

A new theory of time

Abstract We motivate and develop a new theory of time and apply it to a few test cases in physics.

1 Introduction

This paper looks at how an A-theory applicable to physics might be implemented. The plan of the paper is

1 Introduction and Outline

2 AB-series time

3 Ontological privacy

4 Panpsychism

5 Definitions and rates

6 Time $T(\tau, t)$

7 Picture of AB-series time

8 Physics, A) big bang, B) Schrodinger's Cat, C) ontic states, D) qualia, E) probability distributions, F) Born, G) Bell, H) EPR, I) entropy

2 AB-series time

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

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

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

The B-series is a series of times ordered by the relation of 'earlier-than' (or 'later-than'). The B-series is usually thought of as going from earlier times to later times. It could be argued the B-series is the kind of time that's most often used in physics. For example, the time parameter of the Schrodinger equation is a B-series. The B-series relations do not change. 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, is also a part of a comprehensive view of time. The A-series consists in the *ontologically private* (defined below) *now* and *becoming*. In contrast to the B-series, the A-series values change. Also in contrast to the B-series, going 'backward in time' is undefined, on this view.

'I'll meet you 2 hours from now'. B-series time. 'Tomorrow never comes'. A-series time.

It's a Zen observation that

“Time constantly goes from past to present and from present to future. This is true, but it is also

true that time goes from future to present and from present to past.”

(Suzuki 1986), p. 17 or 33. The former is the B-series (interpreted as 'earlier-times to later-times') and the latter is the A-series. As in several theories of time, instead of asserting 'time goes from past to present to future', it'd be more appropriate to assert 'time goes from earlier times to later times as it goes from future to present to past'. As later and later times become present, time to go on.

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

3 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 when a *different* system S' specifies the ontic state of 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, as might be appropriate in QBism, though to be sure it is the ontological questions that concern us here.

4 Panpsychism

I am conscious, and this is certain to a degree even greater than the certainty that there are physical laws. But there is, in one sense, nothing special about my composition—I'm made of electrons and quarks etc. Thus there is good reason to think that the basic elements that make up my brain are accompanied by the basic elements of subjective experience—qualia. One is led to the hypothesis that an electron is accompanied by a quale—a subjective experience—for example, the color green. Perhaps a muon is accompanied by a blue quale. There's been an amount written about this and surrounding ideas but the basic idea is clear enough and is called (Dualist) Panpsychism. (Stanford 2017). (Other correlates to qualia such as complexity could be entertained.)

'Ontological privacy' in the sense of the above is basically what happens with the Inverted Spectrum, familiar from the philosophy of mind (Stanford, 2018). Suppose Alice looks at the leaves on a tree and she experiences the color green. She cannot know, in some ontological sense, that if her friend Bob looks at the same leaves he experiences the same (color) quality.

Now suppose they look at a color circle. Alice's color spectrum does not determine Bob's color spectrum, for Alice. Bob could have a systematically 'opposite' color experience. This is basically the Inverted Spectrum (Wikipedia 2019). Indeed, it may be that Alice has a single definite spectrum, whereas Bob's spectrum can *vary* over a wide range of spectrums or even other possibilities, for Alice. Alice's (qualitative) experience while looking at the leaves, in some ontological sense, leaves Bob's experience without a definite value (for Alice), and therefore this color-parameter is 'ontologically private'.

The theory of time explored in this paper posits that the A-series characteristics of time are (or could be) ontologically private. A consequence would be that Alice's '*now*' does not determine when the

Cat's 'now' is, to some extent. One wants ontological parsimony. It may indeed be Alice's 'green' is the same as Bob's 'green'. But that doesn't imply that a brain b_1 can *verify* the experiences of an *other* brain b_2 . Suppose, for example, Alice is able to verify that the experiences of Bob are the same as hers, perhaps by bringing together the brains as part of a larger brain b_3 . But then the larger brain b_3 still can't verify the contents of an *other* brain, b_4 , outside of b_3 . There is no experiment b_1 can do, even in principle, to determine what b_2 's qualia are. So that result should be in the ontology, if possible.

5 Definitions and rates

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

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

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

Define

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

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

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

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

Define

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

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

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

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

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

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

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

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

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

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

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

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

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

$$(2) \quad dt/dt = 1 \text{ sec./}e, \quad dt'/dt' = 1 \text{ sec.'/}e'$$

which give in the obvious units

$$(3) \quad dt/dt' < 1, \quad dt'/dt > 1,$$

It's not clear what

$$(4) \quad dT'/dT$$

is.

Suppose an alien moves around the Andromeda galaxy. Depending on how it moves, the alien's plane of simultaneity may be, for example, in our (in the Milky Way, here on earth) future, or in our past, or

varying. But that does not prevent us from existing 'now'.

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 right*, it is 'now', and it can be measured by (via a distribution on) the variable τ via the presentism function $p(\tau)$. The stop-watch measures how much later than dinner is tonight than the present value, or how much earlier breakfast was this morning than the present value. The increasing-in-value (in a convenient coordinate system) of the stop-watch is represented by the arrow in the diagram, 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 change, in the model.

The value on the stop-watch is an *empirical* question, as is the paper.

6 Time $T(\tau, t)$

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

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

$$(5) \quad ds^2 = dT^2(\tau, t) + \sum_{i=1}^3 dx_i^2$$

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

$$(6) \quad ds^2 = dT^2(0, t) + \sum_{i=1}^3 dx_i^2 = -dt^2 + \sum_{i=1}^3 dx_i^2$$

which imply

$$(7) \quad dT(0, t) = dt$$

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

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

The condition that $t = t'$, in appropriately scaled units, says that the event is simultaneous in both

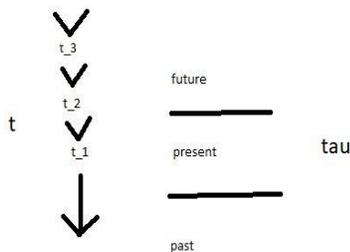
frames of reference, the un-primed frame and the primed frame. This is, of course, *not* the same condition that the event is in both presents, which would be the condition $\tau = \tau'$ in appropriately scaled units (of e and e' respectively). The latter condition cannot be given in the A-series coordinates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

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

7 Picture of AB-series time

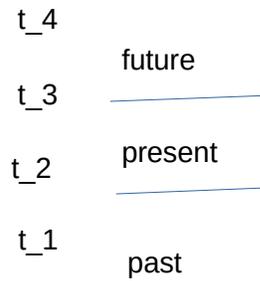
One doesn't need to suppose the present is a single infinitesimally small point centered at, for example, $\tau = 0$. For each τ there could be a degree of 'existence' or 'actuality' or 'presentness' $p = p(\tau)$, so the *now* is spread out in A-series time somewhat. (Smith, 2010). One attractive example is for p some Gaussian function of τ . Also non-symmetric functions. A place on τ is thus assigned a degree of existence/actuality/presentness $p(\tau)$, and there's no reason to make the assumption that the present is at $\tau = 0$ only (in the obvious coordinatization). The growing-block theorist supposes the past is real, which might be defined as $p(\tau) = 1$ for $\tau < 0$ and $\tau = 0$, for a particular system. The block theorist would have $p(\tau) = 1$ for all τ . A presentist (like me) has $p(\tau) > 0$ on the support of τ .

This is the model

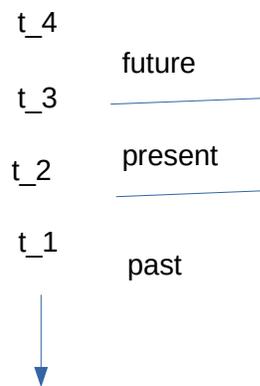


t_1 is earlier than t_2 which is earlier than t_3 ... The earlier-times to later-times timeline stays in one ordering (of one kind or another), but the whole timeline moves from future to present to past, with the present staying put. (The present does not 'move up the B-series' as in some spotlight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

Toward justifying the diagrams. 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.



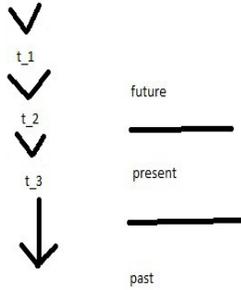
There should be a way to represent the A-series 'becoming'. The B-series doesn't change (except space-like separated events, a triviality for us). So the A-series and the B-series must change relative to each other while keeping the same 'now'. The above picture is modified to



Moreover, this accords with experience.

In music there is tempo. A-series. And relative location in the score (including relative duration). B-series. The theory accords with the 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 in the past the movie is.

Time-reversal goes as



t_3 and then an earlier time t_2 and then an even earlier time t_1 become from Alice's future to her present and then to her past. As earlier and earlier times become present to her, time appears to be going in reverse. Time-reversal invariance obtains only for a B-series, on this view. Time-reversal for an A-series is undefined. There's no unit of going from past to future defined in the A-series. (The evolutions in the graphs are path-connected via $r = 0$.)

There is a time-reversal

$$(8) \quad (\tau, t) \rightarrow (\tau, -t)$$

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 at least one of the notions of time-reversal in physics.

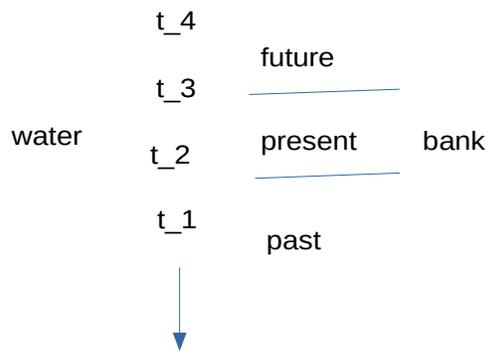
These time-reversals are dubious:

$$(9) \quad (\tau, t) \rightarrow (-\tau, t)$$

$$(10) \quad (\tau, t) \rightarrow (-\tau, -t)$$

except at $\tau=0$ (or its generalization given by the presentism function $p(\tau)$) 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.)

The river metaphor may be diagrammed as.



8 Physics

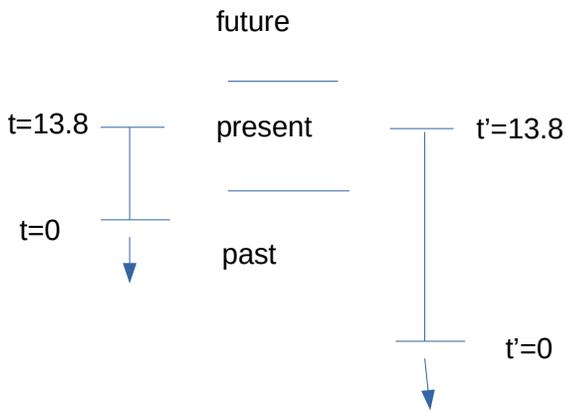
A) big bang

These are two different questions:

1. how much *earlier* than now was the big bang?
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 $t = 13.8$ billion years. This could mean the big bang is 13.8 billion years *earlier than* now. It is not always necessary that $\tau = t$ (in appropriately scaled units of es and seconds, respectively). It may be possible that, for example, $\tau \rightarrow -\infty$, in which case Alice must go infinitely far *into her past* before getting to the big bang. This interpretation would be the best of both worlds. It's 13.8 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. This bears on the question of whether there could have been a *first* moment of time.

Another scenario:



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

B) Schrodinger's Cat

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

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

But if, during the experiment, Alice and the cat never are in a shared present, or shared 'now', then there is 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

$$(11) \quad f(T(\tau, t), T'(\tau', t'))$$

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

$$(12) \quad f(T(\tau, t), t', T(\tau, t) \times \tau')$$

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 f has τ and τ' on an equal footing, too. (The above form of f is just an example.)

One wants to model, starting with time t , the map to the quantum state, and from there, if possible, the map to the (real) value of an experimental outcome. However instead of starting with a single real time variable, t , we now start with a 'single' (possibly complex) time parameter T that is a function of two other 'time' parameters, t and τ , each of these being real numbers. Thus the new function f is, e.g. $f(T(t, \tau), \dots)$.

For time t to quantum state $\Psi(t)$ one has

$$(13) \quad \Psi : \mathbb{R} \rightarrow H$$

where H is a complex Hilbert space. (Is this \mathbb{C}^n ?) ... Yet there is another quantum process (this is the 'measurement problem'), projection. For a given eigenvector one projects by multiplying by a Hermitian operator, and that yields the (real) value of the outcome of an experiment. So for operator O one has something like

$$(14) \quad O : H^* H \rightarrow \mathbb{R}$$

But an eigenvector isn't given before measurement—only their probabilities p_i (via the amplitudes), (the probability of obtaining that value in the future),

$$(15) \quad p_i, \text{ real number } [0, 1]$$

What is possible with some function $f(T, \dots)$? In particular, is it possible to combine (7) and (12) and (14) such that

$$(16) \quad f : \mathbb{R} \rightarrow \mathbb{R}$$

for some stochastic f ?

The Schrodinger equation is

$$(17) \quad i\hbar \frac{d}{dt} |\Psi(t)\rangle = \hat{H} |\Psi(t)\rangle$$

Apparently, the first time variable t in the left-hand side is a B-series. The second time variable t in the left-hand side is a B-series. The time variable t in the right-hand side is a B-series. It's not clear whether operator H is a function of just an A-series or both series. Nor what happens when $\Psi(t)$ is replaced with something like f as in (12).

Combining (7), (12) and (17) one has

$$(18) \quad \hbar \frac{d}{dT} f = \hat{H} f$$

Of course the function f was just an exuberant guess.

C) Ontic states

There is the question of the relationship between a quantum state and an ontic state. In the Ontological Models framework (OM) one models a quantum state by a distribution D over all ontic states [Spekkens, Leifer 2014]. These are parameterized by at most one time variable t . In AB-theory there is a distribution $D1$ over the ontic states parameterized by (τ, t, t') (Alice's A-series, Alice's B-series, and Bob/cat's B-series) and there is a distribution $D2$ over the ontic states parameterized by (t, t', τ') . There is no distribution $D3$ over states parameterized by (τ, t, t', τ') , as there would be in the OM 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. Is this a kind of knowledge-restriction [Spekkens, Leifer 2014]? There's more information in $D1$ union $D2$ than there is in $D3$, but only one, $D1$ or $D2$, is given. There is the question of what this could say about the 'psi-ontic' vs. 'psi-epistemic' interpretations.

There should be a theorem as to when the 'now' of the cat and the 'now' of Alice (the experimenter) can be identified in some way, with the respective B-series not fixing each other. A C-series or R-series might be appropriate.

D) Qualia

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

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

$$(19) \quad \Diamond P \rightarrow P$$

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

There is the issue of counter-factuals. 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 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 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'. So they can't be absolutely nothing, but they can't be factual, either.

E) Probability distributions

In salient forms of Dualism there is no ontic state that contains both Alice's A-series and Bob's A-series

while they are different systems. Therefore there is no probability distribution over one.

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

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

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

One has

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

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

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

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

$$(22) \quad p_{\text{perspectival}} = (p_{\text{objective}})^2$$

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

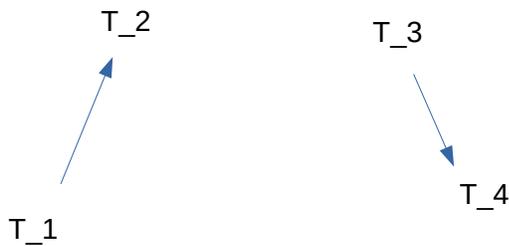
F) Born

In view of (7) let us optimistically put time $T_1 = (0, 0)$ and time $T_2 = (i\tau, t)$, normalized in some way. We can ask what is the probability that they become the same time, $T_1 = T_2$, at collapse? There is a probability $p_A(T_1 \rightarrow T_2)$. Here, T_2 is in the future of T_1 , by τ , and also T_2 is later than T_1 , by t . But p_A is not the answer. An experimental outcome is revealed only in the present, $\tau = 0$. So we would seem to want the probability p' ($T_1(0, 0)$ and $T_2 = (0, 0)$) but that's not right since these two times are ontologically private. We want the probability

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

to actualize the path from both perspectives. This gives

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



Here T_3 is at the time T_2 but given coordinates $(0, 0)$. This implies T_4 (compared to time T_3), will have coordinates $(-i\tau, t)$. If T_2 is in the *future* of T_1 , by the amount τ , from the perspective of T_1 , then T_4 is in the *past* of T_3 , with coordinate $-\tau$, from the perspective of T_3 . Therefore when $T_3 = (0, 0)$, $T_4 = (-i\tau, t)$. Also $p_{AB} = p_A p_B$. The first transformation in (24) is followed by the second transformation in (24) which are given by $(i\tau, t) \times (-i\tau, t)$ so that we have $p_{AB} |T_2|^2$.

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

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

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

G) Bell

Suppose Alice and Bob are space-like separated and one electron goes to each of them and Alice measures the spin of her electron. There is the well established notion that Alice can't send Bob a signal (about what spin he will eventually measure) faster than the speed of light. There is also the notion that when Alice measures her electron's spin, she immediately knows the spin of Bob's electron. But quantum mechanics says something more than this. It says Alice's result, for an angle chosen by Alice, will at least sometimes instantaneously affect the result that Bob will eventually measure, for the spin of his electron, at an angle chosen by him.

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

But 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. (The *thought* of an external object is itself temporally situated.) One might say it acts as a *non-local self-evident variable*.

H) EPR

Is it the case that P and Q have something like the same A-series but different respective B-series?

EPR: "One could object to this conclusion on the grounds that our criterion of reality is not sufficiently restrictive. Indeed, one would not arrive at our conclusion if one insisted that two or more physical quantities can be regarded as simultaneous elements of reality only when they can be simultaneously measured or predicted. On this point of view, since either one or the other, but not both simultaneously, of the quantities P and Q can be predicted, they are not simultaneously real. This makes the reality of P and Q depend upon the process of measurement carried out on the first system, which does not disturb the second system in any way. No reasonable definition of reality could be expected to permit this."

<https://journals.aps.org/pr/pdf/10.1103/PhysRev.47.777>

In the context of the EPR paper, this is an argument that quantum mechanics is *incomplete* as an ontological theory. In the AB-theory, one wants having the same A-series to be a sufficient condition for the reality of both P and Q. One supposes the pair of particles may indeed have different B-series but nevertheless share the same A-series. As a result, they are real 'now' or 'simultaneously', i.e. simultaneously in the sense of the A-series, translating from the EPR paper appropriately.

I) Entropy

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

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

which suggests

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

where (23) says the A-series entropy of a system decreases as the system 'becomes' from the future

through the present into the past. That would be because, for some system, there are more microstates in the future that will eventually become present, that are consistent with the present, than there are present states that are consistent with the present.

An interesting condition is

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

More References forthcoming

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