Minimal textures in seesaw mass matrices and their low
and high energy phenomenology

Srubabati Goswami\textsuperscript{a,b,*,} Subrata Khan\textsuperscript{a}, Werner Rodejohann\textsuperscript{c}

\textsuperscript{a} Physical Research Laboratory, Navrangpura, Ahmedabad 380009, India
\textsuperscript{b} Harish-Chandra Research Institute, Chhatnag Road, Jhunsi, Allahabad 211019, India
\textsuperscript{c} Max-Planck-Institut für Kernphysik, Postfach 103980, D-69029 Heidelberg, Germany

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In an attempt to find minimal scenarios we study the implications of Dirac and Majorana mass matrices with texture zeros within the type I seesaw mechanism. For the Dirac mass matrices we consider 5 zero textures which we show to be the most minimal form that can successfully account for low energy phenomenology if the Majorana mass matrices are chosen minimal as well. For those, we consider both diagonal and even more minimal non-diagonal forms. The latter can be motivated e.g. by simple \textit{U}(1) flavour symmetries and have two degenerate eigenvalues. We classify the allowed textures and discuss the ramifications for leptogenesis and lepton flavour violation.

\textsuperscript{*} Corresponding author at: Physical Research Laboratory, Navrangpura, Ahmedabad 380009, India.
E-mail addresses: sruba@prl.res.in (S. Goswami), subrata@prl.res.in (S. Khan), werner.rodejohann@mpi-hd.mpg.de (W. Rodejohann).

1. Introduction

Spectacular results from neutrino oscillation experiments in the past decade have established the existence of neutrino masses and lepton mixing on firm footing. However, the smallness of the neutrino masses still continues to be an enigma. The most elegant mechanism for generating small neutrino masses is the seesaw mechanism in which one adds heavy right-handed singlets (type I) \cite{1}, scalar triplets (type II) \cite{2} or fermion triplets (type III) \cite{3} to generate small neutrino masses at low scale. In the context of the type I seesaw mechanism the mass matrix for the left-handed neutrinos obtained through seesaw diagonalization depends on the Dirac type Yukawa coupling matrix of the neutrinos ($m_D$) as well as on the bare Majorana mass matrix ($M_R$) of the heavy right-handed neutrinos:

$$m_\nu = -m_D M_R^{-1} m_D^T.$$  \hspace{1cm} (1.1)

Reconstruction of seesaw mass matrices from low energy observations is a challenging task. The main problem is the mismatch in the number of parameters because in general the seesaw framework contains more parameters compared to what can be obtained from measurements at low energy and it is not possible to fix the high energy parameters entirely from low energy data \cite{4} (for an overview, see \cite{5}). One possible solution is the appearance of “texture zeros”. In general, “zeros” imply vanishingly small entries in the mass matrices whose origin can be traced to flavour symmetries. Consideration of texture zeros in the seesaw mass matrices provides a useful way to handle the problem of parameter mismatch since assumption of texture zeros leads to a reduction of the number of parameters at high scale and thus strengthens the predictive power of the model.

Implications of two texture zeros in the low energy Majorana mass matrix have been studied in \cite{6–8} and one texture zeros have been studied in \cite{9} (see also \cite{10} for the case of additional equality of mass matrix entries). Texture zeros in both the charged lepton and neutrino mass matrices have been studied in \cite{11}.

Within the framework of seesaw mechanism it is often considered more natural to consider texture zeros appearing in the Yukawa coupling matrix $m_D$ and/or the heavy neutrino mass matrix $M_R$ \cite{12–14}. In particular, it has been shown in \cite{13} that if $M_R$ is diagonal and if one assumes that all light neutrino states are massive then the maximal number of zeros that can be accommodated in $m_D$ is four. The phenomenology of those cases is studied in detail in Ref. \cite{14}. We will relax this assumption here since the low energy data allow one of the neutrino states to be massless. In that case, as we show, even with a diagonal $M_R$ one can obtain allowed textures consistent with low energy observations for a $m_D$ with 5 zeros. The results in \cite{13} were obtained assuming both the charged lepton mass matrix and the heavy neutrino mass matrix to be diagonal. In this Letter we assume the charged lepton mass matrix to be diagonal but relax the assumption of a diagonal $M_R$. However, we insist in non-singular $M_R$ in...