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Supersymmetry breaking by higher dimension operators

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Abstract

We discuss a supersymmetry breaking mechanism for $\mathcal{N} = 1$ theories triggered by higher dimensional operators. We consider such operators for real linear and chiral spinor superfields that break supersymmetry and reduce to the Volkov–Akulov action. We also consider supersymmetry breaking induced by a higher dimensional operator of a nonminimal scalar (complex linear) multiplet. The latter differs from the standard chiral multiplet in its auxiliary sector, which contains, in addition to the complex scalar auxiliary of a chiral superfield, a complex vector and two spinors auxiliaries. By adding an appropriate higher dimension operator, the scalar auxiliary may acquire a nonzero vev triggering spontaneous supersymmetry breaking. We find that the spectrum of the theory in the supersymmetry breaking vacuum consists of a free chiral multiplet and a constraint chiral superfield describing the goldstino. Interestingly, the latter turns out to be one of the auxiliary fermions, which becomes dynamical in the supersymmetry breaking vacuum. In all cases we are considering here, there is no sgoldstino mode and thus the goldstino does not have a superpartner. The sgoldstino is decoupled since the goldstino is one of the auxiliaries, which is propagating

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only in the supersymmetry breaking vacuum. We also point out how higher dimension operators introduce a potential for the propagating scalar of the theory.

1. Introduction

Supersymmetry is one of the most appealing candidates for new physics. It has not been observed so far; thus, it should be broken at some high energy scale if it is realized at all. The central role on how supersymmetry is broken is usually played by the scalar potential of the supersymmetry breaking sector. Scalar potentials in supersymmetry and supergravity have extensively been studied for two-derivative theories. Even though it is known that introducing higher dimension operators spoils the form of the scalar potential, it seems that the theory somehow protects itself from unconventional non-supersymmetric vacua [1]. Our task here is to discuss how scalar potentials are modified and may lead to supersymmetry breaking when higher dimension operators are introduced. The Goldstone fermion associated with the supersymmetry breaking, the goldstino, is described by the Volkov–Akulov action [2], in which supersymmetry is non-linearly realized. In particular, the goldstino dynamics has been related in [3] to the superconformal anomaly multiplet X corresponding to the FZ supercurrent [4]. The multiplet of anomalies X, defined in the UV flows in the IR, under renormalization group, to a chiral superfield X_{NL} which obeys the constraint $X_{NL}^2 = 0$. This constrained superfield is the realization of the goldstino given in [5]. Since the dynamics of the goldstino is universal, the IR action in [3] is the same as in [5]. Constrained superfields have been used before to accommodate the goldstino. Indeed, there are alternative formulations in which the goldstino sits in a constrained superfield, such as a constrained chiral multiplet [6], a constrained vector multiplet [7], a spinor superfield [8], or a complex linear superfield [9]. Constrained superfields have also been used recently in the MSSM context [10–13] and in inflationary cosmology, where the inflaton is identified with the sgoldstino [14]. In addition their interaction with matter has been worked out in [15].

Supersymmetric theories that contains higher dimension operators (derivative or non-derivative ones) have some novel features [16–19]. Among these, an interesting aspect is that higher dimension operators can contribute to the scalar potential. This has been discussed earlier in [1] where a few examples have been given. In particular, theories with no potential at the leading two-derivative level, may develop a nontrivial potential when higher dimension operators are taken into account and may even lead to supersymmetry breaking, as already mentioned above. At this point there are however, two dangerous aspects. The first one concerns the appearance of ghost instabilities. In the type of theories we are discussing, this instability is not present as the theory does not have those higher derivatives terms which might give rise to such dangerous states. The second issue concerns the auxiliary fields. Here, we are still able to eliminate the auxiliaries of the multiplet since they appeared algebraically in the supersymmetric Lagrangian.

We will consider various theories exhibiting supersymmetry breaking in the presence of higher dimension operators. Special attention will be devoted to a globally supersymmetric model for a complex linear multiplet. As we will explain in one of the following sections, the complex linear multiplet, or nonminimal multiplet, contains the degrees of freedom of a chiral multiplet and in addition, two fermions and a complex vector. At the two derivative level, both the extra fermions and the complex vector are auxiliaries and can be integrated out, giving on-shell just a free complex scalar and a fermion. Due to the constraints the complex linear satisfies, there is no superpotential one can write down and the introduction of an F-term for