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Deformation of Axion Potentials: Implications for Spontaneous Baryogenesis, Dark Matter, and Isocurvature Perturbations

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We show that both the baryon asymmetry of the universe and dark matter (DM) can be accounted for by the dynamics of a single axion-like field. In this scenario, the observed baryon asymmetry is produced through spontaneous baryogenesis—driven by the early evolution of the axion—while its late-time coherent oscillations explain the observed DM abundance. Typically, spontaneous baryogenesis via axions is only successful in regions of parameter space where the axion is relatively heavy, rendering it highly unstable and unfit as a dark matter candidate. However, we show that a field-dependent wavefunction renormalization can arise which effectively "deforms"the axion potential, allowing for efficient generation of baryon asymmetry while maintaining a light and stable axion. Meanwhile, such deformations of the potential induce non-trivial axion dynamics, including a tracking behavior during its intermediate phase of evolution. This attractor-like dynamics dramatically reduces the sensitivity of the axion relic abundance to initial conditions and naturally suppresses DM isocurvature perturbations. Finally, we construct an explicit model realization, using a continuum-clockwork axion, and survey the details of its phenomenological viability.

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