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Residual Flavor Symmetries at the Modular Self-Dual Point: Predictive Insights into Neutrino Masses and Mixing

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"We explore the theoretical consequences of residual symmetries that persist at the modular self-dual point $\tau = i$ within modular-invariant frameworks. Assuming the three generations of lepton doublets form an irreducible representation of a finite modular group Γ_N, and that the light neutrino masses arise from the Weinberg operator constructed from modular forms, we demonstrate that the neutrino mass matrix naturally acquires a residual flavor symmetry or antisymmetry, dictated by the modular weight. In the antisymmetric case, one neutrino remains massless, while the remaining two can become degenerate when the mass matrix is real—an outcome independent of the modular level N.

By imposing a compatible residual symmetry in the charged-lepton sector, the structure of the leptonic mixing matrix becomes partially determined, fixing one of its columns and yielding predictive relations among the mixing angles and the Dirac CP phase. These residual (anti)symmetries enable the application of conventional flavor-symmetry techniques within a modular setting, offering a systematic approach to phenomenological predictions. A comprehensive survey over all viable Γ_N groups indicates that the resulting fixed column typically contains $\mathcal{O}(1)$ entries, leading naturally to large lepton mixing. This framework thus provides a symmetry-driven, modular origin of testable patterns in neutrino observables and establishes a bridge between modular symmetry structures and measurable parameters in the lepton sector."

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