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Texture Zeros for Dirac neutrino Mass Matrices

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Abstract

The basic block In this work, we consider some of the phenomenological consequences of having Dirac neutrino masses instead of Majorana masses as assumed in most of the current literature. In order to carry out this analysis, we propose new five-zero textures for the mass matrices of the lepton sector. From our approach, we find new values for the neutrino masses in both, the normal and inverted hierarchy. These zero textures reproduce the U_{pmns} mixing matrix and deliver relationships between the mixing angles and the lepton masses. In order to have reliable results, we have used two different procedures. The first method is based on a least-squares analysis to adjust the lepton masses and the mixing parameters to their corresponding experimental values. The second approach corresponds to the weak basis transformation which is a well-known technique to analyze textures and their implications for neutrino physics. Both the first and second method are consistent with a lightest neutrino mass equal to 4×10^{-3}eV and 3.7×10^{-3}eV, respectively.

Introduction

The textures of the Dirac neutrinos mass matrices have been the subject of several recent studies [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11], This, in part, has been motivated by the non-observation of the double beta decay [12]. As it is well known, the existing experiments have not been able to determine if neutrinos are Majorana or Dirac particles; however, most work on these topics assumes that neutrinos are Majorana, whereas the latter case has not been studied exhaustively. It is interesting to determine the consequences of a given texture on the prediction of the neutrino masses, indeed for Majorana masses, there are several works predicting a mass of a few milielectron volts for the lightest neutrino mass [13, 14, 15], As we will see later these results are very similar to the reported in the present work.

In the interaction space the mass term is given by

$$-\mathcal{L}_D = \bar{\nu}'_L M'_n \nu'_R + \bar{\nu}'_R M'^{\dagger}_n \nu'_L + \bar{\ell}'_L M'_\ell \ell'_R + \bar{\ell}'_R M'^{\dagger}_\ell \ell'_L, \tag{1}$$

in such a way that M'_n and M'_ℓ are the neutrino and charged lepton mass matrices (in the following, primed fields and matrices will refer to the interaction space).

least square method

For the neutral leptons M'_n we take a mass matrix with three texture zeros:

$$M'_{n,\ell} = \lambda^{\dagger}_{n,\ell} M_{n,\ell} \lambda_{n,\ell} \tag{2}$$

Where we have factorized matrices in a phase matrix $\lambda_{n,\ell}$ and a real matrix $M_{n,\ell}$. To define the type of texture it is enough with specifying the zeros of the real matrix, i.e.,

$$M_n = \begin{pmatrix} c_n & a_n & 0 \\ a_n & 0 & b_n \\ 0 & b_n & 0 \end{pmatrix}, \quad M_\ell = \begin{pmatrix} 0 & a_\ell & 0 \\ a_\ell & d_\ell & b_\ell \\ 0 & b_\ell & c_\ell \end{pmatrix}, \tag{3}$$

for this case λ_n and λ_ℓ are diagonal matrices with eigenvalues $(1, e^{i\alpha_{n_1}}, e^{i\alpha_{n_1}+i\alpha_{n_2}})$ and $(1, e^{i\alpha_{\ell_1}}, e^{i\alpha_{\ell_1}+i\alpha_{\ell_2}})$, respectively. Our first aproach is based in a least squares analysis to adjust the lepton masses and the mixing parameters to their corresponding experimental values. In this case the rotation matrices are written in terms of the lepton mases. They are subject to the constraints coming from the U_{pmns} matrix and the best value for the lightest neutrino mass in this fit is 3.7×10^{-3} eV. We can consider this result as a texture prediction. In this approach, the agreement with the experiment is below two sigmas and the fit goodness is acceptable.

The Weak basis transformations

In the context of the SM it is always possible to implement the so called weak basis transformation (WBT), which leaves the two 3×3 quark mass matrices Hermitian, and do not alter the physics implicit in the weak currents. Such a WBT is a unitary transformation acting simultaneously in the up and down quark mass matrices [16, 17, 18]. That is to say $M_{\nu,ell} \longrightarrow M^R_{\nu,\ell} = U M_{\nu,\ell} U^\dagger$ where U is an arbitrary unitary matrix. By assuming in the interaction space the texture of the mass matrix for the leptons as

$$M'_\ell = \begin{pmatrix} 0 & |C_\ell| & 0 \\ |C_\ell| & 0 & |B_\ell| \\ 0 & |B_\ell| & A_\ell \end{pmatrix} \equiv U_\ell D_\ell U^\dagger_\ell \tag{4}$$

(5)

it is possible to find the most general unitary matrix U_ℓ that diagonalizes the lepton mass matrix M'_ℓ.4 For this case, when solving numerically to obtain the texture of neutrino mass matrix, in the normal hierarchy for the lightest neutrino mas we obtain $m_1 = 0.0037$ eV.

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