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High Reheating Temperature without Axion Domain Walls

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We investigate a cosmological scenario in which the Peccei-Quinn (PQ) symmetry remains broken in the entire history of the Universe, thereby avoiding the formation of axion strings and domain walls. Contrary to the conventional expectation, it is demonstrated that appropriately chosen scalar interactions are able to keep the PQ symmetry broken at arbitrarily high temperatures. We carefully examine the finite-temperature effective potential in a model with two PQ breaking scalar fields. The existence of flat directions plays a vital role in suppressing axion isocurvature perturbations during inflation by stabilizing a PQ field at a large field value. The viable parameter space consistent with theoretical and observational constraints is identified. Our scenario provides a minimal path for PQ symmetry breaking that addresses both the axion domain wall and isocurvature problems while permitting arbitrarily high reheating temperatures accommodating high-scale baryogenesis scenarios such as thermal leptogenesis.

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