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Exploring the Landscape of Spontaneous CP Violation in Supersymmetric Theories

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The strong CP problem remains one of the most important unresolved issues in the Standard Model. Spontaneous CP violation (SCPV) is a promising approach to the problem by assuming that CP is an exact symmetry of the Lagrangian but broken spontaneously at the vacuum, which enables the generation of the observed Cabibbo-Kobayashi-Maskawa (CKM) phase without reintroducing a nonzero strong CP phase. Supersymmetry (SUSY) provides a natural framework to accommodate such a mechanism, as SUSY can not only protect the scale of SCPV from radiative corrections but also suppress problematic higher-dimensional operators generating a strong CP phase. In the present study, we explore the realization of SCPV in two distinct SUSY scenarios. First, we investigate SCPV in the exact SUSY limit, extending the spurion formalism developed in non-supersymmetric theories and introducing a method to determine whether the given superpotential satisfies the necessary condition for SCPV. Second, we construct a model in which CP is spontaneously broken at an intermediate scale along pseudo-flat directions, stabilized by soft SUSY breaking and non-perturbative effects of a gauge theory. The latter setup predicts light scalars in the SCPV sector whose masses are determined by the SUSY breaking scale.

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