We present a proposal for reconciling a hybrid theory of time that combines the A-series and B-series with special relativity. The idea is that B-series positions are related to each other and contain the information of relativity. A-series features are related to actual (quantum) systems. Being tied to actual systems avoids the problems of A-series features being tied to spacetime points or hypothetical frames of reference. This interpretation might be called hybrid-fragmentalist: I'll just call it hybrid time.

A- and B-series information

In 1908 McTaggart defined the A-series {past, present, future}, and the B-series {earlier, simultaneous, later} [McTaggart, 1908] A-series information, for the purposes of this note, includes the information of an ontologically privileged 'now' or present, and genuine temporal becoming.

There has been a struggle to reconcile the A-series features of our world with special relativity. This is primarily because relativity tells us that simultaneity is relative to one's frame of reference. Fine suggested it would be possible to accommodate these facts if reality is fragmented. “Fragmentalism “is the view that reality is not “of a piece”, but rather fragmented into different parts that cannot be joined together without contradiction: “ . . . no two [fragments] can be regarded as belonging to a single coherent whole”” [Fine 2005, p. 262].

Two recent objections to this view are

1. “Attributing a privileged present moment to each frame of reference is to take frames of reference too seriously. A frame of reference is a coordinate system. Minkowski spacetime can be coordinatised in many distinct ways. But these coordinate systems are not really a part of reality.” [Baron 2017]

2. “We will argue ... that the fragmentalist interpretation of special relativity is problematic, since it is at odds with the best explanation of why various relations (notably the Lorentz transformations) hold between inertial frames.” [Hofweber and Lange 2016, p. 873]

Both of these objections are met by the idea that fragments are tied to actual physical systems, and not hypothetical frames of reference, in the following way. A complete temporal specification of an event e is given by 1. A-series information tied to an actual (quantum) system S, and 2. B-series information of where the event is in the B-series structural relations. The two series are not inter-reducible, so both kinds of information are required: e = e(aS, b, x) , where aS is the A-series value relative to system S, b is the B-series value, and x is the spatial coordinate. This idea accords well with the indexical nature of A-series information. Further, this would explain why, 110 years after McTaggart's definitions, a consensus has not been reached as to which series is more fundamental.

1 second per second

Note a common puzzle in the philosophy of time is whether the locution “1 second per second” makes sense. In hybrid time one may define the '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, and these have different dimensions. It's also possible to compare the B-series times of a moving frame with the B-series times of a reference frame—that's what the Lorentz transformations do.

It is illustrative to consider Wigner's Friend. I will return to relativity below.
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

\[
|\psi_{\text{initial}}\rangle_f = |1\rangle_c + |0\rangle_c
\]

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

\[
|\psi\rangle_f |1\rangle_c + |0\rangle_c \rightarrow \{ |\text{happy}\rangle_f |1\rangle_c, |\text{sad}\rangle_f |0\rangle_c\}
\]

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

\[
|\psi\rangle_{fc} = \left( |\text{happy}\rangle_f |1\rangle_c + |\text{sad}\rangle_f |0\rangle_c \right)
\]

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

\[
|\psi_{\text{initial}}\rangle_{fc} \rightarrow \{ |\text{joyful}\rangle_f |\text{happy}\rangle_f |1\rangle_c, |\text{woeful}\rangle_f |\text{sad}\rangle_f |0\rangle_c\}
\]

Happily, hybrid time provides a solution. The idea is that the definite outcomes in (2) at \( b = 15 \) are, for the friend, at the time \((a, b) = (\text{present}_f, 15)\). However, those outcomes are at the time \((a', b') = (\text{present}_w, 15)\) for Wigner. The dependence of the present on the physical system allows for two different presents without contradiction. The circumstance of the classical friend+cat state is in Wigner's future. So, writing \( \text{state}_{fc} \) for the state of the combined friend+cat system, we have at \( b = 15 \),

\[
\text{state}_{fc}(\text{present}_f, 15, x) \neq \text{state}_{fc}(\text{present}_w, 15, x)
\]

And no contradiction has arisen.

Evolution in Hybrid Time

What does physics look like in this hybrid time? Suppose measuring apparatus \( M \) is going to make a measurement on quantum system \( S \). We want \( S \) to 'evolve through time' in \( M \)'s A-time, from future to present to past. We also want \( S \) to 'evolve through time' in B-time, from e.g. 1 second to 2 seconds to 3 seconds. A typical evolution, neglecting the spatial coordinate, might be

\[
S(\text{future}_M, 1) \rightarrow S(\text{present}_M, 1) \rightarrow S(\text{present}_M, 2) \rightarrow S(\text{present}_M, 3) \rightarrow S(\text{past}_M, 3)
\]

In (6) the system \( S \) at \( b = 1 \) is in \( M \)'s future. Then \( M \) experiences temporal becoming, and \( S \) comes into \( M \)'s present. In \( M \)'s present, \( S \) evolves from \( b = 1 \) to \( b = 3 \). Then, via the same temporal becoming, \( S \) recedes into \( M \)'s past.

Can system \( S \) experience B-evolution when it is in \( M \)'s future? Answering this question would require a great deal of philosophy this modest note will not enter into, though I suspect the answer is yes.
The relativity of simultaneity

An observer stands on a train station platform and measures that a traincar moving in the +x direction is struck by lightening simultaneously at its back and front ends when the car is half way past at time \( b = 1 \) second. The car is moving at \( .9c \) and is 1 light-second in length. Another observer is sitting at the center of the car at rest relative to the car. According to the Lorentz transformations he measures that the lightening hits the back of the car at \( b' = 3.33 \) seconds and lightening hits the front of the car at \( b' = 1.26 \) seconds. [physics 2018]

The lightening strikes are simultaneous for the platform observer but not for the car observer. But in hybrid time there is no contradiction because the platform observer and the car observer each carry their own notion of the present or 'now'. According to the platform observer the lightening strikes at \((a, b) = (\text{present}_{\text{platform}}, 1 \text{ sec.})\). According to the car observer the lightening strikes at \((a, b) = (\text{future}_{\text{car}}, 1 \text{ sec.})\). Then, according to the car observer, the lightening strikes the front of the car at \((a, b) = (\text{present}_{\text{car}}, 1.26 \text{ sec.})\) at that \( B \)-time the platform observer gives the lightening strike a temporal value \((a, b) = (\text{past}_{\text{platform}}, 1.26 \text{ sec.})\). According to the car observer the lightening hits the back of the car at \((\text{present}_{\text{car}}, 3.33 \text{ sec.})\) at which time the lightening has hit the front of the car in his frame at \((\text{past}_{\text{car}}, 1.26 \text{ sec.})\).

Thus, among other virtues, hybrid time does not succumb to objections (1) and (2).

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References


Baron, Sam, (2017), 29 November, “Time, physics, and philosophy: It's all relative” Philosophy Compass
