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Wilson loop and its correlators in the limit of large coupling constant

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Abstract

In this paper we study Wilson loops in various representations for finite and large values of the color gauge group for supersymmetric $\mathcal{N} = 4$ gauge theories. We also compute correlators of Wilson loops in different representations and perform a check with the dual gravitational theory.

1. Introduction

Supersymmetric Wilson loops as well as their correlators both with chiral primary operators and with other Wilson loops are remarkable observables of the supersymmetric Yang–Mills gauge theories (SuSy YM) and provide stringent tests of AdS/CFT correspondence. Due to the fact that the propagator is constant on a circle the computation on the CFT side can be performed with a matrix model as it was demonstrated with the help of localization [1].

As discussed in a number of papers [2,3] in the case of large coupling constant the computation of a Wilson loop's vacuum expectation value in the framework of a matrix model can be significantly simplified. In the present paper we consider the very same limit of large coupling constant and perform some matrix model calculations for the vacuum expectation value of the Wilson loop in different representations, for its correlators with another Wilson loop and with chiral operators both for finite number of colors N of the gauge theory and for large N. Fur-

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thermore, we compare a correlator between two $\frac{1}{2}$-BPS Wilson loops, one of which is in the fundamental representation of the gauge group and the other in a representation associated with a Young tableau with several long lines, with the corresponding quantity on the AdS side and find perfect agreement.

The paper is organized as follows: in Section 2 we calculate a vacuum expectation value of a Wilson loop in a general representation and perform calculation for finite number of colors N. We proceed with considering the large N limit of the previous case. In Section 3 we turn to the correlator of a symmetric Wilson loop with primary chiral operators, again both for finite and large N. Finally in Section 4 we study the correlator of the two Wilson loops discussed in the previous sections both from the point of view of the matrix model and on the AdS side.

2. Wilson loops in arbitrary representations

We consider a $\frac{1}{2}$-BPS circular Wilson loops on S^4 in $\mathcal{N}=4$ super Young–Mills theory with gauge group $U(N)$. The vacuum expectation value of the WL defined as

$$W_{\mathbf{R}} = \frac{1}{N}\left\langle \mathrm{tr}_{\mathbf{R}}\, e^{\mathcal{C}} \right\rangle_{vev} = \frac{1}{N}\left\langle \mathrm{tr}_{\mathbf{R}} P \exp\left[\oint_{\mathcal{C}} ds \left(i A_\mu \dot{x^\mu} + \vec{n}\cdot\vec{\Phi}(\dot{x})\right)\right]\right\rangle_{vev} \tag{2.1}$$

due to localization can be found as a $U(N)$ matrix model integral [1]

$$W_{\mathbf{R}} = \frac{1}{N}\left\langle \mathrm{tr}_{\mathbf{R}}\, e^{a}\right\rangle . \tag{2.2}$$

The averages in the matrix model are defined as

$$\langle f(a)\rangle = \frac{1}{Z}\int da\, \Delta(a)\, e^{-N\sum_u a_u^2}\, f\left(\sqrt{\lambda/2}\, a\right), \tag{2.3}$$

where

$$Z = \int da\, \Delta(a)\, e^{-N\sum_u a_u^2} \tag{2.4}$$

with $da = \prod_{u=0}^{N-1} da_u$ being the Lebesgue measure in the space of eigenvalues of the matrix a in the fundamental representation (absorbing numerical coefficient irrelevant for the calculation of averages) and $\Delta(a)^{\frac{1}{2}}$ being the Vandermonde determinant

$$\Delta(a)^{\frac{1}{2}} = \prod_{u<v=0}^{N-1} (a_u - a_v)\ . \tag{2.5}$$

A representation $\mathbf{R}$ of the $U(N)$ group is specified by the Dynkin labels $\lambda = (\lambda_0, \lambda_1, \ldots \lambda_{N-2})$ and a central charge Q, or equivalently by a Young tableau with rows of length K_u given by

$$K_u = \sum_{j=u}^{N-2} \lambda_j + \frac{Q - \sum_{j=0}^{N-2}\lambda_j}{N}, \qquad u = 0, \ldots N-1\ . \tag{2.6}$$

Let us introduce the orthonormal basis $\{e_i\}$ with $e_i \in \mathbb{R}^N$ and write the $U(N)$ simple roots as $\alpha_i = e_i - e_{i+1}$ for $i = 0, \ldots N-2$. The character of a representation is given by the Weyl formula