Cognition and the Need for 'Timeless Interactions' Math

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2022-06-13.11:30 EDT Mon
https://www.patreon.com/posts/can-particles-be-67551687

Comment on Patreon Hossenfelder post:
Can a particle really be in two places at once?

@Rad Antonov,

Thank you for your interesting comments! I especially liked your phrase "timeless interactions" — see my remarks at the end— since it succinctly captures the idea that large-scale time builds up _from_ smaller-scale interactions rather than being pre-existent. A few responses are below. I've also posted an easily accessible copy of this remark at sarxiv.org, as I like to do when my responses get long (which is, um… often? :)

Human Cognition and Physics

"… It struck me as one of those propositions that most physicists would probably say has to hold, so no one had bothered to prove it.

As with the delightfully profound example of Noether's theorems, I find these types of proofs deeply fascinating. My reasons may differ a bit from those of most folks, however, as I am especially intrigued at how humans model the world in cases of incomplete knowledge, particularly given that we are a species with cognitive abilities closely tied to leader-focused tribal societal behaviors and limited lifespans.

These factors influence our cognitive styles and analytics in blatant and subtle ways. Blatant because, for example, we are at this very moment conversing on a web-based implementation of a Patreon tribe with exclusive membership and implicit requirements for at least some minimal level of fealty to the leader of that tribe. Subtle because, as we age and become more deeply aware of our mortality, our fear that our life's work means nothing grows. With that fear, our willingness to explore new paths often shuts down. Even the most radical iconoclast often morphs with age into a defender of what once was radical but now has become entrenched. A further complication is that age often also brings power, and with that power, a desire to shut down exploration by others as well.

The Subtlety of Emotional Biases

Far more subtle, though, is the incredibly complex suite of survival-focused emotional biases that speed our decisions in cases of danger. This "common sense" suite can cause us to assign priorities so that even the possibility of questioning them becomes invisible. An example? Sure. How many times have you seen a popular press article or read a published paper on the profound mystery of why the color charges of quarks _never_ occur in isolation but only when associated with oddly fractional electric charges? Folks don't see that as a mystery because we "know" Maxwell's equations capture all that is needed to know about electric charge. Why would one complicate that pristine and deeply historical beauty with ugly entanglements involving some extremely short-range newcomer called the strong force? The idea that the electric force _breaks downs_ into symmetric combinations of a single electric-color charge at the nucleon level never occurs to us. Mathematically, however, that is the simplest explanation for why no grand unified theory ever succeeded in merging the strong and electric forces: They cannot merge because the two never separated, and physicists cannot prove or disprove that which they cannot see.

In short, humans are kind of complicated.

A Question of Implication Direction

For both Noether's work and the paper you noted, there lies beneath the logic an assumption that the mathematics of infinitely smooth manifolds _must_ be the underlying fabric of reality. That idea once was an explicitly tribal assumption, an actual debate between groups questioning whether the underlying fabric of the universe is entirely classical — infinitely smooth — or "something else."

Noether's brilliant insight was realizing a deep link between smooth symmetries and the conservation of specific quantum numbers. As a dedicated formalist, she assumed reflexively that the connection flows from the infinitely smooth symmetry to the conserved quantity. However, if mathematical precision is the goal, that level of smoothness is never possible, not even in "many worlds," since all such models _begin_ with "locations" (wave collapses, really) of objects that only then begin spreading as waves.

The more physically plausible alternative — one I doubt very seriously that Noether ever contemplated — is that _conservation_ is the deeper axiom, and that is this absolute conservation that drives the emergence of smoothness. The level of smoothness is limited only by the resources applied but remains finite for that very reason.

Can this reverse-flow version of Noether's theorem be proved? In one sense, it already has. The finite-resolution algorithms that implement photon waves and Schrödinger waves do so by "renormalizing" the math in ways that ensure conservation. But these are clumsy and exceedingly noisy proofs indeed. The proposition of _emergent_ smoothness rather than _assumed_ smoothness is one that physicists don't see as needing proof and so tend not to bother to prove it by creating conservation-first proofs.

The Answer to the Video's Question

Along those lines, a quick note: The title of Dr. Hossenfelder's video posed the question, "Can particles really be in two places at once?"

I worry that the somewhat hand-wringing discussion on how incomprehensible and abstract quantum mechanics is at the end of the video has obscured the simple answer to this question:

Yes, particles _can_ be in two places at once, and there's nothing the least bit fuzzy or esoteric about it.

The simplest example of an electron being physically, measurably, and impactfully in two places is a single-electron 2p atomic orbital. As long as that orbital exists — which it does trivially at the energy levels characteristic of chemistry — all possible methods of measurement, including chemistry and growing crystals, observe the charge of that electron as two very distinct lobes on either side of the atom. I would not be writing this, and you would not be reading this if that were not true, since otherwise chemistry would not work and living organisms would not exist, including us.

Jake, the Superposition!

In contrast to that assertion, superposition _models_ of orbitals choose instead to look into the future for all of the ways a more compact and point-like electron might emerge from a classical orbit if you hit it with, say, a high-energy photon. That's the subtlety and danger of "pure" states since they paradoxically create that purity by assuming energy conditions that never exist in real atoms. The model asserts that all those futures are equally real and superposed inside the atom to form the orbital.

It's a fantastically effective model that has made most of our modern world possible. However, in terms of _experimental_ observations, it's just a handy model for calculating possible futures — energy-induced dynamic transitions, such as those seen in semiconductors — rather than a good way of describing the state of the electron before such transitions. In real-world experiments, if you _don't_ add enough energy to ionize the electron, a 2p electron stays in two rather badly blurred locations. The shape-giving split location and the blurring are perfect for chemistry.

If you add enough energy to induce a transformation of the (always self-entangled and non-local) orbital, it "instantly" transforms into a different, more compact, single-lobe body of charge that looks more like a particle. But that's a future-transition world in which the original chemistry of that atom no longer exists and one in which you and I would be boring balls of plasma.

It's always a good idea not to confuse calculation models for predicting possible future transitions with how the world looks before such transitions. In that earlier world, most of the valence electrons of your body are _typically_ in two or more places at once.

Lorentz Transformation

"… Maybe we have to re-examine [notions of causality], like what do we mean by time?

Yep. It always goes back to time.

"… Is it some universal measure proportional to entropy, an observer-dependent coordinate governed by Lorentz transformations? …

Ah, Lorentz transformations! Now _that_ is an exciting story, indeed, one that touches and binds worlds at all scales.

Timeless Interactions

"… or perhaps some emergent quantity that is only manifest as the result of fundamental, timeless interactions (to coin a new oxymoron)?

I like "timeless interactions" because it nicely captures just how deeply the special relativity principle resides in reality's structure.

Interactions are timeless because _every_ observer's clock is as supreme as any other clock in the universe. Similarly, every observer has its uniquely-defined space, without any need for some external definition of spacetime.

The universe as a whole thus is timeless in the sense that it has no hold on any observer. But all of that falls apart when even two such frames interact.

Colliding systems become single systems, and new, shared sets of coordinates become necessary to predict the outcomes of such interactions. Many such collisions result in emergent spacetime, and unlike the Minkowski fiat version, it has finite granularity. Angular momentum, for example, is defined and implemented solely by whatever object _you_ choose to spin in a direction opposite your own. Timeless interactions of this type thus are also "angular-momentum-free" interactions. Behaviors are independent and authentic states of macroscopic objects, much like quantum spin attaches to particle-scale objects.

These, too, must coordinate when separate frames with their own previously independent angular momentum pairs interact. Part of that interaction involves defining shared x, y, and z coordinates to ensure absolute conservation of the spin axes of all those new angular momenta.

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[2022-06-13.11:00 EDT Mon]
https://sarxiv.org/2022-06-13.1130.pdf