MAIN SCIENTIFIC ACHIEVEMENTS OF VLADIMIR GRIBOV

L.N. Lipatov

Vladimir Naumovich (BH) was born in 1930 in Leningrad. In 1952 he graduated from Leningrad University. In 1954 he started to work at the Theoretical Department of the Ioffe Physico-Technical Institute. At that time the Theoretical Physics Department was headed by Ilya Mironovich Shmushkevich. A member of the Department Karen Avetovich Ter-Martirosyan was the first theorist who appreciated the Gribov talent and introduced V.N. Gribov to the Academicians Lev Landau and Isaac Pomeranchuk.

From the very beginning V.N. Gribov manifested himself as a very active researcher. Initially his interests were in the statistical physics but soon he began to work on the problem of hadron production near threshold, using the approach, based on the S-matrix unitarity and dispersion relations. V. Gribov applied a generalization of the Landau method for the analysis of singularities of the Feynman diagrams in the framework of the Mandelstam representation.

By the end of the fifties V.N. Gribov became interested in the problem of the high energy hadron scattering. At that time I. Pomeranchuk formulated an important theorem about the asymptotic equality of the particle and antiparticle cross-sections. Usually theorists used the so-called diffractive model based on the black-disc approximation for the s-channel partial waves, but V. Gribov demonstrated in Nucl. Phys. **22**, 249 (1961), that this model contradicted the t-channel unitarity constraints. He suggested possible modifications of the diffractive model. One of them was realized in the BFKL approach at QCD 15 years later. Another one was equivalent to the Regge ansatz.

The fact, that the Regge-type asymptotics of scattering amplitudes is in an agreement with general principles of the S-matrix approach was established by V. Gribov in Sov. Phys. JETP **14**, 478 (1962). He proved with the use of the elastic unitarity condition the presence of the Regge poles in the j-plane of the t-channel partial waves in Sov. Phys. JETP **15**, 873 (1962) and obtained many consequences of the t-channel Regge approach including the factorization relations for total cross-sections in the paper Phys. Rev. Lett. **8**, 343 (1962) written with I. Pomeranchuk. In Sov. Phys. JETP **14**, 1395 (1962) V. Gribov constructed the t-channel partial wave in terms of the absorptive parts of the amplitude. It corresponds to the so-called Gribov-Froissart representation.

Significant theoretical efforts were put to understand a phenomenon of an approximately constant behavior of high energy cross sections. A special Regge pole, the Pomeron, was invented to describe their asymptotics and to guarantee the fulfilment of the Pomeranchuk theorem. There are physicists who think that the tag of this pole should be attached to Gribov because of his decisive contribution to the diffractive phenomena at large energies. Also he constructed the space-time picture of high energy processes corresponding to the Pomeron exchange and applied it to the photon and electron scattering off hadrons generalizing the vector dominance model in Sov. Phys. JETP **29**, 483 (1969); **30**, 709 (1970) and the Glauber approach in J. Nucl. Phys. **9**, 369 (1969).

S. Mandelstam understood that the t-channel partial waves should have also more complicated j-plane singularities. They appear according to V. Gribov, I. Pomeranchuk and K. Ter-Martirosian from the multi-particle unitarity relations considered in Phys. Rev. **B 139**, 184 (1965). To take into account all pomeron interactions V. Gribov constructed the so-called Reggeon Calculus in Sov. Phys. JETP **26**, 414 (1968). The scattering amplitudes built with its use satisfy the t-channel unitarity constraint. In the end of sixties V. Gribov gave a review of his theory of the complex angular momentum in the lectures given for the theorists of the Ioffe Physico-Technical Institute.

The search of the strong coupling solution of the Gribov effective theory, which satisfies the t and s-channel unitarity, was initiated by Gribov and Migdal in Sov. J. Nucl. Phys. **8**, 1002 (1968. On the other hand, V. Gribov found the weak coupling solution in Sov. J. Nucl. Phys. **17**, 313 (1973). The pomeron here has rather unusual properties and is similar to a graviton. An analogous relation between the pomeron and graviton was obtained recently in the framework of the AdS/CFT correspondence. An important ingredient of the Gribov theory was the Abramovsky-Gribov-Kancheli cutting rule discovered in Sov. J. Nucl. Phys. **18**, 308 (1974).

V. Gribov together with V. Gorshkov, G. Frolov and me constructed explicitly high energy scattering amplitudes at QED in the so-called double logarithmic approximation in Sov. J. Nucl. Phys. **6**, 129, 361 (1967). With the use of the dispersion relations he significantly increased the region of applicability of the photon bremsstrahlung factorization for the high energy hadron collisions in Sov. J. Nucl. Phys. **5**, 280 (1967). Also the Pomeranchuk singularity in QED was studied by V. Gribov together with G. Frolov and me at the leading logarithmic approximation (LLA) in Sov. J. Nucl. Phys. **12**, 994 (1971)..

In the end of sixties it was popular to work in the field of the hard processes. For the simplest such process - e^+e^--annihilation to hadrons V. Gribov with I. Pomeranchuk and B. Ioffe obtained the important result, that its cross-section behaves at large energies as that for the process $e^+e^- \to \mu^+\mu^-$. *Sov. J. Nucl. Phys.* **6**, 427 (1968). Also the Bjorken scaling for the structure functions of the deep-inelastic *ep*-scattering was discovered at SLAC. Its explanation was given by J. Bjorken and R. Feynman within the framework of the quark parton model, where the transverse momenta of partons assumed to be restricted at large Q^2.

V. Gribov did not believe in this restrictness and insisted on calculations of structure functions in renormalized field theories. Indeed, later in the paper Sov. J. Nucl. Phys. **15**, 438 (1972) we with him demonstrated that the Bjorken scaling is not valid in traditional field theories. The same conclusion was in our paper Sov. J. Nucl. Phys. **15**, 675 (1972), where we discovered a simple relation between structure functions of deep inelastic scattering and fragmentation functions for the e^+e^- annihilation to hadrons. The search for non-abelian gauge models of strong interactions with an approximate Bjorken scaling resulted in the discovery of QCD in which the coupling constant has the remarkable property of asymptotic freedom at large Q^2. Generally the Q^2-evolution of the partonic distributions and fragmentation functions is described in QCD by the Dokshitzer-Gribov-Lipatov-Altarelli-Parisi equations.

After publishing the papers devoted to deep inelastic scattering V. Gribov began to work on more fundamental problems of QCD which were beyond the applicability of perturbation theory. He discovered the important property of nonabelian gauge theories which is known as "Gribov's ambiguities" Nucl. Phys. **B 139**, 1 (1978). He demonstrated that in covariant gauges the gauge freedom is not fixed completely. Namely, there remain gauge copies which are the field configurations related to each other by discrete gauge transformations. V. Gribov attempted to relate these ambiguities to the quark and gluon confinement, which attracted a great interest in the Soviet Union and abroad.

Gribov worked fruitfully also in other branches of elementary particle physics. In particular he gave a clear physical interpretation to instantons in the Minkovsky space-time as field configurations describing the quantum tunneling between different vacuum states. It is interesting, that before the well known Hawking paper devoted to black holes V. Gribov asserted in his discussion with Ya. Zeldovich that these objects should emit particles as a consequence of quantum effects. Note also, that the most general theory of neutrino oscillations was constructed in the Gribov-Pontecorvo paper Phys. Lett. **B28**, 493 (1969). Now this field of investigations is one of most active in the elementary particle physics.

From 1980 up to 1997 V. Gribov continued to work on fundamental problems of QCD. In the paper Phys.Lett. **B 194**, 119 (1987) he showed, that the quantum anomalies in quantum field theories lead to the absence of the stable vacuum state. If an anomaly exists, there is a flow of various physical quantities from the Dirac sea to the real world. The Gribov interpretation of anomalies is fruitful for an explanation of relevant phenomena in solid state physics. V. Gribov was interested also in the dynamic problems of the charge renormalization. In particular he investigated the Moscow zero charge and screening of charged particles in massless QED in paper Nucl. Phys. **B 206**, 103 (1982).

V. Gribov was not satisfied by the Mandelstam explanation of the confinement in QCD as the anti-Meissner effect and suggested a new idea based on the existence of light quarks in Physica Scripta **T 15**, 164 (1987). He used an analogy with a nucleus having a large electric charge. It is known that, if this charge exceeds a critical value, the ground state is not a bare nucleus but an ion having at least one additional electron. Due to the vacuum polarization in the strong electric field an electron-positron pair is produced. The electron remains in the bound state, whereas the positron goes to infinity. The vacuum is rearranged. A similar mechanism was suggested by V. Gribov to explain the confinement in QCD. Because the quark charge grows at large distances it could exceed some critical value for which a similar rearrangement of the QCD vacuum takes place. The important role is attributed in this mechanizm also to the exchange by π-mesons Phys. Lett. **B 319**, 291 (1993). V. Gribov wrote down equations for the Green functions and presented arguments in favour of confinement within this approach. In July 1997 he completed a preprint devoted to his confinement idea but the main results were going to be presented in the next paper (see Ref. Eur. Phys. J. **C10**, 91 (1999)). Now it seems to be difficult to convince the scientific community in the validity of Gribov's idea. Some time will pass before its possible acceptance.

In each paper of Gribov one can find a number of analogies which in one way or another are useful for elementary particle physics. In particular, he attempted to relate the confinement problem with the theory of complex angular momenta. Within QCD the gluons and quarks are not point-like particles. They are always surrounded by clouds of other partons. If one would rotate such extended object, its energy would be a function of angular momentum. In perturbative QCD the interaction hamiltonian for reggeized quarks and gluons is known. Therefore the Gribov Pomeron field theory built fourty years ago has a direct application to QCD. The dynamics of gluon interactions at high energies has remarkable mathematical properties, and it is not excluded that QCD itself might be discovered as a result of the natural development of the high energy approach by V. Gribov and his collaborators.

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