San Juan de Pasto, 14 de noviembre de 2019

Señores
Departamento de Física
Universidad de Nariño

Asunto: socialización NNN19

Cordial saludo,

La presente carta es para socializar mi participación en el **20th International Workshop on Next generation Nucleon Decay and Neutrino Dectectors (NNN19 (https://indico.cern.ch/event/835190/)** realizado en la Universidad de Medellín (Medellín, Colombia) del 7 al 9 de noviembre de 2019. Mis actividades en el congreso fueron las siguientes:

- Presentación del trabajo en calidad de póster titulado **"Texture Zeros for neutrino Mass Matrices”:** en este trabajo *En el Modelo Estándar, deducimos una configuración con cinco ceros de textura para las matrices de masa del quark que no es del tipo Fritzsch. Es válido y genera todas las cantidades físicas de interés: eso incluye las masas quark, los ángulos internos del triángulo unitario Cabibbo-Kobayashi-Maskawa, y la fase responsable de la violación de la simetría de la paridad de carga. Para lograr esto, debemos incluir fases no físicas en las matrices unitarias que diagonalizan las matrices de masa del quark para llevar la matriz de mezcla Cabibbo-Kobayashi-Maskawa a su forma estándar.*

- Presentación del trabajo en calidad de póster titulado “**Mixing angles from five texture zeros of the quark mass matrices**”: en este trabajo *Al suponer masas de Dirac para los neutrinos en un modelo con las interacciones y partículas del Modelo Estándar al incluir tres neutrinos derechos, obtenemos configuraciones con cinco ceros de textura para las matrices de masas de neutrinos. Estas matrices están construidas de tal manera que reproduce los ángulos internos del PMNS y la fase de violación de CP en el sector de leptones. De este trabajo, se esperan predicciones no triviales para las masas de neutrinos.*

- Participación en las diferentes conferencias y talleres impartidos en el congreso.

Atentamente

Yithsbey Giraldo
Docente

Anexo el certificado de presentación y participación, así como de los trabajos presentados.

UNIVERSIDAD DE MEDELLIN

Medellín 12 de noviembre del 2019

Asunto: Certificado de asistencia al evento.

Apreciado Profesor Yithsbey Giraldo, por medio de la presente certificamos su asistencia al evento **20th International Workshop on Next generation Nucleon Decay and Neutrino Dectectors (NNN19)** (https://indico.cern.ch/event/835190/), realizado en la Universidad de Medellín del 7 al 9 de noviembre de 2019. Así mismo cerfificamos que presentó los posters:

- Texture Zeros for neutrino Mass Matrices
- Mixing angles from five texture zeros of the quark mass matrices

Cordialmente

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Alex Marcelo Tapia Casanova
Co-chair, NNN19
Profesor de Tiempo Completo
Facultad de Ciencias Básicas
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Mixing angles from five texture zeros of the quark mass matrices

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Noviembre 8 de 2019

Abstract

In the Standard Model, we will deduce a configuration with five texture zeros for the quark mass matrices that it is not of the Fritzsch type. It is valid and generates all the physical quantities of interest: that includes the quark masses, the inner angles of the Cabibbo-Kobayashi-Maskawa unitary triangle, and the phase responsible for the violation of the charge-parity symmetry. To achieve this, we must include non physical phases in the unitary matrices that diagonalize the quark mass matrices to bring the Cabibbo-Kobayashi-Maskawa mixing matrix to its standard form.

Introduction

- Models like the Standard Model (SM) or its extensions, where the right fields are $SU(2)$ singlets, it is always possible to choose a suitable basis for the right quarks using the unitary matrix coming from the *polar decomposition theorem* of linear algebra, in such a way that the up and down quark mass matrices become hermitian matrices, i. e.,
$$M_u^\dagger = M_u, \quad \text{y} \quad M_d^\dagger = M_d.$$
- In the SM, left and right quarks can be transformed unitarily, so that the gauge currents remain invariant, and as a result, the quark mass matrices are transformed into new equivalent matrices. This process basically consists of a common unitary transformation applied over M_u and M_d which is known as a "Weak Basis" (WB) Transformation [1], as follows:
$$M_u \to M_u' = U^\dagger M_u U, \quad M_d \to M_d' = U^\dagger M_d U,$$
where U is an arbitrary unitary matrix that preserves the hermiticity of quark mass matrices.
- Any physically viable quark mass matrix can be derived from specific quark mass matrices by making a WB transformation.

$$U_u^\dagger M_u U_u = D_u = \begin{pmatrix} \lambda_{1u} & 0 & 0 \\ 0 & \lambda_{2u} & 0 \\ 0 & 0 & \lambda_{3u} \end{pmatrix},$$
$$U_d^\dagger M_d U_d = D_d = \begin{pmatrix} \lambda_{1d} & 0 & 0 \\ 0 & \lambda_{2d} & 0 \\ 0 & 0 & \lambda_{3d} \end{pmatrix},$$
$$\text{CKM mixing matrix} = V = U_u^\dagger U_d,$$

where
$$|\lambda_{1u}| = m_u, |\lambda_{2u}| = m_c, |\lambda_{3u}| = m_t,$$
$$|\lambda_{1d}| = m_d, |\lambda_{2d}| = m_s, |\lambda_{3d}| = m_b.$$

and
$$\lambda_{1q} < 0 \oplus \lambda_{2q} < 0 \oplus \lambda_{3q} < 0.$$

for $q = u, d$.

Quark masses and CKM mixing matrix

The mass of quarks and the observed parameters of the CKM matrix $|V_{ij}|$ are given in the SM scheme at a renormalization scale of $\mu = m_Z$ [2]:
$$m_u = 1.38^{+0.42}_{-0.41}\,,\ m_c = 638^{+43}_{-84},\ m_t = 172100 \pm 1200\,,$$
$$m_d = 2.82 \pm 0.48\,,\ m_s = 57^{+18}_{-12},\ m_b = 2860^{+160}_{-60}.$$

$$|V| = \begin{pmatrix} 0.97427 \pm 0.00014 & 0.22536 \pm 0.00061 & 0.00355 \pm 0.00015 \\ 0.22522 \pm 0.00061 & 0.97343 \pm 0.00015 & 0.0414 \pm 0.0012 \\ 0.00886^{+0.00033}_{-0.00032} & 0.0405^{+0.0011}_{-0.0012} & 0.99914 \pm 0.00005 \end{pmatrix},$$

1. The basic quark mass matrices

The diagonal representation u [3, 4]:
$$M_u = D_u = \begin{pmatrix} \lambda_{1u} & 0 & 0 \\ 0 & \lambda_{2u} & 0 \\ 0 & 0 & \lambda_{3u} \end{pmatrix},$$
$$M_d = V D_d V^\dagger.$$

The diagonal representation d.
$$M_u = V^\dagger D_u V,$$
$$M_d = D_d = \begin{pmatrix} \lambda_{1d} & 0 & 0 \\ 0 & \lambda_{2d} & 0 \\ 0 & 0 & \lambda_{3d} \end{pmatrix},$$

Five numerical texture zeros

2. Pattern with one and two diagonal zeros

Permutation matrices	Two diagonal zero patterns $(p_i\, M_q\, p_i^T)$	One diagonal zero patterns $(p_i\, M_q\, p_i^T)$
$p_1 = \begin{pmatrix} 1 & & \\ & 1 & \\ & & 1 \end{pmatrix}$	$\begin{pmatrix} 0 & \|\xi_q\| & 0 \\ \|\xi_q\| & 0 & \|\beta_q\| \\ 0 & \|\beta_q\| & \alpha_q \end{pmatrix}$	$\begin{pmatrix} 0 & \|\xi_q\| & 0 \\ \|\xi_q\| & \gamma_q & 0 \\ 0 & 0 & \alpha_q \end{pmatrix}$
$p_2 = \begin{pmatrix} 1 & & \\ & & 1 \\ & 1 & \end{pmatrix}$	$\begin{pmatrix} 0 & 0 & \|\xi_q\| \\ 0 & \alpha_q & \|\beta_q\| \\ \|\xi_q\| & \|\beta_q\| & 0 \end{pmatrix}$	$\begin{pmatrix} 0 & 0 & \|\xi_q\| \\ 0 & \alpha_q & 0 \\ \|\xi_q\| & 0 & \gamma_q \end{pmatrix}$
$p_3 = \begin{pmatrix} & & 1 \\ & 1 & \\ 1 & & \end{pmatrix}$	$\begin{pmatrix} \alpha_q & \|\beta_q\| & 0 \\ \|\beta_q\| & 0 & \|\xi_q\| \\ 0 & \|\xi_q\| & 0 \end{pmatrix}$	$\begin{pmatrix} \alpha_q & 0 & 0 \\ 0 & \gamma_q & \|\xi_q\| \\ 0 & \|\xi_q\| & 0 \end{pmatrix}$
$p_4 = \begin{pmatrix} & 1 & \\ 1 & & \\ & & 1 \end{pmatrix}$	$\begin{pmatrix} 0 & \|\xi_q\| & \|\beta_q\| \\ \|\xi_q\| & 0 & 0 \\ \|\beta_q\| & 0 & \alpha_q \end{pmatrix}$	$\begin{pmatrix} \|\gamma_q\| & \|\xi_q\| & 0 \\ \|\xi_q\| & 0 & 0 \\ 0 & 0 & \alpha_q \end{pmatrix}$
$p_5 = \begin{pmatrix} & & 1 \\ 1 & & \\ & 1 & \end{pmatrix}$	$\begin{pmatrix} \alpha_q & 0 & \|\beta_q\| \\ 0 & 0 & \|\xi_q\| \\ \|\beta_q\| & \|\xi_q\| & 0 \end{pmatrix}$	$\begin{pmatrix} \alpha_q & 0 & 0 \\ 0 & 0 & \|\xi_q\| \\ 0 & \|\xi_q\| & \gamma_q \end{pmatrix}$
$p_6 = \begin{pmatrix} & 1 & \\ & & 1 \\ 1 & & \end{pmatrix}$	$\begin{pmatrix} 0 & \|\beta_q\| & \|\xi_q\| \\ \|\beta_q\| & \alpha_q & 0 \\ \|\xi_q\| & 0 & 0 \end{pmatrix}$	$\begin{pmatrix} \gamma_q & 0 & \|\xi_q\| \\ 0 & \alpha_q & 0 \\ \|\xi_q\| & 0 & 0 \end{pmatrix}$

3. Numerical quark mass matrices (in MeV units)

$$M_u' = \begin{pmatrix} 0 & 0 & -79.32 + 154.72i \\ 0 & 5539.2 & 28125.9 + 6112.8i \\ -79.323 - 154.72i & 28125.9 - 6112.8i & 167126.0 \end{pmatrix},$$

$$M_d' = \begin{pmatrix} 0 & 13.891097 & 0 \\ 13.891097 & 0 & 421.41405 \\ 0 & 421.41405 & 2797.9042 \end{pmatrix}.$$

Five analytical texture zeros and the CKM mixing matrix

The texture matrix of five zeros previously obtained has the following standard structure:
$$M_u = P^\dagger \begin{pmatrix} 0 & 0 & |\xi_u| \\ 0 & \alpha_u & |\beta_u| \\ |\xi_u| & |\beta_u| & \gamma_u \end{pmatrix} P, \quad M_d = \begin{pmatrix} 0 & |\xi_d| & 0 \\ |\xi_d| & 0 & |\beta_d| \\ 0 & |\beta_d| & \alpha_d \end{pmatrix},$$
where $P = \operatorname{diag}(e^{-i\phi_{\xi_u}}, e^{-i\phi_{\beta_u}}, 1)$ (with $\phi_{\beta_u} \equiv \arg(\beta_u)$ and $\phi_{\xi_u} \equiv \arg(\xi_u)$). We have nine free parameters to reproduce ten physical magnitudes: six (6) quark masses, three (3) mixing angles and one (1) CP violation phase in the CKM matrix, which implies physical relations between the quark masses and mixings.

4. The mixings

$$|V_{ud}| \approx |V_{cs}| \approx |V_{tb}| \approx 1,$$
$$|V_{us}| \approx \left| \sqrt{\frac{\alpha_u - m_c}{\alpha_u}} \sqrt{\frac{m_u}{m_c}} - e^{i(\phi_{\beta_u} - \phi_{\xi_u})} \sqrt{\frac{m_d}{m_s}} \right|,$$
$$|V_{cd}| \approx \left| \sqrt{\frac{\alpha_u - m_c}{\alpha_u}} \sqrt{\frac{m_u}{m_c}} - e^{i(\phi_{\xi_u} - \phi_{\beta_u})} \sqrt{\frac{m_d}{m_s}} \right|,$$
$$|V_{cb}| \approx \left| \sqrt{\frac{m_s}{m_b}} - e^{i\phi_{\beta_u}} \sqrt{\frac{\alpha_u - m_c}{m_t}} \right|,$$
$$|V_{ts}| \approx \left| \sqrt{\frac{m_s}{m_b}} - e^{-i\phi_{\beta_u}} \sqrt{\frac{\alpha_u - m_c}{m_t}} \right|,$$
$$\frac{|V_{ub}|}{|V_{cb}|} \approx \sqrt{\frac{m_u}{m_c}} \left| \frac{\sqrt{\frac{\alpha_u}{m_t}} - e^{-i\phi_{\beta_u}} \sqrt{\frac{\alpha_u - m_c}{\alpha_u}} \sqrt{\frac{m_s}{m_b}}}{\sqrt{\frac{\alpha_u - m_c}{m_t}} - e^{-i\phi_{\beta_u}} \sqrt{\frac{m_s}{m_b}}} \right|,$$
$$\frac{|V_{td}|}{|V_{ts}|} \approx \sqrt{\frac{m_d}{m_s}},$$
where it is considered $\alpha_u \ll m_t$. Let's consider $\alpha_u \gtrsim m_c$ to adjust the experimental data, which gives $(\phi_{\beta_u} - \phi_{\xi_u}) \sim -\pi/2$, which is an important contribution term for the CP violation.

Conclusions

The main conclusions of this work are:

- We found only two different numerical texture patterns of five zeros.
- We have nine free parameters to reproduce ten physical magnitudes: six (6) quark masses, three (3) mixing angles and one (1) CP-violation phase of the CKM matrix, which implies physical relations between the quark masses and mixings.
- The Gatto-Sartori-Tonin (GST) relationship is maintained, and an important contribution of the CP violation is still shown in the context of the model.

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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

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

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:

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

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.,

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

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 masses. 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

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

$$(5)$$

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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