BFKL Catch Up!

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I give a brief overview over the most recent progress in the field of standard dilute BFKL.

1 Introduction

Although there is hardly any doubt that Quantum Chromodynamics (QCD) is the proper theory to describe strong interactions, it is still far away from being completely solved. Even at large scales where the coupling constant becomes small, a perturbative calculation at a fixed order is not the end of the story. Whenever one considers kinematic regions characterized by two different large scales, logarithms of the ratio of these two scales appear at each order of perturbation theory and – being large – compensate the smallness of the coupling. A resummation of logarithms of the type $[\alpha_s \ln s]^n$ is realized by the leading logarithmic (LL) Balitsky-Fadin-Kuraev-Lipatov (BFKL) [1, 2, 3, 4] equation. It took almost twenty years to extend it to next-to-leading logarithmic accuracy (NLL) by resumming terms of the type $\alpha_s[\alpha_s \ln s]^n$ as well [5, 6].

Both the LL and the NLL BFKL equation are still being studied with great eagerness to improve the accuracy of theoretical predictions for concrete observables as well as to increase our fundamental knowledge about quantum field theory itself. The aim of my contribution to the 13th International Conference on Elastic and Diffractive Scattering is to give an overview over the most recent progresses. An exhaustive discussion of them at this place is not possible. That's why I strongly encourage the reader to have a look at the original works instead and to consider this short article just as an appetizer.

2 Recent Developments

The "gold-plated" process to test BFKL dynamics is the scattering of virtual photons. The virtualities of the photons can be tuned to be of equal, or at least similar, scale such that DGLAP like evolution in the transverse momenta is suppressed offering a clean environment described by the BFKL equation. In Ref. [7] an already existing NLL BFKL calculation of the production of two vector mesons [8, 9] has been collinearly improved leading to more 'sensible' energy scales. The same team has studied the total hadronic cross section of virtual photon scattering in the NLL approach [10]. With the inclusion of the LO quark box contribution an agreement with OPAL data [11] has been obtained.

Another very famous candidate for BFKL physics are forward jets in hadron collisions. In Ref. [12] such jets with a large rapidity gap in between have been investigated and the authors obtain a good agreement with Tevatron data [13, 14]. NLL BFKL calculations for Mueller-

Navelet jets [15] exist already a bit longer [16, 17] and suffer from the same handicap as all previously mentioned NLL BFKL calculations: the impact factors are taken into account only at LO accuracy. However, a full NLL BFKL calculation of Mueller-Navelet jets is under way [18].

Phenomenologically very interesting is the revival of the 'discrete Pomeron' which recently has been studied [19] to describe HERA data (see also the according contribution at this conference). A phenomenological topic which became extremely popular due to the advent of the LHC is the central in- or exclusive production of Higgs particles or other objects with the appropriate quantum numbers [20, 21, 22, 23, 24, 25, 26, 27] (since at this conference a whole session was dedicated to this subject, I refer to the according contributions as well).

Also on the more theoretical side impressing progress has been made. In Ref. [28] the NLO evolution of colour dipoles has been calculated. The linear version of this evolution should reproduce the BFKL equation. While at LL this is easily verified, at NLL there were some discrepancies to the calculation of the NLL BFKL kernel in the Möbis representation [29, 30]. It was just recently [31] that the situation could be clarified. Still under investigation is the issue of conformal invariance. This feature of the LL kernel is obviously spoilt by the running of the coupling at NLL. However the approach of Ref. [28] additionally induces artificial conformal variant terms due to their regularization procedure and also the approach of Ref. [29, 30] produces conformal variant terms which are not caused by the running of the coupling. Most probably they are connected to scale ambiguities.

As another consequence of the running coupling, the LO eigen-functions $(k^2)^\gamma$ of the LL kernel are eigen-functions of the NLL kernel only if one accepts the eigen-value to become an operator. This problem has been addressed in two recent works. One idea is to shift γ by $\alpha_s\beta_0/(4\pi)$ such that formally the eigen-equation is only violated beyond the accuracy one is working at [32]. Another idea is to numerically solve the eigen-equation [33]. Unfortunately none of these three ways is completely satisfactory.

I would also like to draw the reader's attention to two not quite pigeonholable but nevertheless very interesting publications. In Ref. [34, 35] a remarkable relation between soft gluons away from jets in electron positron annihilations and the BFKL equation in coordinate space has been identified and studied. In Ref. [36] it is shown how the correct treatment of kinematics can improve the LO colour dipole evolution in colour dipole perturbation theory, and that as a natural consequence large dipoles are suppressed.

Related to the BFKL equation is the BKP equation [37, 38] for the evolution of three instead of two gluons. It's solution is called the Odderon since it is C-odd while the Pomeron is C-even. Two solutions to the LL BKP equation are known: the so called JW-Odderon [39] with an intercept smaller than 1, and the BLV-Odderon [40] with an intercept identical to 1. Now, in Ref. [41] it has been shown that the intercept of the BLV-Odderon remains to be 1 even if the running of the coupling is taken into account, and in Ref. [42] the intercept has been shown to remain stable against complete higher order corrections. The Odderon has also been investigated in the context if gauge/string duality where the counterpart of the Odderon can be identified with the Kalb-Ramond field in Type IIB string theory [43, 44]. It should also be mentioned that there are new proposals to search for the perturbative Odderon in experiments [45, 46].

At the moment, supersymmetry is one of the most actively studied issues in high energy physics. The $\mathcal{N} = 4$ case is especially interesting because the complete vanishing of the β-function to all orders makes the theory conformal invariant. Moreover it is supposed to be related to string theory by AdS/CFT correspondence. In $\mathcal{N} = 4$ supersymmetry the asymptotic Bethe ansatz [47] is accurate to three-loop order. The correct result for the anomalous dimension has to meet the BFKL pole structure which – due to the resummation – is in some sense an all order result. This interplay has been studied in detail in Ref. [48].

It is known that the all order BDS ansatz [49] for maximally helicity violating scattering amplitudes in $\mathcal{N} = 4$ supersymmetry is wrong for more than five external legs [50, 51]. In Refs. [52, 53, 54] the origin of this mismatch has been further investigated and could *e.g.* be traced to a class of diagram whose cut contribution is missed. Many more objects in the BFKL world are now on the way to be reinvestigated in the $\mathcal{N} = 4$ supersymmetric case, like the R-current impact factors [55, 56] – which can be considered to be the counterpart of the virtual photon impact factor – or like the triple Pomeron vertex [57].

3 Outlook

This is just a very packed presentation of the latest news in BFKL physics. Since (fortunately) there are no strict borders between the different subfields of physics, I might have missed some works which one could as well include in such a collection. Therefore, I apologize for not being literally complete. Moreover, I apologize for not summarizing because I am sure that the chapter of BFKL physics is not yet completed.

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