Holographic Principle and Weak Forces

P. R. Silva – Retired associate professor – Departamento de Física – ICEx – Universidade Federal de Minas Gerais (UFMG) – email: prsilvafis@gmail.com

Abstract- The holographic principle is applied to the weak interactions as a means of estimating the zero-point energy of a gas of degenerate neutrinos filling the universe.

In a nice paper entitled: "Cosmological Interpretation of the Weak Forces", Satio Hayakawa [1], have discussed the cosmological origin of the weak forces (please see also reference [2]). In those papers [1,2], Hayakawa equaled the zero-point energy of a neutrino gas filling the universe to the product: - the Fermi interaction G_F times the number density of the neutrino gas N_υ / V. The equality reads

$$\tfrac{1}{2}\,\hbar\omega = G_F(N_\upsilon / V). \tag{1}$$

In order to estimate the zero-point energy of this system Hayakawa [1,2] took in account the balance between the attractive gravitational interaction of the gas of particles and the repulsive energy of a degenerate Fermi gas. He also considered the relation

$$N_\upsilon\, m_\upsilon = N_n\, m_n. \tag{2}$$

In (2), N_υ is the number of neutrinos in the universe and m_υ their masses, being N_n the number and m_n the mass of the nucleons. In his calculations, Hayakawa estimated the zero-point energy of the neutrinos oscillations, the number of these particles filling the universe and the neutrino mass. By using relation (1), he also was able to estimate the weak Fermi constant G_F. Inspired in Hayakawa ideas [1,2], we have worked out a modified model [3], which results are in relative agreement with the previous ones obtained by him. Besides this, by using relation (1) we got an expression for G_F as a function of α (the fine-structure constant and M_W (the mass of the boson which intermediates the weak interactions). When compared with the usual way of to express GF as found in the literature [4], we were able to determine a value for the electroweak mixing angle.

Recently the Holographic Principle (HP) [5,6,7] has been proposed as a means to explain that the quantity of information contained in a space-volume in the presence of a gravitational field is encoded in the surface area of its event horizon. The aim of the present note is to use HP in order to deduce relation (1).

Here we quote two postulates of HP as stated by McMahon [7], but adapted to the present calculations. They are

. The total information content in a volume of space is equivalent to a theory that lives only on the surface area that encloses the region.

. The boundary of a region of this volume contains at most a single degree of freedom per Fermi area.

The modified second postulate deserves some explanation. The Fermi coupling constant G_F plays an analogous role as the Newton constant G in the gravitational interaction case. Therefore it is possible to define, by taking ħ = c = 1,

$$L_{SF} = \sqrt{G_F}. \qquad (3)$$

We call L_{SF}, the second Fermi length (not to be confounded with the Fermi length of the free electrons in metals, for instance). Naturally, the idea behind (3), permit us to define the Fermi time t_F and the Fermi mass M_F. We have

$$t_F = L_{SF}/c, \qquad \text{and} \qquad M_F = 1/\sqrt{G_F}. \qquad (4)$$

Fermi units of weak interactions, the analogous of the Planck units in the gravitational case, have been discussed in more details in a previous paper [8].

In reference [8] we have defined a modified Fermi coupling G_F^* through the relation

$$G_F^* = G_F\, c^2/\hbar^2. \qquad (5)$$

From (5) we observe that G_F^* coincides with G_F, once we take h = c = 1.

Let us apply the holographic principle (HP) to our problem. By using the stationary condition for the energy we write

$$\Delta F = \Delta U - T\, \Delta S = 0. \qquad (6)$$

Now we define ($h = c = k_B = 1$)

$$\Delta U = N_\upsilon\, c/(2R), \qquad \upsilon = 3T, \qquad \Delta S = \pi\, R^2/G_F. \qquad (7)$$

Inserting (7) into (6) we obtain

$$N_\upsilon\, G_F = (\upsilon/2)\, (4/3)\, \pi\, R^3. \qquad (8)$$

Putting $(4/3)\, \pi\, R^3$ equal to V (the volume of the universe) and recovering h, we get

$$G_F\, N_\upsilon/V = \tfrac{1}{2}\, h\upsilon = \tfrac{1}{2}\, \hbar\omega, \qquad (9)$$

A result quoted by Hayakawa [1,2].

It is worth to point out that, as was first proposed by Roberto Onofrio [9] in a form of a conjecture: "the weak interactions are peculiar manifestations of quantum gravity at the Fermi scale, and the Fermi constant is related to the Newtonian constant of gravitation."

Therefore definitions (3) and (4) keep a direct relationship with Onofrio's work [9].

References

[1] S. Hayakawa, Cosmological Interpretation of the Weak Forces, Progress of Theoretical Physics, **33**, 538-539 (1965).

[2] S. Hayakawa, Atomism and Cosmology, Progress of Theoretical Physics, **Suppl.**, p.532 (1965).

[3] P. R. Silva, Weak Interaction and Cosmology, arXiv:0804.2683 [physics.gen-ph] (Apr. 2008).

[4] R. J. Blin-Stoyle, Nuclear and Particle Physics, Chapman & Hall, 1992.

[5] G. 't Hooft, "Dimensional Reduction in Quantum Gravity", arXiv: gr-qc/9310026(1993).

[6] L. Susskind, "The World as a Hologram", arXiv: hep-th/9409089(1994).

[7] D. McMahon, "String Theory Demystified",Ch. 15, Mc Graw Hill, 2009

[8] P. R. Silva, Fermi Scale and Neutral Pion Decay, viXra:1512.0321 (Dec.2015).

[9] R. Onofrio, "On weak interactions as short-distance manifestations of gravity", arXiv:1412.4513v1[hep-ph],(Dec.2014).