Gedankenexperiments reconciling quantum mechanics, relativity, and our experience of time

This short informal note gives 4 Gedankenexperiments for A-theories of time and what turns out to be the Presentist Fragmentalist interpretation of quantum mechanics. Very clearly equations can be used to describe the situations considered but we don't pursue them here because the point here is conceptual resolutions (revolutions?). An A-theory of time has both an A-series (future/present/past) and a B-series (earlier/simultaneous/later) that characterize one dimension of time. Here are 5 mini-arguments for A-theories before we get to the 4 actual Gedankenexperiments.

1. One argument that the two series cannot be reduced to each other is that the debate itself has gone on for 2,500 years (since Heraclitus and Parmenides). If one series were clearly more fundamental than the other this would not have happened.

A second argument is the mini-experimental result that there are *two* temporal parameters required for narrowing the search for finding a video on YouTube. These are "Upload date," namely, within a week of 'now' or within a month of 'now,' etc… which is the A-series, and "Duration," namely, the end of a video is 4 minutes later than the beginning, or 20 minutes later than the beginning, etc... which is the B-series. If one series were really more fundamental than the other, having just one temporal parameter would surely have been sufficient. We don't see this fact as an epistemological or UI curiosity but as a very important check on ontology. The very mundaneness of this observation makes this a devastating critique of B-theories.

A third argument is that several thought experiments implicate the same realist interpretation of quantum mechanics that employs both series.

A fourth argument is that this interpretation gives a single account of both manifest time and relativistic time. Indeed, this might be a unique achievement as of 11/26/2024. Many references are going to be given in a possible subsequent version of this short informal note. But, while most papers in this part of the literature acknowledge the need for an A-series and its consistency with the relativity of simultaneity, we believe that is not clear that they have actually achieved it in a natural and fully satisfactory way that is clearly implementable in physics.

A fifth argument is that this theory has been derived from more fundamental philosophical considerations (spectrum inversion), which we don't go into here.

2. The first Gedankenexperiment is this. Suppose dinner tonight is 6 hours later than lunch today. With respect to our present both lunch and dinner are in our future, then (consecutively) in our present, then (consecutively) in our past. The number of hours that dinner is later than lunch does not change as it is a B-series. But the future/present/past status changes 'relative' to' or 'in relation to' our present as it is an A-series.

Where does relativity come in? We will assume that lunch and dinner are in the same place, so they are time-like separated. For time-like separated events their temporal order does not change, but the 'duration' between them might change. So, depending on the (relative) motion of Bob, in his frame of reference our dinner might be 7 hours (of his hours) later than our lunch, or 8 hours later. But the fact remains that dinner is later than lunch, and, importantly, the fact remains that both are in our future, then our present, and then our past. This is also true in Bob's frame of reference. The ordering is a B-series and the changing state is an A-series.

3. The second Gedankenexperiment is Alice-in-the-sun.

Consider the common observation that "if the sun went out right now, we wouldn't feel it for 8 minutes." Suppose we say 'now' at 12:00 PM on Earth, and the sun suddenly goes out. Due to the finite speed of light, c, we would receive this information only at 12:08 PM. The light (and gravitation) would not get out for us until 8 minutes later than 'now'. This exemplifies the B-series notion of time, constrained by relativity.

Now consider quantum entanglement in this context. This non-local behavior was first formally derived by Bell (though the EPR paper implicitly uses it). If Alice is at the sun's center and measures one of an entangled pair of particles at 12:00 PM (Earth time), her choice of measurement orientation instantaneously affects the outcomes of experiments done on the other entangled particle here on Earth, despite the 8-minute light travel time (this is part of the content of Bell's theorem). This exemplifies A-series time.

The A-series has a 'now' or 'present moment' that extends throughout space. But this is compatible with the relativity of simultaneity because each quantum system forms a 'fragment' of reality and, crucially, does not include the information of another fragment's A-series. Thus for each fragment there is an A-series 'now' and a spacetime which encodes the information of relative simultaneity as usual. But there is no contradiction because there are not multiple 'nows' in a single fragment.

In the example above we on Earth form one fragment. Alice in the sun forms another fragment. And the (non-local) entangled pair forms another fragment. When the experiment is done, by either Alice or us, this combines the desperate A-series into one A-series, giving a single 'now' for the combined system. Before the measurement there is no time at which—no single 'now' in which—all three fragments have a definite classical state relative to each other. Thus the two-particle entangled pair does not decide, so to speak, which orientation they are in *until* actual measurement. This is what accounts for the greater-than-classical correlations that happen in quantum mechanics, in the Presentist Fragmentalist realist interpretation. This also resolves the mystery of why the whole non-local wavefunction collapses upon observation even though a particle is found to be in only one place.

The effect only shows up in a comparison of the statistics of Alice and us, in retrospect as it were, because the information of which orientation Alice had her measurement apparatus in is constrained by the speed of light exactly because that is B-series information.

4. The third Gedankenexperiment is Bob-in-Andromeda. A common scenario investigated is when we are here, on Earth, and Bob is orbiting a star in the Andromeda galaxy. It is asked what are the implications about time for Bob's events (in our frame of reference), given relativity. But this can be turned on its head. We can ask what are the implications for our time, here on Earth, in Bob's frame of reference, given relativity and, now, additionally, quantum mechanics.

Consider Bob orbiting a star in Andromeda. His A-series 'now' extends throughout the universe instantaneously for his fragment of reality. However, for most orientations events that are simultaneous in his relativistic frame of references are not simultaneous in our frame of reference. A consequence is that some events in our frame of reference, say, a clock reading 2:00 pm, will cycle through being earlier then, simultaneous with, and later than, a clock reading (say, 3:00 pm) in Bob's 'now' in his frame of reference. But here's the point. What does *not* happen is that as Bob orbits his star we cycle through magically being transported into our own past, our 'now', and our own future. The temporal ontologies of the A-series and the B-series are different, though can be combined into one account in fragmentalism. So no paradox arises.

This apparent paradox is resolved by recognizing that each fragment has its own A-series, and there is no fact of the matter about the synchronization between different fragments' A-series values. This allows for both instantaneous non-local quantum effects and the relativity of simultaneity.

5. The fourth Gedankenexperiment is Einstein's Train (Merriam, 2022b). Alice is standing on a platform of a train station. Bob is in a train that is moving relative to the station on a track that is next to and parallel with the platform. Two lightening bolts strike the beginning and end of the train at the same 'time' in Alice's frame of reference. Perhaps she learned of what time the lightening struck by a record written on two pieces of paper carried to her after the strikes. In Bob's frame of reference the lightening strikes are not simultaneous. Thus, simultaneity is relative in some sense.

Yet when Alice did her experiment, it was 'now' for her. If we asked her what time it is as she performs her experiment (to see what time the bolts strike) she will say ''now', obviously,' as there is no other possible time to do it, and, further, the station clock happens to read 12:00 noon. As I am taking the action to call my sister I am doing it 'now' regardless of what time of day it is. There is no other time than 'now' to perform the experiment. And there is no other time than one's 'now' to perform *any* scientific experiment whatsoever. But notice an issue will arise when she makes the mundane observation that as she performs her measurement in her 'now,' there is, at that exact time, also some state Bob is in, even though he is in the moving train.

Bob's experiment is exactly the same except he is in the (relatively) moving train, and that the outcome of his experiment is that the lightening strikes are not simultaneous. Nevertheless, just like Alice, Bob performed and had no choice but to perform his experiment in his 'now'.

The issue that arises comes from this:

(1) 'now' is simultaneous with itself

Since both Alice and Bob have ‘now’s, and they must be simultaneous with themselves, but their planes of simultaneity are different, their ‘now’s must be different. That’s all there is to it.

The issue then is that when it is ‘now’ for either one of them it is ‘now’ throughout the universe. Alice’s ‘now’ spatially encompasses Bob and Bob’s ‘now’ spatially encompasses Alice. But this is exactly where quantum mechanics comes in. In Alice’s ‘now’ there is no fact of the matter as to the relative time of Bob’s ‘now,’ and *vice versa*. When Alice performs her experiment in her ‘now’ there is no fact of the matter about when Bob’s ‘now’ is, even though they can calculate relative B-series information. That uncertainty in the relative states (times) of the two ‘now’s is exactly the origin of quantum mechanical behavior. For Alice in her ‘now’ the evolution of the time of Bob’s ‘now’ is stochastic (or random) to some extent. And it is ontologically stochastic because there is no fact of the relevant matter.

Conclusion

These arguments and, as in the MO of the early Einstein, considerations of Gedankenexperiments of everyday affairs, clearly show the need for both an A-series and a B-series and that they are compatible.

To a first approximation the time of relativity is a B-series and the time of quantum mechanics is an A-series. (Again, the relativity of simultaneity is handled by the fact that each quantum system has its own A-series which fragments reality.) These two series interrelate in any theory of quantum gravity. This is one important part of the Presentist Fragmentalist interpretation of quantum mechanics. This scenario as well as others can very clearly be described by equations but the point here is the (more difficult) conceptual issues.

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