The 2nd Workshop on Grand Unified Theories: Phenomenology and Cosmology (GUTPC 2025)

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Book of Abstracts

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$SU(5)$ Yukawa sectors at NLO

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$SU(5)$ grand unified model, which unifies SM quarks and leptons in $\overline{5}$ and 10 dimensional irreducible representations˜(irrep), yields observationally inconsistent tree-level Yukawa relations when only a single $5_{\rm H}$ or $45_{\rm H}$ dimensional irrep having a single Higgs contributes to the Yukawa sector. For instance, only $5_{\rm H}$ dimensional Higgs in the Yukawa sector yields $Y_d = Y_e^T$, while $45_{\rm H}$ gives $3Y_d = Y_e^T$. These inconsistent tree-level Yukawa relations can be rendered viable by switching on one-loop corrections to different Yukawa vertices. The former scenario requires extending the minimal model by $SU(5)$ singlets, while the latter requires splitting in the mass of scalars residing in the same multiplet. Other setups are also explored where radiative effects make the inconsistent tree-level frameworks viable. Importantly, the findings highlight the feasibility of the simplest Yukawa sector when accounting for quantum corrections and substantial threshold effects.

2

High-quality Peccei-Quinn symmetry from the interplay of vertical and horizontal gauge symmetries

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We explore a class of axion models where an accidental U(1) Peccei-Quinn (PQ)
symmetry automatically arises from the interplay of vertical (grand-unified)
and horizontal (flavor) gauge symmetries. Focusing on a specific SO(10) or Pati-Salam realization, we analyze the quality of the PQ symmetry and demonstrate that
the model non-trivially reproduces the Standard Model flavor structure. A high-quality axion, immune to the PQ quality problem, is obtained for ma ⊠ 0.01 eV, corresponding to a post-inflationary PQ-breaking scenario. A distinctive feature of this setup is the presence of parametrically light fermions, known as anomalons, introduced to cancel the gauge anomalies of the flavor symmetry. We
investigate their cosmological production in the early universe, highlighting
how measurements of ΔNeff could serve as a low-energy probe of the UV dynamics addressing the PQ-quality problem.

3

Unification of Particles and Symmetries in An Affine SU(8) Lie Algebra

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We present the recent progresses of a unified framework based on an affine SU(8) Lie algebra. This is found to be the minimal Lie algebra where three-generational SM fermions can transform differently. Accordingly, we describe how to generate the observed SM quark/lepton mass hierarchies and the CKM mixing patterns with one unique SM Higgs boson. We also discuss the gauge coupling unification in this framework, where one unique SUSY extension with anti-symmetric superfields is allowed.

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Minimal dark matter in SU(5) grand unification

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Minimal dark matter is an attractive candidate for dark matter because it is stabilized without the need to impose additional symmetries. It is known that the SU(2)L quintuplet fermion can serve as a minimal dark matter candidate, with its mass predicted to be around 14 TeV, based on the thermal production mechanism. In this work, we embed the quintuplet dark matter within non-supersymmetric SU(5) grand unified theories. We find that two pairs of colored sextet fermions are required at the O(1-10) TeV scale to achieve gauge coupling unification, with the unification scale near the reduced Planck scale. These colored sextet fermions become metastable because their interactions are suppressed by the unification scale. Our model can be tested through comprehensive searches for colored sextet fermions in collider experiments, as well as through indirect and direct detection methods for minimal dark matter. Once the minimal dark matter scenario has been experimentally confirmed, it will have implications for modifying string theories.