Contribution ID: **100** Type: **not specified**

Small Instantons and the Post-Inflationary QCD Axion in a Special Product GUT

Tuesday, 26 August 2025 16:20 (20 minutes)

We present a new framework of grand unification that is equipped with an axion solution to the strong CP problem without a domain wall problem when the Peccei–Quinn (PQ) symmetry is spontaneously broken after inflation. Our grand unified theory (GUT) is based on a symmetry breaking pattern, SU(10) ×SU(5)1 →SU(5)V ⊃SU(3)C ×SU(2)L ×U(1)Y, where SU(5)1 and a special embedding of SU(5)2 ⊂SU(10) are broken to a diagonal subgroup SU(5)V. The model contains a vector-like pair of PQ-charged fermions that transform as (anti-)fundamental representations under SU(10), so that the domain wall number is one. However, after the GUT symmetry breaking, the number of vector-like pairs of PQ-charged colored fermions is larger than one, which seems to encounter the domain wall problem. This apparent inconsistency is resolved by small instanton effects on the axion potential which operate as a PQ-violating bias term and allow the decay of domain walls. We propose a domain-wall-free UV completion for an IR model where the domain wall number appears larger than one. The model gives a prediction for a dark matter axion window, which is different from that of the ordinary post-inflationary QCD axion with domain wall number one.

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Session Classification: Parallel talks (2)