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$D = 11$ massless superparticle covariant quantization, pure spinor BRST charge and hidden symmetries

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Abstract

We consider the covariant quantization of the $D = 11$ massless superparticle (M0-brane) in the spinor moving frame or twistor-like Lorentz harmonics formulation. The action involves the set of 16 constrained 32 component Majorana spinors, the spinor Lorentz harmonics $v_{\alpha q}{}^{-}$ parametrizing (as homogeneous coordinates, modulo gauge symmetries) the celestial sphere S^9. There presence allows us to separate covariantly the first and the second class constraints of the model. We show that, after taking into account the second class constraints by means of Dirac brackets and after further reducing the first class constraints algebra, the system is described in terms of a simple BRST charge $\mathbb{Q}^{\text{susy}}$ associated to the $d = 1$, $n = 16$ supersymmetry algebra. The study of the cohomology of this BRST operator requires a regularization by complexifying the bosonic ghosts for the κ-symmetry, λ_q, and further reduction of the regularized cohomology problem to the one for a simpler complex BRST charge $\tilde{\mathbb{Q}}^{\text{susy}}$. This latter is essentially the pure spinor BRST charge by Berkovits, but with a composite pure spinor constructed from the complex $d = 9$ spinor with zero norm, $\tilde{\lambda}_q$, and the spinorial harmonics $v_{\alpha q}{}^{-}$. This exhibits a possible origin of the complexity (non-Hermiticity) characteristic of the Berkovits pure spinor approach.

The simple structure of the non-trivial cohomology of the M0-brane BRST charge $\mathbb{Q}^{\text{susy}}$ finds explanation in the properties that the superparticle action exhibits in the so-called 'covariantized light-cone' basis, where the M0-brane action is expressed in terms of κ-symmetry invariant variables. The set of gauge symmetries in this basis reduces to the $[SO(1,1) \times SO(9)] \otimes K_9$ Borel subgroup of $SO(1,10)$. Imposing their generators as conditions on the superparticle wavefunctions, we arrive at the covariant quantization in terms of physical degrees of freedom which hints possible hidden symmetries of $D = 11$ supergravity. Besides $SO(16)$, which in the twistor like Lorentz harmonic formulation is seen already at the classical level, we discuss also some indirect arguments in favor of the possible E_8 symmetry.

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1. Introduction and summary

1.1. Introduction

A covariant quantization of the massless $D = 11$ superparticle (see [1,2]) has been recently considered [3] in its twistor-like Lorentz harmonics formulation [4] (see also [5–8]). This new, covariant *supertwistor quantization* leds to the linearized $D = 11$ supergravity multiplet in the spectrum (in agreement with the light-cone results of [2]) and permitted to find a possible origin of the hidden $SO(16)$ symmetry of the $D = 11$ supergravity [9]. In this paper we study the BRST quantization of the $D = 11$ massless superparticle model in that approach and then turn back to the covariant quantization of physical degrees of freedom (different from the supertwistor one in [3]) to search for an explanation of the simple structure of the superparticle cohomologies.

The $D = 11$ superparticle is interesting on its own, as the simplest of the M-theory superbranes, the M0-brane, and because its quantization produces, as noticed above, the linearized $D = 11$ supergravity multiplet. Nevertheless, our main motivation is to look for the origin and geometric meaning of the 'pure spinor' formalism by Berkovits [10]. Recently, a breakthrough in the covariant description of quantum superstring theory has been reached in this pure spinor framework: a technique for loop calculations was developed [11] and the first results were given in [11–13]. In particular, two new multiloop theorems useful in a resent investigations of the possible finiteness of $N = 8$ $D = 4$ supergravity [14] were proved in [13]. On the other hand, the pure spinor superstring was introduced—and still remains—as a set of prescriptions for quantum superstring calculations, rather than as a quantization of the Green–Schwarz superstring. Despite a certain progress in relating the pure spinor superstring [10] to the original Green–Schwarz formulation [15], and also [16] to the superembedding approach [17–20],[1] the origin and geometrical meaning of the pure spinor formalism is far from being clear. Possible modifications of the pure spinor approach are also being considered (see e.g. [26]).

In this context, the Lorentz harmonic approach [5–8,27–32], in the frame of which a significant progress in solving the problem of covariant superstring quantization had already been made in late eighties [28,29], looks particularly interesting. Although no counterpart of the recent progress in loop calculations [11,12] has been reached (yet) in the Lorentz harmonics framework, its relation with the superembedding approach [17–20], transparent geometrical meaning [6–8, 27,30] and twistor-likeness [6–8] justifies the hope that its further development (in the pragmatic

[1] Notice also the recent progress [21] in derivation of the pure spinor ghost measure for loop calculations, which was originally proposed in [11] on the ground of a series of very elegant but indirect arguments involving the picture changing operator characteristic of the RNS (Ramond–Neveu–Schwarz) string model [22,23]. This was reached, however, by starting from the pure spinor superstring by Berkovits, covariantizing it with respect to the worldsheet reparametrizations by introducing two-dimensional gravity and quantizing this sector *à la* Batalin–Vilkovisky [24]. Thus, although the subject of [21] was the quantization of Berkovits pure spinor model rather than the original Green–Schwarz superstring, a deeper understanding of the loop calculation technique has been reached already at this stage. The approach similar to [21] was also developed in earlier [25].

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