The Twin Paradox as Frame Ripping

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https://www.youtube.com/watch?v=PO4a2zO8zW8&lc=UgxUfKTHm9GGraGnfL54AaABAg.9deBfoVaThP9e0AgpNEaZa

Comment on YouTube The Science Asylum post:
This Paradox Took 17 Years To Solve. It's Still Debated.
https://youtu.be/PO4a2zO8zW8

@Dukjin Im thanks, you have some interesting thoughts there. However, your comment as written contains some confusion about how the string-breaking effect works. I'll address that first, then address at least three questions I see in your comment. I'll use (create, really) the phrase "frame ripping" for the full generalization of string breaking, since the stress begins at the particle level, not just for spaceships.

First, the clarification on how frame ripping works:

Frame ripping occurs _only_ when you accelerate two or more objects to the same speed in the same direction from _your_ frame, the rest frame. Where did the cars start before accelerating? In your frame, as parked cars. Is there frame ripping? Absolutely, and that's why it's a great question. But since frame ripping is a relativistic effect, it's going to be an incredibly small effect for cars accelerating only to 70 mph.

I suspect that the thought problem you had in mind was closer to this: Assume your two special delivery cars from Betelgeuse have finally arrived. The Betelgeuse Speedy Car Delivery truck, which promises muon-speed delivery (99.5% c), just zipped by you, still at full speed. The Speedy truck then pushes your cars out of their truck with their patented interstellar car deliver system, accelerating them both instantly to 99.5% of what _Speedy_ see as light velocity. At that point, the cars finally appear motionless relative to you. You sign the delivery form, and _then_ the two cars accelerate and extra 70 mph more to do whatever they were intended to do.

In _this_ case, yes, you get an enormous frame rip relative to the muon-velocity car delivery truck. In fact, the cars end up 10 times farther away from each other than they were on the interstellar carrier. Any string tied between them gets broken many times over! The impact of the additional 70 mph, however, doesn't even show up after that large of an acceleration, though it does add a tiny bit more separation between them.

So again, in summary: Frame ripping occurs _only_ relative to the starting frame, and it's always a relativistic effect. It doesn't become noticeable until you reach significant fractions of the speed of light, and it doesn't care about any other frame except the launch frame.

With that out of the way, let's get back to your questions. I think the third one is the most interesting since it addresses issues related to the twin paradox.

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(1) "[How does this frame ripping work, e.g., for] two cars [going the same direction] in traffic [at] 70 mph?"

Here's the key point to keep in mind for these kinds of questions: When you accelerate particles or points _individually_ from the rest frame, they retain the same distance from each other in the rest frame. For example, imagine cosmic rays creating two 99.5% c downward traveling muons in the earth's atmosphere at the same earth-clock-moment, e.g., 22:00.00.0000 GMT. The only difference between them is that one muon is a kilometer lower than the other one. They will _keep_ that 1 km separation all the way to the ground — there are no Lorentz compressions because both muons _started_ in the rest frame, and that frame doesn't change.

But what does it look like from the perspective of the muons?

The _muons_ do get Lorentz compressed by a factor of 10. Thus the 1 km of rest frame distance looks to them like 10 km and continues to look like 10 km until they expire.

For two muons this matters not one whit, since they were never linked together in the first place. But what if you instead had a 1 km metal from the location of the top muon to the location of the bottom muon and somehow accelerated the entire wire "instantly" up to 99.5% c? The 1 km wire would see a 10 km end-to-end distance after acceleration and be ripped to pieces by it. That's why I call it frame ripping.

Now, the point of all that is this: Frame ripping is extremely easy to calculate for any velocity since it's nothing more than the Lorentz factor time the length of the object when it was in the rest frame. That's because the individual pieces, even if vaporized into plasma, _are_ Lorentz compressed and thus see the original distance as longer by that same factor, only multiplied in this case.

So, back to your first question. I hope you don't mind if I switch to metric, as it's easier:

Assume you start with two cars 100 meters (about 100 yards) apart and accelerate both to 100 km/h (about 62 mph). After accelerating, they use a laser to measure their new distance apart from their moving perspective. Howe much farther apart are they?

If x is the distance between the two cars and v is their final velocity, the new distance as measured by the cars is {gamma}*x, where {gamma} is the Lorentz factor of special relativity. The added length {Delta}x thus is just is {gamma}*x – x. The full equation is:

{Delta}x = x/sqrt(1-(v^2/c^2)) – x

Substituting x=100 m and v = 100 km/h = 10^5/3600 m/s = 27.7777777778 m/s gives:

{Delta}x = 100/sqrt(1-((10^5/3600)^2/(299792458)^2)) – 100
= 4.405365x10^(-13) m

That's about 0.2% of the diameter of one silicon atom, or about 400 proton diameters. Such distance changes are within the range of modern optical interferometers, and much higher velocities would get the difference up into, e.g., the micrometer range. Getting the accelerations to synchronize would be much, much trickier.

Still, I must admit that this is not necessarily an impossible experiment. On the other hand, it's not that necessary, because…

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(2) "… when in your lifetime you have ever observed any odd effects of relativity, that would break a string due to both vehicles accelerating?"

Last week, when I used my smartphone GPS to drive to a nearby city. GPS satellites absolutely _must_ take these kinds of mutual changes into separation into account to get the levels of accuracy needed to keep from telling you to turn off into a lake. At satellite velocities and separations distances, no string would survive linking them without adding in the frame ripping correction. I have no idea what GPS tech folks call "frame ripping," but I'm sure it's got some label somewhere in their technical manuals.

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(3) "[Since special relativity is observer symmetric, why doesn't frame ripping tear _us_ apart, since we] … are all traveling at near c, relative to your sentient muon?"

Ah, now _that_ is perhaps the most interesting question! After all, isn't special relativity adamant that _every_ frame is equally valid? So why _do_ muons falling from the sky live longer than muons on the ground, and why does the twin in a spaceship live longer than the one on the ground?

The answer always resides in this question: Which frame was the _starting point_ for creating the other frame? The starting frame always gets the fastest clock, and the derived frame always gets the slower clock.

There is a deep connection between time dilation and frame ripping, which I'll explain in a moment. But that kind of connection to such a famous thought problem is why it would be nice if more textbooks on special relativity understood and explained how frame ripping works. It's not entirely missing since, for example, those GPS satellites won't work without taking this effect into account, and the string problem would still be unsolved. But it's certainly not explained well.

The connection between frame ripping and time dilation is this: Clocks cycle and _cycles_ always use the _ripped_ frame, that is, the length of the new frame as seen from the originating frame. Thus each cycle of the clock must traverse the _full_ length of the original ripped frame, even when that length is no longer apparent to the Lorentz compressed objects within the frame. Consequently, clock cycles — the finite fabric of experimental time, as opposed to silly mathematical abstractions that try to make time into an infinitely dense, infinitely continuous Minkowski "substance" — _always_ slow in the derived frame but _never_ in the originating frame. It's not a coincidence that frame ripping is {gamma}*x and time dilation is {gamma}*t because they are _the same thing:_ It's the frame ripping that's slowing down the clocks by exactly the same proportion.

Finally, some of you may have just thought "If frame ripping along x is what slows clocks down, why can't I just make a clock that only cycles in the yz plane?" The problem, in that case, is the yz plane still gets carried along with the clock, so motion in that plane is no longer in the yz rest plane. It too ends up moving more and more along stretched x, and thus equally time dilated.

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