Hybrid Time Physics draft

A- and B-series information

In 1908 McTaggart defined the A-series {past, present, future}, and the B-series {earlier, simultaneous, later}. [1]

A typical timeline will tell us that the state s of a system S at a time $b = 1$ second (I'll sometimes just write $b = 1$), comes before the state of S at $b = 2$, which in turn comes before the state of S at $b = 3$. Minkowski spacetime is much more complicated but the same order-relation idea applies. In this way the states of S are a function of a B-series of times b, given by $s = s(b)$. But this leaves out the information of whether S at, say, $b = 2$, is past, present, or future. S is indeed one of these. But that is A-series information (whose value I'll denote by a). Thus, without conceptual contortions, I claim, the complete temporal specification of the state of a system requires both kinds of information, $s = s(a, b)$. In this case they are not inter-reducible and both are needed for the complete temporal specification of a system. In view of hybrid temporal logics, one may say the state of S is a function of 'hybrid time'.

1 second per second

Here is an application of adopting hybrid time. A common puzzle is whether the locution “1 second per second” makes sense. The interpretation need not be torturous. One may define the 'rate of flow of time' or 'rate of temporal becoming' in terms of B-seconds per A-second. This is the change in B-series information per change in A-series information.

It's *also* possible to compare the B-series time of a (perhaps moving) frame with the B-series time of a reference frame—that's exactly what special relativity does. But that's not what we're talking about in the previous paragraph.

It may in addition be possible to compare the B-series change of a moving frame with the A-series change of a reference frame. This would be non-trivial, as the reverse is dubious.

Special Relativity

Physicists are skeptical of A-series information as described above, not least because of special relativity. However, I claim, relativity doesn't contradict A-series information. Consider an experiment leading to special relativity. Let's suppose I walk over to the experimental-physicist-on-the-street. He claims that special relativity implies the block universe (for the purposes of this note I will suppose the block universe is equivalent to the assertion that the universe is completely defined with B-series information only). I ask him to show me an experiment that shows this conclusively. He performs, say, the Michelson-Morley experiment in front of me. At some moment m he gets the datum that the speed of light is c, which, however, he can only get and show me in a present moment, for which a = present.

At another present moment m', (and in general for a different inertial frame), he demonstrates the datum that the speed of light is c'. However, he can only demonstrate to me the value c' in a present moment, for which a' = present. Then he notes that (in general) $c' = c$ and, through an ingenious chain of arguments, draws us to the conclusion of the relativity of simultaneity.

Has he demonstrated that A-series information is ruled out? No, he's done nothing of the sort. The performance of the experiment itself cannot avoid the A-series information. The relativity of simultaneity is seen to be strictly B-series information, as 'simultaneous with' means one is comparing the temporal order of two events (or states).

Thus we argue from experimental *data* rather than from a *theory* that has already under-interpreted the temporal aspect of those data... With general relativity the situation is the same, only that the experimentalist adds to his repertoire demonstrations involving, say, two test-balls in an elevator. Indeed this form of argument would seem to be extremely general with respect to the methodology of science.

Physics in Hybrid Time

Having thus established that the state of a system requires for its complete definition both A-series and B-series information ;-), what does physics look like in this hybrid time? A state is given by s = s(*a*, *b*) where *a* is an A-series value and *b* is a B-series value. The A-series values are from at least the set {past, present, future}. For a simple example suppose the B-series values are chosen from the ordered set {1 sec., 2 sec., 3 sec.}[1]. We want S to 'evolve in time' with respect to the A-series information from future to past (S is first future, then present, and then past). We also want S to 'evolve in time' with respect to the B-series information from 1 to 3 (seconds). So we want to start at s = s(future, 1) and end at s = s(past, 3). There are 6 ways to do this, monotonically changing by 1 successive value either the A information or else the B information, for each successive state. For two examples take

(1) s(future, 1) → s(present, 1)→ s(present, 2)→ s(present, 3)→ s(past, 3)

and

(2) s(future, 1) → s(future, 2)→ s(present, 2)→ s(past, 2)→ s(past, 3)

In the first evolution, the system S is given a value s at *b* = 1 sec., but S obtains this value in the future. Then, s takes on a value at *b* = 1 sec. but S has flowed into the present. Etc. In the second evolution, the system S is given a value s at *b* = 1 sec., and S obtains this value in the future. Then s takes on a value at *b* = 2 sec., but S is still in the future. Etc. One may construct functions like s(*a*,*b*) = {*b*^2+1 for *a* = future, *b*^2 for *a* = present, and *b*^2-1 for *a* = past}.

Evidently if *b* has *n* possible values there are $n(n+1)/2$ of these kind of evolutions to the final state. Of course in general the number of evolutions will depend on the particular hybrid logic used.

Suppose that s represents the position *x*. What is the definition of the momentum *p*? For classical S what's the evolution of S in phase space? The hybrid notion of 'phase space' is evidently more complicated than the notion defined with only B values of time. At a minimum there should a derivative with respective to B-time *and* a derivative with respect to A-time.

Reconciling Bach's Coffee Cantata with actual milk [2]

It may be objected that A-series information doesn't add information to the structure or behavior of a system. That's true (in a sense), but it adds information to the description of the total reality of the system. The situation, I contend, is the same with (ontological) qualia. On the canonical reading, qualia don't add to the structure or behavior of a (physical) brain, but here they are. 3rd -person information

1 That is, a 1st second, a 2nd second, and a 3rd second, as opposed to durations of 1, 2, and 3 seconds.

does not suffice to derive in any way the 1st -person information of qualia. A *theory* of qualia will not do. Similarly, B-series information is independent of the question of whether a state is actualized (a = present), so does not suffice to derive in any way A-series information. The actual milk is like the A-series and the Cantata is like the B-series.

A- and B-series Wigner's Friend

Here is the Wigner's friend experiment in obvious notation for the cat c, friend f, and Wigner w. The initial state at $b = 0$ minutes of the cat-and-friend system is

(1) $|\Psi_{initial}\rangle_f \left(|1\rangle_c + |0\rangle_c\right)$

At time $b = 10$ minutes the friend opens the box and state (1) evolves as

(2) $|\Psi_{initial}\rangle_f \left(|1\rangle_c + |0\rangle_c\right) \rightarrow \{|happy\rangle_f |1\rangle_c,\ |sad\rangle_f |0\rangle_c\}$

At time $b = 15$ the cat-and-friend system is in either definite end state in (2), but Wigner has not entered the laboratory yet. So the description of the cat-and-friend system from Wigner's point of view is the superposition

(3) $|\Psi\rangle_{cf} = \left(|happy\rangle_f |1\rangle_c + |sad\rangle_f |0\rangle_c\right)$

The paradox is that the state in (3) is not the same state as the definite end state(s) in (2). Suppose at time $b = 20$ Wigner enters the laboratory. Then state (3) evolves as

(4) $|\Psi_{initial}\rangle_w \left(|happy\rangle_f |1\rangle_c + |sad\rangle_f |0\rangle_c\right) \rightarrow \{|joyful\rangle_w |happy\rangle_f |1\rangle_c,\ |woeful\rangle_w |sad\rangle_f |0\rangle_c\}$

Happily, hybrid time provides a solution. The idea is that the definite outcomes in (2) at $b = 15$ are at the time (a, b) = (present, 15) for the friend. However, those outcomes are at the time (a, b) = (future, 15) for Wigner. They are in the friend's present, but in Wigner's future. They *must* be in Wigner's future because (at $b = 15$) Wigner is not *presently* interacting with the laboratory in any way, by assumption. (Nevertheless their B-series times, $b = 15$ minutes, will coincide---unless there is relative motion...)

Apparently, if the above solution works, 1. possible 'future' outcomes may 'presently' be in a superposition. 2. the A-series information must be witnessed by (or 'anchored to') a definite system. 3. two systems may interact (presently exchange information) only if both of their A-values are 'present'. 4. hybrid time is not 2-dimensional time: the possible A values together with the possible B values are not given by their Cartesian product.

Finally, in view of the mysterious complex amplitudes of quantum mechanics and the curious relativistic metric, one wonders if the rate of temporal becoming in terms of B-series information per A-series information is not simply “1 B-second per A-second” but something like i B-seconds per A-second.

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References

[1] McTaggart, 1908, "The unreality of time", https://philpapers.org/rec/MCTTUO

[2] Dolev, 2017, "Time, Experience and Quantum Gravity", Quantum Gravity: Physics and Philosophy, 43:42, https://www.youtube.com/watch?v=3MiwJlIXw1Y