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# IS TIME INSTANTANEOUS?

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The argument has been made by Hoyle, Hoffmann, Ballard, and others that all events in the Universe happen together and that 'time' is an illusionary ordering device. A critical review is given of this idea in the context of modern cosmology. It is possible that "time is instantaneous", but it is more useful to say that "the world is simultaneous". This accords with the view of Eddington, wherein labels like 'time' are recognized as subjective inventions.

## *Introduction*

Time is a tricky concept in physics. In recent years a new view of it has been proposed, apparently independently, by several workers. Thus Hoyle writes, "All moments of time exist together"[1,2], while Hoffmann says, "For us believing physicists the distinction between past, present and future is only an illusion, even if a stubborn one"[3], and Ballard suggests that we should "Think of the universe as a simultaneous structure. Everything that's ever happened, all the events that *will* ever happen, are taking place together"[4]. What follows is a brief examination of the idea that (in some sense) time is instantaneous. It is mathematical in places, but will go back to the philosophical belief of Eddington[5], namely that many of our physical concepts are invented rather than discovered.

## *The nature of time*

There are many opinions on this, which have been treated extensively in the books and review articles by Gold[6], Davies[7], Whitrow[8], McCrea[9], Hawking[10], Landsberg[11], Zeh[12], Woodward[13], and Wesson[14]. In regard to the question of whether events can actually be viewed as simultaneous, two themes have become noticeable in modern physics. On the small scale, the many-worlds interpretation of Everett[15] envisages that all outcomes of quantum-mechanical processes are possible, but that we are only aware of one which we call reality. This view, according to De Witt[16] and others, is both mathematically and physically consistent. On the large scale, the theory of general relativity as formulated by Einstein leads to cosmological models which evolve in a time direction set by the Big Bang. This dependence on an initial singularity may be unsatisfactory, but the models are in approximate agreement with astrophysical data, even while they leave questions unanswered (which have been noted by Rees[17], Dyson[18], and others) concerning what happens in the very late Universe.

In the absence of a theory which unifies quantum mechanics and general relativity, it is impossible to know if the two themes just mentioned admit of a consistent view of time, though some results about what time means in grand-unified field theory will be given below. Here, we note that time was apparently a puzzling concept even before the development of modern physics. For example, Newton, in his *Principia* (Scholium 1), stated that "Absolute, true and mathematical time, of itself, and from its own nature, flows equably without relation to anything external, and by another name is called duration." This sentence is often quoted in the literature, and is widely regarded as being in opposition to the nature of time as embodied later in relativity. However, prior to that sentence, Newton also wrote about time and space that "... the common people conceive these quantities under no other notions but from the relation they bear to sensible objects." Thus Newton was aware that the "common" people in the 1700s held a view of time and other physical concepts which was essentially the same as the one used by Einstein, Minkowski, Poincaré, and others in the 1900s as the basis for relativity.

Given the several different opinions that have been discussed about the nature of time, it is perhaps not surprising that some modern workers have sought to discard the concept. This idea has been popularized by the phrase "time is instantaneous". This is inaccurate, however. What authors like Hoyle[1,2], Hoffmann[3], and Ballard[4] are saying is that events happen simultaneously in a manner that gives the *illusion* of steadily flowing time. Thus from Ballard: "It's possible to imagine that everything is happening at once, all the events 'past' and 'future' which constitute the universe are taking place together. Perhaps our sense of time is a primitive mental structure that we inherited from our less intelligent forbears". This is reminiscent of Eddington[5]. And from Hoyle: "There is no such thing as 'waiting' for the future"[1] and "It could be that when we make subjective judgements we're using connections that are non-local ... there is a division, the world divides into two, into two completely disparate stacks of pigeon holes"[2]. This is reminiscent of Everett[15]. However, as pointed out by Hoyle, the approach to this idea need not be mystical (ref. 1, p. 7). He considers a four-dimensional world with coordinates $x^{123} = xyz$ of space and $x^4 = t$ of time and a surface



$$\phi(x^{1234}) = C \tag{1}$$

Here $C$ is a parameter which defines a subset of points in the world. Changing $C$ changes the subset, and "We could be said to live our lives through changes of $C$."

So far so good. But as Hoyle himself realized, writing down (1) does not resolve the fundamental issue: What are the $\phi$ surfaces? He speculated that they could be derived from known physical fields, like electromagnetism. The latter does play a part in the function of the human brain, but it would seem more likely that changes of $C$ in (1) are related to quantum phenomena, perhaps amplified by the brain in the manner suggested by Penrose[19]. But other questions also arise. A relation like (1) technically describes a 3D hypersurface in a 4D manifold. Now 4D manifolds, either flat or curved, are sufficient (separately) to describe electromagnetism and gravity, respectively, *via* Maxwell's equations and Einstein's equations. However, to describe both fields together really needs a curved 5D manifold, as realized in the 1920s by Kaluza and Klein[14]. And it is now generally acknowledged that to accommodate the other fields of particle physics requires even higher-dimensional spaces, as in 10D super strings and 11D super gravity. How is the dimensionality to be chosen? And more important from the viewpoint of calculation, what are the governing field equations?

Perhaps surprisingly, some progress can be made towards answering these questions and elucidating the nature of time by considering the intermediate case of 5D Kaluza-Klein theory with the 5D analog of Einstein's equations. Let an extra coordinate be $x^5 = l$, whose nature is yet unknown. A solution of the field equations is specified by an expression for the interval, which is the analogue of the distance (squared) between two nearby points in the manifold. There are many such solutions known[14], but one has particularly basic properties[20]. It is given by

$$dS^2 = l^2 dt^2 - l^2 e^{i(\omega t + k_x x)}\, dx^2 - l^2 e^{i(\omega t + k_y y)}\, dy^2 - l^2 e^{i(\omega t + k_z z)}\, dz^2 + L^2\, dl^2 \tag{2}$$

Here $\omega$ is a frequency, $k_x$, *etc.*, are wave numbers, and $L$ measures the size of the extra dimension. Equation (2), while it may look complicated, has some very informative aspects: (*a*) it describes a wave, in which parts of what are commonly called space can come into and go out of existence; (*b*) it can be transformed by a change of coordinates to a flat manifold, so what looks like a space with structure is equivalent to one that is featureless; (*c*) the signature is $+ - - - +$, so the extra coordinate acts like a second time.

These properties allow of some inferences relevant to the previous discussion: (*a*) even ordinary 3D space can be ephemeral; (*b*) a space may have structure which is not intrinsic but a result of how it is described; (*c*) there is no unique way to identify time.

These results can be traced to the principle of covariance, or the realization that the coordinates (labels) used in physical theories are changeable (arbitrary). This principle is used regularly in general relativity to alter the forms of expressions, and is a (partial) recognition of the fact that problems in physics may be set up in a way that is intuitively convenient but not mathematically convenient. In other words, covariance warns us not to rely on (subjective) intuition. Indeed, intuition becomes increasingly unreliable as physics becomes increasingly complex. It is deceptive even in the case of a flat, 4D space of the kind that might underly (1) above. The interval in this case is given by $ds^2 = dt^2 - dx^2 - dy^2 - dz^2$, and in many books it is stated that $ds = 0$ describes the path of a photon that propagates between points in 3D space over a certain time, defining the speed of light as approximately 300 000 km s$^{-1}$. This pedestrian interpretation obscures the subtlety of space-time: $ds = 0$ defines two points in 4D which are *coincident*. (This view does not necessarily upset the concept of time-ordering on the light cone, but does make it obsolescent. In this view, the number 300 000 has no real meaning, as emphasized in other contexts by Hoyle and McCrea.) The same argument can be applied to the 5D manifold of (2) above and others like it. Indeed, a detailed analysis shows that $dS = 0$ in 5D can correspond to $ds = 0$ (photons) or $ds \neq 0$ (massive particles) in 4D [21], where, however, the essential point is that *via* $dS = 0$ all particles are in contact in some sense in the higher-dimensional manifold. This provides a neat explanation of otherwise puzzling data on the uniformity of astrophysical quantities in the Universe[22,23]. In any grand-unified theory of $N$ dimensions, $dS_N = 0$ should not necessarily be taken as a statement about the propagation of particles in some space of less-than-$N$ dimensions. It is rather a statement about *coincidence* in a world whose complexity we do not fully understand.

*Conclusion*

It has been argued by several workers[1–4] that events in the Universe happen at the same time, or that "time is instantaneous". The considerations above show that it is more accurate to say that events in the Universe happen at zero interval, or that "the world is simultaneous".

Whether or not this is actually the case is not a question of mysticism but a question of science: it depends on definitions of geometry, notably with regard to dimensionality and signature. While the preceding discussion has concentrated on time, it has been realized since the advent of special relativity that this label has to be amalgamated with that of space. Also, it has been realized since the formulation of general relativity that time and space coordinates can be mixed, blurring their individuality in the concept of covariance. The last is now widely regarded as being a necessary ingredient of any good theory of physics. It is also generally acknowledged that the most promising route to a unification of gravity, electromagnetism, and the interactions of particles is *via* an extension of space-time to higher dimensions. If covariance rules, progress in physical theory will involve a reorganization of concepts and a shift to more sophisticated mathematics. This could have been foreseen, and was by a few workers,



most conspicuously Eddington[5]. His view of physics has become prevalent in a slow but methodical development that is still in progress: the world is objective, but the means by which it is described, including the label 'time', are subjective.

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