Could neutrinos appear in several p-adic mass scales?

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Abstract

There are some indications that neutrinos can appear in several mass scales from neutrino oscillations. These oscillations can be classified to vacuum oscillations and to solar neutrino oscillations believed to be due to the so called MSW effect in the dense matter of Sun. There are also indications that the mixing is different for neutrinos and antineutrinos. In the following the possibility that padic length scale hypothesis might explain these findings is discussed.

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1 Introduction

There are some indications that neutrinos can appear in several mass scales coming from neutrino oscillaiton data [4]. These oscillations can be classified to vacuum oscillations and to solar neutrino oscillations believed to be due to the so called MSW effect in the dense matter of Sun. There are also indications that the mixing is different for neutrinos and antineutrinos.

In TGD framework padic length scale hypothesis might explain these findings. The basic vision is that the p-adic length scale of neutrino can vary so that the mass squared scale comes as octaves. Mixing matrices would be universal. The large discrepancy between LSND and MiniBoone results [6] contra solar neutrino results could be understood if electron and muon neutrinos have same p-adic mass scale for solar neutrinos but for LSND and MiniBoone the mass scale of either neutrino type is scaled up. The existence of a sterile neutrino [7] suggested as an explanation of the findings would be replaced by p-adically scaled up variant of ordinary neutrino having standard weak interactions. This scaling up can be different for neutrinos and antineutrinos as suggested by the fact that the anomaly is present only for antineutrinos.

The different values of Δm^2 for neutrinos and antineutrinos in MINOS experiment [5] can be understood if the p-adic mass scale for neutrinos increases by one unit. The breaking of CP and CPT would be spontaneous and realized as a choice of different p-adic mass scales and could be understood in zero energy ontology. Similar mechanism would break supersymmetry and explain large differences between the mass scales of elementary fermions, which for same p-adic prime would have mass scales differing not too much.

2 Experimental results

There several different type of experimental approaches to study the oscillations. One can study the deficit of electron type solar electron neutrinos (Kamiokande, Super-Kamiokande); one can measure the deficit of muon to electron flux ratio measuring the rate for the transformation of ν_μ to ν_τ (super-Kamiokande); one can study directly the deficit of ν_e ($\overline{\nu}_e$) neutrinos due to transformation to ν_μ $\nu_{\overline{\mu}}$ coming from nuclear reactor with energies in the same range as for solar neutrinos (KamLAND); and one can also study neutrinos from particle accelerators in much higher energy range such as solar neutrino oscillations (K2K,LSND,Miniboone,Minos).

2.1 Solar neutrino experiments and atmospheric neutrino experiments

The rate of neutrino oscillations is sensitive to the mass squared differences Δm^2_{12}, Δm^2_{12}, Δm^2_{13} and corresponding mixing angles θ_{12}, θ_{13}, θ_{23} between ν_e, ν_μ, and ν_τ (ordered in obvious manner). Solar neutrino experiments allow to determine $sin^2(2\theta_{12})$ and Δm^2_{12}. The experiments involving atmospheric neutrino oscillations allow to determine $sin^2(2\theta_{23})$ and Δm^2_{23}.

The estimates of the mixing parameters obtained from solar neutrino experiments and atmospheric neutrino experiments are $sin^2(2\theta_{13}) = 0.08$, $sin^2(2\theta_{23}) = 0.95$, and $sin^2(2\theta_{12}) = 0.86$. The mixing between ν_e and ν_τ is very small. The mixing between ν_e and ν_μ, and ν_μ and ν_τ tends is rather near to maximal. The estimates for the mass squared differences are $\Delta m^2_{12} = 8\times 10^{-5}$ eV^2, $\Delta m^2_{23} \simeq \Delta m^2_{13} = 2.4\times 10^{-3}$ eV^2. The mass squared differences have obviously very different scale but this need not means that the same is true for mass squared values.

2.2 The results of LSND and MiniBoone

LSND experiment measuring the transformation of $\overline{\nu}_\mu$ to $\overline{\nu}_e$ gave a totally different estimate for Δm^2_{12} than solar neutrino experiments [6, 7]. If one assumes same value of $sin^2(\theta_{12})^2 \simeq .86$ one obtains $\Delta m^2_{23} \sim .1$ eV^2 to be compared with $\Delta m^2_{12} = 8\times 10^{-5}$ eV^2. This result is known as LSND anomaly and led to the hypothesis that there exists a sterile neutrino having no weak interactions and mixing with the ordinary electron neutrino and inducing a rapid mixing caused by the large value of Δm^2 The purpose of MiniBoone experiment [6] was to test LSND anomaly.

1. It was found that the two-neutrino fit for the oscillations for $\nu_\mu \rightarrow \nu_e$ is not consistent with LSND results. There is an unexplained 3σ electron excess for $E < 475$ MeV. For $E > 475$ MeV the two-neutrino fit is not consistent with LSND fit. The estimate for Δm^2 is in the range $.1 - 1$ eV^2 and differs dramatically from the solar neutrino data.

2. For antineutrinos there is a small 1.3σ electron excess for $E < 475$ MeV. For $E > 475$ MeV the excess is 3 per cent consistent with null. Two-neutrino oscillation fits are consistent with LSND. The best fit gives $(\Delta m^2_{12}, sin^2(2\theta_{12}) = (0.064\ \ eV^2, 0.96)$. The value of Δm^2_{12} is by a factor 800 larger than that estimated from solar neutrino experiments.

All other experiments (see the table of the summary of [7] about sterile neutrino hypothesis) are consistent with the absence of $\nu_\mu \rightarrow n_e$ and $\overline{\nu}_\mu \rightarrow \overline{\nu}_e$ mixing and only LSND and MiniBoone report an indication for a signal. If one however takes these findings seriously they suggest that neutrinos and antineutrinos behave differently in the experimental situations considered. Two-neutrino scenarios for the mixing (no sterile neutrinos) are consistent with data for either neutrinos or antineutrinos but not both [7].

2.3 The results of MINOS group

The MINOS group at Fermi National Accelerator Laboratory has reported evidence that the mass squared differences between neutrinos are not same for neutrinos and antineutrinos [5]. In this case one measures the disappearance of ν_μ and $\overline{\nu}_\mu$ neutrinos from high energy beam beam in the range .5-1 GeV and the dominating contribution comes from the transformation to τ neutrinos. Δm^2_{23} is reported to be about 40 percent larger for antineutrinos than for neutrinos. There is 5 percent probability that the mass squared differences are same. The best fits for the basic parameters are $(\Delta m^2_{23} = 2.35\times 10^{-3}, sin^2(2\theta_{23} = 1)$ for neutrinos with error margin for Δm^2 being about 5 per cent and ($\Delta m_{23}^2 = 3.36 \times 10^{-3}, sin^2(2\theta_{23}) = .86$) for antineutrinos with errors margin around 10 per cent. The ratio of mass squared differences is $r \equiv \Delta m^2(\overline{\nu})/\Delta m^2(\nu) = 1.42$. If one assumes $sin^2(2\theta_{23}) = 1$ in both cases the ratio comes as $r = 1.3$.

3 Explanation of findings in terms of p-adic length scale hypothesis

p-Adic length scale hypothesis predicts that fermions can correspond to several values of p-adic prime meaning that the mass squared comes as octaves (powers of two). Even electrons could do so and the poorly understood heavy fermions[11] for which effective mass can be by a factor 1000 larger than for ordinary electron might be actually electrons for which Mersenne prime M_{127} has been tempparily replaced with the smaller prime- even Mersenne prime M_{107} characterizing hadronic space-time sheets. An interaction with the heavy nuclei is involved with the process which might explain the result. This is of course just a light hearted proposal: the definition of the effective mass is based on dispersion relation energy of electron and rather formal. By energy conservation electrons should appear as off mass shell particles during the massive period.

The simplest model for the neutrino mixing assumes universal topological mixing matrices and therefore for CKM matrices so that the results should be understood in terms of different p-adic mass scales. Even CP breaking and CPT breaking at fundamental level is un-necessary although it would occur spontaneously in the experimental situation selecting different p-adic mass scales for neutrinos and antineutrinos. The expression for the mixing probability a function of neutrino energy in two-neutrino model for the mixing is of form

$$P(E) = sin^2(2\theta)sin^2(X) \ \ , \ \ X = k \times \Delta m^2 \times \frac{L}{E} \ \ .$$

Here k is a numerical constant, L is the length travelled, and E is neutrino energy.

3.1 LSND and MiniBoone results

LSND and MiniBoone results are inconsistent with solar neutrino data since the value of Δm_{12}^2 is by a factor 800 larger than that estimated from solar neutrino experiments. This could be understood if in solar neutrino experiments ν_μ and ν_w correspond to the same p-adic mass scale $k = k_0$ and have very nearly identical masses so that Δm^2 scale is much smaller than the mass squared scale. If either p-adic scale is changed from k_0 to $k_0 + k$, the mass squared difference increases dramatically. The counterpart of the sterile neutrino would be a p-adically scaled up version of the ordinary neutrino having standard electro-weak interactions. The p-adic mass scale would correspond to the mass scale defined by Δm^2 in LSND and MiniBoone experiments and therefore a mass scale in the range .3-1 eV. The p-adic length scale assignable to eV mass scale could correspond to $k = 167$, which corresponds to cell length scale of 2.5 μm. $k = 167$ defines one of the Gaussian Mersennes $M_{G,k} = (1 + i)^k - 1$ $k = 151, 157, 163, 167$ varying in the range 10 nm (celle membrane thickness) and 2.5 μm defining the size of cell nucleus proposed to be fundamental for the understanding of living matter [1].

3.2 MINOS results

One must assume also now that the p-adic mass scales for ν_τ and $\overline{\nu}_\tau$ are near to each other in the "normal" experimental situation. Assuming that the mass squared scales of ν_μ or $\overline{\nu}_\mu$ come as 2^{-k} powers of $m_{\nu_\mu}^2 = m_{\nu_\tau}^2 + \Delta m^2$, one obtains

$$m_{\nu_\tau}^2(k_0) - m_{\overline{\nu}_\mu}^2(k_0 + k) = (1 - 2^{-k})m_{\nu_\tau}^2 - 2^{-k}\Delta m_0^2 \ \ .$$

For $k = 1$ this gives

$$r \ = \ \frac{\Delta m^2(k=2)}{\Delta m^2(k=1)} = \frac{\frac{3}{2} - \frac{2r}{3}}{1-r} \ \ , \ \ r = \frac{\Delta m_0^2}{m_{\nu_\tau}^2} \ \ . \tag{3.1}$$

One has $r \geq 3/2$ for $r > 0$ if one has $m_{\nu_\tau} > m_{\nu_\mu}$ for the same p-adic length scale. The experimental ratio $r \simeq 1.3$ could be understood for $r \simeq -.31$. The experimental uncertainties certainly allow the value $r = 1.5$ for $k(\overline{\nu}_\mu) = 1$ and $k(\nu_\mu) = 2$.

This result implies that the mass scale of ν_μ and ν_τ differ by a factor 1/2 in the "normal" situation so that mass squared scale of ν_τ would be of order 5×10^{-3} eV^2. The mass scales for $\overline{\nu}_\tau$ and ν_τ would about .07 eV and .05 eV. In the LSND and MiniBoone experiments the p-adic mass scale of other neutrino would be around .1-1 eV so that different p-adic mass scale large by a factor $2^{k/2}$, $2 \leq 2 \leq 7$ would be in question. The different resuts from various experiments could be perhaps understood in terms of the sensitivity of the p-adic mass scale to the experimental situation. Neutrino energy could serve as a control parameter.

4 CP and CPT breaking

Differet values of Δm^2_{ij} for neutrinos and antineutrinos would require in standard QFT framework not only the violation of CP but also CP [8, 9] which is the cherished symmetry of quantum field theories. CPT symmetry states that when one reverses time's arrow, reverses the signs of momenta and replaces particles with their antiparticles, the resulting Universe obeys the same laws as the original one. CPT invariance follows from Lorentz invariance, Lorentz invariance of vacuum state, and from the assumption that energy is bounded from below. On the other hand, CPT violation requires the breaking of Lorentz invariance.

In TGD framework this kind of violation does not seem to be necessary at fundamental level since p-adic scale hypothesis allowing neutrinos and also other fermions to have several mass scales coming as half-octaves of a basic mass scale for given quantum numbers. In fact, even in TGD inspired low enery hadron physics quarks appear in several mass scales. One could explain the different choice of the p-adic mass scales as being due to the experimental arrangement which selects different p-adic length scales for neutrinos and antineutrinos so that one could speak about spontaneous breaking of CP and possibly CPT. The CP breaking at the fundamental level which is however expected to be small in the case considered. The basic prediction of TGD and relates to the CP breaking of Chern-Simons action inducing CP breaking in the modified Dirac action defining the fermionic propagator [2].

One can indeed consider the possibility of a spontaneous breaking of CPT symmetry in TGD framework since for a given CD (causal diamond defined as the intersection of future and past directed light-cones whose size scales are assumed to come as octaves) the Lorentz invariance is broken due to the preferred time direction (rest system) defined by the time-like line connecting the tips of CD. Since the world of classical worlds is union of CDs with all boosts included the Lorentz invariance is not violated at the level of WCW. Spontaneous symmetry breaking would be analogous to that for the solutions of field equations possessing the symmetry themselves. The mechanism of breaking would be same as that for supersymmetry. For same p-adic length scale particles and their super-partners would have same masses and only the selection of the p-adic mass scale would induces the mass splitting.

There is an article about CPT violation[10] of the dynamics defined by what the authors also call Chern-Simons term. This term is not identical with the measurement interaction term introduced in TGD framework. It is however linear in momentum as is also the measurement interaction term added to Chern-Simons Dirac action and this is what is essential from the point of view of CPT. The measurement interaction term has a formal interpretation as $U(1)$ gauge transform but having non-trivial physical effect since it is added only to the Chern-Simons Dirac action term but not to Kähler-Dirac action. The linearity with respect to momentum suggests CPT oddness of the measurement interaction term. In absence of the measurement interaction CPT would be intact but the change of the sign of the measurement interaction term in PT would bring in CPT violation. One must however notice that in TGD framework both imbedding space level and space-time level are involved and this does not allow straightforward application of standard arguments.

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