An approach to Dirac neutrino masses through the use of texture zeros

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Abstract

In this work, we propose new five-zero textures for the mass matrices in the lepton sector in order to get theoretical values for the neutrino masses. In our approach, we go beyond the standard model by assuming Dirac masses for the neutrinos, this feature allows us to make a theoretical prediction for the lightest neutrino mass in the normal and inverted ordering. These textures have enough free parameters to adjust the U_{PMNS} mixing matrix and the charged lepton masses. The weak basis transformation which is a well-known technique to analyze textures and their implications for neutrino physics, by this method the lightest neutrino mass consistent with the restrictions coming from the zeros of the mass matrices is found between $\approx 5.9\,meV < m_{n_e} < 3.5\,meV$ for the normal ordering, and $\approx 2.2\times 10^{-2}\,eV < m_{n_\tau} < 2.6\times 10^{-2}\,eV$ for the inverted ordering.

Introduction

- The textures of the Dirac neutrinos mass matrices have been the subject of several recent studies, this, in part, has been motivated by the non-observation of the double beta decay.
- The existing experiments have not been able to determine if neutrinos are Majorana or Dirac particles.
- In this work, we assume that neutrinos are Dirac particles.
- This allows us to use the weak basis transformation, the polar decomposition theorem, and the most recent experimental data, to make predictions based in a given texture for the lepton mass matrices.
- In the SM plus right-handed neutrinos the lepton mass terms are given by
$$-\mathcal{L}_D = \bar{\nu}_L M_n \nu_R + \bar{\ell}_L M_\ell \ell_R + \text{h.c}, \qquad (1)$$
where $\nu_{L,R} = (\nu_e, \nu_\mu, \nu_\tau)^T_{L,R}$ and $\ell_{L,R} = (e, \mu, \tau)^T_{L,R}$. The matrices M_n and M_ℓ in (1) are in general 3×3 complex mass matrices.
- So, as far as the SM is concerned, we may treat without loss of generality M_n and M_ℓ as two hermitian quark mass matrices, with 18 real parameters in total.
- It is always possible to perform a weak basis transformation in the hermitian mass matrices in such a way that it is always possible to have hermitian mass matrices with three texture zeros which do not have any physical implication.

The Weak Basis transformation in the lepton sector

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. 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

$$M'_\ell = \begin{pmatrix} 0 & |C_\ell| & 0 \\ |C_\ell| & 0 & |B_\ell| \\ 0 & |B_\ell| & A_\ell \end{pmatrix} \equiv U_\ell D_\ell U_\ell^\dagger \qquad (2)$$

it is possible to find the most general unitary matrix U_ℓ that diagonalizes the lepton mass matrix M'_ℓ.

2. The most general mass matrices for the lepton sector

As a result, the most general representation for the mass matrices in the lepton sector can be put in the form:

$$\begin{aligned} M_n &= (U_{\text{PMNS}}) D_n (U_{\text{PMNS}})^\dagger, \\ M_\ell &= D_\ell, \end{aligned} \qquad (3)$$

where the mass matrix for the charged leptons is diagonal, while the neutrino mass matrix contains the U_{PMNS} mixing matrix.

Results

When solving numerically obtain matrices with five texture zeros and neutrino masses:

2. Numerical matrices with five texture zeros and neutrino masses

Normal Ordering	
Five texture zeros	**Neutrino masses (eV)**
$M'_n = \begin{pmatrix} 0 & 0.00427236 + 0.00689527i & 0 \\ 0.00427236 - 0.00689527i & 0.0194623 & -0.0122955 + 0.0244187i \\ 0 & -0.0122955 - 0.0244187i & 0.0251821 \end{pmatrix}$ eV, $M'_\ell = \begin{pmatrix} 0 & 7.57544 & 0 \\ 7.57544 & 0 & 432.237 \\ 0 & 432.237 & 1671.71 \end{pmatrix}$ MeV.	$m_1 = 0.00353647$ $m_2 = 0.00929552$ $m_3 = 0.0504034$
$M'_n = \begin{pmatrix} 0 & 0 & -0.00489586 + 0.00794938i \\ 0 & 0.0355447 & 0.0072234 + 0.0197325i \\ -0.00489586 - 0.00794938i & 0.0072234 - 0.0197325i & 0.0196131 \end{pmatrix}$ eV, $M'_\ell = \begin{pmatrix} 0 & 7.57544 & 0 \\ 7.57544 & 0 & 432.237 \\ 0 & 4.32237 & 1671.71 \end{pmatrix}$ MeV.	$m_1 = 0.00587719$ $m_2 = 0.0104135$ $m_3 = 0.0506216$
$M'_n = \begin{pmatrix} 0.109986 & 0.0344946 & -0.00839257 - 0.0334014i \\ 0.0344946 & 0 & 0.0285942 + 0.116565i \\ -0.00839257 + 0.0334014i & 0.0285942 - 0.116565i & 0 \end{pmatrix}$ eV, $M'_\ell = \begin{pmatrix} 0 & 7.57544 & 0 \\ 7.57544 & 0 & 432.237 \\ 0 & 432.237 & 1671.71 \end{pmatrix}$ MeV.	$m_1 = 0.119802$ $m_2 = 0.12011$ $m_3 = 0.129925$
Inverted Ordering	
$M'_n = \begin{pmatrix} 0.0256538 & -0.0361561 & -0.0145163 - 0.0304148i \\ -0.0361561 & 0 & -0.00545041 - 0.0266385i \\ -0.0145163 + 0.0304148i & -0.00545041 + 0.0266385i & 0 \end{pmatrix}$ eV, $M'_\ell = \begin{pmatrix} 0 & 7.57544 & 0 \\ 7.57544 & 0 & 432.237 \\ 0 & 432.237 & 1671.71 \end{pmatrix}$ MeV.	$m_1 = 0.0559316$ $m_2 = 0.0565884$ $m_3 = 0.0263106$
$M'_n = \begin{pmatrix} 0.0212438 & -0.0379867i & 0.0227727 - 0.0207074i \\ 0.0379867i & 0 & -0.00871077 - 0.0224079i \\ 0.0227727 + 0.0207074i & -0.00871077 + 0.0224079i & 0 \end{pmatrix}$ eV, $M'_\ell = \begin{pmatrix} 0 & 7.57544 & 0 \\ 7.57544 & 0 & 432.237 \\ 0 & 432.237 & 1671.71 \end{pmatrix}$ MeV.	$m_1 = 0.0540069$ $m_2 = 0.0546868$ $m_3 = 0.0219237$

Conclusions

The main conclusions of this work are:

- We found five different numerical texture patterns of five zeros.
- We extended the SM by adding Dirac mass terms for the neutrinos and mass matrices with five texture zeros for the lepton sector.
- The lightest neutrino mass is found between $\approx 5.9\,meV < m_{n_e} < 3.5\,meV$ for the normal ordering, and $\approx 2.2\times 10^{-2}\,eV < m_{n_\tau} < 2.6\times 10^{-2}\,eV$ for the inverted ordering.

References

[1] G.C. Branco, D. Emmanuel-Costa, R. Gonzalez Felipe, Phys.Lett.B477, 2000 [hep-ph/9911418].

[2] K. Nakamura et al. (Particle Data Group), JP G 37, 075021 (2010) and 2011 partial update for the 2012 edition (URL: http://pdg.lbl.gov).

[3] Yithsbey Giraldo, Phys.Rev.D86,093021(2012).

[4] Yithsbey Giraldo, Phys.Rev.D91,038302(2015).