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Nuclear Physics B 909 (2016) 360–393

NUCLEAR PHYSICS B

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All-loop correlators of integrable λ-deformed σ-models

George Georgiou [a], Konstantinos Sfetsos [b], Konstantinos Siampos [c,*]

[a] *Institute of Nuclear and Particle Physics, National Center for Scientific Research Demokritos, Ag. Paraskevi, GR-15310 Athens, Greece*

[b] *Department of Nuclear and Particle Physics, Faculty of Physics, National and Kapodistrian University of Athens, Athens 15784, Greece*

[c] *Albert Einstein Center for Fundamental Physics, Institute for Theoretical Physics/Laboratory for High-Energy Physics, University of Bern, Sidlerstrasse 5, CH3012 Bern, Switzerland*

Received 5 May 2016; accepted 17 May 2016

Available online 26 May 2016

Editor: Stephan Stieberger

Abstract

We compute the 2- and 3-point functions of currents and primary fields of λ-deformed integrable σ-models characterized also by an integer k. Our results apply for any semisimple group G, for all values of the deformation parameter λ and up to order $1/k$. We deduce the OPEs and equal-time commutators of all currents and primaries. We derive the currents' Poisson brackets which assume Rajeev's deformation of the canonical structure of the isotropic PCM, the underlying structure of the integrable λ-deformed σ-models. We also present analogous results in two limiting cases of special interest, namely for the non-Abelian T-dual of the PCM and for the pseudodual model.

1. Introduction and motivation

One of the most intriguing conjectures in modern theoretical physics is the AdS/CFT correspondence [1] which, in its initial form, states the equivalence between type-IIB superstring theory on the $AdS_5 \times S^5$ background and the maximally supersymmetric field theory in four

* Corresponding author.

E-mail addresses: georgiou@inp.demokritos.gr (G. Georgiou), ksfetsos@phys.uoa.gr (K. Sfetsos), siampos@itp.unibe.ch (K. Siampos).

http://dx.doi.org/10.1016/j.nuclphysb.2016.05.018

dimensions, i.e. $\mathcal{N} = 4$ SYM. In recent years, a huge progress has been made in calculating physical observables employing both sides of the duality. These calculations managed to probe the strongly coupled regime of the gauge theory which is practically unaccessible by other means. The key feature that allowed this progress is integrability. $\mathcal{N} = 4$ SYM from one side and the two-dimensional σ-model from the other, are believed to be integrable order by order in perturbation theory. It is clear that one way to construct generalizations of the original AdS/CFT scenario is to try to maintain the key property of integrability.

The aim of this work is to study the structure of a class of two-dimensional σ-models, the so-called λ-deformed models constructed in [2]. For isotropic couplings the deformation is integrable in the group case and in the symmetric and semi-symmetric coset cases [2–5] (for the $su(2)$ group case integrability is preserved for anisotropic, albeit diagonal couplings [6]). They are also closely related [7–12] to the so-called η-deformed models for group and coset spaces introduced in [7,8] and in [13–15], respectively. This relation is via Poisson–Lie T-duality and an analytic continuation of coordinates and of the parameters of the σ-models [10–12]. There are also embeddings of the λ-deformed models as solutions of supergravity [16–18].

In particular, we shed light into the structure of the λ-deformed models by computing the two- and three-point functions of all currents and operators exactly in the deformation parameter and up to order $1/k$. This work is based and further extends symmetry ideas and techniques originated in our previous work in [19]. The results of this work are summarized in section 7.

Our starting point is the WZW action

$$S_{\mathrm{WZW},k}(g) = -\frac{k}{4\pi}\int \mathrm{d}^2\sigma\, \mathrm{Tr}(g^{-1}\partial_+ g g^{-1}\partial_- g) + \frac{k}{24\pi}\int_B \mathrm{Tr}(g^{-1}\mathrm{d}g)^3\,, \tag{1.1}$$

for a generic semisimple group G, with $g \in G$ parametrized by X^μ, $\mu = 1, 2, \ldots, \dim G$. We will use the representation matrices t_a which obey the commutation relations $[t_a, t_b] = f_{abc}t_c$ and are normalized as $\mathrm{Tr}(t_a t_b) = \delta_{ab}$. These matrices are taken to be Hermitian and therefore the Lie-algebra structure constants f_{abc} are purely imaginary. The chiral and anti-chiral currents are defined as

$$J_+^a = -i\,\mathrm{Tr}(t_a\partial_+ g g^{-1}) = R^a_\mu \partial_+ X^\mu\,, \qquad J_-^a = -i\,\mathrm{Tr}(t_a g^{-1}\partial_- g) = L^a_\mu \partial_- X^\mu\,. \tag{1.2}$$

The left and right invariant forms $L^a = L^a_\mu \mathrm{d}X^\mu$ and $R^a = R^a_\mu \mathrm{d}X^\mu$ are related as

$$R^a = D_{ab}L^b\,, \qquad D_{ab} = \mathrm{Tr}(t_a g t_b g^{-1})\,. \tag{1.3}$$

We are interested in the non-Abelian Thirring model action (for a general discussion, see [20,21]), namely the WZW two-dimensional conformal field theory (CFT) perturbed by a set of classically marginal operators which are bilinear in the currents

$$S = S_{\mathrm{WZW},k}(g) + \frac{k}{2\pi}\sum_{a,b=1}^{\dim G}\lambda_{ab}\int \mathrm{d}^2\sigma\, J_+^a J_-^b\,, \tag{1.4}$$

where the couplings are denoted by the constants λ_{ab}. An action having the same global symmetries as (1.4), and to which reduces for small values of λ_{ab} has been derived in [2] (see also [22] for the $SU(2)$ case), by gauging a common symmetry subgroup of an action involving the PCM model and the WZW actions. It reads [2]

$$S_{k,\lambda}(g) = S_{\mathrm{WZW},k}(g) + \frac{k}{2\pi}\int \mathrm{d}^2\sigma\, J_+^a(\lambda^{-1} - D^T)^{-1}_{ab}J_-^b\,, \tag{1.5}$$