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Towards the Fradkin–Vasiliev formalism in three dimensions

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Abstract

In this paper we show that using frame-like gauge invariant formulation for the massive bosonic and fermionic fields in three dimensions the free Lagrangians for these fields can be rewritten in the explicitly gauge invariant form in terms of the appropriately chosen set of gauge invariant objects. This in turn opens the possibility to apply the Fradkin–Vasiliev formalism to the investigation of possible interactions of such fields.

0. Introduction

One of the effective ways to investigate interactions for higher spin fields is the Fradkin–Vasiliev formalism [1,2] (see also [3,4]). Initially this formalism was developed for the massless higher spin fields (some examples may be found in [5–9]). But the most important ingredients of such formalism are frame-like formalism and gauge invariance and the frame-like gauge invariant description exists for the massive higher spins as well [10,11]. Thus, in-principle, this formalism can be applied to the investigation of possible interactions for any system with massive and/or (partially) massless fields (some examples can be found in [12–15]).

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At the same time it is a common belief that the Fradkin–Vasiliev formalism operates in dimensions equal or greater than four only. Indeed, as far as the massless higher spins in $d = 3$ are concerned, one has mostly deals with the Chern–Simons theories (e.g. [16–19]) that is tightly connected with the fact that such massless fields do not have any local physical degrees of freedom being pure gauges. But there are three cases when higher spin fields in $d = 3$ do have some physical degrees of freedom: bosonic massive field, bosonic partially massless field of the maximal depth and fermionic massive one. In this paper we show that for all these cases one can rewrite the free Lagrangians in the explicitly gauge invariant way in terms of the appropriate set of gauge invariant objects. This, in turn, can serve as a starting point for the application of Fradkin–Vasiliev formalism to investigation of possible interactions for such fields. Our construction will be based on the frame-like gauge invariant formulation for the massive bosonic and fermionic higher spin fields in $d = 3$ [20,21] (see also [22–24]).

The paper is organized as follows. In Section 1 we give a short review of the main features of the Fradkin–Vasiliev formalism. We separately consider massless and massive case and show that in the massive case there is a possibility to extend the formalism to three dimensions. In Section 2 we consider bosonic higher spin field (both massive and partially massless cases) while in Section 3 we consider massive fermionic case. In the Appendix using massive spin 2 as the simplest non-trivial example we show that it is indeed possible to adopt the results of [11] to three dimensions. But the analogous result for the arbitrary spin would require a lot of rather complicated calculations so in the main part of the paper we find all necessary formulas from scratch directly in $d = 3$.

Notation and conventions. We use a frame-like multispinor formalism where all objects (one-forms or zero-forms) have local indices which are completely symmetric spinor ones. To simplify expressions we will use condensed notation for the spinor indices such that e.g.

$$\Omega^{\alpha(2k)} = \Omega^{(\alpha_1\alpha_2\dots\alpha_{2k})}$$

Also we will always assume that spinor indices denoted by the same letter and placed on the same level are symmetrized, e.g.

$$\Omega^{\alpha(2k)}\zeta^\alpha = \Omega^{(\alpha_1\dots\alpha_{2k}}\zeta^{\alpha_{2k+1})}$$

AdS_3 space will be described by the background frame (one-form) $e^{\alpha(2)}$ and the covariant derivative D normalized so that

$$D \wedge D\zeta^\alpha = -\lambda^2 E^\alpha{}_\beta\zeta^\beta$$

where two-form $E^{\alpha(2)}$ is defined as follows:

$$e^{\alpha(2)} \wedge e^{\beta(2)} = \varepsilon^{\alpha\beta} E^{\alpha\beta}$$

In the most part of the paper the wedge product sign $\wedge$ will be omitted.

1. Fradkin–Vasiliev formalism

In this section we provide brief review of the Fradkin–Vasiliev formalism. Our aim here to look for the possibilities to apply this formalism to higher spins in three dimensions. We begin with the massless case and then we consider the massive one.