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Higher-spin fields in braneworlds

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Abstract

The dynamics of higher-spin fields in braneworlds is discussed. In particular, we study fermionic and bosonic higher-spin fields in AdS_5 and their localization on branes. We find that four-dimensional zero modes exist only for spin-one fields, if there are no couplings to the boundaries. If boundary couplings are allowed, as in the case of the bulk graviton, all bosons acquire a zero mode irrespective of their spin. We show that there are boundary conditions for fermions, which generate chiral zero modes in the four-dimensional spectrum. We also propose a gauge invariant on-shell action with cubic interactions by adding non-minimal couplings, which depend on the Weyl tensor. In addition, consistent couplings between higher-spin fields and matter on the brane are presented. Finally, in the AdS/CFT correspondence, where bulk 5D theories on AdS are related to 4D CFTs, we explicitly discuss the holographic picture of higher-spin theories in AdS_5 with and without boundaries.

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1. Introduction

The problem of consistent higher-spin (HS) gauge theories is a fundamental problem in field theory. After the description of their free dynamics [1,2], only negative results for their interactions were obtained [3,4]. For example, it was realized that HS fields cannot consis-

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tently minimally interact with gravity. However, by allowing additional gaugings, one may introduce counter terms, which make the propagation of HS fields in curved backgrounds well-defined. By appropriate completion of the interactions, Vasiliev equations are found, which are the generally covariant field equations for massless HS gauge fields describing their consistent interaction with gravity [5–7].

Nowadays, there is a renewal interest in HS gauge theories. A basic reason for this is that HS theories exist on anti-de Sitter spaces AdS [8], signaling their relevance in the AdS/CFT correspondence. In this framework, as a general rule, conserved currents in the boundary CFT are expected to correspond to massless gauge fields in the bulk [9]. A weakly coupled boundary gauge theory for example contains an infinite number of almost conserved currents, which will be described by a dual HS gauge theory defined in the bulk of AdS. Although much remain to be done in this direction, specific progress has been made in three-dimensional CFTs. It was proposed in [10] for example, that the singlet sector of the three-dimensional critical $O(N)$ vector model is dual, in the large N limit, to a minimal theory in four-dimensional anti-de Sitter space containing massless gauge fields of even spin of the kind studied in [5]. String theory also gives additional support to HS fields. Indeed, string theory, contains an infinite number of massive HS fields with consistent interactions. In the low-tension limit, their masses disappear. Massless HS theories are thus the natural candidates for the description of the low-tension limit of string theory at the semi-classical level [11]. The hope is that the understanding of the dynamics of HS fields could help towards a deeper insight of string theory, which now is mainly based on its low-spin excitations and their low-energy interactions.

A generic massless bosonic particle of integer spin s in an n-dimensional spacetime is described by a totally symmetric tensor of rank s, $\phi_{\mu_1\mu_2\ldots\mu_s}$, while a fermionic particle of spin $s+1/2$ by a totally symmetric tensor-spinor of rank s, $\psi_{\mu_1\mu_2\ldots\mu_s}$. These fields are defined up to gauge transformations and they are subject to certain constraints such that the corresponding theories are ghost free. This means that they describe exactly two propagating modes of $\pm s$ and $\pm(s+1/2)$ helicities, for bosons and fermions, respectively. Such theories may be obtained as the massless limits [1,2] of massive HS theories [12] or by gauge invariance and supersymmetry, as the latter relates HS fields to known lower spin ones [13].

In flat Minkowski spacetime, the gauge transformations of the HS fields are

$$\delta\phi_{\mu_1\mu_2\ldots\mu_s} = \partial_{(\mu_1}\xi_{\mu_2\mu_3\ldots\mu_s)}, \qquad \delta\psi_{\mu_1\mu_2\ldots\mu_s} = \partial_{(\mu_1}\epsilon_{\mu_2\mu_3\ldots\mu_s)}, \tag{1.1}$$

where the parenthesis denote the symmetrized sum of s-terms (without the usual combinatorial $s!$) and $\xi_{\mu_2\mu_3\ldots\mu_s}, \epsilon_{\mu_2\mu_3\ldots\mu_s}$ are totally symmetric rank-$(s-1)$ tensor and tensor-spinors, respectively. In addition, we impose on these fields the strongest gauge invariant constraints

$$\phi^{\mu\nu}{}_{\mu\nu\mu_5\ldots\mu_s} = 0, \qquad \gamma^\nu\psi_\nu{}^\mu{}_{\mu\mu_4\ldots\mu_s} = 0, \tag{1.2}$$

which means that the bosonic HS fields are double traceless, while the fermionic ones are triple γ-traceless (as a trace in the fermionic conditions can be considered as due to two γ matrices). These conditions give constraints for $s \geqslant 4$ and $s \geqslant 7/2$ for bosons and fermions, respectively, and eliminate their lower-spin components. In addition, one can