Making Sense of Gravity

An Introduction to Full Relativity

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A new perspective on the nature of space and time challenges our existing picture of the universe based on Special and General Relativity. It leads to an exciting new theory, 'Full Relativity', with its simple understanding that gravitational attraction arises from a loss in the mass held by matter as it moves into a denser region of other matter. The invisible field that permeates all space and gives rise to gravity's action-at-a-distance is not a distortable fabric of space-time. Movement relative to the required field, and changes in its strength, alter clock-rate. Thus, they change the scale of time. However, the change in scale of "space" is apparent, rather than real. The distance between objects does not change, it is the energy and inertia of objects that change. The magnitude of the field determines the speed of light, which alters the amount of energy trapped by the standing wave patterns of particle states. This stored energy is, as Einstein pointed out, mass. The same matter stores less mass when the speed of light is faster. All four fundamental interactions (strong, electromagnetic, weak, and gravitational) are related by the broken gauge invariance of the field that determines the oscillations of particle states and the energy they can trap. Changes in the magnitude and asymmetry of the pair of chiral components of this background field change the speed of propagation of the field and the mass and inertia of the particles. The reasons why the new perspective is demanded are set out, and it is shown that the standard predictions of General Relativity are reproduced. The incredible benefits go far beyond explaining gravity. They include removing the need for dark energy, dark matter, cosmic inflation, singularities inside black holes, and a big bang, while solving the flatness and horizon problems of the existing consensus model of cosmology. They also provide the beginnings of a physical model underlying the Standard Model of particle physics.

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The background to gravitational attraction

The idea of a field, or medium, or aether, was introduced to explain action-at-a-distance. Rubbing an amber rod could make nearby hairs stand up, a magnet could attract metal objects, and planets could be gravitationally attracted by the Sun. All these effects are at a distance, across seemingly empty space. An invisible medium (a field or fields) that can carry light and other radiation, and forces including gravity, is essential. A revised understanding of the nature and effects of the field(s) that permeate space, and determine the movement of objects that we can see and touch, allows us to make sense of gravity [1]. A background field that alters and is altered by massive objects, is essential.

Physics teaches that an oscillating pendulum has no kinetic energy at the top of its swing. It then loses gravitational potential until, at the lowest point, kinetic energy is at a maximum and potential is at a minimum. The difference in potential has been converted into energy of motion. On the upward swing, the work done in lifting the mass higher, the integral of the vertical force by the change in height, restores the potential. This gravitational potential (Φ) is the energy gained per unit mass. But what is mass? Einstein came up with the answer in 1905: "*The mass of a body is a measure of its energy content*" [2]. 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*" [3]. However, he and others failed to perceive that the same body of matter (without a change in state) might store different amounts of energy if the total field from all other matter changed.

The gravitational potential falls off inversely with distance (i.e. as $1/R$). Therefore, the contribution to the total potential from the enormous number of distant galaxies far outweighs that from the Earth and Sun and their mass will only induce small gradients in what appears to be a constant total background field that determines the local energy stored (mass) per unit of matter.

Newton's equation of motion is a time-independent, energy-balance equation [see **Box 1: Newton's universal law of gravitation**]. Energy is conserved but a massive object cannot store as much energy when nearer other matter, i.e. when the background field increases. The work done in raising an object against the force of gravity becomes a gain in stored energy per unit mass ($\Delta E / m$), so that the fractional change in the total mass of the small mass m is, to a good approximation:

$\Delta m / m = \Delta E / E \cong -G_N M / Rc^2 = \Delta\Phi / c^2$, where $\Delta\Phi$ is the change in potential.

It is the fractional decrease in mass ($m = E / c^2$), or energy, with distance R from a point source of mass M , relative to zero at infinite separation (i.e. $R = \infty$).
When the object falls, the energy lost as mass appears as kinetic energy (KE) of motion. The KE gained by falling objects can be explained as a loss in their stored energy. The total stored energy per unit mass is enormous, with a 1 kg object containing the energy of a 20 megaton (of TNT) hydrogen bomb. Hence, the fractional change is small and the factor G_N / c^2 will be small and nearly constant.

In hindsight, it is very clear that gravitational attraction is just a reflection of conservation of energy. We know that when matter and antimatter annihilate all the energy is released as massless radiation, no mass is left. Mass is only stored energy. Gravitational potential is the fractional increase in mass (stored energy) with increase in separation (e.g. height). The work done in overcoming the gradient in potential is stored as increased mass of the raised object. Objects shed mass by moving closer to other objects. This new understanding of gravity, in which the mass and motion of objects is determined by the effects of all other objects (the background), is termed "Full Relativity".

General Relativity's fabric of space-time, whose geometry is distorted by massive objects and their movement and energy, keeps mass constant but allows the time and space, in which objects are embedded, to vary. This background [see **Box 2: The background field of space-time**] must give kinetic energy to objects as space and time become more distorted, while leaving stored energy unchanged.

Full Relativity's variable mass has the same matter storing less energy when it moves into a region of lower potential as the background field increases. The released energy does not need to be radiated as photons (electromagnetic quanta) and neither the number nor type of atoms need to change. It is shed by doing work to accelerate the matter. Why and how this might happen will be presented later. It reflects the nature of both matter and the background.

Implications of variable mass

So why hasn't anyone realised or observed the reduction in mass. The first part of the answer is simple. The amount is very small, because the background is very large. Newton's universal law of gravitation has: $F = G_N Mm / r^2$. The force falls off as the inverse square of the distance. However, the change in potential ($\Delta\Phi$), or energy per unit mass, is $\Delta\Phi = \Delta E / m = G_N M / r$, so the influence of the large mass M only falls off as $1/r$. Moreover, all masses, independent of direction, sum to give the total background field. As a result, the billions or trillions of distant galaxies, despite their enormous distance, contribute far more to the total field than the nearby Earth or Sun. The Earth's force of gravity arises from just the tiny gradient it produces in the enormous background field. The force actually depends on the change in total field, but the background is so large that the gradient appears independent of the total. Hence, the value of G_N appears constant. The fractional loss in mass of a small mass, in approaching a massive object to distance R from far away, is $G_N M / Rc^2$. The fractional loss in reaching the Earth's surface, for the current background from the rest of the universe, is approximately 6 x 10^{-10}.

The second part of the answer is also simple. The effect has, in fact, already been observed. If the gravitational force is stronger, the change in energy is larger, and the pendulum swings faster. Every object or particle, whether matter or radiation, has a de Broglie wavelength of oscillation inversely proportional to the energy carried. The frequency of oscillation is proportional to the energy carried as in $E = \hbar\omega$. Time, frequency, and the rate of ticking of a clock are directly proportional to the energy carried. The fractional changes in energy, mass, and time, change in unison with a change in gravitational potential. Thus, the observed changes in time of the clocks of the GPS system, which General Relativity attributes to the effect on time of differences in gravitational potential, come from the change in stored energy. It is just the understanding of how the effect arises that has changed.

The fractional change in a small mass with distance from a large source of mass also explains the known advance in the perihelion of Mercury. Its mass reduces when its eccentric orbit takes it closer to the Sun. Conservation of momentum means that its speed is then faster than that expected if its mass and inertia remained constant. The effect exactly matches that predicted by General Relativity from its distortion of time with change in potential. The already observed, but previously unexplained advance in the perihelion, was the first success of Einstein's theory of gravity with its linked distortion of space and time that kept the speed of light constant. The new understanding does not have General Relativity's matched distortion of space, but this is dropped from the calculation of the latter's prediction because the small change in mean distance of the eccentric orbit, relative to a circular orbit, has negligible effect on the fractional advance per orbit.

The second prediction of General Relativity was that light would be bent by twice the amount previously expected. This was famously confirmed in a solar eclipse of 1919. The amount was predicted to be doubled from that due to the falling of light, or loss of potential energy, in a gravitational field. Under General Relativity, the doubling comes from a matched contribution to the slowing of time in the contraction of distance. Under Full Relativity, it will be argued that it is a change in wavelength of paired components of the background field that gives rise to the observed doubling.

The third prediction of General Relativity was a slowing of time deeper in a gravitational field. It was not until 1959 that the experiments of Pound & Rebka showed that photons were not resonantly absorbed at a detector higher in a tower unless given a boost in energy. Thus, their frequency appeared redshifted as predicted. Consequently, it has been widely accepted that: "photons lose energy in escaping a gravitational field". However, Newton's law of gravitation implies that photons should not gain or lose energy in a gravitational field because their mass is zero. The standard explanation of why they appear to lose energy is that they are attracted because of the kinetic energy seen in their momentum. However, a number of authors have pointed out that, under General Relativity, the loss of energy is a mistaken belief [4-6]; instead, the redshift is because the "standards" of frequency (i.e. of time) have changed. These authors claim that an apparent blueshift in the energy levels of atoms arises from a change in the units ("standards") of time. The gradient in gravitational potential, an acceleration field, changes the distortion of the metric of space-time. However, both explanations are unsatisfactory because the units of time, and hence the frequencies, of both atoms and photons should be equally affected, meaning that no relative shift should be seen.

Full Relativity's change in the stored energy of matter provides a simple explanation that overcomes this serious problem. The experimentally observed apparent loss of energy (a redshift relative to the detecting atoms) is instead a real increase (by the opposite amount) in stored energy (a blueshift) of the atoms. The energy of the massless photon is unaffected by a gravitational field. It is not the properties of the field of space-time between objects that changes but the properties of objects.

The atomic transitions of increased energy happen faster, so time (i.e. clock-rate) is faster. The two theories give the same increase in clock-rate ($\Delta\Phi / c^2$). However, under General Relativity, the apparent loss of photon energy (redshift) is attributed to it being attracted because of its momentum, and therefore in proportion to its kinetic energy. This led to the faulty conclusion that all forms of energy, including that from gravitational acceleration, give rise to an increased distortion of space-time. The result is a feedback mechanism in which distortions of space-time give rise to increased energy which further increases distortion as mass/energy density increases. This is the cause of General Relativity's necessary singularities inside black holes [7]. Once mass density exceeds a critical value the positive feedback sends the distortion to infinity. Such singularities confirm that either the theory is faulty or, at the very least, that it no longer applies in the limit of very high densities.

Full Relativity's decrease in energy held per unit of matter, with an increasing background from other mass, provides a negative feedback, avoiding the singularity. If the density of matter increases within a region, but the background from outside this region remains constant, then the mass held per unit matter within the region decreases. Black holes are regions where matter collapses into very high density but they do not contain singularities, or trap (massless) light because of loss of energy after emission. Any emitting transitions would be of extremely low energy (long wavelengths) and there would be no event horizon behind which light, or changes in gravity which travel at the speed of light, should be trapped. This permits black holes to rotate around stars and each other, which should be impossible because of General Relativity's uncrossable event horizon.

Mass as stored energy is not a new concept. It has been accepted for many years that a box enclosing a gas weighs more (has more mass) than the same box and same amount of unenclosed gas. Enclosing the gas means that a pressure is exerted on the walls proportional to the trapped momentum. Heating the gas increases the momentum and therefore the pressure and mass. In addition, the gas will provide additional inertia if there is a change in the velocity of the box. With a change in velocity the gas molecules will hit one wall with more momentum than the opposite wall, resisting acceleration until the new equilibrium is established. It is also accepted, that if a box of perfect mirrors could be "filled" with light, the massless photons would contribute to the total mass of the box by an amount equal to their energy divided by c^2. Thus, it should be seen that any mechanism that constrains momentum to the same location, increases the total mass and inertia of the constraining object.

Variable mass also explains why General Relativity has some implausible features. The differential form of Newton's equation, on which Einstein's field equation of General Relativity is based, assumes that the flux of the purported field (gravitational acceleration - the force per unit mass) is conserved. That is, the amount flowing through the surface enclosing a fixed amount of matter is constant, i.e. the flux is independent of the density of that matter. This is not true under Full Relativity, because the mass stored by the same amount of matter reduces as its density increases. The first consequence, under General Relativity, is that empty space free of matter (i.e. nothing) will appear to act as a source of repulsive gravitation (if density reduces). The second consequence is that Einstein's field equation has the distortion of space-time dependent on the density of energy/momentum. This requires that the solutions of Einstein's equation must vary with the mean separation of matter (distance) and increase or decrease with time. These consequences led to the concepts of a Schwarzschild radius, black holes and event horizons, and (given the Hubble redshift) that the universe must be expanding, with the expansion being in the empty space between objects without the objects moving. This is explained more fully in **Box 5: Problems with General Relativity**.

The astute reader may have noticed that the claim, that gravity can be explained by the mass of the same matter changing, provides an even bigger challenge to the existing belief system. If Einstein's most famous equation, $E = mc^2$, which arose in Special Relativity, holds true, then the change in mass is associated with a variable speed of light. An increase in the mass of matter, which holds energy E_0 at the current position, from m_0 to m_1, implies a decrease in the speed of light, such that $(c_1 / c_0)^2 = m_0 / m_1$. So, the new perspective requires a faster speed of light when the background field is larger. This will be the case if the local density of matter increases while the rest of the much larger background remains constant. The speed will also have been faster earlier in the life of the universe, if the background has decreased over time as the universe has evolved.

General Relativity as a theory of gravity

The core idea of the existing theory of gravity, General Relativity, is that there is a background fabric of space-time, which gets distorted by mass and energy/momentum. However, the speed of light remains constant for the local observer not feeling a gravitational force. Further details are given in: **Box 4: A brief introduction to General Relativity**.

Einstein's noted that an observer in free-fall felt no gravitation. Gravity appeared to be transformed away by acceleration and the laws of physics appeared to be the same as in the non-accelerating (inertial) frames of Special Relativity. He also proposed that inertial mass (its resistance to acceleration) and gravitational mass (its attraction by other mass) were equivalent. This claimed invariance of the laws of physics is called the Einstein or Strong Equivalence Principle. In hindsight, the proposal that physics in a frame, freely falling in a gravitational field, is equivalent to physics in an inertial frame without gravity, is a giant leap of faith that ignores the background field. An object accelerating in a gravitational (force) field is continually moving to a lower potential but a stronger background field. The mass of the object will be decreasing as the speed of light increases.

Special Relativity's faulty concept of a fabric of space-time (see Boxes 2 & 3), which kept c and mass constant, was taken over into General Relativity. Retaining the fabric meant that a change in time with gravitational potential was matched by a change in distance scale so that measured c stayed constant. Space and time could now expand or contract with changes in the strength of the gravitational field. This reinforced the strange idea that “space is not a thing” and can expand without objects moving. The required changes in mass and c are small so it is understandable why they are not obvious. The fractional difference in c between that on Earth and the satellites of the global positional system (GPS) is tiny (3 x 10^{-10}). However, the change in mass still shows up in the ongoing small adjustments to clock-rate. General Relativity’s claimed changes in distance do not, in general, come into the predictions that have been tested; except for the bending of light, where Full Relativity has the doubling of bending arising from changes in wavelength in both electric and magnetic fields.

General Relativity’s equation of motion, Einstein’s equation, has m and c independent of a stationary, isotropic, and uniform density of surrounding mass. This is because it has the gravitational force per unit mass (i.e. acceleration) as the conserved vector field. Equal distortions of time and distance from mass/energy in opposite directions cancel (which is hard to understand for distortions which are changes in magnitude). Thus, there is no effect of the background from the uniform large-scale distribution of distant galaxies. Full Relativity has the total background field giving rise to a scalar gravitational potential. This potential reflects the changes in mass with changes in the speed of light.

A basic difference between the two theories, for gravity, comes from general relativity keeping both mass and $c =$ (distance)/(time) locally constant for observations at the object, but distance contracted and time slowed when viewed from a higher potential. Full relativity has an increased c and time slower at the lower potential but the scale of distance is constant. Local matter cannot then hold as much energy, so time (clock-rate) slows, but the scale of distance is unchanged.

General Relativity is based on a generalisation of what is known as the differential form of Newton’s gravitational equation, also known as Poisson’s equation for gravity:

$\nabla^2\Phi = 4\pi G_N \rho$, where ρ is the mass density and G_N is Newton’s gravitational constant.

This Poisson equation is derived from Newton’s universal law of gravitation:

$F = G_N Mm / r^2$, after combining it with his second law (the equation of motion):

$F = mg$, where $\vec{g} = -\nabla\Phi$.

Gravitational acceleration $\vec{g}$ is minus the gradient of the potential Φ. The units of gravitational and inertial mass m have been equated in Poisson’s equation, so that any changes of inertia due to the background field are absorbed into the value of G_N.

General Relativity has curvature, a distortion of the geometry of space-time by the potential, dependent on the gradient of the acceleration field ($\nabla^2\Phi$). The generalisation also extends mass density to include the energy/momentum density of surrounding matter as the source of the acceleration field. However, the derivation of Poisson’s equation, via Gauss’s law, assumes that the flux of the “field” of gravitational acceleration is conserved. The flux from electric charge is independent of the density of charge. However, the flux from the mass of the same amount of matter varies with the density of the matter so Gauss’s law fails [see **Box 5: Problems with General Relativity**].

Under General Relativity, gravity is not a real force, but a distortion of the space and time in which objects exist but the speed of light is constant. This has meant that it cannot be unified with the three other fundamental forces or with quantum mechanics. Full Relativity gives rise to a real force, appears consistent with quantum mechanics, and can reproduce the predictions of General Relativity. Any force that traps momentum gives rise to mass and mass varies with a background which alters the speed of light. The background can change the properties of objects and the speed of light, rather than distort the space and time in which they exist. These differences allow a path to unification.

Must the speed of light be constant?

The needed changes in the local speed of light are very small and most of the evidence that it is constant appears to come from the success of General Relativity's predictions. So there is a need to explore how the belief in a constant speed of light arose as a first step in mounting a challenge.

The concept of a fabric of space-time, linking space and time into a constant speed of light, first arose in Special Relativity (when there was no gravitational force present, so that the gravitational potential and background field were constant). Special Relativity applies within inertial frames, i.e. when there is no acceleration. However, a region at a different gravitational potential can only be reached via an acceleration. Hence, there is no requirement for the same value of light-speed in another region which has a different constant potential. Einstein assumed, because of observations such as those of Michelson & Morley, that it always had the same value and so missed the possibility that mass, as stored energy, could have a variable conversion factor if the background from other mass was different.

General Relativity then built on this space-time fabric using assumptions which included that mass and the speed of light were constant for the local observer. The "fabric" has a geometry that can be distorted by massive objects but links a malleable distance and time into a constant speed of light.

Introduction to Special Relativity

It is a difficult task to challenge aspects of Special Relativity because it is now so strongly embedded in our scientific education and culture. There is also a huge range of experimental evidence that supports its validity. However, the majority of experimental evidence, which amounts to consistency with the Lorentz transformation (LT), is not being challenged. Full Relativity maintains the validity of the behaviour captured by the LT but challenges its interpretation, under Special Relativity, and that it establishes the validity of the hypotheses used. The key conclusions, such as time dilation, that nothing can travel faster than the speed of light, and the deduction of $E = mc^2$, remain. However, the claims that physical laws are completely independent of a constant velocity relative to a background (only motion relative to the observer is important), that the measured speed of light is the same for all observers, and that there is a fabric of space-time, all need qualification or rejection. Full Relativity involves subtle differences in meanings or interpretations of terms, particularly between apparent and real effects seen by observers in different frames.

Einstein's method, used to derive the LT, sought to relate the same events (locations in space and time) seen in a moving and stationary frame, with all values referred back to the stationary frame [8]. Each frame is a set of spatial (x, y, z) coordinates with a time (t) coordinate based on having a clock at every point, with all clocks, stationary relative to each other within that frame, synchronised.

Using this thought experiment, Einstein deduced that time was slowed, and distances contracted, in the moving frame for observers in the stationary frame. Moreover, time was slowed and distances contracted by the same amount in the stationary frame for observers in the moving frame. The underlying time in each frame was the same but observers in relative motion, towards or away, would see the other's clocks slowed. Space and time only had a sort of relative existence and it was only their combination in terms of the speed of light that was constant.

In Special Relativity, the <u>observation</u> that the underlying speed of light was constant independent of the speed of the emitting object was upgraded to a (second) postulate. However, the observation was subtly changed into the claim that the observed (measured) speed of light was constant independent of the speed of the object or receiver [see **Box 3: Special Relativity**]. The relationship between events seen by an observer moving at a constant velocity and a stationary observer was then deduced. As part of this deduction, as will be explained (see Box 3), a faulty argument led to the claim that the moving and stationary observers would each measure the other's clocks as running more slowly. This is not correct if one observer's clock is running more slowly because of movement relative to a stationary background. The clock of the stationary observer must be running relatively faster.

The information (presented in Box 3) shows that the deduction of the Lorentz transformation was fortuitous. Moreover, the transformation applies to the same location in each frame only if $x = vt$ is used in the expression for the time dilation $t' = \gamma(t - vx / c^2)$, and $t = 0$ is used in the expression for the location $x' = \gamma(x - vt)$. The time and distance in the moving frame (travelling at v relative to the stationary observer) are then $t' = t / \gamma$ and $x' = \gamma x$. The changes in scale are opposite rather than matched. The clocks in the moving frame tick more slowly causing light to appear, and be measured, to travel further. However, the reduced distance between objects is only apparent. The fabric of a linked but malleable space and time, that can be altered by the speed of the observer, is not correct.

Einstein's first postulate was the "principle of relativity": the laws of physics are independent of motion at constant speed. That this principle, based on apparent behaviour at low speeds, applies at all speeds, is a giant leap of faith. It turns out not to be true. The claim that the measured values of distance change with speed of movement (relative to either the observer or the background) is faulty, only apparent distance changes. The claims that only relative motion between observer and observed is important and that each moving observer will see the other observer's clocks slowed are based on a faulty argument and are not correct.

Special Relativity (constant c) has time slowed and the scale of space contracted, as a function of speed relative to the observer, along the line of relative motion. Full Relativity has the time (clock-rate) and frequency of massive objects slowed, but the scale of space unaltered, by motion relative to the nearly stationary background. The speed of massless light is insensitive to motion relative to the background, so its apparent speed and distance travelled increase, if the massive observer is moving relative to the background. However, the underlying c and distance are unchanged.

Full Relativity has the slowing of time applying to all massive objects, including clocks, moving at high-speed relative to the background. The observer with the slower clock will determine that the same light is moving faster. The imposed requirement, of Special Relativity, that both observers would measure the same speed of light, meant that a matching change in the scale of space, to that in time, had to be inserted. The experimental tests have only ever compared clocks where one has a higher mean speed relative to the other, or where elementary particles are moving at high-speed relative to the nearly stationary background from distant galaxies. The slowing of clock-rate for the moving observer is real, but it is for movement relative to the background and not for movement relative to the observed clock. Space, the distance between objects, is not and cannot be altered by relative motion of the observer. However, apparent distances will be increased if the observer's clock is running more slowly.

Space-time is an illusion and must be replaced

The fabric of space-time was proposed in order to give a constant measured speed of light. However, the evidence is not that the measured speed is independent of high-speed motion of the observer. Instead, there is strong evidence that the underlying speed of light is independent of the speed of the emitting object. It is consistent with the light emitted from binary stars. If the light emitted by a star moving away travelled more slowly ($c - v$), then by the time it reached us it could be overtaken by light emitted later in its orbit when it was moving towards us (at $c + v$). There is no evidence for such an effect. A constant underlying speed is consistent with the inability of any experiments, like the interferometer experiments of Michelson and Morley, to see shifts in the arrival time of light because of motion relative to the background. It is also consistent with the aberration of starlight. This is a movement in the apparent direction of a star with the speed of the Earth's movement in its orbit at right angles to the direction of the star. The effect is similar to what we observe when travelling in the rain. Rain that is coming from one side when we are stationary appears to come increasingly from the front as our speed increases. The arrival time depends on distance travelled at constant speed, but there is still a Doppler shift in received wavelength whose amount depends on the relative velocity between source and receiver.

Dilation/contraction of space-time is based on a misinterpretation of how a slowing of clock-rate, with speed of the clock relative to the background, affects the apparent speed of light when its underlying speed is constant. In Special Relativity, time being slowed was wrongly assumed to mean that more time would elapse while light at a constant speed appeared to travel a given distance. Light would then take the same time to travel a contracted (less) distance. This kept the measured speed of light, rather than the underlying speed, constant. It is the latter that is in agreement with the transformation that Lorentz proposed to explain observations. These included that the rate at which electrons were bent by an electric field slowed, became more difficult, as they moved faster. His proposed reason why the Michelson-Morley interferometer experiments showed no evidence of movement relative to the aether was that the length of the arms must be contracted in the direction of motion. He proposed that larger intervals between ticks, giving slower time (time dilation), must be matched by shorter distances travelled (length contraction), making the arm lengths appear constant.

There are also basic flaws in the argument used by Einstein to conclude that only relative motion mattered. He assumed (in his thought experiment) that the lack of time-dependence of position coordinates after a two-fold application of the Lorentz transformation (v followed by $-v$) meant that there had been a return to the stationary frame. This faulty deduction led to the conclusion that each moving observer would see the other's clock slowed. However, the frames being compared only overlapped at time zero and so the two-fold transformation was comparing frames moving in opposite directions away from the origin of the stationary frame, after initial coincidence. The apparent return to the stationary frame arose from using the x coordinate to mean both the separation of all matched points in two frames (after overlapping at $t = t' = 0$) and the distance from the origin in the stationary frame. [Further details can be found in **Box 3: Special Relativity**]. The slowing of time is observed for massive clocks (including unstable elementary particles) moving relative to our nearly stationary position in the background from all other massive objects. If the observer is moving at high-speed relative to a clock that is stationary in this background, then the stationary clock should be found to tick faster, not slower, than the observer's clock. However, this expectation has not been tested.

General Relativity's space-time distorted by massive objects, with its non-Euclidean geometry (altered by the gradient of the potential) is an illusion. A fabric with distortions of distance matching the distortions of time does not exist. Instead, only time (clock-rate) is slowed when an increased background increases the speed of light and reduces mass. The original ("flat") fabric claimed a constant measured speed of light by interpreting $t' = t / \gamma$ as slowed (dilated) time but $x' = \gamma x$ as shorter rods (less distance). The reality is that time is slowed by movement giving an apparent increase in distance travelled. When the background increases (deeper in a gravitational field), Full Relativity has slower (dilated) time paired with faster c and constant distance, whereas space-time has slower time paired with shorter distance giving constant c .

Moreover, incorporating space-time into General Relativity has some real drawbacks. First, it contradicts the observation that the plane of oscillation of a pendulum remains fixed relative to the distant stars while the Earth rotates beneath it. This is despite the gravitational acceleration of the

Earth being dominant. Similarly, gyroscopes maintain their direction even if their orbit rotates around the Sun. These are in agreement with Mach's principle that inertia must arise from the rest of the stars in the Universe. However, General Relativity has no effect from a uniform, isotropic background. Identical distortions from opposite directions cancel. Second, it has a distortion which arises from all other matter and gives energy to objects as matter moves closer. Hence, empty space (no other matter) must carry an enormous pool of energy, and gives up more of this energy as it becomes more distorted when the amount of matter (or its density) increases. Time then slows and eventually stops at an event horizon around an infinitely deep hole (the singularity inside "black" holes). It is also inconsistent with quantum mechanics which is based on an underlying time that is not altered by its environment. Finally, it cannot be combined with the other three forces of the remarkably successful theory - the Standard Model of particle physics - because its gravitational attraction is not a real force. This theory has the Higgs field giving rise to mass, which seems to be incompatible with General Relativity's constant mass giving a distortion of space-time.

Full Relativity's background explains gravity

The integral of the gravitational force F over distance r corresponds to a change in energy of $\Delta E = \int_{r=\infty}^{r=R} F dr = G_N Mm / R$, where the value of the potential has been chosen to be zero at infinite separation of the masses. This arbitrary choice is possible because the force between two masses (e.g. the Sun and all the objects rotating around it) appears to involve a constant value of G_N. However, constant G_N is an assumption that needs to be questioned. If the total background potential is very large, compared with the potential from a local concentration of mass, then the value of G_N will be hardly changed and local effects will be closely proportional to the gradient in potential (i.e. the force). A simple calculation based on the number of visible stars and estimates of their distance indicates that, for a potential that falls off only as $1/R$, rather than as $1/R^2$, the potential from just our galaxy at the Earth's surface is at least a thousand times that from the Earth, and probably more than a hundred times that from our Sun. Moreover, because there are more than a trillion (10^{12}) galaxies in the visible universe, their total potential should be far greater than that from just our galaxy. If the density of galaxies and their average mass was constant, then the contribution of each spherical shell would grow indefinitely with distance, if a $1/R$ dependence held. So this needs more thought.

Full Relativity replaces Einstein's hypotheses for Special Relativity (when there is no gravitational acceleration) by postulating that: i) the time and frequency of massive objects depends on their speed relative to the stationary background due to all other massive objects, and ii) the speed of (massless) light is independent of the speed of the emitting object. However, in order to explain gravity, it also postulates that the speed of light increases in proportion to the magnitude of the background. Light-speed increases with decreased gravitational potential (increased background) which reduces the energy that can be stored by massive particles, in accordance with $m = E / c^2$. The reduction in stored energy is the source of the kinetic energy of gravitational attraction.

If the total background determines the speed of light, then it alters the conversion factor between mass and energy. The effect of a given excess of stored energy will be reduced as the background flux from all other sources increases. In contrast, General Relativity keeps mass constant and uses a tensor formulation in which static gradients in potential from opposite directions cancel, so that the strength of gravity is independent of a uniform, stationary background. The revised theory has gravity, energy, and momentum, fully dependent on the background which is why it has been called Full Relativity.

Full Relativity's variable speed of light links an undistorted distance with a clock-rate that is directly proportional to the mass held per unit matter and also dependent on the clock's speed of movement relative to the background. This replaces the fabric of space-time linked by a locally constant speed of light, in which distance as well as time are distorted by mass and energy, and by relative movement of the observer. This is the first and most important step in making sense of gravity.

Full Relativity rejects the claims of Special and General Relativity that the distance between objects not in relative motion (misleadingly labelled as "space") can be altered, respectively, by the speed of the observer and the presence of other massive objects. The claim that the real (not the apparent) distance between objects (not in relative motion) can be altered without the objects encountering inertial resistance to acceleration when changing their relative velocity should be seen as very unlikely.

General Relativity has had some mighty successes, but Full Relativity reproduces its key experimentally confirmed predictions using the background that gives rise to gravitational potential. This additive background alters the speed of light, with each contribution (from mass δM) reducing inversely as the distance from the massive object (i.e. as $\delta M / d$). These scalar contributions sum, independent of direction, as does gravitational potential energy. The increased speed of light reduces the mass (stored energy) that can be held by the same matter (that currently holds energy E), in accordance with $m = E / c^2$. This reduction in energy means that clock-rate slows (time is dilated). The reduced mass is seen as the familiar reduction in gravitational potential ($\Phi = -G_N M / R$). Gravitational potential energy is lost, becomes more negative relative to its value at maximum separation, with decreasing distance R from a point source of mass M. The loss of mass is the source of the kinetic energy gained by objects accelerating in a gravitational field. Full Relativity replaces space-time with a variable time (due to changes in energy or speed of movement) altering the apparent distance-travelled in an undistorted space. They are linked by a speed of light that is faster if the size of the scalar background from massive objects is larger.

The observations of the effects of high-speed relative motion can only be explained by a real slowing of time with movement of massive clocks relative to an effectively stationary background from other mass. The slowed decay rate, of unstable elementary particles, is because they are moving at high-speed relative to the locally balanced background. If observers could travel at high-speed relative to unstable elementary particles and clocks, that are stationary relative to the background, then they would observe them decaying and ticking faster relative to the observer's clocks.

A real slowing of time (in the absence of gravity) can be explained by a frequency and clock-rate of massive objects that is reduced by motion relative to the background from all other massive objects. The interpretation in Special Relativity is that less time, in the other frame, is matched by less distance covered by the same light. This allowed the incorrect conclusion that space and time are linked into a fabric of space-time that keeps the observed speed of light constant. Keeping measured c constant for all moving observers requires that larger time intervals, giving slower time (time dilation), be matched by larger distance intervals. This is opposite to the length contraction of the original interpretation of the Lorentz transformation (LT) and requires an inverted interpretation of its terms [see **Box 3: Special Relativity**].

Time being slower (on a second clock relative to a first clock) means that the same light will travel further in the time indicated by the second clock. Distances will appear to expand (length intervals will appear contracted). The revised understanding is that the speed of massless fields (including light) is independent of motion of an emitting source (that has mass) relative to the background. However, all sources and clocks have mass, and their time is slowed by movement. The changes in distance are only apparent and not real. This changed understanding enables a theory in which LT-like behaviour holds but the speed of light varies with the magnitude of the background. Gravity can then be explained by a background that requires an increase in the energy stored as mass when the speed of light decreases. The increase in energy increases the clock-rate (time) of massive objects. Gravity is not due to differences in mass/energy density distorting the geometry of space-time (the metric) but leaving mass unchanged. Nor is its strength independent of a uniform, stationary background (as claimed by General Relativity). Full Relativity has an analogous link between time and distance travelled but has a constant distance scale joined with a mass and time (clock-rate) that depend on the background via the speed of light.

Full Relativity, in replacing Special Relativity, has objects with mass (massive objects) sensitive to their speed of movement relative to a background from all other mass. However, massless light is insensitive to such movement, although its speed is determined by the magnitude of the background. Thus, light does not perceive movement of the background, rather than motion cannot be attributed to the background (as Einstein claimed [9]).

In Newtonian gravity, equal gradients in the force fields per unit mass (i.e. gravitational acceleration) from opposite directions cancel leaving the second derivatives of the potential. In General Relativity, the metric is the relativistic generalisation of this potential and curvature is the second derivative of the metric. The acceleration field (equal to minus the gradient of the potential) is assumed to be a conserved flux from each massive object that decreases in proportion to the increase in surface area ($4\pi R^2$) surrounding the object. It therefore varies inversely as distance squared, following: $a = F / m = G_N M / R^2$. However, acceleration is a vector field in which fluxes from opposite directions cancel. Thus, under Newtonian gravity and General Relativity, the components of a steady, isotropic, uniform background cancel. Contributions from equal stationary masses in opposite directions cancel. This should be seen as surprising if the flux from each object produces a distortion. Distortions, that are reductions in distance or time (scalars) from matter, must be independent of direction. They must add rather than cancel.

The key question is therefore whether a potential that falls off as $1/R$ is possible when the surface area around a source increases as $4\pi R^2$. An unconstrained flux of energy through the surrounding surface, as with light (photons) from a lamp, falls off as $1/R^2$. A $1/R$ dependence implies that the flux does not carry energy, which appears consistent with the strength of gravity of a given mass being conserved over time. Instead of carrying energy, the background field (flux) determines how much energy massive objects can store. A $1/R$ dependence also implies that there is some opposing aspect, like a semi-pervious barrier, that inhibits the decrease in background field with distance.

A more complex background is needed

The loss of mass with a changing speed of light explains gravity, but does not explain why the effect of the field falls off only as the inverse of the distance. Moreover, if a photon does not have mass, why does it bend towards a massive object that increases the speed of light and does not distort space? Why does a photon have constant speed when there is no change in gravity but resists changes in direction? How can massive objects be sensitive to changes in velocity (speed or direction) but not need a force to maintain constant velocity? How can an object know how fast it is going relative to the background, if this explains the slowing of time with speed?

The speed and direction of the motion of massive objects remains constant if there are no forces acting. However, changes to this constant velocity of motion, i.e. acceleration of the object, are resisted. This resistance to change, inertia, is sensitive to changes in direction even at constant speed, when the amount of energy is unchanged. Inertia and the vector nature of momentum require a more complex dependence on the background than a simple scalar effect on the energy that can be stored.

Additional aspects of the background are also needed to explain the inverse decrease of gravitational potential with distance.

A two-component background explains inertia and the bending of light

Full Relativity proposes that the nature of momentum, and the $1/R$ dependence of gravitational potential indicate that a two-component background is required. The handedness (chirality) of weak interactions and the Higgs mechanism for giving particles mass, indicate that it is a chiral background from matter and anti-matter. [See **Box 6: Gauge invariance and the Higgs mechanism**.]

Full Relativity proposes that the opposite chirality of matter and antimatter means that a change in one chiral component is shared by inducing a change in the other component. The two-component background can then give rise to a "clout", which corresponds to the effect of the background from matter and antimatter on the local properties of matter and fields. The effect of a change in either type, when the contributions are similar, only falls off as $1/R$ from a point source (a small excess of either stored energy). The total clout determines the speed of light and reflects the sum of all contributions from massive sources (after allowing for the opposing interactions from matter and antimatter). The $1/R^2$ dependence of gravitational <u>force</u> arises from the gradient of a potential <u>energy</u> that only varies as $1/R$. It has now been established via the Aharonov-Bohm effect that the potentials, rather than the forces, are the underlying quantities for electromagnetism and gravitation [10,11].

In General Relativity, the distortion of space-time is based on the field of gravitational <u>force</u> per unit mass (acceleration). This faulty choice, of the gradient (a vector field), means that nearby sources should dominate and that distortions of distance and time from opposite directions cancel. However, Mach's principle, as seen in the constant orientation of gyroscopes relative to the "fixed" stars, means that distant sources must dominate.

The two-component background appears to act like opposing springs where winding up one is resisted by an unwinding of the other. The mean tension increases but the size of the change in speed of propagation of signals is not as large if only one of the pair of components of the total field is changed. It means that gravitational potential ($-G_N M / R$), the effect on energy of an excess of either component, only falls off inversely with distance (as observed) rather than with distance squared. Consequently, the enormous, and proposed equal numbers (see below), of surrounding galaxies dominate in determining the total field and the speed of light (c). This means that fractional changes in c are small, so that gravity appears weak. However, the proposed large and equal numbers of distant matter and antimatter galaxies means that their contributions to the background will be nearly matched except within concentrations of one type of matter, such as within central regions of galaxy clusters or the core of isolated galaxies.

All particles have a de Broglie wavelength indicating that they have an oscillation/rotation, which is consistent with quantum mechanics and with particles being standing-wave states. Full Relativity further proposes that the frequency of the cycle, per unit mass, of all particles varies with the matter/antimatter asymmetry of the background. The internal oscillations/rotations resist changes in the velocity of objects, that is, give rise to inertia. Massive particles have matched opposing counter-rotating components of the same chirality. Movement of an object (at speed v relative to a stationary background) will change the components by the non-relativistic Doppler shifts of $(c+v)/c$ and $(c-v)/c$. The mean frequency of oscillation will be slowed by $1/\gamma = \sqrt{(1+v/c)(1-v/c)}$ and the resistance to further changes in speed will be increased by γ.

It is proposed that the trapped momentum of the massless photon is held in spin ½ oscillations of opposite chirality (but 2π out-of-phase). The magnitude of the angular momentum vector is constant and aligned with the photon's direction of motion. Hence it resists (has inertia against) changes in direction but travels at constant velocity in a constant background.

The decrease of frequency and inertia with decreasing chiral asymmetry means that inertia will decrease away from the centre of an isolated galaxy (of just matter or just antimatter). However, it will be almost constant within our solar system (miniscule in size relative to the galaxy). Asymmetry, and therefore inertia, will reduce with distance from the centre of an isolated galaxy giving rise to an apparent increase in the strength of gravity. The change is slow within a broad distribution of matter, because contributions from all directions sum. However, the value drops off as $1/R$, at large distance R, as the source becomes more point-like; until the background level of asymmetry is approached. Inertial and gravitational mass can only be equated across different regions, as is done in General Relativity, after allowing for any changes in inertia and changes in the speed of light with location.

The clumping of matter, within a uniform background, decreases the stored energy per unit of matter because the speed of light will increase within that clump (if the clout from outside the clump is constant). However, its contribution to clout outside the clump will decrease. Objects moving closer gain KE and lose mass. However, the changes are reversed if the objects move past each other and apart again. The local change in the sum of clouts, due to clumping of sources of constant mass about a mean distant location, is negligible. However, clumping increases asymmetry and, under FR, this will increase inertia within the clump, which will slow the speed of movement of massive objects leading to contraction of orbits. The stored energy per unit of matter will decrease as like matter concentrates within regions even if the total amount of matter/antimatter (and, hence, average matter density) is constant within a stationary (non-expanding) universe. Hence, the clumping of matter will reduce the mean magnitude of the background, even if there is no change in total matter or in the total volume occupied. Thus, clout should decrease as the universe evolves, leading to an increasing redshift going back in time, without expansion being required.

The proposals appear able to remove the need to hypothesise the existence of dark matter by explaining galaxy rotation curves and gravitational lensing. There are many other consequences of the revised understanding including that gravitational waves are not travelling distortions of space-time and do not carry energy. The LIGO interferometers will, instead, detect changes in gravity, from the orbital rotation and merger of black holes, via propagating changes in the speed of light (via clout).

Full Relativity's replacement equation

In a first approximation, Full Relativity's replacement for Einstein's equation is Newton's law of gravitation. This is an instantaneous energy balance equation in which the gravitational force is the gradient of the local total potential. This is accurate within our solar system for circular orbits and the moderate speeds encountered. For objects that significantly change their distance from a major source of gravitational attraction, e.g. the Sun, a correction is needed for the reduction in mass as distance to the source decreases (but momentum is conserved). This should be sufficient for accurate current predictions within regions of similar asymmetry to our solar system and for the current epoch.

The second level is to incorporate the value of the speed of light and the asymmetry at a new location or different epoch relative to that at our current location and time by adjusting the apparent value of G_N / c^2 according to the expected values of c and inertia. This should be sufficient to cover behaviour in ours and other galaxies except at high speeds and extreme concentrations of matter (e.g. neutron stars and black holes). The next level is to allow for the finite propagation speed of gravity which will lead to effects such as apparent non-central forces, Doppler shifting of forces due to relative motion, and increases in inertia with speed of movement relative to the background.

Full Relativity's consequences for cosmology

An increase in the speed of the fields, whose standing wave patterns give rise to particle states, reduces the momentum that can be trapped in their oscillations. The reduction in stored energy (mass) with increased background, which gives an increase in the speed of light, then explains gravitational attraction. An increased distortion of the geometry of space-time in which unchanged objects reside is replaced with an undistorted space in which embedded objects are altered by the background. Movement relative to this background, arising from all other mass, slows time. The speed of light and properties of objects are altered by the magnitude and asymmetry of the background. These properties include mass, frequency, and inertia.

The predictions of Full and General Relativity diverge as increasingly different backgrounds affect the speed of light, mass, clock-rate, frequency, and inertia. The differences remove the need for unexpected cosmological observations and consequences of General Relativity.

No singularities and no pool of energy in empty space

As set out, General Relativity has a positive feedback mechanism in which distortions of space-time give rise to increased energy which further increases distortion as mass/energy density increases. This gives rise to the need for an enormous pool of energy when then are no objects and no distortion. Under Full Relativity, the pool of energy is held in the objects as mass, and there is a negative feedback mechanism with the mass per unit matter decreasing as density increases. This prevents singularities.

No event horizons which would prevent black holes from orbiting

Time is slowed near massive objects because the energy held per unit matter decreases with increasing density. Light, and gravity, can still escape freely at the speed of light but, for black holes, the emission frequencies of electromagnetic radiation are strongly shifted to longer wavelengths and any light emitted can be trapped by bending. There is no uncrossable event horizon because neither light nor gravity are trapped by loss of energy, or by a change in time (clock-rate).

If event horizons existed then General Relativity's force carrying gravity should not be able to cross (as changes in the gravitational field propagate at c), so stars would not orbit black holes or vice-versa. Supporters of General Relativity propose that the distortion of space-time exists beyond (i.e. outside) the event horizon. However, a manifestation of infinite time dilation is that it would take an infinite time (of the outside observer) for any signal to leave a black hole. Thus, changes in the position or strength of the source, inside the event horizon, should not be able to be detected.

No accelerating expansion and no need for dark energy

The observation that led to the claim that the expansion of the Universe was accelerating came from a comparison of the distance of type 1A supernovae deduced from their observed brightness and the distance deduced from their observed redshift. Originally this redshift was taken to be a Doppler shift indicating that more-distant galaxies were moving away faster. However, under General Relativity, this redshift has been re-interpreted as an expansion of the "space" between objects which stretched the wavelength of photons travelling through this "space". Under Full Relativity, the distance between objects (space) cannot expand without the objects moving, and the momentum carried by photons does not change after emission.

Local type 1a supernovae appear to release the same amount of energy and so their apparent brightness can be used as a direct measure of distance to be compared with the wavelength shift. Under General Relativity, the observed brightness of distant supernovae is lower than expected from their distance based on the wavelength shift of their host galaxy and a constant rate of expansion. This led to the conclusion that the universe is now expanding faster than in the past, the so-called "accelerating expansion" [12]. Gravity had been expected to slow the expansion, so dark energy was hypothesised to drive the expansion of the universe faster now than in the relatively recent past. Hence, this dark energy has the very unusual property of a negative pressure that opposes gravity more strongly as the density of matter, the number of galaxies per unit volume, decreases!

The background from distant stored energy, and the speed of light, will decrease as the universe evolves, becoming increasingly clumped. However, General Relativity has assumed that the field that gives rise to the curvature of space-time is gravitational acceleration; a vector field with a conserved flux. Such a conserved flux assumes that mass is constant. Newton's and Einstein's field equations then require that empty space free of matter can appear to act as a source of negative gravity [see Box 5]. If mass per unit matter increases over time it will necessarily give the appearance of an invisible dark energy that pushes objects apart more strongly. If the redshift of distant galaxies is taken to mean the Universe is expanding then there will be an apparent accelerating expansion whose source will appear to be the increase in empty space. Full Relativity predicts such an apparent dark energy.

Full Relativity avoids the need for any expansion and for the ad hoc hypothesis of dark energy. Space is undistorted, but the properties of objects and the speed of light (linking distance and time) depend on the background. The change in speed of light, with the decreasing background when matter clumps as the universe evolves, means that light from earlier supernovae has travelled faster and therefore further. Thus, Full Relativity implies the speed of light (c) was faster than now ($c = c_0$), earlier in the history of the universe. The energy levels of atomic transitions will be redshifted because of the change in background clout during the transmission time of the signal. The redshift will reflect the lower energy of the atoms at the time of photon emission because the energy and momentum of the photon are both conserved. The trapped momentum of the energy levels of atoms when the photons were emitted will have been lower in proportion to c_0 / c, and the energy levels will have been lower in proportion to $(c_0 / c)^2$. The ratio of the apparent photon wavelengths at emission to reception will be in proportion to the ratio of the clouts at emission (ρ) to reception (ρ_0), i.e. $\lambda_{rec} / \lambda_{em} = c / c_0 = \rho / \rho_0$. Photon energy and momentum do not change during transmission (except for Doppler shifting due to relative motion).

Under General Relativity, the redshift of the wavelength λ of light from distant galaxies is attributed to the increase in size of the universe, or scale of the fabric of space-time, between when the light was emitted R and received R_0. Thus $R_0 / R = \lambda_{rec} / \lambda_{em} = 1 + Z$, where $Z = (\lambda_{rec} - \lambda_{em}) / \lambda_{em}$, is predicted. Under Full Relativity, the change in redshift with time must allow for the distance travelled by light per unit of underlying time. Massive clocks will be ticking more slowly if they carry less energy but the energy of an already emitted photon does not change. Since the speed of light was faster in the past, the light will have travelled further during intervals of constant time, with $\lambda_{rec} / \lambda_{em} = c / c_0 = 1 + Z$. The brightness (total energy emitted) of a source of fixed energy gives a direct measure of distance, independent of the speed of travel. Hence, the distance, based on brightness (emitted energy), will not be linearly dependent on Z, based on wavelength shift. In order to plot how distance has changed with time, the luminosity distance must be divided by a factor that corrects for the speed of light. This factor will be the integral of ($1 + Z$), which is the ratio of the speeds of light over time. If the shift in wavelength is due entirely to the change in clout, then the luminosity distance (with no correction for expansion) will have been increased by a factor of $Z(1 + Z / 2)$. The correction is achieved by dividing the brightness distance by $1 + Z / 2$, under the assumption that distance scales are fixed. The uncorrected (blue) and corrected (green) times since emission are plotted against Z in Figure 1.

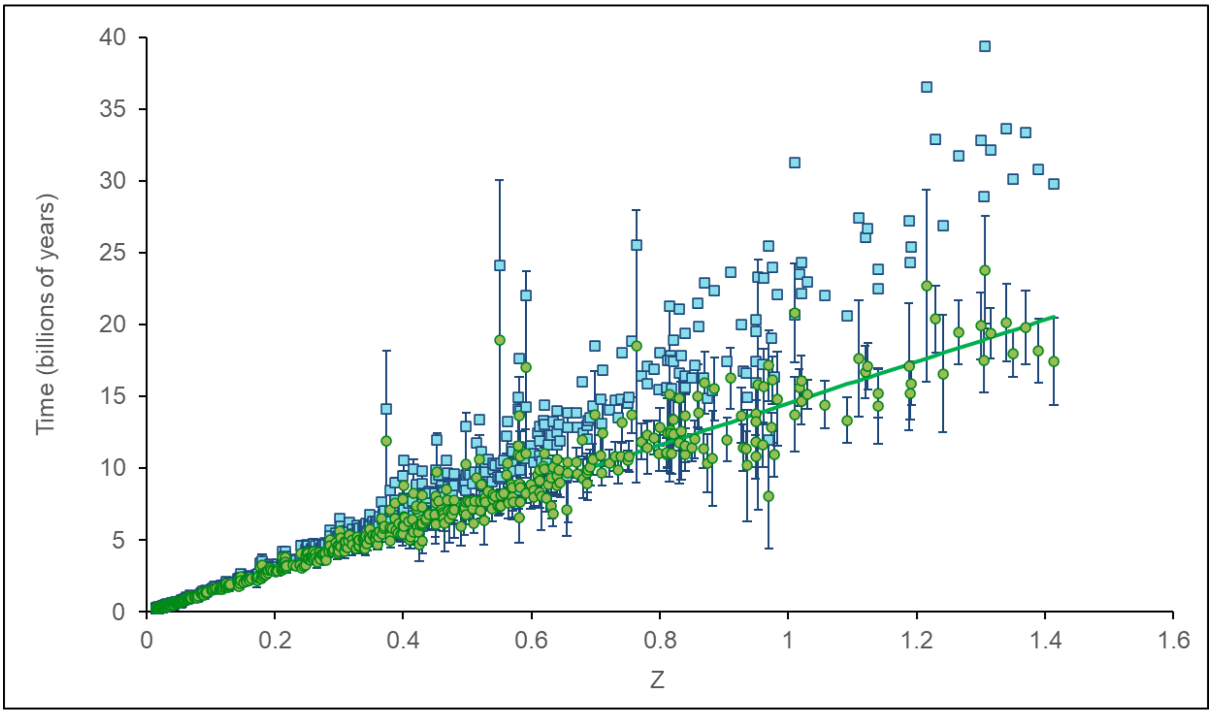

Fig. 1 The redshift of type 1A supernovae with uncorrected and corrected time since emission.

The correction entirely removes the unexpected faintness. The data is in agreement with the redshift being entirely due to the change in emission energy with c. There is no need for the ad hoc hypothesis of an invisible energy that grows as the space (distance) between galaxies increases, or for the need to explain the remarkable coincidence, that dark energy is just now becoming dominant when it should drive the universe away from its currently observed flatness.

No cosmic inflation or big bang

The redshift of distant galaxies arises not from expansion but from the lower frequency of emission when light-speed was higher, meaning matter held less energy and massive clocks ran slower but light, gravity and all force fields travelled faster. These differences remove the need for any expansion and therefore for a big bang. They also remove the need to hypothesise an incredibly rapid initial expansion of the Universe, called cosmic inflation. This had been postulated to explain the "horizon" problem. The observed uniformity of the large-scale distribution of distant galaxies and of the cosmic microwave background seemed to require that the early universe had been in thermal equilibrium. Yet the parts are now so far apart, that for the current speed of light, they could not have interacted in the lifetime of the universe. It also sought to explain the "flatness" problem. If the geometry of space had deviated ever so slightly from flatness, then the curvature would have been rapidly amplified over time. Yet, it is observed to be close to flat.

Cosmic inflation proposed an exponential expansion of space in the early universe. The hypothesis was that the universe expanded by some 20 orders of magnitude between the first 10^{-36} to 10^{-32} seconds after the big bang. This incredibly rapid expansion, much greater than the speed of light, locked in the initial uniformity. Following the inflationary period, the universe continued to expand, but at a slower rate. The proposal has been widely accepted and rewarded [13].

The hypothesis was initially seen as untenable, as the existing laws of physics say that infinite energy is needed to get even the smallest amount of matter moving at the speed of light. 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. However, this incredibly rapid expansion was claimed to be allowed because it is "space itself" that expands rather than that the objects move! That is, distance, the size of the empty vacuum between massive objects can increase, faster than the speed of light, without the objects moving. It relies on the concept of space-time (with an invariant speed of light!) being a distortable geometry (metric) of the fabric of space-time. The scale of distance between objects and the scale of time applicable to those objects has become a mere relationship; so that “space is not a thing”. This lack of reality is a play on words and makes no sense.

No need for dark matter

Full Relativity has changes in asymmetry altering oscillation frequency and, therefore, inertia. The reduced change in the speed of light, when only one component of the two-component background changes, and the increase in inertia, together cause ongoing clumping within regions of like matter and a reduction in the background elsewhere over time.

Inertial acceleration is equal to the force per unit mass needed to produce a given change in the velocity of an object. Inertia, the resistance to acceleration from a given force, will depend on the product of the gravitational mass (the amount of trapped energy/momentum) and its resistance to any change in the velocity of the object carrying energy/momentum. The size of this resistance should depend on the way the energy/momentum is stored, as it may affect the ease with which it can be changed. The magnitude of any resistance to change could be altered if the speed or direction of the trapped internal movement (rotation or oscillation) is altered by the background field. Under Full Relativity, inertia changes in proportion to the degree of asymmetry in the contributions to clout, as the asymmetry will induce a rotation of the standing-wave pattern. Such changes will occur with distance from an excess of just one type of matter against a background of near-zero asymmetry, such as an isolated galaxy. The frequency of oscillations, and therefore inertia, will decrease away from the centre of our and other galaxies but be almost constant within a relatively small region the size of our solar system. If the local asymmetry within this region is dominated by the potential from our galaxy, then, when we look elsewhere, there will be an apparent increase in the strength of gravity at any location of lower asymmetry. The inertia will change in proportion to the ratio of asymmetry at another location to that at our location. These will change in approximate proportion to the ratio in the potentials (from the excess in the $\delta M / r$ sums of all contributions of like matter). This assumes the excess is a small fraction of the total. Once out of the near field, but still where the one nearby galaxy is dominant, but has become more like a point source, the gravitational force will decrease as $1/R^2$. However, the inertia per unit mass will decrease as $1/R$. As a result the strength of gravity will appear to reduce as $1/R$ (rather than $1/R^2$). This is the rate of decrease in the acceleration needed to maintain a circular orbit of radius R. The result is that the orbital speed of the outer stars of a galaxy, will tend to a constant value independent of R, as observed. A diffuse halo of an invisible dark matter is no longer needed.

A gradient in asymmetry will also cause light to bend. The effect of asymmetry on inertia can then explain both the flat rotation curves of spiral galaxies and gravitational lensing, without the need for dark matter. Gravitational attraction depends on the gradient in stored energy determined by the large total background of clout from matter and antimatter. The total clout determines c and the asymmetry of its components determines inertia. These changes in inertia seem able to explain the observed radial acceleration relationship of vastly different galaxies [14]. Full Relativity might then explain the Tully-Fisher relationship between the asymptotic speed of galaxy rotation curves and galaxy luminosity and why Modified Newtonian Dynamics (MOND) appears to explain galaxy observations better than dark matter halos.

Full Relativity demands and appears to allow an equal quantity of antimatter

Full Relativity's explanation of gravitational lensing and galaxy rotation curves via inertia requires nearly equal backgrounds from matter and antimatter.

The speed of light was much faster and inertia and mass per unit matter were much smaller early in the evolution of the universe. This would seem to lead to rapid annihilation of any matter with antimatter for which the components of velocity towards each other were strong enough to overcome the small gravitational attraction. Full Relativity therefore proposes that the apparent dearth of antimatter is because most of the matter in opposite regions annihilated until they became separated into interlaced regions of gravitationally bound like-matter. The mass of the matter increased as the speed of light slowed and the clumping of like matter increased over time, as the Universe evolved. This led to the formation and contraction of galaxies as inertia increased, which maintained the separation of matter and antimatter. Therefore, the presence of the antimatter regions is no longer revealed by annihilation.

Agreement with the predictions of General Relativity

Three predictions of General Relativity were proposed by Einstein [see Box 4]. The first explained the observed small anomalous advance in the perihelion of the slightly eccentric orbit of Mercury. The advance arises from the distortion of time with distance from the sun. The distortion of time is claimed to alter the speed of objects as well as how fast their clocks tick. The claimed additional distortion of distance has a negligible effect on the rotation rate of the point of closest approach and is ignored.

Under Full Relativity, there will be a fractional change in velocity due to the changes in mass, but conservation of momentum. The fractional change in velocity is the same as that attributed to the supposed distortion of time. The change in mass does not change the eccentricity of the orbit because the central mass is dominant and the orbital speed relative to the speed of light is negligible. The radial gravitational acceleration with distance is independent of the size of the small mass, because the gravitational force (being a fractional change in mass) is per unit mass. The predicted orbital advance is the same because, in this case, the effect of GR's distortion of distance is negligible.

Evidence that a contraction of distance as well as time occurs might be construed from the detection of a Schwarzschild precession in the orbit of a star near the supermassive black hole at the centre of our galaxy [14A. However, the fit to the data of the highly eccentric orbit examines the change in orbital direction only in the region of the pericentre. It therefore examines general relativity's predicted effect of the supposed distortion of spacetime at nearly constant distance, and so is testing the effect of only the time component. Under full relativity this will arise from the change in momentum due to the increased asymmetry when closer to a large point source of mass from like matter. The predictions should therefore agree.

The second prediction was that the bending of light should be twice that predicted by the supposed loss of photon energy (redshift) in a gravitational field, because both time and distance were distorted. Under Full Relativity it cannot be gravity (in terms of an attraction due to the photon's momentum or a distortion of space) that doubles the bending of light because light does not gain or lose energy in a gravitational field, and distance is not distorted by matter. The speed of light does vary with clout so photons going along separated paths will have different speeds. The speed of light increases with clout so it will be faster closer to a massive object. This, at first, seems to contradict the observation that light entering a medium of slower light-speed bends towards the perpendicular. However, such refraction is consistent with Fermat's principle that light takes the path of least time and so, within a medium (the vacuum), should bend in the direction of greater light-speed. It is proposed that photons should change direction in a gravitational field by an amount proportional to the gradient perpendicular to the direction of motion. It is then proposed that the amount of bending is doubled because pairs of chiral rotations (i.e. the two components seen in the split into electric and magnetic fields) change with the gradient in clout. The oscillation frequencies of the pair of components increase closer to a massive object leading to twice the bending towards the object.

The third prediction was a gravitational redshift of photons escaping a gravitational field. Under Full Relativity, this is a blueshift, by an equal amount, in the energy of atoms and, as has been shown, overcomes many problems with General Relativity.

A fourth prediction, by Shapiro, is a delay in the travel time of electromagnetic radiation (e.g. radio waves) from planets or spacecraft as they pass near or behind the Sun. A delay of the expected amount has been observed. However, the expected delay is determined by a fit to the expected change in signal arrival times due to the amount bending changes the path length. This removes the changes in apparent orbit from any changes in light-speed and so the predictions will match. Any increase in the speed of light should lead to an apparent contraction of distance. It is not clear whether this is large enough to be seen. However, since General Relativity assumes a slowing of time is matched by a contraction of distance the predictions should be the same for both theories.

Subsequent predictions have included an expanding universe and black holes. As discussed, the blueshift rather than a redshift and that photons do not lose energy after emission indicates that the universe is not expanding and changes our understanding of the properties of black holes.

Einstein's equations also predicted that travelling distortions of space-time, gravitational waves, would exist. The waves are claimed to be ripples in the fabric of space-time that travel at the speed of light. The incredible technology of the LIGO interferometers has now enabled the observation of gravitational radiation (waves) from merging black holes and neutron stars.

Full Relativity accepts that gravitational waves exist in terms of travelling changes in clout. However, these "waves" do not involve a distortion of space or carry energy. Instead they alter the local speed of light (and so can be detected by laser interferometers) and alter the mass that can be stored by matter. The change in the value of clout reflects a change in the distribution of mass. The apparent oscillations of the "waves" reflects only the change in clout from the oscillation in the location of masses. The textbook arguments commonly taken to establish that gravitational waves carry energy-momentum have been found wanting [16]. Full Relativity claims that the observation of gravitational waves in the LIGO detectors only establishes that propagating changes in the gravitational field alter the apparent relative lengths of perpendicular light paths by changing the speed/wavelength of light.

The first evidence for gravitational waves came from changes in the orbital motion of binary pulsars (rapidly rotating neutron stars). The changes in their orbits over time were consistent with the expected rate of energy loss from energy-carrying gravitational radiation. 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. However, the calculation of the energy radiated is an average of the quadrupole moment over all directions. This reflects the variations in the gravitational field due to the difference in arrival time and direction because of the finite propagation time. The differences in expected orbital energy arise because of the non-central forces and changes in inertia, and the forces, with separation and velocity. These change the expected energy-momentum stored in the orbits and the pulsars [1]. 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".

There are other, more recent, predictions of General Relativity that need to be compared to Full Relativity. However, it seems they will be explained by the finite speed of gravitational changes and similar arguments to those above.

How to apply Full Relativity

The way Full Relativity can be applied to cosmology is similar to that followed for General Relativity. Einstein's equation of General Relativity combined the differential form of Newton's gravitational equation with his equation of motion ($F = ma$). It built in the finite propagation time of gravity, using a constant speed of light/gravity, via the tensor formulation that distorted time and distance. Mass and the ratio of inertial to gravitational mass were assumed constant. Predictions in General Relativity from Einstein's equation then required that starting conditions, in terms of an initial distribution of mass, energy and momentum, be input. This has been done for many simplified distributions with high degrees of symmetry. These inputs determine the initial geometry of space-time. The time evolution of the metric and the movement of matter and energy can then be investigated. This is now commonly done iteratively in computer simulations to, for example, test how fast galaxy clusters evolve with and without dark matter.

A similar approach can be followed with Full Relativity. Newton's original universal law of gravitation can be used. If the speed of massive object is significant then the finite (but variable) propagation speed of changes in the gravitational field may need to be included. Newton's equation then needs to be combined with his second law but with the ratio of inertial to gravitational mass, determined by the background asymmetry, altering the value of G_N . The value of G_N at each location will need to be adjusted by a factor proportional to ratio of the local asymmetry relative to that at our position in our galaxy if the asymmetry is significantly different. The initial conditions need to include the location and velocity of both nearby and distant masses or some simplification of the mean background field from both matter and antimatter and its rate of change. These would allow the calculation of G_N and c for any location, and the mass, inertia, and movement of objects over time. The time evolution could then be examined by computer simulation on progressively finer grids. This could be used to examine the evolution of galaxy distribution and structure over time.

Consequences for particle physics

The first three forces (strong, weak and electromagnetic) have been unified in terms of consistency with Special Relativity (relativistic), with quantum mechanics (quanta) and with underlying fields that carry the quanta. These relativistic quantum field theories of elementary particles and their interactions are collectively called the Standard Model. Under General Relativity, the fourth force, gravity, is not a real force and it is not possible to unify it with the other three. Moreover, there is a different explanation of mass in the Standard Model, in which it arises from the "Higgs field".

Full Relativity links gravity to particle physics and quantum mechanics via the shared background. This is strongly supported by the speed of propagation of electromagnetic fields being the same as that of gravity. It is proposed that mass arises from any force (strong, electromagnetic, weak or gravitational) that confines momentum to a location. It is not just the purported "Higgs field", but any trapping of momentum, that gives rise to mass. The explanation of the nature of particles and their fields is linked to the explanation of the gravitational field.

The model that unifies all four forces must not only be consistent with the Standard Model but explain it. Full Relativity proposes that all particles are standing wave patterns of multiple chiral components of the underlying field. Massive particles store energy in cyclic oscillations about a mean location. This appears to because they have oscillating chiral components that provide equal forces in opposing directions. It is further proposed that the stored energy trapped by these oscillations/rotations needs to increase if the speed of propagation of the field components decreases. Work must be done to maintain the same standing-wave pattern if the speed of light decreases. Movement of the matched components relative to a balanced background increases one rate of rotation and reduces another to maintain the force balance. The relative speed of rotation of the matched components changes. The result is that massive particles have a “memory” of their speed relative to the background and relative to the matched component. This gives rise to an inertia that is dependent on the asymmetry of the background and is sensitive to changes in velocity.

Full Relativity has mass as stored energy, yet the massless photon has momentum and can carry energy to new locations and can spontaneously change into charged lepton/antilepton pairs. Moreover, the photon only exists as a wave packet travelling at the speed of light. A particle, such as the photon, that arises from equal contributions from opposite chirality components, can be expected to have no internal resistance to changes in speed if there is no net oscillation, relative to the centroid, along the direction of constant speed. It will be constrained to travel at a constant speed that is determined by the background, but this speed will change with the magnitude of the background. The finite extent of its oscillations perpendicular to its direction of motion will mean that it will respond to gradients in the magnitude of the background by changing direction.

These considerations lead to a different perspective on the Standard Model. The current perspective is that each particle has its own “field” and that the coupling of this field to the Higgs field determines its mass. The new perspective is that the Higgs mechanism indicates that it is the chirality of both the background and of the chiral components of the wave-function (oscillating “field’) that gives rise to the trapping of energy around a central location. Each elementary particle has its own pattern of components and relative orientations that give rise to different amounts of trapped energy (mass). The trapping of a variable amount of mass corresponds to the spontaneous breaking of gauge invariance, i.e. the Higgs mechanism [see **Box 6: Gauge invariance and the Higgs mechanism**.]

Initial implications for particle physics, based on the nature of massless and massive particles, and of quantum mechanics seem to include:
- the photon is the “missing” ninth gluon that is a balanced travelling superposition of three gluons and has no (single vertex) strong interactions. It has aligned equal components of opposite chirality. However, its wavefunction can also be seen as a superposition of particle and antiparticle states.
- neutrinos, like the photon, are massless because their net angular momentum is in the plane perpendicular to the direction of motion. However, individual components can have directions other than in the perpendicular plane. There appear to be three possible superpositions of different numbers of components trapping momentum that are massless because the oscillation frequency of the trapped momenta varies but the sum of their components is always perpendicular to the direction of motion. They can then oscillate between such massless states. However, their wave functions cannot be split into a superposition of particle and antiparticle states.
- massive particles have counter-rotating and oppositely directed components of the same chirality.
- pairs of oppositely charged leptons (spin=½), have numbers and magnitudes of rotating chiral components that can be superimposed to give a photon.
- the number of chiral components of the leptons are related to those of the quarks and neutrinos of the same family.

Given the potential removal of the need for dark matter, dark energy, cosmic inflation, and neutrino masses, and the (claimed) presence of an equal quantity of antimatter, there seems to be little evidence for new physics beyond the Standard Model. This should influence the choice of, and resources that go into, future theoretical investigations, experiments and accelerators. Ultimately, Full

Relativity should lead to the prediction of all the masses and coupling constants of the Standard Model as a function of the properties of the background from all matter.

Opportunities and observational tests

Many details of Full Relativity need more work and many consequences need to be examined. These include the implications for galaxy evolution and dynamics, how spiral arms form and develop, the separation of matter and anti-matter, and explaining the baryon/photon ratio and features of the cosmic microwave background. The proposed explanation of the source of inertia should be further developed and the value of Planck and Newton's constants related to the expected value of asymmetry within our solar system. The value of inertia with position in our and other galaxies should be related to the rise and fall rates of the light curves of supernovae.

A clear pair of differences in the theories is that Full Relativity only has an apparent distortion of distance while General Relativity assumes mass remains constant for the local observer. These differences may explain a well-known discrepancy in the movement of distant spacecraft that was christened the Pioneer anomaly. The two Pioneer spacecraft, going in markedly different directions, showed a similar unexpected slowing relative to their predicted movement and location based on General Relativity. These predictions assumed a constant speed of light and a distortion of distance but may or may not have included an effect equivalent to the change in mass on the spacecraft momentum (via the change in time). These differences may offer an alternate explanation of the cause of the slowing of the spacecraft. Currently, the proposed, and accepted, explanation has been selective heat radiation against the direction of motion. What is needed is an investigation of the sign and magnitude of all the terms in both Full and General Relativity's predictions of the expected measured distance and speed. If the distance is based on the timing of returned signals, using a constant speed of light, then the slowing of the speed of light further from the Sun should lead to a delay and therefore an <u>increase</u> in apparent distance (not a contraction). On the other hand, Full Relativity's increase in mass should provide an additional increase in the speed of the spacecraft with increased distance from the Sun (if inertia per unit mass decreases). An effect of the same magnitude may have been incorporated General Relativity's prediction due to the change in time with change in gravitational potential.

Special Relativity has all clocks moving with the observer showing the same time, if they have not been accelerated since synchronisation. However, measured clock-rate should be slowed by relative speed of the observer. Full Relativity proposes that the time of clocks moving relative to the stationary background should be slowed. Therefore, a clock moving at high-speed relative to the background (in a constant gravitational field) should see the decay of stationary unstable elementary particles, or the ticking of other such clocks, occurring faster. If this can be confirmed then the fabric of space-time is eliminated. [There is the complication that our galaxy would appear to be in free-fall acceleration towards a concentration of other galaxies.]

Summary

Both the recognition that Newtons law of gravitation is an energy-balance equation, and the acceptance that a massless photon should not lose energy in escaping a gravitational field, demand a new theory of gravity. If mass is the stored energy of matter, as Einstein proposed, then it inevitably follows that massive atoms gain energy, when work is done on objects in raising them against the force of gravity. The kinetic energy of gravitational acceleration arises from a loss of mass when matter falls closer to other matter. In turn, this means that the speed of light is not constant and that gravity is not a distortion of space-time. The need for dark energy, cosmic inflation and a big bang are removed, and the observed current flatness of space-time and the uniform distribution of distant galaxies are no longer problematic. Moreover, the confirmed predictions of General Relativity appear to be reproduced.

The actual postulates used in Special Relativity – the complete independence of physical laws to speed of motion and that the measured speed of light is independent of the speed of the observer – must be rejected. Objects with mass are sensitive to motion relative to the background from all other mass, and the underlying speed of (massless) light is independent of the speed of the emitter. However, light-speed is dependent on the total potential from all mass. The conclusion, under Special Relativity, that relative motion between observer and object, dilates time and contracts the actual and measured distance while keeping the speed of light constant, is faulty. The conclusion that each pair of relatively moving observers will see the others clocks slowed is also faulty. Motion relative to the stationary background dilates time and using this slowed time for a measurement leads to an apparent contraction of distance. The moving observer will see the clocks of the stationary observer run faster.

The supposed fabric of space-time in which distance and time are subjective and can be distorted by motion, while the speed of light is constant, is an illusion that was taken over into General Relativity. This theory took the observation, that an observer falling freely in a gravitational field felt no force, to mean that the laws of physics were also independent of acceleration. It led to the conclusion that gravity was not a real force but a warping of the geometry of space-time. The lack of a force is also an illusion; instead the gravitational force is balanced by inertial resistance to acceleration. The falling observer is continuously moving into a region of higher mass density in which the speed of light is faster but the mass held by the same matter is reduced.

The new theory, Full Relativity, replaces both Special and General Relativity by reaffirming that a background field is essential. This field arises from competing, but nearly equal, contributions from matter and antimatter, predominantly due to distant galaxies. These have contracted into interlaced, but gravitationally bound, separate regions of like matter and antimatter.

The introduction of the concept of a pair of chiral background components allows effects of the background to reduce more slowly (as $1/R$) with distance. This is why distant galaxies dominate and the background field is related to the gravitational potential, rather than to the acceleration field. The small asymmetry in the contributions from matter and antimatter, which will occur within isolated galaxies, enables a mechanism that gives rise to resistance to acceleration (and hence inertia). This, in turn, removes the need for dark matter by explaining galaxy rotation curves and gravitational lensing. It also explains the link between inertial and gravitational mass, including why an object that contains enough energy to destroy a city can be thrown many metres by a puny human.

The removal of the need for ad hoc hypotheses, together with the avoidance of singularities inside black-holes and that gravity can cross their supposed uncrossable event horizons, provides strong evidence for the validity of Full Relativity. In addition, unreasonable postulates, faulty understanding and assumptions, logical errors and inconsistencies in Special and General Relativity have been demonstrated together with how they necessarily give rise to apparent effects such as dark energy and contracted distances without movement. Moreover, unlike General Relativity, Full Relativity is consistent with Quantum Mechanics, appears to remove all current evidence for physics beyond the Standard Model of particle physics, and is consistent with the Higgs mechanism as a source of mass. Nevertheless, critical analysis and further development are needed and the suggested observational tests should be made and new ones explored.

Box 1: Newton's universal law of gravitation

Newton deduced that the motion of the planets and their moons could be explained in terms of a gravitational force (F). An invisible force on a small mass (m) arises from a point source of large mass (M) at a distance (r) across empty space. It obeys:

$F = G_N Mm / r^2$, where G_N is referred to as Newton's gravitational constant.

It was labelled as a universal law because it appeared to apply, with the same value of G_N, on all scales of distance and mass from apples falling off trees to stars rotating within galaxies. The same value of G_N can be used from small lead balls in a torsion pendulum to the moons around the planets and the planets around our Sun and other stars. The stars of galaxies also rotate gravitationally around their galaxy's centre of mass. However, the speeds of the outer stars are consistently faster than expected given the visible mass. The hypothesised explanation is a halo of invisible "dark matter", that neither emits nor absorbs light and only interacts gravitationally. This explanation requires, in total, about five times as much dark matter as the ordinary, visible matter that makes up ourselves and the stars and planets. Currently, no candidates for such dark matter have been observed and none is expected within the Standard Model of particle physics.

Newton's equation of motion is an energy-balance equation. The energy lost as mass (seen as gravitational potential energy) appears as kinetic energy (KE) of motion. The KE gained by falling objects comes from a loss in their stored energy. Energy is conserved but a massive object cannot store as much energy when the background increases. The gain in stored energy per unit mass in raising an object distance dx against F is:

$$\int (F/m)dx = \Delta E / (m + \Delta m) \cong \Delta mc^2 / m = -G_N (1/r_2 - 1/r_1) = \Delta\Phi$$

using $\Delta E = \Delta mc^2$ and $\Delta\Phi$ as the change in gravitational potential (energy) with distance r from a point source of mass M .

The fractional decrease in energy or mass at distance $r_1 = R$, relative to that at infinity ($r_2 = \infty$), is:

$$\Delta m / m = \Delta E / E \cong -G_N / Rc^2 = \Delta\Phi / c^2 \qquad 1.1$$

The value of G_N is constant only in the limit that the fractional changes are small and if the background from matter other than M is not changing over time or with location. Although, small changes in its value can be hidden by adjusting the presumed mass M in observations of distant systems.

The equation of motion has also assumed that the inertial mass (m_i) seen in the kinetic energy gained through acceleration, is the same as the gravitational mass (m_g) that determines the force of attraction ($a = F_i / m_i = F_g / m_g$). If they are not the same, but there is a fixed relationship between inertial and gravitational energy (i.e. $m_i = \alpha m_g$), then equating the units of mass ($m_i = m_g = m$), means that the value of α has been incorporated into G_N. If inertia of the same mass varies with another aspect of the background, the value of G_N and the apparent strength of gravity, will vary with that aspect of the background.

The observed acceleration of objects is independent of their mass. All objects falling freely in the same gravitational field, independent of their mass or material, fall at the same rate in a vacuum. Experiments rotating objects of the same mass but different materials around each other also show that centrifugal (inertial) forces, at the same location, are independent of the material. However, this still allows mass, independent of the material, to change with the background.

The energy balance equation (1.1), of Newtonian gravity, is dimensionless and so is independent of how fast gravity propagates. Newtonian gravity is instantaneous and assumes G_N is constant. Mass, as stored energy, is independent of time if the background does not change with time. It is a sort of "frozen" energy, yet it can give rise to kinetic energy which is an energy of motion which has a time dependence through velocity. Thus, Newton's equation applies in the limit that the speed of the bodies is small relative to the speed of propagation of gravity.

Box 2: The background field of space-time

Einstein at first claimed that an aether or background was superfluous in Special Relativity. He later conceded that; "*According to the general theory of relativity space without ether is unthinkable; for in such space there not only would be no propagation of light, but also no possibility of existence for standards of space and time*" [9]. He proposed that this new aether, in which the density of energy/momentum determines the existence and distortion of space-time, enabled acceleration and rotation to be perceived. However, he noted that: "*The idea of motion may not be applied to it*".

A "background" (a field or fields) had been proposed as necessary to convey action-at-a-distance ever since the effects of static electricity and magnets and compasses had been observed. Maxwell established that electric and magnetic fields travelled at the speed of light in empty space and, more recently, changes in gravity (the gravitational field) have been shown to travel at this speed. The magnitudes of these three unseen fields, in which neither masses or charges need to be in direct contact, are quantified in terms of the force or energy (potential) per unit charge or unit mass that can be given to another mass or charge as a function of distance and speed.

The concept of space-time, which also acts as a background, first arose in Special Relativity, which applies when there is no acceleration, so speeds are constant. Special Relativity proposed that space and time are not fixed but are part of a "fabric" that links them into a constant measured speed of light. The space and time of events seen by an observer travelling with the observed objects is always the same. However, the space and time, measured for objects by an observer in relative motion, are altered. The changes in distance and time are in proportion to the relative speed, but are by equal amounts so that the observed speed of light (distance divided by time) remains the same for all observers. The distortion is only along the direction of constant velocity, and not in perpendicular directions, so the geometry of space-time remains Euclidean, meaning that the fabric is "flat".

Special Relativity was given that name because it applied to the special case of relative motion at constant velocity. Einstein realised that it needed to be generalised to include accelerated motion. In General Relativity, he proposed that the geometry (metric) of space-time is not fixed. The geometry in which we live and unchanged objects exist, can be altered by massive objects via the gravitational acceleration they induce. Space-time is distorted by matter (via its energy and momentum). John Wheeler summed it up as: "Space-time tells matter how to move; matter tells space-time how to curve." Under General Relativity, gravitational acceleration does not come from a real force. It is just the curvature of space-time. The more massive an object the more space-time is bent, which appears as a stronger gravitational acceleration. [See **Box 4: A brief introduction to General Relativity**.]

General Relativity is based on Newton's law of gravitation but allows for a finite propagation time of gravity. Its standard predictions are consistent with Newton's law in the limit that gravitational effects are transmitted instantaneously.

Box 3: Special Relativity

Einstein's paper "On the electrodynamics of moving bodies" [8] noted that the interaction between magnetic and electric fields depended only on relative motion. Together with the unsuccessful attempts to discover any motion of the earth relative to the 'light medium', it "*suggested that the phenomena of electrodynamics as well as of mechanics possess no properties corresponding to the idea of absolute rest*". They instead suggested that: "*the same laws of electrodynamics and optics will be valid for all frames of reference for which the equations of mechanics hold good*". He raised this conjecture (the "Principle of Relativity") to the status of a postulate, and also introduced another postulate: "*that light is always propagated in empty space with a definite velocity* c *which is independent of the state of motion of the emitting body*". He used these postulates to derive a relationship between the distance and time coordinates of the same events seen in a moving and stationary frame. Then showed that the transformation left Maxwell's equations of electrodynamics unchanged. The transformation turned out to be the same as that already put forward by Lorentz, with help from Poincaré, that had been found to describe observed behaviour. This included the motion of electrons in a cathode ray tube. They became more difficult to bend with increased speed; as if time slowed or their mass increased. Einstein concluded that only relative motion was important and that the introduction of a "luminiferous ether" would prove to be superfluous as an "absolutely stationary space" was not required.

Full Relativity (FR) maintains the validity of the behaviour captured by the Lorentz transformation (LT) but challenges its interpretation, under Special Relativity (SR), and that it establishes the validity of the hypotheses used. The key conclusions of SR, such as time dilation, that nothing can travel faster than the speed of light, and $E = mc^2$, remain. However, the claims that physical laws are completely independent of a constant velocity of either object or observer (only relative motion is important), that the measured speed of light is the same for all observers, and that there is a fabric of space-time, all need qualification or rejection.

Trouble with the postulates

Einstein based Special Relativity on the postulates that the laws of physics were independent of motion at constant velocity (the "principle of relativity") and that the observed speed of light was constant. He claimed that: "*If a system of coordinates* K *is chosen so that, in relation to it, physical laws hold good in their simplest form, the same laws hold good in relation to any other system of coordinates* K' *moving in uniform translation relatively to* K*"* [17].

This principle of relativity was based on observations, including: "*that experiments upon the earth tell us nothing of the fact that we are moving about the sun with a velocity of approximately 30 kilometres a second*" [3]. An observer in a closed space, for example in a windowless train carriage smoothly travelling at constant speed, appears to be unable to tell whether they are moving. Two people can still play table-tennis and a ball that goes straight up comes straight down. The principle requires physical laws for any object moving at constant velocity to be the same as they are for the object at rest. Therefore, it was postulated that an observer in an inertial (non-accelerating) frame cannot determine an absolute speed or direction of travel in space, and may only speak of speed or direction relative to some other object.

However, it is a remarkable leap of faith to assume that there are no changes in any properties if the train, and its table-tennis playing passengers, are moving at a speed close to the speed of light relative to the background of stars and galaxies. Full Relativity agrees that it is still possible to play table-tennis but claims that the faster the train is travelling the slower the players' watches will be ticking and the harder they will have to hit the ball. The apparent independence of motion is in the limit that the speed of movement relative to the background, from the rest of the mass in the universe, is small relative to the speed of light.

Einstein's original second postulate was: "*that light is always propagated in empty space with a definite velocity c which is independent of the state of motion of the emitting body*" [8]. In his analysis he then claimed: "*that light (as required by the principle of the constancy of the velocity of light, in combination with the principle of relativity) is also propagated with velocity c when measured in the moving system*". This is a misunderstanding. It is not the measured speed of light that is required to be independent of movement of the observer. The observational requirement is, and was, that the (underlying) speed of light is independent of the speed of the emitting object. Moreover, the measurement of speed must take into account movement of the observer during the time taken for propagation of the light between source and observer.

For a constant underlying speed of light, the distance travelled by light, per unit of observed time (ticks of a clock), increases if the observer's clocks are slowed. (FR proposes that this occurs due to motion relative to the background, not relative to the observer.) Keeping the measured speed of light constant for observers whose clocks are slowed requires distances (the space between objects) to be reduced. Under Full Relativity, time dilation arises because the clocks of objects and observers (which both have mass) are slowed by high-speed motion relative to the background from all other massive objects (primarily galaxies). However, the speed of (massless) light is not affected. Consequently, its speed will measure faster, but is actually unchanged if the background is constant. The misunderstanding, that the measured speed must be constant, explains why the "space" of Special Relativity's space-time, the apparent distance between observed objects, is reduced by the slowing of time when there is movement of the observer relative to the background. The same distances travelled take smaller time intervals of slower clocks (a smaller number of longer intervals between ticks).

Einstein's method, used to derive the LT, sought to relate the same events (locations in space and time) seen in a moving and stationary frame, with all values referred back to the stationary frame [8]. Each frame is a set of spatial (x, y, z) coordinates with a time (t) coordinate based on having a clock at every point, with all clocks, stationary relative to each other within that frame, synchronised. The moving frame (x', y', z', t') was allowed to have different scales of distance and time, as a function of the constant relative speed (v), from those in the stationary frame.

The first problem is that, a priori, such a method cannot yield the time (clock-rate) of a moving clock without the clock being examined, unless additional assumptions are made. Relating the positions with time of the same events, back to the stationary observer, amounts to measuring the position of a moving object as a function of your time without any information on the rate at which the clocks on the moving object are ticking. SR claimed that all clocks that were stationary relative to their observer would show the same time i.e. have the same clock-rate. This was based on Einstein's "conjecture" (the first postulate of SR) that the laws of physics (electrodynamics, optics, and mechanics) were independent of motion at constant speed. The assumption therefore demanded that the clock-rate would be the same in all inertial frames, and this was inserted in the claimed derivation of the LT.

FR claims that the first postulate, "the principle of relativity", the apparent independence of motion is in the limit that the speed of movement relative to the background is small relative to the speed of light. The invariance of electromagnetic interactions is because massless electric and magnetic fields travel at speed c . Their interaction with each other depends on relative speed of source and receiver (because the speed of massless light is independent of movement of the background). The different effect on the speed of charged particles (increased inertia) is seen because massive particles are sensitive to movement at high-speed relative to the nearly stationary background of the observer.

Trouble with the deductions and conclusions

The acceptance of SR seems to have been because it claimed to deduce the LT between the coordinates of the same events seen by a moving and stationary observer, and because of the subsequent successes of GR with its distortion of space-time. The LT appeared consistent with observations that the speed of light was constant, that time was slowed (increasing inertia) for moving objects, and that only relative motion mattered for massive objects as seen in Maxwell's equations (of electrodynamics).

Einstein's derivation and interpretation of the LT has a number of problems. He sought a relationship between an event with coordinates in a stationary frame (K) and the same event in a frame (k) moving with velocity v. (Note: a slightly different coordinate notation is used here.) He argued that "the principle of the constancy of the velocity of light" in the stationary system, in combination with the first postulate - the "principle of relativity" - that the laws of physics are independent of motion at constant speed, meant that light also propagated with velocity c when <u>measured</u> in the moving system. The analysis therefore demanded that $c = x/t = x'/t'$ for light in both frames. That is, the additional assumption, that distances in the moving frame changed in the same ratio as changes in clock-rate, was inserted as fact. However, the original second postulate was that light is always propagated in empty space with a definite velocity c which is independent of the state of motion of the emitting body. The subtle change amounts to the assumption that: if the time of a moving system proceeds at a slower rate than in the stationary frame, then distances must be <u>reduced</u> in the same proportion, so that the measured speed of light, using the time and distance of the moving frame, will be unchanged. The constancy of the <u>measured</u> speed was built into the derivation. However, if clocks are ticking slower in the moving frame, then the apparent speed of light for the same distance must be <u>increased</u>.

He then considered a ray of light, emitted from the origin of system k at time t'_0 along the x-axis to x' where at time t'_1 it is reflected back to the origin, arriving at time t'_2. These times are those in the moving system so it was claimed that $\frac{1}{2}(t'_0 + t'_2) = t'_1$ must hold. This equation was used to deduce a relationship between the time (t') of the moving frame and the time (t) of the stationary frame. However, although events at time t'_0, t'_1 and t'_2 are stationary in the moving frame and can be synchronised in that frame, positions 0 and 2 are not the same location in the original stationary frame. The average distance to their positions is slightly larger than the distance at the time of reflection because the signal transmission time is larger for the longer path. The faulty equation incorporated the change in simultaneity into the supposed time of the moving frame.

Einstein also incorporated a scale factor $\phi(v)$. This function applied to time and distance coordinates, to allow their scales to differ between the two frames and appeared in the derived equations:

$$t' = \phi(v)\gamma(t - vx/c^2),\ x' = \phi(v)\gamma(x - vt),\ y' = \phi(v)y,\ z' = \phi(v)z$$

The equations are those of the LT within the multiplicative factor $\phi(v)$.

His analysis then examined a third frame (K'') relative to which the origin of system k was moving in the opposite direction (velocity $-v$) and found that a twofold application (v followed by $-v$) of the LT gave:

$$t'' = \phi(v)\phi(-v)t,\ x'' = \phi(v)\phi(-v),\ y'' = \phi(v)\phi(-v),\ z'' = \phi(v)\phi(-v)z$$

The doubly-transformed x'' coordinates had no time dependence. This was taken to mean the double transformation gave a return to the original (stationary) frame and, therefore, to its clock-rate. Thus, relatively moving observers would each see the other's clocks as slowed. However, the time-independence is not because of a return to the stationary frame. Instead, the two-fold application compares the coordinates (relative to the stationary frame) of two frames moving at the same speed in opposite directions away from the origin after initial coincidence (i.e. after all three frames overlapped at time zero). Their distances match with time (although going in opposite directions). This explains the lack of a time dependency, but the frames are not at rest relative to each other.

Einstein's argument that the moving observer will also see time slowed in the stationary frame is flawed. The inverse transformation is not achieved by reversing the sign of the velocity. The two frames only overlap at time zero. Using $-v$ is only the inverse transformation for the origin ($x=0$) and for zero velocity. The two-fold transformation does not give a return to the original frame (as claimed) unless $v=0$, when there is no slowing of time. If time is found to be slowed in going to the moving frame, then time must be increased in returning.

The apparent return to the original coordinate arises from mixing the interpretations of the terms of the LT (see below). A comparison of matched locations in the two frames, using the LT, requires $x=\Delta x=vt$ for the change in location of all points (which were matched at $t=0$) with time. Thus, $t'=t/\gamma$ and $x'=\gamma x_0$ apply, where x_0 was the distance of any point from the origin at $t=t'=0$. Using x as a separation distance of matched locations in the expression for time and for a location relative to the origin in the expression for position gives a faulty cancellation. Moreover, transforming from the time (t') of the moving frame back to a stationary frame requires using the inverse transformations for the same events (reversing the velocity only applies if it has no effect on time). If time is actually slower in the moving frame, then the inverse transformations are $\phi^{-1}(v)=1/\phi(v)$ and $x''=x_0/\gamma$. All dependence on the unknown clock-rate in the moving system is removed.

However, Einstein concluded that $\phi(v)=\phi(-v)=1$ for all coordinates. He thus arrived at the equations of the LT together with the faulty conclusion that it was only the relative motion that mattered. Each observer would see the other observer's time slowed and distances contracted.

Subsequently, it was argued that the postulate that only relative motion mattered was confirmed because the LT converted $x^2+y^2+z^2=c^2t^2$ into $x'^2+y'^2+z'^2=c^2t'^2$. It was argued that this means that spherical radiation of light, at speed c, in the stationary frame is also observed in the moving frame (i.e. is seen by both moving and stationary observers). This is false. It means, instead, that spherical radiation of light occurs independent of movement of the emitter and the radius of the sphere will be doubled if the clock-rate is halved. Independence of the speed of the observer only gives the same measured speed of light if the unobserved scale of distance is shortened by a matched amount to the slowing of time. Moreover, the distortions are only for the "time" and distance along the direction of motion. These weird distortions arise from assuming that a constant underlying speed of light (when the observer is moving in the x direction) means $c=x'/t'=x/t$. The faulty assumption requires that the distance travelled by the same light is reduced by the same amount as the decrease in clock-rate of the observer (but only in the coordinate of the direction of motion).

Under SR, the measured speed of light (distance travelled per unit time), of the same photons, is claimed to be unchanged even if the clocks of the moving frame/observer are slowed. Instead, the physical requirement is that the apparent spacing between distance markers will be reduced if the same light is measured using slower clocks. If the speed of light is independent of movement of the emitting source, but the scale of distance is constant for all observers, then a decreased clock-rate (slowing of time) for a moving clock means that the same light will be observed to travel further per tick (increased distance). The numerical value for the speed of light, measured within the moving frame, will then be faster.

Special Relativity's dependence of observed distance and time on relative speed between observer and observed led to the perception that space, the scale of distance between objects, and the scale of time were both flexible and only their combination in terms of light-speed had a real existence. This idea is at the core of the disputed paradoxes of relativity. Students happily accept that relative motion between observer and object will lead to apparent effects, but many do not realise that the theory requires the effects to be real. The idea that space and time are malleable, or have a subjective nature, seems to be more readily accepted by those who see that the scale of coordinate frames can be arbitrary. It ties in with the use of the word "space" (in Minkowski's influential explanation of SR as a fabric of space-time in "Raum und Zeit", which translates as "Room/Space and Time"). Einstein used spatial and temporal coordinate frames in his derivation of SR and allowed for possible changes in scale. He incorrectly deduced that the scale of the transformation between observers would be the same for both observers so that each saw a slowing of time, which was matched by a contraction of distance to keep light-speed constant. However, the position coordinates represented the fixed separations between the positions of the same events seen by observers in relatively moving coordinate frames. The initial choice of scale is arbitrary but the ratio of scales of a transformation from the second frame to the first will be the inverse of that from the first to the second. In addition, the ratio of scales for observers moving at different speeds, but seeing the same events cannot change the underlying spacing. The actual distance between events cannot be altered by motion of the observer. A subjective "space" instead of a fixed "separation distance" allowed the idea that space could expand because the observer was moving.

Trouble with the interpretation of the Lorentz transformation

The LT and its interpretation in terms of a fabric of space-time is at the heart of SR and GR.

The LT for constant velocity (v) in the x-direction is:

$$x' = \gamma(x - vt)$$
$$y' = y$$
$$z' = z$$
$$t' = \gamma(t - vx / c^2)$$

where $\gamma = 1/\sqrt{1 - v^2 / c^2}$.

The first, and basic, interpretation of the LT is that the transformation maps the same locations with time of two arrays of points in space (frames) when the arrays are moving apart at constant velocity after coincidence at time zero. The frames correspond to a set of positions at fixed relative locations within each array. The time (clock-rate) within each array is constant (all clocks within a frame are synchronous) but the rate could differ between the two frames, depending on the velocity. The value of x, in the LT equation for t', is then $x = \Delta x = vt$; the separation of the location of every matched point in terms of the time (t) of the (nominally) stationary frame. Hence, $t' = \gamma(t - v^2 t / c^2) = t / \gamma$.

The LT requires that the rate of passage of time in the moving frame be slower; divided by the factor γ. The equation for x' at $t' = t = 0$, relative to the origin of, and within, the moving frame, is $x' = \gamma x$ and $x = x' / \gamma$. This requires a change in the accepted interpretation. The scales of the matched arrays of points (locations) in each frame, that remain matched for all time, are not the same in the two frames if time is proceeding at different rates in each frame. The locations are coincident (once the separation with time, i.e. vt is taken into account), but the scales of the x and x' axes are different. Matched locations have their distance scale inverted relative to their time scale.

There is also a second interpretation of the LT in which the vx / c^2 term (in t') can be seen as a correction to the arrival time (in the time units of the stationary observer) of signals received by the moving observer. These will be advanced or delayed by the movement during signal transmission. The amount depends on the fractional relative movement (v/c) during the transmission time (x/c) and the sign of the $(v/c)(x/c)$ term changes sign at $t=0$, for the origin. The expression $x=vt$ applies to the separation Δx of matched locations. It decreases when $t<0$ and increases when $t>0$. (The coordinate x cannot <u>also</u> be used to indicate a position relative to the origin.)

If the underlying distance between objects and the speed of light are not altered by relative motion of the observer, then light must travel further to reach any point in a frame moving away or a shorter distance for movement towards. However, this does not change the time (clock-rate) in either frame, it just alters the timing of events that were coincident in the stationary frame when seen from the moving frame. If the changed distance travelled by the light is Δx, then the change in time taken is equal to v/c times $\Delta x/c$, i.e. to $-v\Delta x/c^2$, where v is positive for movement away with increasing time. The corrected time is $t_c = t - v\Delta x/c^2$, in the time and velocity units of the stationary frame. If $\Delta x = vt$ is substituted, then the time taken will be $t' = t(1-v^2/c^2) = t/\gamma^2$.

If the primed coordinates are taken to refer to apparent positions with time, then this reduction in time can be split equally between an apparent $t' = t/\gamma$ and apparent $x' = \gamma x$ with an increased apparent velocity. If the moving clock is slowed relative to the stationary clock by $t' = t/\gamma$, then the distance scale will increase, giving an apparent distance travelled of $x' = \gamma x$, for the same velocity.

Einstein argued that the distance expression $x' = \gamma(x - vt)$ means that "*a rigid body which, measured in a state of rest* [i.e. $v=0$]*, has the form of a sphere, has in a state of motion (viewed from the stationary system) the form of an ellipsoid of revolution*" with $x' = \gamma x$ (i.e. the scale of the *x*-axis is increased by the factor γ) [8]. Taking the distance to the moving frame as $x = vt$ after coincidence at $t = t' = 0$, means (as above) that $t' = t/\gamma$. However, the sign of the $(v/c)(x/c)$ term changes at $t=0$, giving $t' = \gamma t(1+v^2/c^2) \neq t/\gamma$ when the object is approaching. Hence, it does not give an ellipsoid of revolution. (Moreover, this distance to the moving frame only applies to the origin because of the coincidence requirement for both x and x'. If it is taken to apply to the separation of matched points, with all the clocks within a frame showing the same time, then x can no longer also be used to indicate a position in the stationary frame).

Einstein's interpretation arrived at $x' = \gamma x$ and $t' = t/\gamma$. He then took $x = x'/\gamma$ as the length that objects of length x' (in the moving frame) will have in the stationary frame, so that the size (length) of moving objects appears shorter (FitzGerald contraction) in the stationary frame. On the other hand, he took the time (t') of a clock in the moving system as "*nothing else than the summary of the data of clocks at rest in the system*" [8]. Therefore, $t' = t/\gamma$ (not $t = \gamma t'$ as per $x = x'/\gamma$) was taken to be the time of the moving clock (in terms of the time in the stationary frame) and, since $t' < t$, time was slowed (less time occurred for the moving clock). However, this leaves out the inversion used in interpreting lengths. The correct interpretation of the LT has elapsed time decreasing by $1/\gamma$ giving distances that <u>appear</u> to increase by γ. However, actual distances are unaltered.

The invariant interval of flat Minkowski space-time, within a region in which the underlying speed of light is constant, will only be found if the meaning of distance intervals relative to time intervals is inverted. Einstein arrived at $dt = \gamma dt_0$ and $dl = dl_0/\gamma$, where dt_0 and dl_0 are duration and length intervals in the rest frame, but then inverted their interpretation so that $c = dl/dt$ is claimed to be unchanged in the moving frame even though its clock-rate (time) is slowed. The invariant interval, $s^2 = x^2 + y^2 + z^2 - c^2t^2$, simply reflects Pythagoras and $c =$ distance/time.

Consistency with the revised interpretation of the LT and observations requires that motion relative to a stationary observer, i.e. stationary relative to a background from all other masses, causes a time dilation. It requires, rather than rules out, a background-dependent explanation of the observed kinematics and dynamics of massive objects. Observed behaviour arises from a different pair of postulates than ostensibly used to derive the LT. The underlying speed of light is constant, independent of the velocity of the emitting object (rather than appears, or is measured, to have the same value using inverted time relative to distance intervals) within a constant background. However, the measured value will be increased if the clock used is slowed because of movement relative to the background. In addition, the constancy only applies within an inertial frame, which, in turn, requires a constant background because the speed of light varies with the background. Massive clocks must run slower (time dilates) when moving relative to the background from all other massive objects.

SR has a slowing of time independent of the direction of movement towards or away from the observer. The slowing is inherent only to the magnitude and not the direction of the movement. The rate of passage of time of the object always slows. This implies that it is the movement of the object relative to the stationary location of the observer that causes the slowing. Otherwise movement of the observer affects the actual (not just apparent) time at the object. It also implies that the effects of motion are real, and must be able to be sensed by the object.

In hindsight, it is hard to understand how the belief system of SR came to be so widely accepted. It claims that distance and time (along the direction of motion) are subjective, based on relative motion. The distances between the one array of stationary unstable elementary particles are supposedly contracted and their rate of decay slowed by the relative speed of the observer. Only the combination in terms of matched reductions in distance and time, giving a constant measured speed of light, is supposed to occur. However, it is opposite changes in time and distance, a dilation (slowing) of time matched by increased apparent distance travelled, that are needed to explain the rate at which elementary particles decay.

Deriving the most famous equation

It was Einstein's deduction of the equation $m = E_0 / c^2$ using Special Relativity, that led to his conclusion that the mass of a body is not a constant; it varies with changes in its energy [3]. Hence, all mass should just be seen as stored energy; energy, sustained by oscillation/rotation, held at a location, i.e. trapped momentum, with the conversion factor for mass into energy being c^2.

Einstein's derivation of $\Delta m = \Delta E / c^2$ [2], was based on his initial paper [8] which claimed that the energy (E^*) seen from a moving system of an object travelling at angle ϕ to the observer moving at velocity v relative to the original (stationary) system was: $E^* = E(1 - \frac{v}{c}\cos\phi)\sqrt{1 - v^2 / c^2}$. He then proposed that there were two sets of light waves moving in opposite directions from the original system so that the sum of the energies of the emitted waves of radiation, seen from a moving system was changed by: $\Delta E = E\left\{(1/\sqrt{1 - v^2 / c^2}) - 1\right\}$. (The change in sign of v meant that the $\cos\phi$ terms cancelled). To a good approximation the expression for ΔE meant that the total kinetic energy lost by the stationary system was: $2\Delta E = 2 \times \frac{1}{2}\frac{E}{c^2}v^2$. So that: "*If a body gives off energy L in the form of radiation, its mass diminishes by L / c^2*". He also concluded that: "*If the theory corresponds to the facts, radiation conveys inertia between emitting and absorbing bodies*".

Under FR, this deduction of the relationship is faulty because the momentum of the photons is constant. It is the inertia of massive objects that increases by γ. The success of the argument comes from conservation of momentum of the object before and after it emits equal photons in opposite directions. Its speed of motion relative to the observer is therefore unchanged. There is no net change in energy of the photons relative to the source. The change in energy of the object, from the radiation of back-to-back photons, is from the reduction in mass (stored energy) carried away by the photons, which move at constant speed independent of the observer. There is no kinetic energy lost by a stationary object just because it is seen by a moving observer, although the energy that it can deliver will depend on its velocity relative to both the receiving object and background.

Under FR, the relationship arises from the underlying nature of radiation and matter which are wave-states based on rotating components. The wave nature is seen in the de Broglie wavelength of matter and radiation and in the uncertainty principle of quantum mechanics where time and energy are related via Planck's constant, which has units of angular momentum. The trapped momentum (p) carried by objects can deliver energy in proportion to this momentum times velocity, so $p = \gamma mv$ for massive objects and $E = pc$ for radiation. The observation that $m = E / c^2$ is because gravitational attraction per unit mass comes from a fractional loss in stored energy. The trapped momentum increases with a decreasing speed of light, according to $1/c$. This implies that slower changes in the components of the underlying field (travelling at c) allow larger changes to be trapped.

It is proposed that the photon has a pair of components of opposite chirality relative to the direction of motion. Its angular momentum is aligned with its direction of motion so it travels at constant speed, but has inertia (resistance) to changes in direction and can carry the energy of its trapped momentum to a new location. Massive objects have rotating components of the same chirality relative to their direction of alignment and so trap energy relative to the centroid of motion. Motion of the centroid relative to the stationary background has opposite effects on the chiral components leading to inertia that increases in proportion to $\gamma = 1/\sqrt{1 - v^2 / c^2}$.

Box 4: A brief introduction to General Relativity

The path to General Relativity (GR) was complex and built on Special Relativity's (SR) concept of a fabric of space-time. The first step was what is now called the Weak Equivalence Principle – that there is no difference between inertial and gravitational mass. The next step was Einstein's realisation that an observer in free-fall felt no gravitation. Gravity appeared to be transformed away by acceleration and the laws of physics were (appeared to be) the same as in an inertial frame. This claimed invariance of the laws of physics is called the Einstein or Strong Equivalence Principle. The principle claims firstly that physics in a frame, freely falling in a gravitational field, is equivalent to physics in an inertial frame without gravity. It then claims that physics in a non-accelerating frame with gravity $\vec{g}$, is equivalent to physics in a frame without gravity, but accelerating with $\vec{a} = -\vec{g}$.

This ultimately led Einstein to replace the invariant interval of the Euclidean (flat) space of SR,

i.e.: $ds^2 = c^2 dt^2 - (dx^2 + dy^2 + dz^2)$ where $x_1 = x,\ x_2 = y,\ x_3 = z$

with: $ds^2 = g_{\mu\nu} dx^\mu dx^\nu$ where $x^0 = ct,\ x^1 = x,\ x^2 = y,\ x^3 = z$.

The metric $g_{\mu\nu}$ is a 4 x 4 matrix and there is a sum over the indices for repeated terms. The flat, undistorted metric of SR has only the diagonal terms of (-1,1,1,1) with the others zero. The cross-terms involving both distance and time allow for the finite propagation speed of gravity (at c).

Einstein concluded that the metric was the relativistic equivalent of the gravitational potential (Φ) as expressed in the differential form of Newton's gravitational equation ($\nabla^2\Phi = 4\pi G_N \rho$). His replacement equation then expresses how mass, energy, and momentum, distort space and time. This is a generalisation of the observation that the source of the acceleration field is (appears to be) the gradient in mass density (ρ). Once an initial distribution of matter, energy and movement is set out then Einstein's gravitational equation (actually a coupled set of equations) can be used to predict how it will evolve over time.

Einstein used his new equations to explain the small mismatch between the predicted and observed orbit of Mercury. The point of closest approach (the perihelion) of the elliptical orbit advances slightly faster than expected from Newtonian gravity. Under GR, the change in space-time means that orbital velocity varies slightly with distance from the Sun. He proposed two further predictions. The next was the amount that light would be bent when it travelled past a massive object, such as our Sun. The bending would be twice as strong as it would be if Newton's law held and light energy fell crossing a gravitational field. The amount of bending was doubled because both space and time were distorted.

During a total solar eclipse in 1919, the positions of the stars in the bright Hyades star cluster were photographed. The positions were compared with those of the same cluster taken at night. Einstein's prediction was correct and he immediately became famous and GR became accepted. This bending of light around massive objects is now called gravitational lensing and has been seen in the distorted and multiple images of distant galaxies and quasars as the light is bent by intervening galaxies.

The third prediction was of a gravitational redshift or slowing of time deeper in a gravitational potential. It was not confirmed until 1959 when changes in the frequency of light moving in the Earth's gravitational field were measured. Subsequent tests using a maser sent into space have confirmed the predicted redshift to an accuracy of 0.01%. Remarkably, the effect is also needed in everyday life for the Global Positioning System (GPS) to work. Your phone receives signals from the GPS satellites orbiting Earth to pinpoint your location. The satellites need to be precisely synchronised. However, from SR, their speed means that their time will run slightly slower and, from GR, the weaker gravitational field means their time will run slightly faster. If the satellites' clocks were not corrected for these competing effects, the GPS triangulation of position would drift. So the predictions are good.

A fourth prediction (by Shapiro), which is primarily a result of the bending of light, is a delay in the travel time of electromagnetic radiation (e.g. radio waves) from planets or spacecraft as they pass near or behind the Sun. This Shapiro delay has been observed.

Subsequent predictions have included an expanding universe, gravitational waves, and black holes. The latter, extremely dense concentrations of mass, produce such a large gravitational redshift that time stops and nothing travelling at the speed of light can escape. Hence the name. Such a "hole" was first imaged in a relatively close galaxy with a very large, compact, concentration of mass at its centre. It has now also been imaged (at long wavelengths) in our galaxy where the orbits of nearby stars indicated a very compact object, smaller than our solar system, but with millions of times the mass.

Einstein's equations predicted that travelling distortions of space-time, gravitational waves, would exist. According to GR, occur from movement of non-spherical systems of massive objects, but only become significant in catastrophic cosmic events like colliding black holes. The waves are claimed to be ripples in the fabric of space-time that fan out through the universe at the speed of light. The first evidence was from changes in the orbital motion of binary pulsars (rapidly rotating neutron stars). The changes in their orbits over time were consistent with a calculation of the expected rate of energy loss from gravitational radiation. The incredible technology of the LIGO interferometers has now enabled the observation of gravitational radiation (waves) from merging black holes and neutron stars.

Under GR, there are other, more complex, predictions of delays and changes in behaviour due to the changes in distance and timing of cosmological events. All such predictions appear to be in agreement with observation. It is therefore necessary for any replacement theory of gravitation to be able to reproduce such predictions. (This is shown to be possible for FR in the main text.)

Box 5: Problems with General Relativity

General Relativity (GR) is necessarily faulty because it is based on a non-existent fabric of space-time in which the actual distance between objects can be altered by movement of the observer and by the presence of massive objects. It also incorrectly assumes that mass and the speed of light are constant (for the local observe) whereas mass as stored energy renders this impossible. The increase in stored energy of the same object when lifted in a gravitational field means mass is not constant. The observation that the release of energy in photon emission, fission, and fusion, all follow $m = E_0 / c^2$ means that an increase in mass of the same matter corresponds to a reduction in the speed of light. The requirement that the mass of the same matter changes with the background from other matter also means the equation on which GR is based (Poisson's equation for gravity) is faulty. GR assumes that mass is constant and that the (vector) field of gravitational acceleration is the conserved field that is the source of gravity. A necessary consequence is that General Relativity mistakenly requires an invisible, repulsive, dark energy that increases with a decreasing density of matter.

Einstein's field equation is based on a generalisation of the differential form of Newton's gravitational equation:

$$\vec{\nabla}.\vec{g} = -4\pi G_N \rho \tag{5.1}$$

The curvature of space-time and the differential (divergence) of the acceleration ($\vec{g}$) are directly proportional to the stress-energy tensor, the generalisation of mass density (ρ) to the density of energy and momentum. The hidden assumption in deriving this differential form (Equation 5.1) is that mass is independent of the surrounding mass 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. This appears analogous to electrostatics where an electric field ($\vec{E}$) due to a static charge distribution gives rise to a force ($\vec{F} = q\vec{E}$) on another charge (q). The derivation of the differential form follows from applying Gauss's law to the gravitational force law, as is done for electromagnetic fields [18]. 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:

$$\vec{g}(\vec{r}) = -G_N M\hat{r} / r^2 \qquad \text{where } \hat{r} \text{ is the unit radial vector.} \tag{5.2}$$

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

$$\oint_S \vec{g} \cdot d\vec{A} = -4\pi G_N M \tag{5.3}$$

The area integral on the LHS is the gravitational field flux through any closed surface S, and M on the RHS is the total mass enclosed inside S. However, constant flux through the enclosing surface assumes that the flux from an arbitrary distribution of matter is constant, independent of the distribution. This requires the mass of each component to be independent of the location of other components (as applies to charge). If mass is dependent on the background from surrounding matter, then this assumption does not hold.

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 LHS, and the mass on the RHS can be expressed as the integral of the mass density function ρ, giving:

$$\int \vec{\nabla} \cdot \vec{g} dV = -4\pi G_N \int \rho dV \qquad (5.4)$$

If this equality holds for any volume, the integrands on both sides must also be equal, giving Eqn. 5.1. However, the equation does not hold if the density of surrounding mass alters the mass held by a constant amount of matter, because this will alter the magnitude of the flux. The equation will also require modification if the background affects the ratio of inertial to gravitational mass.

The divergence of a vector field ($\vec{\nabla}.\vec{g}$) is the extent to which the vector field flux behaves like a source at a given point. It is a local measure of the extent to which there is a larger flux exiting an infinitesimal region of space than entering it. Technically, the acceleration field ($\vec{g}$) corresponds to a flux entering a region, a sink rather than a source, but it is still proportional to the enclosed sink.

If the magnitude of a radial vector field about a point source reduces as $1/R^2$, then the divergence of a field that does not include a source is zero because the surface area around a source increases as $4\pi R^2$. Thus, if the gravitational acceleration falls off as $1/R^2$, as is observed, from a constant source of mass, then the RHS of equation 5.1 should be zero (except within any sources of mass). For an electric field around an isolated charge the RHS is zero except at the point charge. The implication, of the (claimed) non-zero value for all volumes, is that the reduction in mass density from including an increased volume of empty space containing the same number of constant sources, reduces the magnitude of the sink. Thus, empty space devoid of any matter reduces the negative divergence in the gravitational field and therefore acts as a source of gravitational repulsion. Contributions to the flux of gravitational acceleration come from a volume outside any visible source of mass. This empty space appears to alter the strength of the gravitational field by an amount that depends on the enclosed mass density.

A vector field that arises from mass (a form of energy) and provides energy to matter at a distance without losing energy appears inconsistent. The nonzero divergence implies that the surrounding space can act as a source of energy, even when no mass is enclosed. This is something from nothing. GR is based on an equation that does not apply if mass (stored energy) per unit matter is dependent on the background. It necessarily leads to an apparent increase in repulsion, if the mass of the same amount of matter decreases when the density of matter increases. This gives the appearance of an invisible, repulsive dark energy as the mass per unit matter decreases.

The dependence of curvature on density also leads to a feedback mechanism in which the density of energy/momentum changes the magnitude of the distortions of space with time. Thus, Einstein's equation predicts an expanding or contracting universe in which the amount of empty space between objects changes, without the objects moving. This is possible because "space" is seen as a relationship with time ("not a thing"), whereas it is the constant distance between objects not in relative motion.

Einstein, like others at the time, believed the universe was unchanging and so introduced the cosmological constant in his equation in order to obtain a static universe as a solution. Subsequently, when the apparent (Hubble) expansion of the universe was observed, he considered the cosmological constant as his biggest mistake. More recently, the cosmological constant has been interpreted as the vacuum energy of the universe. As explained above, such an energy density appears to correspond to a negative pressure, giving rise to a repulsive force that increases with distance. A vacuum-energy dominated universe expands exponentially. This (artefact of a faulty equation) has been proposed as the cause of an impossibly rapid cosmic inflation of the universe in a negligible amount of time immediately after the assumed big bang. This cosmic inflation is supposed to explain what are known as the flatness and horizon problems (see earlier).

The problems with GR can also be seen to arise from the postulate of the Strong Equivalence Principle: that physics in a frame, freely falling in a gravitational field, is equivalent to physics in an inertial frame without gravity. This postulate is unreasonable when free-fall in a gravitational field means that the object is continuously moving into regions of increasing mass density (which explains the appearance of a generalisation of ρ in Einstein's equation). The object's mass is steadily decreasing and the gravitational force is still present but balanced by the inertial resistance to acceleration.

Box 6: Gauge invariance and the Higgs mechanism

The strong, weak, and electromagnetic forces have been unified in the Standard Model of particle physics as gauge invariant relativistic quantum field theories of elementary particles and their interactions. Gauge invariance is best understood as a reflection of some underlying symmetry giving rise to a conserved quantity. In electromagnetism the components of a uniform, isotropic background of stationary electric (or magnetic) fields cancel. There is no electric field inside a conducting sphere, because the charges spread uniformly and vectors from opposite directions cancel. Even if the sphere is charged to a million volts there is no field inside. This can be seen as arising from conservation of electric charge. Total charge is not created or destroyed and its magnitude is not affected by the amount of surrounding charge. The electric and magnetic fields arise from gradients in a scalar and vector potential. The influence of charge, seen in these fields, is a conserved flux.

In the Standard Model, the proposed mechanism for giving all fundamental particles (electroweak bosons, quarks, and leptons) mass, is called the Higgs mechanism. This mechanism was based on the idea of a "spontaneously broken" gauge invariance. The exchange particle (a scalar, i.e. spin = 0, boson – the Higgs particle) then becomes "charged", i.e. massive. The spin = 1 exchange particles of the strong interaction (the gluons) and of electromagnetic interactions (the photon) are massless, whereas those of the weak interaction (the $\mathrm{W}^{+}, \mathrm{W}^{-}$ and Z_{0}) have mass. Moreover, only the weak interaction violates parity where mirror interactions are not identical. They show a dependence on chirality (a left or right handedness).

The discovery of the scalar Higgs particle, with the expected properties including its mass, is strong evidence that the mechanism for giving elementary particles mass is a broken gauge invariance that includes a background-dependent scalar interaction. The masses of all particles in the Standard Model arise from their interaction with this field, with the observed mass depending on the particle's "energy absorbing" ability, and on the strength of the Higgs field. If this is the source of mass then we must be living in a world where there is an interaction between elementary particles and their surroundings, that gives rise to their mass, which is scalar and not gauge invariant. The initial gauge invariance has been broken. Hence, the discovery of the Higgs boson implies that mass, and hence gravitational attraction, arises from a background dependence. The gauge invariance of the source of gravity has been broken, which is inconsistent with constant Newtonian gravity which is gauge invariant and General Relativity which is locally gauge invariant over small distances and times.

Under Full Relativity, mass per unit matter and inertia are not conserved quantities. The amount of stored energy depends on the total potential, i.e. the background from all other mass. The symmetry has been broken in two ways. First, chirality of particles allows particle/antiparticle pairs that do not cancel (energy remains), and so matter and antimatter are not completely opposite (both have positive mass). Second, the chiral components of the background differ. This asymmetry allows inertia, with its sensitivity to speed relative to the background and resistance to changes in velocity.

Notes and references

[1] Further details of Full Relativity can be found at www.fullyrelative.com with old versions of the ideas as the theory was developed, including a draft book (still under revision), and more on the implications for the Standard Model and quantum mechanics. These can be downloaded free of charge.

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[6] Cheng, T.P. 2009. *Relativity, gravitation and cosmology: a basic introduction*. Oxford University Press, 2nd ed. pp.77-79.

[7] One half of the 2020 Nobel Prize for Physics was awarded to Roger Penrose "*for the discovery that black hole formation is a robust prediction of the general theory of relativity*". The citation included: "*In January 1965, ten years after Einstein's death, Roger Penrose proved that black holes really can form and described them in detail; at their heart, black holes hide a singularity in which all the known laws of nature cease. His groundbreaking article is still regarded as the most important contribution to the general theory of relativity since Einstein*".

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Quotations are based on the English translation of: *On the electrodynamics of moving bodies*, The Principle of Relativity, [1923] by Methuen & Co. Ltd., London.
Available as a pdf file at: https://www.fourmilab.ch/etexts/einstein/specrel/specrel.pdf.

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[12] The 2011 Nobel Prize for Physics was awarded to Saul Perlmutter, Brian P. Schmidt and Adam G. Riess "*for the discovery of the accelerating expansion of the Universe through observations of distant supernovae".*

[13] The 2014 Kavli Prize in Astrophysics was awarded to Alan Guth, Andrei Linde and Alexei Starobinsky "*for pioneering the theory of cosmic inflation*".

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