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MSSM soft terms from supergravity with gauged R-symmetry in de Sitter vacuum

I. Antoniadis [a,b], R. Knoops [c,d,e,*]

[a] LPTHE, UMR CNRS 7589 Sorbonne Universités, UPMC Paris 6, 75005 Paris France
[b] Albert Einstein Center, Institute for Theoretical Physics Bern University, Sidlerstrasse 5, CH-3012 Bern, Switzerland
[c] CERN Theory Division, CH-1211 Geneva 23, Switzerland
[d] Section de Mathématiques, Université de Genève, CH-1211 Geneva, Switzerland
[e] Instituut voor Theoretische Fysica, KU Leuven, Celestijnenlaan 200D, B-3001 Leuven, Belgium

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Abstract

We work out the phenomenology of a model of supersymmetry breaking in the presence of a tiny (tunable) positive cosmological constant, proposed by the authors in arXiv:1403.1534. It utilizes a single chiral multiplet with a gauged shift symmetry that can be identified with the string dilaton (or an appropriate compactification modulus). The model is coupled to the MSSM, leading to calculable soft supersymmetry breaking masses and a distinct low energy phenomenology that allows to differentiate it from other models of supersymmetry breaking and mediation mechanisms.

1. Introduction

In a recent work [1], we studied a simple $N = 1$ supergravity model of supersymmetry breaking [2] having a metastable de Sitter vacuum with an infinitesimally small (tunable) cosmological constant independent of the supersymmetry breaking scale that can be in the TeV region. Besides

* Corresponding author.
E-mail address: rob.knoops@cern.ch (R. Knoops).

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the gravity multiplet, the minimal field content consists of a chiral multiplet with a shift symmetry promoted to a gauged R-symmetry using a vector multiplet. In the string theory context, the chiral multiplet can be identified with the string dilaton (or an appropriate compactification modulus) and the shift symmetry associated to the gauge invariance of a two-index antisymmetric tensor that can be dualized to a (pseudo)scalar. The shift symmetry fixes the form of the superpotential and the gauging allows for the presence of a Fayet–Iliopoulos (FI) term, leading to a supergravity action with two independent parameters that can be tuned so that the scalar potential possesses a metastable de Sitter minimum with a tiny vacuum energy (essentially the relative strength between the F- and D-term contributions). A third parameter fixes the Vacuum Expectation Value (VEV) of the string dilaton at the desired (phenomenologically) weak coupling regime. An important consistency constraint of our model is anomaly cancellation which has been studied in [3] and implies the existence of additional charged fields under the gauged R-symmetry.

In this work, we study a small variation of this model which is manifestly anomaly free without additional charged fields and allows to couple in a straightforward way a visible sector containing the minimal supersymmetric extension of the Standard Model (MSSM) and study the mediation of supersymmetry breaking and its phenomenological consequences. It turns out that an additional 'hidden sector' field z is needed to be added for the matter soft scalar masses to be non-tachyonic; although this field participates in the supersymmetry breaking and is similar to the so-called Polonyi field, it does not modify the main properties of the metastable de Sitter vacuum. All soft scalar masses, as well as trilinear A-terms, are generated at the tree level and are universal under the assumption that matter kinetic terms are independent of the 'Polonyi' field, since matter fields are neutral under the shift symmetry and supersymmetry breaking is driven by a combination of the $U(1)$ D-term and the dilaton and z-field F-term. Alternatively, a way to avoid the tachyonic scalar masses without adding the extra field z is to modify the matter kinetic terms by a dilaton dependent factor.

A main difference of the present analysis from the previous work is that we use a field representation in which the gauged shift symmetry corresponds to an ordinary $U(1)$ and not an R-symmetry. The two representations differ by a Kähler transformation that leaves the classical supergravity action invariant. However, at the quantum level, there is a Green–Schwarz term generated that amounts for an extra dilaton dependent contribution to the gauge kinetic terms needed to cancel the anomalies of the R-symmetry. This creates an apparent puzzle with the gaugino masses that vanish in the first representation but not in the latter. The resolution of the puzzle is based on the so-called anomaly mediation contributions [4,5] that explain precisely the above apparent discrepancy. It turns out that gaugino masses are generated at the quantum level and are thus suppressed compared to the scalar masses (and A-terms).

The outline of the paper is the following. In Section 2, we present the model and our conventions and show that adding MSSM fields inert under the shift symmetry leads to tachyonic scalar masses. In Section 3, we solve this problem by extending the model with an additional chiral field in the 'hidden' sector, participating in the supersymmetry breaking without modifying the main features of the model and its metastable de Sitter vacuum. In Section 4, we add a visible sector with the MSSM fields and compute all soft breaking terms. In particular, we discuss how gaugino masses are generated and describe the puzzle mentioned above. In Section 5, we discuss the Kähler transformation and show the equivalence of the two representations at the quantum level. We work out the phenomenology in section 6. In section 7 we introduce a non-canonical Kähler potential for the MSSM superfields as a different possible solution to the tachyonic masses.