

Perspectivalism, A-theorism, and their Interpretation of QM

Abstract We motivate and develop an A-theory of time and probe its implied interpretation of quantum mechanics. It will emerge that, as a first take, the time of relativity is a B-series and the time of quantum mechanics is an A-series. There is philosophical motivation for the idea that mutual quantum measurement happens when and only when the systems' A-series become one mutual A-series. This accounts almost trivially for many quantum phenomena, including that the electrons of a Bell pair do not have definite spins 'until' measurement, as 'until' here is an A-series notion.

[references in the process of a format change]

1 Introduction and Outline

In 1908 Minkowski's published a paper on time and space, giving 'Minkowski space', whose invariant encodes special relativity and allows for the generalization to general relativity (Minkowski 1908). Also in 1908 McTaggart's paper on time was published, where he distinguished between two series that characterize time: the A-series and the B-series (McTaggart 1908). In spite of these happening 112 years earlier than this writing, there has arguably not been a clear consensus on the union of these epochal insights. The theory of this paper is a probes one possible attempt at such a union.¹

Explored below, we will take Minkowski space to be given by the metric

$$\Delta s^2 = -\Delta t^2 + \Delta x^2 + \Delta y^2 + \Delta z^2 \tag{1}$$

setting aside the issue of constants for now. This metric has a signature of $(-+++)$.

We will take McTaggart's A-series and B-series to be given by

(1.1) A-series is that series that runs from the future into the present and then into the past, and includes some notion of 'becoming'.

(1.2) B-series is that ordering that distinguishes between earlier times and later times. This is an invariant ordering for time-like worldlines (but not space-like worldlines).

Almost all philosophers call a theory of time with both an A-series and a B-series an 'A-theory', the idea being that A-theorists (almost always) presume the B-series anyway. We'll follow this convention, but it must be understood that one dimension of time in this paper involves both the A-series and the B-series.

Perhaps the most acute issue is that relativity seems to be inconsistent with the 'now' or a 'present' moment. We'll handle this by suggesting 1. on a first take, the time of relativity is a B-series, and the time of quantum mechanics is an A-series, and 2. each closed quantum system has an 'ontologically private' A-series (see below), and 3. when the A-series of two systems 'become' to be the same A-series, then and only then the two systems (mutually) quantum mechanically observe ('measure') each other and then form one system.

1 To put my cards on the table, I am a presentist (Markosian 2016).

It seems odd to have one system have one A-series and another system to have an ontologically different A-series: the ‘now’ of the Experimenter is not the same as the ‘now’ of the Cat in the Schrodinger’s Cat experiment, for example. But this seems less odd than the received implication of special relativity that there is no ‘now’ at all.

It is vital that this interpretation is independently philosophically motivated (see below).

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2 Minkowski (1908), McTaggart (1908)

In Minkowski space there are 4 dimensions and its metric is given in terms of one time parameter and three space parameters, (t, x, y, z) (eq. 1) (Minkowski 1908).

The three space parameters accord with our experience, but the 1 time parameter does not. As McTaggart explained, time that accords with our experience is given by 2 series, the A-series and the B-series. For our purposes, McTaggart, also in 1908, defined the A-series, τ , as that temporal series which runs from future to present and then to past, and the B-series, t , as that series which runs from earlier-times to later-times (McTaggart 1908). τ and t can be varied independently (depending on the situation) so a notion of time that accords with our experience *cannot* be given by just one temporal parameter t .

Thus, to model 'spacetime' that accords with our experience, it could be argued, we need the five variables (τ , t , x , y , z). In this 'McTaggartian spacetime' or 'AB-spacetime' or 'A-spacetime', τ represents the position of an event in the A-series of a given system, t represents the position of the event in the B-series of that system, and x , y , and z represent the spatial positions of the event in the chosen coordinates of that system. This is worth emphasizing: AB-spacetime is given by *five* variables and not *four* as in the case of Minkowski space.

A 'system' for the purposes of this paper can be any closed system and in particular is not assumed to be macroscopic or conscious to the extent humans are. It will be assumed that any of the systems under consideration in this paper can be considered to be microscopic, including ones called 'E', 'Cat', 'Alice', or 'Bob'.

Just as the B-series can be coordinatized by a unit 'second', the A-series can be coordinatized by a unit 'e' (the name 'e' does not designate electric charge in this context). 'e' is the unit of becoming, namely, becoming from the future into the present and then into the past of a selected system. A change of 1 second is a change in the B-series, and a change of 1 e is a change in the A-series.

The countdown to a rocket liftoff, 10... 9... 8... could be seen as counting the number of es. When the announcer says '10' this means that the liftoff, if it is going to happen, is 10 e *in the future* of the control center. In the case of 'flat' AB-spacetime, in the relevant coordinate system, the liftoff is also 10 seconds *later than* the time that the announcer says '10'.

3 AB-series time

McTaggart (1908) identified two different series that characterize time. There is the B-series and the A-series.

“Positions in time, as time appears to us *prima facie*, are distinguished in two ways. Each position is Earlier than some, and Later than some, of the other positions. And each position is either Past, Present, or Future. The distinctions of the former class are permanent, while those of the latter are not. If M is ever earlier than N, it is always earlier. But an event, which is now present, was future and will be past.”

I will not follow McTaggart to the conclusion that time is unreal, but suggest that time is real and has both B-series and A-series characteristics, as most A-theorists posit.

The B-series is a series of times ordered by the relation of 'earlier-than' (or 'later-than'). The B-series is usually thought of as going from earlier times to later times. The B-series relations do not change on time-like worldlines. Also, going 'backward in time' in the B-series just means going to earlier times.

I would argue, as many A-theorists do, the A-series, as not reducible to the B-series in any way, is also a part of a comprehensive view of time. The A-series consists in the 'ontologically private' (defined below) *now* and *becoming*. In contrast to the B-series, the A-series values change. The B-series allows going 'backward in time' and the A-series does not, discussed below.

'I'll meet you 2 hours from now'. B-series time. 'Tomorrow never comes' (if taken literally). A-series time.

It is 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. 17 or 33). The former is the B-series (interpreted as 'earlier-times to later-times') and the latter is the A-series. As in several theories of time, instead of asserting 'time goes from past to present to future', it would be more appropriate to assert 'time goes from earlier times to later times as it becomes from future to present to past'. As later and later times become present, time goes on.

The question is how to incorporate the A-series in physics, while of course retaining the B-series, into what I will for the purposes of this paper call the AB-series, denoting that a single dimension of time has both A-series and B-series characteristics, in a way that is consistent with relativity. The ideas here are related to those of Fragmentalism, Relationalism, and Perspectivalism (Fine 2005, Rovelli 2019, Dieks 2019). The idea will be to add to each system a 'now' and a 'becoming' (of the A-series) that is 'ontologically private' to that system, while retaining the ontologically public B-series interrelations. These are 'private' now's, so, presumably, the *apparent* 'universal now' that humans live in on earth would result from some kind of averaging over the more-or-less ubiquitous private nows.

4 Perspectival Dualist Panpsychism

One significant virtue of the interpretation of quantum mechanics of this paper is that it is independently philosophically motivated.

I am conscious, and this is certain to a degree even greater than the certainty that there are physical laws. But there is, in one 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 consciousness—subjective experience—qualia. One is led to the hypothesis of Panpsychism, for example an electron is accompanied by a quale—a subjective experience—for example, the color green, and perhaps a muon is accompanied by a blue quale. There has been an impressive amount written about this and surrounding ideas but the basic idea is clear enough and is called (Dualist) Panpsychism. (SEP 2017, SEP 2020a). (The idea of other correlates to qualia such as complexity could be entertained.)

Qualia are not a *theory*. Reading about qualia does not help one apprehend (and thereby understand) them any more than reading about swimming across the English Channel helps one actually swim across the English Channel. But that is good: an advance in this area should lie outside the physicist's mainstream conceptual toolkit, since otherwise the interpretation would surely have been put forward already.

'Ontological privacy' is basically what happens with the Inverted Spectrum (SEP 2020b). Suppose Alice looks at the leaves on a tree and she experiences the color green. She cannot know, in some ontological sense, that if her friend Bob looks at the same leaves he experiences the same (color) quality.

Now suppose they look at a color circle. Alice's color spectrum does not determine Bob's color spectrum, for Alice. Bob could have a systematically 'opposite' color experience. This is basically the Inverted Spectrum. Indeed, it may be that Alice has a single definite spectrum, whereas Bob's spectrum can *vary* over a wide range of spectrums or even other possibilities, for Alice. Alice's (qualitative) experience while looking at the leaves, in some ontological sense, leaves Bob's experience without a definite value (for Alice), and therefore this color-parameter is 'ontologically private'.

In Dualism it is a hopelessly frequent observation that my 'green' might not be the same as your 'green'. More precisely, if I see some leaves and green qualia arise in my mind and if you look at the same leaves, then I don't know for sure if the qualia that arise in your mind are what I would call green, and *vice versa*. There is *no fact of the matter* as to whether we see the same 'green'. (It's irrelevant if we actually do see the same green—the point is there no ontic state that contains qualia from both perspectives. Now migrate this observation to each physical closed system, no matter how microscopic. This might be called "Perspectival Panpsychism" where there is no fact of the matter as to whether the qualia associated with one system are the same (qualitatively) as the qualia associated with another system.

The theory of time probed in this paper posits that the A-series characteristics of time are (or could be) ontologically private. A consequence would be that an Experimenter's 'now' does not determine when the Cat's 'now' is, to some extent, in the Schrodinger's Cat experiment, and *vice versa*. This is, possibly, more plausible than the conclusion that the 'now' does not exist at all as in the received interpretation of relativity.

One wants ontological parsimony. It may indeed be Alice's 'green' is the same as Bob's 'green'. But that is irrelevant. The point, in this theory, is there is no ontic state that includes both Alice's qualia (or her A-series) and Bob's qualia (or his A-series) simultaneously. So that result should be in the ontology, if possible.

Is time qualia or merely similar to qualia? (Berg 2010, Farr 2019, 2020c, Smolin 2015) This paper will not attempt to adjudicate the issue. The question seems to be whether epistemic apprehension of time presupposes ontological time in some sense. See Chalmers' Two-dimensional argument against materialism (Chalmers 2007).

5 Note on Qualia and Tense

Philosophers of time have developed *tense* logics and many others. Tense in this paper is associated with the A-series. And the A-series is supposed to be (or be like) the phenomenal, i.e. qualia. Therefore it is plausible that to get a start on finding the logic of qualia one could take a tense logic and modify it appropriately.

One might be willing to entertain the idea that, in obvious notation, the modal axiom

$\Diamond P \rightarrow P$

(2)

is true for the A-series but false for the B-series. If it is true for the A-series then the mere *possibility* of the A-series presupposes the A-series. This is plausible: the possibility is itself temporally situated. Also one might suspect this is true of qualia and false of their physical correlates (Chalmers 2007).

6 McTaggart on Newton

“Absolute, true, and mathematical time, of itself, and from its own nature, flows equably without relation to anything external, and by another name is called duration: relative, apparent, and common time, is some sensible and external (whether accurate or unequable) measure of duration by the means of motion, which is commonly used instead of true time; such as an hour, a day, a month, a year. ” (Newton 1689).

Without getting litigious, we can parse this as

“Absolute, true and mathematical time, of itself, and from its own nature flows equably without regard to anything external, and by another name is called duration” This is the A-series.

“relative, apparent, and common time, is some sensible and external (whether accurate or unequable) measure of duration by the means of motion, which is commonly used instead of true time; such as an hour, a day, a month, a year.” This is the B-series.

What’s new is the constraint of being consistent with relativity (Einstein 1905). This is handled by the B-series of the respective systems in this preliminary theory, though with further development it surely will turn out that both the A-series and the B-series are involved in some way, in addition to the spatial coordinates, among the transformations in these coordinates.

7 Simultaneity versus the Present

7.1 The following argument is often made. For changes in relevant motions of a spaceship in this galaxy, the planes of simultaneity change for events in (for example) the Andromeda galaxy. But this argument can be turned around. For changes in relevant motions of a spaceship in the Andromeda galaxy, its planes of simultaneity for events in this galaxy change. Yet we do not find that our (and thus each microscopic system's) 'now' goes back and forth ‘in time’ depending on the movements of the spaceship in Andromeda. The A-series seems to go in only one direction: future into the present and then into past.

Suppose this alien moves around the Andromeda galaxy. Depending on how it moves, the alien's plane of simultaneity may be, for example, in our (in the Milky Way, here on earth) future, or in our past, or varying. But that does not prevent us from seeming to exist only 'now'

7.2 Consider a third rocket ship in (for example) the Sombrero galaxy. Depending on how it moves, its planes of simultaneity could also vary. Generically, a plane of simultaneity of the rocket ship in the Andromeda galaxy will not be a plane of simultaneity of the rocket ship in the Sombrero galaxy. There are multiple planes of simultaneity going on at once. But then the plane of simultaneity cannot be equated with the ‘present’, as having multiple presents would violate its ontological privilege. So the presentist does not have the option of equating simultaneity and the present available.

7.3 If the sun suddenly went out we wouldn’t get its effects here on earth for about 8 minutes. 8 minutes compared to what?

7.4 In music there is tempo. A-series. And there is relative location in the score (including relative duration). B-series.

7.5 There is a need for two temporal buttons to select a video on Google video. t is how much later than the beginning of the movie the end is. τ can be interpreted as how far into the past the movie has been posted.

8 The interpretation

There is philosophical motivation for the idea that quantum observation of a system happens when and only when the A-series of the quantum system comes *becomes* to combine with the A-series of the reference system. The 'now' of the quantum system combines with the 'now' of the reference system into one 'now'. Thus, in Alice's perspective, Alice measures the spin in a direction of (an) electron when and only when the A-series of Alice and the A-series of the electron-pair become one A-series. Before observation, there is *no fact of the matter* as to whether the 'now' of Alice is the 'now' of the electron-pair. Thus, the spin does not decide—so to speak—which definite value to take on until there is a 'now' of the combined Alice-pair system. The 'until' here is an A-series notion.

Since at least Heraclitus it has been observed that the flow of time (the A-series) is (or is like) what we would now call phenomenal consciousness, i.e. qualia. This is a robust observation for the presentist. Thus we have the obvious hypothesis that the A-series of one system is not the A-series of another system. There is *no fact of the matter* whether the 'now' of one system is 'at the same time as' the 'now' of the another system (see section after Schrodinger's Cat). But clearly there must be just one 'now' when the two systems come together to form one system.

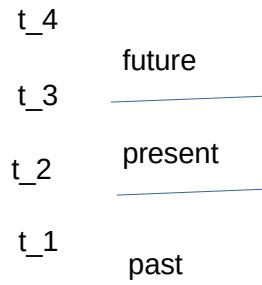
“How does the [quantum] universe know when to apply unitary evolution and when to apply measurement?” (Aaronson 2020d).

The theory of time of this paper posits that unitary evolution applies when two systems do not share the same A-series, and a quantum measurement applies when the two systems come to (or 'become to') share the same A-series.

9 Figures

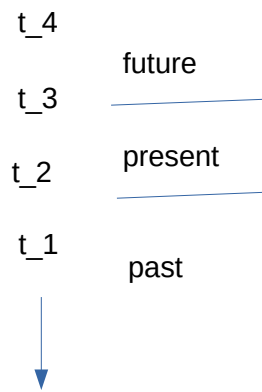
Here is a picture of one dimension of AB-series time for one selected system:

Figure 1



There should be a way to represent the A-series 'becoming'. The B-series doesn't change (except space-like separated events, a triviality for us). So the A-series and the B-series must change relative to each other while keeping the same 'now'. The above picture is modified to

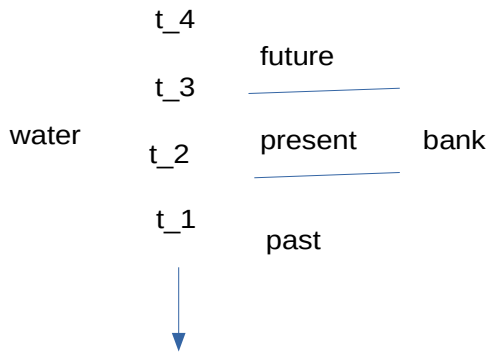
Figure 4



This accords with experience.

Heraclitus' river metaphor may be diagrammed as

Figure 5



10 Ontological Privacy

An ontologically private parameter may be defined as one that takes on a definite value when a system S specifies its own ontic state, but does not take on a definite value in a *different* system S' . This could be because, for S , 1. S' has no such parameter, 2. S' has such a parameter but it does not have a definite value, or 3. there is a parameter and it has a definite value but it is not known or knowable, for some reason (this latter might be appropriate for QBism (Fuchs et. al. 2014), though we are concerned primarily with realist interpretations in this paper).

11 Perspectival Ontology

We do not assume that any of these systems are macroscopic nor conscious, but for conceptual reasons it will be convenient to state things in terms of the Schrodinger's Cat experiment in this section. In this theory a measurement from a system E on a quantum system Cat is in fact a mutual measurement between E and Cat . This is similar to several interpretations.

“The notions of observing system and observed system reflect the traditional notions of observer and system (but any system can play both roles here).” (Rovelli 1996). “ In this paper we ... suggest a perspectivalism according to which quantum objects are not characterized by monadic properties, but by relations to other systems. Accordingly, physical systems may possess different properties with respect to different "reference systems".” (Dieks 2019).

Suppose that for an experimenter E , Schrodinger's Cat is in the state

$$|\Psi\rangle = c_1 |\text{will find cat purring}\rangle + c_2 |\text{will find cat meowing}\rangle \quad (3)$$

in a Hilbert space H . We will assume quantum mechanics is universal, in which case every physically instantiated system must be able to describe (so to speak), *other* systems via quantum mechanics (complications arising from field theories will not distract us in this note).

Therefore, as described by Cat, E is in an analogous state

$$|\Psi\rangle = c_3 |\text{will find E that finds cat purring}\rangle + c_4 |\text{will find E that finds cat meowing}\rangle \quad (4)$$

in a different Hilbert space H' . The long-run statistics of the first and second terms in (3) and (4), respectively, must be the same, so in view of the Born rule we have

$$|c_3|^2 = |c_1|^2 \quad \text{and} \quad |c_4|^2 = |c_2|^2 \quad (5)$$

The state-vector $|\Psi\rangle$ collapses upon observation of Cat by E, and equivalently the state-vector $|\Psi'\rangle$ of E by Cat collapses upon (mutual) observation. In the interpretation of this paper, at observation and only at observation the A-series of E and the A-series of Cat become the same A-series.

12 $M^5 \times M^5$

But not so fast. It is the interface of AB-spacetimes from two ontologically distinct *perspectives*, such as E and Cat, that is (in this model) quantum.

It could be argued that before quantum observation we in fact have (in changed notation)

(12.1) E's 5-dimensional AB-spacetime (τ, t, x, y, z) from the ontological perspective of E,

(12.2) Cat's 5-dimensional AB-spacetime (τ', t', x', y', z') also from the ontological perspective of E

and

(12.3) Cat's 5-dimensional AB-spacetime $(\tau'', t'', x'', y'', z'')$ from the ontological perspective of Cat,

(12.4) E's 5-dimensional AB-spacetime $(\tau''', t''', x''', y''', z''')$ also from the ontological perspective of Cat

where 'before' means a quantum observation (such as E opening the box) is in the future of E and, analogously, in the future of Cat.

The 5 dimensions come from the need for an A-series, a B-series, and 3 space dimensions for each AB-spacetime.

Thus in E's ontological perspective there are in some sense two AB-spacetimes, the first one (12.1) and the second one (12.2). On the other hand, in Cat's ontological perspective, there are in some sense also two AB-spacetimes (12.3) and (12.4). So we would expect (12.1) and (12.2) on the one hand to be quantum mechanically related to (12.3) and (12.4) on the other hand.

What are the (not all independent) 64 (possibly stochastic) relationships between the 8 variables $(\tau, t, \tau', t', \tau'', t'', \tau''', t''')$ before, during, and after quantum observation? And what are the at least 625 relationships between the 20 variables where the space coordinates are included?

A further observation.

An experimental outcome is revealed to E in E's present, $\tau = 0$, and must be in Minkowski space (in the 'flat' case), so that the metric of E's AB-spacetime, in E's ontology, at $\tau = 0$, must conform to the Minkowski metric (setting aside constants throughout)

$$\Delta S_{\text{AB-spacetime}}^2 (\text{at } \tau = 0) = \Delta S_{\text{Minkowski-spacetime}}^2 = -\Delta t^2 + \Delta x^2 + \Delta y^2 + \Delta z^2 \quad (6)$$

This raises the following idea. Suppose that, for general values of τ ,

$$\Delta S_{\text{AB-spacetime}}^2 = +\Delta\tau^2 - \Delta t^2 + \Delta x^2 + \Delta y^2 + \Delta z^2 \quad (7)$$

And suppose

$$\Delta t' = i\Delta t \quad (8)$$

Then

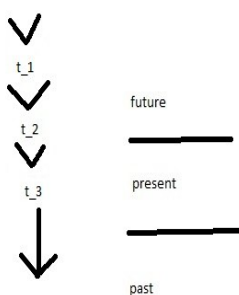
$$\Delta S'_{\text{AB-spacetime}}^2 = +\Delta\tau'^2 + \Delta t'^2 + \Delta x'^2 + \Delta y'^2 + \Delta z'^2 \quad (9)$$

Then, where (7) gives an AdS_5 space (for E's AB-spacetime in E's perspective) in the coordinates (τ, t, x, y, z) , and (9) gives an S^5 space (for Cat's AB-spacetime also in E's perspective) (in changed notation) in the coordinates (τ', t', x', y', z') . The same geometry clearly obtains for the two AB-spacetimes from Cat's perspective, in the coordinates $(\tau'', t'', x'', y'', z'')$ and the coordinates $(\tau''', t''', x''', y''', z''')$, respectively. This, given the supposition of this paper that E's perspective is related to Cat's perspective quantum-mechanically (before mutual observation), cannot not be suggestive of an AdS/CFT correspondence (Maldacena 1998).

13 Time-reversal

Time-reversal goes as

Figure 6



t_3 and then an earlier time t_2 and then an even earlier time t_1 become from Alice's future to her present and then to her past. As earlier and earlier times become present to her, time appears to be

going in reverse. Time-reversal invariance obtains only for a B-series, on this view. Naive time-reversal for an A-series is undefined. There's no unit of going from past to future defined in the A-series. (The evolutions in the graphs are path-connected via $\tau = 0$.)

There is a time-reversal

$$(\tau, t) \rightarrow (\tau, -t) \tag{10}$$

This means that as events become in Alice's A-series (from future to present to past), the B-series times are going from *later* times to *earlier* times. This is the realization of the 'movie going backward' metaphor. This is surely at least one of the notions of time-reversal in physics.

These time-reversals are dubious:

$$(\tau, t) \rightarrow (-\tau, t) \tag{11}$$

$$(\tau, t) \rightarrow (-\tau, -t) \tag{12}$$

except at $\tau=0$ (or its generalization given by the presentism function $p(\tau)$ (see below)) because going from the past to the present to the future would have to go through Alice's present. (A disconnected present would be philosophically dubious.)

14 A Mathematical Definition of the Present and its Duration

Let τ be a real variable that runs from a selected system's future into its present and then into its past a la McTaggart's A-series. We may define a unit of becoming, e , that coordinatizes τ the way seconds coordinatize McTaggart's B-series earlier-times to later-times (e is not the electric charge in this context). By convention we will suppose that $\tau > 0$ means the (A-series) time is in the selected system's future, $\tau = 0$ is its present, and $\tau < 0$ its past.

One doesn't need to make the sizable assumption the present is a single infinitesimally small point centered at, for example, $\tau = 0$. (It may be that the smallest duration is the Planck time anyway.) Define for each τ a 'degree of presentness' $p = p(\tau)$, so the present may be spread out in A-series time somewhat. (Smith, 2010). By convention we will suppose $p(\tau) = 1$ means that τ is fully present, $p(\tau) = 0$ means that τ is fully not present (thus either in the future or the past of the selected system), and $0 < p(\tau) < 1$ means that τ is partially part of the present.

One may consider symmetric functions p , asymmetric functions p , step functions p , infinite-tailed functions p , normalized functions, etc. It would be philosophically dubious to have a disconnected function p .

In obvious notation, the block-world theorist would have $p(\tau) = 1$ for all τ . The growing-block theorist would have $p(\tau) = 1$ for $\tau \leq 0$. The presentist (like me) would suppose τ is at least partially present where $p(\tau) > 0$ (i.e. on the support of p).

Suppose for the sake of argument that an A-series is associated with each physical system the way qualia are associated with each physical system in Panpsychism. Then it may be that one system has a presentism function $p(\tau)$ whereas a different system has a different presentism function $p'(\tau')$.

If for two systems $p(\tau)$ and $p'(\tau')$ are non-point-like then there would be some uncertainty as where in the present τ an event or process is if these two systems come to have the same A-series. So there would seem to be some kind of uncertainty relation here.

It must be emphasized that each selected system there are five not four variables, τ the A-series, t the B-series, and the three space dimensions x^a for $a = 1, 2, 3$, or, in view of section (12), each perspective has 10 variables.

15 An Inequality

Suppose there is a presentism function $p(\tau)$ in ontological perspective p_1 . Then, in that perspective, the A-series spectrum τ' of another system can have any value (the 'now' could be anything in a certain range) up to an accuracy of $p(\tau')$. But if the length of p is (for example) decreased, then the number of states of τ' that are distinguishable is increased, in the perspective of p_1 . It is exceedingly clear there is an inequality here.

16 Time $T(\tau, t)$

This is not a theory of two time dimensions but one time dimension that has two closely related parameters τ and t , such that the time T is given by $T(\tau, t)$. τ is how far in the future an event is and t is how much later than an event is, compared to a possibly microscopic reference system, e.g. 'Alice'. There might be functions f given by $f(T(\tau, t), x^a)$ for $a = 1, 2, 3$.

For one dimension of time $T(\tau, t)$ and three dimensions of space the flat Euclidean metric is given by

$$ds^2 = dT^2(\tau, t) + \sum_{i=1}^3 dx_i^2 \quad (13)$$

Any experimental outcome is revealed to Alice only in her present. Alice's present (or at least the center of it) is the condition $\tau = 0$. (The general condition would use the presentism function $p(\tau)$ discussed earlier.) Also, any experimental outcome that Alice gets must be Lorentz-invariant, i.e. in Minkowski space, in the flat case. Thus for this simple case one has

$$ds^2 = dT^2(0, t) + \sum_{i=1}^3 dx_i^2 = -dt^2 + \sum_{i=1}^3 dx_i^2 \quad (14)$$

which imply

$$dT(0, t) = dt \quad (15)$$

This says the difference in time T is, in Alice's present, equal to i times the difference in B-series clock times.

Light is associated with a constant c that has units of meters per second. It is reasonable to wonder if there is something associated with a constant b that has units of meters per e. The thing would move a constant number of meters for every unit of becoming into Alice's present. This might be infinite in light of the 'Bell' section below.

Reverting to the standard notation of this paper, the condition that $t = t'$, in appropriately scaled units, says that the event is simultaneous in both frames of reference, the un-primed frame and the primed frame. This is, of course, not the same condition that the event is in both presents, which would be the condition $\tau = \tau'$ in appropriately scaled units (of e and e' respectively). The latter condition cannot be given in the A-series coordinates of two different systems.

The idea, then, is that Alice has an at least partly 'ontologically private' spacetime. This is 5-dimensional in the sense of (τ, t, x^a) or 4-dimensional in the sense of $(T(\tau, t), x^a)$. Similarly for Bob. The interface of these spacetimes is taken to be quantum mechanical.

17 Definitions and Rates

Mathematicians were taking square roots of positive numbers, e.g. finding x in the equation $x^2 = 1$. But one wanted to generalize to equations like $x^2 = -1$. There was no real number that did it, so to a real number mathematicians added a non-real parameter i . That is, i is a kind of standardized place-holder for a would-be root, whatever kind of creature that is.

One thing to try, then, is to start with a parameter t whose unit is change in B-series, an interval, in for example seconds. Add a parameter τ whose unit is not an interval in B-series clock time: in AB-theory, τ is part of the A-series, and “ e ” will be a unit of what temporal becoming is like per second, as a kind of standardized place holder, whatever kind of creature it is. Let τ be the future-present-past spectrum. e coordinatizes τ .

Define an *indexical clock* to be a clock that's not accelerating, has relative velocity 0, and is spatially local, to a centered inertial reference frame, all in terms of a B-series.

Define

1 e is what becoming is like for 1 second of indexical clock time

If becoming is indeed phenomenal in the way that qualia are, then, it could be argued, it *must* be 'defined' or 'referred to' in this curious 'what it is like' way, on salient views. E.g. a green quale is defined as 'what it is like' to experience green. The necessity of doing this has to do with their ineffability. e can be well-defined across systems. 1 second is well-defined across systems such as Alice and a protozoan, even though the protozoan doesn't have the mental capacities Alice does. It's plausible that it's the same way with 1 e of A-series time. Just the way one can re-define seconds to be longer or shorter than the usual seconds, one can re-define e s to be further or closer into the future than the usual e s. The physically significant stuff should be invariant under these changes.

It is worth reiterating that one needs *more than 4 numbers* to locate an event in AB-spacetime. For the time $T(\tau, t)$ these *five* numbers are τ , t , and x^a . One specifies τ , how far in the future/present/past the event is, and t , how much later than $t = 0$ the event is, and the three x^a .

Define

1 sec./ $e = d(\text{Alice's B-series})/d(\text{Alice's A-series})$

is the change in 1 second of indexical clock time per change in e . For example, the position of a particle at 1 sec. *later than* $t = 0$ is also 1 e closer to the present from the future (or further into the past).

Consider the rate $r = 2 \text{ sec./}e$. This can be interpreted as meaning there are 2 seconds of indexical clock time per unit of becoming. Presumably, the 2 seconds are in a series. That would seem to imply that, for 1 e , 2 seconds go by, so earlier-to-later relations would appear to go by faster. This would be like the 'speeded up movie' metaphor.

Let the rate r be in units of $\text{sec./}e$. The general idea is

$r > 1$ B-series time appears sped up (earlier-times to later-times appear to be going by faster than normal)

$r = 1$ the change in B-series information per change in A-series information is given by 1 second of indexical clock time per unit e of becoming. This unit e is assumed to be applicable to all panpsychist systems, the way 1 second of indexical clock time is applicable to such systems as a macroscopic Alice or a protozoan.

$0 < r < 1$ B-series time appears slowed down, as in relativistic dilation between Alice's B-series and Bob's B-series, according to either Alice or Bob

$r = 0$ B-series time appears stopped (but the appearance goes on [ref.])

$r < 0$ one appears (from *future* to *now* to *past*) to be going backward in B-series time, i.e. later than to earlier than times, e.g. time-reversal

One may define (for example) dr/de which would have something to do with the rate of becoming accelerating. e^{-2} would be something like "per unit of becoming, per unit of becoming".

Let clock c_2 be above the surface of the earth and clock c_1 be 1 meter directly above c_2 . Let c_2 's time be given by $T(\tau, t)$ and c_1 's time be give by $T'(\tau', t')$. c_2 runs slower than c_1 . So

$$dt/dt' < 1 \text{ sec./sec.'} \tag{16}$$

Each clock registers that later and later respective times are becoming into their respective presents at a rate of 1, i.e.

$$dt/d\tau = 1 \text{ sec./}e, \quad dt'/d\tau' = 1 \text{ sec.'/}e' \tag{17}$$

which allow one to attempt to define, in the obvious units,

$$dt/d\tau' < 1, \quad dt'/d\tau > 1 \tag{18}$$

One could possibly compute

$$dT'/dT \tag{19}$$

but has to be careful as it seems to put the ontologically private 'total times' T and T' on an equal footing.

Let x be the position of a point particle defined relative to a chosen origin in a particular system. One may define dx/dt , the 'rate' at which the position of the particle changes with respect to the B-series time t , i. e. with respect to the 'time' going from earlier times to later times, in units of meters/second.

One may define $dx/d\tau$, the 'rate' at which the position of the particle changes as it 'becomes' from the system's future into the system's present and then into the system's past, in units of meters/e. This neither assumes nor implies the future is predetermined, as there may be many futures which are consistent with the system's present (see below).

The countdown to a rocket liftoff, 10... 9... 8... could be seen as counting the number of es. (Though of course the countdown is in an arbitrary coordinate system.) When the announcer says '10' this means that the liftoff, if it is going to happen, is 10 e in the future of the control center. In the 'flat' case of AB-spacetime the liftoff is also 10 seconds later than the time that the announcer says '10'. This particular case might be given by the rate $r = -1 \text{ sec./e}$. (The value of the B-series goes up as it passes by the present while the value of the A-series goes ('becomes') down into the present.)

An *AB-clock*. Take a piece of paper and write 'now' on it. Put a stop-watch next to it and start it, starting at any chosen value. The paper is 'now', and it can be modeled by (via a distribution on) the variable τ via the presentism function $p(\tau)$. The stop-watch measures how much later than dinner is tonight than the present value, or how much earlier breakfast was this morning than the present value. The increasing-in-value (in a convenient coordinate system) of the stop-watch is represented by the arrow in the figures above, i.e. the A-values of an event in AB-spacetime change and the B-values don't change (up to space-like separation), (McTaggart 1908), i.e. the 'becoming' is represented by the arrow in the figure. The value on the stop-watch is an *empirical* question, as is the reality of the paper.

18 Ontic States (OM)

There is the question of the relationship between a quantum state and an ontic state. One would like to associate a quantum state with a particular ontic state, but the quantum state might not specify which one uniquely, so in the Ontological Models framework (OM) one models a quantum state as a distribution D over all ontic states (Leifer 2014). These are parameterized by at most one time variable t . In AB-theory there is a distribution $D1$ over the ontic states parameterized by (τ, t, t') (Alice's A-series, Alice's B-series, and Bob's B-series) and there is a distribution $D2$ over the ontic states parameterized by (t, t', τ') (Alice's B-series, Bob's B-series, and Bob's A-series). There is no distribution $D3$ over states parameterized by (τ, t, t', τ') , as there would be in a non-perspectival model, because τ and τ' are ontologically private, in (or analogous to) the way the qualia of Alice and the qualia of Bob are ontologically private, where 'Alice' and 'Bob' could be any possibly microscopic system. This seems to be a kind of knowledge-restriction (Spekkens 2005). There's more information in $D1$ union $D2$ than there is in $D3$, but only one, $D1$ or $D2$, can be given. So you only get about half of the total information.

A C-series or R-series might be appropriate (McTaggart 1908, Oaklander 2015).

19 Probability Distributions

In this theory there is no ontic state that contains both Alice's A-series and Bob's A-series while they are different systems. Therefore there is no well-defined probability distribution over one.

This has an exact analogue (equivalence?) to the case of Alice's qualia and Bob's qualia. The question is, what is the probability that, for example, Alice sees green *and* Bob sees yellow, when they each look at some leaves, given the spectrum-inversion possibilities. There is no ontological state that contains both Alice's qualia and Bob's qualia (in Perspectival Dualism), so there is no probability distribution over one. Instead there is the probability distribution over 'Alice sees green and Bob sees yellow'

according to Alice's ontology and her map of Bob's ontology, and there is a probability distribution over 'Alice sees green and Bob sees yellow' according to Bob's ontology and his map of Alice's ontology. Thus the probability that one has 'Alice sees green and Bob sees yellow' in one and the same ontology is the *product* of these two distributions.

Let $p_{\text{objective}}(\tau, t, \tau', t')$ be a probability distribution over the 4 time variables all construed as 'objective'. Let $p_{\text{Alice perspectival}}(\tau, t, t')$ be a probability distribution over 3 temporal variables from Alice's perspective, and $p_{\text{Bob perspectival}}(\tau', t', t)$ be a probability distribution over 3 temporal variables from Bob's perspective. It's conceivable that some function of $p_{\text{Alice perspectival}}$ and $p_{\text{Bob perspectival}}$, that meets the requirement of being a probability distribution, could deviate from, or indeed not allow a corresponding model for, $p_{\text{objective}}$. (This is a calculational question.) If that were the case, there would be the hope of *experimentally* adjudicating between our being in an 'objective', 'perspectival', or something else, ontology.

For example, define sets $A = \{1, 2, 3\}$ and $B = \{1', 2', 3', 4'\}$. Assuming equiprobability of all possibilities (just for this example), what's the probability of picking, for example (2, 3'), at random? $p_{\text{objectival}}(2, 3') = 1/12$. But this also assumes all possibilities are 'equally real'. What's $p_{\text{perspectival}}(2, 3')$? One has, in this case, the possibility of 3' given (conditional on) the state 2, for Alice. i.e., she finds herself to be in one definite state, either 1 or 2 or 3, which in this case is 2. In this case there is a 1/4 chance of the B value to be 3', according to her. She could have been in any one of the three conditional states, however, which brings in an extra factor of 1/3. In other words, according to her, who is actually in state 2, there was only a 1/3 chance that she would have wound up in state 2 (i.e. been in state 2 when the probability was going to be calculated). So, for her, the probability of the mutual state being (2, 3') is $p_{\text{Alice}}(2, 3') = 1/12$. This must be multiplied by the conditional probability from Bob's perspective, as there must be a consensus, as it were, from *both* perspectives, that (2, 3') is the selected state. In this case (2, 3') also has a probability of 1/12, as for Bob there are 3 possible states for Alice, each conditional on Bob's states, so $p_{\text{Bob}}(2, 3') = 1/12$.

One has

$$p_{\text{perspectival}} = p_{\text{Alice}}(3' | 2) p_{\text{Bob}}(2 | 3') \quad (20)$$

Thus, the probability that they agree on (2, 3') is $(1/12) \times (1/12) = 1/144$. In this case, generally,

$$p_{\text{perspectival}} \neq p_{\text{objectival}} \quad (21)$$

The former is the square of the latter, and sums to 1 if the latter does. Informally, one has

$$P_{\text{perspectival}} = (P_{\text{objectival}})^2 \quad (22)$$

for probability distributions $p_{\text{perspectival}}$ and $p_{\text{objectival}}$. They can both sum to 1 because there are more perspectival possibilities than objectival possibilities.

20 Born

This section is somewhat speculative.

In view of (7) let us optimistically put for Alice time $T_1 = (0, 0)$ and time $T_2 = (\tau, it)$, normalized in some way. We can ask what is the probability that they become the same time, $T_1 = T_2$, at collapse?

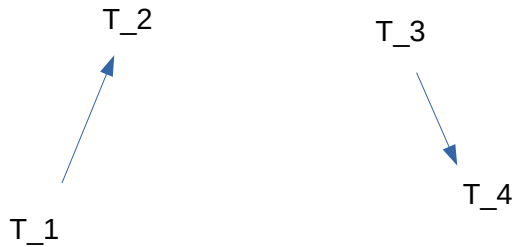
There is a probability $p_A(T_1 \rightarrow T_2)$. Here, T_2 is in the future of T_1 , by τ , and also T_2 is later than T_1 , by t . But p_A is not the answer. An experimental outcome is revealed only in the present, $\tau = 0$. So we would seem to want the probability p' ($T_1(0, 0)$ and $T_2 = (0, 0)$) but that's not right since these two times are ontologically private. We want the probability (see figure 7)

$$p_{AB} = p_A(T_1 \rightarrow T_2) \text{ and } p_B(T_3 \rightarrow T_4) \quad (23)$$

to actualize the path from both perspectives, Alice's and Bob's, where time $T_3 = (0, 0)$ and time $T_4 = (\tau, -it)$. T_2 has a '+' it' because T_2 is later than T_1 , while T_4 has a '-' it' because T_4 is earlier than T_3 . This gives

$$p_{AB} = p_A p_B((T_1 \rightarrow T_2) \text{ and } (T_3 \rightarrow T_4)) \quad (24)$$

Figure 7



T_2 is *later* than T_1 , where τ_{Alice} at $T_1 = 0$. T_4 is *earlier* than T_3 , where τ_{Bob} at $T_3 = 0$. They come together only when $(\tau_{\text{Alice}} \text{ and } \tau_{\text{Bob}}) \rightarrow \tau_{\text{Alice and Bob}} = 0$

Also $p_{AB} = p_A p_B$. The first transformation in (24) is followed by the second transformation in (24) which are given by $(\tau, it) \times (\tau, -it)$ so that we have $p_{AB} |T_2|^2$, or, equivalently, $p_{AB} |T_4|^2$.

This is the probability of the actualization of that temporal path from both perspectives.

The probabilities p_A and p_B are just 'probabilities', and not, in particular, some mysterious things that have the ontology of merely a 'square root' of a probability or indeed a 'complex square root' of a probability. A product of probabilities is a probability, p_{AB} .

It's critical that to get the probability of the actualization of the path one has the probability of p_A of (T_1 to T_2) from the perspective T_1 , *and* the probability p_B of (T_3 to T_4) from the perspective of T_3 . Before observation (collapse of the state function) they are not ontologically one system over which one distribution could be given.

21 Schrodinger's Cat

We will assume the reader is already fluent with the Schrodinger's Cat paradox (SEP 2019). Suppose the experimenter is Alice. At some point (time) during the experiment, Alice describes the cat's state as a superposition, in obvious notation, $[\psi] = [\text{meowing}] + [\text{purring}]$. Yet at that time the cat describes its own state as being in one definite state, either 'meowing' or 'purring', and not in the superposition $[\psi]$. What's going on?

The problem from the perspective of the AB-theory is that we assumed the A-series values of the cat are the same as the A-series values of Alice. But the 'now' of Alice and the 'now' of the cat are taken to be ontologically private. Therefore the 'now' of Alice does not determine (fix) the 'now' of the cat (and vice versa), if they are separate systems, analogous to the case of qualia in the Inverted Spectrum. The ontology ought to reflect that, if possible. In this case, to some extent, Alice cannot determine when the 'now' of the cat is. In particular, she cannot assume that the 'now' of the cat is equivalent to her 'now'. This is so from the beginning of the experiment (when she closes the box) until the end of the experiment (when she opens the box).

But if, during the experiment, Alice and the cat never are in a shared present, or shared 'now', then there is arguably never a *single time* at which the cat gets ascribed different states, one by Alice and one by the cat. That is how the paradox is resolved in this interpretation.

Alice is supposed to describe the cat state in terms of time. We do not have a function

$$f(T(\tau, t), T'(\tau', t')) \tag{25}$$

because it treats τ and τ' on an equal footing, up to $T = T'$. For the interesting function g , with a Cartesian product x , one has

$$g(T(\tau, t), t', T(\tau, t) \times \tau') \tag{26}$$

where the third term comes from the idea that, for each of Alice's times T , the 'now' of the cat, τ' , could take on any value (on the future/now/past spectrum of the cat). But it's not clear if g has τ and τ' on an equal footing, too. (The above form of g is just an exuberant example.)

22 Three Arguments the Future is *not* Predetermined

(22.1) state-vector collapse in quantum mechanics is random (to within the relevant probabilities).

(22.2) quantum statistics in Bell experiments: Suppose there are two entangled electrons. Suppose Alice chooses of her free will the orientation of her detector and measures the orientation of the spin of the electron that goes through her Stern-Gerlach device. Suppose Bob then (sufficiently after Alice) chooses of his free will the orientation of the detector 'behind' his Stern-Gerlach device and measures the orientation of the spin of the electron that goes through this device, at an event that is space-like separated from Alice's choice and measurement outcome. One expects the classical correlations in experiments. But one gets *greater-than-classical* correlations, namely the quantum correlations.

Suppose the statistics of this (entangled) pair of electrons, even if up only to stochasticity, is a function of events/processes in the intersection of their past lightcones. Extrapolating backward, one obviously gets to the big bang. This, super-determinism, establishes all correlations in the universe at the big bang. But then why don't we see *greater-than-quantum* correlations? ... Certainly, there would be correlations up to 100% in the long-run statistics. But we *never* observe such greater-than-quantum

correlations, only quantum correlations. Therefore, the observed statistics of the universe are not consistent with the theory of super-determinism. Instead, they are consistent with free will.

(22.3) free will in some philosophical senses: these are already persuasive to many researchers (SEP 2020b).

23 Counterfactuals

There is the issue of counterfactuals. If Alice closes the box when the cat is purring, and the cat is purring when she opens the box, then it's not clear why the intermediate quantum state should depend on the counter-factual [meowing>. In the AB-theory one might speculate there are two *future* states consistent with Alice's *present*, namely meowing and purring. Neither future state can be ruled out 'now'. (Recall the 'now' is the only A-series time at which the value of an experimental outcome is revealed to Alice.) So they can't be absolutely nothing, but they can't be factual, either. So it would seem that both future states, as regarded, 'now', have the nature of a counter-factual while the box is closed. This makes sense. While neither future state can be ruled out 'now', neither future state can be ruled in, either, in Alice's 'now'.

24 Maps

One wants to model, starting with time t , a map to the quantum state

$$\Psi(t) : \mathbb{R} \rightarrow \mathbb{C}^n \quad (27)$$

and, building on that, if possible, a map via the Born rule to the real value of an experimental outcome

$$|\Psi(t)|^2 : \mathbb{R} \rightarrow \mathbb{C}^{2n} \rightarrow \mathbb{R} \quad (28)$$

However instead of starting with a single real time variable, t , we now have a function g (which is just an example) such that

$$g(T, T') : \mathbb{C}^2 \rightarrow \mathbb{R} \quad (29)$$

But there's not enough information in \mathbb{C}^2 to model (28) and it treats T and T' on an equal footing. So one might try a function like

$$j(T_1 \times T', T_2 \times T', \dots, T_n \times T') : \mathbb{C}^{2n} \rightarrow \mathbb{R} \quad (30)$$

The Schrodinger equation can be written

$$i\hbar \frac{d}{dt} |\Psi(\tau)\rangle = \hat{H} |\Psi(\tau)\rangle \quad (31)$$

The first time variable in the left-hand side should be something like τ or perhaps the complete time $T(\tau, t)$ or even just t' . The second time variable, τ , in the left-hand side is apparently an A-series. The time variable τ in the right-hand side is also apparently an A-series. These are initial guesses. It's not

clear whether operator H itself is a function of just one A-series or something more, or nothing. Obviously this generalizes by relativist corrections, via perhaps through something like dT/idt' , a *different* example given by .

$$\hbar \frac{d}{dT} j = \hat{H}j \tag{32}$$

Of course the function j was just an exuberant example.

25 Bell

Suppose Alice and Bob are space-like separated and the pair of electrons goes to each of them and Alice decides on the orientation of her detector and then measures the spin of a relevant electron. Suppose Bob then does the same at a sufficient time after Alice. There is the well established notion that Alice can't send Bob a signal (about what spin he will eventually measure) faster than the speed of light. There is also the notion that when Alice measures her electron's spin, she immediately knows the spin of Bob's electron. But quantum mechanics says something more than this. It says Alice's result, for an angle chosen by Alice, will at least sometimes instantaneously affect the result that Bob will eventually measure, for the spin of his electron, at an angle chosen by him, and this effect can be non-local. Non-locality has been experimentally verified under satisfactorily weak assumptions (SEP 2019).

This instantaneousness is the condition $\tau = \tau' = 0$ for the future/present/past spectrum of Alice, τ , and the future/present/past spectrum of the pair of electrons, τ' . This is, in this particular case, not merely the assertion that τ and τ' have the same numerical value, but that Alice and the pair have the same A-series, including the same 'now'. But this means that the 'now' acts as a *non-local hidden variable*.

But not so fast. One could contend the variable is not actually 'hidden' at all and is in fact one of the most 'un-hidden' variables known to us, even more so than that there are objects existing outside one's mind (where the *thought* of an object is itself temporally situated). One might say it acts as a *non-local self-evident variable*.

The non-local move here is that the electrons do not have the same past 'before' observation. This dependence would have to be in Alice's *past* and equally in the pair's *past* but these pasts do not have simultaneous values. There is no fact of the matter 'when'—in Alice's A-series—the 'now' of the electrons are, if state is a function of their own A-series. From the ontological perspective of Alice, the electron-pair simply did not have the relevant properties *before* observation, and *vice versa*, because there was no unified notion of a 'now' in which to have physical properties.

26 Quantitative Agreement with Mermin's Example of Non-locality

We closely follow the exposition in (Wikipedia 2020d). Suppose that Alice describes—so to speak—and electron-pair as being in state

$$[\Psi\rangle = c_1 [01\rangle + c_2 [10\rangle \tag{23}$$

This form presupposes a basis but $[\Psi\rangle$ can be written in the basis of any relevant spatial orientation.

Suppose now that Alice's and Bob's detectors are at π rad relative to each other. Then when they measure the spins they will get a 100% correlation. For a second experiment suppose that after the electrons are fired but before the spins are measured Alice turns her detector by $\theta = 1$ rad. The correlation of the spins will be less than 100% by some small amount f_1 . For a third experiment suppose Alice does the same as in the second experiment and Bob does the same as Alice but rotates his detector in the opposite way from Alice by 1 rad from the anti-aligned detector position. Then if the electron pair had spins before observation by Alice and Bob we would have a maximum deviation of $2 \times (\theta \text{ deviation}) = 2f_1$ for the local case.

But in the AB-time theory it is trivial to violate this. The electrons do not possess definite spins for Alice nor Bob until their A-series become one, i.e. until mutual observation the pair system with the Alice-or-Bob system. Thus there is a 2 rad deviation from the anti-aligned detectors at the observations and not two 1 rad deviations. Before observation there is no universal 'now' in which the 1 rad rotations have taken place. We could choose any function we want because we are talking about the correlation at 2 rad and not two correlations at 1 rad. We may take the deviation at 2 rad to be $f_2 = (2\theta)^2 = 4f_1$. But we have just argued that the classical case has a maximum violation of $2f_1$. In fact f_2 is the value given by quantum mechanics. QED.

27 Change in Entropy as a Function of the A-series and B-series

For the entropy, S , of a system the second law of thermodynamics may be stated (SEP 2009)

$$\Delta S = \frac{dS}{dt} \geq 0 \tag{24}$$

In this equation the variable t is a B-series. This is the change in entropy with respect to earlier times going to later times in the case of increasing t . We are led to the question of what happens when changes are defined with respect to the A-series.

One could define quantities $\text{Entropy}_t(t)$, $\text{Entropy}_\tau(\tau)$, and $\text{Entropy}_T(T)$. Informally speaking, one has

$$\text{increasing Entropy}_t(t) \leftrightarrow \text{increasing } t \tag{25}$$

(SEP 2009) which suggests

$$\text{decreasing Entropy}_\tau(\tau) \leftrightarrow \text{decreasing } \tau \tag{26}$$

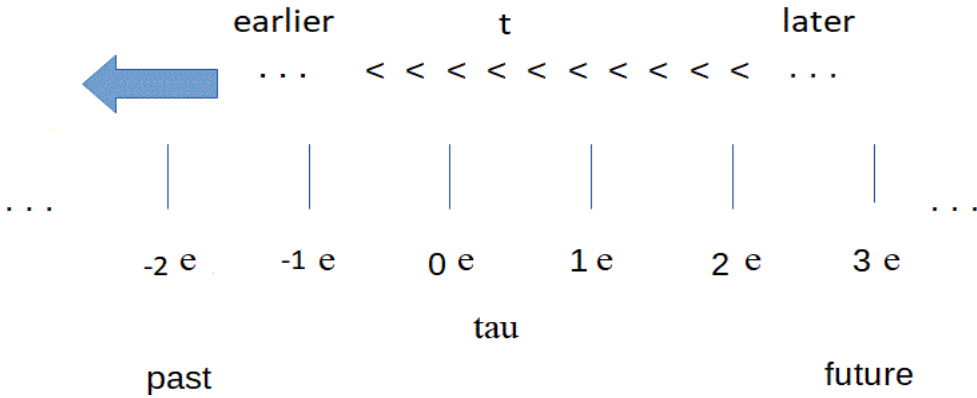
where (26) says the A-series entropy of a system decreases as the system 'becomes' from the future through the present into the past. That could be because, for some system, there are more future microstates that could eventually become present, that are consistent with the microstates of the present, than there are present microstates states that are consistent with the present.

An interesting condition is

$$\frac{d\text{Entropy}_T(T)}{dT} = 0 \tag{27}$$

To reiterate, we have:

Figure 8



As later and later B-series times 'become' from the future into the present and then into the past in the A-series, time goes on.

Times in the B-series get later-than to the right and therefore increase in seconds to the right, but the A-series moves the whole B-series (in es) to the left. It will be assumed that the series have been coordinatized so that the size of 1 second is the same size as 1 e: an event that is 1 second later-than, when it becomes, becomes 1 e further into the present from the future or 1 e further into the past from the present. Thus

$$\frac{dt}{d\tau} = -1 \frac{\text{sec.}}{e} \tag{28}$$

This says the rate of change of earlier times to later times of the B-series, in terms of the 'becoming' of the A-series, for each system, is -1 sec/e. This is *contra* eq. (17).

Given equation (28) we could also consider

$$\Delta S = \frac{dS}{dt} + \frac{dS}{d\tau} = \frac{dS}{dt} - \frac{dS}{dt} = 0 \tag{29}$$

This says the total change in entropy with respect to t and τ is 0. But these are only two possible definitions for change in entropy.

28 Open/closed Future and Past

(28.1) case 1: the future is pre-determined: given the present state of a system there is only one possible future, $f_{\text{pre-determined}}(\tau)$

(28.2) case 2: the future is not pre-determined: given the present state of a system there are multiple possible futures $f_i(\tau, \dots)$. It is argued case (2) is the more plausible case in section (22).

An experimental outcome is given only in the present. But in case (2) there may be many futures f_1, \dots, f_n that are compatible with the state of things in the present. There are many possible definitions of entropy of the future to be tried. Two of these are the sum of entropies at a future time (τ, t)

$$S_{future}(\tau, t) = \sum_1^n S(f_i(\tau, t)) \quad (29)$$

and there is the possibility that the entropy at a future time (τ, t) is a function of all of the futures at that (future) time at once:

$$S_{future}(\tau, t) = S(f_1(\tau, t), \dots, f_n(\tau, t)) \quad (30)$$

Exactly the same considerations apply to the past. Thus,

(28.3) case 3: the past is fixed: given the present state of a system there is only one possible past, $p_{past}(f_i(\tau, t))$.

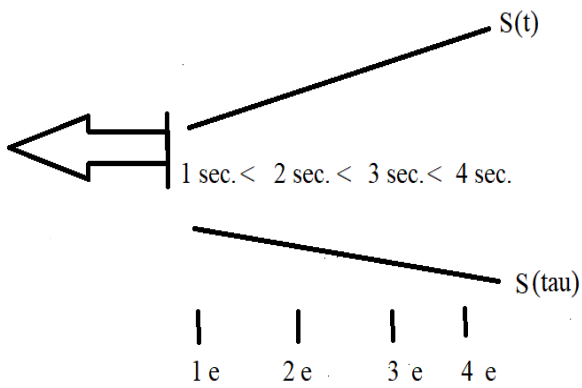
case 4: the past is not fixed: given the present state of a system there are multiple possible pasts, p_i

Case (4) is justified by the idea that experimental outcomes are given only in the present, and there may be many pasts that are consistent with the present state of things. For example, it may be that at some earlier time in the past the function $g = g(\tau, t, p)$, where p is momentum, is consistent with the present state of billiard balls on a pool table. But it might be that another function of another triple $g'(\tau', t', p')$ is also consistent with the present state of the balls, where g and g' are not compatible with each other (i.e. are not a part of the same history).

For example suppose the cue ball is in the middle of the pool table and we know that it got there by being hit (in the past) by a solid ball. Evidently, the solid ball could have come from *any* direction on the pool table, assuming of course it was hit hard enough and in the right direction from its (further in the past) initial position. There is no present or future experiment that could adjudicate the among the possibilities. Therefore it should be the case that we do not assume there is (now) just one past. Therefore there are multiple pasts that are consistent with the present. This is a challenge to the growing-block hypothesis.

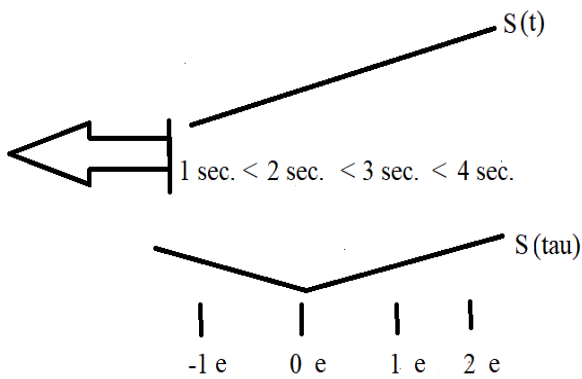
The physicist could try many functions. For example one can find functions such that qualitatively one has

Figure 9



where only t and $S(t)$ move (schematically), and they move to the left. And one can find functions such that qualitatively one has

Figure 10



where the present, $\tau = 0$, is a minimum for the A-series entropy, $S(\tau)$ (for a B-series interpretation see Carroll et al. 2004). Either of figures (9) or (10) could be found given the right function in either case (28) or in case (30).

The physicist might also consider equations like

$$\frac{d^2 S}{dt d\tau} = 0 \tag{31}$$

and

$$\frac{d^2 S}{d\tau dt} = 0 \tag{32}$$

It may be that (31) can be ruled out on ontological grounds. We differentiate with respect to the A-series variable τ first. This ends up giving us one A-series value for *each* of the B-series values t . But in this case the A-series, and therefore the present(s), is (are) not ontologically privileged. This rules out equation (31). This would justify further study at the intersection of philosophy and physics.

29 Past Hypothesis

The Past Hypothesis is the hypothesis that the universe started in a state of low entropy and the entropy has, on average, been increasing ever since (Carroll et al. 2005). This is a problem because—all else being equal—a state of low entropy is enormously less probable than a state of high entropy. Thus the beginning of the universe was enormously less probable than it should have been.

Given equation (27) or equation (29) the past hypothesis problem would possibly be solved in some sense. Here the A-series variable, τ , is related to how things could have been, *given the way they are* (in the present) and the B-series variable, t , is related to how things are, *given how they could have been* (in earlier times). This is an instance of 'two-dimensional semantics' (Chalmers 2007) and is also at the intersection of philosophy and physics. It may be that eq. (27) could help adjudicate between eq. (29) and eq. (30).

30 Big Bang

For any microscopic or macroscopic system Alice these are two different questions:

(30.1) how much *earlier* than now was the big bang?

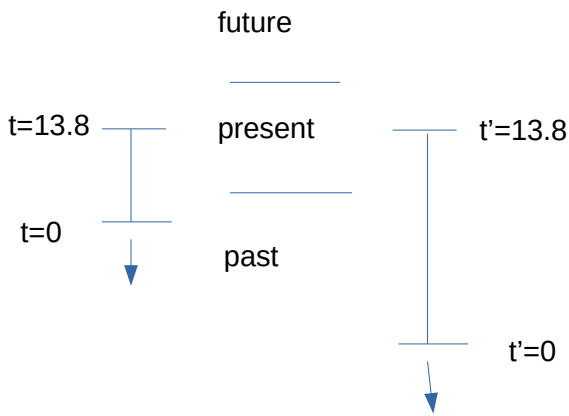
(30.2) how far in Alice's *past* is the big bang?

The big bang may be getting earlier than the present, but that need not be at the same rate as the big bang going into Alice's past. For the sake of argument let the big bang be at time $t = 0$ and the time in which we live $t = 14$ billion years. This means the big bang is 14 billion years *earlier than* now. It is not always necessary that $\tau = t$ (in appropriately scaled units of es and seconds, respectively). It may be possible that, for example, $\tau \rightarrow -\infty$, in which case Alice must go infinitely far *into her past* before getting to the big bang. This interpretation would be the best of both worlds. The big bang could be 14 billion before now (the B-series), but if one tried to go back through time into Alice's past, (the A-series), in some models, one never gets all the way to the big bang. Of course this bears on the question of whether there could have been a *first* moment of time.

1.1.4 the current time may be about 14 billion years *later than* the big bang. But why did the big bang not happen *further* in the past? For example, if the big bang happened instead 100 billion es further into the past than it actually did, then the current 'time', so far as we are concerned, could still be 14 billion years later than it. The big bang and the present could both be 100 billion es further into the past, keeping the B-series constant. There are thus two different time symmetries: one for t and one for τ .

Another scenario:

Figure 11



Supposing these B-series one at a time, in the B-series on the left the big bang is 13.8 billion years *earlier* than now. That is some particular distance in Alice's *past*. In the B-series on the right the big bang is also 13.8 billion years *earlier* than now, but it has gone further into Alice's *past*. There is the rate $r = dt/dt'$ which is or averages 0 in these scenarios.

31 Synopsis of the Theory of Time

31.01. The motivation for this theory is in (31.04). The A-series is the *future/present/past* series and includes *becoming* and is a different series for each different closed physical system, no matter how small. The B-series is the earlier-times to later-times ordering for each system.

31.02. *The mutual quantum observation of two systems of each other happens when and only when their respective A-series become the same A-series.*

This is not an *ad hoc* hypothesis but is the result of a philosophical exploration (see (31.04)).

31.03. In spite of the names and analogies it is *not* assumed that Alice or Bob or experimenter E or Schrodinger's Cat, Cat, are macroscopic or conscious (to a human extent). These are all merely stand-in names for any two closed systems including microscopic systems.

31.04. In Perspectival Dualist Panpsychism there is, for two different systems Alice and Bob, no ontic state that contains specific values of both Alice's qualia and Bob's qualia. This is the philosophical observation that, in this theory, there is simply *no fact of the matter* as to whether my subjective experience of 'red' is qualitatively the same as your subjective experience of 'red' when we each look at an apple that we each call 'red' ('spectrum inversion' or 'qualia inversion'). This is a somewhat common, but it might be argued, extremely robust observation. This is a 'perspectival' ontology. The A-series of a system is like (or is?) qualia. Thus the crux of this theory is to suppose there is no ontic state that contains specific values of both Alice's A-series and Bob's A-series in a single AB-spacetime, until mutual observation (measurement).

31.05. Take, for example, an experimenter, E, and Schrodinger's Cat, Cat. They do not share the same A-series while the experiment is underway (the 'now' of E is not the 'now' of Cat, and the 'becoming' of E is not the 'becoming' of Cat). Therefore during the experiment there is no time at which a contradiction in Cat's ascribed states (one by E and a different one by Cat) arises.

31.06. What might be called McTaggartian spacetime, or AB-spacetime, or A-spacetime, has the *five* coordinates τ , the position of an event in the future/present/past of a selected system, t , the position of the event with respect to the ordering of earlier-times to later-times (which is relative for space-like separated events), and the three space coordinates x^a . The *four* dimensions of Minkowski space, with its *one* dimension of time, t , is, in the viewpoint of this theory, outright incomplete. Also, Minkowski space from the point of view of our *experience* is, it could be argued, incomplete.

31.07. The B-series t is coordinatized by seconds, and the A-series τ is coordinatized by a unit of becoming e (e is not the electric charge in this paper).

31.08. Later and later times *become* from the selected system's future into its present and then into its past. This does not assume the future (or past) is fixed.

31.09. One may envision (micro) islands of AB-spacetimes whose interfaces are quantum-mechanical.

31.10. If Alice's A-series coordinate τ has a definite value then Bob's A-series coordinate τ'' does not have a definite value, and *vice versa*. This is the temporal analogy (equivalence?) to qualia in Perspectival Dualist Panpsychism and is the crux of this theory.

31.11. One may usefully define rates such as dx/dt , $dx/d\tau$, $dt/d\tau$, etc., where, for example, $dx/d\tau$ is the rate of change in position with respect to becoming from future into the present and then into the past in the A-series of the selected system, and has units of meters/ e .

31.12 There might be some metric on each island of AB-spacetime (here is just one example) such as (setting aside constants)

$$(\Delta s_{\text{AB-spacetime}})^2 = + \Delta\tau^2 - \Delta t^2 + \Delta x^2 + \Delta y^2 + \Delta z^2 \quad (33)$$

At the risk of belaboring a point, is worth reiterating that AB-spacetime has *five* not *four* coordinates.

31.13. It might be that there is an island of E and an island' of Cat, both from E's ontological perspective, and analogous islands, island'', island''' both from Cat's ontological perspective. It requires further study to see if these two islands—from within a chosen perspective—have the same metric signature. But the perspectives would still be comparable only via a quantum theory until mutual observation, in this theory.

31.14. The probability $\text{pr}(e_{A \text{ and } B})$ of the actualization of an event $e_{A \text{ and } B}$ when perspectives A and B come together is the probability of the event happening in perspective A, $\text{pr}(e_A)$ and the probability of that event happening from the perspective of B, $\text{pr}(e_B)$. Thus $\text{pr}(e_{A \text{ and } B}) = \text{pr}(e_A) \times \text{pr}(e_B)$.

31.15. The A-series variable τ and the B-series variable t can, depending on the situation, be varied independently. Therefore they cannot be the same temporal variable in all situations. Therefore any theory that aspires to be complete in some sense must account for both variables in one way or another.

31.16. The crux of this theory is (31.04) and leads directly to (31.02).

32 Other realist interpretations of quantum mechanics

It seems odd that two quantum systems would not share the same A-series, or the same 'now', until mutual observation. But, it could be argued, this is less odd than the notion that there is *no* 'now'--even for a particular selected microscopic system—which is one of the received implications of special relativity. Moreover, this proposal has a solid philosophical motivation, which, it might be argued, is in sharp contrast to the other realist interpretations of quantum mechanics on the table as of this writing (which I take to be Many-worlds, GRW, de Broglie-Bohm, and Retro-causality, (IEP 2020)).

Moreover, this encompasses an expression of the Copenhagen interpretation. Bohr: which measuring apparatus one is using must be specified in making predictions about an experiment (SEP 2019). In the theory of this paper, which measuring apparatus one is using must be specified because it must be specified which ontologically private A-series one is using to make predictions.

33 Conclusion

A Bell electron-pair does not take on the pair of values of spins 'until' Alice measures one of the electrons, and *visa versa*, because the A-series *past* of Alice is ontologically not the same as the A-series *past* of the electron system, *until* mutual measurement. In the theory of this paper, this 'until' is the point at which the A-series 'now' of Alice and the A-series 'now' of the electron-pair become one A-series 'now'. This, it could be argued, makes it almost trivially easy to get Bell inequality violations in the physics. Definite values together are not taken on *until* the two A-series become one and have a shared 'now'.

The AB-time interpretation might, optimistically speaking, be suspected of having a few virtues. It takes into account both the A-series and the B-series for each system. And it is motivated by being the implication of a plausible philosophical argument. Most importantly, in its current stage of development, it could be argued, it seems to be in agreement with macroscopic experience.

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