

THE IDEA OF A COSMIC TIME

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***Introduction
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***This paper was written in honour of Franco Selleri,
faithful defender of reason in physics, who committed his efforts to
"the liberation of time from the enslavement to space".***

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Pointing to the cleft between the idea of a *temporal evolution*, central to *modern biology*, and the idea of the *timelessness of reality* derived from the relativization of simultaneity and followed by the fusion of space and time into space-time, both fundamental to *modern physics*, the paper demonstrates that the standard definition of time at a distance is beset with ambiguities that might be solved by making a fresh start which takes its point of departure in the idea of a *Cosmic Time* as proposed by the British Tradition of relativistic cosmology.

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1. INTRODUCTION

In a special issue of *Scientific American* dedicated to *time* (vol.287 no.3, september 2002) a notable sceptic makes fun of the fact that smart people often believe weird things. The innocent reader may be surprised to learn that this ironical remark - targeting at phenomena like astrology, clairvoyance, magnetotherapy, and ufology - is also applicable to some of the allegedly 'scientific' views which are promoted in that issue, such as the opinion reported below.

Scientific American is generally acknowledged to be a serious magazine and Paul Davies, scientist of high repute, is considered to be one of the more reliable mediators of modern physics. Nevertheless Paul Davies makes himself a spokesman of the opinion that, from the point of view of science, the idea of *temporal flux* is nothing but an illusion. He even tries to underpin this view by appealing to the special theory of relativity, invoking the creator of that theory as his main witness. Indeed, Einstein made a queer attempt to comfort the widow after his deceased friend Besso by reminding her of the delusive character of all temporal phenomena!

In contradistinction to physics, which is clearly neither capable of explaining what it means that "time is passing" nor qualified to ascribe a direction to "the arrow of time" (a felicitous phrase coined by A.S. Eddington), there is a large number of other sciences which not merely presuppose the passage of time, hence also its direction, but which in their own way prosper by describing it. At the same time it is equally clear that these historical disciplines - whether they belong to the arts and humanities, or to the social or the natural sciences - would lack all scientific legitimacy if the metaphor of *time-in-flow* could be shown to be meaningless or indefensible.

Turning our eyes towards a science like biology, it is immediately evident that something as fundamental as the doctrine of natural evolution must appear completely nonsensical, devoid of any rational meaning, if the very notion of time's passage cannot be accorded any scientific status. That it cannot is argued by J. Barbour in his book *The End of Time* (1999) which I take to be the final apotheosis of Einstein's programme: to reduce everything in physics to "spacelike concepts". It is paradoxical and highly problematic that the most recent results of natural science force us to choose between physics and biology (Barbour's own way of "solving" their manifest incompatibility, of course, is totally unacceptable). But a similar conflict can be found within physics.

Provisionally accepting the view that modern cosmology began with the general theory of relativity and peaked in the scientific dogma of a big bang it is not only conspicuous, but indeed sensational, how radically the prevailing cosmological paradigm is contradicted by the tendency to deny the physical reality of time. According to the big bang hypothesis our universe originated some 14 billion years ago in a huge explosion that marked the absolute beginning of time ($T=0$). But the arguments against time, which in antiquity were provided by the philosopher Parmenides and his ally Zeno, are nowadays derived from ... Einstein's two theories of relativity!

Hence, according to the unanimous verdict of modern cosmology and biology, everything we observe or experience today, including ourselves, is just the prolonged effects of an evolution that was initiated by the creation of the universe which happened about 14 billion years ago. Nevertheless, referring to the authority of Einstein, certain physicists want to persuade us not just that the passage of time is an illusion, but that the very concept of time lacks all scientific foundation!

The question is: How can we thrust a science that not merely denies what everyone is capable of observing from instant to instant, but which also is in blatant conflict with itself?

2. EINSTEIN ON TIME

In order to throw new light upon all these problems we shall have to reconsider the ideas about time in physics which dominate the heritage from Einstein. How was Einstein's own view? To the philosophical question *What is time?* he responded as a scientist by neglecting philosophy, appealing to what everyone can see by observing a watch, viz. *clock-readings* (numbers marking the counting of time). This answer, of course, is just as ingenious as it is natural and simple.

However, his answer says nothing about the difficulty of deciding whether the observed clock shows the right time. Still less does it inform us about the crucial problem which is this one: how do we mark off a clock that works from one that does not? This, of course, is the condition for deciding whether a clock tells the right time, since a standing clock is "right" once or twice a day. But in consequence of his response, as mentioned above, Einstein simply determined the time of an event as the number immediately read off a clock closely associated with an observer.

From his considerations as described in several publications one can, however, deduce the following distinction: 1) if the observer is close to the event, his reading represents its *local time*, 2) if the observer is far from the event, his reading represents its *time at a distance*, which may be compared to its local time by a calculation taking account of the finite value of the speed of light. That the speed of light seems to be independent of the motion of its source is here decisive.

Now scientific objectivity hinges on the independent verification of data by several observers, so Einstein assumed that all observers agree to calculate time at a distance using the same method. He furthermore prudently stressed the obvious fact that any rational comparison of clock-readings, or epochs, necessarily presupposes that the clocks concerned all go at the same rate (1952 ch.viii): "It (is) assumed that all these clocks go at the same rate if they are of identical construction".

The statement quoted is remarkable for other reasons than its admission of a flowing time: it is put forward before the definition of simultaneity, but after the introduction of the famous train-experiment where train and embankment are struck by two lightnings; and the succeeding argumentation aims precisely at showing that if the two flashes are assumed to be simultaneous with respect to the embankment as a frame of reference they cannot also be supposed to be simultaneous relative to the moving train as a frame of reference, and vice versa.

The clocks referred to belong partly to the train, partly to the embankment, two frames in relative inertial motion, and the statement just quoted therefore concerns clocks in relative motion. It is these clocks that are assumed to be of identical construction and hence to keep the same rate.

In other words: *the special theory of relativity, including its suspension of the classical concept of simultaneity, explicitly relies on this premise concerning clocks in motion that not only do they go, thereby indicating the flow of time, but being identical they even keep the same rate!*

It is precisely on account of this premise Einstein can claim that correctly synchronized clocks will mutually appear to be retarded relative to each other, and that correctly calibrated rods will mutually seem to be contracted relative to each other, both as a consequence of their relative motion!

From Einstein's interpretation of LT (i.e., the Lorentz transformations which constitute the mathematical contents of the special theory of relativity) it follows that the contraction will disappear if the motion is brought to a halt whereas the retardation, being one-sided, leads to an absolute effect. In this way we are confronted with a seeming paradox: a theory which is explicitly based on the premise that all clocks involved are of identical construction, and hence keep the same rate, entails the result that moving clocks do not count the same intervals of time after all!

Mathematically the theory is consistent. Physically it is supported not merely by numerous experiments, but even by the most diverse kinds of experiment. It therefore seems impeccable.

Nevertheless it is reasonable to make the following reservations: 1) No theory contains more truth than the premises it is based on; hence mere lack of contradiction is a necessary but not a sufficient condition for scientific truth. 2) Although a theory may be falsified conclusively, it can never be verified conclusively; therefore no kind of observational support should ever be taken to exclude the possibility that other premises might lead to even more plausible consequences.

How can we tackle the fact that an apparently impeccable theory can be so full of paradox? In order to comprehend this we have to probe for a fuller understanding of Einstein's two theories. Making this effort we shall disclose a serious ambiguity inherent in his definition of time.

STR (i.e., the special theory of relativity) is based on two pillars: (1) the relativity principle, stating the impossibility of determining any absolute motion or rest; (2) the light speed principle, stating the universal constancy of the speed of light, independently of the motion of its source. According to the relativity principle, all inertial observers and their reference frames are equivalent with respect to a scientific description of the laws of nature. According to the light speed principle, light is transmitted with equal speed in all inertial reference frames, irrespective of its direction. The theory is termed 'special' since it is restricted to the consideration of inertial observers which are assumed to be uninfluenced by acceleration/gravitation. GTR (i.e., the general theory of relativity) is based on (3) the principle of equivalence stating the identity of acceleration and gravitation.

In both theories reference frames are in focus. What is understood by a frame of reference? In the first place, frames of reference are abstract entities and thus immaterial; they are conceptual constructs which do not inhere in nature. However, since their geometrical structure is determined by the presence or non-presence of matter they are often treated as if they had a material existence. The general theory is reducible to the special theory when the influence of gravity is negligible; this proves the construction of inertial frames to be prior to the construction of accelerated ones. But the construction of inertial frames involves the notion of time at a distance.

In his famous paper to *Annalen der Physik* (1905 I §1), Einstein made it clear to his reader that our concept of time at a distance, or simultaneity, is based on a definition. Now a definition is chosen because it is convenient and serves a purpose; definitions therefore possess no truth value. But the definition of simultaneity is important, indeed fundamental, since, according to Einstein, "all our judgments in which time plays a part are judgments of simultaneity".

How, then, did Einstein define his concept of simultaneity? He imagined two observers, each of them provided with his own clock, being involved in a steady exchange of light signals, each signal containing information about the clock-readings read off the other observer's clock. Granted that a signal goes zig-zag between the two observers, its reflection being instantaneous, the light speed principle seems to imply that its journey out and home must be of equal duration. It therefore seems rational to define the epoch of reflection as half the sum of the epochs for the emission and the reception of the reflected signal, i.e., as the arithmetic mean of those epochs. This, precisely, is the famous Einsteinian definition of simultaneity, or time at a distance.

In his seminal 1905-paper, Einstein wrote: "We assume that this definition of synchronism is free from contradictions and possible for any number of points", and added the following assumptions

- 1) If clock *A* is synchronous with clock *B* then, likewise, clock *B* is synchronous with clock *A*.
- 2) If clock *A* is synchronous with clock *B*, and clock *B* is synchronous with clock *C*, then clock *A* is also synchronous with clock *C*. In this way *clock synchronism* is both *reciprocal* and *transitive*.

In his later presentation (1952 ch.viii, footnote) he commented on the transitivity assumption: "This assumption is a physical hypothesis about the law of propagation of light; it must certainly be fulfilled if we are to maintain the law of the constancy of the velocity of light in vacuo".

Einstein thus admitted that the light speed principle is closely connected to the definition of clock synchronism; in fact so intimately that the principle makes no sense except when interpreted on basis of the transitivity of simultaneity! However, it is precisely the transitivity of simultaneity which is then jeopardized as a consequence of STR! The point is that the Lorentz transformations, according to Einstein, should be interpreted so that the transitivity of simultaneity holds good only *within* each single inertial frame, whereas it does not hold for comparison *between* such frames.

From the footnote quoted it would seem to follow that the light speed principle is likewise solely valid for the transmission of light *within* a single inertial frame, whereas it is not valid for the comparison *between* inertial frames! This would further seem to imply that the principle can be applied to no more than a single reference frame at a time, not to several frames simultaneously! Hence data referring to more than one frame at a time would seem to be outright incomparable.

Einstein certainly did not doubt that the speed of light must be the same relative to all frames. Apparently he never confronted the issue whether the same photon (whatever that may possibly mean) can maintain the same speed with respect to two different inertial reference frames at the same time (a remarkable feat) or whether the speed of a photon is only constant relative to that frame within which it is observed. However, the situation is going to be worse, still, before it can get any better.

Of course, Einstein did not give up synchronizing the master clocks of different observers. No, he just tacitly synchronized such clocks in another way, by a completely different method! Naturally, physicists need to compare data referring to different inertial frames in relative motion. According to Einstein, the possibility of the comparison of clock readings referring to different frames is guaranteed by the identical construction of the clocks involved. From the light speed principle it then follows that their measuring rods can be properly calibrated so that we can speak of identical meters.

However, this is not sufficient for a rational comparison of clock readings. The observers must also agree on marking off a certain event as signifying the common time zero for their calendars. If the observers ever meet, the event of coincidence will be their natural choice (and if they do not, one of them, or both, could elect an *alter ego* at some fixed distance who does meet the other).

We will now disclose the ambiguity in Einstein's definition of time. It turns out to be intimately connected with the conventionality of the choice of time zero and is reflected in the fact that while we can speak of the instantaneous *coincidence of observers*, taking this as their common time zero, we can only speak of the *coincidence of frames* if it is not instantaneous, but remains permanent. This is the reason why we must distinguish between *proper time*, as shown directly by *the master clock* of a particular observer, and *frame time*, as read off *some slave clock* fixed to his comoving frame. Master clocks are synchronized differently from slave clocks.

The ambiguity, then, inherent in Einstein's definition of distant time, or simultaneity, is this: While he *explicitly* defined *simultaneity within frames* by taking *the arithmetic mean* of the epochs of emission and reception of a reflected light signal, using the master clock of a single observer as a standard for calibrating the readings of his comoving cloud of spatially distributed slave clocks, he *implicitly* defined *simultaneity between frames* by using *the geometric mean* of the very same clock readings, now in order to calibrate the readings of the master clocks of different observers ("a frame" is "a cloud of clocks" associated with an observer; cf. Popper on "clouds" & "clocks").

Small wonder, therefore, that the slave clocks at rest in the comoving frame of one observer are seen to be advanced relative to the master clock of another observer (why not state the facts this way?). The master clock of some particular observer will always *appear* to be retarded with respect to the slave clocks that are fixed to the comoving frame of another observer. But that, of course, does not entail that the master clock of the first observer will deviate from that of the second one.

The argument does not hold good if we compare the master clocks of two moving observers. When properly synchronized, the master clock of an inertial observer can never be retarded relative to the master clock of another inertial observer if only their relative motion remains inertial and collinear. That this is so is simply a necessary consequence of the very definition of master clock synchronism: if the clock of one observer deviates from that of another, one of the two is not a master clock.

A theory of time keeping was outlined by E.A. Milne, 1948, together with G.J. Whitrow; cf. the analyses in Stephenson & Kilmister 1958, H. Törnebohm 1963, and S.J. Prokhovnik 1967. Their method, the so-called radar method, is summarized in the so-called *k*-calculus of H. Bondi. The *k*-calculus can be used to show that the observed retardation of moving inertial clocks originates from different definitions of simultaneity, different methods of synchronization.

Such methods, just like the definitions they are based upon, are purely conventional, as stressed by H. Poincaré (precursor of Einstein, and first to invent the formalism of STR, cf. E.T. Whittaker, 1953, G.H. Keswani, 1964f., and H.A. Lorentz, 1921). So the claim that moving clocks cannot agree is based on convention. The problem is different, however, if the clocks involved are no longer inertial.

The fact that mesons from cosmic radiation penetrate far deeper into the atmosphere of the Earth than possible if the product of their mean life times with the speed of light is taken as a limit in itself shows nothing about meson life-times being protracted due to a relativistic retardation of their internal clocks. When considered in isolation, such observations can equally well be explained by some kind of Newtonian theory allowing the occurrence of so-called super-luminal velocities.

It may still be objected that the observations should of course be interpreted in the light of our knowledge that the velocity of light constitutes a natural limit to the velocities of material bodies. But to this it can be retorted that the speed of light may well constitute a natural limit to all kinds of signals, including moving bodies, without its numerical value being kept constant between frames.

The point is that, in addition to the distinctions mentioned above, we need to make a further one between *the one-way light speed*, which relates to its propagation between a source and a sink, and *the two-way light speed*, which is the mean light speed to and fro for a reflected radar signal. It is indeed easy to see that *a variable one-way light speed follows directly from STR if the theory is rewritten in terms of Törnebohm's absolute coordinates*, although he did not do the job himself; and by the same procedure all traces of time dilatation and length contraction can be eliminated.

For my own, I have made a hard attempt to work out a new theory of relativity in line with Törnebohm's and Prokhovnik's non-standard interpretations of STR. The idea was to combine a variable one-way light speed with a constant two-way light speed and, in accordance with this, to construct a new unitary expression for time at a distance which in some cases is reducible to the arithmetic mean and in other cases is reducible to the geometric mean; see Wegener, 1995.

Interestingly, this theory pulls the teeth out of de Sitter's proof for the one-way light speed independence of the proper motions of binaries. However, just like STR, the theory seems unable to explain the experiment of Sagnac. One might therefore consider the possibility of returning to the theories of Poincaré and Lorentz, cf. J.S. Bell, 1986, and F. Selleri (homepage R38).

3. THE BRITISH TRADITION

The British tradition in relativistic cosmology is represented by E.A. Milne, A.G. Walker, and G.J. Whitrow. All the three were mathematicians, a fact also characterizing their approaches. Milne created the theory of kinematic relativity which was developed expressly as an alternative to the two relativity theories of Einstein. His ambition was to construct a mathematical cosmology by formal deduction from a few definitions and principles; and the outcome, which is extremely ingenious, exploits the radar technique in generalizing STR into a full fledged cosmology.

Walker developed kinematic relativity further so that the theory was no longer exclusively associated with Milne's own world model (which is one of uniform or inertial dispersion from a transcendent point-event, a kind of imaginary "big bang") but, like GTR, became a mathematical technique applicable to a whole range of world models, viz. those that are subject to the property of cosmic isotropy. The *Robertson-Walker metric* (RWM), incorporating the *principle of cosmic isotropy* formally, is still the most important instrument of mathematical cosmology.

Whitrow gave important technical contributions to the development of the radar method. During a longer period he worked on kinematic relativity as the assistant and colleague of Milne. He also became renowned for his inquiries into the history and philosophy of time as reported in his monumental *The Natural Philosophy of Time* - a work which turned out to provide important inspiration for the later founding of *The International Society for the Study of Time* (ISST, 1971). All members of the "kinematic league" were inspired, directly, or indirectly, by Poincaré.

In 1905, some few weeks before Einstein published his STR in the *Annalen der Physik*, the great French mathematician and philosopher of science H. Poincaré published an equivalent but formally more advanced theory in the *Comptes rendus*. In this paper he pointed out that the assumed invariance of light speed makes it possible to unify time and space by making spatial intervals definable in terms of temporal ones, and so he foreshadowed that the idea of *light-time* would do away with the use of the "rigid rod" as a standard of distance. This prophecy was fulfilled with the invention of the *radar technique* in GB shortly before WW2. In another paper he suggested the possibility that the temporal coordinate does not represent "true time", so that time may after all be universal.

Today the *meter* is defined as the path travelled by light in vacuo during $1/299792458$ sec, whereas the *second* is defined as 9192631770 periods of the radiation corresponding to the transition between the two hyperfine levels of the groundstate of the caesium 133 atom (CGPM 1983/1967). The significance of *the radar principle* is unique. Not only is it used in nature by bats and dolphins, but today we can measure the radar distance to a nearby planet with a precision down to centimeters. However, the theoretical importance of the definitions adopted far overshadows their practical one: by stripping the presumed fundamentality off the idea of space they flout the opinion of Einstein that "(physicists) endeavour in principle to make do with 'space-like' concepts alone" (1952 app.v).

In 1929, the astronomer E. Hubble discovered a systematic redshift of spectral lines in the light from distant galaxies. This redshift is usually interpreted as a sign that the galaxies are all receding from each other with velocities which are approximately proportional to their distances. Unless our own galaxy is so privileged as to occupy the very center of the universe, his discovery implies that the system of galaxies is not static, but rather subject to a sort of universal dispersion which has no definite center since any galaxy, or galaxy cluster, can be said to constitute its center. This dispersion is often described as an "expansion of the universe", but should rather be described as a simultaneous and proportional expansion of all distances between (clusters of) galaxies.

In 1965, the physicists Penzias & Wilson observed a strange radio noise that was produced by a highly smooth background radiation coming in from the most distant parts of the universe. The radiation, having a temperature of about 2.7 Kelvin, showed a so-called black-body spectrum. This fact has been interpreted as a proof that the universe originated almost 15 billion years ago in a huge explosion, the "big bang". There are, however, also other ways of explaining the observation, such as re-radiation of stellar light from interstellar grains of carbon (graphite), or spontaneously emitted radiation from a so-called zero point field; cf. Narlikar 1980. What may be said for certain, however, is that both observations clearly show universal space to possess no privileged direction. This fact puts great importance to RWM as the standard metric of the universe.

Milne died in 1950 without ever accepting the RWM, but this does not make his work obsolete. As a nominalist he realized that reference frames are not real things or entities inherent in nature, but abstract constructions of the human intellect; so he asked the question how to construct them. He felt foreign to Einstein's pseudo-metaphysical idea that there is an immanent structure of space. Instead he followed the lead of Poincaré to whom geometry was a construction of the mind made to the purpose of the co-ordination of data, the numerical outcome of experiment and observation.

It is here natural to make a comparison with the choice of geodesic projection in order to obtain the most convenient description of the landscape of a curved surface, such as that of the Earth. Our choice of metric is free, but turns out to restrict our possibilities of description in definite ways. Reality is not to be found in the frame itself, but rather in the data inserted into the frame.

J. Merleau-Ponty, in his book *Cosmologie du XXme Siecle* (1960), compared Milne's world model to *a monadology translated into mathematics*. The German philosopher and multi-genius Leibniz assumed physical reality to be analyzable into certain metaphysical entities called monads. According to Milne, an observer - like a monad - is simply a temporal series of experiences, or events (but he explicitly abstained from "spatializing" this series into a world-line in so-called 'space-time'). Any single observer he assumed to be provided with two instruments: a clock, and a theodolite.

Milne's definition of a clock was purely mathematical, viz. a one-one relationship between the series of events constituting the observer and an ever increasing series of numbers. That an observer is provided with a clock, therefore, to him just meant that he is able to count his own experiences! This puts Milne on a par with A. Mercier, according to whom a clock is an instrument for the counting of time, not for the measuring of time. Since durations can be counted and compared, but not measured, duration cannot pass as a basic concept. Hence, if questioned, both Milne and Mercier would probably have to discard the metaphysics of H. Bergson which is based on the idea of *durée*.

It is clear that the idea of a mathematical clock sketched above does not bring us very far. So Milne attacked two problems of time-keeping: 1) How decide whether two clocks go at the same rate? 2) How determine whether, considering an entire set of clocks, all keep the same rate?

His method for their solution was based on the radar principle which was discussed previously. Clocks keeping the same rate, whose time-keeping has been adjusted to a common time zero, are termed congruent; the mathematical functions describing the respective countings of clocks under comparison, when a zig-zag signal is sent to and fro between them, are termed: signal functions.

Milne's (1949) solution of the two basic problems can now be boiled down to these two points: 1) Two clocks are congruent if their signal functions are symmetric. 2) An infinite number of clocks are congruent if their signal functions are commutative. This implies that even though their mutual distances may change, e.g. by expansion, their relative angles are all preserved.

Although congruence of clocks is not observed empirically, it remains possible theoretically. So we must distinguish between two kinds of observers, viz., sets of equivalent observers whose clocks are mutually congruent, and sets of non-equivalent observers whose clocks are mutually incongruent.

One could imagine the universe to consist of a large (maybe infinite) number of equivalence classes, each of which is made up of a large (maybe infinite) number of mutually equivalent observers. One could even imagine that each pair of equivalence classes had at least one member in common. However, it follows from Milne's two conditions of clock congruence that if two equivalence classes of observers have more than a single member in common they constitute one and the same class.

So Milne postulated that the general structure of our universe is fixed by the existence of a single, unique, and privileged, equivalence class of observers, *the substratum*, whose members are termed *fundamental*, in contradistinction to those observers who do not belong to the substratum, and who may accordingly be termed *accidental*. It is then easily realized that this privileged substratum must constitute *a universal reference frame* for the description of rest and motion.

Translated into common language *Milne thus postulated the structure of the universe to be determined by the existence of a privileged frame of reference and description, consisting of an infinite number of mutually equivalent observers amongst whom the relative angles, though not the distances, are conserved, and whose individual master clocks therefore all show the same time, that is, all keep the same rate, reckoning their time from the same common time zero.*

To sum up: Milne claimed the structure of the universe to be dominated by the substratum, a privileged class of mutually equivalent observers, or particles, whose clocks keep the same time. Since the relative angles between all fundamental observers, members of the substratum, are being preserved, all directions in such a universe are also equivalent, i.e., there is no privileged direction.

This assumption - termed *cosmic isotropy* - makes up the content of *the cosmological principle*. Although the principle is often ascribed to Einstein, even by Milne himself, it was first coined by Milne. So a correlation exists between the isotropy principle and the definability of cosmic time.

Milne assumed the principle to be valid for a particular world model in which the dispersion of fundamental particles always takes place with uniform velocity. Walker later generalized Milne's ideas by developing his own independent version of the RWM so that it remains valid for all world models subject to cosmic isotropy, irrespective of the immanent distance functions. Therefore, if the RWM holds for a specific world model, this model is subject to cosmic isotropy.

Now it follows from Milne's cosmological principle, when interpreted by Whitrow's argument concerning signal functions, that it is possible to define an universal time within any world model fulfilling the principle. The same conclusion follows from Einstein's GTR when interpreted in the light of the RWM whose basic parameter is the very same cosmic time. The fact that such a cosmic time is definable in all world models subject to cosmic isotropy testifies to their rationality. Hence the principle of cosmic isotropy is a reasonable means of excluding certain world models from serious consideration: it clearly excludes the rotating model of K. Gödel, but also the "multiverses" of L. Smolin.

When an adherent of standard relativity claims that the time of one fundamental particle is retarded relative to the time shown in the comoving frame of another fundamental particle, he is perfectly right; but he is nonetheless missing the crucial point which is that if the master clocks of fundamental observers are synchronized correctly they will all show the same time, cosmic time - and if they do not show the same time, the conclusion is that they are not properly synchronized.

As Einstein told us: identical clocks, if exposed to identical forces, go at the same rate.

4. ONE UNIVERSE ONLY

Assuming nature to be governed by laws, it is the task of natural science to map these laws. Only theoretical connections underpinned by observation and experiment can pass as natural laws. Every observer must construct an exact reference frame for the co-ordination of data, the results of observation and experiment, before these can meaningfully be communicated to other observers. Objective science presupposes the ceaseless exchange of information between equivalent observers who agree on common rules as a guarantee that their communication be not marred by inconsistencies.

The communication rules in physical science are rules for the transformation of co-ordinates. It is remarkable that such transformation rules may determine the very form of the laws of nature. In fact, the fundamental law $E = mc^2$, for instance, is derivable from the Lorentz transformations. The demand for consistency thus poses severe restrictions upon the possible form of natural laws. However, the very gist of the preceding paragraphs is that a proper interpretation of the Lorentz transformations presupposes that they be inserted into a cosmological context.

In this way the idea of *cosmology* as *the science of the universe* is brought to the fore. Cosmology can be defined as the science of the universe as a whole, that is, as the general science which brings all scientific disciplines into play in order to encompass the concept of everything. The difficulty, however, is that the universe manifests itself neither to our reason nor to our senses. The universe in itself is nothing but a mysterious X that forever remains *incognito*, unknown to us.

The great German philosopher Kant, as well known, distinguished *reality* from *appearance* or, as he preferred to say, *things as they are in themselves* from *things as they appear to us*. This distinction is eminently relevant with regard to our understanding of the universe of all things. We believe to be in immediate contact with unfeigned reality due to observation and experience. We think that we are able to form a concept about reality-in-itself, and in a sweeping manner we even speak about the world, or everything, identifying the world with the very essence of facticity. But it is not that easy, for in his famous *Critique of Pure Reason*, 1st antinomy, Kant demonstrated that human reason entangles itself in contradictions when attempting to grasp everything at once, inevitably presenting the universe as being both finite and infinite in time as well as space.

Kant was very proud of having shown his antinomies to be limits of all possible experience, and in his *Prolegomena* he declared himself willing to stake his whole doctrine at this single point. *It is therefore interesting to notice that a very simple world model, viz. that of Milne, constitutes a convincing counter-instance to the claim of Kant by showing his 1st antinomy to be dissolvable!*

The point is that Milne's model can be represented mathematically in at least two different ways: 1) as based on the t -scale, the proper time of fundamental observers when taking atomic clocks as master clocks, relative to which such observers mutually recede from each other with constant velocities thereby implying the substratum to be in uniform expansion; 2) as based on the τ -scale, each τ -value being calculated by taking the logarithm of the corresponding t -value, according to which all fundamental observers are at relative rest, thus implying the substratum to be stationary. It is then clear that a finite past at $t \simeq 0$ does not necessarily exclude an infinite past "at" $\tau \simeq -\infty$.

From the mathematics it further follows that the same substratum which, according to t -time, can be mapped in flat 3-space as a sphere with the finite radius $r = ct$ (in spite of its infinite contents), according to τ -time, by contrast, constitutes the stationary contents of infinite hyperbolic 3-space. Thus, mathematically, Kant's so-called antinomy is free of contradiction: everything fits together! But, of course, the difference between reality and appearance is not thereby suspended.

Kant claimed that we shall never know *reality-in itself*; only *reality-for-us* can be grasped. However, by the successive construction and elimination of *universes* in the sense of *world models* we are able to get approximate knowledge of the laws of nature and the structure of the universe. From this point of view cosmology should be given a central position among the natural sciences.

It was mentioned that Milne's cosmology can be viewed as a kind of Leibnizian metaphysics translated into mathematics. Leibniz is famous for having developed the idea of possible worlds, an idea which in our time has become a topic of major importance in formal logics and semantics. (One might wish that some proponents of the current "many worlds" interpretation of quantum mechanics would have spent a little more time to make themselves acquainted with these subjects; that might have saved them from indulging and persevering in the worst of their extravaganzas!) Now it is natural to connect the idea of a possible world with the scientific notion of world model. In this way a bond is drawn between classical *metaphysics* and modern *cosmology*.

The function of a world model is to map the structure of a certain kind of possible worlds. Whereas the model in an abstract way maps the formal properties of some given class of worlds, any single member of that class embodies a temporal succession (history) of concrete observable events. A possible world should thus be imagined as a closed succession of events, or as a finished process. The scientific world model, by contrast, is the formal result of an attempt to map the laws that are valid for a certain class of possible worlds, or of an attempt to decode the structure of these worlds.

Identity of form and contents, structure and existence, hence, can only be realized if the form constitutes its own content, that is, if the structure poses its own existence - but this is impossible, according to Leibniz, the only exception being the divine essence which entails its own existence. (With this argument from contingency he would have refuted Hawking, just as he refuted Spinoza.)

According to Plato there is one world, and "it is and remains the only one" (*Timaios 30D*). To that Leibniz agreed: *we can imagine a veritable infinity of possible worlds, but only one is real.*

Now, what is *possibly true* can be understood as that which is true in some possible world. Likewise, what is *necessarily true* can be interpreted as that which is true in all possible worlds. Further, what is true in fact, or *actually true*, is that which is true in the one and only actual world. We might add that what is *true in terms of natural law* is that which holds good within a certain class of possible worlds on the assumption that they share the structure of a certain world model.

What is wrong with the "many worlds" interpretation of QM is that its adherents confound this by insisting that all worlds produced by the process of quantum bifurcation are "equally real". The result of such nonsense is what logicians have aptly termed: the collapse of modal distinctions. But if it is agreed that the Ψ -function describes a physical necessity which is equally applicable to all possible worlds for which QM holds, then nothing is wrong - yet nothing explained.

A possible world wherein nothing ever happens seems to involve a contradiction in terms. What happens is called: events. Now events always take place in time or, rather, they constitute time. As a consequence each possible world, including the one and only real one, should be understood as a temporal world course, that is, as a linear succession of events forming an unbroken process. *That the actual world is one therefore means that there is in fact only one all-comprehensive time.* And the fact that events occur, which is the nature of factuality as well as the factuality of nature, indicates that time is passing - whence our partitioning of time in past, present, and future.

The principle of the unity of the world, of course, by insisting that there is in fact one world only, excludes "inflationary bubbles", thereby eliminating one of the most cherished recent hypotheses. Why speculate on what must forever remain outside the limits of all possible experience?

The principle that there is only one world involves the postulate of a single universal time. By keeping all investigation within the limits of possible experience it clearly recommends itself, the onus of proof resting upon the shoulders of one who would call it irrelevant or inadequate.

Granted that the very concept of a possible world includes the notion of an unique world time in the sense of a linear course of events, the question arises how to understand such time properly. In order to answer this we shall have to exploit the methods of analysis offered by temporal logic. "A systematic reconstruction of physics would necessitate that a full calculus of temporal propositions be developed and utilized as the basic foundation for physical theory", C.F.v. Weizsäcker 1985.

It is a simple fact which ought to be elevated beyond reasonable discussion that the task of science is triple, viz. 1) *to describe the present*, 2) *to explain the past*, and 3) *to predict the future*. In its very *raison d'être* science therefore presupposes that partitioning which makes it meaningful to speak of the passage of time, hence also its direction; and if some of its practitioners afterwards try to convince us that time is an illusion, and that talk of time's passage is nonsense, then they should be brusquely dismissed with the message that they have totally misunderstood their own business.

It is flatly unacceptable that the scientific establishment feigns the production of "knowledge" which everyone in possession of common sense can see is incompatible with its own premisses!

The principle of *the unity of the universe* (one would think that it was already latent in the very notion of an universe) also yields a solid basis for drawing some other far-reaching consequences. The bond of unity, consisting in the participation of all fundamental particles in the common time of the substratum, prevents the universe from being split up into enclaves delimited by horizons. The postulate of a *cosmic time* is therefore equivalent to the postulate of the absence of horizons (anticipated by Milne 1948 with his *no-horizons* postulate, although he did not see the connection).

As said above, a cosmic time is conditioned by the conservation of angles in the substratum, implying all directions in the world to be approximately equivalent, so that the universe, as predicted about 1450 by cardinal Nicolaus of Cusa (the source of almost all ingenious ideas of Giordano Bruno) can be compared to "a sphere having its center everywhere and its periphery nowhere".

To this we should add that the cosmic sphere does not allow any division of its contents. Not only will the universe emerge in approximately the same way to all fundamental observers, but the observable part of universe will, in principle, coincide with the entire existing universe: everything is visible, if only your vision is sufficiently sharp - so nothing is excluded from "reality". This shows that a formal identity reigns between *world map* and *world view*, to use Milne's terms.

Consequently, the universe constitutes a closed totality comparable to a so-called "black hole". In the words of Plato: "nothing comes into it and nothing goes out from it, for it has no surface". The principle of the unity of the universe, implying the postulate of a cosmic time, is very strong. Indeed, when combined with the assumption that the cosmic sphere is stationary relative to *T*-time, see below, it determines the "skeleton" of the universe, i.e., the structure of its substratum.

As already mentioned, Milne's model was generalized by Walker. According to the metric of Walker, which is formally identical to that of Robertson, it is possible to define a cosmic time for any world model which is subject to the principle of cosmic isotropy. In Milne's world model all fundamental particles recede from each other with velocities that increase with their distances, although the velocity of a single particle relative to some other particle always remains constant. But Walker demonstrated that the assumption of uniform velocities is an unnecessary restriction. Thus angles are conserved during any kind of motion if only it takes the same form everywhere, the only bond being that the general dispersion of particles should be the same function of time.

Oddly enough Milne did not regard his t -time, but only his τ -time, as a genuine world time. In line with this he was reluctant about Walker's attempt to introduce an all-comprehensive time. This fact need not disturb us, however, if we only remember that Milne's t -scale, representing the frame time displayed by the comoving slave clocks of each single observer, is very different from Walker's cosmic T -scale which is identifiable with the proper time shown by their master clocks.

As mentioned above, the mapping of the substratum in Milne's model differs according to whether it is described relative to t -time (*private frame time*) or relative to τ -time (*public proper time*). Walker's metric allows us to replace the many private t -scales with a single unique public T -time. But the τ -scale was already public. In fact, any world model subject to Walker's metric allows us to define an infinite number of public time scales. Of these two are important: T -time & τ -time. In this way Milne and Walker both dealt with two privileged time scales: Milne t & τ , Walker T & τ .

It must now be recalled that a fundamental observer always carries with him with his own master clock, but is surrounded by a cloud of comoving slave clocks following him at fixed distances. According to Walker's T -scale, which was identified as the public proper time read off the master clocks of all fundamental observers constituting the substratum (only differing from Milne's t -scale by not comprising the frame times t of their comoving slave clocks which always deviate from T), the spatial extension of the atoms composing all material bodies in the universe remains invariant whereas the relative distances of fundamental observers vary according to the same function of T . According to his τ -scale, by contrast, all fundamental observers are at rest while their atoms shrink. As Eddington once so strikingly remarked: "The theory of the expanding universe is equivalent to the theory of the shrinking atom!" - 1933, quoted from Whitrow 1961.

The definability of the public T -scale of time is conditioned by the conservation of angles. So the postulate of a cosmic time is correlative to the cosmological principle of cosmic isotropy. This conclusion has far-reaching consequences for a correct interpretation of the Lorentz formulae: if a unique all-comprehensive time is at all definable then it is natural to regard it as being "true time". This time, then, is the public proper time of all fundamental observers belonging to the substratum, and it can thus be read off all atomic clocks which are at permanent rest relative to the substratum.

To be at rest relative to the substratum is not just to keep a fixed distance to a fundamental observer, but to coincide permanently with, indeed to be identifiable with, a fundamental observer. An observer coinciding with some slave clock comoving with, hence keeping a fixed distance to, a fundamental observer, cannot also coincide with the master clock of that observer. So we have to distinguish *accidental observers* from *fundamental observers*, realizing that the clock readings of an accidental observer will always deviate from "true time", i.e. cosmic time. This deviation hints at the possibility of explaining gravity by time. In fact: "**gravitation is time**"; Mercier 1979.

Assuming the definability of a cosmic time we have every reason to reject Einstein's STR and to insist that the Lorentz factor $\gamma = 1/\sqrt{1 - v^2/c^2}$ - the importance of which we do not dispute - should not be applied to describe the retardation of one master clock relative to another because all such clocks go at the same rate and can always have their zeros adjusted to show the same time; rather it might be used to "derive" the RWM as suggested by Whitrow 1961 (ch.V §4).

5. CONCLUSION

Stellar aberration, as well as the experiment of Sagnac, seems to indicate that light in some respects behaves as if it were transmitted by a medium, an aether. That this is so has been argued by Selleri and others in a number of papers. If true it would exclude theories of strong relativity such as that proposed by myself in 1995, allowing only theories of weak relativity that are consistent with the hypothesis of an aether. But an aether must not be stationary. It may be expanding.

The idea of an expanding aether is best interpreted by means of the concept of a substratum of fundamental particles. That light behaves as if it were transmitted by a substratum would imply that light interchanged between two accidental particles, an emitter and a receiver, source and sink, is propagated as if it were interchanged between two fundamental particles, viz. that with which the emitter coincides at the instant of emission and that with which the receiver coincides at the instant of reception. Such transmission can only be described as a process already completed; considering how light is now going to be propagated, therefore, we shall need to calculate probabilities.

It is immediately evident that this peculiar "transmission by substitute" must presuppose that a common time is definable for the two fundamental particles that serve as replacements, one for the emitter, the other for the receiver. In other words, the instant of emission at one place in the substratum must be univocally comparable to the instant of reception at another place in the substratum.

Further it is obvious that an exact location of the events of emission and reception, spatial as well as temporal, within the substratum must presuppose that the electromagnetic waves involved in the propagation of light must have suffered a sort of quantum collapse, the alternative being that electromagnetic energy may propagate indefinitely in the substratum without ever being observed. A substratum theory would thus naturally interpret light in terms of quanta, so-called *photons*.

We have already distinguished between two privileged representations of the substratum: one in terms of the public time T , according to which the atoms as constituents of material bodies at rest in the substratum keep a constant size while the relative distances between fundamental observers change; the other in terms of the public time τ , according to which the relative distances between fundamental observers are constant whereas the sizes of their atomic constituents change. This distinction naturally involves another one between a constant and a variable speed of light.

Now I do not want to dispute that the instantaneous speed of light, i.e. the speed of light defined as a quotient between the spatial and the temporal units of fundamental observers, remains constant. But does this assumption necessarily entail that the average speed of light as integrated over the tempo-spatial interval separating source and sink, emitter and receiver, will also remain constant? Of course not! So we have to consider the possibility of light speeds, i.e. photon speeds, deviating from unity.

The possibility of the speed of light being stretched over cosmic distances as a consequence of the expansion of the universe has been discussed by Prokhovnik in 1967 in relation to a world model that is in fact identical to that of Milne and, more generally, by Whitrow already in 1961.

Let us distinguish the constant light speed $c_o = \text{unity}$ from the variable light speed $c = c(\tau)$, the latter referring to a new τ -scale to be defined shortly. Let us further adopt the standard STR formula for the retardation of clocks: $dt = dT/\sqrt{1-v^2/c_o^2} \equiv dT/\sqrt{1-v^2}$.

Whitrow's derivation of RWM then involves the identities $v \equiv dr/dt \equiv R(t)d\sigma/dt$, whence:

$$(1) \quad dT^2 = dt^2 - dr^2 = dt^2 - R^2(t) d\sigma^2 = \text{invar.}$$

$$(2) \quad dT = 0 \quad \Rightarrow \quad \sigma = \int_1^2 dt/R(t) = \text{const.}$$

Here dT is an invariant element of proper time whereas dt & dr are the standard elements of variable frame time and frame distance, respectively, and $d\sigma$ is an element of distance as measured in the substratum where σ is a fixed ("comoving") coordinate of some other fundamental observer, $R(t)$ being the dimensionless expansion function for such elements. As Phipps has intimated 1986: the only relevant part of Einstein's special relativity is comprised in the formula $dt = dT/\sqrt{1-v^2}$. However, this formula does not imply that differentials of proper time are inexact; clearly the Cern evidence has no bearing on the relationship between the master clocks of fundamental observers.

That the RWM can be reinterpreted so as to allow for a shrinking of atoms follows from

$$(3) \quad c^{-1}(\tau) \equiv dt/d\tau \equiv R(t) \text{ , whence eventually}$$

$$(4) \quad dT^2 = dt^2 - R^2(t) d\sigma^2 = c^{-2}(\tau)\{d\tau^2 - d\sigma^2\}$$

So the expansion of the substratum, which was likened above to a stretching of the average (integrated) light speed, corresponds formally to a secular reduction of the sizes of atoms, which can alternately be described as a secular reduction of the instantaneous (differential) speed of light. This secular reduction is governed by the function $c(\tau)$ in the τ -scale and, being instantaneous and ubiquitous, it is imperceivable, that is, it cannot be observed locally by any observer. A constant light speed over both cosmic and atomic distances would presuppose that $R = c = \text{unity}$.

Notice that $\sigma = \text{const.}$ for any pair of fundamental particles whence $dt = dT = d\tau/c(\tau)$ which, with general agreement concerning a common time zero, would lead to the identification $t = T$. For accidental particles, however, we have $d\sigma \neq 0$, hence also $dt \neq dT \neq d\tau/c(\tau)$. This deviation from true cosmic time might indicate the spontaneous emergence of accelerations - that is: "forces"!

The "cement of the universe", therefore, is not its ubiquitous network of causal connections but that absolute unconditioned all-comprehensive simultaneity which designates a genuine cosmic time. Such cosmic time, as discussed above, both entails and is entailed by the conservation of angles during the expansion of the substratum, that is, during the dispersion of its fundamental particles.

This reign of cosmic symmetry explains a lot that cannot otherwise be explained: for instance, the spontaneous emergence of forces may be seen as a result of local deviations from global symmetry. In contrast to Einstein, Milne did not regard gravity as a brake on the expansion of the universe since he considered it to be a consequence of the expansion; for this very reason he would not perceive the need to revive Einstein's long ailing cosmological constant Λ (quote: "my biggest blunder").

In Milne's kinematic relativity the cosmic substratum serves as a global *compass of inertia* (Gödel) recording all local deviations from the universal dispersion of matter. The arbitrary motion of an object relative to the substratum turns out to be fully described by two pieces of information: 1) its instantaneous velocity relative to that member particle with which it momentarily coincides, and 2) its distance to that member particle relative to which it is momentarily at rest, the first piece being its velocity in the substratum and the second piece being its displacement in the substratum. Together they give us full information about the object's deviation from cosmic symmetry.

The motion of an arbitrary object in the substratum is, however, also influenced by another asymmetry, viz. the deviation of other objects, mainly nearby ones, from the universal symmetry. In order to describe the influence on an object by its local surroundings Milne used an inverted Boltzmann equation presenting the accelerations within a statistical ensemble as a function of their distribution; in this way he succeeded in effecting an ingenious reduction of gravitation to inertia. Einstein, by contrast, spent the major part of his life by his attempt to reduce inertia to gravitation, but to cram forces into the package of curved space-time is a far cry from explaining them.

What can we conclude? STR should be re-interpreted! Mach's principle should be inverted! GTR should be discarded in favour of some new variety of kinematic relativity!

Notes:

1. A dimensional analysis of eq.s (1-4), of course, would require the relevant powers of c_0 to be inserted.
2. It is worth noticing that *time's passage* can be analyzed in terms of *tense logic*; see Wegener & Øhrstrøm, 1996, as well as the kind appreciation by J.R. Lucas, 1999. According to tense logic time exists in the same sense that clock readings exist, viz. as numbers indicating the successive occurrence of events; but that in itself does not imply the real existence of instants. On the whole we should be very cautious to use "reality" or "existence" as predicates.

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