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Original Paper

Reply to Silberstein

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I am very grateful to Professor Silberstein for having written such a thoughtful review of my book, Einstein's Unfinished Revolution (EUR).[1] While his review of the book is generally positive, he gives a strong critique of the research program which the book was written to advocate. Overall, his review is fair minded, and couched in an appeal to my open mindedness, which I appreciate and return. But we do disagree on some points, and I will focus on those, without forgetting the many areas of agreement.

Both of us agree that we are realists, so in a sense this is a debate about what it means to be a naive realist in the face of the issues of quantum foundations. It is rather interesting that adherents to realism can disagree so much about what that commitment requires. Perhaps we realists disagree so much because, being realists, there is more at stake.

For this reason I am thrilled that he focuses his detailed critique on the last third of EUR, which is where I present the research program which I call the causal theory of views (CTV). This is a development building on results from four previous programs: the causal set theory, of Rafael Sorkin, Fay Dowker and friends, the *Energetic* causal set (ECS) program Marina Cortes and I developed, relative locality, which we developed with Giovanni Amelino-Camelia, Laurent Freidel, Jurek Kowalski-Glikman, and the real ensemble formulation of quantum theory.

Mostly he presents a fair sketch of that research program, (although I regret that he fails to give credit to the colleagues I've just mentioned.) But not always - he misses a few key results, which lead to his overall appraisal being somewhat off the mark. In each case the argument goes the same way: he sketches an argument that so and so cannot be accomplished—at least within naive realism. I reply that we have been able to do exactly that in the CTV or ECS[2].

I am very happy about one aspect of his review — which is his inclusion of a paper I wrote a year or so after its publication on quantum physics and qualia[3]. His justification for this is that the arguments of that article do seem to begin exactly where EUR ends. That is certainly perceptive, because the first draft of that essay was originally meant to be the epilogue of EUR. It was dropped late in the process,

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[1] See M. Silberstein (2020). Review of Lee Smolin's "Einstein's Unfinished Revolution", *International Journal of Quantum Foundations* 6, 133-159. https://ijqf.org/archives/6088

[2] The relevant papers are listed in the bibliography cited in the book on pages 245-5. They can also be found on the website http://leesmolin.com/einsteins-unfinished-revolution/related-scientific-papers/

[3] Lee Smolin. The place of qualia in a relational universe, Philarchiv, Jan, 2020.

and another slipped into place, because both the editor and I felt it could use more thought. And indeed I think the essay did benefit from delay. At the same time, scientific study of how a brain gives rise to a mind is in its early stages, and I am happy if I have introduced a few new ideas and hypotheses. It is enough to find a viewpoint on physics that suggests new questions to ask about Chalmers's hard problem, which i think the CTV has done, but in my view very premature to claim to solve it.

While I am glad he put the work in to, as it were, put the book back together, I am disappointed that he does not appear to have given weight to the scientific papers whose results the last part of EUR presents. He does not cite them, and his apparent unfamiliarity with these results greatly weakens his evaluation of the claims so far of ECS and CTV.

A few examples make the point:

His review is organized usefully around a list of talking points, such as ***"Q3: How plausible is it that Smolin can recover spacetime or matter from his fundamental pre-geometric theory (p 20-21)?"***

Professor Silberstein doesn't say — but perhaps doesn't need to, that his arguments apply against a wide range of quantum gravity theories including spin foam models, causal set theories, dynamical triangulations, causal triangulations, Regge calculus, etc. So the stakes are rather high.

He argues that this is impossible in a discrete theory of the kind we study, but the fact is that Marina Cortes and I showed spacetime and matter are recovered as emergent from certain models of Energetic Causal Sets. The series of 4 papers Dr. Cortes and I published between 2013 and 2017 demonstrate this result for the general ECS case, where it is highly contingent, because the result depends on a number of consistency conditions on the existence of global solutions to a large number of local conservation law (ie space emerges given some initial conditions, but not others). We also showed there are always solutions in a class of 1+1 dimensional models, which result in the emergence of 1+1 Minkowski spacetime. Dr. Cortes studied numerically many such solutions, uncovered several interesting properties of them.

It is perhaps worth mentioning that the mechanism we discover for the emergence of space is not generally transferable to arbitrary discrete theories of quantum gravity

A related issue is his disapproval of what we choose to postulate is fundamental: time in the sense of causation, momentum and energy, but not space. Indeed, the main theme of his review is a series of arguments against the proposal that space is or could be emergent from an underlying pre-geometric theory of dynamically evolving causal relations. Since a number of different approaches to quantum gravity aim to accomplish this, I would think that both Professor Silberstein's general arguments against that idea, and our discovery of one way to do go around them will be of wide interest. Indeed, both his negative arguments, and our positive demonstrations rest on the same issue: to the extent to which Leibniz's principles of the PII and MID (multiplicity IFF discernibility.)

Like some others, Prof. Silberstein finds it difficult to conceive of momentum and energy in a world without space.

"Does it even make sense for momentum and energy to be fundamental but not space or time as a parameter?(p 22)

The answer to that question is because they have different views, ie their past causal sets are different. Which is how contrary to Silberstein's assertion, the principles of Liebniz (PII and MID) are satisfied.

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"This would be a violation of a version of Leibniz's law: multiplicity IFF discernibility (MID). There cannot be multiple events without spatiality. This just seems like a matter of logic(p 22)."

One of the most important innovations of the ECS and RE theories is that they give a direct answer to Silberstein's query. The dynamics forces the views of all the different events to be each unique, and hence distinguishable from the others. Multiplicity IFF Discernibility or, in other words, the Principle of the Identity of the Indiscernible, is a consequence of the dynamics of the CTV.

Cortes and I constructed a large class of models in which there is a set of events, linked by causal relations, where those causal relations transfer energy amongst the event; i.e. as the events form, they are endowed with certain amounts of energy-momentum from their predecessors, subject to conservation laws.

When the consistency conditions and conservation laws are all consistently satisfied, the conservation laws then generate emergent space. How do they do this? It can be said that the consistency conditions weave together little proto - regions of space, each with one or two points, into global pieces of Minkowski spacetime.

Where do these little pieces of proto - space come from? The trick is that there is a space input from the beginning, which is momentum space. When you solve the equations of motion you find a correspondence between pairs of points in the dual space to this momentum space and null or timeline lines in the dual momentum space. The consistency conditions weave these all together into a common Minkowski space.

But isn't this backwards? Isn't it the case that Noether's theorem guarantees that when space has symmetries, then momentum, defined prior in terms of space, will be conserved? So what we have done is to discover a kind of inverse of that theorem. This is just what is needed to build a model in which space is emergent contingently from a world without it.

Let me emphasize that the models we are studying are not devoid of structure. There is a space of possible energy and momentum of incoming photons and other quanta and we require a metric to measure how diverse are a pair of views. Then the view is a map from all or part of an S^2 to that space. These are the kinematic structures out of which we build dynamics.

Q2. ***Does Smolin's fundamental theory explain the key phenomenal features of time in keeping with na ïve realism(pages 17 - 19)?***

Professor Silberstein uses LQG-an older theory that I had helped invent in several of his arguments. Unfortunately he seems to take the view that there is a single theory called LQG. Instead I think we have to characterize LQG as a research program (in Lakatos's sense) consisting of many branches which have grown out of a common set of mostly kinematical results.

By now there are several different ways to formulate a dynamical theory that uses the core kinematical results of LQG, which have diverse implications for the nature of time. One may fix a gauge in such a way that a scalar field becomes a clock variable. There is a corresponding Hamiltonian, which develops the states of quantum geometry in that clock variable. That is an old idea, but as Rovelli and I were able to show, it works out also for LQG. Despite some technical challenges other people continue to work on it.

Since the mid 90's, many have been working on path integral approaches to LQG. One natural thing to do, which was first proposed and developed by Fotini Markopoulou[], to combine the kinematics of LQG with the causal set dynamics. Her idea was that the events in the causal set would be drawn from

a small set of moves that change the local structure of the triangulation that defines the spatial quantum geometry.

I have been studying an elaboration of Markopoulou's work in which the causal set of local moves become the events and views of a CTV. It combines the successes of LQG with the possibility that the CTV brings of representing a moving, dynamic present, with an open, non-determined future. (There is also a paper explaining how to construct a spin foam model from an energetic causal set model.)

It is then a bit hard to understand why Silberstein criticizes ECS and CTV as not having a structure that could represent the present moment. As I have explained, there is such a structure and it is described in detail in the energetic causal set papers. We define the (thick) present as events that have not had all their children yet. Being a progenitor of future events is the only way an event contributes to the future, as long as it may still do so it remains part of the present, becoming past only once it can no longer contribute so.

Very recently Clelia Verde and I have formulated a more radical and parsimonious interpretation of these CTV models in which neither the future nor the past exist. We are concerned that the distinctions between past, present and future are in danger of being incoherent given that two of these categories don't actually exist. We propose that the whole world is based on a single distinction — between definite and indefinite, nothing exists or persists, and all that happens is transitions of indefinite to definite circumstances - these are events - that is moments of becoming.

A research program that is able to inspire such radical change in our conception of the world, deserves a better understanding than it has gotten here.

But there is more to say about passage and presence.

Upon reflection, spacetime emergence seems to make the hard problem even harder. For how does conscious experience, which is so intimately tied to our perception of time and space, arise from timeless, non-spatial ingredients?

One other way to respond is to mention that there are geometric spaces built into the formulation of CTV, which are always there-even when no "space" in the ordinary sense has emerged. These are the energy-momentum space and also the two-spheres, on which the views are displayed, as it were.

"What about Presence? Again, there is nothing like Presence or Nowness in Smolin's fundamental theory."

I should say right away that I nowhere claim to have *explained presence* or *nowness* or the *everyday experience of passage.* That would be to solve Chalmer's hard problem. But we can aim to make a different kind of mathematical model in which time, which is to say causation and change, is not erased by positing an equivalence between causation and logical necessity — as happens when a solution to a deterministic differential equation is presented as a mirror of reality, so that everything that is true in nature corresponds to a true theorem about that static mathematical object.

Indeed, exactly for this reason, Roberto Mangabiera Unger and I argue that there can be no mathematical object that is such a good mirror of nature — because any fact about a mathematical object replaces causation with timeless mathematical deduction. To put it the other way, there are at least two true facts about the real world that cannot be mirrored in any mathematical object, and that is presence and passage.

Another way to see this is that no event based ontology can be both deterministic and satisfy the PII. Consider two events that have exactly the same views, i.e. their causal pasts are identical. Then

determinism requires that their causal futures must also be identical; but the PII requires that their causal futures are different.

That is, the PII, by requiring that the same initial conditions (that is the same causal pasts — or views) — lead to different outcomes, makes it impossible that there is a mathematical object, which is fully specified logically, that is a complete mirror of the universe.

This implies that we must expect surprises in the time evolution of the universe, i.e. events whose future implications are unprecedented and are not consequences of their causal pasts.

These are certainly theories that resist reformulation as a block universe. There may be causation but there cannot be determinism.

This really is a theory that is in some respects mathematical that has very different implications for the nature of time than theories that admit a block universe description.

So I have to disagree strongly with Silberstein when he says:

There is nothing like a spotlight or some other metaphysical mechanism or pointer that yields Presence, i.e., no mechanism that tells us which event are really NOW such that we experience them as special. … Smolin does invoke a global preferred frame but it isn't clear how or why that emerges from his fundamental theory or how it would explain Presence even it exists.

First, this is asking for too much, as I said, to explain presence and passages and thus solve the hard problem. But lets weaken the demand a bit.

> There is nothing like a spotlight or some other metaphysical mechanism or pointer *that allows for the possibility* of Presence, i.e., a mechanism that tells us which events are distinguished in exactly such a way that they could be NOW because we experience them as special.

I claim that this is exactly what the CTV does.

He ends this section of the review with:

> *Smolin does invoke a global preferred frame but it isn't clear how or why that emerges from his fundamental theory or how it would explain Presence even it exists.*

This is a key issue that is also addressed in the papers and discussed at length in the two time books[4]. Briefly - if space is emergent then there is by definition a preferred notion of time in the system at the level where space has yet to emerge so any two subsystems may interact.

That gives us a good sequel to the most potentially consequential of the issues on which we disagree - which is what we realists aspire to do with quantum physics.

The core idea of the book is that quantum mechanics requires a completion which is a realistic theory of beables that gives a complete description of individual events. That description, I believe, must be both non-local and contextual - for a simple reason which is that the most natural formulations of locality and contextually have been falsified experimentally.

[4] L. Smolin, Time Reborn, Roberto Mangabeira Unger and L Smolin, The singular universe and the reality of time. (Cambridge University Press)

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"Recall that Smolin thinks QM is false or incomplete and thus, like Einstein, he seeks hidden variables to complete it. The whole point of hidden variables is to get around KS (contextuality) and/or Bell's theorem (non-locality). And yet, this is what Smolin says, "The conclusion is that nature is contextual. This is the case with quantum mechanics, and experiments have been done which confirm this prediction of the theory. So, it must be true in any deeper theory which will replace quantum mechanics" (p. 56,

Now comes the key point of the disagreement:

… his own account has beables that are radically contextual, he calls them "relational hidden variables." Indeed, his hidden variables are also non-local. This seems like a violation of Smolin's own brand of realism and one wonders what is the point of hidden variables at all if they are contextual and non-local, i.e., if they don't skirt KS or Bell? And one wonders, how contextual can a "hidden variable" be and still be hidden, and still keep with Smolin's brand of realism? "

But such realistic, but non-local completions of quantum mechanics have existed for almost a century. De Broglie-Bohm is the best studied example. Another is Edward Nelson's stochastic quantum theory. There are a few others. Steve Adler has published several books on his version of non-local hidden variables theories in which he gives deterministic dynamics to the matrix elements in the Heisenberg picture. Artem Stardupstov does something very similar I have been inventing and studying non-local hidden variables theories since the early 1980's. None of these do everything I would like such a theory to do-but they are enough to show that the concept works, i.e. leads to theories that reproduce QM in a certain limit.

I believe that the actual completion of QM will convince us because it will solve other problems. For example, quantum gravity.

I hypothesize that the home world, so to speak, of the completion of QM is exactly the fundamental theory I propose as the completion of general relativity. There are not two emergences of space - one linked with completing quantum theory and the other which completes general relativity. The one emergence of space comes from a theory which will be the simultaneous completion of general relativity and the quantum world.

Silberstein seems to have trouble with the concept of non-local and relational (and hence contextual) hidden variables.

The aim of science is to give the most complete description of nature as possible. Any move in this direction is good from a realist perspective. Quantum mechanics doesn't do this, hence the need for a completion. Wherever this road leads is where we want to go.

Finally he complains that beables in a realistic theory should look like the furniture, ie the common ordinary things. Whereas my beables look like images of the furniture around us.

Which brings me finally to his critique of my paper on qualia. I'll be very brief. This is a very, very difficult question. And there is a lot to say about a whole range of options across the spectrum of philosophical ideas. So the first thing I have to say is that I wholeheartedly accept his invitation to further dialogue, in which I have much to learn. I hope others in quantum gravity will join us as a lot more is at stake than my person program. More generally, he offers five pieces of advice for us quantum gravity seekers, and I think the most useful thing would be to fold those into such a broader dialogue, rather than my trying to deal with them here.

Let me emphasize that although I believe the body-mind problem is a scientific question, I won't be surprised if the solution requires knowledge of the science of the brain that remains in the future. Against strong odds, I offer four ideas: First, some of the views are also the qualia. Two this can

only be those views that are unprecedented, (which I have argued in the books and papers must exist.) So no laws are broken. Third, energy is related to the colors we perceive. Moreover, only the CTV allows the possibility of all three being true.

Fourth, we have already proposed that the be-ables are the views. This means that the qualia are all be-ables. Not another side of, nor an aspect of them.

be-ables = unprecedented views = qualia.

But what I see when I open my eyes is exactly what we expect a view should look like: a sphere with a fast moving display of colors. The view you see when you open your eyes is not a perception of the word: it is a part of the world.

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