

# Mostly Synchronized

How to synchronize clocks almost, but not quite (... entirely unlike tea) \*

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## 1 Introduction

There have been many attempts made to devise methods by which two clocks, separated by some noticeable distance, can be synchronized so closely to one another, that you can use them to make a measurement of the speed of light in one direction. A recent video describing some of these attempts was published by Veritasium in 2021 [1].

There are many methods to synchronize clocks that are *not* precise enough to measure the one way speed of light, e.g. methods used in computer networks like the Network Time Protocol (NTP) [3] and HUYGENS [2]. These involve measuring the time on a local clock, sending it in messages to other computer systems, and sometimes performing extensive calculations on the contents of sequences of these messages, in order to get closer to a level of synchronization precision that is possible for causal messages passed via signals traveling at the speed of light, or usually slower.

Those methods will not be discussed further in this document.

## 2 Methods that seem like they might be able to allow light-precise clock synchronization

### 2.1 Synchronize stationary clocks with known distance between them by constant-speed traveler

I heard about this from James Ellias, who may have heard about it from someone else (Aviram Rosochotsky?). It would be good to learn who created it, if it is known, and whether there are any published references to it.

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\*With a hat tip to Billy Crystal in "The Princess Bride" and "The Hitchhiker's Guide to the Galaxy" by Douglas Adams

### 2.1.1 First ChatGPT prompt and response

**I asked ChatGPT to comment on it using this prompt:** Consider the following attempt to synchronize clocks precisely enough to measure the one way speed of light, and comment on what about it prevents it from achieving that level of synchronization precision. Two observers A and B with clocks are connected by a rod of known length  $L$ . A traveler C with a precise clock moves with precisely known constant speed  $v$  parallel to the length of the rod, very close to the line of the rod. As C passes near A, they synchronize their clocks with each other by exchanging light signals. Later as C passes near B, they synchronize their clocks. Both A and B know C's speed precisely, and so can calculate the Lorentz factor for C's speed  $v$ , and thus B can calculate the precise amount to update its clock so that it becomes the same as A's clock.

**ChatGPT's reponse:** You're describing a clever attempt to use a moving traveler (C) to synchronize two spatially separated clocks (A and B) without directly assuming the one-way speed of light — a core challenge in the foundations of relativity. The method you outline cannot succeed at measuring the one-way speed of light independently, and the reason lies in an unavoidable circularity tied to the relativity of simultaneity and Einstein synchronization.

Let's break this down step by step:

Setup Summary:

- A and B are at rest in some inertial frame and separated by a known distance  $L$ .
- C moves at known speed  $v$  from A toward B, very close to the line connecting them.
- C passes A, synchronizes clocks with A (e.g., they agree that  $t_C = t_A = 0$ ).
- C continues at constant speed, passes B, and B synchronizes with C's clock.
- B then computes how to adjust its clock so it is synchronized with A's — using:
  - C's speed  $v$
  - The Lorentz time dilation factor  $\gamma$

The Goal

To use this process to establish whether clocks A and B are synchronized in such a way that one can measure the one-way speed of light (i.e., the time it takes light to go from A to B or B to A without assuming it's the same in both directions).

Why This Doesn't Work: Circular Dependence on Clock Synchronization

Here's the core problem:

To determine how much B should adjust its clock using C's reading and time dilation, you must already assume a convention for simultaneity – which depends on the one-way speed of light.

More precisely:

1. When C synchronizes with A, that moment is defined in A's rest frame as the clocks being equal – fine.
2. When C reaches B, its clock shows some time  $t_C$ , and B wants to infer what time A's clock shows now in A's rest frame. But here's the catch:
  - To determine what time it is at A simultaneously with C's arrival at B, you need a definition of simultaneity.
  - But simultaneity in special relativity is frame-dependent, and to determine simultaneity across space, you need to assume something about how signals propagate – in particular, the one-way speed of light.
3. When B applies a correction based on time dilation (i.e., assumes that C's clock ran slow by a factor  $\gamma$ ), that correction is valid only under the assumption that A and B are already Einstein-synchronized – i.e., that the one-way speed of light is the same in both directions.

The Circular Logic

- You use time dilation to calculate the time at A from the clock reading at C when C reaches B.

- But time dilation itself – and the transformation between C’s time and A/B’s time – depends on the synchronization of clocks A and B using Einstein’s method.
- And Einstein synchronization assumes the one-way speed of light is  $c$ .

Hence, you’re assuming the very thing you’re trying to measure.

The Philosophical Core

This goes back to a foundational insight of special relativity (and philosophy of physics):

The one-way speed of light cannot be measured without already synchronized clocks – and clock synchronization requires a convention (e.g., Einstein synchronization), which assumes the one-way speed of light is equal in all directions.

So any procedure that seems to measure the one-way speed of light actually smuggles in that assumption in its setup, typically through how simultaneity or clock adjustments are defined.

What You Can Measure: The Two-Way Speed of Light

All actual physical measurements of light’s speed measure round-trip (two-way) times, which are invariant and do not depend on synchronization conventions. That’s what experiments like Michelson-Morley and modern laser-ranging experiments measure – and all confirm that the round-trip speed is exactly  $c$ .

Related Thought Experiments

- Einstein’s train and platform: Demonstrates relativity of simultaneity.
- Reichenbach’s  $\epsilon$ -convention: Formalizes the idea that you can set the one-way speed of light arbitrarily (as long as round-trip speed is  $c$ ).

Conclusion

The method you described assumes the one-way speed of light in how B corrects its clock using C’s time. That assumption is buried in the application of Lorentz transformations and time dilation, which themselves depend on Einstein synchronization.

Therefore, the setup cannot be used to independently measure the one-way speed of light or synchronize clocks to the required precision without circularity.

Let me know if you’d like this expressed with spacetime diagrams or coordinate transformations to make it clearer.

There are some follow up questions and answers in Appendix [?] that I found interesting, but are relevant for other methods besides this one, hence putting them in an appendix.

## References

- [1] Why No One Has Measured The Speed Of Light, 2021. URL <https://www.youtube.com/watch?v=pTn6Ewhb27k>.
- [2] Yilong Geng, Shiyu Liu, Zi Yin, Ashish Naik, Balaji Prabhakar, Mendel Rosenblum, and Amin Vahdat. Exploiting a natural network effect for scalable, fine-grained clock synchronization. In *15th USENIX Symposium on Networked Systems Design and Implementation (NSDI 18)*, pages 81–94, Renton, WA, April 2018. USENIX Association. isbn:978-1-939133-01-4. URL <https://www.usenix.org/conference/nsdi18/presentation/geng>.
- [3] Wikipedia. Network Time Protocol, 2025. URL [https://en.wikipedia.org/wiki/Network\\_Time\\_Protocol](https://en.wikipedia.org/wiki/Network_Time_Protocol).

## A Q&A with ChatGPT I found interesting

### A.1 Does Einstein’s clock synchronization postulate make it impossible to measure one way speed of light?

**I followed up with this prompt:** Does Einstein’s clock synchronization convention postulate effectively make it impossible to measure the one way speed of light by the very fact of accepting that postulate?

**ChaptGPT’s reponse:** Yes, exactly – and you’ve put your finger on a deep and often misunderstood point.

Short Answer

Yes:

Einstein’s clock synchronization convention defines the one-way speed of light to be equal to the two-way (round-trip) speed of light. As a result, once you accept that convention, the one-way speed of light is not something you can measure independently – it’s a matter of definition, not discovery.

Why This Is So

Let’s step back.

In his 1905 paper, Einstein proposed a convention for synchronizing clocks at different locations in an inertial frame:

To synchronize two clocks A and B, send a light signal from A to B and back to A. If the signal takes time  $t_1$  to go from A to B and  $t_2$  to return, then assume the time for each leg is equal:

$$t_{AB} = t_{BA} = \frac{1}{2}(t_1 + t_2) \quad (1)$$

This is a postulate, not a derived fact. It assumes:

- The one-way speed of light is the same in both directions (A to B and B to A).
- This speed is equal to  $c$ , the measured two-way speed.

So when we say we’ve synchronized two clocks “Einstein-style,” we’ve built in the assumption that the one-way speed of light is  $c$ .

The Circularity

If you now ask:

“Can I test whether the one-way speed of light really is  $c$ ?”

You’re faced with this issue:

- To measure how long it takes for light to go from A to B, you need synchronized clocks at A and B.
- But you synchronized those clocks by assuming the very thing you’re trying to test – that light takes the same amount of time in both directions.
- Therefore, any such measurement cannot independently confirm or refute the one-way speed of light being  $c$ ; it’s conventional.

The Conventionality Thesis

This insight has been formalized in philosophy of physics, especially by thinkers like Hans Reichenbach. He proposed a more general synchronization scheme using a parameter  $\epsilon \in [0, 1]$ , where:

$$t_{AB} = \epsilon(t_1 + t_2), t_{BA} = (1 - \epsilon)(t_1 + t_2) \quad (2)$$

- Einstein synchronization sets  $\epsilon = 0.5$
- But any  $\epsilon \in [0, 1]$  leads to a logically consistent theory, as long as the two-way speed is still  $c$ .

So the one-way speed of light is not an observable quantity – it’s a convention that completes the formalism of relativity.

What Is Measurable?

- The two-way (round-trip) speed of light: Measured directly by bouncing light off a mirror and recording round-trip time with a single clock.
- Observables like time dilation, length contraction, Doppler shift, and light aberration – all frame-independent or computable with Einstein synchronization.

Why All Experiments Agree

Every experiment that measures the speed of light (from Michelson-Morley to modern cavity resonator setups) ultimately measures the round-trip speed. No known experiment can avoid the need for clock synchronization to measure a one-way speed, and thus none can determine it independently.

Conclusion

Yes, Einstein’s synchronization convention defines the one-way speed of light to be  $c$ . Once you accept that postulate:

You’ve removed the one-way speed of light from the list of things you can empirically measure.

It’s not a weakness – it’s a recognition of how time and simultaneity must be operationally defined in special relativity.

Let me know if you’d like examples or spacetime diagrams to visualize this.

## A.2 If we reject Einstein’s clock synchronizatio postulate, does it become possible to measure one way speed of light?

**I followed up a bit further about rejecting Einstein’s postulate:** Suppose one wished to reject Einstein’s clock synchronization postulate, and instead follow a theory such as Lorentz Ether Theory. Does the one way speed of light then become a value that can be discovered, rather than assumed?

**ChaptGPT’s response:** Yes – if you reject Einstein’s synchronization convention and adopt a framework like Lorentz Ether Theory (LET), then the one-way speed of light becomes, in principle, a quantity that could be discovered, not just assumed.

But this comes with important caveats – both philosophical and empirical.

In Lorentz Ether Theory (LET):

- There is a preferred “ether” frame in which light travels isotropically at speed  $c$ .
- In all other frames, light travels anisotropically (i.e., with different speeds in different directions).
- The asymmetry in the one-way speed of light between moving frames is considered physically real, not just a coordinate effect.
- Clocks can, in principle, be synchronized to reveal this anisotropy – if you could find the ether frame or distinguish it experimentally.

So under LET:

The one-way speed of light is not postulated to be  $c$  in all directions – and could be discovered, if you can identify the ether frame or detect the anisotropy.

But Here’s the Catch:

Despite this theoretical openness to a discoverable one-way speed of light, LET makes all the same experimental predictions as Special Relativity (SR) – including:

- Michelson–Morley experiment: LET explains the null result by length contraction and time dilation due to motion through the ether.
- Kennedy–Thorndike experiment
- Ives–Stilwell experiment

Every experiment that tests light speed or time dilation gives results indistinguishable from SR, because LET essentially hides the ether’s effects perfectly.

This is what led Einstein and later physicists to regard LET as superfluous – philosophically heavier but empirically equivalent to SR.

Why LET Still Can’t Measure the One-Way Speed of Light

Even in LET, if you’re inside a lab moving with respect to the ether, and all your measuring devices (clocks, rods) are affected by time dilation and length contraction according to LET, you still can’t tell that your one-way light speed is anisotropic – because:

- Your rods have contracted exactly enough,
- Your clocks have slowed down exactly enough,
- So that all your measurements appear as if light speed is  $c$  in all directions.

So unless you can somehow escape or detect the ether frame (which has never been done), you still can't operationally determine the one-way speed of light.

Summary

Framework	One-way speed of light:	Can be measured?	Requires synchronization convention?
Special Relativity	Postulated = $c$	No	Yes (Einstein convention)
Lorentz Ether Theory	Anisotropic except in ether frame	No, in practice	Yes, but defined by real ether time
If ether frame is found	Then: discoverable	Yes, in principle	No (objective simultaneity exists)

So yes: in principle, LET treats the one-way speed of light as discoverable – but in practice, due to the empirical equivalence with SR and the undetectability of the ether, it remains unmeasurable.

Would you like to explore experimental setups that attempt to measure the one-way speed of light – and why they fail – even from a LET perspective?

### A.3 Experimental setups that attempt to measure the one way speed of light, and why they fail, even from LET perspective

**My next prompt:** Please explore experimental setups that attempt to measure the one-way-speed of light, and why they fail, even from a LET perspective.

**ChaptGPT's reponse:** Great – let's dig into this.

You're asking about experimental attempts to measure the one-way speed of light, and especially why they fail, even under the assumption of a preferred frame like in Lorentz Ether Theory (LET).

This gets at a subtle point in both philosophy of physics and measurement theory: why clock synchronization, or the absence of a universal simultaneity, makes the one-way speed inaccessible, no matter how clever the setup.

General Idea Behind One-Way Light Speed Experiments

To measure the one-way speed of light from point A to point B, you need:

1. A clock at A to mark the light's departure time.
2. A clock at B to mark the arrival time.
3. The clocks must be synchronized in a physically meaningful way that does not assume the very light speed you're trying to measure.

This third requirement is where every setup fails – either explicitly, by assuming Einstein synchronization, or implicitly, by using signals whose behavior depends on light's speed.

Categories of Proposed Experiments (and Why They Fail)

1. Einstein Synchronization Itself

Method: Send a light signal from A to B and back to A. Assume it travels the same speed both ways, so the midpoint of round-trip time is when it hit B.

Why it fails: It defines the one-way speed of light to be equal in both directions. So using it to measure the one-way speed is circular.

2. Slow Clock Transport

Method: Synchronize clocks at the same location, then slowly move one to the other location.

Why it fails:

- In LET: the transported clock experiences time dilation due to movement through the ether, even if slow.
- This makes the result frame-dependent, and if the ether is undetectable, so is the effect.
- In SR: same problem – the result depends on assumptions about simultaneity and inertial frames.

So slow transport can't determine whether any observed discrepancy is due to clock transport or actual light anisotropy.

3. Use of "Clock-Free" Methods (e.g., one-arm interferometers)

Example: A light signal is sent from A to B, reflected back, but with a detector that moves to record the one-way leg specifically.

Why it fails: Even if you cleverly design a setup to record only the forward travel, you still rely on:

- Assumptions about timing mechanisms,
- Mechanical or electromagnetic signals traveling at predictable speeds,
- Which ultimately trace back to synchronization based on light or some equivalent.

So you haven't escaped the need for synchronized clocks or signal calibration that presumes isotropy.

#### 4. Atomic or GPS-like Time Transfer

Method: Use portable atomic clocks, or time-transfer protocols (like those in GPS) to synchronize clocks independently of light.

Why it fails:

- All practical time-transfer methods either rely on round-trip signals (so the same symmetry assumption sneaks in), or require extremely precise control over motion and knowledge of all inertial effects.
- GPS works by assuming SR's validity – not testing it. In fact, GPS is designed assuming the one-way speed of light is isotropic in ECI (Earth-Centered Inertial) frame.

So if you try to use GPS to “measure” the one-way speed, you're assuming what you want to test.

#### 5. Two Clocks Launched in Opposite Directions

Method: Launch two synchronized clocks from a midpoint in opposite directions (e.g., rockets or satellites). They both receive the same light pulse from the midpoint.

Why it fails:

- Time dilation affects both clocks differently depending on their motion.
- Again, interpreting the results requires assuming a simultaneity convention.
- LET would say the different readings are due to motion through the ether; SR would attribute it to coordinate-dependent simultaneity. But the observations are the same.

#### What LET Says About All This

In Lorentz Ether Theory, there's a preferred absolute frame in which the one-way speed of light is isotropic. But:

- Clocks moving through the ether tick slower,
- Rods contract in the direction of motion,
- All measuring devices conspire to hide the anisotropy of light's one-way speed.

This “conspiracy” is not mystical – it's a mathematical consequence of the transformation rules that LET inherits from Lorentz transformations (just like SR does).

So any experiment done with physical clocks and rods, no matter how precise, will give the same result predicted by SR. You can postulate a preferred frame, but you can't detect it.

Bottom Line

Why all known attempts fail (even in LET):

- You always need synchronized clocks at two locations.
- Synchronization requires assumptions – either about signal speeds or time transport.
- LET allows for a true one-way speed of light – but makes it experimentally undetectable, due to the way time dilation and length contraction perfectly hide the ether.

#### What Would It Take to Measure the One-Way Speed?

You'd need:

1. A way to synchronize distant clocks without using light or slow transport or any system affected by ether motion.

2. Or, detect physical effects that vary with light directionality and cannot be explained by time dilation or length contraction – but no such effects have ever been observed.

Closing Thought

Let's quote Einstein himself (paraphrased from his 1905 paper):

“We assume the speed of light to be the same in both directions. That is a stipulation... not a hypothesis about the nature of light.”

This is as true in Special Relativity as it is as a criticism of any experiment claiming to measure the one-way speed.

Let me know if you'd like a diagrammatic explanation, or an overview of how this plays into the design of systems like GPS, or into the philosophy of simultaneity.

## A.4 What would anisotropic speeds of light in Lorentz Ether Theory look like?

**The discussion above and my own investigations led me to ask this:** Theoretically, what would anisotropic speeds of light in different directions look like when moving relative to the ether in Lorentz ether theory?

**ChaptGPT's response:** Excellent question. You're now asking:

If Lorentz Ether Theory (LET) is correct, and there is a preferred “ether frame,” what would anisotropic one-way speeds of light look like in a frame moving relative to the ether?

This dives into how LET conceptualizes the behavior of light and time across different frames – and how it agrees numerically with Special Relativity while maintaining a different interpretive stance.

Basic Setup in Lorentz Ether Theory

- LET postulates a preferred frame – the “ether frame” – in which the laws of physics take their simplest form, and the speed of light is isotropic (same in all directions), equal to  $c$ .
- All other inertial frames move relative to the ether.
- Objects and clocks in moving frames undergo length contraction and time dilation when moving through the ether, as real physical effects.
- The coordinate transformations between frames are still Lorentz transformations – just with a hidden preferred frame underneath.

What Happens in a Frame Moving at Velocity  $\mathbf{v}$  Through the Ether?

Suppose frame  $S'$  moves at velocity  $\mathbf{v}$  relative to the ether frame  $S$ . In  $S$ , light moves at speed  $c$  in all directions.

In  $S'$ , due to LET:

- Light still takes the same total round-trip time over any path (because clocks and rods are distorted in just the right way).
- BUT the one-way speed of light becomes anisotropic in  $S'$ .

Anisotropic Light Speed in LET

Let  $\hat{\mathbf{n}}$  be a unit vector representing direction, and let  $\mathbf{v}$  be the velocity of the moving frame through the ether (both 3D vectors).

Then, in LET, the one-way speed of light in direction  $\hat{\mathbf{n}}$  is given by:

$$c_{\text{one-way}}(\hat{\mathbf{n}}) = \frac{c^2}{c + \mathbf{v} \cdot \hat{\mathbf{n}}} \quad (3)$$

Similarly, in the opposite direction  $-\hat{\mathbf{n}}$ , it becomes:

$$c_{\text{one-way}}(-\hat{\mathbf{n}}) = \frac{c^2}{c - \mathbf{v} \cdot \hat{\mathbf{n}}} \quad (4)$$

This is assuming you're using “true time” and “true rods” (i.e., from the ether frame), and measuring what the moving observer would perceive as the one-way speed.

Note:



- When  $\mathbf{v} \cdot \hat{\mathbf{n}} = 0$ : the direction is perpendicular to motion through the ether  $\rightarrow$  speed =  $c$
- When  $\hat{\mathbf{n}}$  is in the direction of motion, the speed is less than  $c$ .
- When  $\hat{\mathbf{n}}$  is opposite to motion, the speed is greater than  $c$ .

But since LET includes length contraction, time dilation, and asynchronous clocks, all these anisotropies are undetectable with standard equipment.

Derivation Sketch (From Lorentz Transformations)

1. Light in the ether frame obeys:

$$x = ct \quad (5)$$

2. Transform to the moving frame  $S'$  (moving at velocity  $v$  in the  $x$ -direction):

$$x' = \gamma(x - vt), t' = \gamma(t - vx/c^2) \quad (6)$$

3. Solve for the apparent speed  $dx'/dt'$ , and you find:

$$\frac{dx'}{dt'} = \frac{c - v}{1 - (vc)/c^2} = \text{anisotropic} \quad (7)$$

This calculation shows how even though light moves at speed  $c$  in the ether frame, the transformed coordinates show direction-dependent speeds in the moving frame.

Visual/Physical Interpretation

Imagine an observer in a spaceship moving through the ether:

- If they try to measure the time it takes light to travel forward vs backward using clocks at both ends, they'll measure equal times, because their clocks are desynchronized in just the right way (due to Lorentz transformations).
- But in “real” terms (from the ether perspective), the light really did go slower in the forward direction and faster in the backward one.

In this view:

- The one-way speed is anisotropic,
- But the two-way speed is always  $c$ .
- And the instruments conspire to hide the anisotropy.

Philosophical Takeaway

This is where LET and SR diverge philosophically but not experimentally:

Feature	Special Relativity	Lorentz Ether Theory
Speed of light (one-way)	Defined isotropic by convention	Isotropic <i>only</i> in ether frame
Simultaneity	Relative and conventional	Absolute but hidden
Time dilation	Symmetric between observers	Real physical effect due to motion through ether
Preferred frame	None	Exists but undetectable
Experimental predications	Identical	Identical

LET says: There is a “true” frame, and light is only really isotropic in that frame – but our rulers and clocks deform in such a way that we can never prove this.

Summary

- In Lorentz Ether Theory, the one-way speed of light in a frame moving at velocity  $\mathbf{v}$  through the ether becomes anisotropic.
- The apparent one-way speed in direction  $\hat{\mathbf{n}}$  is:

$$c_{one-way}(\hat{\mathbf{n}}) = \frac{c^2}{c + \mathbf{v} \cdot \hat{\mathbf{n}}} \quad (8)$$

- This anisotropy is perfectly compensated by physical effects (time dilation, length contraction, clock desynchronization), making it undetectable.
- Thus, LET and SR yield identical experimental predictions, but differ in interpretation.

Would you like a diagram showing this anisotropy visually, or a code snippet to simulate light paths with anisotropic speed?

## A.5 Correcting something in ChatGPT’s previous answer

**I checked the calculation in the previous answer for  $dx'/dt'$ , and found it is always exactly  $c$ , which seemed not to be what it was intended to show, which was a speed other than  $c$ :** The Lorentz transform sketch you gave showed that  $dx'/dt' = (c - v)/(1 - (vc)/c^2)$ , which is exactly  $c$ . That does not seem to demonstrate what you wanted to show.

**ChaptGPT’s reponse:** You’re absolutely right – excellent catch.

The expression

$$\frac{dx'}{dt'} = \frac{c - v}{1 - (vc)/c^2} = c \quad (9)$$

is indeed exactly equal to  $c$ , so it doesn’t show anisotropy at all. That was a misstep in the sketch – it’s just the standard Lorentz transformation preserving the speed of light for light in any direction (as expected in Special Relativity). So you’re right to point out: it fails to demonstrate what Lorentz Ether Theory (LET) uniquely claims – anisotropy of one-way light speed in moving frames.

Let’s now correctly approach the anisotropy of the one-way speed of light in LET, and distinguish this from what Lorentz transformations show in Einstein’s interpretation (SR).

Correct Perspective: LET’s View of One-Way Light Speed

In Lorentz Ether Theory, the key is to not assume Einstein synchronization of clocks in the moving frame. Instead, clocks are synchronized according to “true” simultaneity defined in the ether frame, and this is what reveals anisotropy.

Setup:

- Ether frame:  $S$
- Moving frame:  $S'$ , moving at velocity  $\mathbf{v}$  relative to the ether
- Light emitted from the origin at  $t = 0$  in all directions

From the ether frame’s perspective, light travels outward spherically at speed  $c$ . But observers in  $S'$  are moving, and their rulers and clocks are affected by length contraction and time dilation in just the right way to hide anisotropy if Einstein synchronization is used.

If instead they use absolute simultaneity from the ether frame to synchronize clocks, then one-way light speed becomes anisotropic in  $S'$ .

Actual Anisotropic Speed in LET

Let’s derive the apparent one-way speed of light in the moving frame  $S'$ , for light traveling in some direction  $\hat{\mathbf{n}}$ , using absolute simultaneity (i.e. clocks are synchronized by the ether frame’s simultaneity).

Let:

- $\mathbf{v}$  = velocity of  $S'$  through the ether
- $\hat{\mathbf{n}}$  = unit vector in direction light is traveling

Then the one-way speed of light in  $S'$ , using ether-defined simultaneity, is:

$$c'(\hat{\mathbf{n}}) = c - \mathbf{v} \cdot \hat{\mathbf{n}} \quad (10)$$

This is *not* relativistic velocity addition – it is simply expressing that if the ether frame sees light move at speed  $c$  and the moving observer travels at velocity  $\mathbf{v}$ , then the observer in  $S'$ , with clocks synchronized according to the ether, will observe light approaching faster or slower depending on the direction:

- In direction of motion ( $\hat{\mathbf{n}} = \hat{\mathbf{v}}$ ): speed is  $c - v$
- Against direction of motion ( $\hat{\mathbf{n}} = -\hat{\mathbf{v}}$ ): speed is  $c + v$

- Perpendicular ( $\mathbf{v} \cdot \hat{\mathbf{n}} = 0$ ): speed is  $c$

This is the LET picture of anisotropy of one-way light speed.

Why Lorentz Transformations Still Show  $c$

The earlier sketch used Lorentz transformations to transform coordinates of light motion – but those transformations assume Einstein synchronization in every frame.

So when you apply the Lorentz transform to light paths from the ether frame into  $S'$ , you always get light traveling at speed  $c$  in all directions, because Einstein's postulate is baked into the transformation.

That's why:

- In Special Relativity: light speed is always  $c$ , even after transforming between frames.
- In Lorentz Ether Theory: light speed is *really* only isotropic in the ether frame; the observed anisotropy in other frames is masked unless you use absolute simultaneity to reveal it.

Summary

- You're right: the earlier expression showing  $dx'/dt' = c$  is correct only when using Einstein-synchronized clocks, and shows no anisotropy.
- To see anisotropy, you must drop Einstein synchronization and use the ether-defined simultaneity, which is not built into the Lorentz transformation.
- In Lorentz Ether Theory, the one-way speed of light in a frame moving at velocity  $\mathbf{v}$  through the ether is:

$$c'(\hat{\mathbf{n}}) = c - \mathbf{v} \cdot \hat{\mathbf{n}} \quad (11)$$

- But this anisotropy is undetectable experimentally, because Einstein synchronization erases it – hence LET and SR make the same predictions.

Would you like to explore how this anisotropy affects time synchronization and simultaneity surfaces in LET?

## A.6 Is Einstein's clock synchronization postulate baked into the Lorentz transform?

Above ChatGPT made this statement:

"So when you apply the Lorentz transform to light paths from the ether frame into  $S'$ , you always get light traveling at speed  $c$  in all directions, because Einstein's postulate is baked into the transformation."

**I decided to follow up on the statement from ChatGPT above with this prompt:** How are is Einstein's postulate of clock synchronization baked into the Lorentz transformation?

**ChaptGPT's response:** This is a very deep and subtle question, and you're right to probe it. The short answer is:

The Lorentz transformation is constructed in such a way that it assumes the Einstein synchronization convention in every inertial frame.

Let's unpack what this really means, step by step.

1. Einstein's Synchronization Convention

Einstein's 1905 method for synchronizing distant clocks is:

1. Send a light signal from clock A to clock B.
2. Assume the light travels at the same speed in both directions (one-way speed =  $c$ ).
3. Set the time on B's clock such that:

$$t_B = t_A + \frac{1}{2}(t_{A'} - t_A) \quad (12)$$

where  $t_A$  is the send time,  $t_{A'}$  is the receive time of the round-trip signal at A.

This convention defines simultaneity in each frame, by assuming isotropic light speed.

You can't measure one-way light speed without synchronized clocks – and you can't synchronize clocks without assuming something about one-way light speed. Einstein's method breaks this circularity by defining both together.

## 2. Lorentz Transform: What It Encodes

The Lorentz transformation between two frames  $S$  and  $S'$ , where  $S'$  moves at velocity  $\mathbf{v}$  along the  $x$ -axis relative to  $S$ , is:

$$\begin{aligned}x' &= \gamma(x - vt) \\t' &= \gamma\left(t - \frac{vx}{c^2}\right)\end{aligned}$$

where  $\gamma = \frac{1}{\sqrt{1-v^2/c^2}}$ .

The Key Thing:

The Lorentz transformation preserves the form of the spacetime interval:

$$ds^2 = c^2 dt^2 - dx^2 - dy^2 - dz^2 \quad (13)$$

and guarantees that light always moves at speed  $c$  in all directions, in all inertial frames, when you use  $(x', t')$  as your new coordinates.

This is only true if:

- You define time  $t'$  using the same synchronization procedure (Einstein's) in each frame.

## 3. Where Synchronization Is Hidden in the Lorentz Transform

Look at the transformed time coordinate:

$$t' = \gamma\left(t - \frac{vx}{c^2}\right) \quad (14)$$

This term  $\frac{vx}{c^2}$  introduces a position-dependent offset in time – it shifts simultaneity in a way that makes light travel at speed  $c$  in  $S'$ .

This shift encodes Einstein synchronization.

Let's explain how.

## 4. What If You Used a Different Synchronization?

Suppose instead of Einstein's convention, you used a more general clock synchronization in  $S'$ . For example, the Reichenbach epsilon convention:

$$t_B = t_A + \epsilon(t_{A'} - t_A) \quad (15)$$

with  $0 < \epsilon < 1$ , where Einstein's method assumes  $\epsilon = 1/2$ .

Then your coordinate transformation from  $S$  to  $S'$  would look different – the time coordinate in  $S'$  would no longer be:

$$t' = \gamma\left(t - \frac{vx}{c^2}\right) \quad (16)$$

but something more general, perhaps:

$$t' = \gamma\left(t - \frac{v(1 - 2\epsilon)x}{c^2}\right) \quad (17)$$

This breaks the symmetry that makes the one-way speed of light the same in all directions.

So:

The form of the Lorentz transformation assumes clocks in every frame are synchronized using Einstein's method, i.e., so that light's one-way speed =  $c$ .

## 5. In Contrast: LET's Viewpoint

In Lorentz Ether Theory, the “true” frame (the ether frame) has real simultaneity, and any other frame is moving relative to that.

In that view, clocks in moving frames are not truly synchronized when using Einstein's convention – they're conventionally synchronized in a way that masks the anisotropy of light's one-way speed.

So from the LET perspective:

The Lorentz transformation doesn't describe “reality” – it describes what you would measure if you synchronized clocks as Einstein prescribes, which conceals the anisotropy due to motion through the ether.

Conclusion: How Is Einstein’s Synchronization Built In?

Element	How it shows Einstein synchronization
Lorentz time transformation	$t' = \gamma(t - \frac{vx}{c^2})$ contains position-dependent shift that enforces Einstein simultaneity
Isotropy of light speed in all frames	Guaranteed only if Einstein clock sync is used
Form invariance of wave equation	Requires Einstein synchronization
Failure to detect anisotropy	Only holds under Einstein synchronization

In short: the Lorentz transformation is constructed such that every inertial observer sees light travel at speed  $c$  in all directions, and this only works if clocks are synchronized according to Einstein’s convention. That’s what “baking in” the synchronization means.

Would you like to see what the Lorentz transformation would look like if you used a non-Einstein synchronization convention, like Reichenbach’s  $\epsilon$ -scheme?

**Take advantage of the offer made by ChatGPT:** Yes.

**ChaptGPT’s reponse:** Great! Let’s construct the generalized Lorentz transformation using a non-Einstein synchronization convention, often called the Reichenbach  $\epsilon$ -convention.

1. What Is the  $\epsilon$ -Synchronization Convention?

In Einstein synchronization, we assume the one-way speed of light is equal in both directions, so:

- Light travel time from A to B = travel time from B to A.
- This corresponds to setting:

$$\epsilon = 1/2 \quad (18)$$

The Reichenbach  $\epsilon$ -convention generalizes this by defining simultaneity asymmetrically:

- When clock A sends a light signal at time  $t_1$ , and receives the return at time  $t_3$ , we say that the event of reception at B happened at:

$$t_2 = t_1 + \epsilon(t_3 - t_1) \quad (19)$$

with  $0 < \epsilon < 1$ .

Thus:

- If  $\epsilon < 1/2$ : Light is faster from A to B than B to A.
- If  $\epsilon > 1/2$ : Light is slower from A to B than B to A.

This is a coordinate choice, not a physical difference – all values of  $\epsilon$  produce the same measurable outcomes.

2. Generalized Lorentz Transformation with  $\epsilon$ -Synchronization

We now modify the Lorentz time transformation to reflect the fact that clocks are not synchronized using Einstein’s method.

The modified transformation becomes:

$$\begin{aligned} x' &= \gamma(x - vt) \\ t' &= \gamma(t - \frac{vx}{c^2}(1 - 2\epsilon)) \end{aligned}$$

Compare this with the standard Lorentz transform (Einstein synchronization,  $\epsilon = 1/2$ ):

$$t' = \gamma(t - \frac{vx}{c^2})$$

So:

The only change is that  $\frac{vx}{c^2}$  becomes  $\frac{vx}{c^2}(1 - 2\epsilon)$ .

This means:

- When  $\epsilon = 1/2$ , you recover Einstein synchronization.
- When  $\epsilon \neq 1/2$ , the time coordinate is shifted to reflect the asymmetric synchronization choice.

### 3. What Does This Do Physically?

This shift changes what events are considered simultaneous in the primed frame:

- Different values of  $\epsilon$  define different simultaneity slices.
- It does not change what anyone measures – round-trip speeds of light are still  $c$ , time dilation and length contraction remain the same.

But it does alter:

- The coordinate velocity of light in one direction vs the other.
- The coordinate time assigned to distant events.

### 4. Coordinate Speed of Light Becomes Direction-Dependent

If a light signal travels in the  $x$ -direction in  $S'$ , the coordinate speed becomes:

$$c' = \frac{dx'}{dt'} = \frac{c - v}{1 - v(1 - 2\epsilon)/c} \quad (20)$$

This depends on  $\epsilon$ .

For example:

- If  $\epsilon = 0$ , then  $t' = \gamma(t - \frac{vx}{c^2})$  shifts more than Einstein's.
- If  $\epsilon = 1$ , the shift goes the other way.

Only for  $\epsilon = 1/2$  does  $c' = c$  in both directions.

Thus, the one-way speed of light is only isotropic if  $\epsilon = 1/2$ .

### 5. Summary

Synchronization Convention	Time Transformation	One-way speed of light
Einstein ( $\epsilon = 1/2$ )	$t' = \gamma(t - \frac{vx}{c^2})$	Isotropic (same both ways)
Reichenbach $\epsilon$	$t' = \gamma(t - \frac{vx}{c^2}(1 - 2\epsilon))$	Anisotropic (depends on direction)

So:

Einstein's synchronization is just one choice among many valid conventions – but it's the one that makes the Lorentz transformation clean and symmetric, and that makes the one-way speed of light come out the same in every direction.

Optional: Minkowski Geometry View

The change in synchronization affects the tilt of simultaneity planes (slices of constant time) in spacetime diagrams.

Different values of  $\epsilon$  result in different choices of how to foliate spacetime.

Would you like a spacetime diagram showing how simultaneity planes tilt with different  $\epsilon$  values?