Reviving Newtonian Time to Interpret Relativistic Space-Time

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Abstract

This article presents a philosophical notion whereby one can view relativistic motion as an emergent result of rationing of Newtonian time between intrinsic dynamics and bodily spatial motion. One surprising aspect of this interpretation is that it represents motion as slow-down with respect to a default state of motion - which is to hurtle at the speed of light (c). Thus any object that we perceive as speeding up is actually slowing down (with reference to the maximum possible speed c) in the opposite direction. This may sound tautological but has important consequence when we see it in terms of time being rationed between intrinsic dynamics and spatial motion.

We could condense the central idea of this article into the following lines:

> *Forget about light clocks and space contraction. Light speed is constant regardless of your speed because of the way Newtonian time gets rationed between intrinsic motion and spatial motion. Light moves ahead of you only for the time you spend on intrinsic dynamics (i.e. relativistic time). During your spatial motion part of the time, you are moving with light.*

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1 Introduction

Following is the definition of time as presented by Newton in his *Philosophiae Naturalis Principia Mathematica*.

> 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: relative, apparent, and common time, is some sensible and external (whether accurate or unequable) measure of duration by the means of motion, which is commonly used instead of true time; such as an hour, a day, a month, a year.

This absolute concept of time ruled physics for centuries until Einstein came up with his theory of relativity that viewed time not as an absolute universal but as a part of an active fabric that is sensitive to the reference frame of motion. The fundamental equations of relativity indicated that time slowed down in moving reference frames. The relativistic equations agree with experiment but has aspects that appear to lack a microscopic interpretation, some of which this article aims at addressing. The notion occurred rather randomly while waiting for a teabag to stew but if we must state the motivation, that would be the observation that sub-atomic entities (whose motions are universally ruled by relativity) seem like unlikely candidates to be bothered to uphold geometric invariants. For the most part they seem like little happy-go-lucky things with a lifestyle too simple and too varied to be all perfectionist about slowing down clocks or shrinking space precisely by factors involving square roots and so on. Not saying that they don't end up displaying such precision, but it would be more pleasing if the relativistic invariants arose from something simpler.

2 Postulates

The usual format of a purportedly scientific theory is to spell out its postulates/axioms. It is often possible to get the same end results by choosing a different set of postulates. For example, the entirety of Euclidean geometry has been for several choices of an equal number of initial axioms. This humble attempt may be seen as a re-postulation of relativistic mechanics. The following points do not qualify perfectly as formal postulates for it draws upon relativistic and Newtonian terminology, but an informal approach is taken for ease of expression.

1. The default behaviour of elemental entities of the world (that even sub-atomic object are composed of) are to hurtle through space at the maximum possible

speed.

2. Any inertial-frame behaviour arises due to elemental entities deviating from this default behaviour by spending some of their time *socializing* - i.e. carrying out intrinsic dynamics in some state-space that is independent of space. The time mentioned here is Newtonian i.e. its rate of passage is not affected by the state of motion. The Einsteinian (relativistic) time is precisely the time spent in intrinsic dynamics. The residue between the Newtonian time and the Einsteinian time is the time spent in spatial motion.

3. The bottom-level evolution equations are linear.

3 Consequences of the Postulates

Now let us examine the consequences of these postulates. In the above, the elemental objects are imagined to be the entities that dwell the very bottom of the composition hierarchy - the staff that both mass and energy - both sub-atomic particles and light quanta are purportedly made of. They are probably wispy spatially distributed assemblies of finer parts of themselves, perhaps leading up to something atomic further down below. The difference in orders of magnitude between smallest physical scales of space (Planck Scale) and sub-atomic scales is much greater than that in the Avogadro number. So, for all intents and purposes, there is plenty of room at the bottom to allow for continua and fields arising from the discrete sub-structures further down. That consideration does not affect our discussion beyond the indication that such entities should be perfectly capable of having intrinsic degrees of freedom in some state-space independent of the configuration space of bodily movements. Quantum mechanics give equations for such intrinsic evolution, in which the internal state of a particle is represented as a vector in a Hilbert space, the evolution is represented as time indexed unitary transformations. The unitary matrix evolution operator can be alternately represented as larger matrices with real elements alone but with skew symmetric distribution of coefficients (e.g. Lanczos form of Dirac equation). The skew symmetric nature of the evolution operator is crucial because the equations represent coupling of the intrinsic state with geometric space, and without skew symmetric transform the orthogonality of space and internal state-space would be violated. The simplest form of this skew symmetry is exhibited by a macroscopic simple harmonic oscillator, for which if the second order equation is written in linear state-space form, the evolution matrix would be necessarily be skew symmetric, indicating that the oscillatory motion is ultimately independent of a bodily motion. In macroscopic classical dynamics bodily motion and harmonic oscillation can happen simultaneously yet independently of each other but the above postulates imply that at a certain level of composition no such time sharing is possible. The intrinsic oscillation and bodily motion must ration the absolute (Newtonian) time between themselves. If you must consider a macroscopic analogy, imagine a robotic Rubix cube machine that must split its CPU clock cycles between those spent in turning its layers and moving the cube. The two motions of such a machine may still appear simultaneous and continuous to an observer if the time-slices are narrow enough to evade detection.

The fact of being entirely composed of such elements comes with additional difficulty of detection. Since we and all our instruments are made of the stuff that obeys the above postulates, we are constrained to see the intrinsic time as *the time* - i.e. although there is a Newtonian time flowing in the background, but we don't have a direct access to it. We can't easily measure it, for all our physical processes progress through intrinsic dynamics.

So, what really happens when a particle or body speeds up? Well, it doesn't. Something appears to speed up only because it has slowed down in the opposite direction - i.e. it is spending more time doing intrinsic stuff. Say a particle is sitting still next to you, and it absorbs a photon and leaves your company at a high speed. While it looks very much like the photon sped it up, but the reality at a certain level of detail might be that its level of intrinsic dynamics has now heightened (i.e. it has a new guest at home) and it can't keep up with your inertial frame. The relative spatial directionality of motion emerges at a higher level of composition, just the way directionality of rigid body rotations emerge when a group of particles get engaged in a certain distance-preserving intrinsic relationship.

So when a particle is accelerating, it is actually slowing down with reference to the default state - i.e. moving at speed of light.

Just the way Newtonian time gets rationed between intrinsic dynamics time (Einsteinian/relativistic view of time), there can be other contenders for slices of time. When two non-coherent (unrelated) sub-atomic objects engage in some mutual-state dynamics, that could become yet another consumer of Newtonian time. This manifests in various phenomena. The Gravitational slow-down of clocks fall in this category. When a particle is in a strong gravitational field its substratum is using some of its time in some mysterious choreography, which manifests as a clock slow-down. Such clock slow-down may be avoided if the particle could radiate away some of its trapped energy as a photon. This behaviour is exhibited by electrons in orbitals around atomic nuclei. When an electron makes a transition to an orbital closer to the nucleus, it engages more heavily in mutual dynamics with the nucleus, but needs to leave some of its baggage to make time for it. Thus an electron that moves to an inner orbital radiates a photon to make more time for the intensified interaction with the nucleus. In this world-view the fundamental currency of motion, intrinsic progression of time, and mutual interaction is time. When an electron within an atomic/molecular orbital absorbs a photon, its time becomes less pre-occupied with the mutual dynamics, to the extent of full disengagement. It can also transition to a remote orbital that demands less commitment to the nucleus, and radiate away some residual energy to keep up with the new demand on time.

4 Derivation of Relativistic Transforms

Let us denote Newtonian time by t, Einsteinian time by T. Let X denote the spatial displacement of a particle with respect to you, an inertial observer.
Imagine a regime of motion that is valid for some small interval within which the particle negotiates a linear dynamics (i.e. a spatial dynamics described a linear differential equation). The linearity is the 3^{rd} postulate as stated above. We understand that a linear dynamics involving X and T would have the following form.

$$\frac{dX}{dt} = AX + BT$$

$$\frac{dT}{dt} = CX + DT$$

Where A, B, C, D are some coefficients. We seek an equation for which X/T is bounded for all t with a bound of c (as the most it could do is squander all its Newtonian time in intrinsic dynamics, thereby falling behind the default motion by c). The diagonal coefficients cause exponential growth or decay, neither of which can represent a finite bound. Thus the form of the equation can be of the form :

$$\frac{dX}{dt} = BT$$

$$\frac{dT}{dt} = CX$$

The coefficients are dependent on units of time and space, but if we normalise the quantities in terms of physical units - viz. Planck units (i.e. let p_x be Planck length and

p_t be Planck time), then the coefficients should become equal. Thus the equations take the form:

$$\frac{1}{p_x}\frac{dX}{dt} = k\frac{T}{p_t}$$

$$\frac{1}{p_t}\frac{dT}{dt} = k\frac{X}{p_X}$$

Rearranging a bit, we get:

$$\frac{dX}{dt} = k\frac{Tp_x}{p_t}$$

$$\frac{p_X}{p_t}\frac{dT}{dt} = kX$$

And since $\frac{p_x}{p_t}$ is c, we have:

$$\frac{dX}{dt} = kcT$$

$$\frac{d(cT)}{dt} = kX$$

This may be written in matrix form as follows:

$$\begin{pmatrix} \frac{dX}{dt} \\ \frac{d(cT)}{dt} \end{pmatrix} = \begin{pmatrix} 0 & k \\ k & 0 \end{pmatrix} \begin{pmatrix} X \\ cT \end{pmatrix}$$

Let us call this differential equation the **energization flow** as it claims to describe the *state evolution* that happens in response to acquisition of additional energy. The finite-time evolution equation is the exponential of the linear differential evolution matrix times t. Thus we have the following solution:

$$\begin{pmatrix} X \\ cT \end{pmatrix} = \begin{pmatrix} cosh(kt) & sinh(kt) \\ sinh(kt) & cosh(kt) \end{pmatrix} \begin{pmatrix} X_0 \\ cT_0 \end{pmatrix}$$

This is the equation that gives relativistic time and space as noted by the inertial observer. The moving particle may pretend to be oblivious to this change and express its observations in terms of its inertial frame. Thus any space-time coordinate in the moving particle's inertial frame (X_0, T_0) will transform by the above equation to give the space-time coordinate in the original observer's frame. To get the opposite transform, we can invert the above matrix. It's determinant is 1 by the hyperbolic trigonometric identity $cosh^2(kt) - sinh^2(kt) = 1$, which makes the inversion simpler.

$$\begin{pmatrix} X_0 \\ cT_0 \end{pmatrix} = \begin{pmatrix} cosh(kt) & -sinh(kt) \\ -sinh(kt) & cosh(kt) \end{pmatrix} \begin{pmatrix} X \\ cT \end{pmatrix}$$

We still have not defined the notion of relative velocity. We can only ever measure velocity in terms of X and T (i.e. relativistic space and time), so the velocity of the particle with reference to the observer will be X/T corresponding to the origin within the particle's frame. So if we put $X_0 = 0$ and $X = vT$, we get the following:

$$0 = X_0 = cosh(kt) * vT - sinh(kt)cT$$

Therefore $v = c\, tanh(kt)$ or $tanh(kt) = v/c$. Next we can use the following hyperbolic trigonometric identities

$$sinh(x) = tanh(x)/\sqrt{1 - tanh^2(x)} = \frac{v}{c}\frac{1}{\sqrt{1 - v^2/c^2}}$$

$$cosh(x) = 1/\sqrt{1 - tanh^2(x)} = \frac{1}{\sqrt{1 - v^2/c^2}}$$

When these are put back into the above transformation matrices, we get exactly the Lorentz transform. The following hyperbolic identity gives a clue as to why relativistic relative velocities add like $tanh$ functions.

$$tanh(a + b) = \frac{tanh(a) + tanh(b)}{1 + tanh(a)tanh(b)}$$

It is also worth noting that no matter how long the linear differential equation evolves, the relative velocity between the particle and the observer can approach at the most c (since $v = c\, tanh(kt)$ and $tanh$ can at the most take the value 1). Approaching a relative velocity of c corresponds to coming to a grinding halt.

5 Ramifications

This section lists a few ramifications of the above theory.

- One of the key aspects of the above theory is a clarification of the concept of relative velocity. The *relative velocity* that is constrained to be less than c is based on *inertial ancestry*. To illustrate the idea, please suppose that a space ship is launched from the earth and is receding at speed v_1, which in turn launches a daughter ship that moves away from the mother ship in the same direction at a relative speed of v_2. And the daughter ship launches another (grand-daughter) ship that recedes at a speed v_3, then the earth, the mother-ship, and the daughter ships are inertial ancestors of the grand-daughter ship. Under conditions of inertial lineage the relative velocities would be combined by the formula

$(v_1 + v_2)/(1 + v_1 v_2)$, and as such the relative speed will never exceed c. This is so because after all the history of motion is governed by *successive application* of the aforementioned *energization flows*. But two objects that were never inertially in lock-step could have relative velocity greater than c and up to $2c$. To illustrate the latter point consider that two sub-atomic particles that were emitted in nuclear decay are being accelerated in a stack of two particle accelerators, one going clockwise and the other counter-clockwise until they both achieve a speed of almost c. Then the magnetic field is opportunistically switched off when the two particles are at their closest approach in a cycle, and left to travel in the opposite directions. They are then detected at two distant detectors at a distance of say, d from the point of release. Surely they will reach the detectors at time $t = d/c$, which would mean that the gap between them increased at a speed of $2d/t = \frac{2d}{d/c}$, which is $2c$. There seems no reason to insist that the relative speed of recession needs to be $(c + c)/(1 + c * c/c^2)$ in the frame of the particles (by compressing space and what not), since these were never inertially locked in with respect to each other. The same probably could happen for mutually distant galaxies unless an inertial ancestry is implied.
Having a mutual relative speed greater than c doesn't mean that one can outrun light emitted by the other. Light's is never inertially locked in with its emitter, and since inertial speed in any direction can't exceed c (after all, every entity's speed emerges from slowing down with respect to c), light travelling in the same direction (i.e. chasing direction) will always catch up.

- The twin paradox does not arise in this theory because the time dilation is introduced explicitly on one observer by the *energization flow* described above, and not by a mutual equivalence of the frames of reference.

- This theory gives a more self-consistent resolution of the question underlying Mach principle, in that inertia arises by slowing down with reference to the maximum possible speed, and not with reference to an arbitrary cosmological frame.

- Time dilation of decay processes happen precisely alike in accelerators (i.e. highly curved paths) and atmosphere (linear paths), which suggests that inertial-frame is not a requirement for time dilation - something that is implied by Einsteinian derivation of time dilation. In the above *energization flow* model of time dilation, the directionality and path curvature does not play a role so the curved path behaviour is explained by default.

6 Discussion

We posted this article on a web-forum called quora.com with a request a critique, and received some very helpful comments. This section will present a discussion of such comments. The comments would be formatted as quotes followed by our response. The following comments are from **Erik Anson**, Ph.D. student of Physics/Cosmology.

> (The article) defines *time* in a way such that it can't actually be measured by actual clocks; instead, it is an artificial quantity constructed by applying the inverse of time dilation to the times that would actually be measured.

Special relativity describes the geometry of space-time intrinsically as a manifold whereas here we try to speculate a linear space model from which such geometry could emerge.

> If you're looking for a *time* measurement that is frame-invariant, it's a better bet to use proper time, rather than some externally-enforced *Newtonian* time. The initial equations come out of nowhere. Yes, I know that they are meant to come from the 3rd postulate, but not only is that postulate itself unmotivated, it's also not even clear what is meant by it until the equations appear later. So, basically, that postulate may as well read, *these differential equations work*.

The initial equations may be justified by the consideration that only linear flows can be permanently stable. Even the simplest non-linearity in an evolution equation (e.g. Volterra-Lotka systems) can give rise to massive diversity of behaviour at best, and chaos/instabilities at worst. And we did start with the most general linear form, so there is nothing to justify beyond rejecting the non-linear.
I admit that it wasn't clear how the postulates influence the equations. I shall try to clarify that here.
Firstly the temporal speed (i.e. rate of accumulation of relativistic time) has a positive coefficient with respect to spatial displacement (i.e. the second equation) because the more the particle falls behind in space (and hence displaces), the more it is rationing its time in favour of intrinsic (i.e. non-spatial) dynamics. Secondly the spatial speed is positively correlated with accumulation of relativistic time (i.e. the first equation), because the more the particle accumulates time in its intrinsic dynamics the more it falls behind in space.

> The *twin paradox* is not an actual paradox; it just looks like a paradox if you try to apply SR in a sloppy way.

I did not mean that the twin paradox is an unresolved question. I meant that the question arose in the first place due to the SR postulate of *perfect equivalence of inertial frames*. It's resolution is based on breaking the equivalence/symmetry by requiring one of the twins to get back to the other through an accelerated motion. A better question is *yes, so the equivalence isn't perfect, so how exactly would you qualify it?* How should we fill up the blanks in "*Inertial frames are equivalent to the extent* ___________". I hope it is not *what it takes to derive Lorentz transform*.
I also have a thing or two against the resolution argument in that it fails to work if we try some variants of the usual *twin paradox*. Following a couple of such variants:
Variant 1 : Two spaceships are moving at different velocities in a straight line. Neither ever accelerates in our experiment, but they communicate through two trains of bullets that pass by both ship in opposite directions. They imprint the bullets digitally with their local time-stamps and read the imprints coming from the other spaceship. They will notice a drift in clock rates between their clocks with which they can decide whose clock is running slower, without ever needing to accelerate during this experiment, of course they may have accelerated earlier on to get to the speed states that they are in. Any clock drift detected through those communication bullets would reflect such pre-determined prior history of accelerations.
Variant 2 : What if both twins accelerate to come back together? In that case the argument *one accelerated and the other didn't* doesn't work, and at least calls for a more quantitative relationships between accelerations and expected observations.
It seems to me that these variants point towards the fact that *accelerations* cause dilations. The SR postulates seem to downplay the role of acceleration by claiming that the dilation is caused by the need to enforce the invariant.

> I'm not sure what you mean by *equivalent mutual invariance*.

I meant *mutual equivalence of the frames of reference*. I have rephrased it now.

> *Slowing down with reference to the maximum possible speed*… relative to what? This isn't as frame-independent as is claimed. Yes, the difference between $v = c$ and $v < c$ is frame-invariant, but $v_1 < v_2$ with $v_1, v_2 < c$ is not.

Since all matter start off in an indeterminate state of motion, it is impossible and meaningless to determine an absolute motion of matter. That's why we are limited to talking about and measuring relative speeds only. That doesn't mean that a direction or state of motion is intrinsically meaningless.

If you don't accept the proposed picture, think of an alternative universe where the proposed picture actually holds - i.e. all matter start off as by forming some swarms/wisps/flocks (in a sub-sub-atomic scale) that, in order to maintain the union, spends some fraction of the time in intrinsic interactions and the remaining moving at the spatial speed. Now ask yourself as to how different that would look from our world. I did and it seems pretty intuitive to me that it would end up looking much like our relativistic mechanics.

I hesitate to challenge Einstein's work for obvious reasons (e.g. being perceived as insane) but the arguments of special relativity (at least as presented in high-school level texts) do seem very unsatisfactory. For example, remember the light-clock in the derivation of time dilation. Why should that sort of arrangement me the gold standard for passage of time. Do particles age by reflecting electromagnetic radiation back and forth in direction perpendicular to the direction of motion. Why not a similar light clock aligned at an angle θ to the direction of motion. Why not aligned with the direction of motion?

I came across an alternative derivation, which I find more satisfactory but also has a gap. I quote the derivation with my paraphrasing below. Einstein's fundamental postulates of relativity are given as follows :

Postulate 1 The velocity of light in vacuum (denoted by c) is a constant, irrespective of uniform speed of the observer

Postulate 2 In inertial frames, all motions in the absence of forces are uniform velocities in a straight fixed line

Postulate 3 No inertial reference frame is preferred to another

Consider two inertial reference frames, one moving at a speed v relative to the other. Say one of the frames is that of a rail-track attached to the ground, the other being that of a train moving at a constant speed on the track. An event in the world is customarily located by two coordinates representing *where* and *when* - i.e. a position coordinate and a time. For simplicity let us consider that only the coordinate along the length of the train or track is of interest. For convenience of consideration, let's say that the origins of the two reference frames were coincident at zero time. An event is noted when a beam of light projected from the tail of the train at zero time reaches a detector near the front of the train. Let's say the time and location measured within the train's own reference frame for this event are t' and x' respectively. Let the time and location of this event in the ground frame be t and x respectively.

By postulate 1, $x = ct$ and $x' = ct'$ i.e. the speed of the train has no effect on the measured speed of light! As counter-intuitive as it might sound based on our everyday experience, we must take it as a given in the relativistic model of space-time - i.e. the speed of light is not negotiable, but the fabric of space and time itself is free to compress or dilate in relative-terms and according to the relative uniform motion. Let us try to capture this relative transformation (dilation/compression) of space-time as a linear transform given below :

$$x' = ax + bt$$

$$t' = Ax + Bt$$

Where a, b, A, B are coefficients that potentially vary with speed. Postulate 3 means that if we can determine the coefficients of this transformation, as a function of the relative speed v, the inverse transform is given by substituting v with $-v$. Let us write this down with an emphasis on the fact that the coefficients are functions of velocity.

$$x = a(-v)x' + b(-v)t'$$

$$t = A(-v)x' + B(-v)t'$$

At time t in the ground frame, the position of the origin of the train's frame (i.e. where $x' = 0$) is vt. So we can write

$$0 = a(v)vt + b(v)t$$

So $b(v) = -a(v)v$. Let us put this back into $x' = a(v)x + b(v)t$ and get $x' = a(v)(x - vt)$. Invoking postulate 3 on $x' = a(v)(x - vt)$, we get $x = a(-v)(x' + vt')$.
If we now invoke postulate 1 (i.e. $x = ct$ and $x' = ct'$), we get (with the intention of eliminating x) :

$$ct' = a(v)t(c - v)$$

$$ct = a(-v)t'(c + v)$$

Substituting t from the latter into the former, we get :

$$ct' = a(v)\frac{a(-v)t'(c+v)}{c}(c - v)$$

i.e.

$$a(v)a(-v) = \frac{c^2}{(c+v)(c-v)}$$

The derivation thus far departs from the usual textbook ones in that we have emphasized that the transformation coefficients are functions of speed, and while invoking postulate 3 (i.e. that the inverse transform is equivalent to negative velocity substitution), we have negated the function parameters for the coefficient functions. We do not tacitly assume that a is an even function, which in effect would have led to the following solution (commonly denoted by the symbol γ)

$$a = \frac{1}{\sqrt{1 - v^2/c^2}}$$

Instead, an inspection of $a(v)a(-v) = \frac{c^2}{(c+v)(c-v)}$ suggests that there are two solutions:

$$a(v) = \frac{1}{1 - v/c}$$

$$a(v) = \frac{1}{1 + v/c}$$

Either of the above could satisfy the postulates and thus serve as a legitimate Lorentz transform. On what ground do we rule out these solutions and assume that a(v) is an even function?

The above still may be a minor objection and may be addressed by claiming that the usual γ is some kind of a superposition (geometric mean) of the above solutions. Maybe, one could speculate, that this multi-solution situation indicates that motion happens through alternations of dilations and contractions. In any case it seems unsatisfactory to derive fundamental insights from mathematical expressions.

It is more satisfactory when mathematical equations (invariants) fall out of microscopic behavioural descriptions. To give an analogy from another physical problem - consider the case of steady state diffusion (Laplace's equation $\nabla^2 phi = 0$. This describes diffusion process and so does its variational form (i.e. the equilibrium distribution minimises $\int\int\int(\frac{\partial\phi}{\partial x})^2 + (\frac{\partial\phi}{\partial y})^2 + (\frac{\partial\phi}{\partial z})^2 dxdydz$). That would be sufficient to shut up and compute, but Einstein's proof that diffusion is equivalent to microscopic random (Brownian) motion of atoms and molecules is way more satisfactory. So much so that this work of Einstein is widely held as the final theoretical confirmation of the atomic hypothesis.

The reason I feel that there may be some elements of truth and insight in the current article is that it bears strong analogy with Einstein's work. Just the way the special

relativity starts with equivalence of inertial frames, and general relativity starts with equivalence of acceleration and gravitational force, this article has as its basis another equivalence - the indistinguishability of acceleration from retardation. Thence comes the hypothesis that all the energization that we perceive as acceleration could actually be deccelerations for all we can ever know. The conclusion that it gets us is also very satisfying because of its connection with microscopic behaviour. So far I have engaged in a mathematical treatment, which may look unsatisfactory. How does the intuitive statement of the central concept sound (as given in bold face below)?
Forget about light clocks and space contraction. Light speed is constant regardless of your speed because of the way Newtonian time gets rationed between intrinsic motion and spatial motion. Light moves ahead of you only for the time you spend on intrinsic dynamics (i.e. relativistic time, the time you can measure). During your spatial motion part of the time, you are moving with light.
Muon decays confirm the time dilation implied by this because the ageing of particles progress as some kind of a state-machine that finally transitions into the decayed state - and the transitions happen during intrinsic interactions (not during spatial motions). Bigger multi-particle assemblies could have other modes of ageing, so the fantastic promise of special relativity - i.e. *speed up to last longer* might not hold in the macroscopic world.

> Whether the path of a particle is *straight* or *highly curved* has no impact on the time dilation calculated by Special Relativity. It is the reference frame that needs to be inertial in SR, not the particles we're talking about; particle accelerators pose no problem at all.

What I mean that SR requires inertial frames (rectilinear uniform velocity), and SR predicts time dilation. The time dilation observed is exactly equal to what we would get by putting the scalar speed (of curvilinear motion in the accelerator) into the expression for γ.So it seems that the postulates of SR asks for more stringent requirements than it needs to. That doesn't make it wrong but a more general theory would *require* a *strictly* necessary pre-condition.

7 TL;DR

This article presents an attempt to interpret relativistic space-time in terms of linear dynamics. It resurrects the Newtonian concept of time and postulates that the relativistic behaviour emerges due to rationing of Newtonian time between intrinsic and spatial motion. In this interpretation the apparent acceleration of a particle is nothing but a retardation with reference to a default state of moving at speed of light.