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#1-7 SO(10) Model with Peccei-Quinn Symmetry and Impact of Family Symmetry on Neutrino Oscillations

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In this work, the grand unified theory (GUT) of SO(10) is analyzed in the context of Peccei-Quinn ($\mathrm{U}(1)_{\mathrm{PQ}}$) symmetry and family symmetries. The SO(10) framework is chosen because it's a good candidate that can offer a possible solution for reconciling the Standard Model (SM) interactions with many problems that are currently facing particle physics, including dark matter, baryon asymmetry, and neutrino masses .

One of the notable characteristics of SO(10) is that the seesaw mechanism provides a natural explanation for the small neutrino masses. Right-handed neutrinos are part of the model by nature; they contribute to the production of light neutrino masses through the seesaw mechanism, which explains why neutrinos are substantially lighter than other fermions in the Standard Model. Furthermore, by considering the added axions as possible dark matter candidates, the Peccei-Quinn symmetry offers a very convincing solution to the strong CP problem. These axions are produced by breaking Peccei-Quinn symmetry and can be used as cold dark matter in cosmological models.

The integration of family symmetries into the SO(10) GUT model is a significant component of this work. These symmetries present new point of view to address the leptonic interactions and especially neutrino interactions, primarily by the introduction of new criteria that influences mixing angles and neutrino mass hierarchies. They can change the neutrino oscillation patterns, which is useful in understanding difficult phenomena like neutrinoless double beta decay. These changes can largely assist in solving some of the open experimental issues in the field of neutrino research today.

A key part of the work is addressing the unification of gauge coupling constants in the SO(10) GUT framework. The breaking of our model's gauge group is made possible by using multiple Higgs representations in one step, directly to the SM symmetry which is a good indicator that a Grand Unified Theory (GUT) is viable. A proton lifetime lower than 4.5×10^{34} years is predicted, and this is within the sensitivity range of soon to come experiments such as Hyper-Kamiokande. One of the main predictions of GUTs, the detection of proton decay, that could offer strong evidence of the unification at very high energy scales.

This model examines the influence of family symmetries on neutrino oscillations, as well as some potential implications for mixing angles and mass parameters. These symmetries can account for discrepancies in oscillation data observed in experiments like Super-Kamiokande and KamLAND. Data from accelerator, reactor, solar, and atmospheric neutrino experiments can help verify how sterile neutrinos fit into the model. Even a simple numerical analysis shows some irregularities in the usual oscillation patterns, suggesting the possibility of new physics beyond the Standard Model.

By combining family symmetries with Peccei-Quinn ($\mathrm{U}(1)_{\mathrm{PQ}}$) symmetry, the model creates a solid framework for explaining both neutrino oscillations and dark matter. Connecting these theoretical ideas with experimental results opens up new ways to explore the fundamental nature of particles and forces in the universe.

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