On the issue of gravitational radiation and thermonuclear fusion

S I Fisenko
Moscow State Linguistic University, Moscow, Russia
E-mail: StanislavFisenko@yandex.ru

Abstract. In this work, without involving any additional assumptions and constructions (using only the equations of quantum mechanics and the equations of the relativistic theory with the Λ-member), a particle model was obtained, making it possible to calculate the quantum states generated by the gravitational interaction. Gravitational radiation (as a result of transitions over stationary states of a particle in its own gravitational field) can be excited in a dense high-temperature plasma and amplified under certain conditions, but its amplification will lead to compression of the radiating system. Consequently, under conditions of amplification of gravitational radiation, there will not be observed gravitational radiation itself, but only the result of its action. In this case, the quantitative characteristics of the spectrum of gravitational radiation (as radiation of the same level with electromagnetic radiation) can be determined by the broadening of the spectrum of electromagnetic radiation. The very fact of plasma compression by a radiated gravitational field can be used for thermonuclear fusion.

1. Introduction

It is believed that according to the General Theory of Relativity (GR), systems with variable quadrupole or higher multipole moments can generate gravitational radiation. Under this assumption, the power of the corresponding gravitational radiation is proportional to the quadrupole mass distribution tensor of the radiating system \( Q_{ij} \), and the constant \( G \) (Newton’s gravitational constant), that is included in this dependence, gives the order of magnitude of the radiation power. The illegality of using this formula is not in the use of the quadrupole approximation, but in the calculation scheme. The system can emit only in certain quantum states, and this applies to any radiation, regardless of its nature. This is an axiom of quantum mechanics, as well as the existence of an elementary source of radiation having these states. While GR provides no quantitative estimates for the emission spectrum of gravitational waves, interferences of unknown origin are misrepresented as such. Moreover, the frequencies of such interferences change from time to time, and the classical theory does not predict them. Consequently, the theoretical prediction of the spectrum of gravitational radiation requires evaluation of quantum states, transitions between which cause radiation.

2. Gravitational radiation of an elementary source of a gravitational field

The problem of calculating quantum states corresponding to gravitational radiation is directly related to the problem of combining the principles of quantum mechanics and the relativistic theory of gravity. Einstein’s field equations do not impose any numerical limitations on the \( \kappa \)
constant which binds geometric properties of space-time to the spatial distribution of matter. The value of \( \kappa = 8\pi G/c^4 \) (where \( G \) is the Newtonian gravitational constant, and \( c \) is the speed of light) is chosen to comply with the classical Newtonian theory. The relativistic gravity equations in their most common form include the \( \Lambda \) term. Applying the limiting transition to weak fields hereto will result not to the Poisson equation, but in the equation

\[
\Delta \Phi = -4\pi \rho G + \Lambda c^2
\]

(1)

where \( \Phi \) is the scalar field potential, and \( \rho \) is the source density.

This circumstance, ultimately, is decisive for discarding the \( \Lambda \)-term, since only in this case GR is a generalization of the classical gravity theory. Thus, the numerical values \( \kappa = 8\pi G/c^4 \) and \( \Lambda = 0 \) in the equations of general relativity are not related to the origin of the equations, but only follow from matching GR to the classical theory.

From the 70’s onwards, it became obvious [1], that the numerical value of \( G \) in the quantum field is incompatible with the principles of quantum mechanics. In several papers [1] (including in [2]) it was shown that the coupling constant \( K \) is acceptable in the quantum region, and \( K \approx 10^{40} G \). This fact follows from the combination of expressions for the Compton wavelength and the gravitational radius. Consequently, the essence of the problem of generalizing relativistic equations at the quantum level lies in the matching of the numerical values of the constants in the quantum and classical domains.

In the development of these results, a model is proposed based on the following assumption:

A gravitational field within the region of localization of an elementary particle of mass \( m_0 \) is characterized by the values of the gravity constant \( K \) and of the constant \( \Lambda \) that lead to the stationary states of the particle in its proper gravitational field, and the particles' stationary states as such are the sources of the gravitational field with the Newtonian gravity constant \( G \).

In the approximation of the fine structure caused by relativism, the problem of stationary states of an elementary source in its proper gravitational field will be reduced to solving the following equations:

\[
f'' + \left( \frac{\nu' - \lambda'}{2} + \frac{2}{r} \right) f' + e^\lambda \left( K^2_0 e^{-\nu} - K^2_0 - \frac{l(l+1)}{r^2} \right) f = 0
\]

(2)

\[
-e^{-\lambda} \left( \frac{1}{r^2} - \frac{\lambda'}{r} \right) + \frac{1}{r^2} + \Lambda = \beta (2l + 1) \left\{ f^2 \left[ e^{-\lambda} K^2_0 + K^2_0 + \frac{l(l+1)}{r^2} \right] + f^{'2} e^{-\lambda} \right\}
\]

(3)

\[
-e^{-\lambda} \left( \frac{1}{r^2} + \frac{\nu'}{r} \right) + \frac{1}{r^2} + \Lambda = \beta (2l + 1) \left\{ f^2 \left[ K^2_0 - K^2_0 e^{-\nu} + \frac{l(l+1)}{r^2} \right] - e^\lambda f^{'2} \right\}
\]

(4)

\[
\left\{ -\frac{1}{2} (\nu'' + \nu'^2) - (\nu' + \lambda') \left( \frac{\nu'}{4} + \frac{1}{r} \right) + \frac{1}{r^2} \left( 1 + e^\lambda \right) \right\}_{r = r_n} = 0
\]

(5)

\[
f \left( \sqrt{\Lambda^{-1}} \right) = 0
\]

(6)

\[
f \left( r_n \right) = 0
\]

(7)

\[
R \left( \sqrt{\Lambda^{-1}} \right) = \Lambda
\]

(8)

\[
\int_{\sqrt{\Lambda^{-1}}}^{r_n} f^2 r^2 dr = 1
\]

(9)

Equations (2)-(4) follow from equations (10)-(11)

\[
\left\{ -g^{\mu\nu} \frac{\partial}{\partial x_\mu} \frac{\partial}{\partial x_\nu} + g^{\mu\nu} r_0^{\alpha} \frac{\partial}{\partial x_\alpha} - K^2_0 \right\} \Psi = 0
\]

(10)

\[
R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R = -\kappa (T_{\mu\nu} - \mu g_{\mu\nu}),
\]

(11)
Equations in this form are obtained after substituting $\Psi$ in them in the form

$$\Psi = f_{El}(r) Y_{lm}(\theta, \varphi) \exp\left(-\frac{iEt}{\hbar}\right)$$

and explicit calculations in the metric of a centrally symmetric field, the interval in which is determined by the expression [3]

$$dS^2 = c^2e^\nu dt^2 - r^2(d\theta^2 + \sin^2\theta d\varphi^2) - e^\lambda dr^2$$

As denoted above: $f_{El}$ is a radial wave function describing the states with a certain energy $E$ and orbital momentum $l$ (hereinafter indices $El$ are omitted), $Y_{lm}(\theta, \varphi)$ are spherical functions, $K_n = E_n/\hbar c$, $K_0 = cm_0/\hbar$, $\beta = (\kappa/4\pi)(\hbar/m_0)$, $\kappa = 8\pi K/c^4$.

The righthand sides of equations (3)-(4) are calculated from the general expression for the energy-momentum tensor of a complex scalar field:

$$T_{\mu\nu} = \Psi^+_{,\mu} \Psi_{,\nu} + \Psi^+_{,\nu} \Psi_{,\mu} - (\Psi^+_{,\mu} \Psi_{,\mu} - K_0^2 \Psi^+ \Psi) g_{\mu\nu}$$

The corresponding components $T_{\mu\nu}$ are obtained by summing over the index $m$ using characteristic identities for spherical functions [4] after substitution in (13) the wave function in the form $\Psi = f(r) Y_{lm}(\theta, \varphi) \exp\left(-\frac{iEt}{\hbar}\right)$.

Condition (5) in the general case has the form $R(K, r_n) = R(G, r_n)$. Neglecting proper gravitational field with constant $G$, we write this condition in the form $R(K, r_n) = 0$, which corresponds to equality (5).

In the simplest (from the point of view of the initial mathematical estimates) approximation, the problem on stationary states in its proper gravitational field (with constants $K$ and $\Lambda$) was solved in [5]. From the solution of this problem it follows:

a) For numerical values $K \approx 5.1 \cdot 10^{31}$ Nm$^2$kg$^{-2}$ and $\Lambda = 4.4 \cdot 10^{29}$ m$^{-2}$ there is a spectrum of stationary states of the electron in its proper gravitational field (0.511 MeV ... 0.681 MeV). The ground state is the observed rest energy of the electron 0.511 MeV. Such a numerical value $\Lambda$ bears deep physical meaning: the introduction of a constant term independent of the state of the field into the Lagrangian density. This means that space-time at the quantum level has an irremovable curvature that is associated neither with matter nor the gravitational field.

b) Such stationary states are sources of a gravitational field with constant $G$.

c) Transitions over steady states of an electron in its own gravitational field lead to gravitational radiation, which is characterized exactly by constant $K$, i.e. gravitational radiation is a single-level radiation with electromagneticone (electric charge $e$, gravitational charge $m\sqrt{K}$). In this regard, it does not make sense to say that gravitational effects in the quantum region are characterized by a constant $G$. This constant refers only to the macroscopic region.

Considering the numerical values of the electron energy spectrum, the experimental confirmation of the existence of such a spectrum should manifest itself in peculiarities of the characteristic radiation spectra of a high-temperature plasma. In [6] and Figure 1, the characteristic parts of the spectrum of soft x-ray radiation of micropinches are presented. Accounting for the known broadening mechanisms does not completely fit the exactbroadening pattern of the detected portion of the micropinch radiation spectrum [6]. This evidences the presence of an additional mechanism for broadening of the detected part of thecharacteristic radiation spectrum that is due to the contribution of excited electron states in proper gravitational field.
The measured line of Fe He-δ with energy of 8.488 keV (broken curve) as compared with the calculation (smooth curve) [7].

Two groups of researchers, independently of each other [8,9], reported that a new radiation line with an energy of 3.57 keV was detected in the X-ray spectra of galaxy clusters. This radiation should go from a hot intergalactic gas that fills a cluster of galaxies, but, unlike other identified radiation lines, this cannot be attributed to any atomic transition. The results of these measurements are shown in Figure 2. At the same time, the resonance of the spectra of stationary states of electrons in their own gravitational field and the spectra of multiply charged ions can produce not only the registered emission line, but also other lines of a similar property [10,11]. It is quite possible to expect detection of such lines upon a detailed recording of the emission spectra of astrophysical objects in the energy range above 8 keV.
With the help of Kerr-Newman metric, an estimate of the numerical value of $K$ [2] can be obtained by using the numerical value of the orbital moment equal to the electron spin. Thus, it can be assumed that the physical nature of the spin is probably such that it is the value of the orbital angular momentum of a particle in its own gravitational field. This gives reason to believe that the use of the Klein-Gordon equation is far from elementary.

3. Compression of high-temperature plasma by radiated gravitational field

For the above transition energies through stationary states in proper gravitational field, the object that can exhibit gravitational radiation as a mass phenomenon is a dense high-temperature plasma [10]. The presence of cascade transitions from the upper excited levels to the lower ones will cause electrons excited in the energy range above 100 keV to emit in the eV region, i.e. energy will be transferred across the spectrum to the low-frequency region. Such a mechanism of energy transfer must be accompanied by extinguishing spontaneous radiation from lower energy levels of an electron in its own gravitational field to exclude radiation with photon energy in the keV region. To do this, in thermonuclear plasma it is necessary to have ions with energy levels of electrons close to the energy levels of free excited electrons. The extinguishing of the lower excited states of the electrons will be especially effective in the presence of a resonance between the energy of the excited electron and the energy of excitation of the electron in the ion. Consequently, the set of actions for compressing a dense high-temperature plasma by a radiated gravitational field must include such elements as:

a) Formation and acceleration of plasma with multiply charged ions by an accelerating magnetic field in a pulsed high-current discharge.

b) Injection of plasma from the region of the accelerating magnetic field

The sequence of such actions is provided in the two-section chamber of the MAGO unit (Figure 3, the development of Russian Federal Nuclear Centre (All-Russian Research Institute of Experimental Physics), Sarov [12]. Its design scheme most closely matches the proposed method of forming stable states of a dense high-temperature plasma in the mode of explosive magnetic generator) with magnetohydrodynamic flow of the plasma and the subsequent conversion of the plasma bunch energy (in the process of braking) into the thermal energy of the plasma. This provides for both further heating of the plasma, and the excitation of gravitational radiation and its transfer along the spectrum to the long-wavelength region with subsequent compression of the plasma under conditions of locking the radiation and its amplification [11].

Above, the energy spectrum of stationary states of an electron in its own gravitational field is given in the simplest form. The greatest inaccuracy pertains to an estimate of the numerical value of the first stationary state $E_1$, with accuracy growing as it approaches $E_\infty = 171$ keV. Accounting for all quantum states will give a more detailed spectrum, especially in its upper part. But already from this approximation follows the possibility of resonant transitions over the levels of stationary states of electromagnetic and gravitational interactions. The populations of the quantum levels and, consequently, the characteristics of the spectrum turn out to be significantly different for plasmas with different contents of multiply charged ions. Physically, this is defined by the competition of the processes of radiative transition (i.e., spontaneous emission) and nonradiative transition when an atom collides with an electron. When the upper energy levels of an electron in plasma of multiply charged ions are exited, cascade transitions to lower energy levels will lead to the transfer of gravitational radiation to the long-wavelength part of the spectrum [11]. However, it is clear that this is not enough for amplifying the gravitational radiation of the plasma. *The thermonuclear plasma should be composed of several types of multiply charged ions. Their concentrations and sequence numbers should be such that (using the resonance of the spectra of energy levels) there is an inversion of populations along the spectrum of stationary states of an electron in its own gravitational field.*
Figure 3. The physical scheme of preliminary production of thermonuclear plasma in MAGO chamber.

In the case when the concentration of multiply charged ions is low, and their spectrum of energy states does not meet the prerequisites for amplifying the gravitational radiation of electrons, there micropinch will occur [6] followed by its subsequent rapid decay.

4. Conclusion
1. For numerical values $K \approx 5.1 \cdot 10^{31} \text{Nm}^2\text{kg}^{-2}$ and $\Lambda = 4.4 \cdot 10^{29} \text{m}^{-2}$ there is a spectrum of stationary states of an electron in its own gravitational field (0.511 MeV ... 0.681 MeV). The ground state is the observed rest energy of the electron 0.511 MeV. *Such a numerical value bears a deep physical meaning: the introduction of a constant term independent of the state of the field into the Lagrangian density. This means that space-time at the quantum level has an irremovable curvature that is associated neither with matter nor the gravitational field.* These stationary states are sources of a gravitational field with a Newtonian gravitational constant $G$.

2. Transitions between the stationary states of an electron in its own gravitational field lead to gravitational radiation, which is characterized specifically by constant $K$, i.e. gravitational radiation is a single-level radiation with electromagnetic (electric charge $e$, gravitational charge $m\sqrt{K}$).

3. Accounting for the known broadening mechanisms does not completely fit the exact broadening pattern of the detected portion of the micro pinch radiation spectrum. This evidences the presence of an additional mechanism for broadening of the detected part of the characteristic radiation spectrum that is due to the contribution of excited electron states in proper gravitational field.

4. The compression of plasma by a radiated gravitational field can be used for the purpose of thermonuclear synthesis in pulsed high-current discharges of the two-chamber type.
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