NEUTRINO MASS MATRIX TEXTURES AND ROLE OF NON-ABELIAN DISCRETE SYMMETRIES

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Abstract: We study the role of non-Abelian discrete symmetries on neutrino textures. Textures are predictive as the neutrino parameters are correlated by texture conditions. The predicted correlations or numerical values of neutrino parameters can be probed at various experiments. This can validate the role of non-Abelian discrete symmetries. Such symmetries also have other roles in cosmology due to formation of domain walls. These walls can be made unstable leading to gravitational waves with characteristic spectrum and peak frequency.

Keywords: Neutrino mass; Flavour Symmetry; Texture Zero

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1 Introduction

Neutrinos are among the most mysterious and elusive particles in the universe. These subatomic particles are created by the sun, stars, and other celestial phenomena and are incredibly small, with no electric charge and nearly zero mass. Neutrinos interact via the weak nuclear force and gravity [1], making them extremely difficult to detect as they pass through matter almost undisturbed. Billions of neutrinos emanating from the sun pass through the human body every second without leaving a trace. Despite their elusive nature, scientists have confirmed the existence of neutrinos through sophisticated detectors and have found that they come in three flavors or types: electron, muon, and tau neutrinos [2]. Research on neutrinos continues to unravel the secrets of the universe, shedding light on cosmic events, dark matter, and the fundamental laws of physics [3]. The paper is organised as follows. The theoretical and computational method is described in section 2. In section 3, the results and discussion of our study is given and our conclusions are summarized in section 4.

2 Theoretical and Computational Method

Symmetry is a fundamental concept that permeates various aspects of nature, art, and human perception [4, 5]. In physics, symmetry refers to the idea that laws remain unchanged under specific transformations, such as rotations or reflections. This concept underlies the conservation of energy, momentum, and angular momentum. In geometry, symmetry describes the harmony and balance found in shapes, like spheres, crystals, or snowflakes. In art and architecture, symmetry creates visually appealing compositions, conveying balance, order, and beauty. Biological systems also exhibit symmetry, from the radial symmetry of flowers to the bilateral symmetry of human faces [6, 7]. Symmetry plays a crucial role in our cognitive processing, influencing perception, aesthetics, and even emotions, as our brains are wired to recognize and respond to symmetrical patterns. This universal language of symmetry connects disparate disciplines, revealing the intricate and beautiful structures that govern our universe [8, 9, 10].

The Yukawa Lagrangian for charged lepton can be written as

$$-\mathcal{L}_{\rm CL} \supset Y_e \overline{\ell_e} H e_R + Y_\mu \overline{\ell_\mu} H \mu_R + Y_\tau \overline{\ell_\tau} H \tau_R + \text{h.c.} \tag{1}$$

The details are given in appendix A.

3 Results and Discussion

Neutrino mass matrix textures refer to the patterns and structures within the matrix that describes the masses and mixing of neutrinos. The neutrino mass matrix, typically represented by the symbol M_ν, is a 3×3 matrix that encodes the masses of the three neutrino flavors (electron, muon, and tau) and their mixing parameters. The Lagrangian is given in equation (1). The result for texture 1 is shown in figure 1. The parameter details are given in table 1. Texture zeros, where certain elements of the matrix are zero, can reveal underlying symmetries or dynamics. Researchers have identified various textures that can accommodate experimental data, such as the normal hierarchy, inverted hierarchy, and degenerate scenarios[1]. These textures often imply specific relationships between neutrino masses and mixing angles, providing valuable insights into the underlying physics. For instance, the $\mu-\tau$ reflection symmetry texture predicts maximal θ_{23} mixing, while the tribimaximal mixing texture predicts specific values for θ_{12} and θ_{13} [11, 12, 13, 14]. Studying neutrino mass matrix textures helps theorists constrain models, understand neutrino properties, and make predictions for future experiments, shedding light on the fundamental nature of neutrinos and the universe.

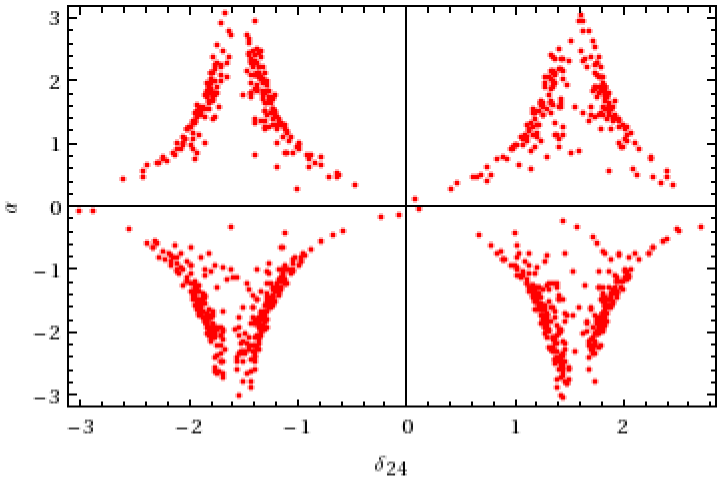

Figure 1: Neutrino parameter correlations for texture 1.

Symmetry		a (θ_{13})	Δm^2	δ_{CP}
A_4	Present work	6.188	49.48	4.78
	References	6.058 [12], 6.10 [13], 6.08 [14]	55.51 [14], 59.2±5 [1]	6.8±2 [15]
S_4	Present work	5.748	62.98	4.84
	References	5.65 [14], 5.5005 [4], 5.514 [2]	40.6±14 [5]	7.3±1 [3]

Table 1: Neutrino parameter details for texture 1.

Neutrino mass refers to the incredibly small amount of mass possessed by neutrinos, among the lightest particles in the universe. For decades, the Standard Model of particle physics assumed neutrinos were massless, but experiments have since confirmed that neutrinos do have mass, albeit tiny. The discovery of neutrino oscillations, where neutrinos change between flavors (electron, muon, and tau), provided conclusive evidence of non-zero mass. Measurements from experiments like Super-Kamiokande, Sudbury Neutrino Observatory, and T2K have

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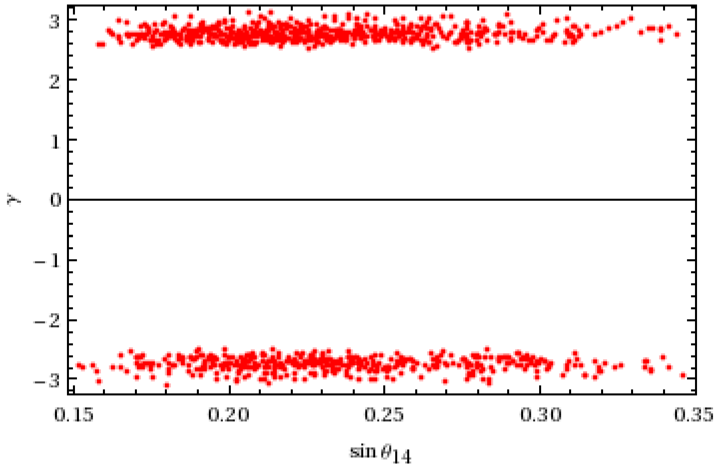

Figure 2: Neutrino parameter correlations for texture 2 and texture 3.

	Model	Texture 2	Texture 3
Non-Abelian Symmetry (A_4)	4.7	7 [5], 6.9±0.2[1]	3.9 [8], 4.0 [9], 6.0 [2]
Abelian Symmetry (Z_N)	17.2	17.0±0.2 [5], 18.8 [6]	17.0 [2], 24.0 [15]

Table 2: Neutrino parameters for texture 2 and texture 3.

established that neutrino masses are at least 0.02 eV, significantly smaller than other particles. The results for texture 2, 3 are shown in figure 2 while the details of the parameters are given in table 2.

4 Conclusions

The nature of neutrinos remains an open question in particle physics, with two competing hypotheses: Dirac and Majorana neutrinos. Dirac neutrinos, named after Paul Dirac, are fermions with distinct particle and antiparticle states, similar to electrons and positrons. In contrast, Majorana neutrinos, proposed by Ettore Majorana, are their own antiparticles, meaning a neutrino can annihilate itself. This distinction significantly impacts neutrino behavior and experimental signatures. Dirac neutrinos conserve lepton number, whereas Majorana neutrinos violate it, allowing for processes like neutrinoless double beta decay.

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A Symmetry group

A_4 is a discrete group of even permutations of four objects. Geometrically, it is an invariance group of a tetrahedron. It has 12 elements which can be generated by two basic objects S and T which obey the following relation

$$S^2 = T^3 = (ST)^3 = 1 \tag{A.1}$$

The A_4 group has three one-dimensional irreducible representations 1,1′ and 1″ and one three dimensional irreducible representation 3.

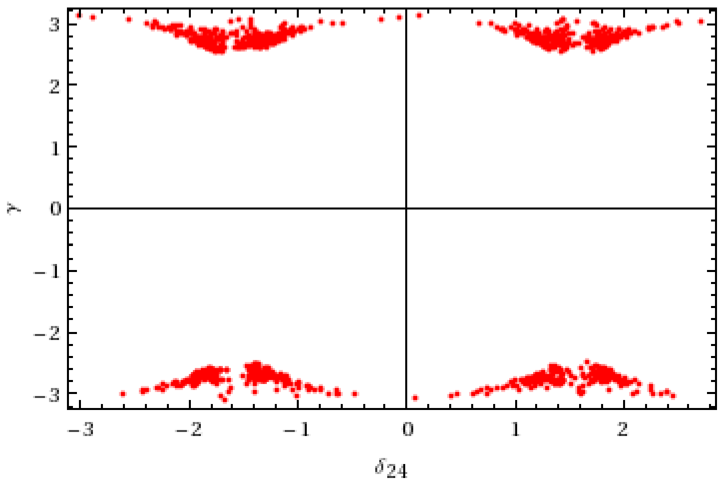

Figure A.1: Sample figure for appendix and the way it should be numbered.

col1	col2	col3
Multiple row	cell2	cell3
	cell5	cell6
	cell8	cell9

Table A.1: Sample table for appendix showing the way it should be numbered.

The permutation group of 4 objects, denoted as S_4, is a mathematical group that consists of all possible permutations of the 4 objects. It has 24 elements, representing the different ways to arrange the objects. These elements include the identity permutation (no change), 6 transpositions (swapping two objects), 8 3-cycles (rotating three objects), 6 4-cycles (rotating all four objects), and 3 double transpositions (swapping two pairs of objects). The group operation is function composition, where the result of applying two permutations sequentially is another permutation in the group. S4 is a non-abelian group, meaning that the order of applying permutations matters. It plays a crucial role in various areas of mathematics, such as combinatorics, group theory, and representation theory, and has applications in computer science, cryptography, and physics. The details are in equation (A.1) and table A.1.

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