Research note:
An outline of the problem of special relativity, and the proper solution to it — part 2

A research note by
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Abstract

This document assumes the context of the problem definition in part 1 of this document.

In this part, we once again discuss the problem from various angles, and evolve our new solution. For this purpose, we consider several thought experiments that deal with a simpler version of the problem, viz., the problem of just *light propagation* (and not a more complicated problem of arbitrary motions of the electric charge). However, an expert could easily see that even if the discussion proceeds in the simpler settings, the arguments and the solution do generalize to the most general settings too.

This document is preliminary in nature, and its main purpose is two-fold: (a) to claim originality and independence of thoughts for the ideas being presented here, and also (b) to claim priority for any new ideas here (if these are indeed found to be new).

The text here is written in a hurried manner, with the purpose being just to note the main points. This *is* a research *note*.

A formal paper covering the same ideas will be written in the near future (of a few months).

Contents

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1 An initial setup for thought-experiments

In this document, we will consider several different kinds of physical setups that suggest different thought experiments. It's convenient to begin our discussion with the following setup.

1.1 The physical setup: physical frames and mathematical coordinate systems

Consider a lab window with three sliding glass panes. These panes slide horizontally in their respective grooves; the grooves are parallel to each other, with the same perpendicular separation (air-gap).

Consider a Cartesian system attached to the labsuch that its positive x-axis runs horizontally to the right, the positive y-axis vertically upward, and hence, the positive z-axis towards the viewer. Assume that the middle pane lies in the $z = 0$ plane.

Assume that each of the three panes is marked with its own Cartesian system attached to the such that its positive x-axis runs horizontally to the right, the positive y-axis vertically upward, and hence, the positive z-axis towards the viewer.

Assume that the origins of the three frames coincide when they all are at the center of the window. (Thus, the window has yet another frame attached to it, i.e., attached to the lab.) When any pane is moving, we consider the $t = 0$ s instant to be that when the origin that frame is at the center of the window-i.e.-lab frame. Implication: At $t = 0$, the respective origins of all the three frames coincide.

Throughout this document, we will consider only those panes which either remain fixed or move with constant speed of $\sqrt{3}/2\ \mathrm{m/s}$, both with respect to the lab-frame.

Now, assume that the middle pane has a hole carrying a light bulb (which is interchangeably called "emitter" too). In all cases, we assume that the bulb emits a single flash of light that lasts for infinitesimally small duration. In all cases, we assume that the light is emitted at $t = 0$ s — whether the pane carrying the bulb is fixed or moving.

Next, we suppose that the outer and inner panes carry a dense square array of CCD pixels that can detect an instantaneous flash of light. For convenience, we call them Screens.

Physical and mathematical frames

For obvious reasons, we regard each Screen (a glass pane + CCD pixels) as the physical frame, and the mathematical device of the Cartesian frame attached to it as the mathematical frame. Note that the marking of the Cartesian frame on a Screen is only for convenience in visualization; the Cartesian frame (its axes and tuples of numbers i.e. coordinates) exists only in thought, not in the physical world out there. We denote the mathematical frames as "F1" and "F2," and the physical frames (Screens) as "S1" and "S2".

Notice that if you have three spatially discrete physical objects such that (i) any three of them are non-collinear but lying in a plane, and a fourth object that is not in the aforementioned plane, and (ii) the four objects never change their respective locations with respect to each other, then this group of objects forms a physical frame. This is a primary definition of the term "physical frame."

By extension, if four different parts of a continuous (spatially discrete) object, such as a brick, also fulfill the above conditions, then the continuous object may also be regarded as a physical frame. That's why, we regard the Screens as physical frames. Indeed, in each Screen, each CCD pixel itself is a distinct (spatially discrete) object, and they all maintain the same relative locations, whether the Screen overall is in motion or not.

1.2 Idealizations for thought-experiments

Finally, to give the setup the touch of a thought-experiment, we will introduce the following idealizations:

Point-thin objects

Assume that each CCD-pixel is a point-object, each pane is a point-thin surface, and the light-bulb too is a point-object. Further, assume that the air-gap between any two panes is zero. As a consequence of all these assumptions: All the panes and the light bulb lie in the same plane. Let this plane be the $z = 0$ plane.

Although this assumption looks drastically unrealistic, it is not. If you practically implement the above system with actual objects (none of which is point-thin), and make actual measurements, then the measured data would sure differ from the data generated in the idealized setup. However, the differences in these two data-sets consist of only *systematic* deviations (or "errors") that are constants. Therefore, such deviations can be subtracted in a post-processing stage so as to obtain the "ideal" data.

Thus, this idealization leads to simplicity without compromising on realism.

"Speed of light" (c)

Assume that the electric permittity of all the materials is ϵ_0 $\mathrm{F/m}$ and the magnetic permeability of all the materials is μ_0 $\mathrm{H/m}$. Thus, the constant c, defined as $c \stackrel{\text{def}}{=} 1/\sqrt{\epsilon_0 \mu_0}$ has the value of $1\ \mathrm{m/s}$ through all the media considered here.

This assumption only changes the numerical values of quantities (or variables) of interest, but not the nature of the physical relationships between them. In short, it only simplifies calculations, without impacting the physics under consideration here.

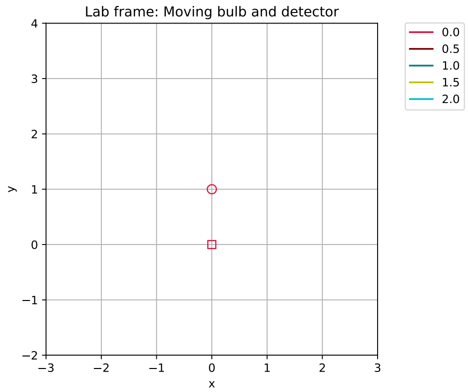
2 Motion of the light emitter and detector in the middle pane

Consider the middle pane, which carries the bulb at $(0, 1, 0)$ and a special detector at $(0, 0, 0)$. Suppose that the middle pane moves to the right with x-speed of $\sqrt{3}/2\ \mathrm{m/s}$.

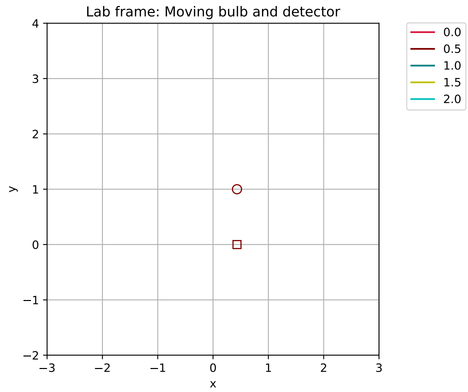
Figure 1 depicts snapshots in the motion of the middle pane carrying the bulb and a special detector.

The markers with open circles show the light bulb (the emitter); the markers with open squares show the special detector which is put in the same glass pane as the bulb. (Thus, we have three sets of detectors: the set of pixels in S1, another set of pixels in S2, and a special pixel mounted below the bulb in the middle glass pane carrying the bulb.) Different colours denote different instants (in the lab-clock).

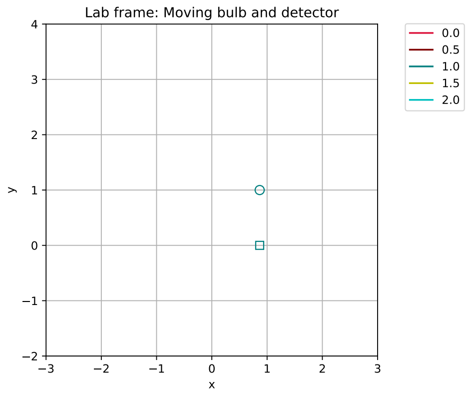
We won't directly need the lab frame any further, because we will always make sure to keep at least one of the three panes fixed with its origin at the center of the window. In fact, for the rest of this document, we will always keep the S1 screen physically fixed to the lab frame.



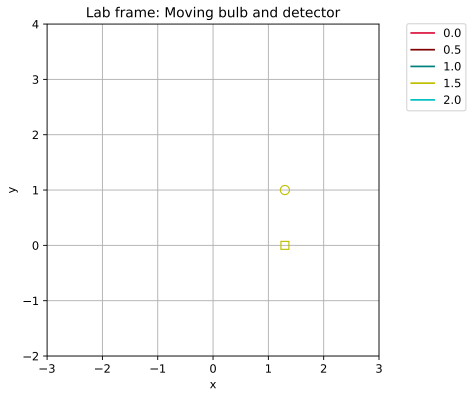
(a) $t = 0.0$ s



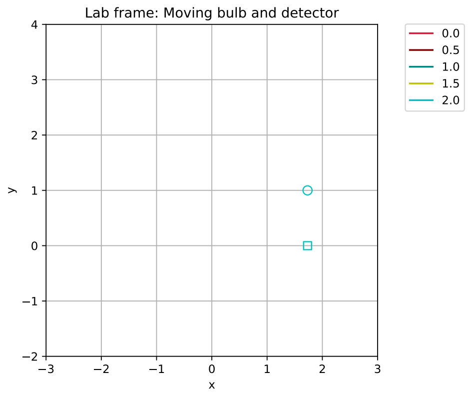
(b) $t = 0.5$ s



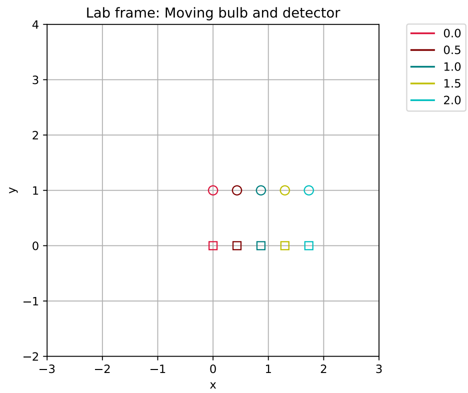
(c) $t = 1.0$ s



(d) $t = 1.5$ s



(e) $t = 2.0$ s



(f) All the different locii for the different instants superposed

Figure 1: Motion of the middle pane carrying the bulb and a special detector, described using the lab frame. Figures 1a to 1e show a separate plot for each instant. Figure 1f shows all the instantaneous positions superposed in one plot.

3 Detection of light with CCD Screens: Simplest scenario — both the Screens kept fixed to the lab

Suppose that both the Screens S1 and S2 are kept fixed with respect to the lab-frame at all times, with their origins coinciding with the center of the lab-window. We call this case the **Case 0**.

As mentioned earlier, the light bulb only emits light at $t = 0$ and this is the instant when it is at the origin of the lab-frame. How would the ideal CCD pixels in S1 and S2 register the expanding light-front?

3.1 Procedure followed in making the plots

To depict the progression of the light-front (as detected in the Screens at any given instant (given by the *lab-clock*), we follow the following procedure:

- First observe the physical location of the light-front with respect to each physical frame S1 and S2 by recording which physical pixels from which Screen had fired at that lab-instant,
- and then, translate the physical locations of the firing pixels to their corresponding tuples of numbers, by making a reference to the agreed scheme of the mathematical frame F1, and similarly also for F2.

Most discussions drop the aforementioned two parts of this procedure, but we wanted to make explicit what is physical and what is mathematical.

3.2 A separate plot for each instant in the progression

Figure 2 shows the progression of the light front with passage of time.

For later reference (in side comments), focus on the x-axis (i.e. the $y = 0$ line, which is *not* at the center of figure but just below it), and observe the following:

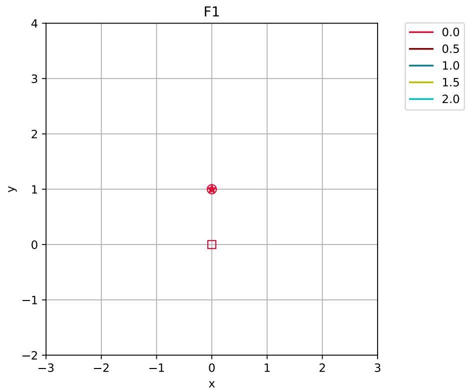
- The locus for $t = 1$ s (shown in teal) hits the x-axis at $x = \sqrt{3}/2 \approxeq 0.866$ m. At this instant, the detector (on the middle pane) is not at the same point.
- The locus for $t = 2$ s (shown in cyan) hits the x-axis at the position $x = \sqrt{3} \approxeq 1.73$ m. At this instant, the detector (on the middle pane) *is present* at the same point, and so, it does fire at this instant.

BTW, for ease of reuse of these diagrams, we have dropped the physical units in these plots. However, in this document, read the spatial unit as meter and the temporal unit as second.

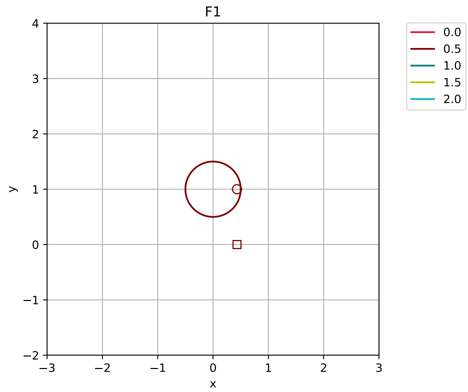
3.3 A single plot for all the instantaneous states of the single flash

Figure 3 shows the same experiment as in Figure 2, but now, for convenience, all the instantaneous locii of a given frame are superposed to obtain a single plot. Both F1 and F2 show identical patterns.

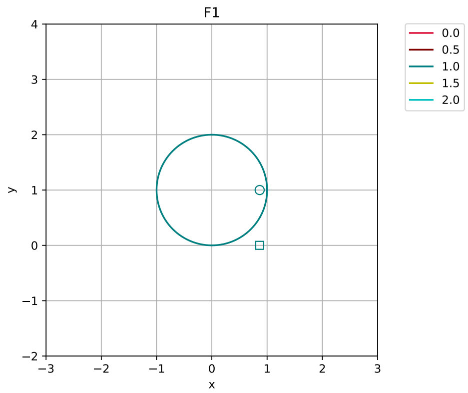
From this point onwards, we shall show only such superposed plots. However, carefully note that the different circles in a given plot do *not* depict five different flashes emitted in succession.



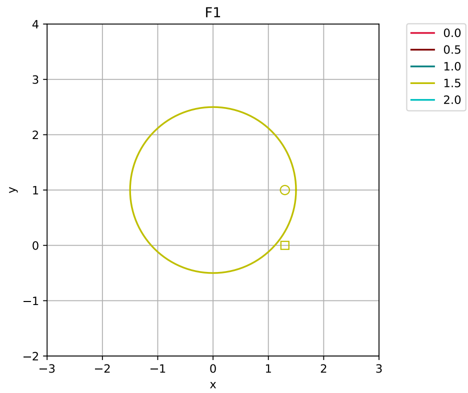
(a) $t = 0.0$ s



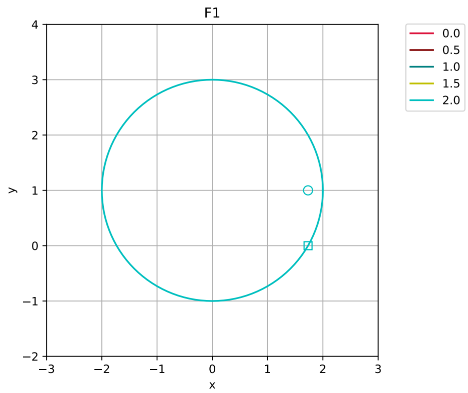
(b) $t = 0.5$ s



(c) $t = 1.0$ s



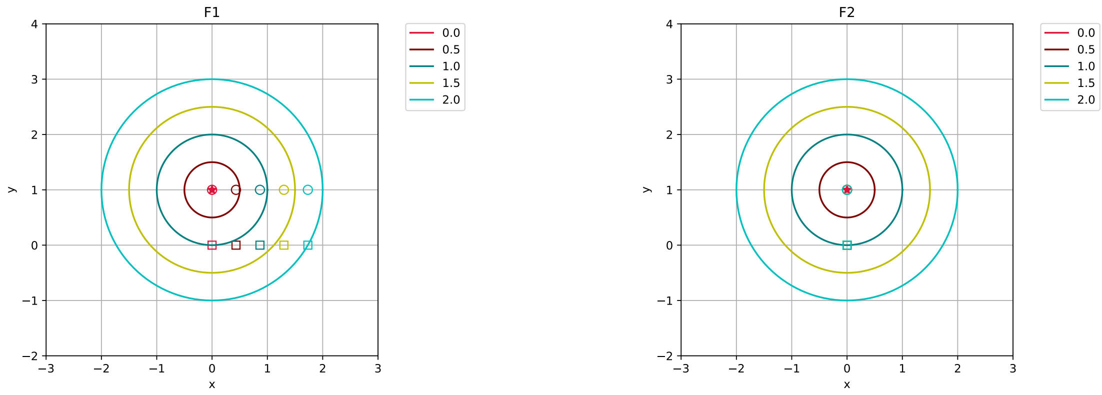
(d) $t = 1.5$ s



(e) $t = 2.0$ s

Figure 2: Case 0: Both the Screens fixed. Both the Screens (S1 and S2) record the detection events at the directly adjacent pixels. Therefore, both the mathematical frames F1 and F2 show identical locii. Hence, only one set (the one for F1) is shown here.

Instead, they depict *one and the same flash* as it expands in space with time.



(a) **(b)**

Figure 3: Case 0: Both the Screens fixed. Same experiment as in Figure 2, but now, for convenience, all the instantaneous locii are superposed in a single plot. Both F1 and F2 show identical patterns. However, while Figure 3a shows the emitter and detector (of the middle pane) as relatively moving in F1, Figure 3b shows them as relatively stationary in F2. Note that the different circles do *not* depict five different flashes emitted in succession. They depict one and the same flash as it expands in space with time.

3.4 Experimental validation

Figures 2 and 3 showed the plots using the *mathematical* frames F1 and F2. However, enough experimentation has been done to indirectly and directly validate that such predictions are correct. Thus, in the titles of these plots, we could have said the *physical* frame S1 in place of F1, and the *physical* frame S2 in place of F2.

Indeed, even by STR, since both the Screens are fixed, they also are fixed with respect to each other. Therefore, you could even say that the two mathematical frames F1 and F2 are not mathematically different at all; instead, they only are two identical copies of what essentially is one and the same mathematical frame.

With that said, we emphasize: We *still* could have put the names of the *physical* frames in the titles of the plots in Figures 2 and 3. We could have done that with full *experimental* justification too. Mathematically, the F1 and F2 in this case might be copies of one and the same mathematical frame; but physically, these mathematical copies are attached to two *different* physical objects (Screens). When copies are attached to different objects, it's not always clear that they must be describing the same physics. That's why, it was important to clarify that these plots would remain valid even in a *physical* sense.

4 Detection of light with CCD Screens: Main scenario — S1 fixed to window, S2 and bulb co-move to the right

This document is written for experts. Given all the detailed explanation in the preceding section, it might have seemed as if this document were written for the layman. It is not. All those details were meant for the *expert*, for it is the expert who routinely confuses what is physical and what is mathematical. Another reasons for all those details was that we also wanted to introduce the specifics of our setup and notation. But once these considerations are covered, the further description can progress in a more rapid manner.

Throughout the rest of this document, we will consider only one physically distinct scenario: The glass pane S1 remains fixed to the lab, and glass pane S2 co-moves with the middle pane (that contains the bulb and the special detector).

Thus, S1 remains fixed with its origin coinciding with the origin of the lab-frame, and both S2 and the light-bulb are co-moving at a constant speed of $\sqrt{3}/2$ with respect to the lab-frame. (From this point onward, all the units are being dropped (for ease of typing!).)

5 The mainstream description of the main physical scenario

The mainstream description uses the Lorentz transformations (LT).

5.1 What the two "M"s say

Another notation: "M" is for the mathematic*

From this section onward, we find it convenient to introduce the symbol "M"; it stands for all: "mathematics," "mathematics-wise" or "mathematically," "mathematician," and even "mathematical-physicist."

We now introduce two identical "M"s, one each attached to a physical frame "S" (and therefore to its corresponding mathematical frame "F"). Thus, M1 remains attached to F1 (and S1) at all times; M2 remains attached to F2 (and S2) at all times.

What M1 says

Figure 4 shows what M1 predicts happens in this Sub-Case (-LT), when S1 is fixed with respect to the window, whereas S2 and the bulb are co-moving to the right with respect to the window. Colours denote locii at different instants in the lab frame. Figure 4a shows what M1 predicts happens in F1; Figure 4b shows what he predicts as happens in F2.

Once again, markers with open circles denote the emitter (as in contrast to center of radiation), and markers with open squares denote the detector (from the bulb-frame).

Since S1 is fixed to the lab-window, the description in Figure 4a can be taken as being well validated by experimentation. In fact, it's exactly the same experiment as in Figure 3a.

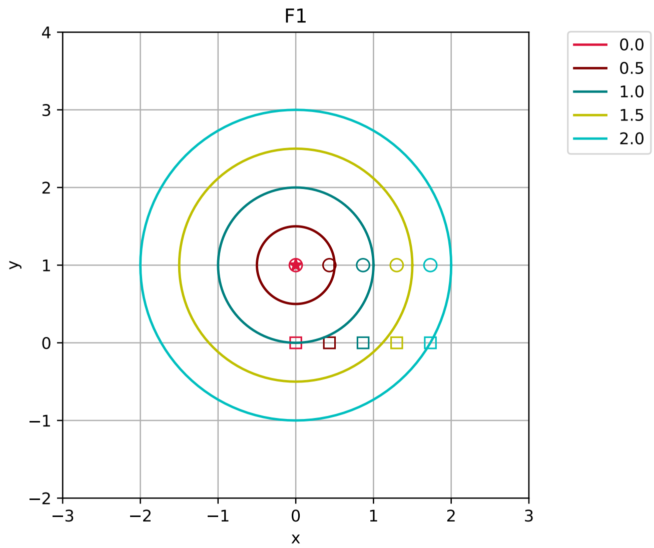
For prediction about F2, however, M1 uses LT. This prediction, shown in Figure 4b, has never been directly validated by experimentation.

Why does M1 say as he does? Well, because M1 has applied LT (the Lorentz transformations) in going from F1 to F2.

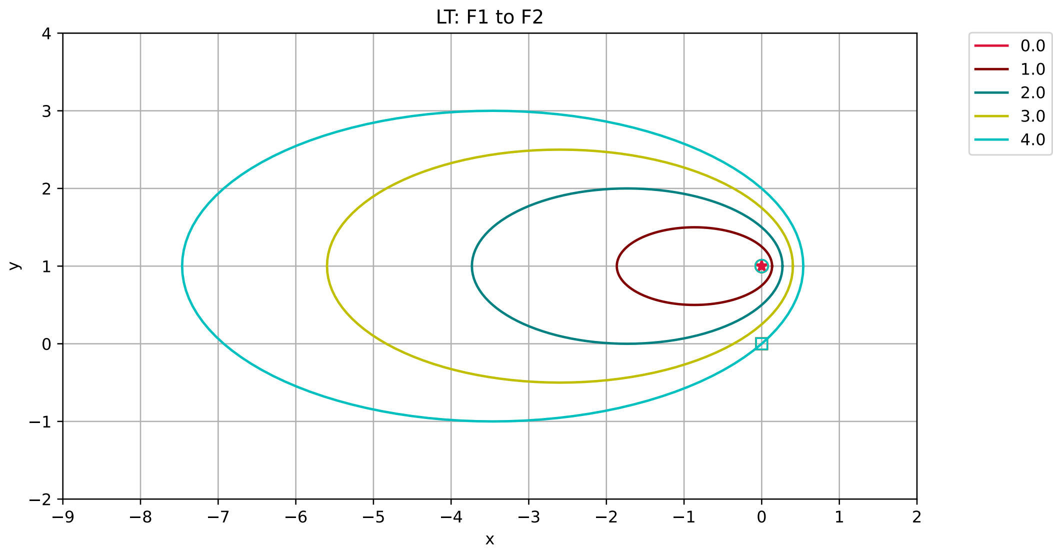
But why did he apply the LT?

Well, because in F2, the bulb has to appear as stationary, with the emitter velocity $\vec{U}_E = \vec{0}$. If you don't first LT all the quantities [1], and then input these LT-ed coordinates into the laws of ED (classical electrodynamics), then you won't get the right predictions. But by first LT-ing the

[1] a fuller list list will be given later, but for the time being, note that LT and taking its inverse requires transforming: spatial and temporal coordinates, velocity, acceleration, EM fields, force, mass, energy



(a) What M1 predicts for F1 (experimentally verified with S1)



(b) What M1 predicts as happening in F2 (*not* experimentally verified with a physical S2 moving at high speeds approaching *c*).

Figure 4: Case LT-M1: Description according to M1 who is attached to F1. In Figure 4a, S1 is fixed to the lab-window and therefore does not involve high-speed screens. So, this description can be taken as being well validated by experimentation. However, as to M1's prediction for F2, as depicted in Figure 4b M1 has used only the *mathematics* of LT. This prediction has *never* been *directly* validated by experimentation

quantities, you do get the right predictions — even if the quantities are valid only in the LT-ed frame (more on this limitation, later).

For instance, in F1, the light-front reaches the x-axis line after a time delay of 1 s, which happens at the pixel at $(0, 0, 0)$ in F1. This is shown in teal colour in Figure 4a. However, in F1, the emitter is seen as moving to the right, and so, its instantaneous position is continuously changing. Therefore, the instantaneous separation vector is continuously changing. But *to have the same light-speed in all the inertial frames*, you need the space- and time-coordinates changing accordingly. Therefore, in F2, we must have the teal locus touching the x-axis at $t = 2$ s, which is what Figure 4b shows.

The preceding aspect is just one way of putting the logic required for LT. Yet, it does illustrate the mainstream reasoning as to why M1 must think that the shapes of the locii have to be different in F2; why space and time coordinates have to change according to LT.

What M2 is supposed as saying

Figure 5 shows what STR says M2 *would* describe for the same physical scenario as in Figure 4, i.e., when S1 is fixed with respect to the window, and S2 and the bulb are co-moving to the right with respect to S1.

STR says that if M2, who is attached to F2, were to describe this process, he *would* describe it as shown in Figure 5. Figure 5a shows what M2 would predict as happenning in F2. Figure 5b shows what M2 would predict as happenning in F1. For this prediction, M2 is again supposed as using LT. Since S2 here is supposed as moving with high speed with respect to lab, neither prediction has *ever* been validated by *direct* experimentation.

Why then does STR say that in Figure 5a, M2 would see concentric circles? STR seems to give no justification at all; it seems simply to assert it (in reference to its postulate of the constancy of light *signal*).

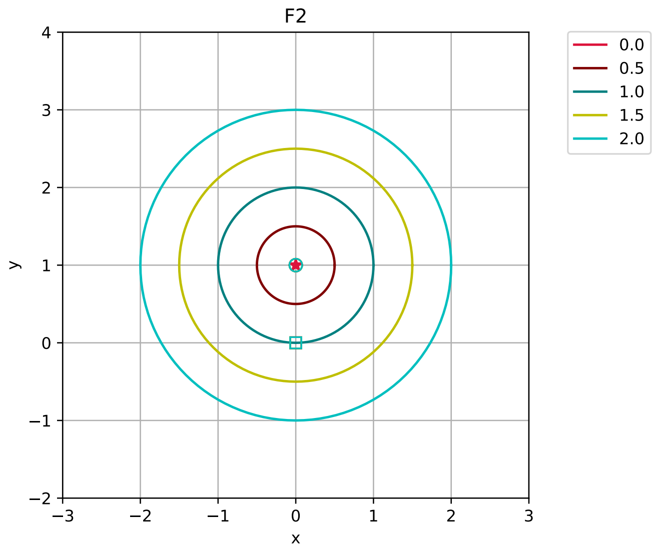
Why did ED (electrodynamics) say, before STR came on the scene, say that in Figure 5a, M2 would see concentric circles? Well, the ED people referred to how fields are calculated in a reference frame. If the emitter is stationary in a frame, then the separation vector from the retarded-instant emitter-position to the present-instant frame-point would never change with time. Therefore, any field signal (light, or first-/zeroth-order signals) would travel with a time delay (in the given frame) of $\Delta t = c/\Delta x$. Then, they believed that the ED laws (Maxwell's equation plus Lorentz' force law) hold in the same form in any inertial frame. So, relying on this assumption, and the form of the law (and hence the calculations just indicated), they believed that such would be the physical reality.

As to Figure 5b, M2 forwards exactly the same reasons for using LT as M1 did. The argument just flips F1 to F2 and vice versa (and also flipping all the other quantities like velocity, acceleration, mass, etc., defined in each).

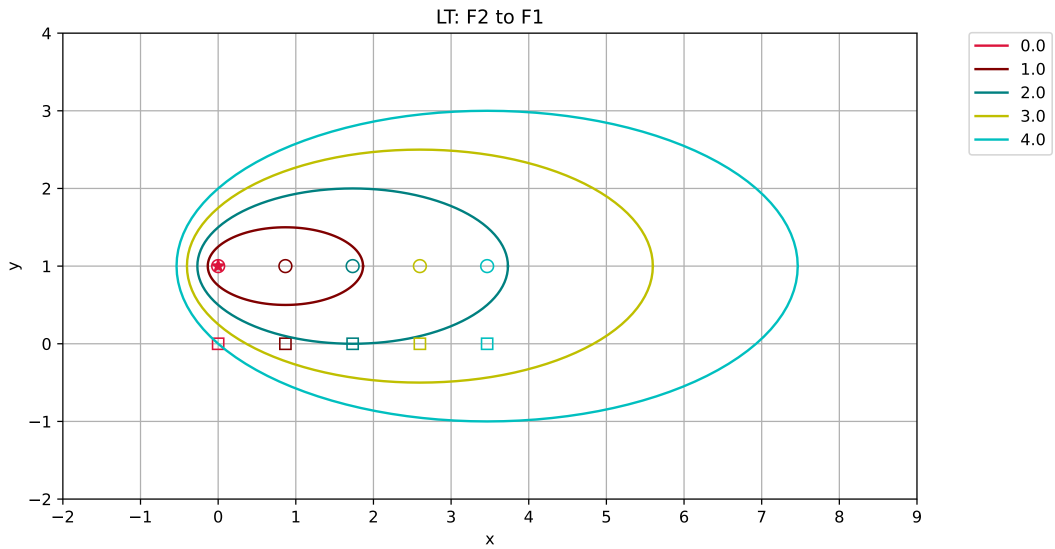
Local instants

An important observation is in order.

In the Case 0, i.e. in Figures 3a and 3b, all the events lying on an instantaneous wavefront (i.e., a circle of a given colour) occur at the same instant (e.g. $t = 0, 0.5, 1.0, \dots$). The legend of



(a) What STR says M2 would describe as happening in F2



(b) What M2 predicts as happening in F1

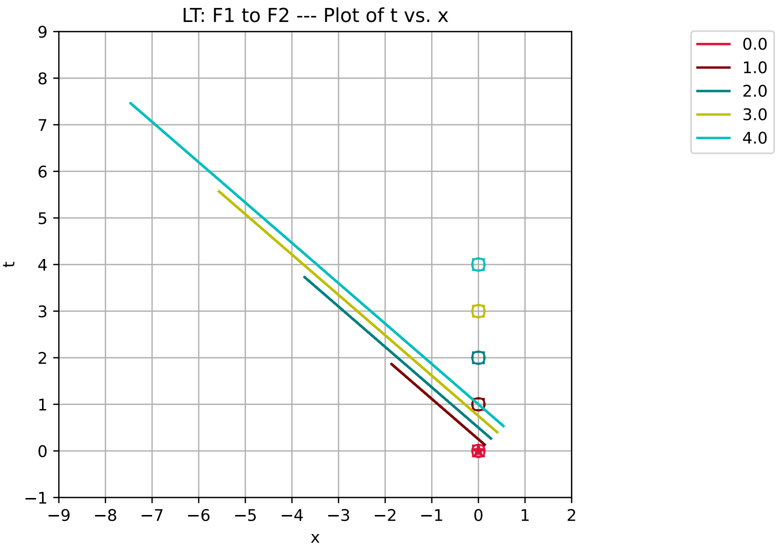
Figure 5: Case LT-M2: STR says that if M2, who is attached to F2, were to describe this process, he *would* describe it as shown above. In Figure 5a, M2 is supposed as riding a physical S2 that is supposed as moving with high speed with respect to lab. For prediction about F1, M2 is again supposed as using LT. Such prediction, too, has never been validated by direct experimentation.

these two plots show this common instant. The same is true also in Figures 4a and 5a.

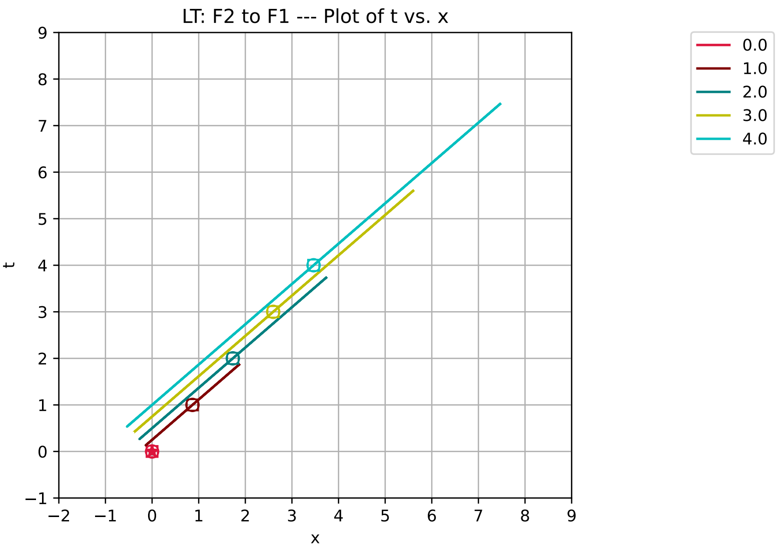
However, in the Case LT-M1 and LT-M2, i.e. in Figures 4b and 5b, the instants shown by the *legends* of the plots are somewhat *misleading*. The reason is:

the respective events on a given ellipse do not all occur at the same instant.

Instead, there is a systematic variation of the *pixel-local* time with x-coordinate. Figure 6 shows the variations of local time-coordinate values along the locii, as a function of the x-coordinate.



(a) Case LT-M1: M1 describes the local pixel-times vs x-coordinates for F2; *cf.* Figure 4b

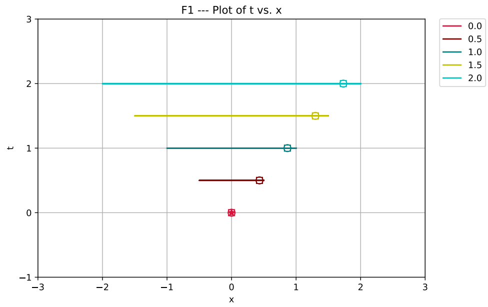


(b) Case LT-M2: M2 describes the local times vs x-coordinates for F1; *cf.* Figure 5b

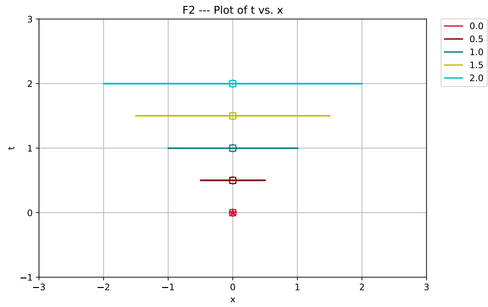
Figure 6: Local times vs x-coordinates for the "other frames" (F2 for M1 and F1 for M2), when LT is used

Consider the graph of any single line from Figure 6. Any *interior* point on such a line stands for two separate pixels having the same x-coordinates. The two end-points stand for a single pixel.

For ease of comparison, we also make plots of local instants vs. x-coordinates for the "self-frames" of M1 and M2, i.e., the sub-cases given by Figures 4a and 5a. These are shown in Figure 7.



(a) M1 describes the local times vs x-coordinates in F1; *cf.* Figure 4a



(b) M2 describes the local times vs x-coordinates in F2; *cf.* Figure 5a

Figure 7: Local time vs x-coordinate for "self-frames" i.e. F1 for M1 and F2 for M2

A comment about the spherical surfaces vs. rings

Notice that in the "self-frames" (i.e. F1 for M1 and F2 for M2), the expanding light-front is in the form of a spherical surfaces (which appear as circular in the 2D cross sections of S1 and S2); *cf.* Figures 4a and 5a. *All* of the points on a given sphere (circle in 2D) corresponding to a time t exist at that time. As time marches to the immediately next instant in the frame, *all* the points of that sphere cease to exist at once.

On the other hand, in the "other-frames" (F2 for M1 and F1 for M2) that use *LT-ed coordinates*, the nature of the locii is curious. You might think that they are *complete* ellipsoids (they appear as ellipses in the 2D cross sections of S1 and S2), in the sense that the entire ellipsoid exists at the same time, as shown in Figures 4b and 5b. Text-books and university teaching routinely describe them as being ellipsoids. **Insert the link to the IITB course-work assignments**. **TBD**

However, some careful thought reveals a different picture. There are two important points to note: (i) The local instants in the LT-ed locii do differ. (ii) However, in any given LT-ed frame (F2 for M1 and F1 for M2), there is only a *single clock* valid for that *entire frame*. (This point is different from the STR idea that different frames carry different clocks).

Therefore, any ellipsoid in a given LT-ed frame does not get "deposited" in one shot. Instead, the locus represents an *evolution* that occurs over a *finite (non-zero)* time period.

In particular, as Figure 6a shows, the evolution begins at the RHS end-point in Figure 4b, and with the passage of the frame-time of F2, it proceeds to the left. Similarly, as Figure 6b shows, the evolution begins at the LHS end-point in Figure 5b, and with the passage of the frame-time of F1, it proceeds to the right.

But in either frame, as the frame-time marches to the next instant, any events for a particular local-time *cease to exist.*

Therefore, we cannot even say that the locii in the LT-ed frames have the shape of an ellipsoidal cup for some time before the complete ellipsoid appears. The only thing we can say is that pairs of points on an ellipse (or line-rings on an ellipsoid) fire at a certain instant — and only for that instant. In the very next instant, this pair (or ring) completely ceases to exist, and it is the adjacent pair (or line-ring) of the firing pixels that now come into the picture.

In short, the only description permitted for the LT-ed frame is this: A group of rays emanates from the flash point, reach their corresponding points on the locus (a pair for a 2D section, a line-ring for the 3D ellipsoid), and terminates there. Then, another group of rays, emitted in the next instant, reach the locus and intercept them at the adjacent points. Thus the locus of the light-receiving points is in the form of a travelling ring. It comes to *progressively* cover the ellipse (ellipsoid in 3Dd) over a period of time. But there never is the complete ellipsoid at any time during this process.

Thus, by necessity, we have to abandon the continuum surface description of classical ED for the light-front, and instead, we have to adopt a more subtle description that is primarily ray-based (or ring-based).

Analytical solutions for ED are difficult, and they would become even more difficult for describing the moving ring locus. However, PyCharge could handle them easily because even for a surface consisting of many field-points, it only calculates the separation vector for each field-point *separately* (albeit with Python `ndarray` vectorized loops for efficiency).

5.2 An aside about the terminology used in Special Theory of Relativity (STR)

BTW, according to the STR terminology, if you take a pair of events, then a *greater* difference in their LT-ed spatial coordinates implies a *contraction* of space (*not* expansion), but a greater difference in their LT-ed temporal coordinates implies a *dilation* of time. If you are a layman who still has arrived here, and if this circumstance confuses you, go check with an expert. Given below is an informally written description.

Hint

Here is the procedure the relativists follow.

Take two F1 events that are simultaneous but distant, for space contraction. Take two F1 events such that they occur at different instants but have the same x-coordinate.

Take the frame in which you have the concentric circles as your primary reference frame, e.g., F1 for M1 Figure 4a (or F2 for M2 in Figure 5a). Then, the frame that shows "crowding" ellipses becomes the "other" frame (F2 for M1, F1 for F2). We will give the logic from M1's viewpoint, but realize that the same logic also is employed by M2.

Take the locus of any single colour, say teal.

For understanding the "contraction" of space, in each plot, locate the two events at the two extreme points along the x-axis on the teal coloured-plot.

For M1, the plot in Figure 4a shows the physically correct representation of the two events, and the plot in Figure 4a shows the space- and time-coordinates that M2 in F2 must be "measuring." To make the two representations match, since F1 is the gold standard for M1, F1 is to be left untouched, and it is the Δx in *F2* which has to be made to match with the Δx in F1. To do that, the *spatial mesh* of F2 has to be *compressed* along the x-axis by a factor of γ (which is 2 in our example plots). During such a compression, the x-coordinate numbers attached to the locus points in F2 remain the same. It's only the underlying mesh which gets compressed, but the coordinates assigned in F2 to the teal points are still left intact. Once such a compression is made, then, F2 will become, according to M1, real — because it will match with *his* gold standard i.e. F1. So, according to M1, the *real state* of F2 is that in which the entire F2-space is compressed along the x-axis.

Note: M1 regards the *mesh* of F2 to be *mathematical* enough to be malleable. At the same time, he also regards the so compressed mesh to be directly physical. So, even if the *difference* Δx in the LT-ed numbers (the values of the x-coordinates) in the F2 frame remain bigger (even after compression), STR people *don't* call it a space *expansion.* Instead, referring to the compression of the entire *mesh* (around the $x = 0$ point where both frames coincide at $t = 0$), they call it "space contraction."

In short, the mainstream treatment says that it's the *compressed* mesh of F2 that is *physical* — even if it was regarded as *mathematical* enough to be malleable in the first place. Now, since the other frame is *also* deemed to be so *physical* (because its representation of the events coincide with that in F1), they declare: "Moving objects contract," or worse: "the entire space contracts in the other frame."

For understanding the "dilation" of time, in each plot, locate the two events at the two extreme points along the y- or z-axis on the teal coloured-plot.

Once again, for M1, the plot in Figure 4a shows the physically correct representation of the two outermost events (along the y-axis now!). Following the same logic, it is the Δt in *F2* which has to be made to match with the Δt in F1. To do that, the *temporal mesh* of F2 has to be *stretched* along the t-axis by a factor of γ. During such a streching, the t-coordinate numbers attached to the locus points in F2 remain the same. Once such a stretching is done, then the temporal axis of F2 will become, according to M1, real — because it will match with *his* gold standard i.e. F1. So, according to M1, the *real state* of F2 is that in which the entire time-dimension of F2 that is streched (along the t-axis).

Thus, once again, the time dimension of F2 is regarded as mathematical enough to be malleable (strechable), and yet, its stretched state is also regarded to be physical enough to be real. Thus, the STR people once again declare: 'Time runs slowly in moving objects," or worse: "the entire time dimension dilates in the other frame."

Other explanations of the logic behind this terminology might be available elsewhere. Consult them. They could be useful. But note, no reference would carry any comment on the *contradiction* of treating a frame as both mathematically malleable, and yet, *also* physically real.

5.3 Who is right? M1 or M2? both? neither?

The most important fact to be noted first

Experiments have not been able to settle this question. There is no technology using which we could've performed experiments that involve two physical frames moving at relative speeds comparable to c.

Thus, the first thing to note is that any answer given to this question has to be in the form of a *hypothesis*, not as an experimentally measured fact.

Of course, not all hypotheses are equally good. Some are simpler. They by design include conceptual coherence with the rest of knowledge. They therefore also lead to simpler (or fewer) calculations. Such hypotheses are to be preferred.

STR is not such a hypothesis because it leads to too many conceptual incoherences and even more complicated procedures than what would be possible with a simpler theory (viz., our theory). Note: STR remains just a hypothesis despite its claim that it's a well validated "theory." And, even as a hypothesis, it's a very poor hypothesis, as we will continue pointing out.

The mainstream answer

The mainstream answer to the question: "Who is right? M1 or M2?" is: "*Both* of them are right." Consult Griffiths for a most lucid explanation of the supposed "logic" behind this answer.

What are the assumptions behind this answer? what are its implications?

To begin with, note that there is no unique description for one and the same physical process. In fact, space and time depend on "observer".[2]

The mainstream treatment equates the calculations done using two mathematical frames with physically occurring processes, and their end-results with physical observations (recorded by physical instruments).[3]

BTW, the mainstream treatment ("consensus") does not (any longer) care to look into this aspect: If both of them are right, but they make different claims for the same process, then this difference *also* makes both of them *wrong*. Let's leave it at that, and let's turn to our development.

5.4 Our thoughts / analysis / comments

What could be the essential source behind all the troubles with the mainstream explanation?

Most (at least many) of the people might think that it's the LT which is unrealistic because it changes space and time coordinates. We beg to differ.

Relativity itself has been known since Galileo's time. The fact that *some* properties of the same object must change when described using different physical frames, is perfectly sound. In Newtonian mechanics (NM Ontology), it's well borne by direct experiments too.

The idea of coordinate transformations is nothing new either. Therefore, if F1 maps to compressed/stretched F2, that could've been actually fine. The microscope and the telescope, or the cinema projector and solar collector, are the simplest examples of coordinate transformations. So, that's not where the trouble lies, in our opinion.

The real trouble isn't even that the coordinate transformations are unreal. In case of telescopes and microscopes, or cinema projectors and solar collectors, we know that the transformations are virtual, not real. Just because an object *appears* larger than life on a cinema screen, we do not believe that it actually has become bigger.

The real trouble with the mainstream solution (for solving the problem of having a correct rela-

[2]This whole field of STR is so richly illustrative of philosophical errors that any philosophical observations would have to be relegated to footnotes. We don't always care to make such observations, but for now, specifically here, observe how the philosophy of Subjectivism is at work.

[3]Here, observe how the philosophy of Intrinsicism is at work.

tivistic description for ED phenomena) is two-fold: (i) transformations are regarded as working *both* ways (to F2 from F1, *and* to F1 from F2), and (ii) the starting point along each way (forward or backward) is in itself regarded as being perfectly real.

If the transformations were to be regarded as working only one-way, there won't be any issue. The cinema projector is a magnifier (a "diverger"); the parabolic array of a solar reflector is a concentrator. Both of these devices act only one-way. The cinema film is really small; the projected image may be very big in size, but the process of projection does not make the *film* itself bigger. The focus of the solar collector has a small region; the concentration of sun-rays doesn't make the Sun itself small. They both act one-way: from a physical object to its effect on *another* physical object — not from a physical object (or process) to a bigger/smaller version of the same physical object/process.

But the mainstream STR says that LT acts both ways, and both the end-points are real.

Since LT does enable using ED laws (Maxwell's equations + Lorentz' law), we may first regard it as a one-way process, and thus say that the changes in coordinates (and other quantities) are virtual, they are not real. If so, it must be the second part which ought to be the root of the troubles. The second part says that both M1 and M2 can claim that the simple pattern of concentric circles is what they do in fact see in their own frames, even if the other must see ellipses.

So, it's the idea that both M1 and M2 are claiming reality for concentric circles in their own frame and elliptical patterns for the other frame, which is trouble-some. It's contradictory. *Both* the claims cannot be maintained at the same time — not unless objectivity is sacrificed.

But in the absence of direct observation at high enough speeds or controlled experimentation, how may we analyze this problem?

In the next section, we will look into another thought experiment. Before turning to the next section, however, one final point about this section, in case you didn't notice: All our plots in this section were for *mathematical* frames (F1 and F2). We didn't use the symbols S1 and S2 for the *physical* Screens, simply because we couldn't have done our experiments at the physical speeds of $\sqrt{3}/2\,c \approxeq 0.866\,025\,404\,c \approxeq 259\,627\,884\ \mathrm{m/s}$.

6 Experiment-W1 with water waves

Another notation: "Ph" is for the physic*

From this section onward, we find it convenient to introduce the symbol "Ph"; it stands for all: "physics," "physics-wise," "physically," "physically measured," "physicist" and even "engineer."

6.1 The experiment with a pond and a drone

Consider a situation similar to the physical scenario we discussed earlier, but now with water waves.

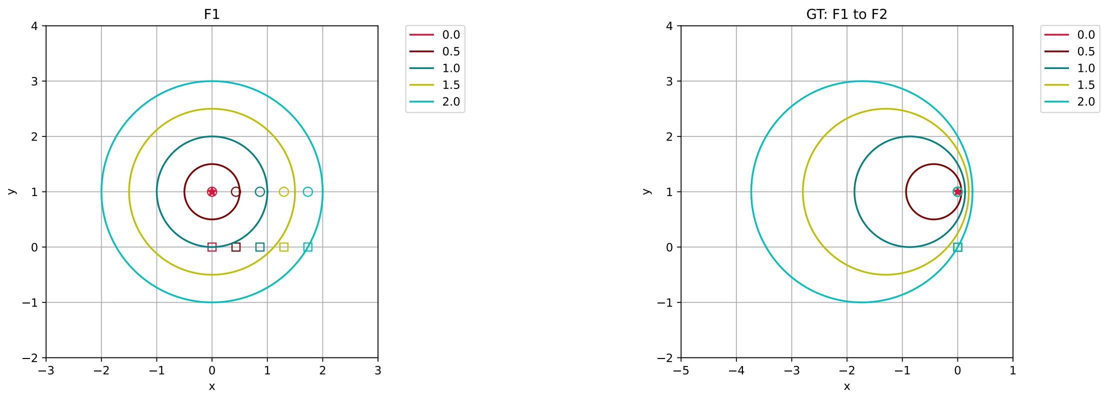
Suppose you drop a pebble in a quiscent pond. Waves emanate on the surface of the water body. Assume that the disturbance is infinitely sharp, and therefore, only a single wavefront emanates.

Suppose that the speed of waves in the pond-frame is $c = 1$ m/s.

Suppose that the expanding wavefront is experimentally recorded by using the light that bounces off them, using a Screen of CCD pixels, S1. The evolution would look precisely like Figure 2, and the superposed plot like Figure 3a.

Suppose that you have a drone carrying another Screen of CCD pixels, S2. Suppose again that the S2 and S1 coincide at $t = 0$ when the flash is emitted. Suppose again that S1 is moving parallel to the x-axis with a constant velocity of $\sqrt{3}/2c \approxeq 0.866$ in x-direction.

Figure 8 shows the plots. Figure 8a shows what P1 predicts (using physics and maths) and also experimentally measures in F1. Figure 8b shows what P1 predicts (using physics and maths) as would be recorded by P2, which turns out to be exactly matching with what P2 measures in F2.



(a) P1 *predicts* and *measures* in F1

(b) P1 *predicts* for F2; P2 *measures* in F2 and confirms P1's prediction

Figure 8: Experiment involving GT

Two questions

1. In the above description, it was assumed that P1 predicts and measures the pattern in F1, but P2 only measures the pattern in F2. The question is: Could P2 also have predicted (using physics and maths) the pattern he measures?

2. To make the situation as similar to that involving light, what aspect of this experiment would have to be modified so that P2 could also measure *concentric* circles in his frame?

7 The special pixel "ET-S1" from the S1 screen — the pond experiment

Notice that in case of the pond-and-drone experiment, the water body in the pond acts like the middle pane — the physical location where the waves are generated. The CCD Screen attached to the ground (pond) acts like the Screen S1. The CCD Screen attached to the drone acts like the Screen S2.

Therefore, we will answer this question — how P2 might not just measure but also predict the patterns he sees — in reference to the more general terminology of S1 and S2. This way, it would become convenient to transfer our lessons from the water waves to the light waves.

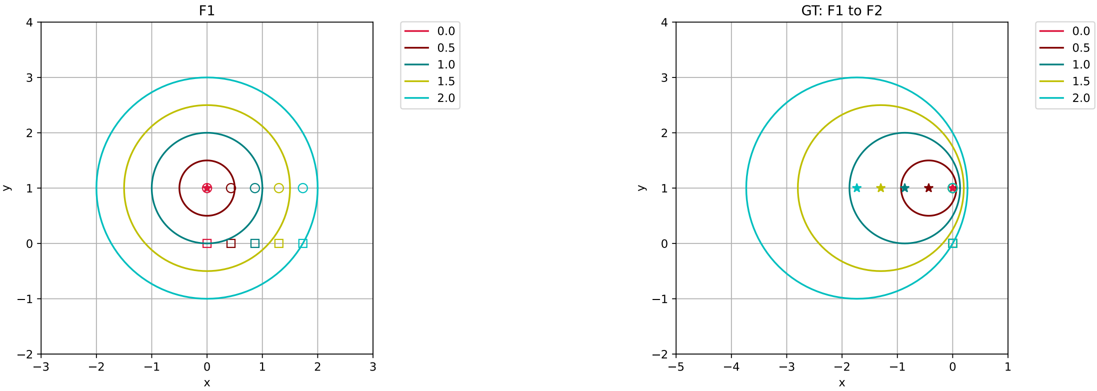
(Doing so is possible, even if water waves exist in material media and light waves are conditions in EM fields in "free space".)

7.1 The special pixel "ET-S1" from the S1 screen — the pond experiment

When the emission event occurs, there is a unique pixel in S1 which is directly behind the bulb (or directly above the location on ground where pebble was dropped into water). Let's call this the *emission-time S1 pixel*, or the "ET-S1" pixel for short. It *physically* resides on S1.

Since S2 is moving to the right with respect to S1, it could record the ET-S1 pixel as moving to the left from F2 — if we arrange for the ET-S1 pixel to send a special light signal to S2.

For the pond experiment, experimental measurements from both F1 and F2 are possible, and so, we will re-plot everything, now also showing instantaneous positions of the ET-S1 pixel in *both* the frames. The result is shown in Figure 9. It is the same as Figure 8 but with the addition of stars that show ET-S1 positions at different instants.



(a) P1 *predicts* and *measures* in F1

(b) P1 *predicts* for F2; P2 *measures* in F2 and confirms P1's prediction

Figure 9: Experiment involving GT — with ET-S1 pixel shown

Since we have assumed that flash emission occurs at $t = 0$, and since this also is an instant when both the frames coincide, the ET-S1 is seen at this location in *both* the frames. Hence the *red* star is always at $(0, 1, 0)$ in both the frames.

Having examined this variation, we can pin-point the meaning of the instants that were noted in the legend of Figures 4b and 5b. The instants noted in the legend are the local instants for the special pixel ET-S1.

7.2 Center of radiation: The point in a frame where the flash is seen as separating from the emitter

By inspection of the stars in Figure 9, it is almost visual to conclude that:

> *In each frame, waves radiate outward not from the instantaneous position of emitter (marker with open circles) but from the instantaneous position of "ET-S1" (as seen in that frame).*

Thus, even if the bulb is seen as moving in a frame (here F1), the expansion of the flash does *not* occur around the moving *bulb*; it occurs around the point where the flash was *initially* emitted.

Although literature does not have a word for it, we find it convenient to define a new concept that captures this observation; we call it the center of radiation.

In the frame where the bulb is seen as moving, viz. in F1, the emitter coincides with the center of radiation only once, which occurs at the instant of emission.

Now, another observation:

> *The special pixel ET-S1 is important, because it acts as the center of radiation in all the frames. This observation is made only for the pond frame.*

7.3 The special pixel "ET-S1" from the S1 screen — the light experiment

Figure 10 shows the stars (ET-S1 pixel positions) when LT is involved.

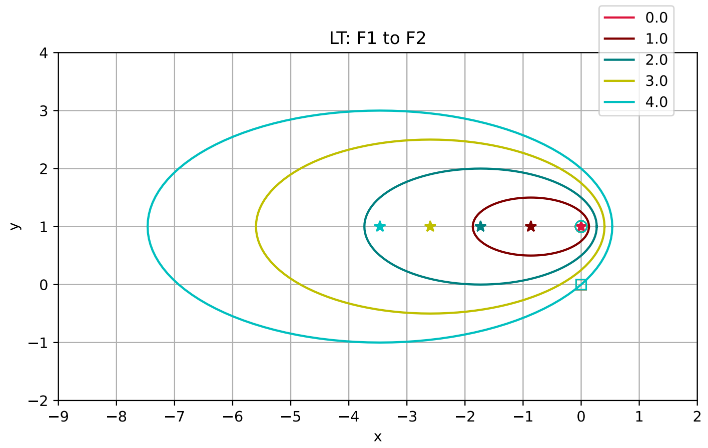


Figure 10: M1 *predicts* for F2. No one has been able to make experimental observation

Figure 11 shows the ET-S1 pixel positions on the local time-vs-x-coordinate plot.

Observe that since, in case of light, the locii are elliptical, and there also is a time variation along x-axis, we cannot speak of ET-S1 as the center of radiation. However, also note that

> *Even in case of the experiment with light, the stars (instantaneous positions in a frame of the pixel ET-S1) do remain at the spatial and temporal center for the corresponding ellipses.*

How about ET-S2?

Yes, we can define a similar special pixel in the S2 frame, too. It would be useful in general. However, for the special setups we are considering in this document, it's not necessary to define ET-S2. The reason is that in all the setups in this document, the emitter and detector pair always moves with S2. So, the emitter (shown by open circle markers) is always at ET-S2.

7.4 Similarities and differences — pond waves vs. light waves

Here are the important similarities and differences regarding the pond and the light experiments.

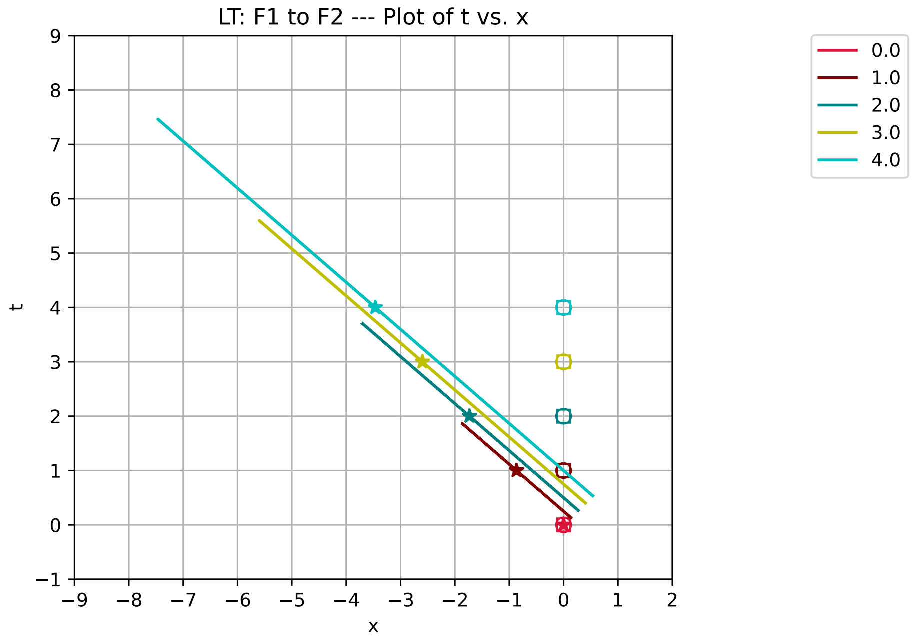


Figure 11: Time vs. x, with ET-S1 pixel positions shown. *Cf.* Figure 6a.

Differences

- In the pond experiment, P1 uses the Galilean transformations (GT) for making predictions as to what would be observed in F2. In the light experiment, M1 uses the Lorentz transformations (LT).

- In the pond experiment, P1 sees the circles being radiated from the center of radiation (i.e. the ET-S1 pixel) in his frame. In the light experiment, complete ellipsoids don't exist at any one instant. However, their centers do match with the ET-S1 pixel.

- In the pond experiment, P2 has *physically* measured the process, not just *calculated* it. In the light experiment, M1 and M2 only calculate the predictions; none has been able to perform the experiment.

- In the pond experiment, *P2 doesn't experimentally observe concentric circles* as was described for light in Figure 5a. Instead, he observes a pattern of crowding locii. In the light experiment, M1 asserts that the locii are ellipses (with differing local times in the same ellipse); M2 asserts that they are circles; none has made any experimental observation.

Similarities

- In both the experiments, F2 has ET-S1 pixel (star) as moving to the left, with the same velocity (the negative of the velocity of F2 w.r.t. F1).

- In both the experiments, The successive locii are centered around the instantaneous position of ET-S1.

7.5 Answer to the question: How might P2 *predict* what he *observes?*

The answer to the first question posed in Sec. 6.1 should be obvious by now. There are at least two ways:

P2 can experimentally measure the instantaneous positions of ET-S1 from his frame (F2), and input them into the laws of acoustics "as is," in order to make predictions.

P2 can take the measured emitter position at the emission instant $t = 0$ (it's the red star in F2). He can then inverse-Galilean transform (IGT for short) this position from F2 to F1 to get the emission position at $t = 0$ in F1 (which, by our assumptions, again happens to be $(0, 1, 0)$ but this need not in general be the case). He can then *calculate* the pattern of the *concentric* circular locii in reference to F1 (which also physically exist in S1). Finally, he can forward-GT the so calculated locii from F1 to F2, and get the crowding circular locii in F2. The last are what he has *predicted*, using *calculations* alone (apart from the measurement of the initial flash position in his own frame).

Finally, he can compare the calculated locii with the locii he has actually observed, and find that the two match.

There could be other tricks to do the same calculations. All such ways crucially depend on these items of knowledge that P2 has:

1. P2 knows that the expanding wave patterns were physically created in the medium that was stationary in F1 but in a relative motion in his own frame (F2).

2. P2 knows that these waves were not created in a medium that was stationary in his own frame.

3. Thus, the waves he is observing (experimentally measuring) are the waves that exist in the "other" frame's medium.

4. For the aforementioned reasons, he may *calculate* the observed waves, but knowing that the medium of the observed waves was in a relative motion, he acknowledges that he cannot apply the laws of acoustics "as is" in his own frame (F2).

Thus, answer to the first of the two questions posed Sec. 6.1 is now obvious, and in a way, it brings to the fore the role played by the instantaneous locations of the ET-S1 pixel, because at all times, in this experiment, ET-S1 pixel has the same coordinates as that of the *physical* center of radiation. Indeed, in the pond experiment (as in contrast to the experiment with light), there is a *unique* center of radiation; it firmly belongs to F1.

For providing an affirmative answer to the second question, however, we have to modify the experiment, which we do in the next section. For establishing relations of such experiments with the light phenomenon, however, will take several more sections, and will require us to undertake not just a comparative analysis of GT and LT, but also some further thought-experiments. These will involve some known principles. Some PyCharge simulations could also be thrown in. Further, for clarification (in anticipation of polemics by others), we might have to add some additional sections, even if we withhold for the time being some informed comments from the angle of QM.

8 If you are smart . . .

If you have read through this document up to this point, including the idea of the center of radiation and the special pixels in each frame (ET-S1 and ET-S2), and if you are smart enough, you might have already anticipated our solution.

Still, let me give out the whole story, in the briefest manner possible.

Attach a trough containing water to the moving drone. Drop a pebble in the *trough*. Now, P2 begins to see the concentric circles in F2, as required by STR thought experiments.

In fact, P1 is able to see both his concentric waves and the IGT'ed form of P2's concentric circles. (IGT: Inverse Galilean tranform. The forward transform is for going from F1 to F2. Inverse for F2 to F1.)

As to light:

Conduct a PyCharge simulation in 3D.

Each physical frame S1 and S2 is represented by a rigid wire-frame.

Have a massive charge represent the bulb. Shake it a bit — prescribe the usual x-velocity of $\sqrt{3}/2$ and some instantaneous acceleration for the instantaneously emitted flash.

In each frame S1 and S2, there is a massive charge at $(0, 1, 0)$ at $t = 0$. This charge is attached by a spring to the wire-frame. (ED can't explain stability of matter; so we model the stable matter using the mass-spring-wire mesh system.)

The changes in the field due to the bulb-charge (i.e. the signal / light) reach the adjacent charges in S1 and S2, and makes them shake.

Consider S1, for example. The charge in S1 which is adjacent to the bulb at the emission time is *not* a detector in S1, but acts as an emitter for S1. Its shaking creates a secondary light. (You could've predicted this generation of the secondary wave-front without using ED. In my developement I did (without ED). You need only the Huygens-Fresnel principle. I had studied it during my PhD.) This charge thus acts as both the ET-S1 charge and the center of radiation for the *secondary* radiation in *S1*. This secondary radiation spreads in S1. Pixels are nothing but array of yet another set of charges attached by springs to the wire-frame. When they begin to shake, it's regarded as the process of light detection.

Ditto for S2.

But S2 is in motion w.r.t. S1. Doesn't matter, as far as time-delays are concerned. A point-charge in motion, when its velocity changes, still radiates *spherical* wavefronts of changes in the EM fields, from the instantaneous position of the point charge in a frame.

So, the ET-S2 charge too generates a *secondary* radiation which spreads *spherically* — whether viewed from F1 or F2.

So you have one primary radiation (by the bulb-charge) and two secondary radiations (one each by ET-S1 charge and ET-S2 charge). Under the idealization of point-thin physical frames, the primary radiation coincides with the secondary radiation of ET-S2 charge. So, essentially, you have two radiating wavefronts, not one. Let's call them ET-S1 and ET-S2 radiations.

Now, assume that under idealized scenario, P1 in S1 can measure both the ET-S1 radiation and the ET-S2 radiation. Ditto for P2.

Now a bit about the mainstream description i.e. confusion. Consider the detection event at the detector below the bulb. People developing LT observed that in F1, the detection occurs at $t = 2$ s, and in F2, they thought, it would occur at $t = 1$ s. So, they set up the enterprise of developing LT. Once it was at the hand, Einstein fell for such framing, inverted the idea a bit (ED implies LT and ED also implies constancy of c; so take the latter as the postulate and trace back in hierarchy to "derive" LT from it.)

None realized that the framing of the question itself was bad.

When P2 has a detection event at $t = 1$ s, the radiation so detected is the ET-S2 radiation, not the ET-S1 radiation. If he were to also continue detecting, he would detect the ET-S1 radiation too — at $t = 2$ s.

Thus, both P1 and P2 detect two events: one at $t = 1$ s and another at $t = 2$ s. Note: In S1, P1 would detect the $t = 1$ s event at the S1 location $(\sqrt{3}/2, 0, 0)$, not $(\sqrt{3}, 0, 0)$. But, there would be two events, one each to ET-S1 radiation and ET-S2 radiation.

Once you understand this much, converting this physical understanding into maths is pretty straight-forward.

Of course, the above is a pretty a well ordered story. My thoughts didn't progress so linearly. Earlier (even for the ICCTPP 2024 paper), I was thinking more in terms of GT and LT, and so, I went into circles. (The ICCTPP 2024 paper has a good case-study, but it was more of a study of LT itself; not directly useful as the description in this section, which occurred to me only later.) In fact, the idea of the trough experiment became fully clear only about 10 days ago, followed immediately by Huygens' principle. The above PyCharge simulation occurred as I was writing this document.)

Bottomline: The whole LT and therefore STR puts in wrong words the problem they solve. The problem they solve is relating the measurement of ET-S1 radiation in F1 with the measurement of ET-S2 radiation in F2. It is emphatically not the problem of relating the measurement of ET-S2 (i.e. primary) radiation in F1 and F2. The two "observers," in short, aren't "seeing" the same light-propagation process because there isn't just one light in the first place. None realized that.

One last word, rather, a question: Why do we not see the "other" event due to the "other" radiation in our experiments?

Answer: Each molecule forms a physical frame of reference. Molecules move randomly. So, you have 10^{23+} frames, all randomly moving. Energy conservation applies. The original light gets distributed over random frames. So you would have as many detection events as there are these frames, but their signals would be too weak (and at different times anyway). The "cross"-detection doesn't "condense" to one big event. So, you see in your physical frame only the ET-your frame radiation.

If careful containers were to be created and moved at high speeds, with some further experimental details (like, amplifying the “other” secondary radiation for sending to “this” frame), our explanation would be borne by the experiments.

In any case, we have a consisten ontology, physics, and also a mathematical description that involves no space contractions and time dilations.

Other points like utility of STR in RQM and all will be dealt with later. Essentially: You don’t need space-contractions and time-dilations; you only need the EM fields.

More, later, may be after 2–4 weeks.

[E&OE]