Towards an AB-series interpretation of time in physics

Abstract How can McTaggart's A-series notion of time be incorporated into physics while retaining the B-series notion? It may be the A-series 'now' can be construed as ontologically private. How is that modeled? Could a definition of a combined AB-series entropy help with the Past Hypothesis problem? What if the increase in entropy as a system goes from earlier times to later times is canceled by the decrease in entropy as a system goes from future, to present, to past?

1. Famously, McTaggart (1908) identified two different notions of time. They are the A-series and the B-series. The B-series is a series of times ordered by the relation of 'earlier-than' (or 'later-than'). For example $t_1 < t_2$ means time t_1 is earlier than time t_2. Obviously, the B-series is usually thought of as going from earlier times to later times. It could be argued the B-series is the notion of time that's most often used in physics. For example, both coordinate time and proper time are B-series. And the time parameter of the Schrodinger equation is a B-series. The B-series relations do not change. Also, going 'backward in time' in the B-series just means going to earlier times.

The A-series is also a part of a comprehensive view of time. Suppose my current watch time is t = 2:19 pm. In the A-series it's recognized that a time (or event or structure at a time), say t = 4:19 pm, is first in my future, then in my present (what I'll call *now*), and then in my past. In contrast to the B-series, the A-series values change. Also in contrast to the B-series, going 'backward in time' in the A-series is undefined, on this view.

So in a sense the B-series goes from past to future, and the A-series goes from future to past. It's a Zen observation that "Time constantly goes from past to present and from present to future. This is true, but it is also true that time goes from future to present and from present to past." (Suzuki 1986), p. 33. Assuming this isn't just a conjunction of opposites, the former is a B-series (interpreted as 'earlier to later') and the latter is an A-series.

This note is an attempt to speculate over why the A-series is needed and how it might be introduced to physics, while of course retaining the B-series. The idea here is related to Tense Realism, Perspectival Realism, and Fragmentalism, (Hare 2010), (Fine 2005). Many observations in this note are not new. The idea will be to add to each system a 'now' (of the A-series) that is ontologically 'private' to it, to the ontologically 'public' B-series interrelations already in use in physics. If successful it would have implications, for example for the definition of entropy.

2. Ontological privacy An ontologically private parameter is one that takes on a definite value when a system specifies its own ontic state, but doesn't take on a definite value when a different system specifies the ontic state. This could be because, for the other system, 1. there is no such parameter, 2. there is a parameter but is doesn't have a definite value, 3. there is a parameter and it has a definite value but it's not known which one, for some reason.

3. Panpsychism I am conscious, and this is certain to a degree even greater than the certainty that there are physical laws. There is in some sense nothing special about my composition—I'm made of electrons and quarks etc. Thus there is good reason to think that the basic elements that make up my brain are accompanied by the basic elements of subjective experience—qualia. One is lead to the hypothesis that an electron is accompanied by a quale—a subjective experience—for example, the color green. Perhaps a muon is accompanied by a blue quale. There has been a highly non-trivial amount written about this and the surrounding ideas but the basic idea is clear enough and is called (dualist) Panpsychism. (Stanford 2017)

A quale may be construed as an ontologically private thing [refs.] For example, I may experience what I know as 'green' when I look at the leaves of a tree. But I cannot know that you experience the same quale (i.e. what I would call green) when you look at the same leaves. This banal observation shows my quale has a definite value for me, but your quale does not have a definite value for me. And vice versa. One could also consider the case where your quale does not even have a parameter for me.

Some notion of 'temporal becoming' is often supposed to be a feature of the A-series view. Temporal becoming, for the purposes of this note, is that flow by which a local clock time is first future, then *now*, and then past. Temporal becoming is often understood phenomenally. (Loury 2016). If panpsychism is true and temporal becoming is phenomenal then arguably every system experiences temporal becoming.

4. Times It might be argued that complete description of a system in time must incorporate both series. The B-series is what physicists normally use: all systems agree that a time of 1 sec. on a watch comes before a time of 2 sec. on that watch, etc. General relativity preserves the order of events on a time-like worldline. The idea will be to incorporate the A-series as a different ineffable variable *now* for each system.

5. Simultaneity Alice orbits the earth and Bob is in the Andromeda galaxy. For some configurations, the planes of simultaneity of Alice change so that Bob is in Alice's B-series later than, present, earlier than, present, later than, etc...

"But (bringing the subject into the story) my *now* advances along my trajectory at one second of my personal experience for each second that passes on my watch, which follows the same trajectory as I do. And your *now* advances along your trajectory at one second of your personal experience for each second that passes on your watch, which follows the same trajectory as you do." Mermin, (2018), p. 33. We might be able to say Alice's *now* advances along her worldline in an ontologically private way at a rate of one second of personal experience for each second that passes on her watch. Also, Bob's *now* advances along his worldline in an ontologically private way at a rate of one second of personal experience for each second that passes on his watch. But, for Bob, it is not true that his *now* varies back and forth through his clock times (with these planes of simultaneity), for example for local time t, through $t = 15$, $t = 10$, $t = 5$, $t = 10$, $t = 15$, as Alice would have it.

The *now* is an empirical feature. Alice and Bob may agree on the order of all of their watch's ticks along each person's worldline—this is the B-series information. This information is effable. Yet Alice and Bob, in this view, may experience their own senses of *now*—this is the A-series information.

6. Double slit Suppose that in laboratory time, an electron is fired from a gun at $t = 0$ seconds and lands on the screen at laboratory time $t = 10$, at which time the experimenter in the laboratory checks the screen to see where the electron has landed. It's obvious that from $t = 0$ through $t = 10$ the experimenter experienced a *now*, I'll call now_L, that informed him of the watch-time at which he was actually existing.

For the experimenter, the electron also went from watch-time $t = 0$ to $t = 10$ (assuming non-relativistic speeds). But for the experimenter, there is no value for the the electron's variable now_e indicating when in the electron's A-series these events are. So for some laboratory clock time, say, $t = 8$, now_e may have been, for example, at laboratory watch-time $t = 2$ or watch-time $t = 5$... now_e does not have to be at the same watch-time as now_L. Nevertheless, for the electron now_e is a parameter with a definite value—a watch-time that classifies the relevant events as future, now_e, or past.

7. Path integrals In the path integral formulation one has for the transition kernel K

$$K(x_f, T; x_i, 0) = \int_0^T [Dx(t)] \exp[\frac{i}{\hbar} S(\int_0^{T'} L dt')]$$

Here are two different coordinates of time. There is the laboratory time going from 0 to T, and there is the time t' in the time-integral of the Lagrangian in the action S. This latter time is a B-series. The laboratory time is at least a B-series.

8. Ontological Models To prove the PBR theorem (roughly, that quantum mechanics is psi-ontic) it's assumed that "the ontic state space of a composite system should be a Cartesian product of the ontic state spaces of the subsystems", (Leifer 2014) p. 104. How does one generalize to the ontic state space of two subsystems each with ineffable parameters?

For example suppose, for simplicity, Bob may parameterize Alice's ontic state space with the effable time variable $0 \leq t \leq 10 = O_A$ (informal notation), with only one state per clock time t. But according to Alice, her ontic state space is also parameterized by an ontologically private time now_A together with the states parameterized by t. The now_A take on each t value at some point, in this line of argument, so she gives her ontic state space as (isomorphic to) the Cartesian product of O_A with O_A. Similarly for Bob. It might then be that the ontic state space of the Alice-Bob composite system is the Cartesian product of O_A with O_A with O_B with O_B. But that can't be right because *ipso facto* it puts all four ontologies on an equal (public) footing.

9. Two-dimensionalism

The two-dimensional intension is a function f: $W_A \rightarrow (W_C \rightarrow E)$, from actual worlds to counterfactual worlds to (counterfactual) extensions. (Nimtz 2008), (Chalmers 2002). Where do things stand with respect to McTaggart's A-series, B-series, and the combined AB-series?

The A-series, for the purposes of this paper, has two parts: (1) temporal becoming, (2) presentism.

As for (1), if temporal becoming is phenomenal (in the way qualia are), then temporal becoming is a good candidate for being a 'phenomenal concept' in the sense of (Chalmers 2009). In that case W_A is the experience of a rate of 1 second of experiential time per second of local clock time. W_C are the counterfactual worlds where the rate of experiential time to local clock time takes on a different value. For example if that rate is 2, then it would take half as much local clock time to have an experience. If temporal becoming isn't phenomenal I don't know.

As for (2), W_A is *now* I will consider other times that it could have been. For example if it is 4:19 in the afternoon *now*, I'll consider other (counterfactual) times it could have been. For example 4:21 or 4:17. These counterfactual worlds allow W_C to be a function to the set (future worlds, present, past worlds). E is the counterfactual 'actual' time in that world.

W_A of the A-series is the conjunction of W_A of (1) with W_A of (2). W_C is, apparently, the counterfactual worlds in which temporal becoming happens at a rate other than 1 or the current time is not *now*.

As for the B-series, W_A is the entire network of before-after relations among events. W_C are the networks that could have been. I don't know what E is.

The AB-series. W_A = conjunction of the W_A of the A-series and the W_A of the B-series. The W_C are, apparently, those counterfactual worlds where time is characterized by the AB-series, but differ in some way. I don't know how by many parameters these counterfactual worlds differ. I don't know what E is again.

10. Arguably a physical quantity at a counterfactual time is itself counterfactual in AB theory. If so, the action S that occurs in the transition kernel *K* (above) is counterfactual, with the possible exception of when $t' = t$.

It would seem an ontic state in the OM framework can only be an actual world. Worlds which are counterfactual are not candidates for being ontic states in the OM framework in that case. Yet one may posit there is a 'degree of being actual' d in [0, 1], (Smith 2010). The degree of the corresponding counterfactual is d' = 1 – d.

One may take various derivatives. The derivative *d*(d)/*d*(d') equals -1. We also have that the derivative *d*(laboratory A-series now_L)/*d*(laboratory B-series *t*) = 1 in some units, and *d*(electron A-series now_e)/*d*(electron B-series *t*) = 1 in some units. The degree d'' of the action S defined above would be some function of the degree d' of the electron's B-series times *t*. The energy T in the Lagrangian L in the action has units of $kg^1 \bullet m^2 \bullet s^{-2}$. So the electron B-series time appears in the denominator, squared. So it might be that d'' = d' or that d'' = d'^2. There is no derivative $d(now_L)/d(now_e)$, on this view, because both parameters are ontologically private (and not of the same system).

A function of a public parameter is public. A function of a private parameter is private to that system. A function of two public parameters is public. A function of a public and a private parameter is private to that system. There are no functions of private parameters of two different systems.

Time-reversal invariance obtains only for a B-series.

The Past Hypothesis involves the idea that the early universe had low entropy. That's a problem because there are dramatically more states of higher entropy than states of lower entropy. *Ceteris paribus* one expects the initial state of the universe to have had high entropy. Happily, this calculation involves only a B-series. B-series entropy increases as one goes from earlier times to later times. If one adds A-series information, perhaps in the form of ontologically private parameters, maybe the problem goes away. For example what's the decrease in A-series entropy, per some unit, as the state of a system goes from future to *now* to past? Does this value depend on whether the future is branching? Does it cancel the B-series entropy?

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