Memories of Lev Lipatov, a scientist and a man

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Memories of Lev Lipatov, a scientist and a man
Date of birth: May 2, 1940
Place of birth: Leningrad, USSR (now St.Petersburg, Rusia)
Date of death: September 4, 2017
Place of death: Dubna, Moscow region
1962 Graduated from the Physical Faculty of the Leningrad State University. Supervisor M. Braun
1963 Joined Gribov’s group at the Ioffe Physical Technical Institute
1968 Candidate of sciences
1970 The Leningrad Nuclear Physics Institute in Gatchina (now: Petersburg Nuclear Physics Institute, PNPI)
1974 Doctor of sciences.
1990 Professor
1997 Head of the Division of Theoretical Physics of PNPI
1998 Member of the Physics Department of the St.Petersburg State University
1997 Corresponding member of the Russian Academy of Science
2011 Full member of the Russian Academy of Science
Lev Lipatov is well known to the world scientific community as one of the founders of contemporary theoretical high-energy physics.

Awards:  
1995 Humboldt Research Award, Alexander von Humboldt Foundation  
2001 The Pomeranchuk Prize  
2006 The Marie Curie Prize  
2015 The European Physical Society Prize in the field of particle physics and high-energy physics

The scientific heritage left by L.N. Lipatov is so great that I will be able to cover only a small part of it.


Sov. J. Nucl. Phys. 6 (1968) 95
Errors in earlier papers of A.A. Abrikosov and G.A. Milekhin and E.S. Fradkin were improved. The double logarithmic asymptotics of two-particle processes in Quantum Electrodynamics were investigated in all cases. A table of the necessary corrections for the cross sections for forward and backward scattering was given.

\[ s \to \infty, \quad t \text{ is fixed; } \mathcal{Z} \text{ is } t\text{-channel charge.} \]

\[ Z = 0; \quad A = A_B \frac{2}{\xi} I_1(\xi); \quad \xi^2 = \frac{2\alpha}{\pi} \ln^2(s). \]

\[ Z = 2; \quad A = A_B e^{-\xi^2/2} \int_{c-i\infty}^{c+i\infty} d\ell e^{l\xi} \frac{d}{dl} D_{1/4}(l) \]

\[ = A_B e^{-\xi^2/2} \left\{ \begin{array}{ll}
-8 e^{-2.261\xi} \cos(1.843\xi) & \text{if } \xi \gg 1 \\
1 - \frac{5}{8} \xi^2 + \frac{35}{192} \xi^4 & \text{if } \xi \ll 1
\end{array} \right\} \]
Later a new powerful method (infrared evolution equation) for summation of the double logarithmic corrections was developed.

The main point of the method consists in isolating virtual particle with the lowest transverse momentum in the graph. The physical idea, the separation of the softest interactions, is similar to the renormalization group. An essential ingredient of the method is Gribov’s bremsstrahlung theorem.


The infrared evolution equation, based on a gauge invariant dispersive method, was used to obtain double logarithmic asymptotics of scattering amplitudes in the case of broken gauge symmetry, to the standard model of electroweak processes.
L. N. Lipatov,
“Double-logarithmic asymptotics of scattering amplitudes in gravity and supergravity,”

J. Bartels, L. N. Lipatov and A. Sabio Vera,
“Double-logarithms in Einstein-Hilbert gravity and supergravity,”
JHEP 1407 (2014) 056
The asymptotic behaviour of non-decreasing with energy cross sections was determined in the main logarithmic approximation. The $j$-plane singularities in the channel with vacuum quantum numbers were investigated near $j = 1$.


In the language of the Regge- Gribov theory, the *pomeron intercept* (the position of the most right singularity in the plane of complex angular momenta) was found in quantum electrodynamics, and the Pomeron was shown to be a fixed branching point.

Already in these studies Lev 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.

Soon after the experimental discovery of Bjorken scaling in deep inelastic electron-proton scattering, V. N. Gribov and L. N. Lipatov performed summation of the main logarithmic contributions to the cross sections of deep inelastic scattering and inclusive annihilation in two field-theory models, demonstrated the *scaling violation* and derived the famous *reciprocity relation* connecting the structure functions of the two processes.

Deep inelastic ep scattering and deep inelastic annihilation cross sections were found in vector and pseudo-scalar meson theories assuming the coupling constant $g^2 \ll 1$, but $g^2 \ln |q^2| \sim 1$. It was shown that in a vector theory, despite a rapid drop of electromagnetic form factors, the ep deep inelastic scattering amplitudes increase with $|q^2|$ at fixed $\omega$.


A little later (in 1974), Lev reformulated the obtained results in the parton language and derived the equations of evolution of parton distributions with transferred momentum in renormalizable field theories.

L. N. Lipatov,
“The parton model and perturbation theory,”

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.
G. Altarelli and G. Parisi,
“Asymptotic Freedom in Parton Language,”
A novel derivation of the $Q^2$ dependence of quark and gluon densities (of given helicity) as predicted by quantum chromodynamics is presented. The main body of predictions of the theory for deep-inelastic scattering on either unpolarized or polarized targets is re-obtained by a method which only makes use of the simplest tree diagrams and is entirely phrased in parton language with no reference to the conventional operator formalism.

D. J. Gross and F. Wilczek,
“Ultraviolet Behavior of Nonabelian Gauge Theories,”
It is shown that a wide class of non-Abelian gauge theories have, up to calculable logarithmic corrections, free-field-theory asymptotic behavior.
It is suggested that Bjorken scaling may be obtained from strong-interaction dynamics based on non-Abelian gauge symmetry.

Received 27 April 1973

H. D. Politzer,
“Reliable perturbative results for strong interactions?”

An explicit calculation shows perturbation theory to be arbitrarily good for the deep Euclidean Green’s functions of any Yang-Mills theory and of many Yang-Mills theories with fermions.

Received 3 May 1973
H. Georgi and H. D. Politzer,
“Electroproduction scaling in an asymptotically free theory of strong interactions,”
We analyze electroproduction in a non-Abelian gauge model of the strong interactions using the techniques of Christ, Hasslacher, and Mueller. The theory is asymptotically free and consistent with scaling up to logarithms. All logarithmic factors appear as inverse powers of $\ln(-q^2)$ and hence vanish as $(-q^2) \to \infty$.
Received 30 July 1973.

Immediately after the discovery of asymptotic freedom in non-Abelian gauge theories, Lev began studying high-energy asymptotics in such theories and revealed the vector-boson Reggeization property.

L. N. Lipatov,
“Reggeization of the Vector Meson and the Vacuum Singularity in Nonabelian Gauge Theories,”
Sov. J. Nucl. Phys. 23 (1976) 338
Yad. Fiz. 23 (1976) 642.
Further development of this investigation

V. S. Fadin, E. A. Kuraev and L. N. Lipatov,
“On the Pomeranchuk Singularity in Asymptotically Free Theories,”

led to calculation of the high-energy amplitude in the spontaneously broken Yang-Mills model within the leading logarithmic approximation, and has shown that the vector meson is reggeised whereas the Pomeranchon is a fixed branch point located at the right hand from $j = 1$.

E. A. Kuraev, L. N. Lipatov and V. S. Fadin,
“Multi - Reggeon Processes in the Yang-Mills Theory,”
Sov. Phys. JETP 44 (1976) 443
E. A. Kuraev, L. N. Lipatov and V. S. Fadin,
“The Pomeranchuk Singularity in Nonabelian Gauge Theories,”
Sov. Phys. JETP 45 (1977) 199

In 1978, it was shown by Lev and I. I. Balitsky that this equation can be used in quantum chromodynamics, where it is widely known now as the BFKL equation.

I. I. Balitsky and L. N. Lipatov,
An impressive result of the masterly technique was shown by Lev in the calculation of high-order coefficients of perturbation series in quantum field theory.

L. N. Lipatov,
“Divergence of the Perturbation Theory Series and the Quasiclassical Theory,”
Sov. Phys. JETP 45 (1977) 216

L. N. Lipatov,
“Divergence of Perturbation Series and Pseudoparticles,”
JETP Lett. 25 (1977) 104

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.
L. N. Lipatov,
“The Bare Pomeron in Quantum Chromodynamics,”
Sov. Phys. JETP 63 (1986) 904

V. S. Fadin and L. N. Lipatov,
“High-Energy Production of Gluons in a QuasimultiRegge Kinematics,”
JETP Lett. 49 (1989) 352
Yad. Fiz. 50 (1989) 1141
L. N. Lipatov,  
“Pomeron and odderon in QCD and a two-dimensional conformal field theory,” 
It was shown that the problem of solving the Bethe-Salpeter equations in LLA for t-channel partial waves corresponding to Feynman diagrams with many reggeized gluons is simplified significantly by using their conformal invariance in the impact parameter representation and the separability property of their integral kernels. In particular, for the three gluon system with the odderon quantum numbers a one dimensional integral equation was obtained.
L. N. Lipatov,
“Hamiltonian for Reggeon interactions in QCD,”

It was shown, that the interaction of the reggeized gluons in the leading logarithmic approximation of the multicolour QCD has a number of remarkable properties including the duality symmetry. The duality relation for the Odderon wave function takes a form of the one-dimensional Schrödinger equation. It gives a possibility to express the Odderon Hamiltonian as a function of its integrals of motion.

H. J. de Vega and L. N. Lipatov,
“Exact resolution of the Baxter equation for reggeized gluon interactions,”
J. Bartels, L. N. Lipatov and G. P. Vacca,
“A New odderon solution in perturbative QCD,”
A new bound state solution of the three gluon system in perturbative QCD was found. It carries the quantum numbers of the odderon, has intercept at one and couples to the impact factor $\gamma^* \rightarrow \eta_c$. 
Interest in Reggeization problems and reggeon interaction remained with Lev all his creative life.

L. N. Lipatov,
“Graviton Reggeization,”
Inelastic amplitudes of the graviton-graviton scattering in the multi-Regge kinematics of produced gravitons were calculated. The problem of the graviton reggeization was discussed in gravity and in supergravity.

J. Bartels, L. N. Lipatov and K. Peters,
“The Pomeranchuk singularity and vector boson reggeization in electroweak theory,”
In 1995, Lev constructed an effective action for high-energy processes in quantum chromodynamics based on reggeized gluons

L. N. Lipatov,
“Gauge invariant effective action for high-energy processes in QCD,”

in 2001, reggeized quarks were included in this action

L. N. Lipatov and M. I. Vyazovsky,
“QuasimultiRegge processes with a quark exchange in the t channel,”

in 2011 an effective action in gravitation was constructed.
L. N. Lipatov,
“Effective action for the Regge processes in gravity,”
Phys. Part. Nucl. 44 (2013) 391

The diagram technique developed on this basis

E. N. Antonov, L. N. Lipatov, E. A. Kuraev and
I. O. Cherednikov, “Feynman rules for effective Regge action,”

is successfully applied both in theory and in phenomenology.
S. Bondarenko, L. Lipatov and A. Prygarin,
“Effective action for reggeized gluons, classical gluon field of
relativistic color charge and color glass condensate approach,”
S. Bondarenko, L. Lipatov, S. Pozdnyakov and A. Prygarin,
“One loop light-cone QCD, effective action for reggeized gluons
and QCD RFT calculus,”
V. S. Fadin and L. N. Lipatov,
“Next-to-leading corrections to the BFKL equation from the gluon and quark production,”

V. S. Fadin, M. I. Kotsky and L. N. Lipatov,
“One-loop correction to the BFKL kernel from two gluon production,”

V. S. Fadin and L. N. Lipatov,
“BFKL pomeron in the next-to-leading approximation,”

S. J. Brodsky, V. S. Fadin, V. T. Kim, L. N. Lipatov and G. B. Pivovarov,
“The QCD pomeron with optimal renormalization,”
JETP Lett. 70 (1999) 155
A. V. Kotikov and L. N. Lipatov,
“NLO corrections to the BFKL equation in QCD and in supersymmetric gauge theories,”

A. V. Kotikov, L. N. Lipatov and V. N. Velizhanin,
“Anomalous dimensions of Wilson operators in N=4 SYM theory,”

A. V. Kotikov, L. N. Lipatov, A. I. Onishchenko and V. N. Velizhanin,
“Three loop universal anomalous dimension of the Wilson operators in $\mathcal{N} = 4$ SUSY Yang-Mills model,”
We present results for the three-loop universal anomalous dimension $\gamma_{uni}(j)$ of Wilson twist-2 operators in the $\mathcal{N} = 4$ Supersymmetric Yang-Mills model.
These expressions are obtained by extracting the most complicated contributions from the three loop non-singlet anomalous dimensions in QCD which were calculated recently. Their singularities at $j = 1$ coincide with the predictions obtained from the BFKL equation for $N = 4$ SYM in the next-to-leading order. The asymptotics of $\gamma_{uni}(j)$ at large $j$ is in agreement with the expectations based on an interpolation between weak and strong coupling regimes in the framework of the AdS/CFT correspondence.

J. Bartels, L. N. Lipatov and A. Sabio Vera,
“BFKL Pomeron, Reggeized gluons and Bern-Dixon-Smirnov amplitudes,”

J. Bartels, L. N. Lipatov and A. Sabio Vera,
“N=4 supersymmetric Yang Mills scattering amplitudes at high energies: The Regge cut contribution,”
L. N. Lipatov and A. Prygarin,
“Mandelstam cuts and light-like Wilson loops in N=4 SUSY,”
Phys. Rev. D 83 (2011) 045020

L. N. Lipatov and A. Prygarin,
“BFKL approach and six-particle MHV amplitude in N=4 super Yang-Mills,”
Phys. Rev. D 83 (2011) 125001

J. Bartels, L. N. Lipatov and A. Prygarin,
“MHV amplitude for 3-3 gluon scattering in Regge limit,”


Apart from the research work, Lev 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 pupils and colleagues and even found time to write original textbooks.

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.

He was an active speaker and an attentive listener.
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Memories of Lev Lipatov, a scientist and a man
Lev loved science endlessly. He was so much engaged in it that he could 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 loved poetry and in his youth wrote poetry.

He was an excellent chess player. His fellow student recalled how Lev played blindly in chess in the back of a truck, taking first-year students to agricultural work.

He was a very kind man. The circle of his acquaintances included people of different ages and different social positions, and he treated all of them equally without any hint of arrogance or even of feeling his significance in this world and his position.
There are nice recollections about Lev written by her daughter Irina Lipatova http://www.proza.ru/2018/02/21/2191

He was a wonderful family man. He loved very much his parents, his wife, two his daughters, five grandchildren and (up to now) three great-grandchildren.

He managed to built "datcha"for his family and loves to stay there.
He was very fond of movement, walking, action.

He loved life very much
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Memories of Lev Lipatov, a scientist and a man
The blessed memory of Lev Lipatov will always live in our hearts, in his outstanding achievements, and in the work of his disciples and followers.
THANK YOU FOR ATTENTION