Available online at www.sciencedirect.com

ScienceDirect

Nuclear Physics B 905 (2016) 73–95

NUCLEAR PHYSICS B

www.elsevier.com/locate/nuclphysb

Pure gravity mediation and spontaneous B–L breaking from strong dynamics

Kaladi S. Babu [a], Kai Schmitz [b,*], Tsutomu T. Yanagida [b]

[a] Department of Physics, Oklahoma State University, Stillwater, OK 74078, USA
[b] Kavli IPMU (WPI), UTIAS, The University of Tokyo, Kashiwa, Chiba 277-8583, Japan

Received 29 July 2015; received in revised form 18 December 2015; accepted 24 January 2016

Available online 26 January 2016

Editor: Herman Verlinde

Abstract

In pure gravity mediation (PGM), the most minimal scheme for the mediation of supersymmetry (SUSY) breaking to the visible sector, soft masses for the standard model gauginos are generated at one loop rather than via direct couplings to the SUSY-breaking field. In any concrete implementation of PGM, the SUSY-breaking field is therefore required to carry nonzero charge under some global or local symmetry. As we point out in this note, a prime candidate for such a symmetry might be B–L, the Abelian gauge symmetry associated with the difference between baryon number B and lepton number L. The F-term of the SUSY-breaking field then not only breaks SUSY, but also B–L, which relates the respective spontaneous breaking of SUSY and B–L at a fundamental level. As a particularly interesting consequence, we find that the heavy Majorana neutrino mass scale ends up being tied to the gravitino mass, $\Lambda_N \sim m_{3/2}$. Assuming nonthermal leptogenesis to be responsible for the generation of the baryon asymmetry of the universe, this connection may then explain why SUSY necessarily needs to be broken at a rather high energy scale, so that $m_{3/2} \gtrsim 1000$ TeV in accord with the concept of PGM. We illustrate our idea by means of a minimal model of dynamical SUSY breaking, in which B–L is identified as a weakly gauged flavor symmetry. We also discuss the effect of the B–L gauge dynamics on the superparticle mass spectrum as well as the resulting constraints on the parameter space of our model. In particular, we comment on the role of the B–L D-term.

* Corresponding author.
E-mail address: kai.schmitz@ipmu.jp (K. Schmitz).

http://dx.doi.org/10.1016/j.nuclphysb.2016.01.023

1. Introduction: SUSY and *B–L* breaking by the same chiral field

Pure gravity mediation (PGM) [1,2] is an attractive, viable and minimal scheme for the mediation of supersymmetry (SUSY) breaking to the visible sector.[1] The main idea behind this mediation scheme is that, given a rather high SUSY breaking scale of $\mathcal{O}\left(10^{11}\cdots 10^{12}\right)$ GeV, soft SUSY breaking in the minimal supersymmetric standard model (MSSM) can be solely achieved by means of gravitational interactions. In PGM, squarks and sleptons receive large masses of the order of the gravitino mass, $m_{3/2} \sim 100\cdots 1000$ TeV, via the tree-level scalar potential in supergravity (SUGRA) [5]. Meanwhile, gauginos obtain one loop-suppressed masses around the TeV scale via anomaly mediation (AMSB) [6]. Because of the large sfermion mass scale, PGM easily accounts for a standard model (SM) Higgs boson mass of 126 GeV [7], while, at the same time, it is free of several notorious problems that other, low-scale realizations of gravity mediation are usually plagued with. PGM solves, e.g., the cosmological gravitino problem [8] and (depending on $m_{3/2}$) successfully evades a number of bounds on flavor-changing neutral currents and *CP* violation [9].[2]

In particular, PGM does not suffer from the cosmological Polonyi problem [11], which one typically encounters in ordinary gravity mediation. There, the SUSY-breaking (or "Polonyi") field X couples directly to the chiral field strength superfields belonging to the SM gauge interactions,

$$W \supset \frac{X}{M_{\rm Pl}}\mathcal{W}^\alpha\mathcal{W}_\alpha\,, \tag{1}$$

with $M_{\rm Pl} = (8\pi G)^{-1/2} \simeq 2.44\times 10^{18}$ GeV denoting the reduced Planck mass and which results in gaugino masses of $\mathcal{O}\left(m_{3/2}\right)$. To be able to write down such couplings in the superpotential, one has to require that the field X be completely neutral. This, however, potentially leads to severe problems in the context of cosmology. Given a completely uncharged field X, the origin $X = 0$ does not have any special meaning in field space, which is why X is expected to acquire some vacuum expectation value (VEV) of $\mathcal{O}(M_{\rm Pl})$ during inflation, $\langle X\rangle \sim M_{\rm Pl}$. In this case, a huge amount of energy ends up being stored in the coherent oscillations of the Polonyi field after inflation. Once released in the perturbative decay of the Polonyi field at late times, this energy then results in dangerous entropy production as well as unacceptably large changes to the predictions of big bang nucleosynthesis. A number of solutions to this infamous Polonyi problem have been put forward over the years in the context of ordinary gravity mediation (see, e.g., [12,13]). At the same time, PGM resolves the Polonyi problem in the arguably simplest way, i.e., by requiring that the origin of the Polonyi field *does* have a special meaning. This is readily done by requiring SUSY to be broken by a *non-singlet field*, i.e., in PGM, one assigns nonzero charge to the Polonyi field, so as to single out the origin as a special point in field space. During inflation, X is then easily stabilized at $\langle X\rangle = 0$, by means of a Hubble-induced mass term around the origin, and we no longer have to worry about large-amplitude oscillations of the Polonyi field after inflation.[3] This solves the Polonyi problem.[4] Meanwhile, given a charged SUSY-breaking

[1] For closely related mediation schemes, see [3,4].

[2] Other low-energy observables such as proton decay may, however, still call for additional flavor structure [10].

[3] Here, we face, in fact, a discrete choice w.r.t. the coupling of X to the inflaton field Φ in the higher-dimensional Kähler potential, $K \supset k\, M_{\rm Pl}^{-2}\, |\Phi|^2\, |X|^2$. In order to furnish X with a *positive* Hubble-induced mass, the coefficient k needs to be *negative*. This is, however, a perfectly natural assumption, which we will adopt in the following.

[4] We emphasize that it is the suppressed VEV of the Polonyi field at the end of inflation that primarily allows one to solve the Polonyi problem in PGM. The fact that the mass of the Polonyi field is typically very large in PGM, $m_X \sim$