Fragmental Presentism and Quantum Mechanics

Abstract This paper develops a Fragmentalist theory of Presentism and shows how it can help to develop a interpretation of quantum mechanics. There are several fragmental interpretations of physics. In the interpretation of this paper, each quantum system forms a fragment, and fragment f1 makes a measurement on fragment f2 if and only if f2 makes a corresponding measurement on f1. The main idea is then that each fragment has its *own* present (or ‘now’) until a mutual quantum measurement—at which time they come (‘become’) to share the same ‘now’. The theory of time developed here will make use of both McTaggart’s A-series (in the form of future-present-past) and B-series (earlier-times to later-times). An example of an application is that a Bell pair of electrons does not take on definite spin values *until* measurement because the measuring system and the Bell pair do not share the same present (‘now’) until mutual quantum measurement, i.e. until they ‘become’ to share the same A-series. Before that point the ‘now’ of the opposing system is *not* in the reference system’s fragment. Relativistic no-signaling is preserved within each fragment, which will turn out to be sufficient for the general case. Several issues in the foundations of quantum mechanics are canvassed, including Schrodinger’s cat, the Born rule, modifications to Minkowski space that accommodate both the A-series and the B-series, and entropy.

1 Introduction and Outline

This interpretation of quantum mechanics and the resolution of the measurement problem are well-known problems. This paper presents a new possible solution to these problems. It might be called “Fragmental Presentism”, but this name requires elaboration.

There are several notions of “Fragmental” physics in use. In (2005) Fine introduced the notion of fragmentalism. The idea is that reality is divided up into fragments. One way to put this is to say that states-of-affairs in different fragments may be incompatible with each other. What is true in one fragment need not be true in another fragment. Reality is ‘divided up’ into various fragments in some ontological sense.

In Fine’s original fragmentalism, it is supposed that different relativistic frames of reference form different fragments, so that what is true in the frame of reference of one relative velocity is not necessarily true in the frame of reference of another relative velocity. This is not the notion of fragmentalism applied in this paper.

Another notion of fragmentalism is to apply to quantum mechanics in the follow sense. If Schrodinger’s Cat is in the state

[psi> = [alive> + [dead> (1)

then the basis vectors [alive> and [dead> form two different fragments. This is problematic, as (Iaquinto et al. 2020) argues. It is not that each vector forms a fragment, since in the fragment of the reference system the state of the cat is the *one* vector [psi>, whose definition happens to be given in terms of the two basis vectors. This is also not the notion of fragmentalism applied in this paper.

The notion of this paper is that each quantum system forms a fragment. Each fragment has its own A-series. A mutual quantum measurement happens when and only when the A-series of the two systems become one A-series of the combined system.

What is true in one fragment need not be true in another fragment. For example, to an experimenter Alice outside the box of the Cat experiment, the reality of the Cat is that it is in the one state [psi>. Nevertheless, the reality of the Cat for the cat itself is that it is in either state ‘alive’ or else state ‘dead’. There is no contradiction because Alice and the Cat form two different fragments, so the state of the cat does not have to be adjudicated *in a present*. In other words, there is no single ‘now’ at which time the state of the Cat must be adjudicated before mutual quantum measurement. The state of the Cat only has to be consistent at the *time* of measurement, not before. There is a great deal more to be said about this, but that is the purpose of the rest of the paper.

There is also a notion of “Perspectival A-series”. The idea here is that each position in the A-series is its own *perspective*, and these divide up the A-series, in an attempt to get rid of the “super-times” problem. (Lowe 1987). It is not necessary to go into the details of this class of ideas, except to say it is not the fragmentalism of this paper either (though in fact they are compatible).

In 1908 Minkowski 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 (future/present/past) and the B-series (earlier-times to later-times) (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 insights. The theory in this paper probes one possible attempt at such a union and explores its implied interpretation of quantum mechanics.[1].

To start with, we will take the invariant on Minkowski space to be given by

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

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.

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 with the understanding that one dimension of time in this paper involves both the A-series and the B-series.

Perhaps the most acute problem for presentism is that relativity seems to be inconsistent with a universal ‘now’. This will be handled by supposing there is a ‘universal ‘now’’ only with respect to

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

each quantum system (i.e. each fragment). The ‘now’ of each fragment extends throughout space and (it will be seen) accommodates relativistic effects, but does not include the ‘now’ of other fragments.

Suppose Alice is standing at a train station and Bob is standing in a train that is moving past the train station. Then for most orientations the pairs of events that are simultaneous in Alice’s frame of reference are not the pairs of events that are simultaneous in Bob’s frame of reference. One tends to jump to the conclusion that there is, in addition, no ‘now’ because that would seem to require a pair of events that is simultaneous in one reference frame to be simultaneous in all reference frames. But, using the freedom that two temporal series and fragmentalism gives us, that conclusion does not hold in this theory.

It will transpire that a specific ‘now’ in Alice’s (where ‘Alice’ could be microscopic or non-local) ontological perspective implies there is *no* specific temporal value of a ‘now’ for Bob, though the relativity of simultaneity obtains for Alice from within her fragment. And *vice versa*.

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 is less odd than the received implication of special relativity that there is no ontologically privileged ‘now’ at all.

This accords with the actual relativistic thought experiment. At a given ‘now’ Alice has it that the train is going by in (her) Minkowski space (i.e in her fragment), in which a unique global ‘now’ *of Bob* cannot be defined. And *vice versa*.

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

The plan of the paper is as follows

2 Fragmental Panpsychism

One significant virtue of the interpretation of quantum mechanics of this paper is that it is independently philosophically motivated in the sense that the philosophy implies the interpretation and not the reverse (see section 20 Realsit..). This philosophy of this section is not meant to argue that one must be a panpsychist or that things in this theory are as easy to model as a Newtonian point particle in 3-d Euclidean space. Instead it is meant to give an important motivation for a theory of time that leads to a realist fragmentalist interpretation of quantum mechanics.

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 protons 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 lead to the hypothesis of Panpsychism, for example that an electron is accompanied by a quale—a subjective experience—for example, the color green, and perhaps a proton is accompanied by a blue quale. There has been an impressive amount written about this and cognate ideas but the basic idea is clear enough and is called (Dualist) Panpsychism. (Robinson 2017, Goff et al. 2020). (The idea of other correlates to qualia such as complexity or entropy could be entertained.)

Qualia are not a *theory*.[2] Reading about qualia and the concepts of structure this reading elicits does not help one apprehend (and thereby understand) qualia 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 the area of interpretations of quantum mechanics should lie outside the physicist's mainstream conceptual toolkit, since otherwise the interpretation—to the extent it is an advance—would have been put forward already, surely.

"Oh, how could we all have been so blind, so long!""

Wheeler (1990)

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2 To the scientist who is 'sure' there are no qualia, I might suggest that, starting from 1st grade, it takes 15 years of studying math and physics to get to the Schrodinger equation, and ask for how many years has he or she been meditating and solving (not merely reading about) Zen koans? There is an 'internal' technology required to get an accurate understanding of qualia that is analogous to the mathematical technology required to understand the Schrodinger equation, and things cannot be made simpler than that.

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 (or experience) for sure if the qualia that arise in your mind are what I would call green, and *vice versa*. In fact, I *can’t* know (experience), so this observation has ontological import. This is a kind of Fragmentalism.

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, via Panpsychism, migrate this observation to each physical closed system, no matter how microscopic or non-local. This might be called “Fragmental Panpsychism” where there is no fact of the matter as to whether the qualia associated with one system (and one fragment) are the same (qualitatively) as the qualia associated with another system (and its fragment). The point is there is no ontological state that encompasses both. And in this case there is no fact of the matter as to whether they ‘actually are’ the same. If they were both ‘actual’ from every perspective then they would be part of the same ontic state *ipso facto*, but they are not.

We want to generalize this a little bit. Suppose Alice and Bob 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 color 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 *vice versa*. We could therefore say this color-parameter is 'ontologically private' (Byrne 2020).

The noun “5 inches” uniquely determines an actual length with respect to a chosen coordinate origin in the actual world for multiple people. The noun “green quale” does *not* uniquely determine qualia in the actual world for multiple people. They are ineffable (Tye 2018). This doesn’t mean science cannot deal with irreducibly 1st-person phenomena, it just means science has to deal with them differently than 3rd-person phenomena. The strategy of this paper is ontological perspectivalism.

The theory of time probed in this paper posits that the A-series characteristics of time are ontologically private. A consequence would be that, for example, 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—it could be argued—more plausible than the conclusion that the ‘now’ does not exist at all, as in the received interpretation of relativity.

Is time qualia or merely similar to qualia? (Berg 2010, Farr 2020, Smolin 2015, Wheeler 2020, Beyer 2020, Husserl (...)) This paper will not attempt to adjudicate the issue.[3] The question seems to be whether epistemic apprehension of time presupposes ontological time in some sense. See (Chalmers 2007).

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3 It is surely not a coincidence that qualia and the A-series ‘present’ can be thought of as ‘modes of presentation’. (Tye 2018, Zimmerman 2005). (However, the theory of this paper is not committed to that particular description.)

One desires ontological parsimony. The point, in this theory, is there in no ontic state that includes both Alice's qualia (and therefore her A-series) and Bob's qualia (and therefore his A-series) simultaneously. So that result should be in the ontology, if possible.

Note Dualism is not an endpoint: there is Idealism, Monism, etc. (Chalmers 2019).

> "It's a very outrageous thing I'm saying. I'm saying that what is going on in our brains, which is making us conscious, is going beyond current physics. It's not outside physics, it's outside *current* physics." (Penrose 2021).

3 Note on Qualia and Tense

1. Philosophers have developed many temporal logics which have A-series tensed terms and B-series untensed terms (Goranko et al. 2020). Philosophers have also developed many quantum logics which purport to capture the logic of quantum mechanics (Wilce 2017). It remains to be seen if a quantum logic can be recovered from a fragmental temporal logic.

Of course, not every realization of a quantum logic is a relevant candidate. For example, for the set of propositions in a Hilbert space one finds non-distributive ortho-modular lattices (Pavicic 1999). But some of these lattices arise from modeling incompatible measurements. We are also concerned with incompatible *beables*, where 'to be' means 'to be' *at a given time*.

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

$$\Diamond P \rightarrow P \tag{3}$$

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. Analogously one might suspect this is true of qualia and false of their physical correlates (Chalmers 2007).[4]

4 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 to 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 with realist interpretations in this paper).

5 Fragmental Ontology

4 Famously, Nagel (1974) defined "an organism has conscious mental states [i.e.. qualia] if and only if there is *something that it is like* to *be* that organism—*something it is like for* the organism." [some emphasis added.] Thus suggests the idea that a physical system has an A-series associated with it if and only if there is *something it is like* for that system to be in a 'present' and to experience 'becoming'. (This would not necessarily be a proof there is an A-series (in light of the ongoing mind-body discussion), but one suggestion for its criterion.)

We do not assume that any of these systems are macroscopic or conscious to the extent humans are or local. Fragmental panpsychism is non-anthropomorphic in the sense that not only are human brains related to consciousness (and thus the A-series) but every closed physical system *whatsoever* (no matter how simple or non-local) has as part of its ontology ‘consciousness’ to the extent that that is required for the Presentist A-theory of this paper.

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 an experimenter-system E on a quantum system Cat is in fact a *mutual* measurement-interaction between E and Cat. This is broadly similar to several other 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, in obvious notation, for an experimenter E, Schrodinger’s Cat is in the state

$$\left|\Psi\right\rangle = c_1\left|\text{will find cat purring}\right\rangle + c_2\left|\text{will find cat meowing}\right\rangle \tag{4}$$

in a Hilbert space H.[5] 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.

Therefore, from the perspective of the Cat-system, E is in an analogous state

$$\left|\Psi''\right\rangle'' = c_3\left|\text{will find E that finds cat purring}\right\rangle'' + c_4\left|\text{will find E that finds cat meowing}\right\rangle'' \tag{5}$$

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

$$|c_3|^2 = |c_1|^2 \text{ and } |c_4|^2 = |c_2|^2 \tag{6}$$

The state-vector [Ψ> collapses upon observation of Cat by E, and equivalently the state-vector [Ψ">" 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.

6 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

5 Where it’s assumed that if the cat is meowing it stays meowing and if the cat is purring it stays purring in the relevant senses.

> 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 [for time-like separated events] 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' *now* and *becoming*. In contrast to the B-series, the A-series values change in some sense. The B-series allows going 'backward in time' and the A-series does not, to be discussed below.

'I'll meet you 2 hours after 4 o'clock'. 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. In this theory of time, instead of asserting

1. 'time goes from past to present to future'

as is often done, it would be more appropriate to assert

2. '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 sometimes call the AB-series, denoting that a single dimension of time has both A-series and B-series characteristics, in a way that care will be taken to make it consistent with relativity (Monton 2009). As noted, the ideas here are related in various ways to those of Fragmentalism, Relationalism, and Perspectivalism (Fine 2005, Rovelli 2019, Dieks 2019).[6] 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 (see below), while retaining the ontologically public (but relativized) 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.

6 In the philosophy of time, time is sometimes argued to be 'perspectival' in the sense that each moment in the A-series constitutes its own perspective. (Ludlow 2016).

7 Definitions and Rates

Let’s start at another beginning. 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 it 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 temporal becoming, as a kind of standardized place holder, whatever kind of creature it is. Let τ be the future-present-past spectrum. The idea will be *e* coordinatizes τ.

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

Define

7.1 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 for each τ for a system. 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 (or past) than the usual *e*s. The physically significant stuff should be invariant under these changes.

Define

$$r \text{ sec.}/e = \text{d(Alice's B-series)/d(Alice's A-series)} \qquad (7)$$

is the change in 1 second of indexical clock time per change in *e*, for Alice, in Alice’s fragment. For example, the position of a particle at 1 second *later than* $t = 0$ is also 1 *e* closer to the present from the future (or further into the past from the present) relative to some event for the ‘flat’ case of AB-spacetime with the obvious coordinitazition.

Consider the rate $r = 2$ 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 seconds/*e*. (These rates will be revised later.) The general idea is then

$r > 1$ 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 each panpsychist system, 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 goes by slowed down.

$r = 0$ B-series time appears stopped (but the *appearance* goes on as usual in the A-series)

$r < 0$ time appears (from future to present to past) to be going backward in B-series time, i.e. later times to earlier times, e.g. time-reversal, or watching the movie go backward.

One may define (for example) d*r*/d*e* which would have something to do with the rate of becoming accelerating through the A-series. 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(τ, t) and c_1's time be give by T'(τ', t'). c_2 runs slower than c_1. So

$$dt/dt' < 1 \text{ sec./sec.'} \qquad (8)$$

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

$$dt/d\tau = 1 \text{ sec.}/e \quad \text{(this will be revised to -1 below),} \qquad dt'/d\tau' = 1 \text{ sec.'}/e' \qquad (9)$$

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

$$dt/d\tau' < 1, \qquad dt'/d\tau > 1 \qquad (10)$$

And one could try to compute

$$dT'/dT \qquad (11)$$

but one has to be careful as it seems (10) and (11) put the ontologically private 'total times' T and T' on an equal footing—though might be definable without the Inverted Spectrum (quantum) properties of the respective A-series.

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/dτ, 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 *e*s. (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 sec./e, necessitating a revision of the rates above. (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.)

To reiterate, 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 clock-time when the announcer says '10'. When the announcer says '9' this means the liftoff, if it is going to happen, is 9 e *in the future* of the control center. However, the beginning of the countdown is still 10 seconds *later than* the liftoff—it's just that 1 second has receded 1 e into the past.

We would say '3 *minutes* later than 2 pm' but, supposing it is 'now' 2 pm, we wouldn't say '3 *minutes* in the future of 'now'', instead we mean '3 *e* in the future of 'now''.

In high school we learn to plot the position x of a classical point-particle as a function of time, i.e. we plot x(t). But here t is a B-series. Assume for the sake of argument we omit the Spectrum Inversion aspects of the A-series and the multiple-futures/pasts of the A-series. Then we can also plot x(τ) where τ is an A-series. In this case x(5) means the position x at 5 *e* in the future (which might be wholly or partially in the present given the Presentism Function, see below). x(0.1) means the position x at 0.1 *e* in the future(/present). x(-2) means the position at 2 *e* in the past(/present). Thus with the more complete notion of time we want to plot x(τ, t), or x(T(τ, t)).

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(τ). 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 value on of the paper.

If a clock 'slows down' as it falls into a black hole, from our viewpoint, then the rate r = [sec.'/*e*] decreases in magnitude.

8 McTaggart (1908) meets Minkowski (1908),

In Minkowski space there are 4 dimensions and its invariant is given in a metric 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 (in one interpretation) which here will be associated with each quantum system no matter how small or non-local, 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* parameters and not *four* as in the case of Minkowski space.

8.1 If the sun suddenly went out 'now' we wouldn't get its effects here on earth for about 8 minutes. 8 minutes compared to what? Both the A-series 'now' and the current B-series clock-time.

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

8.3 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 relative to 'now' that the movie has been posted.

8.4 On many streaming menus there is a line representing 'now' and horizontally extended schedules of shows which characterize the relevant B-series.

It is crucial 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.

The B-series is like space in that t is in seconds and x is in meters, but in light of the speed of light c being a conversion factor in some circumstances, the time t can be measured in meters [ref.] (special relativity). So in some important ways the B-series is like space. Thus it is the A-series aspect of time that is not like space. The A-series is measured in units of *e*s and not in units of seconds (or meters). There is the question of what is, if there is one, a (variable?) conversion factor from *es* to meters. Since the 'now' is non-local it could be infinite.

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' (note 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.

9 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 first by the B-series of the respective systems, though with further development it could turn out that both the A-series and the B-series are involved in some specific ways, in addition to the spatial coordinates, among the transformations in these coordinates.

Who was right in this theory: Heraclitus or Parmenides? Ans: *both* are needed. There are *two* series that characterize *one* dimension of time: one Heraclitian (the A-series) and one Parmenidean (the B-series).

One possibility, explored below, is that the movement of the B-series past the A-series is given by an operator (an operator that is not a static map but irreducibly *operates*). This operation, which operates at mutual measurement, apparently corresponds in some way to an operator operating on a state in quantum mechanics.

10 Simultaneity versus the Present

10.1 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.

In other words, suppose this alien moves around the Andromeda galaxy. Depending on how it moves, the alien's plane of simultaneity may be (in the Milky Way, here on earth) earlier-than or later-than some chosen coordinate origin. But that does not prevent us from seeming to exist in a unique ontologically privileged 'now'

10.2 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 we do not find ourselves to be in multiple presents *and* having multiple presents would violate its (the present’s) ontological privilege. So the presentist does not have the option of equating simultaneity and the present available.

11 A Mathematical model 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 fully future or the fully 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.

Suppose we equate 'the present' with 'existing'. Then, 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).

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.

12 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.

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

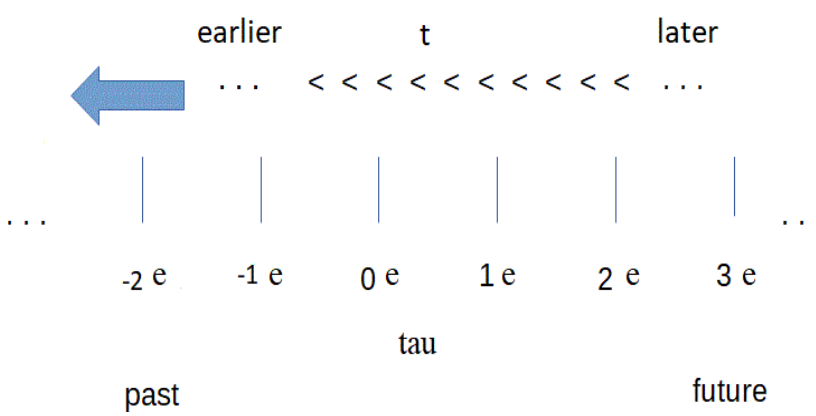
The theory of time of this paper posits that unitary evolution applies when two systems do not share the same A-series, and a mutual quantum measurement applies when the two systems come to (or 'become to') share the same A-series.

In fact, the ‘dual’ solution to the black hole paradox (Susskind…) requires two different quatum descriptions—one from the outside and one on the surface of the black hole. This would seem to be an argument for fragmentalism.

13 Figures

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

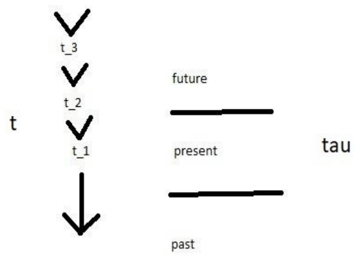
Figure 1



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.

Figure 2

This is another model

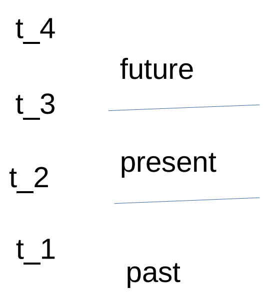


t_1 is earlier than t_2 which is earlier than t_3... The earlier-times to later-times timeline stays in one ordering (of one kind or another), but the whole timeline moves from future to present to past, with the present staying put. (The present does not 'move up the B-series' as in some spotlight theories because *ipso facto* the presents wouldn't be ontologically privileged.) As later and later B-series times become present, time goes on.

The arrows in the figures above are probably given by an operators, in light of sections below. Obviously these would have something to do with the operators in quantum mechanics

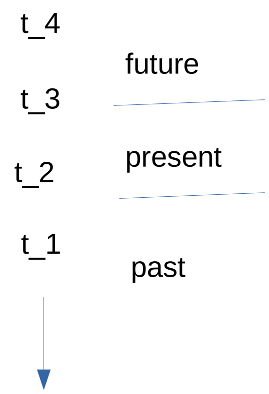
Toward justifying the figures. One cannot say there is a 'now' in one location on the B-series and there is a different 'now' somewhere else on the B-series because then neither 'now' would be ontologically privileged *ipso facto*. Ontological privilege implies there is only *one* 'now'. Yet since there is only one 'now' different 'times' would require different locations on the B-series.

Figure 3



There should be a way to represent the A-series 'becoming'. The B-series doesn't change (on time-like separated events). 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

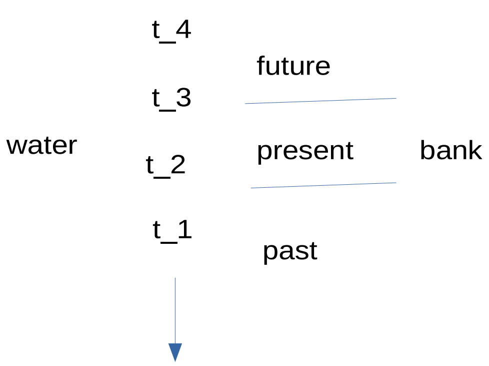
Figure 4



This accords with experience.

Heraclitus’ river metaphor may be diagrammed as

Figure 5



There is the problem of ‘super-time’. One can represent 1-d space on a horizontal x-axis, and 1-d time on a vertical axis, and motion through this space-time as a curve on the t-x plane. But, having represented time as a static mathematical axis, we seem to have lost something. We’ve lost the genuine ‘motion’ or ‘becoming’ or ‘unique present’ that we were trying to capture about time. Thus one must have a point that ‘goes’ up the time axis. But to do this, the point must move in a kind of ‘super-time’--one in which the point moves up the original time axis. But then we can represent this super-time on its own axis. But this axis is also a static mathematical object. So to get real motion we need a super-super-time and… and we have an infinite regress.

But if the actual movement of the B-series going past the A-series is modeled by an operator we don't have to get lost in the infinite regress of super-times (Romero 2012), because an operator is not merely a map but *operates*.

14 Time T(τ, t)

This is not a theory of two time dimensions but one time dimension for each system that has two closely related parameters τ and t, such that the 'total' time T is given by T(τ, t). τ is how far in the future an event is and t is how much later than an event is, in the coordinates of 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(τ, t) and three dimensions of space the flat Euclidean metric is given by

$$ds^2 = dT^2(\tau, t) + \sum_{i=1}^{3} dx_i^2 \qquad (12)$$

Any experimental outcome is revealed to Alice only in her present. (You cannot *demonstrate* an experimental outcome to me that is in my future or in my past.) Alice's present (or at least the center of it) is the condition τ = 0. (The general condition of course uses the presentism function p(τ) 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

$$ds^2 = dT^2(0, t) + \sum_{i=1}^{3} dx_i^2 = -dt^2 + \sum_{i=1}^{3} dx_i^2 \qquad (13)$$

which imply

$$dT(0, t) = i dt \qquad (14)$$

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. But 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 not the same condition that the event is in both presents, which would be the condition τ = τ' in appropriately scaled units (of e and e' respectively). The latter condition cannot be given in the A-series coordinates of two different fragments.

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.

No-signaling in one fragment is sufficient for no-signaling in general because the EPR criterion for reality does not hold in this fragmental quantum mechanics. No-signaling in one fragment implies no-signaling in a measuring fragment with probability 1 even though this does not imply the reality of the signal in both fragments before measurement.

It is reasonable to suppose that relativistic no-signaling, together with the particular strength of quantum correlations between space-like separated measurements, give quantitative relationships between respective A-series and B-series.

15 $M^5 \times M^5$?

This section is somewhat speculative.

But not so fast. It is the *interface* of AB-spacetimes from two ontologically distinct *fragments,* 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)

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

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

and

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

(15.4) E's 5-dimensional AB-spacetime (τ''', 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, alternately, in the future of Cat.

Thus in E's ontological perspective there are in some sense two AB-spacetimes, the first one (15.1) and the second one (15.2). On the other hand, in Cat's ontological perspective, there are in some sense also two AB-spacetimes (15.3) and (15.4). So we would expect (15.1) and (15.2)) on the one hand to be quantum mechanically related to ((15.3) and (15.4)) on the other hand.

What are the (not all independent) 64 (possibly stochastic) relationships between the 8 variables (τ, t, τ', t', τ'', t'', τ''', 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)

$$\Delta s_{\text{AB-spacetime}}^2 \text{ (at } \tau = 0) = \Delta s_{\text{Minkowski-spacetime}}^2 = -\Delta t^2 + \Delta x^2 + \Delta y^2 + \Delta z^2 \qquad (15)$$

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

$$\Delta s_{AB\text{-spacetime}}{}^2 = + \Delta\tau^2 - \Delta t^2 + \Delta x^2 + \Delta y^2 + \Delta z^2 \tag{16}$$

And suppose

$$\Delta t' = i\Delta t \tag{17}$$

Then

$$\Delta s'_{AB\text{-spacetime}}{}^2 = + \Delta\tau'^2 + \Delta t'^2 + \Delta x'^2 + \Delta y'^2 + \Delta z'^2 \tag{18}$$

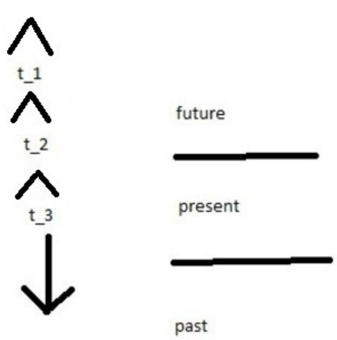
Then, where (16) gives an AdS_5 space (for E's AB-spacetime in E's fragment) in the coordinates (τ, t, x, y, z), and (18) gives an S^5 space (for Cat's AB-spacetime also in E's fragment) in the coordinates (τ', t', x', y', z'). The same geometry clearly obtains for the two AB-spacetimes in Cat's fragment, in the coordinates (τ'', t'', x'', y'', z'') and the coordinates (τ''', t''', x''', y''', z'''), respectively.

There is simply *no fact of the matter* as to the A-series state of a relatively-quantum system in the AB-series spacetime of a reference system 'until' the reference system and the relatively-quantum system 'become' to share the same A-series. This is equal to (or in exact analogy to) how it is that there is *no fact of the matter* as to whether you and I experience the qualitatively same 'green'. Each AB-spacetime requires at least *five* parameters.

16 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 in some sense 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.

There is a time-reversal

$$(\tau, t) \rightarrow (\tau, -t) \tag{19}$$

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:

$$(\tau, t) \rightarrow (-\tau, t) \tag{20}$$

$$(\tau, t) \rightarrow (-\tau, -t) \tag{21}$$

except at τ=0 (as the evolutions in the graphs are path-connected at $\tau = 0$) (or its generalization given by the presentism function p(τ) (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.)

17 Ontological Models

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 ontic state a system is in uniquely, so in the Ontological Models framework (OM) one associates quantum state with a distribution D over all ontic states (Harrigan et al. 2010, Leifer 2014). In the traditional OM framework the ontic states have been 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-fragmental 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 or non-local system.

This is an ontic interpretation of the 'knowledge-restriction' model (Spekkens 2005).

> "What kind of theory would be appropriate for an agent living in a world that is essentially classical but where there is a fundamental restriction on how much knowledge can be acquired about the physical state of any system? Formalizing such a restriction, one can define several toy theories that are found to have a rich structure similar to that of quantum theory, including a notion of coherent superposition and entanglement. These theories are also found to have analogues of a wide variety of quantum phenomena, such as complementarity, interference, teleportation, no-cloning, and many quantum cryptographic and communication protocols. The diversity and quality of these analogies provides compelling evidence for the view that quantum states are not states of reality -- as most interpretations suggest -- but rather states of knowledge that are incomplete (and cannot be completed). The question ``what is the nature of the reality to which this knowledge refers?" remains open in this research program..."

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 half of the total information. It could be argued this theory is psi-epistemic *and* psi-ontic.

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

18 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 (different fragments). 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 the 'same' green? Let's instead use the example where Bob sees (what Alice would concur is) 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, so there is no probability distribution over one. Instead there is the probability distribution over, for example, '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 $p_{objective}(\tau, t, \tau', t')$ be a probability distribution over the 4 time variables all construed as 'objective'. Let $p_{Alice\ fragment}(\tau, t, t')$ be a probability distribution over 3 temporal variables in Alice's fragment, and $p_{Bob\ fragment}(\tau', t', t)$ be a probability distribution over 3 temporal variables in Bob's fragment. It's conceivable that some functions of $p_{Alice\ fragment}$ and $p_{Bob\ fragment}$, that meet the requirements of being a probability distribution, could deviate from, or indeed not allow a corresponding model for, $p_{objective}$. (This is a calculational question.) If that were the case, there would be the hope of *experimentally* adjudicating between our being in an 'objective', or 'fragmental', 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? $p_{fragmental}$ (2, 3') = 1/12. What's $p_{fragmental}$(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.

This must be multiplied by the conditional probability from Bob's perspective, as there must be a consensus, as it were, from *both* fragments, that (2, 3') is the selected state.

One has

$$p_{fragmental} = p_{Alice}(3' \mid 2)\, p_{Bob}(2 \mid 3') = (1/4)(1/3) = 1/12 \qquad (22)$$

which is the same answer but *via* a different interpretation. In the case of $p_{objectival}$ we are choosing one pair, (2, 3') out of the 12 pairs (n, n'). In the case of $p_{fragmental}$ we are choosing one number for n' (i.e. 3') given n, i.e. n = 2, *and* choosing one number for m (i.e. 2) given m' (i.e. m' = 3'). We get the same answer and this holds for pairs that are not equi-probable.

19 Schrodinger's Cat

Finally we come to the stem ‘paradox’. I will assume the reader is in some sense already fluent with the Schrodinger's Cat paradox (Faye 2019). Suppose the experimenter is Alice. The traditional ‘paradox’ is that at some point (time) during the experiment, Alice describes the cat's state as a superposition, in obvious notation, [psi> = [meowing> + [purring>.[7] 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 during the experiment. But in this theory 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, equal to or exactly 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

$$f(\mathrm{T}(\tau, \mathrm{t}), \mathrm{T}'(\tau', \mathrm{t}')) \tag{23}$$

because it treats τ and τ' on an equal footing, up to T = T'. For the interesting function g, from Alice’s perspective, one may have

$$g(\mathrm{T}(\tau, \mathrm{t}), \mathrm{t}', \mathrm{T}(\tau, \mathrm{t})\ \tau') \tag{24}$$

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.)

20 Bell

Suppose Alice and Bob are space-like separated and a pair of entangled 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 orientation chosen by Alice, will at least sometimes instantaneously affect the result that Bob will eventually measure, for the spin of his electron, at the orientation chosen by him, and this effect

7 Obviously we are assuming that if the cat is meowing it remains meowing in its own perspective, and similarly for purring.

can be non-local. Non-locality has been experimentally verified under satisfactorily weak assumptions (Berkovitz 2019).

This instaneousness 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 variable*.

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 Alice and the electron pair become to share the same A-series, they share one parameter τ. This parameter is non-local in that for example positions $x(\tau, t)$, $x'(\tau, t')$ are both partially a function of the one parameter τ. Upon observation/measurement/collapse both systems come to share the same A-series, and it's irrelevant how far away something is 'now'.

The pair does 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 their state is a function of their own A-series before observation. 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.

Later, Bob comes to share the same A-series.

21 One example of non-locality

We closely follow the exposition in **(**Wikipedia 2020) for simplicity. Suppose that Alice, in obvious notation, describes—so to speak—and electron-pair as being in state

$$[\Psi> = c_1 [01> + c_2 [10> \qquad (25)$$

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

Suppose now that Alice's and Bob's detectors have the same relevant orientations. 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 oriented detector position. Then if the electron pair had spins before observation by Alice and Bob we would have a maximum deviation of 2 × (θ deviation) = $2f_1$ for the local case.

But in the AB-time theory it is almost trivial to violate this. The electrons do not posses definite spins for Alice nor Bob *until* their A-series become one, i.e. until mutual observation of the pair system with the Alice-or-Bob system. Thus there is a 2 rad deviation from alignment at the detectors and not two 1 rad deviations, when they finally achieve the same 'now' via a measurement interaction. Before observation there is no universal 'now' in which *both* the 1 rad rotations have taken place.

We can choose any function we want to here, 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.

22 Four 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 whichever electron it turns out 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 stochasticisity, 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 more correlations up to 100% in the long-run statistics. But we don't 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 (O'connor 2020).

(22.4) if free will were not causally efficacious then the subjective experience associated with a human brain would have been evolutionarily irrelevant. But then 'what it's like' to be a human should make no more sense than a subjective experience chosen *at random*.

23 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 factual, but they can't be completely out of the discussion, 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'.

An *actual* future state is a *possible* present state.

For a germane but alternative account of counterfactuals see (Shenker 2020).

This brings up the question: is the Schrodinger equation just the diffusion equation on future states?

24 Open/closed Future and Past

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

(24.2) case 2: the future is not pre-determined: given the present state of a system there are multiple possible futures $f_i(\tau,\ )$. 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, ..., 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)

$$S_{future}(\tau,t) = \sum_{1}^{n} S(f_i(\tau,t)) \tag{26}$$

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:

$$S_{future}(\tau,t) = S(f_1(\tau,t), ..., f_n(\tau,t)) \tag{27}$$

Exactly the same considerations apply to the past. Thus,

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

(24.4) 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 preset, 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(τ, 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'(τ', 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 (past)).

In other words, suppose the 8 ball is in the middle of the pool table and we know that it got there by being hit (in the past) by the cue 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* experiment that could adjudicate 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.

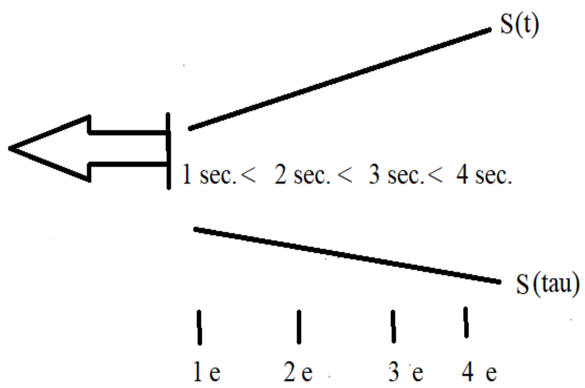
Indeed from an EPR-like thought-experiment Einstein et al. (Einstein et al. 1931) conclude

> "It is hence to be concluded that the principles of the quantum mechanics must involve an uncertainty in the description of past events which is analogous to the uncertainty in the prediction of future events."

Their thought-experiment is a powerful argument for presentism.

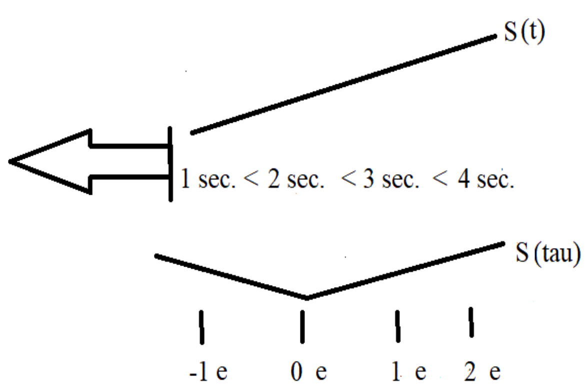
The physicist could try many functions. For example one can find functions such that qualitatively one has

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 (26) or in case (27).

The physicist might also consider equations like

$$\frac{d^2 S}{dt d\tau} = 0 \tag{28}$$

and

$$\frac{d^2 S}{d\tau dt} = 0 \tag{29}$$

It may be that (29) 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 (29). This would justify further study at the intersection of philosophy and physics.

25 An Inequality

Suppose there is a presentism function $p(\tau)$ in ontological fragment p_1. Then, in that fragment, the A-series spectrum τ' of another system can have any value (its '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 fragment of p_1. It is clear there is an inequality for the fragmental case here.

26 Partial derivation of the Born Rule

Consider two systems, Alice and Bob (which could microscopic, spatially extended, or etc...), and two possible outcomes of a measurement interaction, m_1 and m_2. Let the interaction be in the future of Alice's present. Let p_1 and p_2 be 'chances' in some sense (to be defined below) that the interaction produces outcome m_1 or m_2, respectively. A fragmental (quantum) interaction is not a measurement of Alice on herself, but an interaction between the two distinct systems Alice and Bob. Thus it would be unphysical to require that p_1 and p_2 sum to 1, as we would for probabilities in an 'objectival' complete set of outcomes. Instead we require that m_1 (or m_2) is achieved from *both* fragments, Alice *and* Bob. Let p_3 and p_4 be the 'chances' associated with the respective outcomes m_1 and m_2 in Bob's fragment.

Then, fragmentally, we can only require that the *product*

$$(p_1 + p_2)(p_3 + p_4) \tag{30}$$

sums to 1. This gives

$$p_1p_3 + p_1p_4 + p_2p_3 + p_2p_4 = 1 \tag{31}$$

We cannot have inconsistent measurements in the two fragments. If Alice gets outcome m_1 then Bob must get outcome m_1 also, and Bob must not get outcome m_2. Similarly, if Alice gets outcome m_2 then Bob must get outcome m_2 also, and Bob must not get outcome m_1. This implies that for the associated 'chances' p_1, p_2, p_3, p_4,

$$p_1p_4 = 0, \quad p_2p_3 = 0 \tag{32}$$

as these would correspond to different outcomes of the same interaction in the two fragments. Further, Alice and Bob make use of the same theory in describing the opposite system (quantum mechanics), so in the long-run statistics the outcome m_1 must be equally probable in both fragments, and similarly for outcome m_2. Thus

$$p_3 = p_1, \quad p_4 = p_2 \tag{33}$$

Applying eqs. (32) and (33) to eq. (31) we get

$$p_1^2 + p_2^2 = 1 \tag{34}$$

for the 'chances' p_1 and p_2 from Alice's perspective, and the analogous equation from Bob's perspective

$$p_3^2 + p_4^2 = 1 \tag{35}$$

This is how the Born probabilities for real numbers p_i can be derived in fragmentalism.

Of course Alice and Bob must agree on the measurement outcome upon mutual observation. But the fact that this derivation *uses* the fact that Alice and Bob must have the same outcome is a great virtue. For something as fundamental as the Born rule we would desire to use something fundamental in the derivation.

But (34) and (35) only constrain the p_i to be complex. If the p_i are associated with the future/past τ and the *later* t for Alice and the future/past τ' and the *earlier* t' for Bob then the p_i can be complex, and the revisions to the equations above would seem to give exactly the Born rule, the explication of which is left for later work.

Further, (34) and (35) generalize to more than two possible outcomes of a measurement interaction. They are generalizable to *n* possible outcomes provided there are only two fragments: the reference system A and the relatively-quantum system B (or, equivalently, the reference system B and the relatively-quantum system A). In for example a GHZ state it could be argued there are still only two such fragments and not four fragments (the reference system and the three quanta). In fact, this must be so because of the (irreducibly) quantum behavior of the three quanta together, in the fragment of the reference system. An additional argument is provided by the quantum behavior of Bell pairs.

Here is an attempt at such an explication. 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, $\tau = 0$. Experimental outcomes are given only in the present.

> "Nothing has happened in the past; it happened in the Now. Nothing will ever happen in the future; it will happen in the Now." (Tolle, 2004).

You cannot *demonstrate* to me an experimental outcome that is 5 minutes in both of our futures. The same holds for the past. It could be argued every scientist should be a presentist.

So we would seem to want the probability p (T_1(0, 0) and T_4 = (0, 0)) but that's not right since these two times are ontologically private. We want the probability (see figure 7)

$$p_{AB} = p_A(T_1 \rightarrow T_2) \text{ and } p_B(T_3 \rightarrow T_4) \qquad (36)$$

to *actualize* the path in *both* fragments, Alice's and Bob's, where time T_3 = (0, 0) and time T_4 = (τ, -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

$$p_{AB} = p_A p_B((T_1 \rightarrow T_2) \text{ and } (T_3 \rightarrow T_4)) \qquad (37)$$

Here is another attempt. Suppose that for the *combined* system

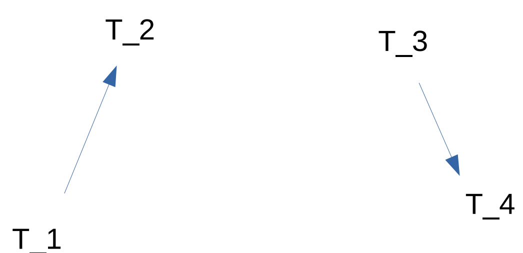
$$dt''/d\tau'' = -1 \text{ sec.}''/e'' \qquad (38)$$

justified by the idea that later (greater t) B-series times becomes into lesser (from positive to 0 to negative) τ as they become from the future and then into the present and then into the past. So they have opposite orientations.

From that (combined) fragment, it may be the (previous) separate fragments have

$$dt/d\tau = i \text{ sec.}/e., \quad dt'/d\tau' = i \text{ sec.}'/e' \qquad (39)$$

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 (τ_{Alice} and τ_{Bob}) $\rightarrow \tau_{\text{Alice and Bob}} = 0$

Also $p_{AB} = p_A p_B$. The first transformation in (36) is with the second transformation in (36) which are given by (τ, it) × (τ, -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 in both fragments.

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 p_A and p_B 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) in the fragment T_1, *and* the probability p_B of (T_3 to T_4) in the fragment of T_3. Before observation (collapse of the state function) they are not ontologically one system over which one distribution could be given.

27 Maps

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

$$\Psi(t)\colon \mathbb{R} \to \mathbb{C}^n \tag{40}$$

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

$$\Psi(t)\colon \mathbb{R} \to \mathbb{C}^{2n} \to \mathbb{R} \tag{41}$$

However instead of starting with a single real time variable, t, we now have, for example, a function g such that

$$g(T, T')\colon \mathbb{C}^2 \to \mathbb{R} \tag{42}$$

But there’s not enough information in $\mathbb{C}^2$ to model (41) and it treats T and T’ on an equal footing. So one might try a function like

$$j(T_1 \times T', T_2 \times T', T_3 \times T', \; \ldots, T_n \times T')\colon \mathbb{C}^{2n} \to \mathbb{R} \tag{43}$$

28 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 (Maroney 2009)

$$\Delta S = \frac{dS}{dt} \geq 0 \tag{44}$$

In this equation the variable t is evidently 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 $\mathrm{Entropy}_t(t)$, $\mathrm{Entropy}_\tau(\tau)$, and $\mathrm{Entropy}_T(T)$. Informally speaking, one has

$$\text{increasing } \mathrm{Entropy}_t(t) \leftrightarrow \text{ increasing } t \tag{45}$$

(Maroney 2009) which suggests

$$\text{decreasing } \mathrm{Entropy}_\tau(\tau) \leftrightarrow \text{ decreasing } \tau \tag{46}$$

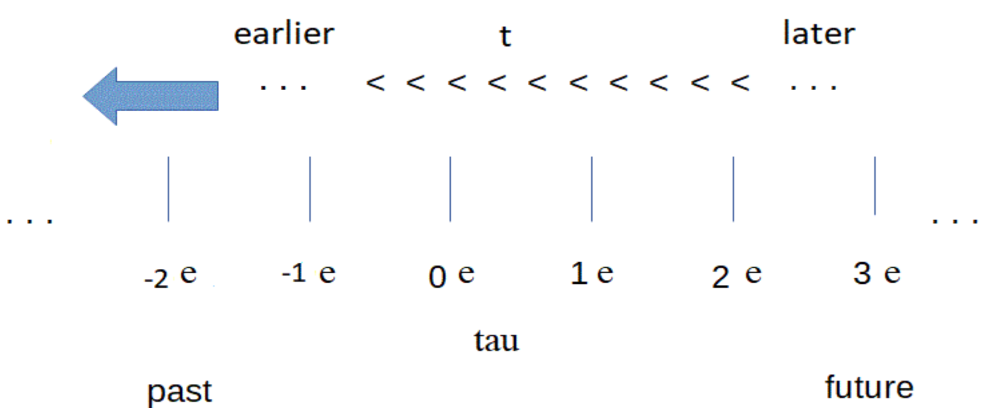
where (46) says the A-series entropy of a system decreases as the system ‘becomes’ from the future through the present into the past. That could be because, for some system, there are more future microstates that could eventually become present, that are consistent with the microstates of the present, than there are present microstates states that are consistent with the present.

An interesting condition is

$$\frac{d\mathrm{Entropy}_T(T)}{dT} = 0 \tag{47}$$

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 (operator?) moves the whole B-series (in *e*s) 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

$$\frac{dt}{d\tau} = -1 \quad \frac{\text{sec.}}{e} \tag{48}$$

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 revises eq.s (9), (10), and (11).

Given equation (47) we could also consider

$$\triangle S = \frac{dS}{dt} + \frac{dS}{d\tau} = \frac{dS}{dt} - \frac{dS}{dt} = 0 \tag{49}$$

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.

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. 2004). 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 improbable.

Given equation (47) or equation (49) 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 the way they could have been* (in earlier times). This is an instance of two-dimensional semantics, and encompasses anthropic principles in the sense that we can take the *current* (averaged A-series) state of the universe as a data point in one of the semantic dimensions (Sloan et al. 2020, Chalmers 1999, 2002a, 2002b, 2002c, 2004, 2005, 2007, Schroeter 2017, 2019, Garci-Carpintero et al. 2006). Two-dimensional semantics seems necessary when there are two kinds of information that are not reducible to each other, such as 1st-person qualia and 3rd-person brain states, or, analogously, the current (the averaged A-series at 0) state of the universe and the earlier/later (B-series) states.

It may be that eq. (47) could help adjudicate between eq. (28) and eq. (29).

30 Big Bang

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

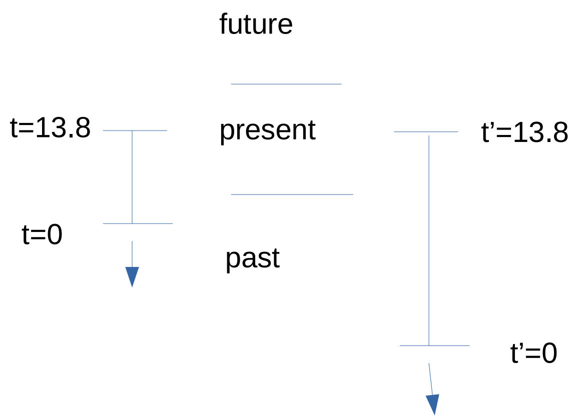
(30.1) how much *earlier* than now was the big bang?

(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 τ = t (in appropriately scaled units of *e*s 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. 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 is further into Alice's *past*. There is the rate r = dt/dτ which is or averages 0 considering the left timeline to the right timeline.

31 Realist interpretations of quantum mechanics

I take this interpretation of quantum mechanics to be realist. It seems odd that two quantum systems would not share the same A-series, or the same 'now' nor the same 'becoming', until mutual observation. But, it could be argued, this is decidedly 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.

Other realist interpretations, such as Many-worlds, GRW, Bohm, have the property that if quantum mechanics were to be supplanted by a radically different theory tomorrow, then the interpretation might not work or even make sense. One may wonder what would happen, for the sake of argument, if a theory analogous to General Relativity supplanted quantum mechanics tomorrow. The Many-worlds interpretation might not make sense or even be formulatable in this new theory. The form of quantum mechanics drives the form of these interpretations.

The interpretation of this paper has a different character. The philosophy drives the interpretation. If a theory were to supplant quantum mechanics tomorrow, then it would *still* be the case that our qualia are primary and that any physical theory must be consistent with an accurate understanding of them. It would *still* be the case that the presentation of the A-series is phenomenal. There would *still* be the possibility of the philosophical notion of Spectrum Inversion. This is a kind of robustness—it could be argued—that the other realist interpretations do not have. (Chalmers 2020 , Lewis 2020, Griffiths 2019, Lombardi et al. 2017, Myrvold 2018, Penrose 1989.)

This theory is not only realist, it is *super*-realist, since it is a theory based on data that are *pre-theoretical*.

This interpretation explains a peculiarity expressed in the Copenhagen interpretation. Bohr: which measuring apparatus one is using must be specified in making predictions about an experiment (Valente 2020). 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.

32 Conclusion

Is the theory of this paper less than half wrong?

Dinner today is 5 hours later than lunch today. But this does not give me the information of whether dinner is in my future, present, or past. Thus two series are required to characterize time. The problem of anthropocentrism is removed by panpsychism (ironically).

Philosophically, the A-series either is or is analogous to qualia. This allows the Spectrum Inversion argument to be applied to the A-series—and implies a kind of fragmental presentism.

"Such-and-such property of the quantum system did not take on a definite value until observation." The interpretation here takes this very literally, where 'until' is an A-series notion. This allows a new account of Schrodinger's Cat and other experiments.

It is a unification of sorts, unifying 1. some (but not all) aspects of consciousness, 2. both the A-series and the B-series, and 3. the behavior of quantum systems before, during, and after measurements.

At this stage of development the theory is plausibly in agreement with experience.

The cafe advertised breakfast served any time. So I ordered French Toast during the Renaissance.
–Steven Wright

Someone asked me 'can you tell me what time it is?' I said 'yes, but not now'.
–Steven Wright

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