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Gluing hexagons at three loops

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Abstract

We perform extensive three-loop tests of the hexagon bootstrap approach for structure constants in planar $\mathcal{N}=4$ SYM theory. We focus on correlators involving two BPS operators and one non-BPS operator in the so-called $SL(2)$ sector. At three loops, such correlators receive wrapping corrections from mirror excitations flowing in either the adjacent or the opposing channel. Amusingly, we find that the first type of correction coincides exactly with the leading wrapping correction for the spectrum (divided by the one-loop anomalous dimension). We develop an efficient method for computing the second type of correction for operators with any spin. The results are in perfect agreement with the recently obtained three-loop perturbative data by Chicherin, Drummond, Heslop, Sokatchev [2] and by Eden [3]. We also derive the integrand for general multi-particle wrapping corrections, which turns out to take a remarkably simple form. As an application we estimate the loop order at which various new physical effects are expected to kick-in.

1. Introduction

In [1] a simple proposal for studying 3-point correlation functions in planar $\mathcal{N}=4$ SYM was put forward. It is a sort of *divide and conquer* strategy where the 3-point correlator – represented as the usual string pair of paints – is cut into two simpler hexagonal building blocks which are

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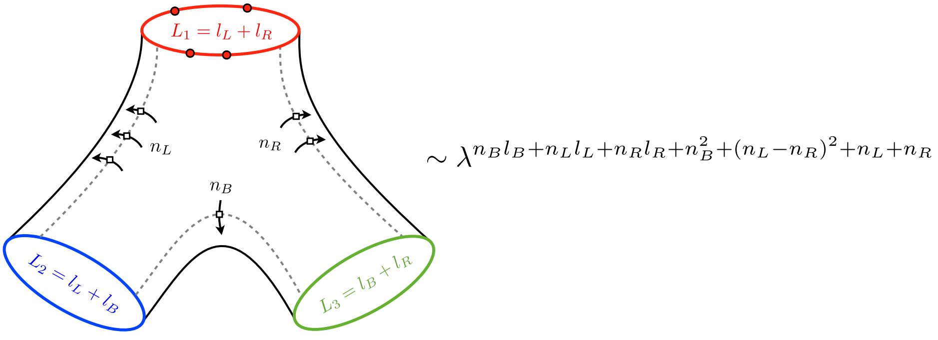

Fig. 1. A pair of pants is cut into two hexagons [1]. The excitations on the non-BPS operator (on the top) can end up on either half and we should sum over those possibilities. Stitching the hexagons back into the pair of pants amounts to integrating over the various rapidities of the mirror particles at the dashed lines. A process with n_L mirror excitations on the left dashed line, n_R on the right and n_B at the bottom shows up at $n_B l_B + n_L l_L + n_R l_R + n_B^2 + (n_L - n_R)^2 + n_L + n_R$ loops as indicated in the figure and explained in Appendix A. It is nice to note that the number of particles needed grows very slowly with perturbation theory. We see that up to three loop order, for instance, we can either have the vacuum in all dashed lines or a *single* particle in a *single* dashed line. The latter Luscher type corrections will only show up for very small bridges l_L, l_R and l_B, related to the lengths of the three external operators as also indicated in the figure.

bootstrapped using integrability and then stitched back together. The cutting procedure involves summing over partitions of the rapidities of the physical particles while the stitching back together requires integrating over the rapidities of the mirror particles, see Fig. 1. The leading process with no mirror particle exchanged is called the *asymptotic* result while processes with mirror excitations travelling around are referred to as *wrapping effects*.

In this paper we present a series of tests for the hexagon picture, at both the asymptotic and wrapping levels, by confronting its predictions with available perturbative data. The focus will be on state-of-the-art correlators, involving two BPS operators and one non-BPS operator in the so-called $SL(2)$ sector, for which explicit results are culminating at three loops [2,3]. There are several new effects, on the integrability side, showing up at this loop order precisely. It is the first time the dressing phase [4], which here enters as an ingredient in the hexagon form factor proposal [1], contributes to the asymptotic part of the structure constant. It is also the first time on the wrapping side that some mirror channels open up. As already sketched in [1], a single mirror particle passing through one of the edges adjacent to the non-BPS operator ($n_L = 1$ or $n_R = 1$ in Fig. 1) first shows up at three loops. The same particle but in the edge opposed to the non-BPS operator ($n_B = 1$ in Fig. 1) shows up earlier, at two loops already. At three loops however we can access to the quantum corrected version of this process, and notably to the first effect of the mirror dressing phase. These are all the novel effects that will be studied here within the hexagon approach and confronted with perturbation theory. In all cases, as we shall see, a perfect match will be observed.

Note added: As we were writing up this work, we received the three loop analysis [18] which overlaps substantially with some of our results.

2. Data

The comparison between theory (i.e. integrability) and experiment (i.e. direct perturbative computations) is one which involves compromise. From the integrability side, the simplest data to produce concern large operators, for which finite size corrections are suppressed. On the other