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**THE IDEA OF A COSMIC TIME
DEBUNKING "THE EINSTEINIAN REVOLUTION"**

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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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Summary

*Pointing to the cleft between the idea of a temporal evolution,
central to modern biology, and the idea of the timelessness of reality,
fundamental to modern physics, the present paper demonstrates that the
standard definition of time at a distance is beset with ambiguities which
might be solved by making a fresh start taking its point of departure
in the idea of an absolute Cosmic Time in accordance with the
British Tradition of Relativistic Cosmology.*

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1. INTRODUCTION

In a special issue of *Scientific American* dedicated to *time* [287 no.3, sept.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 such as astrology, clairvoyance, magnetotherapy, and ufology, is also applicable to some allegedly scientific views promoted in that issue, e.g. the opinion reported below:

Scientific American is generally acknowledged to be a serious magazine and Paul Davies, a scientist of high repute, is regarded as 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 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 contrast to physics, which is neither capable of explaining what it means that "time is passing" nor qualified to ascribe a direction to "the arrow of time" (a happy 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 even 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 basic 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 *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. But a similar conflict can be found *within* physics.

Considering the view that modern cosmology began with the general theory of relativity and peaked in the dogma of "big bang" it is not only conspicuous, but sensational, how radically the prevailing cosmological paradigm is countered by the trend to skip time of physical reality. According to the "big bang" hypothesis our universe began some 14 billion years ago in a huge explosion that marked the zero of time. But the arguments against time, in antiquity provided by Parmenides and Zeno, are today derived from .. Einstein's two theories of relativity!

Thus, according to the unanimous verdict of modern cosmology and biology, everything in the world observed or experienced today, including ourselves, is nothing but the prolonged effects of an evolution initiated by the creation of the universe which happened about 14 billion years ago. Nevertheless, referring to the authority of Einstein, some physicists want to persuade us not just that the apparent passage of time is an illusion, but even that the very concept of time lacks all scientific foundation! So the question today is this one: How can we thrust a science which not only denies what everyone can observe with his own senses from instant to instant, but which also is in blatant conflict with itself?

2. EINSTEIN ON TIME

In order to throw new light upon these problems we 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 ignoring philosophy, appealing to what we all can see by observing a watch, viz. *clock-readings* (numbers marking instants). 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 of the crucial problem which is this one: how do we distinguish a clock that works from one that does not? Of course this is a condition for deciding if 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 permanently associated with an observer.

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

Scientific objectivity hinges on the independent verification of data by several observers, so Einstein assumed that observers agree to calculate time at a distance using the same method. He furthermore prudently stressed the natural fact that all rational comparison of clock-readings, or epochs, necessarily presupposes that the clocks concerned go at the same rate [1920 ch.viii]: "It (is) assumed that all these clocks go at the same rate if they are of identical construction".

The statement quoted is notable for other reasons than its frank admission of time's flow: it was presented 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 taken to be simultaneous with respect to synchronous clocks at rest on the embankment, they cannot also be supposed to be simultaneous with respect to synchronous clocks co-moving with the train, and *vice versa*. The clocks, being of identical construction, are assumed to be pairwise synchronized.

*Therefore the special theory of relativity, including its suspension of the classical notion of simultaneity, explicitly relies on these premises concerning clocks in motion that not only do they go, thus indicating **the flow of time**, but being identical they even keep **the same rate!***

From such premises, however, Einstein drew the conclusion that correctly synchronized clocks will mutually appear retarded relative to each other, and that correctly calibrated rods will mutually seem contracted relative to each other, all in consequence of their relative motion! From Einstein's interpretation of the Lorentz transformations (*LT*), which are the mathematical contents of his special relativity, it follows that the contraction will vanish when the motion is brought to a halt, whereas the retardation, being one-sided, leads to an absolute effect.

We are therefore confronted with an obvious paradox: a theory which is explicitly based on the premise that all clocks involved are of identical construction, thus keeping the same rate, entails that clocks in relative motion do not count the same intervals of time after all!

Mathematically the theory is *consistent*. Physically it is *supported* not merely by a lot of experiments, but even by the most diverse kinds of experiment. It therefore seems impeccable. Nevertheless it is *mandatory to make the following reservations*: 1) No theory contains more truth than the premises it is based upon; so a mere lack of contradiction is a necessary, but not a sufficient, condition for its truth. 2) Although a theory can be falsified conclusively, it can never be verified conclusively; therefore no kind of observational support should ever be assumed to exclude the possibility that other premises might lead to even more plausible consequences.

How do we cope with the fact that a seemingly consistent theory is so full of paradox? In order to grasp this we must first probe for a deeper understanding of Einstein's theories. Making this effort we shall find a serious ambiguity inherent in his definition of time.

SR (special relativity) is based on two pillars: (1) *the relativity principle*, stating the impossibility of determining absolute motion or rest; (2) *the light speed principle*, stating the universal constancy of light speed, 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' because it is restricted to the consideration of observers in inertial motion assumed to be uninfluenced by acceleration or gravitation. **GR** (general relativity) is also based on (3) *the principle of equivalence* stating the identity of acceleration and gravitation.

In both theories reference frames are in focus. What do we mean by a frame of reference? Of course, *reference frames* are *abstract entities* and *therefore immaterial*; they are conceptual constructs not inhering in nature. However, as their geometrical structure is influenced 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 if the influence of gravitation 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 that our concept of time at a distance, or simultaneity, is based on definition. Now a definition is chosen because it is convenient and serves a scientific purpose; hence definitions have 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 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. Therefore it appears rational to define the epoch of reflection as half the sum of the epochs for emission and reception of the reflected signal, that is, as the arithmetic mean of those epochs. This, precisely, is the famous Einsteinian *definition of simultaneity*, or time at a distance.

In his 1905-paper, Einstein wrote: "We assume that this definition of synchronism is free from contradictions and possible for any number of points", adding these further 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*. Thus *clock synchronism* is both *reciprocal* and *transitive*.

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

Einstein thus openly admitted that *the light speed principle is intimately connected to the definition of clock synchronism; in fact so intimately that the principle makes no sense except if interpreted on the basis of the transitivity of simultaneity*. Now it is precisely the transitivity of simultaneity which is jeopardized in consequence of **SR**. The point is that, following Einstein, the Lorentz transformations 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* inertial frames. But *from the footnote just quoted it would seem to follow that the light speed invariance is only valid for light propagation within a single inertial frame*, whereas it is invalid for the comparison between inertial frames. This further seems to entail that the light principle can be applied only to a single reference frame at a time, not to several frames simultaneously. Thus data referring to more than one frame at a time seem to be incomparable!

Einstein had no doubt that the light speed must be the same with respect to all frames. Apparently he never confronted the issue whether *the same photon* (whatever that is?) retains the *same speed* relative to *two different frames* at the same time (quite a feat!), or whether its speed is only constant relative to that frame wherein it is *observed*. This can hardly be decided by appeal to principle. But the situation is going to be still worse, before it can get any better. Of course, Einstein did not relinquish synchronizing the master clocks of different observers. No, he tacitly synchronized such master clocks in another way, by a different method!

Physicists need to compare data that refer to different inertial frames in relative motion. According to Einstein, the possibility of comparing clock readings from various inertial 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 their meters being identical. But this is not sufficient for a comparison of such frames. The observers must further agree on *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. If they do not, one of them could elect an *alter ego* at a fixed distance who does meet the other.

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

The ambiguity 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 taking **the geometric mean** of the same epochs, in order to calibrate the readings of the *master clocks* of different observers (in fact: "a frame" is a "cloud" of "clocks" associated with an observer; cf. Popper).

Small wonder, then, that the slave clocks at rest in the comoving frame of one observer are advanced relative to the master clock of another observer! Why not state the facts this way? The master clock of a 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! Comparing the *master clocks* of two fundamental observers we find *no retardation*: if properly synchronized, the master clock of a fundamental observer can never be retarded relative to the master clock of another fundamental observer if their relative motion is inertial and collinear. That this is so is *a simple consequence of the definition of fundamental observers*: if the clock of one observer deviates from that of another, at least one of them is not fundamental!

A *general theory of time keeping* was outlined by E.A. Milne [1948], in collaboration 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 upon which they are based, are purely conventional, as stressed by H. Poincaré, precursor of Einstein, and the first to invent the **SR**-formalism; cf. E.T. Whittaker [1953], G.H. Keswani [1964], and H.A. Lorentz [1921]. We conclude: *the claim that moving clocks do not agree is based on a convention, nothing else!* The problem is altogether different, however, if the clocks involved are no longer inertial.

The fact that mesons from cosmic radiation can 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 prolonged due to a relativistic retardation of their "internal clocks". When considered in isolation, such observations can just as well be explained by a Newtonian theory allowing the occurrence of super-luminal velocities. To this it can be objected that the observations must naturally be interpreted in the light of our knowledge that the speed of light constitutes a natural limit to the velocities of material bodies.

But to this it can be replied that the speed of light can be a natural limit to all signals, including moving mesons, without its numerical value being kept invariant between frames. The point is that 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 does follow directly from **SR** 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 (cf. ch.1, app.).

For my own part, I have made a hard attempt to work out a new theory of relativity in analogy with Törnebohm's and Prokhovnik's non-standard interpretations of **SR**. My idea was to combine a variable one-way light speed with a constant two-way light speed and, in line with this, to invent *a new unitary expression for time at a distance which in some cases is reducible to the arithmetic mean and which in other cases is reducible to the geometric mean*; cf. ch.s 3-4. This theory pulls the teeth out of de Sitter's proof for the one-way light speed independence of the proper motions of binaries. But, like **SR**, the theory may be unable to explain the experiment of Sagnac. Thus one should probably rather 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 the names of E.A. Milne, A.G. Walker, and G.J. Whitrow. They were all mathematicians, as shown by their approaches. Milne created the theory of kinematic relativity which was developed expressly as an alternative to the 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 **SR** into a full fledged cosmology.

Walker developed kinematic relativity further, so that the theory was no longer solely associated with Milne's world model, which is one of uniform dispersion from a transcendent point-event, a kind of imaginary "big bang". Like **GR**, it then became a mathematical technique applicable to a whole range of world models, viz. all those that are subject to cosmic isotropy. The *Robertson-Walker metric (RWM)*, incorporating the *principle of cosmic isotropy* formally, is still the most significant instrument of modern mathematical cosmology.

Whitrow gave important technical contributions to the development of the radar method. During a longer period he worked on kinematic relativity as an assistant and colleague of Milne. He later became renowned for his inquiries into the history and philosophy of time which are reported in his monumental *The Natural Philosophy of Time*, a work that turned out to provide inspiration for the 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 weeks before Einstein published his **SR** in the *Annalen der Physik*, the great French mathematician and philosopher of science Henri Poincaré published an equivalent but formally more advanced theory in the *Comptes rendus*. In this paper he pointed out that the invariance of the speed of light enables us to unify time and space by defining spatial intervals in terms of temporal ones, and so he foreshadowed that the idea of *light-time* would replace the use of a "rigid rod" as the standard of distance. This prophecy was fulfilled with the invention of the *radar technique* in GB shortly before WW2. In another paper he suggested that the temporal coordinate does not represent "true time"; so time may after all be universal.

The significance of *the radar principle* is unique. Not only is it used in nature by bats and dolphins: today we measure the radar distance to a planet with a precision down to centimeters. The *meter* is now defined as the path travelled by photons *in vacuo* in 1/299792458 sec; further, the *second* is defined as 9192631770 periods of the radiation corresponding to the transition between two hyperfine levels of the groundstate of the caesium 133 atom (*CGPM* 1983/1967). The theoretical importance of these definitions far overshadows their practical one: by stripping the presumed fundamentality off the idea of space, they flout the view of Einstein [1920 app.v] that "(physicists) endeavour in principle to make do with 'space-like' concepts alone".

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

In 1965, the physicists Penzias & Wilson observed a strange radio noise produced by a highly smooth background radiation (**CBR**) coming from the most distant parts of the universe. The radiation, having a temperature of ca. 2.7 Kelvin, showed a so-called black-body spectrum. This fact has been interpreted as proof that the universe originated almost 14 billion years ago in a huge explosion, the "big bang". But there are other ways of explaining this observation, such as re-radiation of stellar light from interstellar grains of carbon (graphite), or radiation emitted spontaneously from a so-called zero point field, cf. Narlikar [1980]. What may be said for sure is that both observations clearly show universal space to have no privileged directions. This fact puts great importance to **RWM** as the standard metric of the universe.

Milne died in 1950 without accepting **RWM**, but this does not make his work obsolete. As a nominalist he realized that reference frames are not real things or entities in nature, but abstract constructions of the human intellect; so he asked the question how to construct them. He felt foreign to the pseudo-metaphysical idea of Einstein that there is a natural or immanent structure of space. Instead he followed the lead of Poincaré who saw geometry as a construction of the human mind made to the purpose of the co-ordination of data, the numerical results of observation or experiment. It is here natural to make a comparison with the choice of geodesic projection which aims at obtaining the most convenient description of the landscape on a curved surface such as that of the Earth. Our choice of geometry is free, but turns out to restrict our possibilities of description in definite ways. Reality is not to be found in the spatial frame itself, but rather in the observational data which are inserted into the frame.

The German philosopher and multi-genius Leibniz took physical reality to be analysable into some metaphysical entities called monads. In his book *Cosmologie du XXme Siecle* [1960], J. Merleau-Ponty compared Milne's world-model to a *monadology translated into mathematics*. According to Milne, an observer like a monad can be viewed as a temporal series of experiences or events; but he 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 mathematical: 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 be fundamental. So, if questioned, Milne and Mercier would probably have rejected 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 basic problems of time-keeping: 1) How decide whether two clocks go at the same rate? 2) How determine whether, considering a cloud of clocks, all keep the same rate?

His method for their solution was based on the radar principle discussed previously. Clocks keeping the same rate, their time-keeping being adjusted to a common time zero, were termed *congruent*; the mathematical functions describing the countings of the clocks compared, when a zig-zag signal is sent to and fro between them, were termed *signal functions*.

Milne's solution of his two problems can now be boiled down to these two main points: 1) Two clocks are congruent if their signal functions are reciprocal, or symmetric. 2) Infinitely many clocks are congruent if their signal functions are commutative; the latter property implies that even though their mutual distances change, their relative angles are preserved.

One can imagine the universe to consist of a large, maybe infinite, number of equivalence classes, each one made up of a large, maybe infinite, number of mutually equivalent observers. One could even imagine each pair of equivalence classes to have at least one common member. However, it follows from Milne's two conditions of clock congruence that if two equivalence classes have more than a single member in common, the classes in question must be identical. Hence we have to distinguish between two kinds of observers: equivalent ones whose clocks are mutually congruent, and non-equivalent ones whose clocks are not mutually congruent.

In fact, Milne held that the general structure of the universe is fixed by the existence of a single, unique and privileged equivalence class of observers, the *substratum*, whose members are termed *fundamental*, in contrast to observers who do not belong to this class and who may therefore be termed *accidental*. It is easily realized that this privileged substratum constitutes a *universal reference frame for the description of rest and motion of particles*.

To sum up: Milne claimed the structure of the universe to be dominated by a substratum, i.e., a privileged class of equivalent observers, or particles, whose clocks all keep the same time. All relative angles between fundamental observers, members of the substratum, are preserved. Moreover, all directions in such a universe are equivalent, i.e., there is no privileged direction. The principle of cosmic isotropy constitutes the essence of the so-called cosmological principle. Albeit the principle is often ascribed to Einstein, even by Milne, it was first coined by Milne.

Milne took the principle to be valid for a specific world-model in which the dispersion of fundamental particles always takes place with uniform velocity. Walker 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 their general scale functions of distance. Thus, if the *RWM* holds for a specific world-model, this model is subject to cosmic isotropy. The definability of a cosmic time turns out to be closely related to the principle of isotropy:

It follows from Milne's cosmological principle, when interpreted by Whitrow's argument concerning signal functions, that it is possible to define a universal time within any world-model fulfilling the principle. The same conclusion follows from Einstein's *GR* when interpreted in the light of *RWM* whose basic parameter is the very same cosmic time. The fact that a cosmic time is definable for all world models subject to cosmic isotropy testifies to their rationality. Hence, the principle of cosmic isotropy may be used as a means of excluding certain world models from consideration, such as the "rotating universe" of Gödel or the "multiverse" of Smolin.

So when an adherent of standard relativity says that the time read off the master clock of a certain fundamental observer is delayed relative to the time shown by the slave clocks distributed over the co-moving frame of another fundamental observer, he is perfectly right; nevertheless he is missing the crucial point which is that, if the master clocks of fundamental observers are synchronized correctly, they will show the same time, viz. cosmic time; and if they do not show the same time the conclusion is that they are not properly synchronized.

As Einstein said: identical clocks, exposed to identical forces, keep the same rate!

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4. ONE UNIVERSE ONLY

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

The rules of communication in physics are rules for the transformation of co-ordinates. It is remarkable that such transformation rules may determine the very form of nature's laws. In fact, the basic law $\Delta E = \Delta mc^2$, for instance, is derivable from the Lorentz transformations. The demand for consistency exposes the possible form of natural laws to severe restrictions. 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, i.e., 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 shows itself neither to our reason nor to our senses. The universe in itself is a mysterious X that remains *incognito*, forever unknown to us.

The great German philosopher Kant, as we know, 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 clearly relevant to our understanding of the universe as a totality 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 essence of facticity.

But it is not that easy, for in his *Critique of Pure Reason*, 1st antinomy, Kant showed that human reason entangles itself in contradictions when attempting to gauge everything at once, inevitably presenting the universe as both finite and infinite in both time and space. Kant was so proud of having shown his antinomies to be the limits of all possible experience that, in his *Prolegomena*, he declared himself willing to stake his entire philosophy at this single point. It is therefore interesting to notice that a very simple world-model, viz. Milne's, constitutes a counterinstance to this claim of Kant by showing his 1st antinomy to be dissolvable!

The point is that Milne's model can be represented mathematically in two different ways: 1) as based on the t -scale, the frame time of fundamental observers using atomic clocks as their master clocks, relative to which such observers recede from each other with constant velocities, implying the substratum to be in uniform dispersion; 2) as based on the τ -scale, each τ -value being found from the logarithm of the corresponding t -value, relative to which all fundamental observers are at rest but their atoms steadily shrinking, implying the substratum to be stationary.

So a finite past starting at $t = 0$ does not exclude an infinite past going back to $\tau \simeq -\infty$! From the mathematics it furthermore follows that the substratum which, according to t -time, can be mapped in flat 3-space as a sphere with finite radius $r = ct$ in spite of its infinite contents, according to τ -time by contrast makes up the stationary contents of infinite hyperbolic 3-space.

So, 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 can never know *reality-in-itself*, only *reality-for-us* can be grasped. However, by successive constructing and eliminating *universes* in the sense of world-models, we can obtain approximate knowledge of the laws of nature and the structure of the universe. From this point of view cosmology assumes a central position among the natural sciences.

It was said 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 today has become a topic of major importance in formal logics and semantics. One might wish that the proponents of the "many worlds" interpretation of quantum mechanics would have spent a little more time to make themselves acquainted with modal logic; this 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 idea of a world-model. In this way a *close bond* is disclosed between *classical metaphysics* and *modern cosmology*. The function of a world-model is to map the structure of a certain class of possible worlds. Whereas the model in an abstract way maps the formal properties of some given kind of worlds, any single member of that class embodies a temporal succession (history) of observable events. So a possible world can be imagined as a closed succession of events, or a finished process.

A scientific world-model, accordingly, is the formal result of an attempt to map the laws valid for a certain class of possible worlds, or an attempt to decode the structure of these worlds. Hence identity of form and contents, structure and existence, can only be realized if the form constitutes its own content, i.e., if the structure poses its own existence; but this is impossible, Leibniz insisted, the only exception being the essence of God which entails "his" existence. With this argument he would have refuted Hawking as clearly as he refuted Spinoza.

Plato said: there is *one world only*, and "it is and remains the only one" (*Timaios 30^d*). 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 what is true in the one and only actual world. We may add that what is *true in terms of natural law* is what 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 termed: the collapse of modal distinctions. But if it is said that the Ψ -function describes a probabilistic necessity that is equally applicable to all possible worlds for which *QM* holds, then nothing is wrong, yet nothing explained.

A possible world wherein nothing at all ever happens involves a contradiction in terms. What happens we call events, and events always take place in time or rather: they make up time. Consequently *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 thus means that there is in fact a single all-comprehensive time.*** And the fact that events happen - which is the nature of factuality and the factuality of nature - indicates *time's passage*, whence our partitioning of time in *past, present, and future*.

The principle of the unity of the world, postulating that there is in fact one world only, excludes "inflationary bubbles", thus eliminating one of the most cherished recent phantasms. Why speculate on that which must forever remain outside the limits of all possible experience? The principle that there is one world only entails the postulate of a single unique world time. By keeping all investigation within the limits of possible experience it recommends itself, the onus of proof resting upon the shoulders of one who would call it irrelevant or inadequate.

Granted that the notion of a possible world includes the notion of a 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 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 (its) basic foundation", C.F. v. Weizsäcker said.

Indeed, *time's passage can be analysed in terms of tense logic*, cf. Wegener & Øhrstrøm [1996]; cf. the kind appreciation by J.R. Lucas [1999]. According to tense logic, time exists in the same way as clock readings, viz. as numbers indicating the successive occurrence of events; but that in itself does not imply "the real existence" of time or instants. But the old quandary posed by the question: "how fast, then, does time run?", allows of a very simple answer, since the rate of an atomic clock, e.g., can always be estimated relative another atomic clock.

It is a simple fact which stand beyond any reasonable discussion that the task of science is triple, namely: 1) to *describe the present*, 2) to *explain the past*, and 3) to *predict the future*. In its very *raison d'être* science presupposes that partitioning that 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, they should be dismissed with the message that they have totally misunderstood their own business.

It is flatly unacceptable that the scientific establishment should feign the production of so-called "knowledge" which everyone can see is incompatible with its own premisses!

The principle of *the unity of the universe* (one would think that this 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-horizon postulate*).

As already mentioned, a cosmic time is conditioned by the conservation of angles in the substratum, implying all directions in the world to be (almost) equivalent, so that the universe, as predicted ca 1450 by Nicolaus Cusanus - the source of almost all the brightest ideas of Bruno - can be compared to a *sphere having its center everywhere and its periphery nowhere*.

To this we may add that the cosmic sphere does not allow of 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 the universe, in principle, coincides with the entire existing universe: nothing is outside reality; it is all visible, if our sight is sufficiently sharp (cf.p.21 lin.10f.).

For that reason *world map* must be formally identical to *world view*, to use Milne's terms. Consequently, the universe must constitute a closed totality, similar 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 outside". The principle of the unity of the universe determines the structure of its substratum.

Milne did not view 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 universal time. But this need not bother us if we remember that Milne's t -scale, representing the frame time t displayed by the comoving slave clocks of single observers, is very different from Walker's cosmic T -scale which is identifiable with the proper time shown by their master clocks.

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

According to Walker's T -scale, which is identified as the public proper time read off the master clocks of all fundamental observers, members of the substratum, the spatial extension of the atoms composing all bodies in the universe remains invariant, while the relative distances of fundamental observers vary according to the same function of T . But according to his τ -scale, fundamental observers are at rest while their atoms shrink. As Eddington once aptly remarked: "The theory of the expanding universe is equivalent to the theory of the shrinking atom!".

The idea of a cosmic time can be seen as a corollary to the principle of cosmic isotropy. This conclusion has far-reaching consequences for the interpretation of the Lorentz formulae: if a unique all-comprehensive time is at all definable, then why not regard it as "the true time"? This time is the public proper time of all fundamental observers belonging to the substratum and can be read off all atomic clocks which are permanently at rest relative to the substratum.

An observer associated to a slave clock comoving with, hence keeping a fixed distance to, a fundamental observer, cannot coincide with that observer. So we shall have to distinguish *accidental observers* from *fundamental observers*, realizing that the clock readings of accidental observers always deviate from "the true time" which is cosmic time. This deviation hints at the possibility of explaining gravity by time. In fact: **gravitation is time**; cf. Mercier [1979].

In Milne's cosmology, the cosmic substratum functions as a *compass of inertia* (Weyl) marking all local deviations from the universal dispersion of matter. The arbitrary motion of an object relative to the substratum is therefore completely described by two pieces of information: 1) its instantaneous velocity relative to that fundamental particle with which it momentarily coincides; 2) its distance to that fundamental 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 inform us of the object's deviation from cosmic symmetry.

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

5. SUGGESTIONS

As stated by Phipps, 1986: what is relevant of Einstein's **SR** is comprised in the γ -factor. However, this factor does not imply that differentials of proper time are "inexact", as opined by Phipps; there is no reason at all to suppose that standard frame time should be "exact", and the Cern evidence has no bearing whatsoever on the relationship between fundamental observers.

Realizing the definability of a cosmic time, we have every reason to reject Einsteinian **SR** and to insist that the γ -factor $1/\sqrt{1-v^2/c^2}$, the importance of which we do not dispute, cannot be applied to describe the retardation of one fundamental master clock relative to another, since such clocks keep the same rate and can always be adjusted to show the same cosmic time.

Now stellar aberration, as well as the Sagnac experiment, 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. But an aether needs not be stationary, since it may be expanding. Such aether is best interpreted in terms of a substratum of fundamental particles.

That light behaves as if it were transmitted by a substratum means that light exchanged between two accidental particles, source and sink, emitter and receiver, is propagated as if it were exchanged 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, we shall need to make a calculation of probabilities.

It is at once obvious that such peculiar "transmission by substitute" must presuppose that a common time is definable for the two fundamental particles which serve as substitutes, one for the emitter, the other for the receiver. 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. If the transmission is instantaneous these two instants may even be simultaneous, i.e. relative to cosmic time, i.e. the proper time read off the atomic master clocks of fundamental particles.

Further it is clear that an exact location of the events of emission and reception, spatial and temporal, within the substratum must presuppose that the electromagnetic waves involved in the propagation of light have suffered a sort of "quantum collapse", the alternative being that electromagnetic energy is transmitted indefinitely in the substratum without ever being received. So a substratum theory would naturally interpret light in terms of "photons", understood as the instantaneous exchanges of quanta of action between emitter and receiver, source and sink.

We earlier distinguished two important representations of the substratum: one in terms of the public time T , according to which atoms as constituents of objects at rest in the substratum keep a constant size, the mutual distances between fundamental observers expanding; the other in terms of the public time τ , according to which the distances between fundamental observers are constant while the sizes of their atoms are shrinking. Disregarding quantum instantaneity, this distinction involves another one between a constant and a variable "speed of light".

Now I do not deny that the momentary "light speed", 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 imply that the average "light speed", as integrated over the tempo-spatial interval separating source and sink, emitter and receiver, must likewise remain constant? Of course not! So we have to consider the possibility of "photon speeds" deviating from unity.

The possibility of the speed of light being stretched over cosmic distances, due to the expansion of the universe, was discussed by Prokhovnik (cf. this book, ch.1 p.10).

Let us distinguish the constant light speed $c_o = 1$ from the variable light speed $c = c(\tau)$, the latter referring to a new τ -scale to be defined shortly. Let us also adopt the standard **SR** formula for clock retardation, as expressed by means of the famous γ -factor:

$$\gamma = dt/dT = 1/\sqrt{1-v^2/c_o^2} \equiv 1/\sqrt{1-v^2}$$

where t represents standard *frame time* and T represents so-called *proper time*.

In his monumental book on *The Natural Philosophy of Time* (1961), Whitrow suggested an analogy between the γ -factor of **SR** and the Robertson-Walker metric of modern cosmology. The analogy emerges if we make the identification $v \equiv dr/dt \equiv R(t) d\sigma/dt$, whence:

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

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

Here dT is an invariant element of *timespace* (better: *supertime*, as proposed by Mercier), and $d\sigma$ is an element of distance as measured in the substratum where σ is a fixed ("comoving") coordinate of some distant fundamental observer, while $R(t)$ is a dimensionless scale function for such elements, also called *the expansion factor* of the substratum. However, it is clear that, in this analogy, dt & dr can no longer be elements of ordinary frame time and frame distance.

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

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

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

Thus the expansion of the substratum, compared above to a stretching of the average *integrated light speed*, corresponds formally to a secular reduction of the sizes of atoms, which can equivalently be described as a secular reduction of the momentary *differential light speed*. This secular reduction is determined by the function $c(\tau)$. Being instantaneous and ubiquitous, it is imperceptible, i.e., it cannot be observed locally by any observer.

For any pair of fundamental particles, $\sigma = \text{const.}$, 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 we have $d\sigma \neq 0$, whence $dt \neq dT \neq d\tau/c(\tau)$. This deviation from true cosmic time might indicate the emergence of spontaneous accelerations, i.e. of "forces".

Hence the "cement of the universe" is not its ubiquitous network of causal connections in "space-time", but rather 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 preservation of angles (in private flat space) during the expansion of the universe or, rather, during the dispersion of its substratum of fundamental particles.

The reign of cosmic symmetry explains a lot that is else not explainable: the spontaneous emergence of forces, e.g., can be seen as the 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, taking it to be a corollary to universal expansion or, rather, dispersion. For this reason he would not perceive the need to revive Einstein's long ailing cosmological constant Λ .

Einstein once described his use of the cosmological constant as "my biggest blunder". One may well wonder whether this was really the worst of his blunders ...

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