

PERSONALIA

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In memory of Lev Nikolaevich Lipatov

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Lev Nikolaevich Lipatov, the outstanding theoretical physicist, Full Member of the Russian Academy of Sciences (RAS), and Head of the Division of Theoretical Physics of the Petersburg Institute of Nuclear Physics, died suddenly on September 4, 2017 in the 78th year of life. Russian science lost one of its brightest representatives.

Lev Nikolaevich Lipatov is well known to the world scientific community as one of the founders of contemporary theoretical high-energy physics. The significance of his works goes far beyond the theoretical description of particular processes; they underlie the application of perturbative quantum field theory to the interaction of high-energy elementary particles. His studies are of primary importance not only for modern collider experiments, but also for providing insight into the evolution of the Universe. Their influence on world science is confirmed by the huge number of related papers published in scientific journals. Several international conferences devoted to the memory of Lev Nikolaevich have already been planned.

L N Lipatov was born on May 2, 1940 in Leningrad. Fortunately, he evaded the tragedies of the blockade because, at the end of August 1941, he was evacuated to the Tambov region and returned to Leningrad in 1944. In 1962, he graduated from the Faculty of Physics of Leningrad State University, and in 1963 entered the postgraduate course of the Theoretical Department headed by V N Gribov at the A F Ioffe Physical–Technical Institute of the USSR Academy of Sciences.

The late 1950s and early 1960s were times of disbelief in the applicability of quantum field theory to the description of strong interactions, and the search for alternative approaches. The Regge pole theory was popular, and it was transformed, for the most part due to V N Gribov's efforts, into the relativistic theory of complex angular momenta — the Regge–Gribov theory. However, quantum field theory was not rejected by Gribov's group, but was actively employed to compare its outcome with Reggeization ideas and for the construction of the reggeon diagram technique. This field includes Lipatov's early work fulfilled together with V N Gribov, V G Gorshkov, and G V Frolov in 1966–1970. Found in this work, which became classical, were high-energy asymptotics of scattering processes in quantum electrodynamics in leading logarithmic approximation. The amplitudes of the processes with cross sections decreasing with energies showed double logarithms different from conventional ones (so-called Sudakov logarithms), and the methods of their summation were worked out. Later on, Lev Nikolaevich radically modified this method applying the infrared evolution equation discovered by him. The leading single logarithm contributions were summed up and the asymptotic behavior of the cross sections at high energies was found for processes with nondecreasing cross sections. In the language of the Regge–Gribov theory, the pomeron intercept (the position of the far-right singularity in the plane of complex angular momenta) was found in quantum electrodynamics, and the pomeron was shown to be a motionless branching point.

Lev Nikolaevich Lipatov
(02.05.1940 – 04.09.2017)

Already in these studies Lev Nikolaevich demonstrated a remarkable ability to find elegant and mathematically rigorous solutions to exceedingly difficult problems and to break through where it was considered yet impossible. This was undoubtedly acknowledged by V N Gribov, who began to think of him as an equal.

All his creative life, Lev Nikolaevich was at the forefront of high-energy physics and the front moved forward largely thanks to his efforts. In 1971–1972, soon after the experimental discovery of Bjorken scaling in deep inelastic electron–proton scattering, V N Gribov and L N Lipatov took advantage of summation of the main logarithmic contributions to the cross sections of deep inelastic scattering and inclusive annihilation in two field-theory models to demonstrate the violation of scaling and to derive the famous 'reciprocity relation' connecting the structure functions of the two processes. It was shown that in quantum field theory the parton distributions are not constant, as in the naive

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parton models providing the Bjorken scaling, but depend logarithmically on the transferred momentum. A little later (in 1974), Lev Nikolaevich reformulated the obtained results in the parton language and derived the equations of evolution of parton distributions with transferred momentum in renormalizable field theories. Essentially, the equations are renormalization group equations and are universal: it is only the kernels of the equations that depend on the form of the theory. These kernels were computed in quantum chromodynamics in 1977, and the equations are now referred to as DGLAP. The parton distributions obtained with their help are an essential part of the theoretical description of processes with the participation of high-energy hadrons. Later (in 1985), Lev Nikolaevich and co-workers derived more general equations of evolution for quasiparton operators that underlie the description of polarization phenomena and calculations of power-law corrections to the cross sections of hard hadron processes.

Immediately after the discovery of asymptotic freedom in non-Abelian gauge theories, Lev Nikolaevich began studying high-energy asymptotics in such theories and revealed the vector-boson Reggeization property. In 1975, on this basis, he derived (along with co-workers) in the leading logarithmic approximation the equation of evolution with energy for amplitudes in theories with spontaneous symmetry breaking, giving mass to all gauge bosons. In 1978, Lev Nikolaevich and his student showed that this equation can be used in quantum chromodynamics, where it is widely known now as the BFKL equation. This equation defines the asymptotics of the amplitudes of processes with exchange by two reggeized gluons in any color state. In BFKL theory, the pomeron determining the asymptotics of the amplitude of observed processes represents the bound state of two reggeized gluons in the colorless state. In 1998, after many years of work, Lev Nikolaevich and co-authors derived the BFKL equation in the next-to-leading logarithmic approximation. At the present time the BFKL theory is one of the leading tools to theoretically describe the experimental data obtained at modern accelerators.

An impressive result of the masterly technique was shown by Lev Nikolaevich in the calculation of high-order coefficients of perturbation theory series in quantum field theory using for calculations the solutions of classical field equations and quantum fluctuations around them. The highest level of mastership is confirmed by the fact that, although arguments in favor of the asymptotic character of the series were put forward as far back as the 1950s, no reliable estimates of these coefficients had existed before Lev Nikolaevich's work. The computational method developed by him was immediately highly rated by specialists and became classical; it is widely applied not only in elementary particle physics, but also in solid state and statistical physics. Other examples of the unsurpassed mastership of Lev Nikolaevich are the proof of conformal invariance in the space of impact parameters of the kernel of the BFKL equation for colorless states (1986), the holomorphic separability of the Hamiltonian of pair interaction of reggeized gluons in the limit of a large number of colors (1990), equivalence between the interaction Hamiltonian of n reggeons and the Hamiltonian of the Heisenberg spin model, in which spins are Moebius group generators, and the complete integrability of reggeon dynamics in multicolor quantum chromodynamics (1994).

Interest in Reggeization problems and reggeon interaction remained with Lev Nikolaevich all his creative life. In 1982, he showed that the graviton, as well as the gluon, lies on the Regge trajectory, and in 2007 he studied Reggeization in the electroweak sector of the Standard Model. For several years, he was engaged in construction of the Regge theory for quantum chromodynamics and the quantum theory of gravitation. In 1995, he constructed an effective action for high-energy processes in quantum chromodynamics based on reggeized gluons; in 2001, reggeized quarks were included in this action, and in 2011 an effective action in gravitation was constructed. The diagram technique developed (together with his co-workers) on this basis is now being successfully applied both in theory and in phenomenology.

Lev Nikolaevich obtained a number of remarkable results in the maximally extended supersymmetric Yang–Mills theory. In particular, he and co-workers revealed the integrability of equations for anomalous dimensions (1997), calculated two-loop corrections to the BFKL equation in this theory (2000), calculated four-loop anomalous dimensions (2004–2007), revealed complete integrability of scattering amplitudes (2009), showed the incompleteness of the BDS-ansatz, and calculated the correction function to it (2009–2012). The maximal transcendentality principle proposed by him (2003) first appeared as a brilliant conjecture. Later on, it was more than once confirmed and is now being widely applied in theoretical studies. The hypothesis concerning the pomeron and graviton duality looks more and more grounded.

The results obtained by L N Lipatov are widely known throughout the world community. The scientific school founded by him united theorists from many countries, including Russia, Germany, France, the USA, Spain, Israel, and Poland. He received many scientific awards, among which are the Humboldt Prize (1995), the I Ya Pomeranchuk Prize (2001), the Marie Curie Prize (2006), and the Prize of the European Physical Society in the field of particle physics and high-energy physics (2015). The significance of the results obtained by L N Lipatov is confirmed by the huge number of references (over 26,000) to his works.

Apart from the research work, Lev Nikolaevich carried out pedagogical activities at St. Petersburg State University. In spite of the constant deep submergence in science and time-consuming administrative duties, he did not impose lecturing on his disciples and colleagues and even found time to write original textbooks. Moreover, he participated in organizing many schools and conferences both in Russia and abroad. Especially well known are the Winter Schools on theoretical physics and the conferences *Hadron Structure and Quantum Chromodynamics* organized by him.

Lev Nikolaevich loved science endlessly. He was so much engaged in it that he would not notice the surrounding problems. Science took up almost all his thoughts. He was ready to speak about it always and in any state. Together with the passion for science, he possessed perfect human qualities. He was a very kind man. The circle of his acquaintances included people of different ages and different social strata, and he treated all of them equally without any hint of loftiness or even of feeling his significance in this world and his position.

The blessed memory of Lev Nikolaevich Lipatov will always live in our hearts, in his outstanding achievements, and in the work of his disciples and followers.

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