The Role of Energy in the Twin Paradox

Terry Bollinger
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https://www.youtube.com/watch?v=FGoAZKyI6ZY&lc=UgxKJzVJWQmTFSD8vwN4AaABAg.9_j6tNVGTxr9etkrTqnl6o

Comment on the YouTube Dialect post:
Solutions to the Twin Paradox are STILL Wrong
https://youtu.be/FGoAZKyI6ZY

@bobdole57 "if one twin … never returns … special relativity says you can't compare their times." I think you've captured Einstein's later views very nicely, but your assertion is still experimentally false. Seed the traveling twin's path in the rest frame with countless microscopic clocks, all synchronized to the rest twin's clock. As the traveling twin sweeps up these occasional clocks, they broadcast both twins' timestamps. The resulting data shows the traveling twin's time as slower at every point in her journey. Delightfully, the Poincaré symmetries _require_ this to happen.

I'm never satisfied with my understanding of a challenging problem, especially if it remains hard to explain. Below are some ideas I've been working on in the past four months since I posted that comment. I always check the literature first and try to give credit to earlier work whenever I can find it. As best I can tell, these ideas are new.

The only experimentally self-consistent way to analyze twin problems is to recognize that a new frame is a linear momentum excitation of some well-defined set of particles enclosing a volume of space.

The originating (or root, or rest) frame keeps the same clock rate during excitation. That's no surprise. However, clocks in the excitation particle set — the new frame — begin moving slower the instant they energize. That's the critical twin difference: Added energy.

The excited particle set also undergoes Lorentz contraction. This contraction is an actual and potentially messy multi-path process that requires energy to compress the particle set along its axis of motion. All clocks in the compressed space must then resynchronize since, without clock resynchronization, it is impossible to differentiate between space and time in the new frame. For large-volume objects at near-light velocities, this process of _frame settling_ — that is, Lorentz contraction and internal clock resynchronization — can be remarkably prolonged.

Only after the frame settles does it gain the ability to re-analyze incoming data and reinterpret it according to its new and local-only definition of space and time. It's worth the effort since this new way of interpreting the universe is just as valid as any other. The bit that the Poincaré symmetries fail to address is not the lovely symmetries of the resulting frame but the fact that it is a _created_ frame_. It has a well-defined origin in the origin frame, and it possesses excitation energy.

So again: Why does the traveling twin age more slowly? Because she, and she alone, is part of an excited set of particles forming a new, minuscule inertial frame: Her spaceship. The very existence of this frame remains a secret to most of the universe for a long time, so it's not good analytical thinking to treat it as "equal" in that sense. Her clocks start ticking slower the instant they receive their share of the acceleration energy, and they continue to tick slower until the removal of that excitation energy.

Are there still strange things going on? Oh yes, indeed, but they revolve more around how we insist on applying the comforting concepts of "space" and "time" to particle sets that feel no need to keep those two concepts as separate as we do. That's a deeper story for some other time.

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Follow-up comment:
https://www.youtube.com/watch?v=FGoAZKyI6ZY&lc=UgxKJzVJWQmTFSD8vwN4AaABAg.9_j6tNVGTxr9eu-7SbGpCI

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@bobdole57 that is a beautiful response, thank you! Not only do the seeded clocks break the symmetry by preferring the rest frame, but they take time to create and can only feed data back at lightspeed.

Yet without some version of such a network -- our atmosphere is one example -- the very definition of an xyz "space" starts getting quite ratty around the edges. Just as our senses usually treat light and sound as "simultaneous" and get away with it, our xyzt framing of space and time usually gets away treating specific components of spacetime as genuinely simultaneous. They cannot be. Special relativity tells us that as bluntly as possible, but alas, our brains are optimized to think otherwise.

One thing that is not at all ambiguous, however, is energy excitation. No matter how one interprets SR philosophically, following the energy -- the addition of momentum energy relative to a set of related particles -- you get completely unambiguous predictions of direct-contact clocks comparisons at any point in the path. Direct-contact clock comparisons are always best since they remove the ambiguity of comparisons involving light delays and thus produce causally irreversible results.

Energy-based analyses of twin-class problems are necessarily hierarchical since each new frame begins as a lower-energy state that is part of a root, origin, or "rest" frame. The hierarchy changes depending on which frame you select as the root of all others, and the Poincaré symmetries ensure that every root-frame choice works. However, the Poincaré symmetries do _not_ ensure that the frame selected is anywhere near the base of the energy excitation hierarchy. Only the excitation history provides that information.

I find it particularly fascinating that the Poincaré symmetries are perfectly fine with the co-existence of this rigidly specific hierarchy based on energy levels. One way to think of it is that the energy hierarchy deals with origins, while the Poincare symmetries deal with perspectives.

A good example is two galaxies colliding at relativistic speeds, which is a situation roughly equivalent to two vast clouds of internally synchronized clocks colliding. Under the _perspective_ of the Poincaré symmetries, observers in both galaxies see the other galaxy as Lorentz contracted with clocks moving slower than their own. But what the Poincare symmetries _don't_ address is the excitation origins of the two galaxies. The excitation history determines not how quickly the clocks tick but how the clocks are _set_ before they begin ticking.

Thus if _only_ the left-hand colliding galaxy is excited (accelerated) before the two galaxies pass through each other, the inhabitants of the left-hand excited galaxy witness a most curious situation while sampling passing matter from the right-hand unexcited galaxy. While they see the clocks of the unexcited galaxy ticking slower than their own, the version of the right-hand galaxy they see is from what the excited galaxy observers would label the distant future of the universe as a whole — a _time offset._

I do not know precisely why time offsets are not part of standard special relativity texts and literature, but the fact that I have to say this at all in a 2020s discussion of the twin paradox kind of says they are not well known even if they do exist. I've never seen them.

Think it through, and you can see how energy-hierarchy time offsets nicely resolve all special relativity causality paradoxes. Because the clocks in the excited galaxy run slower in _absolute_ terms than those of the rest-frame galaxy, by the time the sloth-like observers in the excited galaxy finish observing the rest galaxy, it _is_ the distant future of the universe. The lovely Poincaré symmetries provide the second trick in the process, ensuring that the clocks of this distant-future rest galaxy change slowly relative even to the slow clocks of the excited galaxy. That is difficult to show without a figure, but the transformations are not complicated. They closely resemble the expansion and compression of one of those expandable gates parents use to keep toddlers off staircases.

Time offsets have another impact: they introduce _structure_ into the interior of a Lorentz-compressed object. Thus it is a bad idea to model all points in the interior of a highly Lorentz-compressed object as "simultaneous" in time because they are not: They experience an effect I call an _age gradient_ in which the front of a Lorentz compressed object has a later timestamp than the back of the object. The age gradient idea does not seem to exist in the literature, either, but it's not complicated. Here's an example: What is the velocity of a 100 m spaceship if its front-end clock is 100 ns faster than its back-end clock? Answer: About ⅓ c.

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PDF: https://sarxiv.org/apa.2022-08-18.2320.pdf

YouTube Fermilab: _Twin paradox: the real explanation_
Video: https://youtu.be/GgvajuvSpF4
Comment:https://www.youtube.com/watch?v=GgvajuvSpF4&lc=Ugw_sw8gjmN6j76dFE14AaABAg

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Uh... wow. Your video on the twin paradox was about four years ago, so I apologize in advance for bringing up a problem others likely have previously mentioned. On the other hand, I now have a better solution that is curiously compatible with what you said.

If you replace your three immediate-contact exchanges of time readings with a much larger set of similar exchanges scattered along the entire travel path, you end up with continuous, irreversible time dilation for both fast-moving ships. Your idea of pairing two ships traveling in opposite directions thus _assumes_ that both ship frames are time dilated independently of any other parameters in your thought problem. Thus you assumed your solution _a priori,_ and any discussion of multiple ships is just noise.

I assume you've been hit with this before, so again, my apologies for bringing it up again. The good news is that you made this _a priori_ assumption correctly.

Frames are excited states of matter encompassing small regions of spacetime that, after a settling period, they "own" as their private definitions of time and space. The ship clocks slowed the instant they were accelerated — energized — from earlier rest-frame collections of matter. The energized clocks in such systems continue to tick slowly as they sail into and out of your example. The slowing effect that results from adding momentum energy is every bit like sticking something into a freezer, and it doesn't go away until you remove that momentum energy by decelerating the particles back to lower-energy rest.

I just posted a somewhat expanded version, but still incomplete, description of the excited state interpretation of frames on another YouTube channel. An easy-to-access, non-advertising PDF of it is here: https://sarxiv.org/apa.2022-08-18.2320.pdf

The most profound irony is that the Poincare symmetries _require_ this kind of specificity. The lack of recognition stems from deeply entrenched historical confusion — or perhaps just a lack of attention — to how Lorentz contraction affects the interiors of volume-enclosing, non-point-like objects.

Internal Lorentz structuring is a different topic for another time. However, I must note that the issue of non-trivial internal spacetime structure in Lorentz compressed objects is shockingly relevant to the modeling and interpretation of QGP data.

For example, all dynamical models that interpret LHC Pb-Pb collision data approximate the colliding lead nuclei as having identical internal spacetime structures. They do not. That's a problem since the extreme Lorentz compressions in Pb-Pb collisions make their divergent internal spacetime structures relevant to correctly interpreting the data.

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