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Gauging MSSM global symmetries and SUSY breaking in de Sitter vacuum

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Abstract

We elaborate on a recent study of a model of supersymmetry breaking we proposed recently, in the presence of a tunable positive cosmological constant, based on a gauged shift symmetry of a string modulus, external to the Standard Model (SM) sector. Here, we identify this symmetry with a global symmetry of the SM and work out the corresponding phenomenology. A particularly attracting possibility is to use a combination of Baryon and Lepton number that contains the known matter parity and guarantees absence of dimension-four and -five operators that violate B and L.

1. Introduction

In a recent paper [1], we performed a detailed study of the phenomenology of a supergravity model of supersymmetry breaking [2,3], having a metastable de Sitter (dS) vacuum with a tiny (tunable) cosmological constant, independent of the supersymmetry breaking scale. The model

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is based on a shift symmetry associated with a string modulus (dual to a two-index tensor) that we consider to be in the dilaton supermultiplet for definiteness, which is gauged using a vector multiplet. Depending on the Kähler basis, the shift symmetry becomes a gauged R-symmetry that fixes the form of the superpotential as a single exponential and allows for the presence of a Fayet–Iliopoulos (FI) term. The model has thus three parameters: the strengths of the superpotential and the FI-term, and the exponent of the exponential superpotential. The first two can be tuned to fix the vacuum energy at a tiny positive value, while the latter determines the vacuum expectation value (VEV) of the dilaton. The overall scale then controls the supersymmetry breaking, or equivalently the gravitino mass, driven by expectation values of both F- and D-auxiliary components of the chiral and vector multiplet.

The model can be easily coupled to an observable sector containing a supersymmetric extension of the Standard Model (MSSM). To avoid anomalies [4], we considered all MSSM fields inert under the shift symmetry, in a Kähler basis where the $U(1)$ is not an R-symmetry, and a constant (modulus independent) gauge kinetic function. In the simplest case however scalar masses are tachyonic which can be avoided, without modifying the main properties of the model, by introducing either a new 'hidden sector' field participating in the supersymmetry breaking, similar to the Polonyi field [5], or dilaton dependent matter kinetic terms [1]. In both cases, an extra parameter is introduced with a narrow range of values, in order to satisfy all required constraints. All scalar soft masses and 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, while gaugino masses are generated at the quantum level, via the so-called anomaly mediation contributions [6], and are naturally suppressed compared to the scalar masses.

It follows that the low energy spectrum is very particular and can be distinguished from other models of supersymmetry breaking and mediation, such as mSUGRA and mAMSB. It consists of light neutralinos, charginos and gluinos, where the experimental bounds on the (mostly bino-like) LSP and the gluino force the gravitino mass to be above 15 GeV and the squarks to be very heavy, with the exception of the stop which can be as light as 2 TeV.

In this work, we study the possibility that the gauged shift symmetry is identified with a known global symmetry of the Standard Model (SM), or more generally its supersymmetric extension, keeping the nice properties of the model, namely the existence of the metastable dS vacuum with a tunable cosmological constant and a viable spectrum of superparticles consistent with all experimental constraints. A particular attracting possibility is to use a symmetry that contains the usual R-parity, or matter-parity (depending on the Kähler basis) of the MSSM. We find that this is indeed possible and analyze explicitly the anomaly free symmetry $B - L$ (when adding three right-handed neutrinos), where B and L stand for the baryon and lepton number respectively, or the combination $3B - L$ which has the advantage of forbidding all dimension-four and dimension-five operators violating baryon or lepton number in MSSM. It turns out that the phenomenology of these two cases is similar to the results we found in the case where SM fields are inert under the shift symmetry [1], with a few minor differences, such as that the stop squark can become lighter to about 1.5 TeV. Actually the model contains an extra parameter, the unit of $B - L$ charge q for the SM fields, that allows to extrapolate between the present analysis and the one of Ref. [1]. It turns out though that q is bounded from the requirement of existence of the electroweak vacuum.

We also address the question if the problem of tachyonic scalar masses can be solved without adding extra field or modifying the matter kinetic terms, by appropriately choosing the transformations of the MSSM fields, due to the extra D-term contribution in the scalar potential since SM fields are now charged under the $U(1)$. However, the answer turns out to be negative due to