SEVEN NEW LESSONS ON PHYSICS

A GUIDE TO NEW PERSPECTIVES IN FUNDAMENTAL PHYSICS

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This document is a draft booklet intended for a wide scientific audience, but it needs some familiarity with modern physics.

Some additional details of the work and references can be found at www.fullyrelative.com

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PREFACE

These lessons are written for those who have some knowledge of fundamental physics and a passionate desire to understand the how and why of the world around them. Most will be aware of Einstein and his discovery of a theory of a curved spacetime (general relativity) that explained gravity, and also his discovery of the wave/particle nature of light that led to quantum mechanics. The first applies to the very large, the second to the, very small. However, there is a conceptual conflict between their treatment of time and where they overlap, they appear incompatible. Quantum mechanics has time as universal and absolute, whereas general relativity regards the flow of time as malleable and relative. Then, at high energies and short distances, it appears that space and time should become lumpy (quantised). My claim is that a change in the understanding of gravity is required and that this leads to a changed perception of wave/particle duality and the Standard Model of particle physics. My intention here is to introduce an alternate understanding of gravity, and then explore the benefits and consequences for not only cosmology but many areas of fundamental physics.

The distinguished Italian theoretical physicist, Carlo Rovelli, penned a best-selling introduction to the accepted theoretical pictures in his outstanding 'Seven Brief Lessons on Physics', published in English by Penguin in 2016. It describes the currently accepted theories that cover the scales from the very large (general relativity, gravity and cosmology), through to the very small (waves, elementary particles and quanta). A set of new perspectives is set out here in seven expanded lessons. The first aim is to compare and explain the previous (Rovelli's) and new perspectives as simply and clearly as possible. Therefore, many quotations from Rovelli's book have been included (in *italics*). This has allowed me to contrast the new perspectives with those that most theoretical physicists and astrophysicists currently accept, though there would be disagreement on some details. It also enables an appreciation of where and why I see that new perspectives are demanded and how they overcome difficulties and inconsistencies. This has needed greater elaboration of the old and new ideas but I hope the required study time will be rewarded. My further hope is that the joy of discovery, evident in Rovelli's lessons, can also be conveyed.

What is set out in these lessons involves substantial changes in, or challenges to, the accepted understanding in fundamental theoretical physics. However, the claimed advantages include: the removal of the need for dark energy, dark matter, singularities inside black holes and cosmic expansion; overcoming the flatness and horizon problems; and, the beginnings of an understanding behind the Standard Model. Thus, there must, and will be, enormous scepticism, particularly because the current theories appear "proven" by the many successes of their experimental predictions. In response, arguments are presented as to why and where the alternate hypotheses can make similar predictions, including why general relativity predicts an <u>apparent</u> "dark energy". In addition, several new observational consequences and experimental tests are proposed. Ultimately, the scientific method demands that critical examination of the arguments and evidence will decide the way forward.

It is my contention, that the claimed benefits in the removal of unexpected ad hoc hypotheses and apparent inconsistencies point in one direction, but the observational and experimental tests will be the arbiter. My contention is that the greatest is the removal of what I perceive as relativity's subjective reality for events, whose properties can be altered by the location, environment, or speed <u>of the observer</u>, relative to the events being examined. This restores the existence of an underlying reality that is independent of who is watching.

Be sceptical, find mistakes or problems, see opportunities, make improvements and enjoy the journey!

FIRST LESSON: The background to Einstein's picture of gravity

The new first lesson is in response to Rovelli's "The Most Beautiful of Theories". This referred to Einstein's theory of general relativity, which was published in 1915. It is an extraordinary idea, as Rovelli puts it, *"a stroke of pure genius: the gravitational field is not diffused through space; the gravitational field is that space itself. This is the idea of the theory of general relativity. Newton's 'space', through which things move, and the 'gravitational field', are one and the same thing."* Rovelli saw it as: "*a moment of enlightenment. A momentous simplification of the world: space is no longer something distinct from matter, it is one of the 'material' components of the world. An entity that undulates, flexes, curves, twists. We are not contained within an invisible rigid infrastructure: we are immersed in a gigantic flexible snail-shell. The sun bends space around itself and the Earth does not turn around it because of a mysterious force but because it is racing directly in a space which inclines, like a marble that rolls in a funnel; it is the curved nature of the walls which causes the marble to roll. Planets circle around the sun, and things fall, because space curves."* Moreover, *"it isn't only space that curves; time does too….time passes more quickly high up than below, nearer to the Earth."* In this view, gravity is not a real force but a warping of a combination of space and time (spacetime) by a gradient in the density of mass and energy from matter.

It indeed should be seen as an extraordinary idea because it has the distance (referred to as 'space') between objects, not in relative motion, linked to how fast clocks tick ('time') in a way that keeps the local speed of light constant. The "*walls*" of the funnel are a slope in space and time that depends on the difference in gravitational potential (due to mass and energy) between locations. Space and time have become malleable, they can distort; expanding and contracting in different directions. It is only their combination in terms of a universally constant local speed of light that has a real existence. For an observer at a higher gravitational potential the clocks at a lower potential tick more slowly and space (the scale of distance) is contracted in the same proportion. This means that the distance between objects can change without the objects moving. The next lesson will outline an alternate et of perspectives based on a different picture of reality. In order to choose, we must understand how, where and why they are different and examine the evidence. This new first lesson sets the scene by examining the background, the fabric of spacetime, to Einstein's theory of gravity.

Einstein's extraordinary idea was built on his earlier (1905) special theory of relativity[1], *"which elucidates how time does not pass identically for everyone: two identical twins find that they are different in age, if one of them has travelled at speed"*. The theory has movement at constant speed giving rise to matched changes in space and time which keep the speed of light constant, independent of the speed of the observer. This could be seen as a fabric of spacetime, as made clear by Minkowski in a 1908 presentation on Einstein's special relativity, entitled "Raum und Zeit"[2]. He stated that: "Henceforth space by itself, and time by itself, are doomed to fade away into mere shadows, and only a kind of union of the two will preserve an independent reality". The German word 'raum' translates as room or space. Space and time ('zeit') could be seen as a relationship – spacetime - that keeps the speed of light constant. Individually, space and time had become subjective, dependent on relative movement between objects and observer. This fabric of spacetime was taken over into general relativity, so it is necessary to first understand how it arose and examine if it is a misunderstanding.

In 1687, Newton had published his universal law of gravitation. It proposed a force that acted on bodies, across empty space, in proportion to their mass. In 1865, fifty years before Einstein's new theory, James Clerk Maxwell working with Michael Faraday had written down a set of equations for the propagation and interaction of electric and magnetic fields. Subsequently, Maxwell showed that his equations for electric and magnetic fields could be combined into an oscillating wave that travelled at the observed speed of light. This established that light, and radio signals, are electromagnetic waves of different frequency carrying energy across empty space at a fixed speed. The component fields had been known since antiquity. Waving an amber rod, which had been rubbed in a silk cloth, could lift the hairs on your forearm; and lodestones, naturally occurring magnets, had been found to attract iron. Thus there were now three fields (electric, magnetic and gravitational) that enabled action-at-a-distance across a vacuum, empty of any detectable matter or fluids[3]. These fields reflect a background or medium that allows electromagnetic radiation and the effects of electric charge, magnets and gravity to be conveyed across seemingly empty space. The simultaneous arrival of light and gravitational signals from a merging of neutron stars has shown that their changes all travel at this one speed[4].

When Einstein introduced his first theory of relativity in 1905, he claimed that an aether or background was superfluous. It was called special relativity because it only applied to the special case of motion at constant velocity and when there was no gravitational field. 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”[5]. He proposed that this field, a fabric of spacetime, in which matter distorted space and time, enabled acceleration and rotation to be perceived, but not motion at constant speed. (A sort of effective aether.) He thus accepted that some sort of background field or medium was essential.

Action-at-a-distance necessarily requires a field or fields. This will be called a medium, a field, a background, or a combination of these terms. Later lessons will argue that it does not have substance in the sense of mass, but allows gravitational and electromagnetic effects and radiated energy (e.g. light) to be transported to different locations.

The special theory of relativity applies to movement at constant speed and direction, <u>in the absence of a gravitational field</u>. What it claims, when there is no gravitational <u>force</u>, is that all clocks that are stationary relative to the observer show the same time and rulers have the same length. However, it claims that time slows and space shrinks (the spacing contracts), for the one set of observed objects, when there is relative motion between the set of objects and observer. The effect is constant for a given speed but gets larger at higher speed. It is also claimed to be independent of whether the motion is towards or away, and to be the same if object and observer are swapped. These claims need to be treated with caution because they claim actual properties for the same array of objects (their clock-rate and spacing) that depend on the observer’s motion relative to the array. The observed spacing is altered by movement relative to the observer but not by movement relative to any background.

The special theory started from the apparent inconsistency of electromagnetic interactions with those of Newton and Galileo for solid objects. Maxwell’s equations had changing electric fields generating magnetic fields and vice-versa, but the size of the induced fields depended on the relative speed of the magnet or carrier of electric charge, i.e. source and receiver, and not which one was moving. Similar behaviour had already been seen in the aberration of starlight. The speed of light appeared independent of the speed of the emitting object. More recent, stronger, evidence is seen in that the light reaching us from each star of a binary system takes the same time for the same distance. The time is independent of whether either star is approaching or receding. This differs from what we observe if we throw a ball from a moving car. The ball goes faster (relative to the ground) when it is thrown forward. This does not happen with light, otherwise the light emitted later in an orbit, when the star was approaching, might reach us before the light emitted earlier, when it was receding. No such effect is seen even when the light has taken many years to reach us. Einstein drew on the observation that light-speed was independent of the speed of the emitter, and the result that the interferometer experiments of Michelson and Morley could not detect any effect of the movement of the Earth around the Sun on the speed of light[6], to postulate that the speed of light (in vacuo) was fixed. This is a big step from it being independent of the speed of the emitter.

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

It seems a remarkable leap of faith to assume that there are no changes in any properties (for the on-board observer) if the hypothetical train is moving at close to light-speed relative to the background of stars and galaxies. We know that elementary particles are more difficult to accelerate and decay more slowly as their speed relative to the particle accelerator approaches the speed of light. My proposal is that it is movement of objects with mass, relative to the background medium and not to another observer, that causes time (of moving clocks and observers) to slow. However, movement of massless light (an electromagnetic wave) is insensitive to movement relative to the background medium. The consequences are: that it is still possible, for example, to play table-tennis, but the faster the train is travelling the slower the players' watches will tick and (given that force is the rate of change of momentum per unit time) the harder they will have to hit the ball[7].

Einstein used his postulates to derive a relationship between the distance and time coordinates of the same events seen in a moving and stationary frame. This transformation, already widely known by 1905, was named after Hendrik Lorentz. It left Maxwell's equations of electrodynamics unchanged and accurately described observed high-speed behaviour. This included the motion of electrons, which became more difficult to bend (using magnets or electrically charged plates) as their speed increased. It was as if time slowed and their mass increased with speed. Einstein's apparent derivation of the Lorentz transformation was taken as evidence that his postulates and deductions were correct.

However, the original and subsequent derivations apear logically and mathematically flawed and his postulates questionable. (This is explained at greater length in Appendix A.) Einstein's light-speed postulate was initially stated as: "light is always propagated in empty space with a definite velocity c which is independent of the state of motion of the emitting body". This is in agreement with observation. However, 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. It is proposed in Appendix A that this is a misunderstanding due to the hidden assumption that identical clocks, moving with different observers, keep the same time and will give the same measured value of light-speed. The observational requirements are that the underlying speed of light is independent of the speed of the emitter and that measurements must take into account movement during the time taken for signal transmission. By underlying, I mean the actual speed of an object, be it a car, a planet or a photon, that is independent of who or what is looking (i.e. of the observer's or instrument's movement). It is based on a reality that is independent of the observer, such as could be found if there was knowledge of instantaneous locations, and if corrections are made for changes in timing of signals due to relative movement during transmission. The hidden assumption in Einstein's derivation was that clock-rate was independent of the speed of the clock relative to the background. This was a reflection of the suspect principle that there were no consequences of high-speed motion. Einstein's analysis had therefore inserted that light would travel the same distance for each tick of a clock stationary with respect to the observer, independent of their joint movement relative to the background. The constancy of the observed speed was built into his derivation. However, if clocks tick more slowly because of movement relative to the medium, then the apparent distance and measured speed will increase (for everyone using the slower clock), but the underlying distance and speed are unchanged.

For a constant underlying speed of light, the distance travelled by light, per unit of observed time, increases if the observer's clocks are slowed. Keeping the measured speed of light constant for observers whose clocks are slowed will force a matched reduction in the size of the rulers used. The alternative is that time dilation comes from the slowing of clocks that are moving relative to the background field from all other objects having mass. All massive objects, including clocks, will then have their frequency (of ticking), and therefore time, slowed by such movement. However, the speed of (massless) light is not affected. It is proposed to be independent of movement of the source relative to the background or observer. Consequently, its speed will measure faster, but is actually unchanged, if the background is constant but the observer is moving relative to the background. The requirement, that the measured speed must be constant, explains why the 'space' (the distance scale) occupied by objects will appear to be reduced by the slowing of time with movement of the observer. Instead, the same distance travelled will take less time, fewer ticks of a slower clock. The word 'space' has been interpreted as a flexible amount of room, whereas it is the distance between objects not in relative motion. It is not possible for this underlying distance to be altered by movement of the observer[8].

After appearing to derive the Lorentz transformation (see Appendix A), Einstein concluded that only relative motion was important and that an 'absolutely stationary space' was not required. However, the conclusion that it did not matter who was moving arose from confusing 'reverse' with 'inverse'. Einstein performed a 'two-fold' Lorentz transformation by replacing the speed v with the speed $-v$, a reverse transformation that has the moving frame travelling in the opposite direction relative to the stationary frame. He found that there was no time-dependence of the initial and doubly-transformed coordinates. He therefore concluded that the reverse transformation had returned time and space to the values of the stationary frame. The conclusion is unjustified because the stationary and moving frames only overlapped at time zero so the reverse transformation was comparing two frames moving away at the same speed in opposite directions after initial coincidence. There is no difference in relative separation with time because, at all times, they are at equal distances from the origin. Hence, his subsequent conclusions that clocks moving with the observer (not in relative motion) must keep the same time and that relative motion, in any direction, must slow time (clock-rate) seen by an observer for the clocks in the other frame, were not established.

Subsequent derivations of the Lorentz transformation have mostly relied on the correctness of the principle of relativity, and so inserted the requirement that the speed of light is the same for different observers moving with their clocks (i.e. $c = x/t = x'/t'$). However, if the clocks of the moving frame are ticking slower (by $1/\gamma$), then the clocks of the stationary frame must be ticking faster (by γ, the inverse amount). Anything else throws away the concept of an underlying reality[9]. This was a criticism in a book, written in 1931, with input and support from many leading physicists, although it also included objectionable and faulty criticisms[10]. The degree and extent of the ongoing criticism of his logic and mathematics is not widely appreciated[11]. There is no basis for the claim that each observer "sees" the other's clock as slowed. It has not been experimentally tested using a clock going at high-speed relative to the free-fall background. It arose because, Einstein's thought experiment, did not allow for the change in transmission time of signals when an observer is in motion. He used the term in the Lorentz transformation that corrects for the arrival time of signals to introduce a contraction of space that cancelled the slowing of clocks with movement. This allowed the effect of movement of clocks 'relative to the observer' to replace movement 'relative to the field from all other mass'.

Clocks being slowed with movement may or may not require that massive objects be foreshortened in the direction of motion. However, the empty distance (i.e. spacing) between unconnected objects should not be altered. Einstein mixed the interpretation of the meaning of the value of distance (x) in the Lorentz transformation ($x' = \gamma(x - vt),\ t' = \gamma(t - vx/c^2)$) from the stationary ($x,\ t$) to the moving frame ($x',\ t'$). In the first equation it refers to distance from the origin and in the second equation to distance from the matched point in the stationary frame (Appendix A). This forces a distortion of space when the times (clock-rates) in the two frames differ.

Given these subtle differences, the new perspective is that the previously accepted idea of a linked spacetime that keeps the measured speed of light constant, despite movement of the observer, is an illusion. It claims a malleable space and time, dependent on relative motion between observer and observed, linked into a four-dimensional spacetime with a fixed speed of light. Instead, the new perspective is that, time can be altered but not distance (spacing) and that, within an inertial frame the speed of light is constant, in the absence of a gravitational force. This means that the field from all surrounding mass is constant, otherwise there would be a gradient giving an acceleration (non-inertial motion). Massless light is insensitive to its motion relative to a uniform background field from mass. Clock-rate (of massive objects) slows with movement relative to this balanced field, not from movement relative to the observer. The principle of relativity only applies when the massive source and receiver have a negligible (relative to c) difference in speed relative to the background. The space between objects cannot be changed by movement of the observer. Instead, only clock-rate slows, which gives an apparent increase in distance travelled, which has been mistakenly inverted into a contraction of length. The underlying speed of light is constant, if there is no change in the gravitational field. However, there is no need for this speed to have the same fixed value if the field (seen in the gravitational potential) from surrounding mass changes.

Special relativity applied to motion at constant velocity. Gravity accelerates objects and so applies when velocity is changing. Therefore, Einstein sought to extend the concept of spacetime to constant acceleration. Galileo had established that all objects accelerated at the same rate, under gravity, in a vacuum. Newton had found that both resistance to acceleration (inertia) and gravitational attraction depended on mass, with no dependence on the type of matter[12]. Einstein took this to mean that inertial mass and gravitational mass were the same property.

The next step was his realisation that an observer in free-fall (an unimpeded acceleration under gravity) felt no force. Gravity appeared to be transformed away. Therefore, he postulated that the laws of physics were the same when there was no force being felt. This could be achieved if the observed spacetime was distorted by differences in gravitational potential with position. Relative to an observer at a higher gravitational potential the clocks at the lower potential needed to run slower and space contract. This echoed his earlier deduction in special relativity that observations were changed by relative motion; now they were also changed by relative potential. He further postulated that a constant gravitational force was equivalent to a matched constant acceleration in the opposite direction. The proposal is that in an enclosed spacecraft you cannot tell the difference between constant acceleration and being in a constant gravitational field. This is now known as the Einstein Equivalence Principle - the outcome of experiments in a freely falling laboratory are (claimed to be) independent of the velocity of the laboratory and its location in spacetime, provided the observers and objects are within the same region in which variations in the strength of the gravitational field are negligible. A spacecraft can revolve around the Earth or Sun without the people on board ever feeling accelerated (remaining weightless). Hence, it is possible to equate a curved path in spacetime with a given strength of gravity. Gravity can be explained as a (hypothetical) curvature in the geometry of spacetime by massive objects. The idea of a curved spacetime was implemented in Einstein's equation relating curvature to the surrounding density of energy and momentum. The more massive an object the more spacetime is distorted, which appears as a stronger gravitational acceleration. John Wheeler summed it up as: "Spacetime tells matter how to move; matter tells spacetime how to curve". However, it has been pointed out that a variable light speed theory can reproduce predictions arising from a distorted spacetime[13].

The first success of general relativity was that it offered an explanation for a previously observed phenomenon. A small increase in the rate of advance of the point of closest approach to the Sun of the planet Mercury's slightly eccentric orbit. The theory became widely accepted after the subsequent observation of the predicted amount of bending of light when it passed close to the Sun. The curvature of both space and time in spacetime are claimed to produce a doubling of the change in apparent positions of stars seen during a solar eclipse. Subsequently, there have been many more apparent successes. These include, that when its fuel is exhausted, a large star can collapse "*under its own weight, to a point where it bends space to such a degree that it plummets into an actual hole". "The whole of space can expand and contract. Furthermore, Einstein's equation shows that space cannot stand still; it must be expanding." "In 1930 the expansion of the universe was actually observed."* This refers to the Hubble redshift of galaxies whose apparent speed of recession steadily increases with distance in all directions. The apparent expansion gave rise to the idea of a very hot explosion from an initial point, the 'big bang'. This appeared consistent with the remnant diffuse glare of the observed cosmic microwave background. This almost uniform radiation is explained as the first light that escaped the hot gas of the explosion when it cooled enough for atoms to form, but which has now been stretched to long wavelengths by the expansion of empty space. *"And, further still, the theory contends that space moves like the surface of the sea. The effects of these 'gravitational waves' are observed in the sky on binary stars, and correspond to the predictions of the theory…"*. Rovelli, like most theoretical physicists, was convinced that all this *"was reality"*.

However, space is a measure of the fixed distance between objects not in relative motion, it is not a substance and should not be able to oscillate like a wave. The same distance (space) should not be distortable in proportion to the movement of whoever is looking at it or by the change in gravitational field relative to their location. In addition, the observation that a person falling freely in a gravitational field feels no force should not be taken to mean the laws of physics are unchanged when the surrounding medium (the gravitational potential field) changes. The gravitational force only appears to be transformed away. Instead, it is balanced by the force, on every atom in the person or object, from inertial resistance to acceleration. Free-fall movement into regions of increased mass density means that the magnitude of the surrounding field is increasing. Under both the previous and proposed new understanding, time dilation occurs when the field from surrounding mass is larger. However, general relativity's hypothesises a matched distortion of space (that keeps the locally measured speed of light constant) when there are differences in gravitational potential relative to the location of the observer. Just as for special relativity, the matched changes in distance, the spacing between objects with changes in potential, have not been experimentally confirmed. Indirect tests, such as the bending of light, having alternate explanations.

A field that can carry light and other radiation, and forces including gravity, and that is altered by massive objects, is essential. However, Einstein's spacetime field in which the speed of light is locally constant because space and time (clock-rate) change in unison, must be questioned. It appears to be based on several misunderstandings, with unsatisfactory derivations and "proofs". The observed independence of the speed of light from the speed of its source has been taken to mean that the measured speed is independent of movement of the observer. Instead, if the underlying speed of light is constant, but the time (clock) of the observer slows with their speed (relative to the background), then the speed of light will measure faster. The change in underlying distance travelled is the inverse of the change in time. However, keeping the measured distance constant required larger underlying distance intervals to be inverted to contracted 'space' between objects (Appendix A). Thus contracted space (apparent distance using a slower clock) was matched with the accepted interpretation that increased time intervals meant dilated (expanded) time, i.e. slower ticking clocks. It allows the questionable conclusion that both relative motion and a gravitational field produce changes in the scale of space (distance) as well as time, while the speed of light is invariant.

The new perspective is that the distance between objects not in relative motion is unaffected by motion of the observer or by the magnitude of the background. The time for massive objects, including clocks, is slowed by movement relative to the background, and massive clocks tick faster when at a higher gravitational potential. However, the speed of massless electromagnetic radiation is independent of its movement relative to the background. Within a region of constant background (i.e. no gradient in gravitational potential) the speed of light is constant. However, there is no requirement that the speed of massless fields be independent of the magnitude of the background. An invariant four-dimensional combination of space and time, can still exist when the speed of the observer varies and for different magnitudes of the gravitational potential. It has an undistorted distance travelled by light matched by the product of the speed of light and the time taken. The value is always zero and therefore invariant, even if the speed of light changes with gravitational potential.

Key changes in perspective from Lesson 1 and Appendix A are:

- A background field is essential for explaining action-at-a-distance and propagation of light
- The principle that the laws of physics are independent of motion at constant speed is faulty
- The principle of relativity applies to interactions of massless fields but not to massive objects
- Time dilation with movement comes from movement relative to the field from all other mass
- The underlying speed of light need only be constant if the background from mass is constant
- The measured speed of light will double if the clock-rate of moving clocks is halved
- Distance intervals (space) only appear to contract because time (clock-rate) is dilated (slowed)
- A contraction of distance between objects from relative motion of the observer does not occur
- The derivation of a fabric of spacetime in special relativity is challenged because:
    - a constant underlying speed of light was replaced with a constant measured speed
    - the altered signal arrival times due to the finite speed of light were incorrectly incorporated
    - only a simplified form of the Lorentz transformation, with a different inverse, is allowed.

The currently accepted fabric of spacetime cannot be used to explain gravitational attraction. Time can be altered by movement relative to the background and by gravitational potential, but the distance scale (i.e. "space") between massive objects should not be alterable.

SECOND LESSON: A less exotic but more realistic picture

As set out in the first lesson, Einstein's theory led to a picture in which gravity was a distortion of a fabric of spacetime. It allowed space and time to ripple like the sea, to expand and contract, and to form holes that can swallow stars. Rovelli explained that the expansion of space had been observed, that we knew that the cosmos contained a more-or-less uniform background of billions upon billions of distant galaxies, and that "*we now know that this immense, elastic cosmos, studded with galaxies and fifteen billion years in the making, emerged from an extremely hot and dense small cloud.*"

However, the alternate picture of the nature of the cosmos and gravity retains only the observation of the enormous and more-or-less uniform background of galaxies. The rest of the description of their nature and history is different. The first difference is that, as lesson one explains, its distance scale is not elastic. My hope is to explain clearly why the problems with the previous picture render it untenable, while the advantages, simplicity and realism favouring the new picture seem overwhelming. Be prepared to be challenged. As one professor of astrophysics told me, when declining to discuss it: "It contradicts everything I have been taught".

One of the most beautiful understandings in our world is that energy is conserved. Perpetual motion machines do not exist. In principle, a device such as a wheel could go on spinning forever and never slow down. However, for a start, we would have to get rid of any friction in its bearings, put it in a perfect vacuum, balance it perfectly, and make it from materials that did not induce currents in their surroundings. In real situations, the initial energy of the wheel will gradually decrease. It is lost to the wheel but not to the universe. Friction turns the lost energy into vibrations/heat, the energy of motion (kinetic energy) of atoms and molecules. Then there is material energy that can be stored or released by compressing or releasing the equilibrium state of a material. Chemical energy can be taken in or released depending on the energy stored in the electronic bonds of the initial and final states. Nuclear energy can be released when a heavy nucleus splits into components whose mass is less (fission), or when light nuclei combine into a bigger nucleus of lower total mass (fusion). The reverse, energy being taken in, is also possible, but usually only temporarily. Kinetic energy and the electromagnetic energy of light (electromagnetic radiation) can also be taken in or released. However, the beautiful discovery, made over many centuries, was that the total amount is constant. You don't get something for nothing.

Gravitational attraction as a simpler concept already exists. An oscillating pendulum has no kinetic energy at the top of its swing. It then loses potential energy 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 picture actually has gravitational potential being the energy gained per unit mass. But what is mass? Einstein came up with the answer in 1905, when he derived $m = E / c^2$: "The mass of a body is a measure of its energy content"[1]. Mass is the energy stored in a body. He later observed that: "Mass and energy are therefore essentially alike; they are only different expressions for the same thing. The mass of a body is not a constant; it varies with changes in its energy"[2]. In the derivation of his famous equation, the changes in energy were those from a change in the state of the object (energy levels of an electron within an atom) from the emission of back-to-back photons, in comparison with those from relative movement. The conclusions were derived from the results of special relativity, which applies in the absence of acceleration (including gravitational acceleration) and hence in a constant background from surrounding mass. Einstein and others did not perceive that the same particles of matter (e.g. electrons or unexcited nuclei) might store different amounts of energy if the background field from all other matter changed.

As well as incorporating spacetime, general relativity was built on Newtonian gravity. Newton had deduced that the motion of the planets and their moons could be explained in terms of a gravitational force. An invisible force on a small mass arises from a point source of large mass at a distance across empty space and obeys $F = G_N Mm / r^2$. It was labelled 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 from trees to planets revolving around stars. However, it requires an invisible dark matter to explain galaxy rotation and has no time dependence, which effectively assumes that gravity propagates instantaneously.

An equation of motion, that includes time dependence, arises from equating the force of Newton's second law ($F = ma$) with the force of his gravitational law. It is assumed that the mass m is the same for the force needed to overcome inertial resistance and the force of gravitational attraction. Under general relativity, the gain in energy of the falling object comes from an increased distortion of spacetime. Under the new picture, the gain in energy comes from a loss in stored energy (a reduction in gravitational potential energy). The kinetic energy gained by falling objects comes from a loss in their mass, which is stored energy.

Putting it mathematically, the gain in stored energy per unit of (assumed negligibly small) changes in mass, in raising an object infinitesimal distance dr against F, is:

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

where $\Delta E = \Delta mc^2$ has been substituted, and $\Delta\Phi$ is the change in gravitational potential (energy per unit mass) with distance r from a point source of mass M.

It can be re-written as the <u>fractional</u> decrease (loss) in energy or mass at distance $r_1 = R$, relative to that of zero at infinity ($r_2 = \infty$):

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

This expression can be put into words. Combining Einstein's famous equation with two of Newton's equations, for the simplest case of a small mass moving directly away from a large massive object, gives a very simple result. A dimensionless energy balance equation. The fractional energy <u>input</u> (from lifting the mass) is the gravitational potential energy per unit mass. It equals the fraction of stored energy <u>output</u> (as the lost mass is converted to kinetic energy when the object falls). It will appear to be the same fraction for all objects if the total energy stored as mass is huge. The contribution from a large nearby mass has negligible effect on the enormous total background field.

The deduction of this dimensionless relationship does not say which values (G_N, M, c) change, but we know that the fractional changes are small from the observed tiny change in potential at the GPS satellites. Moreover, the amount is consistent with $\Delta f / f = \Delta\Phi / \Phi$ and so with the fractional increase in energy of atoms being the source of the entire fractional increase in frequency of the clocks of the GPS satellites. This indicates that the energy of photons must be independent of gravitational potential, as should be expected from inserting $m = 0$ in Newton's gravitational equation.

Gravitational potential energy comes from the fractional increase in <u>inertial</u> mass (stored energy) with increase in height. The work done in overcoming gravitational attraction (i.e. lifting the object) is stored as increased <u>inertial</u> mass of the raised object. Mass is variable. The same matter stores less energy in a larger background field (i.e. when closer to other mass). When an object falls, the energy is not released as electromagnetic radiation and neither the number nor excitation state of atoms change. It is shed by doing work to accelerate the matter. Gravitational attraction comes from matter shedding mass by moving faster (gaining momentum) when closer to other matter. Energy and momentum are conserved. I've termed this new understanding of gravity 'full relativity' because the mass and motion of objects is determined by the effects of all other objects (the background).

The previous picture failed to appreciate the consequence of combining the two most famous equations in physics, Einstein's $E = mc^2$ and Newton's $F = G_N Mm / r^2$. Objects with mass (m) gain energy as they accelerate under the force of gravity (F) when they fall towards each other. This energy must come from somewhere. However, the first equation indicates that mass is stored energy, and the necessary conclusion is that the force of gravitational attraction arises from a loss of energy stored as mass. This difference should be a sticking point for just about every current physicist because they have been taught that the mass of any given object at rest is constant and the speed of light (c) is fixed in the absence of a difference in gravitational potential between object and observer. However, they have also been taught that mass will change in fission and fusion, when the matter changes state, or from chemical reactions, or even by being heated. Ultimately, the new picture is a reflection of the rule of life that you don't get something from, or for, nothing!

Somehow, it just was not previously appreciated that the same, seemingly identical, matter could hold different amounts of energy if the surrounding field (from other mass) changed. A bit like the volume of the same balloon changing when the outside air pressure changes. The possibility was probably more easily hidden by referring to it as 'gravitational potential' rather than 'gravitational potential energy per unit mass'. If an object (with mass) is lifted against the force of gravity, then energy changes by the amount of work done (force times distance). Where has this energy gone? General relativity has it decreasing the distortion of spacetime. The revised perspective is that it is stored in the object as increased mass. The same massive particles, e.g. atoms, store more energy when positioned higher in a gravitational field. Therefore, the energy levels of their atomic transitions will be increased (blue-shifted). On the other hand, the energy and momentum of photons, which are massless, is unchanged.

The first consequence is that the speed of light must be larger closer to other massive objects because the potential, the fractional change in energy stored as mass ($\Delta m / m$), decreases when the magnitude of the field from surrounding mass (both matter and antimatter) is larger. The change in energy stored as mass can then agree with $\Delta m = \Delta E / c^2$. Time-independent "rest" mass decreases as c increases. Full relativity challenges both the invariance of rest mass and the constancy of the speed of light.

However, we must point out a subtle and important feature of gravitational potential energy per unit energy. It is a fractional change, and so is a dimensionless ratio, but is measured in terms of the kinetic energy (based on speed of movement) of massive objects with change of location in a gravitational potential. This is why we have labelled the change as being in inertial mass. We must allow for the possibility that the inertia of the same, time-independent, gravitational mass will vary with another aspect of the background, besides the one that changes the speed of light. Inertia and inertial mass are already known to vary with speed (special relativity) and be sensitive to changes in speed and direction relative to the background of distant galaxies (Mach's principle). We will see in a later lesson that inertia, the resistance to changes in velocity, should be expected to decrease when the field from surrounding like-matter decreases. It will be proposed that inertia per unit matter will reflect the asymmetry between the contributions to the background field from matter and antimatter.

The contributions to the background field from each and every mass is dependent on its size and distance but independent of direction. The contributions sum to determine the total field. The Earth's force of gravity arises from the tiny gradient it produces in the enormous background field. The force 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 inertial 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, is approximately 6 x 10^{-10}. A simple calculation based on the number of visible stars (having an estimated total of 5 x 10^{10} solar masses) and estimates of their distance (a mean distance of 10 to 20 kiloparsecs) indicates that the potential from 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. There are more than a trillion (10^{12}) galaxies in the visible universe, so their contribution to the total background will be far greater than that from just our galaxy (if the $1/R$ dependence of Newton's gravitational potential holds over all distances).

However, even this tiny effect of variable mass has already been observed. It is seen in the changes in time of the clocks of the global positioning system (GPS). Every object or particle, whether matter or radiation, has a frequency of oscillation proportional to the energy carried. Time (the relative number of events), frequency, and the rate of ticking of a clock are directly proportional to the energy carried. Therefore, clocks holding more energy must tick faster. In fact, these days the standards of time are based on the frequency of light from very specific transitions between two atomic energy-levels of a pure element. This frequency is observed to change with even a few centimetres change in height of the clock. The fractional change in frequency ($\Delta\Phi / c^2$), with a change in gravitational potential, is the same for the local, current values of the accepted and new theories[3]. General relativity attributes the effect to a distortion of spacetime, by differences in potential, on clocks and atoms of constant energy levels. It has clocks running slower (a bigger spacing between ticks), because (at lower potential) they sit in a region of dilated time, but it also has space contracted. Under full relativity, gravity and changes in clock-rate come from changes in the energy (and frequency) of the atoms of the object (including those of our most sensitive clocks), rather than from changes in a spacetime in the emptiness between objects, and it has no contraction of space (distance). The frequency of every transition is changed in proportion to the change in stored energy.

The expression $m = E / c^2$ implies that the energy and momentum stored in the same matter, that currently stores energy E and momentum E / c, will decrease as the speed of light increases. Thus, work has to be done to increase the trapped energy/momentum as the speed of light reduces with increased distance from a large massive object. This decrease in c and increase in clock-rate matches the increase in energy (that can be delivered by an increased mass travelling at the increased speed). The fractional change in gravitational potential energy (change in energy per unit of mc^2) is the same as the fractional change in time.

Tests of the constancy of the speed of light have mostly been tests of whether the speed of light is independent of direction (e.g. Michelson-Morley) or for paths that have negligible changes in potential over short periods of time (e.g. distant binary star orbits). The invariance of Maxwell's equations under a Lorentz transformation apply to the interactions of fields travelling at the speed of light and do not impose a requirement that that speed be the same when the background field varies.

The agreement in the predicted change in time is not the only place where the lauded successes of general relativity are reproduced. Three predictions, based on the distortion of spacetime by massive objects, were proposed by Einstein. The first explained the, already known, small anomalous advance in the perihelion of the eccentric orbit of Mercury. The discrepancy in advance was explained by the distortion of time with distance from the Sun. The change in time was claimed to alter the speed of objects (that dwelt in that spacetime) as well as how fast clocks ticked. However, the matched distortion of distance (in spacetime) has a negligible effect on the rotation rate of the point of closest approach to the Sun and is ignored in the prediction. Under full relativity, the fractional change in velocity comes from the effect of the changes in mass with changing distance in an eccentric orbit.

The change in clock-rate does not alter the speed of objects except via its effect on mass and inertia. Conservation of momentum means that speed increases as inertial mass reduces. The size is the same as general relativity's slowing of time in the spacetime in which objects reside. Its "proper" time is larger at the object relative to that at zero potential, i.e. coordinate time, and this is assumed to increase the centripetal acceleration, and hence orbital velocity, at smaller distances. The effect of full relativity's change in mass on the orbital gravitational force can be ignored because gravitational acceleration is per unit mass. The predicted orbital advance is the same for both theories.

Einstein's second prediction was that light would be bent in passing close to a massive object. It follows from gravity being a curved path in spacetime. Even light, although travelling much faster and so less affected by the distortion in time, would follow a curved path. The amount of bending was predicted to be twice that expected from the supposed lower photon energy (redshift) deeper in a gravitational field, because both time and distance were distorted. General relativity has time running slower and 'space' contracting, deeper in a gravitational potential. Time dilating was taken to mean that light took longer to travel. Space contracting meant that distances were shortened. This kept the speed of light constant for observers at the location of the path. A doubling of the bending over that from a redshift of photon energy, was predicted because, under general relativity, both distance and time were reduced when seen by an observer at a higher potential. This doubling was observed. However, the explanation is suspect because the proposed effects on time and distance should cancel as they keep the speed of light constant at the location of the photon.

The time (of a clock) is observed to run more slowly closer to a massive object. According to general relativity, a light signal will take a longer time to traverse a given distance in the presence of a (larger) gravitational field[4]. It proposes that the slowing of time (closer to a massive object) means that a light ray passing perpendicular to the object will be bent in the direction of "slower time", i.e. towards the object. At first, this appears consistent with Fermat's principle, also known as the 'principle of least time' – the path taken by a light ray between two points is the path that can be travelled in the least time. The principle correctly accounts for the behaviour of light rays including Snell's law governing the refraction of light passing from a medium of higher speed to one of slower speed. (It has been extended to all particles as the 'principle of least action'.) However, the path of least time is the one where light takes less time to travel a given distance (a fixed distance that is independent of the observer). When applied to a light ray passing through a medium with a gradient in speed across the path, it predicts that the ray will bend in the direction of greater light-speed. This is consistent with light travelling further between the ticks of a slower clock but not with the claim that light will take longer to travel a given distance. The problem traces back to the inversion in the treatment of time relative to distance set out in Lesson 1 and Appendix A. A dilation in time intervals needs an expansion of distance intervals if the speed of light is to remain constant. Moreover, if the speed of light is invariant at the location of the light ray there should not be any bending.

Under full relativity, changes in time apply to massive objects, but not to quanta travelling at the speed of light. A gradient in speed, perpendicular to the direction of motion, will cause light to bend in the direction of <u>increased</u> speed. The speed increases by the fractional decrease in energy per unit matter closer to a massive object; which will bend light towards the increase. Photons should not bend in a gravitational field due to changes in energy of atoms[5]. Instead, it is proposed that the wavelengths of both the electric and magnetic oscillations of the photon decrease inversely with c .

A third prediction of general relativity was a gravitational redshift, a decrease in frequency with increasing potential. It seemed consistent with all objects, including photons, losing energy in escaping a gravitational field. This redshift appeared to be confirmed by a beautiful series of experiments first reported in 1960 by Robert Pound and Glen Rebka who examined light sent up or down between sensors in a tower. They found that photons emitted at a lower excited crystal were not resonantly absorbed at the matched upper detecting crystal unless they were given a Doppler boost in energy (by motion of the emitter). The experiment was repeated with the positions of the source and receiver reversed. The photons (gamma rays) were only resonantly absorbed when the boost (or decrease) in energy compensated for the supposed gravitational redshift of the photons with height. This appeared to confirm that photons lose energy with increased altitude and hence were redshifted. Consequently, most textbooks state or imply that a photon loses energy in escaping a gravitational field. It is also common to see the statement that a photon falls in a gravitational field, even though it has no mass.

This 'falling' of photons appeared to contradict Newton's universal law of gravitation, which has the gravitational force proportional to mass. It was therefore necessary to postulate that the massless photon was attracted in proportion to its momentum (energy of movement). Hence, it was concluded that all forms of energy gave rise to gravitational attraction. This is why general relativity has the geometry of spacetime distorted according to the surrounding momentum, as well as energy, density.

Not all theoretical physicists, including notably Julian Schwinger (Nobel Prize 1965), have agreed with this explanation of the redshift. Schwinger put forward that the photon did not lose energy and instead it was the 'standards of time' that changed[6]. Russian theorist Lev Okun explained that it should be understood as a blueshift in the energy of atoms from the changes in time[7]. Ta-Pei Cheng also explained that the energy of massless photons is unchanged (consistent with Newton's law) but the energy of massive objects, including atoms, increases with altitude[8]. However, all three still seem to have seen the change in energy as only apparent, due to the change in time arising from the distortion of spacetime (when seen by an observer at a higher potential). Full relativity, takes the explanation one step further. It is the increased energy (not a distortion) that gives faster time. The energy of the atoms of the detector and therefore their frequency increases. Energy and frequency are blueshifted with increasing altitude, giving an apparent redshift of photons, whose energy is unchanged after emission. The blueshift of clocks (and atoms) with height has been exhibited as an absolute phenomenon, an increase in frequency and ticking rate. As Lev Okun pointed out, and full relativity demands, the explanation of the gravitational redshift in terms of a naive "attraction of the photon by the earth" is wrong. There is no gravitational redshift of massless photons. Instead, there is a blueshift (increase in energy) of massive atoms.

Conclusions:

Gravitational attraction arises from a fractional decrease in stored energy when massive objects move closer together and the speed of light increases. It is simply conservation of energy and not a distortion of spacetime. The speed of light increases closer to all objects having mass (according to the total background) and this means that they cannot store as much energy. To increase the separation of massive objects requires work which gets stored in the objects as mass. All particles then oscillate/tick faster. This mass is released as kinetic energy of motion when objects move closer to each other.

Differences in the magnitude of the background from other mass alter the mass held by particles at each location. They may also alter inertia. These changes cause gravitational acceleration (Newton's law). The gravitational potential field whose gradient determines the force of gravitational attraction is very large and hardly affected by local mass. This potential falls of only as $1/R$ with distance (R). It therefore forms an almost uniform background away from large concentrations of mass and the gradient appears independent of the total field.

A subtle additional point is that changes in the strength of gravity have also been observed to travel at the speed of light and so relative motion between masses should give rise to a Doppler shifting (similar to that seen for light in binary star systems) giving apparent changes in direction and field strength. The magnitude and gradient of the background medium will depend on the sum of the components from all mass, with the strength of each component altered by relative movement.

The original standard predictions of general relativity involved misinterpreting an increase in distance travelled by light per unit time as a decrease in the scale of 'space' between objects. However, general relativity's predictions, and observed behaviour, do not require distances to be contracted or establish that there is a gravitational redshift of photon energy and wavelength. Instead, a blueshift in the energy of atoms explains observations, while general relativity's slowing of the time for light to travel a given distance should have the opposite effect to its contraction of space and cancel any bending of light. The observed behaviour is reproduced by full relativity. Time and the speed of light are altered by the magnitude of the background medium. No contraction of the distance between stationary objects, when placed at a lower gravitational potential, is needed; and none has been observed.

THIRD LESSON: Waves lead to uncertainty

Quantum mechanics is the remarkably successful theory of what happens at very small scales. It made the transistor, and therefore computers, possible. It provided an understanding of the periodic table, and therefore of all of chemistry. However, it has always had an underlying problem of interpretation. How is it that small objects behave somewhat like particles and somewhat like waves and that only the probabilities of different outcomes can be predicted? It seems as though nature does not have definite, real values until they are measured. The wave function, which carried the information about the oscillating fields, came to be interpreted in terms of a probability density. Currently, it is widely accepted that this uncertainty is inherent and that the wave function collapses into a definite state at the time of measurement and that reality is inherently non-local (distant states can appear entangled).

However, the new understanding of gravity, in which the background field can change the properties of particles, alters the way we picture particles and their interactions. The particle masses and frequencies have a fixed relationship for a given background but vary with the background. We observe that particles can diffract like waves but do not diffuse in all directions. They do not cause or suffer a transition until they carry sufficient energy for a separated final state otherwise they retain their identity and properties over time. This suggests that what we perceive as particles and radiation (photons) are states that arise from confined oscillations of the background field (Appendix B). The states can have definite properties and a fixed or moving centroid, but their cyclic wave nature, which arises from and is dependent on the background, means that their instantaneous pattern of components can vary with location due to superposition and cannot be known with certainty.

All particles, not just photons have wave properties. Their discrete values would appear to come from massive particles being localised periodic oscillations – a cyclic "standing-wave". It is proposed that all elementary particle states are such cyclic wave states so that interactions and transitions occur in discrete steps. Energy and its corresponding frequency of oscillation are continuous but each cyclic pattern (particle state) has fixed energy at constant velocity in a given constant background. Any photon (light quanta), once emitted, carries a fixed quantity of energy. However, the amount delivered depends on the velocity of the receiver relative to the source. A more precise determination of a particle's energy/momentum, using another wave, requires more time or shorter wavelength. The better you establish where a particle is, the less you know about how fast it is changing or moving.

Photons, wave packets of light, produce an interference pattern when passing through a double slit, but if you check which slit each photon goes through then the interference pattern disappears because each photon has its own wave properties and their wave function can extend across both slits. The width of the diffraction pattern depends on both the frequency of the photon and the spacing of the slits. All particles actually behave in this way. Energy and momentum must be conserved but their values cannot be exactly determined during an interaction. It makes it seem as though they are not really somewhere until they are measured. This has resulted in nearly one hundred years of debate. How can energy come in different fixed lumps with observation or measurement altering which lump and where it is? It seemed that an object is not in a definite state or location before you measure it. A first step in understanding is that it is the wave nature of everything that gives rise to uncertainty and the standing-wave states give rise to the apparent lumpiness. The more difficult step in comprehension is that (in scattering) the particles/photons seem never to lose track that they are part of a single packet. They are not broken up into smaller pieces[1]. This will be covered in the next lesson and Appendix B.

In 1900 the German physicist Max Planck used a trick to calculate the electromagnetic radiation energy inside a hot box. He imagined that it came in lumps or "quanta". Remarkably, this accurately reproduced the experimental results. However, it was a surprise because, up until then, energy had appeared to be continuously variable. Some five years later Einstein showed that light comes in packets. These are now known as photons. Light is emitted and absorbed only in fixed units and none are absorbed until the energy of each single photon crosses an energy threshold, that is characteristic of the absorbing substance. This was later explained as the amount of energy needed to excite the electrons of an atom of the substance out of its lowest level (ground state) into the first of its set of allowed levels (excited states). Electrons can only jump from one atomic orbit to another, emitting or absorbing a fixed quantity of energy characterised by the frequency of the emitted photon.

In 1925, the mathematics of quantum mechanics was first set out by Werner Heisenberg using arrays called matrices. In 1926, Erwin Schrödinger set out quantum theory in what he termed 'wave mechanics'. He subsequently showed that wave mechanics and matrix mechanics were equivalent. Both methods can be seen as a way of incorporating the observed phenomenon that only certain values, for transitions between states, are allowed. They also incorporate the means of calculating the probability of a transition between the set of allowed values. Wave mechanics is based on an expression (Schrödinger's equation) which defines how something called the wave function changes with time. It has a continuous, definite time evolution, but the probability of which allowed value will be observed depends on the square of the amplitude of the wave function (actually the product of the amplitude and its complex conjugate). It appears that reality is not definite but inherently random.

It is this introduction of a probability, rather than a definite value, that has been at the heart of all arguments and controversies since. *"Heisenberg imagined that electrons do not always exist. They only exist when someone or something watches them, or better, when they are interacting with something else. They materialize in a place, with a calculable probability, when colliding with something else. The 'quantum leaps' from one orbit to another are the only means they have of being 'real': an electron is a set of jumps from one interaction to another. When nothing disturbs it, it is not in any precise place. It is not in a 'place' at all"*. Thus, it seemed to Heisenberg, and Rovelli, that "*the essential reality of a system is indescribable" and that "we must accept that reality is only interaction"*.

"Einstein did not want to relent on what was for him the key issue: that there was an objective reality independent of whoever interacts with whatever." He "*remained convinced that things could not be as strange as it* [quantum mechanics] *proposed – that 'behind it' there must be a further, more reasonable explanation." "A century later we are at the same point. The equations of quantum mechanics are used daily in widely varying fields: by physicists, engineers, chemists and biologists. They are extremely useful in all contemporary technology. Without quantum mechanics there would be no transistors. Yet they remain mysterious. For they do not describe what happens to a physical system, but only how a physical system affects another physical system."*

Einstein thought that there must be a deeper underlying theory that would allow definite predictions by some sort of hidden variable. In 1964, John Bell, an Irish physicist working at CERN, determined that the predictions of any such hidden variable theory would be different from those of quantum mechanics. Subsequent experiments were consistent only with quantum mechanics and were recognised by the 2022 award of the Nobel Prize for: "experiments with entangled photons, establishing the violation of Bell inequalities and pioneering quantum information science".

The proposed new understanding builds on that of Schrödinger and his famous cat that was a mixture of being both alive and dead until the box was opened. He introduced this cat to illustrate what he saw as the absurdity that outcomes were undefined, a mixture of possibilities, until measured. The new perspective comes from wave mechanics. The components of the field that allows action-at-a-distance, plus particles and quanta, have an underlying wave nature. Waves oscillate and superimpose. They can add and they can cancel and produce standing-wave patterns. Think of a violin string playing a harmonic of the fundamental note. There are fixed places, the nodes, where the string is not moving. Similarly, in an organ pipe or flute the air pressure fluctuates about the mean pressure with position along the pipe. Between the nodes where waves cancel, for example at the maxima, the pressure does not sit still at the maximum value. A pure note cycles through all the intermediate values, yet always has the opposite value to that between the next nodes. The pressure varies at most places but the phase difference between any two locations, the relative position in their cyclic oscillation, can be constant.

If the component contributions to the wave function from different directions arrive at different times, then there can be a cyclic rotation. Moreover, we know that in weak interactions the behaviour can be different for something akin to turning either a left-handed or right-handed screw. It is not easy to picture such time-varying behaviour that can go positive and negative and have different handedness, in three dimensions. However, it is proposed that such a complex field can give rise to a huge variety of repetitive, cyclic patterns. The finite time for propagation of changes in three dimensions allows a force of fixed magnitude to vary continuously in direction within a limited location. This appears consistent with stored energy reducing as c reduces and the size of the limited location decreases.

We know that atoms can be surrounded by a fixed pattern of electron orbitals, some with the lobes seen in the pictures of chemistry books. The lobes are not solid regions of something or nothing. Instead the amplitude of their oscillating field components, about zero or a mean value, varies with location in the lobe. The orientation of these lobes in three-dimensional space will be different depending on the relative phases of their components. If we want to know the orientation, then we have to use another wave state, for example a photon, to interrogate it. The interaction will depend on the relative orientation and magnitudes of the wave function's components at the time of the interaction. Therefore, the outcome appears to be governed by the probability that the overlap and interaction, for all relative phases, of the two wave functions will give the observed new state. This new wave state, once it settles into separated moving particles, is always observed to have the same total energy and momentum. The actual outcome is definite but it is impossible to acquire the needed information without altering the states. A detector with a gradient in its magnetic field can align states that have spin. The orientation of the spin axis will then point in a particular direction. However, until the interaction occurs and aligns the axis, the previous orientation is not known. For a spin ½ particle (e.g. an electron) the new spin state will be aligned either up or down relative to the detector. However, this only means that the alignment of the axis of spin angular momentum (perpendicular to the resultant plane of its pair of angular momentum components) was within the same hemisphere as the measurement axis before it was aligned with the axis of measurement.

We do not have a tool that lets us simultaneously determine two orthogonal values of a wave function, that continually oscillates in two or three dimensions. It is a bit like asking someone to determine the frequency or location of a vibrating and rotating string by touch, without altering how it vibrates. In order to know the frequency of a wave we have to measure it over many cycles and do this without altering its frequency or the direction of its changes. In order to know its instantaneous position we must touch it so quickly that it appears stationary. The (Heisenberg) uncertainty relationships between energy and time, and momentum and position, reflect the difficulty of measuring waves with waves. The components have definite and continuous values but we can only determine them with limited accuracy. Moreover, we just have no way of determining relative phases without altering them.

The probability of a particular outcome can be predicted by averaging over the possible phases (allowing for the degree of time and spatial overlap) but, since we do not have the relative phase information, any given outcome appears statistically determined. There is no need for an infinity of universes (the multiverse) where there is a split at every interaction or observation, or a collapse of the wave function on opening the box to find whether the cat is alive or dead! Things still happen if your eyes are closed or no-one measures it. The "particles" of measurement, including photons, have a wave character, including a finite extent. If their components oscillate relative to a mean location, then they can appear point-like, always being centred on the same location, but they still have a finite spread. Appendix B goes into the nature of particles and measurement in more detail.

Quantization corresponds to fixed notes (constant frequency, with a definite or spherical mean orientation, and amplitude). The emitted note varies with the change in energy of the interaction, given the allowed transitions. Quanta reflect the allowed energy of transitions and do not imply an underlying discontinuous space, time or momentum.

Thus, it is proposed that cause and effect exist in which the components of one wave cannot reach or affect another wave until they overlap. There is no need for space or time to have any granularity. The maximum values of steady and oscillating electric and magnetic fields can be known, and the energy and frequency of a photon, a travelling oscillation between such fields can have a definite value. However, if we want to get precise information about the (central) location of a wave-object, we need to use a very energetic (high frequency) photon or any other "particle" (also a wave state).

Under the new perspective, the location and movement of the observer cannot distort the observed spacing or location of other (untouched) objects, because space is the distance between objects. Space/distance cannot foam or writhe and twist. It is just that knowledge of the precise location of an object with wave properties, at the time another wave packet (a photon) reaches it, requires a very energetic (highly localised) photon. The interaction can then change the state and motion of the particle and can even give rise to new particles.

The problem with Bell's proof that a hidden variable theory would give different values from that of quantum mechanics arises from assuming that a fixed value in one direction implies that there is no oscillation of the components relative to that direction. The polarization (the phase relationship between electric and magnetic fields) of each of a pair of 'entangled' photons (spin 1) from back-to-back emission will match, in order to conserve angular momentum. For electrons, the axes of spin ½ angular momenta, perpendicular to their rotation, will be opposite for 'entangled' pairs. For both polarization and spin, the measurement procedure forces the time-varying 3-D property into a new alignment (direction). This alignment (up or down) will be that measured for all subsequent measurements in the same direction.

The alignment sensed by the measurement of the (oppositely directed) spin of a pair of 'entangled' electrons will depend on the relative phases of the projection of the original spin on the chosen measurement direction. However, the directions of the instantaneous components of the electric and magnetic fields are oscillating or rotating about the direction of the angular momentum vector. The measurement procedure (typically a gradient in the magnetic field) will align the magnetic moment with the chosen measurement direction. Similarly, the polarization of a pair of entangled (spin 1) photons will be aligned by a polarizer but the phase of the electric and magnetic fields will still vary along the direction of motion. A beam splitter will produce two streams of complete photons with each stream containing photons within the same half-cycle (π) of a continuous range of phase with distance along the stream. An interference pattern will still arise when the two streams are brought back together.

The hidden variable lies in the unknown phase relationships between the components of the wave function in three-dimensional space. The value(s) exist, but we do not know them and cannot simultaneously know them because measurement of one alters the other(s). Thus, spin ½ particles, which originally had opposite directions of their angular momentum vectors before being separated, retain a definite value when measured along the same axis and a variable correlation between measurements made at different angles. Einstein, was justified in refusing to accept the correlation unless there was a definite, but hidden, relationship. The observed correlation between 'entangled' states does not involve an interaction between the particles only when either is measured[2]. It is not possible to gain such instantaneous knowledge, faster than the speed of light, about a distant object. This was what Einstein referred to as "spooky action at a distance". The information exists in the wave functions but it cannot be accessed without altering the state.

The understanding also questions the claim that 'quantum computing' could greatly speed calculations because the wave function is a mixture of all possible states. It is based on the idea that a set of entangled states contains the information about all the possible contributions, or components, of the total set. Making a single measurement will therefore, it is claimed, take into account the probability of all different possible results. This is misleading. A reproducible result is possible when all component states are set up with matched phase relationships relative to the one chosen axis. However, there should still be varying phase relationships, and therefore correlations, when the set is interrogated from another orientation. For other orientations, the mean correlation of many results can be predicted, but not the value of an individual result. It seems that the answer should always reflect the extent of the unknown phases inserted in the initial setup relative to the orientation(s) used in the setup and measurement.

Conclusions:

- The uncertainty present in quantum mechanics reflects the difficulty of determining wave properties with waves. The phase relationships cannot be determined without altering the phase. This allows the interpretation of the wave function in terms of a probability distribution.
- Electrons do not only exist when someone or something watches them, or materialize in a place only when colliding with something else. The 'quantum leaps' from one orbit to another do not mean they are not 'real'. The essential reality of a system exists independent of interaction. Reality exists but waves lead to uncertainty.
- Causality and definiteness are present but blurred and hidden. Schrödinger's cat is always either alive or dead, we just cannot access the needed information without looking.
- Particles are standing-wave states that are confined but have finite extension or location. They are not point-like.

FOURTH LESSON: Particles are complex waves that carry energy

Rovelli's original fourth lesson "Particles" briefly summarized the strange, but wonderfully successful, Standard Model (SM) of particle physics. Its successes included the prediction of the Higgs particle, subsequently found at the Large Hadron Collider in 2012. The SM is a theory that links three of the four known fundamental forces within a self-consistent underlying framework. The three are labelled the strong, electromagnetic and weak; the fourth, gravity is missing. The new understanding of gravitational attraction alters the way we picture the relationship of fields to particles and quanta. It provides a path to linking gravity with the other three forces into one unified theory. A guide to the path and a new picture lies in the reality that everything that happens must have a cause.

The SM framework combines the concepts of fields, quanta and relativity, together with the insertion of underlying symmetries in the properties of the different fields. It has successfully "predicted" the masses and strengths of all known fundamental particles and their interactions, including the requirement for the Higgs boson. However, its "predictions" for the masses and strengths of all particles are calculations that rely on the input of a minimum sub-set of the observed masses and interaction strengths. It also has some strange mathematics, called renormalization, where one infinite value happens to, or is arranged to, to cancel another because of the underlying symmetries[1].

These led Rovelli to propose: "*So, for the moment we have to stay with the Standard Model. It may not be very elegant, but it works remarkably well at describing the world around us. And who knows? Perhaps on closer inspection it is not the model that lacks elegance. Perhaps it is we who have not yet learnt to look at it from just the right point of view; one which would reveal its hidden simplicity*."

Rovelli, and most other physicists, assumed that all physical fields, including gravity, are "*made of quanta*", and their interactions are therefore granular, involving fixed lumps. In addition, only the probability of a particular outcome could be determined. Each of the four forces had a field with a characteristic exchange quantum (the photon and graviton) or quanta (the 8 gluons of the strong interaction, and the vector bosons of the weak interaction) and these appeared to come in fixed amounts. However, as explained in Lesson 3, the characteristic light spectra of atoms (and fixed steps of other interactions) is because transitions occur only between the energy levels of allowed states. The possible energy of a photon has a continuous range proportional to a continuous value of oscillation frequency. The underlying electric and magnetic fields also have a continuous range of strengths and changes in their strength propagate at the speed of light. Their combination as a photon, electron or other elementary particle, requires the oscillation to conserve total energy. For the photon it is between equal amounts of electric and magnetic energy. There is no need for quanta to be limited to fixed lumps; that is just a reflection of the available standing-wave patterns. Hence, a gravity based on a continuous range of changes in mass does not need quanta of the gravitational field (i.e. gravitons). There is no need for changes in gravity to come in lumps. Quantization is not needed.

The new understanding of gravity is that it arises from a field that "permeates" everything. However, it is not just everywhere in space, it also seems to give rise to the states that we call particles and quanta. All particles and quanta appear to be made from oscillating components of this complex field. They all have a wave nature which somehow traps energy at a stationary or travelling location. All massless quanta (exchange particles) carry energy in oscillations travelling at the maximum possible speed. Both particles and quanta have a de Broglie wavelength (λ) which is smaller, and oscillations are at higher frequency (f), in continuous proportion to the amount of trapped energy (E). When a massive particle releases energy as a photon, this massless packet carries energy in oscillations in the plane perpendicular to its direction of motion, but travels freely with unchanging energy at light-speed. Thus, mass needs to be defined as the product of the energy carried and its resistance to acceleration. This is consistent with inertial mass having a fixed proportionality to gravitational mass at the same location and time, and with massless particles not losing energy in escaping a gravitational field. It also seems consistent with Planck's constant (h) in $E = pc = hc / \lambda = hf$ having units of angular momentum. Photons appear to include a set of oscillating components aligned with the direction of motion that produces a centroid that always move freely at c (so not trapping additional momentum), but driven by a perpendicular set of rotating components (see Appendix B).

There is no indication that light-speed is limited to only certain values. It depends on the magnitude of the medium (the field) from the effect of all other mass, and it is the same speed for electric, magnetic and gravitational fields. Under full relativity, the amount of energy that can be stored in stationary massive particles decreases as the speed of light increases. The speed and energy are not necessarily the same elsewhere or at other times. However, the fractional change in energy has been observed to high accuracy to be the same for every material (when measured at the same time and location). Consequently, changes in the speed of light must also alter the amount of energy that can be trapped inside the nucleus and all elementary particles. It must have the same effect on masses associated with the strong and electroweak interactions. These are powerful indications that everything (including the particles and quanta of the strong, electromagnetic and weak forces) are different aspects of the one underlying multi-component field.

The loss of mass with an increasing speed of light explains gravity, but does not explain other properties, such as momentum. How can massive objects resist changes in velocity (speed or direction), and have more resistance at higher speeds, but not need a force to maintain constant speed? How can an object know how fast it is going relative to the background, if this explains the slowing of time with speed? Why does the effect of the field, seen in the gravitational potential, fall off only as the inverse of the distance. These properties need causes.

The speed and direction of the motion of massive objects (i.e. momentum) remains constant if there are no forces acting. However, increases in, and decreases from, any velocity, i.e. acceleration, are resisted. This inertial resistance applies to changes in direction even at constant speed, when the energy carried is unchanged, and the amount of resistance is observed to increase non-linearly with speed. For special and general relativity this speed is relative to the observer whether it is towards or away. For full relativity it is the speed relative to the background (and to changes in velocity relative to the current velocity). Inertia and the directional (vector) nature of momentum require a more complex dependence on the background than a gravity that merely changes the energy that can be stored. Resistance to acceleration, but not to constant speed, means there must be multiple components of the field, within particles, with oscillations about mean values that provide a memory of the current speed and orientation relative to the background.

Both Newtonian gravity and general relativity have the acceleration field (force per unit mass), dependent on the gradient in potential (its slope). They assume that the force factor (G_N), the slope per unit of potential, is constant independent of the total potential. This requires gradients in potential from opposite directions to cancel, so that a constant, uniform background has no effect. However, inertia appears to depend on the distant fixed stars because gyroscopes continue to point in the same direction relative to distant galaxies, independent of changes in direction relative to the much larger gradients from the Earth and Sun. It must be the total from all directions, and not just its gradient, that matters. In addition, experiments have shown that the magnitude of both electromagnetic and gravitational potentials, and not just their slope (the difference between levels with distance), can affect results. For example, a change in the magnetic (force) field in the space between, but not across, the paths of a double slit experiment, using electrons, shifted the position of the fringes in the interference pattern. The magnetic potential for the paths was changed but not the magnetic force[2]. Hence, potential, not its gradient, must be the determining factor.

However, gravitational potential energy only falls off inversely with distance (i.e. as $1/R$). This is, or should be, seen as a big surprise. The brightness of light sources, the number of photons going through the same lens, falls off inversely as the square of the distance. The same is seen for radio waves and sound and even the chance of being hit by a bullet. The flux of energy-carrying fields must fall off inversely with the increase of the area of the enclosing surface (i.e. as $1/4\pi R^2$), otherwise the flow of energy is not conserved. How can a field that determines behaviour at other places fall off so slowly with distance? The first necessary implication is that the field that determines the strength of gravity does not carry energy and so cannot be made of particles or quanta of energy. Otherwise, the effect of the flow of energy (total flux through an enclosing surface) would be increasing with distance. Instead, the field must only determine the energy that can be stored by massive objects.

The proposed explanation of the slow decrease with distance is that there are two nearly equal components of the background field, with the second component inhibiting changes in the effect of the first component[3]. This would seem possible if the components behave like left-handed and right-handed screws. Such handedness is called chirality. Full relativity proposes that this inhibition of changes in the magnitude of the opposing components results in both components only changing by the square root of the amount expected. The mean value then reduces as $1/R$ (as observed for gravitational potentials). It is proposed that the speed of propagation of changes in the field is reduced in proportion to this reduction in total potential. Gravitational attraction arises when less energy needs to be held in the same matter, to maintain the same standing-wave state. The trapped momentum needs to increase in inverse proportion to the value of c, when inertia is constant; and inertia, the resistance to changes, should be expected to depend on the speed of the changes relative to c (i.e. on v/c) and the relative magnitudes of the chiral components (i.e. their asymmetry).

One consequence of this slower ($1/R$) decrease in potential with distance is that the contribution of the billions of distant galaxies to the total potential, for a uniform distribution of galaxies, will dominate. Hence, the fractional change in mass due to the potential of a nearby mass, seen in the factor G_N/c^2, is small and nearly constant, because the background potential is very large and its asymmetry (and hence inertia) should be small. This is reflected in the enormous stored energy per kilogram of mass. A 1kg object, that we can throw some distance against Earth's gravity, contains the amount of energy released by a 20-megaton hydrogen bomb!

In the Standard Model of particle physics the strong, weak, and electromagnetic forces have been brought together by allocating a field to each force. The oscillation(s) of each field come in lumps (particle quanta) whose exchange gives rise to the force. The single exchange particle of the electromagnetic force is the massless photon which interacts with charged particles including electrons (leptons). The strong force has eight massless, neutral gluons which interact with quarks (which are particles that have a property called colour and fractional electric charges). The protons and neutrons in the nuclei of atoms are made from groups of three quarks. The weak force has three massive exchange particles (bosons) which interact with the massless neutrino plus all massive particles. In order to explain the source of mass, an additional field was introduced. Interactions with this Higgs field and its exchange particle, the Higgs boson, are the proposed source of the mass of other particles. Quarks, leptons and neutrinos all have a half unit of a property called spin and come in three generations (of similar families grouped by increasing mass). Each family has a pair of quarks with charge $+\frac{2}{3}$ and $-\frac{1}{3}$, a lepton (charge -1) and a neutrino, each with its antiparticle[4]. Each quark also comes in three 'colours' (which is just a label for an additional property). The exchange particles all have unit spin (bosons) except the Higgs which has zero spin. The interactions of these fields obey the rules of quantum mechanics, with its interconversion of mass and energy in fixed lumps (quanta), and those of a relativity that has transmission of massless interactions at the speed of light and the observed effects from high-speed motion on time and energy/momentum. The force fields also share a feature called 'gauge invariance'. They therefore collectively come under the umbrella of gauge-invariant relativistic quantum field theories. It sounds complex, and is, but it has been remarkably successful in predicting observed behaviour. Basically the calculations work but the reasons behind the structure, why the mathematics works, is not fully understood.

However, the cancellation of infinities (renormalization) is associated with the property of gauge invariance. The behaviour was first encountered in electromagnetism[5]. A constant value at a given location can be added to the scalar electric field potential without affecting the electric force (no change in gradient). Similarly, a gradient (with distance) of a scalar function can be added to the vector potential without affecting the magnetic force. Gauge invariance requires a relation between these added terms which amounts to a null 4-vector potential which just shifts the phase of the quantum mechanical wave function. The invariance (independence of results) when taking all phases into account is known as gauge invariance and is a cornerstone of the Standard Model. All three forces have such a gauge invariance, an additional underlying symmetry (when charge, spin/parity and time are taken into account). My view is that the null 4-vector potential just reflects conservation of energy and momentum at all times for the total energy/momentum held in the component fields (see Appendix B). Particle wave functions have cyclic oscillations in the phase of their standing-wave components so that the probability of any interaction will vary with the arrival time, as well as the magnitudes, of the components of the interacting particle/quanta.

Paul Dirac, combined quantum mechanics and Maxwell's equations of electromagnetism to come up with quantum electrodynamics (QED), the first quantum field theory. He did this by introducing an extra symmetry with a second component of spin ½. The electron needed a matched component separated by a gap in energy. This was initially seen as a hole in a sea of negative charge. Subsequently, it was observed as an identical particle to the electron except for its positive charge. This positron was the first case of an antiparticle. It was found that a particle and its antiparticle could annihilate releasing the gap in energy. (All known particles have an antiparticle and all the energy is released. The amount is always in the same proportion to the total mass, so all mass must be stored energy.) Both electrons and positrons have two states (in which the half units of spin must point in opposite directions when a pair of such fermions in an atom have matched rotational momenta). The exchange particle, the photon (with a whole unit of spin) can flip a spin ½ state without changing its energy, and (under quantum field theory) the photon is considered to be a virtual state of an electron and positron.

Gradually, all the particles, observed first in cosmic rays and then in ever more powerful accelerators, were found to fall into, fundamental (lowest energy) and excited states of the family groups outlined above. The electromagnetic and weak interactions were linked into an electroweak theory where the massless, chargeless, spin 1 photon of electromagnetism was partnered by three massive bosons (spin 1), one without charge, and a pair of opposite charge. Martinus Veltman and Gerard 't Hooft showed that a gauge symmetry (the addition of the Z_0 with matched properties to the photon except for mass) allowed the infinities in the mathematics to cancel. Finally, a gauge symmetry of the three colours and anti-colours of three families (flavours) of quarks and anti-quarks interacting via 3 x 3 = 9 massless gluons with colour plus anti-colour, was shown to tame the mathematics of the strong force. One gluon, which was an equal mixture of all three colours, and so did not interact with coloured quarks, would be missing. In addition, only colourless states of 3 quarks (e.g. protons and neutrons) or a quark plus anti-quark (mesons) or their combinations (e.g. pentaquarks) would be observed outside the nucleus. The theory became known as quantum chromodynamics (QCD).

The Standard Model has all particles linked under related gauge invariant quantum field theories. No way could be found to include gravity. The model needed to include mass because gravitational attraction is proportional to mass, with most particles having mass, and because mass and energy can interconvert. However, introducing massive exchange particles always seemed to break the underlying gauge invariance. In order to solve this problem a mechanism was proposed as far back as the 1960s. It became known as the Higgs mechanism. It was based on the idea of a "spontaneously broken" gauge invariance. The underlying symmetry (the gauge invariance) had been present in the theory but was destroyed by a random fluctuation. The common analogy is a ball sitting at the top of an exactly round hill or Mexican hat. A tiny fluctuation sends the ball off in one direction and the system is no longer symmetric. One exchange particle (the spinless Higgs) then becomes massive and causes the bosons of the weak interaction that have unit spin (the W^+, W^- and Z_0) to also gain mass. The exchange particles of the strong interaction (the gluons) and of the electromagnetic interaction (the photon) remain massless. The mass of the exchange particles is related to the violation of parity by the weak interaction, where interactions that look the same in a mirror are not identical. The interactions show a dependence on chirality (a left or right handedness) in three dimensions. Why the leptons and quarks also gain mass is not clearly understood within the Standard Model, but the amount of mass is seen as reflecting the strength of their interaction with the Higgs boson.

The discovery of the Higgs particle, with the expected properties, using the Large Hadron Collider at CERN was announced on the 4th of July 2012. It is strong evidence that the prime mechanism for giving elementary particles mass is a broken gauge invariance that includes a background-dependent spinless interaction (labelled the Higgs field). The masses of all particles, according to the Standard Model, arise from their interaction with this field. It follows that we must be living in a world where there is an interaction between elementary particles and their surroundings, that gives rise to their mass, involving a field that breaks gauge invariance. 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 field which has chiral components, and in which gauge invariance of interactions has been broken. This is inconsistent with gauge invariant Newtonian gravity and general relativity which is gauge invariant (at any given time and place). The handedness (chirality) of weak interactions and the Higgs mechanism for giving particles mass, demand that energy can be trapped by interactions of chiral fields. Thus, fields from both matter and antimatter (which in weak interactions exhibit opposite handedness) are likely to be involved.

Full relativity's explanation of gravitational attraction as arising from a reduction in mass (stored energy) of particles, when the background from other matter and the speed of light increases, leads to a new perspective for particle physics. Mass decreases when the density of surrounding matter increases. This is a broken gauge invariance relative to that seen in electromagnetism. The strength of gravity is not independent of a uniform background from other mass, whereas the electromagnetic interaction is independent of a uniform background of charge. Hence, it is proposed that all particles are cyclic oscillations (3D "standing-wave" patterns) based on the one background field that includes both left and right-handed components and gives rise to colour, mass and charge. Competing effects of opposed chirality can lead to trapping of energy. Any such mechanism that gives rise to trapping of energy at a location will be a source of mass. The amount of energy will be larger when the region of trapping is smaller. There does not appear to be any need for a different field for every force or for every particle. The possible particles and the size and properties of their interactions result from different mixtures and strengths of multiple components of the one field with two chiralities.

Full relativity proposes that there are combinations of oscillating components which are supportive, rather than opposed, in the direction of motion, sustained by oscillations perpendicular to this direction. These lead to massless exchange particles travelling freely at the maximum speed c. They carry momentum to new locations, and their speed and oscillation frequency varies with the magnitude of the background, without any change in energy being required. However, the energy that can be delivered by the fixed quantity of momentum is increased or decreased by the relative velocity between source and receiver. (Their angular momentum is perpendicular to their direction of travel.) All massive particles, including the integer spin exchange particles (bosons), and the scalar Higgs, must instead have opposing components that store energy, or trap momentum, and so give rise to mass and inertia. It is proposed that this revised picture will eventually be shown to explain the Standard Model and allow calculations of all particle masses and interaction strengths from the amount and distribution of other matter and antimatter.

The opposite chirality of components of the field from matter and antimatter allows a change in one chiral component of the background to be shared by inducing a change in the other component. The mean value increases but the size of the change is more strongly resisted with increasing difference (i.e. asymmetry) between the components. It is proposed that the resulting property, which will be labelled "clout", determines the speed of light, and the competition between chiral components results in a gravitational potential that only falls off inversely with distance. It is further proposed that antimatter galaxies are present in equal numbers to matter galaxies, but are not recognised because they are no longer colliding with matter galaxies. Their contributions to clout will be nearly matched except near and within isolated concentrations of one type of matter (i.e. galaxies and galaxy clusters).

Chiral components within particles allow particle and antiparticle pairs that both trap the same amount of (positive) energy. These particle pairs do not cancel (energy in the form of photons remains after annihilation), implying a broken symmetry. The contributions of chiral sources to the background (outside the particles) can also differ with location relative to large concentrations of like matter (e.g. the centres of isolated galaxies). All particles have a de Broglie wavelength indicating that they have an oscillation/rotation. This is consistent with quantum mechanics and with particles being standing-wave states. The opposite rotation properties of chiral components also appear to point to an explanation of why the probabilities of quantum mechanics involve both the wave function and its complex conjugate[6].

The chiral components allow oscillation patterns ("particles") that can be sensitive to changes in speed and orientation relative to their current values. Hence, it is further proposed that the energy required for an increase in velocity relative to c for one chiral component is larger than the decrease in energy required for the opposing chiral component. This difference increases with the matter/antimatter asymmetry of the local background, so that inertia depends on asymmetry. Stored energy depends on the clout via c and the inertia per unit of gravitational mass increases with asymmetry. The ratio of inertial to gravitational mass will therefore vary. Equating the units of mass (as done in general relativity) incorporates the local ratio of asymmetry into the apparent strength of gravity. Asymmetry and inertia can be expected to decrease away from a concentration of just matter or antimatter.

This has important consequences. Matter/antimatter asymmetry, and hence inertia, will increase with decreasing distance to sources of just one type of matter. The speed of light will also increase so that mass will reduce, and the effect on momentum will be multiplied by the change in inertia. The change in speed of light, which depends on the change in total clout, will be much smaller than the change in asymmetry, i.e. the fractional difference between matter and antimatter potentials. However, gravitational force depends on the gradient in total potential and is per unit of gravitational mass, while kinetic energy and momentum of massive objects reflect inertial mass which includes the change in both inertia and stored energy. The value of Newton's gravitational "constant" will be determined by the product of inertia (per unit of stored energy) and stored energy (gravitational mass). Thus, gravitational force will appear to increase away from an isolated galaxy or galaxy cluster, if it is the key determinant of local asymmetry, but be approximately constant within a region the size of our solar system.

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. The local change in clout, due to clumping of sources of constant mass about a distant location, is negligible. This is because the mean distance is effectively constant. However, clumping increases local asymmetry and so increases inertia within a clump of like matter (e.g. a galaxy), which will slow the movement of massive objects leading to contraction of orbits. Like matter will concentrate within regions even if the total amount of matter/antimatter (and, hence, average matter density) is constant within a stationary (non-expanding) universe. Clumping reduces the background clout, even if total matter and volume are unchanged. Hence, the stored energy per unit of matter will still decrease as the speed of light decreases with total clout. Thus, the speed of light should decrease as the universe evolves and gravitational mass (stored energy) should increase. This means that an increasing redshift (decreasing mass per unit matter and increasing speed of light) will be observed going back earlier in time, without expansion being required. The change in inertia with time will not be seen locally because frequency/time reflects the local value of asymmetry at the time of measurement.

An initially nearly uniform background of matter and antimatter, will gradually separate and contract into isolated regions in which particle masses and inertia increase over time. The "spontaneous" breaking of gauge invariance is a gradual event.

Summary:

The proposed new understanding (full relativity) is that space and time are not a flexible background in which objects of fixed (rest) mass are embedded and the speed of light is fixed. Instead, it is the properties of objects (particles and quanta which have cyclic wave patterns from different numbers and mixtures of components) that vary with the magnitude of the chiral contributions to the one background field. It is further proposed that the balanced mean of the opposing chiral components of the background from matter and antimatter determines the speed of changes in gravity, and of light and any other massless particles/quanta. Thus, the maximum local speed of propagation depends on the balanced mean of chiral components from all other objects. The opposing chiral components can explain why gravitational potential energy only falls off inversely with distance (i.e. as $1/R$) so that distant galaxies dominate in determining the background and that movement is relative to this distant background. Massive particle states trap momentum at a mean location (e.g. via pairs of oppositely directed components of like chirality). The oscillation/rotation frequency per unit mass, and therefore inertia, is proposed to depend on the degree to which movement alters the current balance in chiral contributions from matter and antimatter. The increase in inertia with asymmetry means that the clumping of matter over time will lead to a steady decrease in the speed of light and hence, a needed increase in the energy levels per unit matter, as the universe evolves. The broken gauge invariance of the Higgs mechanism as a source of the mass that determines the strength of gravity is inconsistent with general relativity. Full relativity's role of a direction-independent background field that: i) determines the energy that can be stored by matter via the speed of light, independent of the type of matter, and ii) the nature (broken gauge invariance) of the proposed Higgs mechanism, strongly suggests that the Standard Model and full relativity are based on one and the same field. In addition, the observation that variations in the strength of gravity, the strength of electric and magnetic fields, and electromagnetic waves (photons), all travel at the same speed, also strongly indicates that all four fundamental forces, particles and interactions arise from this one underlying multi-component field. Full relativity proposes this as a key step towards their ultimate unification and explanation. Appendix B puts forward proposals towards the visualisation of particles in terms of the component fields and their confinement.

FIFTH LESSON: Escaping quantum gravity and the dark side

Rovelli's fifth lesson "Grains of Space" outlined the paradox that the 'most beautiful theory' (general relativity) and quantum mechanics "*cannot both be right, at least in their current form, because they contradict each other*". The proposed resolution was to combine them by replacing a continuous spacetime with one that comes in tiny lumps or grains. This proposal had been labelled 'quantum gravity'. It sought to combine gravity and its curved but continuous space with a quantized flat space that has fixed, but discontinuous, leaps in energy governed by probabilities. For Rovelli, spacetime was a physical field and all physical fields had a quantum character: granular, probabilistic, and visible only through interactions. He asked: *'Can we build a conceptual framework for thinking about the world which is compatible with what we have learnt about it from both theories?"*

This lesson explores the consequences and benefits of the changed perspectives that spacetime is an illusion, that a quantum gravity is not required, that time and energy can be continuously variable, and that mass, the speed of light and inertia are dependent on the background. Moreover, there is no reason to think that the spacing between objects comes in small jumps or that what happens is random and subjective. The new lessons indicate that it is questionable hypotheses and interpretations that give rise to general relativity's subjective reality that distorts time and space according to relative gravitational potential, and relative motion, of the observers. The new lessons instead present arguments that it is the magnitude of, and motion relative to, the background that alters time, that distance scale is constant and that reality is definite, not random. It is just that we are unable to determine the unknown relative phases of wave interactions. This lesson shows there are remarkable benefits. The problematic singularities, and uncrossable event horizons, of black holes no longer occur; the unexpected dark energy and dark matter, that ostensibly made up 95% of the universe, are artefacts of the differences; and yet the lauded successes are reproduced.

Newtonian gravity and general relativity have mass and the speed of light independent of a uniform background from surrounding mass. This is because they have equal gravitational accelerations from opposite directions cancelling. This feature should sound warning bells. Contractions from opposite directions cannot cancel. If a change in the amount of surrounding matter causes a contraction of space, then it needs to be opposed by an expansion of space in order to cancel. General relativity has no effect due to the background from a steady, uniform, large-scale distribution of distant galaxies. It assumes there is no change in the gradient (giving the force) even though such a background should change the total potential, as scalar potentials must add.

Taking special relativity's spacetime over into general relativity was made possible by assuming that a gravitational force disappeared under free-fall; so that gravity was transformed away (Lesson 1). The reality is that the force is still present but exactly matched by the force resisting acceleration. A freely-falling object is continuously moving into a region of lower potential. Removing the force also amounts to removing any effect of a change in total potential. Keeping spacetime with its constant speed of light requires matched changes in distance and time, when the observer travels with the object which is being observed. Both space and time are claimed to expand or contract, when there are differences, relative to the observer, in the gravitational potential, or in the relative speed of the observer and object. In a gravitational field, the changes in space and time perceived by a stationary observer at a different potential are claimed to bend light in the same direction even though an observer, always at the location and potential of the photon, should perceive a fixed speed of light. This malleability, a subjective existence dependent on the observer's relative location and movement, seems to be what has enabled the strange idea that "space is not a thing" and can expand without objects moving.

A basic difference between the two theories, for gravity, comes from general relativity keeping both locally observed mass and c invariant, but changed energy, slower time and less space giving the same $c =$ (contracted distance)/(slower time), when measured from a higher potential. Full relativity has an increased c and time slower at a lower potential but the scale of distance is constant. Local matter cannot then hold as much energy which drives gravitational attraction. However, another change with decreasing potential comes from the increase in asymmetry, which increases oscillation frequency per unit of stored energy, so inertia increases and time (mechanical clock-rate) slows. General relativity, with matched changes in the geometry of space and time from differences in potential, gives predictions that can also arise from changes in time and energy with the speed of light, but no change in distance scale. This is seen in Einstein's first three predictions (see Lesson 2).

A fourth prediction, by Shapiro, is a delay in the travel time of electromagnetic signals from planets or spacecraft as they pass near or behind the Sun. The delay is primarily determined by the amount that bending changes the path length, and so the predictions will match; and the expected delay has been observed. However, full relativity's increase in the speed of light along and across the path deeper in a gravitational potential is the cause of the bending. General relativity has the speed of the photon constant, but distances contracting and light frequencies faster when "seen" by an observer at a higher potential. Full relativity's increase in the speed of light is not easily detected because it affects the determination of orbital paths. It will be hidden by the standard method of removing the uncertainty in orbital parameters by fitting for the logarithmic dependence expected from bending.

Einstein's equations also predicted that travelling distortions of spacetime, energy-carrying gravitational waves, would exist. The waves are claimed to be ripples in the fabric of spacetime that travel at the speed of light. The incredible technology of the LIGO interferometers has now enabled the observation of gravitational effects radiating from merging black holes and neutron stars. Full relativity accepts that gravitational ''waves'' exist in terms of travelling changes in potential. However, these "waves" do not involve a distortion of space or carry energy. Instead, they alter the local oscillation frequency and speed of light (and so can be detected by laser interferometers) and alter the mass that can be stored by matter. The changes in clout reflect changes in the distribution of mass. The apparent oscillations of the "waves" reflects cyclic changes in the position of masses. The common textbook arguments that gravitational waves carry energy-momentum have been found wanting[1]. The observation of gravitational waves only establishes that propagating changes in the gravitational potential alter the apparent relative length of perpendicular interferometer light paths. Full relativity claims this to be an effect of changes in the wavelength (and speed) of light in proportion to the dimensionless quantity $G_N M / rc^2$ (not from changes in the length of the arms). The gravitational changes, propagating "waves" (of variations in gravitational clout) do not carry energy.

The initial evidence for energy-carrying gravitational waves came from changes in the orbital motion of binary pulsars (rapidly rotating neutron stars). Their changes in orbit over time appeared consistent with the expected rate of energy loss from energy-carrying gravitational radiation[2]. However, the observed energy loss has been calculated relative to that for a constant orbit, i.e. one with no change in energy. This reference orbital energy is based on a Newtonian orbital equation for a circular binary orbit of equal mass pulsars, and so is constant. It does not include the effects of apparent (retarded) positions due to the finite speed of gravity or the effect of changing momentum with orbital separation. These will alter the energy for a given orbit and the non-central forces will give accelerations which will change orbital parameters. The orbital period, the energy stored as mass, and rate of advance of the axis of closest approach (periastron) will be altered.

The direction and strength of the gravitational field must reflect the earlier position and relative velocity of the other pulsar. Under both general and full relativity, differences from constant orbital parameters arise because of the non-central forces in combination with non-circular symmetry due to ellipticity and unequal pulsar masses. Full relativity was able to predict the perihelion advance of Mercury by the change in inertial potential with distance from the Sun, and no change in distance scale. This matched the prediction based on general relativity's change in the time component of spacetime altering velocity but with a negligible effect from its change in distance scale. It appears, but needs critical examination, that the apparent rate of loss from energy-carrying gravitational "waves", relative to a Newtonian loss-free orbital energy, will match the actual rate of change in orbital energy and periastron advance expected from full relativity[3].

Apart from reproducing key predictions initially deduced from general relativity, full relativity solves other problems and unexpected observations, collectively referred to as the dark side. The first of these is the supposed singularities at the centre of black holes. These are predicted by general relativity when the density of matter becomes infinitely large as it is squeezed into what becomes an infinitely deep hole. The hole is surrounded by an event horizon which nothing can cross from the inside. In the past, such infinities have always been taken to mean that there is a mistake in the maths or the assumptions of the theory. General relativity has a positive feedback mechanism, akin to the screech when a microphone is put near a speaker that amplifies the sound picked up by the microphone. Its distortions of spacetime arise from energy but the distortions give rise to increased energy which further increases distortion which increases mass/energy density. Above a certain level, this feedback gives rise to an infinite density, a singularity. Half of the 2020 Nobel prize in physics was given to Sir Roger Penrose for the discovery that black hole formation (with a singularity at the centre) is a robust prediction of the general theory of relativity.

Under general relativity, there is negligible distortion of spacetime when the density of matter is tiny. As matter moves closer under gravity this same matter, of constant mass, gains kinetic energy. Thus, total energy increases with the density of matter and there is a need for an enormous pool of energy when space is empty of objects and there is no distortion.

Under full relativity, the pool of energy is held in the objects as mass, and there is a negative feedback, because the mass (stored energy) held by matter decreases as its density increases. So singularities are prevented. This also means that the time and emission frequencies of the sources (atoms) are markedly reduced near and within very massive objects (including black holes). However, their light and their gravitational flux, do not lose energy or reduce after emission. They are not prevented from escaping by a loss in energy and will travel at an increased speed nearer the black hole. There is no event horizon from a supposed gravitational redshift that traps light or causes time to stop. Nevertheless, at the densities of black holes, the emission frequencies of all electromagnetic transitions will be at much longer wavelengths and may not be visible. In addition, most such radiation should be trapped by bending, leaving an apparent "hole". If an uncrossable event horizon did exist for light, then general relativity's energy-carrying gravity-waves, which are known to travel at the speed of light, should also not be able to cross. No gravitational waves, carrying energy, or information about changes in the position or strength of the source, inside the event horizon, should then be detectable or observable from outside. In which case, a black hole should not be able to orbit another black hole or star, because its gravitational field should not be able to escape. Any acceleration of the location, or change in magnitude, of its distortion of spacetime within the supposed event horizon, should not be able to be sensed in a finite time.

Einstein realised that the feedback mechanism of general relativity meant that space must be either expanding or contracting. He therefore added a term to his equation, the so-called cosmological constant (Λ), that enabled a steady-state universe. After the Hubble redshift was observed in which the light of distant galaxies was steadily shifted redder with distance, he labelled the cosmological constant his biggest mistake. The redshift was initially taken to be a Doppler effect, meaning that the recession velocity of galaxies steadily increased with distance. Under general relativity, this redshift has been subtly re-interpreted as an expansion of the 'space' between galaxies, over time, which also stretches objects travelling through that space. Such an expanding space is claimed to increase the wavelength of photons, reducing their energy. This appears inconsistent because any expansion of the scale of space should apply to all space and all embedded particles whose wavelength reflects their energy, in which case no changes would be detectable.

Both the Doppler and general relativity interpretations of the redshift have an expanding and cooling universe that began in an enormous explosion, the 'big bang', when matter was all together some 13.7 billion years ago. Evidence for this stretching of wavelength is claimed to be seen in the cosmic microwave background. This is a very uniform long-wavelength radiation coming from all directions in the sky. It is the first light that could escape once the supposedly hot dense gas of the early universe had cooled sufficiently for neutral atoms to form. Subsequently it has purportedly been stretched so much that it appears to be that expected from a heat source at only 2.7 °C above absolute zero.

Full relativity has no expansion of 'space'. Instead, the redshift is a reduction in the energy of the emitting atoms as we look back earlier into the evolution of the universe. The earlier emitted photons have lower energy. They do not lose energy after emission and the speed of light will have been faster at emission in inverse proportion to the reduction in energy at emission. The Hubble redshift of distant galaxies does not necessitate that they are moving away or that space is expanding. It is just that their atoms held less energy at the time their light was emitted.

In 1998 two groups examining the relationship between the brightness of distant supernovae and the redshift of their host galaxy came to the conclusion that the rate of expansion had begun increasing over relatively recent times. The 2011 Nobel prize in physics was awarded for this discovery. Gravity had been expected to slow the expansion, so 'dark energy' was hypothesised to drive this 'accelerating expansion' of the universe. Such dark energy has the very unusual property of a negative pressure that opposes gravity more strongly as the density of matter, the number of galaxies per unit volume, decreases. The claim of an accelerating expansion relies on a calculated distance based on redshift that assumes a constant speed of light.

Under full relativity, the distance data has to be corrected for the cumulative increase in the speed of light, going back in time. Brightness should decrease as the inverse square of the actual distance and therefore the correction factor to the time taken for light to be received should be proportional to the integral of the received to emitted energy/momentum determined by the apparent change in wavelength. The light will have travelled further for any given Z by the integral of the change in speed. The distance travelled should be increased by the integral of $\lambda_{rec} / \lambda_{em} = 1 + Z$, which is $Z(1 + Z / 2)$ for any given Z. Thus the underlying time taken, based on the current speed of light, requires the brightness distance to be divided by $1 + Z / 2$ to get the travel time taken. The publicly available Union 2.1 data[4] can be plotted with and without correction as seen below (Figure 1). The raw data (blue squares) has light from distant supernovae taking longer than expected. The corrected data (green circles) removes any evidence for an accelerating expansion. The scatter appears to be that expected from the quoted measurement errors, with roughly two-thirds of the points lying within their error bars of the straight line fit. The claimed accelerating expansion is entirely removed by the expected change in emitted energy if the speed of light changes. It therefore removes any need at all for an expansion, and therefore for a big bang. The cosmic microwave radiation reflects how little energy per atom there was early in the history of the universe, not a hot explosion whose radiation has expanded and cooled.

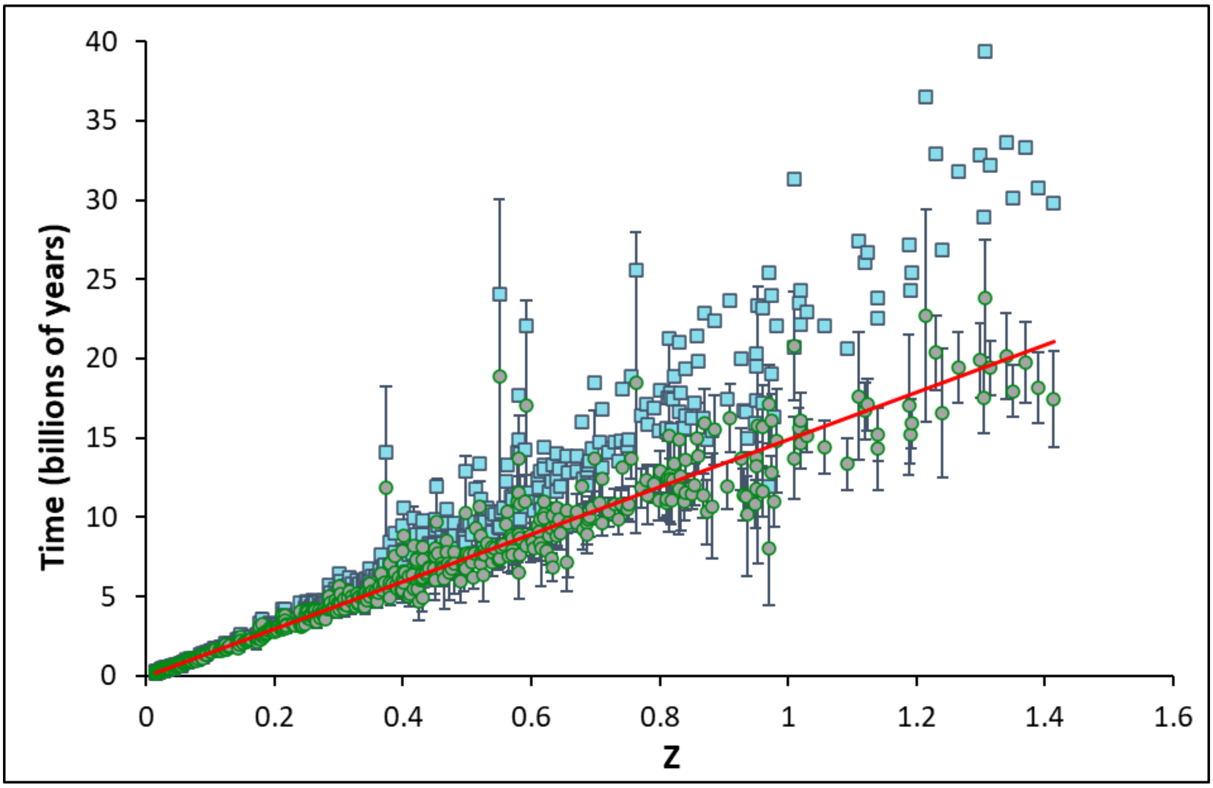

Fig. 1 Time since light emission against redshift for supernovae; before and after (green ○) correction.

The background from distant stored energy, and the speed of light, will decrease as the universe evolves, becoming increasingly clumped. However, general relativity assumes that gravitational potential, the field that gives rise to the curvature of spacetime, is a conserved flux. That is, the total flux through a sphere surrounding the sources of mass remains the same independent of their distribution. Einstein's gravitational equation assumes that increasing the amount of empty space has no effect on the total flux through a surface surrounding that matter. This assumes that the mass per unit matter is constant, independent of how close matter is to other matter. Under full relativity, it is not constant; it reduces as the same matter gets closer. This invalidates the use of Gauss's law in the derivation of the differential form of Newton's gravitational field equation used by Einstein.

As seen from Figure 1, the redshift is explained by a decrease in the stored energy per unit of matter going back in time. It is not due to a reduction in the density of matter from galaxies moving apart. Under general relativity, an increase in empty space, free of matter, will appear to act as a source of negative gravity. General relativity has the redshift of distant galaxies giving the rate at which the universe is expanding and the mass density reducing. The cosmological constant (Λ) was introduced to balance the assumed change in density (from a constant rate of Hubble expansion) to give a steady-state universe. The needed value of the cosmological constant must therefore appear to explain both the apparent steady and accelerating expansion whose source will appear to be the increase in empty space. If, instead, mass per unit matter increases over time, as the speed of light decreases with increased clumping, it will necessarily give the appearance of an invisible dark energy that pushes objects apart more strongly as density appears to decrease because of expansion. The need for dark energy is not only removed but why general relativity causes it to appear necessary is explained (Appendix C).

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

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

Finally, full relativity appears to be able to explain the evidence for halos of dark matter around galaxies[5]. It has inertial mass depending on the product of the energy held and its resistance to changes in velocity. This inertia is hypothesised to be in proportion to the asymmetry between the contributions to clout from matter and antimatter, because asymmetry determines the net change in opposing chiral components needed to achieve a given change in the current velocity of massive particles. Hence, inertia will change with distance from an excess of just one type of matter within a background of near-zero asymmetry. At large distances from a concentration of like matter, the decrease in inertia matches the decrease in centripetal acceleration needed to maintain circular orbits of the same speed. Hence, the orbital speed of the outer stars of an isolated galaxy, will tend to a constant value. This has been observed and was the initial reason for proposing a diffuse halo of dark matter in which the visible stars were embedded.

Inertia will increase towards the centre of a galaxy so the mass inside the central black-hole will be underestimated from the orbital speed of the inner stars. The mass of a star of a given temperature, based on the rate of reactions, may also be altered by inertia. These effects would alter the estimated amount of bending of light by galaxies. The effects on light-speed and of asymmetry on inertia might then explain the flat rotation curves of spiral galaxies, the motion and inertia of galaxies, relative to the currently accepted mass distribution, and gravitational lensing; all without the need for a halo of invisible dark matter, that neither emits nor absorbs light and only interacts gravitationally. Currently, no clear candidates for such dark matter have been observed and none is predicted within the Standard Model of particle physics. Careful analysis and improved understanding of the theory followed by modelling is needed.

Summary:

Full relativity appears able to remove all the dark features. These include black holes that must have a singularity at their centre and an uncrossable event horizon, plus the unexpected dark energy and dark matter. These were ad hoc hypotheses added to explain observations that were unexpected. Together, these unseen new "substances" supposedly made up 95% of the universe, but are shown to be artefacts of the current theory (general relativity). Full relativity removes the need for cosmic expansion, cosmic inflation and a big bang, and predicts the amount and appearance of an apparent dark energy as an artefact of assuming that mass per unit matter is constant. The flatness and horizon problems are also removed and a quantum gravity is not needed and should not be expected. Travelling changes in gravitational strength do not carry energy and are not distortions of spacetime but can be detected by interferometers because they change the speed of light.

SIXTH LESSON: Time flows and matter evolves

The original sixth lesson "Probability, Time and the Heat of Black Holes" looked at how thermodynamics, with its flow of heat always from hot to cold, tied in with the existing gravitational and quantum perspectives. These perspectives had led to some unexpected ideas about the nature and properties of time, such as the past, present and future existing simultaneously. The proposed new understanding has a time that reflects the different rates of progress of the same events seen, or at, different locations and times. The differences with location and time/era all arise from changes in the environment altering time (clock-rate), mass, energy and inertia. Time will steadily progress at the local rate determined by the components of the one underlying field. The new perspectives from the first five lessons can be brought together to give a coherent picture of the nature of the universe and how it evolves over time.

Rovelli put forward that: "*The difference between past and future only exists when there is heat. The fundamental phenomenon that distinguishes the future from the past is the fact that heat passes from things that are hotter to things that are colder. So, again, why, as time goes by, does heat pass from hot things to cold and not the other way round? The reason was discovered by Boltzmann, and is surprisingly simple: it is sheer chance. Boltzmann's idea is subtle, and brings into play the idea of probability. Heat does not move from hot things to cold things due to an absolute law: it only does so with a large degree of probability.*" He also put forward that: "*quantum mechanics predicts that the movement of every minute thing occurs by chance. This puts probability into play as well. But the probability which Boltzmann considered, the probability at the roots of heat, has a different nature, and is independent of quantum mechanics. The probability in play in the science of heat is in a certain sense tied to our ignorance."*

The new ideas on gravity, mass, and changes in time with changes in the background and of changes in the background over time lead to somewhat different perspectives on the relentless flow of heat and time. As explained in the new third lesson, the probability in play in quantum mechanics is not determined by chance. In a way it is related to our, or a particle's, 'ignorance'. Neither we, nor the particle or wave, can know the phase relationship until an interaction occurs. However, that ignorance does not mean that a relationship does not exist and does not have a definite value. Interactions provide both information about, and alter, the properties of the interacting state and its phase relationship to other states. Similarly, the probability that occurs in the science of heat should not be seen as based on '*sheer chance*'. When there is a range of values in energy and movement of components (e.g. atoms), but the stationary regions over which bulk properties are determined have zero relative momentum, then differences in the total energy in each region must move towards the mean. For an isolated object that has regions that have zero mean momentum relative to each other but different total kinetic energy, we can be entirely ignorant of the outcome of any interaction, but the value of energy (temperature) in each region must tend towards the mean with increasing number of interactions.

The flow of heat cannot be associated with a single interaction between a pair of atoms, because every such interaction conserves momentum about the centre of momentum. The flow is related to differences in properties with location. The property of heat and its flow depends on the magnitude and direction of all the momenta of the atoms (including the centre of momenta between any interacting pair). Those hitting a hot wall must, on average, gain momenta in the direction away from the wall and give up some on arriving at a cold wall. The heat will always flow from hot to cold.

For a simple gas of point-like particles, its temperature (heat), is a measure of a bulk property - the average kinetic energy of its atoms. However, for such ideal gases, there is a simple relationship between the equilibrium temperature and the pressure times the volume of the container per atom. This always seems amazing when first encountered, but it has a simple explanation. The energy of motion of the atoms is a measure of their momentum, which is related to the pressure that they will exert on the walls of the container. This pressure is determined by the average outward force per hit per atom per second, on the container walls.

This brings us back to the understanding that mass is trapped energy. It has long been understood that a container of gas is heavier (has more mass) than the same amount of unenclosed gas (even after allowing for the mass of the container). Confining the same momentum to a more limited location (a smaller container) requires a larger force. Confining an ideal gas at higher temperature (increased momentum), in the same container, also requires a larger force and so a higher pressure. Confining more energy within an elementary particle increases its mass.

Rovelli claimed that the movement of heat from hot to cold showed that: "*Probability does not refer to the evolution of matter in itself. It relates to the evolution of those specific quantities we interact with. Once again, the profoundly relational nature of the concepts we use to organize the world emerges.*" He argued that: "*special relativity has shown that the notion of the 'present' is also subjective. Physicists and philosophers have come to the conclusion that the idea of a present that is common to the whole universe is an illusion, and that the universal 'flow' of time is a generalization that doesn't work."* He quotes Einstein: "*People like us, who believe in physics, know that the distinction made between past, present and future is nothing more than a persistent, stubborn illusion*".

The result of any one interaction is exactly known within the limit that the particles are hard and point-like. The bulk properties come from averaging over all such interactions. It is difficult to see how the flow of heat with time can have any dependence on the relational nature of the concepts we choose or quantities we measure. It is not subjective. As explained in lessons one and five, special and general relativity's notion that time and space are malleable and subjective arose from several misunderstandings. It began with the faulty 'principle of relativity', under which the observed time depends on relative motion between observer and events, rather than on the motion of massive clocks relative to the background. Special relativity claims that clocks stationary at the events observed will, in the absence of gravity, all observe the same rate of passage of time independent of any absolute speed. Clocks at different locations, but stationary relative to each other, can all be synchronised by exchanging signals that travel at a constant speed of light. However, relatively moving observers will not agree on the simultaneity of events at different locations. This led to the claim that the time of separated events is not absolute, because time (measured clock-rate) appeared to depend on the relative movement between observer and observed. Under full relativity, this is not correct. Special relativity allowed a subjectivity of perceived space and time according to relative speed between the object and observer, in a way that kept the observed speed of light constant. Its space and time were flexible, but their combination as spacetime appeared to be an unchanging four-dimensional block, in which relative movement allowed the sequence of events to change. It seemed that past, present and future therefore must already exist but different slices of the block are seen because of relative motion. General relativity extended this subjectiveness, dependent on relative motion of the observer, to one dependent on relative gravitational potential of the observer, but not absolute potential. The new perspective is that the "*stubborn illusion*" is not an illusion but a consequence of an underlying reality that is free from the observer's position and motion relative to the events, but in which inertia and energy depend on, and are relative to, the background.

Full relativity has movement relative to the background field altering clock-rate but the underlying time is constant if there is no change in the clout of the field. The order and simultaneity of events may appear to change because of the finite transmission time of signals. However, if the arrival time of the signals is corrected for their travel time, and clock-rates are corrected for movement relative to the background, then a unique order of events under a single clock-rate (synchronicity) exists. It will be maintained to the extent to which the relative clock-rate at different locations and travel times are known and remain fixed. Thus, it will be maintained if the background is constant independent of location and time, i.e. if the total clout is constant.

However, if the background field changes in magnitude, then the speed of light, plus the energy and rate of clocks will change. If the asymmetry between the components of the field changes, then the inertia of a given energy will also change, so the speed of movement of massive objects will be altered. Thus, clocks can tick at different rates at different locations but a unique ordering of events exists if their timing is adjusted for light-speed and clock-rate. Neither "block time", in which past, present and future already exist, nor a flexible space (distance), is needed.

Besides their implications for time, the new perspectives provide a better, and hopefully coherent, picture of the underlying nature of reality. A key change is the strong indication that the background field, quanta, and particles are all aspects of just one background with dual chiral components. Each elementary particle state, including quanta, is proposed to correspond to a unique number and pattern of components. The one underlying field has at least two components which allow cyclic oscillations that can trap energy at a location (particles) or which can carry quantities of energy (quanta) to new locations. The trapped energy can then alter or give rise to a changed background at a given location. The background takes place in a three-dimensional space and has components which exhibit a wave nature. Hence, their magnitudes can add or subtract and vary in phase with time and location. They can also have a left or right handedness of rotation relative to the direction of changes in their magnitude. The inherent rate of change of the components of the field is equal to the local speed of light. The speed is constant if the background is constant but depends on the magnitude of the background. The components appear to be capable of resisting changes in each other. Thus, they can trap a force in a stationary or travelling cyclic pattern.

It is proposed that all four forces (strong, electromagnetic, weak and gravity) are unified under this one background. The division into separate forces, particles and quanta is arbitrary in that these are just the sum total of all possible patterns of wave states that can interact via other patterns of wave states. The underlying field supports waves, in the sense that a variation at a location causes neighbouring locations in all directions to try and cancel the change. The sensitivity to handedness means that a rotation in the pattern of changes can occur. The possible cancellations will also be altered if the magnitude and speed of changes varies with the handedness or with the direction of the changes. As a result, patterns of multiple components can give rise to a variety of 'states', including stationary or travelling (cycling-wave) patterns that resist changes in their location and store energy (mass), and travelling wave patterns that can carry energy to other locations (quanta – both massive and massless). There are obviously many details to be elaborated and quantified but this is the core of the proposed picture. It does seem consistent with the speed of light being related to the magnitude of the opposing chiral components when balanced, and with the degree of their asymmetry determining inertia.

Full relativity appears able to remove the evidence for new physics beyond the Standard Model. Firstly, as stated, it can remove the unexpected dark properties. Secondly, the revised picture of particles and fields appears able to remove two further pieces of evidence. These are the lack of antimatter, when equal quantities are predicted, and non-zero neutrino masses, when, under the Standard Model, they are predicted to be exactly zero. The absence of antimatter is deduced from the lack of any observed annihilation of matter and antimatter galaxies. Non-zero neutrino masses appear to be required because the three types of neutrinos oscillate between types, and such oscillations have always been associated with differences in mass. However, there does not currently appear to be a measure of the relationship between the frequency of neutrino oscillations of different types and the energy carried, analogous to those determined for the massless but easily visible photon. The energy of the neutrino is only ever determined from conservation of energy and momentum of visible particles (which are charged, or decay into charged particles). It is proposed that the three possible neutrino states arise from different numbers and orientations of wave components that, like photons, always travel at the maximum speed. The neutrinos are also 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. Hence, they could have different frequencies, and carry different amounts of energy, even though travelling at the speed of light (appearing massless). If so, they could transform into one another by gaining or losing energy by accelerating a massive particle, while conserving total energy and remaining massless.

Full relativity's explanation of galaxy rotation curves via inertia (see lesson 5) requires nearly equal backgrounds from matter and antimatter. The contributions are dominated by distant matter so that, except within a single galaxy cluster or isolated galaxy, the asymmetry should be small, as expected from the symmetry of matter and antimatter interactions in the Standard Model. The theory has the speed of light much faster and inertia and energy per unit frequency of matter and quanta much smaller early in the evolution of the universe. This would be expected to have led to rapid annihilation of any matter with antimatter for which the components of velocity towards each other were fast enough to allow them to escape the weaker gravitational attraction of their region of like-matter. It is proposed that the apparent dearth of antimatter is because most of the matter in opposite regions annihilated until they became separated into regions of gravitationally bound like-matter. The mass of the matter within each region increased as the speed of light slowed and the clumping of like matter increased over time, as the universe evolved. Clumping of distant matter at a constant mean distance reduces its contribution to the background clout while increasing the speed of light within that clump by a lesser amount (because only one component of clout is involved). Clumping that involves mean movement towards similar matter increases inertia by increasing fractional asymmetry. Any matter near a boundary between matter and antimatter will have lower inertia and so will move faster than expected and more quickly be captured or annihilated. Separate regions would have formed and contracted as mass and inertia increased, which would seem to maintain a separation once it reached a certain level[1]. It may also provide an explanation for the presence of voids in the distribution of galaxies. When separation is complete, the presence of antimatter regions will no longer be revealed by annihilation. This hypothesis needs to be modelled and tested.

The way full relativity can be applied to cosmological dynamics and the evolution of structure is similar to that followed for general relativity. Einstein's equation built in the finite propagation time of gravity, using a constant speed of light/gravity, via a metric of distorted time and distance. Mass and the ratio of inertial to gravitational mass were assumed constant. Predictions then required starting conditions, in terms of an initial distribution of mass, energy and momentum. The time evolution could then be investigated.

So, what is the equation that replaces Einstein's. The best answer that I can give is the equation of motion based on Newton's laws, with adjustments. This (initially) is an instantaneous energy-balance equation in which the fractional change in energy depends on the gradient of the local total potential. It is accurate within our solar system for circular orbits and moderate speeds. For objects that significantly change their distance from a major source of gravitational attraction, e.g. in elliptical orbits around the Sun, a correction is needed for the increase in mass and reduction in inertia as distance to the source increases. Force per unit mass is unchanged and momentum is conserved, but inertia varies. The correction matches what is done already in the low speed and weak field limits of Einstein's equation. It is sufficient for accurate current predictions within regions of similar asymmetry to our solar system and for the current epoch.

The equation can be extended by incorporating the local values of the speed of light and asymmetry at a new location or different epoch, relative to those at our current location and time, by adjusting the value of G_N / c^2 according to the expected values of c and inertia. This should be sufficient to describe behaviour in our 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: i) for the finite propagation speed of gravity, which will lead to effects such as apparent non-central forces; ii) for Doppler shifting of forces due to relative motion; and iii) for increases in inertia with chiral asymmetry and speed of movement relative to the background.

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. The time evolution could then be examined by computer simulation on progressively finer grids.

Summary:

The distinction between past, present and future is reality; not a stubborn illusion. It is spacetime with a flexible distance that is an illusion. Relative movement allows the apparent sequence of events to change (because fields cannot be transmitted instantaneously) and different background potentials alter clock-rate. However, interactions are causal. The probability in play in quantum mechanics does not mean that a relationship does not exist and have a definite value. Interactions are causal and definite. The seeming dependence on chance reflects our ignorance because the needed phase information cannot be obtained without changing the values. Time, clock-rate, mass/energy and inertia can be different in different places and eras, and will steadily progress at the local rate determined by the presence, distance and movement of all other mass. Full relativity appears not only to make sense of gravity and quantum mechanics but to remove all evidence for new physics beyond the Standard Model.

IN CLOSING: Making sense of reality

The original "In Closing" (the seventh lesson) was about "Ourselves". Rovelli claimed that we are limited by our ignorance, the limitations of our senses, and of our intelligence. Therefore, the images that we construct, such as the nature of space and time, are not necessarily reality. In particular, our deductions of Euclidean space and even of Newtonian mechanics are "*in obvious error*". He claimed an "*astonishing world which we explore – where space is granular, time does not exist and things are nowhere*". The perspectives presented in the new lessons, argue that the claimed nature of his astonishing world, with its subjective, granular space that can expand without objects moving, is not reality. Space is Euclidean, time exists, and all things have the extended nature of waves.

A key point to emphasise is that spacetime as a background in which space and time are malleable but in a way that keeps the speed of light constant is demonstrably flawed; it is not just a matter of opinion. The arguments, logic and mathematics that gave rise to special and generality relativity have numerous errors. There is no evidence that the scale of distance between objects not in relative motion, or at different potentials, is flexible; although changes in clock-rate occur. How can empty "space" be malleable? Appendix D goes through the errors that demand a new picture.

Under the new picture, an invisible background medium, a field, that allows forces, including electric, magnetic and gravitational forces, to act at a distance across a vacuum, is essential. The field arises from the energy stored in both matter and antimatter giving opposing (chiral) components that are sensitive, like left and right-handed screws, to the direction of rotation. This complex field enables the diverse array of forces and particles that make up what we are and all we observe. It is proposed that massive particles, which carry a constant quantity of angular momentum when moving at constant velocity in a constant background, are oscillating standing-wave states that trap momentum around a mean location. They will resist changes in the speed of movement of their centroid, but travel at a constant velocity once the oscillations are balanced for the velocity of travel. Massless exchange particles (e.g. photons) have components whose mean location travels at the maximum speed allowed by the background. These are driven by oscillating components perpendicular to the direction of travel which maintain a constant total energy and momentum. Particles can only interact and change state (wave pattern) or properties in discrete amounts (quanta) that conserve total energy and momentum. The frequency of oscillation depends on the energy carried and local asymmetry of the background field. The number, orientation and phases of the particle's chiral components determine the trapped momentum. Changes in angular momentum are resisted in proportion to the oscillation frequency. Gravitational mass reflects the magnitude of the trapped angular momentum, while inertial mass is the product of gravitational mass and inertial resistance. These proposals need further development.

Gravity is simple. When you lift an object, you have to do work to increase its stored energy. This seems to be because, when the speed of light is slower, the opposing wave components, from which all matter is made, take longer to cancel changes from other directions. The strength of the gravitational force arises from the gradient in the total field with location. This alters the speed of light and the energy that can be stored by the same matter. The gravitational force per unit mass is constant (for a given total background and, hence, speed of light) but will appear to vary with location if the background asymmetry, and therefore inertia, changes.

Gravity is not a fictitious force. Space, the distance between objects, is not granular or distortable by the location or movement of the observer. Time exists, but the local rate at which events occur, the speed of light, the energy held by matter and its resistance to acceleration, all depend on the background. This background has changed over time as matter has clumped, increasing inertia and reducing the speed of light. This avoids the need for a big bang, a hot dense initial universe, an expanding universe, dark energy, dark matter, singularities in black holes, and a space (and the wavelengths of its radiations) that can expand without its matter contents moving.

My hope is that you, like me, will find the new understandings incredibly beautiful, exciting and empowering. The underlying simplicity and coherence of the new picture should also give us confidence that what exists makes sense. It can be understood. Nevertheless, we all need to be sceptical, and this includes being sceptical and constructively critical of the new perspectives presented here. Some details are bound to be wrong or only half-right and with that recognition will come a better understanding. Kindly for us, it appears that the nature of reality is straightforward.

Guidance from these lessons towards discovering and understanding the nature of reality include:

- Words, pictures, hypotheses and mathematics can easily hide beliefs and assumptions.
- The idea that distance, the space between objects, is subjective and malleable is nonsense.
- Our world has underlying rules such as conservation of energy and momentum.
  - Hence, you never get something from nothing.
- Unexpected properties, paradoxes and inconsistencies should always ring alarm bells.
  - Infinities in real physical properties indicate a mistake has been made.
- A background field must exist and it allows more complex wave behaviour than realised.
  - Everything (particles, quanta and the background) exhibits wave properties.
- Observations alter the object being observed (if looked at in fine detail).
  - However, things still happen when no-one is looking.
- Waves are not static or at a single location, the fields are continuous.
  - Hence, space is not granular and a continuous time can exist.
- Apparent consistency with observations does not confirm correctness.

Scepticism is always desirable. The new perspectives suggest the problems, assumptions and derivations of special and general relativity might have been examined with more scepticism. It seems that there were early bursts of criticism but this was outweighed by the apparent successes of the predictions. Quantum mechanics appears to have had a more difficult path to acceptance but, again, its remarkable successes appear to have stifled a deeper examination of the nature of measurement and why all particles have wave properties related to their energy. Some awareness of problems with relativity and its inconsistency with quantum mechanics existed for nearly one hundred years. A deeper investigation of the inconsistency might have avoided the effort that went into merging them in string theory or loop quantum gravity. Rovelli explained the latter as follows: "*The idea is simple. General relativity has taught us that space is not an inert box, but rather something that is dynamic: a kind of immense mobile, snail-shell in which we are contained – one which can be compressed and twisted. Quantum mechanics, on the other hand, has taught us that every field of this kind is 'made of quanta' and has a fine, granular structure. It immediately follows that physical space is 'also made of quanta'."* The new picture claims that none of this is reality. Questioning of assumptions behind inconsistencies, might have also reduced the time spent on supersymmetry, entanglement and wave function collapse, black-hole singularities, dark matter, dark energy, and cosmic inflation.

It seems that we have great difficulty in rejecting, or at least critically evaluating, ideas that we have been taught. These beliefs can be strongly reinforced by our peers or circle of acquaintances and by repetition, as well as by consistency with our existing beliefs. Understandably, we find it simpler, easier and quicker, and often safer, to trust "authority". I find it sobering that, in 1864, fifty years before general relativity, James Clerk Maxwell expressed a concern with Newton's gravitational field. To paraphrase him: "If gravitation arises from the action of the surrounding medium, then every part of this medium must possess an enormous intrinsic energy that is diminished by the presence of dense bodies. I am unable to understand in what way a medium can possess such properties". He reasoned that the kinetic energy gained by objects as they moved closer under gravity, increasing the density of matter, must come from the medium. Subsequently, Einstein realised, under special relativity, that the mass of a body is a measure of its energy content and is not a constant. Now, more than one hundred years later, we have not long put two and two together. It is the bodies, not the medium, that carry the store of energy.

Enormous progress has been made in elementary particle physics, astronomy and cosmology over the last century. However, full relativity contends that faulty derivations and deductions, based on misunderstandings and overly-generous assumptions, have allowed special and general relativity to survive over that same period. To my mind, a subjective reality based on the behaviour or location of the observer is unacceptable. However, I'm also humbled by the fact that I used concepts and calculations based on quantum mechanics and relativity in my doctoral studies. I struggled to comprehend why they worked but did not find time to critically examine them. My hope is that this short document, and your efforts, will ensure that a new paradigm wins through. Hopefully, more quickly than that implied by Max Planck in reviewing his own career: "a new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die, and a new generation grows up that is familiar with it"[1].

My perspective is that the history of science has been a meandering journey towards an understanding that we as humans do not have an exalted status in the universe and there is no reason to believe in the supernatural. Einstein fought long and hard against the idea that reality was somehow random and not definite or causal. He believed that instantaneous action-at-a-distance was untenable. However, it became widely believed that he was mistaken. On the other hand, he proposed a relativity that, on careful analysis, put the observer in a privileged position, making the reality of space and time subjective. This view, a relative reality, however, became widely accepted.

It should be clear that I believe that he was right about the first and mistaken about the second. Ultimately, however, the scientific method requires that the arguments, the assumptions and derivations, and their consequences must be critically evaluated. The predictions must then be put to the fire of experimental examination, then revised, rejected, or temporarily accepted.

My position is that the demonstrable mistakes made in special relativity that led to the faulty concept of spacetime eliminate general relativity as a possible correct theory of gravity. The agreement with observations, plus the removal of singularities, of the supposed flatness and horizon problems, and of the need for the ad hoc hypotheses of dark energy, dark matter and inflation, provide strong support for the new theory. My challenge to fellow physicists is to either show fatal flaws in full relativity or to design and carry out an experiment that distinguishes between it and their preferred theory.

There are clear differences in predictions, and explanations, that allow both logical assessment and experimental or observational tests that distinguish between the new and old theories, and more will be found. For example, the dependence of inertia on position within our and other galaxies should be related to the expansion rates of the matter in supernovae explosions. The rate of expansion should reflect the inertia seen in the rotation curve for that galaxy location. The dependence of inertia on asymmetry should also provide an explanation for the observed relationships in rotational behaviour and brightness across a huge range of galaxies, as noted by the supporters of Modified Newtonian Dynamics (MOND)[2]. The new instruments, such as the James Webb telescope, may be able to observe evidence for the contraction in the size of galaxies that should have occured over time.

A yes/no difference between the theories of gravity is in the apparent versus real distortion of distance. This can be tested by examining the location and direct timing signals (using on-board clocks) and returned (reflected) signals to Earth from spacecraft with increasing distance from the Sun. A re-examination of the data from the Pioneer spacecraft under the new theory may help. However, journeys of new spacecraft for which the effects of non-gravitational forces, such as heat radiation, have been removed are probably needed. The predicted changes in time, at the spacecraft, and speed appear to be the same, but, if the distance is based on the timing of signals, then they will need to be adjusted for changes in the speed of light and the location and movement of the clocks. Such an experiment should also be able to investigate the local rate at which time is changing and compare it with the current average for the universe seen in the supernovae data.

Perhaps the most straightforward test is to establish whether it is movement relative to the observer or movement of the observer relative to the background that slows time. It should be possible to compare very low mass but accurate clocks with communication antennae moving linearly towards each other and to a central clock (or spaced pair of clocks) at a very high, but constant, velocity and compare all clock-rates after allowing for movement during the transmission time of signals. This probably has to be done in space, i.e. at high vacuum with room for acceleration, and at a nearly constant gravitational potential. It would probably be beneficial to have all clocks maintaining the same distance from the Sun, which implies a continuous source of thrust.

Many cosmological details also need more work and further consequences need to be examined. These include the implications for galaxy evolution and dynamics, and why spiral arms form and persist; the separation of matter and antimatter; and explanations for the baryon/photon ratio and features of the cosmic microwave background. The proposal that matter/antimatter asymmetry is the source of inertia also needs further investigation. The values of Newton's and Planck's constants should be related to the value of asymmetry at our location in our galaxy and galaxy cluster.

To me, the profound change in outlook presented in this booklet is a global paradigm shift in the sense proposed by Thomas Kuhn in 'The structure of scientific revolutions'. It should jolt us out of a period of normal science (in theoretical physics), throwing new light on ourselves and reality. It not only solves many problems but also raises exciting new questions and directions. These include investigations in cosmology, quantum mechanics and particle physics. In particular, the underlying symmetries that give the gauge invariances of the Standard Model beg for a unified explanation, based on full relativity. Key components of this explanation are put forward in Lesson 4 and Appendix B.

Full relativity explains that the weakness of gravity is because its source is a scalar background potential, with gravitational attraction arising from a fractional change in stored energy/momentum. Therefore, contributions from a uniform, stationary background add, rather than cancel as occurs in general relativity. Moreover, it necessarily leads to a variable mass/energy for matter via a variable speed of light linked to time but with a fixed scale of distance. Gravity comes from a broken gauge invariance which was initially negligible but which has steadily increased over time as inertia and mass per unit matter increased. Quantum electrodynamics has a vector potential in which contributions from opposite directions cancel (a gauge invariance) with parity conserved and a massless exchange particle. It is independent of a uniform background of electric and magnetic fields. The weak interaction is linked to QED via a cancellation that is independent of charge but has a dependence on chirality that gives rise to mass. The strongly interacting quarks interact via gluons that, I suggest, have pairs of orthogonal chiral components. They also interact via electromagnetic and weak exchange particles but these contributions are much smaller. The energy/momentum stored by all these interactions (mass), that gives rise to gravitational interactions, is dependent on the speed of light, which changes with the background potential. The $1/R$ dependence of this potential implies opposing components of opposite chirality.

All these behaviours provide clues towards an explanation of the Standard Model. The key conclusion (see Lesson 4 and Appendix B) is that the gauge invariance underlying the Standard Model arises from strict and continuous conservation of energy and momentum, which confines the wave function by preventing diffusion.

Further suggestions include that the photon should be seen as the so-called ‘missing’ ninth gluon that has no strong interactions because it has net zero chirality but is made up of colour and anti-colour pairs (gluons). It would seem to behave like a triplet of perpendicular gluons. This provides a link between the electroweak and strong forces. The photon cycles between two superpositions of wave components that appear to act like separated charges and aligned rotating charges, that are always matched in energy-momentum. Mass provides a link between the massive bosons of the weak force and gravity, but the background field that gives rise to mass by trapping momentum and energy (via chiral components) must be involved in every massive particle. Heavy quark states can change (flavour) to lighter quark states being able to interact via the weak force. The likelihood that different forces result from symmetries in the particles that arise from the one underlying field then leads on to the speculation that the three “colours” of quarks and gluons just reflect the three orthogonal directions of a three-dimensional (Euclidean) space. Gluons are then combinations of aligned or orthogonal pairs of components of opposite chirality (colour and anti-colour), while quarks are lepton-like states that are missing (or have an excess of) one or two gluon components and so have colour/chirality. They can only maintain an existence by a continual exchange of gluons and their angular momentum between groups of quarks. The amount of angular momentum that can be exchanged reduces as separation reduces, which may then explain the asymptotic freedom of quarks. The plus two-thirds and minus one-third electric charges of the quarks then reflect the removal of available orthogonal directions of the interactions of quarks (missing one or two gluons) which otherwise would be states with charge of ± 1 or 0. The three families of quarks/leptons might then be associated with different numbers (1 to 4 pairs $\pm$ 1 singlet) of components that can give standing-waves in three dimensions. (The wave function components of matched spin ½ might cancel in one orthogonal direction, as seen in the Pauli principle for leptons. Two components could exist in an aligned configuration, while 3 components could exist in a planar configuration with a $\pi/3$ phase difference, and 4 components could exist in a tetrahedral configuration.) These are put forward as suggestions or speculations that might be built on, or trigger someone else to come up with a better picture, for the properties seen in the Standard Model. The ultimate hope is that it will enable the prediction of all the masses and other parameters of a unified theory, including the rates of oscillations between neutrino types.

In finishing, I hope that you have enjoyed the journey. There are good reasons to be optimistic. There is every indication that we have made, and will continue to make, enormous strides in measuring, observing and comprehending our universe and its evolution from the smallest to largest scales of time and distance. Excitingly, its reality, although unfamiliar, appears to make sense. It shows every sign of being comprehensible by such insignificant denizens.

NOTES & REFERENCES

Lesson 1

1. Einstein, A. 1905. *Annalen Der Physik. 17*, 891. On the electrodynamics of moving bodies. DOI: 10.1002/andp.200590006

2. Minkowski, H. 1909. *"Raum und Zeit"*, Physikalische Zeitschrift *10*, 104-111. Translation in V. Petkov (ed.), H. Minkowski, Space and Time: Minkowski's Papers on Relativity, (Minkowski Institute Press, Montreal 2012).

3. The distinction is made between the three fields (electric, magnetic and gravitational) that enable action-at-a-distance across a vacuum (no detectable matter) and electromagnetic radiation. The fields allow energy to be stored at a stationary location in charged and massive objects and the effects of electric charge, magnets and gravity to be conveyed across seemingly empty space. However, these fields do not necessarily carry charge, mass or energy, whereas electromagnetic radiation carries energy in a travelling oscillation between electric and magnetic fields.

4. The gravitational signal and light (gamma-rays) from a distant binary neutron star merger arrived at nearly the same time. B. P. Abbott *et al* 2017 *ApJL* 848 L13. DOI 10.3847/2041-8213/aa920c

5. Einstein A. 1920 Ether and the Theory of Relativity, an address on 5 May 1920 at the University of Leiden, published 1922 in *Sidelights on Relativity*, Methuen, London, pp. 3-24.

6. As set out by Pais, A. 1982. *'Subtle is the Lord …' The Science and the Life of Albert Einstein*, Oxford Uni. Press, p.141, Einstein subsequently acknowledged the influence of the Michelson-Morley results.

7. It is known that time slows for unstable elementary particles travelling at high speed, they decay more slowly. It is also more difficult to change their direction, making their mass appear to increase in proportion to $\gamma = 1/\sqrt{(1-v^2/c^2)}$. Just because it is difficult to detect slow and smooth acceleration of your, or the other person's, train does not mean there is no effect. Constant velocity is maintained in the absence of a force, but this does not mean that acceleration does not become more difficult when your speed approaches a significant fraction of the speed of light.

8. It is necessary to be very careful with the use of both language and mathematical symbols. Slower time (t) will be taken to mean that identical clocks tick more slowly, having larger intervals (dt) between ticks. A larger distance ($dx = x_2 - x_1$) between locations 1 and 2, not in relative motion (i.e. at fixed spacing), means they are further apart, but any such distance should remain unchanged and be independent of who is observing. However, the same event e.g. the same massive object observed to go from location 1 to location 2, will appear to take less time (fewer ticks) if your clock is running slower. Slower time then means that, although the same light ray will take the same underlying time for two observers, it will appear to take less time for the observer with slower ticking clocks. Relative motion between observer and objects will alter the arrival time of signals, but if the arrival time is corrected for the finite propagation speed of signals, the underlying time and underlying distance will be the same.

9. We utilise the concept of an underlying reality when we watch fireworks from a distance, or see a flash of lightning, and count the number of seconds between the light and the arrival of the sound. It depends on the distance the sound has to travel. A bat can track moving objects using reflected sound and avoid stationary objects. If we or a bat were to fly at high-speed relative to the speed of sound we would not expect that the spacing between buildings changes, even if it appears so. The apparent effect disappears if we correct for the changes in the return signal time because of our movement.

10. One Hundred Authors Against Einstein: (English Translation) 2021 of the 1931 collection of "anti-relativity" essays, originally published in German under the title "Hundert Autoren Gegen Einstein" by Hans Israel, Erich Ruckhaber, Rudolf Weinmann.

11. The "G. O. Mueller Research Project", apparently compiled by Friebe, E. and circulated in 2006, "95 Years of Criticism of the Special Theory of Relativity (1908-2003)", documents 3789 publications critical of the theory. http://www.ivorcatt.co.uk/friebe1.pdf . See also: H. C. Ohanian 2008. Einstein's Mistakes, the Human Failings of Genius,W. W. Norton & Co., New York.

12. This has been established to remarkable accuracy for different materials by the null results of Eötvös experiments using a torsion balance with weights of different substances hung at opposite ends of a rod. The direction of the inertial acceleration relative to the gravitational acceleration will change as the Earth rotates. The absence of a torque indicates that gravitational and inertial mass have a fixed ratio when measured at the same location.

13. For example: Broekaert J. 2008 *Foundations of Physics*, 38:409–435, A Spatially-VSL Gravity Model with 1-PN Limit of GRT, and Unzicker, A., Preuss J 2015, arXiv:1503.06763v2 [physics.gen-ph] A Machian Version of Einstein's Variable Speed of Light Theory. However, these theories mimic general relativity by including an effective contraction of distance to match the change in time from the change in c .

Lesson 2

1. Einstein A. 1905 *Annalen Der Physik*. *18*, 639-641. Does the inertia of a body depend on its energy content? DOI: 10.1002/andp.19053231314

2. Einstein, A. 1921. The meaning of relativity, four lectures delivered at Princeton University May 1921, Princeton University Press, NJ.

3. There is no reason to be concerned with the c^2 in the denominator because $\Delta\Phi$ is the gravitational potential energy per unit mass, so the expression amounts to $\Delta\Phi / \Phi$.

4. See, for example, Will, C.M. 1993, *Theory and experiment in gravitational physics*, revised edition, p. 173, Cambridge University Press.

5. A better model of the nature of a photon seems to be needed (see Appendix B) in terms of how changes in c affect both energy and momentum.

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

7. Okun, L.B., Selivanov, K.G. and Telegdi, V.L. 2000. On the interpretation of the redshift in a static gravitational field. *American Journal of Physics*, *68*(2), pp.115-119.

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

Lesson 3

1. Full relativity and what is known about waves give clues as to why particles, as single wave packets, do not diffuse away in all directions or break-up into smaller lumps during interactions where incoming and outgoing particles maintain their identity (see Appendix B).

2. 'Entangled states' or 'quantum entanglement' refers to correlations between the properties of pairs of particles originally formed from the one parent state that remain even when the particles are separated by a large distance. Bell established the existence of inequalities between the predictions

of a local hidden variables theory and quantum theory. Subsequent experimental tests have shown that Bell's inequalities can be violated and therefore cannot be reproduced by a local hidden variables theory, if Bell's "proof" is correct. Quantum formalism predicts correlations between properties measured in different directions but claims that the correlations are statistical only. Bell's argument was that local hidden variable theories necessitated definite pre-determined values but the value was hidden. This is a misunderstanding. It is possible for a rotation (an angular momentum) to have components that rotate about a particular direction and always give the same result in a measurement procedure aligned with that direction. For spinors (spin ½), for which pairs from the same interaction must rotate in planes around vectors that point in opposite directions, each spinor can still have components whose magnitudes oscillate along (as well as perpendicular to) the direction of the vector. A measurement that seeks to determine the angular momentum vector away from its existing direction will additionally depend on the phase in the plane perpendicular to the momentum vector. Thus, aligned detectors will always give opposite results. However, when viewed using detectors aligned at an angle, the direction will appear to be statistically determined according to the probability corresponding to the fractional overlap of the possible and actual hemispheres. Photons (spin 1) have pairs of spinors and give analogous results. The correlation does not require instantaneous (faster-than-light) communication or collapse of the wave function, or that local realism be violated. Bell, J.S. 1987, *Speakable and unspeakable in quantum mechanics*, Cambridge University Press.

Lesson 4

1. A good overview of the nature and history of the problems with infinities and the development of quantum field theory can be found in: Close, F. 2011. *The Infinity Puzzle: quantum field and the hunt for an orderly universe*, Basic Books, New York.

2. The Aharonov–Bohm effect confirms that forces are an incomplete way to formulate physics, and potential energies must be used instead. Aharonov Y, Bohm D. 1959 Significance of electromagnetic potentials in quantum theory. *Phys. Rev.* **115**(3), 485-491. Overstreet C, Asenbaum P, Curti J, Kim M, Kasevich MA. 2022 Observation of a gravitational Aharonov-Bohm effect. *Science* **375**, 226–229.

3. I can't see any alternative explanation to the $1/R$ dependence of electric, magnetic and gravitational potentials. All the other influences that we encounter seem to reduce as $1/R^2$, or faster, with distance from their source in accordance with the rate of increase in the surface area through which the influence is propagating with distance. This weaker dependence on distance is truly remarkable. Charge and/or objects must move for the field(s) to change, and the changes propagate from the moving objects at the speed of light. In addition, the electric and gravitational fields appear to remain constant in the absence of movement.

4. A recommended introduction to the zoo of elementary particles and the characters who found them and put together the current understanding is: Veltman, M.J.G. 2003, *Facts and mysteries in elementary particle physics*, World Scientific Publishing, Singapore. Martinus (or "Tini" to his friends) loved life and was honest and direct, but never malicious, in his criticism. To my knowledge he is the only example of a supervisor who has shared a physics Nobel Prize with his student.

5. Jackson, J.D. and Okun, L.B. 2001. Historical roots of gauge invariance. *Rev. Mod. Phys. 73*, 663-680. Electric charge comes in fixed amounts independent of the amount or direction of other charge. The electric force is proportional to the gradient of the scalar electric field potential. This means that a constant value can be added to the scalar potential (at a given location) without affecting the force. This, and the constancy of charge, amount to an underlying symmetry. Equal electric fields from opposite directions exactly cancel. An observer inside a conducting metal sphere will not sense whether the sphere is charged to a million volts or not, because the contributions cancel. Only

differences in the electric field (voltage) have an effect, not the absolute level. Magnetic fields come from movement of fixed quantities of charge and are proportional to the vector magnetic field potential. This means that the gradient (with distance) of a scalar function ($\nabla\chi$) can be added to the vector potential without affecting the magnetic force. Gauge invariance amounts to a relation between the time-varying constant ($\partial\chi / c\partial t$) added to the electric potential and the gradient of the scalar function. This relation is $\nabla\chi - \partial\chi / c\partial t$. This is consistent with a 4-vector potential $\partial_{\mu}A^{\mu} = 0$. It was found that the wave function of quantum mechanics must then have its phase altered according to $\psi' \to \psi \exp(ie\chi / \hbar c)$. The invariance under an additional symmetry related to space/time and energy/momentum is a cornerstone of the Standard Model. All three forces have such a gauge invariance, an additional underlying symmetry, where aspects (parity, charge, time) of the interactions of particles and fields are conserved.

6. The predicted probability of observed results in quantum mechanics is not the square of the wave function but the product of the wave function and its complex conjugate. This would seem to be consistent with a background that involves balanced components of opposite chirality.

Lesson 5

1. Duerr, P.M. 2019. It ain't necessarily so: Gravitational waves and energy transport. *Studies in History and Philosophy of Science Part B: Studies in History and Philosophy of Modern Physics*, *65*, 25-40. Duerr critically examined four textbook arguments commonly taken to establish that gravitational waves (GWs) carry energy-momentum and found them wanting. He also proposed that, under general relativity, energy is not necessarily carried away by GWs.

2. Taylor, J.H. and Weisberg, J.M. 1989. Further experimental tests of relativistic gravity using the binary pulsar PSR 1913+16. *The Astrophysical Journal 345*, 434-450. General relativity's predicted loss of energy, via GWs, arises from Einstein's equation and the geodesic equation of motion in the limit of weak fields. The rate of change of energy is based on the change of the quadrupole moment in the linearized (i.e. weak field limit).

3. Cheng, T.P. 2009. *Relativity, gravitation and cosmology: a basic introduction*. Oxford University Press, 2nd ed., pp.337-355. A detailed calculation of the energy loss is set out. General relativity has the energy carried away by a gravitational wave proportional to the square of the time-derivative of the wave amplitude, which is the second derivative of the quadrupole moment. The formula for the rate of energy loss is then $dE / dt = (128G_N / 5c^5)\omega_b^2 M^2 R^4$ for a rotating binary system of two equal masses (M) in a circular orbit, of radius R, with angular frequency ω_b . The orbital energy as a function of orbital period is determined from the Newtonian equation of motion, and the rate of change of the period can be inserted using the quadrupole derived energy loss. Corrections can then be made for unequal masses and orbital eccentricity of the binary pulsars. This is consistent with the formulae used by Taylor and Weisberg to determine the energy loss of the Hulse-Taylor binary pulsar.

For a binary system a finite propagation speed of gravity when there is high-speed motion alters the apparent strength, direction and distance of gravitational influences. The above calculation of the rate of energy loss is based on an oscillating energy-carrying distortion of spacetime due to propagating changes in the gravitational potential. The distortion of spacetime incorporates the finite speed of light/gravity via a distortion of distance with time that keeps c constant. These distortions of space and time are assumed to propagate outward in all directions as waves whose amplitude is proportional to the variation in potential seen from that direction. The energy loss is the integral over all directions of the flux of distortions that arises from the quadrupole moment of the rotation of sources of constant mass. The calculated flux is altered by variations in the arrival time of the distortions from each source. Thus, general relativity takes into account the retarded positions and relative velocity of the sources to calculate the rate of change of orbit. Mass is assumed constant so a reduction in the orbital radius and period demands a decrease in gravitational potential and an increase in kinetic energy. The loss of energy is determined by comparison with a fixed circular orbit based on a Newtonian equation of motion with infinite c . It is proposed (but has not been demonstrated) that full relativity should give the same predictions as general relativity if relativistic effects, such as retarded potentials, due to the finite speed of gravity are taken into account. This will mean that the calculated orbital energy for circular orbits with no relativistic corrections will be increasingly overestimated as radial separation decreases and the direction of the retarded potential increases. The orbits and inertial masses of the pulsars will be altered as the non-central forces attempt to convert kinetic energy into gravitational potential energy (with total energy and momentum conserved and, under full relativity, no energy carried away by gravitational waves). Binary systems of millisecond pulsars are very sensitive test beds of multiple relativistic effects (Kramer, M., et al. 2021. Strong-Field Gravity Tests with the Double Pulsar, *Phys. Rev. X* **11**, 041050). Millisecond pulsars are rotating so fast that spin/orbit coupling due to Doppler shifting could alter the rotation frequency of the pulsars over time. It might also be possible to detect the effect of variations in potential within orbit by averaging rotation frequency relative to the periastron, and so as a function of pulsar separation, over many orbits. It is important that their ability to distinguish between general and full relativity be carefully examined.

4. Suzuki N. et al., 2012. *Astrophys. J.* 746, 85.

5. The rotation speed of stars in the disk portions of spiral galaxies is observed to be in poor agreement with that expected from Newtonian gravitation and the observed mass distribution, based on assumptions for the luminance to mass ratio of matter in the cores of galaxies. The rotation curves do not decrease as the inverse square root of distance but are nearly constant outside of the central bulge. Under general relativity, this discrepancy is thought to betray the presence of an unseen halo of dark matter. This extensive halo of invisible matter provides additional gravitational attraction. Diffuse dark matter haloes have also been put forward to explain the observed gravitational lensing of distant galaxies and galaxy clusters, and the evidence for dark matter is considered by some to be compelling, e.g. Garrett K. and Dūda, G., 2011. Dark matter: A primer. *Advances in Astronomy*. Others maintain that there is a crisis, e.g. Kroupa, P. 2012. *Pub. Astron. Soc. Australia* 29, 395. The proposed dark matter can neither absorb nor emit electromagnetic radiation and cannot be attributed to neutrinos. Despite extensive searches no candidates for this non-baryonic dark matter have yet been observed and none is predicted within the Standard Model of particle physics. Similarly, there is no persuasive theoretical explanation for the existence or magnitude of dark energy. Albrecht, A. et al., 2006. Report of the dark energy task force, arXiv preprint astro-ph/0609591. The existing theory, based on general relativity, that has best explained cosmological observations is the ΛCDM model which incorporates a non-zero value of the cosmological constant (Λ) and cold dark matter (CDM) and seems to be in agreement with detailed observations of the cosmic microwave background (Famaey, B. and McGaugh, S. 2013. *J. Phys: Conf. Ser*. 437, 012001). However, it is also claimed that there is poor agreement between ΛCDM and observations of galaxies and dwarf galaxies and that an explanation of the Tully-Fisher relation is needed (Famaey, B. and McGaugh, S. S. 2012. *Living Rev. Relativity* 15, 10).

Lesson 6

1. A study of peculiar velocities of galaxies has suggested that a map of galaxy distribution and movement shows regions where peculiar velocity flows diverge, as water does at watershed divides.

Tully, R., Courtois, H., Hoffman, Y. *et al.* The Laniakea supercluster of galaxies. *Nature* **513**, 71–73 (2014). https://doi.org/10.1038/nature13674

Lesson 7

1. Planck, M. K. 1950. Scientific Autobiography and Other Papers. New York: Philosophical library.

2. McGaugh, S.S., Lelli, F. and Schombert, J.M. 2016. Radial acceleration relation in rotationally supported galaxies. *Physical Review Letters*, *117*(20), p.201101.

APPENDIX A: Transforming between moving frames

Einstein's paper "On the electrodynamics of moving bodies" [A1] 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". So 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 a second postulate – that the speed of light was constant. 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. This transformation left Maxwell's equations of electrodynamics unchanged. The transformation turned out to be the same as that already put forward by Lorentz, with subsequent corrections from Poincaré, describing observed behaviour. This included the motion of electrons, which 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.

There is much evidence supporting the slowing of time, and an increase in inertia with speed, and the Lorentz invariance of electromagnetism. However, most of this experimental evidence is not being challenged. Full Relativity (FR) maintains the validity of the behaviour captured by the Lorentz transformation (LT) but challenges the interpretation, under Special Relativity (SR), that it establishes the validity of the hypotheses used, and that the scale of space and shape of rigid objects can be distorted. The key conclusions, such as time dilation, that nothing can travel faster than the speed of light, and the relationship $E = mc^2$, 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 malleable fabric of spacetime, are all rejected.

The LT relates the time and distances of the same events, or of sequences of events, seen by observers in relative motion. 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 [A1]. 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, <u>within</u> that frame, synchronised. The moving frame (x', y', z', t') was allowed to have different scales of distance and time, as a function of relative speed, from those in the stationary frame.

The first problem is that, a priori, such a method cannot yield the time of a moving clock without the clock being examined. 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 moving clocks, if stationary relative to their observer, would show the same time. 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. This assumption demands that clock-rate is the same in all inertial frames, and was <u>inserted</u> in Einstein's claimed derivation of the LT. Subsequent derivations have mostly used the 'principle of relativity'- that all observers moving at constant velocity perceive the same results, including the same fixed speed of light – to obtain the LT.

Einstein 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” [A2]. This version of the principle of relativity claimed to be 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” [A3]. An observer in a closed space, for example in a windowless train carriage smoothly travelling at constant speed, appears to be unable to tell they are moving. The principle requires physical laws for any object moving at constant velocity to be the same as for the object at rest. Thus, the postulate became that an observer in an inertial frame cannot determine an absolute speed or direction of travel in space, and may only speak of relative velocity.

However, it is a remarkable leap of faith to assume that there are no changes in any properties if the train is moving at close to light-speed relative to the background of stars and galaxies. FR agrees that, for example, 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 much less than 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” [A1]. 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 measurer. The observational requirement is, and was, that the (underlying) speed of light is independent of the speed of the emitter. However, his analysis demanded that $c = x/t = x'/t'$ for light in both frames. The constancy of the measured speed was built into the derivation. This is faulty. If clocks are ticking slower in the moving frame, then the distance is unchanged, but the apparent distance and measured speed are increased.

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. Keeping the measured speed of light constant for observers whose clocks are slowed requires distances to be reduced. Under FR, time dilation arises because the clocks of objects and observers (which both have mass) are slowed by motion relative to the background from all other massive objects. 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 SR’s spacetime, the distance between objects not in relative motion, is reduced by the slowing of time with movement of the observer. The same distance travelled takes less time; fewer ticks of a slower clock.

The invariance of Maxwell’s equations under the LT is because massless electric and magnetic fields travel at speed c and their interactions depend only on relative speed of the sources. The effect of speed, seen on charged and uncharged massive particles, comes from increased inertia. This arises because massive particles are sensitive to movement relative to the nearly stationary background.

Einstein 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. His derivation arrived at the LT, which for constant speed in the x-direction is:

$$x' = \gamma(x - vt),\ y' = y,\ z' = z,\ t' = \gamma(t - vx/c^2), \text{ where } \gamma = 1/\sqrt{1 - v^2/c^2}.$$

It supposedly relates the coordinates of the same events seen by a moving and stationary observer. However, his derivation and interpretation of the LT has a number of problems.

Einstein 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 $(t_0' + t_2')/2 = t_1'$ must hold. This equation was used to deduce a relationship between the time of the moving frame and the time 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 stationary frame. The average distance to their positions is larger than the distance at the time of reflection because of movement during signal transmission. Thus the relationship incorporated the change in simultaneity due to finite travel time of light (between locations in the other frame) into the supposed time of the moving frame.

Einstein also included a function $\phi(v)$ that allowed the scales of time and distance to differ between the two frames, and it was present in the equations of the initially derived transformation:

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

These equations are those of the LT except for the function $\phi(v)$. His analysis then examined a third frame (K'') which, relative to the origin of system k, was moving in the opposite direction (with velocity $-v$) and found that a two-fold application (v followed by $-v$) of the transformation gave:

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

The doubly-transformed position coordinates had no time dependence. This was taken to mean the two-fold transformation gave a return to the original (stationary) frame and, therefore, to its clock-rate. Thus, Einstein concluded that $\phi(v) = \phi(-v) = 1$ for all coordinates, and arrived at the equations of the LT. 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 dependence, but the frames are not at rest relative to each other. 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 if the unit of time (rate of ticking) is independent of absolute movement of the clock. If time is found to be slowed in the moving frame, then time must be increased in returning. However, the alternative proposed by Einstein was that observed clock-rate was increasingly slowed by relative speed of movement of the observer independent of direction. He then used the slowing of time to argue that a rigid spherical body must be foreshortened in just the direction of motion. The result was a contraction of distance that kept the speed of light constant. Time and shape/size had become subjective dependent on the relative movement of the observer. A side-effect is that the time and spacing claimed to be seen by every observer for another relatively moving frame, is non-linear. The clock-rate is $t' = t/\gamma$ (where $\gamma = 1/\sqrt{1 - v^2/c^2}$). Thus, a third observer midway between two oppositely moving clocks is required to see a smaller total slowing than the observers at each clock, due to the non-linearity of γ !

A first interpretation of the LT can be based on Einstein's intention that the transformation maps the same locations with time relative to 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 within each array is constant (all clocks within a frame are synchronous) but the rate differs between the two frames, depending on velocity. A comparison of matched locations in the two frames, using the LT, requires $x = \Delta x = vt$ for the change in location of points (which were matched at $t = 0$) with time. Thus, if $x = vt$, then $t' = \gamma(t - vx/c^2) = t/\gamma$ and $x' = \gamma x_0$ apply, where x_0 was the distance of any point from the origin (in the stationary frame) at $t = t' = 0$. Using x for both the separation between matched locations in the LT expression for time, and for a location relative to the origin in the expression for position (x'), is not allowed. The inverse transformation for matched locations requires $\phi(-v) = 1/\phi(v)$. Hence, for v positive, $\phi(v) = 1$, so that, if $x' = \gamma(x - vt)$ and $t' = t/\gamma$, then the inverse transformation has $x = (x' + vt')/\gamma$ and $t = \gamma t'$, which indicates that this interpretation of the LT requires a real slowing of time in the moving frame.

A second interpretation of the LT has the vx/c^2 term (in t') correcting the arrival time (in the stationary frame) of signals received from the moving system. These will be advanced or delayed by the movement (x) 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 at $t = 0$, for the origin. If $v > 0$ for an approaching source, the arrival time decreases when $t < 0$ and increases when $t > 0$. The position expression $x' = \gamma(x - vt)$ applies to the separation $\Delta x' = \gamma \Delta x$, in the second frame when using time $t' = t/\gamma$, of the separation $\Delta x = x - vt$ of the same (i.e. matched) locations in the two frames. However, if the altered arrival time of the signal has been correctly removed, then $t' = \gamma t$ and $x' = \gamma x_0$. This requires a changing scale of distance that matches the change in the scale of time. The same light ray must move γ times as far as in the stationary frame if the clock-rate of the moving frame is γ that of the stationary frame. It could only apply if $\gamma = 1$.

Einstein's interpretation of the LT claimed that a spherical object, stationary in the moving frame, would be "seen", by an observer at rest in the stationary frame, as foreshortened in the direction of motion, because its x- dimension must reduce by the factor $1/\gamma$ for both observers (stationary in their own frames) to see a sphere (if $x' = \gamma x$). This is just a cancellation of the effect of a slowed clock-rate by imposing a reduced distance scale in order to keep the "observed" speed of light constant. It has used the correction needed for delays/advances in signal arrival time due to different distances travelled during transmission to alter the distance scale.

Einstein sought to prove that any ray of light, measured in the moving system, has the velocity c, that it has in the stationary systems. This would establish that: "the principle of the constancy of the velocity of light is compatible with the principle of relativity". The conclusion appeared to be 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 claimed that this meant 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, because: i) a slower clock in the moving frame means that the same light ray will appear to travel further; ii) the delays/advances in signal propagation times due to the relative movement of the frames become increasingly different for locations that were matched at time zero; and iii) the time for the same light ray, emitted from the initially overlapping origins, to arrive at locations away from the origin also changes by different amounts between moving frames. Once the timing is fully corrected, then spherical radiation occurs relative to an origin moving away at $\Delta x = -vt$. Under Einstein's proposed interpretation the equation of spherical motion also appears to hold in the moving frame because the squared result can be achieved by $c = \pm x/t = \pm x'/t'$ giving $x^2 - c^2t^2 = 0 = x'^2 - c^2t'^2$ and it is assumed that $y^2 + z^2 = y'^2 + z'^2$. The slowed time in the moving frame has been cancelled by a contraction of space when it actually means that the same light ray travels further.

The corrected interpretation means 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. The delays or advances in signal arrival time must first be applied to obtain the correct position of the source (at emission) after allowing for its movement during signal transmission. This position is based on the "known" (i.e. inserted) velocity of the source relative to the observer. The radiation will then be spherical but the centre of the sphere will be moving along the x'-axis at speed $x'/t' = -\gamma v$. If the corrections are not applied and radiation is assumed to obey $x'^2 + y'^2 + z'^2 = c^2 t'^2$ about the origin of the moving frame, then the unobserved scales of distance and time are distorted by matched amounts (i.e. by $x' = \gamma^2 (x/\gamma) = \gamma x$) because of the imposed restriction of $c = x'/t' = x/t$.

In failing to make the timing corrections, the faulty interpretation uses the timing correction factor vx/c^2 in determining time (t') that applies to signal transmission distances of x. However, it then uses the separation $x - vt$ of the two origins with time, in determining distance (x'). This separation distance ($x - vt$) only stays the same as the signal transmission distance (x) for the origins of the two coordinate frames. The inconsistency yields imagined (unobserved), distorted, distance and time coordinates for the frame moving away from the stationary source of spherical emission. Under these distorted coordinates, the distance and time for light to propagate both reduce, making the signal arrival times consistent with an imagined spherical set of locations with the same speed of light.

The LT only applies for $\Delta x = vt$, so that $x' = \gamma(x - vt)$, $y' = y$, $z' = z$, $t' = t/\gamma$. Allowing $\Delta x = vx/c^2$ to apply to locations other than the origin leads to a distorted distance and time. This is the mistake behind the claimed visual distortion and rotation of an object, passing at close to the speed of light, known as the Terrell effect. It is an imagined effect that does not occur.

Einstein's faulty conclusion that the principle of relativity held, and only relative speed mattered, led to the perception that space, the scale of distance between objects, and the scale of time were both flexible (observer dependent). Only their combination in terms of a fixed light-speed had a real existence. However, the position coordinates ("space") represent the fixed separations between the positions of the same events seen by observers in relatively moving coordinate frames. The scale of time 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 and time could contract in unison because the observer was moving.

If the rate of passage of time in the moving frame ($t' = t/\gamma$) is 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 $x' = \gamma x$. 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 their time is proceeding at different rates. Matched locations have their distance scale inverted relative to their time scale.

The change in timing of $t' = t/\gamma$ will give rise to an apparent $x' = \gamma x$ increase in distance travelled (i.e. apparent velocity). However, if timing signals emitted by the moving clock are available, or the distance to the clock at the time of emission is known, then the one-way and/or return signal advances or delays can be removed. It will then be found that the moving clock is slowed relative to the stationary clock by $t' = t/\gamma$, if the LT is to be correct.

Einstein arrived at $x' = \gamma x$ and $t' = t/\gamma$. However, 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 is (appears) shorter (FitzGerald contraction) in the stationary frame. On the other hand, he took the time of a clock in the moving system as "nothing else than the summary of the data of clocks at rest in the system" [A1]. This is the time (t') at rest in the moving system. He then concludes that $t' < t$ so that clocks are ticking slower in the moving frame. However, this leaves out the inversion used in interpreting lengths, which should have $t = \gamma t'$ as the size (amount) of time that "moving time" t' has in the stationary frame. In which case, more time should appear to pass on moving clocks when viewed from the stationary frame. This inversion of time relative to distance means the factors of γ now cancel and each observer ostensibly sees the others clocks slowed and distance contracted.

To understand what has happened we need to consider some subtleties in what we mean by time. Time is the rate at which events involving movement occur. If the time interval (dt) between ticks of a clock decreases, we say that the clock is ticking faster. If two clocks measure the same events and the timing is corrected for any delays in the signals reaching the clock, then the duration of the events should be found to be the same, if the clocks are ticking at the same rate. The concept of spacetime involves intervals, and such intervals are now normally represented by $dx^2 + dy^2 + dz^2 - c^2 dt^2$, and under a LT they are claimed to transform into $dx'^2 + dy'^2 + dz'^2 - c^2 dt'^2$. However, if the interval between ticks (dt') is smaller, then time (t'), measured by a clock, is proceeding faster. Consistency with the observed slowing of time, means $t' = t / \gamma$ must be replaced with $dt' = \gamma dt$ if referring to intervals. The distance interval that light travelling at the same speed will <u>appear</u> to travel is $dx' = \gamma dx$ and $c = dx / dt = dx' / dt'$.

If the time intervals in the moving frame were smaller (by $1/\gamma$), than the intervals in the stationary frame, then its clocks would be ticking faster. The inversion between the treatment of time and distance (and time and distance intervals) has allowed the misunderstanding that the measured speed of light is constant. However, it is the underlying speed that is constant with the slowed time of a moving frame giving an apparent increase in distance travelled by the same light ray.

The clocks in the moving frame tick more slowly causing light to appear, and be measured, to travel further per tick. 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, does not exist. The invariant interval of flat Minkowski spacetime, within a region in which the underlying c is constant, will only be found if distance intervals are apparent and inverted relative to time intervals. Einstein's matched changes in time and distance kept measured c unchanged. The invariant interval, $ds^2 = dx^2 + dy^2 + dz^2 - c^2 dt^2$, simply reflects Pythagoras and the underlying $c =$ distance/time. This relationship allows a 4-vector covariance for space and time and for energy and momentum. However, space remains undistorted while distance travelled by light will vary with the speed of light.

The deduction of the Lorentz transformation was fortuitous. Consistency with the LT and observations requires that motion, relative to that observed in a stationary background from all other mass, 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. These are: the underlying speed of light is independent of the velocity of the emitting object, and time is slowed by movement relative to the balanced background.

Strong evidence, that the underlying speed of light is independent of the speed of the emitting object, is seen in the light emitted from binary stars. If the light emitted by a star moving away travelled more slowly then, by the time it reached us, it could be overtaken by light emitted later in its orbit when it was moving towards us. The observed arrival time depends on distance travelled independent of the star's velocity. However, there is still a Doppler shift in received wavelength whose amount depends on the relative velocity between source and receiver. A constant underlying speed is also consistent with the inability of the interferometer experiments of Michelson and Morley to see shifts in the arrival time of light because of motion relative to the background.

The factor of γ in time dilation ($t' = t / \gamma$) must arise from the effect of high-speed motion of massive objects relative to the background from all other massive objects. It was initially deduced from observations of the motion of charged particles (electrons and helium nuclei) in electric and magnetic fields. Any current derivation, not based on a physical model, arises from a fortuitous relationship between apparent and real effects. However, the dependence of γ, the inverse of the product of $\sqrt{(c+v)/c}$ and $\sqrt{(c-v)/c}$, appears consistent with the proposal for a model in Lesson 4. The inhibition of changes in the magnitude of the opposing chiral components, that gives rise to a potential that only reduces as $1/R$, results from both components only changing by the square root of the amount expected.

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 claimed to be contracted (and their rate of decay slowed) as a function of the relative speeds of any number of observers. Only the combination of matched reductions in distance and time, giving a constant measured speed of light, is supposed to occur. However, the opposite changes in time to that in distance, a dilation (slowing) of time matched by increased apparent distance travelled, is needed. If the observer is moving at high-speed relative to unstable elementary particles that are stationary relative to the background, then they should be found to decay faster, not slower. However, the experimental tests have only 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 observer's clock. Space, the distance between objects, cannot be altered by motion of the observer.

FR, in replacing SR, has 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 that the idea of motion cannot be attributed to the background (as Einstein claimed [A4]). A simplified LT applies and there is no requirement for c to be constant.

References (Appendix A)

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APPENDIX B: Interpreting and visualising wave functions

Full relativity proposes that what we perceive as particles and radiation (photons) are states that arise from confined oscillations of the background field. Under quantum mechanics, as Weinberg pointed out: "Born found that when a particle strikes a target like an atom or atomic nucleus the wave function radiates out in all directions, with a magnitude decreasing as $1/r$, where r is the distance to the target (…) This seemed to contradict the common experience that though a particle striking a target may indeed be scattered in any direction, it does not break up and go in all directions" [B1]. This led to Born's proposal that the wave function (ψ) gave a probability of the location of a particle at position x at time t proportional to $|\psi(x,t)|^2$. However, an alternative understanding is based on a revised interpretation of the wave function. It is proposed that it arises from a multi-component underlying field that can trap energy at a stationary or travelling mean location. Full relativity proposes that gravitational attraction comes from a gradient in this field because the speed of light is proportional to the magnitude of the field. The trapped force from the strong and electroweak interactions reduces as the speed of light increases.

In lesson 4 it is argued that the trapping of energy is because there are left and right-handed (chiral) components to the background, which has opposing chiral components. The opposing components explain why the potential decreases as $1/r$ with distance from a source of stored energy (mass).

If states can store energy, it means there is a mechanism that prevents the fluctuations of the wave function from freely spreading out in all directions. We are familiar with plane and spherical surface waves in water and in air (sound) where the restoring force (necessary for an oscillation) is in the line opposite to the increase in amplitude or density. However, if a change in magnitude or direction necessarily causes restoring forces in other directions (while keeping the total energy/momentum constant) then a spatially confined state can arise, if the propagation speed of changes is finite. Such states will appear like a wave packet that does not diffuse away in all directions.

Wave states, both particles and radiation, necessarily involve a restoring component. These enable wave functions which have components that are cycling in the three spatial dimensions with time but whose total energy/momentum (including angular momentum) is unchanged. Based on full relativity with its background of opposing chiral rotations, it is proposed that the total energy/momentum is strictly and continuously conserved before, during and after an interaction. Matrix mechanics and Schrödinger's time-dependent wave equation express the step change of one unit in angular momentum in interactions of a photon with a spin ½ charged particle. The presence of real and imaginary components of the formulation of matrix and wave mechanics can be seen as a way of incorporating directionally varying contributions of continuous rotations. The flipping of the direction of spin (to the opposite direction) reflects the conservation of angular momentum independent of the original spin direction. The presence of the Hermitian conjugate in the probability interpretation of the wave function can be seen as resulting from the chirality of opposing components.

Weinberg pushed against the probability interpretation of the wave function in stating: "The right way to combine relativity and quantum mechanics is through the quantum theory of fields, in which the Dirac wave function appears as the matrix element of a quantum field between a one-particle state and the vacuum, and not a probability amplitude" [B2]. However, it is potentially misleading to see the field as being quantised. It is the difference between standing-wave states that is quantised. The total momentum (trapped and free) is always conserved but the continuous time evolution of the restoring components is hidden by having the relativistic field theory, i.e. the Standard Model (SM) of particle physics, couched in terms of the fields (particle or vacuum) being "lumpy" (quantum).

Ohanian has argued that a concrete physical picture of the half-integral spin of an electron (or other particle state) exists. "On the basis of an old argument by Belinfante [Physica **6**, 887 (1939)] it can be shown that spin [is] a circulating flow of energy in the wave field of the electron" [B3]. "Likewise, the magnetic moment [is] generated by a circulating flow of charge in the wave field." Spin is not: "a mysterious internal angular momentum for which no concrete physical picture is available".

It is proposed that particles and radiation quanta arise from oscillations of different numbers, directions and phases of matched and/or opposite chiral and non-chiral components. An initial eigenstate (set of components giving a standing-wave state) cannot split into another set of separated components unless momentum is continuously conserved. However, we cannot be aware of the instantaneous phase relations without altering them. The probability interpretation simply reflects the lack of knowledge. There is an underlying continuous, causal, behaviour that cannot be known without measurement and any measurement alters the state.

Measurement of a confined particle state can reveal a possible instantaneous configuration allowed by conservation of energy/momentum. However, a new superposition of the same particle (but pointing or travelling in a changed direction) does not automatically include all possible relative phases of the wave function components. The phase relationships that give rise to a particular orientation must be preserved. Any given state prepared in a particular orientation (a qubit) is not, and does not include, a superposition of all possible states of the same particle.

The Standard Model considers that elementary particles (e.g. electrons/positrons) are point-like but able to interact with the virtual particles of their surrounding field. They have a "bare mass" but the interaction with their own field gives rise to increased mass. This interaction has the problem that its value will become infinite if the particle is truly point-like. This led to the introduction of a procedure called renormalisation where a second infinity, from a related interaction, cancelled the first allowing calculation of finite values. The Standard Model also introduced a surrounding "vacuum" field, of zero spin, associated with the Higgs boson, that gave mass to all particles in proportion to the strength of their interactions with the Higgs field. However, full relativity has any wave function that traps energy via opposing directions of angular momentum giving rise to mass.

The Standard Model is based on a set of gauge invariances based on continuous functions. In QED the gauge invariance is associated with a null 4-vector electromagnetic potential $\partial_\mu A^\mu = 0$. This requires the results of QED to be independent of the phase of the wave function. Such an invariance under a symmetry applicable to each of the three forces related to space/time and energy/momentum is a cornerstone of the Standard Model. All three forces have such a gauge invariance, an additional underlying symmetry, where aspects (independence of charge, parity, handedness x time) of the spatial and temporal interactions of particles and fields are conserved.

Gravity, the fourth force, does not involve the exchange of a "particle" nor is it a distortion of spacetime and not a real force. What full relativity establishes is that a revised 4-vector formulation of space/time and energy/momentum is still possible, but a distortion of distance (space) is not required. Instead, the speed of light varies, and with it the stored energy/momentum. All forces involve gradients in energy; in potential energy with respect to rate of change of position, or in movement energy (momentum) with respect to time x c. A higher rate of change with distance or time x c corresponds to larger trapped momentum (increased mass). It is proposed that the key underlying requirement is that energy and momentum are <u>continuously</u> conserved. The conservation of the 4-vector interval, independent of the phase of its components, provides the underlying gauge invariance that unifies all forces.

The interaction of massless fields is insensitive to movement relative to the background but the wave function of massive particles will not be invariant to a Lorentz transformation (and its correct inverse) that does not take into account movement relative to the background (see Appendices A and D).

Elementary particles are not point-like but an interaction is at the overlap of the centroids. A photon of higher energy has a shorter wavelength and so any interaction is more precisely located at the centroid but it does not mean that an electron has no extent. Ohanian has pointed out that the spin ½ of fermions can be seen as a circulating flow of energy and that the magnetic moment can be seen as a circulating flow of charge. It is therefore desirable to come up with physical pictures of such flows (in terms of wave function components), firstly for both electrons and photons, but then for all elementary particles.

An initial proposal is that a photon consists of matched sets of three orthogonal components of opposite chirality with one component of each set aligned in the direction of motion but π out-of-phase so that their centroid travels at the speed of light. The components orthogonal to the direction of motion rotate in the same direction with the superposition of their oscillations about zero leading to a wave function that appears to alternate between an electric and magnetic field. It is sensitive to a gradient in an electric field and its phase can be changed by a magnetic field. The electron and positron are similar sets of orthogonal but now opposed components of matched chirality. However, it needs to be appreciated that the division into three orthogonal components is for each point in space and their directions can change with position. This can be seen in Ohanian's analysis of a spin ½ wave function (in terms of continuous electric and magnetic fields) having a circulating flow of energy. The superposition of counter-rotating and oscillating positive and negative components gives rise to: i) a stationary centroid, ii) pairs of components (or flows) rotating at $\pi/4$ to the axis of angular momentum, and iii) the trapping of a fixed quantity of opposing angular momentum giving either a source or sink of matched energy (i.e. a positive or negative charge state).

Because the moving photon has components of both chirality it can cancel one component of an electron or positron in one direction and replace it with an identical component in another direction (flipping the direction of spin) while continuously conserving energy and momentum.

These suggestions and their implications need much further work.

References (Appendix B)

[B1]. Weinberg, S. (2012) 'HISTORICAL INTRODUCTION', in *Lectures on Quantum Mechanics*. Cambridge: Cambridge University Press, pp. 1–28.

[B2]. Weinberg, S. (2012) 'PREFACE', in *Lectures on Quantum Mechanics*. Cambridge: Cambridge University Press, pp. xv–xvii.

[B3]. Ohanian, Hans C. (1986-06-01). "What is spin?". *American Journal of Physics*. **54** (6): 500–505.

APPENDIX C: Why general relativity causes an apparent dark energy

The differential form of Newton's equation, on which Einstein's field equation of general relativity (GR) is based, assumes that the flux of the field of gravitational acceleration (the force per unit mass) through the surface enclosing a fixed amount of matter is constant (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 consequence, under general relativity, is that increasing the amount of empty space free of matter will give rise to an apparent source of repulsive gravitation.

Newtonian gravity has a field of gravitational acceleration that is proportional to the gradient of a potential. The differential form of Newton's field equation ($\nabla^2\Phi = 4\pi G_N \rho$) has the second derivative (the Laplacian) of this gravitational potential (Φ) directly proportional to mass density (ρ). GR generalises this formulation so that the second derivative of the metric (the fabric of spacetime) is directly proportional to the energy/momentum tensor (the generalisation of 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 [C1]. 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 2nd law to give an equation of motion. This yields a vector gravitational acceleration field (force per unit mass $\vec{F} / m$) due to a point mass M of:

$$\vec{g}(\vec{r}) = -G_N M\hat{r} / r^2 \qquad \text{where } \hat{r} \text{ is the unit radial vector.} \qquad (1)$$

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

$$\oint_S \vec{g} \cdot d\vec{A} = -4\pi G_N M \qquad (2)$$

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 clout from surrounding matter, then this assumption does not hold. Gauss's law does NOT hold for the potential field that gives gravitational acceleration.

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:

$$\int \vec{\nabla} \cdot \vec{g} dV = -4\pi G_N \int \rho dV \qquad (3)$$

If this equality holds for any volume, the integrands on both sides must also be equal. Hence:

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

$$\nabla^2\Phi = 4\pi G_N \rho \qquad \text{given } \vec{g} = -\nabla\Phi \qquad (5)$$

However, the equation does not hold because the density of surrounding mass alters the mass held by a constant amount of matter, and this will alter the magnitude of the flux.

The divergence of a vector field ($\vec{\nabla}.\vec{g}$ here) 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 corresponds to a flux entering a region, a sink rather than a source but it is still proportional to the size of 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 equations 4 & 5 should be zero (except within any sources of mass). The implication, of the non-zero value is that a reduction in mass density from increasing the volume of empty space in which constant component sources reside, reduces the magnitude of the sink. Thus, increasing the empty space between 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 the volume outside the visible source of mass. This background of empty space appears to alter the strength of the gravitational field by an amount that depends on the enclosed mass density.

Reference (Appendix C)

[C1]. Cheng, T.P. 2009. *Relativity, gravitation and cosmology: a basic introduction*. Oxford University Press, 2^{nd} ed. P.62.

APPENDIX D: Throwing away spacetime and its curvature

The deduction of a spacetime that links space and time via a constant speed of light is wrong. The arguments, logic and mathematics that gave rise to it are all faulty. Special and generality relativity are therefore both in error and necessarily lead to inconsistencies, although appearing to give agreement with many observations. We go through the key errors to allow a better appreciation of why it is not just a matter of opinion.

Einstein derived what became known as special relativity in his 1905 paper "On the electrodynamics of moving bodies". This paper introduced a derivation of the Lorentz transformation (LT) between the position and timing of the same events seen using coordinate systems (frames) in relative motion. This LT had already been derived from an analysis of experimental observations of the behaviour of charged particles moving at high speed. The LT, for constant speed in the x-direction is:

$$x' = \gamma(x - vt),\ y' = y,\ z' = z,\ t' = \gamma(t - vx/c^2) \text{, where } \gamma = 1/\sqrt{1 - v^2/c^2}.$$

It relates the coordinates of the same object seen by a moving and stationary observer. The term vx/c^2 in the time in the moving frame is essential to correct for the advance/delay in the arrival time of signals when there is relative movement, in order to maintain any synchronicity. It only holds for matched events if $x = vt$, in which case $t' = t/\gamma$, and a light ray in the moving frame will appear to travel γ times the distance when using a clock that ticks more slowly by $1/\gamma$.

As set out in Appendix A, Einstein's derivation, based on a thought experiment, is flawed. The first problem was the method used. The positions with time of events in the moving were related back to the stationary observer using the time of the stationary observer. This was based on the conjecture (the principle of relativity) that the laws of physics (electrodynamics, optics, and mechanics) were independent of motion at constant speed. Thus the method assumed that all moving clocks, if stationary relative to their observer, would "show" the same time. The method inserted this as fact.

Einstein claimed that the measured speed of light is independent of movement of the measurer. The observational requirement is, and was, that the (underlying) speed of light is independent of the speed of the emitter. However, his derivation inserted that $c = x/t = x'/t'$ for light in both frames. The constancy of the measured speed was built into the derivation. This is faulty. If clocks are ticking slower in the moving frame, then the distance is unchanged, but the apparent distance and measured speed are increased.

In his derivation, Einstein 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 $(t'_0 + t'_2)/2 = t'_1$ must hold. This equation was used to deduce a relationship between the time of the moving frame and the time 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 stationary frame. The average distance to their positions is larger than the distance at the time of reflection because of movement during signal transmission. Thus the relationship incorporated the change in simultaneity due to finite travel time of light (with position in the other frame) into the supposed time of the moving frame.

Einstein also included a function $\phi(v)$ that allowed the scales of time and distance to differ between the two frames, and it was present in the equations of the initially derived transformation, based on the faulty equation for average distance:

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

These equations are those of the LT except for the function $\phi(v)$. His analysis then examined a third frame (K'') which, relative to the origin of system k, was moving in the opposite direction (with velocity $-v$) and found that a two-fold application (v followed by $-v$) of the LT gave:

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

The doubly-transformed position coordinates had no time dependence. This was taken to mean the two-fold transformation gave a return to the original (stationary) frame and, therefore, to its clock-rate. Thus, Einstein concluded that $\phi(v) = \phi(-v) = 1$ for all coordinates, and arrived at the equations of the LT. 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 (but are in opposite directions).

A comparison of matched locations in the two frames, using the LT, requires $x = \Delta x = vt$ for the <u>change</u> in location of points (which were matched at $t = 0$) with time. This corrects for the advance/delay in transmission time between matched locations. Thus, $t' = \gamma(t - v^2 t / c^2) = t / \gamma$ and $x' = \gamma x_0$ apply, where x_0 was the distance of any point from the origin (in the stationary frame) at $t = t' = 0$. Using x for both the separation between matched locations in the LT expression for time, and for a location relative to the origin in the expression for position (x'), is not allowed. The inverse transformation for matched locations requires $\phi(-v) = 1 / \phi(v)$. Hence, for v positive, $\phi(v) = 1$, so that $x' = \gamma x_0$ and $t' = t / \gamma$, and the inverse transformation has $x = x_0' / \gamma$ and $t = \gamma t'$. If there is a slowing of time for the observer in one frame the corrected LT requires a real slowing of time in the other. The two frames only overlap at time zero. Using $-v$ is only the inverse transformation if time is independent of movement (so that $\gamma = 1$). If time is found to be slowed in going to the moving frame, then time must be increased in returning.

The claim that "the principle of the constancy of the velocity of light is compatible with the principle of relativity" was because the LT converted $x^2 + y^2 + z^2 = c^2 t^2$ into $x'^2 + y'^2 + z'^2 = c^2 t'^2$. It was claimed that this meant 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, because of the mixed interpretations of the terms of the LT. Using $x = vt$ means that the spherical radiation applies only to the origin ($x' = 0$) of the moving frame. However, the equality also holds for $c = \pm x / t = \pm x' / t'$ because $y^2 + z^2 = y'^2 + z'^2$ and $x^2 - c^2 t^2 = 0 = x'^2 - c^2 t'^2$, but results in a time that is distorted by the same amount as distance so that the speed of light appears constant. The reality is that the underlying speed of light is independent of the time kept by massive clocks moving at a constant high-speed relative to a constant background from massive objects. There is no requirement that this speed be independent of the magnitude of the background. It only requires that the speed of light using clocks that run at different rates in the same background, but maintain synchronicity when corrected for the different rates, agree on the distance travelled by light per unit of synchronised time. This means that distance, the space between objects not in relative motion, cannot be distorted.

The principle that the laws of physics are independent of motion at constant speed is faulty. The relativity of motion applies to interactions of massless fields (which are insensitive to speed relative to the background from massive objects) but massive objects are sensitive to their speed of motion relative to the background. Time dilation with movement comes from movement relative to the field from all other mass. The measured speed of light will double if the clock-rate of moving clocks is halved.

Distance intervals (space) only appear to contract because time (clock-rate) is dilated (slowed). The derivation of a fabric of spacetime in special relativity is fatally flawed. The constancy of the underlying speed was mistakenly replaced by the constancy of the measured speed of light, and the apparent independence of speed relative to the background was mistakenly assumed to apply independent of speed. Hence, the fabric of spacetime is an illusion and cannot be taken over into accelerated motion and used to explain gravitational attraction.

As set out in Lesson 2, combining Newton's laws establishes that gravitational attraction arises from a decrease in stored energy when massive objects move closer together. It is simply conservation of energy and space is not distorted. Massive objects cannot store as much energy when closer to other objects having mass, and the speed of light increases. To increase their separation requires work which gets stored in the objects as mass. Massive clocks then hold more energy and tick faster (time speeds up). This mass is released as kinetic energy of motion when objects move closer to each other. Time can be altered by gravitational potential, but not distance (i.e. "space"). However, an invariant spacetime interval, with variable c, exists as distance = speed of light x travel time. The underlying speed of light is constant only for a constant background from massive objects.

The original standard predictions of general relativity involved misinterpreting an increase in distance travelled by light per unit time as a decrease in the scale of 'space' between objects. These predictions do not require distances to be contracted or establish that there is a gravitational redshift of photon energy and wavelength. Instead, a blueshift in the energy of atoms explains observations, while general relativity's slowing of the time for light to travel a given distance should have the opposite effect to its contraction of space and cancel any bending of light. As set out in Lessons 2 and 5, the observed behaviour is reproduced by full relativity. Time and the speed of light are altered by the magnitude of the background medium. No contraction of the distance between stationary objects, when placed at a lower gravitational potential, is needed; and none has been observed. 'Space' is not flexible and distances cannot expand without objects moving. There is no curved spacetime.

The differential form of Newton's equation, on which Einstein's field equation of general relativity (GR) is based, assumes that Gauss's law for the flux, from the mass of a constant amount of matter, through a closed surface is constant. This is violated if mass is stored energy and gravitational attraction reflects changes in stored energy (Appendix C), that depend on the speed of light. GR's requirements for a constant speed of light and that gravitational attraction disappears under free-fall allowed distortions of distance by relative gravitational potential of the observer to approximately mimic the behaviour that an object accelerating under gravity is continually losing mass as it moves into a region of decreased background potential (increased matter density) and faster light-speed.

The Einstein or Strong Equivalence Principle does not hold. This 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 $\vec{a} = -\vec{g}$. The first has no change in background or velocity and so constant mass and inertia. The second has an ongoing increase in velocity, mass and inertia.

The change in energy held as the speed of light decreases looking back in time completely removes any evidence for an accelerated expansion in the supernovae data and hence removes the need for dark energy. The cause is a change in the background field as matter clumps. This clumping then explains the redshift going back in time without the need for any expansion at all. There is no curvature of space which agrees with the otherwise incredible coincidence demanded by GR that space is flat (Euclidean) just now when we are looking but will rapidly move away from flatness. GR predicts that this should happen only once in the life of the universe.