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SPACE, TIME, AND A NEW APPROACH TO THE PRINCIPLE OF RELATIVITY

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ABSTRACT. This paper describes in great details a thin-shell model (as contrasted to a full-volume model) and its impact on basic concepts within the contemporary cosmology. Although speculative to some extent about the idea of introducing a gravitational fluid in order to imagine a possible expansion mechanism, the paper nevertheless is in agreement with the recent result of the general theory of relativity where the expansion of the ponderable matter is assumed to had taken place infinitely fast at the beginning. However, we analyzed the existing evidence from a more fundamental point of view where space and time appear as two interrelated physical quantities, are treated like those of the angular momentum and a lifetime, or any other similar physical quantities. This viewpoint seems to be in full agreement with our assumption concerning the observed recession of clusters of galaxies. To expose a possible link between the present thin-shell model and some contemporary research, in the framework of field theories, we outlined a spiritual basis for a double principle of relativity. There is, on one hand, a well established electromagnetic principle of relativity where the speed of light c plays a dominant part. However, there appears on the other hand, also a specifically gravitational principle of relativity where the speed of gravity c_g takes a supreme position in a dynamical description of the ponderable matter.

Key words: Thin-shell model, gravitational fluid, stability conditions, clusters of galaxies

1. INTRODUCTION

There is presently a great interest to study the relativistic cosmology, masses of elementary particles, as well as the problem of a space-time structure. In the framework of practical experimental measurements the problem is reduced to searching for the nature of inertial and gravitational forces. There is a tendency to verify experimentally the general theory of relativity and overcome difficulties that arise in the interpretation of the measuring process within the mentioned theory. Usually, experiments are directed towards detecting a number of relativistic effects in relation to Newton's theory of the universal gravitation (1687) which appears in Einstein's theory of general relativity (1915 - 1916) as a first-order approximation in a weak gravitational field. In the framework of these experiments, various improvements of the theory of gravitation are being constantly analyzed. On one hand, they should indicate any possible departure from the theory of general relativity while, on the other hand, they contain Newton's classical mechanics as a limiting case.

Here as a criterion physicists use Mach's idea about the inertia of a material object generated by the attraction of ponderable matter including infinitely distant masses. (The expression ”ponderable”, according to Einstein, is used to designate ”heavy”, or ”massive”.) In his study about classical mechanics (1883) Mach introduced the idea that one can measure only relative motions, time intervals, velocities, and accelerations. Mach has postulated that the accelerations could be defined only with respect to the center of mass of all the material objects in the universe. If there are large and distant masses, like stars and galaxies, Mach wrote, then we can fix with them our immovable system of reference with a great degree of accuracy. In Newton's classical mechanics this reference system would be the inertial reference system. Uniform and linear motions of any material object in this reference system only mean that there is no considerable influence on its motion coming from small and nearby masses compared with a similar influence of the massive and distant material objects.

In his natural philosophy, Newton had in mind that uniform motions, by which we measure time intervals, might not exist in nature and that motions are either accelerated or decelerated. However, this difficulty, according to Newton, is characteristic only for the relative motions, i.e. the motions in a space relative to the massive material objects. According to Newton's conception, mass is just a quantity of matter. In addition to a relative space, Newton has introduced the concept of an absolute space, which is all the time "identical and motionless". A relative space, according to Newton's philosophy, is only a movable part of the absolute space. In the absolute Newton's space all processes take place in the absolute time, which does not change in its course, in contrast to the relative time that one can measure by employing the motion of material objects.

There are two almost parallel lines of research rather different, and nobody can tell whether they are convergent one to the other or might be still divergent. One is the question of a finite velocity by which the gravitational interactions propagate over large distances, while the other is the problem of unifying the fundamental interactions in nature. We shall try in the present study to establish certain points where these two apparently nonparallel lines come close or even might meet one another.

Before we continue we must emphasize that Einstein in his work on the general theory of relativity started from the very well known Mach's principle for which we believe to have resolved the problem of inertia. This principle has been formulated and reformulated many times, in order to be linked with the question of the universal gravitation, for instance: Einstein (1978), Ginsburg (1964), Janković (1963), Konopleva (1978), Landau and Lifshitz (1975), Misner *et al* (1973), Novaković (1980), Ray (1987), Synge (1960), Wheeler and Feynman (1949), and Wheeler (1964).

According to Einstein's idea we cannot speak of space in the abstract but only of the space which belongs to a certain material object. In order to free ourselves from an abstract concept of space we must speak of "bodies of reference", or "space of reference". Also, the properties of a space-time continuum which determine inertia must be regarded as field properties of space, in analogy with the electromagnetic field, Einstein (1978).

An experimental verification of general relativity under the terrestrial conditions is exposed by Ginzburg (1964) for three crucial tests, as predicted by Einstein's field equations, notably: (a) Gravitational shift of frequency; (b) Deflection of light rays in passing through the solar gravitational field; (c) Precession of the perihelion of the planets.

It is interesting to emphasize that Janković in his textbook on the foundations of Theoretical mechanics has calculated, in addition to Newton's gravitational force K/r^2, the effect of a corrected law of the universal gravitation due to a possible force term α/r^3, where K,α are certain constants. He also calculated a shift of Mercury's perihelion due to a relativistic change of its rest mass. This effect is generated by the theory of special relativity, rather than the general theory of relativity, to yield $1/6$ in comparison with the standard effect. Hence, 42" arcseconds per century (general relativity) must be supplemented by additional 7" arcseconds per century (special relativity). This would amount to a total 49” arcseconds per century, which would represent an astonishing discrepancy in comparison with the astronomical observations (42” per century).

In a series of papers Wheeler and Feynman (1949, 1964) studied some of the key principles from which Einstein started in writing down his famous field equations. It is now clear that Wheeler and Feynman had in mind a specific speed of gravity which had to be introduced in order that the field equations of Einstein be complete. They considered what kind of description of the interactions and motions is possible which would at the same time be: (1) Well defined; (2) Economical in postulates; and (3) In agreement with empirical evidence.

Briefly, the inertial mass of a given material object is caused by its interaction with all the other material objects in the universe.

As a result of contemporary research we have accumulated a knowledge by which Einstein’s theory of general relativity may be reduced, in the case of weak gravitational fields and within the framework of a non-relativistic approximation, to Newton’s law of the universal gravitation. In addition, we know that Newtonian classical mechanics explains nicely the planetary motions in the solar system by reducing each of them to either an ellipse (perhaps a circle), or a parabola.

It should be emphasized that Einstein himself, in his study about the relativity of inertia of a fiducial test material object, has assumed a spherical distribution of the universal ponderable matter. Einstein calls it *the empty material shell in rotation*. Having calculated an accelerating effect of such an material shell on a fiducial test particle - Einstein in fact discloses his assumption about the distribution as well as the shape of the initial ponderable matter. This actually is some physical field before a grand expansion had taken place.

In other words, any increase of inertia of a given material object (in this sense also the inertia of the elementary particles), in agreement with Mach’s principle of inertia, is conditioned by the accumulation of heavy masses in its neighborhood. It is very important to emphasize that the question of how rapidly this attraction propagates over large distances, if based only on Mach’s principle, remains totally unclear. However, any gravitational attraction, according to Laplace’s celestial mechanics, must be manifested with a finite speed, yet considerably larger than the speed of light. Wheeler, in his brilliant study about the impact of Mach’s principle on the solutions of Einstein’s equations of general relativity, puts forward the following question.

How can Mach’s principle make sense when it implies that the accelerated test mass acts on all the other masses in the universe and that they in turn have to act back on this particle? What is more important, there is no rigorous equivalence between the outgoing and retarded ways of evaluating the potentials in electrodynamics. Of course, one would like here, as in Feynman’s analysis of electrodynamics, to see more of the inner workings of the machinery by which: (1) the propagation in time and (2) a formally instantaneous propagation necessarily yield the same solution of Einstein’s field equations!

The present work is dedicated to the study of a simplified expansion mechanism, where the entire amount of the ponderable matter, in the form of a material shell, had once started to expand. The identity of individual clusters of galaxies is that catalogued by observational astronomy. We elaborate here the idea of general relativity, with a ponderable matter being distributed in the form of a fluid, in order to compute the radial component of the expansion velocity of a given cluster of galaxies. To compare theoretical figures with the observed recession velocities we developed a rather simplified model as follows.

(1) If the entire ponderable matter is being squeezed into a shell with a nuclear density, the gravitational field would be so strong that no light could escape. So we introduce the speed c_f of this fluid by which it can generate and transfer its momentum to the ponderable matter.

(2) We assume that an internal distribution of the ponderable matter is arranged in the form of a thin layer, where a thickness of the layer is very small compared to the external diameter, in such a way as to secure the motion of various clusters of galaxies rather independently one from the other. According to our evident observation, the motion of various clusters of galaxies tend to move in a single plane. For more details, see Payne - Gaposchkin (1965), and Wilkinson (1981).

(3) All particular motions within a given cluster of galaxies, speaking in terms of classical mechanics, seem to be arranged and organized by the action of Newton's law of the universal gravitation. This applies to the rotation of stellar systems about the center of mass of a given galaxy, as well as to the rotation of individual galaxies about the common center of mass of a given cluster of galaxies.

Therefore, we may start from the following simple assumption about a mechanical model where the mass m' of the entire ponderable matter had been squeezed into a spherical shell of the radius r_0. What is more, the action of the solely gravitational forces keep bound the entire ponderable matter up to a beginning of the epoch, $t = t_0$. This model can be developed further to evaluate the radial component of recession velocities, each velocity to be taken approximately the same for anyone individual member of the cluster of galaxies, once the expansion had started, in terms of the epoch t. Evidently, here we may neglect the angular momenta of the cluster as a whole. Each cluster is assumed to continue its recession from the common absolute center of mass, independently from the other clusters.

Before the grand expansion takes place the material pieces are bound together, thanks to an interplay between the electromagnetic and various interatomic forces. In order to outline an actual expansion triggering mechanism one has to study in details the gravitational fluid by applying fluid dynamics, including a realistic estimation of the number of clusters of galaxies which had been generated after the grand expansion had taken place. This idea is furthermore elaborated to take into account an observed recession of clusters of galaxies in order to relate it to the expansion mechanism of the universal gravitational fluid. A new approach to the principle of relativity is developed and linked with the grand expansion mechanism.

2. AN EFFECTIVE INTERACTION RESPONSIBLE FOR THE MOTION OF A TEST PARTICLE

Ever since the time of Newton physicists and philosophers have been asking the science of physics, why we investigate the origin of forces rather than their consequences which we all observe around us, like motion, light, energy, and a vast body of similar phenomena. The answer is not very simple. First of all, we investigate what we think is the true course of the concrete phenomenon; and secondly, we try to reduce as many phenomena as possible to a common origin, thus inventing the fundamental force, or the fundamental forces. With the development of Maxwell's equations in electrodynamics the question has been reduced to searching for the fields, rather than forces, in order to solve a concrete problem. Nevertheless, objections coming from historians as well as philosophers were directed towards the elimination of the concept of natural forces altogether! Their views were oriented to asking the solutions of equations of motion rather than the construction of the forces, or fields. However, things become even more complicated when one starts to study a specific problem. In either case, be it the question of force, or the question of field, one runs into the vicious circles as can be demonstrated from the following simple system of questions and answers.

We shall divide our discussion into two parts, one due to Newton (to emphasize the concept of force), and another due to Maxwell (to emphasize the concept of field), in the form of a questionnaire.

(N) 1) Are there forces in Nature? No, there are not! - 2) What are there in Nature? There are equations of motion. - 3) How do we solve the equations of motion? In such a way as to enable us the reduction of fundamental variables to space and time. - 4) What do the solutions depend on? We have to introduce a specific force acting on the given test particle, subject to certain boundary conditions. - 5) Are there forces in Nature? ...

It is obvious that we cannot break, even with the best will, the line in order to get out of the present vicious circle, unless we introduce some fundamentally new concepts associated with the concepts of space and time. The next approach is even more obvious as to the vicious circle problem.

(M) 1) Are there forces in Nature? No, there are not! - 2) What are there in Nature? There are fields. - 3) How do you construct the fields? You have to introduce various components which depend on space and time, and probably some other physical variables. - 4) How do you test the existence and the character of the fields? You have to introduce a fiducial test particle in such a way as to enable its coupling to the field. - 5) How do you solve the equation of motion for the test particle? By reducing the equation of motion to the action of a concrete force, subject to certain boundary conditions. - 6) Are there forces in Nature? ...

As in the former case, it becomes obvious that we cannot break the line in order to get out of another vicious circle, unless we introduce some additional fundamentally new concepts concerning space and time.

Before considering a specific dynamical model for the application to the grand expansion problem we must expose some very reasonable and acceptable answers to the following three very fundamental questions.

(1) *What is the proper introduction of the system of space coordinates and consequently a set of transformations which connect one system of such coordinates with the other?*

Let us review the actual situation that we face in Celestial mechanics. If we want to explore the planetary motions and the motions of their joint satellites, it would be of course very reasonable to link our system of coordinates with the center of mass of the entire solar reference frame; in other words, it would be desirable to fix the origin of the space coordinates at the center of the solar mass. We can continue this line of arguments to include the mass of our galaxy. Therefore, if we want to explore the motions of various stars and stellar clusters within our galaxy itself, then it would be desirable to fix the origin of such a system of space coordinates at the center of mass of the entire galaxy. By continuing this line of arguments, we will come to the conclusion that a collection of various galaxies within a cluster of galaxies would be linked with the center of mass of such a cluster of galaxies. Finally, the entire ponderable matter must be associated with an absolute center of mass which can be linked with the origin of an absolute system of spatial coordinates.

(2) *What is the most reasonable definition of an inertial reference frame, or an inertial system of coordinates, and consequently the principle of relativity?*

It is indeed very hard to offer any reasonable answer to this question. All constituents of matter, in all kinds of form and shape, microscopic or in large proportions, are in one or another state of motion. Therefore, it is impossible to define a material object which would be absolutely still and motionless, or is moving with a constant velocity. In other words, any material object is either accelerating or decelerating; its acceleration is either positive or negative, and never it will be equal to zero. From this point of view, there are no inertial frames of reference which are neither accelerating nor decelerating. Consequently, we are not able to define a proper principle of relativity as we used to do in electrodynamics and particle physics. Nevertheless, we hope that we can introduce an approximation to this concept in such a way as to ensure a clear approach to what is an exact meaning of the principle of relativity and how one can estimate the degree of its exactness, or the degree of its approximation. Now we come to the most important question of the whole of Theoretical physics.

(3) *What is a reasonable definition of the concept of kinetic energy, and consequently a binding energy and the total energy of a given material object?*

This is to be tested within a specific model introduced to describe the motion of ponderable matter. In particular the principle itemized under (1) and (2) cannot be defined unless we introduce the concept of force. As we know such a concept of force is missing in the theory of special relativity, simply because the conceptual basis of the theory rejects the idea of force but accepts only the idea of field. One has to confess that such a state of affairs is a serious deficiency in the theory of special relativity. However, if the motions of given test particles are studied within an absolute system of coordinates, which are attached to a unique center of mass involving the entire ponderable matter, then we can take over Lorentz transformations with the speed of gravity c_g to replace the speed of light c. In doing so we can also take the kinematical as well as dynamical equations, with c_g replacing c everywhere. In particular the energy will be related to the inertial mass of the test particle in the same way as before, i.e. $E = mc_g^2$, and similar equations. This problem will be examined in more details in the last section of the paper.

Consider a large sphere of the radius a and a point P that could be located either inside the sphere or outside it at a distance r from the origin O of a rectangular system of coordinates. (Alternatively it is named a Cartesian system of coordinates). Suppose that the spherical surface of a thickness Δ and density μ represent the ponderable matter of a total mass m'. Therefore the test particle of mass m will have a potential energy, due to the presence of the rest of the universal ponderable matter, as follows,

$$V(r,a) = -4Gm\mu r^2 \Delta K(r,a), \tag{1a}$$

where G is the constant of universal gravitation (Cavendish constant). It should be emphasized that all universal physical constants (among them the constant G) are given in the appendix.

Also the total mass, if the thickness Δ is considerably small in comparison with the actual radius r, is given by

$$m' = 4\pi\mu r^2 \Delta. \tag{1b}$$

The integral in equation (1a) can be evaluated according to Figure 1. It is given by

$$K(r,a) = \int_0^\pi \frac{\sin\vartheta d\vartheta}{\sqrt{r^2 + a^2 - 2ra\cos\vartheta}}. \tag{1c}$$

Here the angle ϑ runs in the interval $\vartheta \in [0,\pi]$. Having introduced a substitution $x = \cos\vartheta$, where the new variable runs in the interval $x \in [-1,1]$, we can write

$$K(r,a) = \int_{-1}^{1} \frac{dx}{\sqrt{r^2+a^2-2rax}},$$

$$\int_{-1}^{1} ...dx = \int_{-1}^{0} ...dx + \int_{0}^{1} ...dx = K_1(r,a) + K_2(r,a). \tag{2}$$

Here the integrals K_1, K_2 have obvious definitions. There are two integration regions to be distinguished by the limiting point $x = a$; one where $r < a$, another where $r > a$. Based on the above introduced equations,

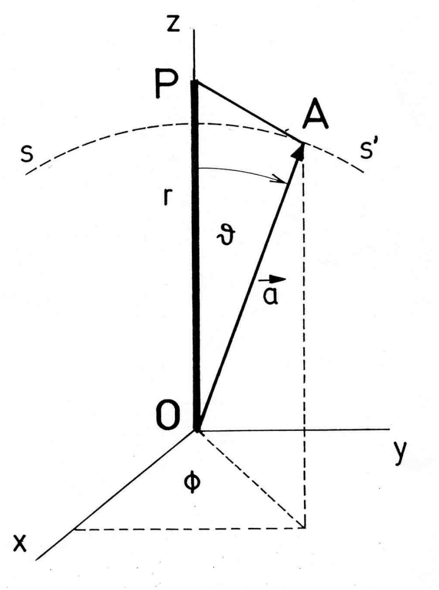

Figure 1: A system of spherical coordinates r, ϑ, ϕ, centered at O, represents a spherical distribution of ponderable matter. A current mass is placed at A, while the motionless test particle is placed at P. An arc ss' represents a section of the thin spherical layer separated by a distance a from the origin.

$$K_1(r<a) = K_2(r>a) = \int_{-1}^{0} \frac{dx}{\sqrt{r^2+a^2-2rax}}$$

$$= \frac{r+a-\sqrt{r^2+a^2}}{ra}. \tag{3a}$$

Furthermore,

$$K_2(r<a) = \int_{0}^{1} \frac{dx}{\sqrt{r^2+a^2-2rax}} = \frac{\sqrt{r^2+a^2}-a+r}{ra};$$

$$K_2(r>a) = \frac{\sqrt{r^2+a^2}-r+a}{ra}. \tag{3b}$$

Using equations (1a,b) to (3a,b),

$$V(r,a,(1)) = -\frac{C}{2a}\Big[K_1(r<a) + K_2(r<a)\Big];$$

$$C = 4\pi G \mu r^2 \Delta = Gmm'. \qquad (4a)$$

Therefore,

$$V(r,a,(1)) = -\frac{C}{a}; \quad r \in [0,a]; \qquad (4b)$$

$$V(r,a,(2)) = -\frac{C}{2a}\Big[K_1(r>a)+K_2(r>a)\Big]$$
$$= -\frac{C}{r}; \quad r \in [a,\infty]. \qquad (4c)$$

Equations (3a,b) to (4a,b,c) may be taken as a definition of an effective single particle potential energy responsible for the motion of a test particle under the influence of all the ponderable matter.

3. SPACE AND TIME AS PHYSICAL QUANTITIES

Let us introduce in the first place the fundamental concepts of *relative time* and of *relative space* to be connected with the speed of light c. Relative time is just a duration, or a time interval, or an infinitesimally short instant of time, whereas a relative space is just a distance separating two given points in space. In the second place, we need concepts like the *universal time, universal space* to be connected with some universal speed c_g. A universal time is just an absolute, overwhelming, cosmic and cosmologic time, while a universal space is the absolute, cosmic, and cosmologic space which is everywhere present. The former set of concepts is associated with the name of Albert Einstein, whereas the latter set is associated with the name of Isaac Newton.

We shall start our detailed analysis by repeating briefly the essential postulates on which both relativity theories are based, special (Einstein, 1905) and general (Einstein, 1915 - 1916). The first two postulates are as follows:

(R1) All inertial systems of reference are equally valid in the sense that the laws of Newtonian classical mechanics are strictly obeyed.

(R2) The speed of light in all inertial systems of reference is a constant quantity. This is usually named the *principle of the constant velocity of light*. This postulate is consistent with electromagnetism; it will be compared with a similar postulate assumed to be responsible for the physical origin of gravitation. This last postulate will shortly be itemized as (R2') where the speed of light (c) will be replaced by a speed of gravity (c_g).

By analyzing the motion of a test particle in a gravitational field, Einstein has noticed that there is an exact equality between the inertial and gravitational mass of a given material object in the same gravitational field. What is more important, he has interpreted Mach's principle in the sense that all reference systems are valid where there is some degree of equivalence between the inertial and gravitational forces.

We shall call for a serious attention to the fact that an angular moment of any test particle is a constant of motion. But this fact can be established only under the cost that the time is an absolute, universal concept. To prove this we start from a set of certain definitions. In a system of spherical coordinates, in a plane, the angular momentum $\vec{M}$ under the action of a central force is best analyzed if the rectangular coordinates x,y are expressed in terms of the spherical coordinates r,φ, Figure 2. We write

$$\vec{r} = r\vec{e}_r = r(\vec{e}_1 \cos\varphi + \vec{e}_2 \sin\varphi);$$

$$\vec{e}_r = \vec{e}_1 \cos\varphi + \vec{e}_2 \sin\varphi;$$
$$\vec{e}_\varphi = -\vec{e}_1 \sin\varphi + \vec{e}_2 \cos\varphi. \tag{5}$$

By definition

$$\vec{M} = \vec{r} \mathrm{x} \vec{p}; \quad \vec{p} = m\vec{v};$$
$$\frac{d\vec{M}}{dt} = \frac{d\vec{r}}{dt} \mathrm{x} \vec{p} + \vec{r} \mathrm{x} \frac{d\vec{p}}{dt} = 0. \tag{6}$$

First of all, vectors $d\vec{r}/dt$ and $\vec{p}$ are collinear, hence this vector product will vanish iden-

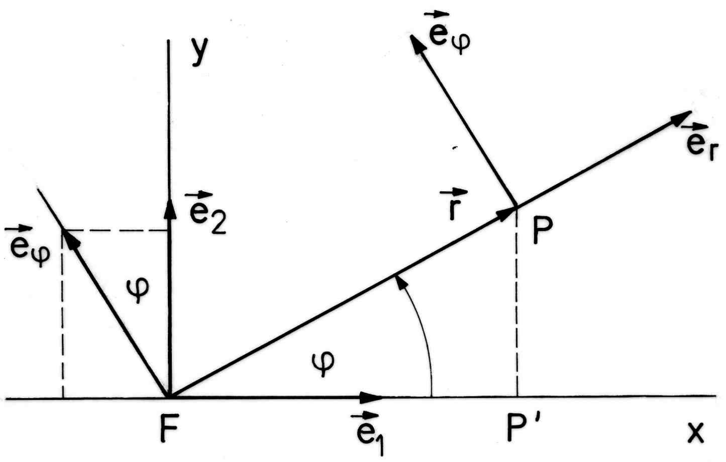

Figure 2: A system of spherical coordinates in a plane x, y, alternatively r, φ, represents a test particle at P moving under the action of a central force whose origin is at F. Depicted are two simultaneous pairs of unit vectors: $\vec{e}_1, \vec{e}_2$ in the xy system of coordinates, and $\vec{e}_r, \vec{e}_\varphi$ in the spherical system of coordinates.

tically. Secondly, the vector $\vec{r}$ is collinear with the central force, hence the second term in (6) will also vanish identically. From (6) one concludes that $\vec{M}$ is a constant of motion, provided only if the time variable t is independent of any systems of coordinates, thus assuming that it is a universal, or the absolute quantity.

The angular momentum, hence a spin of all the elementary particles, is a true constant of motion, subject to the action of central forces. On one hand, the quantity $\vec{M}$ is a constant of motion if the test particle moves under the action of a central force. On the other hand, if a central force is in action then the test particle, or test particles, under the action of such a force will experience the constant of motion. Clearly, the above exposed arguments may be extended to include a specific shape of the central forces in a given system of coordinates. It turns out that a force with a radial dependence $1/r^2$ is sufficient to keep a test particle in closed orbits, hence in stable trajectories, as materialized by circular or elliptical motions.

A special attention is paid to the problem of angular momentum in References: Bondi (1961, 2001), Burghes and Downs (1975), Dirac (1962), Goldstein (1980), Hajkin (1962), Landau and Lifshitz (1987), Novaković (1991), and Rith and Schäfer (1999).

Let us review facts about the most important consequences of the gravitational field equations. (i) The general theory of relativity is reduced, under certain conditions, to Newton's law of the universal gravitation, thus implying tentatively a possibility that the speed of gravity (a speed by which gravitational interactions propagate over large distances, c_g) might be greater than the speed of light, c, or even infinite. (ii) Whether c_g is infinite or finite must be resolved by concrete experiments, similar to those related to the gravitational wave effects. (iii) What is extremely important, the general theory of relativity does not offer any explanation as to possible physical origins of the forces which appear in non-inertial reference frames, such are the centrifugal and Coriolis forces. (iv) Concepts like the origin of the universe, or the speed of gravity different from the speed of light, are not embraced by the general theory of relativity. These concepts require a more fundamental theory, or at least a more fundamental approach within the existing general theory of relativity, by introducing an absolute space and time.

Einstein's theory has succeeded in the explanation of a displacement of Mercury's perihelion in its orbiting around the Sun, although astronomical observations in this particular region are part of the most difficult and most precise kind of optical measurements. Furthermore, it offered a reasonable explanation for a deflection of light quanta from a straight line as coming to the Earth from distant stellar objects due to the Sun's gravitational attraction. However, it did not offer any explanation, nor did it give any clue, as to a possible physical origin of the forces which appear in non-inertial reference frames (centrifugal and Coriolis forces). As we well know the former forces appear when the planets move round a given stellar mass, whereas the latter forces come from the motion within an accelerated reference frame.

A special attention is paid to the concept of space in References: Cristea (1977), Henry (1995), Kasper (1987), Misner *et al* (1973), Pavšič (2001), Weinberg (1989), and Wilkinson (1981).

There are a number of specific pieces of evidence which indicate that there exists a more fundamental speed than the speed of light. One of those are the papers: Wheeler and Feynman (1949) and Wheeler (1964). In order to pursue the present line of research we postulate a gravitational principle of relativity by replacing item (R2) in the present section, by the item (R2') as follows.

(R2') The speed of gravity in all inertial systems of reference is a constant quantity. This we will name the *principle of the constant velocity of gravity*.

A review of fundamental forces (strong, weak, electromagnetic, gravitational) is given in Table 1. Forces that generate the stability of the system, (1) either have the origin in the potential like $V(r) = -k/r$ (Coulomb, Newton), (2) or alternatively they start from a three - dimensional harmonic oscillator in the form $V(r) = kr^2$.

Table 1. A review of fundamental forces

Subject	1	2	3	4
Force	*Strong*	*Weak*	*Coulomb*	*Newton*
Field	*Spinor*	S,V,T,A,P	*Vector*	*Tensor*
Cpling	g	$G_\mu = G_V$	e	G
Range	*Short*	*Short*	*Long*	*Long*
Gnrator	*Space*	*Time*	*Stblity*	*Stblity*
Phnmena	*Nuclear*	*Decay*	*EM*	*Gravity*

It should be emphasized that, on one hand, space is generated by the action of strong interactions, in fact by the presence of the nuclear spin. Either through electromagnetism or gravity this then guarantees a stability of the physical system. On the other hand, time is generated by the presence of various decaying processes, starting from the proton - neutron system. It continues through the set of light nuclei (such are the structures of He, Li, Be, B, C, ...) up to the heaviest stable nuclei known so far (uranium, plutonium, ...).

A nuclear shell model, independently for protons and neutrons, is reviewed in Figure 3. Here the magic numbers are obtained from a study of a three-dimensional isotropic harmonic oscillator, with a strong spin-orbital coupling, Novaković (1991) and Heenen and Nazarewicz (2002). These numbers are:

$$Z_{mag} = N_{mag} = 2, 8, 20, 28, 50, 82, 126, 184.$$

In his theory about the origins of stellar energy Bethe (1939) introduced a cycle, nowadays known as the *Bethe cycle*, which connects the following four closed cycles: 1) Carbon C^{12} to carbon C^{13}; 2) Carbon C^{13} to nitrogen N^{14}; 3) Nitrogen N^{14} to nitrogen N^{15}. 4) Finally from nitrogen N^{15} to oxygen O^{16} and back to carbon C^{12}, each cycle being accompanied with a liberation of light particles, such are: electrons (e^-), positrons (e^+), γ rays, as well as neutrinos, antineutrinos, and ordinary photons. These nuclear reactions are:

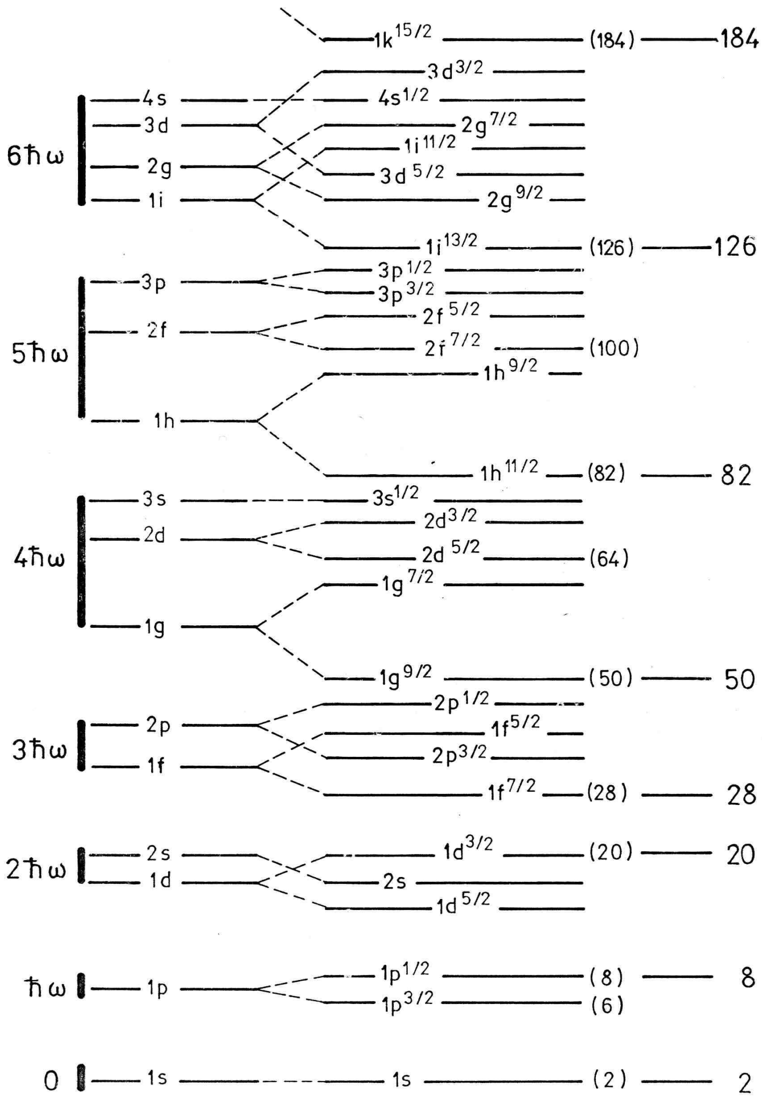

Figure 3: Nuclear energy levels, independently for protons and neutrons, according to the shell model in quantum mechanics with a three-dimensional isotropic harmonic oscillator. One can easily identify the set of magic numbers, $Z_{mag} = N_{mag} = 2, 8, 20, 28, 50, 82, 126, 184$.

$$C^{12} + p \Rightarrow \gamma + e^+ + C^{13} + \nu;$$

$$C^{13} + p \Rightarrow N^{14} + \gamma;$$
$$N^{14} + p \Rightarrow O^{16*} \Rightarrow N^{15} + e^{+} + \nu;$$
$$N^{15} + p \Rightarrow O^{16*} \Rightarrow C^{12} + He^{4}.$$

By the symbol $e^{+} + \nu$ one should understand a pair of leptons: one electron, one neutrino. In this way a carbon - nitrogen cycle generates a synthesis of a helium atom (actually, the α particle) out of four hydrogen atoms (actually, out of four protons) which are accompanied with two β transformations. A probability of capture of the protons is relatively small, so that a duration of a Bethe's cycle, according to a nuclear theory, is something like $6 \cdot 10^{6}$ years.

Bethe's approach to the liberation of stellar energy as coming from a star evolution is also reconsidered by Burbidge (1963) and by Burbidge and Lynds (1970).

Now suppose that we wish to extend Bethe's theory to involve the entire system of ponderable matter starting from protons and carbon atoms up to the highest observed stable heavy nuclei, that is lead ${}_{82}Pb^{208}$, with $Z = 82, N = 126$, and uranium ${}_{92}U^{238}$, with $Z = 92, N = 146$.

1) We start from a carbon cycle ${}_{6}C^{12}$ including nuclei from hydrogen up to oxygen ${}_{8}O^{16}$. Here the intermediate charge numbers are restricted by the interval

$$Z \in [1,8].$$

This cycle is composed of eight nuclear members as above indicated.

2) Next cycle will be named a silicon cycle, after ${}_{14}Si^{28}$, with $Z = N = 14$, to include eight nuclei whose charge numbers are given by the interval

$$Z \in [9,16].$$

This cycle extends from florin up to sulphur.

3) Yet another eight nuclear members will be named the titanium cycle after ${}_{22}Ti^{48}$, with $Z = 22, N = 26$. This cycle will include all the nuclei whose charge numbers are within the interval

$$Z \in [17,24].$$

We can continue this process of making equal groups out of the nuclear charges until we pass over all nuclear magic numbers, ${}_{20}Ca^{40}$, ${}_{28}Ni^{58}$, up to the nuclei of lead and uranium, as already above mentioned. Now the most frequent process taking place is a scattering of protons by a Coulomb field generated by the ever increasing nuclear charge Ze. The probability to penetrate into the nuclear volume, $P(Z,v)$, is a function of two parameters: the above introduced nuclear charge and a velocity of penetration v, according to a textbook on quantum mechanics by Landau and Lifshitz (1987). Therefore this function can be written

$$P(Z,v) = exp\Big(- \frac{2\pi}{\hbar v} Ze^{2} \Big), \tag{7}$$

where the above expression is a good approximation within the conditions so far imposed on the ponderable matter. It is very instructive to notice that a ratio over two penetration probabilities in a successive order of application is a quantity independent of the charge number. Indeed, if we divide one probability with $Z+1$ and the previous one with Z with the same velocity v we obtain,

$$\frac{P(Z+1,v)}{P(Z,v)} = exp\Big(- \frac{2\pi}{\hbar v} e^{2} \Big). \tag{8}$$

Suppose that the total number of nuclei belonging to the carbon cycle is Q_1, while the total number of these nuclei within the next cycle is Q_2. Let the probability of creating all the members of Q_2 out of Q_1, per unit time, be w_1. This includes various collisions of protons with the nuclei of Q_1. In particular, this includes eight members of Q_1 out of which there will be generated another eight members of the next higher cycle, i.e. the cycle Q_2. So one can admit that w_1 is proportional to a quotient which consists of the numerator $1, 2, ..., 7, 8$ while its denominator is the total number of nuclei taking part in these various collision processes, hence $8, 9, ..., 14, 15$. Therefore one should expect for the above mentioned quotient,

$$w_1 = \frac{1}{8}, \frac{2}{9}, ..., \frac{7}{14}, \frac{8}{15}. \tag{9}$$

It is very obvious how these ratios are constructed from successive numerators and denominators. The first member, $1/8$, comes from the assumption that one proton may collide with eight members of Q_1 in order to generate one member of Q_2. The second member, $2/9$, comes from the assumption that one proton must collide at least two targets of Q_1 in order to create a member of the next cycle Q_2. Actually, we have no exact theoretical model of detailed ordering of the members of Q_2. However, we know that a given Q_1 must be a number anything between the lowest probability $1/8$ and the highest probability $8/15$.

We can write,

$$Q_2 = w_1 Q_1,$$

by knowing that these quantities refer to the probabilities normalized to a unit time. We can continue this consideration, provided that each proton has a sufficient number of targets for the continuing collision process. Hence,

$$Q_3 = w_2 Q_2, ... Q_n = w_{n-1} Q_{n-1}, \tag{10}$$

where Q_n is to be identified with a uranium cycle, or any higher cycle beyond uranium. In this particular case we write $n = 92/8 = 11.5$. Each $w_1, w_2, ...$ may take any of the values given by equation (9).

Hence we can write

$$Q_n = \prod_{i=1}^{n-1} w_i \cdot Q_1. \tag{11}$$

Using a similar procedure we can estimate the time interval involved in a process that will pass over to generate the quantity Q_2 out of Q_1, per unit time. The time interval $T(Q_2)$ is inversely proportional to the probability w_1. Therefore, by having designated $q_1 = 1/w_1, q_2 = 1/w_2 ...$, we write

$$T(Q_2) = q_1 T(Q_1), \quad T(Q_3) = q_2 T(Q_2), ..., \tag{12}$$

where each particular q_i is restricted by an interval similar to that in equation (9). For instance,

$$q_1 = \frac{15}{8}, \frac{14}{7}, ..., \frac{9}{2}, \frac{8}{1}, \tag{13}$$

according to equation (11). A similar series of numbers holds for the other probabilities $q_2, q_3, ...$

We can write a relationship similar to equation (11),

$$T(Q_n) = \prod_{i=1}^{n-1} q_i \cdot T(Q_1). \tag{14}$$

A special attention is paid to the concept of time in References: Černin (1987), Gribanov (1987), Hajkin (1962), Heisenberg (1930, 1970), Marić (1986), Migdal (1989), Ostriker and

Streinhardt (1995), Ray (1987), Stephani (1982), Wheeler and Feynman (1945, 1949), and Zlatev *et al* (1999).

Suppose that such a physical system starts an expansion. We identify its individual material pieces as clusters of galaxies, each with roughly 10^3 galaxies. The total energy for each material piece is a constant of motion, expressed as the sum over the kinetic and potential energies. We introduce here the speed of gravity, c_g, that is a speed by which gravitational interactions propagate over large distances. Using a non-relativistic approximation (in the sense that velocities are considerably smaller compared to the speed of gravity) we introduce a radial component of the velocity v_0 and a radius r_0 of the material shell, at the beginning of the epoch t_0. In this particular research the angular momentum that may be associated with a given cluster of galaxies is neglected.

A gravitational principle of relativity, with c_g playing the role of a supreme speed, affects the mass m of a material body and its energy E in a similar way as in the theory of special relativity except that c is replaced by c_g. As a special concept let us introduce m_{rest} as the mass of a cluster of galaxies in the absolute reference frame whose origin is at rest all the time. Hence,

$$m = \frac{m_{rest}}{\sqrt{1-\alpha^2}}; \quad E = mc_g^2; \quad \alpha = \frac{v}{c_g}. \tag{15}$$

In the present approach we introduce a radial component of the velocity v and a radius r, at the present-day epoch t. The total energy is a constant of motion, given by a two-fold equation relating the kinetic and potential energy of a given cluster of galaxies. We use a non-relativistic approximation in the sense that all the radial velocities of the clusters of galaxies are considerably smaller than the speed c_g. Therefore,

$$m\Big(\frac{1}{2}v_0^2 - G\frac{m'}{r_0}\Big) = m\Big(\frac{1}{2}v^2 - G\frac{m'}{r}\Big) = const. \tag{16}$$

Here m designates the mass of a given material piece at the beginning of the expansion process. G designates the constant of the universal gravitation, while m' is a mass of the entire ponderable matter.

There are six parameters which determine a dynamical behavior of the present model completely, those are: v_0, r_0, a total mass m', v, r, and the constant term in equation (16). However, there are only two independent equations so far, and two fixed quantities. Therefore, we need two more equations to establish the present model completely. (i) The constant term above mentioned may be estimated on the basis of a nuclear binding energy, actually to be neglected for most part of the present approach. (ii) A connection between the quantities v and r will be established by the methods of observational astronomy. So far, for a closed system which is concentrated to a small volume, we can say that the constant term is restricted by

$$-\frac{2}{m}const = l^2 = \frac{\varepsilon}{m}; \quad \varepsilon < \frac{mc^2}{100}. \tag{17}$$

Notice that the lower limit in equation (17) is presumably even much smaller. In view of our next approximations, we may assume that the constant term is equal to zero. This is equivalent to using an overall flat or nearly-flat metrics.

A two-fold equation (16), on account of equation (17), can be written in a differential form,

$$\Big(\frac{dr}{dt}\Big)^2 - \frac{k}{r} = -l^2; \quad k = 2Gm', \tag{18}$$

where k and l are certain constants of the model. The equation of motion (18) is solved exactly in the next section.

4. EQUATION OF MOTION FOR A FIDUCIAL TEST PARTICLE

Let us start from the following differential equation,

$$\frac{dr}{dt} = \sqrt{\frac{k}{r} - l^2}; \tag{19a}$$

$$k = 2Gm'; \quad -\frac{2}{m} const = l^2 = \left| v_0^2 - 2G\frac{m'}{r_0} \right|. \tag{19b}$$

We write the solution

$$\int_{r_0}^{r} \frac{\sqrt{r}dr}{\sqrt{1-\lambda r}} = \sqrt{k}\left(t - t_0\right); \quad \lambda = \frac{l^2}{k}. \tag{20}$$

Here the parameter λr must be smaller than 1 in order to secure a proper convergent integration. By a series expansion,

$$\left(1 - \lambda r\right)^{-1/2} = 1 + \sum_{n=1}^{\infty} \gamma_n \left(\lambda r\right)^n. \tag{21}$$

The integration leads to

$$\frac{2}{3}\left(r^{3/2} - r_0^{3/2}\right) + \sum_{n=1}^{\infty} \frac{2\gamma_n}{2n+3}\left[(\lambda r)^{n+3/2} - (\lambda r_0)^{n+3/2}\right] = \sqrt{k}\left(t - t_0\right). \tag{22}$$

It is clear that the expansion series in (22) is convergent. Indeed, using Stirling's formula for large values of n we obtain,

$$n! \approx n^n e^{-n}\sqrt{2\pi n};$$

$$lim\frac{2\gamma_n}{2n+3} = lim\frac{\gamma_n}{n} = (-1)^n\frac{n^{-3/2}}{\sqrt{\pi}} = 0. \tag{23}$$

Actually, the expansion series contains positive and negative terms, in turn, each tending to zero as the values of n tend to infinity. Therefore, this series is absolutely convergent. The integral in equation (20) is also convergent whenever

$$\lambda r < 1; \quad l^2 r < 2Gm'. \tag{24}$$

A qualitative approach as to whether and to what extent the above inequalities (24) are fulfilled is exposed at the end of the paper.

5. PHYSICAL PROPERTIES OF A GRAVITATIONAL FLUID

When we keep in mind the physical description as a mathematical basis, we can develop two rather distinct approaches to the expansion problem. Depending on whether a thickness of the spherical shell Δ_0 is small or large in comparison with the external radius of the ponderable matter, r_0, we can construct two rather different approximations; (a) Thin-shell model (if Δ_0 is small); (b) Full-volume model (if Δ_0 is replaced by the entire initial radius r_0).

The present model is based on the assumption that the entire ponderable matter, at a given arbitrary epoch, is contained in a thin material shell of radius r, while its thickness is Δ, considerably smaller compared to the radius. The interior of the volume is filled with a gravitational fluid. This concept may require rather large initial velocities, compared to the speed of light, in order that the clusters of galaxies expand up to the volume that is today accessible to us by observational astronomy.

We can employ the equations of fluid dynamics to connect certain parameters. Let p and $S = 4\pi r_0^2$ stand for a pressure and a surface area, respectively, related to a given material piece. If a fluid acts for a short time interval, δt, then the product $pS\delta t$ is actually a short action of the force imposed by the fluid on the material piece. Clearly, this force will generate the momentum $m\delta v$, i.e. a product over the mass of the material piece and a change of its velocity. So far, we have made no approximations, these relations are exact. In mathematical terms,

$$pS\delta t = m\delta v, \tag{25}$$

where δv can be replaced with the initial velocity v_0. We can eliminate the product $S\delta t$ altogether by introducing a concrete model to describe the mechanism which will generate the initial velocity of the material piece od the mass m. Let ρ and μ_0 designate, respectively, a density of the fluid and a density of the material shell with a thickness Δ_0. We can write,

$$p = \frac{1}{2}\rho c_f^2; \quad m = \mu_0 S\Delta_0; \quad \Delta_0 = c_f \delta t. \tag{26}$$

Here c_f is a speed by which the gravitational fluid flows before it generates the initial momentum mv_0. It should be emphasized that the left-hand side of equation (25) is actually a linear momentum of the fluid transferred to the material shell which comprises the fluid. On the left of (25), also (26), there is a final value of the pressure which operates within the gravitational fluid just before it starts a grand expansion. It would be right to introduce some initial pressure p_1 and also a final pressure p_2. In this case it would be correct to write a difference $p = p_2 - p_1$ for the above introduced pressure, hence,

$$(p_2 - p_1)S\delta t = \mu_0 S\Delta_0 \delta v =$$

$$\mu_0 S\Delta_0 v_0 = \mu_0 S c_f v_0 \delta t.$$

This leads to

$$p_2 - p_1 = \mu_0 c_f v_0; \quad \Rightarrow v_0 = \frac{\rho}{2\mu_0} c_f. \tag{27}$$

So far, equations (25) to (27) are exact and could be applied to various physical examples, such are: An expansion of the cosmic ponderable matter; or the explosion of an ordinary grenade; or finally the expansion of a poisonous gas in the coal mine. All these problems may be reduced to the same fundamental equations of motion.

The first example is distinguished from the remaining two examples only by the presence of the universal gravitational field. The most important problem is how to evaluate the speed by which the fluid flows before it concentrates its destruction on the material shell.

We may start from the basic equation of state in fluid dynamics. Let p and V designate the pressure and volume of an ideal gas, respectively. At an absolute temperature T, the ideal gas with the mass $m_f = \rho V$, satisfies the following equation of state,

$$(p_2 - p_1)V = \frac{m_f}{M_f} RT. \tag{28}$$

Here R designates the gas constant, M_f is the mass of a mole of the ideal gas, see Yavorsky and Pinsky (1987). Using equations (26) and (28) we may estimate the speed c_f by which the gravitational fluid (here represented by an ideal gas) generates the expansion of the material shell. Hence,

$$p_2 - p_1 = \frac{\rho}{M_f} RT; \quad \Rightarrow c_f = \sqrt{2\frac{RT}{M_f}}. \tag{29}$$

There are three crucial points where one has to concentrate his attention.

(1) We may apply equations (27) to (29) to estimate the initial velocity by which the hadronic matter had started its expansion. Let ε be an elementary energy quantum that had been associated with a three-dimensional isotropic harmonic oscillator whose energy levels are related to the absolute temperature T by using a high - temperature limit

$$\varepsilon = 3k_B T. \tag{30}$$

Here k_B designates Boltzmann's constant. Introducing Avogadro's number N_A and the speed of gravity c_g, whose order of magnitude compared to the speed of light is still unknown, we can write,

$$\delta m_q = m_{q0} - m_{qb}; \tag{31a}$$

$$M_f = nN_A \delta m_q. \tag{31b}$$

Here the introduced quantity δm_q designates a mass difference between a free elementary material block which takes part in the structure of the gravitational fluid (m_{q0}) and that of the bound elementary material block (m_{qb}). One needs n such elementary blocks to combine in order to produce the stable state of a material unit M_f of the gravitational fluid. This quantity may be named a *coordination number*. A similar approach is outlined by Perkins (1987) in relation to the structure of the proton. Hence, the factor n in front of equation (31b).

Digression 1. Coordination number for a molecular hydrogen H_2 is 2, while for a molecular oxygen O_2 it is 32, because the oxygen mass is 16 times the hydrogen mass.

Furthermore, we may assume that the amount of energy ε comes entirely from the mass excess δm_q. Mathematically,

$$\varepsilon = \delta m_q c_g^2. \tag{32}$$

Using equations (29) to (32) we obtain

$$c_f = c_g \sqrt{\frac{2R}{3nk_B N_A}}. \tag{33}$$

Here M_f designates a molecular mass of a small material piece, the tiniest material entity of which the gravitational fluid is composed. Constants appearing under the square-root symbol, that is the ratio $R/k_B N_A$, leads to a value of the order 1. Assuming that there are n quarks or / and anti-quarks for each proton to be created, equations (29) and (33) go over to,

$$c_f = \left[\frac{2}{3n}\right]^{1/2} c_g; \quad v_0 = \frac{\rho}{2\mu_0}\left[\frac{2R}{3nk_B N_A}\right]^{1/2} c_g. \tag{34a}$$

Equation (34a) is an exact formula. However, if we assume that the quantity $R/k_B N_A$ is indeed very approximately equal to 1, then we can write the initial velocity of the expanding clusters of galaxies

$$v_0 = \frac{\rho}{2\mu_0}\left(\frac{2}{3n}\right)^{1/2} c_g. \tag{34b}$$

Digression 2. Quantity M_f has a secondary importance in relation to the fluid dynamics of a gravitational fluid.

(2) The estimation above mentioned, where the initial velocities of the expansion mechanism are obviously considerably greater than the speed of light, should not cause any embarrassment since such a mechanism develops before the principle of special relativity had been established. This situation can be understood as the state of matter where the gravitational fluid dominates over the strong nuclear forces. Once the hadronic matter had expanded, the state of development of clusters of galaxies had been progressing through the application of the principle of special relativity and quantum mechanics as we know them.

(3) It should be emphasized that within the present model, although it starts with a general idea about the gravitational fluid, still one needs at least three various parameters to be determined by performing a series of concrete experiments. Those are: a density of the fluid (ρ), a speed by which gravitational interactions propagate over large distances (c_g), and the mass M_f of elementary material blocks as required by fluid dynamics. Alternatively, this last parameter can be replaced by the coordination number n, since M_f and n are related by equation (31b).

On one hand, the energy and time are spread over certain intervals, δE and δt, respectively. According to a Heisenberg uncertainty relation connecting these two physical quantities, we can write,

$$\delta E \cdot \delta t = \hbar; \quad \delta E = m_q c^2, \tag{35}$$

where $\hbar$ is Planck's constant divided by 2π.

(4) An estimation of the thickness of a spherically symmetric distribution of the ponderable matter Δ_0 and an initial radius r_0 is given by another equation

$$\Delta_0 = \gamma r_0. \tag{36}$$

We start form the observation that a linear dimension today L (i.e. in our epoch), is a function of the time difference $(t - t_0)$ of a star system or the entire galaxy, or the entire cluster of galaxies, in comparison with its depth. In other words with its thickness Δ, a function of the time difference $(t - t_0)$, it is a quantity of the order 10^3. If we assume here that this quotient is the same as that at the beginning of the grand expansion then one may write,

$$\frac{L}{\Delta} = \frac{\left(4\pi r_0^2/N\right)^{1/2}}{\Delta_0} = 10^3, \tag{37}$$

where N is a number of pieces on which the entire ponderable matter had been smashed into the present shape at the time instant $t = t_0$.

The number N is indeed the total number of clusters of galaxies that are left to our observation today. And this number is something like $N \in [10^9, 10^{10}]$, according to the most recent evidence. Hence, equations (36) and (37) go over into

$$\Delta_0 = 10^{-3}\left(4\pi r_0^2/N\right)^{1/2}. \tag{38}$$

Of course, the number of clusters of galaxies N might have changed since the grand expansion, so that there might exist a relationship between N and the time interval $(t - t_0)$. But this is highly unlikely to take place owing to a dynamical development within the clusters themselves, since the instant $t = t_0$, where the expansion develops with respect to an absolute center of mass. Therefore the number N in a sense is a constant of motion. Having this in mind we arrive at a rather important conclusion by which the parameter γ can be estimated with a high degree of certainty. Indeed, using equations (37) and (38) we arrive at

$$\gamma = 10^{-8}. \tag{39}$$

Digression 3. Just like the quantity M_f in Degression 2, a parameter γ has a secondary importance for a dynamical behavior of clusters of galaxies.

This furnishes a discussion about the fundamental mechanism associated with a grand expansion.

6. A RECESSION OF CLUSTERS OF GALAXIES

Our arguments become even more persuasive when we consider systems of galaxies (also named *clusters of galaxies* or *galactic swarms*) in order to calculate the velocities which are associated with their mutual relative recessions. Many of the members of the galaxies are bright enough to allow for the measurement of their radial velocities. We shall assume that a galactic swarm in our theoretical model is well represented by a huge number (apparently 500 to 1000) of clusters of galaxies. Each cluster as a whole is apparently receding from the solar system at a speed of $1200km/s$, or even greater. What is more important, individual galaxies in the cluster are moving with relative speeds approximately $500km/s$, or even greater.

Suppose that two neighbor clusters P and A are moving away from a common absolute center O with the velocities $\vec{v}$ and $\vec{v}'$, respectively. Since those two clusters of galaxies occupy the same spherical shell of the ponderable matter, we may assume that their relative motion is developed within a single plane which is parallel but still close to the plane of our own cluster of galaxies.

Here for the sake of brevity we may assume that a thickness of the spherical shell can be neglected. Therefore, these two vectors have the same intensity, i. e. $v' = v$. On one hand, a velocity $\vec{u}$ of one cluster of galaxies relative to the other cluster may be written,

$$\vec{u} = \vec{v}' - \vec{v}; \quad u = v \cdot sin\vartheta. \tag{40}$$

In equation (40) ϑ designates an angle closed by the vectors OP, OA, Figure 1. On the other hand, all the linear dimensions along the direction of the motion are shortened according to the theory of special relativity (length-contraction effect). So, we may eliminate this angle by writing,

$$PA = r\sqrt{1-\beta^2} \cdot sin\vartheta; \quad \frac{u}{PA} = \frac{v}{r\sqrt{1-\beta^2}}; \quad \beta = \frac{v}{c}. \tag{41}$$

Here r designates the actual distance OP, taken to be equal to the distance OA, taken furthermore to be equal to the radius of a spherical distribution of the ponderable matter at the present-day epoch. In other words, we take in the current approximation as a model variable $OP = OA = r$. It is easy to estimate the ratio u/PA for a number of clusters of galaxies in order to observe that this quantity is almost a constant of motion, according to Table 2. Numerical data of the first three columns in Table 2 are taken from Payne - Gaposchkin (1965). Numbers given in the fourth column are evaluated by using (41). In addition, the crucial data concerning the Virgo cluster are identical to those reported in: Payne - Gaposchkin (1965), Ferguson *et al* (1997), Friedman *et al* (1994), Pierce *et al* (1994), Tanvir *et al* (1995).

Table 2. Clusters of galaxies, their distances relative to our own galactic center, speeds of recession, and the quantity u/PA, in units $10^{-18}s^{-1}$. Here MLyr stands for one million light years. Notice that A in the second column varies from one cluster of galaxies to another, while P designates the position of our own cluster of galaxies.

Galactic swarm	Distance PA, MLyr	Relative velocity, km/s	u/PA, units $10^{-18}s^{-1}$
Virgo	16.29	+1,200	7.75
Pegasus	48.87	+3,800	8.18
Pisces	45.61	+4,360	10.06
Cancer	58.64	+4,800	8.62
Perseus	71.67	+5,200	7.63
Coma	91.22	+7,500	8.65
UrsaMajorI	169.41	+11,800	7.33
Leo	208.51	+19,600	9.89
Gemini	267.15	+23,000	9.06
Bootes	456.12	+39,000	9.00
UrsaMajorII	469.15	+42,000	9.42
Hydra	Missing	+61,000	Missing

By observing Table 2, equation (41), we obtain on the average,

$$\frac{u}{PA} = \left(8.69 \pm 1.37\right) \cdot 10^{-18} s^{-1}. \tag{42}$$

If we now identify the ratio in (42) with the ratio $v/r\sqrt{1-\beta^2}$ in (41) we can estimate the radial component of the velocity at the present-day epoch, as well as the other parameters which are associated with the nearly-flat metrics. Therefore, we expect the following equations to apply to the present-day epoch;

$$\frac{v}{r\sqrt{1-\beta^2}} = \frac{u}{PA} = \eta. \tag{43}$$

Here η is just a numerical value for the ratio u/PA as cited in equation (43). We have made no approximations so far in the present analysis. There are two distinct models as to the density of the ponderable matter: (1) a model where the entire volume had been filled; (2) a model where only a thin spherical shell had been filled. We follow the latter one.

A thin-shell model is characterized by the following equation of motion, at a given epoch, according to (22) with the neglect of those terms which contain l^2,

$$\frac{2}{3}\left(r^{3/2} - r_0^{3/2}\right) = \sqrt{k}\left(t - t_0\right); \tag{44a}$$

$$k = 2Gm'; \quad t' - t_0' = \frac{t - t_0}{\sqrt{1-\beta^2}}. \tag{44b}$$

Of course, the quantity $(t' - t_0')$ must be obtained from some empirically available evidence. Notice that all the time intervals along the direction of the motion are enhanced, according to the theory of special relativity (time-dilation effect), as may be observed from equation (44b). A qualitative approach whether and to what extent equations (43) to (44a,b) are fulfilled is exposed at the end of the paper.

7. FUNDAMENTAL PARAMETERS OF THE COSMOLOGIC MODEL

Here we enumerate all physically relevant parameters of the cosmologic model which we can either evaluate exactly or estimate with a high degree of confidence. These are;

(F1) $\Rightarrow$ Present - day radius of the entire ponderable matter, r;

(F2) ⇒ Present - day velocity of recession of a given cluster of galaxies, v;

(F3) ⇒ Total mass of the ponderable matter, m', assuming that this quantity does not vary with time;

(F4) ⇒ Present - day time interval, $(t - t_0)$. Now we recall equation (16), by omitting the constant term on its right side, and also equations (42) to (44a,b). Therefore, for the present - day epoch,

$$\beta c = \eta r \sqrt{1-\beta^2}; \tag{45}$$

$$(\beta c)^2 r \sqrt{1-\beta^2} = 2Gm'; \tag{46}$$

$$2r^{3/2} = 3\sqrt{2Gm'}(t - t_0); \tag{47}$$

$$t' - t_0' = \frac{t - t_0}{\sqrt{1-\beta^2}}. \tag{48}$$

In equation (47) we have neglected the term $r_0^{3/2}$ in comparison to the term $r^{3/2}$. Unknown quantities are: $v, r, m', t - t_0$, whereas those known are:

$$\eta = (9 \pm 1) \cdot 10^{-18} s^{-1}; \quad t' - t_0' = 10^{10} yr. \tag{49}$$

From equations (47) and (48) we find

$$4r^3 = 9(2Gm')(1-\beta^2)(t' - t_0')^2. \tag{50}$$

Now from (45), (46), and (50), upon eliminating m', we arrive at

$$1 - \beta^2 = \frac{2}{3\eta(t' - t_0')}. \tag{51}$$

This equation is sufficient to determine the parameter β. Using the data from (49) we obtain,

$$v = \beta c; \quad \beta = 0.866 \pm 0.015. \tag{52}$$

Notice that the upper limit of β corresponds to the upper limit of η; and vice versa.

Based on equations (45) and (52) we can determine the parameter r,

$$r = (5.8 \pm 0.3) \cdot 10^{25} m. \tag{53}$$

Unlike the previous case the upper limit of r corresponds to the lower limits of β, η; and vice versa. Now using equations (48) and (52) we can estimate the time interval $(t - t_0)$. Indeed,

$$t - t_0 = \sqrt{1-\beta^2}(t' - t_0') = (4.97 \pm 0.25) \cdot 10^9 yr. \tag{54}$$

Digression 4. If we had used data of Section 3, especially equations (5) up to (14), we would have obtained a considerably higher value for the present-day epoch than that estimated in equation (54).

Finally, we are able to estimate the total mass of the entire ponderable matter, m'. Using equations (46), (52), and (53) we arrive at

$$m' = \frac{(\beta c)^2 r \sqrt{1-\beta^2}}{2G} =$$

$$(1.46 \pm 0.10) \cdot 10^{52} kg. \tag{55}$$

Notice that the upper limit of β, and a lower limit of r, correspond to the lower limit of m'; and vice versa. All equations which relate the four fundamental quantities $v, r, m', (t - t_0)$ extremely crucially depend on the estimation of the time interval $(t' - t'_0)$ which was taken from numerous evidence on the basis of nuclear physics phenomena.

Besides, β is a time dependent quantity itself and therefore not quite reliable for the estimation of the remaining two, i.e. the radius of a spherical distribution of the ponderable matter, as well as its total mass. However, it is the important assumption that the initial velocity v_0, although large in comparison to the speed of light c, sharply dropped to values approximately equal to c, and certainly to those smaller than c. If we neglect that dependence, for which we assume to had lasted only a small fraction of the total interval $(t' - t'_0)$, then we might consider a reasonable approximation of the above estimated quantities which represent $\beta, r, m', (t - t_0)$.

(F5) ⇒ Average inter-particle distance $< r_{12} >$, at the beginning of the grand expansion;

(F6) ⇒ Initial radius of the spherical distribution of the ponderable matter, r_0;

(F7) ⇒ Initial velocity of a single cluster of galaxies after the grand expansion had taken place, v_0. The entire mass of the ponderable matter is defined by

$$m' = 4\pi \mu_0 \varepsilon r_0^3, \tag{56}$$

where μ_0 is some initial density of the ponderable matter. This quantity depends on the distance $< r_{12} >$ which separates two neighboring protons in the state of plasma. Let us look at Table 3. Here are listed three key parameters that are associated with various states of plasma: (i) weakly ionized plasma that corresponds to some binding energy of the electron in hydrogen; (ii) plasma in a state somewhere between the weakly ionized and that completely ionized; and (iii) a completely ionized plasma where the nucleons (protons, neutrons) collide with one another in a close vicinity.

Table 3. Binding energy E_b; average separation distance of two particles in contact $< r_{12} >$ in comparison to Bohr's radius $a_0 = 0.529 \cdot 10^{-10} m$; and absolute temperature T to be considered equivalent to binding energy E_b.

Plasma	E_b, eV	$< r_{12} > /a_0$	T, K
i	10	1	10^5
ii	10^3	10^{-2}	10^7
iii	10^6	10^{-4}	10^{10}

The important parameter here is a probability of ionization defined by the laws of statistical mechanics,

$$P(E_b) = exp\Big(-\frac{E_b}{k_B T}\Big), \tag{57}$$

where E_b is a binding energy normalized to one particle.

Let us give a more profound explanation of the items (i) - (iii) presented in Table 3. In the first place, (i) will be materialized as if a hydrogen atom is separated into a proton on one side and the electron - on the other. Second, (ii) will represent a state of plasma when a hydrogen molecular ion is formed, H_2^+, so that a given proton performs an orbital motion about the axis that is materialized by two free electrons. Finally, (iii) is a state of plasma which describes the situation where the electrons are entirely separated from the host protons while the protons themselves start approaching each other, hence increasing the probability of a reaction

$p + p \rightarrow d + E + e^+$, where E is some liberated energy. Therefore we can define the initial density by

$$\mu_0 = \frac{m_p}{< r_{12} >^3}, \tag{58}$$

where m_p designates a proton mass.

Now we are able to establish a relationship between r_0 and v_0. Suppose that a given cluster of galaxies has N_0 protons at the instant of the grand expansion, where this quantity has an order of magnitude

$$N_0 = \frac{m'}{N m_p} = 10^{69}. \tag{59}$$

We inserted the present - day number of clusters of galaxies $N = 10^{10}$ into equation (59) in order to obtain the initial number of these clusters, N_0.

There are three more fundamental parameters, according to our initial approximation. These are

(F8) $\Rightarrow$ Density of the ponderable matter at the initial instant of the grand expansion, μ_0;

(F9) $\Rightarrow$ Time interval δt necessary for the grand expansion to take place; and finally

(F10) $\Rightarrow$ Speed of gravity c_g, by which a gravitational interaction spreads and extends over large distances, and a speed c_f by which the gravitational fluid transforms its momentum to the initial state of the ponderable matter. The initial equation of motion for a given individual cluster of galaxies is given by (16), here rewritten in the form

$$N_0 m_p \left(\frac{1}{2} v_0^2 - G \frac{m'}{r_0} \right) = -\kappa N_0 m_p c^2, \tag{60}$$

where κ designates an appropriate dimensionless constant, c is the speed of light. This κ must be determined by comparing the term on the right - hand side of (60) with the binding energy of a single proton as estimated in Table 3. Taking the state of plasma between (ii) and (iii) we can write,

$$E_b \in [10^3, 10^6] eV = \kappa m_p c^2. \tag{61a}$$

It follows,

$$\kappa \in [10^{-6}, 10^{-3}]. \tag{61b}$$

Based on equation (58) and Table 3, we obtain μ_0 in a wide interval of values,

$$\mu_0 \in [10^9, 10^{15}] kgm^{-3}; \tag{62}$$

while, according to equation

$$m' = 4\pi \mu_0 \varepsilon r_0^3, \tag{63a}$$

we obtain a value for r_0 in a rather broad interval,

$$r_0 \in [10^{15}, 10^{17}] m. \tag{63b}$$

Now we are in a position to estimate the initial velocity v_0 of the grand expansion. If we neglect the term with κ in equation (60) then we obtain,

$$v_0 = \left[2G \frac{m'}{r_0} \right]^{1/2} \in [3 \cdot 10^{12}, 3 \cdot 10^{13}] ms^{-1}. \tag{64}$$

It should be emphasized that an upper limit of μ_0 corresponds to a lower limit of r_0 but an upper limit of v_0; and vice versa.

Finally, equations (31a,b) to (33) yield a formula which connects two above introduced fundamental velocities of the gravitational fluid

$$c_g = \left[\frac{3nk_B N_A}{2R}\right]^{1/2} c_f. \tag{65}$$

Now we should use the genuine definitions of c_g (it is the speed by which a gravitational interaction propagates over large distances) and c_f (a speed by which a wave of expansion propagates in the gravitational fluid). These are

$$r_0 = c_g \delta t; \quad \Delta_0 = c_f \delta t. \tag{66}$$

We can estimate a time interval here introduced by using certain assumptions as follows. First of all, we must admit that the ratio r_0/Δ_0 is identical, on the basis of equation (66), with the ratio c_g/c_f. Hence, using equations (36), (39), and (66), we obtain

$$c_g = 10^8 c_f, \tag{67}$$

wherefrom, based on equation (65), it follows

$$\left[\frac{3nk_B N_A}{2R}\right]^{1/2} = 10^8; \quad n = 10^{16}. \tag{68}$$

Secondly, we can observe that it is necessary approximately 10^{16} elementary particles of the quark - anti-quark type to create one single gravitational particle which would be responsible for the transfer of momentum of the gravitational force to the outer shell of the ponderable matter. This particle we shall call *gravitational fluon*, to connect its existence with the gravitational fluid. As far as its velocity of motion is concerned, it is directly related to the time interval δt. However, this interval is composed of 10^{16} similar intervals on the nuclear level, each of them being equal

$$\delta t(nucl) \approx \frac{\hbar}{m_q c^2} \approx \frac{\hbar}{m_p c^2} = 10^{-24} s. \tag{69}$$

Therefore we obtain the ratio of the two above introduced time intervals,

$$\delta t = n \delta t(nucl) = 10^{-8} s. \tag{70}$$

This value will determine these two fundamental speeds,

$$c_g \in [10^{23}, 10^{25}] ms^{-1}; \quad c_f \in [10^{15}, 10^{17}] ms^{-1}. \tag{71}$$

This is the end of our consideration of the ten fundamental parameters which define a model of a spherically - symmetric distribution of ponderable matter. Six of them are defined at the very moment of its grand expansion ($< r_{12} >, r_0, v_0, \mu_0, \delta t, c_g$) and another four at the present - day state of the ponderable matter ($v, r, m', t - t_0$).

We must emphasize as before that upper limits of c_g and of c_f, according to equations (63a,b) and (66), will correspond to the upper limit of r_0, and vice versa.

8. ROTATIONAL MOTIONS OF GALACTIC SWARMS

Although we solved some of the crucial problems concerning the expansion mechanism, still a rotational motion of clusters of galaxies round their common center of mass, in a plane which is perpendicular to the direction of expansion, remains neglected. (These clusters will be called *galactic swarms* in the present section). Not only that we do not have a right to neglect such a motion, but the rotational dynamics on the whole may play an essential part in contemporary cosmology. According to classical concepts we expect certain conservation principles to apply all the time.

Whitehead's theory of relativity (1922) is devoted to this goal. It is devoted to the assumption by which all dynamical equations of motion, as associated with ponderable matter, are in a close resemblance with Maxwell's equations of the electromagnetic field. Therefore they must generate the acceptable and consistent classical conditions for the appearance of rotational motions of the test particles. In his book about relativity Whitehead speaks openly of the problem of rotations and rotational motions associated with ponderable matter. His criticism is especially directed towards Einstein's general theory of relativity where rotational motions of ponderable matter presents a great mystery.

Whitehead in his theory has emphasized that such a problem exists not only in cosmology, where our studies are devoted to dynamical aspects of large and remote masses, but also exists in the framework of nuclear, atomic, and molecular physics. Here in the domain of very tiny nuclear, atomic, or molecular volumes this deficiency is even more striking because the angular momenta of nuclei, atoms, and molecular structures appear as the most outstanding constants of motion.

So it happens that a material edge aa', as associated with the A galactic swarm, will match perfectly simultaneously with the material edge bb', as associated with the B galactic swarm, Figure 4. In this case a linear momentum along the aa' line will generate an antiparallel linear momentum along the bb' line, so as to make a total linear momentum equal zero as it had just been before the grand expansion had started.

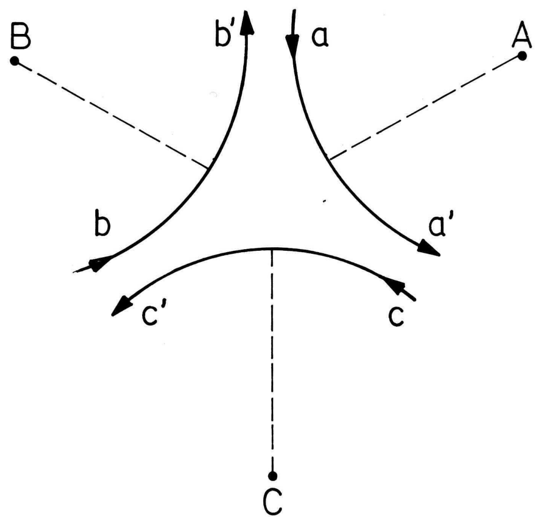

Figure 4: Illustration of the beginning of a large - scale rotational motion within a cluster of three swarms, A, B, C. Here a linear momentum along the aa' line is antiparallel to a linear momentum along the bb' line as might have been observed from the A galactic swarm. A similar description holds for the following linear momenta: bb' will be partially antiparallel with cc', while cc' partially antiparallel with aa'.

Similar conditions hold for the linear momentum along the bb' line as compared with the

cc' line; and also for the linear momentum along the cc' line as compared with the aa' line. Not only this principle applies to the galactic swarms but we arrive at the conclusion, having in mind a large body of empirical data, that this principle applies furthermore to the motion of galaxies one with respect to the other; or to the motion of stars and stellar systems one with respect to the other within a given galaxy. This line of conclusion is far reaching in the sense that the same principle applies to individual planets and their satellites within our solar system of reference.

Observational astronomy teaches us that rotational motions exist all along the stellar tracks and within galactic and intergalactic objects. What is more important, such a rotational motion repeats itself in an almost identical fashion, at least within a given fraction of the spherical distribution of ponderable matter, from galactic swarms down to individual planets and their tiny satellites. Planets round the Sun, stars and stellar systems round the common center of mass within our cluster of galaxies (Milky Way), which is placed somewhere in the middle of the local galactic swarm, - they all experience rotational motions in one identical direction. We have good reasons to believe that all these angular momenta, and the associated mechanical moments of inertia, had started simultaneously at the very instant of time linked with the grand expansion of galactic swarms. This is best illustrated in Figure 4. Here the rotational motion as might be observed from the *A* center of mass is developing in the same direction as if this rotational motion had been observed from the *B* center of mass. Finally, the same conclusion might be reached if a similar rotational motion had been observed from the *C* center of mass.

9. WELL ESTABLISHED FUNDAMENTAL SYSTEMS

All theoretical systems, those that are believed to be acceptable by a rigorous mind, must fulfill three basic postulates, as follows. ⇒ (1) Each theoretical system must be complete; ⇒ (2) It must be consistent with itself; ⇒ (3) It must agree with the experimental evidence. However, in practical terms we are faced with a serious problem of how we can justify and verify, by having solved a concrete theoretical model, that the basic postulates above mentioned are exactly fulfilled. What is more important, it is the question of a specific criterion, or a set of criteria, that we employ rather than the question of the fulfillment of the abstract postulates above mentioned. Therefore, we decide to continue this line by considering some specific criteria as connected with the existing theoretical systems.

(1) Each well established fundamental system must be complete.

This phrase is identical to saying that each theoretical system must be closed in itself. There are, indeed, six well established fundamental systems so far developed within the framework of theoretical physics for which we are interested to consider one by one. These are: *Classical mechanics, Electrodynamics, Statistical mechanics, Quantum mechanics, Theory of special relativity, and General theory of relativity*. Each of these six theoretical systems is closed in itself. In Classical mechanics, for example, the motion of a particle is determined entirely by solving the equations of motion, where a particle moves under the influence of a given force, or a set of given forces. For this particular system it is immaterial how the force or forces depend on space and time. It is only material that the particle must obey the given equations of motion all the time.

Similarly, the motion of an electron in Electrodynamics is determined by solving a set of four Maxwell's equations (two of them are necessary for the definition of an electric field $\vec{E}$, another two for a magnetic induction field $\vec{B}$), in addition to a Lorentz force $\vec{F}$. This completes the theoretical system. As a matter of fact, these vectors $(\vec{E}, \vec{B}, \vec{F})$ may depend on the distribution of electric charges and electric currents in a material medium in order to specify the motion of the electron completely. But this particular requirement does not destroy the well established system of equations necessary for the description of the electron's motion, which makes the theoretical model closed in itself.

We can go on by including the ensemble of identical particles, rather than one single particle separately, as we actually do in Statistical physics to study the states of a given physical model. Here in this physical branch we do not care how the particular energy states are introduced, be it by classical terms, or electro-dynamical, or finally quantum - mechanical; it is only important that we employ Boltzmann's law for the distribution of the individual particles over the energy states regardless of the origin of states. Hence, this physical branch is indeed closed in itself.

It is easy to observe that one meets a similar situation in the remaining three well established fundamental systems (Quantum mechanics, Special relativity, General relativity). Each system above mentioned is closed in itself by knowing in advance the following two criteria: (a) The specific equation of motion, or equations of motion, which the test particle, or test particles, must obey; and (b) The force, or forces, or a set of fields which generate the dynamical law to be obeyed by the test particles.

Quantum mechanics yields a good example of the completeness principle. From what we know - we have only one alternative, either to accept the principles of this physical branch as a unique piece of our knowledge, or reject the entire physical branch altogether. There is no possibility of remedying these principles in any way. Hence, it represents a fundamental system closed in itself.

Special relativity unifies space and time into a single entity as they are connected through the speed of light. Not only space and time, but also the linear momentum and energy of a test particle are united into a single entity. Here by the *unification* we understand that if one quantity of a given entity (for example, space, or the linear momentum) is varied according to a certain set of equations then the other quantity of this entity (time, or the energy) will vary according to the same set of equations.

Unfortunately, it is not so obvious with the following two very important concepts in contemporary physics: the *rotational motions* and *angular momenta*. In the first place, these two physical concepts are not related in any way through the principles of Special relativity. Secondly, if one quantity is varied according to a certain equation (for instance, a rotational velocity of the test particle), then the other quantity, actually the angular momentum, in most theoretical models where a driving force depends according to the $1/r^2$ law will represent a constant of motion.

This problem is not resolved in a satisfactory way even in General relativity. Here the inertial mass of a test particle m_{in} is related to its gravitational mass m_{gr} in a certain way. It is actually postulated as an identity $m_{in} = m_{gr}$ in Einstein's field equations. Nevertheless, the question of how the rotational motion of a given test particle is related to its angular momentum within General relativity (except in some approximations, more - or - less classical) remains insufficiently clear so far as Einstein's equations are concerned.

(2) Each well established fundamental system must be consistent with itself.

In other words, it must be self-consistent. This principle is actually a guide through a variety of approaches and approximations all over theoretical physics. Let us think of a perturbation calculus within Quantum mechanics. Consider for instance the binding energy of two electrons in a helium - atom problem. Here, the energy of stationary states must be expressed by a determinant where the energy as a variable appears on both sides of the self-consistent equation. It is the unknown quantity that we have to evaluate, on one side, but it appears also as an independent variable among various matrix elements of the electron - electron interaction, on the other side. Hence, the binding energy as an unknown quantity appears simultaneously on both sides of the above mentioned equation. In other words, one has to solve a self-consistent equation of motion. There are similar examples in other physical branches.

(3) Each well established fundamental system must agree with the existing experimental evidence.

Let us be clear about the final goal of any research line within a given fundamental theoretical system. Actually, the final goal is not to explain a particular experiment (although it is along the general line) but to discover, consider, describe, and then explain in full rigor a natural phenomenon or indeed a series of phenomena if they are related to one another in any possible way.

Of course, each and everyone well established theoretical system must include the explanation of a given experiment by all means, but this does not necessarily justify its final commitment, simply because the experiment in question could be (i) misleading, (ii) insufficient, or even (iii) wrong. In the first place, a particular measurement in question might be correct but not relevant for the established theoretical system, so as to misguide the entire line of research. In the second place, it is perhaps desirable or even absolutely necessary to perform a series of experimental measurements in order to extract a certain phenomenon before the specific theoretical model could be applied. Finally, in the third place, one has to be rather careful in undertaking the difficult task of explaining something that is not fully established on empirical grounds, something that we might call a wrong experimental evidence.

Electromagnetism and gravitation are developed, according to a large empirical evidence, in four independent stages. Those are;

(L1) stage. Maxwell's electrodynamics built up on various experimental evidence of Coulomb, Ampere and Oersted, as well as on Faraday's idea of *field forces* rather than the forces themselves.

(L2) stage. Includes the equations of motion for a specific test particle, as is believed to be the electron, developed by H. A. Lorentz.

(L3) stage. Potential energy of the electron is reduced to the energy of the electric field, whereas its kinetic energy is connected with the energy of the magnetic field. As a result there appeared a relationship linking the rest mass of an electron m_e with its classical radius r_e as follows,

$$\frac{e^2}{r_e} = m_e c^2. \qquad (72)$$

(L4) stage. Finally we must include Dirac's discovery where the electron has an angular momentum $\vec{M}$ composed of two parts, one coming from the action of a central force (or the orbital angular momentum), another from the presence of an electromagnetic field known as the *spin angular momentum*,

$$\vec{M} = \vec{r} \mathrm{x} \vec{p} + \frac{\hbar}{2}\vec{\sigma}, \qquad (73)$$

where $\vec{r}, \vec{p}$ are vector quantities, while $\vec{\sigma}$ is also a vector but may have two different orientations in a magnetic field.

(G1) stage. Includes the geometrical models of F. Gauss and of B. Riemann, based on tensor quantities used by Einstein to construct a general theory of relativity. This stage is developed in a close analogy with *(L1) stage*.

(G2) stage. Includes a further analogy with electromagnetism in the sense that a test particle had to be associated with the gravitational field, parallel to the Lorentz force. It is actually Mach's principle that will serve as a guiding and driving force in the development of theoretical physics in a tight analogy with *(L2) stage*.

(G3) stage. Nuclear forces are here of great importance since a charge e is replaced by a nuclear charge g with a coupling constant $\kappa_p = m_\pi c/\hbar$. It would be equal to zero in the case of electromagnetism; in other words $\kappa_e = m(photon)/\hbar$, leading to an infinite range of the actual electrostatic forces. However, it is equal to $\kappa_p = 1/r_p$ in the case of nuclear forces. Hence we can write, in analogy with *(L3) stage*,

$$\frac{g^2}{r_p} exp(-\kappa_p r_p) = m_p c^2, \tag{74}$$

where obviously m_π designates the mass of a meson. By assuming that r_p for a proton is approximately equal to r_e for an electron we obtain a reasonable agreement between theory and experiment with the nuclear coupling constant $g \approx 70|e|$.

(G4) stage. This is the most mysterious part of the entire research project where we assume that each proton, and independently a neutron, has a total angular momentum similar to that of the electron,

$$\vec{M} = \vec{r} \mathrm{x} \vec{p} + \frac{\hbar}{2}\vec{\sigma}, \tag{75}$$

where $\vec{\sigma}$ may take one of two possible orientations in a magnetic field. However, there is nothing similar to anything like Dirac's equation for the nucleons (p, n) as formulated by Dirac in the case of an electron!

Nevertheless, we can carry on this analogy with electromagnetism to introduce a specific gravitational field for the fundamental material object, in the sense that a potential energy of the field is equal to the rest energy $m_{ob}c_g^2$ with its classical radius r_{ob}. Using an analogy with *(L3) stage* we write,

$$\frac{e^2}{r_e} \Rightarrow G\frac{m'}{r_{ob}} m_{ob}, \tag{76a}$$

$$m_e c^2 \Rightarrow m_{ob} c_g^2. \tag{76b}$$

We thus have obtained an equation of far-reaching consequences,

$$Gm' = r_{ob} c_g^2. \tag{77}$$

The characteristic radius of that material object is obtained by inserting m' from equation (55) and c_g from (71) into (77),

$$r_{ob} \in [10^{-8}, 10^{-4}]m. \tag{78}$$

10. A NEW APPROACH TO THE PRINCIPLE OF RELATIVITY

A theory of special relativity as well as the general theory of relativity are full of rather convincing examples within the framework above mentioned. As mentioned before, the conventional approach to the principle of relativity rejects the concept of force but instead it accepts the idea of field which is supposed to materialize the substance and the essence of all the happenings with a ponderable matter. This concept is supposed to be the beginning of everything both in classical as well as in quantum - mechanical happenings. A conventional approach is based on topological elements, like strings or membranes, which then serve as the building blocks in a universal theory of gravitation. However, as soon as we come to the question of quantization we immediately must introduce some procedure which starts from the assumption that there are boundary conditions. They then determine sets of energies and sets of linear momenta as the discrete but enumerable numbers. Clearly, since the boundary conditions are formulated, they represent an implicit assumption about the existence of certain forces which then keep those conditions stable while we are performing the quantization procedure.

Once the boundary conditions are introduced, it is then immaterial how they are formulated so long as they represent an open assumption about the action of a certain force, or a system of forces, which then keep fixed those conditions while the quantum effects take place. What is more important all relations between space coordinates and the duration of a certain physical event is associated with a specific stellar system, or a specific planetary system, within the cluster of galaxies. In other words, the motion of a certain test particle, a test body in general, is related to the local system of spatial and temporal coordinates which are firmly fixed by this particular cluster of galaxies.

Therefore, those clusters then appear as the only objects in the universe capable to define the absolute space and time (x, y, z, t), leaving out the question of the local motions as described by some local system of spatial and temporal coordinates (ξ, η, ζ, τ). In the first instance, the motion is controlled by some supreme speed, supposed to be the speed of gravity c_g. In the second instance it is performed by a conventional vocabulary where the speed of light c plays the observational quantity which interrelates all the mechanical and electromagnetic phenomena. Using a topological framework we might say that all phenomena take place in the system of coordinates fixed by the absolute building block materialized by the clusters of galaxies while local happenings are then controlled by some local space coordinates (ξ, η, ζ) and a local time duration which plays the role of a local time coordinate τ, where the speed of light only in this restricted region has a certain dominant position.

Let us introduce generalized expressions for the squared line elements ds^2 and ds'^2, according to Figure 5. We write,

$$|PP'|^2 = ds^2 + ds'^2 - 2ds \cdot ds' cos\omega;$$
$$ds^2 = dy^2 + dz^2 + dx^2 - (c_g dt)^2;$$
$$ds'^2 = dy^2 + dz^2 + dx'^2 - (c_g dt')^2. \tag{79}$$

Furthermore, since ω is a small angle, we can expand $cos\omega$ as follows,

$$cos\omega \approx 1 - \frac{\omega^2}{2} + \ldots$$

Having introduced abbreviations,

$$PP'^2 = d\sigma^2 + d\sigma'^2; \quad a = dy^2 + dz^2;$$
$$b = dx^2 - (c_g dt)^2; \quad b' = dx'^2 - (c_g dt')^2; \tag{80}$$

we can write a series of expansions, keeping terms up to second - order in ω as well as in $b/a, b'/a$. The result is given by

$$ds = \sqrt{a}\Big(1 + \frac{b}{2a} + \ldots\Big);$$
$$ds' = \sqrt{a}\Big(1 + \frac{b'}{2a} + \ldots\Big). \tag{81}$$

It is clear now that we can compare a gravitational principle of relativity (where the supreme speed is c_g) with an electromagnetic principle of relativity (where such a speed is just the speed of light c). In the first place, we must carry on the above introduced second - order series expansions,

$$d\sigma^2 \approx \frac{1}{2}(a+b)\omega^2 =$$

$$\frac{1}{2}\left[dy^2 + dz^2 + dx^2 - (c_g dt)^2 + ...\right]\omega^2;$$

$$d\sigma'^2 \approx \frac{1}{2}(a+b')\omega^2 =$$

$$\frac{1}{2}\left[dy^2 + dz^2 + dx'^2 - (c_g dt')^2 + ...\right]\omega^2. \qquad (82)$$

In the second place, we shall introduce a set of relative coordinates ξ, η, ζ to be associated with

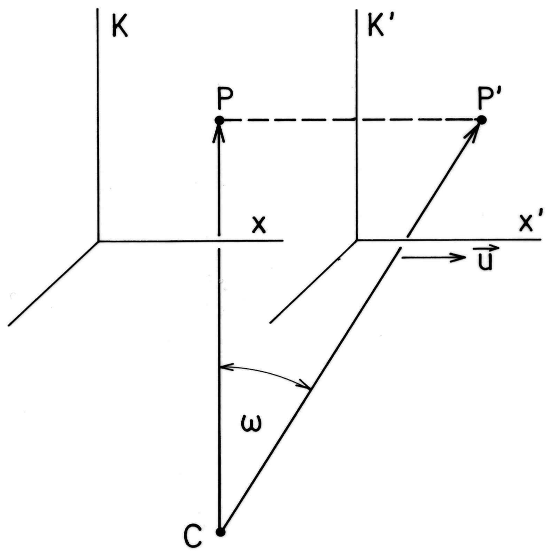

Figure 5: Two systems of relative coordinates, K, K', with respect to an universal center of mass, C. A linear coordinate x' which is fixed in K' moves with a relative speed $\vec{u}$ with respect to the linear coordinate x which is fixed in K.

a local environment,

$$\xi = \frac{\omega}{\sqrt{2}}x; \quad \xi' = \frac{\omega}{\sqrt{2}}x';$$

$$\eta = \frac{\omega}{\sqrt{2}}y; \quad \zeta = \frac{\omega}{\sqrt{2}}z; \quad c = \frac{\omega}{\sqrt{2}}c_g. \qquad (83)$$

Now we can write the squared line elements $d\sigma^2$ as well as $d\sigma'^2$, each being associated with its own local system of Cartesian coordinates, as follows,

$$d\sigma^2 = d\xi^2 + d\eta^2 + d\zeta^2 - (cdt)^2;$$

$$d\sigma'^2 = d\xi'^2 + d\eta'^2 + d\zeta'^2 - (cdt')^2. \qquad (84)$$

It is rather obvious to consider equations (79), which express the squared line elements with c_g appearing as a supreme speed, as the central definition of the gravitational principle of relativity.

Similarly, one should consider equations (84), where the speed of light appears as a supreme speed but only within local systems of reference, as a suitable definition of the electromagnetic principle of relativity. These principles do not contradict one another; they only complement one aspect of the space - time continuum (absolute, or universal, or cosmologic) with another such an aspect (relative, or measurable with optical instruments, or associated with a local environment).

11. DISCUSSION AND CONCLUSIONS

(1) Here we must seriously turn to the paper by Grön (1986), which is devoted to the question as to why we have to assume an infinite speed at the beginning in order to relate the grand expansion with contemporary optical observations. One can relate a time interval at the beginning $(t-t_0)$ with a present-day time interval $(t'-t'_0)$. The former interval is defined in some absolute reference frame, while the latter one refers to our own reference frame which moves away through space with a velocity v with respect to the absolute origin O, Figure 1. According to the theory of special relativity, especially the time-dilation effect, these two time intervals are related by

$$t'-t'_0 = \frac{t-t_0}{\sqrt{1-\beta^2}}; \quad \beta = \frac{v}{c}. \tag{85}$$

From equations (7) to (14) we can estimate the interval $(t-t_0)$ as follows. Using every q_i to take any value between its minimum $15/8 \approx 2$ and its maximum 8, we can write

$$T({}_{92}U^{238}) = [10^3, 10^9] \cdot T({}_6C^{12}), \tag{86}$$

where the time duration for a carbon cycle, according to Bethe, may be taken $6 \cdot 10^6$ years. Hence, the total time interval since the grand expansion may be taken as any value between its minimum $6 \cdot 10^9$ years and its maximum $6 \cdot 10^{15}$ years.

(2) In fact, we can use equation (85) to estimate a speed by which our own reference frame is moving through space. On one hand, the observed lifetime of the universe, i.e. the former interval, if based on a large body of evidence within nuclear physics, may be assumed 10^{10} years. However, the latter interval may be obtained from equations (42) to (44a,b) and equations (45) to (52), jointly with Table 2, and Figure 1. These data lead to

$$v = (0.866 \pm 0.015) \cdot c. \tag{87}$$

This result is what we must expect from a strict application of the principles of special relativity.

(3) Clearly the parameter β is smaller than 1, but may be taken equal to 1, which would lead to a conclusion that recession velocities are close to the speed of light. We can imagine that various material pieces had been bound, just before the expansion had started, by only interatomic and molecular forces whose binding energies are at least three orders of magnitude smaller in comparison with similar energies at the nuclear level. So we can assume $l^2 = 10^{-3}c^2$.

(4) It is possible to say something about the maximum value related to a time duration $(t_m - t_0)$ within the present theoretical model. Actually, this quantity can be estimated from

$$v = 0; \quad r = r_m = \frac{2Gm'}{l^2}; \quad t_m - t_0 = \frac{4Gm'}{3l^3}. \tag{88}$$

It should be emphasized that all observable quantities, so far as their reliability is concerned, might be divided into two classes. In the first class, highly reliable, one can enumerate the observed relative recession velocities of galactic clusters as represented through the quantity η;

also the present-day epoch as obtained from a huge empirical evidence at the level of nuclear physics as represented by the time interval $(t' - t'_0)$. The second class may contain quantities rather uncertain in two ways; they may not be represented by clearly defined entities (density of the ponderable matter μ; radius of the universe r). In this same class one may include those that are not open to direct observations, e.g. thickness of the ponderable matter (Δ) in a thin-shell model. Finally, the age of the universe, according to our equation (88), is approximately equal to 10^{13} years.

APPENDIX: UNIVERSAL PHYSICAL CONSTANTS

Here we quote the following physical constants used in the present work: Constant of the universal gravitation, G; speed of light, c; distance traveled by light during one year (light-year), Lyr; Planck's constant divided by 2π, $\hbar$; Avogadro's number, N_A; gas constant, R; Boltzmann's constant, k_B; charge of the electron, e; rest mass of the electron, m_e; rest mass of the proton, m_p; distances given in parsec (ps);

$$G = 6.673 \cdot 10^{-11} m^3 kg^{-1} s^{-2}; \quad c = 299.79250 \cdot 10^6 ms^{-1};$$

$$Lyr = 3.1536 \cdot 10^7 sc = 9.45425 \cdot 10^{15} m;$$

$$\hbar = 1.0545 \cdot 10^{-34} Js; \quad N_A = 6.022 \cdot 10^{23} molecules/mol;$$

$$R = 8.3143 J/mol \cdot K; \quad k_B = 1.38 \cdot 10^{-23} J/K;$$

$$e = 4.803 \cdot 10^{-10} esu = 1.60210 \cdot 10^{-19} As;$$

$$m_e = 9.1091 \cdot 10^{-31} kg; \quad m_p = 1.67252 \cdot 10^{-27} kg;$$

$$1eV = 1.60210 \cdot 10^{-19} J = 1.60210 \cdot 10^{-12} erg;$$

$$1ps = 3.085 \cdot 10^{16} m = 3.26 Lyr;$$

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