Gravitationally confined relativistic neutrinos

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Abstract. Combining special relativity, the equivalence principle, and Newton’s universal gravitational law with gravitational rather than rest masses, one finds that gravitational interactions between relativistic neutrinos with kinetic energies above 50 MeV are very strong and can lead to the formation of gravitationally confined composite structures with the mass and other properties of hadrons. One may model such structures by considering three neutrinos moving symmetrically on a circular orbit under the influence of their gravitational attraction, and by assuming quantization of their angular momentum, as in the Bohr model of the H atom. The model contains no adjustable parameters and its solution, using a neutrino rest mass of 0.05 eV/c², leads to composite state radii close to 1 fm and composite state masses close to 1 GeV/c². Similar models of relativistic rotating electron - neutrino pairs give a mass of 81 GeV/c², close to that of W bosons. This novel mechanism of generating mass suggests that the Higgs mass generation mechanism can be modeled as a latent gravitational field which gets activated by relativistic neutrinos.

1. Introduction

The potential importance of gravitational interactions between neutrinos was first discussed by J. Wheeler in 1957 [1], long before it was shown that neutrinos have mass [2, 3]. In a book [4] and a series of recent papers [5, 6, 7] we have presented a simple Bphr-type model of three relativistic electron neutrinos of rest mass \( m_0 \) each, rotating around their center of mass. Their motion is described by

\[
F = \gamma m_0 \frac{v^2}{r} = \frac{G m_0^2 \gamma^6}{\sqrt{3} r^2}; \quad \gamma = (1 - \frac{v^2}{c^2})^{-1/2},
\]

where the centripetal force in the RHS is expressed via Newton’s universal gravitational law but with gravitational, \( \gamma m_0 \) [4, 5, 8], instead of rest, \( m_0 \), masses. This expression has been found to be in excellent agreement with GR both in the microcosmos of quarks and in the macrocosmos of planetary systems [9].

The second model equation is obtained from the de Broglie wavelength equation, i.e.

\[
r(n_B) = \frac{n_B^2 \lambda}{\gamma m_0 v}; \quad n_B = 1, 2, 3, ...
\]
For $\gamma >> 1$ equations (1) and (2) have an analytical solution [4, 5], which for $n_B = 1$ is
\[ v \approx c \quad ; \quad \gamma = 3^{1/12} (m_{pl}/m_o)^{1/3} = 7.163 \times 10^9, \quad (3) \]
and also
\[ r(n_B = 1) = \frac{\hbar}{\gamma m_o c} = 0.63 \times 10^{-15} m \quad ; \quad F = \frac{hc}{r^2}. \quad (4) \]
Therefore
\[ m = 3\gamma m_o = 3^{13/12} (m_{pl}m_o^2)^{1/3}. \quad (5) \]
For $m = m_n = 939.565$ MeV/c$^2$, the neutron mass, equation (5) gives
\[ m_o = 0.0437 \text{ eV}/c^2, \quad (6) \]
which lies in the mass range of the heaviest electron neutrinos, i.e. 0.05±0.01 eV/c$^2$ [2, 3, 4]. This implies that u and d quarks have the same rest mass as the heaviest electron neutrinos [2].

The (partial) electric charges of quarks [10] can be rationalized by the charge-induced dipoles in the rotating neutrinos, as already discussed in the rotating neutrino model [6]. Using the above $m_o$ value of 0.0437 eV/c$^2$ one can calculate within 1% the masses of $W^\pm$ [6], $Z^0$ [7] and H bosons, modeled as rotating $e^+$, $e^-$, $\nu_e$ and $\bar{\nu}_e$ structures. Equations (3) and (5) demonstrate that three neutrinos of initial mass 0.131 eV/c$^2$ create, due to the gravitational field they generate, a new mass of 939.565 MeV/c$^2$.

In the present work we focus on the thermodynamic properties of such gravitationally bound rotating lepton states and on their implications for the Higgs mass generation mechanism and for the emission of gravitational waves.

2. Gravitational and kinetic energy of the rotating neutrinos
Upon using the second equation (1) and defining $r_s = 2Gm_o/c^2$ (the Schwarzschild radius of a neutrino), one obtains that for $\gamma >> 1$ [4, 5]
\[ r \approx (r_s/(2\sqrt{3}))\gamma^5. \quad (7) \]
Using equation (7) to eliminate $\gamma$ from the first equation (1) one obtains
\[ F = m_o c^2 \left( \frac{2\sqrt{3}}{r_s} \right)^{1/5} \frac{1}{r^{4/5}}. \quad (8) \]
Upon integrating this equation between $r_{min}(= 2.343 \times 10^{-63} m)$ [4, 5] and $r$ one obtains
\[ V_G(r) - V_G(r_{min}) = -\int_{r_{min}}^r Fdr' = -5m_o c^2 \left( \frac{2\sqrt{3}}{r_s} \right)^{1/5} (r^{1/5} - r_{min}^{1/5}). \quad (9) \]
The last term is negligible and using equations (7) and (5) one obtains
\[ V_G(r) = -5\gamma m_o c^2 = -(5/3)m_n c^2. \quad (10) \]
As shown recently [11], equation (10) is of general validity, and in particular it is also valid for the cases of $W^\pm$ and $Z^0$ bosons (with $m_n$ replaced by $m_{W^\pm}$ and $m_Z$ respectively).

One can then compute the Hamiltonian, $\mathcal{H}$, of the three neutrino system, i.e. the sum of rest energy, $m_o c^2$, kinetic energy, $T = (\gamma - 1)m_o c^2$, and potential energy, $V_G$.
\[ \mathcal{H} = 3m_o c^2 + 3(\gamma - 1)m_o c^2 - 5\gamma m_o c^2 = -2\gamma m_o c^2. \quad (11) \]
The fact that $\mathcal{H} < 0$ implies that the baryon formed is stable, a condition which fails when the number of neutrinos exceeds five.

In classical thermodynamic terms this Hamiltonian is the Internal Energy, $U$, of the formed rotational bound state. Since the initial internal energy of the three neutrinos is their rest energy, $3m_\nu c^2$, it follows that the $\Delta U$ for the reaction $3\nu_e \rightarrow n$ is given by

$$\Delta U = \mathcal{H} = -2\gamma m_\nu c^2 = -(2/3)m_n c^2.$$  \hfill (12)

According to the first law of Thermodynamics, $\Delta U = Q - W$. Since $W = 0$ (neutrinos penetrate any container and thus cannot produce work) it follows from (12) that

$$Q = \mathcal{H} = -2\gamma m_\nu c^2 = -(2/3)m_n c^2.$$  \hfill (13)

Since heat interactions (in the macroscopic sense) are not possible for the three neutrino system, it follows that radiation (electromagnetic or gravitational) is the only means of removing this very significant energy generated. The latter mode of energy transfer, i.e. emission of gravitational waves, appears much more likely (Fig. 1).

3. Conclusions

The present simple model of mass generation via gravitational confinement of relativistic neutrinos shows that gravity by itself can create mass via hadronization and therefore suggests that the Higgs mass generating field may be interpreted as a latent gravitational field which is activated by the presence of relativistic neutrinos. Indeed it has been shown recently [6, 7, 11] that $W^\pm$, $Z$ and Higgs bosons can all accelerate neutrinos to very high (>300 MeV) relativistic kinetic energies, suitable for hadronization [11, 12].

![Figure 1. Plot of equations (9), (10) and (11) using (7) for $\gamma(r)$. (Note that $V_G(r)$ and $\mathcal{H}(r)$ exhibit both asymptotic freedom ($r \to r_{\min}$) and confinement [4, 5].)](image)

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