THE NATURE OF TIME

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An essay concerning the nature of time from the Normal Realist standpoint

CONTENTS

Part 1: Questions Regarding the Nature of Time

Section 1: Time and Change 1

Section 2: The Discrete Nature of Time 4

Section 3: The Relative Nature of Time 5

Section 4: The 'Arrow' of Time 7

Section 5: Time Travel 9

Part 2: Time Dilation in Uniform Motion

Section 6: The Passage of Time........ 12

Section 7: Time Dilation and Time Travel 16

Section 8: Mass Increase with Speed 18

Section 9: Minkowski Space-Time........ 20

Section 10: The Normal Realist Cone Model 21

Part 3: Time Dilation in Orbital Motion

Section 11: The Pope-Osborne Angular Momentum Synthesis (POAMS) 24

Section 12: Time Dilation ion Orbital Motion 25

Section 13: Stellar Collapse and 'Black Holes' 27

Section 14: 'Wormholes' in Space-Time and Time Travel 31

Part 4: Space and Time on a Cosmological Scale

Section 15: The Nature of Space on a Cosmological Scale 34

Section 16: Time on a Cosmological Scale 38

Part 5: Time in Relation to Mankind and Society

Section 17: Time at its Dynamical 'Cutting Edge'........ 42

Notes and References 44

THE NATURE OF TIME

By Anthony D. Osborne

Part 1: Questions Regarding the Nature of Time

Section 1: Time and Change

Man has always been aware of the passing of time, by noticing the passing of days and nights, the changes in the seasons, ageing, birth, death, and so on. Even the earliest civilisations constructed calendars in order to record the days and times of the year [1].

Questions concerning the fundamental nature of time have occupied the minds of philosophers, scientists and theologians alike since the time of the ancient Greeks. For example, is time absolute or relative? Is time continuous or fundamentally discrete? A famous quote by St. Augustine, dating from almost 2000 years ago reads:

'What then is time? If no-one asks of me, I know; if I wish to explain to him who asks, I know not.'

Modern societies generally use the word 'time' in two different senses. Firstly, it is used as some agreed (at least locally) conventional label associated with a particular event, as in the question, 'What is the time?' Without such a conventional label, there would be chaos in human society. Secondly, it is used in the sense of the passing of time, *i.e. duration*, such as a journey taking two hours. However, the first meaning is essentially a special case of the second, since 'the time' represents, of course, the passage of time after an agreed temporal reference. For example, when we say it is 11.00 am on the 26th July 2008, what we mean is that eleven hours have passed since twelve o'clock the previous night, which occurred at the end of the 206th day of the year 2008. In turn, 2008 is a label in the Christian calendar for the 2008th year since the birth of Christ. (Of course, this is not quite so, due to complications arising from the change from the Julian to Gregorian calendar in the 18th century.) Hence, from now on, we shall be primarily concerned with time in the sense of duration.

The nature of time is intimately connected with the phenomenon of *change*. On a practical level, we are aware of the passing of time only through observation of change. The nature of time itself remains elusive, since it is not *directly* observable. We know that time is passing by observing successive days and nights, the ageing of our friends and relatives, the change of position of the hands on an analogue clock, the change of display on a digital watch and so on. For Ernst Mach, the passage of time can be recorded *only* by observing changes. He wrote [2]

'It is utterly beyond our power to measure the changes of things by time. Quite the contrary, time is an abstraction, at which we arrive by means of the changes of things.'

According to our Neo-Machian Normal Realist philosophy, scientific knowledge of the world rests, not on any absolutist, God's-eye-view intuitions or precepts about underlying realities (the so-called 'realism' of classical physics) but always on our very best interpretations of *phenomena*. These phenomena are the only physical reality which is manifest in *all* the observational (*i.e.* sensory and instrumental) categories [3]. Hence, in Normal Realism, we follow Mach's viewpoint, that time is manifest only in the observation and recording of change.

The nature of space is as elusive as the nature of time. For example, stars are separated by the vast expanse of *empty* space, which means that there is *nothing* between them. But if space is nothing, then how can it be something we can think and talk about? Once again, according to Normal Realism, we are aware of the space that surrounds us only by observation and measurement. This awareness comes through observing objects change their positions and we extrapolate a mathematical model for space through the measurement of distance between various objects. In other words, once we have a means of measuring distance, we can set up a three-dimensional Cartesian coordinate system, say, which describes the position of any point relative to a fixed origin – the observer.

This 'relationist' view naturally extends to our ideas of the 'universe'. At its extreme, this view goes so far as to deny the very *existence* of space and time as entities in their own right. According to this view, the 'universe' of space and time is no more than a projection of human perception – that is to say, a construct of pure convention, with no meaning apart from that.

Certainly from a *scientific* point of view, the only way of studying the passage of time is through local measurement. In this sense, it makes perfect sense to talk of duration in terms only of data produced by some chosen measuring device. This definition of duration is known as an *operational* definition [4]. Any question concerning time which, in principle, is not answerable by observation and experiment is dismissed as being not a proper question for scientific investigation.

Of course, an observer may record the passage of time using any 'device' whatsoever, whether that 'device' is one found in nature or in some man-made mechanical or electronic clock. However, in order to define a unit of one second for example, there has to be an agreed reference instrument, from which all man-made devices may be set. Then any two observers situated at the same point, using two different recording devices, will agree on the passage of one second. At the present time, the frequency of a certain spectral line emitted by caesium atoms is used to provide a reference frequency and hence a 'standard' second [5].

We can now, therefore, record passages of time very accurately, in fact, far more accurately than distance as measured by a graduated measuring 'rod'. For this reason, radar is often used to measure distances to a very high degree of accuracy by using the conversion factor *c*, traditionally labelled as the 'speed of light', which converts observational time into distance. Using this conversion factor, one metre is equivalent to 0.000000003335640952 of a second, as recorded by a caesium atomic clock. This length corresponds to the historical definition of one metre as determined by the length between two marks on a particular bar of platinum kept in Paris [6].

It was the ancient Greeks who were the first to study the nature of time from a philosophical point of view. We have said, earlier, that the passage of time is characterised by change. It was the view of Heraclitus that change is real, while constancy is a static instant of this dynamic change and so only apparent. This is the so-called 'dynamic' view. In contrast, Parmenides and Zeno argued that change is only apparent and that constancy is real [7]. This is essentially the 'static' view, which maintains that all moments in time are equally real and that there is no changing present. In this sense, all times already exist. Zeno presented a number of 'paradoxes' involving time and motion, the most famous of which concerns a moving arrow [8]. He argued, essentially, that since a moving arrow is stationary in any instant of time (the 'now') it is always stationary. Following Heraclitus, Aristotle defined time as motion which can be enumerated. Hence, in answer to Zeno's paradox concerning the arrow, Aristotle argued that the flow of time *is* the motion of the arrow. The 'dynamic' view of time supported by Heraclitus and Aristotle can be considered historically to be the precursor of Mach's view and ultimately the Normal Realist view of time, as presented above. According to this view, the passage of time is real, so that future times as such do not exist relative to the present and events *unfold in time*.

Section 2: The Discrete Nature of Time

One of the fundamental questions concerning time is whether a time interval is continuous or ultimately discontinuous (discrete). The basic premise in constructing any mathematical model in physics is that time is continuous. This premise is necessary in order to be able to use calculus, which is concerned with continuous rates of change. This approach has worked well in most areas of applied mathematics, at least on the macro-scale. However, on the micro-scale, quantum theory postulates that time is *quantised*, *i.e.* ultimately discrete, like every other physical measure. This is also a basic premise of our Normal Realist philosophy [9].

As explained earlier, according to Normal Realism, our knowledge of the physical world is derived from observation and measurement. Since any measurement is ultimately discrete, we maintain that by using this operational definition of time, the implication is that time is ultimately discrete. When we look at the hands on a clock, they appear to move continuously but when we look closely, they move in a sequence of discrete jumps. All digital time pieces clearly measure only discrete intervals of time. The most accurate atomic clocks known employ the frequency of vibration of atoms which is ultimately a discrete measure.

The fact that we need to suppose that time is continuous in order to construct any mathematical model of motion can be squared with the fact that it is ultimately discrete by using the 'correspondence principle' of quantum theory. This states that, essentially, although all physical measures are ultimately discrete on a small enough scale, these discrete units are so small that the measures appear, for all practical purposes, to be continuous on the macro-scale.

Although Aristotle maintained the 'dynamic' view of time, he was a four-element theorist for whom all physical measurements were continuous. Hence, although the view of time in Normal Realism has its roots in Aristotle's view of the passage of time recorded by change, its roots also lie in the ideas of Democritus and the 'atomists' involving the discrete nature of physical measures.

Section 3: The Relative Nature of Time

It is clear that a 'point in time' meaning a label with respect to an agreed temporal reference point must be relative to the observer. For example, it is meaningless to say 'It is now 11.30 am'. Such a label has meaning only if it is associated with a point in space, to provide an *event*. For example, we may say it is 11.30 am in Trafalgar Square in London but at that same moment, it will be 2.30 am at Santa Monica Pier in Los Angeles. Before the division of Earth into time zones in 1884 as a result of an international agreement, a given time was only relative to a particular town, 'Glasgow time' being different from 'London time' for example. This made the interpretation of railway timetables, for example, very problematical! In fact, the advent of the railways was directly responsible for this International agreement. Conventional time labels for events are relative in other ways. For example, when we say it is the year 2008, this is only relative to our Western Culture/Christian viewpoint. This year has a different label in the Jewish or Muslim calendars.

When we observe the stars from Earth we customarily assume that we are observing how they once *were*, that the information takes time to reach us, the greater the observational distance the greater, in retrospect, is the time. So in this sense, on an astronomical scale, the present time is only local.

Although it seems obvious that a particular time must be specified relative to an observer, it is not at all clear as to whether the *passage* of time is independent or dependent on the observer. The study of this question is apparent in the works of Aristotle. For him, the study of time must involve its measurement, which involves the comparison with an agreed absolute standard. But how do we know such an absolute standard exists at all points in space, so that it is the same for all possible observers? Well, we don't. It was Newton who first formally proposed that time flows uniformly – that it does not change pace, either at different points in time or relative to different observers at different places. In an often quoted passage, Newton states,

'…absolute, true, mathematical time, (which) of itself, and from its own nature, flows equably without relation to anything external.'

This certainly seems a reasonable supposition to make, the second part of it being supported by our everyday experience of time on Earth. However, there is certainly no direct evidence to support the fact that an interval of time is the same for *all* observers, everywhere at once. Newton began with this particular concept of time in order to formulate his laws of motion. His postulate states that time is not determined by motion or anything else in nature. Rather, it supposes the existence of an absolute standard 'clock' which records time independently of anything else [10]. In the same way, Newton postulated the existence of an absolute space, which exists independently of the presence of any observer. This is essentially the 'realist' view of time and space.

Leibniz was quick to realise that Newton's concept of 'absolute time' was irrelevant to observational science. As appreciated by Aristotle, duration is recorded only by observation. So we need to begin with the premise that duration is relative to the observer, since we have no empirical evidence to the contrary. This observational approach agrees fully with our Normal Realist philosophy. Indeed, from a practical point of view, it is not sensible to try to determine whether two separate events occurring at different places can take place simultaneously since a finite observer can be at only one place at one time.

Although Poincaré was the first to consider relative time measurement, it was Einstein who first showed that Newton's assumption that time flows uniformly, independent of the observer, is at odds with experimental evidence. In particular, he showed that two events which are recorded as simultaneous relative to one observer will not be recorded as simultaneous when recorded by another observer moving at a constant velocity relative to the first. Concerning his formulation of Special Relativity, Einstein wrote [11]

'My solution was really for the very concept of time, that is, that time is not absolutely defined but there is an inseparable connection between time and the velocity of light.'

According to Einstein's Special Theory of Relativity, duration is a relative measure, and the same is true in our neo-phenomenalist replacement of Special Relativity. Although, in our Normal Realist approach, it makes no sense to talk of the 'velocity of light', there is an inseparable connection between observational space and time, given in terms of the conversion factor c. The consequences of this, in terms of the time dilation effect, are discussed in the following, Section 6.

The question as to whether or not the passage of time can change rate from one time period to the next is probably not a question for empirical science. In 1898 Poincaré wrote a paper in which he posed the question of whether or not a time interval of one second today is the same passage of time as one second a thousand years ago. It certainly does not appear likely that an observer would be able to compare an interval of, say, one second over long periods of time. So it is not surprising that Poincaré's question still remains unanswered.

Section 4: The 'Arrow' of Time

Time differs fundamentally from space in two different ways. Firstly, it is one-dimensional rather than three-dimensional, and secondly, it is *anisotropic* which means that the passage of time 'flows' in one direction only, from the past to the future. In other words, there is a privileged temporal direction; the passage of time cannot be reversed. This privileged direction is generally known as the 'arrow' of time. We all have everyday experience of this asymmetrical nature of time. For example, we know that if we throw a ball at a window, we may smash it, but we never observe a window mending itself and ejecting a ball back into our hands. Of course, we may record a video of someone throwing a ball and smashing a window. Running this video backwards shows the ball being ejected from the window and the window mending itself. But this copy of reality is not reality itself and the reversal of the video player's process does not reflect a reversal of time. It is, of course, simply that the video stills are presented in reverse order. Note that, in any case, it is possible to run the film backwards only because in real time the ball has already been thrown through the window. As another example, as human beings we are starkly aware of the 'arrow' of time through the realisation that the ageing process cannot be reversed.

Duration appears to be the only physical measure which is unidirectional. As a one-dimensional measure, it can only increase, whereas other measures, such as mass, distance, and energy, can decrease as well as increase. Hence, the distinction between the past and future (relative to an observer) is much more fundamental than between left and right, up and down, heavier and lighter *etc*.

The obvious question, then, is why should the 'flow' of time be unidirectional in this way? From our Normal Realist standpoint, the passage of time is recorded through observation of change and any observation depends on *information*. In this way, as time passes, we gather ever more information. The fact that this accumulated amount of information can never decrease provides an indication of why time is anisotropic. There are also other considerations which highlight the asymmetry in the passage of time [12]. One primary consideration is that of causality. The anisotropic nature of time is illustrated by the rule that a *cause* always *precedes* an *effect*. For example, the act of pressing a light switch will cause the light to come on but not conversely. What we do can direct the future but not the past, which remains fixed. Another consideration is that we may obtain a detailed and reliable knowledge of the past but not of the future.

A principal reason for the 'arrow' of time is generally argued to be the Second Law of Thermodynamics. This law appears in various forms which can be shown to be all equivalent. Basically, it states that in any isolated system, *entropy*, a measure of disorder, increases with time [13]. In other words, this law states that with any change, the order of a system decreases, *i.e.* that significant order becomes less probable. Hence, as time 'flows on' it is more probable that a system will be in a disordered state than an ordered one. Think of constructing a Lego model from a large number of small pieces. The ordered state of the completed model is unique among all the possible combinations of the pieces and is highly unlikely to occur at random. Otherwise, without the modeller, there are a huge number of disordered states – uncompleted or wrongly completed models. This increase in disorder over time is manifest in nature as the process of decay.

The Second Law of Thermodynamics was originally proposed by Clausius in the middle of the 19th century. This was really the first physical law which reflected the asymmetrical nature of time. Until its appearance, all physical laws, such as Newton's Laws of motion for example, were symmetrical in time [14].

It should be noted, however, that there are localised exceptions to this Second Law. For example, crystals can grow in certain chemical solutions, representing an increase in order, but such instances are relatively rare. In this sense, the Second Law applies globally rather than locally. In other words, it is generally postulated that, overall, the net disorder increases with time, although there may be local exceptions. Nevertheless, there are problems associated with using the apparent general increase of entropy as the sole basis for time's anisotropic nature [12]. Some theoretical physicists and philosophers argue that the Second Law cannot be projected to the universe as a whole. Others argue that just because the Second Law appears to be true at the moment, it need not be valid for all time. Some go as far as to believe that time may eventually be reversed, when, for example, the 'universe' begins to collapse, which they call the 'heat death of the universe'! However, to say 'the law of entropy is universal' is not logically the same as saying that 'the universe, as such, is subject to the law of entropy'.

A full philosophical discussion of the asymmetry of time is provided in reference 12.

Section 5: Time Travel

The aspect of time which fascinates people the most is the possibility of 'time travel'. In this respect, the nature of time is fundamentally different from the nature of space. In space, it is clear that we may travel in any direction we wish and vary our speed. Initial thoughts concerning time generally tend to suggest that it is not possible to travel back in time or to vary the rate at which we persist through time. However, let us examine the possibility of 'time travel' a little more carefully. First, we need to be clear as to what we mean by 'time travel'. In one sense, we are all 'travelling' in time into the future simply by persisting. We have discussed, earlier, some of the reasons why time has to be a relative concept, so it makes sense to talk of 'time travel' only in relation to some reference 'clock' (any suitable timepiece). Consider, then, a fixed standard clock at a particular point in space. The time as recorded by this reference clock is usually called the *coordinate* or *external* time – that is, objective time, as opposed to subjective time, or time as we sense it. Now consider an observer *A*, standing relatively stationary at this fixed point in time and space and whose clock is synchronised with this standard clock. We assume that *A*'s clock always records the standard passage of time relative to himself, that it is not reset in any way and does not lose time or stop, *etc*. This time as recorded by *A*'s clock is generally known as his, *i.e.*, A's, *proper time*. If, after some passage of time as recorded by *A*'s clock, the reference clock and *A*'s clock are no longer synchronised, then *A* may be said to have *time travelled* relative to that fixed reference clock.

Under this criterion, if it were technologically possible to place a living person in cryogenic suspension and then revive that person, say a thousand years from now, this would *not* be classed as time travel in the sense we have discussed. It would be simply that this person has lived longer than everyone else because his/her 'biological clock' has temporarily stopped. A clock placed with that person but not cryogenically suspended will record the same passage of time as that of the fixed reference clock. The situation is simply that the person's life-processes have been suspended throughout all the intervening years without his being conscious of it.

There are two basic possibilities for time travel. One is the idea of a 'time-slide', in which the time traveller, due to relative motion, passes through all the intervening times as recorded by the fixed reference clock but at a different rate. This sort of 'time-slide' into the future is now accepted by the majority of mainstream physicists. Any such trip is by no means logically problematical since it cannot causally undermine what has already happened. The time dilation effect predicted in Special Relativity and our Normal Realist alternative of that theory, which is firmly supported by empirical evidence, shows that time-slides into the future are both logically and physically possible [15]. This is demonstrated in the following, Section 6. Both General Relativity and POAMS (the Pope-Osborne Angular Momentum Synthesis), our neo-phenomenalist alternative to that theory, show that time-slides into the future can also be caused by the presence of a massive body [16].

This first idea, then, is that of the time-slide. The other idea which deserves a mention is that of the 'time-jump', in which the traveller does not pass through the intervening years [17]. This will be discussed in due course. Meanwhile, let us consider, in contrast to time-slides into the future, the possibility of time travel into the past. To say the least, this appears to be highly improbable due to the fact that it creates the possibility of changing events that have already taken place, which involves backward causation. Usually we think of an effect as *preceded* by a cause. Initial thoughts, therefore, tend to suggest that time travel into the past is logically unsound.

However, we must be careful not to jump too quickly to conclusions here. For example, it has been argued that a type of backwards causation occurs in quantum theory. According to that theory, the state of a quantum system is indeterminate in certain respects, until a measurement is conducted, the action of which determines a 'collapse of the wave function' into physical actuality [17]. Nevertheless, what has been said about the asymmetry of time indicates that an actual time-slide into the past is not possible, which rules out backwards causation.

However, let us now investigate a little more carefully the other possibility, namely that of a *time-jump* into the past. According to the static-block, or Parmenidean view of time, events which occur at a given (coordinate) time are fixed and cannot be changed [17]. So the argument which says that, at least logically, time travel into the past is possible goes something like this. A time traveller cannot *change* the past since his or her existence at a particular point in time has *already* happened (in objective or coordinate time, that is). The 'time traveller' obviously cannot *recall* being there previously since that event is still in his or her *future*. For example, a man cannot travel back to, say, a week earlier in time and at that same time meet himself at that point whilst already aware, from his future knowledge of what has already happened that he *did not* meet himself at that point. A woman cannot go back and kill her own mother before she was born, since that woman *was* born ...

and so it goes. In other words, we do not have the *freedom* to change history in which whatever we choose to do is already 'done and dusted'. This is related to what is sometimes known as the *chronology protection conjecture*, according to which the laws of physics 'conspire', as it were, to prevent (macroscopic) events in the present moment from carrying information into the past. Although *logically* or purely theoretically possible, any such idea of *actual* time travel into the past still seems, to say the least, highly unlikely since it confounds the known laws of physical causality.

Despite this caveat of the physical impossibility of backward causality, some writers have shown that time travel into the past is logically possible by creating multi-dimensional models of time which project all possible pre-determined futures branching-off from any actual event. However, we have no solid reason to suppose that time is like this. Nevertheless, theories involving the possibility of 'parallel universes' are popular, especially with writers of science fiction. If time travel into the past were to take the form of passing from one 'universe' to another, then there would be no logical contradiction in that view; each jump into the past would create another possible future 'universe'. However, this scenario does not involve travelling into one's *own* past and so may be discounted as time travel in the strict sense. Most philosophers are agreed that in any model which supposes a one-dimensional time and a single 'universe', time travel into the past entails unavoidable logical paradoxes [17]. For example, if a person was able to time-jump freely and return to a time when he already existed, there would then be two of him at that time, but a person cannot possibly occupy the same point in time more than once. After all, if that were the case, then he could travel forwards and then back to the earlier time again and again to create three of him, four of him and so on which, logically, is a reduction to absurdity!

Of course, there is a huge difference between a scenario being theoretically possible and that scenario being *physically* possible. One can propose any number of postulates one wishes, but in order to have a scientific theory rather than a metaphysical one, the implications of that theory have to be susceptible of being empirically verified. According to both Special Relativity and our neo-phenomenalist alternative, time travel into the past is not physically possible [16]. In contrast, some theoretical physicists believe that General Relativity allows for the possibility of time-jumps into both the past and the future, whereas our alternative approach in the form of POAMS does not [18]. We will return to this question later.

Part 2: Time Dilation in Uniform Motion

Section 6: The Passage of Time

As we have stated in Section 3, the *passage* of time may vary between different observers, so that duration is relative, not absolute. Prior to the advent of Special Relativity in 1905, it was generally assumed that the passage of time was an absolute quantity, since everyday experience did not indicate otherwise. But as we have seen, once we know that there is a universal constant 'conversion factor', c, which determines a constant relationship between observational time and distance for *all* observers, it becomes plain that the passage of time must be relative to the observer. Two observers moving at some significant speed v relatively to each other in space can never agree on the time interval between two events occurring at particular observational distances and times. This is essentially because the optical information regarding each event directly reveals a relative time-lag in the object in accordance with its distance, in the constant distance-time rate c, which is the same for all observers. That is to say, in the telescope of an observer, an identical clock which is, say, 300,000 kilometres away will be seen to read one second of time earlier than his own clock, while another identical clock twice the distance away will be seen to read two seconds behind, and so on. Hence, for observers in uniform relative motion, events that occur simultaneously relative to one cannot occur simultaneously to another [19]. This should become perfectly plain in due course.

We can obtain an explicit formula for the passage of time as recorded by a relatively moving clock in terms of the same passage of time recorded by a fixed reference clock. This is by using the conversion factor c plus some simple geometry and algebra [16]. For instance, consider a body X which moves uniformly (*i.e.* with constant speed, v say, in a fixed direction) relative to an observer situated at some fixed point O. In classical physics, the distance, s, of X relative to O at any time t, is described by a straight line plotted against two perpendicular axes, labelled s and t. This line has a constant gradient $v = s/t$ and if X passes O at time $t = 0$, then this line passes through the origin. The equation of this line is then $s = vt$, as shown in Fig. 1(a), below. In other words, after time t has elapsed for X, he is at a distance vt from O. This passage of time is the same as viewed by all observers of X regardless of distance or relative motion. Note that in classical physics, X and O record the same passage of time.

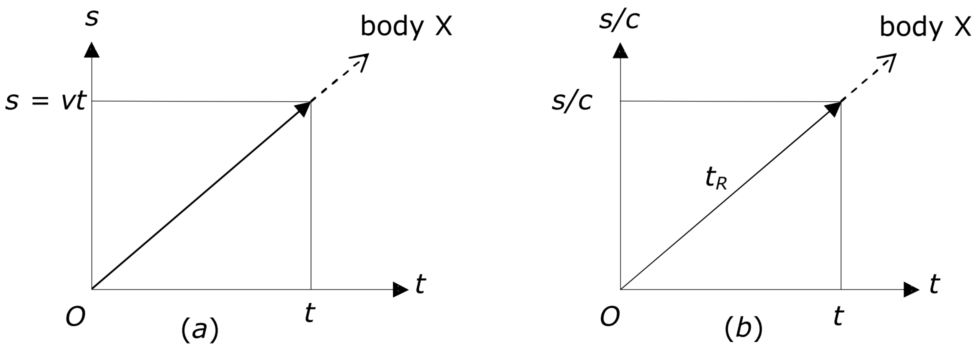

Fig.1: Time Dilation in uniform motion

In Fig. 1(a), there is no special significance attached to the *length* of the line with equation $s = vt$ for a given value of t, since in this traditional kind of representation there is no fundamental interconnection between distance and time as such. Taking into account our postulate that there is an observer-independent conversion factor, c, which converts observational distance into observational time and *vice versa*, this situation is radically changed. In this case, a fixed geometrical relationship is established between the dimensions of s and t. Hence, it is to be expected that with this overall connection, motion must affect time in some way. This is because motion is now a *geometrical* combination of time measures, analogous to the lengths which determine an ordinary area. In contrast to classical physics, however, we do not assume that time is observer-independent. In this case, the natural measure of the passage of time, t, is as recorded by a 'clock' which *moves with the body X*, since this is the only time measure associated with X which is independent of the time of the observer.

To reiterate, the body X travels a distance s measured in metres relative to O in a time t recorded in seconds *by X's clock.* This distance s can also be measured in seconds by the use of the conversion factor c. Then the distance-time diagram, Fig. 1(a), becomes the *two-dimensional time* diagram, Fig. 1(b). In this latter figure, the two axes (labelled s/c and t) are both measured in units of seconds. Bearing in mind that the line segment OX represents the path of X's clock relative to O, it follows, therefore, that the length of OX in this second diagram is the resultant time t_R, as recorded by O, for X's clock to reach its position relative to O after its time t. Then t_R will be simply the length of the hypotenuse of the triangle in Fig. 1(b), given by Pythagoras's theorem as

$$t_R^{\,2} = t^{\,2} + (s/c)^2$$

Now the speed, v, of X relative to O (*i.e.*, *relative to O's clock*) is given by $v = s/t_R$, so that,

$$t_R^{\,2} = t^{\,2} + (vt_R/c)^2$$

Re-arranging then gives

$$t^2 = t_R^{\,2} - (v^2/c^2)t_R^{\,2}$$

and hence,

$$t = (1 - v^2/c^2)^{½}\, t_R \qquad \text{(TD)}$$

Equation (TD) is known as the *time dilation formula* and is the same, here, as the standard formula derived in Special Relativity by different means [20].

The formula (TD) gives the time t as registered on a relatively moving clock in terms of the time, t_R, registered on an observer's clock. For any non-zero relative speed v, which is less than c, the factor $(1 - v^2/c^2)^{½}$ is less than 1, so that this formula shows that a moving clock runs *slower* and so is time-dilated *relative* to an observer's clock. Hence, the formula clearly shows that the passage of time is *relative* to the observer. Equation (TD) also indicates that c cannot be treated as if it were a speed since, otherwise, for v equal to c, t is zero, independently of the observer time t_R. In this case, the 'travelling' clock would register no time at all, regardless of how great the distance 'travelled' might be. This resultant time t_R, as registered by the observer, O, is, for obvious reasons, known as the *observational time* or sometimes as *coordinate time*. The corresponding time, t, registered by the moving body itself, as viewed in his telescope and/or spectroscope is, the *proper time* of that body.

It should be emphasised, here, that this time dilation is a *relative* effect, not an absolute one. If we imagine X to be the observer, then O moves uniformly relative to X with speed v, so that according to X, it is O's clock which appears to run the slower of the two. There is no contradiction here since this is a relative effect. Indeed, there is only an apparent contradiction if we try to think of the effect in terms of both O and X together, in a 'God's-eye-view' way, *at the same time*. In our Normal Realist philosophy, this is not possible since there is no such 'God's-eye-view' which we can legitimately presume to take, all phenomena being ultimately dependent on the finite, point-centred observer.

According to the scientific *operational* definition of time, the only way that we may study the time dilation effect is through the recordings of clocks. But does a moving clock running relatively more slowly imply that time itself is running relatively more slowly? In theory, one way to address this question is to study the effect of time dilation on biological ageing due to relative motion. Unfortunately, due to the present state of our technology, we are not yet in a position to do this. However, a 'clock' represents *any* device capable of recording a passage of time. This includes biological clocks, so that there is no reason to suppose that biological ageing should be exempt from time dilation. In other words, a space-traveller moving uniformly relatively to Earth should age at a slower biological pace than the rest of us – that is to say, *relative to us*.

When Einstein first discovered the time dilation formula, he struggled with some of its philosophical implications. In particular, since it implies that the recording of time is always relative to a particular observer, how can we attach any meaning to 'now'? He eventually concluded that 'now', meaning something essentially different from past and future, was a human concept rather than a scientific one [2]. Einstein wrote:

'…there is something essential about the "now" which is outside the realm of science.'

The time dilation result clearly does not agree with what we usually think of as 'commonsense', but this is only because, since any speed necessary to detect an effect lies beyond our everyday experience. However, this time dilation has been verified by experiment, beyond reasonable doubt. One of the first such experiments was performed by Ives in 1938. He measured the frequency of vibration of hydrogen atoms when at rest relative to the laboratory and again when they were moving at a speed of 1760 kilometres per second. Ives found that the frequency decreased, corresponding to an increase in time per vibration. This increase in time per vibration was exactly the amount predicted by the formula (TD)[21].

Another of the earliest verifications of the time dilation effect concerns elementary particles known as *muons.* These occur in appreciable numbers in the Earth's upper atmosphere and are unstable; they decay with a mean lifetime of approximately 2.2×10^{-6} seconds when observed at rest. Muons have a speed of about $0.9965c$ relative to an observer on Earth, so that according to classical physics, the mean distance that the high altitude muons could cover before decaying is about 650 metres. In that case, the high altitude muons should not be detected at sea level. However, muons are, in fact, found in significant numbers at sea level, as first detected in experiments performed by Rossi and Hall in 1941[22]. The explanation is that with $v = 0.9965c$ and $t = 2.2 \times 10^{-6}$ seconds, (TD) gives the muons a mean lifetime of $t_R \approx 2.64 \times 10^{-5}$ seconds, relative to Earth. Hence, the high altitude muons are able to travel a mean distance of about 7.9 kilometres before decaying, relative to Earth and so can easily reach Earth's surface, as observed.

Section 7: Time Dilation and Time Travel

The time dilation formula, (TD), implies that (human) time travel into the future as a *time-slide* (see above) *is* an actual theoretical consequence of relativity theory. For the moment, we shall consider a theoretical scenario and discuss the practical difficulties later. Suppose that a space traveller *T* sets off from Earth in a spacecraft and after an initial period of acceleration, in order escape the Earth's atmosphere and to increase his speed to 0.6*c*, he travels uniformly at constant speed 0.6*c* relative to Earth. Suppose *T* visits a planet, a distance of, say, three light-years away before reversing his motion and returning to Earth with an opposite uniform velocity at the same constant speed 0.6*c*. Note that *T* has to decelerate and accelerate again in order to visit the planet whereas the terrestrial observer of the motion does not. Let us assume that the time *T* spends on the planet is very short compared to the rest of his trip. Then according to an observer, *E*, on Earth, the space traveller *T* takes $t_R = 6 \div 0.6 = 10$ years to complete the round trip. However, ignoring the very short periods of non-uniform motion on take-off and touch-down, according to (TD) with this value of t_R and $v = 0.6c$, the time recorded by *T* for the round trip on clocks relatively stationary to himself (including his own biological clock) is only $t = 0.8 \times t_R = 8$ years. Hence, when *T* returns to Earth, he has effectively returned two years into the future relative to Earth time. He has time-slid into the future since two extra years have passed on Earth where everyone has aged an additional two years relative to the traveller. The time dilation formula, (TD), shows that the faster *T* is able to travel, the greater the time-dilational effect, and the further he is able to travel, the longer is the period of the time slide into the future. For example, if *T* could embark on a round trip of 1000 light years at a speed of 0.998c, then he would return to Earth after 1002 terrestrial years, whereas the trip according to his own clock would only take about 63 years! When he returned to Earth all of his family and friends would have died long ago, so such a trip may not be very appealing to contemplate!

A famous controversy which has surrounded the time dilation formula, (TD), from soon after its first appearance, is the so-called 'clock paradox' or 'twins paradox' [23]. Consider the same scenario as outlined above, where, now, the space traveller, *T*, and the Earth observer, *E*, are identical twins, who are exactly the same age before *T* begins his round trip in space. After the trip, *T* meets up again with his stay-at-home brother *E*. Ignoring the accelerations and decelerations on take-off and touch-down, it follows by (TD), as above, that when the twins meet up again, *T* will be relatively younger than his twin *E*.

The alleged 'paradox' is this. Initial thoughts suggest that *T* could claim with equal right that it was he who remained where he was, while it was *E* who went on the round trip, with the consequence that *E* should be the younger when they meet again. However, there is no such paradox, because it must be remembered that equation (TD) applies only to relatively *uniform* motion. As long as *T* continues to move uniformly away from *E*, then each observer's clock runs slower relative to the clock of the other. However, in order to compare clocks, *T* has to go on a round trip and return to Earth. In order to make this trip, *T* has to undergo an initial period of acceleration and when he reverses direction to return to Earth (even if he does not visit a planet) this necessarily involves a period of deceleration and acceleration, which has definitely observable and measurable physical, (*e.g.* visceral) effects. In contrast, the observer *E* who remains on Earth does not experience these effects of non-uniform motion. Hence, the observational frames of *E* and *T* are not physically (and so not mathematically) interchangeable. In summary, there is no 'paradox', since the argument that there is a paradox assumes a symmetry between the frames which, in fact, there cannot be.

It follows, then, that although (TD) applies for most of the journey of *T* relative to *E*, the periods of acceleration and deceleration of *T*, no matter how short compared to the length of the whole journey, destroy the otherwise symmetrical situation between *E* and *T*. A good analogy for the fact that very short periods of non-uniform motion have a huge impact on the whole journey has been provided by Bondi. Imagine, he says, travelling in a car at a constant speed along a straight road. Suppose at some point, the car turns right and continues to travel at constant speed along another straight road. Even though the period of non-uniform motion, when the car turns right, is negligible, it has a very large effect on the car's destination!

There is another way to think of why *T*'s initial acceleration makes a relatively large contribution to the eventual age difference between

T and *E*. At the end of *T*'s initial acceleration to speed 0.6*c*, say, he is transferred to an inertial frame relative to which the distance he has to travel has *already* been shortened by a factor of 0.8. So after this brief period, he has to travel a distance of only 8 light-years, relative to himself, rather than 10 light-years.

In conclusion, it can be shown that it is the space-traveller *T* that ages less than his stay-at-home brother *E* after *T*'s round-trip [24]. The fact that there is no paradox and that it is *T* who ages less than *E* is firmly supported by empirical evidence. For example, as we have seen, those experiments that involve accelerating muons support this conclusion [25]. Another set of experiments which verified both the time dilation formula (TD) and the conclusion of the 'twins paradox' were performed by Hafele and Keating in 1972. Such experiments involved monitoring atomic clocks carried on commercial jet flights around the Earth, both in easterly and westerly directions. It was found that the moving clocks registered a time period less than relatively stationary clocks when the jets returned, by an amount predicted by (TD) [26] [27].

Note that although formula (TD) indicates that time-slides into the future are theoretically possible, since relatively moving clocks are slowed it provides no information with regard to time-slides into the past. As stated previously, according to our Normal Realist approach which takes into consideration the unidirectional nature of time, time-slides into the past are not possible. This conclusion is certainly not contradicted by (TD). Of course, when we look out into space, we are looking into 'the past' of objects by observing events that, in the classical way of thinking, have already happened, since, in that way of thinking, the information regarding those events takes time to reach us. This time delay is determined by the observational distance/time conversion factor *c*. So in order to travel back in time by travelling in space, we would have to exceed the 'universal speed limit' of *c*, which according to both Special Relativity and our Normal Realist alternative to that theory, is not possible.

Section 8: Mass Increase With Speed

We have shown how the time dilation formula, (TD), makes 'time travel', in the sense of time-slides into the future a proven fact. This has been recorded in experiments involving elementary particles and tiny time differences registered on relatively moving atomic clocks. However, in order for a human space-traveller to 'travel' into the future in the way described in the last section, we would have to be able to accelerate macroscopic objects up to appreciable fractions of *c.* To accelerate such an object requires energy. Such energy is used when work is done in producing a force. The greater the mass of a body, the greater has to be the magnitude of the applied force in order to produce a given magnitude of acceleration. The force needed to accelerate a human being to the extent of exhibiting appreciable time dilation would be far greater than human flesh could ever stand.

Now, both Special Relativity and our Normal Realist alternative predict that the effective mass of a relatively moving body *increases with its speed*. To be specific, suppose that an observer *O* observes a body *X* of constant mass moving uniformly with constant speed *v*. Let the mass of *X*, as recorded by an observer travelling with *X* be m_0 (known as the *rest mass* of *X*) and the mass of *X,* as recorded by *O*, be m_R. Then [28]

$$m_R = (1 - v^2/c^2)^{-1/2} m_0 \qquad \text{(MI)}$$

Note that for non zero *v*, m_R is greater than m_0, so that a body in relative uniform motion has a larger mass relative to the observer than that recorded in its own rest frame. (Compare formula (MI) with formula (TD).)

The fact that mass increases with speed was first detected by Kaufmann and Bucherer in the early 1900's. While investigating beta ray radiation, they found that the speeds with which elementary particles were ejected from different radioactive substances were appreciable fractions of *c* and that the greater the speed, the greater the effective mass of the particle. Using (MI), they found that the *rest* mass of each particle was the same and equal to the standard rest mass of an electron. They also discovered that each particle had the same electric charge as an electron and so concluded that beta ray radiation was caused by electrons being ejected at high speeds from radioactive materials [29].

It follows, then, from formula (MI) that the greater the speed of a moving body, the greater the magnitude of the force, and hence the greater the energy required to accelerate it, and the more energy that is imparted to the body the more massive it becomes. This means that we would need an enormous amount of energy to accelerate a macroscopic object, such as, for example a bullet or a human body, up to any appreciable fraction of *c*; more energy, in fact, than we could possibly supply. The formula (MI) shows that it is certainly not possible to accelerate objects right up to 'speed *c*', since this would require an infinite amount of energy, resulting in an infinite mass. This is another reason why *c* cannot sensibly be interpreted as a speed. From a practical point of view, then, it would be very difficult for a human being to travel significantly into the future. Besides, the '*g* force' experienced by a space traveller in accelerating up to an appreciable fraction of *c* within a reasonable period of time would, as we have said, not be physically survivable!

Section 9: Minkowski Space-time

We have seen that, according to the time dilation formula, (TD), the passage of time as well as positions in space are relative to the observer. It is clearly not adequate, therefore, to talk about a particular observation of an observer *O* occurring at a particular point in space. Rather, that particular observation must be specified not only by its position in space but also by the *time* at which it happens relative to *O*. An observation occurring at a point in space and at a particular time relative to *O* is called an 'event'. Hence, when we talk of observations, we are really talking about such *events*. In standard orthodox Relativity, the set of all these events is known as 'space-time'. The hyphen in 'space-time' conveys the fact that space and time are intimately connected, in the way that has been described.

Recall that if a clock *X* moves uniformly relative to *O*, with constant speed *v*, then (TD) gives the proper time, *t*, as recorded by *X*, in terms of the observer *O*'s time t_R. Remember that the proper time is independent of any particular observer and so serves as an *absolute,* rather than a relative parameter. The set of all events, *i.e.*, space-time, together with proper time *t*, serving as an independent parameter, provides a mathematical model for studying relative uniform motion, known as *Minkowski space-time*. It is this model which forms the basis of study of relativistic kinematics and dynamics [15][28][30]. Minkowski first presented his space-time concept in a lecture given in Gottingen in 1907. He presented a less technical account at the eighteenth Congress of German Scientists and Physicians in Cologne, in September 1908. He began this now famous second lecture with the words [2]:

'The views of space and time which I wish to lay before you have sprung from the soil of experimental physics, and therein lies their strength. They are radical. 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.'

Now, whether or not Minkowski's space-time exists as a physical reality, rather than simply as a convenient mathematical model, is an open philosophical question. The 'substantivalist' view is that the 'universe' is, in reality, truly a four-dimensional space-time manifold, rather than this space-time simply being a mathematical model. (This view is sometimes known as the *four-dimensionality thesis*.) In contrast, from our Normal Realist standpoint, we would say that since, from empirical evidence, we cannot determine the answer to this question of the reality or otherwise of the Minkowskian manifold, and since we have no 'God's-eye-view' that we can ever presume to be a party to, we can claim only that space-time is no more than a convenient mathematical model of reality.

Section 10: The Normal Realist Cone Model

Our Normal Realist derivation of the time dilation formula, (TD), provides a three-dimensional *model* for the phenomenon of time dilation. Recall that (TD) gives the proper time, t, as recorded on a relatively moving clock X in terms of the same passage of time, t_R, as recorded by a relatively stationary observer O. Our derivation of (TD) depends on the relationship between t, t_R, and s/c, the latter being the observational distance, converted into seconds, travelled by X, in the time relative to O. This relationship is given by

$$t_R^{\,2} = t^{\,2} + (s/c)^2 \qquad \text{(C)}$$

(see Section 6). If t, s/c and t_R are all treated as variables in this equation, then it represents a right-circular *cone* in three dimensions, relative to three mutually perpendicular time axes, t, s/c and t_R, respectively. As such, this conic surface represents a three-dimensional graph of time dilation, as shown in the plates below. The axis of the cone is the t_R axis and its apex is situated at (0, 0, 0). The end and side elevations of such a graph for non-negative values of t, s/c and t_R, are shown in Plates 1 and 2 respectively. This model illustrates effectively the relationship between any given values of t, s/c and t_R and clearly indicates that t is less than t_R for non-zero relative speed v. The larger the value of s/c, the greater is the difference between t and t_R.

For any fixed value of t_R, (C) is the equation of a *circle* of radius t_R, centred at the origin. Such circles are shown in the end elevation of the cone, as indicated in Plate 1. On the other hand, if t is fixed and the time-measure s/c is plotted against the time-measure t_R, the result is a *hyperbola* with equation

$$t_R^{\,2} - (s/c)^2 = t^{\,2}$$

Such hyperbolæ are shown in the side elevation of the cone, as indicated in Plate 2. As can be seen, any such hyperbola is asymptotic to the lines described by equations $s = \pm\, ct_R$.

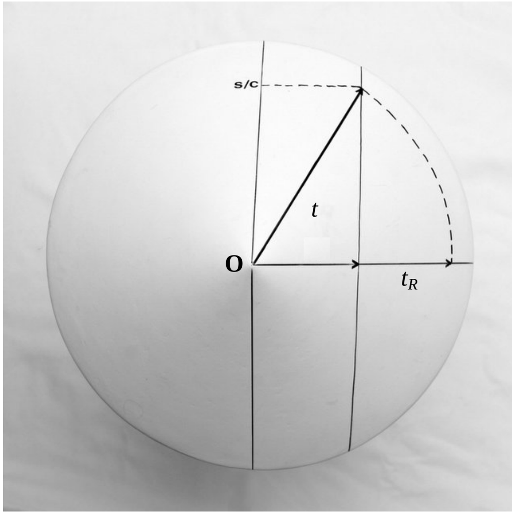

Plate 1: End elevation:

The Newtonian aspect of motion

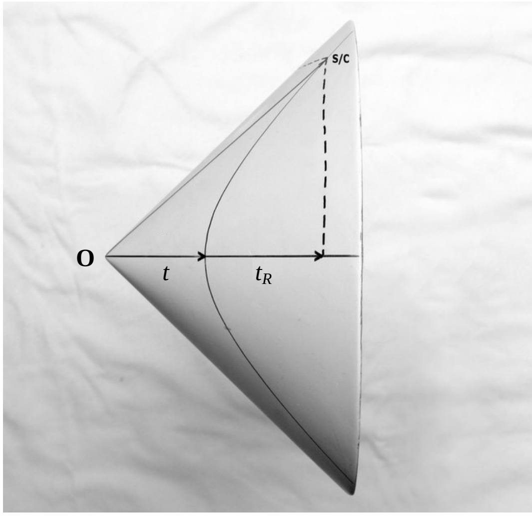

Plate 2: Side elevation:

The Einsteinian aspect of motion

The Conic Surface Graph of Motion

In both Special Relativity and our Normal Realist alternative to that theory, no information can be transmitted at a speed greater than *c*. At first sight this appears to be at odds with the various Newtonian *instantaneous* connections such as the universal conservation laws. This is not surprising since Special Relativity and Newtonian physics are not compatible in other ways. However, our cone model shows there is no conflict between the two theories in this respect, since both aspects of motion are depicted on the same three-dimensional (conic) graphical surface. The explanation is as follows.

There are two distinct speeds associated with the uniform motion of a body *X* relative to an observer *O*. The first is what we can describe as the 'Newtonian' speed, which is s/t, where *s* is the distance travelled by *X* in its proper time *t*. The second is what can be described as the 'Einsteinian' speed and is s/t_R, where t_R is the time taken for *X* to travel the distance *s* relative to *O*'s clock. Our conic representation of time dilation clearly shows how the Newtonian speed-unlimited graph of physical motion (the end elevation of the cone shown in Plate 1) and the Einsteinian speed-limited aspect (the side elevation of the cone shown in plate 2) can be equally represented *with no conflict whatsoever on the same conic surface*. What is represented in the end elevation, Plate 1, as a theoretically unbounded Newtonian speed appears in the side elevation, Plate 2, as the Einsteinian 'speed limit' *c*. This 'speed limit' *c* appears as an asymptote to the graphs representing material particle motion and so, again, is not a speed as such.

Although it was not surprising that Special Relativity appeared to be in conflict with Newtonian physics, much more of a concern during the 1920s and 1930s was that it also appeared to conflict with quantum theory. According to quantum theory, it is possible, in principle, to create a pair of particles with complementary properties. Each particle may have either property until the property of one particle is recorded by observation. Then quantum theory states that the other particle must *instantly* have the complementary property, irrespective of the spatial separation between the particles [2][30]. Hence, quantum theory implies that some type of *instantaneous action-at-a-distance* takes place, which clearly contradicts Special Relativity.

However, in terms of our cone model, there is no contradiction between instantaneous action-at-distance and the existence of a universal 'speed limit'. Our answer to the question as to whether action-at-distance is instantaneous or time-delayed is plainly that *it is both*. In quantum theory, as in Newtonian mechanics, there is, as can be seen from Plate 1, no limit to the speed at which quantum influences may travel between fundamental particles, whereas for relativists, as can be seen in Plate 2, no physical influence whatsoever may be conveyed faster than the 'speed limit' *c*. There is no contradiction here, since the instantaneity takes place in one observational dimension, whereas the time-delay takes place in a different observational dimension.

What we are saying here is that an action may have *both* time-delayed and instantaneous *components*, without there being any logical contradiction. A good analogy lies in the running of a film. In this case, the instantaneous connection between objects in the still frames is analogous to the 'instantaneous' component of interaction, t, and the analogy of the observationally time-delayed component t_R, is the sequencing of those stills in the running of the film. In our Normal Realist approach, this is called the Cinematic Model of combined quantum instantaneity and relativistic time-delay.

Part 3: Time Dilation in Orbital Motion

Section 11: The Pope-Osborne Angular Momentum Synthesis (POAMS)

We have shown in Section 6 that in our Normal Realist approach to relativity, there is a time dilation effect associated with linear motion, just as there is in Special Relativity. Recall that if t denotes the time as registered on a relatively moving clock, X, and t_R denotes the same passage of time as registered on an observer's clock, O, then

$$t = (1 - v^2/c^2)^{\frac{1}{2}}\, t_R \qquad \text{(TD)}$$

where v is the constant speed of the clock X relative to O. We now investigate the effect on time in *non*-linear motion, in particular in the orbital motion of the planets, stars and satellites in our solar system and beyond.

In Newtonian theory, all *free* motion, *i.e.* motion not subjected to any external 'force', is linear so that observed orbital motion, which Newton saw as unnatural, is explained by the presence of an unseen *in vacuo* 'force of gravity', which distorts the assumed natural straight line paths into orbital trajectories. However, we maintain that uniform motion is never observed. According to the Pope-Osborne Angular Momentum Synthesis (POAMS), therefore, in contrast to Newtonian theory, the natural path of any particle is the observed trajectory followed by the particle when it moves freely under the influence of nothing but its own angular momentum. This is without any need of supposing the existence of an unseen *in vacuo* 'gravitational force' [31].

Since, in POAMS, the trajectory of any freely moving particle is naturally orbital, such a particle moves non-uniformly, *i.e.*, it has non-zero acceleration, so that its speed is generally not a constant. We show in reference 31 that the natural trajectory of a particle depends on the mass, M, of the body which it is orbiting. More generally, it depends on the mass of a whole system of bodies, taking the orbital angular momentum of the particle relative to the centre-of-mass of such a system. These considerations indicate that, for natural orbital motion, (TD) has to be extended to provide a formula for t_R which depends on M and, in general, a variable speed v.

In the hypothetical situation in which all influences are essentially removed, allowing a particle to move in isolation in empty space, then its trajectory might seem to follow part of a straight line so that it would seem to move uniformly, in which case, (TD) would apply. In this way, POAMS aligns itself with two of the basic premises of Einstein's General Relativity [32]: the presence of matter causes the trajectories of freely moving particles to be non-uniform and orbital, and that to a limited extent, (TD) applies. The second premise is essentially, *Einstein's Principle of Equivalence.* Both POAMS and General Relativity remove the need for assuming an *in vacuo* 'gravitational force' to explain the natural trajectories of freely moving particles. Both POAMS and General Relativity maintain that the reason we feel a 'gravitational force' on the Earth's surface is because our bodies are prevented from following their natural force-free orbit below that surface. Hence, POAMS is more aligned to General Relativity than it is to Newtonian theory, although it retains some aspects of both theories.

In POAMS, since the paths of freely moving particles are naturally curved, the geometry of the associated space-time must be *non-Euclidean*, unlike the Euclidean, absolute space and time envisaged by Newton. In other words, in POAMS, the presence of matter changes the geometry of space-time, away from Minkowski space-time (see Section 9). This, of course, is also, essentially, the third fundamental premise of General Relativity.

However, there are fundamental differences between POAMS and General Relativity. The latter provides a mathematical model in which the 'flat' space-time geometry of Special Relativity is 'curved' due to the presence of matter. In contrast, POAMS, with its Normal Realist foundations, begins with the postulate that all free motion is orbital and that, based firmly on observation, angular momentum is conserved. There are also other fundamental differences; notably, that the space-time manifold of General Relativity is continuous, whereas in POAMS, space-time is discrete at the fundamental quantum level.

Section 12: Time Dilation in Orbital Motion

We now turn to one particular situation: the simplest case of just one particle, *P*, orbiting a massive body, *B*, treated as an isolated paired and balanced system, that is, with no external effects to be taken into account. This provides a simple model of a planet orbiting the Sun to a good degree of approximation. In this simple example, we assume that neither the body *B* nor the particle *P* is spinning. In this case, according to Newtonian theory, *P*'s trajectory is determined by Newton's laws of motion and his inverse square law relating to his presumed *in vacuo* 'gravitational force'. These laws demand that the orbital angular momentum of *P* is conserved, and that if the orbit of *P* is closed, then the trajectory of *P* is an ellipse [33]. In this way, Newton was able to explain why the planets move in elliptical orbits around our Sun, as observed by Kepler.

In complete contrast to Newtonian theory, POAMS *begins* with the premise that angular momentum is holistically conserved, so that in this simple two-body instance, the orbital angular momentum of *P* relative to *B* is constant. In the case where the orbit of *P* around *B* is *closed*, the constancy of *P*'s orbital angular momentum dictates that *P* moves in an elliptical orbit exactly as predicted by Newtonian theory [34]. To reiterate, in contrast to Newtonian theory, in POAMS the orbit of *P* is the orbit that *P* naturally follows when not subjected to any external forces or constraints, rather than a non-linear orbit caused by an invisible *in vacuo* 'gravitational' force.

We turn now to a replacement for (TD) which applies to the orbital trajectories of the freely moving particles. Let us first consider the case of the particle *P* 'freely moving' in a *circular* orbit around the body *B*, of mass *M.* We shall consider only the case in which *B* is static (non-rotating *etc*.) and ideally spherical. In this case, it can be shown that the proper time, *t*, recorded by a clock carried with *P*, is given by the following formula: [35]

$$t = (1 - 3GM/(rc^2))^{1/2}\, t_R. \qquad \text{(TD)*}$$

In this revised formula, *G* is the Newtonian gravitational constant, whilst *r* is the radius of *P*'s orbit and t_R is the time as recorded by an 'external observer' far distant from the orbit of *P*. In POAMS, this 'external time', is the zero end of the scale of time-dilations, called *deep space time* (DST) [36]. This formula provides the basis for calculations which predict that clocks in the Global Positioning Satellites orbiting the Earth should run faster relative to Earth clocks. The amount predicted agrees very closely with what is actually observed [37]. The orbital time dilation formula (TD)* is the same as predicted by General Relativity, except that in Einstein's theory, *r* does not measure exactly the radius of the orbit [38].

POAMS, then, as does General Relativity, predicts that time is dilated, not only by speed but also in the free orbital motion in the presence of a massive body. The analysis in reference 35 shows that even if *P* is *relatively stationary* in the vicinity of *B*, there is a time dilation effect given by

$$t = (1 - 2GM/(rc^2))^{1/2}\, t_R.$$

A clock on the surface of the Earth will therefore run more slowly than a clock which is not subjected to Earth's influence. However, the mass of the Earth is not large enough to have an appreciable effect on the passage of time. Specifically, the clock on Earth loses roughly 10^{-9} seconds in an hour, which is scarcely noticeable [2]. Much larger, more massive bodies will have a significant effect on even stationary clocks.

More generally, let us now consider the case in which the particle *P* moves in a non-circular orbit about the body *B*. Again, *B* is assumed to be perfectly spherical and spinless. Since *P*'s orbit is not a circle, the radial distance, *r*, of *P* from *B* depends on the angle, *θ*, which the radial axis of *P* makes with some fixed axis any at point. In this general case, it can be shown that the proper time, *t*, recorded on *P*'s clock relative to DST, t_R, is given by

$$c^2 \mathrm{d}t^2 = c^2 F(r)\mathrm{d}t_R{}^2 - (1/F(r))\mathrm{d}r^2 - r^2 \mathrm{d}\theta^2, \qquad \text{(TD)**}$$

where $F(r) = 1 - 2MG/rc^2$ [39]. This is the same formula that is derived in General Relativity, being the metric for the 'equatorial plane' of what is called 'Schwarzschild space-time' [40]. As in General Relativity, the formula (TD)** can be thought of as determining the space-time geometry surrounding a spinless spherical body. Again, as in General Relativity, it can be shown that this space-time geometry determines that a freely moving particle *P* in an almost closed orbit about the body *B* follows an elliptical orbit, the *perihelion* (the point of closest approach of *P* to *B*) of which advances very slowly in the manner of a Spirograph [41].

It can be shown that from the equations of motion for freely moving particles associated with (TD)**, in the formalism of POAMS the orbital angular momentum of *P* relative to *B* is conserved. Newtonian theory cannot produce such an orbit since such an orbit cannot be derived from an inverse square law involving 'gravitational force' [39]. In this way, the POAMS equations of motion are more general than Newton's and are able to derive at least one of the space-times projected by General Relativity.

Section 13: Stellar Collapse and 'Black Holes'

We turn now to the end point in the evolution of stars and, in particular, stellar collapse, which, according to certain theories opens up the possibility of time travel. Theory and observation tell us that certain types of stars implode at the end of their life and shrink in size towards a 'white dwarf' state, whilst others explode to form supernovas. Some theories predict that stars of a certain critical mass continue to shrink to a critical radius. In this case, General Relativity predicts that such a star will continue to collapse to form a 'space-time singularity'. This, it is said, is a region in which the fabric of space-time is literally torn apart by the enormous 'gravitational' effects caused by the collapsing star.

In General Relativity, with its interpretation of light travelling as 'photons', it is possible for light to be bent due to gravitational effects on those alleged 'particles' [42]. In the scenario of a star collapsing to a point just described, the implication is that these 'gravitational' effects are so enormous that light inside the region determined by the critical radius is so bent that it cannot 'escape' to the outside region. The physical implication of this is that the collapsed star is invisible to any external observer and hence the term 'black hole' was introduced to describe this final stage of stellar collapse [43].

As a particular example, in Einsteinian General Relativity, the external space-time geometry of a collapsing non-rotating spherical star is described, as we have seen, by Schwarzschild space-time. In this theory it is possible for such a star, given that it has a certain critical mass, to shrink in size to its *Schwarzschild radius*, $r = 2MG/c^2$ [44]. Having reached this critical radius, according to General Relativity it is possible for the star to shrink to a radius of *less* than $2MG/c^2$, so that the signs of dt_R^2 and dr^2 in (TD)** are interchanged. In this case, mathematics tells us that the radius r becomes a *time-like* variable. Since no physical effect can halt the monotonic increase of such a variable, the implication in General Relativity is that once a star has collapsed through its Schwarzschild radius, it continues to collapse to form a 'space-time singularity' at the radius $r = 0$. According to (TD)**, this is a point at which the time is infinitely dilated.

In the General Relativistic scenario of a 'black hole' just described, a freely moving space-traveller, in his own proper time, can reach the Schwarzschild radius surrounding the 'black hole' in finite time and fall in. Once he enters this region, he suffers the same fate as the collapsed star and can never return. He will be torn apart by the enormous 'gravitational' effects long before he reaches the 'space-time singularity' at $r = 0$. On the other hand, according to the clock of an external observer who remains at a safe distance, the space-traveller can never actually reach the Schwarzschild radius, since from (TD)**, time is infinitely dilated there. From this we may conclude that the existence of a 'black hole' in the above sense can never be verified by means of any physical experiment, for if an observer enters within the Schwarzschild radius to verify the existence of the 'space-time singularity', he can never return to communicate his results! In this way, the 'space-time singularity' at $r = 0$ is surrounded by what is esoterically called an *event horizon* at the Schwarzschild radius.

Before we continue, it needs to be stressed that what we say concerning 'black holes' depends very much on how such entities are defined. The original meaning of the term 'black hole', first coined by Laplace in the eighteenth century [45], was simply a name for a centre of mass so large that light cannot escape its 'gravitational effects' and so is effectively invisible. We shall take the term also as implying the existence of a 'space-time singularity' since, in our Normal Realist view, the concept of such an absurdity is in conflict with common sense. More formally, we take a 'black hole', as in General Relativity, to mean the region contained within the 'event horizon'.

It needs to be stressed that a 'black hole' is a product purely of mathematical theory, and although it generates much speculative interest, as a *meaningfully real physical* object it has no place in our Normal Realist philosophy. This is because, as we have explained, in the case of a collapsing non-rotating star, the theoretical existence of the 'black hole' can in no way whatsoever be empirically verified. In effect, the 'event horizon' conceals the singular core from any possible observation. The only observable facets of such an object would lie in any effects it might have on its surroundings, and such 'effects' may well have other logical explanations.

Be that as it may, 'Schwarzschild space-time' does produce some practical consequences. Derived in General Relativity as a specific solution of the Einstein Field Equations it provides a good model of our solar system in that it predicts physical effects which agree with empirical and observational evidence. However, it must be recalled that the same model can be produced by POAMS [39]. Although this model predicts all the observable phenomena within our solar system, and so is a good theoretical model, there is no compelling reason for supposing that this model will accurately predict what may happen at the end point of stellar evolution.

As explained in reference 39, the POAMS derivation of what is essentially the Schwarzschild metric, (TD)**, depends ultimately on the time dilation formula for circular motion, (TD)*, so that r is *greater than* $3MG/c^2$ in (TD)**. Remember that in POAMS, (TD)** amounts to the general time dilation formula along the path followed by any freely moving material particle in the otherwise empty space surrounding an ideally spherical, spinless body. Hence, in contrast to General Relativity, in which (TD)** is simply a solution to the Field Equations with no restriction on the value of r (except that it cannot be negative), in POAMS, there is a definite built-in restriction, in (TD)**, on the values of r. In other words, in POAMS, there is no reason to suppose that the theoretical Schwarzschild radius is ever actually reached in stellar collapse, let alone the predicted 'space-time singularity' at $r = 0$. This means, of course, that the same practical consequences that are claimed on behalf of General Relativity follow equally from POAMS but without any of those mysterious 'singularities' that are invoked by General Relativity. (It is worth noting, here, perhaps, that a synonym for 'singularity' is 'absurdity'.)

There are other space-times predicted by General Relativity, besides this Schwarzschild space-time, which are taken to imply the existence of 'black holes'. For example, the case of a rotating star is modelled on *Kerr space-time* [46]. In this scenario when the star collapses to form a 'black hole', rather than the enclosed 'space-time singularity' being formed as a point, there is a *ring singularity* of a particular radius enclosed within two event horizons. It is now generally accepted in General Relativity that any rotating star which collapses to form a 'black hole' will eventually settle down to a stationary state described by the Kerr solution. Moreover, the size and shape of this 'black hole' depends only on its mass and rate of rotation, not on the nature of the body from which it has collapsed: this claim is famously paraphrased as, 'a black hole has no hair' [47] [48].

Now it is not necessary for us to examine every possible theory in order to provide the Normal Realist arguments against the physical existence of 'black holes'. The Normal Realist philosophy is based firmly on observation and, as we have said, the very nature of the theoretically alleged 'black hole' prevents its existence from being empirically verified since observational communication with any outside observer is prevented by the presence of the event horizon. So when scientists claim that there is experimental evidence for the existence of a 'black hole', what they really mean is not that 'black holes' have been observed but that what is actually observed are certain phenomena which could, in theory, have been caused by the presence of a 'black hole'. So from the Normal Realist point of view, we stress that 'black holes' cannot exist as physical objects since there is *absolutely no empirical evidence whatsoever for their existence.* It is to be borne in mind, therefore, that these 'black holes' are *purely theoretical* predictions of General Relativity and that there are many alternative theories which do not predict the presence of these 'space-time singularities' [49].

The 'Holy Grail' for the believers in the existence of 'black holes' has always been the binary star system, Cygnus X-1. This system consists of a star together with an invisible companion. If one star of such a binary system were a 'black hole', then it would accrete matter from its visible companion. Theory predicts that this would form a gaseous disc around the 'black hole', which would become hot enough to produce intense bursts of X-rays. Such bursts of X-rays were first detected coming from Cygnus X-1 in 1971[50]. In POAMS, we have an alternative argument to explain the phenomenon in Cygnus X-1, based purely on angular momentum considerations – in short, that all ordinary angular momentum systems have barycentres which, in themselves, are the 'eyes' of vortices such as whirlpools, cyclones and spiral galaxies [51]. There are, of course, other claimed evidences of the existence of 'black holes', as, for example, in the case of the data supplied by the radio galaxy M87. But again, this so-called 'evidence' can be disputed on the same rational grounds.

Many physicists, then, regard the predicted existence of 'space-time singularities' in General Relativity as being, not evidence for the existence of real 'cosmic sinkholes' but rather as an indication of the fact that General Relativity is not valid at a small enough scale; for example, at the end point of stellar collapse. In other words, they regard General Relativity as an incomplete theory. We agree with this sentiment. In POAMS, as has been shown, we have argued that (TD)**, for example, may not be valid for r less than $3MG/c^2$. Also, in POAMS, space-time is ultimately discrete on a small enough, analytical scale. This addresses the widely held view that General Relativity and Quantum Mechanics must somehow be amalgamated in order to produce a better model of observed physical phenomena. Some of these physicists argue that a quantised version of General Relativity would perhaps prevent space-time singularities from occurring [52]. Many highly contrived theories, therefore, are claimed to have succeeded in reconciling the two. In contrast to these contrivances, the Angular Momentum Synthesis of POAMS includes a version of Relativity which is quantised throughout every root and branch.

Section 14: 'Wormholes' in Space-time and Time Travel

We have shown that according to our Normal Realist approach to uniform motion, time travel into the future is at least theoretically possible to a limited extent according to the time dilation formula. This possibility presents no logical or moral difficulty. But what about the possibility of time travel in the more general setting of POAMS and General Relativity?

As stated earlier, in POAMS, as in General Relativity, the space-time geometry is non-Euclidean since the path of a freely moving particle is curved. In General Relativity this non-standard geometry leads to the purely *mathematical* possibility of the existence of 'wormholes' in space-time which connect one part of space-time to another. This possibility is projected essentially because General Relativity maintains that space-time becomes so warped due to the presence of matter that distinct regions may be interconnected. This is analogous to an ordinary sheet of paper being bent so that its top and bottom touch. This idea was first put forward by Einstein and Rosen in 1935 and 'wormholes' were originally termed 'Einstein-Rosen bridges' [53]. The idea is that these twists in the fabric of space-time occur due to enormous 'gravitational effects', and so can occur only in the neighbourhood of a 'space-time singularity'. Since these 'wormholes' connect one distant *event* to another, which of course, involves time as well as space, their theoretical existence opens up the possibility of time travel, both into the future and the past! Such an idea has formed the basis of many good stories for science fiction writers and film makers alike!

Certainly, General Relativity allows the possibility, in theory at any rate, of a 'wormhole' in the case of gravitational collapse, when 'space-time singularities' are formed. In the case of the Schwarzschild model for a non-rotating 'black hole', it is not possible for a space-traveller, once through the event horizon, to avoid the 'space-time singularity'. So even if the 'wormhole' was there, the traveller would not be able to pass through. However, in the case of the Kerr model for a rotating 'black hole' it is theoretically possible for a traveller to avoid the space-time singularity and pass through a 'wormhole', thereby travelling in time as well as space [46].

We have already discussed the problems associated with time travel into the past. It is important to note, however, that even if it were possible to pass through a 'wormhole' connected to another event in space and time, this does not necessarily imply the possibility of *closed time-like curves* whereby a traveller could end up at the same point in space but back in his own past. For example, the physical laws which might enable a traveller to pass through a 'wormhole' may be such that they always restrict the traveller to arriving at an event at a point some distance away from where he starts out, so that he cannot interact with his earlier self at the same point. Some theorists have even gone so far as to suggest that there is a multiplicity of space-times sprouting from 'wormholes', so that a traveller can never end up in *his own* past!

So now, from our Normal Realist point of view let us examine this possibility of time travel through these alleged 'wormholes in space-time'. Mathematical models are clearly worthy of study in their own right and project many interesting theoretical possibilities. The problem comes when some of these theoretical possibilities are entertained as physical fact. It should come as no surprise to learn that there is no place for ‘wormholes’ in POAMS, since there is *no empirical evidence whatsoever for their existence*. In our view, even in General Relativity, they simply pose interesting mathematical possibilities of particular space-times which are solutions of the Einstein Field Equations. To interpret such mathematical extrapolations as physical fact is far-fetched to say the very least. However, in POAMS, this mathematical possibility cannot occur even theoretically. We have previously stated there are no ‘space-time singularities’ in POAMS since the various time dilation formulae are not valid at the level of quanta, where space-time is ultimately discrete, so that at that ultimate analytical level other considerations have to be taken into account, which preclude those possibilities. Even in widely supported theories, such as Quantum Gravity, the existence of ‘space-time singularities’ remains highly dubious. Without such ‘singularities’, there can be no possibility of ‘wormholes’. In General Relativity, the mathematical possibility of ‘wormholes’ occurs simply as an extrapolation of the space-time geometry which forms the basis of the mathematical model. By contrast, in POAMS, there are no such extrapolations since POAMS relies on a model based on observation, with time dilation playing a fundamental role. In other words, in POAMS there is no physical reality assigned to a ‘curved space-time manifold’ as such.

Part 4: Space and Time on a Cosmological Scale

Section 15: The Nature of Space on a Cosmological Scale

We turn now to the consideration of space and time on a very large scale – a *cosmological* scale. We have shown how time is dilated in both uniform and orbital motion. This leads to questions regarding the nature of *time* in the cosmos, but first let us consider the nature of *space* on that cosmological scale. In order to do this, we need to make clear the meaning of the word 'universe', at least from our Normal Realist point of view.

From the time of the Greek Eleatic cosmologists, the word 'universe' has been taken to mean 'everything there is' in what they conceived as an everlasting and *unchanging* (*i.e.*, overall-conserved) unity, or whole [54]. Following from this Eleatic basis, we shall take the 'universe' to mean the 'all-encompassing whole'. In other words, the universe consists of *all* the stars, planets, life-forms, interstellar debris, all energy, time and space, *etc*. e*tc.*, excluding nothing whatsoever.

Prior to the time of Copernicus, the space in which we live was thought to have a natural boundary. This natural boundary was removed when Earth was no longer regarded as the centre of the universe. Following from that time, space was thought to be infinite and everlasting. This view was reinforced by Newton's concept of *absolute space*, that is to say, infinite three-dimensional Euclidean space*.* Initially, Newton proposed that the universe consisted of a finite amount of matter situated in finite space. However, according to his universal law of gravitational attraction, in this scenario, eventually all the matter would come together to form a single 'clump'. Hence, he rejected this idea of finite space and, instead, viewed the universe as an infinite amount of matter in infinite space.

By the early part of the twentieth century, other ideas concerning the nature of the universe had emerged. For example, it was proposed that space could be *finite with an eventual boundary* or it could be *finite with no boundary* – this is analogous to travelling around the Earth and finding no natural boundary, despite the fact that the surface of the Earth is finite. This latter idea was originally supported by General Relativity. Einstein showed that the average density of matter in Newton's universe would have to be zero, so that such a universe 'ought to be a finite island in the infinite ocean of space' [55]. (Note, here, the conundrum of a 'space' existing beyond or outside the 'universe'.)

From our Normal Realist point of view, it makes no sense to attempt to create suitable models of the whole universe since we do not possess a 'universal' God's-eye-view. We cannot sensibly speculate as to whether the universe is finite or infinite since this cannot be ascertained by local observation of any sort. On the other hand, it certainly makes no sense to postulate that the universe has a boundary since, if it did, it would have to be embedded in something else. This is illogical as far as linguistic analysis goes since, as we say, the *universe* should encompass *everything* that there is.

The above arguments against the Newtonian model of the universe and for the finite but unbounded universe formulated originally in General Relativity, were based on the belief that the universe is *static*, that is, unchanging over time. Certainly a finite amount of matter would eventually collapse together in a static Newtonian universe. However, if, over time, all the bits of matter are *receding* from one another, then this need not happen. In 1929, a discovery was made by Edwin Hubble and his co-worker Vesto Slipher which led to the belief by the majority of physicists that the 'universe is expanding' over time. This negated the original General Relativistic arguments for a finite and unbounded universe. It should be noted before we examine this claim that from the POAMS point of view, a finite amount of matter may not collapse in on itself since there is no Newtonian *in vacuo* gravitational force of attraction to draw them together. Instead, the particles move in their natural force-free orbits due to angular momentum considerations alone.

What Hubble and Slipher actually discovered was that the light-spectra of the farthest galaxies are always shifted towards the red. Hubble found that this red-shift in the light's wavelength is proportional to the estimated distance of any galaxy to a good degree of approximation. Now it is a well-known observed fact that when a light source is receding from an observer, its light-spectrum is shifted towards the red, whereas when it is approaching the observer, its spectrum is shifted towards the blue. This is a consequence of the time dilation formula, (TD), and is known as the (optical) Doppler Effect [56] [57]. The natural interpretation of the majority of physicists was that Hubble's red-shift was due to a recession of the galaxies from us and from one another at an appreciable speed. This implies that the 'universe is expanding' at the present time. However, it must be appreciated that the observed red-shift in the light-spectra emanating from galaxies does not logically imply that those galaxies must be receding. The fact that all speeds of recession cause red-shifts does not imply that in observing red-shifts we are observing speeds of recession.

Many scientists argue that since, in their interpretation, the universe is expanding at the present time, it has been expanding at the same rate since time began. The argument is that there is no reason for supposing otherwise. Thus, extrapolating backwards into the past implies that some fifteen billion years ago, the whole universe of matter, space and everything that there is, including time itself, exploded into being from an initial 'space-time singularity', this event being popularly known as the 'Big Bang'. In General Relativity, there are space-times which are solutions of the Einstein Field Equations and which purport to model the entire universe. These cosmological solutions lead to the Friedmann models, which predict an expanding universe originating from just such an initial 'space-time singularity' [58]. More generally, in any cosmological model derived from General Relativity under physically reasonable conditions, an initial 'space-time singularity' is predicted to occur [59].

From our Normal Realist viewpoint, however, there can be no explanation of the Hubble redshift that is more absurd than the esoteric 'Big Bang' theory, to which there is no logical, philosophical or commonsense meaning. Once again, in General Relativity this prediction follows from an extrapolation of the Field Equations by many orders of magnitude beyond the range for which its validity has been established. We have to be extremely cautious, therefore, of any mathematical prediction based on such an extrapolation, and in no sense can anyone claim that these equations actually represent physical reality. However, incredibly, there have been models produced that claim to give a true picture of the universe, moments after the 'Big Bang' [60]! It is these 'hot universe' models that predict the existence of a 3^{o} K microwave background radiation at the present time, being the remnants of the alleged 'cosmic fireball'. However, these models do not satisfactorily explain why, for instance, this radiation is observed to be nearly the same in all directions.

Nevertheless, a large number of physicists argue that the existence of the isotropic microwave background is observational evidence which supports the 'Big Bang' theory. This radiation was first discovered by Penzias and Wilson in 1965 [61]. However, although the presence of this radiation may be consistent with an initial explosion, it certainly does not imply that there really was one. Like all observations, it is a matter of speculative interpretation, good or bad. Besides, there are certainly other much more plausible explanations for the presence of the background radiation which do not involve a 'Big Bang' [62] [63]. Since the 'Big Bang' is in no way *directly* observable, we would argue, especially from our adopted phenomenalist perspective, that it makes no sense to discuss it as though it were an actual physical *phenomenon*.

The view, then, that the universe exploded into being from an initial 'space-time singularity' is bizarre to say the least. It has to be realised that this view is based on many different assumptions, any one of which may be false. Certainly the simplest and, seemingly, most 'obvious' interpretation of the Hubble red-shift is the generally adopted one of a Doppler Effect due to galactic recession. However, as we have said, there is no *logical* reason why the red-shift needs to be interpreted in that way. Another possible interpretation from the POAMS point of view is that the red-shift is the effect of relativistic time dilation due to relative motion, which increases with distance [64]. Like the Doppler Effect, time dilation shifts the frequencies in a light-spectrum, *en bloc* towards the red. However, unlike the Doppler shift, time dilation applies not uniquely to recessional motion but to all motions in any direction whatsoever.

But now let us just suppose, for the sake of argument, that the galaxies are actually receding. From a linguistic point of view, there are great difficulties in interpreting this to mean that 'the universe is expanding'. Since we have defined the 'universe' to be '*all* that there is', then against what may we presume to record its alleged 'expansion'? Since there is nothing outside it, not even empty space, then what can that 'whole universe' possibly be expanding into? From our Normal Realist standpoint, since this implication of cosmic expansion makes no sense, any extrapolation from it concerning the 'geometry of the universe' is just speculative nonsense. Anyway, to assume that the galaxies are receding is to assume that the magnitude of the orbital angular momentum of the galaxies overall is somehow increasing, which, from our POAMS perspective, since angular momentum is holistically conserved, such an overall expansion would be difficult, if not impossible to explain.

One solution of the problem of cosmic expansion is provided by the steady state model, first proposed by Bondi and Gold [65] and independently by Hoyle [66]. In this model, it is accepted that the galaxies are receding but that this is due to more matter being continuously created in order to maintain the constant density of the observable galactic collection. So, although in this view the galaxies are continually receding, there was no initial 'space-time singularity' such as the 'Big Bang'. However, even though the full implications of this particular steady-state theory are far from complete, its predictions of both the expansion and the continuous creation of matter are already unempirical. That is, we neither see the universe expanding nor observe matter being created.

Even if we suppose that the galaxies are receding at the present time, there is no reason to suppose that they were receding at the same rate in the past – or, of course, even receding at all. The huge extrapolation back into the past to a primordial 'Big Bang' is generally based on physical assumptions which may not hold. For example, it has been assumed that any collection of observable galaxies is *homogeneous*, *i.e.*, has uniform density and is *isotropic*, *i.e.*, the number of stars per unit solid angle is the same in all directions. However, this need not be the case. In fact, more recent observational evidence suggests that the galactic collection is not homogeneous but fractal [67] [68].

In our view, then, in predicting an initial 'space-time explosion' which created the universe, General Relativity simply reveals its own theoretical limitation. The prediction of such a 'singularity' – literally an absurdity– implies that the theory is not valid on that point. Indeed, as in the case of a 'black hole', Hawking has now argued that the possibility of such a 'singularity' vanishes when quantum effects are taken into account [69].

Section 16: Time on a Cosmological Scale

We have seen that it is not only the time allocated to an event but also the *duration* of any process that is relative to an observer. At first sight, therefore, it makes no sense to talk about the 'age of the universe' since there is no *absolute time* in the sense of Newton. For example, the information that we receive from the furthest star cluster visible from the Hubble space telescope, shows us *right here and now* objects and processes whose atomic clocks lag several thousand million years behind ours. (In Normal Realism, as we have seen, this is not to be confused with the customary idea of 'the speed of light' as a space-travelling conveyor of that information.)

Certainly, from a purely mathematical point of view it is possible to introduce a commonly measured time on the cosmological scale, usually known as cosmic time [70]. From that mathematical point of view the universe consists of all possible events in space-time at all possible cosmic times. In POAMS, however, the only 'cosmic time' it makes sense to speak of is our Deep-Space Time (DST). As already explained, this is the datum time which, like the temperature of zero degrees Kelvin, is the zero of the scale of all time-dilations, *i.e*., the proper-time registered by a theoretical clock situated relatively motionless at a theoretically infinite distance from other masses.

But now let us think: if all the observational times of the various possible observers throughout the universe differ, then where, in all this, is the 'present moment'? The answer Normal Realism gives is that when a particular event such as a star exploding occurs, it is the proper time of that event *as we see it* which registers, at the level of quantum instantaneity (see above), the present moment both here and at that star. That is to say, at the level of quanta, the moment at which that star explodes is the same for both the star and ourselves. But, of course, different *relative* times will be allocated to this same moment by different observers. This is due to time-dilation caused by relative orbital motion between those observers, mass differences and so on. It means that the only cosmic present moment we can sensibly speak of is our own individual, instantaneous observational cross-section of the whole collection of events whose relative times are different.

It is, then, only within the context of this viewer-projected temporal cross-section that we are able to consider the question of the 'age of the universe'. Certainly before the twentieth century, it had always been assumed that the universe was absolute and unchanging in its own cosmic time: that it had either existed for all time in this state or else had been created in this state at some finite time in the past. This notion of a universe being 'created' at some finite time in the past inevitably suggests the existence of a 'creator'; in other words, some kind of divine Prime Mover. This was a problem for some Greek philosophers, including Aristotle, who believed that 'the world' and the human race had existed and would exist for ever, which removed any question of its 'creation' and, of course, a 'creator'.

This question of whether or not the universe had a beginning in time has been pondered by philosophers throughout the ages. In the eighteenth century, Kant argued that there was no more logical reason for supposing that the universe had a beginning than that it had not. He argued that there is no logical difference between having an infinite period of time before any event, as in the case of the universe having no beginning, and the universe having a finite-time beginning [71]. In that case, there would be no need to postulate any initial 'singularity'. However, as already discussed, with Hubble's discovery of the red-shift in the light-spectra from galaxies comes the facile inference that the galaxies are receding, hence that the universe is expanding and therefore evolving over time, regardless of whether or not there was an initial 'space-time singularity'. Now in General Relativity nothing is incompatible with the *static block* conception of time. (Recall, here, that the static block, or Eleatic view, maintains that all moments in time are equally real and determinate and that all change is merely apparent). However the concept of the universe expanding, hence evolving, in cosmic time is, of course, a *dynamic* model of time: that is, the Heraclitan view that it is change that is real and that constancy is only apparent. This latter view is that of the universe in a truly universal 'tide of becoming' [72]. However, due to the linguistic problems stated earlier, from our Normal Realist standpoint, there are problems with both of these static and dynamic views of time in presuming to extend the present moment as experienced locally to the 'universe' as an objective whole.

As already discussed, one of the possible implications of an expanding universe is the one which is most popular these days, namely, that the whole universe began with the 'Big Bang' from an initial 'space-time singularity'. On this premise, it is possible to extrapolate backwards in cosmic time to the 'Big Bang' to determine the finite 'age of the universe'. One of the problems associated with this view of the 'Big Bang' is the question of cause and effect. What could possibly have *caused* this event to take place? General Relativity gives no answer to this question since in that theory the universe *began* with the initial singularity and the theory is not valid for considering anything prior it. A possible answer of course, would be that the 'Big Bang' of cosmic creation was caused by divine intervention. In fact, in 1951 the Catholic Church officially pronounced the 'Big Bang' model to be in accordance with the Bible. Some people have argued that the physical laws which hold in the universe must have been originally decreed by a creator, since there had to be precisely the right physical conditions in the 'Big Bang' for the creation of a universe capable of sustaining intelligent life, which, in turn, is capable of interpreting those laws. However, a model for the beginnings of the universe first proposed by Linde in 1983 indicates that there are all sorts of different initial conditions for the 'Big Bang' that could have produced the universe in its present form [69].

As stated in the last section, since the advent of quantum theory, many highly respected theorists have concurred that General Relativity in itself fails to describe the early stages of its implied 'initial space-time singularity'. For them, this means that the theory needs to be supplemented with what has become known as 'Quantum Gravity', thus taking quantum mechanical effects into consideration [69]. From this, many attempts to unify quantum theory and General Relativity have followed. For example, Milne's theory of cosmology attempted to unify these two theories and included a non-constant value for the gravitational constant, G, over cosmic time. The prediction of Milne's cosmology was that of a static universe of infinite age, which prediction acted as a precursor of the steady-state theory, referred to in the last section.

Once again, from our Normal Realist perspective, it makes no sense to speculate as to whether the universe began at some time in the past and has evolved to its present state over a finite period of cosmic time, or whether it had no beginning. We can never ascertain by empirical evidence which alternative is correct, so that there is no advantage in speculating about such things. What we can definitely say is that, from our point of view, it is illogical to contemplate the possibility of time travel into the past as far as cosmic time is concerned. This is because it seems undeniable that whatever has happened can never be un-happened. For instance, it is difficult – one might say impossible – to think that if our Earth, with ourselves and all natural and human history were wiped out, say, by the Sun turning into a supernova, all those events that have happened on Earth were somehow cancelled, so that they never took place. To reject this nihilistic possibility is logically to conclude that whatever we were, whatever we may have done in this life will, in a sense, forever remain. One obvious sense in which this permanence may be conceived is that in which those events are items in the memories of surviving witnesses to those events, or in some recorded history, in libraries, carvings, fossils in rocks and so on. However, in our example of the Sun becoming a supernova, all those records would certainly be annihilated, yet it is difficult to think that even this would un-happen those events in themselves, that it would somehow make them never to have occurred.

This leads to a fundamental question: in what sense can past events or happenings be thought of as *existing*, especially in their known chronological order? Histories may be true or false, whereas, according to our premise, events that have truly happened, in this 'immortal' sense, have to be *absolutely* true, regardless of whether we know it or not. Extending this 'permanence' to all observers and all objects everywhere suggests a whole universe evolving in some all-over, *absolute* sense. The present moment, then, is the point in that dimension at which objects and observers physically interact with one another – that is to say, when things actually *happen*, after which everything remains unchanged and unchangeable in cosmic history. The point at which we can intervene in things, to however small or large an extent, is the 'cutting edge' of that advancing history as it evolves among an unimaginably large host of interacting point-centres, like innumerable strands on a cosmic loom from which the rich tapestry of our natural existence is woven.

Part 5: Time in Relation to Mankind and Society

Section 17: Time at its Dynamical 'Cutting Edge'

The relatively small extent to which we have the freedom and responsibility to control events – to 'make history' – naturally raises the question of *responsibility* for our actions. This leads in turn to the question of moral judgement; hence, for many people, the question of whether there is some great Judgemental Being. This Being, like ourselves but on a prodigiously larger scale, is in control of things and with whom or what we might have meaningful communication. As a matter of fact, this is the common assumption underlying all the various world-religions. Of course, whether or not such a Being exists remains an open question. But at least, our information-based, Normal Realist approach to physics removes all grounds for assuming that scientific reason makes atheism obligatory. This disposes of the incipient 'God of the Scientists', with its presumed absolutistic and ubiquitous overview of the universe as a determinate mechanical whole. What replaces it is an altogether more humane concept of 'the powers that be' to which it makes sense to make supplication in the form of prayer. (Quite obviously, it makes no sense to pray to a Machine!)

Such, then, we believe, is the nature of time, which is in no way mechanically or otherwise predetermined. What allows us such freedoms as we have to choose and deliberate our actions lies in indeterminacy, or the looseness, of events at the fundamental quantum level. This gives is the freedom which makes us responsible, for our actions as much as our inactions, with no possibility whatsoever of 'opting out' of the inexorable temporal process. Whatever is done is done, permanently, and there is no going back on it. If we judge that some action we have taken is one we regret, then at least, for so long as we may survive, we have the freedom to take further actions to 'atone' for it in some way that is more to our liking and that, perhaps, of our neighbours.

As for the prospect of 'time travel', we have seen that there can be no causal intervention from now into past history. The only way in which we can 'travel in time' is by travelling in space, by means of which we may 'overtake' one another as 'time-slides' in the manner of the twins in the relativistic non-paradox situation. It may fairly be said, then, that the Synthesis known as POAMS includes not only all forms of angular momentum but also most of those commonsense conceptions of space and time which lie at the root of our social history. This, of course, involves moral responsibility, together with those ideas of 'eternal verities', such as Truth, Justice, Goodness and so on, without which no human society can function, or even survive. Included in this is always, at its utmost fringes, *religion* in some form or another. Of course, the question of whether these 'verities' extend universally and whether any of our traditional religions apply beyond this miniscule planet of ours, can be answered only in terms of pure belief. So far as POAMS is concerned, it is scarcely credible that, say, either the Christian, the Muslim, the Hindu or any other terrestrial religion holds throughout the whole manifold of other societies that there must surely be in the immensity of galactic space.

Nevertheless, one definite 'eternal verity' which seems non-arbitrary is that of Truth. For instance it is a complete contradiction to claim that there is no such thing as truth and then claim that this statement is true. This means that the existence of truth is literally undeniable. Next is the verity of freedom for any complex organism whatsoever to 'make history' in its own right and enjoy or suffer the consequences of its decisions. This implies some measure of responsibility among any terrestrial or extraterrestrial social organisms for their actions, which may be judged 'good' or 'bad', 'right' or 'wrong', 'just' or 'unjust', *etc. etc*. analogously with our society here on Earth. This entails something cosmical akin to what, in the language peculiar to this planet, we call 'religion'.

Beyond this, any question of the 'correct names' for these religions and their associated deities, becomes completely nonsensical, as is doubly so in warring with one another over the choice of these names. To realise this should curb some of the excesses of those priests of the various religions who, from their standpoint of human finitude, presume to speak on behalf of the infinite. Normal Realism is fully cognisant of this finitude in our scientific endeavours to understand nature, and repudiates dogmatism of any kind. Its basic synthesis, then, is not only of Relativity and Quantum Theory but also of Physics, Philosophy, Cosmology, Commonsense, the Humanities – and even Theology. This is, surely, the broadest we can manage in terms of our knowledge of nature at this present time. All this, of course, is intimately connected with our views as to the nature of time in relation to ourselves, our society and the cosmos.

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