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PERSONALIA

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Vladimir Vladilenovich Kocharovsky (on his 70th birthday)

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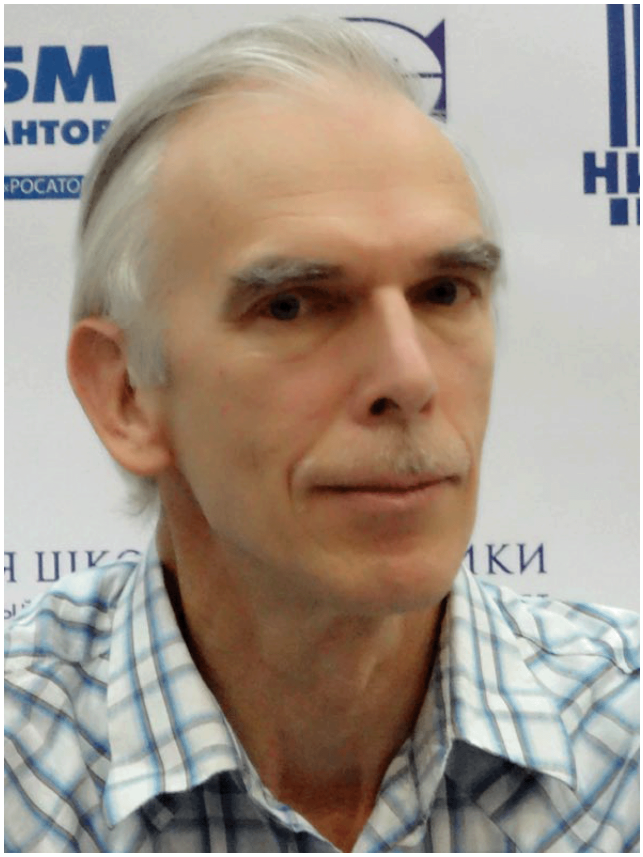
On October 15, 2025, the theoretical physicist, Academician of the Russian Academy of Science (RAS), head of the Astrophysics and Space Plasma Department at A.V. Gaponov-Grekhov Institute of Applied Physics, and doctor of physical and mathematical sciences Vladimir Vladilenovich Kocharovsky celebrated his 70th birthday.

V.V. Kocharovsky was born in the city of Sverdlovsk (now Ekaterinburg) and, since 1958, has lived in Nizhny Novgorod (formerly Gorky). Together with his twin brother, Vitaly Vladilenovich Kocharovsky (who also became an outstanding theoretical physicist), he graduated with a gold medal from Physics and Mathematics Lyceum No. 40, continued his studies at the Radiophysical Department of N.I. Lobachevsky Gorky State University (he was a Lenin scholarship recipient), and finished his education with IAP RAS (then IAP USSR AS) postgraduate courses under the supervision of the renowned astrophysicist Professor Vladimir Vasilyevich Zheleznyakov. Then, he consistently worked at IAP RAS: from 1978 to 2011 he took up all posts of research worker, eventually becoming head of a sector at the Department of Astrophysics and Space Plasma Physics. Since 2011, he has been heading this department. Since 2012, he has been a professor at N.I. Lobachevsky State University of Nizhny Novgorod (courses Plasma Astrophysics and Current Problems in Physics), where he teaches at the Faculty of the Higher School of General and Applied Physics, founded on the basis of IAP RAS.

In 1986, he defended his Ph.D. thesis, "Linear interaction of electromagnetic waves in inhomogeneous weakly anisotropic media," and in 1998, his D.Sc. thesis, "Mode superradiation in open resonators and extreme generation modes of electromagnetic fields by ensembles of quantum and classical oscillators."

The results of V.V. Kocharovsky's research in the field of theoretical physics and astrophysics have been highly appreciated by specialists in Russia and abroad. He has published over 400 original papers and 15 scientific reviews. All of his publications are characterized by a novel statement of the problems and an original approach to their solution, logical and clear physical arguments, deep insight into the processes and phenomena, a combination of analytical and numerical calculations, and a thorough substantiation and presentation of the models and approximations used.

His scientific interests as a universal physicist are quite extensive, namely, cosmic plasma and radio astronomy, cosmology and gravitation, high-energy and elementary particle physics, physics of space gamma-ray bursts and quasars, jet and shock-wave astrophysics, neutrino astrophysics and cosmic-ray acceleration, theory of radiation of



Vladimir Vladilenovich Kocharovsky

neutron stars and black holes, physics of solar atmosphere and planet magnetospheres, laboratory astrophysics and laser plasma, wave propagation and polarized radiation transport, electrodynamics of continuous media and radiophysics, nonlinear oscillations and waves, coherent and nonlinear optics, quantum optics and laser physics, classical and quantum field theory, physics of many-body systems and solids, physics of semiconductors and liquid crystals, low-temperature physics and superconductivity (including high-temperature superconductivity), phase transitions and Bose-Einstein condensation, problems of quantum calculations, and the advantage of quantum computers and simulators over classical ones.

In particular, V.V. Kocharovsky obtained some significant results in the study of different types of cosmic radiation sources and is a follower of Academicians V.L. Ginzburg and V.V. Zheleznyakov in this area, heading it at IAP RAS.

V.V. Kocharovsky investigated several *fundamental problems* in such different fields of physics as nonlinear dynamics of negative-energy waves in quantum gravitation and quantum electronics, light-matter interaction in quantum

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optics and laser physics, nonadiabatic mode coupling in electrodynamics of continuous inhomogeneous media and photon crystals, microscopic theory of critical phenomena in phase transitions, collective processes in neutron-star and black-hole magnetosphere plasma, mechanisms of acceleration and radiation of particles and the origin of superhigh-energy cosmic rays. He developed new quantum methods for the analysis of natural phenomena of an exponential level of computational complexity (inaccessible to classical computers) using matrix permanents and hafnians.

Worthy of note among V.V. Kocharovsky's theoretical results is the development of the notion of negative-energy waves and their dissipative instability in active media with quantum and classical oscillators, explaining the phenomenon of collective spontaneous radiation, and allowing an analytical description of its macroscopic quantum fluctuations. It was precisely the method for describing superradiation as dissipative negative-energy wave instability that made it possible to predict the existence of this phenomenon in classical systems of plasma physics and electronics and to find it under electron and hole recombination in semiconductor heterostructures. In particular, the first classical counterpart of Dicke superradiance, cyclotron superradiation, was proposed. In quantum optics, the method of phenomenological quantum electrodynamics of continuous active media for the analysis of collective quantum instabilities in nonequilibrium systems was developed. Renormalizability and causality of the quantum gravitation theory with the Hamiltonian unlimited from below was proved using the above-mentioned notions in the model of a conformally flat gravitational field interacting with a massive scalar field of matter, and the coexistence of infrared and ultraviolet asymptotic freedoms was discovered.

V.V. Kocharovsky obtained important analytical results in the physics of condensed media. He predicted the effect of Bragg-Coulomb electron paring as a result of electrons purely Coulomb interaction and the overturn processes under Bragg resonance leading to high-temperature superconductivity in layered compounds. Predicted and studied were the properties of quasiparticles of a canonical ensemble in a Bose–Einstein condensate (BEC), which make it possible to clarify its quantum statistics and dynamics of formation. In particular, anomalously large non-Gaussian fluctuations of the number of particles in a BEC was pointed out for the first time, and an analytical theory of the universal behavior of these fluctuations in the critical region of phase transition, including the structure of the lambda point in the critical BEC region for an ideal gas, was formulated. BEC fluctuations beyond the critical region for an interacting gas with a homogeneous or inhomogeneous condensate were calculated. A microscopic phase transition theory was formulated, reducing the solution to the problem of critical phenomena, including those for the three-dimensional Ising problem, to a calculation of the matrix permanent. On its basis, a universal estimate of complexity of quantum calculations was pointed out, and the possibility was substantiated of using for them fluctuations in a system of interrelated photons in a resonator and atoms in a Bose condensate. The universality of the matrix permanent and hafnian for describing the complexity level of critical phenomena and quantum information processes in many-body physics, fractal structures and chaos, and number-theoretical and *P*-hard problems in computational complexity theory has been revealed. Formulated and proved was a fundamental theorem on the hafnian, which provides an explicitly computable formula for the generating function of the matrix hafnian characterizing all *P*-hard computational problems. A scheme for sampling the number of BEC atoms in various excited states of supercondensate (Boson sampling) was proposed as a many-body quantum simulator, and it was proved that, when realized in atom-photon simulators, this scheme may demonstrate the advantage of quantum systems over classical computers.

V.V. Kocharovsky has elaborated several new methods to generate continuous and pulsed electromagnetic radiation in various active media. For example, he proposed using the phenomenon of superradiation to obtain unique modes of pulsed laser radiation with a low-Q resonator and continuous pumping. For superradiant lasers, a theory of mixed generation modes with a discrete and continuous radiation spectrum was developed, indicating, in particular, an efficient way of mode self-synchronization, and spontaneous symmetry breaking during the generation of one polariton mode in a homogeneous laser with a mirror-symmetric cavity was proposed. Proposed and realized were new types of semiconductor lasers — laser transistors and interband cascade lasers allowing the simultaneous generation of double-frequency radiation in optical or near infrared ranges and difference-frequency radiation in mid- or far infrared ranges in a continuous mode at room temperature. Intracavity nonlinear mode mixing in injection heterolasers of this type and direct-gap superradiance upon collective recombination of electrons and holes in semiconductor structures were experimentally obtained under V.V. Kocharovsky's guidance.

A striking example of the combination of theory and applications is his qualitative analysis of linear interaction of electromagnetic waves in inhomogeneous anisotropic media and in plasmas, which explains the polarization properties of radiation from magnetospheres of stars and planets and underlies the polarization diagnostics of inhomogeneous magnetoactive plasma in laboratories and space (the magnetospheres of the Sun, Jupiter, and Earth), as well as fiber lightguides and liquid crystals.

V.V. Kocharovsky has investigated a number of exotic quantum electrodynamic effects in a superstrong magnetic field as referred to neutron stars and primordial black holes. Thus, the possibility was indicated of the existence of annihilation-cyclotron lines of MeV radiation from neutron stars and the transformation of high-energy Hawking radiation from black holes into the MeV energy range due to an electromagnetic cascade in the ejected plasma at the last stage of their evaporation (hours and minutes). The shape of the cyclotron lines of X-rays from neutron stars was shown to be determined the scattering quantum. A method was developed for analyzing the dynamic spectrum of radio pulsars, providing information on the structure of the radio emission source in the magnetosphere of a neutron star. An analytical theory of self-consistent synchrotron and inverse Compton radiation, as well as its two-photon self-absorption and the processing of ultra-hard radiation on soft (X-ray) radiation, which provided for the first time a correct interpretation of observational data on cosmic gamma-ray bursts, blazars, and microquazars, was developed.

Results of an astrophysical nature may be supplemented with the following, far from complete, list of V.V. Kocharovsky's achievements in space plasma physics: the inevitability of the presence of a significant part of free

neutrons was established and their significant role in the dynamics and radiation of relativistic shock waves and jets near compact astrophysical sources was predicted, including the birth of neutrinos in the neutron-proton relativistic wind. Developed was a model of compact star collapse induced by a primary black hole which ended up inside. A new conversion mechanism for cosmic ray acceleration was proposed, driven by multiple transitions of particles from a charged state (protons, electrons) to a neutral state (neutrons, photons) and back, and fundamental electrodynamic constraints were established for all possible cosmic accelerators of particles of extremely high energies up to $10^{21} - 10^{22}$ eV. This provides the first qualitative classical explanation of the origin of super-high-energy cosmic rays, and their potential sources, as well as the maximum achievable charged-particle energies, were pointed out.

Specific features of multiscale multicomponent current structures, including turbulent ones, in both space and laboratory (laser) plasmas, have been studied using analytical and numerical methods. New classes of stationary current sheets and filaments with a self-consistent magnetic field in collisionless relativistic astrophysical and magnetospheric plasmas have been constructed analytically. Models of magnetopauses have been elaborated for the magnetospheres of planets, including Earth, and for the boundaries between magnetic clouds of the stellar (solar) wind for arbitrary non-Maxwellian particle energy distributions, such as kappa distributions, including in the presence of the shear of magnetic field lines. A theory of formation and self-similar evolution of Weibel-type magnetic turbulence in weakly collisional magnetoactive plasmas with anisotropic velocity distributions of particles, including a quasilinear stage of evolution, nonlinear growth saturation effects, and an anomalous self-consistent electric conductivity, has been developed. The existence of magnetopauses with consistent magnetic turbulence was predicted. Several transient filamentary structures of electric current and related megagauss magnetic fields in an expanding laser plasma with hot electrons formed by the ablation of targets with femtosecond pulses of multiterawatt lasers were interpreted. The propagation of a nonlinear Alfven pulse in a variable-diameter magnetic tube in the solar chromosphere was analytically described, and the electric field of the pulse was shown to be able to accelerate electrons up to an energy of the order of 1 GeV and to inject them into the coronal part of the loop.

V.V. Kocharovsky was a disciple of V.V. Zheleznyakov; in the 1980s and 1990s, he also went through an active scientific interaction with V.L. Ginzburg, who influenced the breadth of his scientific interests. About 15 years ago, V.V. Kocharovsky succeeded V.V. Zheleznyakov as head of the Department of Astrophysics and Space Plasma Physics and soon became editor-in-chief of the journal *Izvestiya Vuzov. Radiofizika* (*Radiophysics and Quantum Electronics* in English translation), i.e., inherited the position previously held only by V.L. Ginzburg and V.V. Zheleznyakov.

V.V. Kocharovsky is also a member of the editorial board of the journal *Pis'ma v Astronomicheskii Zhurnal* (*Astronomy Letters* in English translation), a member of several scientific societies, including the International Astronomical Union (elected in 1999), the Committee on Space Research, the European Physical Society, the American Physical Society, and the Optical Society of America. He is involved in the applied research and organization of scientific work. He is a member of RAS's commissions on education and pseudoscience and was long a member of the Council on Megagrants of the RF Ministry of Education and Science, and currently is a member of the Expert Council of the Russian Science Foundation. V.V. Kocharovsky received a scholarship for outstanding Russian scientists, was awarded the jubilee medal, "300th Anniversary of the Russian Academy of Sciences," the Medal of the "Order of Merit for the Fatherland," II Degree, and the RAS Certificate of Honor for his practical contribution to science.

V.V. Kocharovsky is a professor at UNN State University: among his students are now nine candidates and one doctor of sciences. He has headed the IAP RAS Seminar on Theoretical Physics for over 35 years. He is also the head of the IAP RAS postgraduate courses in physics and astronomy. He is actively involved in popularizing scientific knowledge and supporting the level of school education in physics. He is responsible for the long-term organization of the annual Nizhny Novgorod Festival of Sciences, Arts, and Technologies, Fenist, with a large number of invited talks aimed at various segments of the population and schoolchildren. He annually organizes the Round Table for physics and mathematics teachers of the Nizhny Novgorod region in the form of a five-day seminar at one of the summer boarding houses, where about 100 teachers discuss methodical problems of education, share experiences, and come to know interesting scientific news. He is also the main scientific trustee of the Nizhny Novgorod Planetarium, one of the leading planetariums in the country, and the organizer of the annual Nizhny Novgorod school astronomy Olympiads.

Colleagues and friends of Vitaly Vladilenovich wish him on this noteworthy birthday sound health, happiness, and new creative achievements.

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