Available online at www.sciencedirect.com

ScienceDirect

Nuclear Physics B (Proc. Suppl.) 246–247 (2014) 63–67

NUCLEAR PHYSICS B PROCEEDINGS SUPPLEMENTS

www.elsevier.com/locate/npbps

Implications of Neutrino Oscillations on the Dark-Matter World

W-Y. Pauchy Hwang

Asia Pacific Organization for Cosmology and Particle Astrophysics,
Institute of Astrophysics, Center for Theoretical Sciences,
and Department of Physics, National Taiwan University, Taipei 106, Taiwan

Abstract

According to my own belief that "The God wouldn't create a world that is so boring that a particle knows only the very feeble weak interaction.", maybe we underestimate the roles of neutrinos. We note that right-handed neutrinos play no roles, or don't exist, in the minimal Standard Model. We discuss the language to write down an extended Standard Model - using renormalizable quantum field theory as the language; to start with a certain set of basic units under a certain gauge group; in fact, to use the three right-handed neutrinos to initiate the family gauge group $SU_f(3)$. Specifically we use the left-handed and right-handed spinors to form the basic units together with $SU_c(3) \times SU_L(2) \times U(1) \times SU_f(3)$ as the gauge group. The dark-matter $SU_f(3)$ world couples with the lepton world, but not with the quark world. Amazingly enough, the space of the Standard-Model Higgs $\Phi(1,2)$, the family Higgs triplet $\Phi(3,1)$, and the neutral part of the mixed family Higgs $\Phi^0(3,2)$ undergoes the spontaneous symmetry breaking, i.e. the Standard-Model Higgs mechanism and the "project-out" family Higgs mechanism, to give rise to the weak bosons $W^{\pm}$ and Z^0, one Standard-Model Higgs, the eight massive family gauge bosons, and the remaining four massive neutral family Higgs particles, and nothing more. Thus, the roles of neutrinos in this extended Standard Model are extremely interesting in connection with the dark-matter world.

Keywords: Models Beyond the Standard Model, Origin and Formation of the Universe, Unified Field Theories and Models

1. Introduction

Our searches for the final extended Standard Model lie at three major clues - neutrino oscillations, which are now firmly established, the existence of three generations, which is clearly seen but unexplained, and the existence of the dark-matter world, which is five times the ordinary-matter world. Our efforts, such as in Hwang and Yan [1], follow the belief that the suitable extension of the minimal Standard Model should allow us to describe the entire world.

Usually in a textbook, the QCD chapter precedes the one on Glashow-Weinberg-Salam (GWS) electroweak theory. Nothing is wrong with it but, to be precise in the language, the starting basic units for QCD are the building blocks of matter while the basic units for the GSW electroweak theory are those left-handed and right-handed components of Dirac spinors. It would be nice (in helping us in thinking) if the framework is formulated all at once, to use common starting basic units - in an extended Standard Model we could see everything consistent with one another. Then, many of the questions which we pose could have broader meanings and implications. Thus, this is what Hwang and Yan [1] tried to do.

We shall work with the Lie group $SU_c(3)\times SU_L(2)\times$

*This article is updated during September 2013, in view of several conceptual breakthroughs of the author.

Email address: wyhwang@phys.ntu.edu.tw (W-Y. Pauchy Hwang)

0920-5632/$ – see front matter
http://dx.doi.org/10.1016/j.nuclphysbps.2013.10.066

$U(1)\times SU_f(3)$ as the gauge group. Thus, the basic units are made up from quarks (of six flavors, of three colors, and of the two helicities) and leptons (of three generations and of the two helicities), together with all originally massless gauge bosons and the somewhat hidden induced Higgs fields. In view of the search over the last forty years, we could assume "minimum Higgs hypothesis" as the working rule.

If we look at the basic units as compared to the original particle, i.e. the electron, it turns out that the starting basic units are all "point-like" Dirac particles. Dirac invented Dirac electrons eighty years ago and surprisingly enough only these "point-like" Dirac particles turns out to be the basic units of the Standard Model. Thus, we call it "Dirac Similarity Principle" - a salute to Dirac; a triumph to mathematics. Our world could indeed be described by the proper mathematics. The proper mathematics may be the renormalizable quantum field theory, although our confidence in it sort of fluctuates in time.

There is no way to "prove" the above two working rules - "Dirac Similarity Principle" and "minimum Higgs hypothesis", and so they would remain as working rules for a while. In fact, it might be associated with the peculiar property of our Lorentz-invariant spacetime. To use these two working rules, we could simplify tremendously the searches for the new extended Standard Models.

2. The Hwang-Yan Statement for the Extended Standard Model

We adopt the basic units as in the paper of Hwang and Yan [1]- those left-handed and right-handed quarks and leptons; the gauge group is chosen to be $SU_c(3)\times SU_L(2)\times U(1)\times SU_f(3)$. Accordingly, we have eight gluons, $W^\pm$, Z^0, the photon, and eight massive family bosons, implying that four neutral family Higgs particles on top of one Standard-Model Higgs.

In the gauge sector, the lagrangian is fixed if the gauge group is given; only for a massive gauge theory, Higgs fields are called for and we postpone its discussions until we have spelled out the fermion sector.

For the fermion sector, the story is again fixed if the so-called "gauge-invariant derivative", i.e. D_μ in the kinetic-energy term $-\bar\Psi\gamma_\mu D_\mu\Psi$, is given for a given basic unit [2].

Thus, we have, for the up-type right-handed quarks u_R, c_R, and t_R,

$$D_\mu = \partial_\mu - ig_c\frac{\lambda^a}{2}G^a_\mu - i\frac{2}{3}g'B_\mu, \qquad (1)$$

and, for the rotated down-type right-handed quarks d'_R, s'_R, and b'_R,

$$D_\mu = \partial_\mu - ig_c\frac{\lambda^a}{2}G^a_\mu - i(-\frac{1}{3})g'B_\mu. \qquad (2)$$

On the other hand, we have, for the $SU_L(2)$ quark doublets,

$$D_\mu = \partial_\mu - ig_c\frac{\lambda^a}{2}G^a_\mu - ig\frac{\vec\tau}{2}\cdot\vec A_\mu - i\frac{1}{6}g'B_\mu. \qquad (3)$$

For the lepton side, we introduce the family triplet, $(\nu^R_\tau, \nu^R_\mu, , \nu^R_e)$ (column) - defined as $\Psi_R(3,1)$, under $SU_f(3)$. Since the minimal Standard Model does not see the right-handed neutrinos, it would be a natural way to make an extension of the minimal Standard Model. Or, we have, for $(\nu^R_\tau, \nu^R_\mu, \nu^R_e)$,

$$D_\mu = \partial_\mu - i\kappa\frac{\bar\lambda^a}{2}F^a_\mu. \qquad (4)$$

and, for the left-handed $SU_f(3)$-triplet and $SU_L(2)$-doublet $((\nu^L_\tau, \tau^L), (\nu^L_\mu, \mu^L), (\nu^L_e, e^L))$ (all columns) - defined as $\Psi_L(3,2)$,

$$D_\mu = \partial_\mu - i\kappa\frac{\bar\lambda^a}{2}F^a_\mu - ig\frac{\vec\tau}{2}\cdot\vec A_\mu + i\frac{1}{2}g'B_\mu. \qquad (5)$$

It follows uniquely [3] that the right-handed charged leptons must form a charged triplet - $\Psi^C_R(3,1)$.

The Higgs mechanism in the minimal Standard Model remains the same. For the family gauge theory, we maintain [4] that all gauge bosons be massive, i.e. ≥ a few TeV.

As slightly differing from the previous effort [4], we would like to write down the $SU_c(3)\times SU_L(2)\times U(1)\times SU_f(3)$ Standard Model *all at once*, the neutrino-mass term becomes

$$i\frac{\eta}{2}\bar\Psi_L(3,2)\times\Psi_R(3,1)\cdot\Phi(3,2) + h.c.. \qquad (6)$$

The cross (curl) product is somewhat new [4], referring to the singlet combination of three triplets in $SU(3)$. The Higgs field $\Phi(3,2)$ is new in this effort, because it carries some nontrivial $SU_L(2)$ charge. We emphasize that the above interaction involves the singlet combination of three triplets - suitable for $SU(3)$; *not* an ordinary matrix operation. It is clear that the definition should exist but in our past experience of defining matrix or number products it remains to be introduced. It changes very much the scope of the renormalizable field theory, because of many "renormalizable" new terms in the lagrangians.