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Symmetric Satellites and Time Dilation: Kinematic Description vs. Dynamic Interpretation

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ABSTRACT

For global navigation satellite systems to provide meter-level positioning, orbital atomic clocks must maintain nanosecond-level stability. Operational functionality requires pre-flight factory calibration to offset relativistic effects, notably a 7 μs/day kinematic delay resulting from Lorentz transformations for satellites orbiting at 14,000 km/h. This correction confirms that velocity-induced time dilation is a physical, cumulative reality rather than a perspective illusion. However, applying pure kinematic special relativity to orbital mechanics introduces fundamental conceptual paradoxes.

This paper presents a thought experiment involving two counter-rotating satellites (A and B) placed in identical circular orbits. While instantaneous pass-by measurements at a relative speed of 28,000 km/h yield a reciprocal kinematic dilation of 28 μs/day, both satellites maintain complete, continuous mutual synchrony over full orbital cycles, remaining synchronized with ground-based clocks. Conventional resolution mechanisms relying on symmetry-breaking accelerations fail, as physical symmetry between the satellites is absolute. Introducing a third, transferred clock (or radioactive decay standard) exposes a severe logical deadlock in pure kinematic reciprocity. We demonstrate that these operational data are logically inconsistent when using Einstein's purely geometric kinematics and instead strongly support the physical framework of Lorentz and Poincaré, in which physical instruments dynamically deform through interaction with an underlying physical medium, masked from local observers by anisotropic signal propagation.

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Introduction

For our mobile devices to determine position, velocity, and heading with meter-level accuracy, satellites across global positioning networks (collectively referred to hereafter as "GPS") must operate with timing precision on the order of nanoseconds (10−9 s).

However, the system cannot function if orbiting clocks remain identical to those on Earth. Maintaining synchronization with ground-based reference clocks requires incorporating relativistic time dilation effects into clock calibration. Once gravitational effects are compensated using General Relativity equations, it remains strictly necessary to account for the kinematic delay derived from Lorentz transformations. For a satellite orbiting approximately 20,000 km above the Earth's surface at a speed of roughly 14,000 km/h (3.9 km/s), this kinematic correction amounts to approximately 7 μs/day [1,2].

It is worth noting that if Earth's gravitational influence were completely removed, and the same clock motion were produced by placing them on the rim of a rotating disc 26,500 km in diameter, with negligible mass, the timing correction required to maintain synchrony with a central clock would be the exact same 7 μs/day. Furthermore, this also represent the reciprocal rate difference observable between two fully inertial systems crossing each other at 14,000 km/h.

This velocity-induced rate adjustment built into pre-flight calibration teaches us that spatiotemporal deformations are neither optical illusions of kinematics nor mathematical artifacts of perspective. The clock lag in orbital motion is a physical, measurable, and cumulative phenomenon. Just as the atomic bomb confirmed with colossal real-world consequences that $\mathbf{E = mc^2}$ is not merely a mathematical abstraction, the 7 μs/day correction in satellites proves that the ticking of moving clocks is physically altered. Were engineers to omit this factory correction, the GPS network would collapse within hours, accumulating positioning errors of several kilometers every day.

Time dilation resulting from relative motion was formally analyzed by Einstein in 1905 (in what would later be popularized in literature as the "twin paradox") using the following terms [3]:
"... *From this there ensues the following peculiar consequence. If at the points **A** and **B** of **K** there are stationary clocks which, viewed in the stationary system, are synchronous; and if the clock at **A** is moved with the velocity v along the line **AB** to **B**, then on its arrival at **B** the two clocks no longer synchronize, but the clock moved from **A** to **B** lags behind the other which has remained at **B** by ½ **t v²/c²** (up to magnitudes of fourth and higher order), t being the time occupied in the journey from **A** to **B**.*

*It is at once apparent that this result still holds good if the clock moves from **A** to **B** in any polygonal line, and also when the points **A** and **B** coincide.*
*If we assume that the result proved for a polygonal line is also valid for a continuously curved line, we arrive at this result: If one of two synchronous clocks at **A** is moved in a closed curve with constant velocity until it returns to **A**, the journey lasting **t** seconds, then by the clock which has remained at rest the travelled clock on its arrival at A will be* $\frac{1}{2} t v^2/c^2$ *second slow. Thence we conclude that a balance-clock at the equator must go more slowly, by a very small amount, than a precisely similar clock situated at one of the poles under otherwise identical conditions ...*"

In 1905, the technology to directly verify this prediction did not exist, nor was it conceivable to deploy clocks in orbit. However, less than a century later, a constellation of over one hundred global positioning satellites allows us to compare the ideas of 1905 conceptually, numerically, and factually with routine technology.

The Validity of Special Relativity in Accelerated Systems
Textbooks frequently assert that Special Relativity is inapplicable in the presence of acceleration, restricting its scope strictly to inertial frames (rectilinear and uniform motion).

In contrast, experimental practice demonstrates that Lorentz transformations predict the behavior of highly accelerated systems with extraordinary precision. This includes the extreme forces required to place clocks into orbit or the intense centripetal forces experienced by unstable particles in high-energy accelerators, whose half-lives, at the end of the process, lengthen strictly as a function of their final achieved velocity, independently of their acceleration history.

In summary, the mathematical framework of Special Relativity operates effectively in mechanically accelerated systems, and this, in itself, poses no conceptual contradiction. The true conceptual breakdown emerges when comparing two clocks orbiting in opposite directions.

Two Counter-Rotating Satellites
To rigorously evaluate the theoretical foundations of this problem, we employ the kind of thought experiment method popularized by Einstein, but grounded in modern GPS infrastructure.

Let us consider two GPS satellites, **A** and **B**, equipped with nanosecond-precision atomic clocks, calibrated on Earth to compensate for the previously mentioned rate differences. Both satellites are placed into the exact same circular orbit, but traveling in opposite directions.

Because they complete one orbital revolution every 12 hours, the satellites pass each other head-on every 6 hours (once at the launch insertion point and once at the orbital antipodes). We assume their trajectories bring them sufficiently close to photograph their respective clock readings or exchange signals at the exact moment of pass-by. This condition allows strict compliance with the definition of simultaneity required by Einstein in 1905, for cross-readings between both satellites.

While in orbit, ground control verifies day after day that—thanks to the 7 μs/day factory calibration—both Satellite **A** and Satellite **B** remain in flawless, continuous synchronization with Earth-bound reference clocks.

A vital methodological detail must be stressed: the calibration performed on Earth remains valid regardless of the intermediate acceleration profile during launch. While accumulated clock time depends on trajectory history, **the instantaneous rate of the clock retains no memory of past accelerations once final cruise velocity is established**.

The Instantaneous Pass-By Measurement
At the instant of crossing, the relative velocity between **A** and **B** is 28,000 km/h.
Applying Lorentz transformations from the quasi-inertial reference frame of Satellite **A**, the relative time dilation factor corresponding to this mutual velocity yields a calculated clock lag of **28 μs/day**.

- An observer on board satellite **A** measures that the clocks on satellite **B** are running at a slower rate, such that if that rate were maintained throughout the journey it would lead to a delay of 28 μs/day with respect to their own.
- Because Lorentz transformations enforce strict kinematic reciprocity between inertial observers, the observation from **B** is an exact mirror image: **B** measures that the clocks of satellite **A** also run at a slower speed, at a rate that, if permanent, would result in a lag of 28 μs/day.

To physically perform this measurement, let's assume that, at the instant of the crossing, each satellite emits two simultaneous light pulses separated by a predetermined spatial distance. According to special relativity, each satellite will determine that the other's pulses were not emitted simultaneously, claiming that the pulse from the front lagged behind the pulse from the rear, which exactly matches the observed clock desynchronization and velocity delay.

The Breakdown of Traditional Explanations
A reader steeped in standard physics textbook arguments will contend that this scenario is merely a variant of the Twin Paradox, where symmetry is broken because "one of the frames was accelerated".

In our experiment, however, this explanation fails:

- Both satellites originated at rest from the same launchpad on Earth.
- Both underwent identical acceleration profiles during orbit insertion.
- Both traverse paths of identical curvature within the same gravitational potential.

Consequently, the physical symmetry between A and B is absolute. What happens when **A** and **B** cross paths again 6 hours later? If the 28 μs/day rate difference were a real cumulative physical effect stemming from relative speed, a net offset should be recorded upon meeting. Yet empirical data and system logic dictate that their clocks remain perfectly synchronized with each other, as both continue to match the Earth-bound master clock.

The Transferred Clock Experiment
To highlight the magnitude of this conceptual conflict, let us introduce a third element: at the moment of crossing, a twin clock (called Clock C) is transferred from Satellite A to Satellite B by means of a pass capture system.

- Clock **C** adopts the role of the "traveling twin": it experiences a real physical acceleration to match Satellite **B**'s trajectory at 28,000 km/h relative to **A**.
- Once aboard satellite **B**, clock **C** operates at the same rate as the main clock of satellite **B**, since its rate, as already

established, does not depend on its acceleration history, but on its final speed.

Note: To eliminate arguments suggesting that mechanical acceleration damages or alters the physical mechanism of Clock C, the clock may be replaced with a sample of radioactive material. The decay half-life of radioactive material is unaffected by prior acceleration, as routinely verified in particle accelerators.

This creates an irreconcilable logical dilemma:

1. Clock **C** must experience a real physical delay relative to **A**, as symmetry was broken when it was instantly accelerated to switch frames.
2. Clock **C** must remain synchronized with the clock in Satellite B, as it now travels alongside it.
3. Yet Satellite **B** never lost synchronization with Satellite **A** upon completing the orbit.

In order for Clock **C** to register an actual physical delay with respect to **A** during the crossing, while simultaneously showing complete synchronization with **A** and **B** on the next lap, we are forced to accept that Clock **C** must somehow "run fast" during another segment of its orbit to compensate for its initial delay.

Conflict with kinematical Einstein's Interpretation

The chosen point of intersection is entirely arbitrary and the phenomenon reproduces identically at any orbital location. In fact, the analysis can be forced at all points in the orbits by placing satellite **A** in an orbit slightly higher or lower than that of satellite **B**. In this way, Kepler's laws will shift the crossing point along the entire path, confirming that what is observationally valid at one point in orbit **A** is also valid at all other points in that same orbit. The same applies to satellite **B**.

So, we are confronted with two experimental facts that directly collide under Special Relativity kinematic framework:

• **Fact 1:** Satellite **A** experimentally detects, during successive crossings along their respective orbits, that the clock on satellite **B** maintains a slower rate than its own throughout the entire orbital path. This slower rate is perfectly in accordance with the relative speed of 28,000 km/h between the two satellites.

• **Fact 2:** Satellites A and B maintain absolute synchronization whenever they cross paths and are permanently synchronized with a third clock Z fixed on Earth.

Because ground synchrony is an indisputable operational fact, we must conclude that the instantaneous pass-by rate measurement does not reflect a real, cumulative physical change in the overall ticking rate of the opposing clock, but is rather a measurement artifact dictated by signal propagation conditions.

This is where Einstein's interpretation encounters a fundamental breakdown.

For Einstein, space is a purely geometric abstraction, and time dilation is a reciprocal effect of perspective between inertial reference frames. However, simple perspective cannot explain why two physical systems with absolute physical symmetry exhibit a delay in the rate of their clocks during their crossing at every point of the orbital path, but a zero cumulative delay when completing a full circuit.

The Lorentz-Poincaré Solution: The Physics of a Supporting Medium

Resolving this conflict in a logically consistent manner requires revisiting the **dynamic physical interpretation** of Hendrik Lorentz and Henri Poincaré [4-6].

Under the Lorentz-Poincaré framework, length contractions and clock-rate slowdowns are real, dynamic, and physical effects caused by the interaction of matter and its associated force fields as they move through an underlying physical supporting medium (ether/space lattice).

In this framework, orbiting satellites do not alter their rate based on "how they observe one another," but rather due to their real physical interaction with the supporting medium as they traverse it at orbital speed across all vector directions in the orbital plane.

• Because both satellites traverse the **same stationary medium at the same absolute speed** (14,000 km/h relative to the Earth's local reference frame), their real, averaged rate slowdowns over a full orbit are identical.

• This explains without contradiction why mutual synchrony is preserved at the end of every orbit. It reveals that the 28 μs/day mutual delay calculated during crossing is merely an operational artifact of instantaneous optical signaling, lacking physical validity when extrapolated across the complete closed trajectory.

Note: *For the purposes of this analysis, it is not important to establish whether the Earth represents a true inertial frame of reference, as it is not for measurements of the type performed by Michelson and Morley. What is important is that both satellites travel in orbits that do not experience differential acceleration. Therefore, the conclusions reached are qualitatively identical to those that would be obtained in a true inertial frame of reference*.

The Masking Mechanism: Why Kinematic Illusions Persist

At this point, a critical observer will ask: If clocks undergo real physical rate alterations when moving with or against the supporting medium, why do ground stations and satellite onboard instruments fail to detect these continuous daily rate oscillations? The answer brings us back to the foundational reason why the Michelson-Morley experiment yielded a null result [7].

Under the dynamic framework of Lorentz and Poincaré, for any translating inertial frame, the signal propagation speed is anisotropic. Consequently, when an observing apparatus moves relative to the supporting medium, the light used to synchronize clocks or transmit time data no longer travels at a uniform speed **c** in all directions with respect to the moving frame of reference. A perfect physical compensation occurs.

In brief:

1. The moving emitter clock undergoes a real physical modification in its ticking rate due to its absolute velocity through the medium.
2. The light signal emitted to transmit the clock reading travels through the medium at a speed that depends on its propagation direction.
3. The signal transit time **rigorously cancels and masks** the physical deformation of the clock from the perspective of the observer.

So, we are attempting to measure physical deformations in nature using a measuring rod made of the exact same flexible material that deforms with motion: light itself.

The "Real" View from a Privileged Reference Frame

If we could observe the system from a hypothetical absolute frame of reference, without the signal's speed limitations, we would see that the supposed circular trajectories and the assumed constant speeds are not. Furthermore, we would see that information (including gravitational interactions) propagates at varying speeds in different spatial directions.

The mathematical symmetry admired in Einstein's formulation is not a magical property of empty geometric space; it is the direct result of a perfect physical masking mechanism, produced by the actual laws of propagation of electromagnetic and gravitational waves. In fact, if gravity did not propagate under the same speed restrictions as light, maintaining operational synchronization across the entire GPS network would be physically impossible.

Conclusions

A rigorous logical analysis of satellite positioning systems demonstrates that the kinematic framework introduced by Einstein in 1905, while mathematically effective as an operational calculation tool, is conceptually incomplete for describing underlying physical reality [8].

The preservation of orbital synchrony between symmetric counter-rotating satellites disproves pure kinematic reciprocity as the ultimate explanation for time dilation. The behavior of orbiting clocks achieves logical consistency only when acknowledging that:

1. The universe possesses an underlying physical supporting medium.
2. Clock rates and material dimensions undergo real physical deformations when moving through this medium.
3. The observed constancy of the speed of light in laboratories is the product of a physical compensation system wherein measurement instruments deform in exact proportion to alterations in signal propagation speed.

The **GPS** network is not merely an engineering triumph; it serves as a large-scale physical experiment forcing a reevaluation of fundamental physics and affirming the dynamic framework of Lorentz and Poincaré.

The Impossibility of Synchronization in Rotating Systems

This topic has been studied repeatedly in the scientific and divulgation literature.

In particular, we will analyze a publication dated on 2000[9], which compiles previous work and claims to have arrived at a solution that would maintain the conceptual framework of kinematic relativity, avoiding paradoxes such as those highlighted in our study. We will demonstrate that this work contains insurmountable conceptual errors, and therefore, it is not only far from invalidating our work, but it actually reinforces the conclusions we have reached.

Below is a summary of that work, using selected paragraphs from it with the intention of avoiding any unintentional alteration. The full publication is available at Internet.

"*...In our parable, Lisa, the protagonist of the paradox, lives on a ring of radius R with a team of observers stationed at every point on her ring. Bart lives on an identical ring. The rings are negligibly separated, rotating at equal and opposite angular velocity v about a common axis…*"

"*…The twins will pass each other periodically, their negligible separation allowing each to read the other's clock….*"

"*… At a certain moment, Bart and Lisa happen to be at the same place, and they notice that their clocks both read t = 0. ... Due to time dilation, Lisa's team observes Bart's clock ticking more slowly than their own clocks by a relative Lorentz factor... Since Bart's clock agrees with Lisa's as he passes her at t=0, time dilation means that his clock will lag behind the clock of the next of Lisa's observers that he passes. As he passes successive members of Lisa's observing team, his clock should be seen to lag further and further behind…*"

"*… The synchronization of clocks on rotating rings presents a special challenge. Here we describe four ways one might choose to synchronize such clocks. In the first two methods, the rings are imagined to be initially nonrotating, that is, initially at rest in the Lab. The clocks are synchronized while at rest, and then the rings are set into rotation. In the last two methods, synchronization is done while the rings are already rotating…*"

"*… In any case, the paradox cannot be evaded if Lisa's clocks are synchronized by Method 4. In this case, the clocks of Lisa and Milhouse are ``correctly'' synchronized. If Lisa and Milhouse are negligibly separated on the ring,* ***their readings will differ negligibly from readings done in a standard special relativity reference frame that is instantaneously comoving with them****. Lisa and Milhouse will therefore observe Bart's clock to run slowly and Bart's clock will lag Milhouse's when they pass each other…*"

Figure 1 illustrates the situation described in this paper, at the moment Lisa and Bart cross paths at a point on their respective routes. The times indicated are arbitrary and serve the sole purpose of highlighting that, from Lisa's perspective, Bart's companions who are traveling with him in his rotating system but are further ahead in the direction of rotation have clocks that show increasingly negative time differences as they move further away from Bart. The opposite occurs with Bart's companions who are behind him in the direction of rotation. In this case, the clocks show times that are increasingly ahead of those in Lisa's system.

As mentioned in the paper itself, these observations are in total qualitative agreement with what would be observed between two genuine inertial systems whose respective synchronizations correspond to Lorentz transformations.

The real problem arises when the authors claim to have synchronized the clocks in Bart's rotating system.

First, it should be noted that only synchronization proposal 4 corresponds to the method developed by Einstein in 1905. The other synchronization proposals are entirely arbitrary and do not correspond to real physical interactions [8]. However, even overlooking this conceptual error, the most serious problem is the assertion that, regardless of the method chosen, synchronizing a rotating system is possible.

The following analysis demonstrates this egregious conceptual error by the authors of this work.

To do this, let's momentarily disregard Lisa's rotating frame and add a true inertial frame, in which Homer is at rest, inside a stationary circle the same size of Bart's rotating ring. Homer's frame meets the requirements of a true inertial frame, and therefore Einstein's synchronism leads to readings from the entire periphery of this disk simultaneously marking time 0, as shown in Figure 2.

Consequently, Bart's clock readings maintain the same conceptual appearance as when viewed from Lisa's system. The fundamental fact is that Bart's friends, as seen from Homer's inertial platform, have clocks that show increasingly negative time differences as they move further away from Bart. The opposite occurs with clocks that are further and further behind Bart.

Once this fact, explicitly mentioned by the authors of the aforementioned work, is accepted, it becomes clear that it is impossible to assign a time reading to the clock in Bart's system, indicated by a question mark in Figure 2. If we were to choose a time reading equal to Bart's (t=0) for both clockwise and counterclockwise rotation of the other clocks in Bart's system, they would have to recover the delays and advances measured in Bart's vicinity, generating a behavior completely contrary to that predicted by the Lorentz transforms.

The same would occur with any time reading assigned to Bart's friend located at the opposite end of the ring.

This situation demonstrates that it is impossible to synchronize the clocks of a rotating system (regardless of the synchronization method chosen) without completely violating the equations governing systems studied using Special Relativity.

What is astonishing is that the authors acknowledge this problem when they say "*When Method 4 is used, there will be a discontinuity in synchronization*", but they complete their analysis as if they had achieved synchronization.

Thus, when they claim "*This conclusion may seem to some readers to evade, not resolve, the paradox*", they are unaware that they are actually denying and evading the paradox.

In fact, the impossibility of synchronizing clocks or interactions in a rotating system has direct consequences for the development of Special Relativity. To arrive at the Lorentz transformatios, starting from Einstein's postulates, it is first necessary to synchronize events. Since we have just demonstrated that this is impossible, the Lorentz transformations lose their global validity and only describe, with greater or lesser approximation, local events (in small sectors of the rotating rings). Given this result, we understand that the altered rhythms can only be accepted as apparent. And the only way for them to be apparent is if the instruments are actually deformed, leading directly to the Lorentz and Poincaré Dynamic Relativity as the only acceptable way to describe these results.

In short, this work only serves to demonstrate that the development we presented in our analysis remains completely valid.

Final Comments

We are aware that the results achieved, which involve the reintroduction of a supporting medium for all physical phenomena, lead to the need of rethinking current cosmological foundations, recreating the image used by physics at the end of the 19th century. This situation is entirely consistent with a concept not yet developed at that time: that matter and waves are not separate phenomena and that, just as waves require a supporting medium, particles can also propagate thanks to their undeniable wave properties.

Additionally, throughout this work, the use of classic spacetime diagrams associated with Relativity was explicitly avoided, since we consider that qualitative logical contradiction does not require this kind of explanatory graphics.

Acknowledgments

Finally, we wish to express our gratitude for the invaluable and selfless collaboration of our friend Angel Torregrosa Lillo during the development of this study. We thank him for his constant critical spirit, which allowed us to improve the way in which we carried out these analyses.

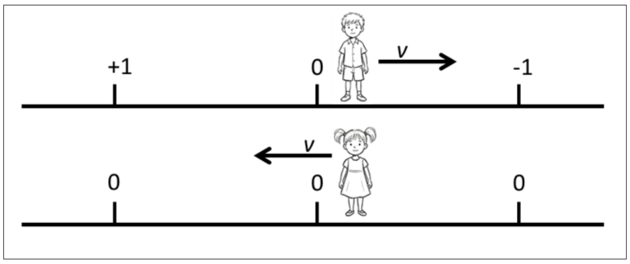

Figure 1: Readings on the clocks of Lisa and Bart's rotating systems, as seen from Lisa's system at the moment of the twins crossing paths

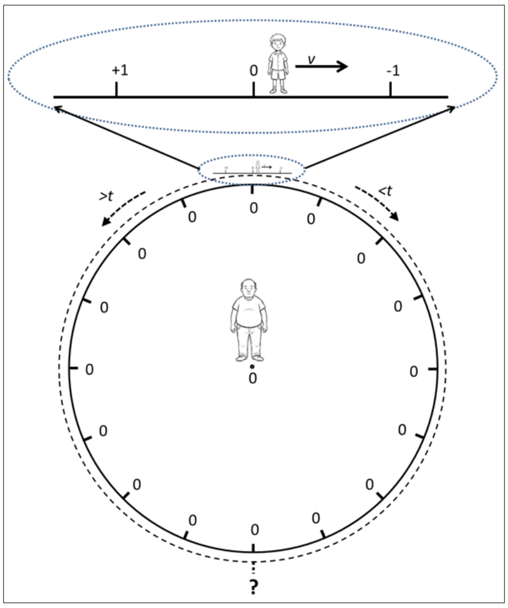

Figure 2: Readings on the clocks of Bart's rotating system (in dashed lines), as seen from Homer's true inertial disk. A reading impossible to obtain using Einstein's equations of kinematic relativity is indicated with a "?"

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