GOING BEYOND THE STANDARD MODEL

B.G. Sidharth
International Institute for Applicable Mathematics and Information Sciences
Hyderabad (India)
and
Udine (Italy)
B.M. Birla Science Centre
Adarsh Nagar
Hyderabad - 500 063 (India)
birlasc@gmail.com

Abstract. In this communication we argue that we can account for the shortcomings of the Standard Model by including noncommutative geometry leading to a non-zero (electron) neutrino mass.

Keywords: particle physics, standard model, Dirac matrices.

It is well known that the standard model of particle physics is as of now the most complete theory and yet there are frantic efforts to go beyond the standard model to overcome its shortcomings. Some of these are:

1. It fails to deliver the mass to the neutrino which thus remains a massless particle in this theory.

2. This apart it does not include gravity, which is otherwise one of the four fundamental interactions.

3. There is the hierarchy problem viz., the wide range of masses for the elementary particles or even for the quarks.

4. It appears that other as yet undiscovered particles exist which could change the picture, for example in supersymmetry in which the particles have their supersymmetric counterparts.

5. The standard model has no place for dark matter, which on the other hand has not yet been definitely found. Nor is there place for dark energy.

6. Finally one has to explain the 18 odd arbitrary constants which creep into the theory.

There are however obvious shortcomings which can be addressed in a relatively simple manner which could enable us to go beyond the standard model.

Let us start with the standard model Lagrangian

$$
\begin{aligned}
LGWS = & \sum_f (\bar{\Psi}_f(\imath\gamma^\mu\partial_\mu - m_f)\Psi_f - eQ_f\Psi_f\gamma^\mu\Psi_f A_\mu)+ \\
& + \frac{g}{\sqrt{2}}\sum_\imath (\bar{a}^\imath_L\gamma^\mu b^\imath_L W^+_\mu + \bar{b}^\imath_L\gamma^\mu a^\imath_L W^-_\mu)+ \\
& + \frac{g}{2C_w}\sum_f \bar{\Psi}_f\gamma^\mu(I^3_f - 2S^2_w Q_f - I^3_f\gamma_5)\Psi_f Z_\mu + \\
& - \frac{1}{4}|\partial_\mu A_\nu - \partial_\nu A_\mu - \imath e(W^-_\mu W^+_\nu - W^+_\mu W^-_\nu)|^2 - \frac{1}{2}|\partial_\mu W^+_\nu - \partial_\nu W^+_\mu + \\
& - \imath e(W^+_\mu + A_\nu - W^+_\nu A_\mu) + \imath g' c_w(W^+_\mu Z_\nu - W^+_\nu Z_\mu|^2 + \\
& - \frac{1}{4}|\partial_\mu Z_\nu - \partial_\nu Z_\mu + \imath g' c_w(W^-_\mu W^+_\nu - W^+_\mu W^-_\nu)|^2 + \\
& - \frac{1}{2}M^2_\eta\eta^2 - \frac{gM^2_\eta}{8M_W}\eta^3 - \frac{{g'}^2 M^2_\eta}{32M_W}\eta^4 + |M_W W^+_\mu + \frac{g}{2}\eta W^+_\mu|^2 + \\
& + \frac{1}{2}|\partial_\mu\eta + \imath M_Z Z_\mu + \frac{\imath g}{2C_w}\eta Z_\mu|^2 - \sum_f \frac{g}{2}\frac{m_F}{M_W}\bar{\Psi}_f\Psi_f\eta,
\end{aligned} \tag{1}
$$

which includes the Dirac Lagrangian amongst other things.

We would now like to point out that all this has been on the basis of the usual point spacetime which is what may be called commutative. But in recent years several authors including in particular the present author have worked with a noncommutative spacetime which originates back to Snyder in the late forties itself. (This was in an attempt to overcome the divergences).

We first observe that it was Dirac [1] who pointed out two intriguing features of his equation: 1. The Compton wavelength and 2. Zitterbewegung.

For the former, his intuition was that we can never make measurements at space or time points. We need to observe over an interval to get a meaningful definition of momentum for example. This interval was the Compton region [2]. Next, his solution was rapidly oscillatory, what is called Zitterbewegung. This oscillatory behaviour disappears on averaging over spacetime intervals over the Compton region. Once this is done while meaningful physics appears, we are left with not points but minimum intervals.

This leads to a noncommutative geometry. One model for this is that of Snyder [3]. Applied at the Compton wavelength this leads to the so called Snyder-Sidharth dispersion relation, the geometry being given by [4]

$$[x_\imath, x_j] = \beta_{\imath j}\cdot l^2. \tag{2}$$

As described in details in reference [5] this leads to a modification in the Dirac and also the Klein-Gordon equation. This is because (2) in particular it leads to the following energy momentum relation ([4])

$$E^2 - p^2 - m^2 + \alpha l^2 p^4 = 0, \tag{3}$$

where α is a scalar constant, $\sim 10^{-3}$ [6, 7]. Though the value of α is of no consequence for the present work, it may be mentioned that α gives the Schwinger term. If we work with this energy momentum relation (3) and follow the usual process we get as in the usual Dirac theory

$$\{\gamma^\mu p_\mu - m\} \psi \equiv \{\gamma^\circ p^\circ + \Gamma\} \psi = 0. \tag{4}$$

We now include the extra term in the energy momentum relation (3). It can be easily shown that this leads to

$$p_0^2 - \left(\Gamma\Gamma + \{\Gamma\beta + \beta\Gamma\} + \beta^2 \alpha l^2 p^4\right\} \psi = 0. \tag{5}$$

Whence the modified Dirac equation

$$\left\{\gamma^\circ p^\circ + \Gamma + \gamma^5 \alpha l p^2\right\} .\psi = 0. \tag{6}$$

The Modified Dirac equation contains an extra term. The extra term gives a slight mass for the neutrino which is roughly of the correct order viz., $10^{-8} m_e$, m_e being the mass of the electron. The behaviour too is that of the neutrino [5, 8].

To sum up the introduction of the noncommutative geometry described in (2) leads to a Dirac like equation (6) and a Lagrangian that leads to the electron neutrino mass.

It must be pointed out that the modified Lagrangian differs from the usual Lagrangian in that the γ^0 matrix is now replaced by a new matrix

$$\gamma^{0'} = \gamma^0 + \gamma^0 \cdot \gamma^5 l p^2$$

that includes the term giving rise to the neutrino mass. We can verify that the modified Lagrangian gives back the modified Dirac equation (6). Further as has been discussed in detail the extra term arising out of the noncommutative geometry is the direct result of the dark energy which thus also features in the modified standard model Lagrangian. This apart this argument has been shown to lead to a mass spectrum for elementary particles that includes all the elementary particles, giving the masses with about 5% or less error [4].

References

[1] P.A.M. Dirac, *The principles of quantum mechanics*, Clarendon Press, Oxford, 1958.

[2] B.G. Sidharth, Das Abhishek, Int. J. Mod. Phys. A., 32 (2017), 175-173.

[3] H.S. Snyder, *Physical review*, 72 (1947), 68-71.

[4] B.G. Sidharth, *The thermodynamic universe*, World Scientific, Singapore, 2008.

[5] B.G. Sidharth, Int. J. Mod. Phys. E, 19 (2010), 1-8.

[6] B.G. Sidharth, A. Das, R. Arka, Electron J. Theor. Phys., 34 (2015), 139-152.

[7] B.G. Sidharth, A. Das, R. Arka, Int. J. Th. Phys., 55 (2016), 801-808.

[8] B.G. Sidharth, *New advances in physics*, 11 (2017), 5-97.

Accepted: 5.01.2018