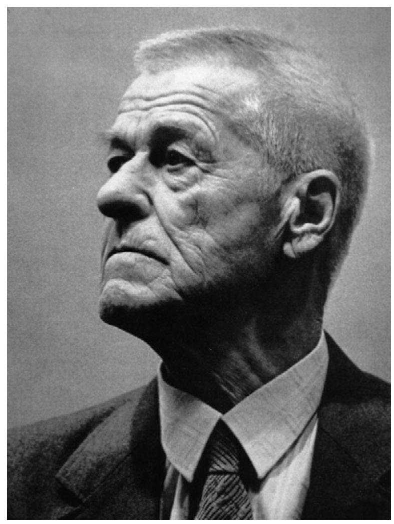
Journal of Applied Mathematics and Mechanics 73 (2009) 245–248

Contents lists available at ScienceDirect

Journal of Applied Mathematics and Mechanics

journal homepage: www.elsevier.com/locate/jappmathmech

LEV VASIL'EVICH OVSYANNIKOV (on his 90th birthday)☆



On 22 April 2009, Lev Vasil'evich Ovsyannikov, the outstanding Russian scientist, celebrated his 90th birthday. During his long career he developed important avenues of research in fluid mechanics, introduced a number of new concepts that added richly to the body of mathematics used in mechanics, and set up a scientific school that has now seen several generations of young scientists. The methods of group analysis of differential equations that he developed have been used by specialists in continuum mechanics and physics worldwide. His role in the development of the Academy of Sciences in Siberia and in founding Novosibirsk State University was invaluable.

L.V. Ovsyannikov was born in the town of Vasil'sursk in the Volga region. His father, Vasilii Zakharovich, was a land surveyor, and his mother, Tat'yana Vasil'evna, was a teacher. Eventually, the entire family moved to Moscow. Interest in science brought him into the circle of mathematicians at the M.V. Lomonosov Mascow State University. One of the problems addressed there was as follows: how to construct the projection of a four-dimensional cube onto a three-dimensional plane passing through the centre of the cube and perpendicular to its principal diagonal. He solved this problem and made a mock-up of the required body, the surface of which had self-intersections. Here, his remarkable geometrical intuition, which he exhibited throughout his scientific work, came to the fore.

In 1937, he entered the Mechanics and Mathematics Faculty of Moscow State University. At that time, future outstanding scientists – K.I. Babenko, I.I. Vorovich, N.N. Moiseyev, and A.D. Myshkis – were students there. The friendships he formed with these scientists were to last for many years to come. It must be said that the level of teaching of mathematics and mechanics at the University in the pre-war years was extremely high. Ossyannikov and his peers were among the first to take the 'Equations of Mathematical Physics' course which was given by S.L. Sobolev and formed the backbone of his celebrated textbook. His scientific supervisor was D.Ye. Men'shov, a prominent specialist in the field of the theory of functions.

His studies were interrupted by the war. He lost his father, who served in the national militia. In the summer of 1941, he worked on the building of defences around Moscow. That same autumn, he graduated from the university and went to the A.F. Mozhaiskii Airforce Engineering Academy in Leningrad (LVVIA). From May to September 1944, he saw action on the Leningrad front. The future aviation engineer gained valuable experience at airfields at the front during this time.

☆ *Prikl. Mat. Mekh.* Vol. 73, No. 3, pp. 339–344, 2009.

0021-8928/$ – see front matter
doi:10.1016/j.jappmathmech.2009.07.017

On graduating from the LVVIA, in 1945 he became a postgraduate student there. His scientific interests shifted towards gas dynamics, which gained powerful momentum in the postwar years as a result of the development of supersonic flight. In 1949, he defended his Candidate dissertation on 'Investigation of gas flows with a straight transition line'. His scientific tutor was S.V. Fal'kovich. At this time, he got to know S.A. Khristianovich, F.I. Frankl', and S.V. Vallander – scientists whose work made the Soviet Union a world leader in the study of gas dynamic problems.

In 1949–1953, he taught at the LVVIA and also at Leningrad State University (LGU). Among his students at the LGU were future academicians G.I. Marchuk, A.S. Alekseyev, and Ye.I. Shemyakin. In 1953–1956, he worked in the research team of Academician M.A. Lavrent'yev on the design of artillery-shell nuclear charges. The work of this team was described in detail in an article by V.M. Titov and A.P. Chupakhin that marked his 80th birthday and was published in *Prikladnaya Matematika i Mekhanika* (1999, **63**(3)).

In 1956–1959, he was an associate professor at the Moscow Institute of Physics and Technology where, besides teaching general mathematics, he organized a student seminar on the study of the theory of Lie groups and its applications to differential equations. Furthermore, he developed an original gas dynamics course for students in the faculty of M.A. Lavrent'ev. The graduates of this faculty were the first scientists working at the Institute of Hydrodynamics of the Siberian Department of the USSR Academy of Sciences, to which he transferred in 1959 on the invitation of M.A. Lavrent'ev and became one of his closest associates.

He began work at the Institute of Hydrodynamics as a senior research fellow in the theory section run by Academician I.N. Vekua. In 1961, he defended his doctoral dissertation on 'Group properties of differential equations'. In the same year he was appointed head of the theory section, and he remains in charge of its research to this day. In 1970–1975 he worked as deputy director and in 1976 he was appointed director of the Institute of Hydrodynamics, which he ran for 11 years. In 1964 he was elected a Corresponding Member and in 1987 a full member of the USSR Academy of Sciences.

Managing the institute did not interfere with his scientific activity. It was at this time that his celebrated books *Group Analysis of Differential Equations* (1978) and *Lectures on the Principles of Gas Dynamics* (1981) were published. The first of these was translated into English and published by Academic Press (1982), and the second, in a substantially extended edition, was republished in 2003.

In the same period, he organized an informal team of scientists – mathematicians, and physicists – to study the wave motions of homogeneous and stratified fluids. The result of this team's work was the publication, under his editorship, of the multicontributor monograph *Non-linear Problems of the Theory of Surface and Internal Waves* (1985, Nauka, Novosibirsk). This monograph won first prize in the basic research competition of the Siberian Branch of the USSR Academy of Sciences in 1987.

When Novosibirsk State University (NGU) opened in 1959, he became one of its first lecturers. He gave the main courses on algebra, differential equations, equations of mathematical physics, and gas dynamics, and updated the 'Introduction to Continuum Mechanics' course. In 1966–1989, he was head of the Faculty of Hydrodynamics, and in 1967–1970 he was Dean of the Mechanics and Mathematics Faculty of the NGU and was in charge of work in drawing up teaching programmes for the Engineering Mathematics Department. Being a passionate advocate of the 'Fiztekh' teaching system, he introduced its principles in his work at the NGU, which in a short period of time was transformed into one of the leading Russian universities.

He developed a mathematics course for students at the Novosibirsk School of Physics and Mathematics, the first of its kind in the USSR. Interest in school mathematics had been aroused in him even earlier, when, together with V.B. Lidskii, A.N. Tulaikov, and M.I. Shabunin, he wrote the bestseller *Problems of Elementary Mathematics*. This problem book, first published in 1960, has been through seven editions.

A feature that distinguished him as a teacher was that he strived to make sure that his courses of lectures were published. The results of this painstaking work were the NGU-published textbooks *Lectures on the Theory of the Group Properties of Differential Equations* (1966), *Lectures on the Principles of Gas Dynamics* (1967), *The Group Properties of Equations of Gas Dynamics* (1968), *Analytical Groups. Introduction to the Theory of Continuous Groups of Transformations* (1972), *An Introduction to Continuum Mechanics* (Part 1, 1976; Part 2, 1977), and *Continuum Wave Motions* (1985).

He set up and ran a large scientific school. Among those he taught directly were four corresponding members of the RAS, ten doctors, and 12 candidates, and his "scientific grandsons" included 18 doctors and tens candidates. The many scientists who have attended his lectures, taken part in seminars led by him, and studied his papers, monographs, and textbooks can rightly be numbered among his school, which extends beyond the boundaries of Russia.

His scientific and organizational activity was broad and varied. For many years he was a member of the praesidium (standing committee) and vice-chairman of the Joint Scientific Council for Mathematics and Mechanics of the Siberian Branch of the USSR Academy of Sciences, an officer of the Department of Problems of Engineering, Mechanics, and Control Processes of the USSR Academy of Sciences, chairman and member of a number of doctoral dissertation councils, and chairman of the Library Council of the Siberian Branch of the Academy of Sciences.

Remember that in 1963 the Siberian Branch of the USSR Academy of Sciences was already 6 years old, but its capital, Novosibirsk, had been closed to foreigners up to that time. He made huge efforts to eliminate this discrepancy. The first foreign guests to visit Novosirbirsk were the 23 participants in a Soviet–US joint symposium on partial differential equations. The USA was represented by the outstanding scientists R. Courant, K.O. Friedrichs, L. Ahlfors, P. Latz and W. Singer. The symposium was of the highest standard; the chairman of the organizing committee was I.N. Vekua and its deputy chairman was Ovsyannikov himself.

More than 40 years ago, the first session of the All-Union Seminar on Analytical Methods in Gas Dynamics, organized by Ovsyannikov together with N.N. Yanenko, B.L. Rozhdestvenskii, and A.F. Sidorov, was held in Novosibirsk. These seminars had an important influence on the development of theoretical gas dynamics in our country. Hundreds of young participants in the seminars passed through his school, and he was the permanent manager of these seminars, the last of which (the 21st) was held in 2006.

The research into the group properties of differential equations that he bagan and which was continued by his students led to Novosibirsk becoming the focal point for specialists in this field of knowledge, which was given a new lease of life after the basic work of Lie in the second half of the nineteenth century. This was borne out by the large international symposium held here in 1978 on theoretical group methods in mechanics. To give some idea of the scientific level of the symposium, it is sufficient to name a few of its outstanding participants: L. Gording, O.A. Ladyzhenskaya, A. Likhnerovich, and L.I. Sedov.

In 1982, on his and V.M. Titov's initiative, the First Lavrent'ev Lectures on Mathematics, Mechanics, and Physics were held. This scientific forum, with the participation of leading Soviet and foreign specialists, became a tradition. In 2005, the Sixth Lavent'ev Lectures were held, and Ovsyannikov was chairman of the programme committee for all of them.

He was active in editing and publishing work. He was Editor-in-Chief of *Zhurnal Prikladnoi Mekhaniki i Tekhnicheskoi Fiziki* (1965–1987), was a member of the editorial board of the journal *Fizika Goreniya i Vzryva*, edited translations of well-known monographs by K.G. Guderley *The Theory of Transonic Flow* and by J. Serrin *Mathematical Principles of Classical Fluid Mechanics*, did a vast amount of work on editing and publishing the collected works of M.A. Lavrent'ev on mathematics and mechanics, and was a senior member of the editorial board of the journal *Prikladaya Matematika i Mekhanika*.

His scientific publications number over 140. A detailed description of his scientific results up to 1999 is contained in papers published in the journals *Prikladaya Matematika i Mekhanika*, *Zhurnal Prikladnoi Mekhaniki i Tekhnicheskoi Fiziki*, and *Izvestiya RAN. Mekhanika Zhidkosti i Gaza* that marked other birthdays. Here we would like to single out his greatest scientific achievements of and also to dwell on results he obtained in the past decade.

His first great cycle of work was on gas dynamics. Features of flow on a straight transition line were discovered and investigated for the first time, and methods were developed for calculating such flows. The equation arising here, $\Delta u = u^2$, was the model for a wide class of quasilinear equations. The study of the non-trivial properties of solutions of this equation by his student S.I. Pokhozhayev stimulated the creation by the latter of a whole avenue of research. Solution of the problem of the outflow of a subsonic jet with critical velocity at the boundary led. Ovsyannikov to a mathematical discovery: it turned out that evening out of the flow occurred at a finite distance from the orifice. This result was the cornerstone of the theory of localization of solutions of degenerative non-linear differential equations, which was being developed actively in Russia and abroad. A substantial contribution to the development of the body of mathematics used in gas dynamics was his study of generalized solutions of the Euler–Darby equations. He described a method for constructing the entire system of partial solutions of this equation, which made it possible to substantiate the numerical method for solving problems of transonic gas dynamics, in particular the problem of sonic flow around a wedge.

Problems of gas dynamics remained his preoccupation for his entire working life. He involved his students in the investigation of these problems, setting them important scientific problems. One of these – the problem of the decomposition of an arbitrary discontinuity on a curved surface (a multidimensional generalization of the classical Riemann problem) – was solved by his student V.M. Teshukov. Of his last works in the field of gas dynamics, we will mention papers in *Zhurnal Prikladnoi Mekhaniki i Tekhnicheskoi Fiziki* (2000) and in *Prikladnaya Matematika i Mekhanika* (2001). As is well known, a characteristic of the solutions of gas dynamics equations is that singularities are formed in a finite time, even if the initial data are arbitrarily smooth. So the families of time-periodic solutions of these equations that he found were all the more unexpected. The solutions he constructed were two-dimensional. Do three-dimensional periodic motions of gas exist? This question still remains unanswered.

When investigating problems of gas dynamics, he had to consider their exact solutions. By the middle of the twentieth century, a large number of such solutions had built up, but a systematic approach to obtaining solutions did not exist. Studying the long-established work of S. Lie, he found within them the key to solving a troubling problem. From 1958 onwards he published work that led to the creation of a new theory – the group analysis of differential equations. The application of the results of this theory is not limited to gas dynamics but covers a wide spectrum of mathematical models of continuum mechanics and physics because the differential equations of these models are based on the fundamental properties of space–time symmetry and the medium moving within it.

The theory he developed was used not only in mechanics and physics but also in other fields of knowledge. Thus, his student N.Kh. Ibragimov, on the basis of this theory, investigated the group properties of spaces equipped with Riemann metrics. He obtained a generalization of Noether's celebrated theorem concerning the laws of conservation for Euler–Lagrange equations of the calculus of variations. Another of his students, Yu.N. Pavlovskii, using theoretical group methods, created the theory of hierarchical control systems.

The greatest achievement of the new theory was the concept Ovsyannikov introduced of the partially invariant solution of a system of differential equations. Suppose the system of equations allows of a local Lie group. If some solution of this system does not change under any transformation of the given group, it is called an invariant solution. Examples of invariant solutions are well known: the motion of a continuum with plane, cylindrical, and spherical waves. The algorithm for finding invariant solutions was developed long ago. However, it may be that the initial solution is not invariant but that its orbit, under the transformations of the given group, occupies an invariant manifold in the space of independent variables and required functions. Such a solution is said to be partially invariant, as it is only some of the required functions that are invariant. To classify partially invariant solutions, Ovsyannikov introduced two integral characteristics – the defect (the number of non-invariant required functions) and the rank (the number of independent variables in the system for the invariant part of the required functions). Invariant solutions have a zero defect.

It turned out that double waves in gas dynamics and functionally invariant Smirnov–Sobolev solutions are partially invariant solutions of the corresponding systems of equations. This led to the development of the theory of partial invariance, which resulted in the construction of new classes of exact solutions of the Navier–Stokes equations, the equations of gas dynamics, magneto hydrodynamics, elasticity theory, plasticity theory, and other models that cannot be obtained by intuitive reasoning. The construction of partially invariant solutions is a non-trivial problem. Its solution required the creation of a special algorithm which he developed.

The abundance of solutions obtained required ordering in their set. Naturally, those solutions that are converted into one another by a reversible change of variables are not considered important. Thus, the algebraic problem arises of constructing the optimal set of representatives of the classes of similar subalgebras of the maximum Lie algebra of invariance of the initial model. He solved this problem "by hand" himself for the algebra of invariance of the equations of gas dynamics with a common equation of state. The problem of constructing optimal systems in the case of a polytropic gas (there are thousands of such systems) was solved by his students using computer algebra software. These studies were conducted within the framework of the SUBMODELS scale programme which was carried out under his supervision for more than 15 years (see the paper in *Prikladnaya Matematika i Mekhanika*, 1999).

The third cycle of research which he undertook covered problems of fluid dynamics with a free boundary. The problem of unsteady waves on the surface of an ideal incompressible liquid was formulated by Cauchy and Poisson in the 1830s. Since that time, many approximate solutions of this problem have been constructed, but the question of the solvability of the problem in a precise formulation has remained unresolved. No less complex is the problem of the motion of an isolated fluid volume. Its solution may be a good approximation for describing the motion of a continuum under the action of pulsed loads, when the forces of inertia pre dominate over viscous and strength forces.

By the middle of the 1960s there was still no body of mathematics for analysing these problems, and Ovsyannikov began to create it. The Rayleigh–Taylor instability inherent in problems of this kind left few opportunities for their resolution in classes of functions of finite smoothness, and analogues of the Cauchy–Kovalevskaya theorem yielding analytical solutions simply did not exist. His remarkable intuition led him to find an analytical solution of the Cauchy–Poisson problem on a Banach space scale. His theorem concerning the solvability of the non-linear, non-local Cauchy problem relied on the concept he introduced of the quasi-differential operator on a Banach space scale. It aroused international interest and led to the appearance of a number of studies developing this avenue of research.

He obtained a class of exact solutions for the problem of the motion of a finite mass of fluid. The proof of the solvability of the plane analogue of this problem is due to him, as are the first results of investigating the problem of the stability of unsteady motions with a free surface of common form. Studying the motions of a two-layer liquid, he predicted the existence of a smoothed-step wave, (Bora wave) which was soon reproduced experimentally.In continuum mechanics, situations where an accurate model of a phenomenon is replaced by an approximate model, and later the simplified model takes on a life of its own, forgetting its origins, are common. This was the case with the classical Cauchy–Poisson problem, which spawned the linear theory of waves on water and shallow-water theory. He proposed a methodology for substantiating approximate models in the theory of surface waves and substantiated both popular approximate theories in classes of analytical solutions. His student V.I. Nalimov proved these theories in classes of functions of finite smoothness, and another of his students, N. I. Makarenko, proved a number of second-approximation models in the theory of long waves.

His services to the state and to his country's science have been highly valued. He was awarded an Order of the October Revolution, two Orders of the Red Banner of Labour, a fourth-degree order "For services to the Homeland", and nine medals, including medals "For the Victory Over Germany" and "For Combat Merits". He was awarded a Lenin prize and a state prize of the USSR, a USSR M.A. Lavrent'ev gold medal (with a prize), an M.A. Lavrent'ev prize from the M.A. Lavrent'ev foundation, and an L.I. Sedov prize (with a medal) of the Russian National Committee on Theoretical and Applied Mechanics. In 2007, he was thanked by the President of the Russian Federation for his great contribution to the founding of the Academy of Sciences in Siberia, for the training of scientific personnel, and in connection with the fiftieth anniversary of the Siberian Branch of the Russian Academy of Sciences.

His ninetieth birthday is a cause of great celebration for all those who have been fortunate enough to come into contact with him. His many students and colleagues and the staff and editorial board of the journal send him their heartfelt congratulations.

V.V. Pukhnachev

Translated by P.S.C.