Physics of Gravitational Fields

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Abstract

After having defined the most important physical properties and the three main types of gravitational field and after having examined dynamics of a moving system into a gravitational field, we prove the theoretical cogency of a gravitational perturbation that propagates in the gravitational field and is caused by the free fall of a massive body. This gravitational perturbation is due to the real gravitational field where motion happens and it isn't related to traces of primordial gravitational waves recently detected in the cosmic microwave background radiation in the order of BICEP2 experiment.

1. Introduction

The great majority of celestial bodies have a mass supplied with a rotary motion round its own axis (active bodies with intrinsic spin) while ordinary bodies (inert bodies) that we observe in our everyday on earth's surface have a non-rotating mass (spinless). We are able to supply these inert masses with a non-intrinsic forced rotary motion round their own axis, like in the event of whirligig (forced spin). Also charged elementary particles have an intrinsic rotary motion round their own axis and consequently an angular momentum (spin), that therefore represents a common property for all active matter from infinitely little to infinitely great.
Experimental evidence confirms that between two any masses an attraction force exists whether in the event of active masses or in the event of inert masses and also between active masses and inert masses. In all these physical phenomena the presence of two gravitational fields, both defined by a gravitational potential, causes those actions of attraction that therefore aren' t actions at distance, as it was believed in the Newtonian gravitation, and are not due to space-time curvature, as it was believed in the Einsteinian gravitation, but they are due just to the interaction of the second gravitational potential with the potential that is present in every point of space since the birth of the first field. After having defined general physical properties, we consider three types of gravitational field:

1. Type I gravitational field caused by an active mass on an inert mass
2. Type II gravitational field caused by an active mass on an active mass.
3. Type III gravitational field caused by an inert mass on an inert mass

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If considered bodies have also an electric charge it is manifest that in that case also an electromagnetic field is generated and the two fields overlap.
In the event of charged elementary particles we have demonstrated just the spin (angular moment of electrodynamic mass) generates electric charge[1] which in its turn causes electromagnetic field.
In the event of one proton and one electron for instance calculations prove the electrostatic force of attraction F_e between the two particles at a range of 1m is given by

$$F_e = \frac{e^2}{4\pi\varepsilon_o} = 2.3 \times 10^{-28}\ \text{N} \qquad (1)$$

while the gravitational force of attraction F_g between the two same particles at the same range of 1m is given by

$$F_g = Gm_pm_e = 10.14 \times 10^{-68}\ \text{N} \qquad (2)$$

It is manifest that the gravitational force working between the two particles is highly smaller than the electrostatic force.

2. Physical properties of gravitational field

Let us consider at first the empty physical space[2], characterized by three space coordinates [x,y,z] and by three physical properties in a vacuum [permittivity ε_o, magnetic permeability μ_o, mechanical constant k_o]. In this empty physical space any type of mass is absent and time is meaningless.
Suppose that a fixed static mass M is placed or forms in one point O of the empty physical space. The point O can be considered the origin in the empty physical space of both, a gravitational field generated by the static mass M and a reference frame S[O,x,y,z,t] in which also time takes on now a physical significance as per the second relationship of relativistic transformations[2] of the Space-Time-Mass domain

$$\mathbf{P}[x,y,z,t] = \mathbf{P'}[x',y',z,t'] + \int_0^t \mathbf{v}\, dt$$

$$dt = \frac{M}{M'} dt' \qquad (3)$$

In fact when v=0, like in our case, we have **P**=**P'** for every t, M=M' , dt=dt' and t=t' , where t=t'=0 represents the initial instant of time in which mass M is placed or forms in the point O, called pole of field.

The gravitational field generated by static mass M is characterized by a scalar gravitational potential with spherical symmetry, which depends on both, the mass M and the distance r from the origin O (fig.1), and it is given by

$$U(r) = -\frac{GM}{r} \qquad (4)$$

where $r^2 = x^2 + y^2 + z^2$, $G = 6{,}67 \times 10^{-11} [Nm^2 kg^{-2}]$ is the accepted value of the gravitational constant and the minus sign means that the potential increases with the distance.

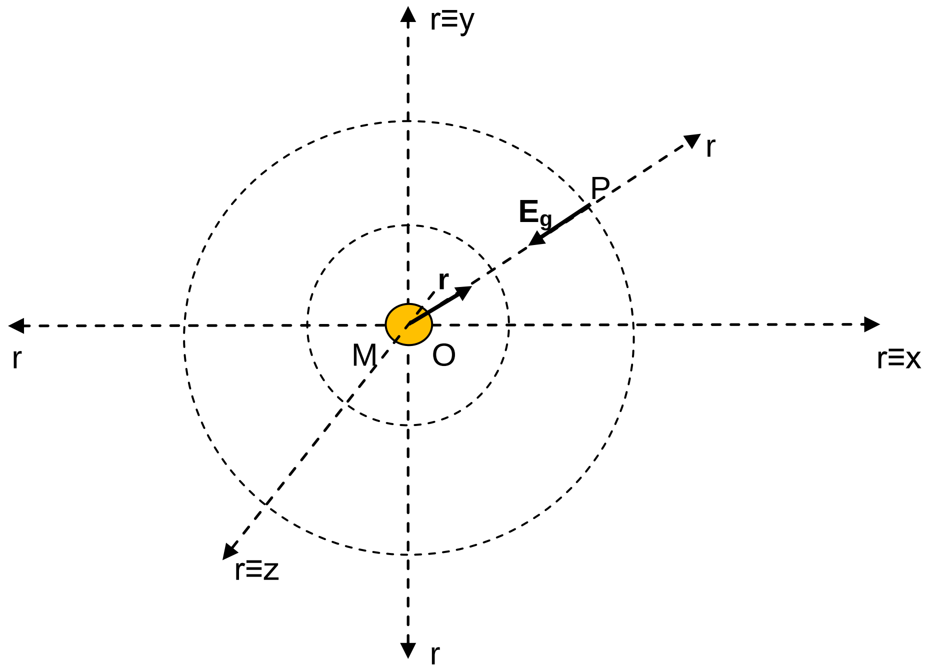

Fig.1 Graphic representation of gravitational field generated by the pole M.

In every point P[O,r] of the field it is possible then to define a vector gravitational field given by

$$\mathbf{E_g} = -\frac{dU}{dr}\,\mathbf{r} = -\frac{GM}{r^2}\,\mathbf{r} \qquad (5)$$

in which **r** represents the unitary vector, that is turned outside the field like in fig.1.
The gravitational field is characterized by equipotential spherical surfaces and it is constant along these surfaces and turned perpendicularly to those surfaces toward the pole of the field.
In practice the gravitational field is observed experimentally through the gravitational force that the field effects on a trial mass m_o. Any inert mass m_o of trial, placed a distance r from the central mass (fig.2), acquires a potential energy $E_p(r)$ into the gravitational field of the pole and it causes the attraction force $\mathbf{F_g}(r)$ between the two masses given by Newton's gravitational law in vector shape

$$\mathbf{F_g}(r) = -\frac{GMm_o}{r^2}\,\mathbf{r} \qquad (6)$$

The intensity of the gravitational force is

$$F_g(r) = \frac{GMm_o}{r^2} \qquad (7)$$

The gravitational field, considering the trial mass, is defined by

$$\mathbf{E_g} = \frac{\mathbf{F_g}}{m_o} = -\frac{G\,M}{r^2}\,\mathbf{r} \qquad (8)$$

and it equals the field that has been calculated in the relation (5).

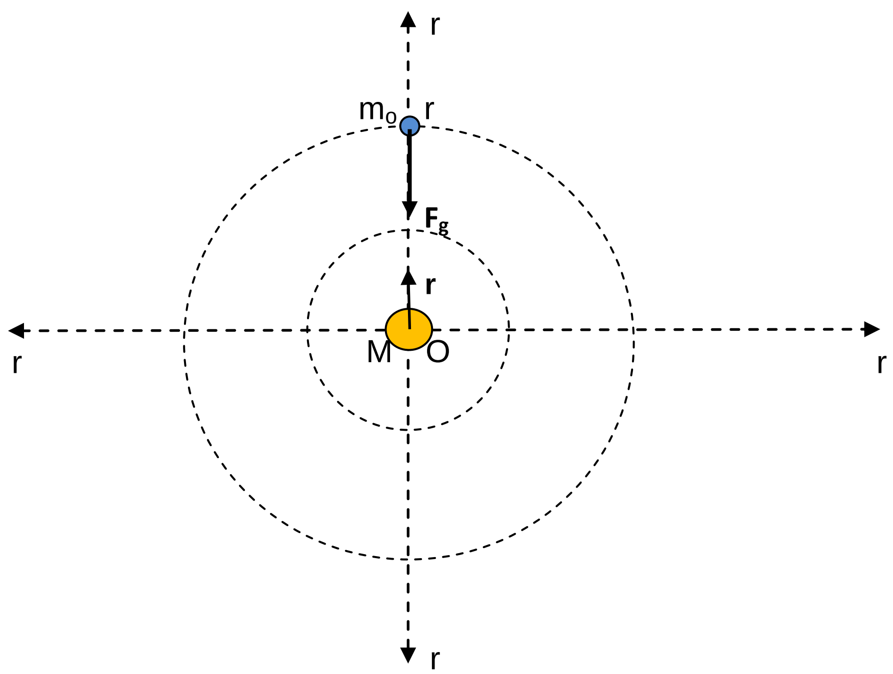

Fig.2 Representation of the gravitational force acting on the trial mass m_o.

Considering the intensity $E_g(r)=GM/r^2$ of the field, the gravitational potential of field is given by

$$U(r) = \int_{\infty}^{r} E_g(r)\,dr = -\frac{GM}{r} \qquad (9)$$

and it is in accordance with the definition given in the relation (4).
It follows that the potential energy $E_p(r)$ of the trial mass m_o is

$$E_p(r) = m_o U(r) = -\frac{GMm_o}{r} \qquad (10)$$

It must be noted also that the gravitational field is a field of non-uniform central force which depends on the square of the distance r between the barycentre of the central mass (pole) and the barycentre of mass that undergoes the gravitational force.
In the theory of gravitational field here developed the gravitational force isn't a force at distance, as instead it is considered in the Newtonian model, because it is caused by the presence of the gravitational potential, that is generated by the pole M, in every point of the physical space of S, since the initial instant in which the pole M is placed or forms in O. The gravitational field is also characterized by lines of force which have the property that a trial body, placed in a point of field, moves along the force line passing for that point. Besides the greater density of lines of force in a region of field represents the greater intensity of field in that region. Lines of force, generally curved, recall the concept of curvature in the Einsteinian gravitational model, where nevertheless the real deflection of light in the gravitational field, according to the line of force in that point, is assumed to be in arbitrary manner the kinematic curvature of the space-time.

3. Type I gravitational field

The type I gravitational field $\mathbf{E_g}$ is generated by any physical system (pole) constituted by an active (rotary) mass M_o that is placed in the origin O of a reference frame supposed at rest S[O,r,t]. The presence of the mass M_o generates in the physical space of S, at every distance r from the origin, a gravitational potential U(r) with central and spherical symmetry that characterizes the gravitational field of the mass M_o. In the type I gravitational field, the mass m_o placed at the distance r is inert and generally is $m_o \ll M_o$. The gravitational force, as per the (6), is given by

$$\mathbf{F_g}(r) = -\frac{GM_o m_o}{r^2}\,\mathbf{r} \qquad (11)$$

The gravitational field at every distance r is therefore defined by

$$\mathbf{E_g} = \frac{\mathbf{F_g}}{m_o} = -\frac{G\,M_o}{r^2}\,\mathbf{r} \qquad (12)$$

Generally the type I gravitational field causes the physical phenomenon of fall of bodies that now we examine. Dynamics of fall of bodies is described by the general law of the gravitational motion[2][3]

$$m_o \frac{dv(t)}{dt} + kv(t) = \frac{G\,M_o\,m_o}{r^2} \qquad (13)$$

in which k is the resistant coefficient of medium.

From the equation (13) we deduce that the speed of fall v(t) depends in general on the mass m_o because of the presence of the external resistant force kv(t). Supposing that external resistant forces are null (k=0) the speed of fall is independent of the mass m_o. In these conditions we have

$$\frac{dv(t)}{dt} = \frac{G\ M_o}{r^2} \qquad (14)$$

Assuming that

$$\frac{dv}{dt} = -\ v\ \frac{dv}{dr} \qquad (15)$$

and supposing that at the initial time t=0 the mass m_o is at the distance r_o with null initial speed $v(0)=v(r_o)=0$, integrating the (14) we have

$$v(r) = \sqrt{\frac{2\ G\ M_o}{r_o}\ \frac{r_o - r}{r}} \qquad (16)$$

The (16) represents the speed of fall of body in the absence of external resistant forces (fig.3). We can observe in figure that in the median range (r_1, r_2) of the fall the motion of the mass is accelerated in uniform manner with good approximation, while the acceleration in the beginning of fall is practically infinite like near the pole.

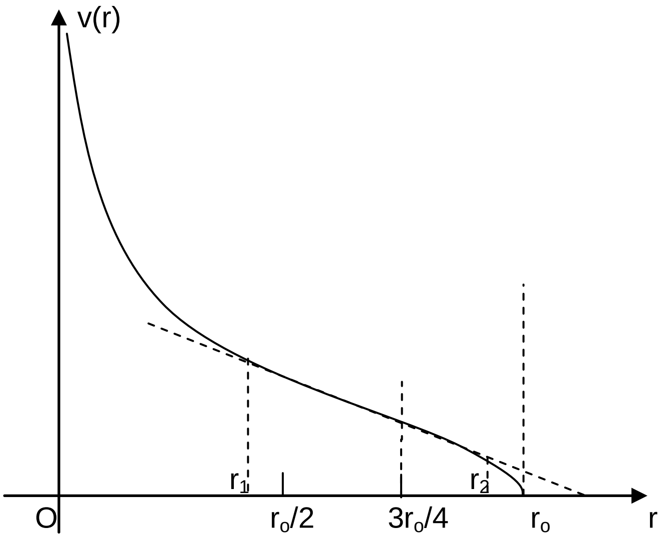

Fig.3 Trend of the speed of fall of a body in the absence of external resistant forces.

In the event that the body with mass m_o comes from infinitely great distance ($r_o=\infty$) the (16) becomes

$$v(r) = \sqrt{\frac{2\ G\ M_o}{r}} \qquad (17)$$

and it is represented by the graph of fig.4.

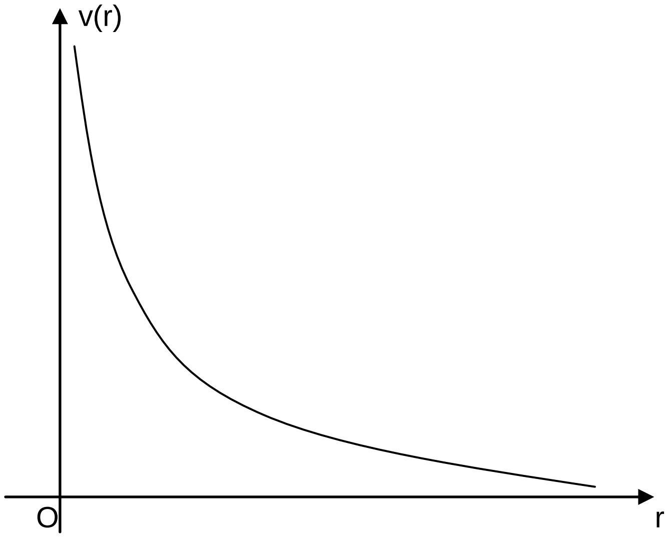

Fig.4 Trend of the speed of fall of a body in the absence of external resistant forces in the event that it comes from infinitely great distance.

The law of gravitational motion (13) is valid not only for ordinary masses but also for elementary particles, whether massive particles or energy quanta. For massive particles (electrons, protons, etc..) we can repeat the same reasoning made for classical bodies considering the electrodynamic mass in place of inertial mass and in the absence of external resistant forces (k=0) we have the same result of speed defined by relations (16) and (17) and by graphs of fig.3 and fig.4.
We know electrodynamic mass of charged particles changes with the speed, but when k=0 the speed of fall is independent of mass and therefore the relativistic effect of variation of electrodynamic mass has no effect on the fall in these conditions.
With regard to energy quanta, that compose the light and in general all electromagnetic radiations with greater frequency than infrared radiation, we know they are energy particles (E=hf) that move with the physical speed of light c. Every energy quantum can be represented by an equivalent mass[3][4][5]

$$m_f = \frac{hf}{c^2} = \frac{h}{\lambda c} = \frac{p}{c} \qquad (18)$$

where f and λ are frequency and wavelength of quantum, $p=h/\lambda$ is the momentum of quantum. Because of its equivalent mass every energy quantum, under the effect of the gravitational field generated by the pole, undergoes an attraction force that causes the following law of motion for quantum (fig.5)

$$\frac{dv}{dt} = \frac{GM_o}{r^2} \qquad (19)$$

from which we deduce, according to the (15),

$$v \frac{dv}{dr} = -\frac{GM_o}{r^2} \qquad (20)$$

In that case v is the physical speed c of energy quanta and therefore replacing we have

$$c \frac{dc}{dr} = -\frac{GM_o}{r^2} \qquad (21)$$

in which the variation dc of the physical speed of energy quantum is caused by the gravitational field. Integrating the (21) we have

$$c(r) = \sqrt{c_o^2 + \frac{2GM_o}{r_o} \frac{r_o - r}{r}} \qquad (22)$$

The (22) represents the radial speed of energy quanta that move in radial manner into the gravitational field starting from the distance r_o.

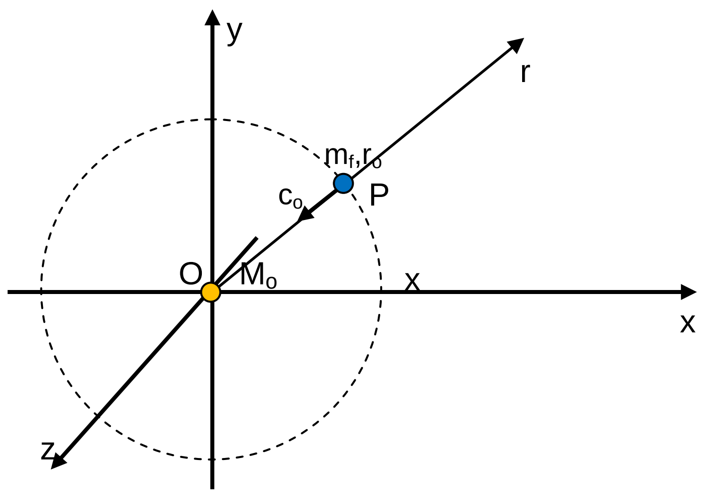

Fig.5 Type I gravitational field in which the mass M_o in the origin O is the pole and the equivalent mass m_f of energy quantum is initially in the point P at the distance r_o from the pole, where it has speed c_o.

It needs to specify the (22) doesn' t represent the relativistic speed of both light and energy quanta, which changes with the relative velocity among different reference frames, but the physical speed, with respect to the reference frame S supposed at rest, which changes in that case because of the gravitational field. The generally measured speed is just the physical speed with respect to local reference frame S in which light and energy quanta move. In the event of earth's reference frame, if it is measured along equipotential or almost-equipotential paths, that are tangential with respect to the earth's surface, the measured physical speed is constant. If instead it is measured along radial paths, we will have smallest variations with respect to the constant value c_o. Charting the (22) we obtain the graph of fig.6.

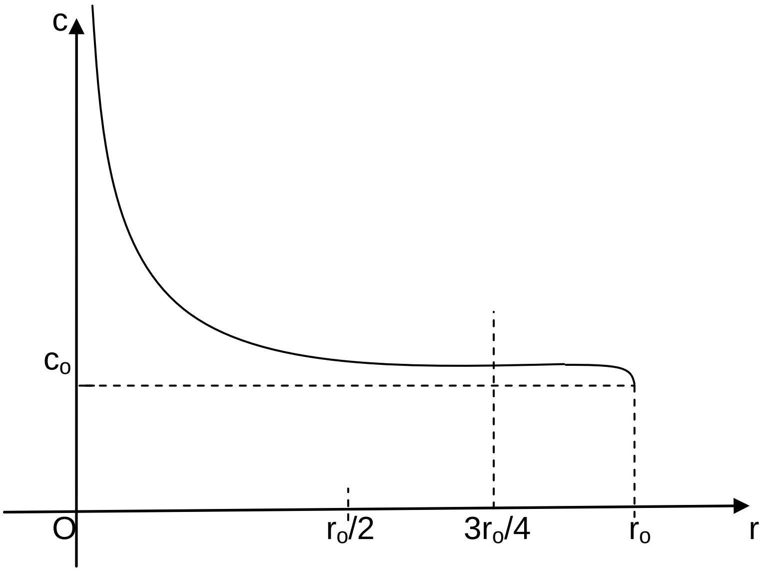

Fig.6 Trend of the physical speed of light and energy quanta that move in radial direction into the type I gravitational field.

If light and quanta come from infinitely great distance ($r_o=\infty$), we have

$$c(r) = \sqrt{c_o^2 + \frac{2GM_o}{r}} \qquad (23)$$

and the corresponding graph is represented in fig.7

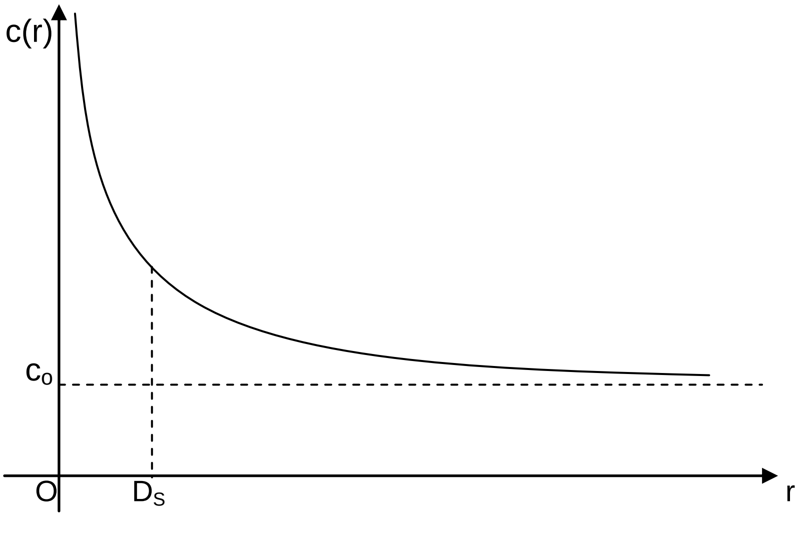

Fig.7 Trend of the physical speed of both light and energy quanta that move in radial direction into the type I gravitational field and come from infinite distance.

Calculating we derive

$$\frac{2GM_o}{c_o^2 r} \ll 1 \qquad \text{for} \qquad r \gg \frac{2GM_o}{c_o^2} = D_S \qquad (24)$$

where D_S is the Schwarzschild distance of the pole mass and it equals 2.95 km for the sun and 8.85 mm for the earth. Because the Schwarzschild distance is relatively small we can suppose that the speed of light is practically constant and equal to c_o into the useful gravitational field of the pole mass. It accounts for the condition $c \approx c_o$ assumed in ref.[6] for the speed of light in the gravitational field of the sun. It is easy to verify that for all celestial masses, and consequently also for the sun, the speed of light with radial motion into the gravitational field, at the Schwarzschild distance, equals the critical speed $v_c = 2\ c$.
With regard to electromagnetic waves (with smaller frequency and greater wavelength than infrared rays), it is possible to repeat the same reasonings that have been made for optical systems with the difference in that case the equivalent mass is associated to the entire electromagnetic wave and not to single energy quanta, like in the event of light and radiations.

4. Type II gravitational field

Type II gravitational field is due to the attraction force operating between two active masses M_1 and M_2. The physical effect of the interaction between the two active masses is an orbital motion[2][3] in which one of the two masses, for instance M_1, generally the greatest mass, works like pole with central symmetry, and the other M_2 works like orbital mass.
In the event that the pole mass is fixed, the orbital motion would be a circumference with equation

$$\frac{x^2}{R^2} + \frac{y^2}{R^2} = 1 \qquad (25)$$

where R is the radius of the circular orbit (fig.8).

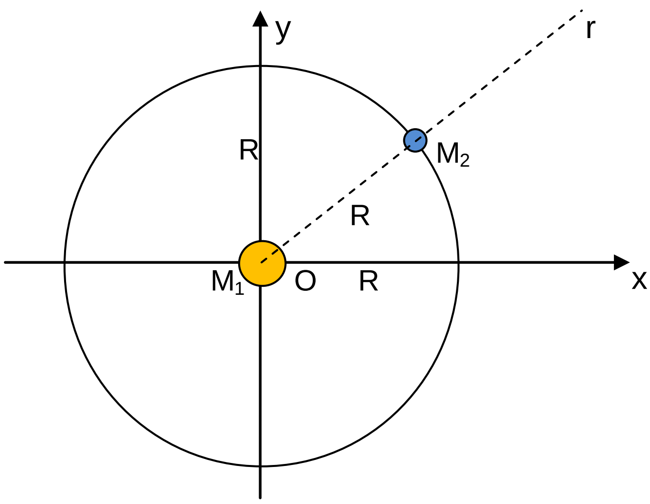

Fig.8 Type II gravitational field generated by an active mass acting on an active mass.

In actuality orbit isn't circular because the mass M_1 working like pole isn't effectively fixed because of the reaction force of the orbital mass M_2 against M_1. Consequently also the mass M_1 moves along a small circular orbit and the composition of the two motions generates an elliptic orbit that has equation

$$\frac{x^2}{R_x^2} + \frac{y^2}{R_y^2} = 1 \qquad (26)$$

The point O', seat of the pole, is the main focus, R_x and R_y are the two semi-axes of the orbit, $h=\sqrt{R_x^2-R_y^2}$ is the distance of the focus O' from the origin O and $e= h/R_x$ is the orbit eccentricity (fig.9).
In every instant t and for every distance d between the two active masses, the orbital motion is generated by the equilibrium of both, the attraction force and the centrifugal force

$$\frac{GM_1M_2}{d^2} = M_2\frac{v^2}{d} \qquad (27)$$

from which

$$v = \sqrt{\frac{GM_1}{d}} \qquad (28)$$

where v is the orbital tangential speed.

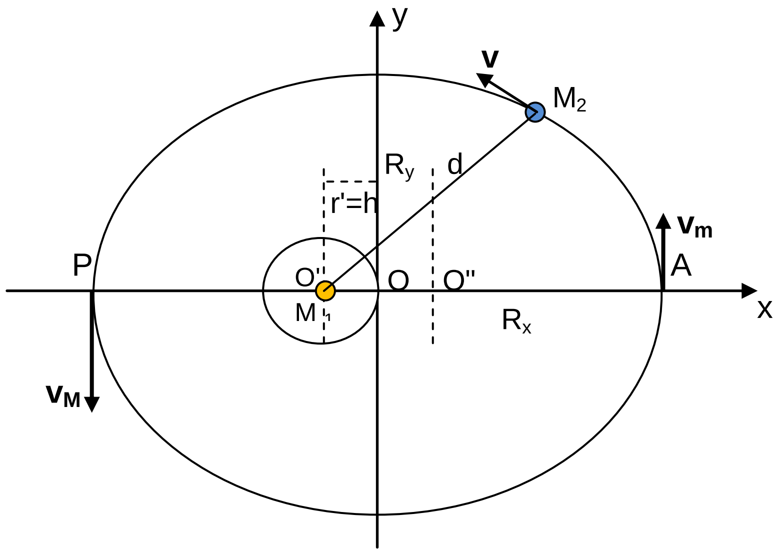

Fig.9 Elliptic orbit generated by a Type II gravitational field

We observe orbital motion is possible only if the (28) is fulfilled. Specifically we see also the orbital tangential speed isn't constant, as it happens with circular orbits, but it depends on the distance d which is variable in case elliptic orbits. The point P of the orbit is the perihelion where the distance from the pole mass is minimum and the orbital tangential speed is maximum. The point A instead is the aphelion in which the distance from the pole is maximum and the tangential speed is minimum.
The orbital motion can be obtained also supplying an inert mass M_2 with an orbital tangential speed, given by the (28), and in that case we have an artificial orbital motion.

5. Type III gravitational field

As per the Cavendish original experiment and the most recent experiments made by more advanced technologies the real presence of an attraction force between two inert masses m_1 and m_2 has been verified and it coincides with the Newton universal attraction force, given by

$$F_g(r) = \frac{Gm_1m_2}{r^2} \qquad (29)$$

where r is the distance between the two masses.
The same experiments have allowed also the accurate calculation of the gravitational constant $G=6.67 \times 10^{-11}$ [Nm^2/kg^2], whose value will can be further improved. It's manifest that every mass generates its own gravitational field and gravitational potential, given by

$$E_{g1}(r_1) = \frac{Gm_1}{r_1^2} \qquad U_1(r_1) = -\frac{Gm_1}{r_1}$$
$$E_{g2}(r_2) = \frac{Gm_2}{r_2^2} \qquad U_2(r_2) = -\frac{Gm_2}{r_2} \qquad (30)$$

The two fields are almost equal because generally $m_1 \approx m_2$ and the attraction force is caused by the interaction between gravitational fields of the two masses
Type III gravitational field, unlike preceding two types, doesn't have central symmetry because no of the two inert masses is really a pole.
We want to remind here that a recent experiment performed by Louis Rancourt, and still in phase of countercheck and adjustment, has proved that a shaft of light passing between two masses changes the effect of attraction. This effect, if further confirmed, would represent an important freshness in the order of interactions between gravitational systems and electromagnetic systems.

6. Gravitational perturbation

In dynamics of Type I gravitational field $a_t=g=dv/dt$ represents the time acceleration or gravitational acceleration and $a_r=-dv/dr$ represents the space acceleration. From (15) we deduce

$$\frac{dv}{dt} = v\, a_r \qquad (31)$$

in which $v=-dr/dt$. From (31) we deduce still

$$a_r = \frac{a_t}{v} \qquad (32)$$

While the time acceleration has the usual physical dimensions $[a_t]=[m/s^2]$, the space acceleration has dimensions of a frequency $[a_r]=[s^{-1}]=[Hz]$.
The time acceleration $g=a_t$ isn't constant and depends on the distance r

$$a_t = g = \frac{GM_o}{r^2} \qquad (33)$$

The space acceleration of a body, falling in the gravitational field from the distance r_o, according to the (16), is given by

$$a_r(r) = -\frac{dv}{dr} = \frac{1}{2}\sqrt{\frac{2GM_o r_o}{r^3(r_o-r)}} \qquad (34)$$

and it is represented graphically in fig.10.

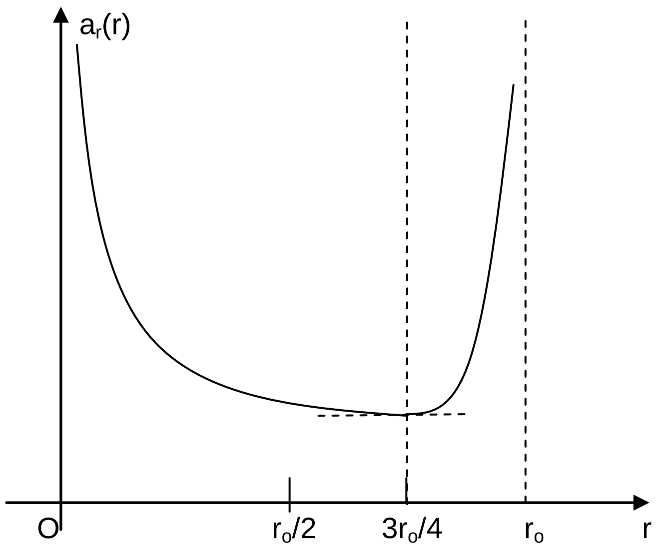

Fig.10 Trend of the space acceleration of a body in free fall from the distance r_o in the Type I gravitational field.

The presence of a physical quantity a_r with physical dimensions of frequency induces to suppose the presence in the Type I gravitational field of a propagative phenomenon in which the inverse of the space acceleration represents the duration T_p, where

$$T_p = \frac{1}{a_r} = 2r\sqrt{\frac{r(r_o - r)}{2GM_o r_o}} \qquad (35)$$

The graph of the duration T_p is just the opposite of the graph a_r in fig.10.
This propagative phenomenon represents a gravitational perturbation that is generated by the interaction of the gravitational field caused by the mass m_o in free fall with the primary gravitational field caused by the pole M_o.
The gravitational field of the pole M_o supplies the mass m_o with the potential energy $E_p(r)$, that as per the (10) is given by

$$E_p(r) = m_o U(r) = -\frac{GM_o m_o}{r} \qquad (36)$$

Because in the gravitational field the total energy $E_t(r)$, given by the sum of both the potential energy $E_p(r)$ and the kinetic energy $E_c(r)$, is constant and equal to

$$E_t(r) = -\frac{GM_o m_o}{r_o} \qquad (37)$$

we deduce that the energy $W_p(r)$ of the gravitational perturbation equals, for every r, just the kinetic energy $E_c(r)=m_o v^2/2$, and therefore for the (16) we have

$$W_p(r) = E_c(r) = \frac{GM_o m_o}{r_o} \frac{r_o - r}{r} \qquad (38)$$

The (34) implies

$$a_r (r_o - r) = \frac{r_o}{2r} v(r) \qquad (39)$$

and from the (39) we deduce physical characteristics of the gravitational perturbation

$$\begin{aligned} \text{perturbation radial length} \quad & \lambda_p = r_o - r \\ \text{perturbation duration} \quad & T_p = 1/a_r = 1/f_p \\ \text{perturbation speed} \quad & c_p = \lambda_p / T_p = \lambda_p f_p \end{aligned} \qquad (40)$$

The front speed of the gravitational perturbation, for every r, is therefore given by

$$c_p(r) = \frac{r_o}{2r} v(r) = \sqrt{\frac{GM_o r_o (r_o - r)}{2r^3}} \qquad (41)$$

A graphic representation of perturbation for every value of r is given in fig.11.
The non-primordial gravitational perturbation has continuous, circular and non-quantum nature. It propagates perpendicularly to the fall direction of the mass m_o.
When r decreases, the speed $c_p(r)$, the energy $W_p(r)$ and the space length λ_p increase.
The perturbation duration instead presents a maximum for $r=3r_o/4$.
In the earth's gravitational field a body of 100kg, which falls from the height of 100km with respect to the earth's surface, generates in corrispondence of the earth's surface a gravitational perturbation with an energy Wp=96.59 MJ, a speed c_p=705.7m/s, an expanse λ_p=100km and a duration T_p=141.7s.

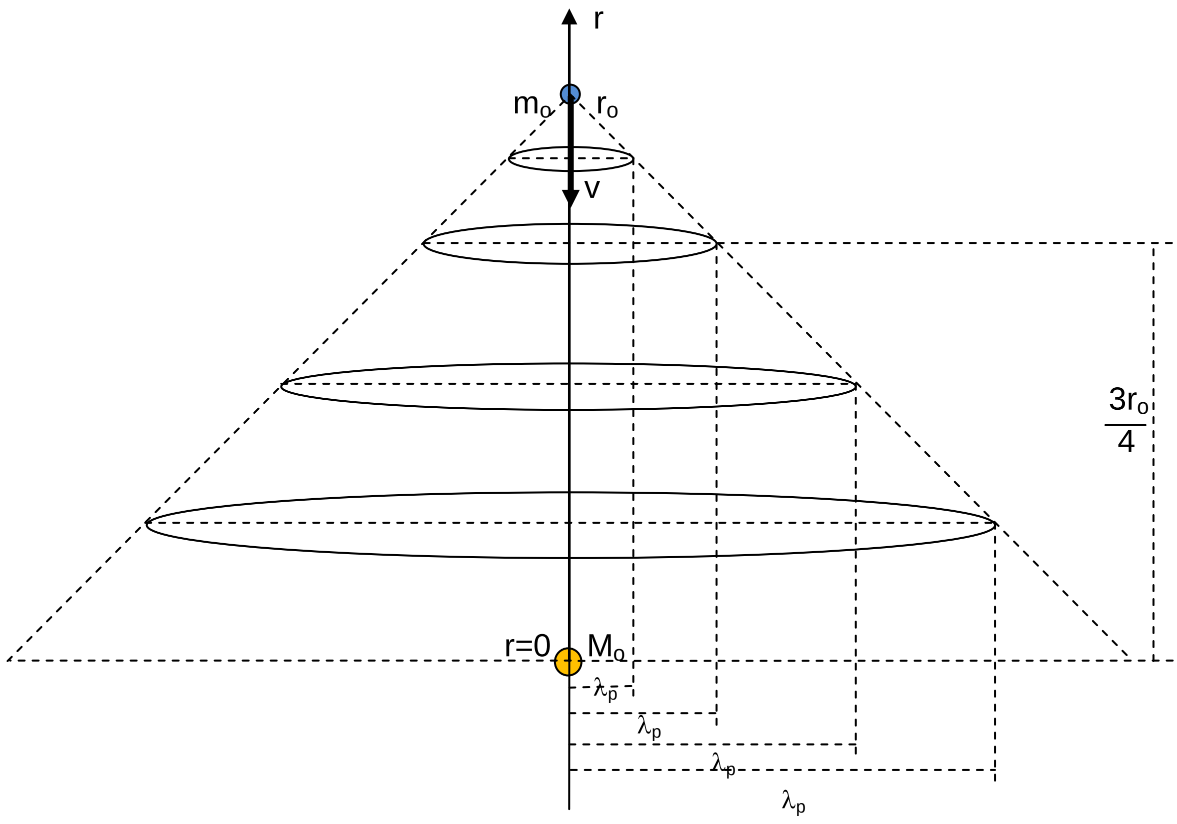

Fig.11 Trend of the circular gravitational perturbation for different values of r and λ_p.

7. The multiple gravitational field

The multiple gravitational field presents more than two masses and it can be considered a sort of Type IV gravitational field. It is easy to verify that this type of gravitational field doesn't have central symmetry (fig.12). Let's suppose that M_1 and M_2 are pole masses and m_o is the trial mass.
In that case in any point P, where the mass m_o is placed, at distance r_1 from the pole M_1 and at distance r_2 from the pole M_2, the following gravitational potentials overlap

$$U(r_1) = -\frac{GM_1}{r_1} \qquad U(r_2) = -\frac{GM_2}{r_2} \qquad (42)$$

The following gravitational fields work

$$\mathbf{E_{g1}} = -\frac{G\,M_1}{r_1^2}\,\mathbf{r_1} \qquad \mathbf{E_{g2}} = -\frac{G\,M_2}{r_2^2}\,\mathbf{r_2} \qquad (43)$$

and consequently the following gravitational forces

$$\mathbf{F_{g1}} = -\frac{GM_1m_o}{r_1^2}\,\mathbf{r_1} \qquad \mathbf{F_{g2}} = -\frac{GM_2m_o}{r_2^2}\,\mathbf{r_2} \qquad (44)$$

The resultant potential, the resultant field and gravitational force in the point P are

$$U_t(r_1,r_2) = -G\left(\frac{M_1}{r_1} + \frac{M_2}{r_2}\right) \quad (45)$$

$$\mathbf{E_{gt}} = -G\left(\frac{M_1}{r_1^2}\mathbf{r_1} + \frac{M_2}{r_2^2}\mathbf{r_2}\right) \quad (46)$$

$$\mathbf{F_{gt}} = -Gm_o\left(\frac{M_1}{r_1^2}\mathbf{r_1} + \frac{M_2}{r_2^2}\mathbf{r_2}\right) \quad (47)$$

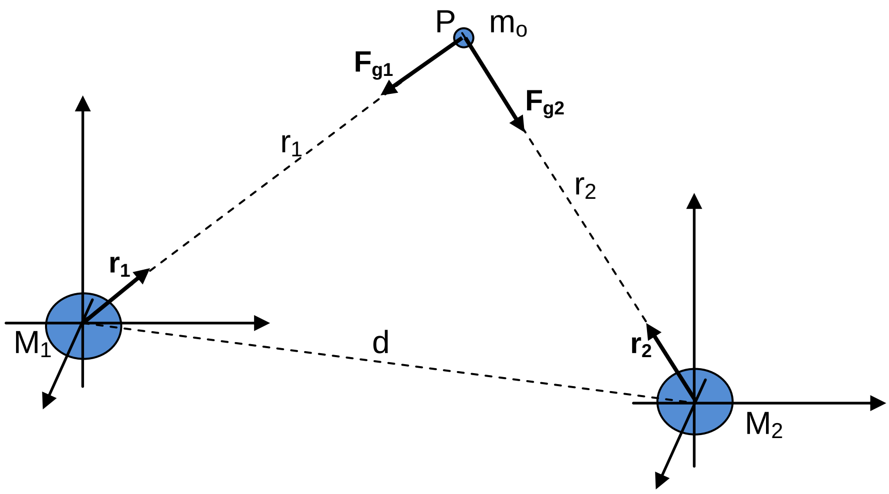

Fig.12 Type IV gravitational field with two pole masses and one trial mass.

The analysis of obtained results allows to affirm that the gravitational field, like all other physical fields, follows the principle of superposition with regard to vector magnitudes but not to scalar magnitudes. It means that if for instance the pole M_1 works with a force of 2 Newtons on the trial mass m_o and the pole M_2 works with a force of 3 Newtons, the resultant force working on m_o isn't a force of 5 Newtons. In actuality also the vector superposition is valid only if poles M_1 and M_2 are fixed and bound. In fact if the two poles are free to move, because of the reciprocal gravitational force of attraction also the vector superposition isn't more valid.

References

[1] D. Sasso, On Primary Physical Transformations of Elementary Particles: the Origin of Electric Charge, viXra.org, 2012, id: 1201.0053

[2] D.Sasso, Physico-Mathematical Fundamentals of the Theory of Reference Frames, viXra.org, 2013, id: 1309.0009

[3] D. Sasso, Dynamics and Electrodynamics of Moving Real Systems in the Theory of Reference Frames, arXiv.org, 2010, id: 1001.2382

[4] D. Sasso, Relativity and Quantum Electrodynamics in the Theory of Reference Frames: the Origin of Physical Time, viXra.org, 2011, id:1109.0018

[5] D. Sasso, On Different Meanings of Mass in Physical Systems, viXra.org, 2014, id: 1401.0047

[6] D. Sasso, Predictions on Observations and Measurements of the Deflection of Light on the Occasion of 2015 Solar Eclipse According to the Theory of Reference Frames, viXra.org, 2014, id: 1401.0188