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$SU(5) \times U(1)_X$ Axion Model with Observable Proton Decay

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We propose a $SU(5) \times U(1)_X \times U(1)_{PQ}$ model, where $U(1)_X$ is the generalization of the B - L (baryon minus lepton number) gauge symmetry and $U(1)_{PQ}$ is the global Peccei-Quinn (PQ) symmetry. There are four fermions families in $\overline{\mathbf{5}} + \mathbf{10}$ representations of SU(5), a mirror family in $\mathbf{5} + \overline{\mathbf{10}}$ representations, and three SU(5) singlet Majorana fermions. The $U(1)_X$ related anomalies all cancel in the presence of the Majorana neutrinos. The SU(5) symmetry is broken at $M_{GUT} \simeq (4 - 7) \times 10^{15}$ GeV and the proton lifetime τ_p is estimated to be well within the expected sensitivity of the future Hyper-Kamiokande experiment, τ_p lesssim 1.3×10^{35} years. The SU(5) breaking also triggers the breaking of the PQ symmetry, resulting in axion dark matter (DM), with the axion decay constant f_a of order M_{GUT} or somewhat larger. The CASPEr experiment can search for such axion DM candidates. With the identification of the $U(1)_X$ breaking Higgs field with the inflaton field, we implement low scale inflection-point inflation with $H_{inf} < 10^9$ GeV which successfully resolve the cosmologically fatal axion domain wall, axion DM isocurvature and SU(5) monopole problems. The vectorlike fermions in the model are essential for achieving a successful unification of the SM gauge couplings as well as the phenomenological viability of both axion DM and inflation scenario.

Summary

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