# CHAPTER 7

# THE GRAVITATIONAL INTERACTIONS

In the framework of the theory of informatons, the gravitational interactions are understood as the reaction of an object to the disturbance of its proper gravitational field by gravitational fields of other objects.

## 7.1 THE GRAVITATIONAL INTERACTION BETWEEN PARTICLES AT REST

We consider a set of point masses anchored in an inertial reference frame $\boldsymbol{O}$. They create and maintain a gravitational field that at each point of the space linked to $\boldsymbol{O}$ is completely determined by the vector $\vec{E}_g$. Each mass is "immersed" in a cloud of g-information. At every point, except at its own position, each mass contributes to the construction of that cloud.

Let us consider the mass $m$ anchored at $P$. If the other masses were not there, then $m$ would be at the centre of a perfectly spherical cloud of g-information. In reality this is not the case: the emission of g-information by the other masses is responsible for the disturbance of that "*characteristic symmetry*" of the proper g-field of $m$. Because $\vec{E}_g$ at $P$ represents the intensity of the flow of g-information send to $P$ by the other masses, the extent of disturbance of the characteristic symmetry in the immediate vicinity of $m$ is determined by $\vec{E}_g$ at $P$.

If it was free to move, the point mass $m$ could restore the characteristic symmetry of the g-information cloud in its immediate vicinity by accelerating with an amount $\vec{a} = \vec{E}_g$. Indeed, accelerating this way has the effect that the extern field disappears in the origin of the reference frame anchored to $m$. If it accelerates with an amount $\vec{a} = \vec{E}_g$, the mass would become "blind" for the g-information send to its immediate vicinity by the other masses, it "sees" only its proper spherical g-information cloud.

So, from the point of view of a particle at rest at a point $P$ at a gravitational field $\vec{E}_g$, the characteristic symmetry of the g-information cloud in its immediate vicinity is conserved if it accelerates with an amount $\vec{a} = \vec{E}_g$. A point mass that is anchored in a gravitational field cannot accelerate. In that case it *tends* to move. These insight is expressed in the following postulate:

*A particle anchored at a point of a gravitational field is subjected to a tendency to move in the direction defined by* $\vec{E}_g$, *the g-field at that point. Once the anchorage is broken, the mass acquires a vectoral acceleration* $\vec{a}$ *that equals* $\vec{E}_g$.

## 7.2 THE GRAVITATIONAL FORCE – THE FORCE CONCEPT

A point mass $m$, anchored at a point $P$ of a gravitational field, experiences an action because of that field, an action that is compensated by the anchorage.

*1*. That action is proportional to the extent to which the characteristic symmetry of the proper gravitational field of $m$ in the immediate vicinity of $P$ is disturbed by the extern g-field, thus to the value of $\vec{E}_g$ at $P$.

2. It depends also on the magnitude of $m$. Indeed, the g-information cloud created and maintained by $m$ is more compact if $m$ is greater. That implies that the disturbing effect on the spherical symmetry around $m$ by the extern g-field $\vec{E}_g$ is smaller when $m$ is greater. Thus, to impose the acceleration $\vec{a} = \vec{E}_g$, the action of the gravitational field on $m$ must be greater if $m$ is greater.

We can conclude that the action that tends to accelerate a point mass $m$ in a gravitational field must be proportional to $\vec{E}_g$, the g-field to which the mass is exposed; and to $m$, the magnitude of the mass. We represent that action by $\vec{F}_G$ and we call this vectoral quantity "the force developed by the g-field on the mass" or the *gravitational force* on $m$. We define it by the relation:

$$\vec{F}_G = m.\vec{E}_g$$

A mass anchored at a point $P$ cannot accelerate, what implies that the effect of the anchorage must compensate the gravitational force. It cannot be otherwise than that the anchorage exerts an action on $m$ that is exactly equal and opposite to the gravitational force. That action is called a *reaction force*.

Between the gravitational force on a mass $m$ and the local field strength exists the following relationship:

$$\vec{E}_g = \frac{\vec{F}_G}{m}$$

So, the acceleration imposed to the mass by the gravitational force is:

$$\vec{a} = \frac{\vec{F}_G}{m}$$

Considering that the gravitational force is nothing but a special force, we can conclude that this relation can be generalized.

*The relation between a force $\vec{F}$ and the acceleration $\vec{a}$ that it imposes to a free mass m is:*

$$\vec{F} = m.\vec{a}$$

## 7.3 NEWTONS LAW OF UNIVERSAL GRAVITATION

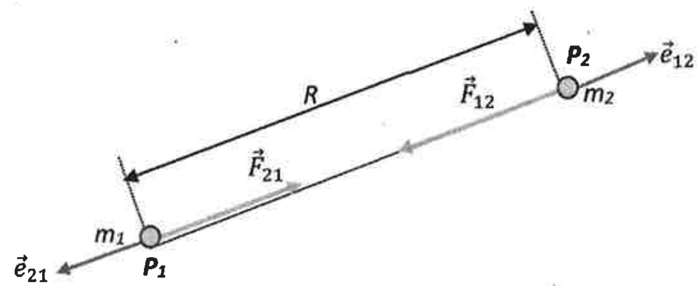


Fig 12

In fig 12 we consider two particles with (rest) masses $m_1$ and $m_2$ anchored at the points $P_1$ and $P_2$ of an inertial reference frame.

*1.* $m_1$ creates and maintains a gravitational field that at $P_2$ is defined by the g-field:

$$\vec{E}_{g2} = -\frac{m_1}{4.\pi.\eta_0.R^2}.\vec{e}_{12}$$

We show that this result is embedded in the GEM description of gravity.

The first GEM-equation - that is the mathematical expression of the conservation of g-information - states that the flux of the gravitational field through an arbitrary closed surface $S$ is determined by the enclosed mass $m_{in}$ according to the law:

$$\oiint \vec{E}_g.\overrightarrow{dS} = -\frac{m_{in}}{\eta_0} \qquad (1)$$

Let us apply this equation to an hypothetical sphere $S$ with radius $R$ centered on $P_1$.

*1*. Because of the symmetry, $\vec{E}_g$ is at every point of that sphere perpendicular to its surface and has the same magnitude. So, at an arbitrary point *P* of the sphere, $\vec{E}_g$ can be expressed as

$$\vec{E}_g = E_{gr}.\vec{e}_r$$

where $\vec{e}_r$ and $E_{gr}$ respectively are the unit vector and the component (with constant magnitude) of $\vec{E}_g$ in the direction of $\overrightarrow{P_1P}$.

Further, at any point of the surface of the sphere: $\overrightarrow{dS} = dS.\bar{e}_r$.

With this information we calculate $\oiint_S \vec{E}\,.\overrightarrow{dS}$:

$$\oiint_S \vec{E}_g\,.\overrightarrow{dS} = \oiint_S E_{gr}.\vec{e}_r\,.dS.\vec{e}_r = \oiint_S E_{gr}.dS = E_{gr}.\oiint_S dS = E_{gr}.4\pi R^2 \quad (2)$$

2. The enclosed mass is $m_1$, so

$$m_{in} = m_1 \qquad (3)$$

Taking into account (2) and (3), (1) becomes:

$$E_{gr}.4\pi R^2 = -\frac{m_1}{\eta_0}$$

We conclude: at a point *P* at a distance *R* from $P_1$ the gravitational field is pointing to $P_1$ and determined by:

$$\vec{E}_g = E_{gr}.\vec{e}_r = -\frac{m_1}{4\pi\eta_0 R^2}.\vec{e}_r$$

In particular at the point $P_2$:

$$\vec{E}_{g2} = -\frac{m_1}{4.\pi.\eta_0.R^2}.\vec{e}_{12}$$

If $m_2$ was free, according to the postulate of the gravitational interaction it would accelerate with an amount $\vec{a}$:

$$\vec{a} = \vec{E}_{g2}$$

So the gravitational field of $m_1$ exerts a "gravitational force" on $m_2$:

$$\vec{F}_{12} = m_2.\vec{a} = m_2.\vec{E}_{g2} = -\frac{m_1.m_2}{4.\pi.\eta_0.R^2}.\vec{e}_{12}$$

In a similar manner we find $\vec{F}_{21}$:

$$\vec{F}_{21} = -\frac{m_1.m_2}{4.\pi.\eta_0.R^2}.\vec{e}_{21} = -\vec{F}_{12}$$

This is the mathematical expression of "Newton's law of universal gravitation"[1]:

*The force between any two particles having masses $m_1$ and $m_2$ separated by a distance R is an attraction acting along the line joining the particles and has the magnitude*

$$F = G.\frac{m_1.m_2}{R^2} = \frac{1}{4\pi\eta_0}.\frac{m_1.m_2}{R^2}$$

$G = \frac{1}{4\pi\eta_0}$ is a universal constant having the same value for all pairs of particles.

## 7.4 THE GRAVITATIONAL INTERACTION BETWEEN MOVING OBJECTS

We consider a number of point masses moving relative to an inertial reference frame $\boldsymbol{O}$. They create and maintain a gravitational field that at each point of the space linked to $\boldsymbol{O}$ is defined by the vectors $\vec{E}_g$ and $\vec{B}_g$. Each mass is "immersed" in a cloud of informatons carrying both g- and β-information. At each point, except at its own position, each mass contributes to the construction of that cloud.

Let us consider the mass $m$ that, at the moment $t$, goes through the point $P$ with velocity $\vec{v}$.

*1*. If the other masses were not there $\vec{E}'_g$ - the g-field in the immediate vicinity of $m$ (the proper g-field of $m$) - would, according to §4.2, be symmetric relative to the carrier line of the vector $\vec{v}$. This results from the fact that the g-indices of the informatons emitted by $m$ during the time interval $(t - \Delta t, t + \Delta t)$ are all directed to that line. In reality that symmetry is disturbed by the g-information that the other masses send to $P$. $\vec{E}_g$, the instantaneous value of the g-field at $P$, defines the extent to which this occurs.

2. If the other masses were not there $\vec{B}'_g$ - the g-induction near $m$ (the proper g-induction of $m$) - would , according to §4.4, "rotate" around the carrier line of the vector $\vec{v}$. The vectors defining the pseudo-gravitational-field $E''_g = \vec{v} \times \vec{B}'_g$ defined by the vector product of $\vec{v}$ with the g-induction that characterizes the proper β-field of $m$, would - just like $\vec{E}'_g$ - be symmetric relative to the carrier line of the vector $\vec{v}$. In reality this symmetry is disturbed by the β-information send to $P$ by the other masses. The vector product $(\vec{v} \times \vec{B}_g)$ of the instantaneous values of the velocity of $m$ and of the g-induction at $P$, characterizes the extent to which this occurs.

So, the *characteristic symmetry* of the cloud of g-information around a moving mass (the proper gravitational field) is in the immediate vicinity of $m$ disturbed by $\vec{E}_g$ regarding the proper g-field; and by $(\vec{v} \times B_g)$ regarding the proper β-induction.

If it was free to move, the point mass $m$ could restore the characteristic symmetry in its immediate vicinity by accelerating with an amount $\vec{a}' = \vec{E}_g + (\vec{v} \times \vec{B}_g)$ relative to its proper inertial reference frame• $\boldsymbol{O}'$. In that manner it would become "blind" for the disturbance of symmetry of the gravitational field in its immediate vicinity. These insights form the basis of the following postulate.

*A particle m, moving with velocity $\vec{v}$ in a gravitational field $(\vec{E}_g, \vec{B}_g)$, tends to become blind for the influence of that field on the symmetry of its proper gravitational field. If it is free to move, it will accelerate relative to its proper inertial reference frame with an amount $\vec{a}'$:*

$$\vec{a}' = \vec{E}_g + (\vec{v} \times \vec{B}_g)$$

• The proper inertial reference frame $\boldsymbol{O}'$ of the particle $m$ is the reference frame that at each moment $t$ moves relative to $\boldsymbol{O}$ with the same velocity as $m$.

## 7.5 THE GRAVITATIONAL FORCE LAW

The action of the gravitational field $(\vec{E}_g, \vec{B}_g)$ on a point mass that is moving with velocity $\vec{v}$ relative to the inertial reference frame $\boldsymbol{O}$, is called the *gravitational force* $\vec{F}_G$ on that mass. In extension of §7.2 we define $\vec{F}_G$ as:

$$\vec{F}_G = m_0.\left[\vec{E}_g + (\vec{v} \times \vec{B}_g)\right]$$

$m_0$ is the rest mass of the point mass: it is the mass that determines the rate at which it emits informatons in the space linked to $\boldsymbol{O}$. If it is free to move, the effect of $\vec{F}_G$ on the point mass $m$ is that it will be accelerated relative to the proper inertial reference frame $\boldsymbol{O'}$ with an amount $\vec{a}'$:

$$\vec{a}' = \vec{E}_g + (\vec{v} \times \vec{B}_g)$$

This acceleration can be decomposed in a tangential $(\vec{a}'_T)$ and a normal component $(\vec{a}'_N)$:

$$\vec{a}'_T = a'_T.\vec{e}_T \qquad \text{and} \qquad \vec{a}'_N = a'_N.\vec{e}_N$$

where $\vec{e}_T$ and $\vec{e}_N$ are the unit vectors, respectively along the tangent and along the normal to the path of the point mass in $\boldsymbol{O'}$ (and in $\boldsymbol{O}$).

We express $a'_T$ en $a'_N$ in function of the characteristics of the motion in the inertial reference system $\boldsymbol{O}$ [2]:

$$a'_T = \frac{1}{(1-\beta^2)^{\frac{3}{2}}}.\frac{dv}{dt} \qquad \text{and} \qquad a'_N = \frac{v^2}{R.\sqrt{1-\beta^2}}$$

($R$ is the radius of curvature of the path in $\boldsymbol{O}$, and that radius in $\boldsymbol{O'}$ is $R\sqrt{1-\beta^2}$.)

The gravitational force is:

$$\vec{F}_G = m_0.\vec{a}' = m_0.(a'_T.\vec{e}_T + a'_N.\vec{e}_N)$$

$$= m_0.\left[\frac{1}{(1-\beta^2)^{\frac{3}{2}}}.\frac{dv}{dt}.\vec{e}_T + \frac{1}{(1-\beta^2)^{\frac{1}{2}}}.\frac{v^2}{R}.\vec{e}_N\right] = \frac{d}{dt}\left[\frac{m_0}{\sqrt{1-\beta^2}}.\vec{v}\right]$$

Finally with:

$$\frac{m_0}{\sqrt{1-\beta^2}}.\vec{v} = \vec{p}$$

We obtain:

$$\vec{F}_G = \frac{d\vec{p}}{dt}$$

$\vec{p}$ is the linear momentum of the particle relative to the inertial reference frame $\boldsymbol{O}$. It is a measure for its inertia, for its ability to persist in its dynamic state The relation between the rest mass an the relativistic mass is previously treated in §4.1.

## 7.6 THE INTERACTION BETWEEN TWO MOVING PARTICLES

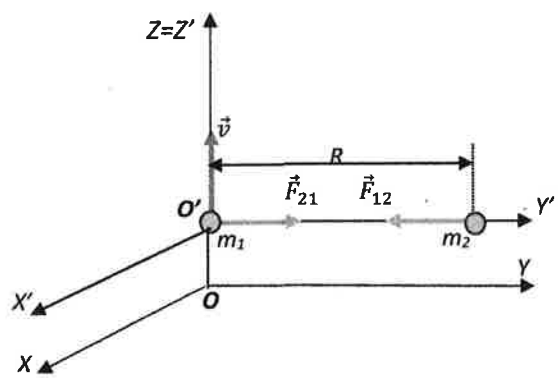


Fig 13

Two particles with rest masses $m_1$ and $m_2$ (fig 13) are anchored in the inertial reference frame ***O'*** that is moving relative to the inertial reference frame ***O*** with constant velocity $\vec{v} = v.\bar{e}_z$. The distance between the masses is $R$.

Relative to ***O'*** the particles are at rest. According to Newton's law of universal gravitation, they exert on each other equal but opposite forces:

$$F' = F'_{12} = F'_{21} = G.\frac{m_{.1}.m_2}{R^2} = \frac{1}{4.\pi.\eta_0}.\frac{m_1.m_2}{R^2}$$

Relative to ***O*** both masses are moving with constant speed $v$ in the direction of the *Z*-axis. From the transformation equations between an inertial frame ***O*** and another inertial frame ***O'***, in which a point mass experiencing a force *F'* is instantaneously at rest, we can immediately deduce the force $F$ that the point masses exert on each other in $\boldsymbol{O}$ [2] :

$$F = F_{12} = F_{21} = F'.\sqrt{1-(\frac{v}{c})^2} = F'.\sqrt{1-\beta^2}$$

*We will now show that also this form of Newton's law of universal gravitation perfectly can be deduced in the framework of GEM.*

*1.* According to §4.5, at a point $P$ - whose position is determined by the time dependent position vector $\vec{r}$ - the gravitational field $(\vec{E}_g, \vec{B}_g)$ of a particle with rest mass $m_0$ that is moving with constant velocity $\vec{v} = v.\bar{e}_z$ along the Z-axis of the inertial reference frame $\boldsymbol{O}$ (fig 14) is determined by:

$$\vec{E}_g = -\frac{m_0}{4\pi\eta_0 r^3}.\frac{1-\beta^2}{(1-\beta^2.sin^2\theta)^{\frac{3}{2}}}.\vec{r} = -\frac{m_0}{4\pi\eta_0 r^2}.\frac{1-\beta^2}{(1-\beta^2.sin^2\theta)^{\frac{3}{2}}}.\vec{e}_r$$

$$\vec{B}_g = -\frac{m_0}{4\pi\eta_0 c^2.r^3}.\frac{1-\beta^2}{(1-\beta^2.sin^2\theta)^{\frac{3}{2}}}.(\vec{v}\times\vec{r})$$

With $\beta = \frac{v}{c}$, the dimensionless speed of $m_0$.

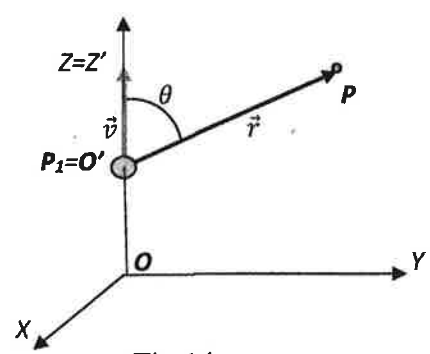


Fig 14

2. In the inertial reference frame $O$ of fig 13, the masses $m_1$ and $m_2$ are moving in the direction of the $Z$-axis with speed $v$. $m_2$ moves through the gravitational field generated by $m_1$, and $m_1$ moves through that generated by $m_2$.

According the above formulas, the magnitude of the gravitational field created and maintained by $m_1$ at the position of $m_2$ is determined by:

$$E_{g2} = \frac{m_1}{4\pi\eta_0 R^2} \cdot \frac{1}{\sqrt{1-\beta^2}}$$

$$B_{g2} = \frac{m_1}{4\pi\eta_0 R^2} \cdot \frac{1}{\sqrt{1-\beta^2}} \cdot \frac{v}{c^2}$$

And according to the force law $\vec{F}_G = m_0.\left[\vec{E}_g + (\vec{v} \times \vec{B}_g)\right]$, $F_{12}$, the magnitude of the force exerted by the gravitational field $(\vec{E}_{g2}, \vec{B}_{g2})$ on $m_2$ - this is the attraction force of $m_1$ on $m_2$ - is:

$$F_{12} = m_2.(E_{g2} - v.B_{g2})$$

After substitution:

$$F_{12} = \frac{1}{4\pi\eta_0} \cdot \frac{m_1 m_2}{R^2} . \sqrt{1-\beta^2} = F'_{21} . \sqrt{1-\beta^2}$$

In the same way we find:

$$F_{21} = \frac{1}{4\pi\eta_0} \cdot \frac{m_1 m_2}{R^2} . \sqrt{1-\beta^2} = F'_{12} . \sqrt{1-\beta^2}$$

We conclude that the moving masses attract each other with a force:

$$F = F_{12} = F_{21} = F' . \sqrt{1-\beta^2}$$

This result perfectly agrees with that based on S.R.T.

We also can conclude that the component of the gravitational force due to the g-induction is $\beta^2$ times smaller than that due to the g-field. This implies that, for speeds much smaller than the speed of light, the effects of the β-information are masked.

It can be shown that the β-information emitted by moving gravitating objects is responsible for deviations (as the advance of Mercury Perihelion) of the real orbits of planets with respect to these predicted by the classical theory of gravitation[3].

## 7.7 THE EQUIVALENCE MASS-ENERGY

The instantaneous value of the force $\vec{F}$ that acts on a particle with rest mass $m_0$, that freely moves relative to the inertial reference frame ***O*** with velocity $\vec{v}$, and the linear momentum $\vec{p} = m.\vec{v}$ of that particle are related by:

$$\vec{F} = \frac{d\vec{p}}{dt}$$

The elementary vectoral displacement $d\vec{r}$ of $m_0$ during the elementary time interval *dt* is:

$$d\vec{r} = \vec{v}.dt$$

And the elementary work done by $\vec{F}$during *dt* is[1]:

$$dW = \vec{F}.d\vec{r} = \vec{F}.\vec{v}.dt = \vec{v}.d\vec{p}$$

With

$$\vec{p} = m.\vec{v} = \frac{m_0}{\sqrt{1 - (\frac{v}{c})^2}}.\vec{v}$$

this becomes:

$$dW = \frac{m_0.v.dv}{\left[1 - (\frac{v}{c})^2\right]^{\frac{3}{2}}} = d\left[\frac{m_0}{\sqrt{1 - (\frac{v}{c})^2}}.c^2\right] = d(m.c^2)$$

The work done on the moving particle equals, by definition, the increase of the energy of the mass. So, $d(m.c^2)$ is the increase of the energy of the mass and $m.c^2$ is the energy represented by the mass. We can conclude:

*A particle with relativistic mass m is equivalent to an amount of energy of $m.c^2$.*

## References

1.**Resnick, David and Halliday, Robert.** *Fundamentals of Physics*. New York - London - Sydney - Toronto : John Wiley & Sons, 1970.

2. **Resnick, Robert.** *Introduction to special Relativity*. New York, London, Sydney : John Wiley & Sons, Inc, 1968.

3.**Tajmar, M and de Matos, C.J.** *Advance of Mercury Perihelion explained by Cogravity*. 2003. arXiv: gr-qc/0304104.