Non-Locality is a Word Without Physical Meaning

Terry Bollinger
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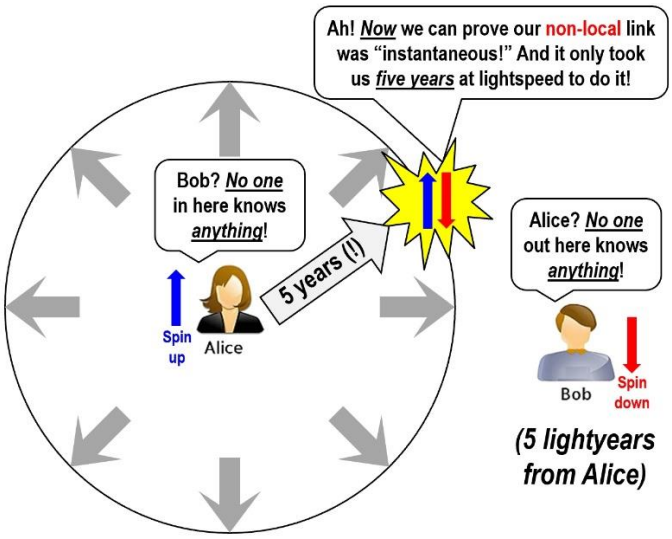

"Non-local" means nothing. We need a deeper understanding of the physics of separation and change.

Non-Locality at the Speed of Light

Despite a century of discussion that began with Albert Einstein and persists animatedly to this day [1], the concept of non-locality — that is, of "spooky action at a distance" — is a word that lacks physical meaning. Asher Peres said it best in 2004 [2] when he described what happens to Bob when distant Alice measures an entangled spin:

> *When Alice measures her spin, the information [remains] localized at her position … until she decides to broadcast it. Absolutely nothing happens at Bob's location. From Bob's point of view, all spin directions are equally probable, as can be verified experimentally by repeating the experiment many times … For Bob, the state of his particle suddenly changes, not because anything happens to that particle, but because Bob receives information about a distant event. Quantum states are not physical objects; they exist only in our imagination.*

What Peres calls a "quantum state … in our imagination" is what an information specialist would call a data relationship — a structure composed of pure information. Peres pointed out that this data structure only emerges after a signal travels at lightspeed or less from Alice to Bob and that at no point does anything Alice does have any impact outside of her future light cone. Given that Alice's data has no impact on the universe outside her light cone and that lightspeed strictly limits how quickly the quantum-state data structure can form, the word "non-local" loses all experimental and causal meaning. It should not be used.

With that said, do you, like me, find Peres's well-reasoned argument deeply unsatisfying?

It feels like a magic trick. You see a final result that your brain tells you violates the known laws of space and time. Someone then explains that this is okay since each step in getting that result respects all those laws. You end up more baffled, not less. What good does it do to know that creating a data structure respects lightspeed limits if the *meaning* of the resulting data structure defies everything you think you know about space and time?

The good news is that there is a more satisfying solution. The bad news is that you won't like it. Here it is: You must stop assuming that "space" and "time" are fundamental to how the universe handles distance and change. Instead, space and time become a local-only, observer-based interpretation of how the universe handles change.

Space and Time as EAs (Einstein Algorithms)

The word "non-local" assumes that the complicated, matter-based, information-intensive, and always-locally-constructed data structures that we call "space" and "time" are universal. The difficulty with this seemingly obvious assumption is that according to Einstein's definitions of space and time until about 1911 [3] are all matter-based, profoundly algorithmic, and require increasing durations and resources to implement over large regions.

We fool ourselves by thinking that once we create a local definition of spacetime, we can reinterpret all incoming information from the rest of the universe in terms of those definitions. Unfortunately, since no single definition of spacetime can be universal, there is no way to make such local-only reinterpretations of the universe fully self-consistent.

We need to recognize that the universe, as a whole, doesn't give a bleep about our local definitions of space and time [4]. It is content to continue using its broader, more baffling definitions of separation and change. While those definitions are more liberal than the ones of local spacetime, they are also utterly resolute in their way. In particular, they never allow causality violations. Once events set history locally, it stays set forever. This irreversibility of local causality should not be a surprise, but fretting too much about abstract non-locality can make it feel like one.

The converse is that the universe powerfully and profoundly supports these local inertial frame spacetime approximations, building them up from the particle level with such astonishing and unexpected properties as rest mass. Nonetheless, an approximation is all these coordinate systems can ever be.

We are addicted to, and overly optimistic about, local spacetime because biological systems leverage the delightful predictive features of spacetime coordinates to maximize survival. Thus, even though some smart folks recognized the parochial nature of inertial-frame-based coordinate definitions over a century ago [5], the constant searching of our hardwired biological imperatives for better predictivity makes us very good at forgetting it.

Does the universe have deeper connections? Absolutely. If it did not, how would we know that an electron on the other side of the universe is identical to one in our laboratories?

However, we must stop talking about non-locality and focus instead on how distance and change work outside local-only, case-by-case definitions of spacetime. Until we understand how locality works, we're not ready to face the more distributed features of our universe.

References

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[5] A. Einstein, *On the Electrodynamics of Moving Bodies*, Annalen der Physik, **17** (10), 891–921 [June] (1905). http://fisica.ufpr.br/mossanek/etc/specialrelativity.pdf