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Tribute to Alexei Borisovich Kaidalov

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Abstract. The author wrote these lines to recollect some personal memories of Alexei Borisovich Kaidalov and of the collaboration the author carried out with him under his guidance for almost 20 years. By doing so the author has once again confirmed the realization of the deep influence that Alexei Borisovich and his contribution to physics had and still has in the spirit of the author, and in the formation of several generations of physicists, both from Russia and from abroad.



Alexei Borisovich Kaidalov
(20.07.1940 - 25.07.2010)



I first personally met Alexei Borisovich Kaidalov (for some biographical reference on Alexei see reference [1]) in the late 80's of last century, during the preparation of my Ph.D. thesis under the supervision of Alfons Capella in the Laboratoire de Physique Théorique et des Hautes Énergies (LPTHE) of the Université de Paris-Sud, Paris XI (France), when Alexei visited the laboratory to collaborate with Alfons and Jean Tran Thanh Van.

I remember that from the very first moment Alexei made a big impression on me, impression reinforced by his patience to invest time in discussing physics with the young doctoral student I was at the time.

After passing my Ph.D. in April 1991, I had to go for my military service in the Spanish Navy for one year, and shortly after finishing my service, when I was wondering which would be the best way of tackling my postdoc activity, in July 1992 Alexei attended, with Konstantin G. Boreskov and with the great Karen A. Ter-Martirosyan, all from the Institute of Theoretical and Experimental Physics (ITEP) of Moscow, the XXII International Symposium on Multiparticle Dynamics, organized in my local University of Santiago de Compostela by the head of the Particle Physics Department, and also advisor of my Ph.D. thesis, Professor Carlos Pajares. The fact of having such a great physicists from a so prestigious institution as ITEP visiting our university was encouraging for the young doctorates in Santiago de Compostela at the start of our research careers.

During this stay in Santiago de Compostela, Karen, Alexei and Konstantin invited me to visit ITEP, where I spent one month in January-February 1993. Apart from the big experience of being in such an important place for the history of theoretical physics during the twentieth century, and from getting a closer image of extraordinary figures, like Isaak Yakovlevich Pomeranchuk, of whom Alexei was the last Ph.D. student, I was friendly introduced to the Russian culture, and treated to enjoy the canonical way of sharing zakuska and vodka.

Later, in October that year 1993, I started a postdoctoral two-year stay at LPTHE in Paris, in the frame of the Human Capital and Mobility Program of the European Union, and Alexei came there to spend several months at the beginning of 1994. The presence of Alexei made an immediate impact on the research activity of the group led by Alfons Capella, and that soon translated into the writing of several papers devoted to the description of low- x physics, papers that I cannot resist the temptation of citing here. In the first of these papers [2], and following the conviction by Alexei that a common description of both the soft and the hard regimes of strong interactions was possible, a phenomenological model based on Regge Theory for the initial condition of $F_2(x, Q^2)$ in the perturbative QCD evolution was presented. In what it was called the CKMT model, we considered the following behaviour of the low- x F_2 structure function:

$$F_2(x, Q^2) \sim x^{-\Delta(Q^2)} ; \Delta(Q^2) = \Delta_0 \cdot \left(1 + \frac{2Q^2}{Q^2 + d} \right) , \quad (1)$$

where Δ_0 and d are free parameters. From the fit to experimental data, the value $\Delta(Q^2 = 0) = \Delta_0 \sim 0.08$ was obtained, what corresponds to $\Delta(Q^2 \rightarrow \infty) \sim 0.24$ (bare Pomeron). According to large N -expansion, we assumed that the Pomeron determines the small- x behaviour of sea and gluons, while secondary reggeons (ρ, ω, f, A_2), with intercept $\alpha_R \sim 0.4 - 0.6$, determine the behaviour of valence quarks. Thus, the following parametrization of the structure functions in the region of small and moderate Q^2 ($0 \leq Q^2 \leq 5 \text{ GeV}^2$), was implemented:

$$F_2(x, Q^2) = A \cdot x^{-\Delta(Q^2)} (1-x)^{n(Q^2)+4} \cdot \left(\frac{Q^2}{Q^2 + a} \right)^{1+\Delta(Q^2)} + B \cdot x^{1-\alpha_R} (1-x)^{n(Q^2)} \cdot \left(\frac{Q^2}{Q^2 + b} \right)^{\alpha_R} . \quad (2)$$

The first term in equation 2 corresponds to the Pomeron contribution with a $x \rightarrow 0$ behaviour given by equation 1. The second term corresponds to the secondary reggeon contribution with $x \rightarrow 0$ behaviour determined by the secondary reggeon intercept α_R . The behaviour at $x \rightarrow 1$ is given by the second factor, with $n(Q^2)$ parametrized as

$$n(Q^2) = \frac{3}{2} \cdot \left(1 + \frac{Q^2}{Q^2 + c} \right), \quad (3)$$

in such a way that, at $Q^2 = 0$, one recovers the same power $(1-x)^{1.5}$ as in the Dual Parton Model (controlled by Regge intercepts, $n(0) = \alpha_R(0) - 2\alpha_N(0) \sim \frac{3}{2}$), and at $Q^2 \rightarrow \infty$ it goes as $(1-x)^3$, as given by dimensional counting rules. The last factor in the two terms of equation 2 is required by equation 1 in order to connect with real photons. By using equation 1, one gets:

$$\sigma_{\gamma p}^{tot}(\nu) = 4\pi^2 \alpha_{EM} \left(Aa^{-1-\Delta_0} (2m\nu)^{\Delta_0} + Bb^{-\alpha_R} (2m\nu)^{\alpha_R-1} \right). \quad (4)$$

The parameters into the model were determined from a joint fit of the $\sigma_{\gamma p}^{tot}$ data and of the NMC data on the proton structure function $F_2(x, Q^2)$ in the region $1 \leq Q^2 \leq 5 \text{ GeV}^2$, and the contribution by u and d valence quarks appears separated as:

$$B \cdot (1-x)^{n(Q^2)} \rightarrow B_u \cdot (1-x)^{n(Q^2)} + B_d \cdot (1-x)^{n(Q^2)+1}. \quad (5)$$

The condition of having two valence u -quarks (charge $2/3$) and one valence d -quark ($-1/3$), determines the values of B_u and B_d . A good fit to the experimental data was obtained up to $Q^2 \sim 10 \text{ GeV}^2$, even before plugging the perturbative evolution in.

Alexei Kaidalov was perhaps the best expert on diffraction in the world, and we devoted a second paper [3] to diffraction, in which we considered the diffraction dissociation of virtual photons in the framework of conventional Regge theory. In that paper we showed that the HERA data on large rapidity gap events were successfully described in terms of the Pomeron structure function, and we obtained the size of the shadowing corrections at low x and large Q^2 .

During these years in Paris, and for many years after, I met Alexei in many conferences and meetings, in particular in Les Rencontres de Moriond, organized every March by Jean Tran Van Thanh, either in Les Arcs or Méribel (France), either in La Thuile (Italy), and where Alexei's skiing exploits almost matched up with the brilliance of his talks. Actually, I was always amazed on how Alexei could, after skiing and devoting time to discuss physics with the many participants who asked him for his advice, prepare such a precise and complete summary talks, that actually gave you the clear and paramount image of the physics activity presented during the conference. In January-February 1998 I stayed at ITEP a second time for 1 month, and the welcome by all the colleagues there, led by Alexei, was again friendly and really fruitful to me.

I have collaborated with Alexei for almost twenty years, on structure functions, diffractive dissociation, hard diffraction, strange baryon production, nuclear structure functions, etc, and I share with him the authorship of fifteen entries (some of them also with others) in hep-Spires, the last one from February 2011. I'm truly aware that this represents a very minimal part of the titanic work and the core contribution Alexei has made to particle physics, but to cite our common papers, to be the M after the K of the CKMT model, and to think of the work we shared and of everything I have learned from him along the years makes me always feel deeply proud.

One concise scheme [1] of Alexei's main scientific goals, based on a document prepared by Alexei himself several years before his death, and in which many important results are for sure omitted, could be the following:

1. The consideration of non-lepton and radiative decays of hyperons, the analysis of the amplitudes of these decays and the calculation of the low boundaries for the decay probabilities.
2. The identification for moving reggeon cuts signatures in experimental data. This meant a very important progress at the time, since the standard thinking was that the Regge pole contribution is enough for the description of the experimental data. Alexei also gave the first model-independent estimate, obtained from particle-reggeon unitarity, of the two-reggeon cut contribution.
3. The reformulation of the one-pion-exchange model on the base of Reggeon approach, and the consequent quantitative description of a large number of experimental data on $pp \rightarrow pn\pi^+$, $pp \rightarrow pp\pi^+\pi^-$, etc., at intermediate energies ($1 - 10 \text{ GeV}/c$), as well as the description of the inclusive processes at high energies. All this resulted in a significant progress in the understanding of the nature of secondary production at these energies.
4. The analysis of high energy diffraction dissociation processes. The investigation of low mass diffractive jets allowed the implementation of the so-called quasi-eikonal model for elastic high energy hadron-hadron scattering. The parameters of the triple-Reggeon interactions which play a fundamental role in the processes of high energy interactions were extracted from the experimental data on large mass diffractive jet production. The main results of this activity were published in a brilliant and comprehensive review, still fully standing today, published in Physics Reports [4].
5. The development of the dispersion sum rules for the Reggeon-hadron scattering that allows to predict some high-spin resonances.
6. The formulation of Quark-Gluon String Model (QGSM) for multiparticle production at high and superhigh energies that allowed the quantitative description of a lot of experimental data in hadron-hadron and hadron-nucleus collisions. The QGSM is an analytical, not Monte Carlo, model based on the topological $1/N$ expansion of QCD amplitudes, on Regge-asymptotics of quark and diquark distributions in the colliding hadrons, and on similar Regge-asymptotics for the fragmentation functions for secondary particle production. The QGSM predictions have been successfully used for the description of the production of secondary particles at collider energies, and they are now confirmed by the corresponding productions at LHC. The QGSM explains, in particular, the baryon charge diffusion at large distances in rapidity space. The QGSM predictions have been also widely used in cosmic ray physics.
7. The analysis of particle production in heavy ion collisions, in which it was shown that the inelastic nuclear screening effects cannot practically change the integral interaction cross section, but they very significantly decrease the inclusive densities of secondaries produced in the central (midrapidity) region.
8. The analysis of heavy quarks and lepton pair production on nucleon and nuclear targets. Throughout his unusually fruitful career, Alexei Kaidalov wrote more than 300 scientific papers, 16 of them cited more than 100 times (for a far from complete list of publications by Alexei, see reference [1]).

Alexei maintained scientific contacts with many physicists, both theorists and experimentalists, working in high energy and cosmic ray physics, and, thus, he was actively collaborating for many years with the groups of Alfons Capella at the Laboratoire de Physique Théorique et Hautes Énergies (LPTHE), then renamed as LPT, in Orsay (France), and with the group of Alan D. Martin at the University of Durham (UK), and with other groups of different countries. In particular, Alexei was in close connection with several experiments at CERN, where he was a member of the ALICE Collaboration.

Alexei was a respected and admired magister by colleagues and friends from all over the world for his many and very important, often seminal, original contributions to the field of particle physics, but here I would specially underline Alexei's genuine generosity in passing to younger

physicists, through clear, and natural explanations, his deep knowledge of the fundamental principles and rules at work under the physics processes.

Aliosha passed away in Moscow, on July 25th, 2010, and we all, colleagues, friends, and students, who heartily miss him, will for ever enjoy and profit from his knowledge and wisdom.

To collaborate with Alexei has ment to me to approach greatness in physics, and a real example of integrity in life.

On top of his dedication to physics and science, Aliosha was a friendly and cheerful person, cultivated, and open-minded, and proud of the Russian culture. He was devoted to his wife, Natascha, and to his family. I want to finish this text by expressing my personal tribute and thoughts of affection to Natasha and to all Alexei's family.

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