Open Access Library Journal

Is Global Simultaneousness Compatible with Special Relativity?

Hans H. Diel

Diel Software Beratung und Entwicklung, Sindelfingen, Germany
Email: diel@netic.de

Received 26 May 2015; accepted 12 June 2015; published 17 June 2015

Abstract

Special relativity theory abandoned the notion of absolute space and time. For many physicists, it also abandoned the notion of global time, *i.e.*, a unique time coordinate that could be assigned to the overall universe. On the other hand, with theories and discussions on the dynamical development of the overall universe, the notion of a global state, which is associated with global time, seems to be very useful, if not unavoidable. This paper discusses to what extent the notions of global states, global time and global simultaneousness can be defined such that they are compatible with Einstein's relativity theories. The results show that the establishment of a global coordinate system requires, in addition to the choice of suitable space and time coordinates the selection of a physical object with an assumed uniform velocity.

Keywords

Space-Time Models, Global States, Global Time, Global Simultaneousness, Direction of Time

Subject Areas: **Modern Physics, Theoretical Physics**

1. Introduction

Time is the most important parameter in physics theories. After the simple time model of classical physics, Einstein's relativity theories made matters more complicated by combining time and space into the four-dimensional space-time and by stating that clocks in different inertial systems run at different speeds. The major goal of physics theories is to support the prediction of a future state of a physical system as a function of an assumed given state. In general, the laws of physics apply to local situations. With most practical applications, the restriction to an isolated local scope represents an idealization. Extension of this local scope of applicability, e.g., by considering the entire universe, is difficult and largely controversial. As a particular example of such an area of global scope, the dynamical development of our overall universe is considered in this paper. With theories and discussions on this subject (see [1]-[4]), the notion of a global state, which is associated with global time, seems

How to cite this paper: Diel, H.H. (2015) Is Global Simultaneousness Compatible with Special Relativity? *Open Access Library Journal*, **2**: e1606. http://dx.doi.org/10.4236/oalib.1101606

to be very useful, if not unavoidable. Some physicists (e.g., [5]), however, question whether the notion of a global state, global time and global simultaneousness is compatible with relativity theories.

After a very rough recapitulation of the time concept of special relativity with a focus on the notion of "local time" (Section 2), the usefulness of "global time" is argued for in Section 3. Having identified the necessity, or at least usefulness, of the notion of global time in general, there are still a number of open questions concerning the relation between global time and local time.

These questions are addressed in Sections 3 and 4:

- Is it possible to assign a global time coordinate to all events during the evolution of the world?
- What does "the age of our universe" mean?
- Is the concept of global states compatible with the theories of relativity?
- Is the concept of global simultaneousness compatible with the theories of relativity?
- Does the dynamical evolution of our world proceed a) in unique global time steps, b) in unique local time steps or c) completely asynchronously?
- What are reasonable models of the space-time topology of our universe?

2. Proper Time = Local Time

Both special relativity theory (SRT) and general relativity theory (GRT) state that physical systems may evolve with clocks running at differing speeds. "Clocks running at differing speeds" means that clock-A in system S_A is running faster (slower) than clock-B in system S_B, provided that the two systems move with different (relative) speeds or reside in differing gravitational field strengths. In SRT and GRT, the different times are called "proper time" or "wristwatch time". In this paper, this is called "systems having different local times".

Famous examples for the occurrence of differing local times are:

1) Particle decay

The decay rate of particles depends on their relative velocity. This has been verified by measurements of the decay rate of particles that originated from cosmic radiation, reaching the earth with high velocity.

2) Black hole

GRT predicts that the local time of a system (e.g., a space ship) that enters a black hole slows down as the system approaches the center of the black hole.

3) Twin paradox

The twin paradox shows that according to SRT, two twins traveling at different trajectories in Minkowsky space and meeting again at a common point in space-time will observe different elapsed times according to their local clocks. With larger traveling distances, the twins may even observe differences in their aging upon meeting again. Within the literature on SRT, numerous versions of the twin paradox exist[1]. The following description is similar to the explanation given in [6].

Figure 1 shows the twins A and B traveling along different trajectories. In the chosen space-time coordinate system, A is assumed to rest, which means that only the time coordinate changes from 0 to 10. B moves from space-time point $P_1 = (0,0,0,0)$ to $P_3 = (5,4,0,0)$ and, from there, returns to $P_2 = (10,0,0,0)$. According to SRT, the elapsed local time τ of a system that travels from space point s_1 and time point t_1 to space point s_2 and time point t_2 is

$\tau = \text{sqrt}\{(t_1 - t_2)^2 - (s_1 - s_2)^2\}$.

For A this is $\tau_A = \text{sqrt}\{10^2 - 0^2\} = 10$.

For B, we have two distances: $\tau_{B1} = \text{sqrt}\{5^2 - 4^2\} = 3$ and $\tau_{B2} = \text{sqrt}\{5^2 - 4^2\} = 3$; together, $\tau_{B1} + \tau_{B2} = 6$.

This means that when A and B meet again at P_2, A is 4 time units (hours, days, or years) older than B.

3. Global Systems and Their Attributes

In general, the laws of physics apply to (physical) systems with well-defined boundaries.

Theories on subjects that consider the universe as a whole (e.g., the wave function of the universe) are difficult and largely controversial. On the other hand, their necessity can hardly be neglected.

3.1. Global States of the Universe

As a particular example of an area of global scope, the dynamical development of our overall universe is here

[1]Sometimes with an incorrect explanation of the cause of the differences in local times.

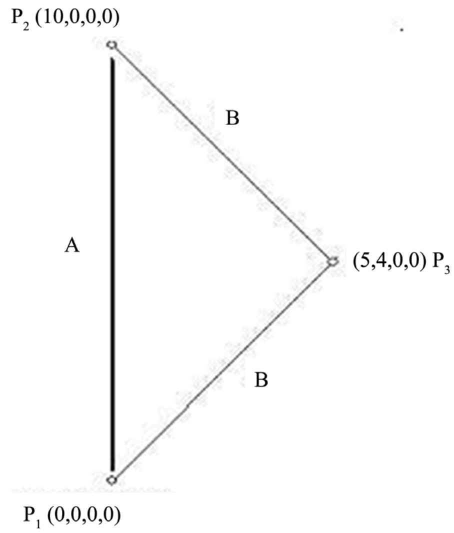

Figure 1. Twins A and B travelling at different trajectories.

considered.

With theories and discussions on this subject (see [1]-[4]), the notion of a global state, which is associated with global time, seems to be very useful or even unavoidable. The following very simplified model of the dynamical evolution of our universe (originally described in [2]) assumes global states evolving in unique global time steps.

Model of the Dynamical Evolution of the World

Let us view the laws for the evolution of the state of the world (*i.e.*, the laws of physics), represented by a "physics-interpreter". The physics-interpreter acts upon the state of the world. The model described here assumes the continuous repeated invocation of the physics-interpreter to realize the progression of the state of the world. The physics-interpreter continuously determines new states. The physics-interpreter acts upon an in-world to generate an out-world.

```
world Evolution (world W): = {
W.t = 0; W.x1 = 0; W.x2 = 0; W.x3 = 0;
W. = initialState;
Δt = timestep; // must be positiv //
DO UNTIL (nonContinueState(W)) {
physicsInterpreter (W, Δt);
}
}
physicsInterpreter(W, Δt): = {
tdt = W.t + Δt ;
W = applyLawsOfPhysics(W, Δt);
discardSpacetimePointsWithTimeCoordinate(W.t < tdt);
}
with state parameters
world: = {spacetimepoint...}
spacetimepoint: = {t, x1, x2, x3, ψ}
ψ: = {stateParameter1, …, stateParametern}
```

3.2. Global Time

With reference to Barbours' work [1], D. Zeh writes in [5] (page 168): "Barbours' essential assumption of global states in the sense of simultaneousness seems to be a relict from his non-relativistic theory. A relativistic theory should replace the global "Now" by "Here and Now". Although it is true that relativity theory has dropped the concept of "global simultaneousness", this does not disallow the idea of a progression of the (global) state in conjunction with a global time.

What Does Global Time Mean?

The twin paradox example (Section 2) helps to explain that for the calculation of the (local) proper time τ for the twins, SRT/GRT allows a suitable coordinate system to be chosen. This includes the specification of the space coordinates for the points P_1, P_2, P_3, as well as the specification of the velocities at which A and B are traveling. The choice for these parameters, of course, must be such that the relations between the positions and between the velocities are in accordance with the specific example. With the example described in Section 2, the positions have been chosen to be $P_1 = (0,0,0,0)$, $P_2 = (10,0,0,0)$, $P_3 = (5,4,0,0)$. This implies that the choice for the velocity of A is $v_A = 0$ because P_1 and P_2 have identical space coordinates (0,0,0). If, in the given example, instead of assuming A to be at rest, we assume that A is traveling with a speed v_A not = 0 such that the space-time points have coordinates $P_1 = (0,0,0,0)$, $P_2 = (10,2,0,0)$ and, accordingly, B is traveling from $P_3 = (5,4.75,0,0)$ to $P_2 = (10,2,0,0)$ (see **Figure 2**), then approximately the same difference in elapsed (local) times is obtained as with the original example.

$\tau_A = \mathrm{sqrt}\{10^2 - 2^2\} = 9.8$.

$\tau'_{B1} = \mathrm{sqrt}\{5^2 - 4.75^2\} = 1.6$ and $\tau'_{B2} = \mathrm{sqrt}\{5^2 - 2.75^2\} = 4.2$; together, $\tau'_{B1} + \tau'_{B2} = 5.8$.[2]

Thus, for the calculation of a concrete example, a coordinate system (including assumptions on the velocities of the moving objects) has to be chosen. For the twin paradox example, this may be considered as the specification of a local coordinate system. Similarly, a global coordinate system can be defined that provides a choice for all possible local coordinate systems.

Definition: A global coordinate system is a space-time coordinate system that assigns coordinates

$X_i = \{t_i, x_i, y_i, z_i\}$ to all space-time points of the scope considered and, in addition, selects an object within the space to which a definite velocity is assigned. (A convenient and useful choice for the velocity gauge is the determination of an object for which a constant velocity of 0 is assumed.)

"Global Time" is understood in this paper as the time coordinate of a global space-time coordinate system. Thus, within this paper, "global time" has a proper meaning only in the context of a global space-time coordinate system, and a global space-time coordinate system (including global time) requires at least one physical object with (assumed) special properties, such as uniform movement. (The inclusion of a physical object with an assumed uniform velocity distinguishes the global space-time coordinate system from the purely mathematical space-time structures, such as, for example, Minkowsky space).

3.3. How to Build a Global Time Clock

Let us assume that the objective of a global time clock is to show not only hours, minutes and seconds but also months and years. Point zero for the years need not be the point in time of the big bang, but should be far

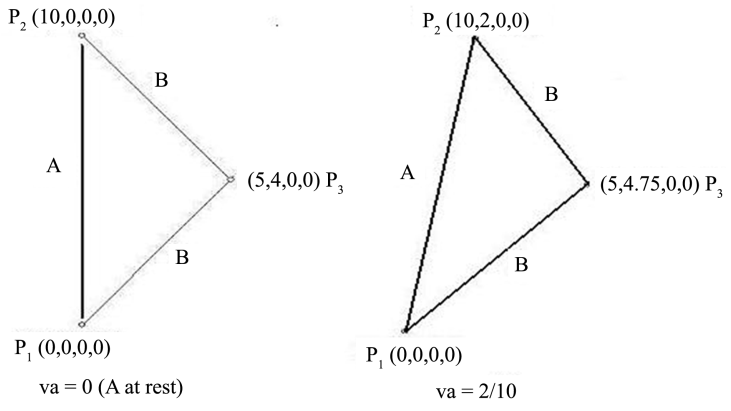

Figure 2. Alternative choices of coordinate system.

[2]The exact determination of the trajectory for B, such that the difference in elapsed proper time s is the same, is outside the scope of this paper.

enough in the past, e.g., the origin of the cosmic background radiation.

It may be difficult to construct a clock that shows the global time continuously. The simplest solution would be a clock that is based on the local time of the cosmic object where the clock resides. The global clock would have to be updated by the time units of the local clock multiplied by a factor f_g, which depends on the velocity of the local object relative to the reference object of the global coordinate system. Whether our cosmologist is able to determine, with reasonable precision, f_g for the earth is not clear (to the author).

3.4. What Is the Age of Our Universe?

The question about the age of our universe presupposes the notion of a global time (*i.e.*, without the assumption of a global time, the question does not make sense). The global time clock described in Section 3.3 would show the age of the universe according to a chosen convention. Although the development of a global time clock faces the difficulties described in the preceding sections, there seems to be agreement that the notion of (global) age of our universe is reasonable. Cosmologists seem to have at least a very rough estimate for the age of our universe.

4. The Dynamical Evolution of the World

In Section 3.1, a very simple model of the dynamical evolution of the world is described. This model, although very simple, raises questions with respect to the time parameter, which necessarily plays an important role in any possible model of this subject. The major questions are:

1) Is the concept of global states, associated with unique points in time, compatible with SRT/GRT?
2) Is the uniform progression (*i.e.*, aging) of the universe reasonable and compatible with SRT/GRT?
3) Does the universe contain, at any point in (global) time, more than a single point in global time?

For the arguments given below, the model described in Section 3.1 implies the answers Yes for (1), Yes for (2), and No for (3).

Some physicists may disagree with the model described in Section 3.1 or may come up with different conclusions for the questions posed. Nevertheless, there should be agreement that the questions are valid (and important) and that a model of the dynamical evolution of the world that provides answers to these questions should exist.

4.1. Is the Concept of Global States Compatible with SRT and GRT?

Global states are hardly imaginable without global simultaneousness, *i.e.*, the ability to specify which space-time points are assigned to a (global) state. Given the definition of a global coordinate system, as defined in Section 3.2, the definition of global simultaneousness is trivial: State components and events assigned to space-time points.

$X_i = \{t_i, x_i, y_i, z_i,\}$ are considered to be globally simultaneous if their t_i are equal.[3]

The global coordinate system defined in Section 3.2 is compatible with SRT/GRT. In addition to the theoretical possibility of global states associated with global time, it must also be shown that with the dynamical evolution of the universe, global states evolve into new global states. This subject is addressed below.

4.2. Is There a Uniform Global Aging of Our Universe?

The definition of a global coordinate system implies that if the state associated with global time coordinate t_i proceeds by the global time step Δgt, then the new state will have the time coordinate $t_i + \Delta gt$. From this, it follows that if (1) a state has assigned a unique (global) time coordinate t_i and (2) the state evolves with a common (global) time step Δgt and (3) the world has started with an initial state at a unique global time t_0, then a global aging of the world can be concluded.

Thus, let us discuss to what extent conditions (1), (2), and (3) are plausible. Condition (1), which assumes that a state has assigned a unique (global) time coordinate, looks quite natural. Practically all of the laws of physics that describe how a state S_0 evolves into a state S_1 assume that state S_0 exists at a unique point in time t_0 (and, similarly, state S_1 exists at a unique point in time t_1). Any deviation from this implicit assumption would make the laws of physics rather cumbersome.

Condition (3), which assumes that the initial state of our universe includes a unique global time t_i, is also the

[3]Notice that this definition of "global simultaneousness" differs from the relativistic notion of bilateral simultaneousness in SRT.

usual assumption implied with the big bang theory. Condition (2) is assumed with the model of the dynamical evolution of the world described in Section 3.1, but is possibly more controversial. With a view of the (local) wristwatch time, which leads to the twin paradox, one may argue that objects traveling at different velocities evolve with local time steps rather than with global time steps. However, this argument ignores that, at the end, when the two objects meet again, they meet at a common point of global time. This means that the same amount of global time steps Δgt is executed on all trajectories that end at an identical global time.

For the model of the dynamical evolution of the world described in Section 3.1, this means that the overall progression of the state of the world (*i.e.*, the global aging) occurs in global time steps Δgt. When the execution is broken down to the individual local systems, the global time steps Δgt have to be filled with differing local time steps Δlt.

The alternative model, where the dynamical evolution of the world would proceed in terms of local time steps Δlt, would make the reunification of diverging trajectories very difficult or impossible.

4.3. Does the Universe Contain, at Any Point in Time, More than the Current Global State?

With the physics interpreter described in Section 3.1, the statement

"discard All Space time Points With Time Coordinate (W.t < tdt);" is contained, which means that the past is discarded. This statement may be considered arbitrary; to the author's knowledge, there is no proof or experiment that demonstrates its truth or falseness. Given that, with the known laws of physics, the prediction of a future state never depends on a past state in addition to the present state, nor is it possible to directly access a past state, the formulation "past states are lost" and the inclusion of the referenced statement appear reasonable.

5. Discussion

5.1. The Feasibility of a Global Coordinate System

The feasibility of a global coordinate system may be questioned for two reasons:

1) The definition of a global coordinate system may be theoretically correct, but the determination of a stable reference base, as required by the definition, may not be possible given what cosmologists know about the process of the evolution of our universe. There is a high chance that it is not feasible to determine a constantly stable reference base. For example, what we know (and what we do not yet know) about dark energy and an inflationary universe may result in a rather unstable reference base. However, a stable reference base is not explicitly requested by the above definition. As long as the dynamic change process is sufficiently understood, the determination of a global coordinate system may still be possible, although more complicated.

2) The definition of a global coordinate system may be feasible theoretically but difficult with the cosmological knowledge we have at present. For example, according to the above definition, the determination of a global coordinate system requires the selection of a physical object (e.g., a star) as a reference point. A suitable object would have to be, as much as possible, unaffected by dynamical developments (e.g., changed gravitational environment or changed velocity) that influenced its proper time in the past and presumably will in the future. As an example for a cosmic object with presumably well-understood uniform development, the aging of the cosmic background radiation could be a reasonable datum point (together with some assumption about the time and initial state of the formation of the cosmic background radiation).

5.2. General Relativity Theory

The major goal of this paper was to show that the notions of global states and global time are compatible with special relativity theory and general relativity theory. The paper provides extensive arguments for the validity of global notions.

Although the arguments given refer mostly to SRT, they are believed to also hold true for GRT. The local time due to GRT is more complicated than the local time due to SRT (as explained with the twin paradox). Nevertheless, the arguments given for the necessity and feasibility of the notions of global time, global states, and global simultaneousness apply equally to GRT.

5.3. The Arrow of Time

Much has been written (for example, [3] [5]-[8]) in regard to the (possible) identification of a direction of time associated with the dynamical evolution of the world. Typically, the discussion starts with the statement that the laws of physics are symmetric under a reversal of the direction of time. Observations that give the impression of the existence of a direction of time are then explained as a consequence of an increase in entropy, as stated by the second law of thermodynamics. Thus, the existence of an arrow of time is established, but it is implied purely from the entropy law. In [2], it is argued that a direction of time becomes apparent, without recourse, to the flow of entropy, based on the laws of physics, if the laws of physics are considered in the context of their overall goal, namely, describing the dynamical evolution of the world. The reasoning described in [2] is based on the simple model of the dynamical evolution of the world, as described in Section 3.1. Because both subjects, the direction of time and the possibility of a global coordinate system, are discussed in view of a model of the dynamical evolution of the world, the question arises whether the global coordinate system defined in this paper implies an arrow of time. The author's answer is that the definition and existence of a global coordinate system does not imply an arrow of time. However, the further subjects of this paper, specifically global states, global simultaneousness and global uniform aging of our universe, have been discussed based on the referenced model of the dynamical evolution of the world, which implies an arrow of time.

6. Conclusions

This paper provides definitions for global items such as global coordinate system, global time, and global simultaneousness, which are compatible with Einstein's relativity theories.

Although SRT and GRT have rejected the a priori existence of an absolute space-time, which implies the rejection of an a priori global space-time coordinate system, this does not disallow the definition of a global coordinate system for our universe by suitable conventions.

The establishment of a global coordinate system requires, in addition to the choice of suitable space and time coordinates, the selection of a physical object with an assumed uniform velocity (e.g., an object that is assumed to be at rest). This distinguishes the global space-time coordinate system from the purely mathematical space-time structures such as, for example, Minkowsky space.

While with theories of the dynamical evolution of the world it may be sufficient (and required) to have a decent definition of global concepts as described in this paper, at present, it may not be feasible to establish a suitable concrete standard for a global coordinate system for our universe.

The most promising candidate for a basis of such a global coordinate system of our universe might be the cosmic background radiation.

References

[1] Barbour, J. (2001) The End of Time. Oxford University Press, Oxford.

[2] Diel, H. (2015) The Direction of Time and the Dynamical Evolution of the World. *International Journal of Physics*, **3**, 12-16. http://dx.doi.org/10.12691/ijp-3-1-3

[3] Penrose, R. (2005) The Road to Reality. Vintage Books, New York.

[4] Smolin, L. (2013) Time Reborn. From the Crisis in Physics to the Future of the Universe. Houghton Mifflin Harcourt, New York.

[5] Zeh, H.D. (2012) Physik ohne Realität: Tiefsinn oder Wahnsinn. Springer Verlag, Heidelberg. http://dx.doi.org/10.1007/978-3-642-21890-3

[6] Maudlin, T. (2012) Philosophy of Physics—Space and Time. Princeton University Press, Princeton.

[7] Horwich, P. (1987) Asymmetries in Time. MIT Press, Cambridge.

[8] Price, H. (1996) Time's and Archimedes' Point. Oxford University Press, Oxford.