The enigmatic neutrinos

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Abstract

We do a careful and consistent study of what masses and mass-mixing between different generations actually means in the Standard Model. We are thus led to a new complementary "Pure Weak Group" basis structure. This allows one to obtain a more basic understanding of wherefrom the wave-corpuscle duality actually arises in quantum mechanics. We show that it is the gauge symmetries, which determine not only the fundamental interactions in particle physics, but is is these that are also the cause of the wave-corpuscle duality in quantum mechanics. We also find a mathematical reason as to why only three generations of particles exist in nature. The wave-corpuscle duality manifests itself differently for the neutrinos. Their corpuscular character demands that they have zero inertial mass and travel with the velocity of light and simultaneously and dually to it, as a wave, they oscillate and have a non-zero and a different "gravitational" mass and which makes them travel superluminally. Hence it is a clear prediction of our model that neutrinos, in a pure oscillation mode, travel with velocites greater than that of light. Also the neutrinos, having a non-zero gravitational mass and zero-inertial mass, become an ideal candidate to be the Dark Matter of the universe.

Keywords: Neutrino physics, Standard Model

(I) Introduction

True to the title of this paper, "the enigmatic neutrinos", there was some recent excitement as to their true nature. First in September 2011 (revised in November 2011) the OPERA Collaboration at Gran Sasso, Italy announced the amazing discovery of neutrinos going faster than light [1]. Next the ICARUS group from the same laboratory announced in March 2012 that they only got neutrinos going at the speed of light [2]. In the meantime the OPERA group continued to critically look at their own results, and now it appears that further analysis of new systematic erros in their experiments, casts doubt on their above claimed result. However, better and more thorough experiments both by OPERA and ICARUS and others are on the way. In this paper we study these enigmatic neutrinos more carefully. And it is a clear prediction of our model, that specifically in the oscillatory phase, the neutrinos should travel faster than light. We discuss this below.

In this paper we shall look at this problem within the framework of the highly successful Standard Model (SM) of particle physics. The SM requires a zero mass neutrino. However, neutrino oscillations have clearly demonstrated experimentally this demands a non-zero mass for the same. This indicates that one has to go beyond the SM in some manner to understand this non-zero mass for the neutrinos. This is conventionally done in some framework of going beyond the SM like the GUTS, SUSY etc. We do not do that in this paper. Instead we actually look inside the SM - in a way looking into the "guts" of the SM. This means studying at a fundamental manner as to what the SM is actually doing and more importantly what it is not doing - nay, actually what it cannot do! As per a careful study of masses it emerges that what is needed is a new "Pure Weak Group" basis structure (to be discussed below) which basically solves the problem.

We shall show that there are thus two kind of masses. The SM provides one kind of mass which we show is actually an "inertial mass" and which requires a corpuscular aspect of the particles. Within the "Pure Weak Group" (PW) basis there arises another independent kind of mass which is logically associated with the "gravitational mass" of the particle and which requires a wave character for the particle. It appears that these two pictures: the SM on the one hand and the Pure Weak Group (PW) basis on the other hand, actually represent a fundamental duality of nature. Thus these two are a fundamental and simultaneously existing aspects of particle physics.

Next we show that the equivalence principle i.e. "the inertial mass" = "the gravitational mass" provides the underlying basis for the "wave-corpuscle" aspect of massive particles in quantum mechanics. (Note: we are using the word corpuscle in "wave-corpuscle" to avoid ambiguity and reserve the word "particle" as a generic name to identify say an electron or a proton).

We shall show that the wave-corpuscle character (i.e. their inertial and the gravitational masses being the the same) holds for all the particles known to us except the neutrinos. Neutrinos are unique and different from all the other particles. We shall show that for the neutrinos the inertial mass is zero (and this make it travel with the velocity of light) and that the gravitational mass is positive and non-zero. Its gravitational mass is what allows it to oscillate and is the basis of its wave nature. This also makes it travel faster than light. Thus the wave-corpuscle duality of quantum mechanics shows that the neutrinos are different. Due to its corpuscular character and its mass being zero, it travels with the velocity of light and simultaneously due to its wave character, having a non-zero positive gravitational mass, it travels with a velocity greater than that of light and also displays oscillations in this process.

Photon displays its wave nature through say interference and diffraction experiments and its corpuscular nature through say the photoelectric effects. In the same manner neutrinos show up its corpuscular nature through direct experiments like $\nu_\mu + n \rightarrow p + \mu^-$ and its wave character through oscillations experiments (so one has to make sure that the detected neutrinos should be the one partaking in oscillations and that it is not a direct one!). The difference with respect to photon here is that for the photon, the corpuscular-wave property holds for the entity existing at the same point. While for the neutrinos, the two aspects are showing up at different locations at different space points. Clearly non-locality is fundamentally required for a proper understanding of what a neutrino really is and as to how it will show up in our instruments.

As to the experimental detection of the velocities of the neutrinos, one has to carefully distinguish between the direct detection of the neutrinos (where they travel with the velocity of light) and the neutrinos in the oscillatory phase wherein they travel with a velocity greater than that of light. The OPERA experiment is unique in that they are actually detecting tau-neutrinos in their beam and for a beam, which started off as a muon-neutrino beam, these tau-neutrinos do necessarily belong to the oscillating neutrinos.

This is thus an unambiguous signature of oscillating character and the tau-neutrinos had to be arising from the oscillating beam. And as per our model we predict that these neutrinos shall be found to be travelling faster than light.

Also as the neutrinos have zero inertial mass and a positive non-zero gravitational mass, hence it will interact gravitationally only (besides its weak interaction) with all the other particles and thus be an ideal candidate to be the Dark Matter of the Universe.

(II) Masses and mass mixing in the SM

The hugely successful SM is based on the group structure $SU(3)_c \otimes SU(2)_L \otimes U(1)_Y$ with three repetitive set of elements called the generations of the fermions. This symmetry is spontaneously broken by a complex scalar Higgs doublet to $SU(3)_c \otimes U(1)_{em}$. The Higgs is basically required to ensure renormalizability of the theory and to generate proper masses for the gauge particle $W^{\pm}, Z^0$ while leaving photon as massless. We state a few salient points as per popular understanding of the SM to allow for a more focussed discussion later.

(a). Electric charge in the SM

Electric charge is defined in the SM as

$$Q = I_3 + \frac{Y}{2} \tag{1}$$

where T_3 is the diagonal generator of $SU(2)_L$ and Y that of $U(1)_Y$. The hypercharge Y is arbitrarily fixed to provide correct charges for the fermions. And because of this arbitrariness, it is believed that the electric charge is not quantized in the SM (e.g. see [3] or any other more recent textbook).

(b). Mass in the SM

For each generation, masses for the fermions are generated through Yukawa coupling with the Higgs. However this mass generation is believed to be arbitrary and inelegant and it has been famously dubbed as "Deux ex mochima" (literal translation: God from the machine; meaning out of the blue to overcome a seemingly difficult problem).

Thus lack of proper charge quantization and arbitrary Yukawa masses are considered as two shortcomings of the SM.

(c). Mass mixing across different generations

However as per Cabibbo we know that quarks mix across generations. So to understand the mass problem one has to expand the language to properly incorporate the three families. "We simplified our construction by taking one family of fermions. In this *approximation* there is no distinction between gauge eigenstates and mass eigenstates" [3]. Hence a generalization for mass mixing across generations is made. Thus Yukawa terms, mixing mass terms across different generations are obtained [3].

Hence on obtains a 3x3 mass matrix which in general may be complex and need not be symmetric or hermitian. Note the important point that the individual mass terms in this 3x3 matrix are Yukawa like mass terms linking fermions across different generations [3]. Clearly the diagonal terms correspond to Yukawa mass term for the same flavour. However in the non-diagonal terms the left-handed fermion would be from one family while the corresponding right-handed terms in the Yukawa would be from a different family [3].

That such terms are fundamentally permitted in the SM have been uncritically accepted. We examine the basis of this assumption below.

(d). Biunitary transformation

We know from a general theorem from Algebra that any complex non-singular matrix can be written as a product of an unitary and a hermitian matrix [3]

$$M = HV \tag{2}$$

Note that $MM^\dagger$ is hermitian and positive and thus can be diagonalized by a unitary matrix S

$$S^\dagger(MM^\dagger)S = {M_d}^2 \tag{3}$$

where ${M_d}^2$ are positive and real.

Given another independent unitary matrix T, the above can be split down to M_d through a biunitary transformation.

$$S^\dagger M T = M_d \tag{4}$$

where at last M_d is diagonal and positive mass eigenvalue.

Such biunitary transformation are obtained by letting the two unitary matrix operators act on the left-handed and the right-handed components of the wave function separately as

$$\Psi_L \rightarrow S\Psi_L$$

$$\Psi_R \rightarrow T\Psi_R \tag{5}$$

(e). Neutrino oscillations

As the neutrino oscillation is an experimentally well established fact, this demands that neutrino have a non-zero mass. Taking cue from the CKM mechanism one demands similar terms for the neutrino masses also, that is mass mixing matrix across the three generations for the neutrinos as well [3]. So given a mass eigenstate and another gauge eigenstates as

$$\begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{pmatrix}_{gauge} = S \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{pmatrix}_{mass} \tag{6}$$

where S is CKM kind of 3x3 matrix. Then this allows for the quantum mechanical oscillations of the neutrinos [3].

(III). Description of our model

(a) Electric charge quantization in the SM

As given in Section II part (A) in a canonical manner the electric charge is defined as in eqn. (1). Historically this was useful in identifying the unification aspect of the weak and the electromagnetic interaction and also helped in identifying neutral weak current where both the weak and the electromagnetic parts play a role in an unified manner.

However a major fault in this definition is that it makes an unambiguous statement that electric charge is not quantized in the SM. As we shall show below that this is wrong. And this fact in itself is highly nontrivial. Hence sticking to this wrong definition of the electric charge in the SM may obfuscate the physics and may be detrimental to our understanding as when we are forced to go deeper into other issues like, in particular as to what mass actually is in the SM, especially with regard to the neutrinos. So first we have to get rid of the wrong definition of electric charge given in eqn. (1).

To do so let us define our model [4,5]. To start with let us first ignore the right-handed neutrino (note that we shall include it consistently below) in say the first generation of particle. In the SM this is represented in the group $SU(3)_c \otimes SU(2)_L \otimes U(1)_Y$ as

$$q_L = \begin{pmatrix} u \\ d \end{pmatrix}_L \sim (3,2,Y_q); u_R \sim (3,1,Y_u); d_R \sim (3,1,Y_d)$$

$$l_L = \begin{pmatrix} \nu \\ e \end{pmatrix}_L \sim (1,2,Y_l); e_R \sim (1,1,Y_e) \tag{7}$$

Let us now define the electric charge in the most general way in terms of the diagonal generators of $SU(2)_L \otimes U(1)_Y$ as

$$Q = I_3 + bY \tag{8}$$

where b is an arbitrary parameter.

In the SM $SU(3)_c \otimes SU(2)_L \otimes U(1)_Y$ is spontaneously broken through a Higgs mechanism to the group $SU(3)_c \otimes U(1)_{em}$. Here the Higgs is assumed to be a doublet ϕ with arbitrary hypercharge Y_ϕ. The isospin $I_3 = -\frac{1}{2}$ component of the Higgs field develops a nonzero vacuum expectation value $< \phi >_o$. Since we want the $U(1)_{em}$ generator Q to be unbroken we require $Q < \phi >_o = 0$. This right away fixes b in (3) and we get

$$Q = I_3 + (\frac{1}{2Y_\phi})Y \tag{9}$$

To proceed further one imposes the anomaly cancellation conditions to establish constraints on the various hypercharges above. First $[SU(3)_c]^2 U(1)_Y$ gives $2Y_q = Y_u + Y_d$ and $[SU(2)_L]^2 U(1)_Y$ gives $3Y_q = -Y_l$. Next $[U(1)_Y]^3$ does not provide any new constraints. So the anomaly conditions themselves are not sufficient to provide quantization of electric charge in the SM. One has to provide new physical inputs to proceed further. There are two independent ways to do so.

Method 1: Here one demands that fermions acquire masses through Yukawa coupling in the SM. This brings about the following constraints:

$$Y_u = Y_q + Y_\phi; Y_d = Y_q - Y_\phi; Y_e = Y_l - Y_\phi \tag{10}$$

Note that $2Y_q = Y_u + Y_d$ from the anomaly cancellation condition for $[SU(3)_c]^2 U(1)_Y$ is automatically satisfied here from the Yukawa condition above. Now using $3Y_q = -Y_l$ from anomaly cancellation along with Yukawa terms above in $[U(1)_Y]^3$ does provide a new constrains of $Y_l = -Y_\phi$. Putting all these together one immediately gets charge quantization in the SM [4,5] as follows:

$$q_L = \begin{pmatrix} u \\ d \end{pmatrix}_L, Y_q = \frac{Y_\phi}{3}; Q(u) = \frac{1}{2}(1+\frac{1}{3}); Q(d) = \frac{1}{2}(-1+\frac{1}{3})$$

$$u_R, Y_u = Y_\phi(1+\frac{1}{3}); Q(u_R) = \frac{1}{2}(1+\frac{1}{3}); d_R, Y_d = Y_\phi(-1+\frac{1}{3}); Q(d_R) = \frac{1}{2}(-1+\frac{1}{3})$$

$$l_L = \begin{pmatrix} \nu \\ e \end{pmatrix}_L; Y_l = -Y_\phi; Q(\nu) = 0, Q(e) = -1; e_R, Y_e = -2Y_\phi; Q(e_R) = -1 \tag{11}$$

Note that in the above quantization of the electric charge, Higgs hypercharge Y_ϕ always cancels out and hence remains unconstrained. This is important as not paying attention to this fact can lead to asking wrong questions, as for example on the possibility of milli-charged particles, which are ruled out by the SM as per the above arguments [6]. A repetitive structure gives charges for the other generation of fermions as well.

Method 2: Next we ignore Yukawa coupling and impose the vector nature of the electric charge [4,5] which means that photon couples identically to the left handed and the right handed charges. That is $Q_L = Q_R$

$$\frac{1}{2}(1+\frac{Y_q}{Y_\phi}) = \frac{1}{2}\frac{Y_u}{Y_\phi}; giving : Y_u = Y_q + Y_\phi$$

$$Q(d) = \frac{1}{2}(-1+\frac{Y_q}{Y_\phi}) = \frac{1}{2}\frac{Y_d}{Y_\phi}; giving : Y_d = Y_q - Y_\phi$$

$$\frac{1}{2}(-1+\frac{Y_l}{Y_\phi}) = \frac{1}{2}\frac{Y_e}{Y_\phi}; giving : Y_e = Y_l - Y_\phi \tag{12}$$

And thereafter charge quantization as in method 1.

Next, note that for the left handed charge of u- (similarly for the d-quark) one obtained: $\frac{1}{2}(1+\frac{Y_q}{Y_\phi}) = \frac{1}{2}(1+\frac{1}{3})$. Note that $\frac{1}{3}$ is the baryon number [4,5]. We suggest that this is a general property and that we should define the baryon number in SM as

$$\frac{Y_q}{Y_\phi} = B \tag{13}$$

Here in the SM the baryon number is arising as the ratio of the hypercharge of the left handed quark with respect to the Higgs hypercharge. Since Higgs is providing the ubiquitous background uniform structure within which the particles exist, this is a consistent definition of the baryon charge for the left handed quarks.

By definition the baryon number is arising for the left handed quark representation. It is important to note that this so called global quantum number is chiral in nature. This is fine, as the weak interaction is only left-handed anyway.

Similarly for the left handed electron the electric charge is $\frac{1}{2}(-1 + \frac{Y_l}{Y_\phi})$ We now associate a lepton number with

$$\frac{Y_l}{Y_\phi} = -L \tag{14}$$

which gives the correct charges. Notice that this is a natural definition of the lepton number. Just as for baryon number in the SM the lepton number arises as the ratio of the hypercharge of the left handed lepton with respect to the Higgs hypercharge and as such is natural to treat this as the lepton number. This more so, as the Higgs hypercharge remains unconstrained by the theory and the lepton number is thus fixed by the background Higgs. And as for the case of the baryon number, the lepton number is also only defined from the left handed representation and is chiral in nature.

So the SM model is showing clearly that the electric charge is consistently quantized in the SM and also that it also throws up the baryon number and the lepton numbers and both of which are rooted on to the Higgs's hypercharge.

Note that because of the different lepton numbers arising internally for each generation there are three different repetitive generations not knowing about each other. These lepton numbers are conserved independently of each other. This is the structure of the SM as found here. All the charges and the masses are generated repeatedly for each generation separately and individually and one not knowing about the other.

(b). Right-handed neutrino

Let us now add the right handed neutrino for the first generation irreducible representation given in eqn.(7). Let it be defined as (in the same notation):

$$\nu_R; (1, 1, Y_\nu) \tag{15}$$

This brings in additional term from the Yukawa coupling given in eqn.(10) as

$$Y_\nu = Y_l + Y_\phi \tag{16}$$

Now $[U(1)_Y]^3$ anomaly condition, with all the Yukawa couplings and the $3Y_q = -Y_l$ condition, does not provide any new constraint on hypercharges. Only that it is consistent with the other conditions. Without ν_R it was this anomaly cancellation condition that gave crucial information which ensured charge quantization. Now with the incorporation of ν_R, the property of electric charge quantization is lost.

Thus, let us now impose an empirical constraint. Let us assume that the the electric charge of this new entity - ν_R is zero. This would be consistent with the overall empirical reality, as any charged ν_R would have made its presence felt in the laboratory or in the cosmological data. Thus we are demanding it to be inert. We find that

$$Q(\nu_R) = \frac{Y_\nu}{2Y_\phi} \tag{17}$$

Note that demanding that $Q(\nu_R) = 0$ means that it is $\frac{Y_\nu}{Y_\phi} = 0$. This means that either $Y_\nu = 0$ or $Y_\phi = \infty$. Now $Y_\phi = \infty$ is ruled out as we saw earlier that all the electric charges had factors like $\frac{Y}{Y_\phi}$ with Y's for different representations of fermions, and which will get messed up with this value of Y_ϕ. Hence necessarily: $Y_\nu = 0$.

What is the significance of this result. We saw earlier that it is the ratio of hypercharges with that of the Higgs hypercharge, that the baryon number and the lepton number, and the thereon the electric charges get defined in the SM. So $Y_\nu = 0$ is special. So right away one sees that we cannot define any lepton number for this ν_R. So though the left handed neutrino exists and is identified by its lepton number which puts it in the left handed doublet with the electron, the so called right handed neutrino is completely unlike it, and has no associated lepton number. This ν_R is colourless, massless, chargeless, weak-isospin-less, hypercharge-less and lepton-number-less.

Once we have realized that ν_R has no lepton number, one sees that hence there cannot be any Yukawa coupling mass for the left handed neutrino.

To understand it we go to Wigner's analysis [7] of the irreducible representation of massless entities for the Poincare group. For massless fields, he showed that in addition when parity is conserved (so for photon), that there are two states of polarization +h and -h, where h stands for helicity. But for massless entities, when parity is not conserved (as in the case of weak interaction), the two states +h and -h are actually two independent and different irreducible representations of the Poincare group. The left handed neutrino gets lumped with the left handed electron by virtue of having a lepton number. And therefore the other entity, the so called right handed neutrino, being of a different representation, is actually another independent entity altogether. And this is exactly what we have found here. Thus our work is a confirmation of Wigner's work on Poincare group. Clearly so far, the so called right handed neutrino has been misunderstood completely. This was shown earlier in ref [8]. The point is that the left handed neutrino has zero inertial mass. And this is true for each generations separately.

Note that primarily because of its inertial nature inclusion of the ν_R had no effect on the analysis done above, as to the masses and the charges of all the fermions in a particular generation in the SM.

(c) On mass in SM

Note that the vector condition $Q_l = Q_R$ imposes exactly the same constraints on hypercharges as does the Yukawa coupling conditions (the Method I and II above). Thus the physical information content of these two methods is exactly the same. Thus the Yukawa mass and the electric charge of a particle bootstrap upon each other. One needs the other to establish its own identity. So the quantized electric charge and Yukawa masses go hand in hand in the SM. What does it all mean?

We take the vector nature of electromagnetism as obvious. However note that this is a highly non-trivial property of electromagnetism. For example the group $U(1)_Y$ above does not have it. As we saw above both the left-handed and the right handed charges arise in the SM. So the vector nature of electromagnetism arises as a nontrivial and derived property in the SM. It arises as a consequence of the spontaneous symmetry breaking by a Higgs doublet which also ensures renormalizability.

However note that the Yukawa coupling is no less fundamental than the vector nature of the electromagnetism, as to the information content vis-a-vis the electric charge quantization. It turns out that the masses through Yukawa coupling for each generation in the SM also arise as a derived property in the SM and is clearly no less basic that the electric charge in it and which too arises as a derived quantity. You cannot dispense with one or the other. Because of this inbuilt characteristic of the electric charge and the mass through Yukawa coupling, these should be treated as being unique predictions of the SM itself, very much like as the neutral currents were a clear prediction of the unification process built into the SM

Also note that as per Wigner's analysis of the Poincare group representation of particles, a massive particle is completely defined by its mass and its spin. We believe that all the massive particles observed in nature correspond to this classification. However note that though the electric charge is such a fundamental property of the particles, it was not included in Wigner's analysis. In spite of this shortcoming, how come, all the massive particles observed so far,do follow the Wigner's classification faithfully?.

On the basis of our analysis here, we have an explanation. The particle's irreducible representation given in terms of mass is good enough as mass in the SM contains as much information about the particle as does the electric charge. Their information content is exactly the same. Hence getting the result with the mass being the only player is as good as bringing in both the mass and the charge into play.

Next point is that the Principle of Relativity states that " Physical laws of mechanics and electromagnetism are covariant in going from one inertial observer to another", Note that clearly the word "mechanics" corresponds to to the word "mass: and the word "electromagnetism" pertains to the word "charge". Also as per our analysis of the complete equivalence between the mass and the charge for a particle in the SM, it means that the charge is as much "inertial" as the mass is. Clearly also that the mass that we obtained in the SM should be termed as "inertial" mass.

We know that mass is an invariant quantity under Loretnz Transformation and electric charge is taken as scalar under the same transformation. However it is well known that it is difficult to maintain Lorentz Invariance for an extended charged body. Hence to ensure Lorentz Invariance for the charges we better stick to the notion of a "point particle". Hence the massive and charged body that we have obtained in the SM necessarily describes a "corpuscular" entity.

Note that all this happens for each generation separately. Both the masses and the charges of each generation are not aware of the presence of the other generations.

(d) On mass mixing in SM?

We have seen above that very strictly the charge quantization and and its one-to-one association with the mass generation of fermions through Yukawa coupling occurs generation by generation. And each generation being independent of the others. There are clearly no Yukawa terms across two different generations within the SM. All such terms are zero in the SM. It is not an "approximation" but an inherent property of the structure of the SM that the charges are quantized and the Yukawa masses obtained are for each generation and independent of the other generations.

How and why does this come about? We know from Cabibbo that mixing does occur between quarks (d,s). So one may ask as to why not the quarks in the same doublet mix as

$$\begin{pmatrix} u' \\ d' \end{pmatrix}_{gauge} = \begin{pmatrix} m_{11} & m_{12} \\ m_{21} & m_{22} \end{pmatrix} \begin{pmatrix} u \\ d \end{pmatrix}_{mass} \tag{18}$$

An immediate answer is that the charge conservation prevents this from happening. But let us go above as to when charge had not yet been created (as per Method I above) but Yukawa masses did exist. So mass mixing or lack of it should arise from how the above matrix will behave with respect to the Yukawa masses in the SM.

We know that as per the Irreducible Representation idea of the Poincare groups, each particle should have its own mass, independent of all others. So clearly if these u-and d- quarks are IR of the Poincare group then they should have masses independent of any mixing. But if they are not IR of the Poincare then this does not hold. How can we be sure that these quarks correspond to the IR of the Poincare group. If they are not, then of course they may mix. That they do not actually mix is because of the following reason.

Note that the charge changing weak currents require two independent flavours say (u d) to exist in the left handed mode only and that their Lorentz structure is of the pure (V-A) kind. This is incorporated in the SM in terms of the groups structure $SU(2)_L \otimes U(1)_Y$. Now chiral this group is spontaneously broken to the non-chiral $U(1)_{em}$ group. This requires currents of vector V nature. Note that a property of the neutral currents (both weak and electromagnetic) is that they require only one flavour. So how does one make sure that this V-A to V transition and 2-flavor to 1-flavour aspect is properly implemented in the SM. We have seen that the mass should be treated as being more primitive than the charge. So this is done by making sure that the mass matrix in eqn. (18) is diagonal. This is done to ensure that the two-flavour to the one-flavour property, as to its mass, is properly maintained. So we demand that in the SM

$$\begin{pmatrix} u' \\ d' \end{pmatrix}_{gauge} = \begin{pmatrix} m_{11} & 0 \\ 0 & m_{22} \end{pmatrix} \begin{pmatrix} u \\ d \end{pmatrix}_{mass} \tag{19}$$

Hence now one has ensured that these particles are actually an IR of the Poincare group, i.e. obtaining their own mass and not bothering about the others. The mass then gives parity conserving electric charge of the electromagnetism (as done by Method I above) and its single flavour character to obtain Lorentz structure of "V" nature. Implementation of the proper spontaneous breaking of the chiral group $SU(2)_L \otimes U(1)_Y$ to the non-chiral $U(1)_{em}$ group was part of the kinematic structure of the SM. The implementation of the same done dynamically, is to ensure that the reduction 2-flavour to the 1-flavour is properly maintained through the mass matrix diagonalization.

Thus only two flavours at a time, and that is what constitutes a single generation of the SM, is all that is needed. All other generations are spurious as to the inbuilt mass and charge structure of the SM for a particular generation is concerned. Next in a repetitive manner, take another generation and that one is immune to the other generations in as much as the mass and the charge are concerned.

Clearly this is the reason that the anomaly cancellations in the SM are well known to be fulfilled generation wise. One would have expected that all the fermions in all the families should have together ensured the cancellation of the anomalies. But it is only generation-wise that the anomalies cancel. And the reason is as above i.e. to ensure that the fermions in the SM form the IR of the Poincare group.

Therefore the complex mass matrix mixing with Yukawa mass terms across different generations as discussed above in the SM (eg see [3]), *does not exist in the SM*. It is completely spurious to the SM.

So if such a mass mixing matrix does exist, on the one hand, it should be outside the framework of the SM and on the other hand, the individual mass terms would have nothing to do with the Yukawa mass terms. Clearly as neutrinos do have some kind of a mass (?) as it is known to oscillate, how such a matrix arises will be discussed below.

So all the massive particles for each generation have inbuilt constraints arriving from the above highly non-trivial structures. Whatever masses and whatever charges we obtain are due to the consistency of the SM. Now along with all this is arising an entity - neutrino, which of course naturally is also part of the above structures also which holds for all the massive particles. But neutrino is massless (besides being chargeless) and this masslessness (and mass here means that it has no inertial mass from the Yukawa coupling in the SM) demands that it take part in charge changing weak currents with a pure (V-A) structure. This additional demand does not exist for any other fermion as they are all massive and charged. So neutrino is unique due to this additional requirement. Hence it says that though neutrino arise in the SM as chargeless and massless particles, it should manifest its pure (V-A) character, as an extra property somehow.

This above fact is very revealing and points to a new and independent structure, which should be dual to the SM structure and also be coexisting and simultaneous to it. We call it "Pure Weak Group" basis structure named as such to incorporate the pure (V-A) structure. It will be this new basis which will provide neutrinos with a new kind of non-inertial and non-Yukawa type of mass.

(d) Pure Weak Group (PW) basis

First note that as neutrinos in the SM have zero (inertial) mass for each generation and with the charge changing current that it participates in, it has pure (V-A) left-handed structure. So it is a pure ν_{gauge} left-handed state. Now if there arises some different mass matrix (different from the Yukawa coupling terms) herein, then for example as in eqn (2) which is complex and non-singular, then for these basis' ν_{mass} and ν_{gauge} are connected by a unitary transformation as in eqn (6). Then $(\nu_{gauge}(MM^{\dagger})\nu_{gauge})$ gives $(\nu_{mass}(S^{\dagger}(MM^{\dagger})S)\nu_{mass}) = {M_d}^2$ which is already diagonal and positive in mass-squared. So a single unitary transformation on a pure left-handed basis gives a chiral diagonal mass-squared. If there is no right handed part to give a biunitary transformation, we have a pure new mass-squared which is non -inertial and non -Yukawa kind of mass. So right away one can see that at the least, we get a mass-squared for the neutrino and this is of an entirely new kind. This is true for each generation of neutrino separately in SM.

So as the neutrino is massless (i.e. its Yukawa mass in SM is zero) then to generate another kind of independent mass for it, we are suggesting a new Pure Weak Group (PW) structure for it. Note that when the exact symmetry $SU(3)_c \otimes U(1)_{em}$ of the SM is restored to $SU(3)_c \otimes SU(2)_L \otimes U(1)_Y$ then all the matter particles become massless, i.e. they do not have any inertial and Yukawa kind of mass. So for the unbroken $SU(3)_c \otimes SU(2)_L \otimes U(1)_Y$ all the fermions are massless and these are all neutrino-like. So what we saw for each neutrino as massless particles in SM, here now all the fermions are massless and all are neutrino -like. So how should we treat them so that these all would have mass-squared associated with them. This is done in the new Pure Weak Group basis below.

For this structure, we assume that in addition to the existing SM structure as above, there exists a parallel and concurrent to it another new "Pure Weak Group" (PW) basis structure. This is based on another group $SU(3)_c \otimes SU(2)_{LP} \otimes U(1)_{YP}$ where the subscript LP labels the Pure Weak Groups and distinguishes this from the corresponding SM group structure. In the SM, the group is broken by a complex Higgs doublet. Below we shall assume that this new PW group is broken by a real three dimensional SO(3) Higgs. So we assume that at the basic and primitive level we have a $SU(3)_c \otimes SU(2)_L \otimes U(1)_Y$ group structure. There exist thereafter two different co-existing and dual paths through which this symmetry is broken. One is our old friend - the SM. The next one is this new PW path. This new kind of duality is essential to our understanding and will actually provide the fundamental reason for other dualities like wave-corpuscle duality in quantum mechanics to exist. So schematically we have the following structures:

$$
\begin{array}{ccc}
 & SU(3)_c \otimes SU(2)_L \otimes U(1)_Y & \\
\swarrow & & \searrow \\
SU(3)_c \otimes SU(2)_{LP} \otimes U(1)_{YP} & & SU(3)_c \otimes SU(2)_L \otimes U(1)_Y
\end{array}
\tag{20}
$$

Note that the defining Higgs in one is SU(2) complex and the other a real SO(3) as below.

We break the PW symmetry group through a triplet of real scalar Higgs field

$$\Phi = \begin{pmatrix} \phi_1 \\ \phi_2 \\ \phi_3 \end{pmatrix} \tag{21}$$

and break only the $SU(2)_{LP}$ group such that the residual symmetry group is U(1). That means that $W^{\pm}$ become massive and W^3 remains massless. We start with a scalar potential [3,7]

$$V(\Phi) = -\mu^2\Phi^2 + \lambda(\Phi^2)^2 \tag{22}$$

Note that minimization of $V(\Phi)$ only determines the magnitude

$$|\langle\Phi\rangle_0| = \frac{v}{\sqrt{2}} \tag{23}$$

One is free to choose the vacuum state which we take as

$$\langle\Phi\rangle_0 = \frac{1}{\sqrt{2}} \begin{pmatrix} 0 \\ 0 \\ v \end{pmatrix} \tag{24}$$

i.e. in the z-direction.

We demand that as the symmetry SO(3) is spontaneously broken we define the charge Q such that only one generator as above is not broken

$$Q\langle\Phi\rangle_0 = 0 \tag{25}$$

which means that charge gets defined as the diagonal generator of SO(3) [7]

$$Q = T_3 = \begin{pmatrix} 1 & & \\ & -1 & \\ & & 0 \end{pmatrix} \tag{26}$$

which ensures that it is W^3 which remains massless and that $W^{\pm}$ become massive and the residual group is $U(1)_z$ which show that the conserved charge is along the z-direction. This is for one-generation.

To understand the role of other role of other generations let us now define the representations of the three generations as per PW group $SU(3)_c \otimes SU(2)_{LP} \otimes U(1)_{YP}$ as

$$\begin{pmatrix} u^i \\ d^i \end{pmatrix}_L \sim (3,2,0); {u^i}_R \sim (3,1,Y_{u^i}); {d^i}_R \sim (3,1,Y_{d^i})$$

$$\begin{pmatrix} \nu^i \\ e^i \end{pmatrix}_L \sim (1,2,0); {\nu^i}_R \sim (3,1,Y_{\nu^i}); {e^i}_R \sim (3,1,Y_{e^i}) \tag{27}$$

where i=1.2.3 correspond to the three generations. So eg.

$$\begin{pmatrix} \nu_2 \\ \nu_2 \end{pmatrix}_L = \begin{pmatrix} \nu_\mu \\ \mu \end{pmatrix}_L \tag{28}$$

As above we had broken the SO(3) symmetry so that the third axis was the unbroken one and thereby the conserved electric charge was T_3. Now as SO(3) is isomorphic to SU(2) we make an additional demand that the conservation between the algebra also extend to the conservation of the charges, thereby translating to the diagonal generator of SU(2) as defining the charge for the fermions as

$$Q = \tau_3 \tag{29}$$

and thus

$$Q \begin{pmatrix} \nu_e \\ e \end{pmatrix}_L = \begin{pmatrix} +\frac{1}{2}\nu_e \\ -\frac{1}{2}e \end{pmatrix}_L \tag{30}$$

Note that the charges here in the group $SU(2)_{LP} \otimes U(1)_{YP}$ are very different from the electric charges we found in the SM. In fact here even the neutrinos are charged! Note also that $Q(e) - Q(\nu_e) =$ -1. So the left handed weak vertex connects properly to $W^\pm$ gauge bosons. And so all is well.

Note that in SM the lepton number arose from the ratio of the fermions hypercharge and the Higgs hypercharge. Here that freedom does not exist, as the electric charge is defined entirely within the group $SU(2)_{LP}$ itself with no contribution from the $U(1)_{LP}$. So how does one generation distinguishes itself from the others? Well, the freedom to choose the vacuum direction, which for the first generation we chose it to be the z-direction, provides the distinction between the different generations. Hence for the second generation let us choose the vacuum as

$$\langle\Phi\rangle_0 = \frac{1}{\sqrt{2}}\begin{pmatrix} 0 \\ v \\ 0 \end{pmatrix} \tag{31}$$

that is now the ground state Φ points in the y-direction.Thus now it is T_2 which defines the electric charge for the second generation. Next then τ_2 gives charges to the fermions. This distinguishes the second generation from the first one. Next choosing the vacuum along the x-direction gives uniqueness to the third generation.

Right away we see that now we have an explanation of as to why there are three generations of fermions in particle physics. This is so because in the PW group the Higgs with three real fields in Φ provides the three directions: z-, y- and x- along which the vacuum may be chosen and which provide different charges to different generations and distinguishes them.

Also this is not just a chance happening or coincidence. It is providing us with a deep and fundamental understanding of the structure of space-time and matter in the universe.

Note that all the fermions in this PW group basis are massless (i.e. have zero inertial mass of Yukawa-type from the SM). However only neutrinos continue to be massless in the SM itself (while all the other particles acquire non-zero inertial Yukawa-kind of mass). As such for the neutrinos the standard analysis of massless particles as representation of the Poincare group would hold [7]. Thus for the massless particle the little group is the Euclidean group in two dimensions E(2). E(2) group is generated by the group of rotations (generated by one say T_z) and translations (generated by L_y and L_x) in the plane. Thus when we choose T_z as the rotation directions (along which the helicity gets defined) then this is exactly is the same as the T_z symmetry breaking direction of SO(3) in the PW group. There is one-to-one correspondence between the two. Similarly for the other two generations,. So the freedom to choose the E(2) group for the massless neutrinos in the SM also provides consistent reason as to why there are three generations of particles.

Now what is the scale of the massive $W^{\pm}$ bosons in the PW group of $SU(3)_c \otimes SU(2)_{LP} \otimes U(1)_{YP}$. We know the scale of the Eletro-weak group in the SM to be about 250 GeV. Now the only scale left and known to us (and which has always been begging for a *proper* explanation) is of course our well known friend, the Planck Mass $(\frac{hc}{2\pi G})^{\frac{1}{2}} = 1.2$ x $10^{19}\frac{GeV}{c^2}$. So the gauge bosons here in PW group may be as heavy as that. One may protest that such a mass is beyond the reach of our accelerators. But this is not relevant here. What is relevant is the Planck length of $10^{-33}cm$ which is the range of the Planck gauge particle as weak force mediator over this range. This length is of course real and relevant. Also note that the Planck mass is anyway much smaller than the infinite mass of gauge boson required to justify the successful Fermi model of the weak interaction!

Now clearly as per the PW model the Planck mass is the reasonable mass for the PW interaction. Now it is a folklore in particle physics that as to gravity, if nothing else, at the least, it would demand quantization definitely at the Planck scale. That is at this mass scale quantization of gravity would become inevitable. Now we reverse the argument. We already have here a quantized theory of the weak interaction which demands a Planck scale mediator of force. Hence as Planck scale is arising consistently in a quantized model here, so there must be lurking the force of gravity in the background somewhere. We have not yet shown fully that indeed there is gravity in this model, but only an intriguing hint that it should be so in this new PW model. Further as discussed above, as to the three generations based on the three space coordinates z-, y-, and x-, consolidates this expectation.

So all said and done, the pattern of the total symmetry breaking in our PW model here is

$$\begin{array}{l} SU(3)_c \otimes SU(2)_{LP} \otimes U(1)_{YP} \\ \downarrow \\ SU(3)_c \otimes [U(1)_z \oplus U(1)_y \oplus U(1)_x] \otimes U(1)_{YP} \\ = SU(3)_c \otimes [\mathbf{U(1)}] \otimes U(1)_{YP} \end{array} \tag{32}$$

And thus $Q = Q_z + Q_y + Q_x$ with

$$Q \begin{pmatrix} \begin{pmatrix} u \\ d \end{pmatrix}_z \\ \begin{pmatrix} c \\ s \end{pmatrix}_y \\ \begin{pmatrix} t \\ b \end{pmatrix}_x \end{pmatrix}_L = \begin{pmatrix} Q_z & & \\ & Q_y & \\ & & Q_x \end{pmatrix} \begin{pmatrix} \begin{pmatrix} u \\ d \end{pmatrix}_z \\ \begin{pmatrix} c \\ s \end{pmatrix}_y \\ \begin{pmatrix} t \\ b \end{pmatrix}_x \end{pmatrix}_L \tag{33}$$

This gives vectors of identical charges as

$$\begin{pmatrix} u \\ c \\ t \end{pmatrix}_L ; \begin{pmatrix} d \\ s \\ b \end{pmatrix}_L ; \begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{pmatrix}_L ; \begin{pmatrix} e \\ \mu \\ \tau \end{pmatrix}_L \tag{34}$$

Where the charges Q are $\frac{1}{2}$, $-\frac{1}{2}$, $\frac{1}{2}$ and $-\frac{1}{2}$ respectively for the above vectors which are all left-handed. Let us look at the neutrino vector and call it L_ν. Recall our discussion in the biunitary transformation section and the discussion at the beginning of the current section. We assume that due to the Higgs spontaneous symmetry breaking there develops a complex chiral mass matrix which defines the chiral field L_ν. The mass matrix product $MM^\dagger$ is hermitian and so for the left handed neutrinos we obtain $\langle L_\nu | MM^\dagger | L_\nu \rangle$ for the left handed gauge state.

There is another way of showing, as we have asserted above, that there are no Yakawa-mass mixing terms across generations in the SM, that if we do insist for a term like the one here, then the nondiagonal terms connecting proper hypercharges of different generations of the left-handed doublets, do not exist.

Next we assume that first the spontaneous symmetry breaking generates a mass vector basis. Next as there also arises a charge defined by the diagonal generator of $SU(2)_{LP}$, that these states may be connected by a unitary transformation $L_\nu = SL_{mass}$ which arises from the mass basis the gauge basis. Then $(\nu_{gauge}(MM^\dagger)\nu_{gauge})$ gives

$$\langle L_{mass} | S^\dagger MM^\dagger S | L_{mass} \rangle = \begin{pmatrix} m_{\nu_e} & & \\ & m_{\nu_\mu} & \\ & & m_{\nu_\tau} \end{pmatrix} \tag{35}$$

where we see that for each flavour these mass-squared are real and positive. So mass-squared comes as a fundamental chiral quantity from the PW group structure. Clearly this mass is non-inertial and non-Yukawa kind.

Note that all the fermions have this diagonal mass squared for each flavour which arises from the mixing of generations and is different from the inertial mass.

What is this mass-squared and where is it coming from? Obviously it is coming from the structure of this new Pure Weak Group symmetry that we have discussed here. It is clearly chiral in nature in contrast to the scalar inertial mass obtained from the SM.

It may be pointed out that such a mass squared had already been labelled as "topological mass' by the author [9]. The word topology therein refers to a study of complementarity between what one identifies as "geometric" in nature and dual to it as what may be referred to as "topological" as to the space-time and matter in the nature. Here we shall not go too deep into that issue and the reader is invited to read that paper for information [9].

Hence it should be clear now that all the particles in addition to their inertial-Yukawa kind of mass arising from the SM have in addition another independent topological mass-squared arising from our new PW structure. These two masses are fundamentally different from each other, i.e. the chiral m^2 is different from the non-chiral ${m_I}^2$ of the inertial masses.

Note that the mass -squared and the charges for all the fermions as per these representations have arisen purely from the spontaneous symmetry breaking of $SU(2)_{LP}$ only, That is the group $U(1)_{LP}$ has played so far no role in the analysis. This is because these left-handed entities were singlet of this group. However from the same representations one sees that there do exist the correponding right-handed entities which are singlet of $(SU(2)_{LP}$ and have undefined, unquantized and unspecified $U(1)_{LP}$ quantum numbers. For different generations these are singlets of different $SU(2)_{z,y,x}$ groups and thus they know which generation they belong to. So the non-zero and unspecified hypercharge numbers that they have, should be identified with some kind of a generation number. Thus we place all the right handed entities of a particular left -handed entity as a vector, say for the neutrino as

$$|R_\nu\rangle = \begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{pmatrix}_R \tag{36}$$

Now this right-handed vector can be inserted in the mass-squared expression to break it up into the individual mass terms as stated in biunitarty transformation section as

$$\langle L_\nu|M|R_\nu\rangle\langle R_\nu|M^\dagger|L_\nu\rangle \rightarrow m.m \tag{37}$$

So the topological mass squared splits up into the single power mass. Note that in the above equation the unspecified hypercharge of various right-handed components cancel and thus though they define a generation, are never actually pinned down as a specific number. It is not quantized and in fact it can be any arbitrary real number rooted on the vacuum. Their main role here is to act on the vacuum to primarily reduce the mass-squared to a simple mass "m". Now what is this mass? It is logical to associate this with the "gravitational mass". Since time immemorial we have been aware of a mass different from the inertial mass and that has been the "gravitational mass". Identifying this new mass with the "graviational mass ' is logical, consistent and seems to be completing the physical reality. Hence as per what we have done so far all the particles have an inertial mass and a different gravitational mass.

But first to the neutrinos. Now neutrino as per what has been discussed here have zero inertial mass and non-zero gravitational mass. So having a gravitational mass, they will partake in gravitational interactions with all the other particles (besides their weak interaction) and thus be a suitable candidate to be the Dark Matter particle of the universe. Earlier one thought that these Dark Matter particles would be some WIMPS arising from some supersymmetric scenario. But now all that is irrelevant on the basis of what we have seen here, It is our good old friend, the neutrino, which is the Dark Matter of the Universe. And so all the effects that we had visualized for the DM, affecting life on on the the Earth [10] and as a new source of energy as proposed for the first time [11], are relevant and valid.

Before we end this section let us point out the interaction Lagragean for the $SU(2)_{LP}$ group is

$$\mathcal{L} = \frac{1}{2}[\sqrt{2}\overline{\nu_e}\gamma_\mu e_L {W_\mu}^+ + \sqrt{2}\overline{e_L}\gamma_\mu \nu_L {W_\mu}^- + (\overline{\nu_e}\gamma_\mu \nu_e - \overline{e_L}\gamma_\mu e_L){W_\mu}^3] \tag{38}$$

Now ${W_\mu}^3$ couples to the neutral currents of ν_e and e where each has a charge of $\frac{1}{2}$ and -$\frac{1}{2}$ respectively and which are not electromagnetic charge or the neutral charges of the SM. So how this new PW neutral current would behave has to be figured out along with the manner that the symmetry is broken as given in eqn. (32) above. We could guess that this should have something to say about the Dark Energy problem - in particular the cosmological constant.

(e) Superluminal Neutrinos

Since in the PW model we necessarily obtained the composite topological mass-squared, we should use the relation

$$E^2 = p^2c^2 + {m_g}^2c^4 \tag{39}$$

and thus $E = pv_p$ where

$$v_p = c\sqrt{1 + \frac{{m_g}^2c^4}{p^2}} \tag{40}$$

This is the phase velocity of the wave and the group velocity is

$$v_g = \frac{\partial E}{\partial p} = \frac{c}{\sqrt{1 + \frac{{m_g}^2c^4}{p^2}}} \tag{41}$$

such that

$$v_g v_p = c^2 \tag{42}$$

So necessarily the neutrinos are travelling with the above phase velocity. Note that this is necessarily as per the wave motion. This thus gives wave character to the neutrino and to all the other entities for which the above equations holds.

Note that in addition the inertial mass equations hold

$$E = m_I\gamma c^2; p = m_I\gamma v \tag{43}$$

where m_I is the inertial mass. Putting this in the above equations we get for the phase velocity $v_p = \frac{c}{\beta}\rangle c$ and the group velocity $v_g = v$ where "v" is the particle velocity when the inertial mass of the entity is non-zero. Thus all the matter particles with non-zero inertial mass travel with the group velocity and for them as de Broglie had pointed out the corresponding phase velocity was fictitious, as that did not carry any physical information. That is for them the group velocity, which was as above always smaller than the velocity of light, was only physical.

For neutrinos as the inertial mass was zero it would act as a corpuscle and it will travel with the velocity of light. But the wave character neutrino travels with the phase velocity arising from the physically relevant oscillation phenomenon, and that is greater than that of light.

The wave-corpuscle duality of quantum mechanics requires the neutrinos to display both these characteristics simultaneously but exclusively - that is when it behaves like a corpuscle and travels with the velocity of light, it will not be acting as a wave. But when it behaves as a wave, it oscillates and travels with a velocity greater than that of light. Mass oscillation is a physically relevant and physically measurable phenomenon and thus the phase velocity does carry physical signal for the neutrino.

However for the particle which had non-zero inertial mass and which in the SM behaved as a corpuscle. Next, these same particles have another gravitational mass arising from the new Pure Weak Group (PW) model proposed here and which as seen above, conforms to the wave character of the entity. Hence using the equivalence principle that

$$m_I = m_g \tag{44}$$

This immediately sets up a basis for the wave-corpuscle duality of quantum mechanics. So now we know where the corpuscle-wave duality of quantum mechanics comes from. This is because underlying there are two dual and complementary realities, the SM and the PW models which are the ones which act simultaneously and in a complementary manner. One is corpuscular in character and the other wave like. Hence the equivalence principle for massive particles brings about the wave-particle duality of quantum mechanics.

This also explains why this wave-particle duality requires an exclusiveness as per Bohr. This is because these two i.e. the SM and the PW are orthogonal and different systems providing basic structures to the gauge and the matter particles. One is corpuscular in nature with velocities always less that of light and the other has a wave nature and with phase velocities always greater than that of light. But as they stand for the same particle, they have the same mass (for massive particles) and thus have to act exclusively.

However for massive particles this makes sure that we are talking of one single entity at a single space-time point whether they act as a corpuscle or they act as a wave. But the neutrino is unique, as to the fact that as it has different inertial mass (actually zero) and a non-zero gravitational mass, it has non-locality built into it intrinsically.

Note the standard picture of a superluminal particle having imaginary mass is unacceptabel. Here the superluminal neutrino has positive mass and has a positive energy and they also oscillate.

Note the meaning of eqn. (42) of the three velocities therein is that only two of these are independent and only two may be physically relevant. The third one then is automatically determined and is therefore "fictitious" as de Broglie would have put it! So for inertially massive particles it is $v_g = v$ as the velocity of the particle and "c" is the other physical velocity. For neutrino it is "c" and v_p which are physically relevant and v_g is fictitious.

Hence it is the oscillating part of the neutrino which is superluminal So when looking for a superluminal neutrino it is essential that one makes sure that the neutrino that one sees in ones detector is actually the oscillating one. Remember that dual to it is another neutrino, which depending upon the technique employed for detection, may be the direct one, travelling with the velocity of light. The OPERA experiment is in a privileged position that they are detecting the tau-neutrinos in an appearance experiment. For a beam which started as a μ-neutrino, detecting a τ-neutrino is the clearest and unambiguous signal that what they see is actually from an oscillating neutrino mode. Hence we feel that at presnt the OPERA collaboration has the best chance of detecting a superluminal neutrino. The ICARUS collaboration, once they can identify the tau-neutrinos in the oscillation mode, may also detect the superluminal neutrinos.

The issue of the helicity of the neutrino is also an important issue. Note that one advantage of the neutrino picture here is that they have a well defined helicity. First they have as a corpuscles, the velocity of light, and hence never at rest and thus helicity is a good quantum number. But one knows well that massive particles do not have well defined helicity as they have a rest frame and thus the massive neutrino would be overtaken and thus helicity reversed. But the catch is that this is true for neutrino which move with v_g. In our picture the mas-squared neutrinos are moving with the velocity v_p and are thus superluminal for which a rest frame does not exist and thus helicity continues to be a good quantum number!

(IV) Conclusions

We found here that the SM gives inertial mass as Yukawa coupling and electric charge quantization on one-to-one basis. It is this which makes these follow the Principle of Relativity for mass and charge and also thus provide them with a corpuscular character.

Next as SM only allows for three different repetitive generations of fermions, it allows for no mass mixing matrix across generations. This led us to propose here a new Pure Weak Group basis (PW) which has the freedom to generate a new and different kind of topological mass-squared and thus the gravitational mass from there. These are chiral in character. This also demands a wave character for interpretation of this mass. All this is non-inertial. These basically obey eqns. (39) and (40) and not eqn (43) above.

We also obtain a new understanding as to why there are three generations of fermions in particle physics. It arises from the fact that there are only three space coordinates z,y, and x. This itself arose from the manner that spontaneous symmetry breaking occurs in the new PW model.

Through the equivalence principle $m_I = m_g$, we obtain a more basic understanding of where the wave-corpuscle duality of quantum mechanics arises for the massive (inertail mass) particles. When neutrinos are included, then we find that at the base of the apparent wave-corpuscle duality in quantum mechanics lies two fundamental, dual and simultaneously existing symmetries of the SM and the PW models. This in turn leads to this quantum mechanical property. So we see that the gauge symmettris, not only dictate the fundamental interactions but also determine this fundamental underlying quantum mechanical reality of quantum mechanics.

Now neutrinos have zero inertial mass and non-zero gravitational mass, and hence they are ideal candidates for the being the Dark Matter particle of the Universe.

Also as zero mass particles they travel with the velocity of light in the corpuscular mode. Simultaneously they also, having non-zero gravitational mass, partake in oscillations and travel with a velocity greater than that of light while displaying a wave character. Thus it acts nonlocally at two different places and may thus solve the horizon problem of cosmology. Thus this prediction of superluminal neutrinos should be confirmed by the experimentalists.

Though not defined explicitly here, the presence of the Planck mass scale in PW model, plus the explicit role of the z-, y- and x- spacial coordinates, and the interplay of continuous hypercharge parameters apparently exploring the global structure of the vacuum, that one feels that gravity should be in here somewhere. That has to be demonstrated next. In addition the unexplained Dark Energy problem or the Cosmological Constant problem should be amenable to the new neutral current inherent in the PW structure of the group $SU(2)_{LP}$.

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