SCALAR GRAVITATIONAL WAVES AND OBSERVATIONAL LIMITATIONS FOR THE ENERGY-MOMENTUM TENSOR OF A GRAVITATIONAL FIELD

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Abstract. From the point of view of a totally nonmetric model of the theory of gravitational interaction, i.e., in the bounds of a consistent dynamic description of gravitation (gravidynamics) a possibility is pointed out of additional loss of energy for the radiation of scalar gravitational waves. Such a radiation arises due to (in particular, periodic) variations, for example, spherically-symmetric pulsations, in a radiating system and is connected with time change of kinetic energy of system. The scalar gravitational 'luminosity' in gravidynamics is of the same order (~\(G/c^3\)) as the system energy loss for the radiation of 'usual' tensor gravitational waves of general relativity. Perhaps, for a binary system with a nonzero eccentricity it is necessary to account for the influence of scalar radiation on a secular variation of the companion's orbit parameters. The contribution of the scalar radiation into a total gravitational 'luminosity' of the system with a radio pulsar PSR 1913+16 can be of the value about 2.2\% of the radiation power of the tensor gravitational waves. It can have a considerable effect at measurements of the fall rate of orbital period (~\(\dot{P}_b\)) of the binary system, and the corresponding contribution into \(\dot{P}_b\) can be equal to \(\Delta \dot{P}_b \approx -0.053 \times 10^{-12} \text{ s s}^{-1}\).

1. Introduction

In this paper as in the very first paper (Sokolov and Baryshev, 1980) on the same topic I continue insisting on an idea that the problem of energy-momentum of gravitational field remains a central problem of gravitational physics. In other words, any theoretical scheme pretending to consistent and complete description of gravitational interaction must give concrete answers to questions about the sign, the value, the localibility of field energy and momentum in every point of space.

Proceeding from general demands being the basis of theoretical field (dynamic) description of gravitation, we grounded in the paper (Sokolov and Baryshev, 1980) the choice of an expression for \(\theta_{ik}\) - the energy-momentum tensor (EMT) of gravitational field. We proceeded from the requirement (Sokolov and Baryshev, 1980; Sokolov, 1992a) that

1. a result EMT must be symmetric \(\theta_{ik} = \theta_{ki}\);
2. it must have a trace identically equal to zero \((\eta_{ik} \theta^{ik} = 0\), where \(\eta_{ik} = \text{diag}(+1, -1, -1, -1)\), that is connected with zero mass of gravitons;
3. the EMT must always give a positively defined density of gravitation field energy \((\theta_{00} \geq 0)\), it concerns every component separately: both scalar field component \((\theta_{00}^{00} \geq 0)\) and the tensor one \((\theta_{00}^{00} \geq 0)\).

However, general principles alone do not give the firm belief that the choice of the field EMT appearance is right. Of course, crucial arguments (besides theoretical ones)
could here be experiments in which the sign and the value of energy would be considerable. As it was noted to the essence of the matter in a paper by Thirring (1961), it turns out that it is in the theoretical field, dynamic interpretation of gravitational interaction where the account for the gravitation field energy continuously distributed in space around the field source gives (at least to the value order) the contribution comparable with observational one in the perihelion shift $\delta \varphi$ of the planet orbits in the Sun field. It is a so-called 'nonlinear effect' or a nonlinear contribution which is not managed to describe totally allowing only for the relativistic lag of gravitational interaction.

In other words, the Mercury's perihelion shift, in particular, requires the calculation of nonlinear corrections to the tensor 4-potential of the Sun field, the corrections arising due to allowing for the EMT of the very field in the right side of the field equations. Naturally, we have used the circumstance and have chosen in papers by Sokolov and Baryshev (1980) and Sokolov (1992a) an expression for the EMT the simplest in a sense from possible ones, satisfying the three above-mentioned conditions and which leads ultimately to the right explanation of the observed shift of the Mercury's perihelion in 100 years. I.e., we used directly the fact that in consistent theoretical field scheme describing gravitation, in gravidynamics (GD) the choice of the EMT is restricted by experiment.

The details of reasoning leading to the choice of the expression for the field EMT and a consistent allowing for nonlinear contribution into the Mercury's perihelion shift effect ($\delta \varphi = \delta \varphi_1 + \delta \varphi_2$) can be found in cited papers (Sokolov and Baryshev, 1980; Sokolov, 1992a). In particular, in Sokolov (1992a) unlike Sokolov and Baryshev (1980) the contribution into the EMT was marked out of every gravitation component - the scalar one, described by a scalar $\psi$, and the tensor one with a tensor potential $\Phi_{ik} (\Phi_{ik} \eta^{ik} = 0)$. In such a case the EMT of gravitational field $\theta_{ik}$ has the appearance

$$\theta_{ik} = \theta_{ik}^{(0)} + \theta_{ik}^{(2)},$$

where

$$\theta_{ik}^{(0)} = a (\psi^i \psi^j - \frac{1}{2} \eta^{ik} \psi^m \psi_m - \frac{1}{2} \psi \psi^{ik})$$

and

$$\theta_{ik}^{(2)} = \frac{4}{3} a (\Phi_{mn} \Phi^{mn,k} - \frac{1}{4} \eta^{ik} \Phi^{mn, i} \Phi_{mn, l} - \frac{i}{2} \Phi_{mn} \Phi^{mn, ik});$$

and where the constant $a$ is determined ultimately only by the choice of the units of potential measurement of scalar and tensor components of gravitation (see later).

It follows from (1), (2), (3) that for the gravitational field of the object of the mass $M$ resting in the origin of coordinates in every point at the distance $r$ from the center independently of Descartes's axes direction the field energy-tension of such a centrally-symmetric problem is given by the tensor

$$\theta_{ik} = \theta_{00} \text{diag}(1, \frac{1}{3}, \frac{1}{3}, \frac{1}{3}),$$

where

$$\theta_{00} = \frac{1}{8 \pi} \frac{GM^2}{r^3}. $$