

PERSONALIA

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Lev Matveevich Zelenyi (on his 70th birthday)

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August 23, 2018 was the 70th birthday of Lev Matveevich Zelenyi, the prominent scientist in the field of space plasma physics, the physics of solar–terrestrial relations, nonlinear dynamics, and the study of planets, brilliant theorist, Academician of the Russian Academy of Sciences (RAS), research supervisor of the Space Research Institute (SRI or IKI in *Russ. abbr.*) RAS, member of the RAS Presidium, full member of the International Academy of Astronautics, foreign member of the National Academies of Ukraine and Bulgaria (2008), Doctor of Physical and Mathematical Sciences, Honored Professor of the Moscow Institute of Physics and Technology (MIPT), and honorary member of the A F Ioffe Institute of Physics and Technology.

Lev Matveevich has devoted almost all his life in science to the work at IKI, where he progressed from postgraduate to Director of the Institute. He is a world-known and frequently cited scientist with recognized results.

Lev Matveevich Zelenyi was born on August 23, 1948 in Moscow. In 1966, he finished the famous physical and mathematical School No. 444 and entered MIPT. As a student, he did practical work at the Scientific Research Institute of Thermal Processes (now the Keldysh Research Center) where he became engaged in nuclear rocket engines. In 1969, when he was a fourth-year student, he was invited to continue his learning at the newly established Space Physics Department, which began personnel training for IKI of the Academy of Sciences of the USSR (now IKI RAS) founded according to a decree by the USSR Council of Ministers of May 15, 1965. According to the plan of the President of the USSR Academy of Sciences, Academician M V Keldysh, this new Institute should have become the leading one in what concerned all research work in space.

In 1972, on graduating with an honors diploma from the Aerophysics and Space Research Faculty of MIPT, Lev Zelenyi came to work at IKI. At first, he solved theoretical problems of electrodynamics under the guidance of Leonid L'vovich Vanyan (the founder of the Space Physics Department at MIPT). However, a growing deep interest in space physics led him to Albert Abubakirovich Galeev, who then became head of the department of Space Plasma Physics. Under his tutorship, Lev successfully defended in 1977 his Candidate of Sciences thesis, "Plasma processes in Earth's magnetosphere". The talented young scientist became one of the few disciples of Academician Galeev with whom he fruitfully worked together and was on friendly terms for years. Zelenyi and Galeev wrote about two dozen papers, of which one, published in the *Journal of Theoretical and Experimental Physics* (*JETP*) in 1976, became truly famous,

Lev Matveevich Zelenyi

proving that current layers — magnetoplasma structures in the tail of Earth's magnetosphere — are metastable, i.e., they can long accumulate large amounts of magnetic energy and then be destroyed and release explosively this energy. In Lev Zelenyi's Candidate thesis, this property of current layers in space plasma was strictly proved and investigated in a wide range of plasma parameters.

Lev Matveevich gradually began working in plasma physics independently and had the first disciples of the own, of whom many became well-known scientists working successfully in our country and abroad. The preparation of the four-satellite international project INTERBOL for the study of key interaction mechanisms of Earth's magnetosphere with the solar wind (with the participation of scientists from 20 countries) began in the 1980s. Although a theorist, Lev Zelenyi nevertheless took part in the preparation of the project, including the argumentation and planning of the experimental problems. From 1992 to 2002, he was a research coordinator of the INTERBOL project and deputy research supervisor of the program. Later on, INTERBOL became

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one of the most successful space projects of IKI (satellites were launched in 1995 and 1996) both in information capability of observations and in the number of discoveries. In 1987, L M Zelenyi defended his Doctor of Sciences thesis and in 1989, after A A Galeev was elected Director of the Institute, he became Head of the Department of Space Plasma Physics, which was then the largest department at IKI. He then managed to rally the department staff and facilitated its survival in the hard years of the 1990s with poor budgeting of national science. From 2002 to 2017, Lev Matveevich was the Director of IKI, and at the present time he is Research Supervisor of the Institute. In those years, the Institute received a new impulse of development and new research avenues appeared. IKI consolidated its leading position in Russian and international science in space programs.

L M Zelenyi plays a key role in organizing fundamental space research in Russia and abroad. From 2013 to 2017, he headed the RAS Council on Space. At the present time, he is Deputy Chair of the Council, a member of the Presidium of the Scientific and Technical Council (STC) of Roscosmos, Head of the Interagency Expert Committee on Space, and a Research Supervisor for the Russian Moon Program (Moon 25–28), the Resonance program, and the Russian part of a project searching for traces of life on Mars, called ExoMars.

In 1997–2000, L M Zelenyi was chair of the working group on space physics of the advisory council of space agencies of the USA, Japan, Europe, and Russia (IACG). From 2006 to 2014, he was the national representative of Russia and a member of the Bureau of the International Committee on Space Research (COSPAR). L M Zelenyi is a member of executive committees of the International Space Institute (ISSI) in Bern (Switzerland) and the International Academy of Astronautics (IAA). He is one of the leading members of the RAS — the organizers of Russian science. In 2003, L M Zelenyi was elected a Corresponding Member, and in 2008 a Full Member of the RAS, and from 2013 to 2017 was Vice President of the RAS. At the present time, he is a member of the RAS Presidium and Bureau of the Physical Sciences Division of the RAS. Since the appearance of the Russian Science Foundation, L M Zelenyi has been a member of its Supervisory Council, and since 2017 he has been a member of the Personnel Commission of the RF Presidential Council on Science.

L M Zelenyi is Editor-in-Chief of the journal *Zemlya i Vselennaya* (*The Earth and the Universe*), a member of the editorial board of the Journal *Priroda* (*Nature*); from 1992 to 2010 he was a member of the editorial board of the *Journal of Geophysical Research — Space Physics*; and from 2002 to 2009 of the journal *Nonlinear Processes in Geophysics*. Since 2015, he has been a member of editorial councils of the journals *Uspekhi Fizicheskikh Nauk* (*UFN*, *Physics–Uspekhi*) and *Vestnik RAN* (*Herald of the RAS*).

Lev Zelenyi has won many awards for his active scientific, scholastic, and organizational work. In 1993 and 1997, he was awarded the State Allowance in the framework of a support program for outstanding scientists of the Russian Federation. In 1999, 2000, and 2010, series of his publications in the *MAIK-Nauka* journals were awarded prizes from the publishing house. In 1999, he received the prize from the A Humboldt International Research Foundation, and in 2003, the Prize of the President of the Russian Federation in education. In 2004, the Polish Government decorated him with the Officer Cross for the development of international cooperation, and in 2008 with the honorary sign of the Federal Space Agency. In 2010, L M Zelenyi received a prize from the International Academy of Astronautics for achievements in space plasma theory. In 2016, he became a laureate of one of the most prestigious COSPAR prizes ''for the development of international collaboration in space research''.

Professor (since 1995) Zelenyi has been actively working in the field of education. Since 1978, he has delivered a faculty lecture course titled *Plasma Physics* to students of the Faculty of the Problems of Physics and Energetics (FPPE) at MIPT; since 2003, he has been head of the Space Physics Department. Two doctoral and ten candidate dissertations have been defended under his guidance. Lev Zelenyi made a weighty contribution to the development of FPPE and of the FIZTEKH system as a whole, and to the extension of links between MIPT and IKI. The Moscow division of FPPE, which is the main base of the faculty and is situated on the territory of IKI, is working successfully owing to his constant attention and support. In 2017, a new Department of Space Physics was founded under the guidance of L M Zelenyi at the Faculty of Physics at the Higher School of Economics.

Lev Matveevich Zelenyi is the author of more than 500 scientific publications. His work covers a wide range of problems in space plasma physics. The solution to the problem of a metastable character of current layer stability in Earth's magnetosphere put an end to the longstanding hot theoretical debates concerning the development of the tearing mode in current layers as a trigger of global magnetospheric perturbations, substorms, which made it possible to explain energy conversion and energy transfer in the magnetosphere. The criteria of metastability for the tail of Earth's magnetosphere were formulated that determine the onset of magnetic reconnection during substorms. A detailed theory of spontaneous magnetic field line reconnection in hot space plasma and the related vigorous particle acceleration was developed.

Lev Matveevich, together with Academician A A Galeev and his disciples M M Kuznetsova (now working at the Goddard Flight Center, NASA, USA) and A V Milovanov (working at IKI and the Italian National Agency for New Technologies in Rome), was engaged in the fundamental problem of the chaotic dynamics of magnetic fields and their role in space plasma particle transport and acceleration. Thus, they solved the problem of the character of solar wind particles penetrating Earth's magnetopause. The conceptions of stationary reconnection dominating at that time were replaced by conceptions of pulsed dynamic reconnection. The theory of magnetic field 'percolation' (magnetic flux transport) through the boundary of the planetary magnetosphere formulated by L M Zelenyi explained the partition of the primarily smooth magnetic surface with currents running along the magnetopause (Earth's magnetosphere boundaries) into chaotic current filaments owing to the development of a system of overlapping magnetic islands. This process can, in turn, result in a random walk of solar-wind magnetic field lines reconnected with the magnetospheric field between randomly located magnetic fragments. Such processes of 'Brownian' motion of magnetic field lines through a magnetic transition layer provided an explanation for the leading role of stochastic mechanisms of solar-wind plasma penetration inside Earth's magnetosphere, the mechanisms determining the energetics of solar–terrestrial relations. It is interesting that the later investigations of Mercury with the American apparatus Messenger confirmed that the same mechanisms are also working in this exotic magnetosphere.

The methods of fractal topology were applied to find the mechanisms of maintaining quasi-equilibrium turbulent current layers that result from the nonlinear development and saturation of unstable plasma modes. This regime is called the nonequilibrium (quasi-)stationary state (NSS), which characterizes the stable state of an open turbulent current system owing to multiscale correlations in space and time. A universal magnitude of the spectral dimension of NSS that provides important information on the turbulent ensemble kinetics and widens substantially the possibilities of an analytical description of plasma turbulence as a whole was found in the context of the formulated theory.

A weighty contribution to space science was made by the work of Lev Matveevich on the development of an essentially new quasiadiabatic approach to the study of rather recently discovered magnetoplasma structures (thin current layers) in space, whose scales of inhomogeneity are comparable to proton gyroradii. A new theory of the dynamics of charged particles in weak magnetic fields (that control their motion only on average) was in fact created as an alternative to the classical leading center theory. The first work in this area in collaboration with the well-known German scientist Jörg Büchner, now a Professor at Berlin University and since 2018 an Honored Professor at Moscow State University (MSU), was published in the late 1980s. A rapid development of these theories began in the early 1990s when L Zelenyi and J Büchner were working at the University of California in the Space Plasma Simulation Group headed by Professor M Ashour-Abdalla (1944–2016). The numerical simulation not only confirmed the basic predictions of the theory, but also allowed the discovery of a number of additional fine effects.

Later on, a scientific theoretical team united around Academician Zelenyi at IKI become engaged in the development of this subject. Theoretical plasma equilibrium models were constructed on the basis of the theory of quasiadiabatic particle motion in complex magnetic configurations. These models provided insight into the internal structure of thin current layers in space plasma and allowed comparison with the experimental data. Nontrivial characteristics of thin current structures, namely, multiscaling, metastability, and nesting were predicted and confirmed owing to the development of quasiadiabatic theory in the last two decades by L Zelenyi and his colleagues Kh V Malova and V Yu Popov by *in situ* studies on dozens of spacecraft that operated near Earth, Mars, Venus, and Mercury. The role of nonadiabatic effects in the acceleration of directed beams of accelerated ions (beamlets) in the tail of Earth's magnetosphere in the interaction with current layers was displayed. New resonance mechanisms of the formation and filamentation of beamlets in current layers were found. Almost all the predictions of the theory of nonlinear filamentation of plasma streams near magnetic separatrices were confirmed in a thorough analysis of numerous experimental data carried out by E E Grigorenko. The paper by Lev Matveevich concerning the new subject recently proposed by him for investigation — the influence of a possible magnetic inversion (reversal of the direction of the magnetic dipole field of Earth) on the radiation situation on Earth and in the near-Earth space — was published in *UFN* in 2018 and aroused lively interest and discussions in the scientific community. In recent years, L Zelenyi has also shown great interest in the study of dust plasma, particularly as applied to processes in the lunar exosphere.

As accomplished as he is in science, Lev Matveevich is very modest in life and advocates the principles of collectivism and continuity in work. He has always emphasized in his work that his results are a logical continuation of the scientific ideas of S I Syrovatsky and V L Ginzburg concerning the study of cosmic rays and reconnected current layers in the solar corona. The numerous organizational affairs could not, however, impede his scientific activity, which plays a great role in his life.

We would also like to mention the L Zelenyi's close relations with the journal *UFN*. In different years, his *UFN* reviews summed up the scientific results of Lev Matveevich and his colleagues, and the review "Quasiadiabatic description of charged particle dynamics in cosmic plasma" was recognized with the 2013 *UFN* Prize.

The friends, colleagues, and numerous disciples of Lev Matveevich give him their best on his jubilee and with all their hearts wish him sound health and creative longevity, new discoveries, and new results, both in space plasma physics and in the study of the Moon and planets.

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