Time is the denominator of existence, and bits come to be in it*

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Abstract

In discussing his proposal that everything is a conglomerate of answers to yes-no questions—that all of *it* derives from discrete *bits*—John Wheeler noted that the physical concept that puts up the greatest resistance to being relegated, in the final analysis, to a world of discrete informational bits, is *time*. But the concept of time in physics is a mess. This is discussed in detail, and a potential resolution is suggested which clarifies present issues. However, rather than leading to a realisation of Wheeler's dream, time's resistance is only strengthened by a clearer idea of its function in modern physics.

1 Introduction

It from bit or bit from it? Can reality be reduced to a conglomerate of 0s and 1s? Is space-time itself a discrete lattice compounding arrays of answers to yes-no questions—bits of information that come to be as quantum interactions chance to occur? Wheeler's hypothesis is both bold and, in its simplicity, highly attractive.

For an ultimate goal of physics has been to describe Nature parsimoniously, through as few basic physical principles as possible. The hypothesis that everything might compound through binary interaction is therefore appealing. And certainly, the hypothesis is supported by the quantum nature of physical particles, the fundamental building blocks of everything we observe.

If a complete description of physical reality could be given through discretised uncertainty that builds up to appear as continuous and precise at macroscopic scales, and if there is no more to it all than the system of observables we've aimed to constrain with science, then perhaps *it*—the four-dimensional quantum-relativistic world of all sensible things—really comes to be as a logically orchestrated system of polar answers—'yes' or 'no'.

The proposition that *it* derives from *bit* ultimately derives from a hope that existence begets existence—that there is no 'underlying' or 'external' aspect of Nature; no basic property that has to hold *a priori* if anything at all should 'exist'—that everything we may think of as a fundamental aspect of reality could in truth be because of the correlation of randomly occurring bits. Regarding time as a key first principle to be done away with if his *it* from *bit* hypothesis would succeed, Wheeler noted that it 'is fed in from outside physics. It has someday to be derived from inside

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physics – when physics is deep enough to measure up to the task' [1]. The idea was that physics would eventually dig deep enough to conclude its most basic premiss—that when *it* would be shown to derive from a lot of randomly occurring *bits*, even the prior 'existence' that's needed for those bits to occur *in* would be necessitated through the deeper physics; that a fully consistent, detailed *description* of what exists might finally *explain why* it *should* exist—why it couldn't *not* exist. Accordingly, he held time as the greatest obstacle to the realisation of his dream [1]:

> Time, among all concepts in the world of physics, puts up the greatest resistance to being dethroned from ideal continuum to the world of the discrete, of information, of bits. Of physics the heart is dynamics, and of dynamics the heart is time...
>
> Of all obstacles to a thoroughly penetrating account of existence, none looms up more dismayingly than 'time.' Explain time? Not without explaining existence. Explain existence? Not without explaining time.

So we're charged with a need to describe *time* in a way that makes sense of *existence*—and a reasonably consistent description of time's function with respect to existence should shed light on the debate raised by Wheeler. But before anything meaningful can be said about time and existence, one point in particular needs clarification: if by *it* we would mean four-dimensional quantum-relativistic space-time, then it *doesn't* exist; it literally can't *exist*.

2 Time is the denominator of verbs, and space-time doesn't exist

On August 16, 2008 in Beijing, Usain Bolt ran 100 m in 9.69 s; a year later in Berlin, he shaved more than 0.1 s off that time, running the same distance. As I type, the computer on my desk isn't simply 'there', it '*is* there', resting (in time) on my desk, the cursor blinking (in time) as I think (in time) what to type (in time), as the seconds tick away in the upper right-hand corner of my monitor. It quickly becomes apparent that the 'in time' qualifier of every verb must be dropped, as implicitly understood, if a point is ever to be made.

We're concerned here with what it may mean for something to *exist*—and specifically, with what it would mean for space-time to exist. As the words (to) *exist*, (to) *be*, *is*, etc., are all verbs, they carry with them an implicit sense of temporality—i.e., nothing can *be*, if not over the course of some nonsingular length of time. *Time is in the denominator of all verbs*, with the copular verb as the principal one; for nothing can *run*, *sit*, *falter*, *discuss*, etc., if it *isn't*.

Relativity complicates such notions of time and temporal passage, which are now thought to lack objective meaning. An instant, according to relativity theory, could take an infinite time to pass in a coordinate system other than the one it's defined in, but throughout that time its extent will be zero in one spatial dimension (cf. the instants in Fig. 1).

But relativistic effects aren't actually relevant to the issue of space-time's non-existence that I'll discuss; for when I say space-time does not *exist*, I mean that in the sense that it is so very wrong—being both a literal and a conceptual fallacy!—when one *has* inferred from relativity that time can't *pass* in the sense that we commonly think to be happening, to say anything like 'The objective world simply *is*, it does not *happen*' [2]; therefore, as correct as it is to begin with, the following ends completely off the mark: 'Due to the absence of an observer-independent simultaneity relation, the Special Theory of Relativity does not support the view that "the world evolves

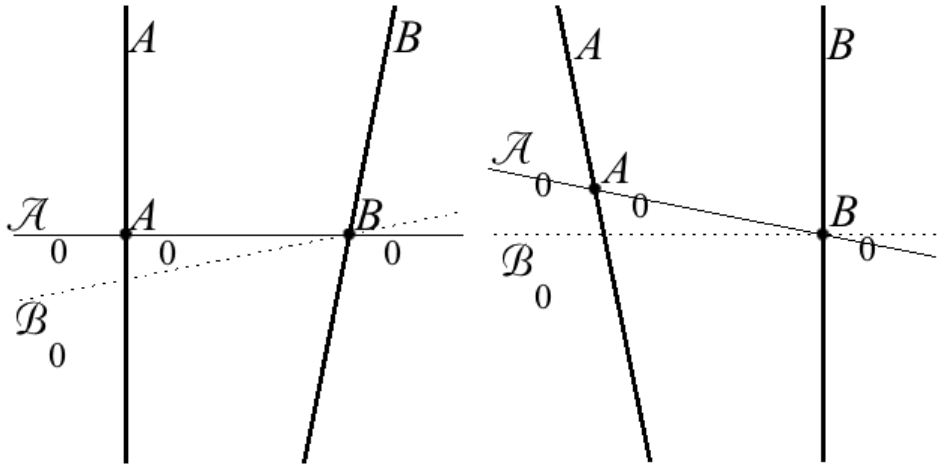

Figure 1: An instant, described in A's proper reference frame (left) and in B's (right), illustrating the relativity of simultaneity.

in time". Time, in the sense of an all-pervading "now" does not exist. The four-dimensional world simply is, it does not evolve' [3].

No verb can ever be applied to the space-time of Einstein and Minkowski without surreptitiously implying it's existence. For whenever we say 'space-time is (this or that)', even if to say it's a fully-laid out block from start to finish, a sense of temporality sneaks in to confuse the issue. But it's an unmistakable consequence of Einstein's relativity, that if anything at all outside of one's light cone could be said to 'exist'—if there is some Physical Reality beyond 'here-this instant'—then all of eternity has to exist [4, 5], and yet it can't really *exist*, because 'existence' is not a word that can apply to all of eternity; it's not an unchanging block that just sits there (in time), as the above two quotations from Weyl and Ehlers imply; it—space-time—*isn't*.

Yet how can we make any headway in explaining what it is, if it isn't. It's very difficult to say anything at all about space-time if we can't even use copula in describing it; to discuss what it 'is' and what it 'is not'. So often we think of space-time as an arena in which things happen. We draw a space-time diagram populated with world-lines and consider simultaneous sets of events in different coordinate frames, often imposing some (possibly) vague, (possibly) sub-conscious idea of flow upon our picture.

But we know this: if, at any particular time t_0 along one world-line A, the three-dimensional set of events that occur at the same 'instant' (call this set $\mathscr{A}_0$) can *really* be called 'simultaneous', then our most objective stance on the meaning of relativity tells us that every event in all of space-time must be 'simultaneous' with those events as well. We know this because it's always possible to draw a world-line B passing through some point B_0 in $\mathscr{A}_0$, and consider what's 'really simultaneous' from the perspective of a body whose existence B describes; i.e., we're considering which set of events $\mathscr{B}_0$ is simultaneous from B's perspective *at* B_0. But if B isn't parallel to A (relative motion), then $\mathscr{B}_0$ is composed of events that are 'earlier' (i.e., at $t < t_0$) and 'later' (at $t > t_0$) than the events of $\mathscr{A}_0$; see Fig. 1.

The relativity of simultaneity therefore implies that, beginning from any one three-dimensional instant, if we would say that the events of that particular instant 'really' occurred then, because it's the set of simultaneous events from one particular perspective, then all of space-time must 'really'

be 'occurring', because the same claim could be made of any event in all of space-time, from the perspective of another observer who 'really exists' *at that instant*.

A stance that's often been taken in order to recover some semblance of 'existence' in light of the implication that space-time 'simply *is*' a four-dimensional block, has been to say that nothing can *really* objectively 'exist' outside an observer's light cone, while the events of the past light cone must be in the past of here-now and those in the future light cone can't have occurred yet; e.g., the Sun doesn't exist 'right now' because we can't receive any information about it 'now' for another eight minutes, according to rest-frame coordinates—'the Sun right now' is nothing more certain than a sixteen minute stretch along its world-line that we can know and say nothing more conclusively about, whereas 'the Sun ten minutes ago' is an event in the past of all possible Earthly observers, and 'the Sun ten minutes from now' has to be in the future of everything on Earth-now, regardless of motion. In fact, Stein [5] has shown that if one asserts the reality of any single event in the 'elsewhere' beyond one's own *here-now*, that's sufficient to require the simultaneous existence of the entire four-dimensional absolute world.

This is indeed a gloomy prospect, and one that Einstein knew well, as Carnap famously related [6]:

> Once Einstein said that the problem of the Now worried him seriously. He explained that the experience of the Now means something special for man, something essentially different from the past and the future, but that this important difference does not and cannot occur within physics. That this experience cannot be grasped by science seemed to him a matter of painful but inevitable resignation. ...Einstein thought that these scientific descriptions cannot possibly satisfy our human needs; that there is something essential about the Now which is just outside the realm of science.

Einstein was well aware of the problem that the relativity of simultaneity places on 'existence'; e.g., after explaining why relativity theory, when interpreted objectively, distinctly favours a block eternity, he and Infeld wrote that 'we can still use the dynamic picture if we prefer it. But we must remember that this division into time and space has no objective meaning since time is no longer "absolute." We shall still use the "dynamic" and not the "static" language...bearing in mind its limitations' [7].

It might have been fine to continue using the dynamic picture and language, as they claim, as long as it was well understood by everyone that a static block is the best description of space-time, and that the verbs we use in describing space-time as being this or that are essentially wrong. It *would* be fine, if using the dynamic picture weren't so misleading.

But for all the many popular well laid out descriptions, such as one given recently by Greene [8] which explains quite clearly how the relativity of simultaneity is inconsistent with a time that flows, the point hasn't been universally appreciated; and others, such as Hawking, have described space-time not only by 'using dynamical language', but really as a dynamical thing [9]: 'Space and time are now dynamic quantities: when a body moves, or a force acts, it affects the curvature of space and time—and in turn the structure of space-time affects the way in which bodies move and forces act. Space and time not only affect but are also affected by everything that happens in the universe.'

In this picture, space-time—all four dimensions of 'existence'—*exists* as a dynamically warping and moulding thing that *evolves* as things happen in it. In Hawking's view, space-time is a Lorentzian metric space with massive bodies moving about and warping it and being acted upon

reciprocally. In order for space-time to *change*—for it to be one four-dimensional thing, and subsequently another, then another, as it *continually updates*—its sequence of states might be described through a fifth, Newtonian absolute time dimension.

But is this essentially very much different from a description of space-time as something that 'simply *is*'? Here, we have an idea of space-time as an unchanging block that sits in our minds as we think of it. Even when we accept the implication of space-time as all four dimensions of existence at once, the mental image of it that we form is not 'just block space-time', but 'block space-time that just *is*'. We add a similar dimension of temporality as in the dynamical picture of space-time, that's unaccounted for in the mathematical theory.

But then the question is: is it all that unreasonable that we should do this? Certainly in our own conscious minds all that exists is the present and the ticking of the clock. If a block universe most objectively corresponds to our physical theory, and that can't be something that's even said to 'exist'—if space-time, apart from its time-like dimension, is *temporally singular*—then how can we possibly account for the apparent flow of consciousness we're experiencing? As noted by Čapek [10],

> If true reality is timeless, *where does the illusion of succession come from?* If time has no genuine reality, why does it appear to be real?
>
> No solution can be found which would not introduce surreptitiously the reality of time *somewhere*. If the illusory reality of time is nothing but a gradual rising of the curtain of ignorance which separates our mind from the complete and timeless insight, then at least *this process of rising is still a process which unfolds itself gradually without being given at once*...

While it's true that human beings are imperfect scientific instruments, should we really have to accept that we have Physical Reality entirely wrong in our minds? The reality of time in consciousness that Čapek notes, which physical theory must account for though Einstein worried that it can't, is inconsistent with the commonly espoused meaning of relativity. Yet even still, because a temporally singular space-time block is impossible for our flowing consciousnesses to grasp, many have tended to fall back on a dynamical description of *local* space-time that endures, and describe things as *happening* locally; but this type of thinking has often led to paradoxes like those involved with time travel, the prospect of which has in fact been investigated seriously in a relativistic context by many top physicists (see e.g. [11], and references therein).

The 'grandfather paradox' provides a useful setting in which to justify calling the time-dimension that space-time is often thought to exist in 'Newtonian'. We can begin with the idea of *Newtonian space-time-time*, as block space-time that *is*—i.e., that *exists* as extraneous Newtonian time ticks away. One could think of a two-dimensional slice of Minkowski space-time as floating upwards, or as simply *existing* in place, in three-dimensional nothingness as æthereal time passes. While this occurs, we focus on a particular point along a world-line, and consciously follow along from there with an observer whose existence the line represents, as the whole space-time evolves. Consciousness within this space-time is like a flowing river, and whenever we like (in our godlike existence) we can pick up and return, e.g., to a favourite point on our hero's world-line, and follow along from there again, just as we'd re-watch a favourite film.

At some point, we get tired of repeatedly watching our favourite parts and allow ourselves to flow on. Eventually, our hero has a eureka moment, and sees how to invent a time machine. His invention will allow him to go anywhere in space-time, and it always returns him exactly to

the point on his world-line that he left; and his body doesn't age while he's time travelling. But while he's travelling about, the absolute time of space-time's existence continually passes. At first, he travels only as an observer; but as he continues travelling the risk of impact increases, and eventually he modifies something that changes the course of history. As time travel stories usually go, the effect of whatever it is he did immediately propagates through space-time. The idea amounts to an instantaneous action-at-a-space-time-distance—which is indeed far *spookier* than anything in what Newton offered. If, in the new reality he's created through this mishap, any of his ancestors aren't born, then he can't be born, and we arrive at the familiar paradox.

But this is no real paradox at all: the fallacy lies in the prior assumption that all past and future events *exist*, as space-time is supposed to *exist*, as an *enduring* block; and the paradox emerges when we consider the further prospect, that the events of space-time may be alterable through acts of free will, as change might take place within the bounds of 'what exists'. This 'paradox' is based on the unjustified, fuzzy idea of a block universe as a flowing river of consciousness that exists in an æthereal Newtonian time, where action-at-a-space-time-distance is imagined to be possible. But relativistic space-time has never been formally developed as such, and should be described more consistently as one particular slice of that space-time-time—an instant of the extraneous Newtonian time. Furthermore, to ever say that space-time 'is' such a slice is wrong, because a temporally singular thing (as in a Lorentzian metric space all on its own) can't *be*—i.e. in time!

3 Then what might be 'existence'?

Space-time does not exist, as temporality lies in the denominator of 'what exists'; no interval of time 'exists' in the modern physics description. Therefore, while relativity theory indicates that space and time are inseparable, notions of *existence* that are commonly considered in a relativistic context seem at best to disprove themselves by contradiction. For if I'm allowed to consider everything that's happening in sync with my own clock as 'what exists', and if another observer who 'exists' by this definition is similarly allowed to define 'what exists', this leads through to the implication of space-time as a whole temporally singular four-dimensional block that cannot exist.

A popular stance to take has therefore been that nothing definitely exists except that which arises through perception here-now, for each observer. This is supported in some sense by the quantum-mechanical implication that nothing definitely exists until it's observed—which, in turn, was presented by Wheeler in support of his view that there is no objective world sitting 'out there'; that [1]

> Not until the observing sense, or observing device…has chosen the question to be asked, and by its registration has made a record long enough lived to produce internal or external action, has an elementary quantum phenomenon taken place that contributes to the formation of what we call reality. No other way do we know to build this reality. Existence? How else is it brought into being except through elementary quantum phenomena?

Is existence some thing that's 'brought into being' through observation, or is there a world that *exists*, with things happening in it through the course of time? The latter idea is certainly what common sense supports, though modern physics is thought to be at odds. If existence is no more than observed quantum interactions, according to the Bohr-ish view of reality promoted by

Wheeler, then the 'it from bit' hypothesis is plausible. And certainly relativity, in its presentation as a theory that's inconsistent with reality being 'what exists out there', has done nothing to dissuade that view.

But our discussion on the unreality of space-time may shed some light on the problem of 'what exists', as it should clarify the relation between that and space-time—i.e., that the events comprising space-time are what *happen* as things *exist*.

This obvious point is worth drawing out more carefully. We've established that space-time does not exist, as the concept of existence assumes a prior sense of temporality that space-time lacks—*time* being a part of it. Space-time is the set of all events that *occur* in reality—the quantum-relativistic field of *happenings*. But there's a prior sense of *existence* that must be satisfied before anything can *happen*—e.g., Usain Bolt exists on Earth; he existed in Beijing during the 2008 Olympics when, on August 16, he stood near the starting line of the men's 100 m final; there is a set of events of finite spatio-temporal extent that *happened* as he stepped into the starting blocks, waited, and reacted to the gun, arriving at the finish line 9.69 s later with a new record. Each of these events is a point within his body at a time and place where his body was—a point in space-time that happened *as he existed*.

The *events* of space-time—the quantum interactions that *occur*—don't *exist*; space-time is a graduating map of everything that occurs in reality, as *it* exists *in time*. The 'reality' that Wheeler spoke of as being built up of quantum phenomena that are observed, *is* space-time ('quantum phenomena contribute to the formation of what we call reality')—and that clearly can't be 'what exists' by any common idea of reality; e.g., nothing but idle speculation, except perhaps a gross misunderstanding of the meaning of relativity, would suggest that the event, when Usain Bolt sauntered across the finish line in Beijing, is something that *exists*, and could possibly be gone to and mucked-about with. Space-time may well build up as a discrete set of quantum phenomena, as Wheeler proposed, rather than as a continuum of events; but before those events can ever occur, there must be some *existence* for them to occur in.

4 On space that exists in time, while space-time maps out as the unfolding of events

As we search for a consistent physical description, we'd like to reconcile that with the common idea of reality, as 'what exists (in time) out there (in space)'—so it will be useful to examine in more detail the source of our current trouble with that—viz., the relativity of simultaneity—with the aim of describing existence in a way that's consistent with the one timelike and three spacelike dimensions we're conscious of, so as not to evoke surreptitiously any extra temporality due to a fundamental inconsistency with language and consciousness.

Actually, as explained elsewhere [13], relativity is not inconsistent with our common idea that reality is comprised of things existing (with passing time) in three spatial dimensions—and current scientific evidence actually supports the common view; but it's worth considering this some more, because acceptance of the realistic alternative to Einstein's interpretation of relativity comes with the price of having to reject the fantastic notion that 'what exists for me' is different from 'what exists for you' because I'm now out for a walk and you're sitting somewhere reading this.

We'll make use of a brief thought experiment à la Einstein: consider two friends, Albert (A)

and Henri (H); A stands in a field and watches H pass to the right in a train car with the doors wide open; both agree that the speed of light is exactly the same from any perspective, and that any perspective is a good one through which to describe what goes on; H has with him a clock that 'ticks' as a photon is reflected *purely vertically* between two mirrors. As the car moves horizontally, A describes the photon's path from the bottom to the top mirror, or from the top to the bottom, as the hypotenuse of a right triangle—which is longer than the photon's path from the perspective of H, who describes it as only the vertical leg, and attributes any horizontal motion to A. A compares the ticks of H's clock with those of a similar one that sits in front of him, with exactly the same vertical space between the two mirrors, and finds that H's ticks take longer—i.e., upon the basis of the two prior assumptions, its impossible *not* to conclude that H's time runs slowly relative to A's.

Later on, the two meet up to compare results and H speaks first: 'You haven't aged as much as I have; your clock ran slower because the photon was bounding off to the right while the one in mine just went up and down. Since both photons had the same velocity, fewer seconds passed here on the ground.' After some brief discussion, they both realise the paradoxical result, that from any perspective, a clock in uniform translatory motion will tick slowly.

Eager to explore this fascinating discovery further, they perform another experiment in which H brings a second clock C onto the train, placing it at the left-end of the open door while he sits at the right-end with the other. He's added a counter to each clock to record the number of ticks, and ensures in his own way that they are precisely in sync as he rolls past A, having accounted for the distance to the clock at the far end of the car and the finite speed of light. But when he gets off the train, A criticises him for having been sloppy: a video recording shows H smiling at a clock synchronisation well done, the two clocks ticking away with precisely the same slowed rate that was previously discovered, and the left one always *just* ahead of the right. But H recorded the experiment as well, and his video shows his clock ticking *earlier*, by precisely the distance between the two clocks divided by the speed of light—i.e., by the additional time it takes a photon to arrive at his recorder when the two clocks are *perfectly in sync*.

They've discovered the relativity of synchronicity—that two spatially separated events can be described in one four-dimensional coordinate system as having occurred at the same time, while in another they'll be described as having occurred at different times—and the question is: did the synchronous set of events that occured in H's set-up *really* take place simultaneously, or did the mis-matched set of clock readings perceived by A *really* occur at the same time? If we consider just a single event along H's world-line (see Fig. 2), we'd like to know what other events *really* happened then—was it the synchronous set according to H, or that according to A?

The common inference has been that it depends who's looking—that the simultaneity of distant events is relative. The idea of an all-pervading 'now' is supposed to be a fault of human perception, as light moves so quickly as to give us the impression that what we see 'now', as time ticks away, is the world we think really exists all around us.

But the problem's not that simple: H *knows* that the reading he perceives from the clock sitting across the train car isn't the reading that's displayed 'now', but one he's informed about by light that travelled through space in time, at a finite speed before reaching his eye; he *knows* this, just as he knows that when someone throws a ball that hits him in the face, the event when the ball is thrown isn't simultaneous with him being hit in the face, but occurs *before*. He's used this knowledge in synchronising the two clocks because he understands basic kinematical principles.

However, being a follower of Galileo and Newton who understands the relativity of inertia, he hasn't seen reason to account for the fact that he and the clock are actually moving. He's taken the

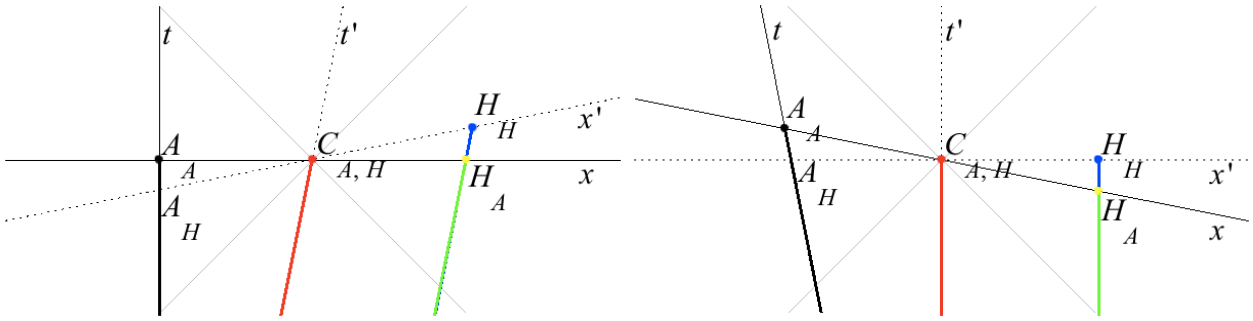

Figure 2: An instant, described in A's proper reference frame (left) and in H's (right). Events A_A, C_A, and H_A are synchronous in A's coordinates, occurring at $t = t_A$; and events A_H, C_H, and H_H are synchronous in H's coordinates, occurring at $t' = t'_H$. (Adapted from [13])

assumption that his own perspective should be as good a one in which to describe the events that occur in reality too literally.

But upon some reflection it comes to him: as he sat a fixed distance from the clock at the other end of the car, when the car was moving it actually took slightly less time for light from simultaneously occurring events to reach him than he'd considered because he was also moving towards the location where the light was emitted, so he intercepted it after it travelled a slightly shorter distance. If he'd accounted for this difference, his clock would still tick slightly before he'd see C tick—by the extra time it takes him and the photons to come together in space—and A would have seen the clocks as properly synchronised.

And now he realises the significance of the relativity of synchronicity he'd discovered with A: the truly simultaneous events at C that he's able to describe by accounting for his own motion towards them, are out of sync in his proper coordinate frame. This is indeed a significant result, for he's now realised Newton's error—i.e., in assuming that truly simultaneous events, occurring at the same absolute time, should be described as synchronous in the proper coordinate frames of all inertial observers, Newton's theory is inconsistent with a constant finite speed of light.

Of course this alternate interpretation of relativity stands in stark contrast to Einstein's, which retains the assumption that simultaneous events are synchronous in the frame of every observer, and rejects the assumption of [12]

> Absolute, true and mathematical time, [which] of itself, and from its own nature flows equably without regard to anything external, and by another name is called duration.

But whereas the former interpretation is inconsistent with any sense of existence, and ultimately disproves itself by contradiction, the latter—which is perfectly consistent with the mathematical theory of relativity, and has been confirmed by cosmological observations [13]—leads to a description that agrees perfectly well with what we commonly think of as existing. And while *it* exists, the quantum-interactions, the *bits* that chance to occur, come together in building the graduating space-time map of all that's ever happened in *it*.

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