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On Stages, Worms, and Relativity[*]

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Abstract

Four-dimensionalism, or perdurantism, the view that temporally extended objects persist through time by having (spatio-)temporal parts or stages, includes two varieties, the worm theory and the stage theory. According to the worm theory, perduring objects are four-dimensional wholes occupying determinate regions of spacetime and having temporal parts, or stages, each of them confined to a particular time. The stage theorist, however, claims, not that perduring objects have stages, but that the fundamental entities of the perdurantist ontology *are* stages. I argue that considerations of special relativity favor the worm theory over the stage theory.

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1. Introduction

Recent work on persistence over time has produced a more fine-grained inventory of views than we had a few years ago. Although there are still two major rival accounts of persistence on the market: three-dimensionalism (3D, endurantism) and four-dimensionalism (4D, perdurantism), distinct varieties of each view have now been identified. For example, philosophers who think that ordinary material objects endure—that they are wholly present at all times at which they exist—now explicitly include those who prefer to run this position together with a certain theory of time, namely *presentism* (roughly, the view that only the present exists),[1] and those who deny this link between the theory of persistence and the philosophy of time.[2] Similarly, four-dimensionalists who think objects perdure—persist by having different temporal parts at different times—comprise those who think that this position presupposes *eternalism* (the idea that all moments of time are on the same ontological footing)[3] as well as those who argue against this connection.[4]

Another important distinction, which has emerged within the perdurantism camp, is between the *worm* theory and the *stage* theory—the distinction with which I am concerned in this paper. The worm theory features an ontology of 4D wholes (spatio-temporal "worms") occupying determinate regions of spacetime. Such entitied have parts, or stages, each of them confined to a particular time (an instant or interval). The

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[1] See, e.g., Merricks (1995, 1999), Hinchliff (1996), Zimmerman (1998), Craig (2000), Markosian (forthcoming), and references to earlier work therein. Prior's classic (1970) should be specifically mentioned.

[2] See, e.g., Mellor (1981), Haslanger (1989), van Inwagen (1990), Rea (1998).

[3] Most four-dimensionalists are eternalists. Merricks (1995), who is a three-dimensionalist, and Carter and Hestevold (1994), who maintain a neutral position, have nonetheless argued for the link between perdurantism and eternalism.

[4] Brogaard (2000) defends presentist four-dimensionalism. Not being presentist four-dimensionalists themselves, Lombard (1999) and Sider (2001, §3.4), have shown that this combination is consistent.

stage theorist, on the other hand, claims, not that perduring objects have stages, but that the fundamental entities of the perdurantist ontology *are* stages.[5]

In the next section, I attempt to draw the distinction between the worm and the stage theories more precisely while explaining what makes both of them varieties of four-dimensionalism. Then I offer an argument defending worms over stages. The argument is based on considerations of special relativity and requires, as a prerequisite, restating the stage view in the relativistic context. It will be convenient to start with the classical framework, that of neo-Newtonian spacetime, and then show what modifications are to be made in the stage theory in effecting a transition to special relativistic (Minkowski) spacetime.

Although I do not embark, in this paper, on the task of defending four-dimensionalism as a whole against three-dimensionalism, I believe that a somewhat similar argument could be applied to this purpose.[6] My strategy presupposes the eternalist framework: it takes the 4D spacetime manifold of point events to be existing in the fundamental tenseless sense and is not concerned to defend this framework against presentism. One reason is that this paper takes relativity seriously, and I agree with many writers[7] that anyone who takes relativity seriously cannot take presentism seriously. At the same time, I believe, contrary to some,[8] that taking relativity seriously does not

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[5] The stage theory has recently been elaborated and defended by Sider (1996, 2000, 2001) and Hawley (forthcoming). References to earlier works can be found therein. The paradigm worm theorist is probably Heller (1990).

[6] See, in this connection, Balashov (2000a, 2000b).

[7] See, e.g., Savitt (2000), Callender (2000), Saunders (forthcoming), and Sider (2001, §2.4).

[8] Earlier work on persistence did not always draw a clear distinction between four-dimensionalism, a particular ontology of material objects, and eternalism or the "block-universe" view, which is primarily a view about time and the nature of events. See, e.g., Taylor (1955). Since special relativity undoubtedly favors the latter, some writers were too quick to conclude that it automatically favors the former as well. This link is implicit in Quine (1950, 1987). Recent contributions to the persistence debate have gone a long way towards dismantling this alleged package deal. See, in this connection, Rea (1998), Balashov (1999, 2000a, and 2000c), Sider (2001). Craig, a presentist endurantist, concedes that "Embracing spacetime realism does not … commit one automatically to … four-dimensionalism or

automatically force one into four-dimensionalism, let alone a particular variety of it. One has to produce a substantive argument to this effect.

2. Stages versus Worms

Both the stage and the worm theorists are four-dimensionalists because both agree that temporally extended objects persist through time by having temporal parts (stages) (cf. Sider 1996, 433). This sets them against the paradigm three-dimensionalist who plainly denies that the notion of temporal part makes good sense when applied to objects (rather than, say, events).[9]

Furthermore, both the stage and the worm theorists typically believe in temporal stages as well as 4D wholes. Indeed, a chief contemporary advocate of the stage theory, Theodore Sider, accepts such wholes because they are aggregates of stages.[10] And worm theorists usually accept stages on the ground that the latter are parts of what they take to be the central entities of their ontology. What is, then, the difference between the two views?

As Sider notes (1996, 433), "spacetime worms are [not] what we typically call persons, name with proper names, quantify over"—and attribute temporary properties to,

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perdurantism" (2001, 94n), but he contradicts himself elsewhere: "Spacetime realism [i.e., the view that all events populating the 4D spacetime manifold tenselessly exist on the same ontological footing] raises a host of problems due to its *entailment* of the doctrine of perdurance …" (2000, 124–5, my emphasis; cf. 2001, 192); "If one is a spacetime realist, then, barring conventionalism, things must have spatio-temporal parts" (ibid., 202n68); "A consistent spacetime realist will … view objects as spatio-temporal entities which perdure" (2001, 94n54). Craig's reasons for thinking (in the end) that the combination of endurantism with eternalism is inconsistent remain unclear to me, especially given that this combination is widely accepted on the basis of a view of predication known as Adverbialism (see Johnston 1987, Lowe 1988, Haslanger 1989, van Inwagen 1990, Rea 1998). More on Adverbialism below.

[9] By far, the strongest expression of this attitude belongs to van Inwagen who has said of temporal parts: "I simply do not understand what these things are supposed to be, and I do not think this is my fault. I think no one understands what they are supposed to be, though of course plenty of philosophers think they do" (1981, 133).

[10] "At one level, I accept the ontology of the worm view. I believe in spacetime worms, since I believe in temporal parts and aggregates of things I believe in" (Sider 1996, 433).

one might add. Stages come closer to filling this bill.[11] To illustrate, consider the famous problem of temporary intrinsics. How can one and the same object—say, a poker—instantiate contrary properties at different times, such as being hot at t_1 and cold at t_2? To solve this problem, the worm theorist attributes hotness to the t_1-stage of the poker worm and coldness to its t_2-stage. But it is the poker worm, not its stages, that should properly be called the poker in the worm ontology. Clearly, the 4D poker cannot instantiate temporary intrinsics simpliciter. It can only do so derivatively, via its temporal parts, or stages. Thus it is unable to do what the enduring poker can, according to the *presentist* three-dimensionalism, do quite naturally: by instantiating hotness simpliciter at t_1 and then (next morning) instantiating coldness simpiciter at t_2. Now this advantage is lost as soon as one rejects presentism in favor of eternalism. In the eternalist setting, the endurantist has to replace the simple properties *hot* and *cold* by their time-indexed counterparts, *hot-at-*t_1 and *cold-at-*t_2 (Indexicalism) or to replace the having of the usual properties simpliciter by their temporally qualified having (Adverbialism).[12]

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[11] Hawley (forthcoming, Ch. 2) describes the difference between the worm and stage views similarly:

> According to [the worm] theory, persisting objects like bananas and tennis balls are four-dimensional, and they satisfy certain predicates with respect to certain times because of the properties of their temporal parts. Alongside [the worm] theory, there is space for an alternative account of persistence, one which retains the four-dimensional metaphysics of perdurance theory whilst rejecting [the worm theory's] claims about predication. … According to [the] stage theory, nothing is wholly present at more than one moment, so endurance theory is false. But [the] stage theory also claims that the satisfiers of sortal predicates like "is a banana" and "is a tennis ball" are momentary things, the very things which instantiate ordinary properties like *being yellow*, *being spherical* or *being banana-shaped*.
>
> Consider the series of momentary stages whose sum is what [the worm] theorists think of as the tennis ball. According to [the] stage theory, when we talk about the tennis ball with respect to different times, we talk about different stages in that series, and each of those stages is a tennis ball. The tennis ball at one moment is spherical, and the squashed tennis ball at another moment is not spherical: the spherical tennis ball and the non-spherical tennis ball are different objects.

[12] For discussions of Indexicalism and Adverbialism, see Lewis (1986, 202–204, 1988), Johnston (1987), Lowe (1988), Haslanger (1989), van Inwagen (1990), Merricks (1994), Rea (1998), Balashov (1999, 2000a, 2000c), Lombard (2000), Hawley (forthcoming).

All things being equal, it would be nice to avoid trading the intuition about the having of temporary intrinsics simpliciter for the (arguably unavoidable) rejection of presentism. And that is what the stage view does. In saying that the poker is hot at t_1, the stage theorist ascribes the usual (not time-indexed) property *hotness* to the poker (i.e., the t_1 poker stage) simpliciter.

This example demonstrates the difference between the two varieties of four-dimensionalism and suggests that, assuming eternalism, the stage theory has an edge over both endurantism and the worm view vis-à-vis the problem of temporary intrinsics. Sider further argues that the stage theory offers the best unified solution to the paradoxes of material constitution and coincident entities (1996; 2001, §5.8).

There is a price to be paid for these gains. To account for persistence and change, the stage theorist is hard-pressed to adopt a temporal version of the counterpart theory. The poker is hot tonight, but it will be cold tomorrow morning. But the poker tonight is just a poker stage confined to a certain time. How can *it* survive till tomorrow and be cold then? Only by bearing a temporal counterpart relation to another poker stage. The latter has a simple property *being cold*, but it is the former, tonight stage (which, remember, *is* the poker, on the stage theory) that has, vicariously, the temporal property *being cold tomorrow*. The analogy to the modal counterpart theory is obvious.

Those who are happy with the modal counterpart theory should welcome the stage view as part of the package deal. Others, of course, will consider this kind of commitment unattractive. But one need not be a modal counterpart theorist to adopt the stage theory. The temporal counterpart relation is a this-wordly affair, and realism about other times and their denizens is not nearly as exotic as full-blown realism about possibilia. Furthermore, transtemporal aggregates of shorter-lived entities are familiar (e.g., from the pervading experience of temporally extended events, such as football games and symphony concerts) in a way transworld aggregates of possibilia are not.

In light of the claimed advantages of the stage view, it should be given careful consideration, along with other views of persistence. My eventual goal is to compare the stage and worm theories in the relativistic context. This will require some preliminary work.

3. Local and Global Stages

The first thing to appreciate is that the notion of stage admits of a *global* interpretation. More precisely, local object stages populate and share global *world* stages.

According to the stage theory, various pieces of furniture in my office are so many furniture stages. I can refer to them collectively when I say, for example, that they overcrowd the room. What does it mean, speaking stage-theoretically? It means that each of these things (two chairs, three book cases, a desk, etc.) taken individually—each thing stage, that is—belongs to the room stage and shares this larger stage with other things and with me (that is, my stage). Similarly, the room stage belongs to the building stage, which itself belongs to the campus stage (if there is such a thing). Everything on the planet Earth populates the Earth stage, which inhabits the Solar system, which, in turn, inhabits the Galaxy, and so on. All local object stages, in short, share a global stage cutting across the entire world. In fact, such a global stage *is* the world. Or, to borrow an expression from Shakespeare and Sider (1996, 433), "all the world's a stage."

Let us call objects (themselves stages, of course) populating and sharing some global stage *stage mates*, by analogy with Lewis's world mates. Consider an example (Figure 1). Descartes in 1620 (i.e., the 1620 stage of Descartes[13]) and Galileo in 1620 are

[13] 'The 1620 stage of Descartes' refers ambiguously to a year-long Descartes' stage and to his momentary stage at a certain time in 1620. Similarly with 'the 1620 world (or global) stage'. Hawley argues that stages must be instantaneous: they "need to be as fine-grained as possible change, and thus they must be as fine-grained as instants, in order to account for possible change in position" (forthcoming, Ch. 2). Sider's works exploit the instantaneous sense too, and I will do the same in my analysis. I will also restrict my consideration to point-like objects having no extension in space. The reader will appreciate that

stage mates because they share the 1620 global stage, which is the entire world in 1620. They also share this *temporal world* with Kepler, but not with Tycho Brahe. The reason is that the 1620 world stage contains a Kepler stage, namely his 1620 stage, but it does not include any stage of Brahe. This cosmologist does not exist in 1620. On the other hand, Descartes in 1600 (i.e., his 1600 stage) and Galileo in 1600 share a global stage with both Kepler and Brahe (i.e., with their corresponding stages). All four are stage mates; they coexist in a single temporal world.

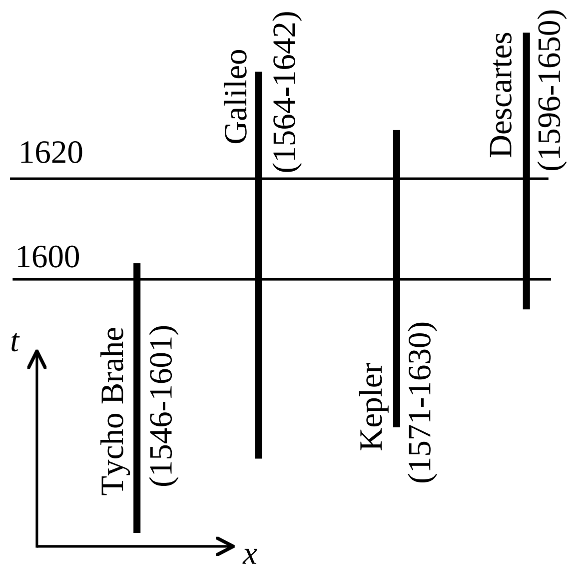

Figure 1.

The notions of existence and coexistence in a temporal world require some comment.[14] It may be objected that the only concept of existence relevant to the 4D framework is the atemporal notion that all spacetime entities, worms and stages alike, exist as parts of the single reality, that of the 4D spacetime manifold. If that is the case, then the distinction made above between Brahe's existence in 1600 and his non-existence in 1620 holds no water. In the basic atemporal sense, Brahe's existence just means his

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nothing important turns on these idealizations. But they do simplify the discussion significantly.

[14] This comment was prompted in large part by very useful discussions with Ted Sider and Mike Rea.

existence in 1600, 1590 and in general at all times between 1546 and 1601. Put in more explicit stage-theoretic terms, what is asserted here is the existence of Brahe's stages in 1546–1601 and non-existence of his stages at other times. The same applies to Descartes, Galileo, and others. But all these cosmologists (i.e., cosmologist stages) coexist with each other as sharing the same 4D spacetime world, and of course they coexist with everything else that ever existed, exists or will exist in the entire history of the universe. All such entities are in the single domain of quantification of the theory.

I agree that this atemporal concept of sharing the single spacetime manifold has its role to play in the 4D framework. But I think it becomes rather trivial, hence useless, when applied to stages as opposed to worms. The basic sense in which complete 4D worms share the same world, or coexist, is indeed the broad atemporal one: they all coexist by populating the same 4D spacetime manifold. But the stage ontology invites a different notion of sharing a world. Stages are confined to particular times rather than being spread over intervals of time. The stages' world is a world stage. It is true but trivial that all stages populate the single 4D manifold and, hence, all coexist. But that is not the issue with which we are primarily concerned when we talk about, refer to, and quantify over stages. A more important notion of coexistence pertinent to stages relates to global stage sharing. In the broad but trivial sense, I (i.e., my current stage) share the single world with George W. Bush (his current stage) and Napoleon (e.g., his 1815 stage). But in our discourse we are inclined to draw a distinction between such cases. And in drawing such a distinction, we are getting at the sense of the coexistence relation such that I bear this relation to Bush but not to Napoleon. This non-trivial notion of coexistence implies a correlated and temporally loaded notion of existence to go along with it. The latter is brought to the forefront when I state, in all seriousness, that Bush *still* exists but Napoleon does so *no longer*. Obviously, both the non-trivial notion of coexistence and the accompanying notion of existence relevant to the stage theory have to do with the sharing of a single temporal world, or a global world stage, by local objects.

Yet one might have doubts about the possibility of accommodating what appear to be two distinct concepts of existence in a single ontology: the universal concept and the restricted one confined to particular global stages. To dispose of such doubts, an analogy with modal realism could be helpful. As noted by Lewis, to quantify correctly over possibilia and, in general, to do justice to the modal discourse, the modal realist needs two different quantifiers: one ranging over the contents of the entire collection of possible worlds and the other restricted to a particular such world (see Lewis 1986, 3, 5–7, and elsewhere). Any two objects populating the Lewisian multi-universe coexist in the broad sense, but those belonging to different worlds do not coexist in the restricted sense. An inhabitant of our world can state, with ontological seriousness, that alien objects do not actually exist (meaning their non-existence in our world). The distinction drawn above between the broad and restricted concepts of (co)existence in the "temporal multi-universe" (i.e., in the complete four-dimensional spacetime manifold, which can be foliated into families of world stages) parallels the Lewisian distinction between the two quantifiers. The first ranges over all stages of all objects while the second is restricted to stage mates—just as the Lewisian special quantifier is confined to world mates. In fact, the first distinction has more intuitive appeal, as it allows the stage theorist to give due respect to familiar differences, such as that between our coexistence with Bush and our lack of coexistence with Napoleon, whereas rather esoteric intuitions are required to recognize the realm of possibilia in the first place. Nonetheless, the parallel is useful as it brings out, once again, important similarities between the modal and temporal discourses.

With this distinction in mind, we can provide a stage-theoretic analysis for much of ordinary discourse about temporally qualified existence and coexistence. Start with a simple observation that the 1620 stage of Descartes coexists with the 1620 stage of

Kepler, but not with his 1615 stage. The first, but not the second pair of stages are stage mates, that is, share a single global stage, or temporal world. Such basic relations among local stages can be used to analyze many familiar locutions.

- The stage-theoretic analysis of ‘In 1620, Descartes coexisted with Kepler and Galileo but not with Brahe’ would go along the following lines: the 1620 stage of Descartes coexists (in the narrow sense)—or shares a global stage (a temporal world)—with some stage of Kepler and some stage of Galileo but with no stage of Brahe. (Note the tenseless mode of present-tense verbs in the analysans here and below.)
- As already noted, ‘Brahe did not exist in 1620’ means that no stage of him exists then.
- ‘Descartes, Kepler, Galileo, and Brahe were contemporaries’ translates into the statement that some stages of Descartes, Kepler, Galileo, and Brahe are all stage mates, for example, their 1600 stages.
- ‘Descartes, Kepler, Galileo, and Newton (1642–1727) were contemporaries at some point or other but not all at once’ translates into the statement that some stage of each of them shares a single temporal world with some stage of another or with some stages of some others, but no single global stage contains stages of all of them.
- ‘Neither Descartes nor Kepler was a contemporary of Ptolemy’ means that no stage of Ptolemy shares a temporal world with any stage of Descartes or Kepler.

Although this framework is transparent enough, some of its features should be noted, as they will play a role in the subsequent discussion.

1. The relation of coexistence in a single temporal world—the stage mate relation—is not a set of dyadic relations between members of pairs of objects (i.e., their stages), but a single *many-place* relation among *n*-tuples of objects. Descartes, Kepler, Galileo, and Brahe coexisted in 1600, not because six dyadic relations obtain between

members of pairs of their stages, but because a single four-place relation obtains among all four.

2. Temporal worlds (global stages) hosting local stages of objects can be individuated by very minimal amounts of their contents. Given a single stage of a single object—for example, Descartes in 1620—the global stage representing the whole temporal world containing him is uniquely fixed: the world in 1620. To put it differently, Descartes' local 1620 stage can be uniquely *extended* to the global 1620 world stage.

3. If a collection of stage mates coexist with O1—that is to say, if the original collection and O1 are related by an *n*-place stage mate relation—and also coexist with O2 (in the same sense), then that collection coexists with both O1 and O2; which is to say that the original collection supplemented by O1 and O2 are related by an *n*+1-place stage mate relation. Thus Descartes in 1600 and Galileo in 1600 coexist with Kepler (his 1600 stage); these cosmologists bear a three-place stage mate relation to each other thereby sharing the 1600 world. Furthermore, Descartes in 1600 and Galileo in 1600 coexist in the same sense with Brahe (his 1600 stage). Not surprisingly, Descartes in 1600 and Galileo in 1600 coexist with *both* Kepler and Brahe by bearing a four-place relation to their corresponding stages and thereby populating the 1600 world. Let us call this feature of the stage mate relation *non-contextuality*. The full meaning of this term will become clear later on.

4. As Descartes grows older he finds himself in temporal worlds with *progressively older* stages of Kepler and Galileo. (Regrettably, some of those later worlds do not contain Brahe.) In this sense, the stage mate relation is *chronologically well behaved*.

5. The above analysis is classical. It exploits the intrinsic geometry of pre-relativistic (Galilean, or neo-Newtonian) spacetime. The classical spacetime manifold can be uniquely foliated into a family of hyperplanes of simultaneity indexed by the

absolute time of Newtonian physics. Every such hyperplane cuts across an entire temporal world. In fact every hyperplane *is* a world or, more precisely, the geometrical locus of a temporal world. Each local stage finds itself on one of the hyperplanes. And the extension of a local to a global stage is achieved by drawing a unique hyperplane of simultaneity through that stage. Figure 1 illustrates these observations.

Classical spacetime provides a rather friendly environment for the stage ontology by making the stage mate relation non-contextual and chronologically well behaved. These benefits are easily overlooked because we normally take pre-theoretical considerations underlying them for granted. These benefits, however, are lost in the transition to special relativity. In the remainder of the paper I shall argue that, on plausible formulations of the stage theory in relativistic (Minkowski) spacetime, one has to surrender non-contextuality and chronologically good behavior of the stage mate relation.

Before we do it, however, let us turn briefly to the worm view and indicate that it suggests a different analysis of the situation considered earlier. On the worm theory, Descartes, for example, is a 4D object (a 1D world line in Figure 1, in which two spatial dimensions are suppressed and, in addition, Descartes and others are taken to be idealized point-like objects) and the same is true of Galileo, Kepler and others. Although one could sensibly talk about their stages and various relations among them, this talk is not ontologically significant in a sense in which the stage theorist's talk of stages is. Ordinary objects, on the worm view, are not stages but worms; the relations among their stages are derivative from more fundamental relations among the 4D wholes. When asked, "How many great cosmologists are there?" the stage theorist will take this to be an incomplete question about cosmologist stages and the appropriate answer will require additional information about the time of evaluation. There are, for example, three great cosmologists in existence in 1620 and four in 1600. The basic objects of the stage ontology populate global stages; their common world, recall, is a stage. The basic objects of the worm ontology, on the other hand, populate the entire 4D spacetime reality. When asked, “How many great cosmologists are there?” the ontologically serious worm theorist should regard this as a complete question that is primarily about perduring wholes, and she will have to list all the great 4D cosmologists—past, present, and future. The list will include Ptolemy as well as Hubble, in addition to Galileo, Kepler, Brahe, and Newton.[15] Now of course, the worm theorist is free to talk about cosmologist stages as well, when confronted with the question “How many great cosmologists were there in 1620?” And here, she could adopt the stage theorist’s approach to local and global stages and their relations described above. But far from considering such relations to pertain to the very essence of existence and coexistence, the worm theorist should regard them as mere *perspectival restrictions* of the more fundamental relations holding among what she takes to be perduring objects—total 4D entities in the spacetime manifold. Thus she would say that, from the perspective of 1620, Kepler but not Tycho coexists with Galileo and Descartes, because the appropriate relation obtains between the 1620 stages of Kepler and Galileo but not between the latter and the 1620 stage of Tycho (there is no such stage), whereas Galileo and Descartes’ common 1600 perspective includes both Kepler and Tycho. These relations are underwritten by the spacetime relations among the corresponding 4D objects populating a single neo-Newtonian 4D world. As already noted, in the end all such objects are equally “world mates.” It normally behooves the worm theorist, but very rarely the stage theorist, to adopt the God’s eye view of the universe.

To take a spatial analogy, consider a depot in the yard of a huge museum of natural science, which stations trains bearing the names of prominent cosmologists and natural philosophers (Figure 2). The tourists sitting in the middle cars of “Descartes” and

[15] Cf. Sider on counting worms in §6 of his 1996 paper.

the front cars of “Galileo” will see each other’s trains and “Kepler” between them (Perspective 1). (Let’s pretend that the cars are made of glass or at least have sufficiently large windows to enable the tourists to see through.) One could imagine them saying, “Look, there is ‘Kepler’ over there. Why didn’t they put ‘Tycho’ as well? He was, after all, just as great!” The tourists in the back cars of “Descartes” and the middle cars of “Galileo,” on the other hand, have a better sense of historical justice: both “Kepler” and “Tycho” are in place (Perspective 2). But of course, the vision of the tourists is always perspectivally restricted and, hence, incomplete. To get the full sense of historical justice, one would need to take the bird’s eye view of the depot.

These perspectival considerations do not seem especially important in the classical case. The news they bring—that the 1620 perspective is different from the 1600 one—is reassuring to all (the stage and worm theorists alike) but not particularly illuminating. As we shall see shortly, the situation is more complicated in the relativistic case.

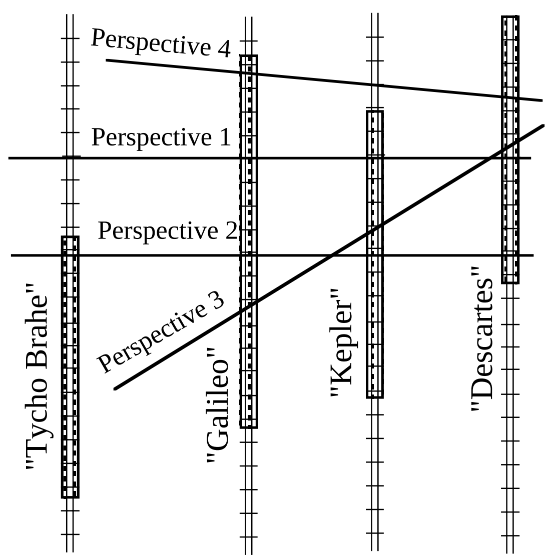

Figure 2.

4. Stages in Minkowski Spacetime

To make a transition to the relativistic case, one should first of all take care to replace the notion of temporal stage with a more general and relativistically acceptable notion of *temporal-like* stage.[16] A global temporal-like stage is simply a 3D hyperplane in spacetime. It is similar to a classical momentary global stage in that it corresponds to a particular time in a given reference frame; but it requires two separate indices for its individuation: a frame and a time in that frame. Two indices, instead of just one, as in the classical case, are needed because of the absence, in the relativistic framework, of the frame-invariant concept of time. Time by itself is not enough to identify such a stage: one has to know in what frame the time is measured.

Figure 3 features various momentary global 3D temporal-like stages in Minkowski spacetime. (Since two spatial dimensions are suppressed in this figure, the stages become 1D lines; but one should not forget that in reality, they are three-dimensional.)

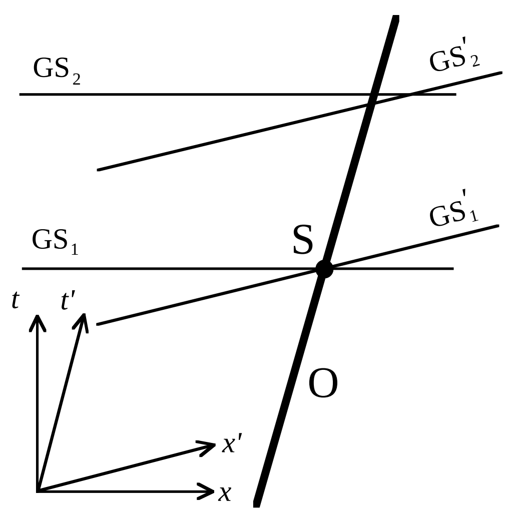

Figure 3. Momentary global stages in Minkowski spacetime. GS_1 and GS_2 correspond to times in frame (x,t) whereas GS_1' and GS_2' correspond to times in (x',t'). The local temporal-like stage S of object O belongs to both GS_1 and GS_1'.

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[16] This term was suggested in conversation by Steve Savitt. As will become clear immediately below, a temporal-like stage is a temporal stage in a particular reference frame.

In the foregoing, we have drawn useful parallels between Lewis's possible worlds and classical global stages. Now we should note an important dissimilarity between the former and relativistic global stages construed as above. Any two Lewisian possible worlds are entirely distinct: no object can exist in more than one such world. On the contrary, any two global temporal-like stages corresponding to different frames of reference *intersect*. Consequently, a single local object can in principle belong to more than one temporal-like world—that is, to more than one global stage. In fact, unless specific restrictions are imposed on the construction of global stages from local ones, any object belongs to an infinite number of worlds.

Just like global temporal-like stages, local ones are also individuated by two indices. This becomes especially important for spatially extended objects. In Figure 4, global stages GS_1 and GS_2 contain two temporal-like stages of the planet Earth. They cut the 4D world volume of the Earth at different angles in spacetime and intersect one another along a two-dimensional circle. (Because one spatial dimension is suppressed in Figure 4, this intersection looks like a one-dimensional line.)

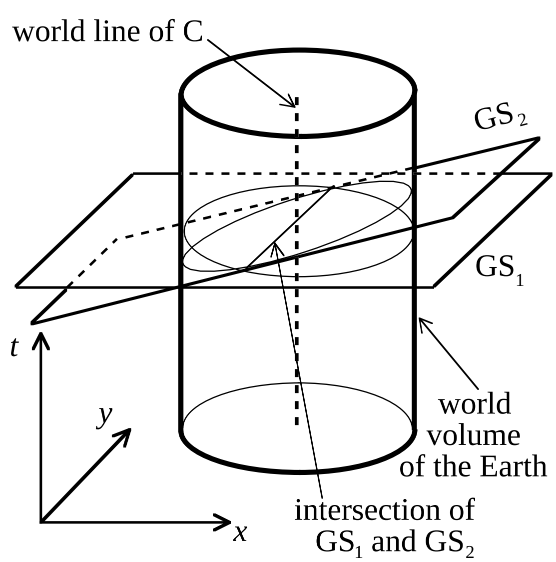

Figure 4. The Earth and its temporal-like stages in Minkowski spacetime.

Such "crisscrossing" becomes less significant for local temporal-like stages of idealized point-like objects (remember that this idealization is adopted throughout most of the paper), such as particle C at the center of the Earth (Figure 4). Its temporal-like stages could in principle be uniquely labeled by just one parameter, for example, the proper time associated with the rest frame of the particle.

5. Global Stage Sharing in Minkowski Spacetime

Let us now turn to the question of how objects can share a global stage in Minkowski spacetime. Here one should be open-minded, as it is difficult to decide in advance what form the stage mate relation must take in the relativistic framework. It is natural to assume that the intrinsic geometrical structure of Minkowski spacetime gives us more flexibility than the rather rigid and unsophisticated geometry of neo-Newtonian spacetime. Hence, it is best to be maximally unprejudiced, consider all the options available, and be prepared to let the chips fall where they may.

For the purpose of discussion, it will be convenient to begin with a non-starter. Suppose there are just two objects, O_1 and O_2. Under what conditions can O_1 share its particular stage, say S^1_1, with *some* stage of O_2? Clearly, there should be a single global stage—a single temporal-like world containing S^1_1 and some stage of O_2. And there are an infinite number of such global stages. Is any one of them distinguished? Not in virtue of the intrinsic structure of Minkowski spacetime alone. But given this structure *and* the instantaneous state of motion of O_1, one global stage hosting S^1_1 is naturally privileged—the one corresponding to the hyperplane of simultaneity in the rest frame of O_1. In Figure 5, it is GS^1_{rest}. As long as we know the velocity of O_1 at the location of S^1_1, GS^1_{rest} is uniquely determined.[17]

[17] Does the concept of velocity make sense for instantaneous stages? One might think not, because the specification of velocity requires the specification of the object's positions at an infinitesimal

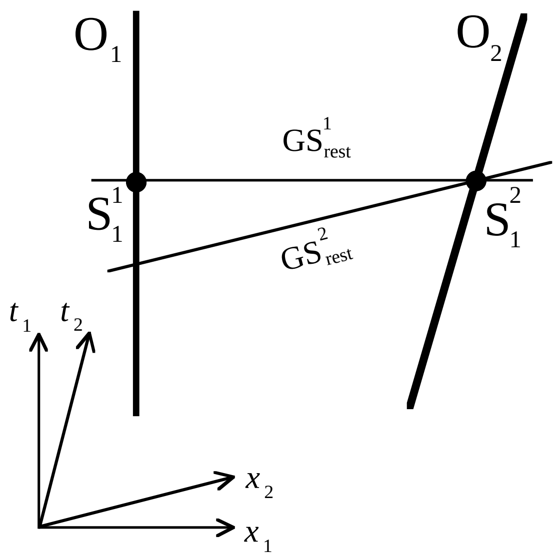

Figure 5.

But if the "global extension" of S^1_1 is defined in this way, it will not, in general, be a global extension of any stage of O_2 and, hence, will not be a common temporal-like world of O_1 and O_2. Indeed, the stage mate relation must be symmetrical, O_1 and O_2 must figure in its specification on a par. But on the present proposal, this, in a great majority of cases, is impossible to satisfy. A global stage such as GS^1_{rest}, distinguished from the point of view of O_1, will not, in general, be distinguished from the viewpoint of O_2. O_1 and O_2 can share a global stage defined as above only if they are at rest with respect to each other. And such cases are extremely rare. If O_1 moves relative to O_2, the global extensions of their stages are "at an angle" and thus no global stage can be their common

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but still extended interval of time, whereas an instantaneous stage exists at a single time (in a given frame). As already mentioned, however, the stage theory adopts a counterpart view of temporal predication. On that view, an instantaneous stage S located at position x at time t (in a particular frame) has all sorts of temporal properties, including such properties as *being at* $x+dx$ *at* $t+dt$. Thus an instantaneous velocity can be attributed to it.

stage (Figure 5). Such objects can never be stage mates and, therefore, can never populate a single temporal-like world.[18]

It is clear, on reflection, that linking global stages to the state of motion of local objects was simply a leftover of the classical view. In the classical case, two object stages shared a global stage whenever they were *co-present* to one another. And co-presence simply meant existing at the same time, the universal Newtonian time of classical physics. By abandoning this latter notion—by making time frame-dependent—special relativity prevents one from associating ontological commitments with coordinate time and simultaneity. But relativity puts something else in their place: the frame-invariant notion of *spacelike relation*, or separation. Two spacetime points are spacelike related just in case there is a reference frame in which they are simultaneous. And this existential fact is itself absolute: if it obtains in any legitimate reference frame, it obtains in every such frame.

This suggests a proposal to ground the stage mate relation in the objective relation of spacelike separation between local object stages. In Figure 5, local stages S^1_1 and S^2_1 of, respectively, O_1 and O_2 are spacelike related and that may be enough to ensure that they are stage mates—that there is a global stage containing both of them, for example, GS^1_{rest}. In this approach, a common global stage is not required to be specific to either O_1 or O_2. It can be just one of the many legitimate (i.e., spacelike) hyperplanes that could be drawn through S^1_1 and S^2_1. That there are many others can be seen as soon as one recalls that two dimensions of space are suppressed in Figure 5.

The extension of this schema to more numerous collections of object stages requires caution. Suppose there are five (or more) local stages of five (or more) objects,

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[18] A point duly appreciated by Sider (2001, §5.8) in his discussion of how to make the stage view consistent with relativity. Sider's vocabulary and agenda there are, however, rather different from mine and his proposal to relativize the truth value of tensed utterances about stages to the rest frame of the

all pairwise spacelike related. In general, there will be no spacelike hyperplane that can be drawn through all of them. Indeed, five or more points in a four-dimensional space do not always lie on a single hyperplane.[19] But one should not infer from this that five or more objects could not in general be stage mates in Minkowski spacetime. Instead, one should adopt a more charitable approach to the (temporally-qualified) notion of coexistence in the stage ontology.

The approach just considered starts with a collection of local stages and then goes on to assert their coexistence (or the lack of it, as the case may be) in a single global stage. But there is no more reason to do things in this order in the relativistic case than in the classical case. In the latter case, we do not begin with, say, the 1620 stage of Descartes, the 1620 stage of Galileo, and the 1615 stage of Kepler, only to conclude that they do not coexist in any single temporal world. That they don't is, no doubt, good news but it is hardly enlightening. A more sensible strategy is to fix attention on a particular stage of Descartes, say his 1620 stage, and then pose the question as to what *objects* it coexists with. It coexists with Galileo and Kepler in virtue of bearing a (classical) stage mate relation to their corresponding 1620 stages, and it does not coexist with Brahe, because there is no Brahe stage in 1620. Most objects in our world come to be and cease to exist. And that is a matter of significance to us when we say that we (that is, our current stages) coexist with Bush but not with Napoleon.

Similarly, one should not be obligated to start with an arbitrary collection of stages in Minkowski spacetime, only to discover that its members could not (in virtue of the above-mentioned geometrical considerations) be stage mates. Instead, one ought to start with a particular object of interest O at a certain time *t* in its life career (which is

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speaker is of no help in handling the ontological issues surrounding the notion of coexistence in the stage world.

[19] Just as four or more points in a more familiar three-dimensional space do not always lie on a single plane.

none other than *proper time* intrinsic to the object and measured in its rest frame) and then pose the question as to what objects it coexists with. Other objects enter into such a relation of coexistence with O at *t* by having stages that bear a single many-place stage mate relation to each other and to S_t, the stage of O at *t*. On this approach, O at *t* turns out to coexist (as it should) with what we would pre-relativistically count as its "contemporaries" and not coexist with any of its "predecessors."

The notion of a relativistic "contemporary" is, of course, different from its classical counterpart. Classical contemporaries exist at the same moment of a single time, the absolute Newtonian time. No such concept is available in the relativistic framework. But there is a good substitute. Each "contemporary" of O at *t* is a *certain age*, the age in question being measured by the proper time of that "contemporary." In the end, this enables all relativistic "contemporaries," including O, to enter into the relation of coexistence with each other on a par. Thus, the 30-year old Data, the 46-year old Captain James T. Kirk, and the 65-year old Captain Jean Luc Picard are "contemporaries" of each other: their corresponding stages are stage mates. On the other hand, Klingon Trevor is the relativistic predecessor of all of them: none of his stages shares a temporal-like world with any stage of the first three (Figure 6).

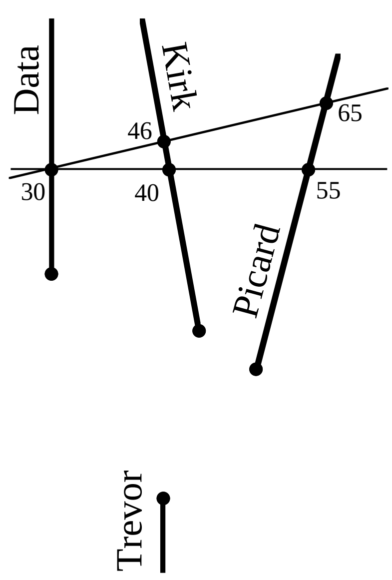

Figure 6.

Notably, the same 30-year old Data is also a "contemporary" of the 40-year old Captain Kirk and the 55-year old Captain Picard. This is a consequence of the latitude allowed by relativistic spacetime. It may look surprising but is surely tolerable. I show below that other features of the relativistic stage mate relation are more pernicious. Before doing it, however, it may be useful to note that the relativistic account developed here gives the right result in the *classical limit,* which is surely a good sign.

The limiting property of scientific theories constitutes the gist of the *correspondence principle*, governing the relationship between an old and a new theory: the former should be (in some sense) a limiting case of the latter when the domain of application is restricted to that covered by the old theory. Thus classical mechanics is a limiting case of relativistic mechanics for velocities much smaller than the speed of light or, alternatively, in the limit $c \to \infty$. Although the validity of the correspondence principle has been called in question by the advocates of incommensurability and related ideas in the post-positivist philosophy of science, it is still used in the foundations of physics as a helpful heuristic device. (Witness recent discussions of the classical limit of different interpretations of quantum mechanics.)

Be this as it may, the classical limit of the relativistic stage mate relation is clearly the old classical relation of existing at the same moment of absolute time. Applied to Descartes and his ilk—objects moving with small relative velocities and separated by small distances—the relativistic analysis simply recovers Figure 1, in which the outsides of the light cones collapse into absolute hyperplanes of simultaneity, thereby forcing all global stages (generally inclined at various angles) to become horizontal. The latitude referred to above evaporates in this limit: Descartes in 1620 has the uniquely-aged Galileo and Kepler as his contemporaries.

6. Contextuality

We are, however, interested in precisely those features of the relativistic stage mate relation that deviate from the classical features. Some such features are unwelcome. It is now time to investigate them. Begin with *contextuality*. Object O at *t* (i.e., its *t*-stage, S_t) coexists with O_1 and with O_2 but *not* with *both*: there is no single temporal-like world containing S_t and some stages of both O_1 and with O_2 (Figure 7). One might wonder, however (and rightly so), why there *should* be such a single world, given that O_2 is in the *absolute future* of O_1. O_1 may be Captain Kirk's great-grandfather and O_2 his great-grandson. It would be rather strange for anyone to be a "contemporary" of both.

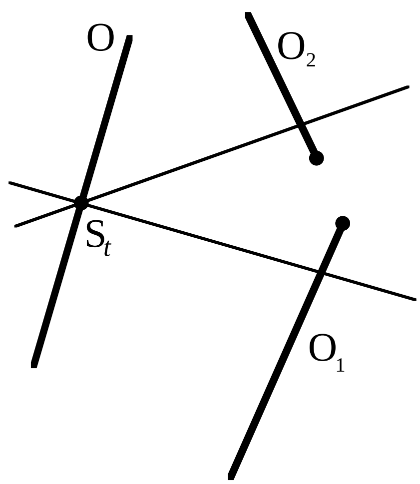

Figure 7.

But the problem is easily reproduced by separating O_1 and O_2 wide enough in space (Figure 8). There we have a situation in which O_1 *does* coexist with O_2 at a given point of its life career (some of their stages share a global stage, e.g. GS*), and O at *t* coexists with O_1 and O_2 but *not with both*.

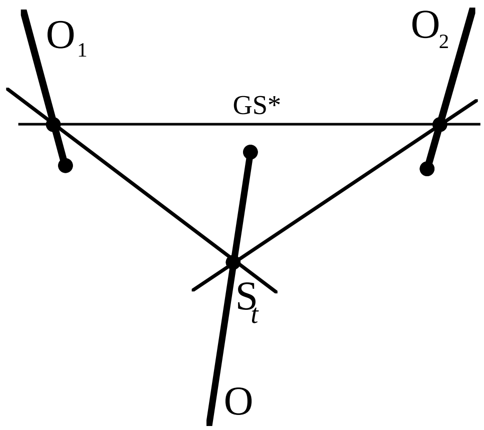

Figure 8.

In fact, a stronger result obtains. Suppose all three objects are entities that come to be and cease to exist. Then given their suitable locations in spacetime, they may coexist pairwise at *some point or other* of their life careers: all three may have stages that bear dyadic stage mate relations to each other. But this does not guarantee that they coexist *all together*. The failure of such mutual coexistence occurs in cases in which no selection of the stages of the three objects can be unified by a single triadic stage mate relation. Thus it may be the case that Data coexists with Captain Kirk, Captain Kirk coexists with Captain Picard, and the latter coexists with Data. Taken pairwise, they all share temporal-like worlds with each other. Taken all together, however, they don't share any single temporal-like world (Figure 9). The same is true of a quadruple of objects. Any three of them may coexist but this does not entail the coexistence of all four. (Considerations of space prevent me from illustrating such a case.)

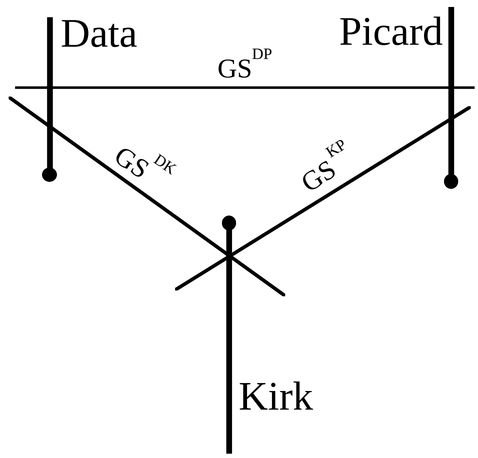

Figure 9. Kirk coexists with Data: they have stages sharing the global stage GS^{DK}. The same is true of Kirk and Picard, and of Picard and Data. But there is no single global stage containing stages of all three.

This result is easily extended to more numerous collections of objects. Take a suitably situated group of *n* objects with finite life spans, such as Star Trek civilizations, that are all created and destroyed. Add two more such objects. It may be the case that the entire initial collection coexists with them taken separately but not with both taken together—even if those two objects, in addition, coexist with each other. A more involved case would include, say, 1000 Star Trek civilizations C_1, … C_{1000} and three more: $C*_1$, $C*_2$, and $C*_3$. All members of the latter group coexist with each other and *any pair* of them coexists with all the members of the first group, C_1, … C_{1000}. And yet, all 1003 do not coexist. (Again, I leave these cases without illustration.)

It may be interesting to find out if coexistence (that is, the temporally qualified coexistence grounded in the many-place stage mate relation) of *all* n–1-tuples of objects O_1, O_2, … O_n need not entail the coexistence of the entire collection. But even if this more general result does not hold, the situation is frustrating enough. Coexistence in the relativistic stage world turns out to be partitioned in a most peculiar way bearing the mark of contextuality. Facts about coexistence among members of a collection of objects, however numerous, become sensitive to what other objects are taken into account. Such facts do not “add up” properly.

Contextuality of coexistence in the stage world should not be confused with the breakdown of transitivity. First, coexistence in a temporal-like world is a *many-place* relation, not a dyadic one. Furthermore, even if consideration is restricted to pairs of objects, contextuality and the lack of transitivity are distinct features. It is true that coexistence between members of pairs of objects in the relativistic stage world is not transitive: coexistence of O_1 with O_2 and of O_2 with O_3 does not entail coexistence of O_1 with O_3. Contextuality, on the other hand, means that coexistence between members of *all* such pairs does not entail coexistence among members of the *whole triple*, O_1, O_2 and O_3.

Why should the stage theorist be bothered by contextuality, but not so much by the lack of transitivity? One reason is that transitivity of coexistence fails even in the classical stage world. I coexist with my father (some of our stages are classical stage mates) and he coexists with my grandfather. But I don’t coexist with my grandfather. But the classical relation of coexistence is free of contextuality. If my father, my grandfather, and I coexist pairwise then we coexist all together. We do not find this remarkable because we simply take it for granted. But for the stage theorist, something important is at stake here.

Indeed, stages live in stage worlds; their common world is a global stage. *That* is what they share—just as objects in Lewis’s ontology share a particular possible world. In a trivial sense, the latter also share the entire collection of Lewisian worlds. But that sense is irrelevant, nothing significant turns on it. All the important features of that ontology, including the modal properties of objects, are grounded in the facts about what objects belong to what worlds. The fact that every object also belongs to the whole collection of worlds bakes no bread. Similarly, the stage theorist should take the facts about what object stage belongs to what temporal world—and what other stages it shares that world with—as the ground of all the important properties exhibited in the stage "multi-universe." These include the temporary properties of objects, the account of change they undergo, and the ways they interact with each other. The fact that all stages of all objects trivially share the single "multi-universe" occupying the entire spacetime manifold is simply too coarse-grained to add anything significant to the picture.

In short, the stage theory must recognize existence in a temporal (or temporal-like) world and sharing such a world as primary categories of its ontology. But then it is natural to expect such categories to obey some reasonable "calculus." And they certainly do so in the classical case, where the stage mate relation is grounded in absolute simultaneity among local stages. Minkowski spacetime suggests a *bona fide* candidate to do a similar job, the relation of belonging to a single spacelike hyperplane, which adequately recovers its pre-relativistic counterpart in the classical limit and is, as we saw, partly successful. The problem with it is that it stumbles upon a simple rule that is, intuitively, part and parcel of the concept of coexistence: if A coexists with B, B coexists with C, and C coexists with A, then A must coexist with B and C.

To be sure, these considerations do not go as far as to refute the stage theory. Rather, they indicate what price this theory has to pay in the transition to relativity. And that is only part of the price. Besides being contextual, coexistence in the relativistic stage world is not well behaved chronologically.

7. Chronology

Let's start with an unproblematic case. The 30-year old Data coexists with the 35-year old Captain Kirk and the 40-year old Captain Picard: they share a common global stage GS_1. As Data grows older and reaches the age of 35, he happens to coexist with a *younger* Captain Kirk, who just turned 32, and a younger, 33-year old Captain Picard: they share a common global stage GS_2 (Figure 10).

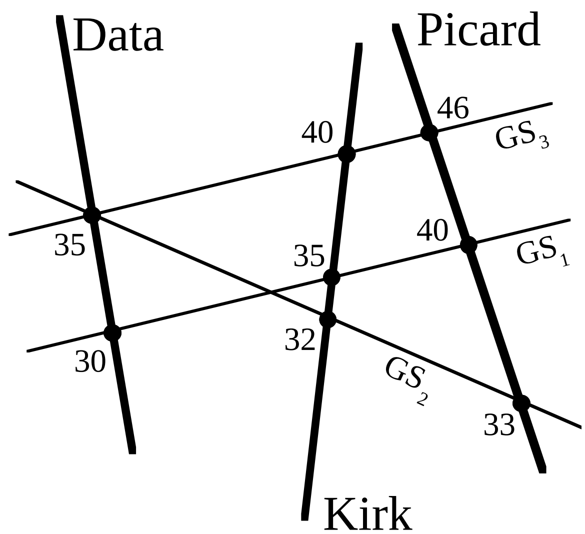

Figure 10.

This, however, is not particularly disturbing. At any moment in his life, Data belongs to an infinite number of temporal-like worlds. The fact that one can pick out a chronologically ill-behaved series of such worlds (e.g., the sequence of GS_1 and GS_2) should not be held against the stage view, as long as another, chronologically well-behaved series *is available*. And it is surely available in the case under consideration; for example, the series including GS_1 and GS_3. The latter global stage, GS_3, features the 35-year old Data, and the correspondingly older Captain Kirk and Captain Picard. One is not saddled with the unpalatable sequence of GS_1 and GS_2, because there is no reason to allow one to exploit the latitude inherent in relativistic spacetime *frivolously*, by sequencing global stages at will. The availability of chronologically well-behaved series of global stages is all that the Star Trek biographer needs to tell a sensible story about the life careers of the three famous characters and their relations to each other.

But there are cases where a chronologically well-behaved series of temporal-like worlds is *not* available and there is no escape from a disturbing conclusion that ageing results in being a contemporary of progressively younger companions. Such a case is represented in Figure 11.

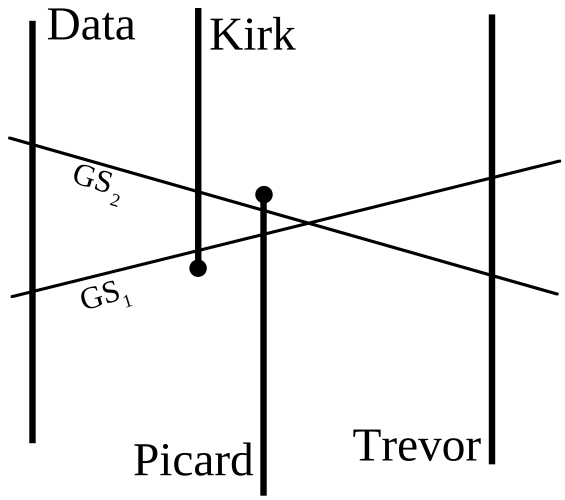

Figure 11. SG_1 and SG_2 form a sequence of global stages that is chronologically well-behaved for Data, Kirk, and Picard. But given the configuration of these objects in spacetime, any such sequence inevitably picks out progressively (or rather regressively) younger stages of Trevor.

Here the most one can do is to identify a chronologically well-behaved series of global stages including the correspondingly ageing Data, Kirk, and Picard, for example, SG_1 and SG_2. Adding Trevor to the picture, however, turns the series into a bad one. As Data, Kirk, and Picard *all* grow older, they find themselves in worlds with the younger and younger Trevor. And that is not the worst possible scenario yet. With some modifications, one could make progressively ageing Data, Kirk, and Picard *unavoidable contemporaries* of, first, Chief Trevor, next the 15-year old Cadet Trevor, then the newly born Klingon baby just named Trevor, and eventually, Trevor's great-grand-grandfather!

This is surely an unwelcome result. Along with contextuality, it brings out the difficulties of formulating the coexistence relation in the relativistic stage world.

8. Discussion

Why is the worm theory not afflicted with the same or similar problems? Because the worm ontology presupposes a different notion of coexistence. All 4D worms coexist with each other in the Minkowski world. This does not mean that one cannot pose temporally sensitive questions about the coexistence of their various parts. But the answers to them do not get at the basic sense of coexistence essential to the worm ontology. They are always restricted to a particular *perspective* in spacetime, just as the answers to similar questions were restricted to a purely temporal perspective in the classical framework.

The perspective in question is associated with a hyperplane drawn through the location of a given temporal-like part of a 4D object. Return to Figure 8 but read it differently now. The figure represents three 4D objects, O, O_1, and O_2—three full-blown spatio-temporal worms, all coexisting together in the single spacetime. These objects have parts, or stages, confined to spacetime points, and associated with each such part are infinitely many momentary perspectives on the single spacetime world. Thus the perspectives linked to the *t*-part of O include those containing some part of O_1 and those containing some part of O_2. As it turns out, there is no perspective containing parts of both O_1 and O_2. The *t*-part of O is unable to share a perspective with objects O_1 and O_2 taken together. Given an appropriate configuration of the three objects (three worms, that is), a stronger result obtains (cf. Figure 9). Taken pairwise, Data, Kirk, and Picard may share spatio-temporal perspectives with each other. Taken all together, however, they may not. But that is quite different from being unable to share a *world*. In a similar vein, being saddled with a chronologically ill-behaved series of perspectives is rather benign in a way in which being saddled with a correspondingly bad series of temporal-like worlds is not. Every such world constitutes an appropriate habitat for an object-stage, but not for an object-worm. Indeed, temporal-like worlds are something in which the objects of the stage ontology live and coexist with each other. The objects of the worm ontology, on the other hand, live and coexist in the much bigger world, the entire Minkowski spacetime. Their more fine-grained temporal characteristics are a matter of perspectivalism, not existence.

Perspectivalism of this sort should not be surprising as it is a general feature of our perception of the world. Tourists sitting in “Descartes” can look out the window at various angles and thus get different perspectives on other trains. Some tourists see “Kepler” between themselves and “Galileo” (Perspective 3 in Figure 2), others don’t (Perspective 4). This is anything but surprising and has nothing to do with the real existence of “Kepler.”

We can view a house from various vantage points and take its pictures. In general, such pictures look very different; in particular, they feature different two-dimensional shapes of the whole construction and its different parts. Such representations are inevitably incomplete, because they are perspectivally restricted, and some do not “add up.” One of them may feature the kitchen and the living room, another the kitchen and the bedroom, and the third the kitchen and the bedroom. There may be no representation featuring all three rooms together, but that is just what is to be expected. In fact, nothing could be more natural than such incompleteness and “contextuality” inherent in spatial perspectivalism. And of course, these features have nothing to do with existence. Every one knows that the real house out there is three-dimensional, and its 3D invariant configuration, complete in every detail, stands behind all partial 2D representations.

Similarly, the objective 4D configuration of worms in the single spacetime stands behind all stage-restricted perspectives. In this sense, it may not be too far off the mark to say that worms are, after all, primary and stages secondary.

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