Essay

On the Synchronization of Clocks

Matti Pitkänen [1]

Abstract

This article originated from a debate with some anti-Einsteinians about synchronization of clocks. At modern times physicists regard this kind of ponderings "philosophical" and something negative. The discussion however led to the question whether it is possible to synchronize clocks in Lorentz invariant manner. The answer to this question is positive quite generally in TGD - put the clocks at hyperboloid of light-cone- and leads to a vision about synchronization in terms of quantum entanglement in a tensor network defined by a tessellation of hyperboloid of M^4.

1 Introduction

This article originated from a debate with some anti-Einsteinians about synchronization of clocks. At modern times physicists regard this kind of ponderings "philosophical" and something negative. The discussion however led to the question whether it is possible to synchronize clocks in Lorentz invariant manner. The answer to this question is positive quite generally in TGD - put the clocks at hyperboloid of light-cone- and leads to a vision about synchronization in terms of quantum entanglement in a tensor network defined by a tessellation of hyperboloid of M^4.

1.1 Einstein did not assume that clock synchorinization is Lorentz invariant

I participated an FB discussion with several anti-Einsteinians. As a referee I have expressed my opinion about numerous articles claiming that Einstein's special or general relativity contains a fatal error not noticed by any-one before. I have tried to tell that colleagues are extremely eager to find a mistake in the work of colleague so that logical errors can be safely excluded. If something goes wrong it is at the level of basic postulates. In vain.

Once I had a long email discussion with a professor of logic who claimed to have found logical mistake in the deduction of time dilation formula. It was easy to find that he thought in terms of Newtonian space-time and this was of course in conflict with relativistic view. The logical error was his, not Einstein's. I tried to tell this. In vain again.

At this time I was demanded to explain why the 2 page article of Stephen Crothers (see `http://vixra.org/abs/1703.0047`). This article was a good example of own logical error projected to that of Einstein. The author assumed besides the basic formulas for Lorentz transformation also synchronization of clocks so that they show the same time everywhere (about how this is achieved see `http://tinyurl.com/jdccns4n`).

Even more: Crothers assumes that *Einstein assumed* that this synchronization is Lorentz invariant. Lorentz invariant synchronization of clocks is not however possible for the linear time coordinate of Minkowski space as also Crothers demonstrates. Einstein was wrong! Or was he? No!: Einstein of course did not assume Lorentz invariant synchronization!

The assumption that the synchronization of clock network is invariant under Lorentz transformations is of course in conflict with SR. In Lorentz boosted system the clocks are not in synchrony. This expresses just Einstein's basic idea about the relativity of simultaneity. Basic message of Einstein is misunderstood!

The basic predictions of SR - time dilation and Lorentz contraction - do not depend on the model of synchronization of clocks . Time dilation (see `http://tinyurl.com/qdnn5h9`) and Lorentz contraction

[1]Correspondence: Matti Pitkänen `http://tgdtheory.fi/`. Address: Karkinkatu 3 I 3, 03600, Karkkila, Finland. Email: matpitka6@gmail.com.

(see `http://tinyurl.com/nuxr9db`) follow from the basic geometry of Minkowskian space-time extremely easily.

Draw system K and K' moving with constant velocity with respect to K. The t' and x' axis of K' have angle smaller than $\pi/2$ and are the in first quadrant.

1. Assume first that K corresponds to the rest system of particle. You see that the projection of segment $(0, t')$ of t'-axis to t-axis is shorter than the segment $(0, t)$: time dilation.

2. Take K to be the system of stationary observer. Project the segment $L = (0, x')$ to segment on x axis. It is shorter than L: Lorentz contraction.

There is therefore no need to build synchronized networks of clocks to deduce time dilation and Lorentz contraction. They follow from Minkowskian geometry.

1.2 Is it possible to have Lorentz invariant synchronization?

The above argument raises a question. Is it possible to find a system in which synchronization is possible in Lorentz invariant manner? The quantity $a^2 = t^2 - x^2$ defines proper time coordinate a along time like geodesics as Lorentz invariant time coordinate of light-one. a = constant hyper-surfaces are now hyperboloids. If you have a synchronized network of clocks, its Lorentz boost is also synchronized. General coordinate invariance of course allows this choice of time coordinate.

For Robertson-Walker cosmologies with sub-critical mass time coordinate a is Lorenz invariant so that one can have Lorentz invariant synchronization of clocks. General Coordinate Invariance allows infinitely many choices of time coordinate and the condition of Lorentz invariant synchronization fixes the time coordinate to cosmic time (or its function to be precise). To my opinion this is rather intesting fact.

What about TGD? In TGD space-time is 4-D surface in $H = M^4 \times CP_2$. $a^2 = t^2 - r^2$ defines Lorentz invariant time coordinate a in future light-cone $M^4_+ \subset M^4$ which can be used as time-coordinate also for space-time surfaces.

Robertson-Walker cosmologies can be imbedded as 4-surfaces to $H = M^4 \times CP_2$. The empty cosmology would be just the lightcone M^4_+ imbedded in H by putting CP_2 coordinates constant. If CP_2 coordinates depend onM^4_+ proper time a, one obtains more general expanding RW cosmologies. One can have also sub-critical and critical cosmologies for which Lorentz transformations are not isometries of a= constant section. Also in this case clocks are synchronized in Lorentz invariant manner. The duration of these cosmologies is finite: the mass density diverges after finite time.

2 What about actual realization of Lorentz invariant synchronization?

What about actual Lorentz invariant synchronization of the clocks? Could TGD say something non-trivial about this problem? I received an interesting link relating to this (see `http://tinyurl.com/gkr62bt`). The proposed theory deals with fundamental uncertainty of clock time due to quantum-gravitational effects. There are of course several uncertainties involved since quantum theory of gravity does not exist (officially) yet!

1. Operationalistic definition of time is adopted in the spirit with the empiristic tradition. Einstein was also empirist and talked about networks of synchronized clocks. Nowadays particle physicists do not talk much about them. Symmetry based thinking dominates and Special Relativity is taken as a postulate about symmetries.

2. In quantum gravity situation becomes even rather complex. If quantization attempt tries to realize quantum states as superpositions of 3-geometries one loses time totally. If GRT space-time is taken

to be small deformation of Minkowski space one has path integral and classical solutions of Einstein's equation define the background.

The difficult problem is the identification of Minkowski coordinates unless one regards GRT as QFT in Minkowski space. In astrophysical scales QFT picture one must consider solutions of Einstein's equations representing astrophysical objects. For the basic solutions of Einstein's equations the identification of Minkowski coordinates is obvious but in general case such as many-particle system this is not anymore so. This is a serious obstacle in the interpretation of the classical limit of GRT and its application to planetary systems.

What about the situation in TGD? Particle physicist inside me trusts symmetry based thinking and has been somewhat reluctant to fill space-time with clocks but I am ready to start the job if necessarily! Since I am lazy I of course hope that Nature might have done this already and the following argument suggests that this might be the case!

1. Quantum states can be regarded as superpositions of space-time surfaces inside causal diamond of imbedding space $H = M^4 \times CP_2$ in quantum TGD. This raises the question how one can define universal time coordinate for them. Some kind of absolute time seems to be necessary.

2. In TGD the introduction of zero energy ontology (ZEO) and causal diamonds (CDs) as perceptive fields of conscious entities certainly brings in something new, which might help. CD is the intersection of future and past directed light-cones analogous to a big bang followed by big crunch. This is however only analogy since CD represents only perceptive field not the entire Universe.

   The imbeddability of space-time as to $CD \times CP_2 \subset H = M^4 \times CP_2$ allows the proper time coordinate $a^2 = t^2 - r^2$ near either CD bouneary as a universal time coordinate, "cosmic time". At a= constant hyperboloids Lorentz invariant synchronisation is possible. The coordinate a is kind of absolute time near a given boundary of CD representing the perceptive field of a particular conscious observer and serves as a common time for all space-time surfaces in the superposition. Newton would not have been so wrong after all.

   Also adelic vision involving number theoretic arguments selects a as a unique time coordinate. In p-adic sectors of adele number theoretic universality (NTU) forces discretization since the coordinates of hyperboloid consist of hyperbolic angle and ordinary angles. p-Adicallhy one cannot realize either angles nor their hyperbolic counterparts. This demands discretization in terms of roots of unity (phases) and roots of e (exponents of hyperbolic angles) inducing finite-D extension of p-adic number fields in accordance with finiteness of cognition. a as Lorentz invariant would be genuine p-adic coordinate which can in principle be continuous in p-adic sense. Measurement resolution however discretizes also a.

   This discretization leads to tesselations of a=constant hyperboloid having interpretation in terms of cognitive representation in the intersection of real and various p-adic variants of space-time surface with points having coordinates in the extension of rationals involved. There are two choices for a. The correct choice corresponds to the passive boundary of CD unaffected in state function reductions.

3. Clearly, the vision about space-time as 4-surface of H and NTU show their predictive power. Even more, adelic physics itself might solve the problem of Lorentz invariant synchronization in terms of a clock network assignable to the nodes of tesselation!

   Suppose that tesselation defines a clock network. What synchronization could mean? Certainly strong correlations between the nodes of the network Could the correlation be due to maximal quantum entanglement (maximal at least in p-adic sense) so that the network of clocks would behave like a single quantum clock? Bose-Einstein condensate of clocks as one might say? Could quantum entanglement in astrophysical scales predicted by TGD via $h_{gr} = h_{eff} = n \times h$ hypothesis help to establish synchronized clock networks even in astrophysical scales? Could Nature guarantee Lorentz invariant synchronization automatically?

What would be needed would be not only 3-D lattice but also oscillatory behaviour in time. This is more or less time crystal (see `http://tinyurl.com/jbj5j68` and `http://tinyurl.com/zy73t6r`)! Time crystal like states have been observed but they require feed of energy in contrast to what Wilzek proposed. In TGD Universe this would be due to the need to generate large $h_{eff}/h = n$ phases since the energy of states with n increases with n [4]. In biological systems this requires metabolic energy feed. Can one imageine even cosmic 4-D lattice for which there would be the analog of metabolic energy feed?

I have already a model for tensor networks and also here a appears naturally [5]. Tensor networks would correspond at imbedding space level to tesselations of hyperboloid $t^2 - r^2 = a^2$ analogous to 3-D lattices but with recession velocity taking the role of quantized position for the point of lattice. They would induce tesselations of space-time surface: space-time surface would go through the points of the tesselation (having also CP_2 counterpart). The number of these tesselations is huge. Clocks would be at the nodes of these lattice like structures. Maximal entanglement would be key feature of this network. This would make the clocks at the nodes one big cosmic clock.

If astrophysical objects serving as clocks tend to be at the nodes of tesselation, quantization of cosmic redshifts is predicted! What is fascinating is that there is evidence for this [1, 2]: for TGD based model for this see [3, 6]! Maybe dark matter fraction of Universe might have taken care of the Lorentz invariant synchronization so that we need not worry about that!

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