A fully relative theory of gravitation

Peter R. Lamb

Institute for Frontier Materials, Deakin University, Geelong Waurn Ponds 3216, Australia

Email: peter.lamb@deakin.edu.au

Abstract

A fully relative, purely scalar, theory of gravitation is proposed which revises Einstein’s formulation of gravity as a distortion of space-time by matter. A scalar theory of gravity is required because light does not gain or lose energy in a gravitational field. The distortion is a real expansion of space proportional to the stored energy density. Matter cannot store as much energy when closer to other matter and the released energy appears as the kinetic energy of gravitational acceleration. The mass of a given amount of energy thus reduces as energy density increases. The product of the speed of light and time interval increases with stored energy density, matching the increase in the scale of space. The revised theory is consistent with quantum mechanics and reproduces the standard predictions of (tensor) general relativity theory for the present local energy density. Singularities are avoided and black holes, as currently conceived, cannot exist. However, the predicted differences, when the universe was denser, remove the need to postulate dark energy and cosmological inflation. The flat rotation curves of galaxies are explained without dark matter. A key test is whether the revised theory can fit the observed gravitational lensing of galaxy clusters without dark matter. However, an Earth-based test of the change in clock-rate with the expansion of the Universe, which appears to account for the Pioneer anomaly, should be possible. Key issues are to demonstrate that the slope of supernovae distance data is in agreement with the value of the gravitational constant, and to resolve whether an alternative explanation for gravitational radiation is viable.
1. Introduction

General Relativity Theory (GRT), as proposed by Einstein, has survived for nearly 100 years and has had remarkable success in predicting observed effects, particularly those occurring in our solar system. These include the precession of the planet Mercury’s perihelion, the bending of starlight by the sun and the redshift of the frequency of light (and radio waves) in a gravitational field. The predicted effect of clocks running slower in a deeper gravitational potential has to be taken into account in order for the satellite-based global positioning system to give correct locations. More recent effects predicted and observed include the Shapiro time delay, the gravitational lensing of galaxies and galaxy clusters and the rate of energy loss of binary pulsar systems. An additional argument for a tensor gravitational theory of the form of GRT is that it is required by a graviton of spin 2. Currently, there appear to be no clear contradictions between observations and GRT.

However, there are some clouds on the horizon, although all of them have supporters and opponents over whether they are real problems. The first clouds are the need to postulate dark matter and dark energy. The observation of the lower than expected brightness of distant supernovae has been taken to imply that there has been an acceleration in the rate of expansion of the universe [1, 2]. This in turn implies that some three-quarters of the universe consists of an unexplained dark energy. The rotation speed of stars in the disk portions of spiral galaxies is observed to be in poor agreement with that expected from Newtonian gravitation and the observed mass distribution, based on assumptions for the luminance to mass ratio of matter in the cores of galaxies. The rotation curves do not decrease as the inverse square root of distance but are nearly constant outside of the central bulge. This discrepancy is thought to betray the presence of a halo of dark matter. Diffuse dark matter haloes have also been put forward to explain the observed gravitational lensing of distant galaxies and galaxy clusters and the evidence for dark matter is considered by some to be
compelling [3], while others maintain that there is a crisis [4]. The proposed dark matter can neither absorb nor emit electromagnetic radiation and cannot be attributed to neutrinos. Despite extensive searches no candidates for this non-baryonic dark matter have yet been observed and none are predicted within the standard model of particle physics. Similarly, there is no persuasive theoretical explanation for the existence or magnitude of dark energy [5]. The existing theory that best explains cosmological observations is the $\Lambda$CDM model which incorporates a non-zero value of the cosmological constant $\Lambda$ and cold dark matter (CDM) and seems to be in agreement with detailed observations of the cosmic microwave background [6]. However, it is also claimed that there is poor agreement between $\Lambda$CDM and observations of galaxies and dwarf galaxies and that an explanation of the Tully-Fisher relation is needed [4, 6, 7].

A second concern is that GRT does not appear consistent with Mach’s principle that inertia is a result of all the other matter in the universe. Mach’s principle reflects the fundamentally relativistic view that movement can only be specified relative to other objects and that therefore there can be no inertia if no other matter is present. This is encapsulated in Special Relativity (SR) which requires that the laws of physics are independent of the relative unaccelerated motion of the observers. GRT sought to extend this principle to include gravitation; however, it allows solutions where there is inertia but no other matter. Under GRT, if the only two masses in the universe are tied by string and rotate about their centre then the string will be in tension. Mach’s principle, however, requires that this tension go to zero because there would be no other object that would allow the rotation to be defined.

For some critics the biggest concern is that, so far, it has not been possible to make GRT consistent with quantum mechanics because the strength of the gravitational potential varies inversely with the separation of the objects. Under GRT, energy corresponds to mass and, at the Planck scale, the available energy becomes enormous due to the Uncertainty
Principle. In quantum electrodynamics the forces also tend to infinity at short distances but are brought under control by renormalization which can be seen as a shielding introduced by the polarization of the virtual particle/antiparticle pairs that arise as the available energy increases. However, the gravity of these particle/antiparticle pairs adds to the gravitational force under GRT and there seems to be no way of avoiding the infinities. Another way this has been expressed is that a quantum field theory of gauge interactions of spin-two fields is not renormalizable. In addition, under GRT all energy contributes to the strength of the gravitational field, so that gravitational energy itself leads to an increase in the field and the theory is non-linear which also leads to infinities. Proponents of string theory see extra dimensions at the Planck scale offering a potential solution.

Another on-going area of controversy, if not inconsistency within GRT, is the apparently different behaviour of space at small and large scales. The expansion of the universe is compared with the stretching of the surface of a balloon under inflation. However, it is argued that the expansion applies only to truly cosmological distances, that is, to the distances between galaxies or galaxy clusters [8]. In the balloon analogy, the galaxies are represented by dots or small coins of fixed diameter stuck on the balloon surface, which is consistent with the lack of any observed expansion of galaxies. As the balloon inflates, the galaxies remain the same size, and the pattern of galaxies simply expands in size [8]. A corollary is that distant galaxies can recede at super-luminal velocities whereas under special relativity this would require an infinite amount of energy. It has been argued that bound systems such as atoms do not expand [9], but why do galaxies bound by gravity behave differently to the universe of galaxies where gravity is the only known binding force? Alternatively, it has been argued that there is no problem because “the expansion of space is neither more nor less than the increase over time of the distance between observers at rest with respect to the cosmic fluid” [10]. However, this seems circular unless the cosmic fluid is
different from space and an aether is being reintroduced? The expansion proposed by GRT takes place where there is little matter but is inhibited where there is matter.

A final concern of some is that, if not even light can escape from a black hole, then how is it that early in the big-bang universe when the density of matter was enormous that it too would not have behaved like a black hole? This conceptual problem appears to be related to the fact that our current theories predict a singularity at the centre of a black hole, which really means that the existing theories are no longer valid. This may also be related to the need for an explanation of the cause of inflation – the extremely rapid expansion of the early universe – that has been hypothesized to account for the observed uniformity of the cosmic ray background across regions that should not have been causally connected.

A revised theory is put forward which is consistent with Mach’s principle and with Special Relativity within an inertial frame and retains the distortion of space-time by matter of GRT. However, the speed of light (c) is allowed to vary between non-inertial frames so that the product of c and the time interval matches the size of a varying space interval. The invariant interval of SR holds within an inertial frame but the magnitude of the interval increases with the amount of matter present. The resultant theory reproduces all the standard predictions of GRT for the local conditions and epoch of our solar system but the changed predictions away from the local, current conditions appears to overcome the need to postulate dark matter and energy and seems to be able to resolve the other concerns.

The potential problems or objections include:

i) how can the speed of light be allowed to vary as this should violate relativity?

ii) if c and mass vary in this way, how is it that the variations have not been observed?

iii) time seems to be increasing as scale increases but the magnitude is only changing by the square root of that proposed by GRT?

iv) this is a scalar theory when a tensor theory has been shown to be essential?
v) the theory must lead to predicted consequences inconsistent with current observations?

vi) how can the equation of motion be consistent with GRT?

As it turns out, all these concerns can be successfully addressed, as will be set out below. In addition, it is shown how the theory is fully relative and that a number of predictions of the revised theory appear to be in better agreement with observation while other predictions should allow a definitive test.

2. Outline of the revised theory

The revised theory is that the stored energy of matter expands both space and the product $c \times$ time-interval ($dt$) equally and by an amount such that the local expansion (scale of space) is proportional to the local energy density. For small changes and the current local conditions, this distortion is mathematically equivalent to the distortion in the underlying geometry (curvature) of space-time proposed by GRT. Key differences, however, are that the expansion or stretching requires more stored energy the more that space is already stretched and that the speed of light and the speed of propagation of gravity (which involve variations in stretch) depend on the energy density. A corollary is that matter cannot store as much energy when the stretch of space increases, i.e. matter releases energy if it moves into a region of increased stretch. The acceleration of local matter depends on the release of stored energy due to a gradient in the total stored energy with distance. Movement into a higher density (lower gravitational potential) results in a change in mass, a release of stored energy, which appears as the kinetic energy of movement. Energy is conserved and a given mass corresponds to increased energy when there is more surrounding matter.

2.1 Background to the existing theory

GRT is based on the interval $ds^2 = -c^2dt^2 + dx^2 + dy^2 + dz^2$ of special relativity, which is invariant under Lorentz transformations. This says the time interval $dt$ between events is
relative because of the finite and constant speed of light, independent of the relative speed of the observers. The requirement that the laws of physics are the same for observers moving at constant velocity then leads to an apparent dependence of mass, length and clock rate on relative motion and the famous $E_0 = mc^2$. In seeking to obtain a theory of gravity, Einstein proposed that physics in a frame freely falling in a gravitational field is equivalent to physics in an inertial frame without gravity. This led to GRT which allows a gravitational field to alter the apparent dimensions of space and time while keeping $c$ and the interval $ds^2$ invariant. GRT introduces the concept of proper time, which is the rate of passage of time for a local clock travelling with the observer. This time is constant at a position remote from any gravitational field but slows with decreasing (more negative) gravitational potential, that is, closer to a massive object. The apparent spatial dimensions $R = \sqrt{dx^2 + dy^2 + dz^2}$ perceived by the distant stationary observer also change by a matched amount to keep $ds^2$ invariant. The space-time dimensions (the metric) are thus curved (geometry is non-Euclidean).

GRT thus proposes a universal absolute space-time well away from the gravity of massive objects, an invariant metric, whose magnitude is not relative. This lack of relativity and the inconsistency with Mach’s principle can be traced to the effective incorporation of the assumption that a constant density of surrounding background matter has no effect (i.e. the theory is gauge invariant). At first sight, this assumption seems plausible because the acceleration, due to a gravitational field, is observed to be proportional to the rate of change of gravitational potential. However, if the gravitational distortions of space from opposite directions add, rather than cancel, then the proportionality remains but the magnitude of the gravitational field reduces as the total potential increases. So the observer, immersed in a uniform density of background matter, sees gravitational forces that depend on the rate of change of gravitational potential due to the nearby matter, but is not aware that the magnitude of the potential depends on the density of background matter.
In GRT any spherically symmetric solution of the vacuum field equations must be stationary and asymptotically flat (Birkhoff’s Theorem). As a result, the metric of a vacuum inside a stationary spherical shell of matter must be the flat Minkowski metric. Thus, under the assumption that a flat metric corresponds to no gravitation, the gravitational field must vanish inside the sphere, which agrees with Newtonian gravitation, and the mass and radius of the spherical shell have no discernible effects upon the laws of physics as they are observed in the interior [11]. Interestingly, it has been claimed recently that this does not mean that the shell of matter has no effect [12]. Instead, it is claimed that the outside mass distribution makes an interior clock run slower. However, the strong, or Einstein, equivalence principle incorporated in GRT requires that a surrounding non-rotating uniform shell has no effect on the observed behaviour and does not lead to any curvature of the spatial dimensions, and that the curvature is the source of the gravitational field. This appears to be inconsistent with Mach’s principle, if inertia is due to gravitation, because it implies that the surrounding matter has no gravitational effect.

This discrepancy is still a highly contentious issue. Woodward and Mahood reviewed the gravitational explanation of the origin of inertia and concluded that GRT dictates that inertia is gravitationally induced [13]. However, they pointed out that GRT allows solutions in which test bodies in otherwise empty space experience inertial reaction forces. They also concluded that inertial reaction forces in GRT are produced by an instantaneous radiative interaction with chiefly the most distant matter in the universe; which violates special relativity.

2.2 The revised theory

The revised fully relative theory (FRT) is based on the notion that, if matter stretches space, then different uniform backgrounds of distant matter will lead to different local background stretching even though there is no local gravitational field (acceleration). A local
concentration of matter will distort space less if there is more background matter and the speed of a wave will depend on the total stretch and therefore will be proportional to the square root of the energy density if the stretch is linear. The revised theory proposes that the total stretch, or scale of space \( R \), is proportional to the energy density \( \Phi \) while \( c^2 \) is proportional to \( R \). In a region of different but constant potential there is still an interval \( ds'^2 = -c^2 dt'^2 + dx'^2 + dy'^2 + dz'^2 \), which is Lorentz invariant, but only within that region i.e. \( ds'^2 \neq ds^2 \). The gravitational potential reflects the change in the stored energy with distance and hence to a change in the spatial dimensions and an identical change in the product \( cdt \).

An increased stretch corresponds to an increased speed of any wave travelling in that space proportional to the square root of the total stretch, which increases the time interval \( (dt) \) by \( R/c \) or the square root of the stretch. Time, interpreted as the relative rate at which events occur, appears slower by \( 1/\sqrt{R} \).

This change in clock rate at the source is only the square root of that given by GRT. However, the number of wavefronts passing per unit time at the receiver is increased by the matched increase in the speed of light so that the apparent time dilation is the same for both theories.

The fact that \( c \) varies means the energy stored in particles as mass, i.e. \( m = E_0/c^2 \), is not constant. An increase in the stretch of space, due to an increase in the presence of other matter, should lead to a decrease in the magnitude of the stretch due to a local particle of matter, by analogy with metal balls on a rubber sheet. Thus, it is proposed that the distortion by a given amount of energy, observed as mass, decreases as the local distortion due to other matter increases.

In addition, it is proposed that the energy stored by a given amount of matter (number of elementary particles) also decreases as that matter moves closer to other matter. This appears as kinetic energy of motion, that is, the matter will be accelerated and the magnitude
of the force will depend on the amount of matter so that the local gravitational acceleration will be the same for different quantities of matter. Thus, the work done on matter as it is raised to a higher gravitational potential, is stored as an increase in the mass (and the stored energy) of the same amount of matter. A photon has no mass and so no stored energy, only the energy of motion (which includes angular momentum).

If the background \( \Phi \) increases then local matter releases stored energy, which appears as kinetic energy. The change in \( \Phi \) is therefore approximately minus the potential of GRT (within our local region of almost constant matter density) because the potential of GRT is the amount of stored energy released by the matter under consideration when the energy density increases. However, if the energy density is primarily due to the background then the energy released varies inversely with the background \( \Phi \). If a small amount of matter moves into a region with double the \( \Phi \) then \( c^2 \) will have doubled and half the energy held as mass by the matter will be released as kinetic energy. The matter will then have one quarter of its original mass (retaining \( m = E_0 / c^2 \)).

A gravitational field arises if there is a gradient or change in the local \( \Phi \) due to surrounding matter. The stored energy affects the scale of the surrounding space and the speed of light, with the presence of other matter reducing the ability of local matter to store as much energy. A gradient in energy density occurs with distance from stationary locations of stored energy (i.e. matter) and the gradient can change with time, when the distance to any matter changes. The magnitude of the gradient will depend on the background energy density. If the background energy density is large and constant then the force (rate of change of momentum with time) per unit of stored energy will be equal to the gradient in energy density with distance. Thus Newton’s law, \( F = ma \), will hold but the mass (additional stretch per unit mass) will decrease with increasing background energy density.
Note that this is a scalar theory. The forces arise only from changes in magnitude of a local energy density with position or time. However, it is different from other field theories in that the properties (the stored energy) of particles in the field are no longer constant, but depend on the total distortion due to all matter.

2.3 Does a variable speed of light violate relativity?

The assumption of the constancy of the speed of light, in empty space, was taken over from the Maxwell-Lorentz theory of electromagnetism. The equivalence of inertial systems (the special principle of relativity) then leads to the result that time and distance are relative, that

\[ ds^2 = -c^2 dt^2 + dx^2 + dy^2 + dz^2 \]

and the laws of nature are invariant with respect to Lorentz transformations. This, however, does not imply that the speed of light has to be identical in a different location where the gravitational potential is different. The problem actually traces back to the idea that a vacuum constitutes “empty space”. If the dimensions of space are determined by matter then it is never empty. The background matter determines \( c \), the product \( cdt \), and the scale of space.

It is commonly thought that the principles of special relativity are only fulfilled if the speed of light is a universal constant. According to Einstein [14] the special theory of relativity was based on two principles: i) every universal law of nature which is valid in relation to one coordinate system, must also be valid, as it stands, in relation to a second coordinate system which is in uniform translatory motion relative to the first, and ii) the constant velocity of light in vacuo. Pais [15] explained Einstein’s postulates as: i) the laws of physics take the same form in all inertial frames, and ii) in any given inertial frame, the velocity of light is the same whether the light be emitted by a body at rest or by a body in uniform motion. At first sight these principles seem to imply that the speed of light must be a universal constant across all inertial frames. However, closer inspection reveals that the speed of light only has to be constant within an inertial frame and there is an assumption that “our”
vacuum is the same everywhere (i.e. the properties of “empty” space are independent of the surrounding matter). The logical jump to the speed of light having the same value in all inertial frames requires that not only the form but also the magnitude of the laws of nature are universal. Constant magnitude seems to follow from the idea that a coordinate frame is a concept or a construct that can be arbitrarily chosen and so should be independent of space and time. However, this contradicts both FRT and GRT which have space and time intervals distorted by matter. The relative scale of inertial frames depends on the relative scale of their regions of space and when one is chosen the other is not arbitrary. The laws of nature will not be universal unless this is taken into account.

Hence the claim that the postulates of special relativity (the constancy of the speed of light in an inertial frame and that all physical laws are valid in all inertial systems) imply that \( c \) is the same in all inertial frames [16], is too generous. They only imply that \( c \) must be the same within an inertial frame. The reason is that an inertial frame at a different constant gravitational potential (a different matter/energy density) can only be reached via an acceleration and the relative scales of the two frames then depends on the acceleration i.e. on the difference in potential.

Under FRT, the metric function \( g_{ab} \) in \( ds^2 = g_{ab}dx^a dx^b \) of GRT is instead a scalar of magnitude \( \Phi^2 \) so that \( ds^2 = (\Phi'/\Phi)^2 ds^2 = (R'/R)^2 (-c_0^2 dt_0^2 + dx_1^2 + dx_2^2 + dx_3^2) \). Space and \( cdt \) are stretched (variable magnitude) rather than curved (but fixed magnitude). The revised theory is still geometric (the field is directly proportional to the distortion of space and \( cdt \)) but always Euclidean within a region of constant stored energy density.

In GRT the “effective velocity” of light is understood to change in the presence of a gravitational field because of the ways that distance and time transform in this field. The gravitational field appears as an acceleration which affects the clock rate. The difference in clock rate is proportional to the difference in potential. The slower clock rate is taken to mean
that time runs more slowly (deeper in a gravitational potential) so that light does not travel as far in a given time and distances appear shortened. It is simpler, and conceptually easier, to have both the scale of space and the actual speed of light increase which will then cause time intervals to dilate. If the scale of space is proportional to the total potential and \( c \) is proportional to the square root of the potential, then the time interval is also proportional to the square root of the potential and \( c dt \) is proportional to potential and \( dt = \frac{R}{c} \). Local Lorentz invariance can still be maintained even though the speed of light varies [17]. Here the interval is invariant (in an inertial frame) only within a region of constant potential. Travelling to a region of different matter content requires movement through a gravitational potential and hence through a non-inertial transformation.

3. **Rationale for the revised theory**

In addition to the need for explanations of dark matter and dark energy and to resolve the inconsistency with quantum mechanics there are other good reasons for demanding a revised theory which is scalar, background dependent and fully relative. These include that if matter distorts space then background matter must also affect local space and time, and that a field that gives up energy should not become stronger.

3.1 **Implications of mass distorting space**

GRT postulates that the speed of light is an invariant and that the cause of gravitation is a curvature in the underlying metric of space-time. A curvature requires distortions, which can only be expansions or contractions, of the dimensions. A spherical shell of matter can be envisaged as an infinite number of small pairs of equally distant masses in opposite directions, each of which is entirely symmetric perpendicular to the line joining them. So any unbalanced spatial distortion can only be an expansion or contraction in the radial direction. The lack of gravitational effects from a stationary spherical shell in GRT can be seen to imply
that spatial distortions from opposite directions cancel, analogous to the cancellation of the influence of electric charges on a surrounding conducting sphere which ensures gauge invariance of electromagnetic interactions. This cancellation of curvature is implausible because symmetry demands that both masses contribute an expansion or both a contraction, so distortions from opposite directions must add rather than cancel.

Another way of seeing this is that if the interval $\text{d}s^2 = -c^2\text{d}t^2 + \text{d}x^2 + \text{d}y^2 + \text{d}z^2$ is to be preserved when there are masses at $x = +a$ and $x = -a$ then time must also be allowed to be negative if a Lorentz transformation is to correspond to a rotation in space-time. The result appears to be that the metric formulation of GRT accidently builds in an assumption that distortions from opposite directions cancel. The result is a theory in which the predicted effects depend on the integral of a gravitational field (acceleration). The field is the derivative of this gravitational potential with distance. Yet the distribution of matter distorts the distance and this is effectively ignored. If matter distorts space then all matter has to affect the distortion. Under GRT, the masses giving rise to the potential are assumed constant and, in addition, all energy (not just the energy stored as mass) contributes to the potential. Keeping the masses constant means that a uniform surrounding shell of matter has no effect.

The fractional effect of an asymmetry in the matter distribution will depend on the total distortion from all matter. Hence, if the total distortion is much larger than the additional distortion due to local matter then the additional distortion will appear on an approximately constant background. A common 2-D analogy is the way metal balls will distort a stretched rubber sheet. With rubber sheets, or springs, the initial distortion introduces a tension that makes further distortion more difficult. A more highly tensioned sheet is distorted less. If this is the case for space, then two predictions follow. Firstly, the effect of additional matter on the distortion of space should decrease when the overall density of matter increases. Secondly, the wave speed of a distortion should increase when more matter is present. A
spherically uniform and stationary distribution of distant matter does not produce a gravitational acceleration. However, it should have an effect such that the magnitude of any acceleration, due to a local inhomogeneity of the matter distribution, is determined by the ratio of the imbalance in extension to the total extension. The revised theory is consistent with these requirements.

The result of ignoring the background potential in GRT is to remove any effect of the change in total potential that occurs when a body is in free fall. The Einstein equivalence principle states that in a freely falling reference frame the physics is the same as an inertial frame with no gravity. However, in general, the two frames are only instantaneously equivalent and, unless you can examine effects over a distance or time interval, it is not possible to determine if the magnitude of the effects is constant. If a body is in free fall towards the earth then the total potential is changing. In both frames, tidal effects are seen in any object of a finite size. The tidal effects indicate the rate of change of potential with distance but this does not establish that the proportionality stays constant. In the freely falling frame the tidal forces are due to changes in magnitude and direction of the gravitational field with position and time, whereas in each inertial frame, the tidal forces are ascribed only to differences in position. The acceleration is taking the frame into a region with a different density of matter. Under GRT this has no effect on the loss of energy with distance. Under the revised theory, the same change in density will have a smaller effect (be a smaller fractional change) when the density of matter is higher. A formulation that reproduces the initially correct tidal forces, but does not incorporate effects due to changes in total potential (i.e. GRT), will only be correct in the limit that any change in potential is small relative to the total potential.

GRT equates gravity with a distortion of a fixed interval of space-time, but an alternative is to have the distortion correspond to a change in the magnitude of the interval in
space-time. The magnitude of $ds^2 = -c^2 dt^2 + dx^2 + dy^2 + dz^2 = \eta_{\mu\nu}dx^\mu dx^\nu$ changes as well as its components rather than the components but not the magnitude. Thus it is proposed that the larger the $\Phi$ the larger the dimensions of space and the greater the speed of light. The acceleration due to a given gradient in $\Phi$ will still reflect the rate of change of the distortion, that is, the slope of space and time. By analogy with the stretched rubber sheet or a spring, the rate of increase in distortion (by local energy) will decrease with increasing distortion, but equally the rate of increase in the scale of space $R$ (due to all matter) will decrease with increasing scale. The distortions and $\Phi$s in two regions of space are predicted to be related by $R_1 / R_2 = (\Phi_1 / \Phi_2) = (c_1 / c_2)^2$. However, the revised theory has both $c$ and $dt$ increasing in proportion to $\sqrt{(\Phi_1 / \Phi_2)}$, which retains $dt =$ distance / $c$. If $R$ corresponds to distance then $c = R / t$ implies $R_1 / R_2 = (t_2 / t_1)^2$. The apparent rate of passage of time is the inverse of the time interval needed for events to occur.

In GRT the tidal forces, which for example cause separated objects in a lift in free fall to move closer together, are equated with curvature, which is the second derivative of the metric. The differences of the gravitational effects on neighbouring points are proportional to the derivative of the gravitational field (acceleration), and the second derivative of the gravitational potential [18]. This is analogous to the Newtonian field equation $\nabla^2 \phi = 4\pi G_N \rho$ where the second derivative of the potential (the tidal forces which reflect the difference in gravitational force with distance) is proportional to the mass density. The field equation(s) of GRT adds in a time dependence, so that the finite propagation speed of gravity is incorporated and gravitational effects are equated with the second derivative of a normalized metric of space-time (i.e. the curvature). FRT still has the gravitational force proportional to the rate of change of a revised potential. However, the value of the potential is affected by the presence of all matter and its relative motion and the distortion is a simple stretching of space.
and of the product \( c dt \). As will be shown below (Section 6); the distortion of a metric of fixed magnitude is, to first order, equivalent to changing the dimensions of space-time and \( c \) as proposed. Equating the size of the tidal effects with the observed strength of gravity and speed of light in our local region means that the magnitude of the effects of gravity will only be correct when the \( \Phi \) is similar to that observed locally. In a location where the energy density is significantly different, for example, closer to the centre of our galaxy, or at an earlier epoch when the universe was denser, then the predictions of GRT will be in error.

3.2 The problem of the source of gravitational energy

If \( c \) varies, then the relationship \( E_0 = mc^2 \) implies that the mass of a stationary object (of fixed energy) decreases in inverse proportion to the square of an increasing speed of light. This appears consistent with the analogy of a stretched rubber sheet where the distortion of the sheet by matter decreases as the total distortion increases. The equation indicates that \( c^2 \) is the conversion factor for the mass equivalent of the same amount of energy in different regions of space, but not necessarily the same amount of matter (number of particles). It is tempting to assume that the same number of elementary particles corresponds to the same energy in different regions of space but this would be equivalent to assuming that the energy of such stationary states is independent of the amount of other matter present. If time varies in different regions then it might be expected that the energy of the time stationary state (an elementary particle) might also vary.

In 1864 Maxwell pointed out the paradox that arose because gravitation was an attractive force: “The assumption, therefore, that gravitation arises from the action of the surrounding medium in the way pointed out, leads to the conclusion that every part of this medium possesses, when undisturbed, an enormous intrinsic energy, and that the presence of dense bodies influences the medium so as to diminish this energy whenever there is a resultant attraction. As I am unable to understand in what way a medium can possess such
properties, I cannot go any further in this direction in searching for the cause of gravitation.”
[19]. If we demand conservation of energy and that the number of elementary particles is conserved when two bodies accelerate towards each other under gravitational attraction, then the medium or particles must give up energy. Hence, we are forced to conclude that the energy of the same elementary particle (or the energy of the distortion of the medium) is lower in the presence of other matter. The simple elegant solution is that the “enormous intrinsic energy” is the energy stored as mass; the same property that led to nuclear weapons. The possibility of a change in stored energy should not be surprising if the dimensions of space are larger and the passage of time is slower.

From the rubber sheet analogy, it should be expected that mass (which should be related to the amount of distortion of the sheet by a given amount of energy) will decrease as the energy density (due to other matter) becomes larger. The relationship $E_0 = mc^2$ reflects the conservation of energy in special relativity and should be expected to hold within all regions, and hence for all values of $c$. However, it is just the conversion factor between mass and energy. The amount of stored energy per particle should also decrease when the background energy is higher. The number of particles $N$ remains constant when an object moves in a gravitational field, so the energy per particle decreases as the $\Phi$ increases and mass must have a strong dependence on $c$. Therefore, it is proposed that $m \propto N / c^2$, so that the energy per particle decreases in proportion to $1 / c^2$. This is consistent with the analogy and with an attractive gravitational force because the stored energy of a particle decreases as it gets closer to other matter.

3.3 What is the cause of time dilation?

The effect of time running slower when moving deeper into a gravitational potential, e.g. as you move closer to the Earth, is well established and is seen in the need to make appropriate corrections to the signals from the satellites of the gravitational positioning system. The GRT
explanation of time dilation keeps the speed of light constant and assumes that the same clock in regions with different densities of matter (e.g. at different altitudes), but in free fall (i.e. not experiencing any force), behaves identically. This means that it is assumed that the energy levels of atoms are unchanged and independent of other matter and that so is time, if there is no force. If there was twice the difference in density of matter then the difference in clock rate, between free fall and stationary, should be expected to double. So the difference in clock rate would depend on the difference in density of matter but the free-fall clock rate is assumed constant independent of the density of matter. A surrounding shell of matter, which changes the density, is proposed to have no effect on the free-fall clock rate. This appears inconsistent; a background dependent explanation of time dilation is required.

3.4 Requirement for a Scalar Theory

The understanding that photons do not lose energy (“fall”) in travelling between regions of different gravitational potential is actually part of standard GRT [20]. The time dilation causes the frequency to appear to be changed but not the energy. As Schwinger [21] has pointed out, the energy of a photon does not change in a gravitational field. Okun et al. [20] have made it clear that the explanation of the gravitational redshift in terms of a naive “attraction of the photon by the earth” is wrong. Cheng has explained that the idea that a light-pulse loses kinetic energy when climbing out of a potential well is erroneous. A photon is not a massive particle and cannot be described as a nonrelativistic massive object having a gravitational potential energy [18]. The photon energy is conserved. The resulting explanation of the gravitational redshift actually leads to the conclusion that the receiver atom is at a higher gravitational potential and therefore that all its energy levels are increased (blue-shifted) [18, 20, 21]. The necessary conclusion is that particles lose gravitational energy when moving to a region with a higher density of matter. Thus the concept that particles, but not photons, must lose energy in moving to a region with a higher density of matter should
not be novel. However, here it is also proposed that the frequency of an electromagnetic transition and the clock rate change and the energy equivalence (the energy that can be stored) of the matter changes.

It has been shown that a graviton of spin 2 necessarily leads to a tensor theory of gravity of the form of GRT [22]. Yet here a scalar theory is being proposed, so how can this be resolved? Arguments for the spin of the graviton have been set out clearly by Hatfield [23]. As a force carrying particle it needs to carry integer rather than half-integer spin. Next, it is found that when the exchanged particle has odd integer spin then like charges repel and opposite charges attract. Given that gravity is universally attractive then it must correspond to even spin. If the exchanged particle has spin 0, then it does not couple to the spin 1 photon. This is because spin 0 corresponds to a scalar field and the calculation of the exchange amplitude shows that a spin 0 graviton only couples to the trace of the stress-energy tensor. However, the stress-energy tensor for the electromagnetic field in Minkowski space is traceless. Hence scalar gravitational fields do not couple gravity to light. It is then argued that since light “falls” in a gravitational field and that light is deflected by massive objects then light couples to the gravitational field and the graviton cannot be spin 0. Spin 2 is the next choice. Finally, it is found that a massless spin 2 graviton couples to the stress-energy tensor in exactly the same way as the gravitational field of general relativity theory. From this it is concluded that, since GRT is in agreement with observation, the graviton must be spin 2.

The photon does not lose or gain energy in a gravitational field, nor is it deflected by the gravitational field. Its path would be a straight line if the distortion was removed. The observed changes in frequency are because of the changes in the dimensions of space-time. The momentum change of the photon is only in direction (not magnitude) and that reflects the change in spatial dimensions (of the space traversed) and so is only apparent. The photon does not interact with or couple to the gravitational field, i.e. to gravitons, or to other photons.
(except elastically via virtual particle/antiparticle pairs). Hence, the graviton should be expected to have spin 0 and a scalar theory of gravitation is required.

The discovery of a Higgs-like scalar boson is evidence that the proposed mechanism for giving particles mass, spontaneous breaking of gauge invariance, involves a scalar field. If this is the source of mass then gravity must arise from a scalar field that is not gauge invariant, which is inconsistent with GRT which is a tensor theory and gauge invariant. Either a scalar field needs to be added or GRT needs to be replaced with a scalar theory.

Brans and Dicke [11] sought to add a scalar component to allow variations in the gravitational “constant” but combined it with the existing tensor theory of GRT. Recently, Novello et al. [24] summarized the difficulties of previous scalar theories of gravity noting that the main handicap of such theories is that gravity does not couple to the electromagnetic field when the source of gravity is the trace of the energy-momentum tensor. It is not a difficulty as it is what is observed. However, as they noted, it leads to a space-time dependent mass. It turns out that this is also consistent with observations and can explain why massive objects gain energy of motion in a gravitational field.

Giulini [25] examined the arguments that Einstein gave on why a special-relativistic theory of gravity based on a massless scalar field could be ruled out merely on theoretical grounds. He concluded that the two main arguments are unsatisfactory and that such a theory seems formally perfectly viable, though in clear contradiction with experiments. However, the primary noted contradiction with experiment was that the theory predicted that a travelling (free) electromagnetic wave would not be bent in a gravitational field. The other noted contradiction was in the calculation of the precession of the perihelion of the planet Mercury, but this was based on the assumptions of GRT for the nature of mass and time.

Giulini also argued that trapped electromagnetic radiation in a box with mirrored walls will induce stresses in the box’s walls due to radiation pressure. This will increase the
weight of the box by $\Delta m = E_{\text{rad}} / c^2$ and, in this sense, bound electromagnetic fields do carry weight (have mass). However, this is not a problem, it is entirely consistent with the revised theory that the total potential, and therefore stretching of space, is proportional to the stored energy density. It also throws light on the argument used by Feynman [23] to rule out a spin zero graviton. He argued that it was inconsistent with an amount of hot gas being more massive than the same gas when cold. This is expected on the basis that higher binding energy (of nuclei) gives increased mass, and increased mass means that the gas is more strongly bound by gravitation. According to his argument, a spin-zero theory leads to the prediction that the interaction energy of the hot gas would be less than that of the cool gas so that the mass is predicted to be lower. However, the argument is flawed because it does not take into account the effect of temperature on the volume or pressure of the gas. The hot gas needs additional pressure to maintain the same volume. This stored energy gives mass (but only if it is stored). In the revised theory, if particles move closer together then the local energy density increases, but the energy stored per particle (mass) decreases, so that the amount of free energy released (the heat of the gas particles in the above argument) is the stored energy of the lost mass. The kinetic energy released does not contribute to the gravitational field (mass) unless the particle is bound. Photons, which are not bound, do not contribute to the gravitational field. Thus the arguments for a spin 2 graviton are flawed and a spin 0 graviton, and hence a scalar theory, is not only possible but actually required, because it cannot be tensor and gauge invariant [23].

3.5 The need for a Fully Relative Theory (FRT)

The original notion behind the Special Theory of Relativity was that motion can only be defined relative to other objects. If information can only propagate at the speed of light then the requirement that physical laws appear the same to different observers, independent of any steady motion, leads to the effects of time dilation and length contraction. In formulating
GRT, Einstein sought to have a theory in which the laws of physics should have the same form in all reference frames.

In Mach and Einstein’s view, space and time just express relationships among processes. Einstein phrased it as: “space is not a thing”, absolute space (or an absolute coordinate system) does not have an independent existence. Under GRT space and time are determined by the matter/energy distribution (but the speed of light is not).

If objects are accelerating relative to a chosen reference frame then spurious inertial forces, e.g. a centrifugal force, arise. This leads to Mach’s paradox (as paraphrased from Cheng [26] in the following paragraphs). If there are two identical elastic spheres, one at rest, and the other rotating about the axis joining them, in an inertial frame of reference; then the rotating sphere is observed to bulge out in the equatorial region. Yet, if the spheres are alone in the world, it cannot be said which one is rotating so the shapes should not be different.

Mach then insisted that it is the relative motion of the rotating sphere with respect to distant masses that is responsible for the observed bulging of the spherical surface. The statement that the “average mass” of the universe gives rise to inertia has come to be called Mach’s principle. A fully relative theory then requires that inertial forces, including the centripetal force causing the bulging of the sphere, should go to zero as the mass of the spheres, relative to the average mass, reduces. GRT does not meet this requirement as the strength of the interaction, and size of the space-time distortions, is independent of a uniform external shell of matter.

The influence of external matter on the magnitude of interactions (and the local stored energy density) should be expected to be large. Given the potential falls off as $1/r$ and there are approximately $3 \times 10^{11}$ stars in our galaxy at an average distance of approximately 27,000 light years; then, if the average mass of the stars was similar to our sun, their contribution to the local potential would be more than 100 times that of the sun.
4. Mathematical development of the revised theory

4.1 A revised framework

A framework is needed that can accommodate relative distances expanding and contracting, together with time and the speed of light, as energy density varies. This means that mass no longer corresponds to a fixed amount of energy, and the energy that can be stored in a particle (standing wave) decreases when there is more surrounding energy. Spacing of objects is now relative, that is the spacing is affected by the presence of other matter. The scale of space has a dependence on the local energy density. Such an approach restores relativity. The interval that is invariant under special relativity, because the speed of light is constant, becomes relative to the energy density.

The guiding principles to be used to negotiate this changed landscape are: i) that energy is a meaningful property within different environments, e.g. when a massive object moves between regions (at least if the total energy of the environment is constant over time); ii) the laws of physics must be the same once the environment is taken into account; and, iii) that movement of matter can only be defined relative to other matter. The aim is to construct a self-consistent formulation that is also consistent with observations.

The weak equivalence principle, that inertial and gravitational mass are the same, provides a starting point. If mass is stored energy relative to \( c^2 \) then a linear distortion (expansion) of space should also be expected to be proportional to \( c^2 \) (because inertia is resistance of mass to a change in distance), so that the mass gets reduced by \( 1/c^4 \) as space expands. This implies that distances should be divided by \( c^2 \), which is a measure of background density, if the laws of physics are to be universal, i.e. independent of the background density of matter.

The proposal is that the scale of space depends linearly on the stored energy density (\( \Phi \)). The local length scale will depend on total energy density from all sources and will
change according to their movement. If the surface area around a source of stored energy increases as \( r^2 \), with distance \( r \) from the source, but the scale of distance is reducing as \( 1/r \) then the contribution of a source of energy to the energy density decreases as \( 1/r \). So the unit of distance and scale of space match and are proportional to the energy density.

If volume depends on energy per unit volume, then energy is proportional to volume squared. Thus a fourfold increase in enclosed energy is needed for a doubling of the volume of the source. If the enclosed energy increases by \((R'/R)^3\) then the energy flux from the source through the surface would be the same at a distance \((R'/R)\). However, the energy density will be the same only if the length scale is reduced by \((R/R')\). The net result is that the volume of space needs to be proportional to the scale of space. Energy is then proportional to scale squared (and volume squared) and energy density = energy/volume is proportional to scale. If the energy flux from other sources has already given rise to a larger volume then the energy flux from a local source will give rise to a smaller increase in volume.

When there is more surrounding matter, then the scale of space is larger and the same amount of matter stores less energy and the increase in scale is smaller for the same amount of energy. Stored energy is spread out as a change in scale (distortion) of space, with objects embedded in this space storing less energy (as mass) when there is more distortion (i.e. the scale is larger). The amount of energy that can be stored is the inverse of the scale of space,

\[
\frac{E'}{E} = \frac{R}{R'} = \left(\frac{c}{c'}\right)^2
\]

but if \( E_0 = mc^2 \) always holds, the mass of the same particles is \( \frac{m'}{m} = \left(\frac{c}{c'}\right)^4 \).

Mass is a measure of the stored energy relative to the background energy density with the energy that can be stored by a particle increasing as the background decreases (Figure 1). Force corresponds to the slope (rate of change of scale with distance) per unit mass and the energy released is the force times distance.
Fig. 1. The mass of the same energy increases when the scale reduces.

It would be nice to just write down the new equation of motion but a better understanding of the meaning of terms such as distance is needed. The equation(s) of motion should correspond to Einstein’s tensor equation with all the non-diagonal terms removed but terms that were previously constant (such as mass and $c$) are now variables. The weak equivalence principle suggests that all such variables must be normalised by the scale of space (or local energy density).

4.2 The principle of stationary action and the equation of motion

The new equation of motion that replaces Einstein’s equation(s) based on the stress-energy tensor is simply based on conservation of energy and momentum. The rate of change of energy density due to the motion of sources of stored energy is minus the rate of change of energy stored as mass. Uniform motion at constant velocity does not involve a change in energy if the background matter is sufficiently uniform that there is no change in the energy density. However, sources of stored energy distort space and the amount of distortion and the energy carried by a given source (group of particles) decreases with increasing background energy density.
The principle of stationary (or least) action has it that \( \delta \int L dt = 0 \), where \( L \) is the Lagrangian, which is the kinetic energy minus the potential energy. The Euler-Lagrange equation of motion is then:

\[
\frac{\partial L}{\partial x} - \frac{d}{dt} \left( \frac{\partial L}{\partial \dot{x}} \right) = 0,
\]

with \( L = \frac{1}{2} m \dot{x}^2 - V(x) \). A difference from usual is that the variables \( x, t, m \) all depend on the local energy density. However, because \( c \) and \( \dot{c} \) are \( \propto \sqrt{R} \), \( x \propto R \) and \( m \propto E/R \) the values of both kinetic and potential energy are independent of the local scale and hence of \( \Phi \) (provided that the reference level of stored energy density is not changing with time). This means that both kinetic and potential energy are valid quantities, across regions that are in equilibrium, even though the units of their components vary. If an object has kinetic and potential energy in one region it will have those same amounts in another region plus or minus the amount that is converted between potential and kinetic energy. The Euler-Lagrange equation then states that the rate of change of momentum (due to kinetic energy, i.e. to the motion of stored energy) with time will be minus the rate of change of potential energy with distance. Conversely, the rate of change of stored energy density with distance will be proportional to the rate of change of kinetic energy with \( c dt \). Note that the equations inherently assume conservation of energy i.e. a closed system in which energy is conserved. If the overall energy density is decreasing with time then the amount of matter influencing the local matter is decreasing so it is not a closed system and the conversion factors will also change. The rate of change of the local stored energy with the scale of space should be equal to the rate at which energy flows out of the system with time. Mass (local stored energy) will increase and the kinetic energy (temperature) will decrease as the background stored energy density decreases.

The implications for conservation of momentum also need to be considered. Force is defined as the rate of change of momentum \( \vec{F} = \frac{d\vec{p}}{dt} \) where \( \vec{p} = (E/c^2)\vec{v} = m\vec{v} \). However, if special relativity is to hold, all velocities must be relative to the speed of light. The
momentum-like quantity that should be preserved is therefore $\bar{p}c = E(\nabla / c) = mc\bar{v}$. The force is then $\vec{F} = d(\bar{p}c) / d(ct)$, which is consistent with time being distance divided by $c$ and work (the change in energy) being force by distance. This is also consistent with $E^2 = m^2c^4 + p^2c^2$ being a conserved quantity and with gravitational and inertial mass having a fixed ratio, as required by the Eötvös experiments.

The approximate equation of motion, which applies to an isolated free particle in response to a static variation in $\Phi$ with position in its environment, can be derived as follows. An increase in energy density with distance will mean that the stored energy of the particle will decrease, this will manifest itself as a force in that direction. The force on a particle with gravitational mass $m_G$ will result in a variation with time of the particle’s momentum. Therefore, $F_i = m_G \partial E / \partial x_i = dp_i / dt$. Special relativity has $\bar{p} = m_i \gamma \bar{v}$, where $m_i$ is the inertial mass, and the gravitational mass density is given by $\rho = \Phi / c^2$. Hence, $d(m_i v_i) / dt = m_G \partial \rho c^2 / \partial x_i$, where the $\gamma$ term has been set to 1 for the low velocity limit. The result is that $a = d(v_i) / dt = (m_G / m_i) \partial \rho c^2 / \partial x_i = \partial \rho c^2 / \partial x_i$. If $\Phi = \Phi_b + Gm/r$ then $a = \partial \Phi / \partial r = -Gm / r^2$ which is Newton’s law of gravitation and it can be seen that it applies in the limit of low velocity. Finding the equation that holds independent of scale should allow $G$ to be derived.

A comment on this approximate equation of motion is in order. In principle, a force should also arise if the stored energy of the particle decreases with time, but does not move relative to other matter. However, this means that the external energy density has increased which corresponds to a spherically symmetric increase in the distance to other matter. This is a back-reaction of the particle on the field, which contradicts the assumption of an isolated free particle.
5. **Changed perspectives of the revised formulation**

The broad change in perspective is that physical laws and properties are relative. There is no absolute time or mass or distance well away from a gravitational field. The lack of a gravitational field actually corresponds to zero mass density, in which case the dimensions of space (distances) would become undefined but would go to zero with increasing separation from the only object.

If the universe expands, i.e. become less dense, then energy of motion will get converted into mass. This would increase the mass density and scale of space so that the rate of expansion would be slowed. If the mass density has reduced then the speed of light has also reduced while the clock-rate has increased, so that looking back in time, the clock-rate for earlier epochs will appear slower. The energy stored by elementary particles will now be higher than in the past which means that all masses have increased and the relative amplitudes of their wavefunctions will have also increased.

The photon does not gain or lose energy when it moves between regions of different $\Phi$. However, it is necessarily an oscillating distortion of net zero mean distortion (no mass) that travels in the field that is space. Hence, its size (wavelength) for the same energy should be expected to appear larger if the scale of space (the density of matter), and energy density, reduces.

The cosmic microwave background (photons) has been red-shifted (longer wavelengths) so the mass density must be lower now than in the past. However, if the temperature is lower now, then the amount of kinetic energy is lower and this means that more of it should be stored as potential energy, i.e. as mass. This would slow any decrease in mass density. Hence, careful consideration needs to be given to the effect of any change in density on the clock-rate and energy levels of massive objects before considering the cause and effects of the cosmological redshift of distant galaxies.
5.1 Time and clock-rate

The revised notion of time is that it is the relative rate at which equivalent events occur in regions of different mass density. Thus, the number of oscillations of a photon as it traverses the same rod in a different location could be considered as the number of events, or ticks of the clock. If space expands in proportion to $\Phi$ but $c$ increases in proportion to $\sqrt{\Phi}$ then the length of the interval of time $dt$, the spacing between ticks, will increase by $\sqrt{\Phi}$. (This implies that the frequency of the oscillation of the photon will be a factor of $\sqrt{\Phi}$ slower, which makes sense if it is thought of as the rotation time in an expanded space.) The spacing between ticks will be larger when the $\Phi$ due to matter is larger, so the relative rate $v'$ at which events in a region of higher $\Phi$ will appear slower when viewed from a region of lower energy density i.e. $(dt/dt')^2 = \Phi/\Phi' = (v'/v)^2 = (c/c')^2 = R/R'$. Time reflects the relative rates at which identical events occur in different regions. Time goes faster when the interval between events (ticks) is smaller. Note the subtle differences here. Under GRT a smaller $dt$ means that time $t$ is going slower when the gravitational potential is more negative so less of a given event occurs (time dilates). Under the revised theory a larger $dt$ means that the interval of time for the same event to occur is longer (time dilates) when the energy density is higher. Under GRT, time going slower means that the number of supposed standard rulers in a given length is larger and so distances appear increased. Under the revised theory it means that the same object becomes longer, so distances actually increase.

The behaviour, in terms of time dilation, of any system having a given energy, momentum and angular momentum should be consistent under the changed distance scale and speed of light, if the system is located in a different region of space. So that, for example, one revolution of the same system, having the same angular momentum and energy, should appear to take relatively longer in proportion to $\sqrt{\Phi}$. The kinetic energy $\frac{1}{2}mv^2$ of mass $m$
will be preserved if the energy content of the mass is proportional to \(1/c^2\) and the normalized velocity \(v/c = dr/dt\) is used. The linear momentum variable that should remain constant for the same amount of energy is \(\vec{p}c = E(\vec{v}/c) = mc^2(\vec{v}/c)\). Hence, normalized momentum defined as \(\vec{p}c = m_i\vec{v}c\) with \(m_i = m_i\) (where \(m_i\) is the inertial mass) should be expected to be the preserved quantity which matches energy. The period for the rotation of the same energy content \((E)\) with the same normalized momentum \((m'v'c' = mvc\) and \(E(v'/c') = E(v/c)\)) will change according to \(dt'/dt = \omega / \omega' = (v/r)/(v'/r') = c'/c\) which is \((dt'/dt) = \sqrt{\Phi'/\Phi}\), as required. The apparent time dilation of events of the same energy in regions of different \(\rho\) is consistent with the revised definition of time. It is also consistent with the conservation of the energy-momentum four vector \((E, \vec{p}c)\). The conservation of the four vector confirms that the formulation maintains general covariance and the theory is Lorentz invariant.

The above behaviour, the consistency of the apparent time dilation, applies to systems between which the ratio of energy density does not change during the time-scale over which the events occur. (The apparent behaviour can be expected to be different if the mass densities change significantly between emission and observation.) However, if the regions are in equilibrium i.e. unchanging with time, then the equivalence principle should hold that the physical laws should be the same once the energy density is taken into account. This is seen to be the case because an identical clock will have the same number of particles and so will have energy and normalized momentum that are both reduced by a factor of \(R/R'\). The same behaviour is observed if distance and the product \(cdt\) are also normalized by dividing by \(R/R'\).

Time \(t\) is now a quantity that indicates the relative rate at which events of the same energy, relative to the background energy, occur. It replaces the GRT concept of “co-ordinate time” that was absolute for all space well away from local gravitational distortions. This makes it clear that “co-ordinate time” is effectively based on the assumption that the
gravitational potential of distant matter has no effect. GRT has actually introduced a sweepingly absolute (i.e. non-relative) concept: the invariant interval of absolute space-time. It is said that, partly for this reason, Einstein and other physicists preferred “invariance theory”, because it involved something that, at its core, was not relative [27].

In a region of constant $\Phi$, the energy of a photon of frequency $\nu$ is $E = h\nu$, from quantum mechanics. If it is assumed that $h$ is constant, independent of $\Phi$, then the relationship indicates that the frequency of a distortion of space (how fast space “vibrates”) that carries the same energy is independent of $\Phi$. However, this appears inconsistent with time varying between regions of different potential, except that time only applies to massive objects. If it is demanded that energy is a meaningful property for both the gravitational potential (energy) of space and the energy of a photon then the value of $h$ must, in some way, reflect the value of the background $\Phi$. In which case, an electromagnetic transition of the same energy should have a higher frequency in a region of space of lower energy density and the same transition in a different region cannot have the same energy. However, it is normally assumed that transitions and energy are unchanged.

5.2 Energy levels and frequency

The revised concept of time and the change in clock-rate at the source means that the frequency and energy levels of the emitter must be different and that the apparent frequency at the receiver will also depend on the change in light speed and scale of space between emitter and receiver. Under GRT the shift in frequency, i.e. the redshift in moving to a higher gravitational potential (e.g. further from the Earth), comes not from the photon but from the energy levels of the atoms, with the levels of the higher emitter/receiver being blue-shifted by an amount equal to the increase in their amount of stored energy, and there is no shift in the frequency of the photons [18, 21]. Under both theories, the energy of a photon, once emitted
is unchanged, but under FRT the scale of space is changed in proportion to $\Phi$ while $c$ and the emitted frequency change in proportion to $\sqrt{\Phi}$ so that $(t'/t)^2 = (dt/dt')^2 = \Phi/\Phi' = (c/c')^2$.

So how can this reduced time dilation and frequency shift be consistent with the apparent time dilation seen in, for example, the Pound-Rebka-Snider experiments? These experiments all appear to be explained by a gravitational frequency shift $\Delta \omega/\omega = \Delta \phi/c^2$, of photons as they move from one region to another. This frequency shift corresponds to $t'/t = \Phi/\Phi'$, if $\Phi = c^2$.

Under FRT, the emitted frequency, at $\Phi'$ relative to $\Phi$, is proportional to $\sqrt{\Phi'/\Phi}$, with a similar shift, $t'/t = dt'/dt = \sqrt{\Phi'/\Phi}$, due to time contraction ($dt' \rightarrow dt$) in moving from $\Phi' \rightarrow \Phi$, so that the total shift appears to be $\omega'/\omega = \Phi'/\Phi$ and $\Delta \omega/\omega = \Delta \phi/c^2$. The total change in $cdt$ is the same in FRT and GRT, but in FRT the change is due to changes in both $c$ and $dt$. The wavelength of light appears to increase (redshift) by $\Phi'/\Phi$, as the energy density decreases, because the scale of space gets smaller. There will be an apparent decrease in the time interval (by $\sqrt{\Phi'/\Phi}$) that it takes light to travel the length of the same ruler because the ruler shrinks by $\Phi/\Phi'$ but $c$ decreases by $\sqrt{\Phi'/\Phi}$. This is consistent with $E = h\nu$ and the frequency appearing to increase by $\sqrt{\Phi'/\Phi}$, because $\nu = c/\lambda$, provided the energy of the photon is unchanged. This in turn implies that $h \propto \sqrt{\Phi'/\Phi}$ so that the product $hc$ is independent of $\Phi$ and with $E = hc/\lambda = h'c'/\lambda'$ being preserved. “Natural units” ($h = c = 1$) can be used across regions in which the scale changes with location provided that the relative scale does not change with time.

If the energy of an electromagnetic transition were the same in all inertial frames independent of the background energy density, then a photon emitted in one frame, that does not gain or lose energy in a gravitational field, will be resonantly absorbed in the other frame,
if the absorber energy levels are unaffected. The different clock rates in the two frames, however, are indicative of the mass and energy levels being different. The shift in frequency seen in the Pound-Rebka-Snider experiments is calculated under the assumptions of constant $h$ and $c$ and ascribed to the blue-shifted energy levels of the atoms (at a higher potential, lower density). This is the same apparent gravitational redshift (of the photon) predicted by the revised theory with $h$ and $c$ varying and the two theories give the same prediction for the shifts in apparent frequency or clock rate.

There is no shift in frequency from the photon losing energy in “escaping” from a gravitational field. This is a mistaken viewpoint [21]. The photon does not lose energy, nor is it “attracted” by the gravitational field; its path is a straight line in the un-distorted space. The change in frequency is because of the change in the scale of space-time and $c$.

Under the proposed theory, the emitted wavelength, for the same spectral line, changes as the ratio of the total $\Phi$s and the emitted frequency changes as the square root of the ratio of $\Phi$s. A particle stores less energy when the background energy density is higher, so all the spectral lines should increase in wavelength (lower energy) when $\Phi$ increases. The energy of the photon, after emission, remains constant while space, and the product $cdt$, expand or contract in going to a region of different $\Phi$. Thus the emitted wavelength is not observed to change. The change exists but is hidden; provided the background level does not change between emission and reception. However, the arrival rate of clock pulses, and hence the frequency ($f$) of the signal, will reflect the increase in clock-rate of $\sqrt{\Phi'/\Phi}$ and apparent increase in the speed of light $\sqrt{\Phi'/\Phi}$, so that clocks at higher altitude (lower density) will appear to run faster by $\Phi'/\Phi$. To repeat; for an approximately constant background $\Phi$, the observer will not see any changes in wavelength of spectral lines with $\Phi$, but there will be an apparent change of $\Phi'/\Phi$ in frequency of the clock at $\Phi$ relative to the same clock at $\Phi'$. 


However, changes in wavelength will appear if the background $\Phi$ is changing over time. In addition, the apparent duration of events of the same energy will increase by the change in the ratio of the $\Phi$s with time. If the universe is expanding, or there is some other mechanism giving a reduction in stored energy density from $\Phi' \rightarrow \Phi$. Then it will be accompanied by an increase in the apparent clock-rate of $\Phi'/\Phi$. The wavelength of emitted photons will get stretched and there will be an apparent Doppler shift of recession of $\Phi'/\Phi$. The change in wavelength (the cosmological red-shift of distant galaxies) does not necessitate movement, but can be attributed to a change in the background energy density with time such that the scale of space changes by $R'/R = \Phi'/\Phi$.

5.3 Energy from matter rather than field

The revised theory has the dimensions of space, time, speed of light and mass dependent on the amount of other matter. The changes in size are relative, in proportion to the relative energy densities. Special relativity has an apparent contraction of objects and dilation of time when an object is moving relative to the observer. It still applies although the magnitude of the contraction and dilation also depend on the amount of other matter because of the change in speed of light and distance scale. GRT is not fully relative, the speed of light is invariant while the change in clock rate produces a change in the “effective velocity” of light and the apparent dimensions of space reduce in the presence of a gravitational field.

The FRT proposal is that space expands by an amount determined by the stored energy density. Space will be expanded about a source of stored energy. The expansion reduces the energy density and the enclosed matter cannot then store as much energy so that an equilibrium is reached. The scale of space will be determined by the total energy density from all sources. The contribution to the local energy density from matter outside the volume will decrease as a source of energy is approached. Particles are stationary states of stored energy, so the energy density near them will be larger and space more expanded. However,
the amount of energy that can be stored in each particle will decrease as the background flux increases.

Therefore, the energy stored as mass varies in a gravitational field. The mass of the same atoms is not constant. It leads to the understanding that when we lift an object higher we need to do work because more energy is being stored in the object as mass. When this object falls under gravity this extra energy is released as the kinetic energy of motion. This is an attractive change in outlook because, under GRT, mass remains constant in a changing gravitational field, although the accelerating mass gains energy from the gravitational field. Therefore, since under GRT all energy is supposed to give rise to gravitational attraction, the field gives up energy but becomes stronger! Under the revised theory, only stored energy (mass) gives rise to gravitational attraction and the kinetic energy gained is equal to the loss in stored energy.

It should be noted that this is in disagreement with GRT where it is assumed that all energy contributes to the gravitational field. Therefore, under GRT, photons give rise to gravity and were a dominant source of gravity in the early universe, and the energy of the gravitational field gives rise to additional gravity so that GRT is a non-linear theory.

If the background energy density increases by $R$ then the size of a local object (of constant energy) will shrink until the energy density at a given surface matches the background energy density. However, the stored energy in the local object will increase. The energy densities will match when the surface area has decreased by a factor of $1/R^2$ and the energy has increased by $R$. This is consistent with stretch (scale) being proportional to the energy density.

The new equation of motion amounts to the gradient of the stored energy density being dependent on the amount and relative motion of all other matter taking into account the time it takes effects to propagate. It still reduces to Poisson’s equation of Newtonian gravity,
i.e. $\nabla^2 \phi = 4\pi G \rho$ but $\rho$, the mass density, is replaced by the equivalent density of stored energy $\Phi / c^2$ with $\Phi$ and $c$ varying. In addition, the scale of space, used in the derivative will also depend on the local stored energy density. (It seems that $G$ will not vary if the reference background density changes because it equates two forms of energy.) The value of $4\pi G / c^2$ will reflect how much the scale of space changes as a function of the change in stored energy. The rate at which the potential can change will be limited by the speed at which any changes in the positions of other matter alter the local energy flux.

The fact that a photon is massless means that it contains no net stored energy in terms of a distortion of space. Only massive objects lose stored energy (mass) as the density of matter increases. Photons do not store energy as mass or give rise to gravitational attraction (as assumed under GRT) and the photon’s (kinetic) energy is unchanged by a gravitational field. However, the energy required to give rise to a photon with a particular wavelength increases as the density of matter increases. A changing flux of stored energy through a surface causes the dimensions of space to change until equilibrium is reached. The changes in dimensions will propagate at the speed of light.

John Wheeler paraphrased GRT as: “spacetime tells matter how to move; matter tells spacetime how to curve”. This idea is retained but is more correctly, but more clumsily, expressed as: “changing space tells matter how to move with time; matter and its movement with time tell space how to change”. The change is an expansion or contraction in the scale of space, not a curve in space-time, proportional to the change in stored energy density. The product of the speed of light and the time interval matches the increase in spatial scale. The invariant interval of GRT is replaced with a relative interval that scales with the stored energy density. The curved space-time of GRT (the metric), which corresponds to a rotation of fixed length in space-time coordinates, is replaced with a simple expansion (or contraction) of
distance scale. The matching expansion is shared equally between the speed of light and the time interval; each depends on the square root of the stored energy density.

6. **Consistency with experimentally confirmed local GRT predictions**

The status of the experimental tests of GRT and of theoretical frameworks for analysing alternate metric theories of gravity have been extensively and systematically reviewed [28]. The first point to make in response is that although FRT is a geometric theory of gravity, it is not a metric theory in the sense of being due to the distortion of an invariant underlying geometry. At first sight, this appears like heresy because it has been noted that: “If the Einstein equivalence principle [EEP] is valid then gravitation must be a ‘curved spacetime’ phenomenon” and that “the only theories of gravity that can fully embody EEP are … ‘metric theories of gravity’ ” [29]. However, FRT claims only that the weak equivalence principle holds and not the stronger EEP because local positional invariance (LPI) does not hold. The magnitude of effects is dependent on the local stored energy density. Physical laws depend on position and are not identical unless the magnitude of their components are adjusted for $\Phi$.

LPI can be tested by gravitational redshift experiments. However, great care needs to be taken in the interpretation of apparent changes in clock rate, frequency and wavelength when electromagnetic radiation is being used, as it may be varying in speed. As set out in Section 5, the two theories give the same prediction for the apparent shifts in time dilation and frequency seen in the Pound-Rebka-Snider experiments.

The next step is to examine how and where a variable $c$ and $ds'^2 = (\Phi' / \Phi)^3 ds^2$ might give different predictions to those of an invariant interval $ds'^2 = ds^2$ with $c$ constant and a distorted metric (i.e. GRT). Firstly, distance, which will vary with the scale of space $R$, is calculated from the return time of electromagnetic signals assuming $c$ is constant and that the local time is $t' = (\Phi / \Phi') t = (\phi' / \phi) t$. Time is assumed faster by just the amount to
underestimate distance by \((\Phi/\Phi')\) so that the scale of space appears unchanged. Secondly, assuming \(c\) constant, but that the “effective velocity” is distance divided by time, overestimates the actual velocity by \(\sqrt{\Phi/\Phi'}\) while assuming \(t'=(\phi'/\phi)t\) overestimates \(t\) by \(\sqrt{(\Phi/\Phi')}\) so that \(c\Delta t\) is overestimated by \((\Phi/\Phi')\), or underestimated by \((\Phi'/\Phi)\). The result is that \(ds'^2\) appears to be \(D^2-c^2dr^2\), where \(D^2=dx^2+dy^2+dz^2\), i.e. the magnitude of the interval appears invariant because of the assumptions made. However, the actual interval is \(ds'^2=(\Phi'/\Phi)^2D^2-(\Phi'/\Phi)^2c^2dr^2\). Assuming \(ds'^2=D^2-c^2dr^2\) and equating this with \(g_{\mu\nu}dx^\mu dx^\nu\), under GRT, means that the observed changes in time \(t'=(\phi'/\phi)t\) must be compensated by inverse distortions of distance so that the magnitude of the determinant of \(g_{\mu\nu}\) is 1. For \(D=0\), GRT has \(g_{00}=-(1+\Delta\phi/c^2)^2\). This corresponds to \(-(\Phi'/\Phi)^2\) if the energy density increases (i.e. the potential \(\phi\) decreases) as a massive object is approached.

The magnitude of the distance term of the apparent metric, that multiplies \(D^2\), will be the inverse of the magnitude of \(g_{00}\) i.e. \((\Phi'/\Phi)^2\). Hence, the predictions of the revised theory match those of the curved metric of GRT, at least when changes in \(\Phi\) are small relative to the mean and while the \(\Phi\) is not varying with time. In addition, the path of the light expands and contracts according to the local \(\Phi\) so the changes in scale of space at the source are invisible, but the path of light that passes near a massive object will be longer and so will appear bent.

The predictions of the two theories are the same if changes are small and the magnitude of the \(\Phi\) is the same as that observed locally. This equivalence extends to the angular deflection, precessions and time delays predicted by GRT. The two theories are not easily distinguished locally unless the differences in total potential are large or a parameter such as the speed of light can be measured with an accuracy better than \(\Delta\phi/\Phi\). However,
the magnitude of gravitational lensing, velocities and clock rates when compared across regions or timescales with a large variation in $\Phi$ will be observed to vary.

The revised theory will be in agreement with all the standard predictions of GRT in the region of our solar system because the apparent distortions of the curved metric of GRT are reproduced. The increase by a factor of two in the bending of light predicted by Einstein, over the pre-GRT calculation, is easily reproduced and has a clearer explanation. The standard GRT calculation of the bending of light is to use the Schwarzschild line element. This element is determined from the solution to the Einstein Field Equation found for space-time exterior to a spherically symmetric mass distribution. It has the form:

$$ds^2 = \left[1 - \frac{2GM}{rc^2}\right]c^2dt^2 - \left[1 - \frac{2GM}{rc^2}\right]^{-1}dr^2 - r^2\left(d\theta^2 + \sin^2\theta d\phi^2\right)$$

For the GRT calculation of the deflection of light by the sun and the calculation of the Shapiro time delay, the value of $ds^2$ is set to zero and the last term is ignored. The first term on the right corresponds to an apparent slowing of the velocity of light because a gravitational field makes time run slower. The second term, the new term over the pre-GRT calculation, corresponds to an apparent contraction in the length of the path travelled of approximately the opposite amount to the dilation in time. The presence of two terms involving $2GM$ leads to an expression for the angle of deflection ($\delta\phi$) of:

$$\delta\phi = \frac{4GM}{c^2r_{\text{min}}},$$

where $r_{\text{min}}$ is the distance of closest approach.

In the revised theory, a $2GM$ term in $dr^2$ or $c^2dt^2$ corresponds to $(\Phi' / \Phi)$ in $dr$. The first $2GM$ dependence of the angle of deflection arises because there is a $\Phi' / \Phi$ increase in distance (and the product $cdt$). The second $2GM$ factor arises because the angular position of the distant light source (e.g. of stars) is being compared with and without the presence of the
intervening massive object (e.g. the sun). The massive object expands space by $\Phi'/\Phi$ so that space is expanded perpendicular to the path of the light ray as well as along the path.

The terms involving $GM$ come from $\nabla \phi = GM / r^2$ and so incorporate the local values of $M$ and $r$. The gradient in potential $\phi$ will be less if the background stored energy density is larger. However, the amount of energy corresponding to mass $M$ will also decrease with background stored energy. The mass (change in energy stored per unit change of background distortion) and distance scale both change with the background $\Phi$, and the expression should be independent of $\Phi$ (when comparing regions in which $\Phi$ is not changing with time). So the value of $G$ would seem to be the proportionality factor between scale of space and energy, and independent of the region of space. The Newtonian and GRT predictions hold across regions if both sides of the equation have the same dependence on $\Phi$. However, unbalanced expressions, such as the lensing formula above, will reveal dependencies on the local $\Phi$.

It needs to be appreciated that because electromagnetic signals are used to measure distances of faraway objects then differences in the speed of light and dimensions of space are hidden (unless comparisons between different $\Phi$s, e.g. via gravitational lensing, can be made). Only differences in clock rates or differences in the magnitudes of gravitational effects (per particle) may be observed. Secondly, if the differences in $\Phi$ are small relative to the background $\Phi$ then the predicted differences in clock rates are nearly the same. However, GRT and the revised theory will give different predictions for the magnitudes of angular deflections and apparent motion (velocities) of matter in regions where the $\Phi$ is significantly different. The last statement applies, for example, to a known amount of matter moving to a different region. It does not apply to objects of the same mass in different regions (different amounts of matter) unless the clock rate or speed of light can also be compared.
So, how should the differences in mass, distance and the speed of light show up in observations of our solar system? For objects gravitationally bound to a large central mass we know that Newton’s inverse square law 

\[ F(r) = ma = m\ddot{\phi} / \dot{r} = GMm / r^2 \]

holds accurately in the limit of low velocities. If the local variation in potential reflects the distortion due to the central object then it should vary according to \( M / r \), although the scale of \( r \) will change if the \( \Phi \) changes (and the central amount of distortion by a given amount of stored energy will be lower in a region of higher background \( \Phi \)). If acceleration reflects the slope of the distortion of space then, in any region, it should be proportional to the rate of change of the total distortion with distance. The force law appears to hold accurately because 

\[ m' / m = (c / c')^4 \]

and 

\[ (R' / R)^2 = (c' / c)^4 \]

so that the radial contraction in the scale of space \( R' / R = \Phi' / \Phi \), which is not visible (but alters the value of \( 1/r^2 \)), is cancelled by the change in mass of an object with a constant number of particles. Acceleration is the rate of change of velocity with time which introduces a dependence of the acceleration on the \( \Phi \) but the effect is cancelled by using the apparent distance (rather than the contracted distance).

Force is the rate of change of momentum with time. If we are to compare regions then we need to compare the effect of normalized momentum per unit of normalized time, i.e.

\[ F = \frac{dP}{dt} = \frac{d(Pc)}{cdt} = GMm / r^2 \]

The right hand side is independent of the ratio of \( \Phi \)s and so Newtonian behaviour will be observed within a region and across regions if the local time is used (and \( G \) is constant).

The lack of variation of \( G \) inside a sphere containing different uniform densities of matter can be confirmed as follows. The \( 1/r \) dependence of the local gravitational potential, 

\[ \phi = -GM / r \]

means that an infinitesimally thin shell of matter, in an otherwise empty space, will produce a uniform constant expansion inside the sphere (\( \propto 4\pi rpd\tau \)). In the limit of a uniform density, a stretch proportional to \( r \) (i.e. an increase in \( r \) from \( R_1 \) to \( R_2 \)) reduces the
volume by \(1/r^3\), so that the ratio of the matter densities, i.e. the densities of particles is

\[
\frac{N_2}{N_1} / \left( \frac{R_2}{R_1} \right)^3 = \frac{E_2}{E_1} / \left( \frac{R_2}{R_1} \right)^2 = \frac{M_2}{M_1} / \left( \frac{R_2}{R_1} \right) .
\]

This is consistent with the ratio of the potentials being \(G_2M_2R_1 / G_1M_1R_2\) if \(G_2 / G_1\) is constant.

The value of the gravitational constant relates the inertial mass to the gravitational mass. This ratio is fixed according to both GRT and FRT. The individual terms in Newton’s equation will vary with \(\Phi\) but the combinations of terms on both sides of the equation are independent of \(\Phi\). Therefore, FRT and GRT are both consistent with the various tests that indicate that \(G\) does not vary with time [30].

7. **Advantages of the revised theory**

7.1 **The avoidance of singularities and black holes**

The revised formulation relates the distortion in the dimensions of space to the amount of matter relative to the background density of matter. In the limit of a very high density of matter the gravitational mass (of a given amount of matter) will tend to zero, which has the attraction, along with other variable mass theories [31], of removing the singularity at the centre of a black hole. In fact, the understanding that photons do not lose energy in a gravitational field also removes the blackness of black holes. The wavelength of a photon of a given energy will appear to increase (because space contracts as the photon moves away from a concentration of matter) but this is not observed because the wavelength of the emitted photon for the same transition is lower. Time, at the source, appears slower to the distant observer so that the observed number of photons per unit time tends to zero, but light can still escape. The frequency of light and passage of time will be slowed enormously but will not be stopped by increasing energy density. There is no event horizon from inside which light, and gravity, cannot escape.
It is not being claimed that gravitational collapse does not occur, for example, when a white dwarf star exceeds a critical density it can, presumably, still be compressed into a neutron star. The gravitational pressure will start to level off with increasing background energy density because more energy is needed to achieve the same fractional increase in $\Phi$. The electron energy levels will also decrease as the density of surrounding matter increases but the ratio of the dimensions of the electron wavefunction to the nucleon wavefunction might be expected to be constant. At extreme densities gravitational interactions will tend to zero so, beyond a neutron star, the object should not collapse to a singularity. However, the nature and properties of the substance at such extreme energy and pressures is unclear.

Einstein argued against the existence of black holes in a paper of 1939 [32]. In light of the revised theory it seems hard to understand how they have become so widely accepted. If the clock-rate goes to zero at the event horizon then there can never have been enough time for any matter from our current universe to have crossed the horizon since it formed. Therefore, they could not have grown in size since they formed. It does not matter that an observer moving with the matter would not have seen the horizon, as far as we are concerned they would still not have reached it. Any radiation from matter that has approached the purported black hole horizon should also be very strongly shifted to longer wavelengths (according to GRT) and spread over a long time so that the black hole should be characterised by an infra-red glow.

Under GRT, the mass of an object does not change in a gravitational field but the object gains kinetic energy and this kinetic energy contributes to the gravitational field. Hence, if an object reaches the event horizon it has gained kinetic energy equivalent to the energy stored as mass ($E_0 = mc^2$) but lost none of its stored energy. Therefore, the energy must have come from the gravitational field, yet this field is now stronger!
Moreover, black holes, as currently conceived under GRT, cannot maintain an existence. As soon as the force is sufficient to prevent light from escaping then gravity would also be prevented from escaping. The gravitational effect of the matter inside the horizon would disappear. The effect would be analogous to punching a hole in the rubber sheet. The distortion of space would disappear at the speed of light, just as the rubber sheet would snap back to an undistorted configuration. The distortion and force due to matter (or charge or the colour of the strong interaction) moves with the matter (or charge or colour) and a change in distortion or force propagates at the speed of light. If the matter disappears behind a horizon then so must any distortion or force. To be otherwise would be inconsistent with our understanding of forces in terms of the exchange of virtual particles.

The cosmological singularity in the early universe is also avoided as mass tends to zero at high densities. This possibility for variable mass theories has been pointed out previously [33] and, more recently, a formulation based on GRT but with rest mass decreasing with gravitational potential has been used to suggest the non-existence of black holes as light can always escape [34].

Huge matter concentrations should have occurred in the early universe and these would have undergone gravitational collapse, at least to neutron “stars” once their fuel was burned. However, the evidence that these are black holes, i.e. have collapsed behind a horizon from which light cannot escape, is all indirect. The purported evidence appears to be: i) the need to explain the energy generation mechanism of active galactic nuclei or quasars, ii) the rotation of stars about an unseen object near the centre of our galaxy, iii) the limited and non-periodic nature of emissions from “invisible” binary companions above a certain mass, and iv) indirect arguments that only a limited range of spins are observed. The first two arguments do not establish that collapse beyond a horizon, or to a singularity, has occurred only that there is a very compact source.
The masses and orbital parameters of stars in binary systems that include a pulsar can be calculated. It is found that pulsars have masses close to the Chandresahkar limit and binary companions of greater mass do not show pulsations. The pulsations are attributed to the rotation of the hot spot at each magnetic pole past the line of the observer. The hot spot arises because the magnetic field channels charged particles towards the poles. It is argued that neutron stars above a certain mass must collapse to black holes and that such objects do not have a surface and so cannot show periodic fluctuations. The lack of heavy pulsars is therefore taken as strong evidence for black holes.

If, however, there is no magnetic field, then there will no longer be pulses. Current theories for the nature of matter at higher densities than can be sustained by Pauli Exclusion of neutrons include "colour superconductivity" [35]. There are several such arguments or models that suggest that, above a certain density, such matter would exclude a magnetic field (as with ordinary superconductivity). This would not remove the surface (as with a black hole) but would, presumably, remove the hot spot because there would not be magnetic poles.

The arguments for all purported black holes having spin between 0 and 1 make many assumptions about e.g. the constancy of mass, c etc.. It seems likely that the revised theory would invalidate the assumptions but it is desirable that the arguments be re-examined.

7.2 No need for dark energy

The most obvious change in matter distribution with time is the apparent expansion of the universe. As a result the speed of light will have slowed, the scale of space will have decreased and time (the clock rate) will have increased (time intervals will have decreased) as the universe has expanded. Currently, the observed redshift of the wavelength \( \lambda \) of light from distant galaxies is interpreted as the apparent increase in the size, or scale of space, of the universe between when the light was emitted \( R \) and received \( R_0 \). This leads to the prediction that \( R_0 / R = 1 + Z \), where \( Z = (\lambda_{\text{rec}} - \lambda_{\text{em}}) / \lambda_{\text{em}} \).
Under the revised theory, if the background (reference) $\Phi$ is constant, then changes in the scale of space with distance are invisible in terms of wavelength shifts. Therefore, changes in wavelength must be due to relative motion of the emitter and receiver, or to an apparent change in distance with time due to a change in the overall $\Phi$ with time. (However, changes in time between locations with different $\Phi$s can be observed.) If the background $\Phi$ is decreasing with time, then the distance scale is decreasing. This change in distance will lead to a redshift in wavelength as a function of distance, while the difference in clock-rate will also reflect the difference in static $\Phi$.

If the stored energy density has decreased over the time, between emission and reception, by $R/R_0$, where $R$ is the scale of space at emission and $R_0$ at reception (and $Z=(R-R_0)/R_0$), then the speed of light will have been higher, $c=c_0\sqrt{1+Z}$ and the time dilated by the same factor, so the apparent amount of radiated energy per unit time will be reduced by a factor of $1+Z$. The luminosity (energy per unit time) of a star (of constant energy) in a region of higher $\Phi$ will be lower by $R/R_0$ because time was running slower and the frequency gets shifted lower. However, the effects cannot be observed unless the energy of the star can be determined (and energy levels depend on the background energy density).

For type 1a supernovae, the total amount of energy released (area under the light curve) appears to be approximately constant, although brighter supernovae increase and decrease in brightness slightly more slowly than fainter ones. However, when time scales of individual light curves are stretched to fit the norm and the brightness is scaled according to the stretch, then most light curves match [36, 37]. It seems that this can be explained under the revised theory. The energy needed to compress electrons into nuclei is determined by the electromagnetic interaction. Electromagnetism is gauge invariant and therefore does not depend on the background density of surrounding charge, but the distortion of space by an
individual particle and the amount of energy each particle stores do depend on the background density of matter. The needed amount of energy per particle should decrease in proportion to $1/\Phi$. However, the needed number of particles for a given distortion increases as $\Phi$. So the total gravitational energy needed to cause such a collapse should be constant. Most of the light emitted, after the explosion, is due to the decay of radioactive nuclei synthesized in the explosion and the rate of light emission will depend on the $\Phi$ after the explosion. The apparent rate of decay of the light curve will depend on the clock-rate apparent $(c \Delta t)$ and so the width will increase with increasing $\Phi$ but the number of particles available to decay will match the increase in width. The light curves of supernovae should therefore scale to the same brightness, when stretched so that the timescales of the light curves match.

The apparent brightness (corrected for rate of decay) will reflect the distance in terms of current dimensions (the variation in the light path with $\Phi$ hides any variation in the apparent magnitude). However, if the background $\Phi$ has reduced over the time in which the light was travelling, the distance scale will have reduced so that past wavelengths will appear longer and past distances will have been greater. The apparent luminosity distance will be increased by a factor of $Z(1+Z/2)$ due to the integrated increase in path length.

The Union 2.1 data [38] for type 1a supernovae in terms of the distance calculated from the luminosity versus the redshift, $Z = \Delta \lambda / \lambda = \Delta R / R$, is given in Figure 2. The distance is first plotted against $Z$, then against $Z(1+Z/2)$ which allows for the increased distance scale at earlier epochs. If the scale is decreasing with time then the distance that the light had to travel becomes progressively larger (going back in time) and the change in scale has to be integrated. A linear fit (red line) shows a constant slope and so removes all indication of the lower than expected brightness that necessitated the hypothesis of an accelerating expansion and the need for dark energy.
Fig. 2. Type Ia supernovae data [38] for luminosity distance versus raw (Z) and corrected
(Z(1+Z/2)) redshift distance scale.

Normally, the supernovae data are plotted assuming a linear velocity-distance law
which applies quite generally in expanding and isotropic models under GRT [39]. In this
case, “… spatial homogeneity and isotropy imply a preferred (universal) space, and the time
invariance of homogeneity and isotropy implies a preferred (cosmic) time. In the co-moving
frame, space is isotropic, receding bodies are at rest, and peculiar velocities have absolute
values” [39].

The revised theory reveals that co-moving coordinates amount to the faulty
assumption that a uniform background density of matter has no effect. The linear velocity-
distance law is based on the assumptions of GRT including constant c, and leads to recession
velocities that exceed the speed of light. The invariant Robertson-Walker line element
corresponds to the assumption of an invariant rate of (cosmic and proper) time. These assumptions must be rejected and instead distance versus redshift (adjusted to compensate for the changed distance scale) should be plotted, as done here. It applies to a homogeneous universe that expands and contracts to match the local energy density between regions.

The constant slope (Figure 2) indicates that, once the distance is corrected for changes in the reference energy density with time, the underlying physical laws are constant and the fractional rate of change of energy density is approximately the same for all regions at a given epoch when averaged over the directions to the supernovae. Most of the scatter appears to be within measurement errors (not shown) but some additional variation might be attributable to a lack of homogeneity and isotropy, particularly in relatively recent times, (having grown since the relative uniformity at the time of emission of the cosmic microwave background), or over the nearer region of space.

WMAP data also provide information about dark matter and energy independent of supernovae results. The data are consistent with a flat universe to better than 1% [40]. A fit to the data using the ΛCDM model (based on GRT) then gives the percentage of baryonic matter as 4.56%, cold dark matter as 22.7%, and the rest as dark energy. The WMAP data suggests that the universe is spatially flat so the value of the Hubble parameter in the conventional formulation of general relativity has been used to determine that it has a critical density of 9.30 x 10^{-27} kg/m^3, using \( \rho_c = 3H_0^2 / 8\pi G \) [41]. However, under the revised theory the universe is necessarily flat and the apparent (fractional) rate of expansion \( (H_0) \) is observed to have a fixed relationship to the energy density.

The scale of space for the current energy density is half what it was at a redshift of 1. The corrected luminosity distance (in current units) to a supernova that exploded when the energy density was twice the current density (redshift of 1) is 4549 Megaparsec (1.40 x 10^{26} m) from a linear fit to Figure 2. The length scale was double that now for objects for which
the light has travelled 6824 Megaparsec ($2.11 \times 10^{26}$ m) or $1.40 \times 10^{26}$ m (in distance units that expand with the scale of space). It seems that this should correspond to the distance scale for the current energy density because this is the change in distance when the current energy density increases by the current amount (i.e. doubles). The rate of change of distance with stored energy is a measure of the distortion of space and so of the strength of gravity. Therefore, the slope of the supernovae data should be related to the value of the gravitational constant and the current speed of light squared. The ratio, i.e. $4\pi G / c^2$ or $9.33 \times 10^{-27}$ m/kg, is dependent on the inverse of the current $\Phi$ and should reflect the change in distortion (distance scale) as a function of the energy density. A rigorous argument is needed that demonstrates the data is consistent. The value of $G$ should be predictable from the supernovae data.

7.3 *No need for Cosmological Inflation*

The proposed phenomenon of inflation, the extremely rapid exponential expansion of the early universe, was hypothesized to explain the uniformity of the cosmic microwave background radiation and flatness of space. The rapid expansion of scale (faster than the supposed constant speed of light!) meant that widely spaced regions could have previously been causally connected and in thermal equilibrium and therefore uniform. Under the revised theory, masses are smaller, time is slower and the speed of light faster, as you go back in time to when the universe was more dense. Therefore, the amount of matter which was causally connected increases in the past and the time available for it to occur also increases. The flatness problem arose because, under GRT, any gravitational attraction increases curvature and therefore drives the universe away from flatness (zero curvature). An accelerating expansion pushes the universe back towards flatness. In addition, under GRT, a flat universe requires the mass/energy density of the universe to be equal to the critical density. However, it appeared to be a remarkable coincidence that this was the current value. Under FRT there is
never any curvature. There can be stretching in each direction but no rotation or transformation between different dimensions. There is no need to postulate cosmological inflation.

The current very slowly changing level of energy density may arise because, when space expands, the speed of light and passage of time slow and any change in the energy density takes longer to propagate. The constant slope would seem to reflect a linear relationship between the scale of space and the energy density. Going back in time the energy density was averaged over a larger amount of matter, so the luminosity/distance relationship should tend to a constant gradient but may move away from this value if the average density of the local region is not representative.

7.4 No need for dark matter

The initial evidence for dark matter was from the rotation curves of galaxies and then from gravitational lensing [3]. Calculations of the expected effects assume that the mass to matter ratio and speed of light are the same as locally observed, and together with the clock rate are independent of the amount of other matter present. None of these assumptions is correct. The matter to luminosity ratio should also increase as the amount of other matter present increases because the clock rate will decrease. The effects appear to be of the correct form to explain the anomalous rotation curves of galaxies and the amount of gravitational lensing of clusters of galaxies without the need to hypothesize dark matter halos.

According to Newtonian mechanics the velocity of rotation should decrease as $1/\sqrt{r}$ in moving away from a large central concentration of matter. However, the Newtonian velocity is calculated assuming that the distance and time scales are independent of the gravitational potential, i.e. that $c$ is constant. The velocities are actually measured using the relativistic Doppler shift $\frac{\omega'}{\omega} = \sqrt{1 - \frac{\beta}{1 + \beta}}$ or $\frac{\Delta \omega}{\omega} \approx \frac{v}{c}$. The measured velocity will then be the
Newtonian velocity multiplied by $\sqrt{\Phi'/\Phi}$, or approximately $\sqrt{r}$ if the potential giving rise to the gravitational attraction is decreasing as $1/\sqrt{r}$. The net effect is that the velocity curve will appear to remain approximately constant, in the region outside the central concentration of matter.

It is observed that the rotational velocities of the stars and gas in spiral galaxies are constant out to great distances [42]. It is also observed that galaxies with a uniform distribution of luminous matter have a rotation curve which slopes up to the edge. These observations are consistent with the above explanation. In general, the dependence of $c^2$ on the $\Phi$ means that for all concentrations of matter a dark matter halo will need to be inferred to explain the rotation of galaxies or the amount of gravitational lensing under the assumption of constant $c$. This might then explain the scaling relation between the size and density of galactic halos [43].

The distribution of radiation, visible matter and mass as deduced from gravitational lensing in colliding galaxy clusters has been used as strong evidence for the existence of dark matter [44, 45]. This needs re-examination not only because the revised theory will yield a different determination of matter distribution but also because, in the revised theory, the number of particles for a given mass decreases with decreasing $\Phi$ and so the estimates of the density of interacting gas may need revision. It appears that much more of the matter may reside in the galaxy cores than the gas, as indicated by the data.

A key confirmation of the revised theory would be if the observed gravitational lensing by galaxy clusters can be explained without the need for dark matter. The bending of light will be approximately in proportion to the square of the energy density i.e. to the change in scale of space along and across the light path. However, this must be estimated from the distribution of the galaxies in a cluster and an understanding of how their size and brightness
vary with energy density. The calculation of the predicted bending and how this may be tested against the observed bending by galaxy clusters is set out in Section 8.3.

Additional evidence of the need for dark matter has been that the estimated baryon density is insufficient to account for the observed elemental abundances of Big Bang nucleosynthesis and WMAP data [3]. However, both these calculations need revision if the masses and hence interactions are dependent on the background energy density.

7.5 Tully-Fisher relationship

An empirical relationship between the intrinsic luminosity \((L)\) and rotational velocity (amplitude of the rotation curve \(W\)) of spiral galaxies has been observed [46]. The relationship \(L \sim W^4\) applies over several orders of magnitude. Since the intrinsic luminosity is inherently independent of dark matter, but dark matter should have an effect on the rotational velocity, the relationship is actually evidence that dark matter does not exist. The relationship appears to be explicable by the revised theory. The amplitude of the rotation curve reflects the value of the speed of light for a given apparent distance from the centre of the galaxy. If the increase in \(\Phi\) (above background) of a galaxy is determined by the matter in that galaxy then a doubling of luminosity implies a four-fold increase in the size of \(\Phi\) (relative to the background \(\Phi\)) for a given apparent distance from the centre of the galaxy. Since the apparent \(W\) should be proportional to \(\sqrt{\Phi'/\Phi}\), it follows that \(L \sim W^4\).

7.6 Possible explanation for the lack of anti-matter

It has been argued that the presence of anti-matter galaxies, or a similar amount of anti-matter to matter, should be expected from the initial symmetry between matter and antimatter. The first point to note is that it seems that the contents of both matter and anti-matter galaxies would be repelled from the boundaries. This is because the masses and dimensions of all particles would grow enormously near a boundary and events would appear to occur much more rapidly. As a result, stars emitting the same energy would be made up of
far fewer atoms and would finish their life-cycles much more rapidly. More importantly, any particle approaching the boundary would have its momentum (and kinetic energy) in the direction of the boundary, converted to potential energy (mass) and so would be deflected away from the boundary at a rate determined by the gravitational attraction. There would therefore be an apparent pressure near the boundary repelling the contents of matter galaxies from anti-matter galaxies and vice-versa. This would seem to push regions of matter and antimatter apart but it would also seem to remove any annihilation signal that would flag a boundary between matter and anti-matter.

A second point to note is that, in a region dominated by matter, a concentration of additional matter increases (expands) the local scale of space, whereas antimatter decreases (contracts) the local scale. The symmetry between matter and anti-matter should therefore not be exact within a region of matter. The symmetry should have been more exact in the past when the stored energy density (we observe) was higher.

7.7 Consistency with quantum mechanics

The revised theory removes the apparent inconsistency between quantum mechanics and general relativity at very small length scales. The inconsistency arises because the uncertainty principle indicates that, at very short distances and times, the available energy can be very large. Under GRT this energy corresponds to a large mass which, because the theory is non-linear, induces such a severe warping of space that a “quantum foam” results [47]. However, if only stored energy corresponds to mass and if, when the stored energy increases, the dimensions of space also increase and mass and time decrease then the infinities do not occur.

The identification of stored energy with a net distortion in the dimensions of space that is proportional to the stored energy relative to the background energy density, seems to have the potential to provide an understanding of the Schrödinger equation, i.e.:
\[-i\hbar \frac{\partial \psi(x)}{\partial t} = H\psi(x),\] where the Hamiltonian $H$ is the total stored energy. An oscillation in the stretch of space that carries energy $H$ will have frequency $\omega$, just like the photon, with the maximum of stretch being $\pi/2$ out of phase with the maximum rate of change (i.e. the total energy will be the stored potential energy when the kinetic/momentum component is zero). The units of stretch are the same as the units of space which explains the presence of the spatial coordinate $x$ as the size of stretch rather than the spatial extent of the wave function. A stationary state, a particle, might then have a fixed central location but a cyclic pattern of distortions in three dimensions. The direction of its angular momentum should be fixed, in the absence of an external torque, because of conservation of angular momentum. This seems to be the start of an explanation of why the wave function is complex and can be dispersion free. A particle is a time stationary state (total energy constant but with the components varying) and could consist of both expansions and contractions about the mean (background) expansion with matter having a net expansion greater than the mean and antimatter having a net contraction relative to the mean. A particle (e.g. an electron), with only spin angular momentum, would be a 3-dimensional standing wave with a rotating expansion/contraction about an axis with a constant orientation in space.

The form of the Schrödinger equation is also consistent with $h \propto 1/c$ (see Section 5.2) so that: 
\[-i \frac{\partial \psi(x)}{c \partial t} \propto H\psi(x),\] with the left hand side having no dependence on the energy density (if $\text{d}x = c\text{d}t$) and if the scale of the amplitude of the wave function (right hand side) is inversely proportional to the energy density. This would also appear to be consistent with the Uncertainty Principle, which reflects the wave nature of matter. The uncertainty ($h/2$) will reduce as the surrounding energy density (proportional to $c^2$) increases.
7.8 **Consistency with Mach’s principle**

If there is no shell of surrounding matter, and no uniform background density of matter, then the distance scale goes to zero except near the only massive object(s). The distortion of space becomes enormous but is confined to the region of the object. A system having the same angular momentum will rotate faster in proportion to $1/\sqrt{\Phi}$. Therefore, for the same speed of rotation, the angular momentum will tend to zero as the background $\Phi$ tends to zero. So the energy and momentum for a given rotation speed of any system tends to zero as the amount of background matter tends to zero. The behaviour of matter is then relative to the presence of all other matter and the proposed theory would appear to be fully relative.

8. **Testable Predictions**

Under the revised theory, gravitational redshifts cannot be directly observed as shifts in spectral lines. The differences in the emitted wavelength of light, between inertial frames at different potentials, exist but are hidden if the frames have equilibrated (i.e. there is no change in the background potential between emission and absorption). The emitted wavelength and energy of light will depend on the potential but the wavelength will expand or contract as the potential changes. The experimentally determined gravitational redshifts are shifts in time (and hence frequency), rather than wavelength, and are based on the assumption that the energy of a given transition is constant. They are in good agreement with GRT [48, 49], but the apparent shifts in clock rate and frequency are the same for FRT and GRT.

The invisibility of gravitational redshifts in wavelength is consistent with a review of shifts in solar spectral lines [54] which found that the shifts could be entirely explained by solar convection, but not consistent with several other studies, notably by LoPresto *et al.* [50]. However, an examination of this paper suggests that the spectral line data have been adjusted using data on relative motions to determine an apparent frequency shift at the solar surface.
This data incorporates assumptions about shifts in time and the constancy of the speed of light and so the procedure needs to be carefully investigated. A large gravitational redshift in spectral lines should also be present in white dwarf stars (or near the horizon of a black hole) under GRT, but the general consensus appears to be that any gravitational shift is potentially confounded by other effects [51].

8.1 Supernovae light curves

An observable consequence of significant changes in the \( \Phi \) (and therefore matter to luminosity ratio) in the region of galaxies is in the light curve of type Ia supernovae (at all \( Z \)). The collapse from a white dwarf is understood to occur when the gravitational pressure exceeds the resistance from electron degeneracy. The total luminosity (energy released), should be determined by the gravitational energy needed to overcome the electron degeneracy and so should be approximately constant. The number of decaying particles and the apparent rate of their decay will depend oppositely on the local \( \Phi \) and this can explain why supernovae light curves can fit a distribution that normalizes the brightness according to the rate of decay [36, 37]. It should be that slower decaying supernovae are found closer to the centre of larger galaxies. It has been observed that SNe Ia occurring in physically larger, more massive hosts are \( \sim 10\% \) brighter, but this was after using the light curve to adjust the brightness [52]. However, if the background \( \Phi \) is large then the variation in \( \Phi \) within a local concentration of matter is smaller. This could mean that the total stored energy has to be slightly larger before compression of the core causes collapse to a neutron star. Thus supernovae nearer the centre of larger galaxies might have more matter and correspond to a larger Chandresahkar limit. This seems to have been observed [53]. This variable limit, dependent on the background \( \Phi \), could explain why white dwarfs without a companion from which to gain mass can exceed the limit; because of the expansion of the universe or movement into a region of lower energy density. It would seem that the uncorrected
brightness should correlate with the background $\Phi$ and therefore with the radial position of the supernova within the host galaxy. Some evidence has been seen for the decay rate being correlated with the morphology of the galaxy [37], but it is not known if the uncorrected brightness has been plotted against radial position or an estimate of the local energy density. However, progenitor metallicity, stellar population age, and dust extinction all correlate with galaxy mass and position in the galaxy, so the observations are unlikely to be a clean test of a revised theory.

Cepheid variables might also allow a mapping of the $\Phi$. Their luminosity is closely related to their period of oscillation, with longer periods corresponding to higher luminosity. A larger $\Phi$ will lead to a slower passage of time and so to a lower luminosity and increased period. However, the number of particles per unit of mass will also change. The mechanism for variations in period with luminosity might lead to a difference between the observed and expected luminosity for the observed period that depends on the local $\Phi$. This would show up as a shift in the luminosity-distance relationship to lower brightness for Cepheids closer to their galactic centre but would be difficult to distinguish from effects due to increasing dust (reddening) and metallicity.

8.2 Change in distance scale due to the expansion of the universe

If the universe is expanding then the density of matter is decreasing and so the scale of space should be decreasing. The number of wavelengths to a distant stationary object will not change but the speed of light will slow so the elapsed time will increase and not as many wave-fronts will return in a given time, so the apparent frequency (of a signal sent to the distant object and back) will decrease.

The rate of contraction of the distance scale can be calculated from a fit to Figure 2. A linear least squares fit (weighted by the quoted error on each point) indicates that the distance travelled by light (in current distance units) in the time that the dimensions of the universe
have doubled ($Z=1$) was 4549 Megaparsecs. So the current fractional rate of expansion of time should be $\sqrt{2c}/(1.40 \times 10^{26})$ or $3.02 \times 10^{18}$ per second. Therefore, if an electromagnetic signal is used to measure distance by a signal received and sent back at approximately the same frequency (locked to the received frequency) then the observed frequency should be uniformly decreasing by an amount $\Delta f / f$ of $3.02 \times 10^{-18}$ s/s².

The Pioneer spacecraft have been observed to have an anomalous deceleration towards the sun of approximately $8 \times 10^{-10}$ m/s² based on a steady downwards drift in frequency of approximately $6 \times 10^{-9}$ Hz/s or 1.51 Hz in 2.11 GHz in 8 years or $2.84 \times 10^{-18}$ s/s² [54]. A more recent analysis has suggested that the anomalous deceleration has been decreasing with time [55], and that the deceleration can be explained by the selective radiation of heat energy in the direction away from the sun [56]. However, it seems that the observed drift in frequency may be fully explained by a change in the scale of space with time. An examination of the thermal modelling shows that the heat radiation comes from two main sources; the radioisotope thermoelectric generators and the waste heat from the electrical equipment. The sources have opposite effects and could be adjusted to nearly cancel. Therefore, it seems possible that thermal radiation is not the explanation, but this needs to be examined by those who have done the modelling.

However, it should also be possible to test for this variation in clock-rate, as the energy density of the universe decreases, using Earth-based experiments. A very high frequency electromagnetic signal could be sent around a large loop and amplified at each pass such that the output signal is locked to the input signal. This should provide a reference frequency that is fixed according to the clock-rate at the time of initial emission, provided the time spent in amplifying the signal is short relative to the time between amplifications. This reference frequency should appear to drift to lower frequencies (compared to a stable clock next to the loop) at the rate predicted from the supernovae data, i.e. $\Delta f / f$ of $3.02 \times 10^{-18}$ s/s².
The acceleration of the Earth’s surface due to rotation and its orbit will alter the clock-rate, but most such effects should be periodic and average to zero. In addition, a signal could also be sent in the opposite direction around the loop.

8.3 Gravitational lensing

The apparent bending of light is due to the change in scale of space along and across the line of sight. The change in scale is proportional to the stored energy density. However, the expansion is not directly visible because the path of the light, and therefore the apparent dimensions, expands and contracts to match the local stored energy density. The scale must therefore be deduced from the apparent matter distribution.

It is necessary to determine the scale (or \( \Phi \)) because the bending will depend on the total length along different paths. The scale should have a \( 1/r \) dependence on distance from an isolated point source (e.g. single compact galaxy in a uniform background \( \Phi \)), but the hidden change in distance scale by the wavelength of light removes this dependence. When there are a number of nearby sources then the change in path length and \( \Phi \) requires knowledge of the location and magnitude of the sources. Unlike GRT and Newtonian gravity, the bending is dependent on the surrounding matter as well as the enclosed matter.

The current gravitational lensing programs fit the observed lensing using GRT. The deflection angle, under the thin lens approximation, is: \( \theta = \frac{4GM(\xi)}{c^2 \xi} \), where \( M(\xi) \) is the “mass density” perpendicular to the line of sight as a function of the perpendicular distance of closest approach (\( \xi \)). So the current formula has a \( 1/r \) dependence.

In order to determine an appropriate mass density distribution the mass to luminosity relationship of stars in different regions of space needs to be known. The synchronous change in the path of light with the scale of space means that the hidden reduction in the apparent
distance to a star is exactly matched by the increase in brightness. The shifts in energy levels are also hidden. However, the luminosity is the energy per unit time, and stars in a region of higher density will have a lower clock rate. The supernovae data gets corrected for this effect by normalising brightness according to the decay rate. In addition, the mass of stars containing a given amount of matter will be lower in a denser, larger galaxy. Hence, the luminosity to energy density relationship is not immediately obvious. However, the Tully-Fisher relationship is consistent with luminosity being proportional to $\Phi^2$, which appears consistent with energy density determining scale.

Light will be focussed at places where there are light paths of equal total distance or, equivalently, equal total $c dt$. The thin lens approximation takes into account the stretching of space both along and across the direction of light propagation. The stretching is proportional to the ratio of the $\Phi$s, i.e. to $\Phi / \Phi' \equiv (1 + \frac{2\Delta \phi}{c^2}) \equiv 1 + 2GM/rc^2$, if the change in potential is small relative to the total potential. The bending is then proportional to $4GM/rc^2$ for a single source, outside the source, immersed in a large background $\Phi$.

In order to calculate this total $\Phi$ the 3-dimensional locations of the galaxies in a cluster need to be known or determined and not just the separation perpendicular to the line of sight. This appears to be an additional parameter beyond those in current gravitational lensing programs. For GRT lensing, each massive object can be considered as a separate source. This is no longer true for FRT because the magnitude of the effect of each source is dependent on the contribution from all other sources. The magnitude of the bending depends on the matter outside the enclosed volume as well as inside.

The broad difference in bending predicted by GRT and FRT can be envisaged as follows. For a single isolated source (galaxy), $c^2$ will decrease almost as $1/r$ for some
distance outside the central region (mimicking a halo of dark matter). In fact, it mimics the standard isothermal sphere of existing gravitational lensing programs where the density falls off as $r^{-2}$ so that the enclosed mass increases as $r$ [57], and the amount of bending is therefore approximately constant. For a cluster, the background $\Phi$ will suppress the size of the apparent halos but will also suppress the amount of lensing by the central galaxies. The lensing will appear to increase away from the central region so that a central halo of dark matter will appear to be required.

A procedure for calculating the lensing of a cluster would seem to be:
i) estimate the 3-D distribution of the galaxies
ii) use this to calculate the $\Phi$, i.e. $c^2$, at any given location (as required) from the sum of all contributing galaxies (independent of direction)
iii) calculate the bending at each point in the lens plane from the vector sum of the bending (i.e. allowing for direction) of all contributing galaxies. The contribution of each galaxy has to be corrected for the local $\Phi$ at each location along the path. To a first approximation the $\Phi$ at the point of closest transverse approach of the light ray to each galaxy could be calculated and used to normalize the contribution of that galaxy for that light ray. The contribution from all the remaining galaxies would be calculated for the same point, taking into account their actual, rather than transverse, distances. A rougher approximation would be to calculate an averaged or smoothed background $\Phi$ from all other galaxies at each galaxy and then use this as a constant that is summed with the $\Phi$ of the galaxy under consideration and used to calculate a representative $c^2$.

This topic needs a more careful analysis and would seem to need new software to explore whether the observed lensing of galaxy clusters can be fitted without the need for dark matter.
8.4 Gravitational waves and their detection

Under both GRT and FRT the length of light paths are altered by the presence of a gravitational field. GRT predicts that oscillating masses will radiate energy in the form of gravitational waves which are travelling variations in the dimensions of space-time. Modern gravitational wave detectors, such as LIGO [58], examine the interference pattern of light of fixed frequency sent down two paths. If such a travelling wave passes through the detector then the path length should vary.

Changes in gravitational potential result from the movement of matter and the resultant changes in the dimensions of space and $c\Delta t$ propagate at the speed of light. GRT has it that energy can propagate through this field in the form of gravitational waves, which are made up of gravitons of spin 2. However, FRT seems to imply that gravitational waves do not exist. Gravitational influences travel at the speed of light but the change (which would correspond to a massless spin zero graviton) is more like a change in sea-level with the tide rather than from waves. A wave (in the sense of a localised periodic oscillation) would seem to require a rotation of its components and this does not seem possible without angular momentum (spin zero), unless there are matched components of opposite angular momentum.

It is known that energy in the form of photons, without mass, can propagate. FRT proposes that photons consist of equal amounts of positive distortion (expansion) and negative distortion (contraction), about the mean value, sustained by having angular momentum but necessarily propagating at the maximum velocity determined by the difficulty of distorting the medium. For normal simple harmonic motion in space of a constant scale the period is independent of the amplitude of the distortion but the energy carried depends on the amplitude. Here the dimensions of space change and it needs to be examined if such oscillations can give rise to a dependence of energy on frequency (i.e. $E = h\nu$).
A graviton of spin zero has no mass and no angular momentum and so would just be a travelling change in the level of distortion. It is not localised and so should not be quantised. Under GRT energy is carried away by gravitational waves and the amount predicted is observed to be in excellent agreement with the amount lost by binary pulsars as observed by Hulse and Taylor [59]. In this reference Taylor concluded that: “the clock-comparison experiment for PSR 1913+16 thus provides direct experimental proof that changes in gravity propagate at the speed of light, thereby creating a dissipative mechanism in an orbiting system. It necessarily follows that gravitational radiation exists and has a quadrupolar nature.” It may be that FRT also allows massless spin zero changes in the field to carry away gravitational energy but an alternative explanation is proposed.

Under FRT the scale of space is determined by the background matter as well as the local matter. If the velocities of the local matter are significant relative to the speed of light then the calculated amount of kinetic and potential energy will be different for observers on the local matter and observers on a stationary centre of mass (i.e. stationary relative to distant matter). If this is the case then energy, stored as mass in a binary system, would be more than that first expected by an observer stationary relative to the centre of mass, because the gravitational field seen by the rotating masses will decrease as their relative velocity increases.

The changes in KE relative to PE and the rate of energy transfer with changes in speed can be calculated for a pair of equal mass binary stars (as shown in Figure 3) in circular orbit. This simple case allows the mechanism to be more clearly understood and for differences from the calculations using GRT to be investigated. It mirrors the approach taken by Cheng [60] using GRT where the effects of unequal masses and eccentric orbits are subsequently added as refinements to the simple case.
The stars in a non-relativistic binary system with a circular orbit have the acceleration needed to remain at a constant separation equal to the acceleration provided by the gravitational potential. Thus: \( MV^2 / R = GM^2 / (2R)^2 \)

giving \( V^2 = GM / 4R \)

and \( V'^2 = GM' / 4(R + \Delta R) \) if the radius increases by \( \Delta R \)

If \( M' = M \) (as under GRT) then the change in KE is:

\[
MV'^2 - MV^2 = \frac{GM^2}{4} \left( \frac{1}{R + \Delta R} - \frac{1}{R} \right) = -\frac{GM^2}{4R} \left( \frac{\Delta R}{R} \right)
\]

so that \( \Delta KE = -\Delta PE / 2 \) because \( \Delta PE = 2F\Delta R = \frac{GM^2}{2R} \left( \frac{\Delta R}{R} \right) \)

This result says that, in a closed system of binary stars, a change of radius in a circular orbit is impossible without violating conservation of energy. This is at low speeds when the dissipative mechanism of gravitational radiation cannot contribute.

Figure 3. Rotating binary with apparent positions shown by open circles.
However, the same conclusion seems, at least at first, to apply under FRT at relativistic speeds. A mechanism is needed that allows different circular orbits without loss of total energy by changing the amount of stored energy (PE relative to KE).

Under FRT the change in KE is:

\[ \Delta E = MV'^2 - MV^2 = \frac{GM^2}{4R} - \frac{GM^2}{4R} \]

whence

\[ \Delta E \approx \frac{-GM^2}{4R} \left( \frac{\Delta R}{R} \right) \], as before

For relativistic circular motion, the proper acceleration is \( \alpha = \gamma^2 V^2 / R \), so the \( V^2 \) on the left hand side and \( M^2 \) on the right hand side get multiplied by \( \gamma^2 \).

The calculation of energy loss due to gravitational radiation under GRT on the basis of small perturbations to the metric gives:

\[ \frac{dE}{dt} = \frac{128G}{5c^5} \omega \phi M^2 R^4 \], where \( \omega \) is the angular frequency [60].

The formulae derived by Peters and Mathews [61] and Paczyński [62] reduce to this form when \( M = M_1 = M_2 \), \( \omega^2 = GM / 4R^3 \) and \( a = 2R \). The same formula should apply to FRT because the effect of a small distortion of the metric in GRT has been shown earlier to be mathematically equivalent to the expansion of the space-time interval.

Using \( \theta = V / c \), which is the relative velocity of the masses (\( V = 2R\omega \)), or the angle between the actual and apparent position of the opposing mass; and that the total (non-relativistic) energy is \( E = GM^2 / 4R \) gives:

\[ \frac{dE}{cdt} = \frac{8}{5} \frac{E}{R} \theta^6 \]

This expression shows that the energy loss is governed by the relative velocity of the two stars, relative to the speed of light. Once the local \( \Phi \) is taken into account, which happens automatically with the scaling of space, then the energy loss is dependent only on a scale
invariant geometric factor and would be expected to be the same for the two theories and their respective space-time intervals, at least in the weak field limit.

The apparent loss of energy under FRT must lie in the fact that the stars are rotating relative to each other at twice their individual speed and that this affects the gravitational field seen by the two stars. Under special relativity the apparent mass is \( m\gamma \) (where \( \gamma = \frac{1}{\sqrt{1 - \beta^2}} \)) and a force acting on a relativistically moving mass \( \vec{F} = m\gamma \vec{a} + m\gamma (\vec{a} \cdot \vec{\beta}) \vec{\beta} \) has components parallel to the acceleration and parallel to the velocity. Hence the apparent force (gravitational field or energy density) seen by the two stars would appear to decrease with increasing velocity. Thus, it is proposed (but not demonstrated here) that the apparent loss of energy due to gravitational radiation under GRT is actually due to an underestimate of the stored energy.

The strong gravitational fields near the surface of neutron stars also offer a test of gravitational theories [63]. The expectation that gravity becomes stronger under GRT would seem to lead to different predictions to that under FRT where mass is reduced. However, effects such as the invisibility of changes in the dimension of space may hide the differences.

9. Discussion

9.1 Einstein’s equivalence principle does not hold

The apparent inconsistency between GRT and Mach’s principle can be traced to the assumption that the outcome of any local non-gravitational experiment is independent of where and when in the universe it is performed. The weak equivalence principle is the equivalence of inertial and gravitational mass so that the trajectory of any freely falling body does not depend on its internal structure, mass or composition [64]. The so-called Einstein equivalence principle states that the weak equivalence principle holds and, in addition, that: the outcome of any local non-gravitational experiment in a freely falling laboratory is
independent of the velocity of the laboratory and its location in space-time (local Lorentz invariance), and independent of where and when in the universe it is performed (local position invariance) [30]. Local position invariance requires or assumes that the background distribution of matter has no effect (in an inertial frame). This has been supported by the argument that a null-geodesic can be used to travel from one point in space-time to another with a different background without any observable consequences. The argument, however, breaks down because it inherently assumes that the sum of infinitesimal changes, from changes in the distribution of external matter, tends to zero. That is equivalent to assuming that the initial and final distributions of external matter are the same. However, if the associated distortions do not cancel, then differences in the mean density of background matter will affect the outcome of experiments that involve mass and the properties of space (i.e. its space-time dimensions). Thus the proposed theory is consistent with the weak equivalence principle but not the stronger Einstein equivalence principle which includes positional invariance. The underlying equivalence principle, that experiments give the same result independent of location, velocity and acceleration, requires that the distortion of space (the amount of matter) is correctly taken into account.

It can now be seen that GRT takes the first step of making the dimensions of space and passage of time dependent on the matter density but by keeping the speed of light constant and introducing distortions of an invariant interval it keeps the magnitude of effects constant rather than relative. This means that inertial forces and the dimensions of space cannot go to zero as the density of background matter disappears.

A Fully Relative Theory requires that all effects are dependent on the local matter/energy density relative to all other matter, that is, relative to the background energy density. Consider a crystal-like lattice with a uniform distribution of locations of higher density. If these locations have fixed properties, that is, they are time stationary states if the
background density, and therefore clock-rate, is constant; then we can identify them as particles. These particles are locations of stored energy and therefore the density of stored energy increases nearer their location but their location has a fixed central position and finite extent with the relative dimensions of distance and the product of $c$ and the time interval (i.e. $cdt$) increasing as the location is approached. The degree to which the particle is localised will depend on its stored energy relative to the background stored energy. The magnitude of the distortion, as perceived by a local observer, will be larger when the background density of matter is smaller. This equates to mass, and stored energy, increasing as the particle moves into a region of lower background energy density.

In the limit that the particles of the crystal-like lattice are uniformly distributed with a fixed density then an object moving through this medium at constant velocity will not detect any difference in the perceived “average mass”. However, the apparent passage of time and dimensions will be different if the velocity is large (in terms of the speed of propagation of variations in energy density) relative to another observer (special relativity). In addition, if the density of the background matter doubles then the distortion by local matter halves.

In Mach’s paradox, the size of the bulge was determined by forces which did not depend on the amount of background matter (under GRT). Under FRT the magnitude of any effect of other matter depends on the flux ratios of their stored energy densities. The ability to determine rotation by just one other tiny object in the universe is then related to the acceleration that would have to be given to that object (the change in stored energy) to have it rotating instead.

The revised theory does not have an absolute space-time but produces the same predictions as a curved metric, for the current local energy density, if the background distribution of matter is fixed. It therefore reproduces the standard results of general relativity, but is consistent with Mach’s principle. The theory is truly relative, whereas GRT
has a space-time of fixed magnitude. Dimensions, time, the speed of light, wavelength and mass are all relative to the amount of other matter present and so the revised theory obeys Mach’s principle. The presence of matter gives space dimensions but the increase in dimensions for a given increase in matter decreases as the density of matter increases. Time lengthens and the speed of light increases with density. A consequence is that the energy of an elementary particle, a stationary state, will decrease as the $\Phi$ (stored energy density) increases. Therefore, the stored energy decreases as objects move closer together which provides an explanation for gravitational attraction.

9.2  *Stretched space versus a curved metric*

The scalar FRT theory has an expansion (“stretching”) of the spatial dimensions, with a matching stretching of the product $c dt$. The tensor GRT theory has a distortion of the underlying geometry (metric) which corresponds to a rotation (curving) of a four-dimensional space-time, but with the speed of light held constant. Both theories require that time is relative so that $dt = \sqrt{dx^2 + dy^2 + dz^2} \ c$. However, GRT makes the assumption that there is a proper time, in the rest frame of the clock, on which all observers should agree. FRT reveals that this assumption holds within a region of constant stored energy density but not between regions of different energy density because clocks run at different speeds in the different regions. It therefore holds between inertial frames (special relativity) but not between frames that can only be reached via an acceleration (general relativity). It follows under GRT, that there is an invariant interval $ds^2 = c^2\ d\tau^2$ that has the same value in all regions. FRT reveals that this interval will not be constant between regions.

In order to maintain the interval as an invariant, GRT proposes that the apparent distance must decrease when the time interval increases. This is why GRT proposes a metric which corresponds to the rotation of an interval of space-time of fixed magnitude. It is this rotation that leads to the concept of curvature of the underlying geometry of space so that the
angles of a triangle do not add up to 180° and a metric tensor that relates the geometry of one region to the geometry of another. FRT is a scalar theory so that the scale of space in all directions is proportional to the local stored energy density but the scale changes between regions.

The difference between the two theories can be envisaged by considering what happens to a triangle as it moves between different regions of space. Under FRT a triangle within a region of constant energy density always has the same shape but its size changes between regions. Under GRT it is always possible to choose a coordinate frame so that the metric is locally flat, which means, for a small enough triangle (within a region), that the shape and size will be the same (between regions). If we consider going from one region to another of higher stored energy density (due to an increasing uniform shell of surrounding matter) in a large number of very small steps, then FRT has a continuous series of similar triangles growing in magnitude while time intervals increase. GRT has a series of identical triangles with time staying constant for all stationary observers and, because the shell is uniform, the observer with the triangles will not have seen any gravitational field. If, instead, the triangles trace the path towards a central massive object then there will always be a gravitational field and when the distant observer looks at the curvature over the whole distance, it is found, under GRT, that the apparent speed of light increases because time slows and the apparent scale of space decreases (in order to keep the interval invariant). The apparent angles of a single triangle, spread over the whole distance, do not add to 180° under GRT. Thus the non-Euclidean geometry only “appears” over large distances.

Under FRT, the change in spatial scale is invisible using electromagnetic radiation but the change in the product $cdt$ can be observed indirectly. However, differences between the predictions of the two theories only show up when the analysis involves a comparison of regions of markedly different stored energy densities.
Under GRT, gravity is a “fictitious” force due to the curvature of space-time. A freely falling reference frame is equivalent to an inertial frame but it does not follow (Einstein equivalence principle) that there are no differences between inertial frames in different regions (local positional invariance). Under FRT, the clocks run at different rates and the relative magnitude of the frames is different in different regions. Gravity is then a real force arising from the inability of matter to store as much energy when the background stored energy density increases.

9.3 Coordinate systems, space-ctime and co-moving coordinates

There is a changed understanding of coordinate systems with FRT. The proposition that physics, as deduced by different observers, should be independent of coordinates only applies if there is no way that the direction and magnitude of other objects influences local dimensions. However, both GRT and FRT have dimensions (the scale of space-time coordinates) depending on the distribution of matter. If only relative motion is observable in physics and no physical measurement can detect the absolute motion of an inertial frame, then an inertial frame is one in which there is no change in the influence of other massive bodies, no relative motion. If the distribution of matter is not homogeneous, uniform and constant then the physics must be different for observers in different environments. Coordinate-free physics only applies within a completely homogeneous and uniform region of constant stored energy density.

The concept of space-time might be better replaced by “space-lightime” or “space-ctime”. This would make it clearer that the scale of spatial dimensions is matched by the product of light speed and time interval. The next step is an appreciation that the scale of the dimensions is also relative, with the difference in scale between two regions being proportional to the difference in their stored energy densities.
The speed of light involves the measurement of a spatial interval $dr$ for a local proper time interval $d\tau$ as recorded by a clock at rest at this position with $\frac{dr}{d\tau} = c$. Under GRT, $c$ is a universal constant, whereas under FRT $c$ varies as the square root of the stored energy density. So the proper time intervals in the two theories are different and it is this that explains why distant supernovae are fainter than expected under GRT. The apparent passage of time will depend on the relative motion between the emitting and absorbing matter and on whether the stored energy density has changed. The concept of co-moving coordinates is flawed.

9.4 Galaxy evolution, Sachs-Wolfe and other effects

The consequences of the revised theory for many other observations, such as for the predicted distribution and evolution of stars and galaxies, need investigation. Some of these are briefly covered here.

The Sachs-Wolfe effect [65], which gives variations in the wavelength of the cosmic microwave background based on the perturbed Einstein Field Equations, cannot be attributed to losses or gains in energy of photons as they move through gravitational potentials. Such changes in energy do not occur. Instead the variations in wavelength must reflect different amounts of expansion due either to different times of emission or to changes in the rate of expansion of regions of different gravitational potential.

The explanation of the Late Time Integrated Sachs-Wolfe Effect under FRT is that the rate of expansion in a galaxy cluster will appear slower (because time is running relatively more slowly). Therefore, the red-shift (due to expansion) will be less; which equals an apparent blue shift. The effect is completely analogous to the explanation that it replaces, the apparent acceleration of the rate of expansion under GRT.
The predictions from baryon acoustic oscillations [66], periodic fluctuations in the density of the visible baryonic matter of the universe, need to be re-examined in light of the revised theory. However, the oscillations should also exist under FRT. Since wavelength changes are not visible, it seems likely that the agreement with observations of such a standard length ruler will be unaffected. The changes in the scale of space are hidden so, as for galaxy rotation, the effects seen correspond to changes in speed of light under FRT instead of the need for dark matter and dark energy under GRT.

The implications of the revised theory for frame dragging and nucleosynthesis also need to be examined.

9.5 Possible implications for particle physics

If a photon has energy, but does not have any net energy stored as mass, yet can split into a (massive) particle/antiparticle pair, then it can be concluded that particles and antiparticles have the opposite effect on the dimensions of space. Hence, antiparticles must induce a contraction in spatial dimensions in the local region of the universe. Antiparticles (like particles) will not be able to store as much energy when the stored energy density increases and so will be gravitationally attracted to a concentration of particles. However, symmetry suggests that, in a region where antiparticles dominate, it will be antiparticles that induce an expansion and particles will induce a contraction. Particles near a boundary between regions will be attracted to the region where the like kind of particle dominates. This appears to be a potential explanation of where the initially equal quantity of antimatter may have gone. Thus antimatter may be present in antimatter galaxies which are also approximately homogeneously spread throughout the universe, and visible, but do not produce an annihilation signal because massive particles cannot cross the boundaries. It seems possible that antimatter could get enclosed within the core of a matter galaxy but this would appear to be an unstable configuration. The presence of both matter and antimatter galaxies would
lower the apparent background energy density so that the background in any region would be dominated by the local excess of like matter.

Light should be able to cross the boundaries between galaxies if photons are symmetric amounts of oscillating expansions and contractions. Their energy should be unchanged and be able to interact with the antiparticles in the anti-matter regions. This would seem to imply that the stored energies in both regions should have the same sign (e.g. both positive) otherwise the absorbed photon would decrease the energy in the anti-matter region. However, it is proposed above that the stored energy densities will cancel. The alternatives would seem to be to have light reflected at the boundaries or totally absorbed.

Quantum electrodynamics is a gauge invariant theory. An arbitrary constant value can be added to the potential without affecting the results. However, this is not so for this revised theory of gravitation. It is not gauge invariant and the masses of all particles decrease with increasing $\Phi$ and so with moving back in time when the density of the universe was larger. This can be compared with the Higgs mechanism, which corresponds to a spontaneous breaking of gauge invariance, and the Higgs boson or Higgs field which interacts with all particles to give them mass. The mechanism and the revised theory of gravitation must be related. In the limit that the stored energy density is enormous, a constant small potential can be added without affecting the results. So gauge invariance is approached as the masses of particles tend to zero. It would appear that the Higgs field that gives particles mass must be equated with the field due to all other matter in the universe. A similar idea was put forward by Talmage [67] who suggested that matter particles have mass because their energy content is determined by the density of the scalar gravitational field. However, the field of the theory presented here acts somewhat differently as the amount of stored energy (mass) per particle is reduced as the density of stored energy (the field) increases.
There seem to be significant implications for the phenomenology of elementary particles and their interactions. The photon has zero mass but can split into a particle/antiparticle pair. Hence, the distortions of space of all such pairs must cancel and the photon must be a travelling wave of a matched pair of distortions oscillating about zero. The photon carries one unit of spin angular momentum and, for fermions, both the particle and antiparticle carry half a unit with each having the same stored energy (mass) but opposite charge. It would seem to follow that the photon has equal amounts of counter-rotating “spin” (with the energy stored as angular momentum) and that positive and negative charges correspond to stationary states of opposite torque and distortions of the opposite sign.

Electromagnetic interactions involve the exchange of a photon between charged fermions (e.g. electron/positron) which each have two states that are π out of phase and can flip between these two states by emitting or absorbing the photon. Strong interactions involve the exchange of spin 1 massless gluons that do not have charge but interact with massive quarks of 1/3 and 2/3 charge and with other gluons. The implication would appear to be that the gluons are travelling waves of pairs of orthogonal oscillations in spatial dimensions (and energy density that is π/2 out of phase). In which case the photon would seem to be able to be identified as the fully symmetric combination of gluons (or the ninth gluon that is not involved in strong interactions). Quarks would then seem to be states of basic fermions which are missing gluons and which can then combine in pairs with complementary missing gluons or triplets in which there is continuous exchange of gluons (and angular momentum can be conserved). The quarks appear to be fractionally charged because only one or two of the three orthogonal directions is available for exchange of photons.

The Higgs particle would seem to be a stationary state that can couple to all particles without exchanging a net amount of angular momentum. It should not be seen as the state that breaks gauge invariance, thereby giving particles mass, but as a state that can interact
with all fermions which is necessary to complete the symmetry of the standard model. Its mass and those of other particles arises because there is an excess of matter in this region of space.

10. **Summary and Conclusions**

A revised theory of gravitation in terms of an expansion of space, and the product $c dt$, dependent on the energy density of matter is proposed. This change in scale replaces the tensor metric of general relativity theory which corresponds to a rotation (curvature) of space-time of fixed magnitude. The distortions of space from opposite directions add rather than cancel so that the magnitude of physical laws is no longer independent of any surrounding shell of matter. Gravitational interactions are therefore not gauge invariant and the strong equivalence principle does not hold. The speed of light is no longer constant and mass varies inversely with the stored energy density. The results of measurements need to be corrected for the background stored energy density before physical laws are universal, that is independent of the place and time at which they occur. Particles cannot store as much energy when the density of other matter increases. The resultant release of energy gives rise to the kinetic energy of gravitational acceleration. The theory leads to a revised concept of time and makes it clear that photons do not lose energy in escaping a gravitational field. This lack of interaction with the gravitational field means that a scalar (spin zero) field theory is required, whereas GRT is a gauge invariant tensor theory with a graviton of spin 2. The proposed theory is shown to reproduce most of the standard predictions of a curved space-time with an invariant metric for the local (current) stored energy density. However, it predicts that gravitational redshifts of wavelength will not be visible (only frequency and time). It is proposed, but needs to be demonstrated, that the apparent loss of energy from binary pulsars due to gravitational radiation, under GRT, is instead an increase in stored energy as mass
because of a relativistic reduction in the gravitational field. Major benefits of the revised theory are that it removes the inconsistency of current general relativity theory with quantum mechanics, removes black holes and gravitational singularities, and appears to avoid the need to hypothesize dark matter, dark energy and cosmological inflation. The theory appears to be fully relative and is consistent with Mach’s principle. The observed cosmological redshift with distance corresponds to a reduction in the background energy density and, under both GRT and the revised theory, should lead to a slowing of time which explains the faintness of distant supernovae without the need for dark energy. This slowing may have already been observed as the Pioneer anomalous deceleration. The anomalous rotation curves of galaxies appear explicable without the need for dark matter. There are many other consequences that still need to be explored and elaborated including the implications for galaxy evolution and for particle physics. A search for correlations between the light curves of supernovae and position relative to galactic centres may help confirm the revised theory. However, the strongest experimental confirmations would be i) a demonstration that the observed gravitational lensing of galaxy clusters can be explained without dark matter, ii) a quantitative observation of the rate of change in clock-rate in agreement with the rate of change of the density of the universe. The key theoretical issues are to demonstrate that the slope of the supernovae distance data is in agreement with the value of the gravitational constant, and to resolve whether the alternative explanation to gravitational radiation is viable.

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