Journal of High Energy Physics, Gravitation and Cosmology, 2024, 10, 1564-1577
https://www.scirp.org/journal/jhepgc
ISSN Online: 2380-4335
ISSN Print: 2380-4327

Gravitomagnetic Waves Predicted by the Theory of Informatons

Antoine Acke

Retired Professor Kaho Sint-Lieven, Now KU Leuven, Faculty of Engineering Technology, Ghent Campus, Ghent, Belgium
Email: ant.acke@skynet.be

How to cite this paper: Acke, A. (2024) Gravitomagnetic Waves Predicted by the Theory of Informatons. *Journal of High Energy Physics, Gravitation and Cosmology*, **10**, 1564-1577.
https://doi.org/10.4236/jhepgc.2024.104088

Received: May 24, 2024
Accepted: October 7, 2024
Published: October 10, 2024

Copyright © 2024 by author(s) and Scientific Research Publishing Inc.
This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).
http://creativecommons.org/licenses/by/4.0/
Open Access

Abstract

In this article we show that the description of the gravitational field as a cloud of g-information implies the phenomenon of "gravitomagnetic" or "gravitational waves"[1] and that accelerated mass particles and radioactive decay are sources of such waves. It is also shown that a gravitomagnetic wave propagating in a certain direction can be understood as the macroscopic manifestation of a spatial sequence of informatons whose characteristic angle is fluctuating along that—with the speed of light—speeding "train". Finally, it is shown that gravitomagnetic waves transport energy in the form of packages carried by informatons. These entities are called "gravitons".

Keywords

Gravity, Gravitational Field, Gravitomagnetic Waves, Informatons

1. Introduction

In the framework of the theory of informatons [1]-[5], a gravitational field is a dual entity, having a field- and an induction component ($\boldsymbol{E}_g$ and $\boldsymbol{B}_g$) simultaneously created by its common sources: time-variable masses and mass flows. It is the manifestation at the macroscopic level of a cloud of informatons: mass and energy less granular entities that—relative to an inertial reference frame—are moving with the speed of light and that are carriers of information referring to the position ("*g-information*") and the velocity ("*β-information*") of their emitter.

The Maxwell-Heaviside [1] equations, that describe how a gravitational field ($\boldsymbol{E}_g, \boldsymbol{B}_g$) is generated and how it evolves in space and in time, imply fluctuations in its intensity that are propagating at the speed of light as waves outward from the source of that field.

[1]Both terms refer to the same phenomenon.

More specifically, from the postulate of the emission of informatons [2]-[5], it can be deduced that an accelerated mass particle is the source of a gravitational field of which the time dependent components of $\boldsymbol{E}_g$ and $\boldsymbol{B}_g$ represent waves that are traveling with the speed of light. It follows that a harmonically oscillating mass particle is the source of an harmonically gravitational wave transporting energy in the form of "gravitons": quanta of energy carried by informatons.

A change of the rest mass of an object—what occurs during radioactive decay—is another source of a gravitational wave. Indeed, the change of the rest mass of an object immediately results in a change of the rate at which it emits informatons which gives rise to a disturbance of its gravitational field that propagates with the speed of light.

Let's also mention that gravitational waves were first proposed by Oliver Heaviside [6] in 1893 and then later by Henri Poincaré [7] in 1905 as the gravitational equivalent of electromagnetic waves. More recently, attention was also paid to the phenomenon in the work of Oleg Jefimenko [8].

2. The Wave Equation

In free space—where $\rho_G = \boldsymbol{J}_G = 0$ —the Maxwell-Heaviside [1] equations are:

$$div\,\boldsymbol{E}_g = 0 \tag{1}$$

$$div\,\boldsymbol{B}_g = 0 \tag{2}$$

$$rot\,\boldsymbol{E}_g = -\frac{\partial \boldsymbol{B}_g}{\partial t} \tag{3}$$

$$rot\,\boldsymbol{B}_g = \frac{1}{c^2}\frac{\partial \boldsymbol{E}_g}{\partial t} \tag{4}$$

To attempt a solution of a group of simultaneous equations, it is usually a good plan to separate the various functions of space to arrive at equations that give the distributions of each.

It follows from (3):

$$rot\left(rot\,\boldsymbol{E}_g\right) = -rot\left(\frac{\partial \boldsymbol{B}_g}{\partial t}\right) \tag{3'}$$

Because [9]

$rot\left(rot\,\boldsymbol{F}\right) = grad\left(div\,\boldsymbol{F}\right) - \nabla^2 \boldsymbol{F}$, where ∇^2 is the Laplacian,

(3') leads to:

$$grad\left(div\,\boldsymbol{E}_g\right) - \nabla^2 \boldsymbol{E}_g = -rot\left(\frac{\partial \boldsymbol{B}_g}{\partial t}\right) = -\frac{\partial}{\partial t}\left(rot\,\boldsymbol{B}_g\right)$$

And taking into account (1) and (4):

$$\nabla^2 \boldsymbol{E}_g = \frac{1}{c^2}\cdot\frac{\partial^2 \boldsymbol{E}_g}{\partial t^2} \tag{5}$$

This is the general form of the wave equation. This form applies as well to the g-induction, as is readily shown by taking first the rotor of (4) and then substituting

(2) and (3):

$$\nabla^2 \boldsymbol{B}_g = \frac{1}{c^2} \cdot \frac{\partial^2 \boldsymbol{B}_g}{\partial t^2} \quad (5')$$

Solutions of this equation describe how disturbances of the gravitational field propagate as waves with speed c.

To illustrate this, we consider the special case of space variation in one dimension only. If we take the *x*-component of (5) and have space variations only in the *z*-direction, the equation becomes simply:

$$\frac{\partial^2 E_{gx}}{\partial z^2} = \frac{1}{c^2} \cdot \frac{\partial^2 E_{gx}}{\partial t^2}$$

This equation has a general solution of the form

$$E_{gx} = f_1\left(t - \frac{z}{c}\right) + f_2\left(t + \frac{z}{c}\right) \quad (6)$$

The first term of (6) represents the wave or function f_1 traveling with velocity c and unchanged form in the positive *z*-direction, the second term represents the wave or function f_2 traveling with velocity c and unchanging form in the negative *z*-direction.

3. The g-Index of an Informaton Emitted by an Accelerated Mass Particle

In **Figure 1**, we consider a mass particle with rest mass m_0 that, during a finite time interval, moves with constant acceleration $\boldsymbol{a} = a \cdot \boldsymbol{e}_z$ relative to the IRF ***O***. At the moment $t = 0$, m_0 starts from rest at the origin *O*, and at $t = t$ it passes at the point P_1. Its velocity is there defined by $\boldsymbol{v} = v \cdot \boldsymbol{e}_z = a \cdot t \cdot \boldsymbol{e}_z$, and its position by

$$z = \frac{1}{2} \cdot a \cdot t^2 = \frac{1}{2} \cdot v \cdot t$$

We limit our considerations to the situation where the speed of the particle remains much smaller than the speed of light: $\frac{v}{c} \ll 1$.

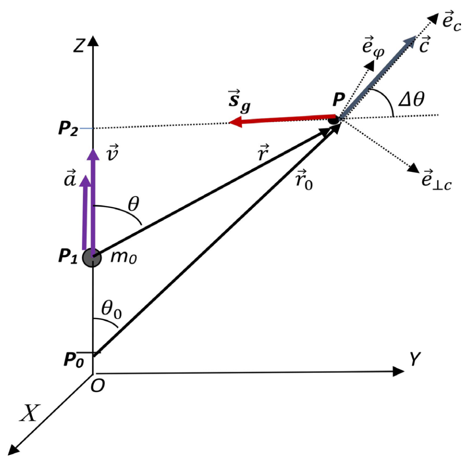


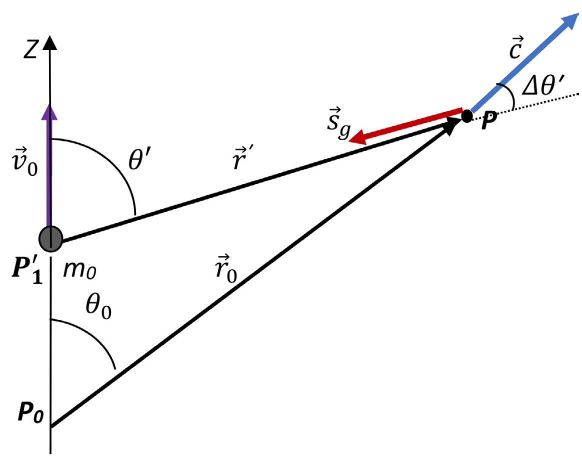
Figure 1. The *g*-index of an informaton emitted by an accelerated particle.

The informatons that during the infinitesimal time interval (t, $t + dt$) pass near the fixed point P (whose position relative to the moving particle m_0 is defined by the time dependent position vector $\boldsymbol{r}$) have been emitted at the moment $t_0 = t - \Delta t$, when m_0 passed at P_0 with velocity $\boldsymbol{v}_0 = v_0 \cdot \boldsymbol{e}_z = v(t - \Delta t) \cdot \boldsymbol{e}_z$. The position of P relative to P_0 is defined by the time dependent position vector $\boldsymbol{r}_0 = \boldsymbol{r}(t - \Delta t)$. Δt, the time interval during which m_0 moves from P_0 to P_1 is the time that the informatons need to move—with the speed of light—from P_0 to P from which we can conclude that $\Delta t = \frac{r_0}{c}$, and that

$$v_0 = v(t - \Delta t) = v\left(t - \frac{r_0}{c}\right) = v - a \cdot \frac{r_0}{c}$$

Between the moments $t = t_0$ and $t = t_0 + \Delta t$, m_0 is moving from P_0 to P_1. That movement can be considered as the resultant (the superposition) of a uniform movement with constant speed $v_0 = v(t - \Delta t)$ and a uniformly accelerated movement with constant acceleration a.

1) In the below figure, we consider the case of the particle m_0 moving with constant speed v_0 along the Z-axis. At the moment $t_0 = t - \Delta t$ m_0 passes at P_0 and at the moment t at P_1': $P_0 P_1' = v_0 \cdot \Delta t$. The informatons that, during the infinitesimal time interval (t, $t + dt$), pass near the point P—whose position relative to the uniformly moving particle m_0 at the moment t is defined by the position vector $\boldsymbol{r}'$—have been emitted at the moment t_0 when m_0 passed at P_0.



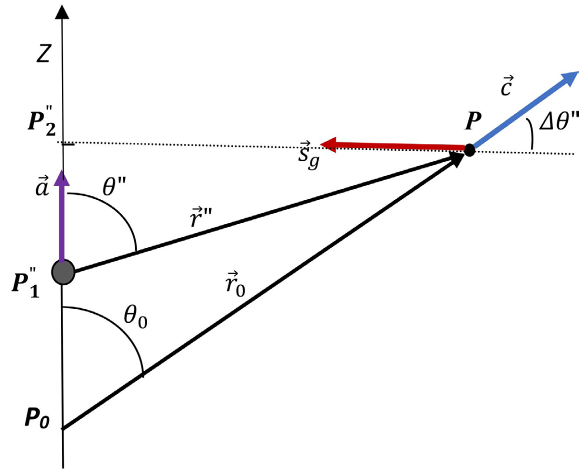
Their velocity vector $\boldsymbol{c}$ is on the line $P_0 P$, their g-index $\boldsymbol{s}_g$ points to P_1':

$$P_0 P_1' = v_0 \cdot \Delta t = v_0 \frac{r_0}{c}$$

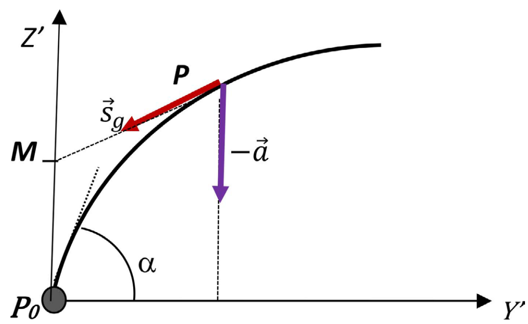
2) In the below figure, we consider the case of the particle m_0 starting at rest at P_0 and moving with constant acceleration a along the Z-axis.

At the moment $t_0 = t - \Delta t$ it is at P_0 and at the moment t at P_1'':

$$P_0 P_1'' = \frac{1}{2} \cdot a \cdot (\Delta t)^2$$



The informatons that during the infinitesimal time interval (t, $t + dt$) pass near the point P (whose position relative to the uniformly accelerated particle m_0 is at t defined by the position vector $\boldsymbol{r}''$) have been emitted at t_0 when m_0 was at P_0. Their velocity vector $\boldsymbol{c}$ points away from P_0, their g-index $\boldsymbol{s}_g$ to P_2''. To determine the position of P_2'', we consider, relative to the accelerated reference frame $OX'Y'Z'$ that is anchored to m_0, the trajectory of the informatons that at t_0 are emitted in the direction of P ($\alpha = \frac{\pi}{2} - \theta_0$).



Relative to $OX'Y'Z'$ these informatons are accelerated with an amount $-\boldsymbol{a}$: they follow a parabolic trajectory described by the equation:

$$z' = tg\alpha \cdot y' - \frac{1}{2} \cdot \frac{a}{c^2 \cdot \cos^2 \alpha} \cdot y'^2$$

At the moment $t = t_0 + \Delta t$, when they pass at P, the tangent line to that trajectory cuts the Z'-axis at the point M, that is defined by:

$$z'_M = \frac{1}{2} \cdot a \cdot (\Delta t)^2 = \frac{1}{2} \cdot a \cdot \frac{r_0^2}{c^2}$$

That means that the g-indices of the informatons that at the moment t pass at P, point to a point M on the Z-axis that has a lead of

$$P_1''P_2'' = P_0M = \frac{1}{2} \cdot a \cdot (\Delta t)^2 = \frac{1}{2} \cdot a \cdot \frac{r_0^2}{c^2}$$

on P_1'', the actual position of the mass particle. And since $P_0P_1'' = P_0P_1'' + P_1''P_2''$, we conclude that:

$$P_0P_2'' = a \cdot \frac{r_0^2}{c^2}$$

In the inertial reference frame $\boldsymbol{O}$ (**Figure 1**) $\boldsymbol{s}_g$ points to the point P_2 on the Z-axis determined by the superposition of the effect of the velocity (1) and the effect of the acceleration (2):

$$P_0P_2 = P_0P_1' + P_0P_2'' = \frac{v_0}{c} \cdot r_0 + \frac{a}{c^2} \cdot r_0^2$$

The carrier line of the g-index $\boldsymbol{s}_g$ of an informaton that—relative to the inertial frame $\boldsymbol{O}$—at the moment t passes near P forms a "characteristic angle" $\Delta\theta$ with the carrier line of its velocity vector $\boldsymbol{c}$, that can be deduced by application of the sine-rule in triangle P_0P_2P (**Figure 1**):

$$\frac{\sin(\Delta\theta)}{P_0P_2} = \frac{\sin(\theta_0 + \Delta\theta)}{r_0}$$

From which it follows that

$$\sin(\Delta\theta) = \frac{v_0}{c} \cdot \sin(\theta_0 + \Delta\theta) + \frac{a}{c^2} \cdot r_0 \cdot \sin(\theta_0 + \Delta\theta)$$

From the fact that P_0P_1—the distance travelled by m_0 during the time interval Δt—can be neglected relative to P_0P—the distance travelled by light during the same period—it follows that $\theta_0 \approx \theta$ and that $r_0 \approx r$. So:

$$\sin(\Delta\theta) \approx \frac{v_0}{c} \cdot \sin\theta + \frac{a}{c^2} \cdot r \cdot \sin\theta$$

We can conclude that the g-index $\boldsymbol{s}_g$ of an informaton that at the moment t passes near P, has a longitudinal component, this is a component in the direction of $\boldsymbol{c}$ (its velocity vector) and a transversal component, this is a component perpendicular to that direction. It is evident that:

$$\begin{aligned} \boldsymbol{s}_g &= -s_g \cdot \cos(\Delta\theta) \cdot \boldsymbol{e}_c - s_g \cdot \sin(\Delta\theta) \cdot \boldsymbol{e}_{\perp c} \\ &\approx -s_g \cdot \boldsymbol{e}_c - s_g \cdot \left(\frac{v_0}{c} \cdot \sin\theta + \frac{a}{c^2} \cdot r \cdot \sin\theta \right) \cdot \boldsymbol{e}_{\perp c} \end{aligned}$$

4. The Gravitational Field of an Accelerated Mass Particle

The informatons that, at the moment t, are passing near the fixed point P—defined by the time dependent position vector $\boldsymbol{r}$—are emitted when m_0 was at P_0 (**Figure 1**). Their velocity $\boldsymbol{c}$ is on the same carrier line as $\boldsymbol{r}_0 = \boldsymbol{P_0P}$. Their g-index is on the carrier line P_2P. According to §3, the characteristic angle $\Delta\theta$—this is the angle between the carrier lines of $\boldsymbol{s}_g$ and $\boldsymbol{c}$—has two components:

1) a component $\Delta\theta'$ related to the velocity of m_0 at the moment ($t - \frac{r_0}{c}$) when the considered informatons were emitted. In the framework of our assumptions, this component is determined by:

$$\sin\left(\Delta\theta'\right)=\frac{v\left(t-\frac{r}{c}\right)}{c}\cdot\sin\theta$$

2) a component $\Delta\theta''$ related to the acceleration of m_0 at the moment when they were emitted. This component is, in the framework of our assumptions, determined by:

$$\sin\left(\Delta\theta''\right)=\frac{a\left(t-\frac{r}{c}\right)\cdot r}{c^2}\cdot\sin\theta$$

The macroscopic effect of the emission of g-information by the accelerated particle m_0 is a gravitational field ($\boldsymbol{E}_g,\boldsymbol{B}_g$). We introduce the reference system ($\boldsymbol{e}_c,\boldsymbol{e}_{\perp c},\boldsymbol{e}_{\varphi}$) (**Figure 1**).

1) With N the density of the flow of informatons at P (the rate per unit area at which the informatons cross an elementary surface perpendicular to the direction of their movement), the g-field at that point is

$$\boldsymbol{E}_g=N\cdot\boldsymbol{s}_g$$

According to the postulate of the emission of informatons, the magnitude of $\boldsymbol{s}_g$ is the elementary g-information quantity:

$$s_g=\frac{1}{K\cdot\eta_0}=6.18\times10^{-60}\ \text{m}^3\cdot\text{s}^{-1}$$

and the density of the flow of informatons at P is:

$$N=\frac{\dot{N}}{4\pi\cdot r_0^2}\approx\frac{\dot{N}}{4\pi\cdot r^2}=\frac{K\cdot m_0}{4\pi\cdot r^2}$$

Taking into account that $\frac{1}{\eta_0\cdot c^2}=\nu_0$, we obtain:

$$\boldsymbol{E}_g=-\frac{m_0}{4\pi\cdot\eta_0\cdot r^2}\cdot\boldsymbol{e}_c-\left[\frac{m_0}{4\pi\cdot\eta_0\cdot c\cdot r^2}\cdot v\left(t-\frac{r}{c}\right)\cdot\sin\theta+\frac{\nu_0\cdot m_0}{4\pi\cdot r}\cdot a\left(t-\frac{r}{c}\right)\cdot\sin\theta\right]\cdot\boldsymbol{e}_{\perp c}$$

2) $\boldsymbol{B}_g$, the g-induction at P, is defined as the density of the cloud of β -information at that point. That density is the product of n, the density of the cloud of informations at P (number per unit volume) with $\boldsymbol{s}_\beta$, their β -index:

$$\boldsymbol{B}_g=n\cdot\boldsymbol{s}_\beta$$

The β -index of an informaton refers to the information it carries regarding the state of motion of its emitter; it is defined as:

$$\boldsymbol{s}_\beta=\frac{\boldsymbol{c}\times\boldsymbol{s}_g}{c}$$

And n, the density of the cloud of informatons at P, is related to N, the density of the flow of informatons at that point by: $n=\frac{N}{c}$.

So:

$$\boldsymbol{B}_g = n \cdot \boldsymbol{s}_\beta = \frac{N}{c} \cdot \frac{\boldsymbol{c} \times \boldsymbol{s}_g}{c} = \frac{\boldsymbol{c} \times \left(N \cdot \boldsymbol{s}_g \right)}{c^2} = \frac{\boldsymbol{c} \times \boldsymbol{E}_g}{c^2}$$

With the expression of that we have derived above under 1 we finally obtain:

$$\boldsymbol{B}_g = -\left[\frac{\nu_0 \cdot m_0}{4 \cdot \pi \cdot r^2} \cdot v\left(t - \frac{r}{c} \right) \cdot \sin\theta + \frac{\nu_0 \cdot m_0}{4 \cdot \pi \cdot c \cdot r} \cdot a\left(t - \frac{r}{c} \right) \cdot \sin\theta \right] \cdot \boldsymbol{e}_\varphi$$

The time dependent components of $\boldsymbol{E}_g$ and of $\boldsymbol{B}_g$ represent waves traveling with the speed c in the direction of $\boldsymbol{c}$ [5] We say that an accelerated mass particle is the source of a "*gravitational wave*" $\left\{ \boldsymbol{E}_g, \boldsymbol{B}_g \right\}$. Its components are both transverse to $\boldsymbol{c}$ and mutually perpendicular.

From the mathematical expressions derived above it can be concluded that at a point *P*, sufficient far from the accelerated particle m_0, the components of the wave under consideration are proportional to $\frac{1}{r}$ and they are determined by the acceleration of the source at the time the involved informatons were emitted:

$$\boldsymbol{E}_g = -\frac{\nu_0 \cdot m_0}{4\pi \cdot r} \cdot a\left(t - \frac{r}{c} \right) \cdot \sin\theta \cdot \boldsymbol{e}_{\perp c}$$

$$\boldsymbol{B}_g = -\frac{\nu_0 \cdot m_0}{4 \cdot \pi \cdot c \cdot r} \cdot a\left(t - \frac{r}{c} \right) \cdot \sin\theta \cdot \boldsymbol{e}_\varphi$$

5. The Gravitational Field of a Harmonically Oscillating Mass Particle

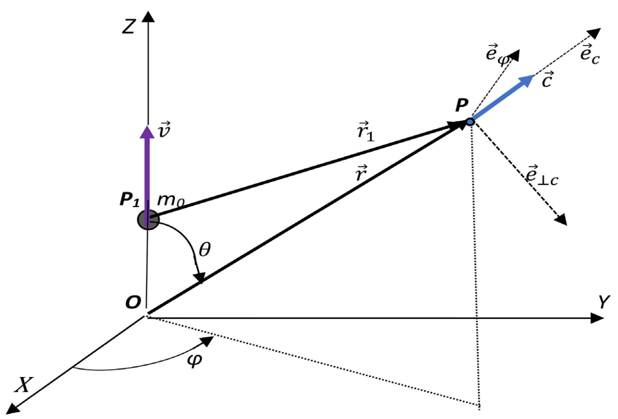


Figure 2. A harmonically oscillating particle.

In **Figure 2**, we consider a mass particle with rest mass m_0 that harmonically oscillates around the origin of the inertial reference frame ***O*** with frequency $\nu = \frac{\omega}{2 \cdot \pi}$. Now *t* it passes at P_1. We suppose that the speed of the particle described by:

$$v(t) = V \cdot \cos\omega t$$

is always much smaller than the speed of light.

The elongation $z(t)$ and the acceleration $a(t)$ are then expressed as:

$$z(t)=\frac{V}{\omega}\cdot\cos\left(\omega t-\frac{\pi}{2}\right) \text{ and } a(t)=\omega\cdot V\cdot\cos\left(\omega t+\frac{\pi}{2}\right)$$

We restrict our considerations about the gravitational field of m_0 to points P that are "far away" from the origin O: we assume that the amplitude of the oscillation is very small relative to the distances between the origin and the points P on which we focus.

Thus, relative to $\boldsymbol{O}$, $B_{g\varphi}$ and $E_{g\perp c}$ are, according the conclusions of the preceding paragraph, in the "far field" expressed as functions of the space and time coordinates as:

$$\begin{aligned}B_{g\varphi}=\frac{E_{g\perp c}}{c}&=\frac{\nu_0\cdot k\cdot m_0\cdot V\cdot\sin\theta}{4\pi r}\cdot\sin(\omega t-kr)\\&=\frac{\nu_0\cdot m_0\cdot\omega\cdot V\cdot\sin\theta}{4\pi cr}\cdot\sin(\omega t-kr)\\&=-\frac{\nu_0\cdot m_0\cdot a\left(t-\frac{r}{c}\right)\cdot\sin\theta}{4\pi cr}\end{aligned}$$

With $k=\frac{c}{\omega}$.

So, an harmonically oscillating particle emits a transversal "gravitomagnetic" wave that propagates out of the mass with the speed of light and that in the "far field" is defined by the previous equations.

The intensity of the "far gravitational field" is inversely proportional to r, and is determined by the component of the acceleration of m_0, that is perpendicular to the direction of $\boldsymbol{e}_c$.

6. Gravitational Radiation

6.1. Poynting Theorem

In free space the components of a gravitational field are completely defined by the vectoral functions $\boldsymbol{E}_g(x,y,z;t)$ and $\boldsymbol{B}_g(x,y,z;t)$. It can be shown [4] [5] that the spatial area G enclosed by the surface S—at the moment t—contains an amount of energy given by the expression:

$$U=\iiint_G\left(\frac{\eta_0\cdot E_g^2}{2}+\frac{B_g^2}{2\nu_0}\right)\cdot\mathrm{d}V$$

The rate at which the energy escapes from G is:

$$-\frac{\partial U}{\partial t}=-\iiint_V\left(\eta_0\cdot\boldsymbol{E}_g\cdot\frac{\partial\boldsymbol{E}_g}{\partial t}+\frac{1}{\nu_0}\cdot\boldsymbol{B}_g\cdot\frac{\partial\boldsymbol{B}_g}{\partial t}\right)\cdot\mathrm{d}V$$

According to the third law of Maxwell-Heaviside:

$$rot\,\boldsymbol{E}_g=-\frac{\partial\boldsymbol{B}_g}{\partial t}$$

and according to the fourth law:

$$rot\frac{\boldsymbol{B}_g}{\nu_0} = \eta_0 \cdot \frac{\partial \boldsymbol{E}_g}{\partial t}$$

So:

$$-\frac{\partial U}{\partial t} = \iiint_G \left(\frac{\boldsymbol{B}_g}{\nu_0} \cdot rot\,\boldsymbol{E}_g - \boldsymbol{E}_g \cdot rot\frac{\boldsymbol{B}_g}{\nu_0} \right) \cdot \mathrm{d}V = \iiint_G div\left(\frac{\boldsymbol{E}_g \times \boldsymbol{B}_g}{\nu_0} \right) \cdot \mathrm{d}V$$

By application of the theorem of Ostrogradsky [9]: we can rewrite this as:

$$-\frac{\partial U}{\partial t} = \oiint_S \frac{\boldsymbol{E}_g \times \boldsymbol{B}_g}{\nu_0} \cdot \mathrm{d}\boldsymbol{S}$$

from which we can conclude that the expression

$$\frac{\boldsymbol{E}_g \times \boldsymbol{B}_g}{\nu_0} \cdot \mathrm{d}\boldsymbol{S}$$

defines the rate at which energy flows in the sense of the positive normal through the surface element $\mathrm{d}S$ at a point P in a gravitational field.

So, the density of the energy flow at P is:

$$\frac{\boldsymbol{E}_g \times \boldsymbol{B}_g}{\nu_0}$$

This vectoral quantity is called the "Poynting's vector". It is represented by $\boldsymbol{P}$:

$$\boldsymbol{P} = \frac{\boldsymbol{E}_g \times \boldsymbol{B}_g}{\nu_0}$$

The amount of energy transported through the surface element $\mathrm{d}S$ in the sense of the positive normal during the time interval $\mathrm{d}t$ is:

$$\mathrm{d}U = \frac{\boldsymbol{E}_g \times \boldsymbol{B}_g}{\nu_0} \cdot \mathrm{d}\boldsymbol{S} \cdot \mathrm{d}t$$

6.2. The Energy Radiated by a Harmonically Oscillating Particle—Gravitons

In §5 it is shown that a harmonically oscillating point mass m_0 radiates a gravitational wave that at a far point Q is defined by (**Figure 2**):

$$\boldsymbol{E}_g = E_{g\perp c} \cdot \boldsymbol{e}_{\perp c} = \frac{\nu_0 \cdot m_0 \cdot \omega \cdot V \cdot \sin\theta}{4\pi r} \cdot \sin(\omega t - kr) \cdot \boldsymbol{e}_{\perp c}$$

$$\boldsymbol{B}_g = B_{g\varphi} \cdot \boldsymbol{e}_{\varphi} = \frac{\nu_0 \cdot m_0 \cdot \omega \cdot V \cdot \sin\theta}{4\pi c r} \cdot \sin(\omega t - kr) \cdot \boldsymbol{e}_{\varphi}$$

And in §4 it is shown that the amount of energy transported by a gravitational wave ($\boldsymbol{E}_g, \boldsymbol{B}_g$) during a time interval $\mathrm{d}t$ through a surface element $\mathrm{d}S$ in the sense of the positive normal is

$$\mathrm{d}U = \boldsymbol{P} \cdot \mathrm{d}\boldsymbol{S} \cdot \mathrm{d}t = \frac{\boldsymbol{E}_g \times \boldsymbol{B}_g}{\nu_0} \cdot \mathrm{d}\boldsymbol{S} \cdot \mathrm{d}t$$

At a point P in the far gravitational field of a harmonically oscillating mass particle m_0, the instantaneous value of Poynting's vector at P is:

$$\boldsymbol{P} = \frac{\nu_0 \cdot m_0^2 \cdot \omega^2 \cdot V^2 \cdot \sin^2\theta}{16 \cdot \pi^2 \cdot c \cdot r^2} \cdot \sin^2(\omega t - kr) \cdot \boldsymbol{e}_c$$

The amount of energy that, during one period T, flows through the surface element dS that at P is perpendicular to the direction of the movement of the informatons, is:

$$\mathrm{d}U = \int_0^T P \cdot \mathrm{d}t \cdot \mathrm{d}S = \frac{\nu_0 \cdot m_0^2 \cdot \omega^2 \cdot V^2 \cdot \sin^2\theta}{16 \cdot \pi^2 \cdot c \cdot r^2} \cdot \frac{T}{2} \cdot \mathrm{d}S$$

And, with $\omega = \frac{2 \cdot \pi}{T} = 2 \cdot \pi \cdot \nu$:

$$\mathrm{d}U = \frac{\nu_0 \cdot m_0^2 \cdot V^2 \cdot \sin^2\theta}{8c} \cdot \nu \cdot \frac{\mathrm{d}S}{r^2}$$

$\frac{\mathrm{d}S}{r^2} = \mathrm{d}\Omega$ is the solid angle under which $\mathrm{d}S$ is "seen" from the origin. So, the oscillating mass particle radiates per unit of solid angle in the direction θ, per period, an amount of energy u_Ω:

$$u_\Omega = \frac{\nu_0 \cdot m_0^2 \cdot V^2 \cdot \sin^2\theta}{8c} \cdot \nu$$

This quantity is greatest in the direction perpendicular to the movement of the particle ($\theta = 90^\circ$) and it is proportional to the frequency of the wave, thus proportional to the frequency at which the particle is oscillating.

It follows that the amount of energy radiated per period by the oscillating particle is:

$$U_T = \frac{2\pi \cdot \nu_0 \cdot m_0^2 \cdot V^2}{8c} \cdot \nu \cdot \int_0^\pi \sin^3\theta \cdot \mathrm{d}\theta = \frac{\pi \cdot \nu_0 \cdot m_0^2 \cdot V^2}{3c} \cdot \nu \quad (7)$$

We posit that the energy radiated by an oscillating mass particle travels through space in the form of particle-like packets of energy, called "gravitons" and that the energy U_g transported by a graviton is proportional to the frequency of the oscillator, so:

$$U_g = h' \cdot \nu \quad (8)$$

h' plays the role of Planck's constant [10] in electromagnetism. Thus, a graviton can be understood as an informaton transporting a quantum of energy $h' \cdot \nu$. From (7) and (8), it follows that the number of gravitons emitted per period by an oscillating particle with rest mass m_0 is:

$$N_{gT} = \frac{U_T}{h' \cdot \nu} = \frac{\pi}{3} \cdot \frac{\nu_0}{h' \cdot c} \cdot m_0^2 \cdot V^2$$

If the particle would be carrier of an electric charge q, it would also be a source of photons: informatons transporting a quantum of energy $h \cdot \nu$. On the basis of the analogy between gravitational and electromagnetic fields [2] we can conclude that the number of photons emitted per period by a point charge q is:

$$N_{fT} = \frac{\pi}{3} \cdot \frac{\mu_0}{h \cdot c} \cdot q^2 \cdot V^2$$

It is reasonable to assume that it are the same informatons that at the moment of their emission will be charged with a graviton and a photon, what implies that:

$$N_{fT} = N_{gT}$$

It follows:

$$h' = \frac{\nu_0}{\mu_0} \cdot \frac{m_0^2}{q^2} \cdot h = \frac{\epsilon_0}{\eta_0} \cdot \frac{m_0^2}{q^2} \cdot h = 7.43 \times 10^{-21} \cdot \frac{m_0^2}{q^2} \cdot h$$

h' is, in contrast to h, dependent on the ratio mass/charge of the emitter if it, as in the case of a proton and an electron, is electrically charged. If the emitter is neutral, as in the case of a neutron, h' depends on the ratio mass/charge of the electrically charged particle with the same rest mass as the emitter.

($h' \cdot \nu$), the quantum of energy transported by a graviton, is in any case negligibly small compared to ($h \cdot \nu$), the quantum of energy transported by a photon emitted by an oscillator with the same frequency. This makes it impossible to observe gravitons that are emitted by electrically charged bodies: in that case the presence of gravitons leads to an insignificant fluctuation of the energy quantum of the photons. We can still note that the quantum of energy transported by gravitons that are emitted by electrons is negligibly small compared to the quantum of energy transported by gravitons that are emitted by protons and neutrons.

7. Gravitational Wave Emitted by an Object with Variable Rest Mass

Another phenomenon that is the source of a gravitational wave is the conversion of rest mass into energy (what per example happens in the case of radioactive processes). To illustrate this, let us—relative to an inertial reference frame—consider a particle with rest mass m_0 that—due to intern instability—during the period (0, Δt) emits EM radiation.

This implies that that particle during that time interval is emitting electromagnetic energy U_{EM} carried by photons (and gravitational energy U_{GEM}[2] carried by gravitons) that propagate with the speed of light. Between the moment $t = 0$ and the moment $t = \Delta t$, the rest mass of the particle is, because of this event, decreasing *with* an amount $\frac{U_{EM}\left(+U_{GEM}\right)}{c^2}$ from the value m_0 to the value m_0'. Because the gravitational field is determined by the rest mass, this implies that if $t < 0$ the source of the gravitational field of the particle is m_0 and if $t > \Delta t$ it is m_0'. It follows that at the moment t the gravitational field at a point P at a distance $r > c.t$ is proportional to m_0, and at a point at a distance $r < c \cdot \left(t - \Delta t\right)$ to m_0'.

During the period (t, $t + \Delta t$) the gravitational field at a point at a distance $r = c.t$ changes from the situation where it is determined by m_0 to the situation where it is determined by m_0'. So, the conversion of rest mass of an object into radiation is the cause of a kink in the gravitational field of that object, a kink that with the speed of light—together with the emitted radiation—propagates out of the object.

We can conclude that the conversion of (*a part of*) *the rest mass of an object*

[2]Negligible in first approximation.

into radiation goes along with the emission by that object of a gravitational wave.

The effect of the decrease—during the time interval $(0, \Delta t)$*—of the rest mass of a point mass on the magnitude of its g-field* E_g *at the point P at a distance r is shown in the plot of* Figure 3.

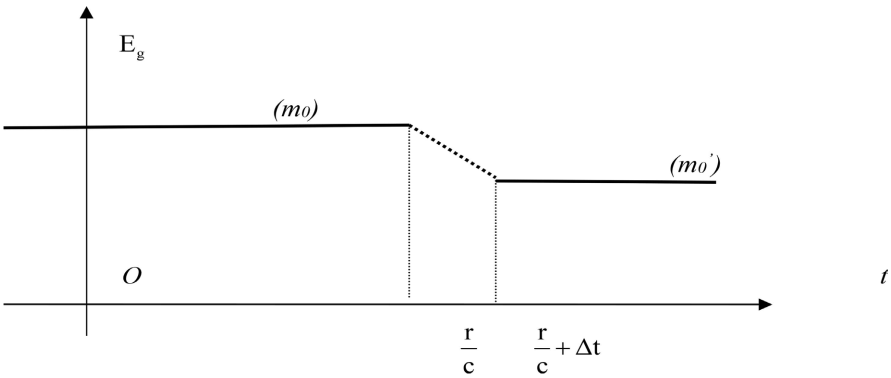


Figure 3. Gravitational wave emitted by an object with variable mass.

1) Until the moment $t = \frac{r}{c}$, the effect of the conversion of rest mass into radiation has not yet reached *P*. So, during the period $(0, \frac{r}{c})$ the quantity of mass-energy enclosed by an hypothetical sphere with radius *r* centered on the particle is still m_0 (the remaining part of the rest mass + all the radiation that during the mentioned period has arisen from the conversion of rest mass). From the first GEM equation it follows:

$$E_g = \frac{m_0}{4\pi\eta_0 \cdot r^2}$$

2) From the moment $t = \frac{r}{c} + \Delta t$, the radiation generated by the conversion of rest mass has left the space enclosed by the hypothetical sphere with radius *r*, that from that moment only contains the remaining rest mass m_0'. From the first GEM equation it follows:

$$E_g = \frac{m_0'}{4\pi\eta_0 \cdot r^2}$$

3) During the time interval $(\frac{r}{c}, \frac{r}{c} + \Delta t)$, the mass-energy enclosed by the hypothetical sphere with radius *r* is decreasing (not necessary linearly) because mass-energy flows out in the form of radiation. So, during that period E_g at *P* is decreasing.

8. Conclusion

The existence of gravitational or gravitomagnetic waves is embedded in the GEM description of gravity. According to the theory of informatons a gravitational wave propagating outward from an oscillating mass particle at the speed of light is the macroscopic manifestation of the fact that the "train" of informatons emitted by that source is a spatial sequence of informatons whose characteristic angle is harmonically fluctuating along the "train" what implies that the component of their g-index perpendicular to their velocity $\boldsymbol{c}$ and their β-index fluctuate in space.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

References

[1] Acke, A. (2024) The Maxwell-Heaviside Equations Explained by the Theory of Informatons. *Journal of High Energy Physics, Gravitation and Cosmology*, **10**, 1003-1016. https://doi.org/10.4236/jhepgc.2024.103061

[2] Acke, A. (2024) Newton's Law of Universal Gravitation Explained by the Theory of Informatons. *Journal of High Energy Physics, Gravitation and Cosmology*, **10**, 918-929. https://doi.org/10.4236/jhepgc.2024.103056

[3] Acke, A. (2024) The Gravitational Interaction between Moving Mass Particles Explained by the Theory of Informatons. *Journal of High Energy Physics*, *Gravitation and Cosmology*, **10**, 986-1002. https://doi.org/10.4236/jhepgc.2024.103060

[4] Acke, A. (1990) Beginselen van de informatonentheorie. Uitgeverij Nevelland.

[5] Acke, A. (2008) Gravitatie en elektromagnetisme. Uitgeverij Nevelland.

[6] Heaviside, O. (1893) A Gravitational and Electromagnetic Analogy, Part I: The Electrician 1893.

[7] Poincaré, H. (1905) Sur la dynamique de l'électron, Les Comptes rendus de l'Académie des sciences de la séance du 5 juin 1905.

[8] Jefimenko, O.D. (1992) Causality, Electromagnetic Induction, and Gravitation. Electret Scientific.

[9] Angot, A. (1957) Compléments de Mathematiques. Editions de la Revue d'Optique.

[10] Resnick, D. and Halliday, R. (1970) Fundamentals of Physics. Wiley.