Corrected edition for the paper on A dilemma in the Physics of Gravitational fields published in Vol 20 No 1, pp 19-40, 1981.

Some minor corrections of the original paper have been made up. Some missing subscripts were replaced. Some observations were placed in footnotes, or in square bracket, so as make everything more clear. May 2004.

A Dilemma in the Physics of Gravitational Fields

[A New Gravitational Theory Based on Properties of Light]

Rafael A. Vera

Instituto de Física. Universidad de Concepción. Chile.

Received March 24, 1980

It is proved that the improper use of local quantities for non-local (NL) situations[1], in which bodies and observers are in different gravitational (G) potential, leads to traditional errors. To obtain reliable results, all of the local and non-local quantities of a single equation must be referred to the standards of an observer in some well-defined position of a gravitational (G) field. The theoretical properties of the NL space and of matter located in it are deduced with the help of physical principles and an electromagnetic wave model for matter. In spite of the fact that the local velocity of light should be constant, the field is a space of variable NL velocity of light, which accounts for its properties. Matter and light virtually propagate themselves without exchanging energy with the external field, in disagreement with traditional assumptions. The G field contracts matter. The results are self-consistent and consistent with the observed facts. Bodies with $r < 2\ GM$ would be different from black holes and they can account for the peak of highest energy of cosmic radiation and other astronomical facts.

1. INTRODUCTION

The original purpose of this work was to look for a direct way of understanding the true physical nature of the gravitational field with the use of the most reliable physical principles and direct reasoning. But, after preliminary essays, soon it was realized that there are two major problems: Most of the traditional local physical quantities are not well defined for non-local situations in strong fields because the reference standards located in different gravitational potentials (GP) are not identical with respect to each other. The improper use of these quantities has lead to fundamental errors of concepts that are deeply embedded in the traditional physics.

On the other hand, the relatively weak tests done for the gravitational theories, after assuming that matter is absolutely invariable after a change of GP, are not an absolute guarantee of the validity of all of their hypotheses and implicit assumptions.

For the above reason, it was thought that it would be better to start all over again from the most elementary base, with a new formalism better defined for more general nonlocal situations in fields and by putting a reasonable doubt on any arbitrary identity that has not been previously demonstrated on the base of some unquestionable physical principle.

The main purpose of the first sections of this article is to introduce the new definitions (formalism) for the non-local situations and to look for the answer to the basic question: *where the gravitational energy comes from?*

For this problem there are two main alternatives:

a) The traditional one, which assumes that the field transfers energy to the body,

---

[1] Any case, in which the objects and the observer are in different distances with respect to a G field source, is called non-local (NL) situation.

b) The nontraditional one, that the body releases a small fraction of its own rest mass-energy.

None of the two hypotheses has ever been seriously demonstrated before.

The simplest demonstrations have been done in Section 3 in order to show which one of the alternatives is consistent with unquestionable principles extensively used in physics.

It may seem hard to believe that the results of this article are in strong disagreement with the mainstream of currently accepted concepts in physics. For this reason some of the statements made in this article, if it is read independently from the main context, may look odd.

On the other hand, the new formalism and the new concepts greatly simplify the understanding of the true physical nature of the gravitational phenomena. The derivation of the theoretical properties of gravitational fields is straightforward. This is done later on with the help of a previously tested electromagnetic wave model for matter. Final tests with the experimental facts are given in the last section. This was done with the purpose of showing that the theoretical values of the non-local masses are consistent with the observed facts.

Unimportant details have been omitted, for reasons of space and simplicity. For similar reasons, the obvious generalizations, from the simplest cases up to the more general ones, are not even mentioned.

2. NON-LOCAL QUANTITIES

Revision of Concepts. Since the properties of space in a conservative field do change from point to point, it should be assumed, unless it is otherwise demonstrated, that the properties of matter located in it should also change from point to point. Rastall (1960), Dehnen et al. (1960), and Thirring (1961) have also pointed out the rather evident influence of the gravitational field on real clocks and rods. Here, for this reason, the relative properties of the standards of observers in fields of different magnitude are *not arbitrarily assumed* to be absolutely identical to each other, which is in contradiction with the identical numbers traditionally assigned to them by the corresponding local observers. Thus here it is found that, the traditional physical relationships between quantities measured in fields of different magnitude are not strictly referred to identical standards. For this reason any quantity measured by a local observer is of no use for another non-local observer in a different G field potential, unless that some unquestionable relationship between their corresponding standards has been previously determined on the basis of some well-tested principle of physics.

Consequently, the traditional (local) physical quantities measured by one observer are not strictly well defined for another "non-local" observer located in a different G field potential. This is especially true when there is an appreciable difference of gravitational potential between them. Then any attempt to establish a "direct" physical comparison or relationship between their quantities leads to wrong results.

In spite of this, it is usual to establish a direct physical relationship with quantities measured by observers in different gravitational potentials. This is the case of conventional physics in which the effects of the change of gravitational potential on matter are neglected. But it should be understood that those relationships, unless that otherwise demonstrated, do not correspond to well-defined physical concepts in the strict sense of the word.

For example, the concept of potential energy of a body has been classically defined after assuming that there are not relative changes of the mass either of the test body or of the standard rods, after a change of distance with respect to the G field source. This is something that has not been proved. On the contrary it is simple to prove that the opposite alternative is the true one, as shown below. Indeed, in strong fields, the traditional concept of potential energy turns out to be as meaningless as the summation of the daily incomes of employees during a strong inflationary period in which the buying power of money changes with time.

As a result of this classical way of reasoning, it is reasonable that some fundamental concepts, based on presumed identities between quantities measured in different G potentials, are wrong.

This is the case of one of the most common assumptions made in traditional physics: that the external field is supposed to exchange energy with the body doing gravitational work. For example, when Einstein (1965) justifies his field equation, he tacitly uses the same idea twice in the same sentence: "...the gravitational field transfers energy and momentum to matter in that it exerts forces upon it and gives it energy." Such hypothesis has never been fairly demonstrated. The question is why the opposite alternative - that the field does not exchange energy with the body - has been traditionally disregarded?

There are at least two main reasons. One of them is the usual tendency to conclude, without a fair demonstration, that the forces applied to a body accelerating by the effect of such forces are bound to transfer energy to the body. This statement is not general, as follows from the next example. Assume a car accelerating on a horizontal road with the power of its own batteries. The road forces acting on the tires do not give up energy to the car although they give up momentum to the car. The energy is obviously given up by the batteries. This statement can be easily demonstrated according to two viewpoints: a direct one and an indirect one.

From the first viewpoint, the road forces are static ones. They have no real displacement because new forces are generated at different contact points of the road with the tires, i.e., they do not give up energy to the car. This is a strong difference with the case of a non self-powered car pulled by a string. The application point of the external force in this last case is displaced with the car, i.e., it gives up energy to the car whose relativistic mass should increase with time.

From the second viewpoint, the kinetic energy is not increased at the cost of an external source of energy but at the cost of its own internal energy. In other words, the increase of the kinetic energy of the car is automatically compensated for by the corresponding decrease of the internal energy of the batteries of the same car. Then, the main characteristic of a self-powered body is that its relativistic mass remains constant, regardless of its increase of velocity. This makes a difference with a car powered by an external source of energy, whose relative mass increases with the energy supplied to it.

Similarly to the above example, in the case of the free fall of a body it is possible to determine, after using the second viewpoint, which of the two alternatives is the true one in the gravitational case. For such purpose it is enough to find out if the relative mass of a body, with respect to some well-defined observer, either increases or does not increase during a free fall. But in this case only the final local relativistic mass of the body is the unique well-known piece of data available at the end of its trajectory. The initial rest mass is referred to a standard of another observer that is different from the one of the final observer, because such standards are in different gravitational potentials. Therefore, the initial local value is of no use for the final observer unless that some relation between their standards can be determined from reliable physical principles or experiments.

Here is where the traditional confusion enters in because it is currently assumed that the initial and the final rest masses, with respect to the final observer, are the same. This gives a positive relativistic mass increase, thus favoring the traditional assumption. But this careless mass-energy balance is meaningless from the strict physical viewpoint because this is made with quantities referred to different standards. A reliable mass-energy balance should be made only when the initial mass is corrected for the difference of gravitational potential between the two locations so that the two quantities become theoretically referred to a common standard.

It may be concluded that in order to establish true physical relationships between quantities measured by observers in different gravitational potentials it is most important that all of the quantities are, in one way or another, referred to some common standard in a well-defined position of the field. For this purpose, it is necessary to define a new type of non-local (NL) quantity corrected for the difference of gravitational potential between the object and the observer. With them it is possible to get strictly homogeneous relationships between quantities measured by observers in different gravitational potentials. The correction relationships can be determined either from experiments or from theoretical deductions according to reliable principles or laws.

This formalism differs from the traditional one in which the influence of the gravitational field potential on basic quantities such as the mass, length and time is often ignored to such a degree that the location of the observer is not even mentioned.

As a result of the influence of the gravitational potential on matter, it is to be expected that matter, instead of the space, can become contracted and curved by the effect of the field gradients. For this reason, the material reference frame of each local observer would be approximately flat only within an infinitesimal local volume in which the deformation produce y the field gradient on matter can be neglected. The traditional physical principles, such as special relativity, can be safely applied within this local volume. A flat theoretical reference frame tangent to this local volume can be used for the local observer for his non-local theoretical deductions by taking into account that the local units of measurement are not bound to be identical with respect to the ones of the observers in different gravitational potentials. In this way every theoretical observer should have the same picture, but with a different scale, for the same reality.

Definitions. The non-local (NL) quantities are defined here as the true quantities that should theoretically exist at a NL position in the field, either according to reliable principles or laws or experimental evidences. Such quantity is referred to some standard body at the position of the theoretical observer who is in a well-defined and fixed position of the G field, at rest with respect to the center of mass of the system

This type of quantity can be unobservable. However it is always possible to find general theoretical relationships between local and non-local quantities according to reliable physical principles. Such relationships are functions that convert local quantities determined by one observer to the system of units of the other non-local observer.

Because of the influence of the G field on the properties of matter, the new nonlocal quantities should depend not only on the relative position of the object, with respect to the field source, but also on the relative position of the observer's standard. This introduces new variables into the traditional physical quantities that normally depend only on the relative velocity of the bodies. Then, the non-local quantities can be regarded as an extension of the relativistic quantities to the more general non-local case in fields. For this reason the term "relative" has also been used here for the non-local quantities, when more emphasis is to be placed on this character. The author also used the terms “apparent” and “true” before (1977, 1978).

The term "*local*" is used here when there is no appreciable difference of G field potential between the object and the observer. Sometimes, in obvious cases, these terms have been omitted.

To avoid distractive variables, a central static field, has been used here most of the times. This one is assumed to be a point source that the radial positions and of the object (r) and of the observer (r'), respectively, fix the well-defined G potentials at such places. Since the last position is fixed, this one is stated by a subscript. For simplicity most of the times it is assumed that the test masses are infinitely small as compared with the central mass.

For example, the notation used here for the non-local mass of a test body traveling with a velocity $\boldsymbol{b} = V/c$, is $m_{r'}(\boldsymbol{b}, r)$. The value of r' is the constant position of the reference standard which fixes its true invariability. The relative velocity $\boldsymbol{b}$ of a body is dimensionless and, therefore, independent of the location of the observer. To the contrary of the local speed of light, the velocity of NL light, with respect to the local observer, is not assumed to be constant:

$$\boldsymbol{b} = V_{r'}(r)/c_{r'}(r) = V_r(r)/c_r(r) = V/c \tag{2.1}$$

When r' and r or $\boldsymbol{b}$ are unimportant, they may be omitted. When only r' is omitted, it is assumed that the observer is at near infinity, which makes the relations look simpler. When both r. and r' are omitted, it can be understood, except in special cases, that they are local values. In order to avoid unnecessary subscripts, the ones for the variables in the parentheses are omitted. But it is to be understood that they are expressed in terms of the units of the observer at r'. In special cases, some physical quantities are shown to be independent of the location of the observer. In such cases values without subscripts are used.

For photons, the place of $\boldsymbol{b}$ in this notation is sometimes used for the velocity $\boldsymbol{b}$ of its source.

Local Standards. Extremely simplified and idealized definitions are used here in order to both save space and avoid distractive variables. For example, it is assumed that when an atom is forced to stop in the field, its kinetic energy is transformed into electromagnetic radiation that is radiated away. This leaves the atom at rest in a free and unexcited state, i.e., at temperature of 0 K^o. Thus no chemical bonds or thermal energy would be ideally present. This is because the rest mass of a body obviously includes to any kind of energy moves altogether with the body, like thermal or kinetic energies. For this reason the present definitions are extremely idealized ones and, therefore, they cannot be reproduced in practice. Many other variables should be clearly defined in a similar way.

Inertial mass-energies are used here, which includes any kind of energy, like the kinetic one, that modes altogether with the body. The local energy of photons and the local mass-energy of the bodies may be ideally compared by inertial methods with the local standard of mass.

The local rest mass-energy of some standard atom at rest in a free and unexcited state has been selected as an ideal unit of both mass and energy anywhere. For observers at r', r, or at infinity (∞):

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

Since the structure of matter is fixed by well defined numbers of wavelengths, the most elementary standard of length may be chosen in terms of wavelengths. According to the quantum theory of the structure of matter, and to the Einstein's equivalence principle, the ratio between atomic diameters and the wavelengths of any of its spectrum lines is expected to be a constant number.

The local unit system can be based on the properties of standard photons. Thus, here, the local wavelength of some well-defined spectrum line emitted the local standard atom at rest has been selected as the standard unit o local length. It local period has also been selected as the standard unit of local time:

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

$$T^o_{r'}\,(0, r') = T^o_r\,(0, r) = T^o_{\infty}(0, \infty) = T^o = 1 \qquad (2.4)$$

Thus from (2.3) and (2.4) the local frequency and the local velocity of light are also unity (constant).

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

$$c_{r'}\,(r') = \mathbf{l}^o_r\,(0, r)/\,\mathbf{T}^o_r\,(0, r) = c_r\,(r) = c = 1 \qquad (2.6)$$

Notice that such constant values come from the implicit normalization made by local observers when they assign arbitrary constant numbers to their standards.

This fact does not preclude the possibility that the non-local velocity of light can be different from unity because the reference standards in different GP are different with respect to each other.

Some physical relationships can become clearer when the mass-energy of the standard atom is expressed as a multiple of the energy of the standard photon:

$$m^o = E^o = Nhf^o = Nh = 1 \qquad (2.7)$$

Thus the new Planck constant, for example, turns out to be equal to $1/N$.

Because of the well-defined (quantized) nature of particles and to the proportional interaction of the gravitational field with every particle of matter, it can be safely assumed that N does not change after a common change of the G potential. This is even more obvious when the standard body is an electron pair or a positronium atom. In such case, the standard photon can be the gamma radiation resulting from its current annihilation into two photons. In this case $N = 2$, exactly. This fact also shows that h is exactly the same for any observer.

3. CONSERVATION PRINCIPLES FOR NON-LOCAL QUANTITIES

I order to find the theoretical relationship between local and non-local quantities it is most important to count with reliable principles. The author (1977, 1978) thought that the most elementary principle is the "mass-energy conservation" which has proved to hold non-locally, i.e., even when the objects are in strong fields such as the ones existing in the nuclei of atoms while the observer is completely out of those fields. Later on, the author (1979) realized that this principle is the result of an even more basic principle for photons.

A Non-local Conservation Principle for Photons. Static conservative fields cannot change the net number of cyclic events observed by means of monochromatic radiation traveling through them along a well-defined trajectory. This rather trivial fact seems to be the most elementary conservation principle from which the basic relationships between local and non-local quantities can be established. Notice that this kind of principle is normally used in physics. Schild (1960), for example, used it in order to show the curvature of the current space-time.

It is simple to prove that: if the net number of signals sent by means of electromagnetic radiation is conserved during its free trip in a static field, then its non-local frequency should also be conserved.

Assume for example that the static observer at r' sends a continuous wave train of electromagnetic waves towards the observer at *r*. The first and the final wave of the train should travel through the same infinitesimal non-local displacement $ds_{r'}(r)$ with the same instantaneous non-local velocities $c_{r'}(r)$. Then they should take the same non-local time to travel between *r'* and *r*. If $t^1_{r'}(r')$ and $t^2_{r'}(r')$ are the local starting times of the first and last wave, respectively. Thus the theoretical non-local time interval $\Delta t_{r'}(r)$ between such waves, when they cross the NL position at *r* is:

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

$$\Delta t_{r'}(r) = \Delta t_{r'}(r') \qquad (3.1)$$

This non-local time interval should not be confused with the local one found by the observer at *r*. The last observer should have his standard clock running at a different rate compared with the one of the observer at *r'* because he is in a different G potential.

If both the number (*n*) of waves and the non-local time interval of the wave train do not change during the trip, then the non-local frequency of the waves reaching *r* should not change either. From (3.1),

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

Since the energy of the photon, with respect to the observer, depends only on its frequency with respect to such observer, then the nonlocal energy of a photon traveling freely in a G field should also remain constant. From (3.2)

$$E_{r'}(r) = hf_{r'}(r) = hf_{r'}(r') = E_{r'}(r')$$

$$E_{r'}(r) = constant \qquad (3.3)$$

It may be concluded that the three quantities: the net number of waves, the nonlocal or relative frequency, and the nonlocal or relative energy of the photons, with respect to an observer in a fixed G potential, should remain constants during their trips in conservative fields. In other words, *no net exchange of waves (signals), or energy, would exist between photons and static conservative fields*. This is a rather obvious conclusion because, once that the temporary electromagnetic perturbation produced by the photon has gone away, the field should recover its original state.

Mass-energy Conservation Principle for Nonlocal Bodies. According to the equivalence between mass and energy, the above conclusion is expected to hold for the relative mass-energy of a body. This can be demonstrated in the following theoretical (thought) experiment.

Assume that a positronium atom (or an electron pair) falls freely from r' in the gravitational field of a central non-local mass $\boldsymbol{M_{r'}}$. Assume that annihilation occurs during the fall at the level r with the emission of two photons traveling in opposite directions, symmetrically to the original path.

If the traditional hypothesis on the G field energy is assumed to be true, then the relative mass-energy of the atoms at r with respect to the observer at r would be larger than the initial rest mass at r' due to the energy $DM_{r'}$ given up by the G field:

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

When the atom annihilates at r, from (3.3), the energy carried away by the photons crossing the radius r' would be

$$E_{r'}(r') = 2hf_{r'}(r') = 2hf_{r'}(r) = m_{r'}(\boldsymbol{b}, r) = m_{r'}(0, r') + \Delta M_{r'} \qquad (3.5)$$

Then the final energy $2E_{r'}(r')$ reaching to the level r' would be larger than the initial mass m^o just by the amount $DM_{r'}$ given up by the central field. Then in principle it would be theoretically possible to use only the part equivalent to $m_{r'}(0,r')$ of the resulting energy to regenerate the test body at r', which could repeat the above cycle rather indefinitely with the net result of converting the G field energy into additional mass or radiation indefinitely. This is, obviously, absurd unless

$$DM_{r'} = 0, \qquad m_{r'}(\boldsymbol{b},r) = m_{r'}(\boldsymbol{0},r') = Constant_{r'} \qquad (3.6)$$

This result can also be expressed in terms of the standards of the observer at rest at r, which is equivalent to multiplying (3.6) by a suitable conversion constant:

$$DM_{r} = 0; \qquad m_{r'}(\boldsymbol{b},r) = m_{r'}(\boldsymbol{0},r') = m^{\circ} = Constant_{r} \qquad (3.7)$$

It is concluded that "*no net exchange of energy should exist between the central field and test bodies or photons traveling freely through it*". "*Bodies would keep their relative masses constant*" until some non-conservative interaction takes place, for example, during a stop.

Then the non-local mass of a body traveling freely in an isolated conservative system remains constant with respect to an observer in a constant G potential because there is not a net exchange of energy between the body and the field. Then the same conservation law should hold for the whole NL mass-energy of the system. This is equivalent to a *mass-energy conservation principle* of a non local system with respect to any well-defined observer in a constant GP.

Non-local Mass-Energy Relations. From (3.7) and the application of special relativity to the final position r, gives

$$\frac{m_r(0,r')}{m_r(0,r)} = \frac{m_r(\boldsymbol{b},r)}{m^o} = \frac{1}{\sqrt{1-\boldsymbol{b}^2}} = \text{Constant} \qquad (3.8)$$

Observe that the larger relativistic mass $m_r(\boldsymbol{b},r)$, compared with the local rest mass $m_r(0,r)$, is a particular case of a larger relative mass that comes constant even from the starting point at r'. From (3.8) *the difference of relative rest mass between r' and r is equal to the kinetic energy released during the stop at r*:

$$\Delta m_{r'}(0,r) = m_{r'}(0,r') - m_{r'}(0,r) = \Delta E_{r'} = m_{r'}(0,r')\left[\left(1-\boldsymbol{b}^2\right)-1\right] \qquad (3.9)$$

Equation (3.9) can also be expressed in terms of the standards another observer at rest at r', which is equivalent to multiplying (3.9) by a well-defined conversion factor. Thus if $Dm_{r'}(0,r)$ is the difference of relative rest mass of the body between r' and r , with respect to the observer at r', then from (3.9) this value is:

$$m_{r'}(0, r') - m_{r'}(0, r) = DE_{r'} = Dm_{r'}(0,r) \qquad (3.10)$$

Then, according to (3.9) or (3.10), *the absolute potential energy of a nonlocal body at r', with respect to the observer at r is well defined by its non-local mass-energy*[2], *i.e., by $m_{r'}(0, r)$ expressed in energy units.*

Observe that "the gravitational work, or the energy released by it, comes not from the G field but from a fraction of the relative rest mass of the same test body". Then, to the contrary of the current assumptions, *"the gravitational work, therefore, is not done by the field but by the body"*.

From (3.10), for a free fall from r to $r + dr$,

$$dE_{r'} = - dm_{r'}(0, r) \qquad (3.11)$$

The non-local rest mass of a body decreases just in the amount of energy released after G work. It is smaller for stronger fields and it should be a well-defined point function.

Equation (3.10) can also be obtained directly from the mass-energy conservation principle applied to the next theoretical experiment carried out in a space free from the influence of external fields.

Assume that a large number N of standard atoms is initially at rest and evenly distributed in a massless spherical shell of initial radius r', each of them tied up to massless strings whose ends are connected to massless mechanisms that transform the energy release from G work into radiation. Assume that the shell falls quasi statically towards the gravity center up to a final rest position of average radius r. The application of the mass-energy conservation principle to the whole system, for an observer at $r' > r$, gives

$$N\, m_{r'}(0, r') = N\, M_{r'}(0,r)+N\, DE_{r'} \qquad (3.12)$$

Here $DE_{r'}$ is the average energy released by each body. Equation (3.12) divided by N gives an expression equivalent to (3. 10), but for each body Obviously, the same result should also be obtained if the bodies fall freely from r´ up to r and giving away the energy released by the gravitational work in any imaginable way.

Notice that this thought experiment shows up, most simply, that the relative rest

---

[2] Notice that, from mass-energy conservation, the local mass of a particle can be defined in absolute terms, i.e., by its net energy-equivalent given m = E = Mc^2 so that the basic mass unit may be just one joule.

mass of a body, with respect to an observer in a fixed G potential, is necessarily a point function.

(Notice that the new concepts coming out from here are radically different from the conventional ones. The local mass of a body is neither a gravitational nor an inertial one. It is just its absolute mass-energy confined it, in any form, most probably as stationary forms of radiation. It is expressed in a common mass and energy units of such observer, which may be just 1 *joule*, which is equal to c^{-2} kilograms of mass. It is of no use to talk about "inertial" or "gravitational" mass because they correspond to different ways to measure the real (absolute) mass-energy of the bodies. Thus *a new kind of absolute G potential of a non local body, with respect to some well defined observer*, can also be defined as the net proportion of the energy that can be released after the total annihilation of that non local body, compared with the one that would be released if it were at the observer's position. Thus the differences of absolute GP are just equal to the traditional differences of GP).

4. DETERMINATION OF NON-LOCAL RELATIONS IN GRAVITATIONAL FIELDS

According to mass-energy conservation, a box with perfect reflecting surfaces cannot change its weight if any fraction of matter contained in it is transformed into radiation provided that no net energy escapes from the box.

Based on this fact, and since the mass and the form of the walls are unimportant, a test body can be replaced by an idealized light box mode of any appropriate form with massless and perfectly reflecting walls containing either a neutral particle or, even better, the radiation resulting from the annihilation of such particles. For example, a particle-antiparticle pair, or a positronium atom, could be used. The radiation resulting from its annihilation into two gamma photons traveling in opposite directions can form standing waves after reflection in the walls of the model whose distances are also self-determined by some well-defined number of wavelengths. This one would emulate the well-defined lengths of the particles.

It is reasonable that the local size of matter and the local size of the model should be related by some proportional constant. For similar reasons, it is assumed that the local rest mass of the model is just equal to the energy of a well defined number N of photons of equal energy *hfr(0,r)* each, which may be called the confined energy of matter. More complex models may, of course, be devised with sets of standing waves of different frequencies in order to study, for example, the effect of the fields on the energy levels of matter.

In order to make the picture even simpler, the model has just two photons forming standing waves in two main orientations of the traveling waves with respect to the field gradient. The two orientations should lead to consistent results[3].

Non-local Acceleration of Gravity.

The light-box model cannot accelerate unless a gradient of the non-local velocity of light exists in the space.

This can be shown by using a particle model either with vertical waves, (Fig.1), or with horizontal ones.

In the first case, assume two monochromatic wave fronts of light starting simultaneously from the center of the light box of height *dr* in opposite vertical directions. (The observer is at rest in some fixed position *r´* in the field). After reflections at *r + dr/2* they will meet at a level below the original center only if the

---

[3] This model emulates in part the well-defined (quantized) structure of uncharged particles. This one is consistent with the equivalence principle from which every "local" ratio is a universal constant. Thus both the "local" ratios between the frequency and the wavelengths of the model should also be some universal constant anywhere.

average relative velocity of light in the upper region is higher than that at the lower region. If $dc(r) = c(r + dr/2) - c(r - dr/2)$, the average difference of relative velocities of the two wave fronts is $dc(r)/2$. From Figure 1, the net displacement dy of the center of the box, after a time $dt(r) = dr/c(r)$, is equal to $-(1/2)[dc(r)/2]dt(r)$. This value should be equal to $(1/2)\, g(0, r)\, dt(r)^2$, then:

$$g_{r'}(0,r) = -\frac{1}{2} c_{r'}(r) \frac{dc_{r'}(r)}{dr_{r'}} \tag{4.1}$$

Then the non-local acceleration of gravity $g_{r'}(0, r)$, with respect to the fixed observer at r', "*is a consequence of the gradient of the non-local velocity of light of the space*". This value is independent of the non-local mass-energy of the body, in agreement with the experiments.

The acceleration of gravity can also be determined from a monochromatic wave front emitted along a vertical source *OO′* of length Dr (Figure 2) that starts its trip horizontally. The net vertical displacement Dy of the wave front after one wavelength of horizontal displacement, occurring during the non-local time interval $Dt(r) = l(0, r)/c(r)$, can be determined according to "Huygen's principle", from which the angle of deviation from its original trajectory is $q = Dl(0,r)/Dr$ and the net vertical displacement $Dy = (1/2)\, l(0,r)q$. By equating Dy with $(1/2)g(0,r)[Dt(r)]2$, equation (4.2) results in the limit when Dr tends to zero:

$$g_{r'}(0,r) = -[c_{r'}(r)]^2 \frac{d\boldsymbol{l}_{r'}(0,r)}{\boldsymbol{l}_{r'}(0,r)\, dr_{r'}} \tag{4.2}$$

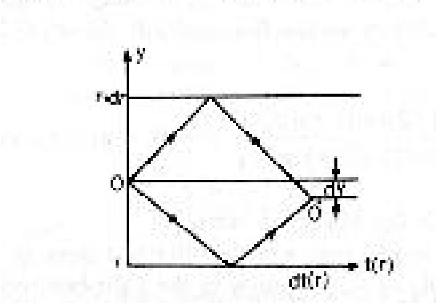

Fig. 1. Nonloc0al space-time diagram for standing electromagnetic waves traveling vertically in a gravitational field within an infinitesimal light box of height *dr*. The larger non-local velocity of light in the upper region as compared with that in the lower regions results in a net displacement *dy* accounting for the acceleration of gravity.

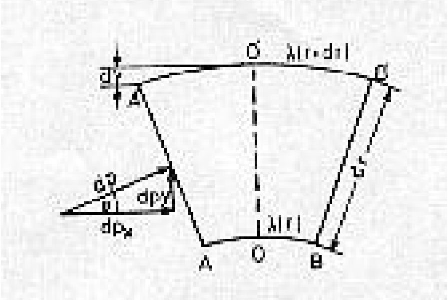

Fig. 2. Deviation of horizontal standing wave front produced by a vertical light source *OO′* in a gravitational field. The vertical displacement *dy* accounts for the acceleration of gravity. The vertical arrow dp_y, shows the momentum provided by an external static force that prevents the fall, which accounts for the weight.

From (4.1) and (4.2) the relative changes of the lengths can be related to the changes of the relative changes of the non-local velocity of light :

$$\frac{d\boldsymbol{l}_{r'}(0,r)}{\boldsymbol{l}_{r'}(0,r)} = \frac{1}{2}\frac{dc_{r'}(r)}{c_{r'}(r)} = d\boldsymbol{f}(r) \qquad (4.3)$$

The gravitational force

The G force of the model can be defined in terms of the non-local energy released when the model displaces itself from a rest at r to a new rest at $r + dr$. Using (3.11) for the observer at infinity, the G work done is:

$$dW_{r'}(r) = dE_{r'}(r) = - dm_{r'}(0, r) = F_{r'}(0, r)\, dr_{r'} \qquad (4.4)$$

from which

$$F_{r'}(0, r) = - grad\ m_{r'}(0, r) \qquad (4.5)$$

Observe that *the relative rest mass of a body replaces its potential energy* in the traditional expression $F= - dU/dr$.

This force can be directly related to the acceleration of gravity, by using (3.9) and (4.5) for $\boldsymbol{b}$ close to zero,

$$F_{r'}(0,r) = -\frac{d_{r'}m(0,r)}{d_{r'}r} = \frac{(1/2)m_{r'}(0,r)d\boldsymbol{b}^2}{dV_{r'}(r)dt_{r'}(r)} = -\frac{m_{r'}(0,r)g_{r'}(0,r)}{c_{r'}(r)^2} \qquad (4.6)$$

This is consistent with the observed facts.

The momentum of the nonlocal model

According to the Huygen's principle, the free trajectory of the particle model is well determined by the propagation of the model waves, which depend on its nonlocal wavelength. Thus the modulus of *the momentum of a nonlocal photon* depends on its relative wavelength $\boldsymbol{l}_{r'}(r)$ according to[4]:

$$p_{r'}(r) = h/\boldsymbol{l}_{r'}(r) = h\, f_{r'}(r)/c_{r'}(r) \qquad (4.7)$$

When the light box falls from a rest from the observer position *r'*, from (3.6) or from wave continuity, the "average" frequency of the waves traveling back and forwards with respect to the observer is conserved because photons do not exchange energy with the G field. Due to the model velocity with respect to any observer at rest, the frequency of the waves traveling backwards would become Doppler shifted by $-\boldsymbol{D}f_{r'}(r)$ while those traveling forward would be shifted by $+\boldsymbol{D}f_{r'}(r)$. This rearrangement of the internal energy does not change the average relative frequency or energy of the model with respect to the observer. Thus from (3,7),

---

[4] Notice that the momentum of a nonlocal photon is proportional to its relative frequency with respect to the observer according to $\boldsymbol{p}_{r'}(r) = h\boldsymbol{f}_{r'}(r)/c_{r'}(r)$ in which $\boldsymbol{f}_{r'}(r)$ can be named as the *"frequency vector"* of the nonlocal photon Thus, according to the above frequency conservation law, the relative change of momentum a nonlocal photon in a G field, with respect to a well-defined observer, is due just to the change of the relative speed of light with respect to such observer.

$$f_{r'}(\beta,r)=\tfrac{1}{2}\left[f_{r'}(0,r')+\Delta f_{r'}(r)\right]+\tfrac{1}{2}\left[f_{r'}(0,r')-\Delta f_{r'}(r)\right]=f_{r'}(0,r') \qquad (4.8)$$

During the fall, according to Doppler effect, the local ratios between frequencies of the wave-components of the moving model and those of the model at rest at the same position are proportional to $\gamma(1\pm\beta)$. Such dimensionless ratio is obviously the same for the observers at *r* and *r'*.

$$\frac{f_r(\beta,r)\pm\Delta f_r(r)}{f_r(0,r)}=\frac{f_{r'}(\beta,r)\pm\Delta f_{r'}(r)}{f_{r'}(0,r)}=\frac{1\pm\beta}{\left(1-\beta^2\right)^{1/2}} \qquad (4.9)$$

From (4.9), the average frequency and the average frequency shift of the moving model at *r*, with respect to the observer at *r'*, are:

$$f_{r'}(\beta,r)=\frac{f_{r'}(0,r)}{\left(1-\beta^2\right)^{1/2}}=f_{r'}(0,r') \qquad \Delta f_{r'}(r)=\frac{f_{r'}(0,r)\beta}{\left(1-\beta^2\right)^{1/2}} \qquad (4.10)$$

Thus (4.9) multiplied by *Nh*, give the corresponding mass-energies. Thus (4.10) corresponds with (3.8), which is also in strict correspondence with special relativity.

The net non-local momentum of the model with respect to the observer can be obtained from the sum of non-local momentum of the confined photons which depend on the difference of frequency of the waves traveling in the opposite directions. From (4.7) such momentum is proportional to $\Delta f_{r'}(r)$. Then, from (4. 1 0), we obtain:

$$p_{r'}(\beta,r)=\frac{Nh\Delta f_{r'}(r)}{c_{r'}(r)}=\frac{Nhf_{r'}(0,r)}{c_{r'}(r)}\gamma\beta=\frac{\gamma m_{r'}(\beta,r)}{\left[c_{r'}(r)\right]^2}V_{r'}(r) \qquad (4.11)$$

This corresponds with special relativity. Observe that the non-local force (4.6) derived from (4.5) corresponds with the one derived from (4.11) and

$$F_{r'}(0,r)=\underset{\beta\to 0}{Lim}\frac{dp_{r'}(\beta,r)}{dt_{r'}(r)} \qquad (4.12)$$

This force can also be obtained directly from the vertical momentum gained by the waves traveling horizontally. Assume, for simplicity, that the wavelengths are almost infinitely small and that the displacement is just one wavelength (see Figure 2). The vertical momentum gained during this trip is:

$$\Delta p_{r'}(0,r)=p_{r'}(0,r)\Delta\theta=-p_{r'}(0,r)\frac{\Delta\lambda_{r'}(0,r)}{\Delta r}=-\frac{Nh}{\lambda_{r'}(0,r)}\frac{\Delta\lambda_{r'}(0,r)}{\Delta r}=-Nh\frac{\Delta f(r)}{\Delta r}$$

(4.13)

Since $\Delta t_{r'}(r)=\lambda_{r'}(0,r)/c_{r'}(r)=1/f_{r'}(0,r)$, from (4.13) and (4.3) we obtain

$$F_{r'}(0,r)=\frac{\Delta p_{r'}(0,r)}{\Delta t_{r'}(r)}=-Nhf_{r'}(0,r)\frac{\Delta \boldsymbol{l}_{r'}(0,r)}{\boldsymbol{l}_{r'}(0,r)\Delta r}=-m_{r'}(0,r)\frac{\Delta \boldsymbol{f}(r)}{\Delta r}$$
(4.14)

The same result is obtained from (4.2) and (4.6). Notice that this value corresponds with the Newtonian values.

Theoretical Properties of Non Local Matter at Rest in the Field.

The relations between the fractional changes of non-local rest mass, frequencies, wavelengths, and the fractional changes of $c_{r'}(r)$, *after a change of position dr in a G field*, can be derived from

$$m_{r'}(0,r) = Nhf_{r'}(0,r) \qquad (4.15)$$

$$c_{r'}(r) = f_{r'}(0,r)\,\boldsymbol{l}_{r'}(0,r) \qquad (4.16)$$

and from (4.3). The result is:

$$\frac{dm_{r'}(0,r)}{m_{r'}(0,r)}=\frac{df_{r'}(0,r)}{f_{r'}(0,r)}=\frac{d\boldsymbol{l}_{r'}(0,r)}{\boldsymbol{l}_{r'}(0,r)}=\frac{1}{2}\frac{dc_{r'}(r)}{c_{r'}(r)}=d\boldsymbol{f}(r) \qquad (4.17)$$

The first three members of (4.17) show that any ratio between relative masses, structural frequencies, or wavelengths should remain undistorted by the common change of the G field potential. The fourth member relates the fractional change of the physical properties of the space in the field.

Notice that equation (4.17) accounts for the *Einstein's equivalence principle,* because, according to it, the "local" physical laws cannot depend on the position of the local observer *because the frequencies and the wavelengths change in the same proportion after the same changes of G potential.* Thus every local ratio remains constant after the same change of G potential so that such changes cannot detected from strictly local measurements.

The change of $d\boldsymbol{f}_{r'}(r)$ defined in (4.17) is dimensionless, i.e., it is obviously independent of the location of the theoretical observer. On the other hand, the function $\boldsymbol{f}_{r'}(r)$ can be more completely defined by the integration of $d\boldsymbol{f}_{r'}(r)$ between the rest position at the observer position (r') and the rest position at r. This can be done either in terms of the body properties or in terms of the space properties:

$$\boldsymbol{f}_{r'}(r)=\int_{\infty}^{r}\frac{dm_{r'}(0,r)}{m_{r'}(0,r)}=\tfrac{1}{2}\int_{\infty}^{r}\frac{dc_{r'}(r)}{c_{r'}(r)}=Ln\left[\frac{m_{r'}(0,r)}{m_{r'}(0,r')}\right]=Ln\left[\frac{c_{r'}(r)}{c_{r'}(r')}\right]^{1/2} \qquad (4.18)$$

.

The function $\boldsymbol{f}_{r'}(r)$ may be called[5] "relative potential" at r with respect to the observer at r'. For a central field, the best experimental value of $\boldsymbol{f}_{r'}(r)$ found below corresponds with the dimensionless difference of G potentials in which the mass is expressed in energy units.

$$\boldsymbol{f}_{r'}(r) = \boldsymbol{f}(r) - \boldsymbol{f}(r') \sim -GM/r + GM/r' \qquad (4.18b)$$

---

[5] This name seems to be a better one compared with the one used in the original manuscript.

The integration of the dimensionless equations (4.17) between r' and r gives the following theoretical properties of matter at rest in the field.

(a) Non-local Gravitational Red Shift and Time Dilation

$$f_{r'}(0, r)/f_{r'}(0, r') = exp[\, f(r) - f(r')] \;=\; [c_{r'}(r)/c]^{1/2} \qquad (4.19)$$

$$m_{r'}(0, r)/m_{r'}(0, r') = exp[\, f(r) - f(r')] \;=\; [c_{r'}(r)/c]^{1/2} \qquad (4.20)$$

The relative frequencies, the relative energies, and the relative masses of each structural part of any body would be theoretically decreased by the same factor. (Notice that this is in the only way in which every local ratio can remain unchanged after a change of G potential). The same fractional changes should occur in the relative frequencies of the photons emitted by atomic transitions between any two energy levels whose values would be affected by the same factor.

From (4.19), the theoretical NL time interval corresponding to a local time interval of a well defined number o *N periods (T) of the clock at r´*, i.e., for $t_{r'}(r') = NT$, would be

$$t_{r'}(r) = t_{r'}(r')exp\, [\, f(r') - f(r)\,] = NT\, [\, c_{r'}(r)/c]^{-1/2} \qquad (4.21)$$

Everything would thus occur at slower rates in the field of lower non-local speed of light as compared with the same phenomenon occurring at infinity. But since all of the local clocks of the same observer would also run at slower rates, local observers in different G potentials would not realize that their clocks are running slower with respect to other observers in different G potentials, unless that they make nonlocal measurements like in G time dilation and G red shift experiments.

(b) Non-local Gravitational Contraction

From (4.17),

$$\lambda_{r'}(0, r)/\, \lambda_{r'}(0, r') = exp[\, f(r) - f(r')] \;=\; [c_{r'}(r)/c]^{1/2} \qquad (4.22)$$

Every length of a body at rest should, therefore, be contracted by the same factor.

A local standard rod at r of just n standard wavelengths has local length: $L_r(0, r) = n\ \mathbf{l}_r(0, r) = n\mathbf{l}°$. From (4.17), the same rod, as viewed from the observer at r', has a relative length given by

$$L_{r'}(0, r)/L_{r'}(0, r') \;= exp[\, f(r) - f(r')] \;=\; [c_{r'}(r)/c]^{1/2} \qquad (4.23)$$

In which the numerical value of the local standard length is $L_{r'}(0, r') = n\ \mathbf{l}_{r'}(0, r') = n\mathbf{l}° = L_r(0, r)$.

"Observers in the lower G potentials should, therefore, have smaller units of length compared with those in higher G potentials".

(c) Non-local Refraction and Relative Velocities. From (2 1) and (4.23), the non-local velocity of a body is contracted by the same factor as the non-local velocity of light:

$$V_{r'}(r)/V_{r'}(r') = c_{r'}(r)/c = exp\, [2f(r) - 2f(r')] \qquad (4.24)$$

From (4.24), the NL refraction index of the space in a G field, with respect to the observer at r', is:

$$n_{r'}(r) = c/c_{r'}(r) = \exp\,[2f(r')-2f(r)]\ . \qquad (4.25)$$

This relation accounts for the deviation of light and for the propagation of matter in the field, as shown below.

(d) Non-local space-time Contraction. The identical fractional changes of the relative frequencies and lengths that matter should have at rest in the field stand up even in the "*non-local space-time*" with respect to some observer in a well-defined GP. Its line element is defined by

$$ds_{r'}(0,r)^2 = [c_{r'}(r)dt_{r'}(r)]^2 - \sum_{i=1}^{3} dx^i_{r'}(0,r)^2 \qquad (4.26)$$

From (4.23), (4.24), and (4.26)

$$ds_{r'}(0,r)/ds(0,r) = \exp[f(r) - f(r')] \ = \ [c_{r'}(r)/c]^{1/2} \qquad (4.27)$$

Then, the non-local space-time interval undergoes the same changes of scale as each of its four coordinates, which is obvious[6].

For the observer at infinity and for a central field, the application of the value $f(r)$ $- GM/r$, found from experiments, to the equations (4.27) and (4.26) gives

$$ds_r(0,r)^2 = [c_{r'}(r)^2 dt_{r'}(r)^2 - dx_{r'}(r)^2 - dy_{r'}(r)^2 - dz_{r'}(r)^2]e^{2GM/r} \qquad (4.28)$$

With the use of (4.25) something like the Yilmaz's metric results:

$$ds_r(0,r)^2 = c^2 dt_{r'}(r)^2 e^{-2GM/r} - [dx_{r'}(r)^2 + dy_{r'}(r)^2 + dz_{r'}(r)^2]e^{2GM/r} \qquad (4.29)$$

The first approximation of (4.29) looks like the Schwarzchild line element. But it seems necessary to point out here that *the true non-local space-time should have all of its coordinates of non-local character* as in (4.26) and (4.28). Notice that in (4.28) the conventional interval cdt has been replaced with $c_{r'}(r)dt_{r'}(r)$ in which the NL speed of light is not constant.

(e) Non-local Charge Depletion. From (4.5), a force is a ratio between a mass-energy change and a displacement. Then, from (4.20), and (4.23) it is simple to prove that the non-local forces, the same as any ratio $m_{r'}(r)/L_{r'}(r)$, are independent of the gravitational field existing at both the observer and the object. This property can be used to find the theoretical changes of the electric changes after a change of G potential.

Since a force can be used to define the local unit of charge, then the centripetal force of an electron charge rotating around a proton can also be used for a natural definition of the charge unit. Then same theoretical force can be derived for an observer

---

[6] Notice that the interval of the fourth coordinate is $c_{r'}(r)dt_{r'}(r)$ in which $c_{r'}(r)$ is position dependent.

in a general non-local position r'. To be consistent with the local physical laws, this one should have the form:

$$F_{r'}(\boldsymbol{b},r)=\frac{m_{r'}(\boldsymbol{b},r)}{R_{r'}}\boldsymbol{b}^{2}=k\frac{e^{+}_{r'}(0,r)e^{-}_{r'}(0,r)}{R^{2}_{r'}}$$

Let us multiply and divide this relation by $M_{r'}(0, r)$ and $m_{r'}(\boldsymbol{b}, r)$, the masses of the proton and of the electron, respectively.

$$F_{r'}(\boldsymbol{b},r)=k\frac{e^{+}_{r'}(0,r)}{M_{r'}(0,r)}\frac{e^{-}_{r'}(0,r)}{m_{r'}(0,r)}\frac{M_{r'}(0,r)}{R_{r'}}\frac{m_{r'}(\boldsymbol{b},r)}{R_{r'}}$$

Since NL forces and the NL ratios of m/R and M/R are independent of the position of the observer, then "the same should be true of the ratios e/M". Therefore, *the non-local charges should change in identical proportion as the non-local mass-energies and the non-local lengths, after a common change of G potential* [7]. This result is another test of self consistency of this approach and of consistency with the Einstein's equivalence principle.

f) Deformation of Matter. The curvature radius of a pseudo horizontal rule determined from Figure 2 and (4.22) is equal to $[d f(r)/dr]^{-1} = [F(0, r)/m(0, r)]^{-1}$.

g) Non-local Forces. The relation between local and non-local momentum can be derived either from (4.7) and (4.22) or from (4.11), (4.20), and (4.24):

$$p_{r'}(r) = p_r(r) \exp [f(r') - f(r)] \qquad (4.30)$$

The relation between local and non-local forces defined from (4.5) is obvious because the force is a ratio between two parameters that change in the same proportion after the same change of GP. because and (4.20) or from (4.12), (4.20), and (4.21). :

$$F_{r'}(0,r)=-\frac{dm_{r'}(0,r)}{dr'}=\frac{dm_{r}(0,r)}{dr}=F_{r}(0,r)=-m_{r}(0,r)\frac{\partial f(r)}{\partial r} \qquad (4.31)$$

The forces are independent of the location of the observer because the rest masses, the energies, and the lengths change in the same proportion after the same change of G

---

[7] Most of the theoretical relationships between local and non-local parameters for electromagnetism in gravitational fields can be derived most simply, for example, by using the particular case of the non-local electromagnetic force between charges moving parallel to each other, like:

$$F_{r'}(\boldsymbol{b},r)=k\frac{q_{r'}(\boldsymbol{b}^{1},r)q^{-}_{r'}(\boldsymbol{b}^{2}r)}{d^{2}_{r'}}[1-\boldsymbol{b}^{1}\boldsymbol{b}^{2}]$$

Since the local electric and magnetic forces are independent of gravitational potential of the system, then all of them, the charges and the distances, must change in the same proportions after the same change of G potential.

potential. Observe that for reason of symmetry in (4.31) the gradient of $\boldsymbol{f}(r)$ should be proportional to the non-local mass $M_{r'}(0, r^o)$ causing the gravitational field.

(h) Non-local Mechanical Energy Conservation. From (3.8) and (4.20) the non-local mass-energy conservation for a body traveling freely in a G field can be expressed by

$$m_{r'}(\boldsymbol{b},r)=\frac{m^o\exp\left[\boldsymbol{f}(r)-\boldsymbol{f}(r')\right]}{(1-\boldsymbol{b}^2)^{1/2}}=const \tag{4.32}$$

From (4.4) the absolute potential energy (PE) of the nonlocal model at *r*, with respect to the observer at *r´*, is just equal to its net energy with respect to the same observer. From (4.17), this one is:

$$PE_{r'}(r) = m_{r'}(0, r) = m^o exp[\, \boldsymbol{f}(r) - \boldsymbol{f}(r')] \tag{4.32a}$$

The non-local kinetic energy the body moving at *r* with the velocity $\boldsymbol{b}$ with respect to the same observer is just equal to the net energy released after a local stop at *r*.

$$KE_{r'}(r) = m_{r'}(\boldsymbol{b}, r) - m_{r'}(0, r) \tag{4.32b}$$

From (3.8) and (4.32a),

$$KEr'(r)=m^o\left[\frac{1}{(1-\boldsymbol{b}^2)^{1/2}}-1\right]\exp\left[\boldsymbol{f}(r)-\boldsymbol{f}(r')\right] \tag{4.32b2}$$

The summation of (4.32a) and (4.32b) gives

$$KE_{r'}(r) + PE_{r'}(r) = m_{r'}(\boldsymbol{b}, r) = constant \tag{4.32c}$$

The approximations of (4.32) up to (4.32c) are consistent with the corresponding traditional expressions for weak fields.

From (4.32b2), for a body traveling freely in a G fields, the velocities and gravitational potentials are related to each other by:

$$\boldsymbol{b}^2 = 1 - Kexp\ [2\boldsymbol{f}(r),-2\boldsymbol{f}(r')] \tag{4.32d}$$

In which $K = m_{r'}(0,r')/m_{r'}(\boldsymbol{b},r)$ is a constant for each trajectory. This value is close to 1, for non-relativistic bodies, and equal to zero for photons.

(i) Non-local Angular Momentum Conservation. This law can be derived directly from the theoretical trajectory of the light-box model. For this purpose assume, for simplicity, that the components of the standing waves are traveling back and forth along the line of movement. The interference of the Doppler-shifted standing waves, whose frequencies are fixed by (4.8) and (4.9), gives net wave amplitude proportional to:

$$A = \sin \frac{2\boldsymbol{p}}{\boldsymbol{l}_{r'}(\boldsymbol{b},r)}[x - V_{r'}(r)t_{r'}(r)]\left[\cos \frac{2\boldsymbol{p}}{\boldsymbol{l}'_{r'}(\boldsymbol{b},r)}[x - c'_{r'}(r)t_{r'}(r)]\right] \tag{4.33}$$

in which

$$\boldsymbol{l}_{r'}(\boldsymbol{b}, r) = c_{r'}(r)/f_{r'}(\boldsymbol{b},r) \tag{4.34}$$

$$\boldsymbol{l}'_{r'}(\boldsymbol{b},r) = \frac{c_{r'}(r)}{\Delta f_{r'}} = \frac{c_{r'}(r)}{\boldsymbol{b}\; f_{r'}(\boldsymbol{b},r)} = \frac{Nh}{p_{r'}(\boldsymbol{b},r)} = \frac{\boldsymbol{l}_{r'}(\boldsymbol{b},r)}{\boldsymbol{b}} \tag{4.35}$$

This wavelength is consistent with the De Broglie wavelength whose speed is:

$$c'_{r'}(r) = c_{r'}(r)/\boldsymbol{b} \tag{4.36}$$

Use of (4.1 1) and (4.34) has been made in (4.35).

A is a product of two traveling wave functions. The amplitude of the first one is modulated by a kind of guide wave of effective wavelength $\boldsymbol{l}'(\boldsymbol{b}, r)$ that determines the orientation of the wave front of the packet of waves according to the interference laws based on the Huygen's principle.

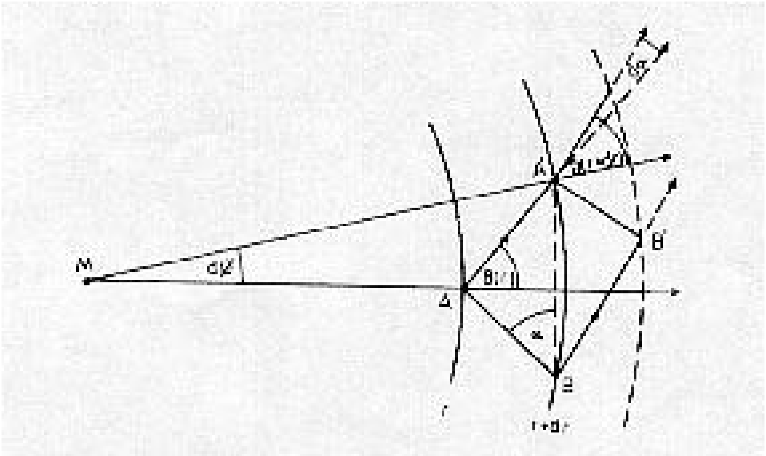

Fig. 3. Propagation of the monochromatic wave front ***AB*** through successive layers of the central field, produced by ***M***, according to electromagnetic principles.

From Figure 3 and (4.35) these waves will be in phase when

$$\frac{d(\sin \boldsymbol{q})}{\sin \boldsymbol{q}} = \frac{d\boldsymbol{l}'_{r'}(\boldsymbol{b},r)}{\boldsymbol{l}'_{r'}(\boldsymbol{b},r)} - \frac{dr_{r'}}{r_{r'}} = \frac{dp_{r'}(\boldsymbol{b},r)}{p_{r'}(\boldsymbol{b},r)} - \frac{dr_{r'}}{r_{r'}} \tag{4.37}$$

The integration of (4.37) gives the non-local angular momentum conservation law of the same form as the traditional one but with non-local parameters:

$$\frac{r_{r'} \sin \boldsymbol{q}}{\boldsymbol{l}'_{r'}(\boldsymbol{b}, r)} = \text{Constant} \tag{4.38}$$

More precisely;

$$\boldsymbol{r}_{r'}\ x\ \boldsymbol{p}_{r'}(\boldsymbol{b},r) = constant = \boldsymbol{L} \qquad (4.39)$$

The good correspondence with the traditional expressions confirms, once more, the reliability of the light-box model for matter.

More explicitly and from (4.39) and (4.1 1), for an observer at r',

$$\mathbf{L} = \frac{m_{r'}(\boldsymbol{b},r)\,\mathbf{r}_{r'}x\hat{\mathbf{a}}}{c_{r'}(r)} \qquad (4.40)$$

From (4.20), (4.23), and (4.24) it is inferred that the numerical value of **L** is independent on the location of the observer.

From (3.7), $m_{r'}(\boldsymbol{b}, r)$ remains constant during any specific free trajectory in a static field. Then it is simpler to define a kind of angular momentum density with respect to some well-defined observer. From (4.40),

$$j_{r'} = \frac{\mathbf{L}}{m_{r'}(\boldsymbol{b},r)} = \frac{r_{r'}x\boldsymbol{b}}{c_{r'}(r)} = \text{Constant} \qquad (4.41)$$

This relation is valid for bodies and for photons. In the last case $m_{r'}(\boldsymbol{b}, r) = hf_{r'}(r)$ is the energy of the photon with respect to the observer which also remains constant. The orbit of the nonlocal photon in the field is fixed from (4.41).

5. EXPERIMENTAL TESTS FOR CENTRAL FIELDS

According to the above definitions, the non-local or relative masses with respect to the observer are the true or effective masses corrected for the differences of gravitational potentials between the object and the observer. Therefore, they should be the true sources of the G field. Then it should be expected that the introduction of non-local quantities in the classical Poisson equation should greatly improve its results, especially in the cases of strong static fields, at least:

$$\nabla^2_{r'}\boldsymbol{f}(r) = 4\boldsymbol{pr}_{r'}(0,r) \qquad (5.1)$$

The integration of (5.1) for the central point body of relative mass $M_{r'}(0,r_o)$ gives a solution:

$$\boldsymbol{f}(r) = -\frac{GM_{r'}(0,r_o)}{r_{r'}} = -\frac{GM}{r} \qquad (5.2)$$

The third member of (5.2) results from the fact that the ratio $M_{r'}(0,r_o)/r_{r'}$ and the value of ϕ(r) are independent on the location of the observer, for which reason the values for the observer at infinity may also be used for it. Thus $M = m\ \ (0,r_o)$ and $r = r$.

For the same reason it is inferred that the constant G may be a universal constant[8] which, anyway, is equal to the classical ratio $\boldsymbol{G}/c^{4.}$

Since the relationships of the last sections have been deduced according to well-proved principles and laws of physics, it seems unnecessary to show further consistency with ordinary physics. Notice that several tests have already been done during the above deductions.

It may be worth mentioning that the non-local field equation (5.1), which is the simplest one that can be imagined, is the one that gives the best fit with the observed facts.

(a) Agreement with the Standard Newtonian Theory. From (4.5), (4.20), and (5.2), for the observer at infinity,

$$F_{r'}(0,r) = -\frac{GM_{r'}m_{r'}(0,r)}{r_{r'}^2} = -\frac{GMm^o}{r^2}e^{GM/r'-GM/r} \tag{5.3}$$

Which resembles Newton' law, but with nonlocal quantities instead of the local ones. For $r' = r$, it corresponds with the Newton's law. In contrast to Newton's law, $F_{r'}(0, r)$ is maximum at $r = GM/2$, and decreases to zero for $r = 0$. No singularity is obtained for $r = 0$ nor for $r = 2GM$, in contrast to general relativistic results.

From (4.1), (4.17), and (5.2), we obtain

$$g_{r'}(0, r) = - [c_{r'}(r)]^2\, GM_{r'}/r^2 \tag{5.4}$$

Which is corresponds with Newtonian Physics.

The use of (5. 1) for the case of a G field produced by a set of n discrete bodies, the G potential at some position r^i would come from the sum of the contributions of the latter ones:

$$f(r^i) = \sum_{j=1}^{n}\frac{GM^j}{r^{ij}} \tag{5.5}$$

M^j is the NL mass of the body j and r^{ij} is the distance between the test body i and the NL bodies j. Each body would thus contribute to the fractional depletion of the nonlocal mass of the rest of the bodies of the system[9]. Each body would thus contribute to the fractional depletion of the non-local mass of the rest of the bodies of the system. The use of (4.5), (4.20), and (5.5) leads to gravitational forces in agreement with traditional physics.

(b) Gravitational Red Shift (GRS) and G Time Dilation. The approximations of (4.19) after use of (5.2) agree with experiments made by Pound and Snider (1965).

Notice that *"The lower non-local velocity of light in a gravitational field should affect in the same proportion to any standing wave that can represent the energy levels in more elaborated models of atoms"*. Then emission spectrum lines should be red-shifted in the same proportion as each individual frequency or the total mass of the

---

[8] Notice that, since the mass-energy unit used here is 1 joule, then the constant G has a numerical value equal to the constant G in the *mks* unit system divided by c^4.

[9] The use of subscripts is unnecessary because the ratio *M/r* does not depend on the positions of the fixed observer

atom, according to (4.19) or (4.20).

It is simple to prove-after use of classical electromagnetism and (4.23) and (4.25)- that the non-local frequency of a LC resonant circuit should also change according to (4.19) after a change of the properties of the dielectric. It seems trivial to show that, according to the Einstein's equivalence principle, some similar relationship must hold for any kind of frequency or energy, such as the nuclear one, whose value depends linearly on the mass.

(c) Gravitational Refraction. According to the GRS phenomenon, light emitted by the atoms of a vertical source in the field is not strictly monochromatic. In a wave front traveling horizontally, according to (4.19), the photons emitted by its lower atoms would have lower non-local frequencies and they would travel with lower non-local speed of light, according to (4.25). The net result is a smaller non-local wavelength of the lower part of the wavefront. This would produce, according to Huygens' principle, downward deviations proportional to $d\mathbf{l}(0,r)/dr = GM/r$. They account for the weight and acceleration of gravity determined from (4.2), (4.17) and (5.2).

A strictly monochromatic wavefront coming from an external source like a star, on the other hand, would have a wavelength with a vertical dispersion derived from (4.17) and (5.2):

$$\mathbf{l}_{r'}(r) = c_{r'}(r)/f_{r'}(r) = \mathbf{l}^{o}\exp(-2GM/r) \qquad (5.6)$$

Its deviation is roughly proportional to $d\mathbf{l}_{r'}(r)/dr = 2GM/r^2$, i.e., the double of the deviation of the internal waves of a horizontal model at rest. Thus the integrated deviation of light coming from field stars, produced by the gravitational field of the sun, is thus approximately equal to $4GM/r^i$, where r^i is the *impact parameter*. This value is in agreement with the experiments of Bertotti et al, (1962).

Equations (4.41) and (5.2) fix the trajectory of a photon in central fields. Its inclination angle, $\mathbf{q}$, is determined by

$$\sin \mathbf{q} = (x_i/x)\exp(-2/x) \qquad (5.7)$$

Where $x = r/GM$, $x_i = r_i/GM$, and r_i is the impact parameter.

Figure 4 gives x vs. $\mathbf{q}$ for some special cases. In the curve ***ABC,*** for $x_i = 3e$, light is only deviated. Curve ***DE*** is for the critical case when light can be temporarily trapped in an orbit at **E**, in the graphic. If the photon had a smaller impact parameter, it would be captured, like in the curve ***EO***. Curve ***IJK*** represents a photon escaping from the internal surface (***LL'***) but later captured at the same surface.

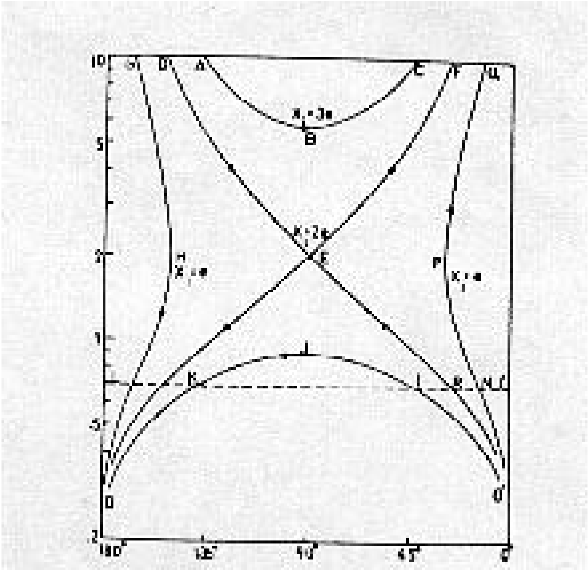

Fig. 4. Inclination angles θ of monochromatic light beams for several impact parameters r_i, and critical escape angles for a semi black body with $r < 2GM$. The values of x are equal to the ratio R/GM, and $x_i = r_i/GM$.

The limiting escape angle, θ_e of photons is determined by

$$\sin \theta_e = (2eGM/r)\exp(-2GM/r), \qquad r << 2GM \qquad (5.8)$$

Super dense bodies with $r < 2GM$ would capture anything traveling with $x_i < 2e$, regardless of its energy, but they would let escape only photons or relativistic particles emitted with an angle lower than θ_e. Therefore, they let photons escape with lower probabilities than a blackbody, for which reason they have been called semi black bodies. They could capture more energy than they can emit due to both the lower escape probability and to the strong gravitational red shift, which can go beyond the limits generally assumed from the theory of general relativity.

In spite of high local temperatures at their surfaces, they should look, as observed from infinity, as if they had temperatures close to $0\,^oK$ with the characteristics of cavity radiation. Some evidence of the existence of these bodies is given below.

(d) Time Delay of Radar Echo from Planets and Mariners. From (4.24) and (5.2), the theoretical time delay of radar echo from a planet is determined by

$$ct = 2(x_e+x_p) + 4GM\ln[(r_p+x_p)/(r_e-x_e)] \qquad (5.9)$$

In which x_e and x_p are the distances along the line of flight from the earth and the planet, respectively, to the point of closest approach to the sun. The distances from the sun of the earth and of the planet, are r_e and r_p, respectively. Equation (5.9) is in agreement with the experiments published by Shapiro et al. (1971) and Anderson et al. (1971).

(e) The Perihelion Shift of Planets. The application of (4.32d) and (4.41) to free orbits gives

$$\left[\frac{dz}{d\alpha}\right]^2 + z^2 = A^2[1 - K^2 \exp 2f(r)]\exp[-4f(r)] \qquad (5.10)$$

where α is the angular position, $z = GM/r$, $A = GM/jc$, and j is the density of angular momentum.

For $f(r) = -z$, the second-order approximation of (5.10) gives a perihelion shift of

$$Da = 6pA^2 = 6GM/a(l - e^2) \qquad (5.11)$$

This value is in agreement with the results of the observations of Shapiro et al. (1971).

It is interesting to know how much experimental errors of the perihelion shift would allow that the ratio $F(0, r)/m(0, r)$ can deviate from the theoretical value (5.3):

$$\frac{F_{r'}(0,r)}{m_{r'}(0,r)} = -\frac{\partial f(r)}{\partial r_{r'}} = -\frac{GM_{r'}}{r_{r'}^2} \qquad (5.12)$$

For this purpose it can be assumed that the ratio $F(0, r)/m(0, r)$ has the form suggested from the results of general relativity,

$$\frac{F_{r'}(0,r)}{m_{r'}(0,r)} = -\frac{GM}{r(r - xGM)} \cong -\frac{GM}{r^2}(1 + xGM/r) \qquad (5.13)$$

$x = 2$ for general relativity. Here x is the maximum factor that can produce results in agreement, within experimental errors, with the observed facts. If $f^d(r)$ is the new field magnitude defined by (5.13), its value can be obtained by equating (5.13) with df^d/dr and integrating. Its approximate value is $(GM/r)(1 + xGM/2r)$. The substitution of this value into (5.10) gives a shift of

$$Da = p(6 + x)A^2 \qquad (5.14)$$

The experiments deviate from (5.11) by about ± 1%, for which reason x must be smaller than *0.06*, i.e., much smaller than the value of ***2*** suggested from general relativity.

(f) Relativistic Cosmic Radiation. From above, the energy non-exchange principle between bodies and G fields turns out to be a consequence of mass-energy conservation, which does hold for any conservative field. It is expected, therefore, that this principle would hold for other conservative fields or for a combination of them. Its application to the case of a *He* nuclei falling rather freely into a super dense star[10] permits a fairly good estimation of the maximum energy of the cosmic radiation that that can result from a rather free fall of particles on neutron stars, along the polar magnetic lines.

Even when the intermediate processes are unimportant for the present purposes, it is expected that, for example, a combination of attractive and repulsive fields should produce different effects on both types of particles. Under dynamical conditions, for

---

[10] This can occur with higher probability along the polar magnetic regions.

example, it is reasonable to expect that the central body becomes positively charged so that protons are likely to be reflected with more probability than neutrons under the combined effect of nuclear, electrostatic, and gravitational fields. While the two particles are bound together, the non-local mass of the repelled particles (protons) would grow at the cost of the decrease of the non-local mass of the attracted particles (neutrons), thus keeping constant the total mass of the He nuclei, according to the non exchange principle. This would hold up to the point of rupture of the nuclear binding[11].

During the fall along magnetic lines, neglecting some probable non-conservative loss of energy on the whole process, the sum of the final non-local masses of the He nucleons should be equal to the initial non-local mass of the He nuclei. From (4.20) and (5.2), the final relative rest mass of the neutrons at rest at the core of high *GM/R* should be negligible as compared to the final relative masses of the protons escaping towards infinity. This global mass-energy balance of non-local masses, before and after the impact, leads to a final relative mass of the two rejected protons just about equal to the initial relative mass of the He atom. The magnetic rigidity equivalent to this mass excess of the protons is equal to 1.6×10^9 V, which is in excellent agreement with the last peak of the primary cosmic ray spectrum observed by McDonald and Webber (1959) in periods of minimum perturbations due to solar flares.

6. CONCLUSIONS

The introduction of non-local theoretical quantities referred to standards in a fixed field at the position of the observer provides a firm basis on which true physical relations can be established between quantities measured in different G potentials. The gravitational phenomena can be understood in terms of quantities that have been previously corrected for the general physical changes that must occur to all of the bodies after a common change of position in a field.

The basic theoretical relationships between local and non-local quantities have been deduced with the help either of the *mass-energy conservation principle* or of a fundamental property of electromagnetic wave, which is wave continuity. Static conservative fields cannot change the net number of electromagnetic waves or light signals traveling through them. From them it was deduced that all of them, the non-local frequencies, the non-local energies and the non-local masses of bodies, represented here by particle models, should remain constants during their free propagation in gravitational fields. This is equivalent to *a non-exchange principle* according to which there is no net exchange of mass-energy between a static conservative field and matter or radiation traveling freely through it.

This result is in clear disagreement with the traditional assumptions that all of the conservative fields should transfer energy to the bodies doing conservative work. In the case of G fields, on the contrary, the energy released comes from the conversion of the equivalent fraction of the rest mass of the same test body into rather free forms of energy. The gravitational work is more properly done by the body, not by the field as it is commonly stated.

As a result of this, the non-local rest mass of the body becomes a measure of its absolute potential energy.

The explanation for the above result and for the gravitational phenomenon becomes clearer after use of the light-box model for matter. *The gravitational field*

---

[11] This process would correspond with the so called "nuclear stripping" of the Oppenheimer type. Neutron would be captured while protons are rejected. Thus this would be a nuclear reaction between a giant macronuclei and an atomic nucleus.

turns out to be a space of variable non-local velocity of light, which accounts for all of its properties. The local velocity of light, nevertheless, is a constant for any observer because of the constant values assigned to their local standards[12].

Similarly to the case of free light, the standing wave packets of the particle models propagate themselves in the field without changing their average non-local frequencies or energies. They are deviated, after a refraction phenomenon, toward regions of lower non-local velocities. Their theoretical trajectories are consistent with the most rigorous experiments.

When a free-falling body is forced to stop in the field, each elementary part of it releases a well-defined fractional part of its own energy which, in one way or another, can go away from the body. As a result of the lower non-local residual mass-energy of each of its parts, and of the lower non-local velocity of light in the new space, the new body would have identical proportions to the original one. But every part of it would have smaller non-local rest mass, length, wavelength, or electric charge. The non-local energy levels and the emitted wavelengths would also change in just the same proportion as the wavelengths defining the structure of matter. The percentage of gravitational red shift observed is just a direct measure of the percentage of the mass difference between the atoms of the object and the observer's atoms.

The good agreement of the tests done in the last section also proves that, effectively, the above equations are more consistent with both the observed facts and the physical principles involved in the deductions. They also prove that the *non-local* rest mass-energy of a body, which is now position-dependent, is the true source of its gravitational field. *The gravitational field itself has no energy, i.e., it is not a secondary source of gravitational field.*

If both the test body and the G field source are replaced by light-box models, it is simple to conclude that *the most elementary gravitation phenomenon is just a photon-photon interaction* in which each one modifies the electromagnetic properties of the space around it.

The bodies with $r < 2GM$ would have theoretical properties different from both plain black bodies and current black holes. Radiation may escape from them but with much lower probabilities than in a black body. They, therefore, may emit both strongly red shifted cavity radiation of nonlocal temperature close to $0°$ K and relativistic cosmic radiation close to the theoretical maximum at magnetic rigidity of 1.6 *GV*. Both types of radiation have been detected. In the primary cosmic ray spectrum observed by McDonald and Webber (1959) there is a sharp decrease of cosmic radiation just after the last peak at 1.6 GV, just as is expected. This seems to prove both that the non exchange principle derived here holds for the other types of conservative fields involved in the generation of cosmic radiation and that *a relatively large fraction of matter in the universe exists in the form of semi black bodies*. This is also consistent with the very much larger mass of the clusters of galaxies when this mass is determined by dynamical methods as compared with the sum of the masses of their luminous bodies.

On the other hand, it seems reasonable to expect that black galaxies would be the natural result of galactic evolution and that their most massive bodies would have reached the state of semi black bodies. This is also consistent with the well-known fact that the density of galaxies observed beyond clusters of galaxies is smaller than the average found in other regions of the sky. Black galaxies would not let see what is

---

[12] Each time that an observer changes of velocity or GP, there is a tacit renormalization of all of his local unit system which is done after assigning the same numerical values to its local standards of time (frequency) and length.

behind them[13].

The absence of a singularity at $r = 2GM$ would open the way for nontraditional alternatives for stellar evolution[14] and for new explanations of many astronomical phenomena (Vera, 1974, 1977). For example, the red shift of a real quasi-stellar "radio source", originally named "quasar" may correspond to a gravitational red shift rather than a cosmological one. This is in agreement with the work of Clapp (1973) based on the Yilmaz (1958) exponential metric.

It seems possible to make a direct comparison of the present results with the ones of general relativity after use of the work of Thirring (1961).

In his original pseudo-Euclidean metric, the unrenormalized quantities are unobservable, the same as the non-local quantities used here. On the other hand, the renormalized metric is directly defined by observable (local) quantities that are in agreement with the Riemannian metric of general relativity.

The unrenormalized lengths, time, electric charges, and the velocity of light are equal to the respective approximations of the non-local values obtained here. The renormalized mass increases with the increase of the field. The non-local mass decreases in stronger fields.

The present results are more consistent with the results of Yilmaz's theories (1958, 1971) than with the ones of Einstein's general relativity. We need not be concerned with the objections made by Will and Nordvedt (1972) because the non-local quantities are not dependent on the velocity of the system relative to the space. Any possible anisotropy phenomena produced by such a relative displacement should affect in the same proportions, and in the same relative orientations, to all of the parts of the system. Since every non-local quantity is a ratio between quantities that are affected by the same kind of changes and in the same proportion, then their ratio should be independent of such a change, unless the changes were nonlinear, which is unlikely[15]. Then, it would be impossible to detect such a linear phenomenon. For practical purposes, therefore, a theoretical observer at rest relative to the mass center of a system can safely assume an idealized working space at rest relative to him.

ACKNOWLEDGMENTS

The author would like to express his indebtedness to Dr. Walter E. Thirring of the Institute for Theoretical Physics, University of Vienna, to Dr. Danilo Villarroel of the University of Chile, and to my colleagues from the Institute of Physics of the University of Concepción, Chile, for helpful discussions and advice.

REFERENCES

Anderson, J. D., Esposito, P. B., Martin, W. L., and Muhleman, D. 0. (1971). "*Proceedings of the Conference on Experimental Test of Gravitational Theories*," R. W. Davis, ed., California Institute of Technology, Technical Memorandum 33-499.

---

[13] Black galaxies resulting from evolution of luminous ones should produce black body radiation close to 0°K.

[14] This is because the black holes would be not the dead end of matter in the universe. Semi-black bodies, after absorbing radiation, can explode thus regenerating star clusters and so on.

[15] Because it would violate the Einstein's equivalente principle.

Bertotti, B., Brill, D. R., and Krotkov, R. (1962). "Experiments on Gravitation," L. Witten, ed., *Gravitation: An Introduction to Current Research*, Wiley, New York.

Clapp, R. E. (1973). "Preliminary Quasar Model Based on Yilmaz Exponential Metric, *Physical Review D*, **7**, 345-355.

Dehnen, H., Honl, H., and Westpfahl, K. (1960). "A Heuristic Approach to General Relativity," *Annalen der Physic*, **6**, 370-406.

Einstein, A. (1965). *The meaning of Relativity,* Princeton University Press, Princeton, New Jersey.

McDonald, F., Webber, B. (1959). *Physical Review*, **115**,194.

Pound, R. V., and Snider, J. L. (1965). "Effect of Gravity on Gamma Radiation," *Physical Review B*, **140**, 788-803.

Rastall, P. (1960). "An Approach to a Theory of Gravitation" *Canadian Journal of Physics*, **38**, 975-982.

Schild, A. (1960). "Time," *Texas Quarterly*, **3**(3), 42-62.

Shapiro, 1. I., Ash, M. E., Campbell, D. B., Dyce, R. B, Ingalls, R. P., Jurgen, R. F., and Pettengill, G. H. (1971). "Fourth Test of General Relativity: New Radar Result," *Physical Review Letters*, **26**, 27-30.

Shapiro, 1. I., Pettengill, G. H., Ash, M. E., Ingalls, R. P., Campbell, D. B., and Dyce, R. B. (1972). "Mercury's Perihelion Advance: Determination by Radar," *Physical Review Letters*, **28**, 1594-1597.

Thirring, E. R. (1961). "An Alternative Approach to the Theory of Gravitation," *Annals of Physics*, **16**, 96-117

Vera, R. A. (1974). "Teoría sobre Evolución Isoentrópica del Universo," *Revista Atenea. Universidad de Concepción* . Concepción, Chile, **429-430**, 196-212.

Vera, R. A. (1977). "Una Nueva Concepción del Universo," *Revista Atenea. Universidad de Concepción,* Concepción, Chile, **435**, 103-127.

Vera, F- A. (1978). "Generalization of Newton’s Gravitational Law for Non-local Quantities”. *First Chilean Symposium on Theoretical Physics*. Universidad Técnica del Estado, Santiago, Chile.

Vera, R. A. (1979). "What Does the Work in a Conservative Field?" *The Einstein Centennial Symposium on Fundamental Physics,* Departamento de Física, Universidad de Los Andes, Bogotá, Colombia.

Will C. M., and Nordvedt, K. (1972). "Experiments Rule Out Preferred-Frame Metric Theories of Gravity," *Bulletin of the American Physical Society,* **17**, 141.

Yilmaz H. (1958). "New Approach to General Relativity," *Physical Review*, **111**, 1417.

Yilmaz H. (1971). "New Theory of Gravitation," *Physical Review Letters*, **27**, 1399-1402.