American Journal of Modern Physics
2013; 2(4): 220-222
Published online June 30, 2013 (http:// www.sciencepublishinggroup.com/j/ajmp)
doi: 10.11648/j.ajmp.20130204.17

Gravitational field of non-conserving mass particle

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To cite this article:
Ghanshyam H Jadhav. Gravitational Field of Non-conserving Mass Particle. *American Journal of Modern Physics.* Vol. 2, No. 4, 2013, pp. 220-222. doi: 10.11648/j.ajmp.20130204.17

Abstract: Gravitational field equations are written in the form of Maxwell's type field equations. Lorentz gauge on the gravitational scalar and vector potentials is discarded by introducing a gravitational scalar field. It makes the mass particles to be time-dependent. The non-conserving part of the mass causes to produce the gravitational scalar field, which further contributes to the gravitational and gravitomagnetic vector fields. This contribution makes possible to produce a repulsive gravitational field by a decaying mass particle beyond a critical distance.

Keywords: Maxwell Type Gravitational Field Equations; Lorentz Gauge, Gravitational Potential, Gravitational Fields

1. Introduction

Many authors have studied the effect of the Lorentz condition on potentials with different aspects in classical electrodynamics. The Maxwell-Heaviside equations prescribe both open dissipative systems as well as equilibrium systems. By imposition of the Lorentz symmetrical regauging, the reduced equation's subset discards open dissipative Maxwellian systems and retains only those in equilibrium [1]. However, the discarded class of Maxwellian systems contains all Maxwellian EM power systems exhibiting COP>1.0, by functioning as open dissipative systems freely receiving and using excess energy from the active vacuum [2], where COP is the coefficient of performance. Similar results have been deduced in [3-7] from the condition of a nonzero charge density from vacuum fluctuations. In [8], the Lorentz condition on potentials of charges is removed by introduction of an electric scalar field, which makes the charges to be time-dependent in nature. The non-conserved part of the charge then causes to produce the electric scalar field, which further contributes to the electric and magnetic vector fields. This contribution makes it possible to produce a negative electric field from a non-conserving positive charge beyond a critical distance. The critical distance depends on the instantaneous value of the charge as well as the rate of decay of the charge. In similar way, the effect of the rate of change of mass on its gravitational field can be studied. Hence, the concept of the gravitational field is analogous to the electromagnetic field as is supported by the reasons i) Newton's law of gravity is analogous to the Coulomb's law, ii) the linearized Einstein's equations for weak fields and slow speeds have same form as Maxwell's equations [9-12] and iii) the geodic equation has the same form as the Lorentz equation of motion [13].

In section 2, the gravitational equations are generalized by introducing a gravitational scalar field G_0, which removes the Lorentz condition on the potentials. In section 3, the gravitational scalar field, in addition to the gravitational vector field and the gravitomagnetic vector field of a time-dependent mass particle, are obtained. It is found that the gravitational scalar field G_0 is a function of the time rate of change of the mass. In section 4, the gravitational vector field and the gravitational scalar field of a stationary time-dependent mass particle have been discussed. Section 5 includes result and discussion.

2. Generalization of Maxwell Type Gravitational Field Equations

The Maxwell-like gravitational field equations [9-11] can be written as

$$\nabla \cdot \boldsymbol{G} = 4\pi\rho_g \tag{1a}$$

$$\nabla \cdot \boldsymbol{H_g} = 0 \tag{1b}$$

$$\nabla \times \boldsymbol{G} + \frac{1}{c_g}\frac{\partial \boldsymbol{H_g}}{\partial t} = 0 \tag{1c}$$

$$\nabla \times \boldsymbol{H_g} - \frac{1}{c_g}\frac{\partial \boldsymbol{G}}{\partial t} = \frac{4\pi}{c_g}\boldsymbol{j_g} \tag{1d}$$

where $\boldsymbol{G}$, $\boldsymbol{H_g}$ are the gravitational vector field and gravitomagnetic vector field, ρ_g, $\boldsymbol{j_g}$ are the source mass density and the source mass current density respectively and c_g is the gravitational wave velocity.

Introduction of a scalar function G_0 into these equations accommodates the time-dependent part of the source densities [8]:

$$\nabla \cdot \boldsymbol{G} + P_1 G_0 = 4\pi\rho_g \tag{2d}$$

$$\nabla \cdot \boldsymbol{H_g} = 0 \tag{2d}$$

$$\nabla \times \boldsymbol{G} + \frac{1}{c_g}\frac{\partial \boldsymbol{H_g}}{\partial t} = 0 \tag{2d}$$

$$\nabla \times \boldsymbol{H_g} - \frac{1}{c_g}\frac{\partial \boldsymbol{G}}{\partial t} - P_2 G_0 = \frac{4\pi}{c_g}\boldsymbol{j_g} \tag{2d}$$

where P_1 and P_2 are operators and G_0 is the scalar field.

As usual the vector fields can be expressed in terms of the potentials,

$$\boldsymbol{G} = -\nabla\varphi_g + \frac{1}{c_g}\frac{\partial \boldsymbol{A}_g}{\partial t} \tag{3a}$$

$$H_g = \nabla \times \boldsymbol{A_g} \tag{3b}$$

These potentials satisfy the usual differential equations,

$$\nabla^2\phi_g - \frac{1}{{c_g}^2}\frac{\partial^2\phi_g}{\partial t^2} = -4\pi\rho_g \tag{4a}$$

$$\nabla^2\boldsymbol{A}_g - \frac{1}{{c_g}^2}\frac{\partial^2\boldsymbol{A}_g}{\partial t^2} = -\frac{4\pi}{c_g}\boldsymbol{j}_g \tag{4b}$$

provided that

$$P_1 G_0 = \frac{1}{c_g}\frac{\partial}{\partial t}\left(\nabla \cdot \boldsymbol{A}_g + \frac{1}{c_g}\frac{\partial \varphi_g}{\partial t}\right) \tag{5a}$$

$$P_2 G_0 = \nabla\left(\nabla \cdot \boldsymbol{A}_g + \frac{1}{c_g}\frac{\partial \varphi_g}{\partial t}\right) \tag{5b}$$

This gives

$$G_0 = \nabla \cdot \boldsymbol{A}_g + \frac{1}{c_g}\frac{\partial \varphi_g}{\partial t} \tag{6}$$

with

$$P_1 = \frac{1}{c_g}\frac{\partial}{\partial t} \tag{7a}$$

$$P_2 = \nabla \tag{7b}$$

The gravitational scalar field G_0 is the actual replacement of the Lorentz condition. Satisfying the Lorentz condition will make the scalar field to zero. The generalized gravitational equations are then

$$\nabla \cdot \boldsymbol{G} + \frac{1}{c_g}\frac{\partial G_0}{\partial t} = 4\pi\rho_g \tag{8a}$$

$$\nabla \cdot \boldsymbol{H_g} = 0 \tag{8b}$$

$$\nabla \times \boldsymbol{G} + \frac{1}{c_g}\frac{\partial \boldsymbol{H}_g}{\partial t} = 0 \tag{8c}$$

$$\nabla \times \boldsymbol{H}_g - \frac{1}{c_g}\frac{\partial \boldsymbol{G}}{\partial t} - \nabla G_0 = \frac{4\pi}{c_g}\boldsymbol{j}_g \tag{8d}$$

3. Fields of a Time-Dependent Mass Particle

For a time-dependent point mass particle, the equations (4) have usual solutions given by Panofsky and Philip [12].

$$\phi_g(x_\alpha, t) = \frac{m(t')}{S} \tag{9a}$$

$$\boldsymbol{A}_g(x_\alpha, t) = \frac{m(t')\boldsymbol{v}(t')}{c_g S} \tag{9b}$$

Where $S = r - \frac{\boldsymbol{r}\cdot\boldsymbol{v}}{c_g}$, $\boldsymbol{r} = \boldsymbol{x}_\alpha - \boldsymbol{x}_\alpha{}'$ and $\boldsymbol{x}_\alpha$ is the field point vector and $\boldsymbol{x}_\alpha{}'$ is the source point vector at the retarded time $t' = t - r/c_g$ and $\boldsymbol{v}$ is the instantaneous velocity of the charged particle.

The electromagnetic fields for such a particle, which is in arbitrary motion, using equations (3), (6) and (9), are as

$$\boldsymbol{G} = \frac{\frac{dm}{dt'}\left(\boldsymbol{r} - \frac{r\boldsymbol{v}}{c_g}\right)}{c_g S^2} + m\left[\frac{\left(\boldsymbol{r} - \frac{r\boldsymbol{v}}{c_g}\right)\left(1-\beta^2\right)}{S^3} + \frac{\boldsymbol{r}\times\left[\left(\boldsymbol{r} - \frac{r\boldsymbol{v}}{c_g}\right)\times\frac{d\boldsymbol{v}}{dt'}\right]}{S^3{c_g}^2}\right] \tag{10a}$$

$$\boldsymbol{H}_g = \frac{\frac{dm}{dt'}(\boldsymbol{v}\times\boldsymbol{r})}{{c_g}^2 S^2} + m\left[\frac{(\boldsymbol{v}\times\boldsymbol{r})\left(1-\beta^2\right)}{c_g S^3} + \frac{\boldsymbol{r}\times\left\{\boldsymbol{r}\times\left[\left(\boldsymbol{r} - \frac{r\boldsymbol{v}}{c_g}\right)\times\frac{d\boldsymbol{v}}{dt'}\right]\right\}}{rS^3{c_g}^2}\right] \tag{10b}$$

$$G_0 = \frac{1}{c_g S}\frac{dm}{dt} \tag{10c}$$

Both the fields $\boldsymbol{G}$ and $\boldsymbol{H_g}$ receive contributions from the instantaneous value of the mass as well as the rate of change of mass with time. Clearly the gravitational scalar field G_0 is a function of the rate of change of mass with time as required. For time-independent mass the scalar field disappears and the above equations reduce to their usual forms.

4. Fields Produced By a Stationary Mass Particle

The gravitational field due to a mass particle at rest is (from equation (10) with $dt' = dt$):

$$\boldsymbol{G} = \frac{\boldsymbol{n}}{r^2}\left[m + \frac{r}{c_g}\frac{dm}{dt}\right] \tag{11}$$

Thus it is possible that $\boldsymbol{G}$ vanishes $r = r_0$, if

$$m + \frac{r_0}{c_g}\frac{dm}{dt} = 0 \tag{12}$$

which gives

$$r_0 = -\frac{mc_g}{dm/dt} \tag{13}$$

Thus, if r_0 to be positive, dm/dt should be negative, i.e. the mass should decrease with time.

Equation (11) with respect of equation (13) gives

$$\boldsymbol{G} = \frac{\boldsymbol{n}m}{r^2}\left[1 - \frac{r}{r_0}\right] \tag{14}$$

It suggests that at $r = r_0$, $G = 0$, at $r < r_0$, G is positive means attractive, and at $r > r_0$, G is negative means repulsive.

5. Results and Discussion

It is always expected that there should exist, any how, a repulsive gravitational field, having significant role in the expansion of the universe. Many authors [13,14] tried to solve the problem of existence of the repulsive gravitational field ether by reforming the general relativity in accordance with Mach's principle or by dealing with the dark energy or gravitational global monopole. Clearly, the net mass of the universe is not constant and is decreasing with time. No one has yet taken into consideration its effect on the gravitational field. The net mass in the universe does not obey the classical continuity equation which further leads to disobey of the Lorentz condition on the gravitational potentials, i.e. $\nabla \cdot \boldsymbol{A}_g + \frac{1}{c_g}\frac{\partial \varphi_g}{\partial t} \neq 0$. This non-zero part is a scalar and is equated to a gravitational scalar field G_0. The calculations show that it can be produced only due to existence of the rate of change of mass with respect to time, as expected. It gives correction to the usual gravitational vector field. If the mass of the particle increases with time, then it gives positive correction to the field due to which the net field increases (equation (10a)). If dm/dt is negative, then it gives negative correction to the field due to which the net field decreases. For a rest mass particle, if it decreases by the rate dm/dt, then below, at, and above the critical distance $r_0 = \frac{mc_g}{dm/dt}$ from the mass particle, its gravitational field is attractive, zero and repulsive respectively, where m is the instantaneous value of the mass and c_g, the gravitational wave velocity. If the mass of the particle is time-independent then the scalar field G_0 disappears with obeying the Lorentz condition by the potentials and the generalized Maxwell type gravitational field equations reduce to their usual form.

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