A theory of time: bringing McTaggart into physics

Abstract This paper proposes an interpretation of time that incorporates both McTaggart's A-series and his B-series, and attempts to cast it in a way that might be usable by physicists. This interpretation allows one to reconcile special relativity with temporal becoming as the latter is understood as 'ontologically private', which is given a mathematical definition. This allows one to define a unit of becoming, as well as the rates of becoming. This paper gives a picture of this interpretation and applies a rough outline of the concepts to several test cases.

1 AB-series time

Famously, 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 won't 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, both coordinate time and proper time are B-series. And 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 is also a part of a comprehensive view of time. It's inescapable that (the option of?) dinner tonight is first in my future, then in my present, and then in my past. 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.

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. Instead of saying 'time goes from past to present to future', we'd say '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 appears 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 (This would usually just be called an "A-series" interpretation in the philosophy of time. But I think that's misleading and as physicists haven't been corrupted yet, will refer to it as an "AB-series" interpretation.) This has been tried (see, for example, PhilPapers (2019) and references therein). They all have difficulties. The ideas here are somewhat related to Tense Realism, Perspectival Realism, and Fragmentalism, (Hare 2010), (Fine 2005) see also e.g. (Markosian 2013), (Roberts 2015), (Carr 2013), (Rovelli 2018), (Miller 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. 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.

2 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 specifies S's ontic state. This could be because, for the other system, 1. there is no such parameter, 2. there is a parameter but is doesn't have a definite value, 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). The first two are mathematical definitions even though they are not in mathematical notation.

3 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 lead 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.)

A quale may be construed, on most readings, as an ontologically private thing. For example, I may experience what I know as 'green' when I look at the leaves of a tree. But I cannot know that you experience the same quale (i.e. what I would call green) when you look at the same leaves. This observation shows my quale has a definite value for me, but not for you, and vice versa.

Some notion of temporal becoming is often supposed to be a feature of the A-series view. Becoming is sometimes understood to be phenomenal at least in some respects the way qualia are. (Loury 2016). Becoming, for the purposes of this paper, is that quality by which an indexical clock (defined below) is first future, then *now*, and then past. If panpsychism is true and temporal becoming is phenomenal then arguably every system experiences becoming. The unit of becoming *e* (defined below) is well-defined in the sense that an interval of 1 second of B-series clock time is defined for a protozoan just as well as it is defined for a human, e.g. Alice, even though the protozoan doesn't have the mental resources of Alice. One second of clock time is the same whether we consider Alice or the protozoan. It's plausible that it's the same way with 1 *e* of A-series becoming. Of course this is not a claim that one must believe (or not believe) this hypothesis. But, I would argue, it is motivated.

Suppose one had good coffee and good pot until 15 minutes ago. Under this condition, it might be that the B-series seems to go by the A-series faster, or slower, than usual. But this just amounts to a re-coordinatization of the relations between B and A. Just the way one can re-define seconds to be longer or shorter than the usual seconds, one can re-define *e*s to be further or closer into the future than the usual *e*s. The physically significant stuff should be invariant under these changes.

4 New symbol, indexical clocks, the unit of becoming, rates of becoming

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

So, one thing to try is: to a parameter *t* whose unit is a change in indexical clock time, for example, a second, add a parameter *g* whose unit is not an interval in B-series clock time. In AB-theory, g 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. e coordinatizes g.

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.

Try the definition

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

If becoming is indeed phenomenal in the way that qualia are, then it *must* be 'defined' or 'referred to' in this curious 'what it is like' way. This is how qualia must be defined, 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.

Define

1 sec./*e* = d(Alice's B-series)/d(Alice's A-series)

is the change in 1 second of indexical clock time per change in *e*.

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.

Let the rate r be in units of sec./*e*. The general idea is this:

$r > 1$ 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)
$r < 0$ one appears (from *future* to *now* to *past*) to be going backward in B-series time, e.g. time-

reversal

One may define d*r*/d*e*. 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".

5 Special Relativity

Four coordinates (t, $\boldsymbol{x}$) are not enough to schedule a meeting between Alice and Bob. Alice must also know if the meeting is to take place in her past or in her future. If it's supposed to take place in her past, she may have already missed it, and should act accordingly. If it's in her future, she may be able to make it, and can act accordingly. Alice can make a *prediction* about whether she'll make the meeting based on *future-now-past* information. So it's falsifiable.

Thus Alice doesn't live in Minkowski space, but a larger space. Minkowski space doesn't have enough *information* to schedule a meeting. One needs something like (g_j, t , $\boldsymbol{x}$) coordinates for systems j. (For the rest of this paper g (defined below) is the private future/present/past spectrum and is not the general relativistic metric, or at least not obviously so.)

Google has two temporal parameters by which one may filter a search for videos. There's 'Duration', the end of the video supposed to be that much *later* than the beginning. And there's 'Time', which might be, for example, one year before *now.* Similarly, YouTube has 'Duration' and 'This year', one year before *now.* There are two buttons. The thing is, how would you keep the same *functionality* with only one button? This might be interpreted as a kind of experimental result: at least two buttons are needed for the temporal parameters. I take this as e*xperimental* evidence that time has both an A-series and a B-series associated with it.

(As I understand it, B-theorists would argue that the 'before *now*' is merely a matter of indexicality and earlier-to-later times. I am looking in the literature for the response that, the problem in this case, is that, for example, time t = 5 is just as indexical as time t = 10. Ipso facto, neither is ontologically privileged. Thus the B-series is insufficient to account for both buttons.)

Alice orbits the earth and Bob is in the Andromeda galaxy. For some orbits, the planes of simultaneity of Alice change so that Bob is in Alice's B-series later than, then simultaneous with, then earlier than, then simultaneous with, then later than, etc...

"But (bringing the subject into the story) my *now* advances along my trajectory at one second of my personal experience for each second that passes on my watch, which follows the same trajectory as I do. And your *now* advances along your trajectory at one second of your personal experience for each second that passes on your watch, which follows the same trajectory as you do." Mermin, (2018), p. 33.

We might be able to say Alice's *now* advances along her worldline—in an ontologically private way—at a rate of one second of personal experience for each second that passes on her watch. Also, Bob's *now* advances along his worldline in an ontologically private way at a rate of one second of personal experience for each second that passes on his watch. But, for Bob, it is not true that his *now* varies back and forth through his earlier-to-later clock times, as Alice would have it. Alice and Bob may agree on the order of all of their watch's ticks along each person's worldline—this is the B-series information. That information is 'effable'. Yet Alice and Bob, in this view, may experience their own senses of *now* —the A-series information. More on this below.

Simultaneity. I assume an explanation would go something like this. Alice, at rest relative to the train station, experiences one *e* of what her temporal becoming is like per second of her indexical clock time. Bob experiences one of his *e* of what his temporal becoming is like per second of his indexical clock time, who is at rest relative to the train, which is speeding by the train station… Events that are simultaneous to Alice are not simultaneous to Bob. On one of the interpretations of 'ontologically private' these are all consistent because, for Alice, Bob's *e* has no particular value, and for Bob, Alice's *e* has no particular value. On another interpretation, for Alice, Bob doesn't even have a parameter *e*, and vice versa.

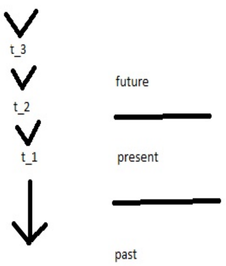
Are we allowed to just stipulate that? If becoming is phenomenal and basically ubiquitous then yes we can just stipulate that. Recall that's because it's like (by hypothesis) the case where I can see green when I look at a patch of leaves but I don't know that you experience the same qualia (those which I would call 'green'), when you look at those leaves. When you look at those leaves you might be experiencing what I would call red, or even experiencing nothing at all. In some ontological sense I can't assign a definite (qualitative) value to what you see. My guesses as to what you see *don't constrain the reality* of what you see. So this is an example where phenomenology fits either of the first two of the above definitions of ontologically private.

General relativity. Let Alice have a clock 1 meter above the surface of the Earth and let Bob have a clock 2 meters above the surface of the Earth at the same latitude and longitude. Alice's clock runs slower than Bob's because she is in a stronger gravitational field. In the theory of this paper, what is being compared here is their B-series information, i.e. the earlier-times to later-times information. Alice's A-series information (becoming, privileged 'now') is not—and cannot be—directly compared to Bob's A-series information, while they are separate systems. If Alice has a 'now', then Bob's 'now' has no specific B-series time associated with it.

6 Picture of AB-series time

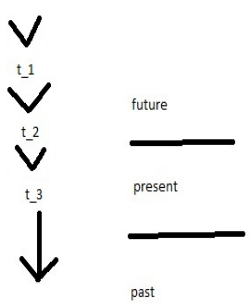
One doesn't need to suppose the present is a single infinitesimally small point centered at, for example, $g = 0$. For each g there could be a degree of 'existence' or 'actuality' or 'presentness' $p = p(g)$, so the *now* is spread out in A-series time somewhat. (Smith, 2010). One attractive example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

A schematic of the AB-series picture of time would go something like



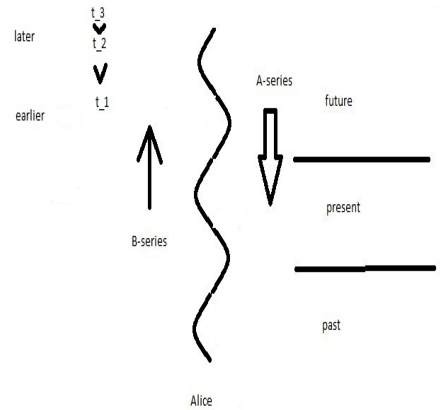
t_1 is earlier than t_2 which is earlier than t_3... The earlier-times to later-times timeline stays in one ordering (of one kind or another), but the whole timeline moves from future to present to past, with the present staying put. (The present does not 'move up the B-series' as in some spotlight theories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

Time-reversal goes like

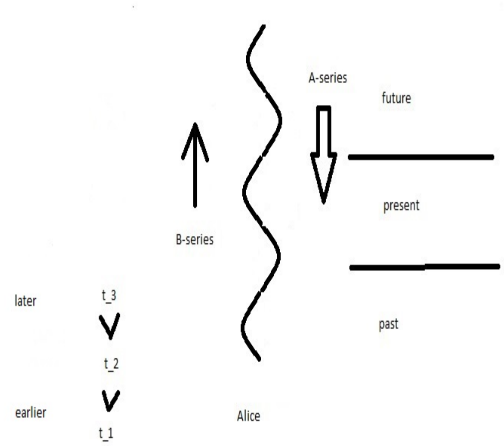


t_3 and then an earlier time t_2 and then an even earlier time t_1 become from Alice's future to her present and then to her past. As earlier and earlier times become present to her, time appears to be going in reverse. Time-reversal invariance obtains only for a B-series, on this view. Time-reversal for an A-series is undefined. There's no unit of going from past to future defined in the A-series.

Two pictures



picture 1



picture 2

where t_3 is later than t_2, which is later than t_1. There are two parameters for one dimension of time. Minkowski space doesn't distinguish between picture 1 and picture 2. Ergo, Alice doesn't live in Minkowski space, but a larger space.

Minkowski space doesn't have enough *information* to schedule a meeting. One needs something like (g_i, t , $\boldsymbol{x}$) coordinates for systems j. One may define functions of these coordinates, $k_j = k(g_j,\ t\ , \boldsymbol{x})$. The point is now that there are no functions of more than one system's private variables g_j, e_j, because these are ontologically private, by hypothesis.

One can chain derivatives if there's only one e_j. For example

$$\frac{d(\text{Alice's A-series})}{d(\text{Alice's B-series})}\frac{d(\text{Alice's B-series})}{d(\text{Bob's B-series})}=\frac{d(\text{Alice's A-series})}{d(\text{Bob's B-series})}$$

…

There's a difference between e the unit of becoming, and g the location along the future/now/past spectrum, and t the interval of a second. Clearly there's some relation between them, like dt/dg = - 1 . The minus sign would come from this. In the B-series time goes *into* the future, to more and more later times. In the A-series time comes *from* the future (into the present and then into the past). Thus, their temporal directions are oppositely oriented. In some cases

(1) $$\frac{dt}{dg}=-1$$

This means the rate of change of the magnitude of earlier-to-later intervals, in seconds, to changing future/now/past information, is minus one. (When it's true is a different question.)

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One has the position x, in meters, as a function of earlier-to-later times, x(t). Now consider the position x of a classical particle, in meters, as a function of both the future/present/past spectrum g, and earlier-to-later times t, such that x = x(g, t). Then, define dx/dt. The units are meters per second. This is the rate of change of x with respect to earlier-to-later times. Define dx/dg. The units are meters per e. This means the rate of change of x with respect to becoming into the present, of Alice. Suppose dx/dg = 1. This has units of meters per e. This means the position changes 1 meter as it becomes 1 e into the present.

In spacetime there are functions of t and x, f = f(t, x) and one can, for example, take derivatives df/dt, df/x, df^2/dtdx, etc.. Here, relative to Alice's present, there may be functions h(g, t, x). There would therefore be derivatives dh/dg, dh/dt, dh/dx, dt/dg, dh^2/dtdg, etc, and there is a need for a new constant (conversion factor) u in units of meters per es, for example u = 15.3 meters/e (analogous to the speed of light *c*, which is in units of meters/sec.). Is there an invariant on (g, t, x) analogous to the interval tau on Minkowski space in (t, x)? For complex numbers c_1 and c_2 one might consider (below) c_1 * u * g, c_2 * c * t, x where in the Minkowski case c_2 is -*i*.

One may consider cases like this. Suppose we want position x as a function of AB time, x = x(g, t). Suppose we hold t constant. Then, as a function of t, the position x doesn't change. But it may still be the case that x changes as it becomes from Alice's future to her present and to her past. For example it might be that dx/dg = 3 meters/e. In an interesting case suppose x(g) is a periodic function.

If there's a non-trivial presentism function p(g) on g then it gets more complicated and becomes a job for physicists.
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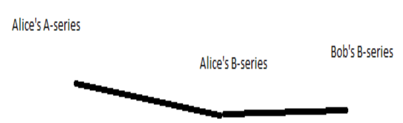
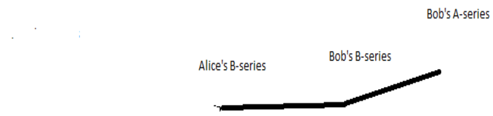
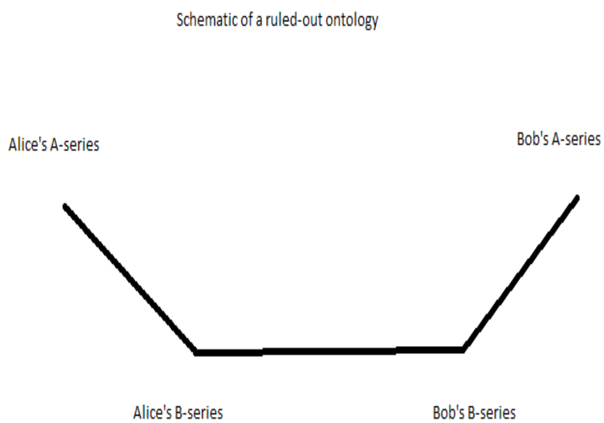
Here's a probably overly simplified schematic of the relevant ontology of Alice:



and there's an analogous ontology for Bob



But there is no ontology that has both Alice's A-series and Bob's A-series:



while Alice and Bob are separate systems, because A-series characteristics of time are ontologically private, in the way that qualia are, by hypothesis. Relativistic dilation occurs between Alice's B-series and Bob's B-series (the copies of which are also related to their respective A-series). Similarly (or is it the same as?), one could replace 'A-series' with 'qualia' and 'B-series' with 'material' in the first two pictures after 'picture 2' above and, surely in the case of qualia, the latest picture above is ruled out.

A function of a public parameter is public. A function of a private parameter is private to that system. A function of two public parameters is public. A function of a public and a private parameter is private to that system. There are no functions of private parameters of two different systems.

7 Seconds, position, experiment

The definition of a second is

> "The second is the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium 133 atom." https://physics.nist.gov/cuu/Units/second.html

One might say this duration (…) is an interval. It's irrelevant to this definition when *now* actually is. But to *actually do* the experiment one cannot avoid the relevant A-series information (i.e. at some time it must come to pass that the physicist performs the experiment in his or her present). So, to make an accurate model of actually doing the experiment, the physicist must add A-series information to their model. How many 'bits' does it take to specify the A-series information?

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The thing to do for the simple case of the point position of a classical particle is along this line. For classical 3-dimensional position $\boldsymbol{x}$, one has $\boldsymbol{x}$ as a function of seconds, $\boldsymbol{x} = \boldsymbol{x}(b \text{ seconds})$. (I'll use '*b*' instead of '*t*' for the number of seconds for reasons to become clear.) Let g be position of the particle on the *future-now-past* spectrum such that $g > 0$ means the particle is in Alice's future, $g = 0$ the middle of the present, and $g < 0$ past. This coordinate is standardized by the unit of becoming e_i. For the AB-series one has $\boldsymbol{x} = \boldsymbol{x}(a\ e_i,\ b \text{ seconds})$. The first coordinate carries the information a of how far in the future/now/past the particle is, for Alice. For example $\boldsymbol{x}(5, 1)$ is the position of the system 5 e in the future of Alice and 1 second later than its position at $t = 0$. So, in 5 e the system will become into Alice's present and her clock will read t = 1 sec. $\boldsymbol{x}(2, 3)$ means the position $\boldsymbol{x}$ when the particle is 2 e in the future of Alice and 3 seconds later than $t = 0$. In 2 e the clock will become into the present and it will read 3 sec.

8 Notes

Time, in the sense that both the A-series and the B-series are needed, in turn, suggests that the dualist's qualia and matter are parameterized by two different variables, and they're probably not of the same nature, in analogy to how the A-series values change and the B-series values don't change on timelike worldlines.

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It's not right to say time goes from 'past to present to future' in this AB-interpretation. Rather it goes from earlier times to later times, as it goes from future to present to past. As later and later times become present, 'time goes on', for a given system.

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A good candidate for being the most fundamental equation in all of physics is distance = rate * time, $d = r * t$. The time variable t here is usually taken to be a B-series. Is the time variable in the rate also necessarily a B-series? If it's an A-series, this might change the interpretation of 'distance' to 'actual distance'.

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One says, for example, let's meet at height 100 m, latitude 100°, longitude 100°, at the time t = January 1st, 2029. What this time really says is to meet at a time that is 2029 years *later than* year 0. This single time coordinate doesn't have the future/present/past temporal information. This is witnessed by the necessity of having at least two buttons for the temporal parameters that filter videos on Google and YouTube.

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There's a large and growing body of proposals for what the correlates ('correlates' given dualism) of the phenomenal are. If panpsychism isn't right and the phenomenal are instead correlated to something else, for example, complexity, and there are relative amounts given by that complexity, then it may be that this would affect the 'amount' of seconds per *e*, *a* seconds/*b* *e*s. That would then have the interpretation that the complexity of a system is correlated to the rate of becoming (i.e. the number of Bob's clock seconds that go by per *e* of Alice).

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I will take this opportunity to be speculative.

Bell

Consider the entangled state $|\Phi\rangle$ defined by

$$|\Phi\rangle = \frac{1}{\sqrt{2}}|10\rangle - \frac{1}{\sqrt{2}}|01\rangle$$

for anti-correlated spins of two electrons e1 and e2. Suppose Alice and Bob are space-like separated and e1 goes to Alice and e2 goes to Bob. When Alice measures the spin of her electron, is the spin of Bob's electron determined *instantaneously* or not? On the one hand, no. Nothing can go faster than light, and the electrons are space-like separated. On the other hand, yes. The present in which Alice measures e1 is the same present in which she instantly knows (infers) the spin value of e2. In the latter case her future can't contain any states where the value for e2 is different than what Bob gets for e2.

In classical physics the position of a system is sometimes given as a function of time, $\boldsymbol{x} = \boldsymbol{x}(t)$. This time variable is a B-series. To incorporate A-series information one apparently introduces ontologically private time parameters g_j for each system j, indicating where on j's future/present/past spectrum the particle is. This makes the physics relative to the present of the observer. $\boldsymbol{x}_j = \boldsymbol{x}_j(g_j, t)$. For example the measurement of e1 by Alice might be at time m = m(3, 4), meaning the measurement is 3 e in the future (of Alice) and 4 seconds later than t = 0. So in 3 *e* the measurement by Alice will be in her present and the clock will say t = 4 sec. (Obviously, it will say t = 1 sec. given temporal equilibrium, dt/dg = 1.)

If we equate the private parameters between e1 and e2, $g_i = g_j$, this has the interpretation that we are in the special case where Alice and Bob have the same *present.* If they are also simultaneous, Alice's inference of what e2 is, and the measurement of e2 by Bob, are simultaneous *and* in the same present. In this case the measurement by Alice of e1 does the job the two measurements: e1 by Alice and e2 by Bob.

Since Alice makes one measurement that is effectively two measurements, instead of Alice getting a result to her measurement '1' or '0' plus epistemic information as in the usual case, her one measurement reveals the whole system, with result '10' or '01', as the combined state hasn't been determined by Alice or Bob, or anything, until then. I think it could be argued that the measurement in this special case, representable by *one* operator (I think) on a Hilbert space, has ontological significance for e1-and-e2. The argument hinges on that.

So in this case Alice doesn't measure '1' or '0' (plus epistemic information), which are 50% anti-correlated. In this special case, she measures '10' or '01', and these are 100% anti-correlated. By varying these two kinds of measurement one can get any probability in between. Happily, the latter is (or acts as?) a non-local condition. Therefore, this interpretation might produce greater-than-local correlations. The special case of quantum mechanics can have spins up to $1/\sqrt{2}$ anti-correlated, about 70%. The percentages are given by $(x)(1) + (1 - x)(.5)$, which gives $x = 2 - \sqrt{2}$ which gives about 0.5857... If it can be explained this way, the correlations at the quantum mechanical limit would be given by about 41.43% of the normal observations and 58.57% of the one-operator observations.

Suppose, for the sake of argument, the future is branching. Suppose system s at time (g_{Alice} , t) is later than the plane of simultaniety of Alice *and* in Alice's future. Suppose this also for Bob. Then the system could be said to be strictly future. Since the future is branching, there's more than one branch with a copy of s that's consistent with what measurements will take eventually take place in the present. In this case measurement by Alice might select which future branch, [10> or [01>, becomes present.

…

There are arguments the future is branching or not branching. There are arguments the future is open or not open. I don't know if the future is open, and I don't know how of if such a future can be represented in this model. A decision only happens in the present, but if the future is open there are decisions in the future. But in this model there is only one present. There are arguments the past is fixed or not fixed (it's not fixed, or at least not selected, in the Consistent Histories interpretation).

...

One (among several) B-series notions of entropy is supposed to be non-decreasing from earlier times to later times. If any one of the above happens then one expects some A-series notion of entropy to be non-increasing (as there are more states in the future that are consistent with the eventual present experiment) as the system goes from future to present to past. The presentism function p(g_i) has to be considered, and one needs to sort out the units. But I'm thinking of the Past Hypothesis problem.

…

9 More notes

Schrodinger's Cat in AB-theory

I will assume the reader is familiar with the Schrodinger's Cat experiment. Suppose WF (for Wigner's Friend, though I will only discuss the cat experiment here :-)) is outside the box. He sets his indexical clock so that t = 0 seconds at the beginning of the experiment (when he closes the box) and so that the experiment ends t = 10 seconds *later than* t = 0 (when he opens the box). Suppose the cat's indexical clock is set the same way. (Recall that a system, so far as this model of time is concerned, may be a person, a cat, a protozoa, or indeed on panpsychism any physical system whatsoever.)

Both WF and the cat have a private A-series parameter as well as a public B-series parameter. Their B-series parameters can be compared, their A-series parameters can not. Thus, for example, for WF at his indexical clock time t = 3 sec., he may have it that the cat is in a superposition

(1) $$\Psi = |\text{will measure it to be meowing}\rangle - |\text{will measure it to be purring}\rangle$$

For WF, his time has a private parameter and a public parameter, respectively, (*g*, *t*), and when he models the cat's public time he does it with another B-series variable, as in relativity, such as (*g*, *t, t'*). However, for WF, the cat's private parameter has no particular value (or in some theories doesn't even exist). And vice versa. In terms of WF's private time parameter, the measurements in (1) will happen 7 *e* in his future because it is 'now' indexical clock time t = 3 and the experiment goes until t = 10 (and there are no relativistic considerations, we'll assume). Thus for WF 'now', the future state of the cat is given at a time (7, 10). As (1) shows, there is not just one classical state of the cat 7 *e* in the future, but rather a superposition of future classical states. This leads one to suspect the future is indeed branching.

In obvious notation we have, for the cat's state as described by WF, as a function of WF's time,

(2) $\text{catstate}(7_{WF}, 10_{WF}) = \Psi = c_1(\text{t}_{WF})|\text{ meowing at g}\rangle - c_2(\text{t}_{WF})|\text{purring at g}\rangle$

(3) $\Psi(g,t) = c_1(3\,\text{sec.})|\text{ meowing 7 e in the future}\rangle - c_2(3\,\text{sec.})|\text{purring 7 e in the future>}\rangle\,)$

If this interpretation can be sustained, apparently, in some cases a future state is represented by a vector in a Hilbert space. This might be motivated in a theory like this. The 'present' is the only time one ever *performs* experiments. One could speculate that an experiment only constrains future states, therefore, only so much. For example, it could be that a classical state/path at t = 10 sec. doesn't have to be selected yet (at t = 3 sec.), and therefore there is more than one future state that is compatible with the eventual present experiment. The urgent question is, what's the interpretation of the complex amplitudes?

What is suggested by this picture is that the collapse of the state vector upon observation, to the extent there is one, has to do with the unification of the two system's private time variables g_{WF} and g_{cat} into one g_{WF+cat}.

One hypothesis is that, with respect to qualia, my experience of green when I look at some leaves *does not constrain*, to me, the qualitative values you experience when you look at those same leaves. The related hypothesis is that it's the same way with 'becoming' and a privileged 'now'.

The cat paradox typically comes from the fact that (what would be in our example) at the cat's indexical time t' = 3 seconds the cat finds itself to be either in state *meowing* or else in state *purring*, and not in a superposition of the two. In the AB theory that's okay because the 'now' of WF *does not constrain*, for WF, the 'now' of the cat. So when WF's cock reads '3 seconds later than t = 0', it is not assumed that the cat's clock reads '3 seconds later than t' = 0'. Instead, when WF's clock reads '3 seconds later than t = 0', the cat's clock, for WF, could read anything between t' = 0 sec. and t' = 10 sec. (or nothing at all in some models), because these different indexical clock times are associated with the 'now' of the cat. Thus, during the experiment, there is no *one time* at which the cat gets ascribed different states.

….

Future paths in AB-theory

Consider

(1) $\int_{1,0}^{0,1} f(g,t)\; dtdg$

Starting from the bottom, integrate f starting 1 e in the future and with indexical clock time t = 0. The top of the integral has time 0 e (which is in the center of the present) at indexical clock time t = 1 sec. (later than) t = 0. They're oppositely oriented because the first parameter comes out of the future while the second parameter goes into the future (later times).

Jubilantly, one could have something like

(2) $$\int_{6,0}^{5,1} f(g,t)\, dtdg$$

start at time 6 e in the future of Alice with an indexical time t = 0 sec. For each e, take all t. Integrate to a time 5 e in the future that has an indexical time t = 1 sec. This set of paths from t = 0 to t = 1 is entirely in the future of Alice, given an appropriate presentism function (for example p(g) = 1 for -1 < g < 1, and p(g) = 0 everywhere else). If the universe is branching appropriately, there are more functions in (2) than in (1), because it's further in the future, and thus in general on more branches. The future will be branching at some rate r' = N/e, for the number of branches per e, given by step functions if the branches are discreet.

In one example above the *f* in (2) are constrained only by the *f* in (1), since it is only in the *present* that an observation *takes place*. In this case, a future path could be anything allowed that is consistent with the path that eventually becomes into Alice's present.
…

The moving spotlight

I'm skeptical of the moving spotlight theory. If you have a spotlight moving over a B-series, that's a problem. If you have the spotlight on a time t = 5 sec., and then have the spotlight on a later time t = 10 sec., there are two spotlights. *Ipso facto* neither is ontologically privileged. Both times have an indexical associated with them, and both times have a spotlight associated with them. If neither time is ontologically privileged, then this idea does not model the A-series 'present'.

Another hypothesis is this, as in the first diagram (above). There is just *one* A-series 'present', and it stays put, I mean, it doesn't go anywhere (the future/present/past part of the first diagram). Instead, B-series times flow from the future to the present and then into the past. There's only one present, and B-series times 'become' into it. Later and later times become into the present.

The *relative* motion between the B-series and the A-series does not capture this model. That's because the relative motion is, I think it could be argued, structural information only. If time were just structural information then probably a B-series could model it. But we have the A-series because 1. some philosophers, like me, would contend there is *experimental* evidence for an A-series as well as a B-series (namely, the need for two buttons for the temporal parameters of video searches), 2. it retains ontological privilege, and 3. it is an interesting hypothesis to consider.
…
Note that the unit of becoming, e, may be as well-defined as seconds are. That is critical. e also does a lot of 'heavy lifting', to use the philosopher's locution.

Billiard balls

Classically and non-relativisticly suppose billiard balls b_1 and b_2 come in from the left and right respectively, both starting at time t_1. They collide at a later time t_2. This situation is in variables (t, x^3). In AB-theory one has: each of the systems b_1(t), b_2(t), and b_1-and-b_2-at-collision(t=2), have B-series associated with them. But only one of these systems can have a future/present/past spectrum associated with it, since, if there were more than one, none of the 'presents' would be ontologically privileged. The variables associated with the system that has the present associated with it are (g_{system}, t, x^3)...

More Notes

"You could not step twice into the same river." – Attributed by Plato to Heraclitus (2019).

How to interpret Heraclitus in this paper? The shore is like the present. The flowing water is like earlier-to-later times flowing into Alice's present, from the future (upstream) through the present and then into the past (downstream).

…

This section is possibly wrong.
In 1+1 spacetime, in terms of t and x, in one convention, we have the invariance of

(1) $\tau^2 = -c^2 t^2 + x^2$

under Lorentz transformations. In what might be called 1+1+1, in terms of g, t, and x, it would be nice if there were some kind of invariant

(2) $\tau'^2 = |c_1|^2 k^2 e^2 - c^2 t^2 + x^2$

for some complex number c_1, and some new constant k in units of meters per e. There is a new constant, a 'conversion factor' in meters/e, in analogy to the speed of light, which is a constant or 'conversion factor', c, in meters/sec. k is the rate the position of the particle changes as it becomes into Alice's present.

The real Tau is in terms of (t, x^3), such that in one convention t → *ic*t, for the imaginary unit i and the speed of light c. We want a generalization to a new invariant Tau' in terms of (g_{system}, t, x^3) and the transformations that leave it invariant. But it's not immediately obvious in what way(s) that's doable, because probability gets involved. This, also, has to do with whether the future is branching. One thing to try is g → -*ih'*g for the imaginary unit i and some constant h' based on Plank's constant h, but the dimensions would be off (it seems). The minus sign between t and g, it was argued, comes from the fact that earlier-to-later times go into the future while future-present-past times come out of the future. Obviously other ideas are possible. The rate that B-series time goes by A-series time, i.e. the rate at which later and later times become into Alice's present, is

(3) $r = -ikg / ict$

and is in units of sec./e. The constant k has units of meters/e. The speed of light c has units of meters/sec..
End of possibly wrong section.

10 Conclusion

> “well, [time] is a bit of a mystery. I'd say we understand about half of it, and the other half is still yet to be explained.” (Carroll, 2010)

The definitions of the B-series and A-series have teeth—B-series values (orderings of whatever kind) don't change on time-like worldlines, while A-series values do change. The B-series is ontologically public while the A-series is ontologically private, which has been given a mathematical definition (though not in mathematical notation) and which allows it to be consistent with the relativity of simultaneity. If the AB-series view of this paper can be sustained, the A-series is clearly the other half to which Carroll referred—the problem has always been how to bring it into physics. In this interpretation of time there is one dimension of time per system (however 'system' is to be defined), and it has both A-series and B-series characteristics, ontologically private and ontologically public, respectively. Later and later B-series times become from Alice's future into her present and then into her past. Also it was argued there is a well-defined unit of temporal becoming, e, (or, rather, that it's as well-defined as a second is), and that it coordinatizes the future/present/past spectrum g. That allows one to define functions f at times (g, t), including various derivatives and other objects of interest.

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