Revised perspectives on mass and gravity provide a path forward in physics

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ABSTRACT

Revised perspectives on mass and gravity open a path to resolving many current issues in cosmology, including the inconsistency between general relativity and quantum mechanics. Mass is already known to be energy stored in a body but it has not been appreciated that the energy held by the same matter may vary. A necessary consequence, given Newton's laws and $E = mc^2$, is that gravitational attraction arises from a fractional decrease in the stored energy (mass) of the same matter as it moves closer to other matter. Hence, the energy levels of atoms will be blueshifted higher in a gravitational field, rather than photons being redshifted. This change is consistent with observations, but implies a variable speed of light that increases when the field from other mass increases. It also implies that light-speed was faster in the past when matter was less clumped. The changes remove the apparent accelerating expansion and thus the need for an invisible dark energy, and for any expansion of empty space at all. They also remove black hole singularities, overcome the flatness and horizon problems, and remove the need for cosmological inflation. General relativity's distortion of distance scale (in spacetime) is not required. Its key predictions appear to be able to be reproduced by a 4-vector energy/momentum formulation, with variable c and time. The changed understanding also throws light on the Higgs mechanism as the source of mass, and on the standard model of particle physics.

1. Introduction

General relativity has the apparent force of gravity being a distortion of the geometry of a continuous spacetime. Quantum mechanics has the other three known fundamental forces arising from the exchange of lumps of energy in which location and time cannot be simultaneously determined and the results are governed by probabilities. Quantum mechanics has an underlying constant flow of time, whereas general relativity has a malleable and relative time. The first step in resolving the inconsistency is to look at the nature of gravitational energy and its relationship to time.

The classroom explanation of gravity uses the concept of gravitational potential per unit mass. When the bob of a pendulum is released it gains kinetic energy and loses potential energy. On the upward swing it loses all its kinetic energy in regaining all of its potential energy (ignoring frictional losses). Where has the kinetic energy, input to the bob in raising its mass through a vertical height against the force of gravity, gone? How is it stored? Einstein actually came up with two answers. Under general relativity, reducing the density of matter by moving the objects apart has reduced the distortion of spacetime. When all objects are completely separated, the density and the distortion go to zero and potential energy is maximised. His second answer came from his derivation of $E = mc^2$ using special relativity. Here he considered the change in energy of an object that radiated a pair of matched photons in opposite directions, so that momentum was conserved. He concluded: "The mass of a body is a measure of its energy content" [1]. Mass is the energy stored in a body. He later observed that: "Mass and energy are therefore essentially alike; they are only different expressions for the same thing. The mass of a body is not a constant; it varies with changes in its energy" [2].

Mass, as stored energy, has long been seen in the differences in weights of atomic nuclei. These differences give rise to the release of enormous amounts of energy in fission and fusion bombs. It is also seen in the accepted understanding that the mass of a gas kept in place by being enclosed in a box is greater than the sum of the masses of an empty box and the same amount of gas. The total mass of the box and enclosed gas also increases with increasing temperature (i.e. kinetic energy) of the gas molecules and with decreasing volume. Similarly, a hot brick is taken to weigh more than the same brick when cold. However, what has not been appreciated is that the amount of stored energy (i.e. mass) of the same particles of matter (electrons, nuclei, atoms, molecules) could (and does) change with the density of surrounding matter. It seems to have been assumed that a change of state was needed, rather than that the mass held by the same matter could reduce as the surrounding mass density increased. Moreover, when matter and antimatter annihilate, including protons and antiprotons, all the mass disappears and all the energy is radiated away but total momentum is unchanged. Hence, all of the mass in all matter is stored energy. The kinetic energy of gravitational acceleration arises from the release of a small fraction of this stored energy (i.e. of its mass). It is simply conservation of energy.

The consequences include that the mass per unit matter decreases when the strength of the background field from other matter increases, and, if $m = E / c^2$ is to be retained, that the energy (E) held locally by the same matter, decreases as the speed of light (c) increases. Thus, the changed perspective demands that the speed of light is variable which contradicts accepted understanding. This apparent disagreement with relativity theory and its successful predictions will be addressed. However, some of the other consequences and benefits need to be examined first.

2. Consequences of variable mass

If mass increases as the surrounding field reduces then all massive particles, including atoms, contain more energy with increasing distance from a large source of mass. The gain in stored energy per unit of (assumed negligibly small) changes in mass, in raising an object distance dr against F, is:

$$\text{Work done per unit mass} = \int_{r_1}^{r_2} (F/m)dr = \Delta E / m = \Delta mc^2 / m = -G_N M (1/r_2 - 1/r_1) = \Delta\Phi$$

where $\Delta E = \Delta mc^2$ has been substituted, and $\Delta\Phi$ is the change in gravitational potential (energy per unit mass) with distance r from a point source of mass M. It can be re-written as the fraction by which the energy or mass at distance $r_1 = R$, is <u>lower</u> relative to a value of zero at infinity ($r_2 = \infty$):

$$\Delta m / m = \Delta E / E = G_N M / Rc^2 = \Delta\Phi / c^2 = -\Phi_R / c^2$$

Combining Einstein's equation with Newton's gravitational equation for the simplest case of a small mass at a distance from a large massive object, indicates that gravitational attraction arises from a fractional decrease in mass/energy. The fractional change in energy is independent of the size of the small mass and of the nature of the matter, as observed. The first attribute can be expected in the limit that the contribution of the large mass to the background is negligible relative to that from all other mass. (Although, the proportionality factor may vary, if the inertial resistance of mass to acceleration also varies with the background field.) The independence from the nature of the matter implies that changes in c affect all forces that trap energy at a location in the same proportion. The fractional energy input (from lifting the mass) will always equal the fractional energy output (as the lost mass is converted to kinetic energy when it falls), but the observed acceleration per unit matter may vary with location if inertia changes.

All massive particles have wave properties with their (Compton) wavelengths being those of a photon having the same energy (proportional to frequency) as the rest energy of that particle. Thus, all atoms, at matched locations, will have the same fractional change in energy and the same fractional change in frequency of photons emitted from all transitions. The size of any change will be proportional to the difference in potential between the locations, independent of the gradient in potential at either location. According to Newton's law a particle of zero mass should not feel a gravitational force. Therefore, the momentum of a photon should not change with location in a gravitational field. Thus, the revised perspective is that an unchanged photon emitted from an atom at a lower potential should need a boost in energy if it is to be absorbed by an identical atom at a higher gravitational potential.

The equivalence principle of general relativity claims that physical laws for an observer in free fall are equivalent to those in an inertial frame without gravity. Thus it claims that such an observer will not be able to detect any physical effects associated with gravity or acceleration [3]. This requirement leads to the prediction that the wavelength of light will be redshifted by gravity with a frequency shift of $\Delta\omega / \omega = -\Delta\Phi / c^2$. It claims a distortion of spacetime such that time runs faster at a higher gravitational potential. A photon will then appear to lose energy in escaping a gravitational field, e.g. when the same photon is observed further from the Earth. To explain this loss it has generally been concluded that the massless photon must be gravitationally attracted in proportion to its momentum, which is a reflection of the energy of motion it can carry to a new location. However, a few authors have claimed instead that the correct understanding, under general relativity, is that it is "the standards of time" that have changed so that the energy levels of the atoms will appear, or be measured, to be blueshifted [4,5,6].

General relativity's predicted gravitational redshift was first observed in a remarkable series of experiments by Pound and Rebka [7]. They examined gamma rays sent up or down between sensors in a tower. They found that photons emitted at a lower excited crystal were not resonantly absorbed at the matched upper detecting crystal unless they were given a Doppler boost in energy (by motion of the emitter). The experiment was repeated with the positions of source and receiver reversed. The photons were only resonantly absorbed when the increase or decrease in energy compensated for the supposed gravitational redshift of the photons with height. This appeared to confirm that photons lose energy with increased altitude and hence were redshifted. However, a blueshift of the atoms but none for the photons gives the same result as a redshift of the photons with no change in the atoms.

The new perspective takes this inverted explanation a step further in proposing that the increase (blueshift) in stored energy held by matter is real. The increased energy necessitates that atomic clocks tick faster. The predicted changes in time, frequency and energy are the same, the cause is different.

The changed viewpoint offers an alternate explanation of the Hubble expansion in which the steady increase in redshift of the light with distance to galaxies was taken to mean that the universe was expanding. Initially this was seen as a simple increasing Doppler shift from increased recession speed with distance from an initial explosion. However, general relativity has a flexible geometry of a linked space and time which demands that 'space' must either expand or contract over time. This led to the apparent redshift being subtly revised into a generalised expansion in which the empty space between galaxies is increasing. This caused the stretching of photon wavelength (but not that of matter) embedded in this space, and led to the interpretation of the cosmic microwave background as the redshifted (cooled) remains of an initial very hot explosion.

Under the revised perspectives, the gravitational clumping of like matter as the universe evolves will increase the local speed of light and therefore reduce the average mass held per unit of matter within clumps and overall. Therefore, clumping will lead to an ongoing contraction and decrease in the contribution of distant matter to the background and a reduction in the speed of light. Thus, looking back in time, it should be expected that the speed of light will have been higher in the past which will show up as a redshift in the energy levels of more distant matter. Moreover, there is no requirement for general relativity's expansion or contraction of the universe, because only energy and time (clock-rate) change and not distance scale (space). Instead, under the new perspectives, the distance between objects (space) cannot expand without the objects moving (being accelerated), and the momentum carried by photons does not change after emission.

The new and old perspectives can be compared using the data from distant type 1a supernovae, which act as standard candles because they explode with nearly the same energy. Their observed brightness determines their distance and this can be compared with either their recession velocity, or their change in photon emission energy, determined from the redshift of the light of their host galaxy. The first option was the experiment done by two groups that led to the hypothesis of dark energy and the award of the 2011 Nobel prize in physics. Both groups concluded that the rate of expansion had begun increasing over relatively recent times. This claim relies on a calculated distance based on redshift determined velocity that assumes a constant speed of light. Gravity had been expected to slow the expansion, so 'dark energy' was hypothesised to drive this 'accelerating expansion' of the universe. Such dark energy has the very unusual property of a negative pressure that opposes gravity more strongly as the density of matter, galaxies per unit volume, decreases.

Under the revised understanding, the distance data has to be corrected for the cumulative increase in the speed of light, going back in time. Brightness should decrease as the inverse square of the actual distance and therefore the correction factor to the time taken for light to be received should be proportional to the integral of the received to emitted energy determined by the change in wavelength. The time should be corrected by dividing by the integral of the received to emitted wavelength, i.e. by $\lambda_{rec} / \lambda_{em} = 1 + Z$ where Z is the redshift. The publicly available Union 2.1 data [8] can be plotted with and without correction as seen below (Figure 1).

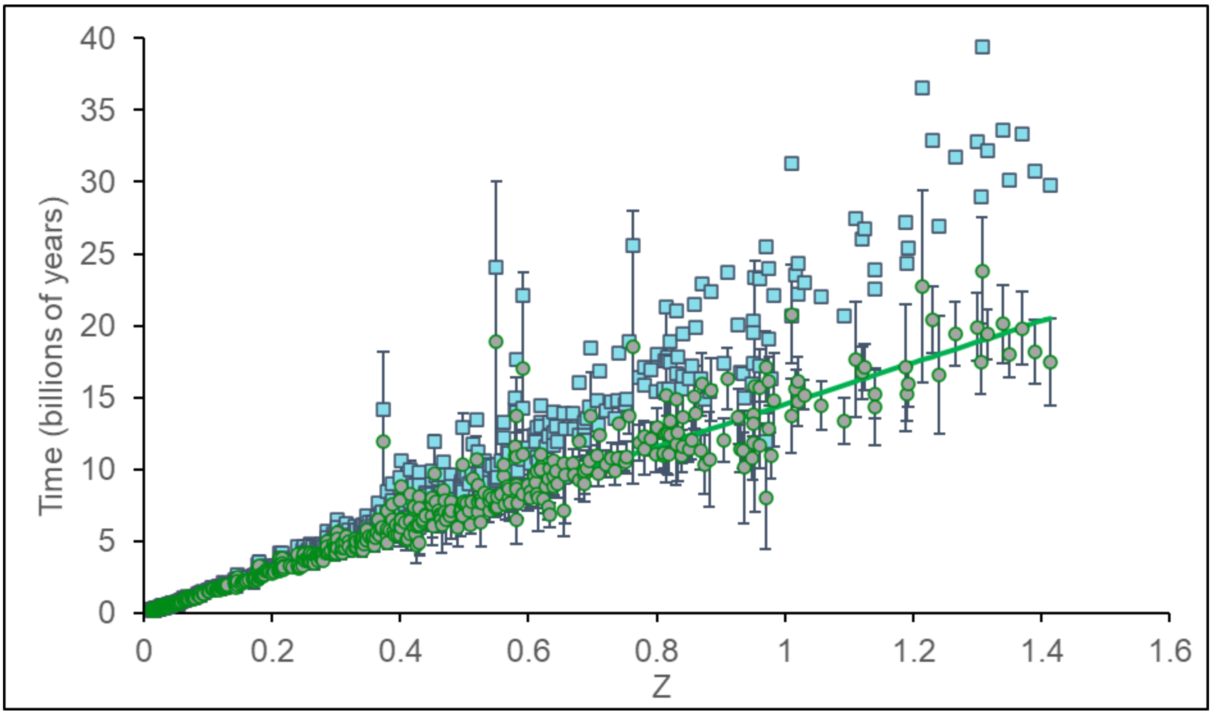

Fig. 1 Time since light emission against redshift for supernovae; before and after (green ○) correction.

The raw data (blue squares) has light from distant supernovae taking longer than expected. The corrected data (green circles) removes any evidence for an accelerating expansion. The scatter appears to be that expected from the quoted measurement errors, with roughly two-thirds of the points lying within their error bars of the straight line fit. The claimed accelerating expansion is entirely removed by the expected change in emitted energy if the speed of light changes. The constant slope removes any need at all for an expansion, and therefore for a big bang.

General relativity's proposal that photons were gravitationally attracted, in proportion to the kinetic energy that can be delivered by their momentum, meant that all forms of energy, including that from gravitational acceleration, must give rise to an increased distortion of spacetime. The result is a feedback mechanism in which distortions of spacetime give rise to increased energy which further increases distortion as mass/energy density increases. This is the cause of general relativity's singularities inside black holes, with part of the 2020 Nobel prize for physics awarded for the discovery that black hole formation is a robust prediction of the theory. Once mass density exceeds a critical value the positive feedback sends the distortion to infinity. Such singularities indicate a serious problem with the theory, including that it does not hold at very high densities.

The revised perspective of a decrease in energy held per unit of matter, with an increasing background from other mass, avoids the singularity. If the density of matter increases within a region, then the mass held per unit matter within that region decreases (unless the total background decreases). This provides a negative feedback which limits the mass per unit matter. 'Black holes' still arise when matter collapses into very high densities but they do not contain singularities, or trap light because of loss of photon energy after emission. Instead, the same emitting transitions now have extremely low energies (long wavelengths) and there is no event horizon at which time stops and from behind which nothing travelling at the speed of light can cross. This overcomes the problem that changes in gravity have been observed to travel at the speed of light, and so should also be trapped. It permits black holes to rotate around stars and each other, which should be impossible under general relativity. However, the observed black shadows (the famous images of black holes at the centre of our and another galaxy) can still arise from the gravitational bending of light.

Under general relativity, an enormous pool of energy needs to be available when the universe is nearly empty of matter and there is almost no distortion of spacetime. This pool of energy is needed as the source of the kinetic energy of objects (of invariant rest mass) that accelerate under gravitational attraction when spacetime becomes more distorted. Under the new perspective this pool of energy is held in the objects as mass. The loss of stored energy, as matter moves closer, slows clocks made of matter, but does not need a distortion of the distance (scale of space) between objects.

A variable speed of light removes the need to hypothesise an incredibly rapid initial expansion of the universe, called cosmic inflation, to explain the 'horizon' problem. The problem arises because the observed uniformity of the large-scale distribution of distant galaxies and of the cosmic microwave background seems to require that all parts of the early universe were in contact and in thermal equilibrium. However, galaxies in opposite directions are now so far apart, that for the current speed of light, they could not have interacted in the lifetime of the universe (calculated from the supposed rate of expansion seen in the redshift). Cosmic inflation also sought to explain the 'flatness' problem. If the geometry of space had deviated ever so slightly from being undistorted (flat), then the distortion (curvature) would have been rapidly amplified over time by gravity (and dark energy). Yet, it is currently observed to be flat (Euclidean), or very close to it. Cosmic inflation proposed that the entire universe expanded by some 20 orders of magnitude (10^{20}) in the first 10^{-36} to 10^{-32} seconds after the big bang. This incomprehensibly rapid expansion, much greater than the speed of light, is claimed to have locked in the initial uniformity and been responsible for most of the current separation.

The inflation hypothesis appears difficult to accept when the existing laws of physics say that infinite energy is needed to accelerate just one electron to the speed of light, let alone billions of galaxies. Moreover, under general relativity, the density of the early universe would have been such that it would have been inside a black hole from which nothing, including our galaxy, could escape. This incredibly rapid expansion has been claimed to be allowed because it is 'space itself' that expands rather than that objects move. That is, distance, the size of the vacuum between massive objects, increased faster than the speed of light, without the objects moving. It relies on space and time being just a malleable relationship giving a constant speed of light, so that 'space is not a thing'.

3. An apparent dark energy is predicted

The revised perspective predicts that general relativity will require an <u>apparent</u> dark energy if the mass per unit matter is dependent on the surrounding mass density. Einstein's field equation of general relativity is a generalisation of the differential form of Newton's gravitational equation:

$$\vec{\nabla}.\vec{g} = -4\pi G_N \rho \qquad (1)$$

The curvature of spacetime and the divergence of the acceleration ($\vec{g}$) are directly proportional to the stress-energy tensor, the generalisation of mass density (ρ) to energy/momentum density.

Newtonian gravity gives rise to a force field ($\vec{F} = m\vec{g}$) that maintains its value while a static distribution of mass is present. The derivation of the differential form follows from applying Gauss's law to the gravitational force law, as is done for electromagnetic fields [9]. The first step of the derivation is to equate the gravitational mass of Newton's universal law of gravitation with the inertial mass of his equation of motion. This yields a vector gravitational acceleration field (force per unit mass $\vec{F}/m$) due to a point mass M of:

$$\vec{g}(\vec{r}) = -G_N M\hat{r}/r^2 \qquad \text{where } \hat{r} \text{ is the unit radial vector.} \qquad (2)$$

This field can be expressed, for an arbitrary mass distribution, as Gauss's law for the gravitational field:

$$\oint_S \vec{g} \cdot d\vec{A} = -4\pi G_N M \qquad (3)$$

The area integral on the left is the gravitational field flux through any closed surface S, and M on the right is the total mass enclosed inside S. If the flux is assumed to be constant, the divergence theorem, where the area integral is the volume integral of the divergence of a vector field, can be used on the left, and the mass on the right can be expressed as the integral of the mass density function ρ, giving:

$$\int \vec{\nabla} \cdot \vec{g} dV = -4\pi G_N \int \rho dV \qquad (4)$$

If this equality holds for any volume, the integrands on both sides must also be equal, giving the differential form (Equation 1). However, if mass per unit matter is not constant, decreasing with increasing volume, it will necessarily give the appearance of an invisible dark energy that pushes objects apart more strongly as their density decreases. If the redshift of distant galaxies is taken to mean "space" is expanding then there will be an apparent accelerating expansion whose source will appear to be the increase in empty space.

4. Time and energy vary, not space

The idea that light-speed was constant initially arose from observations and experiment where it was found that the speed of light was independent of the speed of the emitting source. More recent, stronger, evidence is seen in that the light reaching us from each star of a binary system takes the same time for the same distance. The time taken is independent of whether either star is approaching or receding. This differs from what we observe if we throw a ball from a moving car. The ball goes faster (relative to the ground) when it is thrown forward. This does not happen with light, otherwise the light emitted later in an orbit, when the star was approaching, might reach us before the light emitted earlier, when it was receding. No such effect is seen even when the light has taken many years to reach us. Einstein drew on the earlier information, and the result that the interferometer experiments of Michelson and Morley could not detect any effect of the movement of the Earth around the Sun on the speed of light, to postulate that the speed of light (in vacuo) was fixed.

He combined the constancy of light-speed with another postulate, which he called 'the principle of relativity'. This principle was based on the apparent inability of an observer travelling at constant velocity (in an enclosed space such as a windowless train carriage) to detect their motion when the outside could not be seen. It seemed that no experiment, within the enclosed space, could reveal that movement of the enclosure was occurring. The movement of objects (mechanics) and waves (electrodynamics) seemed to possess no properties corresponding to the idea of absolute rest; only relative motion between objects and observers appeared to have an importance. The combined postulate was that all physical laws were the same for objects moving at constant speed. Thus, it was proposed that all observers would measure the same speed of light. The assumption that relative motion changed space and time, but did it in a way that kept light-speed (distance divided by time) constant (i.e. $c = x/t = x'/t'$), was adopted based on the combined postulate. The space and time of objects perceived by each observer was claimed to be fixed if they were stationary relative to the observer. Otherwise, they were contracted and slowed in proportion to the relative speed of motion between objects and observer.

Special relativity assumes that there are no changes in any properties (for the on-board observer) if the hypothetical train is moving at close to light-speed relative to the background of stars and galaxies. However, we know that elementary particles are more difficult to accelerate and decay more slowly as their speed relative to the accelerator approaches the speed of light. Hence, the possible alternative is that the speed of light after emission is independent of movement of the source, but movement of the source relative to the background medium from all other mass causes time of massive objects (i.e. moving clocks and observers) to slow. Massive objects are sensitive to movement relative to this background, but massless light is sensitive only to the magnitude of the background. Light-speed is then constant for the same constant background, independent of the speed of the source. Special relativity is only claimed to apply in the absence of a gravitational field, i.e. when there is no gradient in the background gravitational potential from surrounding matter. Hence, it provides no requirement for the speed of light to have the same value in a different constant background.

Einstein demonstrated that the Lorentz transformation between a stationary and moving frame left Maxwell's equations unchanged. For a constant speed (v) in the x-direction it has the form: $x' = \gamma(x - vt),\ y' = y,\ z' = z,\ t' = \gamma(t - vx/c^2)$, where $\gamma = 1/\sqrt{1 - v^2/c^2}$. He then claimed that the result: $x^2 + y^2 + z^2 - c^2t^2 = x'^2 + y'^2 + z'^2 - c^2t'^2$, confirmed that light was radiated spherically in both frames at speed c. However, the conclusion results from: i) inserting matched, rather than reciprocal, changes in distance and time, and ii) assigning incompatible meanings to x in the transformation.

The alternate perspective is that the term vx/c^2 in the time t' of the moving frame is essential to correct for the advance/delay in the arrival time of signals (moving at c) when there is relative movement of v/c in the time x/c that light takes to travel the $x = vt$ distance interval between matched points. Hence, the time in the moving frame becomes: $t' = \gamma(t - v^2t/c^2) = t/\gamma$, which is consistent with a real slowing of time (fewer ticks of an identical clock) in the moving frame. The apparent distance between matched points in the two frames, according to the slower time in the moving frame, will then be $x' = \gamma(x - vt)$ for points that were coincident at $t = t' = 0$. If an underlying reality exists independent of the motion of the observer, as should be expected, then distance is not contracted. It is only an apparent effect of a slower clock-rate. The apparent invariant interval arises from using x as both the interval between matched points in the expression for t', and as the fixed distance from the origin in the expression for x'. This is not allowed and forces a distortion of distance.

The apparent, but unneeded, contraction of distance and assumed constant light-speed were taken over into general relativity. These were required by the equivalence principle that observations in free fall are equivalent to those in an inertial frame without gravity. However, this principle is based on the assumption that gravity is transformed away under free fall so that no experiment can detect a difference. This is untenable under the changed perspectives because the mass of the matter is continually reducing and the gravitational force has not disappeared; it is matched by the inertial resistance to acceleration. The invariant interval and four-vector formulation of momentum/energy and distance/time can be retained by having distance scale fixed but a variable speed of light reflecting the time taken for light to travel a given fixed distance. Thus, the many successes of general relativity do not establish that the speed of light is a universal constant for the local observer.

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'" [10]. The revised theory retains Euclidean geometry. It is not a metric theory that distorts the geometry of a linked distance (space) and time. Energy/momentum and time are changed but not distance.

5. Matching the predictions

However, general relativity appears to have had enormous observational validation so this must be maintained or improved without space expanding. First, the advance in the perihelion of eccentric orbits (e.g. of Mercury) is maintained. General relativity's distortion of space is ignored in a weak field because the small change in using time rather than 'proper' time [11], or using mean distance of the eccentric orbit, has negligible effect on the fractional advance per orbit. Thus the rate of advance depends only on the change in time, thus for both current and new perspectives the change in momentum with distance from the central mass and the precession predictions match. In a strong field the change in periastron, Schwarzschild precession, of a star near our galaxy's central black hole has been observed [12]. Here the observed change in orbital angle has been fitted using the rate of change in distance scale of the Schwarzschild metric over just the region of the periastron of an extremely eccentric orbit. It is suggested that this is equivalent to using only the change in time and again the predictions will match.

The predicted Shapiro delay is also the same for both perspectives because the fitting of the observed delay uses the logarithmic dependence of changes in path length due to bending. This removes the effect of any changes in distance scale or speed of light, so the predictions will match if the doubling of bending also holds under the new understanding. This will occur if the amplitudes of the helical oscillations of a photons electric and magnetic field components are both reduced in proportion to the increased light-speed; with Fermat's principle requiring the bending to be towards least time.

The new perspectives have gravitational waves arising from variations in the speed of light due to cyclic changes in the location and movement of massive objects and therefore of gravitational potential. However, gravitational potential only falls off inversely with distance, whereas gravitational force falls of as $1/R^2$. This should be seen as a big surprise, particularly when it has been established via the Aharonov-Bohm effect that the potentials, rather than the forces, are the underlying significant properties for electromagnetism and gravitation [13,14]. The brightness of light sources, the number of photons going through the same lens, falls off inversely as the square of the distance. The flux of such energy-carrying fields must fall off inversely with the increase of the area of the enclosing surface (i.e. as $1/4\pi R^2$), otherwise the flow of energy is not conserved. Thus, under the new perspective, gravitational waves are cyclic variations in received potential. They are not distortions of spacetime. They do not have to carry energy [15], and must not. Instead, they alter travel time, and thus apparent path length; so will be detected by the existing LIGO interferometers.

The immediate challenge is that the apparent loss of energy of rotating binary pulsars appears to agree with general relativity's prediction. However, an examination of the prediction of the apparent energy loss reveals that it is based on a circular orbital equation that does not include changes in apparent (i.e. retarded) positions, doppler shifting, or changes in momentum with potential, and so removes all relativistic effects common to current and new perspectives. The differences in expected orbital energy and rate of change arise because of the non-central forces and changes in inertia, and the magnitudes of forces, with separation and velocity. It appears, but has not been confirmed, that the apparent rate of change in energy, from using the over-simplified orbital energy calculation, will match that being attributed to the loss in energy from energy-carrying gravitational 'waves'. These claims need to be examined and extended to a critical review of the timing changes and their causes in the modelling of more recent pulsar data [16]. The underlying issue seems to be that there can be different explanations for effects of the same magnitude. Other predictions also need to be investigated but appear able to be reproduced by taking into account the finite speed of light, doppler shifting, and the change in momentum with velocity and light-speed.

The new perspectives must also be investigated for consistency with the evolution of the universe, including data from the cosmic microwave background, supposed baryon acoustic oscillations and the persistence of galaxy spiral arms.

6. Implications for particle physics

The standard model of particle physics has the Higgs mechanism, via the Higgs field and its exchange particle, the Higgs boson, as the proposed source of the mass of other particles. The revised gravitational perspective suggests that any interaction that traps momentum at a location gives rise to mass. However, it also implies that the major mechanism arises from the handedness seen in the weak interaction with the background field containing opposing components of opposite chirality from matter and antimatter. The $1/R$ dependence of potential then arises from one component inhibiting changes in the other. This allows contributions from distant matter and antimatter galaxies and galaxy clusters to dominate. The lack of a currently observed annihilation signal implies that early annihilation left gravitationally isolated regions of matter and antimatter as galaxy clusters contracted. They no longer interact and so only appear not to be present in equal quantities.

A dependence of inertia on the local asymmetry between matter and antimatter is then proposed as the explanation for the flat rotation curves and gravitational lensing of isolated galaxies, removing the need for dark matter. It also implies that the masses of central black holes are significantly underestimated. These differences may explain the partial successes of theories of modified Newtonian gravity.

The revised gravitational perspective also suggests that elementary particles are cyclic 'standing-wave' states in three spatial dimensions that trap momentum. Quanta arise from the discreteness of these 'stationary' states, but the size of all quanta vary with the speed of the background field. The one underlying two-component field may then explain all four fundamental forces with gauge invariance being increasingly broken as matter separated into regions of opposite chirality. Thus, the new perspectives may be able to remove most or all of the evidence for physics beyond the standard model while explaining how it works.

7. Experimental and observational tests

There are clear differences in predictions, and explanations, that allow both logical assessment and experimental or observational tests that distinguish between the new and current perspectives. A yes/no difference between the theories of gravity is in the apparent versus real distortion of distance. This can be tested by examining direct timing signals (using on-board clocks) and returned (reflected) signals to Earth from spacecraft with increasing measured distance from the Sun. A re-examination of the data from the Pioneer spacecraft or a new experiment where heat radiation is uniform may help.

Perhaps the most straightforward test is to establish whether it is movement relative to the observer or movement of the observer relative to the background that slows time. It should be possible to compare very low mass but accurate clocks moving linearly towards each other and to a central clock (or spaced pair of clocks) at a very high, but constant, velocity and compare all clock-rates after allowing for movement during the transmission time of signals. This needs to be done in space, i.e. at high vacuum, with lengthy acceleration and a nearly constant gravitational potential.

The new much more extensive data from supernovae should be tested to see if a variable speed of light continues to remove any need for expansion and to provide an accurate determination of the current rate of change of time. Data from the James Webb telescope may provide evidence for the expected contraction in the size of galaxies over time. A test for asymmetry of matter/antimatter as the source of inertia would be the dependence of inertia on position within our and other galaxies. It should be visible in the expansion rates of the matter in supernovae explosions. The expansion rate should reflect the inertia seen in the galaxy rotation curve at the supernova location.

8. Conclusion

The alternate perspectives on gravity and mass overcome the need for a malleable geometry of a linked spacetime that keeps light-speed constant. The removal of many inconsistencies and of the need for unexpected ad hoc hypotheses, such as a repulsive dark energy, provides strong support for their correctness. They also offer a path to a better understanding of the nature of particle interactions. However, arguably their most important benefit is the removal of relativity’s subjective, observer-dependent, malleable reality for events. Ultimately, the scientific method demands that critical examination of the arguments, predictions and evidence decides the path forward.

References

[1] A. Einstein, Ist die Trägheit eines Körpers von seinem Energieinhalt abhängig? [Does the mass of a body depend on its energy content] Annalen Der Physik. 18 (1905) 639. https://doi.org/10.1002/andp.19053231314

[2] A. Einstein, The Theory of Special Relativity, Lecture II, in The Meaning of Relativity. Four lectures delivered at Princeton University, May, 1921. Available from Project Gutenberg as eBook #36276.

[3] T.P. Cheng, Relativity, gravitation and cosmology: a basic introduction. Oxford University Press, 2nd ed., (2009) pp. 69-70.

[4] J.S. Schwinger, 1986. Einstein's legacy: the unity of space and time. Scientific American, New York, (1986) p. 142.

[5] L. B. Okun; K. G. Selivanov; V. L. Telegdi, On the interpretation of the redshift in a static gravitational field, Am. J. Phys. 68 (2000) 115-119. https://doi.org/10.1119/1.19382

[6] T.P Cheng, 2009. *ibid.*, pp.77-79.

[7] R.V. Pound, G.A. Rebka, Apparent weight of photons, Phys. Rev. Lett., 4 (1960) 337. https://doi.org/10.1103/PhysRevLett.4.337

[8] N. Suzuki et al. Ap. J. 746 (2012) 85. https://doi.org/10.1088/0004-637X/746/1/85

[9] T.P. Cheng, 2009. *ibid*., p.62.

[10] C.M. Will, The confrontation between general relativity and experiment, Living Rev. Relativity, 17,4 (2014) p.9. https://doi.org/10.12942/lrr-2014-4

[11] K.-H. Lo, K. Young, Y.P. Lee, Advance of perihelion, Am. J. Phys. 81, (2013) 695–702. https://doi.org/10.1119/1.4813067

[12] R. Abuter et al., Detection of the Schwarzschild precession in the orbit of the star S2 near the Galactic centre massive black hole, A&A, 636 (2020) L5. https://doi.org/10.1051/0004-6361/202037813

[13] Y. Aharonov, D. Bohm, Significance of electromagnetic potentials in the quantum theory, Phys. Rev. 115 (1959) 485-491. https//doi.org/10.1103/PhysRev.115.485

[14] C. Overstreet, P. Asenbaum, J. Curti, M. Kim, M.A. Kasevich, Observation of a gravitational Aharonov-Bohm effect, Science 375 (2022) 226–229. https://doi.org/10.1126/science.abl7152

[15] P.M. Duerr, It ain't necessarily so: Gravitational waves and energy transport, Stud. Hist. Phil. Sci. B 65 (2019) 25-40. https://doi.org/10.1016/j.shpsb.2018.08.005

[16] M. Kramer et al. Strong-Field Gravity Tests with the Double Pulsar, Phys. Rev. X 11, 041050 (2021). https://link.aps.org/doi/10.1103/PhysRevX.11.041050