons and non-soliton perturbations.

Soliton theory opened up the possibility of utilizing optical solitons as digital data in fiber-optic communication lines. Thanks to the efforts of Dr. Zakharov and his students, this avenue of research has greatly diversified in recent years and has found many applications in innovative telecommunication technologies.

The Zakharov – Shabat dressing procedure proposed in 1974 – 1979 has defined the modern state of the theory of nonlinear waves and solitons. The method, which was developed in the framework of the theory of integrable models, finds soliton solutions, or indeed any other solutions, to a nonlinear equation by deforming an arbitrary bare solution. The other approach, proposed and elaborated by Dr. Zakharov and his students, is based on a nonlinear Riemann problem and its modifications. This work was crowned by Zakharov's solution of the classical problem of orthogonal curvilinear coordinate systems in the Euclidean space of an arbitrary dimension. The problem was posed in the early 19th century and is associated with great mathematicians of the past, in particular Riemann and Bianchi. Further development of these methods demonstrated their efficiency in field theory, gravitation, nonlinear optics, and fluid dynamics.

In 1978, in collaboration with V A Belinsky, V E Zakharov solved an important problem in general relativity: integration of Einstein equations for two-dimensional metrics. This enabled classification of solutions using spectral methods based on variable spectral parameters. By applying the method of inverse scattering transform, Zakharov and his students fully solved the superfluorescence problem. In particular, they found asymptotic states: pulses that grow as they propagate in an inversely populated two-level medium, which are similar to a precursor in a stable medium. The progress of the inverse scattering method was radically influenced by Zakharov's paper of 1981 on integrating the Benny equations, which describe wave propagation on shallow water taking into account the nonpotentiality of the velocity field. It is this paper that proposed a method that can be used for studying hydrodynamic-type multidimensional systems.

V E Zakharov collaborated with V S L'vov, S S Starobinets, and others on the theory of parametric excitation of waves by a coherent source, the so-called S-theory. It is based on an original idea of describing above-threshold turbulence with normal and anomalous pair correlators. The theory has become, in some sense, an analog of the BCS theory from superconductivity. Its important result was the prediction of a singular nature of stationary turbulence spectra, later confirmed in experiments on parametric excitation of spin waves in ferromagnets. In the course of this work Dr. Zakharov and his students also developed the theoretical basis for singular spectra of plasma turbulence. These spectra manifest themselves as a set of jets or even points in the k-space and are observed in induced scattering of electromagnetic waves in plasmas.

In recent years V E Zakharov has obtained a set of fundamental results pertaining to the theory of collapse, to fluid dynamics with a free surface, and to the method of the inverse scattering problem. The most significant achievements obtained in collaboration with his students form the theory of 'freak waves'. These waves pose a problem of practical significance for shipping and in the construction of sea platforms. Dr. Zakharov developed the theory of sea surface waves for the purposes of forecasting storms, a theory based on analytical results and direct numerical simulations.

Throughout his scientific carrier Vladimir Evgen'evich has devoted much of his attention to tutoring talented young researchers. Directly under his guidance, a large number of students have found their way in science. Collectively they are referred to as the "Zakharov school" of nonlinear physics, and are renowned worldwide. His students successfully work in many countries. He has helped to organize stipends for outstanding Russian scientists and to support various workshops. He has been Head of the Scientific Council of RAS on the nonlinear dynamics problem (since 1987).

Vladimir Evgen'evich has been the editor in chief of the *East European Journal of Physics* (since 2004) and the *Journal of Nonlinear Science* (1991 – 2001), an editor of the *Journal of Turbulence* (since 2001), *Physics of Life* (since 2002), and *Physica D, Nonlinear Phenomena* (1980 – 1999), and Chair of organizing and program committees of many renowned international conferences, symposia, and workshops on nonlinear physics.

The scientific contribution of V E Zakharov to fundamental studies in physics of nonlinear phenomena earned him State Prizes in 1987 and 1993.

His poetic gift is akin to his universality in science. He is a well-known poet, a member of the Russian Union of Writers. His poetry has been published over the years in the *Novyi Mir* and *Arion* magazines and in book form. His books are invariably in tune with our times, proving A P Chekhov's view "... that an artist's intuition is sometimes worth a scientist's brain, that they have the same goals and the same nature, and that, perhaps, as their methods mature, they are destined to merge one day... ."

His exceptional energy, benevolence, and honesty make him liked by a broad range of people.

Friends, colleagues, and students wholeheartedly extend their best to Vladimir Evgen'evich Zakharov on the occasion of his jubilee and wish him robust health, many happy years of creative work, and many more research achievements.

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