Encountering the puzzle of inert neutrinos once again

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Abstract

From neutrino mixing experiments at LNSD and Mini-Boone there are indications for the existence of inert neutrinos having no weak couplings. The problem of inert neutrinos is very interesting also from TGD point of view. TGD predicts right handed neutrino with no electroweak couplings but mixes with left handed neutrino by a new interaction produced by the mixing of M^4 and CP_2 gamma matrices: this is a unique feature of induced spinor structure and serves as a signature of sub-manifold geometry and one signature distinguishing TGD from standard model. Only massive neutrino with both helicities remains and behaves in good approximation as a left handed neutrino.

The earlier TGD based explanation for the strange features of neutrino mixing relies on the assumption that neutrinos can appear in several p-adic length scales (as also other fermions). The apparent presence of fourth neutrino generation would only correspond to different mass states. The widely different values of mass squared differences deduce from neutrino-antineutrino mixing for LSND neutrinos, atmospheric neutrinos, and solar neutrinos would correspond to different p-adic length scales. The ratios of mass squared splittings are predicted to come as powers of two and the prediction is consistent with the experimental findings.

Also a model for the mixing of neutrinos emerges. The twistor lift of TGD predicts that also M^4 has the analog of Kähler structure. This predicts a new $U(1)$ gauge bosons - U bosons - coupling to fermion number therefore also to neutrinos. U boson would explain CP, P, and T breaking effects and its coupling strength would be of the order of $\alpha_1 \sim 10^{-9}$. The transformation between different mass states of neutrinos could take place via emission of U bosons. This transformation could occur also via a transformation to intermediate dark neutrino transforming to neutrino with a smaller mass by emission of U boson. Emission of U boson could be also involved neutrino mixing and CKM mixing.

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1 Introduction

Sabine Hossenfelder had an interesting link to Quanta Magazine article "*On a Hunt for a Ghost of a Particle*" telling about the plans of particle physicist Janet Conrad to find the inert neutrino (see http://tinyurl.com/ybhcjwu6). The attribute "sterile" or "inert" (I prefer the latter since it is more respectful!) comes from the assumption this new kind of neutrino does not have even weak interactions and feels only gravitation. There are indications for the existence of inert neutrino from LSND experiments (see http://tinyurl.com/y7ktyfrs) and some Mini-Boone experiments (see http://tinyurl.com/y74hmq7c). In standard model it would be interpreted as fourth generation

neutrino which would suggest also the existence of other fourth generation fermions. For this there is no experimental support.

The problem of inert neutrino is very interesting also from TGD point of view. TGD predicts also right handed neutrino with no electroweak couplings but mixes with left handed neutrino by a new interaction produced by the mixing of M^4 and CP_2 gamma matrices: this is a unique feature of induced spinor structure and serves as a signature of sub-manifold geometry and one signature distinguishing TGD from standard model. Only massive neutrino with both helicities remains and behaves in good approximation as a left handed neutrino.

There are indeed indications in both LSND and MiniBoone experiments for inert neutrino. But only in some of them. And not in the ICECUBE experiment (see `http://icecube.wisc.edu`) performed at was South Pole. Special circumstances are required. "Special circumstances" need not mean bad experimentation. Why this strange behavior?

1. The evidence for the existence of inert neutrino, call it $\overline{\nu}_I$, came from antineutrino mixing $\overline{\nu}_\mu \to \overline{\nu}_e$ manifesting as mass squared difference between muonic and electronic antineutrinos. This difference was $\Delta m^2(LSND) = 1 - 10\ eV^2$ in the LSND experiment. The other two mass squared differences deduced from solar neutrino mixing and atmospheric neutrino mixing were $\Delta m^2(sol) = 8 \times 10^{-5}\ eV^2$ and $\Delta m^2(atm) = 2.5 \times 10^{-3}\ eV^2$ respectively.

2. The inert neutrino interpretation would be that actually $\overline{\nu}_\mu \to \overline{\nu}_I$ takes place and the mass squared difference for $\overline{\nu}_\mu and \overline{\nu}_I$ determines the mixing.

2 The explanation of neutrino mixing based on several p-adic mass scales for neutrinos

The first TGD inspired explanation proposed for a long time ago relies on p-adic length scale hypothesis predicting that neutrinos can exist in several p-adic length scales for which mass squared scale ratios come as powers of 2. Mass squared differences would also differ by a power of two. Indeed, the mass squared differences from solar and atmospheric experiments are in ratio 2^{-5} so that the model looks promising!

Writing $\Delta m^2(LSND) = x\ eV^2$ the condition $m^2(LSND)/m^2(atm) = 2^k$ has 2 possible solutions corresponding to $k = 9$, or $k = 10$ and $x = 2.5$ and $x = 1.25$. The corresponding mass squared differences $2.5\ eV^2$ and $1.25\ eV^2$.

The interpretation would be that the three measurement outcomes correspond to 3 neutrinos with nearly identical masses in given p-adic mass scale k but having different p-adc mass scales. The atmospheric and solar p-adic length scales would comes as powers $(L(atm), L(sol)) = (2^{n/2}, 2^{(n+10)/2}) \times L(k(LSND))$, $n = 9$ or $n = 10$. For $n = 10$ the mass squared scales would come as powers of 2^{10}.

How to estimate the value of $k(LSND)$?

1. Empirical data and p-adic mass calculations suggest that neutrino mass is of order .1 eV . The most natural candidates for p-adic mass scales would correspond to $k = 163, 167$ or $k = 169$. The first primes $k = 163, 167$ correspond to Gaussian Mersenne primes $M_{G,n} = (1 + i)^n - 1$ and to p-adic length scales $L(163) = 640$ nm and $L(167) = 2.56\ \mu$m.

2. p-Adic mass calculations [K2] (see `http://tinyurl.com/y9cvb332`) predict that the ratio $x = \Delta m^2/m^2$ for $\mu - e$ system has upper bound $x \sim .4$. This does not take into account the mixing effects but should give upper bound for the mass squared difference affected by the mixing.

3. The condition $\Delta m^2/m^2 = .4 \times x$, where $x \leq 1$ parametrizes the mass difference assuming $\Delta m(LSND)^2 = 2.5\ eV^2$ gives $m^2(LSND) \sim 6.25\ eV^2/x$.

    $x = 1/4$ would give $(k(LSND), k(atm), k(sol)) = (157, 167, 177)$. $k(LSND)$ and $k(atm)$ label two Gaussian Mersenne primes $M_{G,k} = (1 + i)^k$ in the series $k = 151, 157, 163, 167$ of Gaussian Mersennes. The scale $L(151) = 10$ nm defines cell membrane thickness. All these scales could be relevant for DNA coiling. $k(sol) = 177$ is not Mersenne prime nor even prime. The correspoding p-adic length scale is 82 μm perhaps assignable to neuron. Note that $k = 179$ is prime.

This explanation looks rather nice because the mass squared difference ratios come as powers of two. What seems clear that the longer the path of neutrino travelled from the source to the detector, the smaller than mass squared: in other words one has $k(LSND) < k(atm) < k(sol)$. This suggest that neutrinos transform to lower mass neutrinos during the travel $k(LSND) \to k(atm) \to k(sol)$. The sequence could contains also other p-adic length scales.

What really happens when neutrino characterised by p-adic length scale $L(k_1)$ transforms to a neutrino characterized by p-adic length scale $L(k_2)$.

1. The simplest possibility would be that $k_1 \to k_2$ corresponds to a 2-particle vertex. The conservation of energy and momentum however prevent this process unless one has $\Delta m^2 = 0$. The emission of weak boson is not kinematically possible since Z^0 boson is so massive. For instance, solar neutrinos have energies in MeV range. The presence of classical Z^0 field could make the transformation possible and TGD indeed predicts classical Z^0 fields with long range. The simplest assumption is that all classical electroweak gauge fields except photon field vanish at string world sheets. This could in fact be guaranteed by gauge choice analogous to the the unitary gauge.

2. The twistor lift of TGD however provides an alternative option. Twistor lift predicts that also M^4 has the analog of Kähler structure characterized by the Kähler form $J(M^4)$ which is covariantly constant and self-dual and thus corresponds to parallel electric and magnetic components of equal strength. One expects that this gives rise to both classical and quantum field coupling to fermion number, call this $U(1)$ gauge field U. The presence of $J(M^4)$ induces P, T, and CP breaking and could be responsible for CP breaking in both leptonic and quark sectors and also explain matter antimatter asymmetry [L1, L2] (see `http://tinyurl.com/y7h6dyo3` and `http://tinyurl.com/y8xcem2d`) as well as large parity violation in living matter (chiral selection). The coupling constant strength α_1 is rather small due to the constraints coming from atomic physics (new $U(1)$ boson couples to fermion number and this causes a small scaling of the energy levels). One has $\alpha_1 \sim 10^{-9}$, which is also the number characterizing matter antimatter asymmetry as ratio of the baryon density to CMB photon density.

   Already the classical long ranged U field could induce the neutrino transitions. $k_1 \to k_2$ transition could become allowed by conservation laws also by emission of U boson. The simplest situation corresponds to parallel momenta for neutrinos and U. Conservation laws of energy and momentum give $E_1 = \sqrt{p_1^2 + m_1^2} = E_2 + E(U) = \sqrt{p_2^2 + m_2^2} + E(U)$, $p_1 = p_2 + p(U)$. Masslessness gives $E(U) = p(U)$. This would give in good approximation $p_2/p_1 = m_1^2/m_2^2$ and $E(U) = p_1 - p_2 = p_1(1 - m_1^2/m_2^2)$.

   One can ask whether CKM mixing for quarks could involve similar mechanism explaining the CP breaking. Also the transitions changing $h_{eff}/h = n$ could involve U boson emission.

3 The explanation of mixing with dark neutrinos

Second TGD inspired interpretation would be as a transformation of ordinary neutrino to a dark variant of ordinary neutrino with $h_{eff}/h = n$ occurring only if the situation is quantum critical (what would this mean now?). Dark neutrino would behave like inert neutrino. One cannot exclude this option but it does not give quantitative predictions.

This proposal need not however be in conflict with the first one since the transition $k(LSND) \to k_1$ could produce dark neutrino with different value of $h_{eff}/h = 2^{\Delta k}$ scaling up the Compton scale by this factor. This transition could be followed by a transition back to a particle with p-adic length scale scaled up by 2^{2k}. I have proposed that p-adic phase transitions occurring at criticality requiring $h_{eff}/h > 1$ are important in biology [K1] (see `http://tinyurl.com/ycjdkxw7`).

There is evidence for a similar effect in the case of neutron decays. Neutron lifetime is found to be considerably longer than predicted. The TGD explanation [K3] (see `http://tinyurl.com/yaa3cfrq`) is that part of protons resulting in the beta decays of neutrino transform to dark protons and remain undetected so that lifetime looks longer than it really is [L3] (see `http://tinyurl.com/yc8d7sed`). Note however that also now conservation laws give constraints and the emission of U photon might be involved also in this case. As a matter of fact, one can consider

the possibility that the phase transition changing $h_{eff}/h = n$ involve the emission of U photon too. The mere mixing of the ordinary and dark variants of particle would induce mass splitting and U photon would take care of energy momentum conservation.

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