Not linear element, cosmological redshift and deflection of light in the gravitational field

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Abstract

Starting from some questions on General Relativity we make a few critical considerations in concordance with the Theory of Reference Frames (TR).
TR represents firstly a critical viewpoint and secondly an alternative solution with regard to whether Special Relativity or General Relativity, moreover it represents a new answer to problems of dynamics of motion. The new definition of not linear element is the most important concept expressed in this article and particularly we consider the physical explanation of the change of the linear element into a not linear curved element when it is in a gravitational field. In the absence of gravitational field, the geodetic (trajectory along which the work carried out by a force is the smallest) coincides with the linear element and inside the gravitational field it changes into the curved element. We prove that in a gravitational field this change is caused by energy reasons and not by the space and time kinematic warp. A few classical experiments, like cosmological redshift and deflection of light, at last are considered and a new interpretation is given outside General Relativity.

Contents

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1. Critical considerations on General Relativity

The Theory of Reference Frames[1[[2][3] answers questions on inertial and not inertial reference frames (specifically for accelerated reference frames) making use of both the Principle of Reference and the Principle of Relativity. In Einstein's theory questions on accelerated reference frames are treated in General Relativity through the equivalence between accelerated motion and motion in a gravitational field. From the kinematic viewpoint both Minkowski's[4] space-time and Einstein's[4][5] space-time make use of imaginary coordinates. In fact the linear element of Einstein's space-time in the absence of gravitational field is

$$ds^2 = - dx_1^2 - dx_2^2 - dx_3^2 + dx_4^2 \qquad (1.1)$$

We can write the (1.1) like this

$$ds^2 = (i\, dx_1)^2 + (i\, dx_2)^2 + (i\, dx_3)^2 + dx_4^2 \qquad (1.2)$$

where i is the imaginary unit, ix_1 ix_2 ix_3 are the imaginary space coordinates and x_4 is the real time coordinate. Minkowski's linear element is instead

$$ds^2 = dx_1^2 + dx_2^2 + dx_3^2 - c^2dt^2 \qquad (1.3)$$

or similarly

$$ds^2 = dx_1^2 + dx_2^2 + dx_3^2 + (i\, cdt)^2 \qquad (1.4)$$

In Minkowski's space-time the space coordinates x_1 x_2 x_3 are real while the fourth coordinate ict linked to time is imaginary. Moreover in Minkowski's space-time the conservation of physical dimensions is respected while in Einstein's space-time the four coordinates are considered homogeneous similarly.
Then Einstein assumed that under the influence of the gravitational field the linear element of space-time can be represented by the following general relationship

$$ds^2 = \Sigma_{ij}\ g_{ij}\, dx_i\, dx_j \qquad i= 1, 2, 3, 4 \ ; \quad j= 1, 2, 3, 4 \qquad (1.5)$$

where the g_{ij} parameters are the components of the fundamental tensor with 16 elements

$$\begin{pmatrix} g_{11} & g_{12} & g_{13} & g_{14} \\ g_{21} & g_{22} & g_{23} & g_{24} \\ g_{31} & g_{32} & g_{33} & g_{34} \\ g_{41} & g_{42} & g_{43} & g_{44} \end{pmatrix} \qquad (1.6)$$

that respects the relationships of symmetry $g_{ij} = g_{ji}$ with $i \neq j$ (1.7)

From (1.7) it follow that the gravitational field is represented by 10 g_{ij} different components. In the empty space-time where the gravitational field is null the relationships (1.7) become

$$g_{ij}=g_{ji}=0 \qquad \text{with} \quad i \neq j \tag{1.8}$$

It follow that in the absence of gravitational field Einstein's space-time is represented only by 4 tensor components that are, considering the (1.1)

$$g_{11}= -1 \qquad g_{12} = -1 \qquad g_{13} = -1 \qquad g_{14} = +1 \tag{1.9}$$

and the fundamental tensor becomes

$$\begin{pmatrix} -1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & +1 \end{pmatrix} \tag{1.10}$$

With regard to the linear element we have to resolve two questions:

a. is it right to renounce real coordinates and to introduce imaginary coordinates whose physical meaning is dubious?
b. is it right to renounce the different physical nature of space and time and to describe the external world by the single space-time that is neither space nor time and is measurable whether by metres or by seconds?

My answer to these two questions is negative.

2. Coordinates and reference systems

Coordinate is a number that represents the value of any physical quantity with respect to the prefixed standard unity. In general the purpose of physical sciences is to describe the evolution of physical events that happen in a fixed region of space, in a fixed interval of time, in fixed conditions of temperature, of pressure, etcetera. For the correct description of physical event accordingly it is suitable to can command an adequate group of physical quantities that are appropriate for the complete description of event. The group of physical quantities that are essential strictly to the complete description of the event represents the reference system (frame) of event. Generally in order to have a direct and immediate understanding of the event it is useful to represent physical quantities by orientated axes with a common origin. For some events it is important to define the position where the event happens and in that case (x,y,z) coordinates of position are integral part of the reference system. For other events it isn't important to define the position and in that case other physical quantities are used for the description of event. We can have theoretically reference systems with an any n number of coordinates.

3. Linear element and not linear element

The Δs linear element is the length of the line joining two A and B points of the empty space (vacuum) (Fig.1)

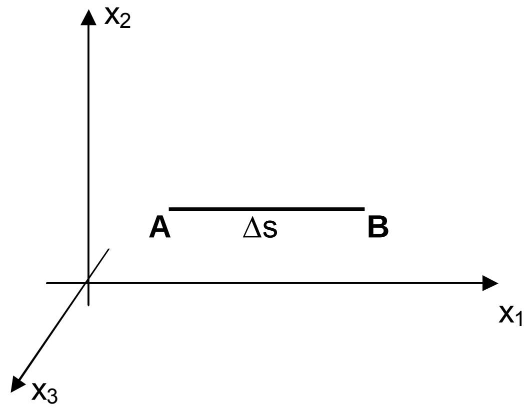

Fig.1 Graphic representation of the linear element in the reference frame (x_1,x_2,x_3)

In order to definy completely the Δs linear element is sufficient to know the position coordinates of the two points, $A(x_1, x_2, x_3)$ and $B(x_1+\Delta x_1, x_2+\Delta x_2, x_3+\Delta x_3)$, with respect to the $S[x_1,x_2,x_3]$ reference frame with three space coordinates. In fact

$$\Delta s^2 = \Delta x_1^2 + \Delta x_2^2 + \Delta x_3^2 \qquad (3.1)$$

If the two A and B points are very close the linear element has infinitesimal length and is represented by ds. In that case the space coordinates of the two points are $A(x_1, x_2, x_3)$ and $B(x_1+dx_1, x_2+dx_2, x_3+dx_3)$ and the length of the linear element is

$$ds^2 = dx_1^2 + dx_2^2 + dx_3^2 \qquad (3.2)$$

The linear element considered in figure 1 is rectilinear, but it is possible to join the two A and B points also by a L curved line with $\Delta s'$ length and in that case the element is not linear (Fig.2).

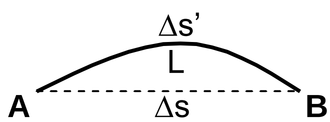

Fig. 2 The L element with $\Delta s'$ length is a not linear curved line

We have to define now the $\Delta s'$ curved element. In the first place we observe that the $\Delta s'$ curved element is always greater than the Δs linear element: $\Delta s' > \Delta s$. In second place we observe that while the Δs linear element is unique, i.e. there is an only straight line joining the two A and B points, there are on the contrary countless curved lines joining the same two points (Fig.3).

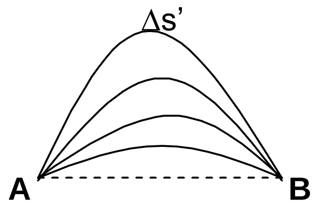

Fig. 3 There are numerous curved lines joining A and B two points.

The first question now is: what among the infinite curved elements do we must consider? The second question is: why and when does the curved element must take the place of the linear element? The answer to these two questions is fundamental for further developments of our considerations.
Let us consider then a physical entity (material point, mass, photon, light ray, electromagnetic wave, etc.…) that must cover the AB distance. Among the infinite possible trajectories what is the real trajectory that physical entity will use in order to link the A and B points?
Accordind to the Quantum Mechanics all the trajectories are similarly possible and therefore the real trajectory is defined by probabilistic considerations. It is right think this answer isn' t always acceptable and indeed it can be assumed only when there is an insufficient knowledge of the problem or a deficiency of analysis of the physical situation. On this account we prefer to give a more satisfactory answer and this demands a more detailed analysis of the problem. To that end it is suited to examine three different physical situations:

1. the A and B points are in a vacuum
2. the two points are on the surface of matter
3. the two points are in the gravitational field.

3.1 The linear element in a vacuum

A vacuum in our definition is the Euclidean three-dimensional space devoid of both matter and field. The Euclidean vacuum has only a geometric meaning defined by the three space coordinates to which it is possible to add each time, according to observed physical event, the time coordinate, the speed coordinate, the temperature coordinate, etcetera. In a vacuum the linear element ds is represented by the straight line joining the two A and B points: $ds^2 = dx_1^2 + dx_2^2 + dx_3^2$. In Fig.4 we have dx_1=dx_3=0 and therefore ds^2=dx_2^2 from which ds=dx_2. We can also write

$$ds = 2r\,tg\alpha \qquad (3.3)$$

We call “geodetic” the line joining the two A and B points, along which the work (dL=Fds) executed by any F constant force for carrying the material point from A to B is minimum.

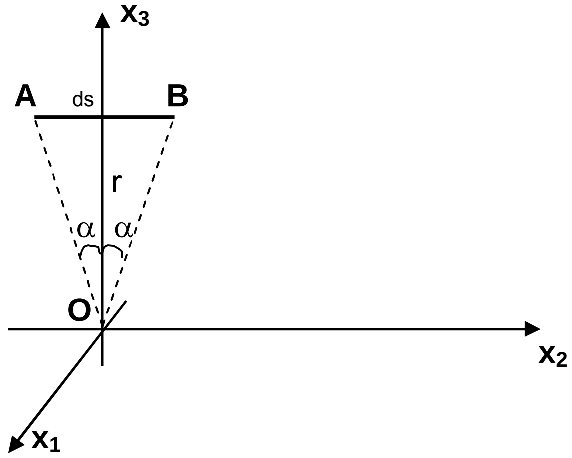

Fig. 4 The ds linear element in a vacuum is a straight line

According to this definition the geodetic in a vacuum is the straight line joining the two A and B points because it is the shortest line.

3.2 The not linear element on the curved surface of matter

If the surface of matter is plane the linear element can be defined as in a vacuum. If the surface of matter is curved then the element isn' t linear and has a different meaning. Let us consider therefore two A and B points on a curved surface (Fig.5).

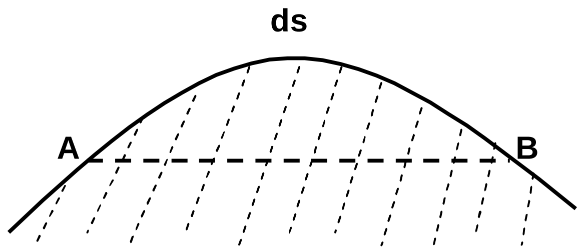

Fig. 5 The ds element on the curved surface is a curved line defined by the curvature of surface

If matter filling the curved surface is rigid then it is manifest a material point in order to move from A to B must go along the curved line defined by surface of matter. In that case the ds curved element coinciding with the surface of matter is the shortest curved line joining the two points on the surface and the geodesic line is defined just by the curvature of matter.

3.3 The not linear element in the gravitational field

Let’s suppose that A and B are two points in space and F_c is the force of the gravitational field generated by the mass M_o placed in the point O (Fig.6).

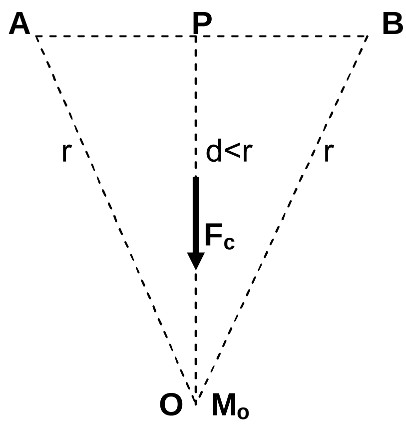

Fig. 6 The A and B points are placed in the gravitational field generated by the M_o mass

The gravitational field has central symmetry[3] and the O point is the pole of the field. The gravitational force of attraction is inversely proportional to the square of distance $F_c=k_a/r^2$ where $k_a=GM_om$ is the action constant. The gravitational field generates in every point a potential energy $E_p(r)= - k_a/r$.
If the O pole of the gravitational field is at infinite distance from the A and B points, the action of the gravitational field in the two points is null and therefore the examined physical situation is coincident with that one in a vacuum. In that case the geodetic joining the two points is the straight line. As that O draws near to the joining line the two points, the intensity of the gravitational field in the two points increases. Let’s suppose besides that the O pole is on the perpendicular line passing through the P central point, like in fig.6.
It’s manifest that along the AB straight line the gravitational field doesn’t have the same intensity in every point because the distance of every point of the line from O is variable. If a material point must move from A to B under a F force, the material point meets a perturbative force first increasing from A to P because the distance r decreases and after decreasing from P to B. It’s also manifest the only line joining the two points along which the gravitational field is constant is the curved line whose points are equidistant from the O pole.
This curved line from A to B coincides with the arc of a c_L circle whose centre is the O pole (Fig.7) and along it the gravitational field doesn’t generate a perturbation to the movement of the material point from A to B.

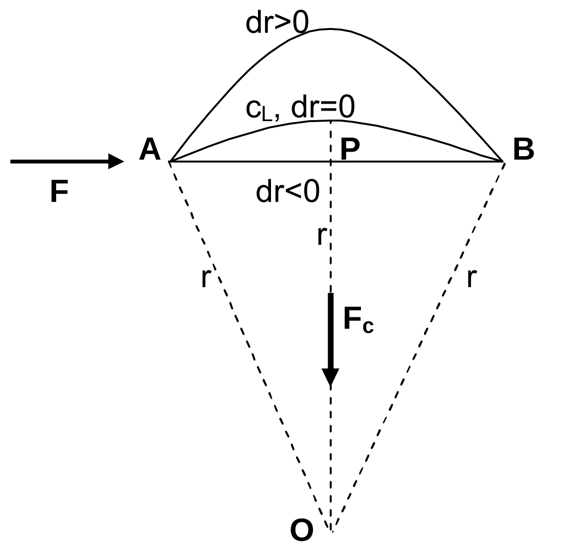

Fig. 7 The only line joining the two A and B points along which the gravitational field doesn't generate a perturbation to the movement of the material point from A to B is the arc of circle whose centre is the O pole. F is a constant force and is external to the field.

If F is a constant force, external to the F_c field and applied in order to move the material point from A to B, the work carried out by the force F is $dL=Fds$.
Our problem is now to search for the geodetic from A to B in front of gravitational field. All the possible lines joining the two A and B points respect along their path one of following three conditions

a. dr<0
b. dr>0
c. dr=0

The a condition (dr<0) comprises also the straight line joining the two A and B points. Along all these lines the F_c gravitational field carries out a work $dW=-dE_p$ that moves the material point towards the pole and removes it from the desired trajectory towards B. Because $dE_p=F_c dr<0$ the work carried out by the gravitational field along any curve that respects the condition dr<0 is positive. In these conditions the dL_t total work carried out by the F force to move the material point from A to B must be able also to offset the dW work carried out by the gravitational field:

$$dL_t=dL+dW>dL=Fds \qquad (3.4)$$

The condition b. (dr>0) isn't realizable in the described situation because F_c is a force field of attraction towards the pole O and the condition dr>0 involves a departure from the pole.
The condition c. (dr=0) is respected only by the c_L curved line that coincides with the arc of a circle whose centre is the pole O. Along this line we have $dE_p=0$

and dW=0. In that case the total work carried out by the F force coincides with dL and assumes therefore the minimum of energy. It follows that the geodetic in front of gravitational field is given by the c_L curved line which is also the equipotential line joining the two points.
In the absence of gravitational field, in a vacuum, the geodetic coincides with the straight line joining the A and B two points. In front of gravitational field the geodetic is modified in the c_L curved line. Such change in front of gravitational field isn' t produced by the space and time warp but is produced by the curvature of the geodesic line for energy' s sake. In front of gravitational field the A point moves in A' and the B point in B' (Fig.8), the linear element ds changes in the c_L curved geodesic line characterized by dr=0. At the same time the ds linear distance between the two points A and B changes into the linear distance ds'<ds between the two A' and B' points. In figure we have $dx_1=dx_3=0$ and therefore it is also $ds=dx_2$.

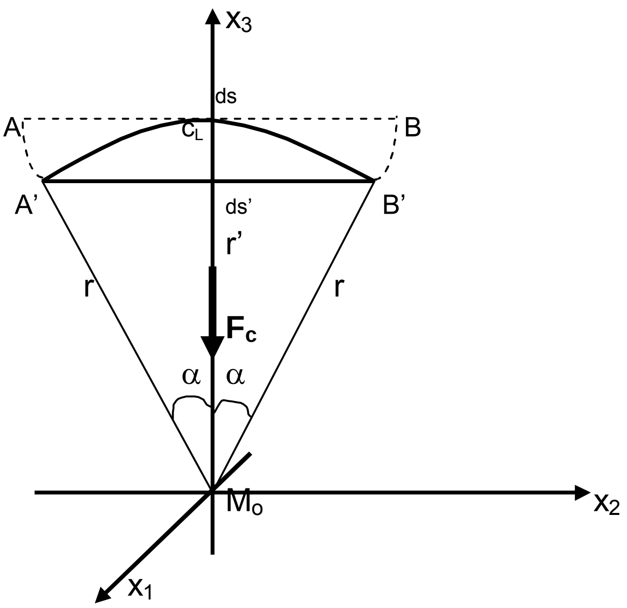

Fig. 8 In the gravitational field the ds linear geodetic changes into the c_L curved geodetic

From the figure we derive

$$ds' = 2\, r \sin \alpha = 2\, r' \,\mathrm{tg}\, \alpha \qquad (3.5)$$

and because in the absence of gravitational field, according to the (3.3), $ds=2r\,\mathrm{tg}\alpha$ we have

$$ds' = \frac{r'}{r}\, ds \qquad (3.6)$$

Because $r'=r\cos\alpha$ we have also

$$ds' = ds \cos\alpha < ds \qquad (3.7)$$

The O pole with M_o mass generates in a vacuum a gravitational field

$$F_g = \frac{G\,M_o}{r^2} \qquad (3.8)$$

and a force of attraction on the material point with m_o mass

$$F_a = \frac{G\,M_o\,m_o}{r^2} \qquad (3.9)$$

The material point moves with v speed along the curved element and therefore it is under the action of the centripetal force

$$F_c = \frac{m_o\,v^2}{r}$$

and being $F_c=F_a$ we have

$$r = \frac{G\,M_o}{v^2} \qquad (3.10)$$

Because $r' = r\cos\alpha$ it is

$$r' = \frac{G\,M_o}{v^2}\cos\alpha \qquad (3.11)$$

and from (3.5) we derive finally

$$ds' = \frac{2G\,M_o}{v^2}\sin\alpha \qquad (3.12)$$

Because $ds'=ds\cos\alpha<ds$ we can also say in front of gravitational field the ds linear distance undergoes an effect of contraction changing into ds' but the c_L geodesic curved element maintains the same length as the ds linear element. We have therefore proved that in the gravitational field the modification of the geodetic is caused by energy reasons and not by the space and time warp.

4. Atomic theory of cosmological redshift

In General Relativity the existence of a cosmological redshift due to the gravitational field is proved and it overlaps to the relativistic Doppler effect. On this account it is hard to measure the cosmological redshift because it is necessary to eliminate Doppler shifts from observed shifts. Experiments effected in 1921[6] and in 1928[7] demonstrated that cosmological or gravitational redshift (called also “Einstein effect”) is really in light that is emitted by the sun and arrives at the earth. The effected measures gave for the Einstein effect relative to the light coming from the

sun the value $\Delta f/f_T = -0{,}2 \times 10^{-6}$, where $\Delta f = f_S - f_T$, f_S is the frequency of the spectrum line emitted on the sun and f_T is the frequency of the same spectrum line emitted on the earth.
We want now to give for the cosmological redshift a different explanation from that proved in General Relativity.
The Doppler effect is a variation of both frequency and wavelength whether for electromagnetic waves or for light (made up photons that are nanowaves[8][9]) caused by relative velocity between emitting source and receiving observer.
The Doppler shift is generated therefore after process of emission. In order to explain the cosmological redshift it is necessary to search for cause in the same act of emission. We know light is made up photons that are generated by quantum jumps of electrons in atom. Quantum jumps of energy are given[10] by

$$\Delta E = E_{n'k'} - E_{nk} = 2RhcZ^2 \left(\left(\frac{1}{n^2} - \frac{k^2}{2n^4} \right) \left(1 - \frac{1}{2} \frac{\alpha^2 Z^2 (k \pm s)^2}{n^4} \right) - \left(\frac{1}{n'^2} - \frac{k'^2}{2n'^4} \right) \left(1 - \frac{1}{2} \frac{\alpha^2 Z^2 (k' \pm s')^2}{n'^4} \right) \right) \quad (4.1)$$

and emitted frequencies are

$$f = \frac{\Delta E}{h} = 2RcZ^2 \left(\left(\frac{1}{n^2} - \frac{k^2}{2n^4} \right) \left(1 - \frac{1}{2} \frac{\alpha^2 Z^2 (k \pm s)^2}{n^4} \right) - \left(\frac{1}{n'^2} - \frac{k'^2}{2n'^4} \right) \left(1 - \frac{1}{2} \frac{\alpha^2 Z^2 (k' \pm s')^2}{n'^4} \right) \right) \quad (4.2)$$

where $R = e^4 m_o / 8\varepsilon_o^2 ch^3$ is the Rydberg constant and $\alpha = e^2/2\varepsilon_o ch$ is the Lamb constant[10]. More simply we can write that emitted frequencies on the surface of the earth are

$$f_T = \frac{e^4 m_T Z^2}{4\varepsilon_o^2 h^3} F(n,k,s,n',k',s') \quad (4.3)$$

where m_T is the electron electrodynamic mass on the surface of the earth and F is a function that equals the term in bracket in (4.2).
Because the emitted radiation on the sun and measured on the earth with respect to the same emitted radiation on the earth shows a frequency variation it is natural to think the electron electrodynamic mass has on the sun a different m_S value from m_T[11]. On this account emitted frequencies by the same atom on the surface of the sun are

$$f_S = \frac{e^4 m_S Z^2}{4\varepsilon_o^2 h^3} F(n,k,s,n',k',s') \quad (4.4)$$

From (4.3) and (4.4) we deduce

$$\frac{\Delta f}{f_T} = \frac{f_S - f_T}{f_T} = \frac{m_S - m_T}{m_T} \qquad (4.5)$$

The variation of electrodynamic mass on the surfaces of the two celestial masses is related to the variation of the potential energy

$$\Delta m = m_S - m_T = \Delta E_p / c^2 \qquad (4.6)$$

where $\Delta E_p = E_p(S) - E_p(T)$ is the difference between the electron gravitational potential energy on the surface of the sun and on the surface of the earth. Moreover we know

$$E_p(S) = m_S\, U(S) \qquad \text{with} \quad U(S) = -\frac{GM_S}{r_S} \qquad (4.7)$$

$$E_p(T) = m_T\, U(T) \qquad \text{with} \quad U(T) = -\frac{GM_T}{r_T} \qquad (4.8)$$

We obtain therefore

$$m_S - m_T = \frac{m_S U(S) - m_T U(T)}{c^2} \qquad (4.9)$$

$$m_S - m_T = \frac{G}{c^2}\left(\frac{M_T m_T}{r_T} - \frac{M_S m_S}{r_S}\right) = \frac{Gm_T}{c^2}\left(\frac{M_T}{r_T} - \frac{M_S m_S}{m_T r_S}\right) \qquad (4.10)$$

and because in any case the variation of electrodynamic mass $m_S - m_T$ is very small we can suppose in (4.10) $m_S/m_T \approx 1$ and therefore we have

$$m_S - m_T = \frac{Gm_T}{c^2}\left(\frac{M_T}{r_T} - \frac{M_S}{r_S}\right) \qquad (4.11)$$

We are now able to calculate the frequency shift due to the variation of electrodynamic mass between the earth' s surface and the sun' s surface.

$$\frac{\Delta f}{f_T} = \frac{f_S - f_T}{f_T} = \frac{m_S - m_T}{m_T} = \frac{G}{c^2}\left(\frac{M_T}{r_T} - \frac{M_S}{r_S}\right) \qquad (4.12)$$

The (4.12) is valid also for any star different from the sun.
From the (4.12) we deduce in particular:

a. if the star coincides just with the earth we have $M_S=M_T$, $r_S=r_T$ and $f_S=f_T$. The earth doesn' t produce on the earth a cosmological redshift.
b. If the star coincides with the sun we have $M_S/r_S >> M_T/r_T$ and therefore

$$\frac{\Delta f}{f_T} = \frac{f_S - f_T}{f_T} = -\frac{GM_S}{c^2 r_S} \qquad (4.13)$$

Replacing the values of G, M_S, c, r_S we obtain just $\Delta f/f_T = -0{,}2\times10^{-6}$ that is the experimental measure of the cosmological redshift generated by sun light.
Also in the Theory of Reference Frames the "Einstein effect" is accurately proved.

5. Deflection of light near to celestial masses

In General Relativity Einstein proved the gravitational field causes a deflection of light near to celestial masses and he calculated the numeric value of this deflection in the event of both the sun (Δ=1,75" seconds of degree) and Jupiter (Δ=0,2" seconds of degree). As from 1919 numerous astronomers have effected experiments in order to measure the numeric value of the deflection of light caused by the sun.
The following experimental results[4] , at times also very different, have been observed on the occasion of total solar eclipses:

Δ= 1,61" (1919, Guinea)
Δ= 1,98" (1919, Brazil)
Δ= 2,36" (1922, Australia)
Δ= 1,77" (1922, Australia)
Δ= 2,13" (1936, Japan)
Δ= 2,01" (1947, Brazil)
Δ= 1,70" (1952, Sudan)

It is possible to observe most of these values are significantly different from the theoretical value calculated by Einstein with respect to the sun (Δ=1,75"). It is also possible to observe the average value of all the measured values of deflection is Δ_m=1,94" and therefore with respect to Einstein' s theoretical value the average percentual error is around 10% which exceeds much the conventional experimental error of measure which is around 1%. Moreover the pointed out error isn' t systematic but statistical from which it follows that randomness is implicit in the considered physical phenomenon and not in the mistaken systematic management of experiments. These considerations induce to think the deflection of light is generated by a cause which has a random intrinsic nature. The most acceptable hypothesis on the deflection of light is that it is due to properties of light and in particular to refraction[12] and we will make use here of this property in order to explain it.
Let us consider at first the situation in which light comes from a star which is on the right of the r straight line near to celestial mass and parallel to the conjoining

line the centres of gravity of both the earth and the celestial mass (fig.9). D_r is the real direction of light, but because of refraction generated by the atmosphere of the celestial mass, the earth's OT observer detects a different and parallel D_a direction.
The h distance between these two directions represents the shift that light undergoes because of the atmosphere of the celestial mass. The h shift must be then transformed into the Δ_o angular deflection (optical deflection). We observe moreover light in reality undergoes a double process of refraction.

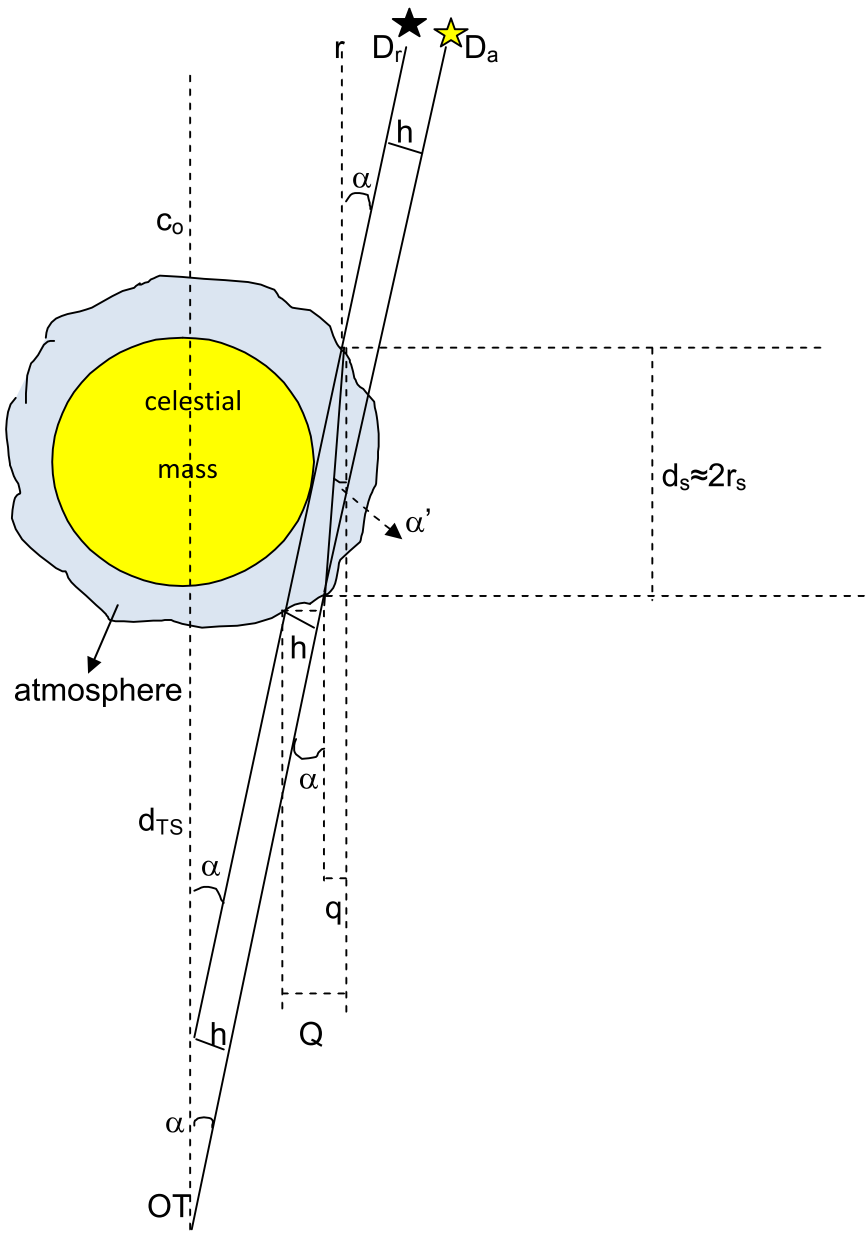

Fig. 9 Because of the double process of refraction of light due to the atmosphere of the celestial mass the OT observer detects light comes from the D_a apparent direction instead of the D_r real direction.

In the first process of refraction we have

$$\frac{\sin\alpha}{\sin\alpha'} = \frac{c_o}{c_s} \qquad (5.1)$$

where $c_o = 1/\sqrt{\varepsilon_o\mu_o}$ is the speed of light in a vacuum, ε_o and μ_o are respectively the dielectric constant (permittivity) and the magnetic permeability in a vacuum. Moreover $c_s = 1/\sqrt{\varepsilon_s\mu_s}$ is the speed of light in the atmosphere of celestial mass, ε_s and μ_s are respectively the permittivity and the permeability of its atmosphere. α is the angle of incidence of light with respect to the atmosphere, α' is the angle of refraction in the atmosphere.
In the second process of refraction we have

$$\frac{\sin\alpha'}{\sin\alpha} = \frac{c_s}{c_o} \qquad (5.2)$$

The effect of the double process of refraction isn' t a variation of the direction of star light (in fact the two directions D_r and D_a are parallel) but only a h linear shift. In the event of the sun we have (see fig.9)

$$Q \approx 2r_s\mathrm{tg}\alpha \qquad (5.3)$$

$$q \approx 2r_s\mathrm{tg}\alpha' \qquad (5.4)$$

where $r_s \approx 697 \times 10^3$ Km is the radius of the sun. Continuing in calculation we have

$$Q - q = 2r_s\,(\mathrm{tg}\alpha - \mathrm{tg}\alpha') \qquad (5.5)$$

$$h = (Q-q)\cos\alpha \qquad (5.6)$$

$$h = 2r_s\,(\mathrm{tg}\alpha - \mathrm{tg}\alpha')\cos\alpha \qquad (5.7)$$

With good approximation $\mathrm{tg}\alpha \approx r_s/d_{ts} = 4{,}65 \times 10^{-3} << 1$ where $d_{ts} \approx 150 \times 10^6$km is the average distance between the sun and the earth. Because α is very small $\cos\alpha \approx 1$ and for the (5.7)

$$h = 2r_s\,(\mathrm{tg}\alpha - \mathrm{tg}\alpha') \qquad (5.8)$$

The α and α' angles are very small and have the same order of magnitude because the speed of light in a vacuum and in the sun atmosphere aren' t very different. Therefore it is possible to assume, being $\mathrm{tg}\alpha \approx 4{,}65 \times 10^{-3}$,

$$(\mathrm{tg}\alpha - \mathrm{tg}\alpha') \approx 10^{-3} \qquad (5.9)$$

and

$$h \approx 2r_s 10^{-3} \qquad (5.10)$$

From the h linear shift we derive the angular deflection

$$\Delta_o \approx \frac{h}{\sqrt{(d_{ts} + r_s)^2 + r_s^2}} \approx \frac{h}{d_{ts}} \qquad (5.11)$$

being $r_s \ll d_{ts}$. In conclusion we have

$$\Delta_o \approx \frac{2r_s}{d_{ts}} 10^{-3} = 9{,}29 \times 10^{-6} \text{ radians} \qquad (5.12)$$

Converting radians into seconds of degree the angular deflection of light is Δ_o=1,92” and this value is very near to the measured average value (we call “Hannon effect” this optical deflection of light due to the double refraction in the atmosphere of the celestial mass).

Variability of the measured values about deflection depends on the noteworthy activeness of the sun atmosphere which generates a variability in time of the values of ε_s permittivity and μ_s permeability because of strong thermal differences in the different layers of the sun atmosphere. It generates a variability of the speed of light in the sun atmosphere and therefore a variation of tgα’. Assuming tgα-tgα’=$0{,}85 \times 10^{-3}$ we have a value Δ_{omin}=1,63” which coincides almost perfectly with the measured minimum value of deflection. Assuming tgα-tgα’=$1{,}20 \times 10^{-3}$ we have a value Δ_{omax}=2,30” which is very near to the measured maximum value. The explanation here provided about deflection of light near to celestial masses when light comes on the right of the r straight line is very satisfactory and at the same time accounts for also variability of measured values.

If light, coming from star, is on the left of the r straight line it is manifest that deflection of light cannot be explained by the process of refraction because in that case light couldn’ t reach the earth’ s observer. Let us see then if deflection can be explained by the effect of gravitational field produced by celestial mass on light (fig.10). In that event we consider that light is a photon beam. Photons are energy quanta (E=hf) which move with the speed of light and have an equivalent electrodynamic mass m_f=hf/c^2. We don’ t know if electrodynamic mass is sensible to gravitational field as inertial mass. Inertial mass is sensible to gravitational field because it has the same nature of mass which generates the gravitational field. Certainly electrodynamic mass doesn’ t generate gravitational field but we don’ t know if it is sensible to gravitational field.

If we point out the existence of a deflection of light due to gravitational field then the problem has affirmative answer.

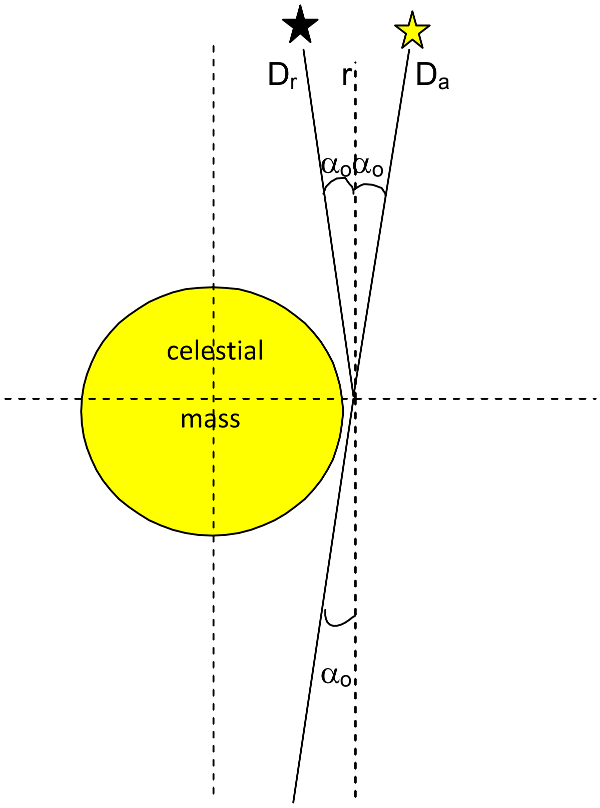

Fig. 10 Deflection of light due to the gravitational field of celestial mass

Let us consider therefore a shaft of light as a photon beam coming from star which is on the left of the r straight line.
Suppose that each photon under the effect of the gravitational field of celestial mass experiences a deflection that can be calculated considering that in gravitational motion we have[3]

$$v \frac{dv}{dr} = - \frac{GM}{r^2} \qquad (5.13)$$

In our case v is the c speed of photons and therefore

$$c \frac{dc}{dr} = - \frac{GM}{r^2} \qquad (5.14)$$

where M is the celestial mass which generates deflection.
Continuing in calculation and considering that $d\text{sen}\alpha/\text{sen}\alpha_o = dc/c_o$ where c_o is the speed of light in a vacuum and because $c \approx c_o$ we have

$$\int d\text{sen}\alpha = \text{sen}\alpha_o \left(- \frac{GM}{c_o^2} \int \frac{dr}{r^2} \right) \qquad (5.15)$$

If Δ' is the half-deflection from infinite distance to r_M distance, because deflection angles are very small, in first approximation we have

$$\Delta' = \frac{GM}{c_o^2 r_M} \, sen\alpha_o \qquad (5.16)$$

where r_M is the radius of celestial mass. The complete deflection is

$$\Delta_g = 2\Delta' = \frac{2GM}{c_o^2 r_M} \, sen\alpha_o \qquad (5.17)$$

In the event that the celestial mass is the sun and the observer is on the earth, being $sen\alpha_o \approx r_S/d_{TS} = 4{,}65 \times 10^{-3}$ we have

$$\Delta_g = 0{,}0196 \times 10^{-6} \text{ radians} = 0{,}004'' \text{ (seconds of degree)} \qquad (5.18)$$

We observe in the case of the sun the Δ_g gravitational deflection, if there is, is about 0,2% than the Δ_o optical deflection and for this account the gravitational deflection is very hard to measure.
We call "Einstein second effect " this hypothetical effect of gravitational deflection of light.

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