Astrophysical and Microcosm's Applications of 2hν Photon Gravitational Mass

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Abstract

Energy Conservation Law for a source of gravity in the model consisting of the sphere with uniformly distributed electrons and positrons, provides twice gravitational photon mass in comparison with equivalent energy material particle and leads to existence of the particles with negative gravitational mass and zero kinematics momentum if we consider the results of the annihilation reaction. Respectively, pair production will be followed by the release of the other particles opposite to them in a "gravitational charge". In the paper is considered the possibility of detecting such particles and their possible influences at distant astronomical objects. Gravastar with the electron mass and bubble structure type is studied under the gravitational mass defect as a result of the presence of negative binding energy assumption. Rotation of energy-momentum-mass vector in the (1+4)D Extended Space Model (ESM) describes the transformation of the gravity field energy density.

Keywords : Gravitational mass, electron positron pair, gravastar, (1+4)D Extended Space Model

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1 Introduction

General thin-wall formalism was developed and applied to the investigation of the motion of various bubbles arising in the course of phase transitions in the very early Universe [1]. The bubble structure has a dense rigid envelope, which is under tension because of liquid substance, pressed apart it from within. Regular

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superconducting solution for interior of the Kerr-Newman spinning particle for parameters of electron represents a highly oblate rotating bubble formed by Higgs field which expels the electromagnetic field and currents from interior to domain wall boundary of the bubble [2]. It was showed that the magnetic moment of a black hole with the same mass, charge and angular momentum as an electron would match that of an electron [3]. The gravastar model was offered alternatively to black holes [4, 5] and has a constant density.

Variational principle of the stationary energy integral of a light-like particle [6-9] for definite Lagrangian produces particle canonical momenta and forces acting on it in the coordinate frame. For weak gravity the analogy between the mechanics of particles motion in the Schwarzschild space and Newton's gravity theory allows to define passive photons gravitational mass. That mass is equal to twice of the material particles mass with same energy calculated from non-gravitational interactions. This corresponds to the Tolman, Ehrenfest and Podolsky result [10-12] for active gravity photon mass in case of interaction between a light package or beam and a material particle. Conservation energy law observance as a gravity source leads to the gamma quanta particles g^- releases. Such model was considered for electron positron annihilation in [8, 9, 14]. This is the case of the positron positive gravitation mass model [13].

ESM is a generalization of the special theory of relativity at (1+4)-dimensional space. In this model a rotation in the extended space is associated with the particle motion in the gravity field in the embedded four-dimensional space-time [15, 16].

2 Electron Positron Pair Production, Astrophysical Applications

The motivation for applying the energy conservation law to a gravitational field source at the annihilation reaction was the extension of the Birkhoff theorem at a sphere with uniformly distributed electrons and positrons. This was done with the assumption that electron positron annihilation does not leads to change in the gravitational mass of the sphere before the particles leaves it. If this condition is satisfied for the entire sphere, energy conservation law as the source of the gravitational field takes place for any annihilating particles pair. Due to the doubled gravitational mass of photons in comparison with the total mass of the electron and positron $2m_{e^-}$, the annihilation reaction additionally leads to the appearance of the particles g^- with a negative gravitational mass

$$m_{g^-}^{gr} = -m_{e^-}, \tag{1}$$

which carry away negative energy as a gravitational field source.

Annihilation process in this case looks as follows

$$e^- + e^+ \to 2\gamma + 2g^-. \tag{2}$$

Production of additional particles g^- besides gamma quanta as a result of electron and positron annihilation is speculative. The energy determined from non-gravitational interactions for these particles is absent. This is due to equality total electron and positron energy with the produced gamma quanta energy. The particles g^- don't have a kinetic momentum. Therefore their detection by standard means of particle registration (like a bubble chamber) is not possible. However, with the passage of light beams through the area with negative energy could leads to defocusing effects, opposites to gravitational lens light focusing [17].

High energy gamma radiation interaction ($> 1022\, MeV$) with matter creates conditions for the gamma-ray electron-positron pairs birth. Inverse annihilation reaction

$$2\gamma \rightarrow e^- + e^+ + 2g^+ \tag{3}$$

leads to the appearance a "gravitational charge" particles g^+. These particles are opposite to g^-. It occurs with extracting pairs of particles g^- and g^+ from a vacuum. Particle g^- is absorbed immediately leaving g^+ with a positive gravitational mass.

We attribute particles g^- and g^+ to bosons and consider a model in which their rest mass is equal to 0. It is assumed that these particles have an electric charge equal to 0 and a spin of 2. A characteristic of particle g^+ having a positive gravitational mass corresponds to graviton, a hypothetical quantum of gravitational radiation [18]. In future works, we intend to study the consequences that could arise in our model when making assumptions that that particles g^- and g^+ have a rest mass.

Fermi Gamma-ray Space Telescope [19] (designed to detect photons with an energy sufficient for such reaction (3)) recorded gamma radiation in the pulsars jets including: Cygnus X-3 [20], in the spectra of gamma-ray outbursts of blazars [21], and production of cosmic rays in supernova remnants [22]. Particles g^+ and g^+ could be used in a model for dark energy and matter.

3 Gravastar

The gravastar is considered as a final object, which is formed as a result of an elementary particles disintegrations process. This is the static spherically symmetrical field with the metric ($c = 1$)

$$ds^2 = f(r)dt^2 - \frac{dr^2}{h(r)} - r^2(d\theta^2 + sin^2\theta d\varphi^2), \tag{4}$$

here $f(r), h(r)$ are metric functions. Gravastar characterized by a shell $r_1 \leq r \leq r_2$, which contains a gravastar Schwarzschild sphere with a radius α. In the outer area matter is absent and this will be Einstein equations Schwarzschild solution with energy and momentum conservation condition [4], which is

$$f(r) = h(r) = 1 - \frac{\alpha}{r}. \tag{5}$$

It corresponds to an isotropic medium and constant proper density ε in interior area with state equation

$$\varepsilon = -p, \tag{6}$$

where p is pressure. Such connection results to the Einstein equations de Sitter solution and corresponding coefficients

$$Cf(r) = h(r) = 1 - \frac{r^2}{R_D^2} \tag{7}$$

Here C is arbitrary constant and R_D is the radius of a curvature of the de Sitter world, which is defined as

$$R_D = \sqrt{\frac{r_2^3}{\alpha}}. \tag{8}$$

It is shown [5] that with exterior boundary

$$r_2 < \frac{9}{8}\alpha \tag{9}$$

the gravastar has finite tension on interior surface of the shell with radius

$$r_1 = 3r_2\sqrt{1 - \frac{8}{9}\frac{r_2}{\alpha}} \tag{10}$$

and negative internal pressure at metric coefficients

$$f(r) = \frac{1}{4}\left(3\sqrt{1 - H^2 r_2^2} - \sqrt{1 - H^2 r^2}\right)^2 \tag{11}$$

$$h(r) = 1 - H^2 r^2, \tag{12}$$

where

$$H = 1/R_D. \tag{13}$$

With coefficients (11), (12) of metric (4) Einstein's equations give constant matter density (G is the gravitational constant)

$$\varepsilon = 3/(8\pi G)H^2 \tag{14}$$

and pressure

$$p(r) = \varepsilon\left(\frac{\sqrt{1 - H^2 r^2} - \sqrt{1 - H^2 r_2^2}}{3\sqrt{1 - H^2 r_2^2} - \sqrt{1 - H^2 r^2}}\right). \tag{15}$$

As the bounds approach the Schwarzschild radius: $r_1 \longrightarrow \alpha^-$ and $r_2 \longrightarrow \alpha^+$, the whole inner area receives constant negative isotropic pressure (6), corresponding to the de Sitter solution. The pressure inside the shell is positive.

4 Gravitational Mass Defect

Spherical body gravitational mass [23] described by metric (4) with radius r_2 is given by

$$M = 4\pi \int_0^{r_2} \varepsilon r^2 dr. \tag{16}$$

Integration performed here for the volume element

$$dV_c = \ 4\pi r^2 dr, \tag{17}$$

this corresponds to the coordinate frame, whereas in its proper frame the given element of space volume will be

$$dV_p = \ 4\pi r^2 h^{-1/2}\left(r\right) dr. \tag{18}$$

Spherical body whole mass defines as follows:

$$M_w = 4\pi \int_0^{r_2} \varepsilon r^2 h^{-1/2}(r) dr. \tag{19}$$

Condition $h\left(r\right) < 1$ means that the body gravitational mass is less than the sum of individual gravitational masses in the case if it constituent elements are situated at the infinite distances [24]. This may reflect that near the masses vacuum goes to a lower energy level. Vacuum contracting manifests in the space curvature. When under the gravity action some masses passed from one static location to another static location, energy may be released in the form of the gravitational and electromagnetic waves. It is assumed that the energy is taken from the vacuum in this case. Vacuum energy state becomes negative near the masses since in the absence of masses it is close to zero. This corresponds to the negative binding energy appearance in the system, which expressed in the presence of a negative mass component as $M_b = M - M_w$.

In ESM [15,16] associated to each particle 4-vector of energy and momentum is completed in extended space $G(1,4)$ with an additional coordinate s to 5-vector

$$\bar{p} = (E, \quad p_x, \quad p_y, \quad p_z, \quad m), \tag{20}$$

where m is a rest mass of the particle. In blank space in a fixed reference system this vector corresponds to two types of various objects with zero and nonzero masses. For simplicity we will record it in (1+2)-dimensional space as

$$\bar{p} = (E, \quad P, \quad p_s). \tag{21}$$

Its hyperbolic rotation in the plane (TS) at the angle ϕ_{TS} yields

$$\begin{aligned} E' &= E\cosh\phi_{TS} + p_s \sinh\phi_{TS}, \\ P' &= P, \\ p'_s &= p_s \cosh\phi_{TS} + E\sinh\phi_{TS}. \end{aligned} \tag{22}$$

With whole density of matter

$$\varepsilon_w = \varepsilon h^{-1/2}(r) \tag{23}$$

in the static case energy-momentum density vector (21) in terms of ESM can be represented as 5-vector

$$\bar{p}_\varepsilon = (\varepsilon_w, \quad 0, \quad \varepsilon_w) \tag{24}$$

Rotation (22) of (24) at the angle

$$\phi_{TS} = (1/2)\ln(h(r)) \tag{25}$$

yields

$$\bar{p}_\varepsilon = (\varepsilon, \quad 0, \quad \varepsilon)\,. \tag{26}$$

This rotation corresponds transition from the whole density of matter to the density as a source of gravity.

5 Microphysics Gravastar Model Application

A particular point of interest for application in microphysics is a situation when the absolute gravastar negative mass component M_b is two times less than the whole mass, which entails

$$M_w = 2M. \tag{27}$$

Equality

$$M_b = -M \tag{28}$$

corresponds to the ratio between the electron mass and gravitational mass of the particle g^- released during annihilation (1). We will check whether condition (27) satisfies constraint (9) in the case of inner space with a metric function (12). With matter density (14) and function (12) masses values (16) and (19) are

$$M = \frac{y^3}{2GH} \tag{29}$$

and

$$M_w = \frac{3y^3}{16GH}\left(\arcsin y - y\sqrt{1-y^2}\right) \tag{30}$$

with $y = Hr_2$. Relation (27) leads to the equation

$$\arcsin y - y\sqrt{1-y^2} = (4/3)y^3, \tag{31}$$

which has solution $Hr_2 = 0.990408$. Taking into account (8), (10) and (13) this gives ratios $\alpha/r_2 = 0.980908$ and $r_1/r_2 = 0.918853$. This solution meets the condition (9) corresponding negative internal pressure and positive pressure on the shell.

6 Conclusions

Birghof's theorem application at a sphere filled with annihilating electrons and positrons (with a doubled gravitational photon mass in compare to material particle with equivalent total energy) allows us to conclude that: during electron-positron annihilation, apart from gamma quanta, particles g^- with a negative gravitational mass are released. Photon conversion reaction into an electron-positron pair will lead to the appearance of an opposite "gravitational charge" particles g^+. These hypothetical particles are classified as bosons with spin 2 and zero electric charge. Photons with sufficient energy for their appearance are contained in gamma-ray blazars outbursts, the jets of pulsars, such as Cygnus X-3, and in cosmic rays productions in supernova remnants. Particles g+ with positive gravitational mass could be considered as candidates for dark energy and matter.

We obtained a whole mass of the gravastar, which was defined as the sum of its constituent elements individual gravitational masses. Hyperbolic rotation of the energy-momentum-mass density 5D vector corresponds in the ESM at the transition from the whole matter density to the density as a source of gravity. In the paper we inspected the gravitational mass defect as a result of the negative binding energy presence. We also considered a situation when the gravastar negative mass component value is two times less than the whole mass. This case reflects to the ratio between the electron mass and gravitational mass of the particle g^- released during annihilation. Such condition corresponds to the negative internal pressure and positive pressure on the shell. It is assumed that during annihilation, particles g^- carry away the binding energy. Their experimental detection may be difficult due to the absence or small value of energy and momentum determined from non-gravitational interactions, which can be estimated by comparing the initial and produced particle characteristics. Accumulation particles with negative energy may produce the defocusing effect, opposites to gravitational lens light focusing.

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