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Interesting Lower Limit for Mass of Excited Neutrinos from Star-Cooling Processes

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ABSTRACT: After some discussions on astrophysical limits on masses of hypothetical excited neutrinos in composite model of quarks and leptons are reviewed, it is qualitatively argued that the derived lower limit of allowed mass values from star-cooling process suggests interestingly that a possible similarity as for pattern of ratio of masses for excited neutrinos to excited charged leptons in composite models may reveal as those of ground states, contrary to an eminent belief that excited neutrinos should have the same order of corresponding charged leptons and excited quarks around envisaged energy scale of compositeness, O(TeV) or more.

KEYWORDS: Neutrino mass, Composite model, Star-cooling, Mass ratio

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In the late 1970's, there appeared a lot of models of composite quarks and leptons [1]. They were mainly motivated by proliferation of finding 'new' quarks and leptons at that time, *i.e.*, charm, bottom, and tau (top wasn't found yet, though its existence was convinced among theorists). One would imagine that quarks and leptons should have internal components, and then naturally one could expect their excited states. Experiments were therefore planned to hunt those excited particles as evidence of new physics beyond the standard model, but so far there have been no successful reports for them from high-energy accelerators [2].

New physics beyond the standard model becomes eminent figure nowadays through neutrino physics to acknowledge Super-Kamiokande [3] and SNO [4], which have established oscillations both of atmospheric and

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solar neutrinos that were pioneered by Homestake [5].

Neutrinos have played important roles in cosmology and astrophysics. So-called neutrino astronomy opens new horizon of astronomy for stars which one could not obtain through usual optical observations, mainly due to the fact that neutrinos can penetrate deeper inside of stars than the light.

It was pointed out in 1941 that neutrinos are important in the stage of stellar collapse [6]. After Pontecorvo emphasized the importance of electromagnetic interactions caused by neutrinos in Astrophysics [7], theorists began to study in various models the cooling rate of stars due to emission of neutrinos from deep inside of stars to take thermal energy out to exterior of stars with them. They can come out without any obstacle from central region of stars because of their weakness of couplings with their environment. Gell-Mann showed a no-go theorem that electromagnetic interaction can't exist for massless neutrinos with the strict local Fermi interaction [8]. Then, in spite of non-renormalizable Fermi interaction, Rosenberg was succeeded in obtaining finite results for electromagnetic interactions of neutrinos in a one-loop diagram with regularization cut-off [9]. In 1970's and even afterwards, some people concentrated to study effects of higher-order perturbations in the renormalizable gauge model and showed their results can avoid the no-go theorem. However, the results give too small electromagnetic interaction of massless neutrinos to cause significant physical phenomena [10].

That is about situation concerned with electromagnetic interactions of neutrinos before and the just after the birth of the renormalizable Glashow-Weinberg-Salam theory. Now the neutrino-oscillation phenomena compel us to consider massive neutrinos sincerely. Certainly models beyond the standard model should be taken seriously on this context. What kind of new physics can be imagined beyond the standard model? For neutrinos' electromagnetic interaction, we have such various models with massive neutrinos as simply extended standard model with added massive neutrinos by hand [11], left-right symmetric models [12], supersymmetric extension of the standard model [13], and so on. There are more degrees of freedom introduced into these models than in the standard GWS theory. Surely composite models of neutrinos exist among them.

Let us discuss composite models of neutrinos in the star-cooling process to get information on masses [14,15]. Since excited neutrinos can decay via electromagnet interaction into ground state assigned to be standard neutrinos, the composite neutrinos are allowed to have the direct coupling to photon so that colliding of a pair of photons in hot plasma deep inside stars would produce a pair of neutrinos. The produced neutrinos would bring some portion of thermal energies out of stars freely. This is the common feature of star-cooling not only in composite models but in various models above.

Possible effective Lagrangian among photon, neutrino, and excited neutrino is given in the reference of [16]. It is described in terms of Pauli coupling when excited neutrinos are supposed to be spin 1/2 particles. The Pauli coupling includes a cutoff-parameter, which is regarded as the composite scale. The present author imagined once the excited neutrinos should have an order of the cutoff, i.e., O(TeV) or above [14]. But the Brazilian group found interestingly that there could be another solution with very light excited neutrinos, besides these heavy solutions, compared with masses of their charged partner [15]. Quoting LEP data [17], they showed that even the lowest limit for allowed mass of light spin 1/2 excited neutrinos can be O(100keV), if these excited neutrinos interact quite weakly with our world which should be made of standard quarks and leptons.

Such simple guess that masses must be around the cutoff should be right for charged particles. Contrary to this guess, the very light excited neutrinos of O(100keV) are interestingly allowed in star-cooling process. If this is indeed true, once again neutrinos can possess so special position even in the excited sector as in the standard neutrinos. This can be quite interesting problem, if the idea of composite quarks and leptons would be supported from other experiments like investigation of deviation for muon anomalous magnetic moment from the standard model.

Compared with light standard neutrino masses of ~ 0.01 eV, these envisaged light excited neutrinos of O(100keV) are massive enough by a factor of 10 million. With the assumed cutoff of O(10TeV) here, possible mass of excited electron is expected to be around the order of 1 TeV. Then the ratio of masses of excited electron to electron in this case may be almost the same order to the corresponding ratio for excited neutrinos to standard neutrinos. Concerned with the ratio of masses between neutral and charge leptons, we would have similar value for both of excited and ground states. This seems to be very amazing hierarchy, if any of excited states exist really.

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