Postscript

"The theory of strong interactions,
now that is quite something"

– *Gribov's opening words to his first lecture on hadron interactions at high energies in 1972*

In the early 1970s V. N. Gribov gave two series of lectures to students of theoretical physics at Leningrad (today St. Petersburg) State University.

The first course was devoted to Quantum Electrodynamics (QED), and Gribov completed it without mentioning the word *Lagrangian*. Such a 'bizarre' approach to QED had a hidden purpose. It aimed higher and represented, in fact, a constructive introduction to Quantum Field Theory (QFT) in general, based on the language of Feynman diagrams – 'the laboratory of theoretical physics', in Gribov's words.

The QED course of 1971 was followed by a lecture series on strong interaction physics; Gribov has later formulated his motivation: 'I wanted to tell everything I ever learnt about hadron interactions'.

The two courses had quite a different fate. The QED lectures appeared, in Russian, in the proceedings of the Winter School of the Leningrad Nuclear Physics Institute (LNPI) in 1974. Its English version, prepared with Gribov's participation, was published by the Cambridge University Press in 2001 as the first volume of the *Gribov Lectures on Theoretical Physics* series.

The second course – Strong Interactions – existed only in the form of handwritten notes taken and preserved by his students. Even in the 1990s when Gribov has been working on Quantum Chromodynamics (QCD) for already more than a decade he thought it was important to write a book based on these old notes. He wanted to do this, and, when we spent a few months with him at the University of Lund in 1991, he proposed

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that we should work together on the manuscript. Gribov has edited a few of the first lectures prepared by Sergey Troyan and one of us (Y.D.). Unfortunately, the lecture course as a whole started taking shape only many years after his death. The book would have certainly been different if he could have participated in its completion.

Why to return to the 'old theory' of strong interactions of the pre-QCD, even pre-quark, epoch? There are several reasons for that.

On the one hand, the Lagrangian theory of strong interactions was spectacularly successful in describing small-distance quark–gluon dynamics (*hard* processes) and became a working tool, in particular, in the search for new physics beyond the Standard Model. At the same time, our understanding of even the most general characteristics of *soft* hadron processes – like total hadron interaction cross sections in the first place – remains where the 'old theory' left it about 30 years ago.

The fact that the old theory had very limited means and, being devoid of microscopic dynamics, had to rely on the most general properties of the relativistic S-matrix theory, turns to its advantage nowadays.

The second reason is deeper, and therefore less obvious. The 'old approach' to strong interactions took off in the early 1960s when it was realized that the general properties of the relativistic S-matrix theory – crossing symmetry, unitarity, causality – put severe restrictions on the possible high-energy behaviour of hadron interactions (elastic, inelastic, total cross sections).

The effective theory describing the high-energy asymptotics of $\sigma_{\rm tot}$, as well as fluctuations in multi-particle production, – the Gribov Reggeon Field Theory (RFT) of interacting pomerons – was constructed. It was a turning point when it has been found to be *intrinsically unstable* in the specific, but the only practically relevant, case of (nearly) constant total cross sections. Looking into possible solutions of the corresponding *infrared unstable dynamics* has helped to develop the theory of second order phase transitions in condensed matter physics (the 'scaling' solution). However, the original pomeron problem remained unsolved. Pomeron instability could not be resolved without an input from outside the S-matrix theory, namely, without understanding the structure of the hadronic vacuum.

For the answer V.N. Gribov turned to QCD. The discovery of *Gribov copies* in 1976, which has changed our view upon non-abelian QFTs, was for him, in fact, a by-product of the search for the pomeron-puzzle solution. He came to the firm belief that the pomeron instability got to be intimately related to the infrared instability of the QCD, i.e. to the physics of quark confinement.

There exists a deep relation between the 'old' and 'new' strong interaction theories, which can not be appreciated without studying both.

The new theory – QCD – has adopted many a notion of its predecessor: the Froissart regime; reggeization of quarks and gluons, and multi-regge kinematics; [QCD, BFKL, 'hard'] pomeron, and the reggeon field theory; impact parameter diffusion; parton screening and saturation; Gribov–Glauber multiple scattering theory, and the Abramovsky–Gribov–Kancheli (AGK) cutting rules. Many important issues of the old theory, its techniques, problems and achievements are, however, not exposed in existing textbooks. This book fills the gap.

Topically, this book overlaps with Gribov's *Theory of Complex Angular Momenta* (TCAM) (Gribov, 2003). There is, however, an essential difference.

The TCAM volume is based on lectures given by V.N. Gribov in 1969 to the audience of *professional theorists*, whereas the present course targeted *university students*. It does not presume, therefore, any additional knowledge beyond quantum mechanics (including the non-relativistic quantum scattering theory), relativistic kinematics and the QFT basics covered by the preceding QED lectures (Gribov and Nyiri, 2001). That is why many general topics not present in the TCAM volume are extensively discussed here: analytic properties of Feynman amplitudes, resonances, electromagnetic interaction of hadrons.

Moreover, this course covers a number of important subjects developed and understood during the 3–4 years that elapsed between the two lecture series. Among them, to name a few, are the s-channel nature of the Regge exchange (impact parameter diffusion) and the structure of multi-hadron production (Mueller–Kancheli analysis of inclusive spectra and the pattern of multiplicity fluctuations, AGK cutting rules, screening, etc.), deep inelastic lepton–hadron scattering and the quark–parton picture, as well as the basics of QCD in the original Gribov approach.

On the other hand, in the TCAM volume some technically involved themes are elaborated in greater detail. So, the two books complement each other in many ways, aiming at a comprehensive exposition of the theory of hadron interactions that preceded Quantum Chromodynamics.

In preparing the book, we used lecture notes taken by Yu. Dokshitzer, V. Petrov, S. Troyan and V. Vechernin in 1972–75.

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