WHAT DOES THE WORK IN A GRAVITATIONAL FIELD?

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ABSTRACT

Introducing a new type of "nonlocal" theoretical quantity relative to standards in a fixed field, it is shown that the mass-energy conservation is a consequence of more elementary "nonlocal" principles for photons. No net exchange of "nonlocal" energy would exist between bodies or photons and the external field. Gravitational work would be done “by the body”, not by the field as traditionally assumed.

With the help of an electromagnetic model for matter the field becomes identified as a space with a gradient of "nonlocal" velocity of light which explains its properties. The results are self-consistent and consistent with traditional physics in weak fields. Agreement with gravitational tests and relativistic cosmic ray spectrum is obtained by assuming that "nonlocal" masses are the true sources of the fields.

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I. INTRODUCTION

A basic assumption made in physics is that the conservative work is done "by the field". When Einstein[2] justifies his equation for the theory of general relativity, he states that "the gravitational field transfers energy and momentum to matter in that it exerts forces upon it and gives it energy" . This traditional hypothesis seems most reasonable, but it has never been demonstrated. The present study shows that the opposite alternative - that the field does not transfer net energy to matter - is consistent with well-established principles and with experimental facts.

One difference between the two alternatives is similar to the one existing between a man accelerated by some external force whose application point displaces with the man and a man accelerating himself by pushing a fixed wall in the opposite direction. The wall gives up only the momentum for the conversion of man's internal energy into kinetic energy of the same man. The relativistic mass of the man relative to the ground should remain constant at a difference with the first case in which the relativistic mass increases.

In order to establish true relations between "nonlocal" quantities, a new theoretical quantity is used here in which everything is expressed in terms of physically equivalent standards. For this reason, this study has been done independently of traditional theories on gravitation. General demonstrations have been made in several different ways with the use of rather trivial theoretical experiments leaving a single hypothesis for final check with gravitational tests. Unimportant details

have been omitted for reasons of space.

II. DEFINITIONS

It is reasonable to expect that the field should determine the properties of matter and of the "local" reference frames. Atoms of the same isotope may not have the same rest mass, diameter and natural emission spectrum when they are at rest in different fields. In spite of this, local observers at the same field of the atoms could not observe such changes because their local standards should have also changed in identical proportions.

Classical quantities would thus not be well defined for "nonlocal" cases in fields if some effect of the field on matter does exist. They should not be used for "nonlocal" cases unless the effects of the field on matter may be neglected.

It is of fundamental importance that "nonlocal" relations are expressed in terms of "physically equivalent" standards, condition insured only when the standards are in a fixed field all at the time.

"Nonlocal" quantities

They are defined here as the true quantity that should theoretically exist - according to well established principles - at a well-defined object location in the field, not expressed in terms of the local standards of the object but in terns of the standards of the observer who is in a fixed field - or at - - at rest relative to the

centre of mass of the system. The location of the observer is the one of his standards which influence on the main field is neglected. They are not directly observable and one of the aims of this study is just to discover straightforward relations between them and with the properties of the space.

Names such as "apparent" or "true" have been proposed for these quantities [11,12]. The names "nonlocal" and "relative" are used here because they seem even more related to it. The word "local" is used when there is no appreciable difference of field between the object and the observer. In obvious cases the words "local" or "nonlocal" are omitted.

The notation used in a central field - for example - for the "nonlocal" mass of a test body travelling with a velocity $\boldsymbol{b}$ (relative to that of light) is: $m_{r'}(\boldsymbol{b},r)$. The radial distances r and r' fix well-defined fields at the object and at the observer, respectively. The value of r' is a constant unless otherwise indicated. The velocity $\boldsymbol{b}$ is dimensionless and therefore independent of the standards and of the location of the observer.

$$\boldsymbol{b} = v_{r'}(r)/c_{r'}(r) = v_r(r)/c_r(r) \quad (2.1)$$

r and r' and may be omitted when their values are unimportant. When r' is omitted, it is understood that the observer is at r or at . The subscript of r is also omitted for simplicity. For photons, the place of a in this notation may be used for the velocity of the source.
The "nonlocal" concept of mass used here corresponds to the inertial one which therefore includes any kind of energy that is bound

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and accelerates with the body. This includes not only its kinetic energy but also any kind of energy that could be associated to its own field that obviously accelerates with the body. No arbitrary separation is made here between the body and its field. This concept is somewhat more general to the one of "relativistic" mass because its value depends not only on $\boldsymbol{b}$ but also on the "relative" field properties at the object location as compared with the ones at the (theoretical) observer.

Standards

Some standard atom at rest in a free and unexcited state has been selected as a test body. Its "local" rest-mass becomes the unit for both: local mass and local energy.

$$m^o_{r'}(0,r') = m^o_r(0,r) = m^o_\infty(0,\infty) = m^o = E^o = 1 \qquad (2.2)$$

The "local" wavelength of, some well-defined spectrum line emitted by the "local" standard atom at rest has been selected as the standard unit of "local" length. Its "local" period To is the "local" unit of time. Its "local" frequency is also unity. Observe that the "local" velocity of light - $c_r(r)$ - is a constant due to the implicit normalization made by local observers when they assign values to their standards.

$$l^o_{'r'}(0,r') = l^o_{r'}(0,r) = l^o_{r'}(0,\infty) = l^o = 1 \qquad (2.3)$$

$$T^o_{r'}(0,r') = T^o_r(0,r) = T^o_\infty(0,\infty) = T^o = 1 \qquad (2,4)$$

$$f^{o}_{r'}(0,r') = f^{o}_{r}(0,r) = f^{o}_{\infty}(0,\infty) = f^{o} = 1 \qquad (2.5)$$

$$c_{r'}(r') = \frac{l_{r'}(0,r)}{T_{r'}(0,r')} = c_{r}(r) = c = 1 \qquad (2.6)$$

From (2.6), the gradient of the "local" velocity of light, when both the observer and the object change of position, is:

$$\frac{dc_{r'}(r')}{dr'} = \lim_{r \to r'} \frac{\partial c_{r'}(r)}{dr'} + \lim_{r \to r'} \frac{\partial c_{r'}(r)}{dr} = 0 \qquad (2.7)$$

But the gradient of the "nonlocal" velocity of light, with respect to an observer in a fixed position, is:

$$\frac{\partial c_{r'}(r)}{\partial r} \neq 0 \qquad (2.8)$$

Expressions similar to (2.7), (2.B) would hold for "nonlocal" masses, frequencies, length and time.

In some cases it is simpler to select an electron-positron pair or a “positronium atom” as standard. One of the gamma photons resulting from its annihilation into N=2 photons may be chosen as standard radiation. From (2.2), (2.5):

$$E^{o}_{r}(r) = nhf^{o} = nh = 1 \qquad (2.9)$$

from which the Planck constant is the same for any local observer and equal to the fraction of the standard mass - 1/N - emitted in the standard photon, according to the well defined structure of matter.

Observers located in fields of different magnitude would have non equivalent standards of mass, length and time. Their "local" physical reference frames would be parallel to the corresponding theoretical (flat) reference frame used here only within an infinitesimal "local" volume. The trajectory of light or a straight rule would become curved under the influence of the field, as shown below.

The time delay for a "nonlocal" observation due to the finite velocity of light has often been omitted, for simplicity.

III. NONLOCAL PRINCIPLES

It is trivial to show that the mass-energy conservation principle is a "nonlocal principle”. It has proved its validity even when the observer and his standards are outside of the strong field involved e.g. in atoms, nuclei, etc. It is reasonable to expect that this
principle is a consequence of even more basic "nonlocal" principles for more elementary objects such as "photons" or bodies in conservative fields.

"Nonlocal" principles for photons

Static conservative fields cannot change the net number of events observed by monochromatic electromagnetic radiation travelling freely through them along a well-defined trajectory. This rather obvious fact seems to be the most elementary principle relating "local" and "nonlocal" quantities.

Assume that the observer at *r′* sends a continuous train of n waves towards the observer at r, both observers being at rest in a static conservative field. The first wave and the final one of the train should travel through the same space with the same instantaneous velocities. Then they should take the same time to travel between r''and r. The theoretical "nonlocal" time interval $\Delta t_{r'}(r)$ for the observer at *r′* should therefore remain constant during the trip.

$$\Delta t_{r'}(r) = \left[t^1_{r'}(r') + \int_r^{r'} \frac{ds_{r'}(r)}{c_{c'}(r)} \right] - \left[t^2_{r'}(r') + \int_r^{r'} \frac{ds_{r'}(r)}{c_{c'}(r)} \right] = \Delta t_{r'}(r') \qquad (3.1)$$

where $t^1_{r'}(r')$ and $t^2_{r'}(r')$ are the "local" starting times of the first and the last wave, respectively.

Due to the fact that both the number of waves and the "nonlocal" time interval do not change during the trip, the "nonlocal" frequency also should not change.
From (3.1)

$$f_{r'}(r) = \frac{n}{\Delta t_{r'}(r)} = \frac{n}{\Delta t_{r'}(r')} = f_{r'}(r') \qquad (3.2)$$

The "nonlocal" energy of a photon depends only on its constant "nonlocal" frequency and the Planck constant which does not depend on the past history of the photons.
From (2.9), (3.2)

$$E_{r'}(r) = hf_{r'}(r) = hf_{r'}(r') = E_{r'}(r) = \text{Constant} \qquad (3.3)$$

It may be concluded that the number of waves, the "relative" frequency, and the "relative" energy of an electromagnetic wavetrain

should remain constant during its free trip in the field. “No net exchange of signals or of relative energy would exist between radiation and a static conservative field”. This seems to be a rather obvious conclusion because once that the temporary perturbation has gone away, the field should recover its original condition.
A trivial check may be made by assuming that (3.2) were not true and that a continuous wavetrain is sent from *r´* to *r* during a long time. Either accumulation or a deficiency of the waves produced in the space between *r'* and *r*, in disagreement with the observed facts. Gravitational red-shift is certainly not a phenomenon occurring during the trip of the waves but a real "nonlocal" time dilation occurring to matter in the field as shown below.

"Nonlocal" principles for bodies

According to the electromagnetic nature of matter, the same principle for the energy of photons is expected to be true for the mass of bodies. This is shown in the next theoretical experiment.

"Assume that a "positronium" test atom - or an e+-e pair - falls freely from r- in a gravitational field of a central "relative" mass M. Assume that annihilation occurs at r with the emission of two photons travelling in opposite directions symmetrically to the original path".

If the traditional hypothesis - that the central field gives up energy to the body- is assumed to be true, the "relative" mass of the

test atom should increase during the fall by the amount of "relative" energy presumably added by the central field.

$$m_{r'}(\boldsymbol{b},r) = m_{r'}(0,r) + \Delta M_{r'} \qquad (3.4)$$

When the test body annihilates itself, the resulting radiation conserves its "relative energy". According to (3.3),

$$m_{r'}(\boldsymbol{b},r) = 2E_{r'}(r) = 2E_{r'}(r') \qquad (3.5)$$

From (3.4), (3.5), the final energy $2E_{r'}(r')$ reaching the level of the observer is larger than the initial mass $m_{r'}(0,r')$ by the amount $DM_{r'}$. It would be, then, theoretically possible to use only part of the resulting energy into generation of a new test atom at the level *r'* which could repeat indefinitely the above cycle with the net result of converting the central mass into radiation. This is obviously an absurd situation unless:

$$\Delta M_{r'} = 0 \qquad m_{r'}(\boldsymbol{b},r) = m_{r'}(0,r') = \text{Constant} \qquad (3.6)$$

The same should happen for the observer at r

$$\Delta M_r = 0 \qquad m_r(\boldsymbol{b}, r) = m_r(0, r') = \text{Constant} \qquad (3.6)$$

The "relative" mass of a free body in a G field should therefore remain constant. Observe that the final "relativistic" mass $m_{r'}(\boldsymbol{b},r)$ is a particular case of a constant "relative" mass for all of the free fall.

$M_{r'}(0,r')$ is larger than $m_{r'}(0,r)$, obviously, just as $m_{r'}(0,r)$ is larger than $m_{r'}(0,r)$.

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Based on this fact, a test body may be replaced by a theoretical "light box" model of any appropriate form with massless and perfectly reflecting walls containing either a particle-antiparticle or a "positronium" atom, or - what is better - the standing waves resulting from the annihilation of the particles. For simplicity and due to the well defined (quantized) structure of matter, a well defined number of wave lengths will also define the length of the model in the field. It is reasonable to expect that the size of matter and the size of its theoretical model should be related by a constant of proportionality. For similar reason, it is assumed that the "relative" rest mass of the model, $m(0,r)$, is just equal to the energy $Nhf(0,r)$ of an even number of monochromatic quantum's of light confined in the box.

"Nonlocal acceleration of gravity"

The above model can not accelerate itself in the field unless a gradient of the "relative" velocity of light exists, as shown below. Assume two wavefronts of light starting simultaneously from the centre of the "light-box" in opposite vertical directions. After reflection they will meet at a level below the original centre only if the average "relative" velocity of light in the upper region is higher than the one in the lower region. If $dc(r)$ is the difference $c(r+dr)-c(r)$, then the average difference of "relative" velocities of the two wavefronts is $dc(r)/2$. After a time $dt(r) = dr/c(r)$, the net displacement of the centre of the box is (Fig.1):

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It may be concluded that "no net exchange of "relative" energy should exist between the central field and test bodies or photons travelling freely through it". Bodies would keep constant their "nonlocal" masses until some no conservative interaction takes place.
If the "relative" mass of each body of a system remains constant, the same should happen for the whole system of several bodies orbiting freely in the field of the others. The well known mass-energy conservation principle results. Vice versa, if this principle is valid for a system, it is simple to show that it should also be valid for each of its component in the field.

IV. NONLOCAL RELATIONS BETWEEN REST-MASS AND CONSERVATIVE WORK

The "local" application of special relativity to a free body in a field and the use of (3.7) give

$$m_r(\boldsymbol{b},r) = m_r(0,r)\left(1-\boldsymbol{b}^2\right)^{-1/2} = m_r(0,r') = \text{Constant} \qquad (4.1)$$

The difference $m_r(\boldsymbol{b},r)$-$m_r(0,r)$ is equal to the kinetic energy $E_{r'}$ and equal to the "relative" conservative work done. Using (4.1)

$$E_r = m_r(0,r') - m_r(0,r) = m_r(0,r)\left[\left(1-\boldsymbol{b}^2\right)^{-1/2} - 1\right] \qquad (4.2)$$

this may be expressed in terms of the standards at r´

$$E_{r'} = m_{r'}(0,r') - m_{r'}(0,r) = m_{r'}(0,r)\left[\left(1-\boldsymbol{b}^2\right)^{-1/2} - 1\right] \qquad (4.3)$$

Eq. (4.3) may also be obtained from the next theoretical experiment.

"Assume a large number of N standard atoms evenly distributed a spherical front of initial radius r^i, each of them tied to massless strings whose opposite end is connected to massless mechanisms at rest at r^i which transform work into other forms of energy which may either stay at r^i or escape to . When the atoms move quasistatically in the field of each other up to the level r^f, the mass-energy conservation applied to the system gives:

$$Nm_{r'}(0,r^i) = Nm_{r'}(0,r^f) + NE_{r'} \qquad (4.4)$$

this divided by N gives (4.3), for each atom. The same result should be obviously obtained if the front of atoms falls freely from r^i to r^f giving away the energy released by gravitational work in any imaginable way before coming to rest.

From (4.3), the "relative" rest-mass of a body becomes identified with its "nonlocal" potential energy in rather absolute terms. The gravitational work (or the energy released by it) is done at the cost of a decrease of the relative mass of the same test body.

V. NONLOCAL THEORETICAL PROPERTIES OF GRAVITATIONAL FIELDS

According to the mass-energy conservation principle, a box with perfectly reflecting walls can not change its weight or its trajectory in a gravitational field if any fraction of the matter contained in it is transformed into radiation provided that no radiation escapes from it

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$$dy = -\tfrac{1}{4} dc(r) dt(r) = -\tfrac{1}{2} g(0,r) dt(r)^2 \qquad (5.1)$$

$$g(0,r) = -\tfrac{1}{2} c(r) \frac{dc(r)}{dr} \qquad (5.2)$$

The acceleration of gravity *g(0,r)* is thus a consequence of the gradient of the "relative" velocity of light. The model virtually propagates itself towards regions of lower "relative" velocities of light.

The acceleration of gravity may also be determined from radiation travelling horizontally within the box. Assume, for example, a wavefront of radiation emitted along a vertical source OO´ of length *dr* (Fig.2) and propagating horizontally. The vertical displacement Δy of the wavefront after one wavelength of horizontal displacement occurring during $\Delta t(r) = \lambda(0,r)/c(r)$ may be determined from Huygens's principle:

$$g(0,r) = -c(r)^2 \frac{dLn\,\lambda(0,r)}{dr} \qquad (5.3)$$

The phenomenological reason for the conservation of the "nonlocal" mass during the free fall becomes clear now: the frequency of the downward waves become "blue-shifted" by Δf due to Doppler effect after successive reflections, while the upward ones become "red-shifted" by the same value. This internal rearrangement does not change the average "relative" frequency or mass within the box.

$$Nhf(\beta, r+\Delta r) = \frac{Nh}{2}\left[f(0,r)+\Delta f\right] + \frac{Nh}{2}\left[f(0,r)-\Delta f\right] = Nhf(0,r) \qquad (5.4a)$$

$$m(\beta, r+\Delta r) = m(0,r) \qquad (5.4b)$$

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This is equivalent to (3.7)

The general relation for the "nonlocal" weight of a body may be obtained after use of (4.3) assuming that the model falls from *r* to *r+dr* where it transforms - after collision, for example - its kinetic energy into radiation. Each internal wave would contribute with the energy *hdf(0,r)*. The gravitational work *dW(r)* is identical to the net energy released:

$$dW(r) = dE(r) = -Nhdf(0,r) = -dm(0,r) = F(0,r).dr \qquad (5.5)$$

From which

$$F(0,r) = -grad\{-m0,r\} \qquad (5.6)$$

F(O,r) _ - grad{ m(O,r)}   (5.6)

"Nonlocal effects of the field on matter at rest"

Using (5.2), (5.3), (5.5), *c(r) = f(0,r).* ***l****(0,r)* and *m(0,r) = Nhf(0,r),*

$$\frac{dm(0,r)}{m(0,r)} = \frac{df(0,r)}{f(0,r)} = \frac{dl(0,r)}{l(0,r)} = \frac{1}{2}\frac{dc(r)}{c(r)} \qquad (5.7)$$

Eq. (5.7) may also be obtained with the use of equations (5.20) which may constitute an independent check of the above expression. The three first members of (5.7) show that the ratio between frequencies and lengths – or any M/L ratio - is not distorted in bodies at rest in the field even

in "nonlocal" (theoretical) observations. The fourth member is the trivial consequence of the first ones.

Eq. (5.7) defines a dimensionless function ***f****(r)* which is independent of the field at the location of the observer. It relates the changes occurring in matter at rest after a change of *c(r).* Similarly to the traditional potential, ***f****(r)* may be defined as "the summation of the fractional changes of "relative" mass (or internal energy released) of a test body changed from a rest at   up to a rest at *r*." A more fundamental definition may be made in terms of (c(r).

$$f(r) = \int_{\infty}^{r} \frac{dm(0,r)}{m(0,r)} = \int_{\infty}^{r} \frac{dc(r)}{c(r)} = Ln\{m^{o}(0.r)\} = Ln\{c(r)\} \qquad (5.8)$$

It is important to emphasize here that the traditional concept of field potential is meaningless in strong fields due to the fact that during the integration along any trajectory across the field, the standards would be changing. The integration would have no more physical sense than the summation of personal incomes during a strong inflationary period. Only fractional, or percentage, changes are independent of the units used for measurements, at a difference with the absolute changes in terms of "local" standards.

The integration of (5.7) between *r'* and *r* for the observer at *r'* instead of *m* , gives the following properties, with the help of Eqs. (1.1) up to (1.5):

a) "Nonlocal" gravitational red-shift (time dilation)

$$f_{r'}(0,r) = r^{o} \exp\{f(r) - f(r')\} \qquad (5.9)$$

$$m_{r'}(0,r) = m^{o} \exp\{f(r) - f(r')\} \qquad (5.10)$$

For a "local" time $t_r(r) = N$ periods, from (5.9)

$$t_{r'}(0,r) = t^{o} \exp\{f(r) - f(r')\} \qquad (5.11)$$

b) "Nonlocal" gravitational contraction.

$$l_{r'}(0,r) = l^{o} \exp\{f(r) - f(r')\} \qquad (5.12)$$

For a "local" length $L_r\,(0,r) = N\ l°$

$$f_{r'}(0,r) = r^{o} \exp\{f(r) - f(r')\} \qquad (5.13)$$

c) "Nonlocal" velocities.

From (5.11) (5.13)

$$V_{r'}(0,r) = V_{r'}(r) \exp\{2f(r) - 2f(r')\} \qquad (5.14)$$

$$c_{r'}(r) = c \exp\{2f(r) - 2f(r')\} \qquad (5.15)$$

The homogeneous decrease of "nonlocal" mass, lengths and frequencies that matter should have at rest in the field is due to both the lower "nonlocal" velocity of light and to the internal energy lost in order to rest again. This contraction is homogeneous even in a "nonlocal" space-time whose line element is defined as:

$$ds_{r'}(0,r)^2 = \{c_{r'}(r)dt_{r'}(0,r)\}^2 - dx_{r'}(0,r)^2 - dy_{r'}(0,r)^2 - dz_{r'}(0,r)^2 \qquad (5.16)$$

"Local" and "nonlocal" quantities become related by

$$ds_{r'}(r)^2 = ds_{r'}(r)^2 \exp\{2j(r) - 2j(r')\} \qquad (5.17)$$

For r'= the "local" line element becomes

$$ds_{r'}(r)^2 = c^2 dt_{r'}(r)^2 e^{2j(r)} - \sum_{j=1}^{3} dx^{j}_{r'}(r)^2 e^{-2j(r)} \ - \qquad (5.17b)$$

The first approximation of (5.17b) is similar to the "Schwarzchild line element" for the value $f(r) = -GM/r$ found below.

The "nonlocal" weight may be obtained from (5.6), (5.10)

$$F(0,r) = m(0,r)\frac{d\boldsymbol{f}(r)}{dr} = m(0,r)\left[-\tfrac{1}{2}\frac{dLnc(r)}{dr}\right] \qquad (5.18)$$

Or using the "nonlocal" momentum of photons defined by:

$$p(r) = \frac{h}{\boldsymbol{l}(r)} = \frac{hf(r)}{c(r)} \qquad (5.19)$$

and adding up the momentums of the Doppler-shifted standing waves propagating up and down within the box during the free fall,

$$dp(\boldsymbol{b},r) = Nh\frac{df(\boldsymbol{b},r)}{c(r)} = Nh\,\bar{f}(\boldsymbol{b},r)\frac{d\boldsymbol{b}}{c(r)}$$

$$F(0,r) = \lim_{\substack{b=0\\ dr=0}} \frac{dp(r)}{dt} = \frac{m(0,r)g(0,r)}{c(r)^2} \qquad (5.20)$$

F(0,r) may also be obtained from the vertical momentum gained by waves travelling horizontally - at the starting point OO' in Fig. 2 - after the time $\boldsymbol{D}t = \boldsymbol{l}(0,r)/c(r)$ equivalent to one wavelength, for example, of displacement.

$$\Delta p_y = p_x\frac{d\boldsymbol{l}(0,r)}{dr} == \frac{Nh}{\boldsymbol{l}(0,r)}\frac{d\boldsymbol{l}(0,r)}{dr} \qquad (5.20a).$$

$$F(0,r) = \frac{\Delta p_y}{\Delta t(r)} = Nhf(0,r)\frac{dLn\,\boldsymbol{l}(0,r)}{dr} \qquad (5.20b)$$

which , after use of (5.3) gives also (5.20)

"Nonlocal" dynamical laws

For free bodies, the use of (2.2), (4.1), (5.10) gives:

$$m_{r'}(\boldsymbol{b},r) = m^o(1-\boldsymbol{b}^2)^{-1/2}\exp\left[\boldsymbol{f}(r) - \boldsymbol{f}(r')\right] = \text{Constant} \qquad (5.21)$$

$$\boldsymbol{b}^2 = 1 - K^2\exp\left[2\boldsymbol{f}(r) - 2\boldsymbol{f}(r')\right] \qquad (5.21b)$$

where $K = m^o/m_{r'}(\boldsymbol{b},r)$ is a constant close to *1*, for non relativistic bodies, and zero for photons. Eq. (5.21) would represent the "nonlocal" mechanical energy conservation.

The "nonlocal" angular momentum law for free orbits may be obtained from the interference of the standing waves in the "light box" in a space of variable c(r). This gives a kind of "De Broglie" wave to which the Huygen principle may be applied, obtaining the rather classical form

$$L = rxp(\boldsymbol{b}, r) = \frac{m(\boldsymbol{b}, r) rx\boldsymbol{b}}{c(r)} \exp\left[2\boldsymbol{f}(r') - 2\boldsymbol{f}(r)\right] = \text{Constant} \qquad (5.22)$$

$$j = \frac{L}{m(\boldsymbol{b}, r)} = rx\frac{\boldsymbol{b}}{c(r)} \exp\left[\boldsymbol{f}(r') - \boldsymbol{f}(r)\right] = \text{Constant} \qquad (5.23)$$

which would be valid for bodies or photons.

VI. CONSISTENCY WITH THE OBSERVED FACTS

The integration of the Poisson equation for a static field should relate "nonlocal" quantities, the same as Newton's gravitational law. It is then reasonable to expect that the introduction of "nonlocal" quantities in these expressions should greatly improve their good fit with the observed facts just because all of the quantities will be expressed now in terms of "physically identical standards".

If ***r(0,r)*** is the density of "nonlocal" mass-energy, the Poisson equation for "nonlocal" sources at rest would be:

$$\nabla^2 \boldsymbol{f}(r) = 4\boldsymbol{p}G\boldsymbol{r}(0, r) \qquad (6.1)$$

Its integration for a central body of "relative" mass $M = M(0,r^0)$ gives:

$$\boldsymbol{f}(r) = -\frac{GM}{r} \qquad (6.2)$$

This value gives a good fit with all of the observed facts.

a) Agreement with traditional laws in weak fields.

From (5.18),(6.1)

$$-\frac{GMm(0,r)}{r^2} = -\frac{GMm^o}{r^2}\exp\left[\frac{GM}{r'} - \frac{GM}{r}\right] \quad (6.3)$$

similar to Newton's law, but for "nonlocal" quantities and "inertial" masses. F(O,r) has a maximum at $r = GM/2$ decreasing to zero for $r = 0$. No singularity is obtained for r=0 nor at $r = 2GM$.

From (5.2), g(0,r) is also consistent with classical physics

$$g(0,r) = -c(r)^2 \frac{GM}{r^2} \quad (6.4)$$

Since the energy is measured in mass units, G is equal to the classical value divided by c^2, and the force is expressed in M/L units. From (5.10) (5.13), G is also independent of r''.

The approximations of (5.21) and (5.23) are also consistent with mechanical energy and angular momentum conservation, respectively.

b) Gravitational red-shift

The approximations of (5.9) and (5.11) agree with the red-shift gravitational tests [3,6] and with the experiments made in 1976 in Maryland. This decrease of frequency of the standing waves of the model should affect in the same proportion every standing wave representing the energy levels in a more complete model for atoms. The emission spectrum resulting from the difference between energy levels should therefore be red shifted in the same proportion as the total mass-energy of the atom as the total mass-energy of the atom as in (5.9) or (5.10). :', is simple to prove, for example, that even the natural "relative" frequencies of

a LC resonant circuit would also change proportionally as exp (C (r)). The same should happen to any kind of energy which is proportional to the "relative" mass.

c) Gravitational refraction

From (5.11), light emitted by a vertical source is not strictly monochromatic due to the gravitational red-shift. These wavefronts travelling horizontally would deviate, according to Huygen's principle proportionally to do $l(0,r)/dr = GM/r^2$, consistently with $g(0,r)$ and $F(0,r)$ determined above. A "monochromatic" wavefront, on the other hand, would have a wavelength determined from (3.2) and (5.15):

$$l(r) = \frac{c(r)}{f(r)} = l^{\,o}\exp\left[\frac{2GM}{r'} - \frac{2GM}{r}\right] \quad (6.5)$$

Its deviation is roughly proportional to $d\lambda(r)/dr = 2GM/r^2$. The integrated deviation of light from stars by the Sun is thus approximately equal to $4GM/r_i$, where r_i is the impact parameter. This is in agreement with the experiments.

From (5.23) and (6.1), the inclination angle of a light beam is completely determined. The limiting escape angle , θ_e , of photons emitted from superdense bodies with $r = 2GM$ becomes determined by

$$\sin\theta_e = \frac{2eGM}{r}\exp\left[\frac{2GM}{r'} - \frac{2GM}{r}\right] \qquad (6.6)$$

Superdense bodies with r - 2GM would let photons escape but with lower probability than a "black-body", reason for which they may be called "semiblack bodies". They could capture more energy than they emit due to

both the lower escape probability and the strong "red-shift" that may go beyond the limits generally assumed from general relativity. They could open the way for new interpretation of astronomical phenomena. Some "quasars", for example, may be formed by superdense bodies with large GM/r at the source where matter emits light.

d) Time delay of radar echo from planets and "mariners"

From (5.15)

$$t = \frac{x_e + x_p}{c} + \frac{2GM}{c} Ln\frac{x_p - x}{r_e - x_e} \qquad (6.7)$$

e) The perihelion shift of planets

The application of (5.21b), (5.23) to free orbits gives:

$$\left[\frac{dz}{d\theta}\right]^2 + z^2 = A^2\left[1 - K^2 \exp 2\phi(r)\right]\exp\{-4\phi(r)\} \qquad (6.8)$$

where θ is the angular position and $z = GM/r, A = GM/jc$.

For $\phi(r) = - z$, the second order approximation of (6.8) gives

$$\Delta\theta = 6\pi A^2 = \frac{6\pi GM}{a(1-.e^2)} \qquad (6.9)$$

a perihelion shift consistent with experiments.

In order to test (6.1) it may be assumed that the ratio *F(0,r)/m(0,r)* departs a little from - *GM/r2* given by (5.18) and (6.2) adopting the form suggested by general relativity : *F/m = - GM/{r(r+xGM)}*. The integration of (6.8) in this case gives a perihelion shift $\Delta\theta = \pi(6-x)A^2$

Since the experiments deviate from (6.9) by ± *1%,* the value of x must be smaller than *0.06* which is much smaller than the value of *x = 2* of general relativity. This seems to indicate that the results from the present study are somewhat different than the ones of general relativity.

f) The last peak of relativistic cosmic radiation

The rough application of the principle of no exchange to a He nuclei falling freely into a "semiblack" star and assuming only conservative interactions, non conservative interactions neglected, leads to a negligible "nonlocal" rest mass of the neutron at the star surface according to (5.10) and, therefore, to a "nonlocal" final proton mass just about twice its normal rest mass. This is equivalent to a magnetic rigidity of 1.6×10^9 volts in very good agreement with the last peak of the primary cosmic ray spectrum in periods of minimum disturbance by solar flares . This is also consistent with the fairly rapid decrease of the average cosmic radiation about this region. This seems to show that a fairly large fraction of matter in the universe would be in a super dense, non visible state. This is also consistent with the very much larger mass of the clusters of galaxies determined by dynamical methods than the sum of the masses of their luminous galaxies. Super dense galaxies seem to be the rather obvious result of galactic evolution

CONCLUSIONS

The introduction of "nonlocal" quantities provides a good

method for understanding the nature of gravitational phenomena together with a good fit with every observed fact.

The "nonlocal" conservation principle would be a consequence of more elementary principles of "nonexchange" of signals or energy between photons or bodies and external fields as observed from a fixed field at rest relative to the centre of mass of the system.

The "nonlocal" properties of the space and of matter in the field have been studied with the help of a previously tested electromagnetic model of matter consisting in a packet of standing waves within a theoretical "light-box".

Bodies and photons would change the properties of propagation of light in the space around them. They would propagate towards regions of lower $c_r(r)$, according to electromagnetic laws. No net exchange of signals, frequencies or mass-energy would occur between free travelling photons and the external fields. The energy for the acceleration of a body should come from its own internal (confined) energy which is released by conservative work. The gravitational work is, therefore, more properly done "by the body" , not by the field, as commonly assumed.

The "nonlocal" rest mass of a body becomes identified with its "nonlocal" potential energy. Freely falling bodies would thus keep constant their "nonlocal" masses and average round trip periods or frequencies. A gravitational contraction factor - $\exp f(r)$ - would be superposed on the normal relativistic contraction effect. "Nonlocal" masses at rest in the field altogether with the natural "relative" lengths, frequencies and wavelengths become decreased by the sane factor

which is proportional to $c_{r'}(r)^{1/2}$

Assuming that "nonlocal" masses are the true source of gravitational fields, the "nonlocal" non-exchange principle gives results consistent, not only with traditional gravitational tests, but also with the highest energies obtainable by conservative fields as shown in the relativistic cosmic ray spectrum. This seems to show that gravitation is, primarily, a photon-photon interaction.

Part of the ideas presented here are fairly consistent with the works presented before by W. Thirring[10], J. Palacios[5] and a relatively large list of authors that have tried to describe gravitational fields in a flat space.

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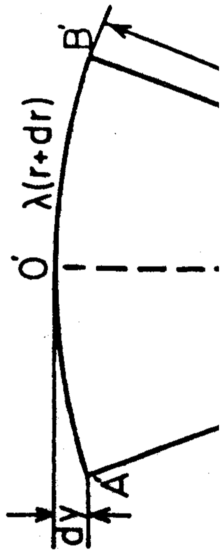

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