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Gravity safe, electroweak natural axionic solution to strong CP and SUSY μ problems

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Particle physics models with Peccei-Quinn (PQ) symmetry breaking as a consequence of supersymmetry (SUSY) breaking are attractive in that they solve the strong CP problem with a SUSY DFSZ-like axion, link the SUSY breaking and PQ breaking intermediate mass scales and can resolve the SUSY μ problem with a naturalness-required weak scale μ term whilst soft SUSY breaking terms inhabit the multi-TeV regime as required by LHC sparticle mass limits and the Higgs mass measurement. In spite of so many advantages these models have a major disadvantage in that global symmetries are incompatible with gravity and hence suffer a generic gravity spoliation problem. We present two models based on the discrete R-symmetry $\mathbf{Z}_{24}^R$-which may emerge from compactification of 10-d Lorentzian spacetime in string theory-where the μ term and dangerous proton decay and R-parity violating operators are either suppressed or forbidden while a gravity-safe PQ symmetry emerges as an accidental approximate global symmetry leading to a solution to the strong CP problem and a weak-scale/natural value for the μ term. Though there are many other solutions to the μ problem, the models based on discrete R-symmetry $\mathbf{Z}_{24}^R$ seem highly motivated. A general consideration of string theory landscape imply a mild statistical draw towards large soft SUSY breaking terms. We can extend this reasoning to the models considered here in which PQ symmetry is broken by a large negative quartic soft term. The pull towards large soft terms also pulls the PQ scale as large as possible. However, this is tempered by the cosmological requirement to avoid overproduction of mixed axion-WIMP dark matter in the early universe. Such requirements lead to an upper bound of $f_a \sim 10^{14}$ GeV with a most probable value of $f_a \sim 7 * 10^{11}$ GeV, which is well below the typical expectation that $f_a \sim 10^{16}$ GeV from string theory.

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