Symmetry Breaking In Four Spatial Dimensions

(draft version)

Assuming the existence of a fourth spatial dimension, w, the symmetry breaking mechanism is explained in terms of the transition of particles from a fourth dimensional space to a three-dimensional space. This dimensional transition was triggered by a drop in the temperature of the universe below the level corresponding to the symmetric phase.

by R. A. Frino
Eng. - Degree from the University of Mar del Plata.
December, 2015 (v1) – January, 2016 (v2)

Keywords: *electromagnetic force, weak force, electroweak force, symmetry breaking, intermediate vector bosons, Higgs boson, Higgs field, hyper-photon, symmetric phase.*

1. Introduction

The electroweak force is a unified formulation of two of the four known natural forces: electromagnetism and the weak force. While there is only one force carrier linked to the electromagnetic force: the photon, there are three different force carriers linked to the weak interaction: the $W+$, $W-$ and Z^o particles (also known as intermediate vector bosons, weak nuclear force carriers, etc.). The electroweak unification theory developed by Weinberg, Salam, and Glashow in 1979, predicts that the force carriers of the weak interaction are massless above the unification energy (on the order of 100 GeV to 250 GeV). However as the universe cooled down below this energy, the $W+$, $W-$ and Z^o bosons acquired mass due to spontaneous symmetry breaking. In other words, the masses of the $W+$, $W-$ and Z^o particles arise from interactions with the Higgs field which has a non-zero average value in every point in space (ordinary 3D space). By the way, a Higgs boson is a ripple in the Higgs field which may be observed when the Higgs field is disturbed. Photons, on the other hand, did not acquire any mass and continued being massless.

In summary, the electroweak theory predicts that above the unification energy, the electromagnetic force and the weak force merge into a single force known as the electroweak force. The $W+$, $W-$ and Z^o bosons were discovered in 1983 at CERN with masses very similar to the predicted values. The measured values of these masses, in kilograms, are

$$m_W \approx 143.1 \times 10^{-27} Kg$$
$$m_Z \approx 162.3 \times 10^{-27} Kg$$

Let's compare these masses with the mass of the proton

$$\frac{m_W}{m_p} \approx \frac{143.1 \times 10^{-27} Kg}{1.172\,621\,777 \times 10^{-27} Kg} = 86$$

$$\frac{m_Z}{m_p} \approx \frac{162.3 \times 10^{-27}\, Kg}{1.172\,621\,777 \times 10^{-27}\, Kg} = 97$$

Where m_p is the mass of the proton. Thus, the mass of the W bosons is about 86 times the mass of the proton while the mass of the $Z°$ boson is about 97 times the mass of the proton.

2. Force Carriers In Four Spatial Dimensions

The Universe, as we observe it seems to have three spatial dimensions: x, y and z. However, a more realistic picture is to think of the universe as having 4 spatial dimensions: x, y, z, and w, plus a temporal dimension, t. The fourth spatial dimension, denoted by w, is a dimension that we cannot observe but whose existence can be indirectly inferred. One property of the fourth dimension is that is orthogonal to the other three spatial dimensions. This is shown in Fig. 1.

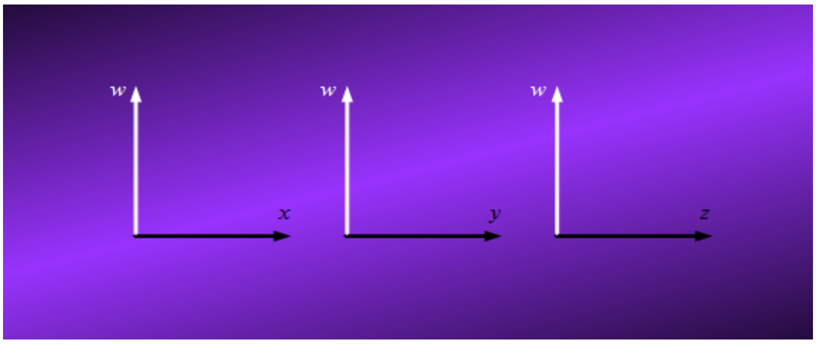

FIGURE 1: *The fourth dimension, w, is normal to the x-axis, to the y-axis and to the z-axis, simultaneously.*

Thus w is normal to x, y and z. The fourth dimension, w, is not to be confused with time. The w dimension is a spatial dimension. The existence of the fourth dimension raises the following question: if there really is another dimension, who are the "inhabitants" of this dimension? For several reasons the possible answer is: the force carriers.

To see why force carriers need another dimension, let us consider the nature of a photon. A photon is the force carrier of the electromagnetic force. The force that binds protons and electrons to form atoms. We may think of a photon as a "projection" of a particle that "lives" in the fourth dimension of space. In order to reflect this fact, I shall call the electromagnetic force carrier: hyper-photon. The existence of another dimension explains the fact that photons have exactly the same speed for all observers in relative uniform motion (one of the postulates of Einstein's theory of Special Relativity). This is because most massive objects such as rocks, bullets, rockets, etc. do not move in fourth spatial dimensions but only in the three dimensions we are familiar with. Thus, no massive particle or body can move with respect to the fourth dimension. The Higgs field does not exist in the fourth dimension. The Higgs field only exists in the three dimensional world (x, y, and z). This means that hyper-photons cannot interact with the Higgs field simply because they "live" in a "world" where the Higgs field does not exist. However, there are other particles that once "lived" in the fourth dimension. These particles are, for example, the intermediate-vector bosons of the weak nuclear force.

The Standard Model tell us that when the energy of the universe was much higher than it is today, these particles were massless. However, the Model does not tell us why this is so. The reason these particles did not have mass, when the energy of the universe was much higher than it is today, is because, at that time, they "lived" in the fourth dimension of the universe: the *w* dimension. But, why do these particles have mass today? When the universe cooled down, below 250 GeV (corresponding to the symmetric phase), these heavy bosons were forced to leave the fourth dimension and moved into the three-dimensional world. Then they acquired mass by interacting with the Higgs field. The Higgs boson interacts with almost all elementary particles except with neutrinos, photons and gluons (as far as we know). Above the temperature corresponding to the symmetric phase, particles, such as electrons, become massless.

Thus, the symmetry breaking mechanism is explained by the fact that a particle makes a transition from the realm of the fourth dimension to the realm of three dimensions. The cause of the transition is a temperature drop. This means that, when the temperature of the universe was low enough, the intermediate vector bosons, this is, the *W*+, *W*- and Z^o particles, were not able to remain in the fourth dimension any longer and were forced to migrate to the three-dimensional world where they acquired mass through interactions with the Higgs field. (see Fig. 2)

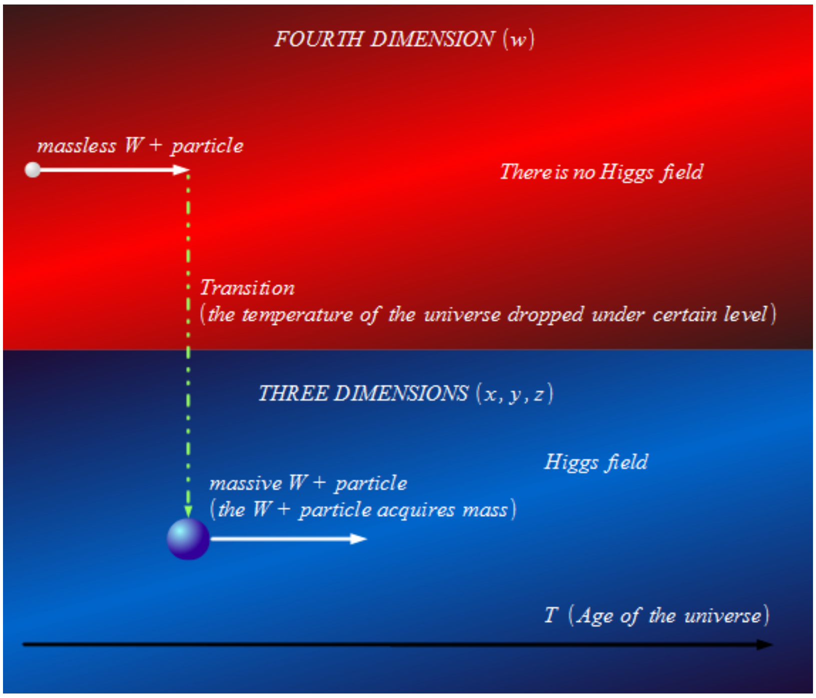

FIGURE 2: *The transition of a W+ boson from the fourth dimensional world to the three dimensional world. After the transition, the intermediate vector bosons acquire mass through interactions with the Higss field.*

3. Conclusions

One question remains unanswered: why didn't photons acquire mass through the same mechanism? Or, in other words, why didn't photons follow the same fate as the three weak intermediate force carriers?. The answer is that hyper-photons are different to the weak force carriers. Hyper-photons will always "live" in a fourth dimensional space[1]. Thus, there is a profound difference between photons and the weak force carriers that the Standard Model is yet to explain.

---

[1] Unless we discover, in the future, that when the temperature of the universe is lower than it is today they acquire mass.