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Gravitational Dynamics: The Result of an Ingenious Macroscopic Higgs Quantum Space Dynamics Phenomenon.

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Abstract: *This work discusses the nature of the gravitational fields in the scenario of the Higgs Theory. The Higgs theory introduces the idea that empty space is filled up by a quantum fluid medium, governed by a complex macroscopic order parameter $\Phi = \phi(r)\, e^{i\theta}$, responsible for the inertial mass of the particles. This HQS materializes the local Lorentz frames (LFs), turning them into local proper LFs, intrinsically stationary with respect to the local HQS. In these proper LFs, stationary clocks show proper time and the one-way velocity of light is isotropic. The observed absence of the solar gravitational slowing on the GPS clocks, moving with Earth round the Sun and the absence of light anisotropy with respect to the orbiting Earth both demonstrate that the moving Earth is stationary with respect to the local HQS and is a local true proper LF. This can make a sense only if the HQS is moving round the Sun according to the Keplerian velocity field $(GM/r)^{1/2}$ consistent with the planetary orbital motions. The present work shows that this Keplerian velocity field creates an ingenious outside-inside centrifuge mechanism that gives rise to a central field of centrifugal forces toward the gravitational center. This inverted outside-inside centrifuge mechanism is entailed by the Principle of Equivalence and is the quintessence of the gravitational fields. While Einstein's General Relativity describes the gravitational dynamics in terms of motion of classical particles along geodesic lines in hypothetical curved spacetime, the present work replaces the spacetime curvature of GR by a Keplerian velocity field of the HQS, in which the gravitational dynamics is the result of the propagation of the particle wave mechanisms with respect to the local HQS, moving in this Keplerian velocity field. This HQS dynamics straightforwardly and effectively solves all the troubles with the observed effects of the gravitational fields on particles, on light and on clocks.*

Keywords: *Fundamental Physics, Higgs Theory, Theory of Relativity, Gravitational Physics, Gravitational Effects.*

1. INTRODUCTION

Gravity is the most intriguing and also the most defiant subject to the human intellect. Newton tried to understand it as a problem of mechanics. Einstein tried to view it as a generalized inertial dynamics in curved empty spacetime. The origin of the inertial motion of the particles and the nature of empty space both channel us to the Higgs theory. The Higgs Theory introduces the idea that empty space is not empty at all, but is filled up by a scalar field, with spontaneously broken symmetries and giving rise to a real quantum fluid spatial medium (boson quantum condensate). This Higgs Quantum Space (HQS) ascertains the nature of empty space and is responsible for the inertial mass and the mechanical properties of the elementary particles. This HQS entails radical changes in Einstein's view about the nature of empty space (vacuum) and about the meaning and effects of motion. Actually, a series of experimental observations, many of them achieved with the help of the atomic clocks in orbit, unveil an active participation of the HQS itself in the life and dynamics of the matter universe.

On the Assumptions of the Special Theory of Relativity.

In the beginning of the past century, Einstein's daring assumptions about the nature of empty space, about time and about the meaning and effects of motion, in the Special Theory of Relativity (STR) have initially faced many criticisms. However, with the experimental confirmation of several of its novel predictions, these criticisms rapidly faded away and the view of the Theory of Relativity (TR) turned into the standard way of thinking physics. Most of the predictions of the TR are now well confirmed experimentally and their impact on practically all fields of physics, especially in high energy physics, is now implemented and well accepted. However, the experimental observations also

have revealed weaknesses and inconsistencies. There certainly is no doubt that the experimental observations are the supreme judge of the scientific theories. Therefore, these problems absolutely need to be revised and amended. In the view of the present work, all these problems are settled naturally in the scenario of the Higgs Theory.

The ground-laying assumption of the STR [1,2] is that empty space contains nothing that can be considered as a reference for rest and for motions, or to be a medium of propagation for light. This has the consequence that motions have no intrinsic meaning. Therefore, any inertial observer can assume that his own inertial reference is a proper reference, in which the velocity of light is intrinsically constant and isotropic, stationary clocks show proper time and meter sticks have the proper lengths. Moreover, *from the view of this generic proper observer*, all the other references, moving with respect to his own one, are non-proper references, in which stationary clocks do not show proper time, light is not isotropic and the meter sticks do not have the proper length. Strangely however, in spite of all these differences, the STR proclaims that all the inertial references are equivalent and none is preferable. This leads to the problematic reciprocal symmetry between observers, giving rise to a large list of unsolvable paradoxes.

In the framework of the STR time intervals, distances and masses have no absolute values. They change as a function of the *relative velocity* according to the well-known Lorentz Transformations. However importantly, the rate of clocks, the speed of light and the length of the meter sticks change in such a way that measurements of the velocity of light, by the method of light go-return round-trips between two mirrors with the help of a clock, give the same value c in all the different references. The effective velocity of light and the effective rate of the clocks thus change with the relative velocity in exactly the same proportion. These facts together with the null results of the Michelson light anisotropy experiments have lead Einstein to postulate the intrinsic constancy and isotropy of light and to proclaim the Principle of Relativity, according to which the fundamental laws of physics are (Lorentz) invariant with changes of the reference, analogously as the laws of mechanics were known to be Galilean invariant.

The Special Theory of Relativity (STR) incorporates many of Einstein's celebrated discoveries. However, the most remarkable one is the orthogonality (linear independence) of the intrinsic dynamics, related with the rest mass-energy of the particles and their extrinsic dynamics (kinetic energy) in ordinary space. The consequence of this orthogonality is that the intrinsic energy or rest-mass-energy $E_0=m_0c^2$ and the extrinsic (relativistic) kinetic energy pc of an elementary particle add up according to the Pythagorean Theorem. The total relativistic energy is: $mc^2 = [(m_0c^2)^2 +(pc)^2]^{1/2}$, where $m = m_0(1\text{-}v^2/c^2)^{-1/2}$ is the relativistic mass. Einstein conceived this orthogonality in a four-dimensional spacetime, expressing it in terms of Four-Vectors that are invariant with changes of the reference. They are the usual 4-vector displacements $(\boldsymbol{r},ict)$, the 4-vector velocities $\gamma(\boldsymbol{v},ic)$, the 4-vector momenta $\gamma m_0(\boldsymbol{v},ic) = (\boldsymbol{p},iE/c)$ etc., where $\gamma = 1/(1-v^2/c^2)^{1/2}$ and $i = (-1)^{1/2}$ indicates that the time axis is orthogonal to the ordinary space coordinate axes. The components of the 4-vectors change with the reference (velocity) in such a way that the magnitude of the 4-vectors remains constant. The present work will show that the invariant 4-velocity simply is the characteristic fixed velocity c, the maximum velocity at which the Higgs Quantum Space (HQS) propagates phase perturbations of its order parameter

Another problem of the STR is with the origin of the inertial mass of the particles. Despite the STR relates the mass of the elementary particles to their total relativistic energy E, it cannot explain their inertial behavior. This problem is intimately related with the fact that, according to the STR, motions have no intrinsic meaning. Only about 60 years later has the Higgs theory and or its Technicolor extensions disclosed the scenario and the physical mechanism that is responsible for the inertial mass. The origin of the inertial mass and the reciprocal symmetry between observers are two major unsolvable problems of the STR. In the scenario of the Higgs theory, they will get a natural solution.

According to the gauge theories, all the particles were originally massless and moving at the velocity of light. Observations however have shown that some gauge particles have large masses. Also the elementary particles in general (fermions) have large masses. The first clue about the origin of the inertial mass of gauge particles, was discovered 1963 by Anderson in superconductivity. [3] The superconducting condensate (SCC) is a quantum fluid of condensed Cooper electron pairs (pseudo-

bosons). Spontaneous breakdown of the U(1) symmetry of the Cooper electron pairs leads to condensation into a macroscopic phase coherent quantum ground state, described by a complex Ginsburg-Landau (GL) like order parameter ($\Psi(r,\theta) = \psi(r)e^{i\theta}$ and giving rise to a vacuum-expectation-value (VEV) $\Psi^*\Psi$. Anderson has discovered that gauge transformations of the superconducting order parameter (testing the mobility), in the presence of a magnetic field, reveals mass terms of the EM field quanta (gauge bosons or photons).

Some years later, after a series of important advances and breakthroughs in the electroweak theory, several authors [4,5] have announced the physical mechanism, by which the gauge bosons (vector bosons of the weak interaction) can get their masses. This mechanism now is known as Higgs mechanism. The Higgs theory introduces the idea that empty space is not empty at all, but is filled up throughout by the vacuum-expectation-value (VEV) of the scalar (Higgs) field with spontaneously broken symmetries. This VEV or Higgs condensate (HC), permeating all of space, is responsible for the mass and the mechanical properties of the elementary particles and here *will be dubbed as Higgs Quantum Space (HQS)*. Shortly after the publication of the Higgs theory, Glashow, Weinberg and Salam announced the mechanism by which Fermions (quarks and leptons), coupling to the hypercharged Higgs VEV via their hypercharges by a Yukawa like mechanism, get their inertial masses. [6]

The Higgs theory introduces radical changes in Einstein's view about the nature of empty space and about the meaning and effects of motion. *Contrarily than affirmed by some authors*, in the view of the present work, if the HQS is responsible for the mass and the mechanical properties of the elementary particles, then it necessarily governs their inertial motion and is their *local* ultimate (*local* absolute) reference for rest and for motion. It however is not a universal absolute reference in the conventional sense, because the HQS, as will be seen, can itself be locally moving. The HQS materializes the local Lorentz frames (LFs), turning them into local proper LFs, intrinsically stationary with respect to the local HQS. It gives back to the motion of particles an intrinsic meaning, which runs into frontal conflict with the ground laying precept of the STR, according to which motions have no intrinsic meaning. Thereby the HQS breaks the reciprocal symmetry of the STR between observers, eliminating most of its problems.

The Higgs VEV, likewise superfluids and the superconducting condensates (SCC), too can be described by a complex macroscopic GL like order parameter $\Phi(r,\theta) = \phi(r)e^{i\theta}$, where $\phi(r)$ is an amplitude and $e^{i\theta}$ is a complex phase factor. This phase factor essentially says that *the local HQS (VEV) can itself move*. If an interacting field causes locally a phase gradient ($\nabla\theta \neq 0$) on the Higgs order parameter, the local HQS necessarily moves along this local phase gradient at a velocity proportional to the magnitude of the phase gradient, analogously as superfluids and the SCC. The VEV of the Higgs (HQS) is an extremely rigid and powerful quantum fluid medium. According to the Weinberg-Salam electroweak model, condensation of the Higgs VEV opens an energy gap of more than 200 GeV. This is 10^{14} times larger than the energy gap of the conventional quantum fluids. The HQS however at the same time is perfectly conservative. Any excitation in it is unlimitedly persistent.

Local motion of the HQS itself has no intrinsic meaning. It has a meaning only with respect to the local HQS at other places. This means that observers, stationary with respect to the local HQS *at different places*, can be relatively moving with respect to each other and even so be both locally proper observers. This is, within an acceptable scientific logic, the maximum possible compliance with the fundamental assumptions of the STR about proper references and about the meaning and effects of motion. The absence of light anisotropy with respect to the orbiting Earth and the absence of gravitational slowing of the GPS clocks by the solar field will be seen to fully corroborate this state of affairs between observers on the planets of the solar system.

In the scenario of the Higgs theory *the one-way velocity of light c is fixed with respect to the local HQS*. This one-way velocity is the maximum velocity at which the HQS propagates perturbations of its order parameter and is the true cause of the invariance of Einstein's 4-vectors. Therefore, motion of an observer's reference (laboratory) with respect to the local HQS, that is, with respect to the local proper LF, gives rise to several real physical effects: Light anisotropy, real time dilation (real clock slowing) and real increase of mass-energy of the particles etc. In these real physical effects, there is no

reciprocal symmetry between observers. *While the clock of an observer, moving with respect to the local HQS, runs slow, clocks, stationary in the local moving HQS (moving in the reference of this observer) show proper time.*

In the second part of this Introduction, on the fundamental assumptions of the General Theory of Relativity (GR), it will be seen that, in the gravitational fields, the HQS is moving in the ordinary space round the Sun (gravitational sources) according to a Keplerian velocity field $(GM/r)^{1/2}$ consistent with the orbital motion of the planets and round Earth consistently with the orbital motion of the Moon. Hence, clocks, stationary *in the ordinary space* within a gravitational field, are implicitly moving with respect to the local HQS at a velocity equal and opposite to that of the HQS ($v(r) = -(GM/r)^{1/2}$ and therefore run slow (gravitational slowing). However, clocks in orbit (with Earth) round the Sun and thus, commoving with the local HQS, are stationary with respect to the local HQS (local proper LF) and do not show any solar gravitational slowing, as observed on the GPS clocks. In the scenario of the HQS, all effects of motion are uniquely due to motion with respect to the local HQS. *There is no reciprocal symmetry between the clock-rates of stationary and moving observers with respect to the local HQS*. This saves Einstein's twin thought experiment (solves the twin paradox), because there is no reciprocal symmetry between the true clock rates of the twins. The true rate is defined by their velocity with respect to the local HQS. Relative velocities between observers, on the other hand, give rise to another class of effects that are reciprocally symmetric between observers. Among them are the apparent frequency (Doppler) shifts of relatively moving radiation sources and observers, relative kinetic energy etc. However, if the HQS itself moves, it carries with it the whole local proper reference (proper LF). Therefore, velocity gradients of the HQS give rise to inertial dynamics on matter-energy. Moreover, the corresponding geometrical deformations of the HQS give rise to real wavelength stretching-compression effects that in practice normally are equivalent to the Doppler shifts, caused by the corresponding relative velocities in the ordinary space. Care is necessary, because this easily leads to confusion.

Actually the one-way velocity of light between orbiting satellites can be measured with sufficient precision with the help of their tightly synchronized atomic clocks in orbit. When atomic clocks are located vertically above the terrestrial station, they can precisely be synchronized by Einstein's method *to the Earth-based clock* to within about 0.1 *ns* (time for light to travel 3 *cm*). This synchronization is especially favorable for clocks in polar orbits and passing vertically over the Earth-based Station, because, as will be seen, the synchronization signal (up and dawn) has everywhere the same velocity along a large range of the satellite positions. This synchronization usually remains stable during about 24 hours to within 0.5 *ns*. The most reliable measurements of the one-way velocity of EM signals (light) were achieved with the help of the tightly synchronized atomic clocks in the robotic twin satellites of NASA's GRACE project, both moving round Earth in the same polar orbit at 500 km of altitude (≈ 1.43 h orbits) and separated by ≈ 200 km. To measure the microgravity effects, their clocks need to be synchronized to better than 0.16 *ns*. These experiments have very clearly shown that the one-way velocity of EM signals (light), exchanged in both senses between these satellites, is anisotropic. [7] The anisotropy is backward to the orbital motion and is almost exactly equal to their orbital velocity of nearly ≈7.8 km/sec. This observation unquestionably proves that the intrinsic light isotropy, postulated by Einstein, is in trouble. On ground however the velocity of light, along North-South directions, is well-known to be isotropic. Both these observations will get a natural explanation in the coming Sections and play an important role in the definition of the velocity field of the HQS, responsible for the gravitational dynamics.

In spite of the fundamental assumptions of the STR lead to a series of unsolvable impasses, actually most physicists consider it as a canonically correct theory. No doubt that the conceptual base of the STR is better than that of Newtonian gravity. However, the fact that measurements of the velocity of light, by the method of light round-trips between two mirrors and the help of a clock, give the same value in any inertial reference obviously is a misleading experimental artifact. The reason is that the light round-trip-times between two mirrors and the round-trip-times (period) of the EM field in the time standard, by which the clocks count time, are affected by motion of the laboratory, *with respect*

to the local HQS, in exactly the same proportion, as is well-known from the Ives-Stilwell experiments. In fact, such measurements only give the average velocity of light over a go and return travel, which in no way proves that the one-way velocity of light is intrinsically isotropic. It is important to note that the Ives-Stilwell experiments were performed with ionized Hydrogen atoms (Protons) in Canal beams, in which they had speeds ranging from 0.064 c km/sec, up to 0.338 c km/sec. These velocities are in the order of ten thousand (10^4) times larger than the effective velocity of the Earth-based laboratories of nearly 8 km/sec with respect to the local HQS, as will be seen in the coming Sections. It hence is clear that the effects of the velocity of the earth-based laboratories with respect to the local HQS fall well out the experimental resolution of all the Ives-Stilwell experiments and in no way could be detected. In the scenario of the HQS, the *one-way velocity of light, transversally to the motion of the laboratory with respect to the local HQS, is slowed, however is isotropic*. *Along longitudinal directions however it is anisotropic*. The present work will show that the light anisotropy experiments searching for effects of the orbital and cosmic motion of Earth gave null results, *not because of the intrinsic isotropy of light, however because the orbiting Earth is almost exactly stationary with respect to the local moving HQS, in the velocity field round the Sun* and giving rise to the solar gravitational field.

On the Assumptions of General Relativity

In Newton's theory of gravitation, two matter bodies, orbiting round their center of mass, exchange real and opposite centripetal forces on each other *through the vacuum.* The reality of these gravitational forces was put in doubt along centuries by many scientists. In Einstein's view, the Newtonian gravitational forces are fictitious and not real forces.

In the General Theory of Relativity (GR) [2] Einstein has introduced the ground laying Principle of Equivalence, according to which the gravitational pull is equivalent to an inertial pull, a fictitious force. All the actually known observations endorse the correctness of this principle. The Principle of Equivalence breaks the Newtonian mechanistic view of gravitation. It *inverts the role of the centripetal and centrifugal forces of the Newtonian gravitational dynamics*. Although the equivalence of gravitational and inertial effects is totally obvious from an empirical view, it never before has been recognized as a fundamental principle, governing the gravitational dynamics. More recently, Quantum Gravity revives the Newtonian view about the gravitational dynamics in terms of momentum exchange (force) via virtual field quanta (gravitons). Exchange interaction is well-known to well describe the interaction in the case of the three stronger fundamental forces. It however visibly fails in the gravitational interaction. Actually Quantum Gravity is in standby, because of unsolvable problems (non-renormalizable divergences). In the present work, gravitation will be seen as the result of a Macroscopic Quantum Phenomenon, in which a Keplerian velocity field of the Higgs Quantum Space (HQS), the local ultimate reference for rest and for motion, creates an ingenious outside-inside centrifuge mechanism, responsible for the gravitational (centrifugal) pull toward the gravitational source. The HQS thus plays a central role in both the microscopic quantum physics of the elementary particles, giving them mechanical properties, as well as in the macroscopic gravitational physics, giving rise to the gravitational dynamics. This opens a way to unify the microscopic quantum physics and the macroscopic gravitational physics and naturally implementing the equivalence of gravitational and inertial effects.

According to the Principle of Equivalence, the gravitational dynamics of free bodies is an inertial dynamics that involves no real forces. The astronomical bodies in orbit move locally according to the Principle of Inertia. Here, it will become clear that they in fact do not move at all with respect to the local HQS. The planets simply are carried round the Sun by the Keplerian velocity field of the HQS creating the solar gravitational field. Their velocity with respect to the local HQS is irrelevantly small. Although the Principle of Equivalence seems to be a very simple statement, it entails an ingenious outside-inside centrifuge mechanism that is totally impossible to conceive within Einstein's view about the nature of empty space. It absolutely requires the involvement of a space with remarkable properties: Yes, a perfectly conservative quantum fluid space that governs the inertial motion of matter-energy. This space must move in the ordinary space in such a way as to create this outside-

inside centrifuge mechanism. Implementation of this spacedynamics entails fundamental changes in Einstein's view about the nature of empty space. Somehow matter bodies must create a dynamical space (Spacedynamics) round them that creates this outside-inside centrifuge mechanism and thereby giving rise to the observed gravitational dynamics. Imagine what a challenging issue it must have been for Einstein to conceive the circular orbital motions of the planets as inertial motions in the empty space of the STR, in which motions have no intrinsic meaning and moreover, without knowing the origin of the inertial behavior of matter. Even so, Einstein's GR is the most splendid and impressive work of mathematical physics. In the view of the present work it however cannot be the true picture.

In the beginning of the past century the precarious experimental survey about the nature of empty space, about the meaning and effects of motions and about the gravitational dynamics gave Einstein plenty of freedom to put in action his remarkable skills in the canonical mathematical physics. In GR, Einstein in fact introduces a dynamical space. He nevertheless implements this dynamics in terms of intrinsic motion along the time axis in a static curved four-dimensional spacetime. Instead of searching for the actual physical causes that implement the principle of equivalence within the gravitational fields, he delegated the responsibility for the observed gravitational dynamics to generalized inertial motion, geodesic motion of classical particles in curved four-dimensional spacetime. In order to define the metric of this curved spacetime, he used the measured velocity of light by the method of light round-trips and a clock affected by gravity that is an experimental artifact. In this way he constructed the impressive and prodigious mathematical framework of GR that explains gravitation as an effect of spacetime geometry. [1,2]

The curved spacetime geometry of GR incorporates the effects of the gravitational fields, turning them into an intrinsic outcome of the curved spacetime. In this way the spacetime curvature of GR transforms away the need of the true physical causes and takes their role in the gravitational dynamics. GR expresses the motion along geodesic lines in terms of the invariant four-vectors. In this metric, the advance of a matter system at the velocity c (not the measured c!), along its respective geodesic line, is an invariant under changes of the reference. From the viewpoint of the present work, this invariant geodesic velocity is exactly the *fixed one-way velocity of light c with respect to the local HQS*. This velocity c is the maximum velocity at which the HQS propagates the phase perturbations of its order parameter. GR uses the invariance of the four-vectors in the curved spacetime as a standard to re-scale the metric of the space and time coordinate axes. In this rescaled spacetime metric (curved spacetime), the orbital motion of free matter bodies in the gravitational fields automatically reproduce the observations, *those known in the beginning of the past century*. Actually however, the usual geometrical interpretation, the geodesic motion and the model of the free-falling inertial references cannot explain a series of new experimental facts, discovered mainly with the help of the atomic clocks in orbit. These facts entail fundamental changes in Einstein's view about the nature of empty space and about the nature and origin of the gravitational dynamics. These facts will be discussed in the light of the Higgs theory in the coming **Sections 3, 4 and 5**.

According to GR, large matter bodies curve spacetime in their neighborhood according to the famous Einstein's equations:

$$G_{\mu\nu} \equiv R_{\mu\nu} - (1/2)g_{\mu\nu}R = 8\pi G T_{\mu\nu} \qquad (1)$$

where $R_{\mu\nu}$ is the Ricci curvature tensor, R is the scalar curvature, G is the gravitational constant and $T_{\mu\nu}$ is the stress-energy tensor of the gravitational source. In reality, these equations contain a conceptual inconsistency in their very origin. The left-hand side is formed by classical quantities, while the stress-energy tensor $T_{\mu\nu}$ in the right term is a quantum mechanics operator. The solution of this inconsistency could be replacing somehow $T_{\mu\nu}$ by an effective classical quantity.

In the neighborhood of a spherically symmetric gravitational source, the metric of this curved spacetime is characterized by the invariant length of the four-dimensional line element ds. For sufficiently weak gravitational fields, ds can be expressed by:

$$ds^2 = [1-(2U)/c^2]^{-1}dr_0^{\,2} + r^2dw^2 - c^2[1-(2U)/c^2]dt_0^{\,2} \qquad (2)$$

The coefficients $(1-2U/c^2)^{-1}$ and $c^2(1-2U/c^2)$ are respectively the relevant diagonal g_{11} and g_{44} components of the Schwarzschild metric tensor, where c is the one-way velocity of light in free empty

space and 2U= 2GM/r is the square of the local escape velocity from the gravitational field. For strong and non-symmetrical gravitational fields other components of the metric tensor too become relevant.

The last term in Eq.(2) expresses the gravitational time dilation as viewed by an external observer. There dt_0 is an infinitesimal time interval in the absence of gravity. From the view of an external observer, the tick rate t' of a clock in the gravitational field, identical to his own one, is slowed. This means a slower time evolution and a slower Imaginary effective velocity along the time axis $c'(r) = i[(c^2–2GM/r)]^{1/2}$, *where c is the invariant one-way velocity of light in empty space* (fixed velocity with respect to the local HQS) and $i = (–1)^{1/2}$ indicates that this velocity is orthogonal to the local ordinary space coordinates. In the first term of Eq.(2), dr_0 is an ordinary infinitesimal radial distance in the absence of gravity. The time interval dt' for a light pulse to travel a distance dr along the radial coordinate, within the gravitational field, can be written as $dt' = dr/c = dr_0/(c^2–2GM/r)^{1/2}$, where the denominator $(c^2–2GM/r)^{1/2}$ again is the effective velocity of light c', however along the radial coordinate. Adding up the square of the effective velocity c' along the time axis and the square of the space like velocity component $2GM/r$ along the r axis and taking the square root, gives exactly c, the one-way velocity of light in empty space (HQS).

From the viewpoint of the external observer, the effective radial velocity of light c' and the effective time rate t' of stationary clocks in the gravitational field both reduce *in the same proportion* toward the gravitational center. Hence, in the view of this observer, local measurements of the velocity of light, by the method of light go-return round-trips and a local clock, within the gravitational field, must give the same value as measurements outside the field. This however clearly is an experimental artifact, based in an improper measuring method, in which c is obtained from the ratio between two time periods: The light round-trip time between two mirrors and the round-trip time (period) of electromagnetic field in the time standard by which the clock counts time. *Both these time intervals are affected by gravity and or by motion in exactly the same proportion* as is well known from the Ives and Stilwell experiments. The present work will show that the gravitational time dilation and the gravitational reduction of the light velocity along r *are real and not apparent effects*. This gravitational slowing of the atomic clocks on Earth is observed by the local laboratory observer. They will be seen to be caused by the implicit velocity with respect to the local moving HQS in the velocity field, creating the gravitational field (please see **Section 3** for details).

According to GR, due to the spacetime curvature, the time axis has different directions outside and within a gravitational field. Within the gravitational field, it has a space-like component along the radial coordinate, which according to Einstein is equal to the local escape velocity from the gravitational field $(2GM/r)^{1/2}$. In its turn, the radial distances have a time-like component. Therefore, from the viewpoint of the external observer, clocks, within gravitational fields, run slower than outside and the speed of light along the radial coordinate is reduced toward the gravitational center. However, from the viewpoint of the observer within the gravitational field, it is the external time axis that has a space like component and radial distances have a time like component. Therefore, from the viewpoint of this observer, the external clocks run slow and the velocity of light is reduced. Well, here it is again, the problematic reciprocal symmetry of the TR. The Schwarzschild solution of Einstein's field equations of course is OK. What is in question here is its usual geometrical interpretation. Despite correctly predicting many observations, GR ends up in difficulties.

Atomic clocks, stationary within the Earth-based laboratories show exactly the gravitational slowing, predicted by GR. This demonstrates that the gravitational time dilation definitely is real and is not an apparent effect, *because these clocks are stationary in the reference of the observer!* It however at the same time shows that time dilation has nothing to do with relative velocity. This breaks the reciprocal symmetry between observers. Most significantly, the GPS clocks, moving with Earth round the Sun, are well-known not to show any gravitational slowing by the solar field. These two observations consistently demonstrate that clocks stationary in the observer's reference can run slow and that moving clocks can show proper time. From the view of the present work, time dilation has nothing to do with relative velocity. It will become clear that it has to do with the velocity of the light sources and of the clocks with respect to the local HQS.

Actually, some people [8] explain the absence of the gravitational slowing of the GPS clocks by the solar field in terms of the Principle of Equivalence, insisting that Einstein's free-falling elevator is a

proper Lorentz frame, in which all the effects of the gravitational field are locally canceled, *including the gravitational time dilation*. However, the cancelation of the gravitational time dilation in a free-falling reference never has been confirmed experimentally. Hence, this allegation has no experimental support. It is moreover affirmed that up from the moment the free-fall of the elevator is stopped, it acquires an implicit upward velocity, equal to the local escape velocity $(2GM/r)^{1/2}$ with respect to the local free-falling reference, supposedly a proper Lorentz frame and hence clocks within the stopped elevator begin to run slow. How can this? According to the TR, clocks stationary in the observer's reference (stationary elevator) should not run slow! Apparently, according to this allegation, it is the upward acceleration that is responsible for the gravitational time dilation. However, several experiments of Muon decay in cyclotrons have shown that accelerations, up to 10^{19} m/sec^2, do not contribute any time dilation.[9]

It also is alleged that the GPS clocks, moving with Earth round the Sun, are free-falling with Earth in the solar field and hence are stationary in the local frame of Earth that is assumed to be a proper Lorentz frame and that therefore this orbital velocity cancels the solar gravitational slowing. However, these same GPS clocks too are in orbit round Earth and, from this viewpoint, they too are free-falling in the Earth's field, which too should cancel the gravitational slowing by the Earth's field. Notwithstanding however, the GPS clocks orbiting round Earth clearly show the gravitational slowing of 1.67×10^{-10} sec/sec by the Earth's field.[8] This evidences that the gravitational clock slowing is real and that the explanation in terms of the Principle of Equivalence, is not a true explanation. In the present work, Earth will be seen to be in fact a proper Lorentz frame. However, it so is not for the reasons based in the Principle of Equivalence. It is a proper reference because it is stationary with respect to the local moving HQS in the solar Keplerian velocity field of the HQS.

A clock, moving with Earth round the Sun along the circular equatorial orbit, obviously is not free-falling in the solar field, because $dr/dt = 0$. If stationary (non-free-falling) clocks run slow because of their implicit upward velocity at the local escape velocity $(2GM/r)^{1/2}$ with respect to the local free-falling inertial reference, how can *the orthogonal (horizontal) orbital velocity* $(GM/r)^{1/2}$ *of Earth* cancel the gravitational slowing of this radial velocity? The horizontal orbital velocity in fact adds a new velocity component, the time dilation effect of which should add up to the local gravitational slowing. Consequently, the orbiting GPS clocks, besides running slow due to the local upward escape velocity, should in addition run slow, due to the orthogonal (horizontal) orbital velocity. *None of these effects is observed!* The explanation in terms of Einstein's free-falling inertial references (IRs) is a fictitious explanation. The model of the free-falling references also has other troubles. What happens with these free-falling references when they reach the gravitational center at the maximum velocity? Do they simply stop and disappear, or do they collide, or do they continue traversing it and emerging at the opposite side? The model of the free-falling references has the feature of an Aristotelian like explanation, according to which free bodies fall because their inertial references fall. They fall because they must fall.

The present work retakes the question of the equivalence of the gravitational and the inertial pulls on from beginning, within the scenario of the Higgs theory, [4,5] assuming that the gravitational pull is a genuine inertial pull and thus a fictitious force. The present work acknowledges the reality of the vacuum-expectation-value (VEV) of the scalar Higgs field with spontaneously broken symmetries and present throughout the whole universe. This Higgs Quantum Space (HQS) gives mass and mechanical properties to the elementary field quanta (particles) of the fields coupling to it.[4,5] The HQS hence is the local ultimate reference for rest and for motions. It however is not a universal absolute reference in the conventional sense, because the HQS, as will be seen, can itself be moving. It is only a *local* ultimate reference. Analogously as superfluids and the superconducting condensates (SCC), the Higgs VEV too is ruled by the complex macroscopic order parameter $\Phi(r,\theta) = \phi(r)e^{i\theta}$, where the phase factor $e^{i\theta}$ gives the HQS all the necessary tools for motion.

The field quanta do not move as classical particles. They propagate as wave-mechanisms in the HQS. The HQS materializes the local Lorentz frames (LFs) turning them into local proper LFs, intrinsically stationary with respect to the local moving HQS. The HQS thus is the obvious and perfect conceptual ingredient to really understand the origin of the inertial dynamics, observed within the gravitational fields. It naturally and straightforwardly implements the Principle of Equivalence. The present work

will show that *the gravitational pull in fact is an inertial pull, however of a very specific nature*. It will turn out *to be a usual centrifugal force (a fictitious force) pointing toward the gravitational center*. This centrifugal force will be seen to be generated by an ingenious outside-inside centrifuge mechanism, created by a Keplerian velocity field of the HQS, responsible for the observed gravitational dynamics.

Likewise an electromagnetic field induces phase gradients on the order parameter of a superconductor, thereby creating screening currents that thrust the magnetic flux outward by Lorentz forces, the matter fields too cause a phase gradient on the Higgs order parameter, generating a velocity field of the HQS round the astronomical bodies. If such a velocity field has a velocity gradient, pointing toward the gravitational center, it creates an inertial force field, thrusting matter toward this gravitational center.

Actually, several experimental observations, like for instance the absence of the gravitational slowing of the GPS clocks by the solar field, the absence of light anisotropy with respect to Earth etc., demonstrate that, for all practical instances, the orbiting Earth is almost exactly stationary with respect to the local moving HQS in the solar field and is a local true proper Lorentz frame (LF). This can make a sense only if the HQS (local LF) is circulating round the Sun according to a Keplerian velocity field consistent with the local planetary orbital motions (velocity increasing with decreasing *r*). The present work will show that the circulation of the HQS round the Sun consistently with the planetary orbital velocities accurately generates all the observed effects in the solar field. The absence of the solar gravitational slowing on the GPS clocks and the absence of light anisotropy with respect to Earth are the main and obvious signatures of the true physical mechanism of gravity. Details will be outlined in **Sections 3 and 4**.

The *absence* of the gravitational slowing of the GPS clocks by the solar field and the *absence* of light anisotropy with respect to the orbiting Earth demonstrate that Earth effectively is stationary with respect to the local *moving* HQS in the solar gravitational field and is a locally true proper Lorentz frame (LF). The coming Sections will show in detail that this can make a sense only if the HQS is moving round the Sun according to a velocity field closely consistent with the Earth's orbital motion. However, Earth obviously cannot be in a privileged kinematical situation in detriment of all the other planets of the solar system. This scenario can make a sense only if all the planets of the solar system are closely stationary with respect to the local moving HQS, which defines a velocity field *consistent with the planetary orbital motions*. This is a very simple Keplerian velocity field of the form:

$$V(\mathrm{r}) = (GM/r)^{1/2} \qquad (3)$$

In this Equation *r* is the usual radial spherical coordinate. This Keplerian velocity field will be seen to implement *the ingenious outside-inside centrifuge mechanism that accurately creates the observed gravitational dynamics.*

In the Keplerian velocity field Eq.(3), the gravitational slowing of atomic clocks *stationary in the ordinary space within gravitational fields and hence implicitly moving with respect to the local HQS*} – $(\mathrm{GM/r})^{1/2}$ is physically real and is due to velocity with respect to the local moving HQS, the moving local proper LF. In the view of an external observer the light velocity along *r* and the rate of a stationary clock seem to reduce toward the gravitational center. The external observer makes this conclusion because *he cannot see their implicit velocity* $-(GM/r)^{1/2}$ *along a perpendicular direction.* He sees only the ordinary velocity. In reality, the one-way velocity of light *the velocity with respect to the local HQS (vacuum),* at any place within the gravitational field, is exactly the same as outside the gravitational field. All differences are due to motions with respect to the local HQS. The one-way velocity is the characteristic fixed velocity of light with respect to the local HQS that is an invariant throughout space. It is identically the same invariant velocity as the geodesic velocity in GR.

GR explains the observed motion within a gravitational field in terms of geodesic motions. In particular, the vertical free-fall is motion along an extreme elliptical orbit, in which the paths between apogee and perigee, in both senses, coincide. The important question to be answered is: Can GR really explain the gravitational pull on a matter body, *stationary within a gravitational field, as an inertial pull?* Inertial forces are created in response to variations of the velocity. The velocity can change in magnitude and or in direction. When only the magnitude varies (direction is fixed) the inertial pull

necessarily is transitory and of finite duration. According to GR, the velocity of the free-falling inertial references equals the local escape velocity $v(r) = (2GM/r)^{1/2}$ from the gravitational field. At any fixed position r_0, the free-fall velocity of these local free-falling references is constant with time and the local acceleration is zero ($dv/dt|_{r_0} = 0$). A velocity, having a constant value in time and a fixed direction in space, cannot give rise to an inertial pull. Therefore, in the model of the free-falling inertial references, the gravitational pull on a body, stationary in the ordinary space within a gravitational field, should vanish. However, observations show that the Earth gravitational field is acting a continuous gravitational pull on matter along billions of years.

The only possible way to give rise to a *continuous and permanent inertial pull* is by motion along a circular path round a fixed axis. In this case, the constant velocity vector continuously changes its direction at a constant rate. In order to move along this circular path, the rotation axis must exert a centripetal force $\boldsymbol{F}_c = m\boldsymbol{a}_c$ on this body, while the body itself exerts an opposite constant inertial force on this same axis, which is the well-known centrifugal force.

The big challenge is conceiving a velocity field of the HQS that *correctly implements the implicit circular motion of a matter body, stationary in the ordinary space within the gravitational field*. In reality there is only one unique possible way to implement such an implicit circular motion. *The locally valid true inertial reference (IR) must be rotating in the ordinary space round a fixed over-head axis at a locally well-defined time rate*. The idea that such a rotating reference is an inertial reference may seem stupid. However, if it is the HQS, the local ultimate reference for rest and for motions that is itself so rotating, this makes a sense and is the physically real situation in a gravitational field. In order to fully visualize this scenario, consider a body, stationary in the Earth's gravitational field and exerting a constant inertial force on its support, pointing toward the Earth's gravitational center. In order to implement this situation, *the stationary body necessarily must be implicitly moving along a circular path round an over-head axis*. This motion is implicit because it is not motion in the ordinary space. It is motion with respect to the local moving HQS. This state of affairs can be implemented only if the local HQS and the locally true proper inertial reference (local Lorentz frame (LF)) are truly rotating, in the ordinary space, oppositely to the implicit motion of this body round the same overhead axis. In this situation the non-IR, in which the matter body is stationary, is (implicitly) rotating oppositely within the true IR. These two oppositely rotating references let this body stationary in the ordinary space, however implicitly moving, with respect to the local HQS, along a circular path within the local true IR and exerting a centrifugal force on the support holding it fixed. In order to implement this inertial dynamics, radical changes in the current view about the nature of empty space and its connection with the motion of matter, are necessary. Fortunately *the Higgs theory has already introduced exactly this change* (please continue).

The above centrifuge mechanism is *the only possible genuine and real physical mechanism that can create the continuous gravitational pull acting for the billions of years and the inertial dynamics observed within the gravitational fields.* The coming **Sections 3, 4 and 5** show the details. They show that this Keplerian velocity field refracts the wave fronts of the elementary particle wave-functions according to a locally well-defined time rate, thereby giving rise to the observed gravitational dynamics. This inertial dynamics involves no classical forces. However, if the free motion of a matter particle is perturbed by a real force, it responds by an inertial force, exactly as demanded by Einstein's Principle of Equivalence **.**

The HQS gives the elementary particles the behavior described by their complex wave-functions. These wave-mechanisms, besides the ordinary dynamics, embody an intrinsic Imaginary dynamics that is the contribution of the local HQS to their physical existence and their mechanical properties. In this scenario *all the real effects of motion are essentially effects, due to propagation of wave mechanisms with respect to the local HQS* that is moving within the gravitational fields. These real effects are not caused by relative velocity. The theories of particle physics outline a rather different scenario, in which the vacuum is filled up by a host of virtual field quanta of the various fundamental force fields, in which the real particles move as classical particles through this virtual medium. The VEV of the Higgs, far from a virtual medium, is a real and dynamical quantum fluid medium, a physically real spatial medium, giving existence and mechanical properties to the particles and governing their inertial dynamics.

Matter bodies that have no velocity with respect to the local HQS (planets in the solar field) necessarily are moving in *direct circular equatorial orbits* and consequently are stationary with respect to the local HQS. This circular motion does not involve a central force field. The matter bodies simply are carried around by the moving HQS along these orbits, which corresponds to local absolute rest in the local proper LF. The Keplerian velocity field will be shown to simulate the fictitious curved spacetime metric of GR. It however affords much more. It directly predicts the absence of the gravitational slowing on the GPS clocks by the solar field and the absence of light anisotropy with respect to the orbiting Earth. It too will be seen to precisely predict the *non-absence* of the gravitational slowing of the GPS clocks by the Earth's field, because they move round Earth along *the non-equatorial orbits, making 55 degrees with the Earth's equator*. It also precisely predicts all the other observed effects of the gravitational fields on light and on clocks, as will be shown in the final **Section 6**.

The observed gravitating systems, like our solar system and the planetary satellites and planetary rings, are highly ordered (polarized) and so are extremely stable systems. The only way they can get or lose momentum and energy is by emitting, scattering or absorbing radiation, electromagnetic radiation, gravitational waves or collisions with other bodies. Loss of energy has the consequence of increasing their binding energy.

Newton explained the gravitational dynamics in terms of fictitious gravitational forces. GR explains it in terms of geodesic motions in hypothetical curved spacetime. The present work replaces Einstein's curved spacetime by a Keplerian velocity field of the HQS Eq.(3) (to be fully defined in the coming **Section 3** (please see Eq.(10)), consistent with the local main astronomical motions. The gravitational dynamics in this Keplerian velocity field is a genuine inertial dynamics. From the viewpoint of this Keplerian velocity field, Einstein's GR essentially interprets the effects of motion of matter in this Keplerian velocity field in terms of geodesic motions in a fictitious curved spacetime. The present work, on the other hand, will show that the gravitational dynamics in fact is caused by dynamics of space (HQS) itself, the same usual space that governs the inertial dynamics of matter bodies around us. In this Spacedynamics, the main astronomical bodies and the observed gravitational effects on light and on clocks simply are the signature of the Keplerian velocity field of the HQS.

In the scenario of the Higgs theory, the real effects of motion with respect to the local HQS, in free space as well as within gravitational fields, are unified. *They are not caused by relative velocity.* Velocity of the laboratory with respect to the local HQS in free space (stationary HQS) causes light anisotropy, slowing of the clock rates and increase of the mass-energy of particles. Within the gravitational fields, the implicit velocity of bodies, stationary in the ordinary space, causes light anisotropy, gravitational slowing of clocks (frequency slowing of the radiation sources) and the increase of mass. The Keplerian velocity field in addition, provides the ingenious outside-inside centrifuge mechanism of gravity, responsible for the observed gravitational pull and the gravitational dynamics.

It must be mentioned that Newtonian gravity as well as GR are well-known to be unable to explain the non-Keplerian rotation of the galaxies. There is no gravitation enough to stabilize them in their much too fast rotation. This non-Keplerian rotation usually is explained in terms of an enormous halo of enigmatic dark matter, the amount of which is 5 times larger than all together the visible matter in the universe. GR too has troubles with the accelerated expansion of the universe. According to GR, the expansion of the universe should be decelerating and eventually collapse in a big crunch. However, observations show that the expansion in fact is accelerating. Where does the huge amount of dark energy come from? Although GR provides the cosmological constant that can describe the expansion, it cannot account for the physical origin of accelerated expansion. The amount of the so called dark energy, responsible for the accelerating expansion, is 14 times larger than the whole visible mass-energy in the universe. Dark matter and dark energy are actually the most serious troubles of cosmology and fundamental physics. Refs.[10] and [11] outline the possible solutions for these problems, within the scenario of the HQS dynamics.

The next **Section 2** discusses the nature of empty space from the perspective of the Higgs theory. **Section 3** shows that a Keplerian velocity field of the HQS is the origin and the quintessence of the gravitational fields. In **Section 4**, it is shown that the Keplerian velocity field of the HQS

straightforwardly and accurately creates the observed gravitational dynamics. **Section 5** shows that the gravitational mechanism of the HQS dynamics is perfectly symmetric with orbital motions. It shows that the effects of the HQS dynamics are independent (orthogonal) to those of the ordinary motions. Finally **Section 6** succinctly describes a large number of observed effects of the gravitational fields on light and on clocks that all are precisely predicted and so corroborate the HQS gravitational mechanism that Einstein has missed.

2. THE NATURE OF THE EMPTY SPACE IN THE SCENARIO OF THE HIGGS THEORY.

The purpose of this Section is not to merge into the details of the Higgs theory. The aim is putting together the very important conclusions about the nature of empty space (vacuum), about the origin of the inertial mass of the elementary particles and about the meaning and effects of motions in free space as well as within the gravitational fields. This constitutes the essential physics background of the gravitational mechanism as will be implemented in the subsequent Sections.

According to the gauge theories, all the gauge bosons mediating interactions should be massless, propagate at the velocity of light and the interactions should be long-range. However, experimental observations have evidenced that the weak nuclear interactions are short range and that the vector bosons (W^+, W^- and Z^0), mediating it, have large masses. In 1963, Anderson has discovered that gauge transformations of the superconducting order parameter, preserving the gauge symmetry and testing the mobility in the presence of a magnetic field, reveal mass terms for the electromagnetic field quanta (photons). The photons thereby get a longitudinal component.

In the sixties of the past century, several scientists, knowing about Anderson's discoveries,[3] inferred that coupling of the vector bosons to definite components of the VEV of a scalar Higgs field, with spontaneously broken symmetries, can be the mechanism giving mass to these vector bosons. The theory had to overcome many difficulties and to make several breakthroughs. However, finally the physical mechanism, giving mass to the vector bosons of the weak force, was published independently by various authors. [5] The most decisive step was made by Peter Higgs, wherefore this mechanism is known by his name.[4]

Shortly after the publication of the Higgs theory, Glashow, Weinberg and Salam (GWS) [6] announced the mechanism by which Fermions can get their inertial mass. According to the GWS theory, the hypercharged left handed doublets of quarks and leptons couple, via the hypercharged Higgs condensate, to their right-handed singlet by a Yukawa like exchange coupling of the form:

$$U(\phi,\psi) = -g\psi^*\phi\psi \qquad (4)$$

In this Equation g is a coupling constant. By this Yukawa like mechanism, the fermion fields are screened, getting inertial mass and their fields becoming confined and quantized. The values of their inertial masses are proportional to the strength of the coupling constant g.

The exact physical mechanism, responsible for creating the rest-mass is not clear. It is possible to imagine that, analogously as in superconductors, that the particle fields create phase gradients on the Higgs order parameter, generating a confined velocity field of the HQS that costs a large amount of energy. The rest-mass however is only a part of the problem of mass acquisition. It is well known that a large part of the mass of the elementary particles is generated by internal dynamics at very high speed. In order to put these particles in motion with respect to the local HQS they need to create additional phase gradients and additional non-confined HQS dynamics and hence additional energy. This additional dynamics is not quantized and gives them mechanical properties. It is independent and orthogonal to that of the confined and quantized rest mass-energy and ads up to it according to the Pythagorean Theorem.

The Yukawa like coupling is a well-known mechanism that dominates the screening of localized stationary charges and or hypercharges. However, moving (electric) charges, due to the phase gradient of their wave-functions, besides their scalar potential, generate a vector potential, which, if curled $\nabla\times\mathbf{A}$, is magnetic field. In a superconductor the magnetic field is not screened by a Yukawa like coupling. The superconductor develops screening currents that cancel sufficiently weak magnetic fields within its bulk, generating a magnetic field opposite and of the same intensity as the applied one. This is the physical mechanism of the well-known Meissner effect. [12] By the Meissner effect,

the superconductor expels out the magnetic field, thereby lowering the energy of the SCC. There is a net gain of energy by macroscopically expelling out the magnetic field. It hence is clear that in the electrodynamics situation, *the Meissner effect plays, besides the Yukawa like screening mechanism, a chief role in the cancelation of the electromagnetic field within the superconductor*. However, electrically neutral particles, moving and porting a hypercharge, may be associated with a curl-free vector potential. Even a curl-free vector potential causes a phase gradient on the charged particle wave-functions and on the superconducting order parameter, as is well-known from the Aharonov-Bohm effect [13].

The Glashow-Weinberg-Salam electroweak theory [6] conceives the ordinary momentum (***mv***) of the hypercharged fermions as a result of their coupling to the local hypercharged HQS. The motion of the fermion particle wave-mechanisms in the HQS is governed by the phase gradient of their wave functions that is associated with a collinear vector potential **A**. For motion of the electrically neutral fermions (neutrons, neutrinos etc.), porting a hypercharge, this vector potential is curl-free.

The aim of the present work is to investigate the important practical consequences of the Higgs theory in the macroscopic world, more specifically in the origin of the gravitational dynamics. To this end, it is important to discuss the origin and the pertinent properties of the quantum condensates and, in particular of the HQS or Higgs-like quantum space.

The physical mechanism that leads to quantum phase coherence is the Bose-Einstein (BE) phase correlation between the particle wave functions that takes place when these particle wave functions (wave packets) overlap with each-other in the ordinary space. This takes place in low temperatures. This mechanism can be described by the Schrödinger Equation. Phase coherence takes place because it reduces the total energy of the interacting particles. When the BE phase correlation is strong enough to overcome the thermal fluctuations, the interacting particles, or system of particles can break their U(1) symmetry, leading to phase coherence, lowering the energy of the system. Particularly, in the case of a boson system, the bosons can all break together their U(1) gauge symmetry and condense into a same *phase coherent macroscopic quantum ground state*. The condensed bosons form a new collective macroscopic quantum ground state, described by a collective wave function, a complex macroscopic Ginsburg-Landau like order parameter [14] of the form:

$$\Phi(r,\theta) = \phi(r)\, e^{i\theta} \tag{5}$$

In Eq.(5), $\phi(r)$ is an amplitude and $e^{i\theta}$ is a complex phase factor, having a Real and an Imaginary component. The phase factor plays a fundamental role in the local mobility of the condensate. In this condensate the bosons are completely entangled and indistinguishable. Their uncertainty in momentum and energy tends to zero and the uncertainty in position and in time tends to be very large. The condensation however does not collapse the bosons into each other. The boson wave-functions only tune to each other, analogously as the fermion atomic orbitals tune in the molecular bonds. Collapse is prevented by the core interaction (electric charge or hypercharge etc.). The equilibrium density of the condensate has a definite value and a definite spatial volume.

The boson coherence transition is a second order phase transition that involves no (considerable) latent heat. The condensation energy is liberated gradually down to absolute zero temperature. It gives rise to a vacuum expectation value (VEV), in which the boson wave functions give rise to a genuine physical continuum. This VEV is extremely uniform throughout the volume of the condensate and, in the case of the Higgs condensate it extends throughout the whole space of the universe. This spatial uniformity can explain the Horizon and Flatness problems of cosmology. [15] In terms of the complex GL like order parameter Eq.(5), the characteristic potential well, created by the BE phase correlation in the condensation of bosons is described by the equation:

$$U(\Phi) = -\mu^2 \Phi^*\Phi + \lambda(\Phi^*\Phi)^2 \tag{6}$$

If $\mu^2 < 0$, the minimum of the potential energy occurs for $\rho=\Phi^*\Phi = 0$ (free particles). However, if $\mu^2 > 0$ then the first energy term is negative and the minimum U occurs for $\rho=\Phi^*\Phi = \mu^2/2\lambda$. In this situation of U, the field Φ has acquired a vacuum expectation value VEV = $(\mu^2/2\lambda)^{1/2}$. In terms of the complex coordinates, this potential well has the form of a Mexican sombrero as shown in **Fig.1**:

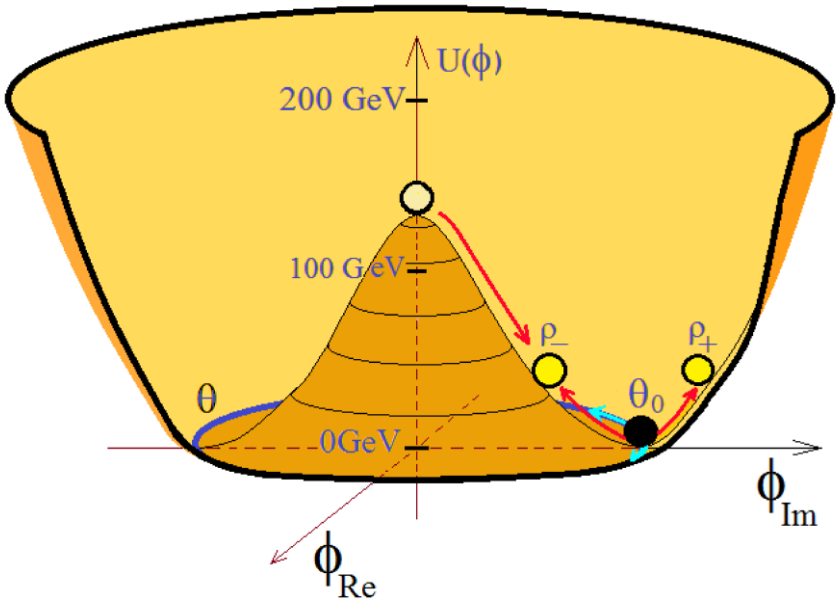

Fig1. *The characteristic potential well, created by Bose-Einstein condensation. The figure depicts the form of the Mexican sombrero potential in terms of the Real and the Imaginary components of the GL order parameter, where the given energy scale is appropriate for the Higgs condensate. A red arrow indicates the transition toward the lower energy phase coherent state with the well-defined phase* θ_0*. The figure also indicates the low volumetric density* ρ_- *and the high volumetric density* ρ_+*situations, giving rise to possible Higgs modes. The global Goldstone mode involves almost no energy and is indicated along the blue bottom circle.*

The physics of quantum condensates is fundamentally different from that of a perfect fluid. While in a perfect fluid the ideal (classical) particles are uncorrelated and each particle moves independently, in the quantum fluids, the condensed bosons are very strongly correlated by their order parameter, forming an integrated physical system. While in a perfect fluid the particles respond all independently to a perturbing field, in a quantum fluid, the response always is collective, coordinated by their order parameter. Their behavior is analogous to that of an army company, the answer of which to any attack always is collective and coordinated by a command. The order parameter is a collective wave function that describes at the same time all the particles of the condensate, which is the VEV of the order parameter. It therefore is impossible to affect one specific boson of the quantum condensate or affect the condensate at only one point, without affecting at the same time all the bosons of the condensate. They all have a non-zero component throughout the whole volume.

According to the Quantum Field Theories (QFT), immediately after the big-bang, all the fundamental force fields were unified, their degrees of freedom being described by the SU(3)×SU(2)×U(1) symmetry group. As the universe expanded and cooled down, a series of spontaneous symmetry breakdowns occurred. In the first Chiral symmetry breakdown the strong nuclear force field SU(3) separated from the electroweak force doublet SU(2)×U(1) and then, when the temperature cooled through 10^{15} K, spontaneous breakdown of the electroweak symmetry resulted in the weak force doublet with SU(2)×U(1) symmetry and the electromagnetic (EM) force field with (Abelian) U(1) symmetry. While the EM field maintained its U(1) symmetry, the weak force doublet, with four degrees of freedom, spontaneously broke into its four components: Two components with spin 1, electrical charges Q = ± 1, weak isospin T_3 = ± 1 and thus weak hypercharge 0; a third component with spin 1, zero electric charge and zero T_3 and hence too with zero hypercharge. Finally the remaining fourth component was characterized by spin zero, zero electric charge (Q = 0), weak isospin T_3 = −1/2 and thus, according to the Gell-Mann-Nishijima formula, with hypercharge +1.

In the view of the Higgs theory, the first three components, of the broken electroweak symmetry, were incorporated to the three massless vector bosons (W^+, W^- and Z^0), confining their weak force field down to a very short-range of only 10^{-19} m and giving them large masses by the Higgs mechanism. The fourth chargeless component remained free. However, when the universe continued cooling

below 10^{-15} K this fourth component spontaneously broke its U(1) symmetry, condensing into a coherent macroscopic quantum state, now known as Higgs condensate (HC), acquiring a vacuum expectation value (VEV) throughout the space of the universe. Likewise the VEV of the superconducting condensate (SCC), this macroscopic quantum state can be described by a complex macroscopic Ginsburg-Landau (GL) like order parameter $\Phi(r,\theta) = \phi(r)\, e^{i\theta}$. The VEV of the Higgs condensate (HC) that is a quantum fluid has physical properties that are closely analogous to those of the SCC. This is not an accident. Both condensates are quantum condensates of bosons (pseudo-bosons in the case of the SCC). However, while the energy gap of the SCC is of only about 1 meV, that of the HC may achieve more than 200 GeV (an energy gap 10^{14} times larger than that of the SCC). [16,17] The similarity between the SCC and the HC was an important hint in the development of the Higgs theory. The present work too inspires it in this similarity.

The Higgs field is an omnipresent quantum fluid medium. It materializes the local Lorentz Frames (LFs), turning them into local proper LFs, intrinsically stationary with respect to the local HQS. The HQS is the ultimate ontological background, from which the material universe gets its physical existence. The HQS is much more than simply a local reference for rest and for motion for matter-energy. It literally governs the inertial motion, the propagation of the matter waves and is their local ultimate (local absolute) reference for rest and for motions. In this scenario, the *motion of matter-energy particles regains an absolute meaning and all the real effects of motion are due to motion with respect to the local HQS and not to relative motions*. The Higgs theory entails radical changes in the current view about the nature of empty space.

The present work, contrarily to the opinion of some authors, assumes that the vacuum-expectation-value (VEV) of the Higgs field is a real quantum fluid, analogous to superfluids and SCC. This VEV is described by a complex order parameter Eq.(5) that comprises a spatial density and has a phase factor. The phase factor describes the mobility of the local VEV in the ordinary space. Likewise for the elementary particles, superfluids and the SCC, the velocity of the local VEV of the Higgs too is proportional to the phase gradient of its order parameter. The VEV of the Higgs is the physical space itself that governs the motion of matter-energy around us and is the local ultimate reference for rest and for motion. If the velocity field of the Higgs VEV is non-uniform in space, it gives rise to an inertial dynamics.

The question with respect to what the HQS itself is locally moving is meaningless, because the HQS, in its ground state, at zero temperature, does not move at all. The phase gradient is zero throughout and the wavelength is infinite. Only motion of the local HQS with respect to the HQS at other locations is meaningful. *This relative velocity of the HQS at different places is the maximum possible compliance of the real world with the fundamental precepts of the theory of relativity (TR).* In fact, the original precepts of the TR, according to which any observer can define his own proper reference, in which the velocity of light is isotropic and stationary clocks show proper time, as postulated by Einstein, are too general. From the perspective of the present work, only with respect to the local HQS (local proper LF) is the one-way velocity of light fixed and isotropic and only clocks stationary with respect to this local HQS show proper time. The original assumptions in the STR, besides going against the common sense, are paradoxical. From the present view, only observers, stationary with respect to the local HQS (local proper LFs), can locally observe proper physics as demanded by the Principle of Relativity. Moreover, neglecting the very small effects of the local gravitational field of Earth, the laws of physics, found on Earth, are the same on all other natural astronomical bodies, moving along *regular direct circular equatorial orbits* round the respective local gravitational sources. Such bodies are all very nearly stationary with respect to the local moving HQS in the respective gravitational fields throughout the universe. This leads to the universality of the laws of physics, independently from the Principle of Relativity.

Quantum fluids are totally inviscid and perfectly conservative. However, due to the strong BE phase correlations, they possess a phase rigidity. In the case of the HQS, this phase rigidity is enormous and so excitations cost large amounts of energy. However, once created, these excitations, if cyclic, are quantized and automatically become indefinitely persistent. From superconductivity it is well-known that a fixed potential difference, applied to a superconductor realizes work at a constant rate and creates a continuously increasing phase gradient $\Delta\theta$. Thereby it increases the velocity of the condensate according to:

$$v(r) = (\hbar/m)\,\nabla\theta \qquad (7)$$

where ħ is the reduced Plank's constant and m is the mass of the bosons. Eq.(7) shows that the electric current intensity increases with the phase gradient $\nabla\theta$. Importantly, this velocity field and or currents are not dissipated at all. They are indefinitely persistent. They can be stopped only by an opposite electromotive force. *This perfect persistence is the key property that gives rise to the inertial behavior of the excitations*. The associated phase gradient however represents phase disorder elevating the potential energy of the SCC.

An electric current in the superconductor is associated with a collinear magnetic vector potential **A**, the curl of which is a solenoidal magnetic field round the current. The phase gradient $\nabla\theta$ of the superconducting order parameter is directly related with the vector potential **A**:

$$\nabla\theta\,(r, t) = (2e/\hbar)\,\mathbf{A}(r,t)$$

Note that the same vector potential causes opposite phase gradients on positive and negative charges. Using Eq.(7) and Eq.(8) the acceleration **a** of the Cooper electron pairs can be written:

$$\mathbf{a} = d\mathbf{v}/dt = (\hbar/m)\,d\nabla\theta/dt = (2e/m)\,d\mathbf{A}/dt = -(2e/m)\mathbf{E} \qquad (8)$$

where 2e is the electric charge of the Cooper electron pairs. Note that, in agreement with the Maxwell equations, a time changing vector potential generates, by Faraday-Lenz induction, a longitudinal electric field $\mathbf{E} = -d\mathbf{A}/dt$ and, if free charges are present, they are accelerated, forming a secondary electric current opposite to the primary current (opposite to the changes). Note also that the time variation of the same vector potential causes an opposite phase gradient and opposite acceleration of positive and negative charges. This shows that the electric charge is an intrinsic dynamical property related with the phase of the respective particle wave function.

Magnetic fields are well-known to be incompatible with superconductivity because their associated vector potential destroys the phase coherence of the Cooper electron pairs, tending to decouple them and to recover the U(1) symmetry of the electrons. In a superconductor, the vector potential **A** gives rise to phase displacements of the order parameter. Such phase perturbations give rise to phase disorder, associated with local persistent currents and elevating the energy of the SCC within the potential well **Fig.1**.

The order parameter of quantum condensates strongly suppresses diffuse and turbulent motions as well as local phase fluctuations of the condensate. At absolute zero temperature, the order parameter almost completely suppresses the fluctuations and zero-point energies. On the other hand, the phase factor of the order parameter plays a fundamental role in the mobility, quantization and the multiplicity of the various local excited states of the condensate. In the conventional superfluids and superconducting condensates such quantized excitations are well-known. They are the very stable quasi-particles (Rotons, Maxons, Kosterlitz-Thouless Vortices and or magnetic Vortices).

Analogously as in the well-known conventional quantum condensates (superfluids and SCC), phase correlation and spontaneous breakdown of the U(1) gauge symmetry of the Higgs bosons too leads to phase coherence and condensation into a macroscopic quantum state. This Higgs condensate (HC) too can be described by a complex macroscopic GL like order parameter: $\Phi = \phi(r)\, e^{i\theta}$. However, while the Bose-Einstein phase correlation between Helium atoms in superfluid ^{4}He and between the Cooper electron pairs in superconductivity is very weak, only (≈ 1 meV) per boson, the correlation between the elementary Higgs bosons is extremely strong. According to the Glashow-Weinberg-Salam electroweak model, [6] the Higgs order parameter opens a huge energy gap of more than 200 GeV (10^{14} times more than the usual superfluids). Therefore, exciting local perturbations in the HQS, costs (comparatively) very large energies, equal to the resting mass-energy of the particles.

The Higgs condensate too very strongly suppresses the phase fluctuations of the Higgs order parameter and the zero point energy of the various force fields. This has very drastic consequences in cosmology, especially in the observed value of the vacuum energy density. The usual estimates of the vacuum energy density, from the perspective of elementary particle physics, find absurdly high values, 120 decimal orders of magnitude larger than shown by the observations. [16,17] Taking into account the drastic suppression by the Higgs order parameter, leads to vacuum energy densities close

to the observed values $\approx 10^{-10}$ ergs/cm^3. The high rigidity of the order parameter and the very low mass density of empty space also is attested by the enormous velocity *c* at which it transmits local perturbations.

Actually, the universe (quantum vacuum) can be conceived as basically a quantum fluid like cosmic background medium, in which the matter universe is the ensemble of all the different persistent and transient excitations. The excitations include the microscopic quantized excitations of the elementary particles as well as the macroscopic excitations of the gravitational fields in the Higgs quantum fluid like background medium. The energy, involved in these persistent excitations, supposedly has been left over by the condensation of the Higgs bosons. The total energy is rigorously conserved in all physical processes. Energy only is transformed. In the usual quantum fluids, transformations of energy are largely suppressed by the order parameter. Therefore, excitations are indefinitely persistent. In the case of the HQS, the order parameter is extremely powerful, which makes the HQS perfectly conservative. The universe is believed to have begun with the Big-Bang in a state of very high energy density. Subsequent accelerating expansion has lowered the energy density by increase of volume. This expansion also has stretched the wave length of the primordial EM radiation and of the de-Broglie matter-waves of the particles, thereby reducing their energy with respect to the local HQS closely to zero and contributing to the accelerated expansion. Actually a large part of the primordial energy has converted it into matter-energy that is visible in the universe. Another large part was dissipated into kinetic energy of global expansion. However, this process is going on.

3. FUNDAMENTALS OF THE HQS DYNAMICS MECHANISM OF GRAVITY.

GR explains the gravitational dynamics in terms of generalized inertial motions along geodesic lines in curved four-dimensional spacetime, as expressed by Eqs.(1) and (2). However, actually several clear experimental observations in the gravitational fields as well as the galactic gravitational dynamics and the global dynamics of the universe cannot be explained within this view. These new observations indicate that Earth, in spite of its orbital and cosmic motions, is very closely stationary with respect to a local physical space (HQS) that rules and governs the inertial motion of matter-energy and is *the local ultimate (local absolute) reference for rest and for motions.* The Higgs theory introduces the idea that space is filled up by a quantum fluid medium to explain the origin of the inertial mass of the vector bosons by the Higgs mechanism. The Glashow-Weinberg-Salam electroweak theory discloses the Yukawa like coupling of the fermions (quarks and leptons) to the HQS via their hypercharges as the mechanism giving them inertial mass.

If the HQS is responsible for mass and the mechanical properties of the elementary particles, it necessarily rules and governs their inertial motions and necessarily is their local ultimate reference for rest and for motions. The HQS materializes the local Lorentz Frames (LFs), turning them into local proper LFs, *intrinsically stationary with respect to the local HQS*. The Higgs theory thus introduces exactly the ingredient that is necessary to understand the origin of the inertial dynamics observed within the gravitational fields. The statement that the orbiting Earth is stationary with respect to the local HQS can make a sense only if the HQS, the local ultimate (local absolute) reference for rest and for motions, *is moving round the Sun consistently with the planetary orbital motions*.

Actually, four well-known experimental observations evidence and define the velocity field of the HQS that is responsible for the gravitational dynamics: **1)** While clocks, stationary in the ordinary space within gravitational fields, show exactly the gravitational slowing, predicted by GR, the atomic clocks of the GPS satellites, moving round Earth and *with Earth round the Sun*, do not show any observable gravitational slowing by the solar field. [18,19] The atomic clocks of the GPS display time with a precision better than 0.5 ns during the *12 hours* period of their orbital motion round Earth. The 24 GPS satellites move along 6 orbits *making 55 degrees with the Earth's equator* and are separated by equal longitudes of 60 degrees. Four satellites are moving in each orbit. The 6 orbits alternate them, two times per year, in the orbit with *orbital plane* nearly aligned with the Earth-Sun axis. The solar gravitational time delay of the clocks in such orbits should be more than *24 ns* during the *6 hours* closer than Earth from the Sun, which would be recovered during the *6 hours* farther than Earth from the Sun. They however do not show any observable gravitational time delay by the solar field. The physicists of the GPS staff explain this absence in terms of Einstein's Principle of Equivalence. [8] They say that the orbiting Earth is free-falling in the solar field, which cancels

locally the effects of the solar field. This explanation however is not consistent with the observed gravitational time delay of these same GPS clocks, orbiting in exactly the same conditions round Earth, by the Earth's field. They show well-defined gravitational delays by the Earth's field. **2)** The light anisotropy experiments on Earth have shown no any light anisotropy effect, despite the evident astronomical and cosmic motion of Earth. [20] **3)** The twin satellites of NASA's GRACE project, moving both round Earth along the same polar orbit at 500 km of altitude and separated from each-other by about 200 km and continuously exchanging EM signals backward and forward between them. The one-way velocity of these electromagnetic signals (light) have shown a clear backward anisotropic velocity of the signals of about 8 km/sec, corresponding to about 17 ns of excess time delay in the forward signal and 17 ns gained in the backward signal. [7] **4)** The arrival of the radio waves, from distant pulsars to Earth based antenna arrays, corrected for their different distances from the pulsars, arrives up to *4.2 microseconds* earlier to the foremost antennas than to the rear antennas along the Earth's orbital motion. They however arrive synchronously to antenna arrays along a direction transverse to the Earth's orbital motion. [18,19]

The first two experimental observations consistently demonstrate that the orbiting Earth is stationary with respect to the spatial medium (HQS) that governs the inertial motion of matter and the propagation of light in the solar field. In the Earth's field, the GPS satellite orbits make *55 degrees* with the Earth's equator. The atomic clocks ported by them clearly are slowed by the Earth's field, showing that they are not stationary with respect to the local HQS in the Earth's field. Moreover, the observed gravitational time delays of the atomic clocks on ground, together with the observed (Mössbauer) spectral red shifts [8,21] demonstrate that the Earth-based laboratories too are not stationary with respect to the local moving HQS. The third observation demonstrates that clocks in polar orbital motions too are not stationary with respect to the local HQS. Their motion gives rise to the observed one-way light anisotropy. Interestingly, the most sensitive Earth-based and genuine Michelson light anisotropy experiments [20] too gave light anisotropy of about 8km/sec, however along nearly West-East directions and none along North-South directions. This observation demonstrates that the Earth-based laboratories are moving with respect to the local HQS along an East-West direction. This very small anisotropy effect however is extremely difficult to detect by the conventional Michelson experiments. Only some of the most sensitive Michelson experiments could barely detect it. [20] Many light anisotropy experiments, used laser cavities. Such experiments with laser cavities are intrinsically unable to detect such small anisotropy effects, because the frequency of the laser light is constrained to the quantized frequency modes in the small laser cavities. The fourth observation demonstrates that the *wave fronts* of (classical) electromagnetic waves from distant pulsars are refracted by the solar field so that they arrive 4.2 microseconds earlier to the foremost antennas on Earth than to the rear antennas. This refraction is not the same thing as the usual aberration of star light that simply is an effect due to the orbital velocity of Earth. The non-synchronous arrival of the pulsar signals shows that, in order to light propagate toward the Sun along a definite radial coordinate, the solar field must refract the wave fronts, developing a velocity component opposite to the Earth's orbital motion. This refraction slants the wave fronts, reducing the effective light velocity along the radial axis $c'(r) = (c^2 - GM/r)^{1/2}$. These four experimental observations can make a sense only if the HQS is moving round the Sun according to a Keplerian velocity field Eq.(10) consistent with the Earth's orbital and cosmic motion and round Earth consistently with the orbital motion of the Moon.

From the conventional view about the nature of empty space (TR), understanding the origin of the above observations in the gravitational fields is well out of reach. The explanation necessarily requires a new conception about the nature of empty space (vacuum) and its role in the gravitational dynamics. The Higgs theory introduces exactly the ingredient that is necessary to understand the true nature of the gravitational physics. The absence of the gravitational slowing of the GPS clocks by the solar field and the absence of light anisotropy with respect to Earth are the signature of the true physical mechanism of gravity.

The present work assumes that, likewise the usual quantum condensates (superfluids and SCC), the HQS, governing the inertial motions of matter-energy, too can move and flow as an inviscid and incompressible quantum fluid. The order parameter Eq.(5) of the HQS contains all the necessary tools for motion. To this take place, just a phase gradient of its order parameter suffices. The above

described observations all together definitely demonstrate that the HQS is moving round the Sun consistently with the Earth's orbital motion, so that the orbiting Earth is stationary with respect to the local moving HQS. However, Earth obviously cannot be in a privileged kinematical situation in detriment to all the other planets and the astronomical bodies in general throughout the universe. All the planets of the solar system must equally be very nearly stationary with respect to the local HQS. Moreover, the zero light anisotropy with respect to Earth suggests that the solar system and all the stars of the Milky-Way galaxy and all the main astronomical bodies throughout the universe must be closely stationary with respect to the local HQS in the respective gravitational fields. The planets can be stationary with respect to the local moving HQS only if this HQS is moving round the Sun according to a *Keplerian velocity field*, consistent with the planetary orbital motions. In terms of the usual spherical coordinates [r, θ, ϕ], the velocity field of the HQS round the Sun that fulfils these requisites and suitably conforms to all the other requisites, has the very simple form:

$$\boldsymbol{v}(r,\theta,\phi) \;=\; (GM/r)^{1/2}\,\mathbf{e}_{\phi} \qquad (10)$$

In this Equation $\mathbf{e}_{\phi}$ is a unit vector along the azimuthal spherical ϕ coordinate. Within the body of a spherical gravitational source of radius R and with uniform mass density, the velocity field of the HQS, increases according to $\boldsymbol{V}(r) = (GM/)^{1/2}\,[(3\text{-}r^2/R^2)/2]^{1/2}\,\mathbf{e}_{\phi}$. The velocity gradient d*V*/d*r* however decreases on from the surface and drops to zero at $r = 0$ (the gravitational acceleration vanishes). Please have a look on **Fig.2**. The HQS too moves round Earth as a Keplerian velocity field Eq.(10), consistently with the Moon's orbital motion.

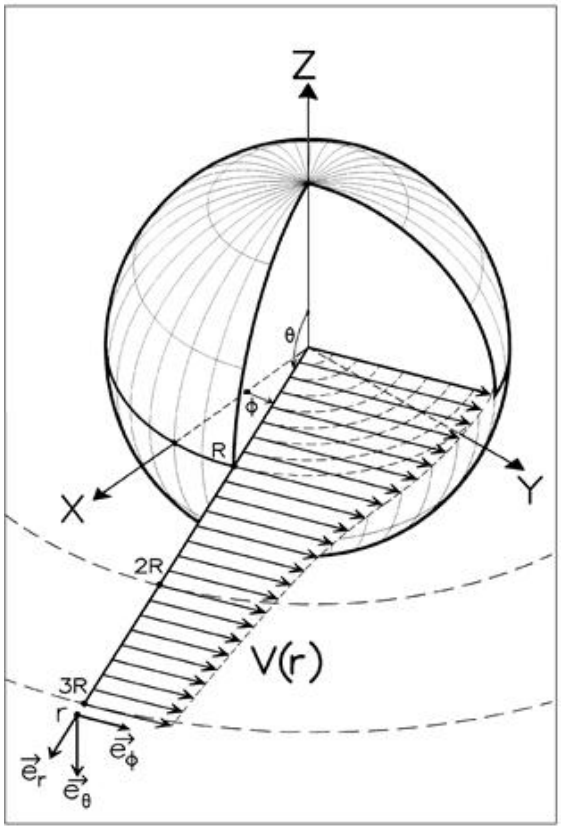

Fig2. *The Figure shows the velocity profile of the HQS, round a spherically symmetric matter body of radius R and homogeneous mass density, along one radial direction as a function of the radial coordinate from r = 0 up to r =3R. For r > R, the velocity is given by Eq.(10) This velocity profile is exactly the same along all radial directions, from the equator to the Poles. The figure too shows the velocity profile within the matter body.*

The velocity field, described by Eq.(10), is a cylindrical velocity field in which the value of the velocity along +ϕ is spherically symmetric. The velocity gradient of this velocity field has only a component along $\mathbf{e}_r$. It is a solenoidal vector field, the divergence of which necessarily is null ($\nabla\bullet V(r) = 0$). This means that the HQS circulates along closed loops as an incompressible fluid in which its local density is conserved. This velocity field hence can be obtained from the vector potential $(2/3)(GMr^3)^{1/2}\,\mathbf{e}_{\theta}$.

The curl of the velocity field Eq.(10) is non-zero. This curl however obviously is not a magnetic field as the HQS ports no electric charges. The HQS however ports weak isospin charge $T_3 = -1/2$ and according to the Gell-Mann-Nishijima formula ($Y = 2(Q - T_3)$, the weak hypercharge of the Higgs bosons is +1. The currents of the HQS thus are electrically neutral currents. Very importantly, the HQS is a quantum fluid ruled by an order parameter $\Phi(r, \theta) = \phi(r)\, e^{i\theta}$. Its velocity field V(r) is governed by the phase gradient of this order parameter according to $\mathbf{V}(r) = (\hbar/m)\nabla\theta$ (Eq.(7)), where $\nabla\theta$ is the phase gradient, the gradient of a scalar function. The curl of such a velocity field necessarily must vanish because $\nabla\times\nabla\theta = 0$. There hence is a trouble! The curl of the Higgs velocity field must be zero, however the curl of the velocity field Eq.(10) is non-zero.

This kind of difficulty is well-known in the circulation fields of quantum fluids and was solved a long time ago by Feynman and Onsager [22], [23]. The flow field of quantum fluids is ruled by an order parameter and their flow velocity is proportional to the phase gradient of this order parameter. If the flow is along closed loops, its divergence is zero and necessarily must satisfy uniqueness solutions. This requirement quantizes the corresponding phase gradient and the associated vector potential. Therefore, in circular flows, the quantized flow can be implemented only if the flow field separates into thin sheets (slices), or in fine flow tubes of quantized currents. According to Feynman and Onsager the phase of the order parameter, in-between the current slices or between the current tubes is undefined and the vorticity can take place only within these singular phase gaps in the form of microscopic or even sub-atomic size quantized vortices, perpendicular to the over-all flow. This leads to an onion like structure, a mixed state (superfluid/normal fluid state), in which the irrotational flow within the quantum fluid slices is intercalated by confined microscopic (sub-atomic size) interstitial vortices. In these conditions, the over-all flow field rotates according to Eq.(10), analogously as a multi-layered roller-bearing.

In type II superconductors under an applied magnetic field an analogous non-homogeneous situation is well-known to occur. It is the mixed normal-superconducting state, in which microscopic quantized current vortices confine the quantized magnetic fluxons that traverse the superconductor. The microscopic rotational flow represents phase disorder of the superconducting order parameter that elevates the energy of the superconducting condensate (SCC) in the potential well Eq.(6) (**Fig.1**). It tends to destabilize the order parameter and to recover the U(1) gauge symmetry. In type II superconductor it however does not immediately destroy the overall superconductivity. It only destroys it along a very fine central core line (Angströms size). Destruction of superconductivity only occurs for very high fields.

A superconductor develops screening currents to cancel the applied magnetic field in its bulk, giving rise to the Meissner effect. The Meissner effect takes place because expulsion of the field lowers the energy of the SCC within the potential well **Fig.1**. For sufficiently weak fields, the expulsion and or cancelation of the field is completed on from the London penetration depth λ. The London penetration depth is finite because the screening currents themselves create a magnetic field that, in principle, is long-range and too needs to be screened by a second layer of screening currents, opposite to the first. The magnetic field, created by this second screening layer, too must be screened by third current layer and so on. For sufficiently low applied magnetic fields, deeply within the SC, there are no magnetic fields, no vector potentials, no phase gradients and no currents.

Superconductors too confine the magnetic field into microscopic quantized magnetic flux tubes. The screening current density $\boldsymbol{J}$ round a quantized magnetic flux tubes falls exponentially with the distance on from the vortex core as ($\boldsymbol{J}(r) = H_{ap}/\lambda \times e^{r/\lambda}$), where H_{ap} is the magnetic field intensity at the core of the quantized magnetic flux tube and λ is the London penetration depth. The London penetration length, which is a characteristic of each SC, scales the exponential decay of the screening current intensity. The *curl* of this current field is non-zero ($\nabla\times\boldsymbol{J} \neq 0$) and yet the flow is inviscid, laminar, quantized and indefinitely persistent. The order parameter of the quantum fluid is responsible for this property.

In the high temperature superconductors, which are not good heat conductors, there can even be created a very curious situation. Quickly cooling down a bulky superconductor, under an applied magnetic field, superconductivity sets on first in a cooler surface layer. The Meissner screening currents, flowing in this surface sheet imprison the magnetic field within the bulk and, on going on

cooling they thrust by Lorentz forces the magnetic field inward and compress it in a central region. The compressed high field intensity weakens or even totally inhibits the onset of superconductivity in a central region and the superconductor assumes the behavior of a permanent magnet. This curious phenomenon is the well-known High field Paramagnetic Meissner Effect. [24] This phenomenon is incredibly similar to the gravitational compression of the mater fields into astronomical bodies.

Another important aspect of the quantum fluids and of the HQS is that the order parameter very strongly suppresses the turbulent and disordered motions. Such motions involve large phase displacements and hence large energies. Vorticity is the natural enemy of the order parameter. However, on the other hand, the order parameter makes the quantum fluids totally inviscid. The flow is inviscid, laminar and perfectly conservative. If the flow of the quantum fluid is along closed loops, it necessarily is quantized.

The HQS in the velocity field (Eq.(10)), created by matter bodies, is electrically neutral. Therefore, the vorticity of the velocity field Eq,(10) is not associated with a magnetic field. This vorticity is of the same nature as that in rotating superfluid Helium. The coupling is via the hypercharges. The screening currents of the hypercharged HQS do not create themselves vorticity on their associated vector potential and so need not to be screened by subsequent opposite current layers like in superconductors. The velocity field Eq.(10) is the quintessence of the gravitational fields that are well-known not to be screened and to be long-range.

The rotational-irrotational mixed state of the HQS in the gravitational fields however is not the whole story. The matter particles move (propagate) in the HQS in the form of wave mechanisms analogously as photons in a superconductor or sound waves in wind gradients. The propagating de-Broglie wave mechanisms of the particles couple to the over-all velocity gradient of the local flow velocity of the HQS. It is not clear if and how much they are affected by the microscopic interstitial vortices between the irrotational slices or loops of the HQS. **Fig. 3** of the next **Section 4** determines the effective refraction rates of the wave fronts of the particle wave mechanisms by an empirical method. Note that the velocity gradient of the velocity field Eq.(10) has only a component along $-\mathbf{e}_r$ and no component in the horizontal plane of the θ and ϕ coordinates.

The rotational flow of fluids usually is illustrated in terms of the rotation of a paddle wheel. Consider a cross like paddle wheel in a *cylindrical* [*r, θ, z*] *irrotational flow field* round the z axis $\mathbf{v}(r) = K/r\ \mathbf{e}_\theta$ (where K is a constant). The opposite torques on respectively the radial pads, (due to the velocity gradient along the radial coordinate) and on the pads aligned along the θ coordinate (due to the rotation round the central axis) are in balance so that the paddle wheel does not rotate at all and $\nabla\times\mathbf{v}(r) = 0$).

Now however imagine that the paddle wheel has broken its legs along θ, remaining only with its radial pads, along *r*. Very interestingly, this broken paddle wheel simulates the behavior of the wave fronts of a particle wave function, propagating along the cylindrical θ coordinate (along the flow field) and with its wave fronts in the [*r, z*] plane. If the pads (wave fronts) are initially along the radial coordinate, the paddle wheel will move with the stream and rotate first oppositely to the cylindrical potential flow (the wave fronts are refracted due to the velocity gradient analogously as sound waves in a wind gradient). However, when its direction has turned sufficiently and the pads point dominantly along the θ coordinate, it will rotate oppositely (in the same sense as the circular flow), due to the flow round the central axis. Eventually the pads will regain back a dominant direction along the radial coordinate and then again rotate in a sense opposite to the flow field. Idealizing this oscillating rotation back and forth, it will continue until completing two oscillation cycles and being back at the initial position with its two pads along the radial direction. In fact the broken paddle wheel never will complete a full 2π rotation of its direction in the ordinary space. It only oscillates back and forth by less than 90 degrees about the initial direction. If the two pads of the broken paddle wheel are aligned along the *z* axis, there will be no rotation at all, because the flow velocity is constant as a function of *z*. **Fig.3**, in the coming **Section 4**, displays such oscillations, however in a Keplerian velocity field.

According to Eq.(10), the velocity of the HQS in the solar Keplerian velocity field is *toward the East* and achieves 436 km/sec on the solar surface. However, due to the slow (differential) rotation rate of the Sun's body *in the ordinary space* round its own axis, the surface velocity *of the solar matter*

toward the same East achieves only about 20 km/sec at the equator and falls to zero toward the Poles according to a sine θ function. Therefore, the effective (implicit) velocity of the solar matter, with respect to the local HQS, achieves 416 km/sec *toward the West* at the solar equator and increases toward the Polar Regions up to 436 km/sec. The velocity of the HQS, in the Earth's Keplerian velocity field, achieves only 7.91 km/sec *toward East* at the Earth surface. Earth too rotates very slowly in the ordinary space toward the same East, which achieves only 465 m/sec at the equator. Hence, the effective West-ward (implicit) velocity of the Earth's matter achieves on surface at the equator about 7.45 km/sec *toward the West* and increases up to 7.91 km/sec at the Polar Regions. Despite the relatively low effective velocity of the Sun's and the Earth's matter, with respect to the local HQS (compared with the velocity of light), the high density of neutral matter represents huge neutral current intensities.

Motion of the HQS according to a Keplerian velocity field will be shown in the next **Section 4** to straightforwardly and accurately create the observed gravitational dynamics on Earth and in the solar system. It also precisely and accurately gives rise to all the observed effects of the gravitational fields on light and on clocks. It moreover can be shown that the non-Keplerian galactic velocity field of the HQS, created by the moving stars in the galactic disk, is consistent with the observed non-Keplerian galactic gravitational dynamics. In this non-Keplerian velocity field, the stars in the galactic disk are very closely stationary with respect to the local moving HQS, analogously as the planets are stationary in the solar field. This possibly leads to the observed galactic gravitational dynamics. [10]

In the light of the experimental observations, described at the beginning of this Section, the only reasonable conclusion is that every planet of the solar system, every solar system in the disk of our galaxy and every galaxy in the universe is locally very nearly stationary with respect to the local moving HQS. This apparently is the essential condition to their formation. The inhabitants of such natural astronomical bodies find that the velocity of light and the rate of their clocks do not evidence significant motion of their planet. They however may find that the velocity of light and the rate of their clocks are very slightly affected by the local weak gravitational field of their own planet. From the present view, these small effects come from the implicit velocity of their laboratories with respect to the local moving HQS in the Keplerian velocity field creating the respective gravitational field. Without this implicit velocity, the integrity of the astronomical bodies simply would be impossible (details in **Section 4**). Such small effects are well-shown by the atomic clocks on Earth and also by the very small nearly West-East anisotropy of light. [8, 20] Moreover, the gravitational and cosmic red-shifts of light from distant sources in the universe are in fact caused by the local gravitational fields at the site of the radiation sources and by the time dependent stretching of their wavelengths along time in their path toward Earth, due to the expansion of the HQS (universe), which is their medium of propagation. The effect of this wavelength stretching or shortening can be shown to be exactly equivalent to the well-known Doppler shifts caused by the respective ordinary relative velocities. This stretching of the wavelength decreases the energy of the EM radiation as well as the phase gradient of the particle wave functions, which decreases their velocity and kinetic energy with respect to the local HQS according to De Broglie's equation ($p=h/\lambda$).

As Earth is almost exactly stationary with respect to the local HQS in the solar field and as the solar system is almost stationary in the galactic velocity field, the only significant velocity of the Earth-based laboratories comes from the local Keplerian velocity of Earth itself that achieves only nearly 8 km/sec on surface. The effects of this low velocity on light and on clocks are extremely small. On Earth, it is in the order of only 10^{-10}. This makes it very difficult to obtain evidence against the assumptions of the TR from earth-based experiments. The results obtained by light anisotropy experiments on Earth *only apparently corroborate the assumptions of the TR.* Visibly, this has misled Einstein to postulate the intrinsic constancy and isotropy of light and to reject any absolute meaning of motions. These assumptions entail the conclusion that any observer can define his own proper reference in which light is intrinsically isotropic and stationary clocks show proper time. These assumptions, besides challenging the common sense, are paradoxical. Actually, several experimental observations, achieved with the help of the tightly synchronized atomic clocks in orbit and described in the beginning of this Section, reveal the fragility of these assumptions. The described experimental observations demonstrate very clearly that the velocity of light is not intrinsically isotropic. The light anisotropy experiments, searching for effects of the Earth's orbital and cosmic motion, gave null

results not because of the intrinsic isotropy of light, however because Earth, despite its orbital and cosmic motion, is locally almost exactly stationary with respect to the local moving HQS. All the astronomical bodies, throughout the universe are nearly stationary with respect to the local HQS in the respective gravitational fields.

The velocity of particles with respect to the local HQS is fundamentally ruled by the phase gradient of their wave functions that is intrinsically associated with a vector potential **A** as described by (Eq.(7)). The magnetic vector potential of moving electrically charged particles is curled $\nabla\times\mathbf{A}=\mathbf{B}$, where **B** is the magnetic field. The magnetic field couples to relatively moving electrically charged particles, creating a transversally non-uniform phase gradient that refracts the wave vector of their wave functions, making them to move along curved paths. The Aharonov-Bohm effect [13] in the two-slit electron interference experiments however shows that a curl-free vector potential $\nabla\times A = 0$ is physically real and causes well observable effects. If the directions of **A** or its values at the two paths of the electron wave-function from the two slits to the screen are different, it causes different phase gradients (no refraction however), accelerating the electron wave function differently along the two paths and thereby displacing the interference pattern on the screen. The presence of a curl-free vector potential ($\nabla\times A = 0$) on a superconductor too couples to the order parameter of the moving electrically charged condensate, causing a phase gradient on the superconducting order parameter and thereby exciting a velocity field (currents) of the SCC along its direction. One could even wonder if a curl-free vector potential, increasing with time, induces by Faraday-Lenz induction an opposite electromotive force, causing a phase gradient on the surrounding SCC and creating a secondary current (velocity field of the SCC).

Ordinary matter, from atoms up to astronomical bodies, can, for all practical instances, be considered as electrically neutral. However, according to the Gell-Mann-Nishijima formula, the electrically neutral matter can port hypercharges. The motion of such neutral matter dominates the macroscopic and cosmic world throughout. From the perspective of the above **Section 2**, all motions that are effective and relevant for physics are those with respect to the local HQS and not relative velocities. Within the Keplerian velocity field, given by Eq.(10) that is the quintessence of the gravitational fields, the relevant velocity of the neutral matter in the slowly rotating astronomical bodies, like the Sun and our Earth, is the implicit velocity $\boldsymbol{v}_{\mathrm{impl}}(r) \approx -(GM/r)^{1/2}\,\mathbf{e}_{\phi}$. These implicit velocities are low, compared with the velocity of light, so that their effects on light, on clocks and on mass are extremely small. However, due to the high matter density, this implicit velocity (velocity with respect to the local HQS) represents a very huge primary neutral current intensity, pointing toward $-\phi$. Apparently this neutral matter current or velocity field along $-\phi$ generates, via a *curl-free* vector potential and coupling of its effective hypercharge to the hypercharged HQS, an opposite neutral velocity field (neutral current) of the HQS along $+\phi$ which is the Keplerian velocity field Eq.(10). This Higgs velocity field is not confined and not dissipated at all.

In the real world, motion of macroscopic neutral fermion matter is ubiquitous. It however is not so completely neutral. The enormous temperature differences between the internal and the external layers that achieve many millions of degrees K in the stellar objects and many thousands of degrees K within the planetary bodies, give rise to large thermoelectric effects. These thermoelectric effects let the internal hotter parts electrically more positive. Besides this are the large effects, due to the enormous pressure differences, the intense convections and differential rotations of the non-exactly neutral matter layers. Therefore, the vector potential, associated with the primary *Westward neutral matter current* generates a weakly curled electromagnetic vector potential field that can change with time, depending on the distribution of the electric charges.

4. The Ingenious Outside-Inside Centrifuge Mechanism of Gravity.

In the view of the present work, gravity is not a fundamental force. There are no real forces acting in the gravitational dynamics of free bodies. Gravity is an inertial dynamics, exactly as conceived by Einstein's Principle of Equivalence. Actually however several clear experimental observations demonstrate that the geodesic motion in the curved spacetime is not the true physical picture. Gravity also is not the result of quantum exchange interaction via virtual gauge bosons, which is known as Quantum Gravity. Gravity is the result of a macroscopic quantum dynamics phenomenon in an astronomical scale, created by the Keplerian velocity field Eq.(10) of the HQS that is the local

absolute reference for rest and for motions of matter-energy. As seen in the previous Sections, the Keplerian velocity field *creates an ingenious and extremely powerful outside-inside centrifuge mechanism*. Only a velocity field of a space (HQS), governing the inertial motion of matter-energy and increasing with decreasing radial coordinate *r*, Eq.(10) can implement this outside-inside centrifuge mechanism. The gravitational dynamics has much similarity with the high field paramagnetic Meissner effect in superconductivity, [24] in which the profile of the screening current intensity increases inward and compresses *the magnetic flux by Lorentz forces in the bulk of the superconductor*. This Section is going to show how exactly the Keplerian velocity field of the HQS compresses the matter fields and creates the observed gravitational dynamics. Please remember that, in the Keplerian velocity field Eq.(10), the planets are stationary with respect to the local moving HQS. They simply are carried round the Sun consistently with the Keplerian velocity field.

As the velocity of the HQS in the Keplerian velocity field Eq.(10) *increases for decreasing r*, the wave fronts of a particle wave mechanism, propagating along $\pm\phi$ are refracted at a local well-defined time rate. For instance, if a particle is *hold fixed* in the ordinary space within the Keplerian velocity field Eq.(10), it will implicitly be moving (propagating) with respect to the local moving HQS along $-\phi$, given by:

$$\boldsymbol{v}_{\text{impl}}(r) = -\text{i}(GM/r)^{1/2}\,\mathbf{e}_{\phi} \tag{11}$$

This velocity is implicit (Imaginary) because it does not take place in the ordinary space. It is orthogonal to all the ordinary space coordinates.

The wave fronts of a particle, moving according to Eq.(11), are in the [r, θ] plane. From the viewpoint of these wave fronts, the local HQS and hence the local inertial reference (IR) is rotating *round an overhead axis*, located a distance *r* above the observation point (laboratory). The idea that such local rotating references are inertial references may seem stupid. However, as the HQS is the local ultimate reference for rest and for motion and is itself so rotating, this is exactly what makes a sense. In fact, motion, without the HQS, would have no intrinsic meaning at all, exactly as assumed in the STR. However, everything says that the HQS in fact is present and is the local ultimate reference for rest and for motions. Hence, the motions get an intrinsic meaning, contrarily than assumed in the STR. Within the Keplerian velocity field, the rotating IRs are only locally valid, so that *to each position in space, there corresponds a different local IR, rotating round a different over-head axis at a different rate*. Such references do not constitute a universal reference in the conventional sense. These local IRs also are not free-falling. *They only are rotating round a fixed overhead axis* at a locally well-defined time rate. Therefore, a particle, stationary in the ordinary space within a gravitational field, remains the whole time in the same local rotating IR. However, in so doing, it will be implicitly moving at a velocity given by Eq.(11), along a circular path within this local rotating true IR, necessarily under an *upward centripetal force* $F_c = mg$, where *m* is the mass of the particle and *g* is the upward *real centripetal acceleration*. As consequence, the particle will exert an opposite *downward centrifugal pull, a fictitious force* of magnitude *mg* on the support holding it fixed. The support normally is the surface of the gravitational source itself.

If such a particle is freed, it will move instantaneously along a *straight line within the local rotating true IR*. However the direction of this straight line rotates together with the local true IR and with it rotates too the (implicit) velocity vector (wave-vector) of the free-particle. The particle will displace it downward, due to rotation of this implicit velocity, to a neighboring IR rotating at a different angular velocity round a different over-head axis and in each such local IR the particle will move according to the law of inertia. The reference, associated with this free-falling particle is locally an inertial reference, however a different one at each position. Contrarily than assumed by some people, with base in the Principle of Equivalence, *the free-falling particle is not a proper IR*. It is not, because it will continue moving with respect to the local HQS according to Eq.(11). The motion will be ruled by the inertial dynamics of each local IR that it will meet along the path.

GR views the motion of elementary particles, in the curved spacetime geometry of the gravitational field as motion of *classical particles*, along specific geodesics, ruled by a generalized principle of inertia. However, according to the present HQS dynamics, *the particle wave mechanisms propagate in the local moving HQS in the Keplerian velocity field* that creates the gravitational field. However, while in GR the gravitational mechanism is geodesic motion in a static curved spacetime, in the

present HQS dynamics, the mechanism is drag and refraction of the particle wave mechanism by differential velocity of the local HQS in the Keplerian velocity field Eq.(10).

The Keplerian velocity field implements an ingenious outside-inside centrifuge mechanism that is responsible for the gravitational pull and for the free-fall, giving rise to the observed gravitational (inertial) dynamics. The implicit rotation rate of the local inertial references is the quintessence of the gravitational fields. No other action of nature can give rise to this inverted outside-inside centrifuge mechanism. The basic ideas of the centrifugal mechanism of gravity can be seen in a preliminary publication. [25]

The implicit velocity (Eq.(11)) of a particle, stationary in the ordinary space, within a gravitational field and thus moving with respect to the local HQS, is physically effective exactly as any motion in free space. It slows down the time rate of evolution of the physical systems (gravitational clock slowing) and causes light anisotropy in the same way as motion of the laboratory with respect to the local stationary HQS (in gravitational free space). Moreover, likewise the time axis, in Einstein's stationary elevator in the fictitious spacetime framework of GR, has an implicit upward space-like velocity component $(2GM/r)^{1/2}$ along the radial coordinate, the implicit velocity Eq.(11) too can be seen as a space-like component of the time axis. However, *its direction is along* $-\mathbf{e}_\phi$ *and not along the radial coordinate* $\mathbf{e}_r$. In this new scenario, the spacetime curvature would involve the time axis t and the ordinary ϕ component.

In the scenario of the HQS dynamics, the local inertial references are not free-falling. They are only rotating round a fixed over-head axis. Therefore, a body moving along $+\phi$ in a *direct circular equatorial orbit* (likewise Earth in the solar field), cancels locally the implicit velocity and thereby cancels the space like component (Eq.(11)) of the time axis. The reference of the so orbiting body thereby gets the status of a true proper Lorentz frame (LF) (stationary with respect to the local moving HQS). In particular this orbital motion cancels locally *all the effects of the gravitational field, including the gravitational time dilation*. The light velocity, in such an orbiting reference, is isotropic and clocks, stationary in it, show proper time. Neglecting the very small effects of the local Earth's field, this is exactly what is observed on Earth. However, this same situation visibly extends to all the astronomical bodies, throughout the universe. They visibly all are moving along nearly direct circular equatorial orbits in the respective gravitational fields and so are nearly stationary with respect to the local HQS. Light on all such bodies is closely isotropic and clocks in all such worlds show very closely proper time. This will say that there is no special place in the universe. All places are very nearly equivalent. This entails the close universality of the laws of physics in all the natural astronomical systems throughout the universe. No need of the Principle of Relativity.

In the Keplerian velocity field Eq.(10), the gravitational time dilation of stationary clocks is not an apparent effect, caused by hypothetical (static) curved spacetime. It is a real slowing of the time evolution of the physical systems (clock rate), caused by their implicit velocity with respect to the local moving HQS in the respective Keplerian velocity fields. Likewise the effects, due to the relative velocity in the STR, the physical effects of velocity with respect to the local (moving) HQS, are independent (orthogonal) from those of the local confined internal dynamics of the particles *resting with respect to the local HQS, that is, with respect to the local proper Lorentz frame*. In free space, the time rate of evolution in a moving reference is described by $t' = t/(1-\boldsymbol{v}_H^2/c^2)^n$, where $\boldsymbol{v}_H$ is the velocity of the reference with respect to the local (stationary) HQS. For longitudinal oscillations of the clock's time standard (along $\boldsymbol{v}_H$), the exponent is n=1 and, for transverse oscillations, it is n=1/2. However, in a reference, stationary with respect to the ordinary space, within the Keplerian velocity field Eq.(10), the time evolution is slowed by the implicit velocity Eq.(11) (the velocity with respect to the local moving HQS) according to $t' = t/(c^2-GM/r)^n$, where again n=1 for longitudinal oscillations of the clock's time standard (along ϕ), and, for transverse oscillations it is n=1/2. To first order, the gravitational time dilation, for longitudinal oscillations of the time standard of the clock, is identical to that predicted by GR ($\Delta t = t(GM/r)/c^2$). However, for transverse oscillations of the clock's time standard, the rate is $\Delta t=(1/2)t(GM/r)/c^2$. On the other hand, the effective velocity of light along the radial coordinate, in the Keplerian velocity field Eq.(10), is $(c^2-GM/r)^{1/2}$, in which $(GM/r)^{1/2}$ is the necessary implicit velocity component of light along $-\phi$ (orthogonal to $\boldsymbol{r}$). Besides the effects of motion of the matter waves with respect to the local HQS, in the Keplerian velocity field Eq.(10),

there are the effects of refractions and stretching/contraction of the wavelengths. The effects of these local geometrical deformations of the HQS, causing wavelength stretching-contractions and thereby affecting the frequency of light and the velocity of the particles v_H with respect to the local HQS according to $mv_H = \hbar/\lambda$. These later effects will be discussed in more detail in the next **Section 5**. Note that all the effects of motion on light and on clocks, in free space as well as within gravitational fields, have the same origin. The cause essentially is the velocity with respect to the local HQS.

From the perspective of the present HQS dynamics scenario, the invariant length ds of displacements along the geodesic line in GR (Eq.(2)) is exactly the distance traveled by *the fixed (one-way) velocity of light c with respect to the local HQS*. This distance is invariant under whatever conditions. It is the characteristic (maximum) velocity at which the very rigid HQS propagates perturbations of its order parameter (Eq.(5)) in empty space. In the language of GR, one could say that the Keplerian velocity field of the HQS simulates a spacetime metric that is equivalent to that of GR. The HQS dynamics predicts the observed effects that, in the TR, are an outcome from postulates. It however accurately predicts observed effects that the TR cannot explain. The absence of the gravitational slowing of the GPS clocks by the solar field and the absence of light anisotropy with respect to the orbiting Earth are examples of such predictions. The HQS dynamics solves all the recurring problems with the light velocity and clock rates within gravitational fields (please see the final **Section 6**. However, it moreover can provide a sound physical explanation to the non-Keplerian rotation of the galaxies without the need of dark matter [10] and also appoints the physical mechanism of the accelerated expansion of the universe. [11]

The wave fronts of a particle, stationary in the ordinary space within the Keplerian velocity field, are in the $[r,\theta]$ plane and propagating with respect to the local moving HQS along $-\phi$ at a velocity given by Eq.(11). Note that the velocity gradient of the Keplerian velocity field Eq.(10) has no horizontal components. It has only a component along $-r$. In the view of the wave fronts of this particle, the local HQS is rotating at a local well-defined angular velocity (Imaginary angle) *round an overhead axis, pointing along* $+\theta$ at any place, from the equator to the Poles. This rotation rate depends on the radial distance r from the gravitational center, however not on the θ and ϕ coordinates. Please remember about the broken paddle wheel, discussed in the previous **Section 3**, however now in the Keplerian velocity field Eq.(10) and in spherical coordinates [r,θ,ϕ]. Moreover, in the Keplerian velocity field the paddle wheel needs not to be floating with the local HQS, but normally is moving with respect to the local HQS. This introduces additional effects that are difficult to deal with and will be solved empirically in the coming pages. The rotation rate $iW(r)\mathbf{e_\theta}$ of the (Imaginary) ϕ velocity component Eq.(11) takes place in the form of an infinite sequence of infinitesimal rotations of specifically the instantaneous ϕ velocity component by Imaginary angles round parallel axes (commutation rules satisfied). This rotation is hyperbolic like and generates an increasing Real velocity component along $-\mathbf{e_r}$.

In the case of a particle, having only a velocity component along the r coordinate, the wave fronts of the particle wave function will be in the [θ, ϕ] plane. The corresponding wave vector rotates in the same sense as the circulation field of the HQS round the gravitational center (rotation vector pointing along $-\mathbf{e_\theta}$). This rotation rate can also be seen as a consequence of conservation of angular momentum *round the overhead axis*. By free-falling, the particle in fact approximates it to the overhead rotation axis because this axis displaces it two times faster than the free-falling particle. The rotation rate of the r velocity component, pointing along $-\theta$, $(-iW_r(r)\ \mathbf{e_\theta})$ too is Imaginary because it too acts only specifically on the instantaneous r velocity component (infinitesimal rotation angles are Imaginary). It accelerates the particle velocity along the $-\phi$ coordinate. The opposite refraction rates of the Imaginary ϕ velocity component and of the Real r velocity component of the particle's velocity vector characterize a hyperbolic rotation, analogously as in the Lorentz transformations and also resembles that of sound waves in whirl-wind.

A particle, having velocity along θ (North-South), necessarily too has a velocity component along ϕ (legs of the paddle wheel along θ). The wave fronts in the [r, θ] plane will not rotate round a vertical axis, because *the gradient of the velocity field Eq.(10) has no horizontal components*. However, when the particles (paddle wheel) traverses the Pole, its wave fronts necessarily acquire a component along the $[r,\phi]$ plane and its implicit velocity will undergo a sudden ±180 degrees turn (the sense depending

on the side it passes by the Pole. This rotation is related with the changing direction of the rotation axes, along $-\theta$ of the local inertial references round vertical (radial) axes. Beyond the Pole, it will continue in the same orbit without rotating round a radial axis. If the orbit is not exactly polar, this turn will be more gradual, however accompanied by very important effects of wave lengths stretching (along direct paths) and or compression (along retrograde paths) that affect the velocity according to $mv_H = \hbar/\lambda$. The effects of these wavelength stretching and compression are exactly equivalent to Doppler shifts. The next **Section 5** makes a more profound analysis of this problem, showing that the effects of the Keplerian velocity field and of the ordinary motions are independent and their effects are orthogonal to each other.

The effects of the wavelength stretching and or shortening along specifically the r, ϕ and θ coordinates are absent. Therefore, describing the effects of the Keplerian velocity field in terms of the effective (hyperbolic) rotation rates of the r, ϕ and θ velocity components automatically includes the effects on the wavelength variations. In this case it however is necessary to find the effective rotation rates of these velocity components.

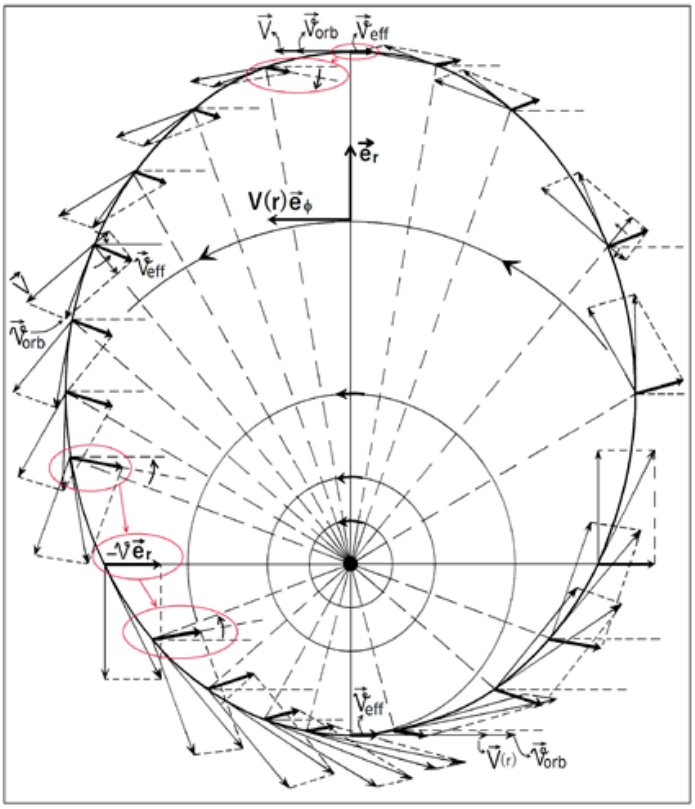

Fig3. *The figure is a very precise graphical representation. The velocity diagrams show* $\mathbf{v}_{eff}$ *(bulky arrows), together with* $\mathbf{v}_{orb}$ *and* $\boldsymbol{V}(r)$ *at a large number of points along the elliptic orbit (*$\varepsilon = 0.5$*).*

As the orbiting planets of the solar system are almost stationary with respect to the local moving HQS (local proper LFs) in the Keplerian velocity field of the Sun, their velocity with respect to the local HQS and hence the effects (the so-called relativistic effects) are very small. Note that the effect of rotating the direction of a very small or zero velocity is zero or only a small perturbation. Direct circular equatorial orbital motion of a local reference (planets) cancels not only the local gravitational (centrifugal) acceleration. It cancels locally *all the effects of the gravitational field, including the gravitational time dilation*. The solar Keplerian velocity field simply carries the planets along the *direct nearly circular equatorial orbits*. There is no need of a central force field for the planets to move along these orbits. In fact *it is the HQS that is so moving*. Physically, the velocities of the planets with respect to the local HQS are irrelevant (the planets are very closely proper LFs). This makes the observed gravitational dynamics in the solar system totally obvious. It is an intrinsic result of the Keplerian velocity field. The planets move all along orbits that are located closely within the equatorial plane of the solar Keplerian velocity field. This minimizes their velocity, momentum and kinetic energy with respect to the local HQS. This also makes their orbits exceptionally stable. The

velocity of light is closely isotropic with respect to Earth, *not because of the intrinsic isotropy of light, however because Earth is almost exactly stationary with respect to the local moving HQS*, the medium propagating light. The velocity of Earth with respect to the local HQS is of only a few hundreds of m/sec, far too small to its effects to be detected even by the actual most sensitive instruments.

In order to obtain quantitative values for the effective refraction rates of the r, ϕ and θ velocity components of the particle wave mechanisms (rotation rates of the broken paddle wheel), the orbital velocity $\boldsymbol{v}_{orb}$ of a particle with a very small mass m in the gravitational field of a very large and spherically symmetric mass M, along an elliptic (equatorial) orbit ε = 0.5) was computed to high precision. The values of $\boldsymbol{v}_{orb}$ together with the Keplerian velocity $\boldsymbol{V}$(r), given by Eq.(10) and the effective velocity $\boldsymbol{v}_{eff}$ was determined by the vector equation:

$$\boldsymbol{v}_{eff} = \boldsymbol{V}(r) + v_{orb} \tag{12}$$

The velocity diagrams, specifying $\boldsymbol{v}_{orb}$, $\boldsymbol{V}$(r) and $\boldsymbol{v}_{eff}$ are plotted to scale at a large number of points along the elliptic orbit in **Fig.3**. They allow reading the variations in direction and in size of $\boldsymbol{v}_{eff}$ (bulky arrows) with enough precision. Please see carefully the encircled velocity diagrams on top and on the left of the Figure. The obtained refraction rates (rotation rates) of the $-r$, $-\phi$ and the $\pm\theta$ as a function of the coordinate r are:

$$\boldsymbol{W}_r(r) = -(1/2)(GM/r^3)^{1/2}\,\mathbf{e}_\theta \tag{13a}$$

$$\boldsymbol{W}_\phi(r) = +(GM/r^3)^{1/2}\,\mathbf{e}_\theta \tag{13b}$$

$$\boldsymbol{W}_\theta(\mathbf{r}) = 0 \tag{13c}$$

Please note the opposite signs in the rotation rates of the r and the ϕ velocity components.

The implicit (Imaginary) velocity along $-\phi$ of the small particle of mass m stationary in the gravitational field, of a very much larger mass M is given by Eq.(11) above. For simplicity, the calculations on from here do not explicitly express the Complex nature of the factors, in favor of the more transparent usual vector calculus, without loss of information. The refraction rate of this implicit velocity, according to Eq.(13b), generates an instantaneous ordinary vertical (Real) downward acceleration given by:

$$\boldsymbol{g}(r) = \boldsymbol{W}_\phi(r)\,\mathbf{e}_\theta \times \boldsymbol{v}_{impl}(r)\,(-\mathbf{e}_\phi) = -GM/r^2\,\mathbf{e}_r \tag{14}$$

Eq.(14) has exactly the form of a formal expression for centrifugal accelerations in a rotating reference and $\boldsymbol{g}$(r) has clearly the nature of a centrifugal acceleration. It represents a spherically symmetric field of *centrifugal accelerations* toward the gravitational center.

However, Eq.(14) is sufficiently precise only for free-fall on from rest along short distances, for which the velocity along r is negligible. For free-fall along large distances of a small mass m in the field of a very large mass M, the following elementary linear differential equation must be solved:

$$d\boldsymbol{v}/dt = \mathbf{A}\boldsymbol{v}_0 \tag{15}$$

where $\boldsymbol{v}$, is the column matrix of the ordinary (Real) r and the implicit (Imaginary) ϕ velocity components of the effective velocity with respect to the local HQS:

$$\boldsymbol{v}(t) = \begin{pmatrix} \boldsymbol{v}_r(t) \\ \boldsymbol{v}_\phi(t) \end{pmatrix} \tag{16}$$

In Eq.(15), $\mathbf{A}$ is the hyperbolic rotation matrix, defined in terms of the Imaginary rotation rates, given in Eqs.(13):

$$\mathbf{A}(t) = \begin{pmatrix} 0 & W_\phi(t) \\ -W_r(t) & 0 \end{pmatrix} = \begin{pmatrix} 0 & W(t) \\ \frac{W(t)}{u} & 0 \end{pmatrix} \tag{17}$$

where W = (GM/r^3) and u = 2M/(M+m) accounts for the asymmetric distribution of velocity and kinetic energies between the interacting masses m and M, without the restriction of m << M.

Dividing both sides of Eq.(15) by v_0 and multiplying by dt and integrating the left hand side from v_0 to v develops into:

$$\log\frac{\nu(t)}{\nu_0} = \int_0^t A(r(t'))dt' \tag{18}$$

where **A**dt is an infinitesimal rotation round parallel axes. This Equation can be re-written in the exponential form as:

$$\nu(t) = \nu_0 \mathrm{Exp}\left[\int_0^t A(r(t'))dt'\right] \tag{19}$$

Expanding the exponential in series and adding up the terms of the series from n = 0 to n = infinite results in:

$$v(t) = \sum_{n=0}^{\infty} \frac{1}{n!}\begin{pmatrix} 0 & \Theta(t) \\ \frac{\Theta(t)}{u} & 0 \end{pmatrix}^n \times \begin{pmatrix} v_r(0) \\ v_\phi(0) \end{pmatrix} = \begin{pmatrix} \cosh\left(\frac{\Theta(t)}{\sqrt{u}}\right) & \sqrt{u}\sinh\left(\frac{\Theta(t)}{\sqrt{u}}\right) \\ \frac{1}{\sqrt{u}}\sinh\left(\frac{\Theta(t)}{\sqrt{u}}\right) & \cosh\left(\frac{\Theta(t)}{\sqrt{u}}\right) \end{pmatrix} \times \begin{pmatrix} v_r(0) \\ v_\phi(0) \end{pmatrix} \tag{20}$$

The value of Θ(t) can be computed by integration:

$$\Theta[r(t)] = \int_o^t W[r(t')]dt' = \int_{r_o^{CM}}^{r^{CM}} \left[\frac{GM}{(r^{CM}+R^{CM})^3}\right]^{1/2} \frac{dr^{CM}}{\dot{r}^{CM}} = -\sqrt{u}\cosh^{-1}\left[\frac{r_o^{CM}}{r^{CM}}\right]^{1/2} \tag{21}$$

Inversion of the final term of Eq.(21) results in expressions for the hyperbolic cosines and sines:

$$\cosh\frac{\Theta(t)}{\sqrt{u}} = [r_o^{CM}/r^{CM}]^{1/2} = [r_o/r]^{1/2} \tag{22a}$$

$$\sinh\frac{\Theta(t)}{\sqrt{u}} = [(r_o - r)/r]^{1/2} \tag{22b}$$

where the last equality is obvious. Using this result, Eq.(20) becomes:

$$\begin{pmatrix} v_r(t) \\ v_\phi(t) \end{pmatrix} = \begin{pmatrix} \sqrt{r_o/r} & \sqrt{(u(r_0 - r)/r} \\ \sqrt{(r_o - r)/ur} & \sqrt{r_0/r} \end{pmatrix} \times \begin{pmatrix} v_r(0) \\ v_\phi(0) \end{pmatrix} \tag{23}$$

For free fall of m in the field of M ($m << M$), on from r_o and initial rest, where $\boldsymbol{v}_r(t=0)=0$, $v_\phi(0) = \boldsymbol{v}_{impl}(r_0) = -(GM/r_0)^{1/2}\,\mathbf{e}_\phi$ and $u = 2M/(M+m) \approx 2$, the final solution of Eq.(15) is:

$$v_r(t) = v_\phi(0)\sqrt{u}\sinh\frac{\Theta(t)}{\sqrt{u}} = -\left[\frac{2GM^2}{M+m}\left(\frac{1}{r(t)} - \frac{1}{r_o}\right)\right]^{1/2} e_r \tag{24a}$$

$$v_\phi(t) = v_\phi(0)\cosh\frac{\Theta(t)}{\sqrt{u}} = V_{impl}(r_o)\left[\frac{r_o}{r}\right]^{1/2} = -\left[\frac{GM}{r(t)}\right]^{1/2} e_r \tag{24b}$$

Eq. (24a) is just the well known expression for the observed free-fall velocity on from rest at r_o. It directly shows that the kinetic energy is equal to the difference between the final and the initial potential energies. Eq.(24b) is just the implicit (Imaginary) velocity as a function of the radial coordinate r. This shows that the refraction rate of the radial velocity component just compensates for the increase of the Keplerian velocity field with the decrease of the radial coordinate. This assures that free-fall, on from rest, goes along a well-defined vertical (radial) path and hence assures conservation of the angular momentum about the gravitational center. Please observe that, for free-fall on from infinity (r_0 infinite), the vertical velocity $\boldsymbol{v}_r(r(t))$ is just square root 2 times larger than the circular orbital velocity, which accomplishes the Virial theorem.

Now re-introducing the Complex notation, it is possible to analyze the relation between the various forms of energy and momenta. In terms of the Imaginary velocity (Eq.(24)) *along* $-\phi$ that is a function of $\cosh(\Theta(t)/u^{1/2})$ [please see Eq.(20)], the corresponding kinetic energy K(r) of *m*, for vertical free-fall on from initial rest at r_0 is $(1/2)m[i(GM/r_0)^{1/2}\cosh(\Theta(t)/u^{1/2})]^2$, where the Imaginary character has been explicitly considered. Using the result of Eq.(24b) this kinetic energy is:

$$K_m(r) = -(1/2)m\ cosh^2[\Theta/u^{1/2}]\ v^2_\phi(0) = -\ (1/2)\ m\ (GM)/r. \quad (25)$$

It is obvious that this negative quantity cannot be a usual kinetic energy. It is an implicit kinetic energy that must be interpreted as a potential energy associated with the free-falling particle. However, potential energy necessarily involves at least two matter bodies. The mass *M* of the gravitational source too is free-falling in the field of *m* toward the Center of Mass. The corresponding implicit kinetic energy is:

$$K(r) = -\ (1/2)MGm/r \quad (26)$$

Adding up equations (25) and (26), gives the total implicit kinetic energy, which in fact is the usual negative potential energy U(r) of the system:

$$U(r) = -\ GMm/r \quad (27)$$

The corresponding Real kinetic energy of a free-falling body *m*, on from initial rest at r_0, in the gravitational field of *M* (*m* << *M*) and for which $u \approx 2$, can be expressed in terms of the square of the $\sinh(\Theta(t)/u^{1/2})$ function (please see Eq.(20)) as

$$K(r) = (1/2)\ m\ 2(GM/r_0)\ sinh^2[\Theta(t)/2^{1/2}] = m[GM/r - GM/r_0] = m\Delta U \quad (28)$$

where Eq.(24a) has been considered. This result shows directly that the kinetic energy is exactly the difference in the potential energies.

Conservation of the total mechanical energy *E* in vertical free-fall can be expressed in terms of the squares of the *cosh* and *sinh* terms as:

$$E(t) = E_0\ [cosh^2(\Theta(t)/2^{1/2}) - sinh^2(\Theta(t)/2^{1/2})] = E_0 = \text{Constant} \quad (29)$$

where E_0 is the initial total energy. The $cosh^2$ term is the potential energy and the $sinh^2$ term is the usual free-fall kinetic energy. This Equation explicitly conveys the orthogonality of the implicit and the ordinary dynamics. It shows that the total resting mass-energy is conserved in the gravitational agglomeration of matter into the astronomical bodies as long as no energy is exchanged with the external environment.

Likewise the total energy of a mass *m*, if $v_0(t = 0)$ is the initial velocity of a free-falling mass *m* in the gravitational field of a mass *M*, this effective velocity too is an invariant under the hyperbolic rotation Eqs.(13):

$$\boldsymbol{v} = v(r(t_0))[\cosh^2(Q(t)/u^{1/2}) - \sinh^2(Q(t)/u^{1/2})]^{1/2} = v(r(t_0)) = \text{Constant} \quad (30)$$

Eqs.(29) and (30) essentially confirm that the gravitational dynamics is an inertial dynamics, in which no real forces are involved.

5. Spherical Symmetry of the HQS Gravitational Mechanism with Orbital Motions.

Consider free-fall experiments on a planet like Earth, rotating at an angular velocity ω round the same axis as its Keplerian velocity field of the HQS that visibly is a common situation. The effective velocity $\boldsymbol{v}_{\text{eff}}$ of a particle, near to the surface of a planet will be given by:

$$\boldsymbol{v}_{\text{eff}}(\theta) = -[(GM/r)^{1/2} \mp\ \omega R\ sin\ \theta]\ \mathbf{e}_\phi \quad (31)$$

where $-(GM/R)^{1/2}$ is the implicit velocity at the planet's surface and $\omega R \sin\theta$ is the ordinary velocity, due to the planet's rotation that depends on the latitude θ. The upper and lower signs are respectively for direct and or retrograde rotation of the planet with respect to that of the local HQS.

However, rotation of the planet, gives rise to a trigonometric rotation rate of the particle's effective velocity $\boldsymbol{v}_{\text{eff}}$ that adds up to the refraction rate, given by Eqs.(13b) for rotation in the same sense as the

Keplerian velocity field of the HQS and subtracts for opposite rotation. The effective rotation rate $\boldsymbol{\omega}_{\text{eff}}$ of the $\boldsymbol{v}_{\text{eff}}$ is:

$$\boldsymbol{\omega}_{\text{eff}}(\theta) = [(GM/R^3)^{1/2} \pm \omega \sin\theta]\, \mathbf{e}_\theta \tag{32}$$

where the same convention for the upper and the lower signs as in Eq.(31) is used.

Considering the effective velocity (Eq.(31) and the effective rotation rate (Eq.(32), the effective gravitational acceleration on the planet's surface is:

$$\boldsymbol{g}_{\text{eff}}(\theta) = \boldsymbol{\omega}_{\text{eff}} \times \boldsymbol{v}_{\text{eff}} = -[GM/R^2 - \omega^2 R \sin^2\theta]\, \mathbf{e}_r \tag{33}$$

The first term in the right hand side describes the gravitational acceleration toward the gravitational center of the planet in the static situation (see Eq.(14)), while the second term is an outward centrifugal term. Eq.(33) shows that the effective gravitational acceleration $g_{\text{eff}}(\theta)$ on the rotating planet's surface *is perfectly symmetric for direct or retrograde rotation of the planet and thus also for direct or retrograde orbital motion of a particle.*

For strictly circular polar orbits with radius r > R, $\boldsymbol{v}_{\text{eff}}$ has velocity components along $-\phi$ as well as along $\pm\theta$. The velocity along $-\phi$ is:

$$\boldsymbol{v}_\phi = v_{\text{impl}}(r) = -[GM/r]^{1/2}\, \mathbf{e}_\phi \tag{34}$$

Along θ the velocity is:

$$\boldsymbol{v}_\theta = \pm [GM/r]^{1/2}\, \mathbf{e}_\theta \tag{35}$$

While $\boldsymbol{v}_\phi$ generates the gravitational acceleration: $\boldsymbol{g}(r) = -GM/r^2\, \mathbf{e}_r$, (please see Eq.(14)), the θ velocity component is not affected directly by the HQS-dynamics (please see Eqs.(13c). However, the rotation rate of the ϕ velocity component plays the role of a centripetal acceleration toward the gravitational center that bents the velocity of the orbiting body $\boldsymbol{v}_\theta$ toward the planet's surface. The effective gravitational acceleration for polar orbits is:

$$\boldsymbol{g}_{\text{eff}}(r) = -GM/r^2 - \boldsymbol{v}_\theta^2/r]\, \mathbf{e}_r \tag{36}$$

where again the first term in the right hand side is the centrifugal acceleration toward the gravitational center (please see Eq.(14)), while the second term is the outward centrifugal effect, due to the circular orthogonal motion along the θ coordinate.

Together the results, expressed by Eqs.(33) and (36), show that the effects of the HQS dynamics and of the effects of the ordinary motions are independent and orthogonal. While the Keplerian velocity field of the HQS Eq. (10) simulates a spherically symmetric central field of fictitious Newtonian gravitational forces, the ordinary orbital motions generate the spherically symmetric outward centrifugal effects, almost exactly as conceived in Newtonian gravity. This shows why treating the motions in a spherically symmetric gravitational field as motions in a hypothetical extended inertial reference under a hypothetical central field of *fictitious gravitational forces* leads so closely to the observed gravitational dynamics. The present work shows that these gravitational forces are in fact centrifugal (fictitious) forces pointing toward the gravitational center. Altogether these facts explain why the Newtonian gravitational theory, based in the fictitious gravitational forces, works so well.

6. Effects of the Keplerian Velocity Field of the HQS on Light and on Clocks.

This Section compares the theoretical predictions of this work and the experimental observations.

6.1. The One-Way Light Anisotropy Measurements.

The most precise measurements of the one-way light velocity and anisotropy were achieved with the help of atomic clocks in the robotic twin satellites of NASA'S GRACE project, moving in the same polar orbit. These clocks need to be synchronized better than 0.16 ns (time for light to travel ≈ 4 cm) and EM signals, are continuously exchanged backward and forward between these satellites. The velocity field Eq.(10) has no component along North-South directions. Therefore, the North-South velocity of these satellites predicts anisotropy of nearly 8 km/sec. The measurements have revealed anisotropy backward to the orbital motion of exactly this value. [7] This observation provides experimental evidence that a spatial medium (HQS) exists, propagating the EM signals at a well defined fixed velocity *c*. This observation unquestionably breaks the light postulate of the TR.

6.2. The Michelson Light Anisotropy Experiments.

The Michelson experiments, searching for light anisotropy due to the orbital and cosmic motion of earth, gave null results. This evidences that Earth is almost exactly stationary with respect to the local HQS. Not only this. These null results show too that the solar system is stationary in the HQS velocity field of the Milky-Way galaxy and that, despite the accelerated expansion of the universe, our Milky-Way is stationary with respect to the local HQS. In the view of the present work, the only motion, that causes relevant anisotropy of light with respect to the Earth-based laboratories, is the local Keplerian velocity field round Earth itself in the sense of the Moon's orbital motion and achieving 7.91 km/sec on surface. However, the anisotropy effect of this velocity is extremely small, only in the order of 10^{-10}, constant the whole day and the whole year and thus extremely difficult to detect. Some Michelson experiments with the highest sensitivity and *rotating within the earth-based laboratories* found nearly West East anisotropies of nearly 8km/sec constant the whole day and the whole year (exactly as predicted). [20]

6.3. Gravitational Time Dilation and Gravitational Spectral Red Shifts.

The gravitational time dilation was precisely measured by the atomic clocks on Earth and in orbit round Earth [8] and the spectral red shifts were measured on Earth by the Mössbauer effect. [21,26] These effects are extremely small, given by $(GM/r)/c^2 \approx 10^{-10}$ to first order. The results of these measurements are in accord with the predictions of the present HQS dynamics and also agree with the predictions of GR. The problem is that the GPS clocks, moving with Earth round the Sun, do not show any gravitational slowing by the solar field. While this observation is accurately predicted by HQS dynamics, it cannot be explained by GR.

6.4. The Excess Time Delay of Radar Signals in Round-Trips Within the Solar System.

According to GR, spacetime curvature lengthens the light path and thereby the travel time of light passing by heavy gravitational sources like the Sun. However, according to the present work, the excess time delay is not due to increase of the geometrical distance. It is due to the effective light velocity within the solar Keplerian velocity field. In the case of round-trips between Earth and Venus, the component of the solar velocity field along the light path increases the effective velocity of light for prograde travels $\boldsymbol{c} + (GM/r)^{1/2}\mathbf{e}_\phi$ and decreases it $\boldsymbol{c} - (GM/r)^{1/2}\mathbf{e}_\phi$ for retrograde travels. The problem is totally analogous to that of light round-trips between two mirrors in a laboratory, moving with respect to the local HQS. Within the solar Keplerian velocity field, the calculation is a little bit more complicated, because the value and direction of the effective velocity depends on the position.

In the present work, the excess (or deficit) time delay was numerically calculated along straight line paths for minimum distances from the Sun R = 2, 4, 8, 25, 50 and 100 million kms (fist column in Table I). The calculation was made separately for travels from Earth to Venus and for travels back from Venus to Earth, in terms of the effective light velocity $\boldsymbol{c}' = \boldsymbol{c} \pm \boldsymbol{V}$, where $\boldsymbol{V}$ is given by Eq.(10) (please see column 2 and 3 in **Table I**. The calculations were made dividing the straight line paths into about 420 segments, shorter segments near to the Sun. The different Earth-Venus distances, due to the orbital positions as well as the slightly different signal path, due to the motion of Earth during each signal round-trip, was taken into account. The obtained results are given in **Table I**. The effective time-delay for full go-return travels is listed in column 4 of **Table I** and plotted in **Fig,4**. The results practically coincide with the excess time delays measured by Shapiro. [27]

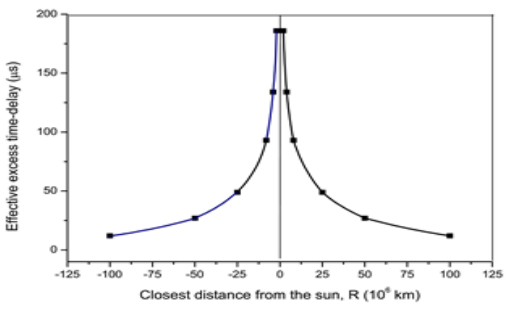

Fig4.*The calculated effective excess time delay, in microseconds (μs), (fourth column in **Table I**. The calculated data curves almost coincide with those, obtained by Shapiro [27]*

Table Caption. The first column lists the values of R in millions kilometer units, the second and third columns give respectively the gain of time (negative) for prograde travels and the loss of time (positive) for retrograde travels in milliseconds (ms) before and after superior conjunction. The forth column gives the effective excess time-delays for full go-return round-trips in microseconds μs).

R (10^6 km)	go: Δt (*ms*)	return: Δt (*ms*)	Δt_{eff} (μs)
100	-51.987	51.999	12
50	-76.697	76.725	28
25	-70.007	70.056	49
8	-48.585	48.679	94
4	-36.699	36.833	134
2	-27.165	27.351	186
0	0.035	0.035	70
-2	27.351	-27.165	186
-4	36.833	-36.699	134
-8	48.679	-48.585	94
-25	70.056	-70.007	49
- 50	76.725	-76.697	28
-100	51.999	-51.987	12

6.5. The Gravitational Light Lensing Effect.

Consider two light beams, coming from two distant stars and propagating past by opposite sides of the Sun. First, when the path has almost only radial components, the wave vectors are refracted according to Eq.(13a) by a total angle $+\alpha$, so that $\boldsymbol{c}$ gets a velocity component $\boldsymbol{v}(r) = (GM/r)^{1/2}$ along $-\phi$. On passing by the Sun, the wave-vectors of the beams with direction nearly along ϕ are refracted oppositely by Eq.(13b). However, while near to the Sun, the solar velocity field is unfavorable to the retrograde beam and so it lasts a little bit more time near to the Sun and refracts a longer time and by a bit larger angle $2\alpha+\delta$. To the prograde beam (passing by the opposite side) the solar velocity field is favorable and it lasts a bit less time near to the Sun and refracts by a bit smaller angle $2\alpha-\delta$. Finally, after having passed by the Sun and going away at the opposite side, the wave vectors again have a dominant radial component and are refracted according to Eq.(13a). This differentiated refraction by δ, near to the Sun, causes a (symmetric) convergence of the beams, which is responsible for the gravitational light lensing effect.

The value of δ can be calculated simply by multiplying the refraction rate Eq.(13b) times the excess (or shortage) of time delays near the Sun. On the solar surface $R=6.9565\bullet 10^8$ m and the refraction rate, given by Eq.(13b), is $W_\phi \approx 0.0359$ deg/sec. Interpolating the value of Δ t into the data in **Table I** for light passing by the surface of the sun, we find the excess time-delay at the retrograde side or the shortage of time-delay at the prograde side of closely Δ t =+13.5 ms. The product $W_\phi \times \Delta$ t gives δ =1.745 arcsec, which is very closely the observed deflection angle, causing the convergence of light passing close by the solar surface.

6.6. The Non-Synchronous Arrival of the Pulsar Signals to Earth-Based Antenna Arrays.

Astronomical observations with the help of interferometric methods can improve the images by orders of magnitude. To achieve this, it is necessary that the signals from the different receivers (antennas) be synchronous, which is achieved with the help of the GPS clocks. It is observed that, while the arrival of the pulsar signals to the antenna arrays along directions transverse to the Earth's orbital motion is synchronous as expected. However, *along the orbital motion of Earth* the arrival is out of

synchrony, up to 4.2 μsec. [18,19] This non-synchronous arrival is not due to aberration, however is a feature due to a refraction rate by Eq.(13a) in the solar field. This refraction rate creates a velocity component of the light signal toward $-\phi$ and correspondingly slants the wave fronts by and angle β given by $\sin\beta=V/c$, so that the wave fronts arrive to Earth inclined by an angle β, reaching first the leading part of the antenna array and only up to 4.2 μsec later the rear antennas.

6.7. The perihelion precession.

A differentiated refraction of the matter-wave of an orbiting body by Eq.(13b), likewise in the light lensing effect **Section 6.6** is responsible for the perihelion precession of elliptical orbits. At the perihelion the direction of the effective velocity $\boldsymbol{v}_{\text{eff}}$ is parallel to the velocity field Eq.(10) and adds up to it. This displaces the orbiting particle (planet) more rapidly than the HQS, so that it has not time enough to recover the tangential direction. It recovers it only somewhat beyond the previous perihelion point. In this way the perihelion advances a little bit in the prograde sense in each orbital round-trip (exact calculation is complex).

6.8. Absence of Effects of the Solar Gravitational Field on the GPS Clocks.

In the view of the present work the slowing of clocks is caused by velocity with respect to the local HQS and not by relative velocity. The effective velocity of the GPS clocks, moving with Earth round the Sun in the solar Keplerian velocity field, is zero, given by:

$$\boldsymbol{v} = \boldsymbol{v}_{\text{impl}}(r) + \boldsymbol{v}_{\mathbf{orb}} \approx (-GM/r)^{1/2}\,\mathbf{e}_{\phi} + (GM/r)^{1/2}\,\mathbf{e}_{\phi} \approx 0 \qquad (37)$$

All clocks orbiting in circular equatorial orbits round an astronomical body that normally is moving itself in a regular circular equatorial orbit round a larger body (star or galaxy), are stationary with respect to the local HQS. Such clocks all are naturally synchronous with respect to each other and all show closely the same proper time throughout the universe.

6.9. Gravitational Slowing of Clocks Moving in *Non-Equatorial* Circular Orbits.

The GPS satellites move round Earth along circular *non-equatorial orbits*, inclined α = 55 degrees with respect to the Earth's equator. They hence have velocity components, given by $v_0(1 - \cos\alpha)$ along $-\phi$ and $v_0 \sin\alpha$ along $\pm\theta$, where α is the angle with respect to the equator or parallels and v_0=3.87 km/sec. The effective velocity at the equator is $v_0[2(1\text{-}\cos\alpha)]^{1/2}$ = 3.574 km/sec and the estimated average velocity is ≈ 0.8×3.574 = 2.86 km/sec. Analogously the Westward velocity of the earth-based station at Colorado highs with respect to the local HQS is about 7.4 km/sec with respect to the local HQS. The velocity of the Cs atoms in the Cs beam of 0.255 km/sec in the time standard of the atomic clocks as well as a small transverse Doppler shift, due to the implicit velocity of the Earth-based stations with respect to the local HQS too must be considered. Altogether these effects achieve closely 4.5×10^{-10} sec/sec. [8]

6.10. Neutrinos from CERN Too Early at Gran-Sasso and Even so not Faster than Light.

2011 scientists from CERN have announced [28] that neutrinos from CERN-CH to Gran-Sasso-IT, 732 km South-East and making 58 degrees with the Meridians, arrived ≈ 60 ns earlier than expected for light. As this result would run into conflict with the light postulate, it was withdrawn shortly later. [29]. According to the present HQS dynamics [30] the velocity of the HQS from West to East is 7.91 km/sec at the Earth's surface. The component of this velocity along the path of the neutrinos is 6.7 km/sec, so that neutrinos *as well as light in vacuum* (HQS) *are predicted to both arrive 54.6 ns too early*. This value is very close to the observations published 2011 and, very importantly, it in no way exceeds the velocity of light, because light in vacuum as well is predicted to arrive too early by the same value. It in fact clearly shows, likewise several other observations, commented above, that the light postulate was made with base in an experimental artifact. A new Mega Neutrino Experiment is in course in the USA. Neutrinos will be shot underground from Fermilab (Chicago) to Stanford (South Dakota), distant ≈ 1300 km *toward the West*. In this experiment, Neutrinos are predicted to reach Stanford more than 115 *ns too late*. However, light in vacuum too will reach 115 ns too late.

6.11. Black-Hole Singularities.

Black holes are Keplerian velocity fields (Eq.(10)) in which the local velocity of the HQS along $+\phi$ achieves the velocity of light V(r)=c. At the event horizon, the *radial component* of the velocity of

light falls to zero, the $-\phi$ component achieves the value of c. According to GR the velocity of light, from the view of an external observer, falls to zero because the length of the radial distances diverges and the local direction of the time axis is purely spatial. From the present HQS dynamics viewpoint, the event horizon of black-holes is anisotropic. The limiting escape velocity for light, *propagating along* $-\phi$, is $\boldsymbol{c}-V = 2^{1/2}$ V, which means that the event horizon is a spherical surface located at r = 2.9144 r_g, where r_g is the gravitational radius of the black-hole, defined by GR. However, a light signal, *propagating along* $+\phi$, has an ordinary (orbital) velocity $\boldsymbol{c} + \boldsymbol{V} = 2c$ and the event horizon is a spherical surface located at $r = 0.08578\ r_g$. Above this event horizon, the direct orbit of light becomes hyperbolic. From the present view, a black-hole is black at the retrograde side and is bright at the prograde side. Also, from the present view, all binary astronomical systems emit gravitational waves of length $\lambda=cT/2$, where T is the orbital period.

7. FINAL COMMENTS.

The present work has discussed the assumptions of the TR in the scenario of the Higgs theory. The Higgs theory introduces the idea that space is filled up by a scalar field with spontaneously broken symmetries, giving rise to a real quantum fluid spatial medium, responsible for the mechanical properties of the particles. This Higgs Quantum Space (HQS) entails radical changes in the view of the TR about the nature of empty space and about the meaning and effects of motion. It breaks the reciprocal symmetry of the TR between observers. The present work replaces Einstein's hypothetical curved spacetime by a Keplerian velocity field $\boldsymbol{V}(r) = (GM/r)^{1/2}\ \mathbf{e}_\phi$ of the real HQS. This Keplerian velocity field creates an ingenious outside-inside centrifuge mechanism, responsible for the observed gravitational pull and the gravitational dynamics. It too creates appropriately all the observed effects of the gravitational fields on light and on clocks. The gravitational dynamics is an astronomical size macroscopic quantum phenomenon. The HQS that plays a fundamental role in the microscopic quantum mechanics world of the elementary particles also plays a fundamental role in the macroscopic gravitational dynamics. The HQS thus connects and unifies microscopic quantum physics and the macroscopic gravitational physics. In the universe there are no special places. All the astronomical bodies, throughout the universe, are very nearly stationary with respect to the local HQS in the respective gravitational fields, which entails the universality of the laws of physics.

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