Physical Time as Human Time

Ruth E. Kastner

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ABSTRACT. This is an invited comment on “Physical Time Within Human Time” (Gruber, Block and Montemayor, 2022). The topic is the nature of time and its various representations in physical theory vs. our experience. In this Comment, I dissent from the standard formulation of the topic as involving a “Two Times Problem,” in which physical time is taken as being at odds with the human sense of a “flow of time.” I provide a brief overview of the case to be made for the contrary view: namely, that physical theory is indeed consistent with a genuine temporal dynamism that takes into account the quantum level in connection with spacetime emergence, the latter being supervenient on specific quantum processes.

Comment.

The authors of “Physical Time Within Human Time” (Gruber, Block and Montemayor, 2022), have kindly invited me to comment on their interesting paper regarding the nature of time and its various representations in physical theory vs. our experience. They introduce their discussion with references to a “two times” problem (TTP), which I take to be the common notion that there is a conflict between (1) “physical time” (equated to metrical time of the 3+1 spacetime manifold) and (2) the experience of “Now” or of a “flow of time” (FOT) corresponding to real change. The authors propose what they see as at least a partial resolution of this conflict by reference to the concept of information processing by an observing or experiencing entity.

My response to this formulation will be somewhat brief, and it will be primarily to dissent from the standard formulation of the topic. Although I don’t pretend to do justice to the full extent of the range of views and formulations mentioned/discussed by the authors, I will attempt to address what I think is the core of the problematic discussed and the basis for my general dissent.

In a nutshell, I would like to deny the prevailing idea that physical theory is in conflict with our experience of time—thus, I deny that there is a “two times problem” (TTP) in a fundamental sense. The apparent TTP arises from a common habit of thought that seems so natural and right that it is almost never questioned: namely, that “all that exists” or that “the universe” is contained within or against a spacetime background or “in a spacetime container.” In other words, the assumption is: all physically real entities exist “in spacetime” or are components of spacetime. In short, the belief is that if one is discussing something physically real, the entity or system in question must be contained in (or be an element of) spacetime. Let us call this assumption the “spacetime background” or STB.

In contrast to the foregoing, I have argued (since Kastner, 2010, 2012) that STB is precisely what quantum theory demands of us to question—that in fact, 3+1 spacetime is *not* the whole physical story, i.e., does not exhaust the cosmological reality of our world. Thus I maintain that the STB presupposition is what is illusory, while the TTP problematic takes it as a veridical component of the world. Lest this point be misunderstood, my claim is that physical theory (i.e., relativity) is indeed correct in its domain of applicability; what I regard as suspect is the prevailing *interpretation* of the theory as implying the STB. The result of the above exploration can lead to a well-supported conclusion that physics need not be taken as being fundamentally at odds with our experience, thus resolving a number of apparent paradoxes (among them the TTP). Again, due to space constraints, I will not be able to lay out that full ontology here, but I invite the interested reader to consult the relevant references provided herein.

The above-mentioned habit of thought—taking spacetime as a fundamental background or container for all that is physically real--leads inevitably to the assumption that “physical time” equates solely to the “1” aspect of the 3+1 spacetime manifold. For those who subscribe to the “block world” or “all at once” picture of spacetime, this implies a static ontology, such that our experience of change and dynamism is seen as illusory or otherwise non-veridical. Hence, an apparent discrepancy arises: a “gap between physics and psychology,” as the authors characterize it. As mentioned above, my research has questioned the existence of such a gap by questioning the usual assumption that “physics describes a block world” (e.g., Kastner 2015, 2016, 2019, 2022)[[1]](#footnote-1) or that physics is delimited by 3+1 spacetime. Instead, physics could indeed be describing *the same world that we experience* as involving change and dynamism from the standpoint of a factually persistent (at least for some length of proper time) entity. In other words, at least some aspects of the FOT may in fact be understood as veridical. Thus, I deny that spacetime cosmologies must be taken as incompatible with our everyday experience of change.

The key ingredient in this new picture is integration of the quantum level in an unorthodox (but I argue fruitful) formulation. This formulation contradicts the apparently prevailing view that a physical system (exemplified by a human being) is “a conglomerate of impermanent events.”[[2]](#footnote-2) However, rather than stemming from “a desire not to be ephemeral,” this view of the matter arises simply from taking quantum physics into account in the ontology, such that it is appropriately integrated with the spacetime level, which is taken as emergent. Perhaps a bit ironically, given the authors’ diagnosis above, this approach involves a kind of acknowledgment that what we usually think of “ephemeral” – “mere” possibility – is a very consequential and physically real component of the universe.

Specifically, a key aspect of the proposed treatment is acknowledging that quantum systems are not components of the 3+1 spacetime construct, but rather are precursors to it, as sources of potentiality (see, e.g. Kastner, Kauffman and Epperson, 2018). In this ontology, the quantum level can be thought of as a fundamental substratum for the 3+1 spacetime construct, which emerges from it in a secondary physical process of event actualization.[[3]](#footnote-3) Thus, a quantum system such as hydrogen atom is indeed a persistent entity at the quantum (substratum) level, even as it participates in the creation of spacetime events. All that is required for this insight is that the system itself not be reduced to spacetime events; the events, as *activities* of the system, are distinct from the system itself.[[4]](#footnote-4)

Before elaborating further the alternative ontology allowing for reconciliation of the supposed dichotomy of times, let us briefly review the apparent discrepancy. As the authors note, this has a well-known historical formulation due to McTaggart (1908) , who called the dynamical aspect of time that encompasses change the “*A* series,” while he labeled the contrasting, block world notion of spacetime the “*B* series.”

The first thing to notice (as I have argued in Kastner 2022, Section 8.1.3) is that McTaggart’s “*A* vs. *B*” duality of temporal notions does not get off the ground unless one subscribes to the idea that there really exists a *B* series, or (in weaker terms) that “physics describes a *B* series”.[[5]](#footnote-5) If physics does not really require this static concept, then there is no essential problem. So the important point to notice, before going any further on this topic, is that the choice to accept the idea that ‘physics describes a *B* series’ is wholly optional, however habitual it has become.

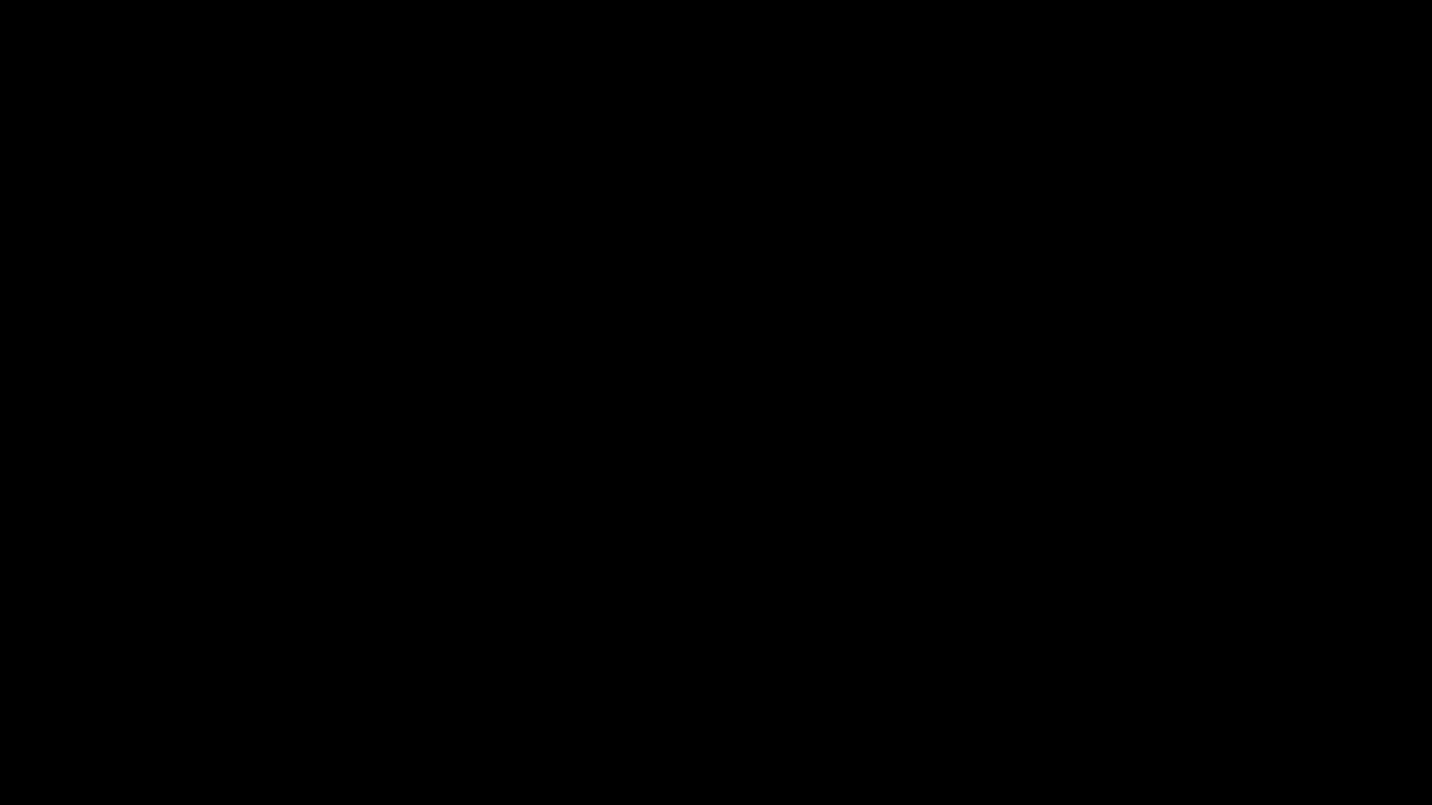
Why does this point seem surprising to us? As I’ve noted (e.g. Kastner 2022, Chapter 8), we are used to drawing a spacetime diagram and populating it with events. We reify the coordinate system as “empty spacetime” and we assume that the events “occupy spacetime.” In other words, we draw a picture of the *B* series. On this representation, the notion of “Now” of course has no meaning, since we could designate any point (or hyperplane) as “Now,” and with respect to that time index, we can point to events that have a larger time index (and are thus in the future direction of that Now). Thus, we draw what looks like a block world (or at least a *B*-series): a set of events that possess only a time ordering with respect to one another. Notions of “past,” “present” and “future” are arbitrary on this reified map. However, it's important to remember that the *B*-series arises as a feature of a particular sort of description or map. It does not automatically follow that the actual territory (the subject of our theory) conforms to this particular sort of map, any more than the ability of an animator to create a movie of a character’s head spinning around in circles means that real heads do this.[[6]](#footnote-6)

Researchers who insist that the *B*-series is obligatory often invoke an argument known as “chronogeometrical fatalism” (CF). In a nutshell, CF depends on arguing that any event outside an observer’s light cone corresponds to an event in the future light cone of some other observer so that the “future” must consist of a set of determinate events.[[7]](#footnote-7) However, I argue in Kastner (2022, §8.1.4) that CF depends on non-obligatory premises: (1) taking a hyperplane of simultaneity as defining “Now” for a particular observer—so that “Now” extends indefinitely into the “elsewhere” region; and (2) viewing spacetime as a substance (“reifying the map” as discussed above; a view known as *spacetime substantivalism*). Einstein himself disagreed with (2), since it leads to other inconsistencies such as the “Hole Problem” (see Norton (2019) for an instructive review). Specifically, Einstein concluded that “There is no such thing as an empty space, i.e., a space without a field. Spacetime does not claim existence on its own, but only as a structural quality of the field.” (Einstein, 1954, p. 155) In this context, “the field” is just a structured set of events, and there is no requirement to assume that this set is static (although Einstein, heavily influenced by Minkowski, did think of it in “block world” terms.) In case this is doubted, Sorkin and collaborators (Sorkin 2003, Bombelli et al, 1987) have provided a specific counterexample in their “causal set” model of spacetime in which the set of events grows in a covariant manner. The bottom line is that CF is not the “knockout blow” that it is generally taken to be for a dynamical ontology of spacetime, nor does covariance require a block world ontology as is habitually assumed.[[8]](#footnote-8)

I have argued (e.g. Kastner 2012, 2016, 2019, 2022) essentially this: that physical theories need not be taken as forcing upon us McTaggart’s *B*-series conception of time. While I cannot hope to fully present the proposed formulation in this brief Note, as alluded to above, it proposes that quantum theory describes a fundamental level of reality that is the source of the emergent spacetime manifold. I have denoted this fundamental level the *quantum substratum* (QS). The QS comprises quantum systems and processes that are not components of 3+1 spacetime.[[9]](#footnote-9) Nevertheless, quantum systems (with nonvanishing rest mass) have basic temporal attributes—essentially “internal clocks” corresponding to fermionic (half-integral) spin. The spin periodicity serves to define proper time and reflects persistence of the quantum system, whose ontological nature is not defined or delimited by any particular spacetime event(s). That is, the continuity of the quantum system obtains in the QS, not “in spacetime.”

The QS can however be seen as a kind of “eternal present” in that it serves as the birthplace of spacetime events. Quantum systems can, under suitable (and well-quantified)[[10]](#footnote-10) conditions, give rise to actualized events, which are the elements of an emergent spacetime construct: thus 3+1 spacetime is supervenient, not fundamental. The events in question are essentially the outcomes of “quantum measurements”; however the term “measurement” has no anthropomorphic content but simply denotes a physically real non-unitary interaction resulting in the transfer of a real (on-shell) photon. Such a transfer establishes a pair of linked, *actualized events*: emission and absorption of the photon, while the photon itself is their invariant connection (a null interval). Thus, even if counterintuitively, what we call “spacetime” is nothing more than a set of events connected by null intervals: in strict ontological terms, there is neither “time” nor “space” (in any invariant sense) in that manifold. Instead, the metrical notions of “time” and “space” are *references* by which we describe the occurrence of those events relative to our own proper time.[[11]](#footnote-11) The latter advances as a process in the QS through its identification with the periodic nature of fermionic spin (which is topologically incommensurable with 3+1 spacetime).[[12]](#footnote-12)

In this picture, the spacetime construct is like the cast-off skin of a snake: events fall away from us as we ourselves persist in the “eternal present” of the QS. We can characterize our persistence by way of our internal clock, which changes its temporal index even as we persist in the present. Another useful metaphor is that we are knitting a garment. While we can number the row that we are knitting at any given moment (i.e., assign a proper time index), we don’t go anywhere “in the garment of spacetime” but remain always outside it as it falls away from our knitting needles. Yet there is clearly change as the raw material out of which events are created (the “yarn”) passes through our fingers. Thus, the present or “Now” does not “move” or “advance”; rather, it changes. This change can indeed by understood as physically real and as described by physical theory, appropriately interpreted. While the full details of this formulation are discussed in Kastner (2022), readers who would like a quick introduction to the picture are invited to view this animation:



1 Animation: "Quantumland and Transactions," also available at https://youtu.be/IrMggF2Ikhw

Given the foregoing, I of course agree with the authors’ comment in their Conclusion that “the experiential past, present, and future[[13]](#footnote-13) are not properties of four dimensional spacetime.” However, that does not mean that they are not veridical or not described by physics: quite the opposite. In the formulation I have developed, these are veridical features of our primary existence (as comprised of quantum systems with nonvanishing rest mass) in the QS (rather than “in spacetime”—the latter, i.e., the STB assumption, being what is illusory).

The conclusion is that physical theory, appropriately interpreted and formulated, fully supports the human experience of the FOT, which has two basic aspects: (1) persistence in terms of a basic quantum-spin clock proper time[[14]](#footnote-14) and (2) participation in the successive actualizations of events (as does any generic atom or molecule). The latter duality could be considered a vestige of the TTP, except that it simply acknowledges two levels to the ontology: one being the continuous (“internal”) proper time applicable to the quantum level, and the other the discrete, metrical aspect of time that consists in labels attributable to actualized events. These labels are defined only relative to persistent quantum systems that participate in their actualization (i.e., neither a time index nor a spatial index is invariant)[[15]](#footnote-15) That is, the spacetime labels do not reflect either “space” or “time” in any fundamental sense but are descriptions relative to the quantum system’s physical dynamics, i.e., processes it undergoes in the quantum substratum.[[16]](#footnote-16)

Thus, according to this formulation, the impression that we “exist in spacetime” is ironically a non-veridical VR-type experience, a feature of a kind of “user interface” that serves the purposes of biological organisms. “Spacetime” (which actually consists neither of space nor time, but simply a structured set of events) is a phenomenal, emergent level that should not be mistaken as the fundamental physical level at which we exist, which is the quantum substratum. The similarities of this picture to ancient knowledge traditions--e.g. the Eastern concept of “Maya” or the shadows on the wall of Plato’s Cave as the phenomenal spacetime level, while the quantum substratum comprises what is “really going on behind the scenes”--may also be noted.

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1. I note that some authors see a discrepancy between 3+1 spacetime and our experience even in a “growing spacetime” model (e.g., that of Ellis 2014, which I briefly discuss in Kastner 2022, Chapter 8). Here I argue however that dropping the fundamentality of spacetime and replacing it with the fundamentality of a quantum level allows us to see that there need be no discrepancy. [↑](#footnote-ref-1)
2. The authors discuss an experiment (Gruber et al., 2020b) in which a subject is wearing a virtual reality apparatus that essentially immerses her in a spacetime map taken as a background against which she can move “back and forth” relative to a time index on the map. They note that the resulting phenomena make it hard for her to track the continuity of a toy dog as portrayed on this 3+1 map. However, the user simply experiences the implications of the model as programmed into the VR apparatus. The ability to illustrate in this manner the model’s implications does not demonstrate that the model in fact describes the world. It should be noted that the experiment does not test (or refute) the experienced continuity of the experimental subject herself. Thus, it remains open to question whether real systems (like people) are in fact reducible to conglomerates of events in a STB. [↑](#footnote-ref-2)
3. The Whiteheadian character of this ontology is discussed in Kastner (2019), Chapter 5. [↑](#footnote-ref-3)
4. The ontology is discussed in some detail in Kastner (2022), Chapter 8. [↑](#footnote-ref-4)
5. Of course, McTaggart asserted his “*B*-series” before modern spacetime theories, which have since been taken as reinforcing it. This underscores the habit of mind that thinks of “the future” as necessarily comprising specific determinate events, which is an optional (even if compelling) metaphysical assumption. In the present author’s formulation, this notion is an illusory component of our thinking that is not supported by empirical experience. [↑](#footnote-ref-5)
6. And here we again recall that the ability to create a VR program modelling what the STB ontology *would* look like or would imply *if* we could “move back and forth in time” does not demonstrate that it is applicable to the real world. [↑](#footnote-ref-6)
7. The CF argument has been colorfully illustrated as “The Andromeda Paradox” by Roger Penrose (1989, pp. 392-3.). I show why this scenario is not obligatory and amounts to mistaking a “spacetime map” for the actual territory in Kastner (2019, §4.7 ). [↑](#footnote-ref-7)
8. I’m dubious that one can truly “unfreeze” the block world ontology, and am unclear on why the authors view (e.g.) Rovelli’s account (2018) as having done so. In that work, he appears to double down on the idea that there is no ontological dynamism (i.e., that physics demands a *B*-series). A review by C. Higgins indicates that she seems to have gotten the same impression: https://www.theguardian.com/books/2018/apr/14/carlo-rovelli-exploding-commonsense-notions-order-of-time-interview [↑](#footnote-ref-8)
9. This interpretation arises straightforwardly from acknowledging that Hilbert space is not commensurable with 3+1 spacetime and that object described by Hilbert space quantities therefore cannot exist in spacetime. In other words, if the Hilbert space states of quantum theory refer to physically real objects, then physical ontology cannot properly be delimited by 3+1 spacetime. [↑](#footnote-ref-9)
10. For details, see Kastner (2022, Chapters 5 and 8; relevant excerpted material is available in preprint form: <https://arxiv.org/abs/2101.00712>, <https://arxiv.org/abs/2103.11245>) and also Kastner and Cramer, (2018), Kastner (2018). [↑](#footnote-ref-10)
11. Thus “inertial frames” are not ontological features of the spacetime manifold but are referential descriptions relative to a quantum system in the QS. The implication is that a “spacetime diagram” drawn with respect to a given inertial frame is a view of actualized events *from beyond spacetime* (but there exist no events in any observer’s “future light cone,” since events are created in the present and fall away from us, or away from any rest-mass system). If there are no actualized events, then there is no view of spacetime--because in that case there *is* no spacetime, just the QS. Einstein likewise noted that “spacetime” should not be identified with any coordinate background but just the invariant set of events themselves, although he described these as “point-coincidences” (Einstein 1916, p. 117). [↑](#footnote-ref-11)
12. This internal spin-clock can be understood in terms of Hestenes’ Zitter model (e.g., Hestenes, 2010). [↑](#footnote-ref-12)
13. I would however deny that anyone ever experiences ‘the future’ in a concrete sensory manner. We experience only in the present and perhaps the immediate past (in the sense that a photon we receive from an emitter was emitted in the past relative to its absorption in the present). [↑](#footnote-ref-13)
14. Of course, living entities are (at least) huge conglomerates of quantum systems and I do not pretend here that it is trivial to assign an appropriate overall proper time to such a complex system, nor do I rule out the relevance of psychological and/or neurological considerations in understanding the ‘internal clock’ of a living being. The point made here is that one can indeed attribute physical reality to the FOT at the quantum level, and that human observers are comprised of quantum systems, such that in principle the same essential FOT applies to us. [↑](#footnote-ref-14)
15. The process of actualization and spacetime emergence can provide a basis for progress in understanding phenomena attributed to “dark matter” and “dark energy”. This idea has been explored in Kastner and Kauffman (2018). [↑](#footnote-ref-15)
16. An example of such a description would be “Clock cycle N is occurring at the actualization of this emission event,” where the cycle has a specific period (e.g. as given by a Zitter frequency; see note 12). [↑](#footnote-ref-16)