Anatoliĭ Alekseevich Logunov (On his sixtieth birthday)

A. P. Aleksandrov, V. A. Ambartsumyan, N. N. Bogolyubov, M. A. Markov, and G. I. Marchuk.

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Academician Anatoliĭ Alekseevich Logunov, a most prominent Soviet physicist, organizer of science and of higher education reached his sixtieth birthday on 30 December 1986.

Logunov's manysided scientific activity has been devoted to establishing a new field of fundamental scientific investigations, which has been developing actively since the beginning of the 1950s,—the physics of elementary particles and high energies, and in recent years—the development of new concepts concerning space-time and gravitation.

Just as many other representatives of the scientists of his generation Logunov began with cosmic-ray physics. His first scientific articles were devoted to the investigation of diffusion and acceleration of cosmic rays in the intergalactic magnetized medium.

A deep influence on Logunov's subsequent scientific activity which determined the style of his work—the choice of the most fundamental, seminal problems and the creation of adequate mathematical methods of investigation,—was exerted by the close scientific contact and collaboration with N. N. Bogolyubov.

Logunov was one of the first to recognize deeply the wide possibilities and power of the methods of quantum field theory in investigating fundamental problems in the physics of elementary particles and high energies. A long series of his papers has been devoted to problems of quantum field theory and the derivation on its basis of the most general physical consequences.

Logunov was the first to give a generalization of the group of finite multiplicative renormalizations, and also of the functional and differential renormalization group equations of quantum electrodynamics, which had previously been established only for the transverse gauge, to the case of an arbitrary gauge for the potentials of the electromagnetic field. These investigations and the work of N. N. Bogolyubov and D. V. Shirkov which taken together solved the problem of a consistent formulation and the use of the method of renormalization invariance in field theory were awarded the State prize of the USSR.

In continuing the investigations that were begun by N. N. Bogolyubov on the creation of the method of dispersion relations, Logunov blazed new trails in the use of this approach for the description of various processes of the interaction of elementary particles. His are the papers that laid the foundation for the derivation of dispersion relations for processes of photoproduction of π-mesons on nucleons. On the basis of dispersion relations taken together with the condition of unitarity he obtained systems of equations which became the foundation for the construction of the theory of strong interactions for the processes of photoproduction in

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the region of low and medium energies. These investigations became a part of a series of papers awarded later a State prize of the USSR.

Being significantly in advance of the interests of those years Logunov laid out new paths for applying dispersion relations to the description of inelastic processes, of "blocks" with virtual ends, and of multiple production of particles.

The proof of the dispersion relations within the framework of axiomatic quantum theory required the introduction of new mathematical apparatus—the theory of functions of many complex variables with boundary values taken from the class of generalized functions. Logunov found new paths for investigating the analytic properties of the scattering amplitude in perturbation theory on the basis of the technique developed by him. The essence of the technique consists of the fact that the analytic properties of the set of all Feynman diagrams are determined by a small number of lower order graphs. This made it possible to prove the dispersion relations for the partial amplitudes in nucleon-nucleon scattering.

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The investigation of the analytic properties of the scattering amplitude became a base which enabled Logunov to find and to give a rigorous foundation for the existence of a number of relations between observed characteristics of processes at high energies. He showed that starting with general principles of quantum field theory it is possible to obtain asymptotic relations for total and differential cross sections. He generalized Pomeranchuk's theorem on the equality of nucleon-nucleon and nucleon-antinucleon scattering cross sections for the case when the total cross sections and the effective range of the interaction increase with increasing energy which agrees with the actual physical picture.

Subsequent investigation within the framework of the axiomatic method of the scattering amplitude as an analytic function of two variables—energy and transferred momentum—led Logunov to introduce the concept of the effective range of the interaction for elastic and inelastic processes. In doing this he arrived at the important conclusion that the effective range of the interaction for any inelastic process cannot be greater than the range of the interaction for the corresponding elastic process.

It is well-known that one of the characteristic features of processes occurring in collisions of two high-energy particles is their essential inelasticity, associated with the possibility of production of new, secondary particles. The higher the energy of the colliding particles the greater is the number of new particles that can be produced as a result of such a collision. The variety and the complexity of description of the final products of the reaction at sufficiently high energies make the traditional methods of investigation inadequate in this case.

In 1967 Logunov advanced a fundamentally new approach to the study of processes of inelastic interaction of particles at high energies. This approach is based on the concept of the so-called inclusive measurement, or inclusive reaction. Instead of keeping track of all the newly produced particles, in this approach the problem is posed of studying the characteristics of only one or a few selected particles of a given kind, taken, however, as a set in all the possible reaction channels.

The inclusive approach made it possible to bring into consideration all the reaction channels and to give a model-independent description of the most important regularities of many-particle processes at high energies on the basis of general principles of quantum field theory.

To appreciate fully the significance of these fundamental investigations of A. A. Logunov turned out to be possible only now when it has become clearly apparent that the study of inclusive processes is the key problem in high-energy physics.

The experimental investigation of inclusive reactions in processes of strong interaction of particles at high energies undertaken using the beams of the Serpukhov accelerator immediately after its commissioning, led to the discovery in 1969 of one of the most important regularities in high-energy physics—the property of scale invariance of these processes.

The discovery of the scale properties of strong and electromagnetic interactions respectively in inclusive hadronic reactions (Serpukhov) and in the deeply inelastic processes of electron-proton scattering (Stanford) opened the way to the modern understanding of the dynamic manifestations of the quark structure of hadrons.

The series of theoretical papers on the investigation of inclusive processes of strong interaction of particles carried out by Logunov and his pupils, and the experimental investigation of these processes at the Serpukhov accelerator, which led to the discovery of the properties of scale invariance were awarded the Lenin prize in 1986.

An important application of the dispersion relations were the superconvergent sum rules first derived by Logunov which related the characteristics of particles and of resonances. In developing this direction he obtained dispersion sum rules for finite energies which served as the basis for the creation of the concept of duality. This most important concept of phenomenological theory relates resonances in the direct channel with the high-energy behavior in the cross reaction channel.

The drive to combine rigorous axiomatic methods with the possibility of dynamic description of processes at high energies led Logunov to the creation of the so-called quasi-potential method in the relativistic two-body problem. The basic equation of this method, called the Logunov-Tavkhelidze equation, is a close relativistic analogue of the Schrödinger equation. Because of this it becomes possible to restore to the wave function of relativistic particles its visualizable probability content, and this opened up wide possibilities for applying this method. On the one hand, this method is most effective in quantum electrodynamics for the calculation of the higher radiative corrections to the levels of bound states; on the other hand, the potential picture of the interaction together with the concept introduced by Logunov of the effective range of the interaction, made it possible to give an easily visualizable, almost quasiclassical description of elastic scattering at high energies.

In recent years Logunov proposed new concepts concerning space-time and on their basis developed a relativistic theory of gravitation.

In this series of papers, following Hilbert and carrying out a detailed analysis of the general theory of relativity, Logunov arrived at the most important conclusion which he formulated in the following manner: "A critical analysis of the general theory of relativity shows that the adoption of its concepts leads to abandoning a number of fundamental physical concepts which lie at the foundations of physics. First of all this is a departure from the laws of conservation of energy-momentum and angular momentum of matter and of the gravitational field taken together. Secondly, this is a departure from the concepts of the gravitational field as a physical field of the Faraday-Maxwell type which possesses an energy-momentum density. Since neither in the macroworld nor in the microworld is there a single experimental indication which either directly or indirectly casts doubt on the validity and the fundamental nature of the laws of conservation of matter, then there is no physical basis for abandoning these laws." This conclusion was that most deep motivation which led Logunov to abandon the concept of the general theory of relativity and stimulated him to develop the relativistic gravitational theory (RGT).

In developing the RGT Logunov in following A. Poincaré developed a concept of the gravitational field as a physical Faraday-Maxwell field described by a symmetric tensor of the second rank possessing an energy-momentum density and spins 2 and 0. By developing the ideas of A. Poincaré, A. Einstein and H. Minkowski, Logunov proposed the generalized relativity principle, which he formulated in the following manner: "No matter what frame of reference we choose (inertial or noninertial), it is always possible to indicate an infinite set of other systems, in which all physical phenomena (including gravitational ones) proceed in the same manner as in the initially chosen frame of reference, so that we do not have and cannot have any experimental possibilities of discovering in which particular frame of reference from this infinite set we find ourselves." This principle guaranteed in the RGT strict validity of the laws of conservation of energy-momentum and angular momentum for matter and for the gravitational field taken together.

Developing the idea of Einstein and of Hilbert concerning the Riemann geometry of space-time, Logunov formulated the principle of geometrization to describe the motion of matter, by introducing the concept of the effective Riemann space-time, which arises as a result of the universal action of the gravitational field on matter. Thus, the effective Riemann space in the RGT has in the literal sense a field dynamic nature.

Logunov put forward a gauge principle basing it on a local noncommutative infinite-dimensional group of coordinate transformations, and this enabled him to define uniquely the form of the Lagrangian density of the gravitational field proper.

Starting with these physical principles, Logunov constructed a complete system of generally covariant equations of the RGT into which the metric tensor of the Minkowski space enters in an essential manner. The latter finds its physical reflection not only in the fundamental conservation laws, but also in the specific form of describing such natural phenomena as gravitational collapse, the development of a homogeneous and isotropic Universe, etc. According to this theory there cannot be in nature any objects of the black hole type in which gravitational compression of matter down to infinite density takes place, and the Universe is infinite and "flat". This leads to the conclusion that the density of matter in the Universe must be equal to its critical value. Consequently, RGT predicts the existence of a large "hidden mass" in the Universe in some form of matter.

RGT explains the entire set of experimental data in the solar system in a unique manner. RGT also predicts the existence of gravitational waves in the spirit of Faraday-Maxwell.

In parallel with the broadening of Logunov's scientific interests, his scientific-organizational activity also was developing. Working in Dubna he expended considerable effort in creating the Laboratory for Theoretical Physics, which now occupies one of the leading places in world science.

Logunov made a tremendous contribution to the creation of the experimental base for and the development of research in particle physics in our country and for raising it to a qualitatively new level. Under his direction a large scientific center was created—The Institute of High-Energy Physics in Protvino. The commissioning in 1967 of the powerful accelerator at the IHEP, the development of the scientific program taking into account the broad-based international collaboration and its successful realization have enriched science by a number of fundamental discoveries.

On Logunov's initiative and with his great support work was undertaken at the IHEP on developing accelerator technology, which led to the construction of a new type of accelerator—a proton linear accelerator with high frequency focusing. Under the direction of Logunov as the scientific director of the IHEP a design was completed and construction is underway of the largest in the world accelerating storage combination.

For his development and commissioning at the IHEP of the proton synchrotron with an energy of 70 GeV Logunov was awarded a Lenin prize in 1970.

The scientific and scientific-organizational activity of A. A. Logunov has been widely acknowledged. He has been elected a full member of the Academy of Sciences of the USSR, he is a member of a number of foreign academies, and an honorary doctor of many universities. His work has been awarded both the Lenin and the State prizes. He is the recipient of high government awards, and has been designated as a Hero of Socialist Labor.

Anatoliĭ Alekseevich Logunov is a member of the Central Committee of the Communist Party of the Soviet Union, he is a deputy of the Supreme Soviet of the USSR, the Vice-President of the Academy of Sciences of the USSR, and the rector of the M. V. Lomonosov State University in Moscow.

We wish Anatoliĭ Alekseevich to continue working with his usual unflagging energy for many years to come for the benefit of our country and of world science. We wish him many years of good health and new remarkable achievements in his manysided activity.

Translated by G. M. Volkoff