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Review Article

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After a Century of Revolution in the Status of Space and Time: Einstein's Train Revisited

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Abstract

Written from a very untutored and limited viewpoint in terms of physics and mathematics, this essay ventures some thoughts that should therefore be regarded as only tentative. Especially as they address a long established idea that sits right at the heart of the scientific discipline of physics. This is the idea of naturally moving reference systems, a notion closely linked to the classical principles of both inertia and relativity. Such inertial reference systems played a key role in some thought experiments published over a century ago, by Albert Einstein. It is a critical reading of one of these original accounts that forms a springboard for some radical discussions, particularly in terms of assumptions about the physical nature of space. The remarkable revolution in such views that's taken place since Einstein's younger days is considered. A development more in accord with this sort of fundamentally modernised world-view suggests a re-appraisal and expanded inclusivity for the inertial reference system concept.

In the old thought experiment account in question, Einstein famously used an imaginary device — a train struck by lightning — to illustrate his earlier reasoning for one of his most revolutionary and enduring concepts: the relativity of simultaneity. Over the century or more since he first put this basic rationale forward in 1905, it's clear it has been largely received with widespread scientific approval. Yet in fact, it's also apparent that Einstein's argument actually depended solely on employing the logic of classical mechanics — albeit well beyond its established domain of application. And it's very troubling that by showing such a clear preference for this old and very conventional but intuitively attractive approach, in effect he allowed it to directly contradict the predictive force of his own new and revolutionary postulates.

In response to this concern, a sort of remedial analysis was undertaken. It accepted Einstein's famous postulates and simply applied them directly to his train scenario — quite independently of the classical transformation he chose to employ instead. It is shown how this meticulous reanalysis led unambiguously to a very different inference about the question of simultaneity. The logical result of applying the postulates was very clear: the observed simultaneity of events is actually not relative to perspective. Rather, this temporal quality seems to be thoroughly conserved across different reference frames, in line with the idea of a universal passage of time. An idea which a majority of physicists probably now consider to be entirely obsolete. They would see the relativity of simultaneity as an integral and established part of the legacy of Einstein's spectacularly successful theorising.

Evaluating what to make of this strikingly disparate and seemingly anomalous outcome compared to Einstein's, leads to discussions set in a more philosophical context. First, a brief overview portrays how metaphysical views on the status of space have radically evolved over the last century. Adopting a more present-day style of understanding, it is suggested how the old notion of naturally moving systems might need to be newly characterised. While inertial reference systems may continue to be conceived as spatially related frameworks of material bodies, all moving uniformly and in unison, this may not represent all that they really are. In addition, it may now be necessary to recognise the significance of a further content for inertial systems. They should be seen as including areas of discrete and equally co-moving spatial and physical field.

Such spatial aspects of reference systems have previously been regarded only as matter-based, geometrical abstractions. They were regarded only as part of a spatial framework derived from the coordinates representing the extension properties of an independent background of immobile and empty space, through which the whole framework of matter is moving. However, from current perspectives on the nature of space, these additional contents could well comprise individuated and co-moving aspects of a highly dynamic and distinctly physical entity. Taken together across multiple reference frames, these co-moving spatial contents would constitute a flexing continuum of super-plastic and holistically extended dynamic fields — such as electric and magnetic fields.

On this conjectural basis the propagation of light would indeed show a constant 'vacuum' speed when directly measured in 'resting' space, just as both Einstein and Maxwell required. But, if a particular reference perspective is artificially adopted as absolutely stationary, or likewise, singled out as the preferred and real viewpoint, then it is explained how its speed relative to light propagating elsewhere might then be considered as basically Galilean in nature, not unlike the situation with the passage of sound. Even so, the fact that the classical transformation procedure has so clearly been superseded by the more generally efficacious Lorentz transformations of the Special Theory of Relativity is certainly not denied. However, the veracity of their assumed basis in the physical length contraction of inertially moving matter and its associated physical time dilation is seriously questioned.

In criticising some aspects of Einstein's earliest assumptions that underpinned his Special Relativity Theory, this essay promotes a view which suggests that some of this thinking would have benefitted from being more relativistic, not less.

1. Introduction

The main idea that surfaces during the course of this essay has to do with the nature of space — and the thought that everywhere and at all scales, it may at all times take the form of relatively moving areas of physical field. This idea sprang from a radical criticism of the ideas that were expressed in one of Albert Einstein's earliest and most revolutionary analyses. As a result I undertook a search of the literature for conceptions that might relate to my sort of critical viewpoint. Ironically, this unearthed its most transparent and unambiguous support also in the concisely chosen words of Einstein — but only when he was writing much later on in life, in his seventies. In 1952, just three years before he died, he expressed his current thinking about the status of space. He had written a new forward for the republication of one of his books. In this forward he considered the problem of space and made a statement which I recognised as contrasting very sharply with some key assumptions he seemed to work with in his earlier days. He wrote:

The concept of space as something existing objectively and independent of things belongs to pre-scientific thought, but not so the idea of the existence of an infinite number of spaces in motion relatively to each other [6, p.3].

After a lifetime of contemplating this sort of topic, he thought this view of physical space (or rather spaces) was "logically unavoidable". But he also acknowledged that at that time, it had yet to play any prominent role in scientific thought. Admittedly, however — and I have to say, in my view unfortunately — this radical shift in metaphysical viewpoint showed not the slightest sign of also making him consider rescinding his much earlier argument for the relativity of time.

In everyday terms, I think many of us normally take space — by which I mean not just 'outer space', but the presence of the universal spatial extension we all seem to inhabit — to be a sort of immaterial 3-D arena in which we are all immersed. When we move, we move through it. We accept that any physical thing can readily move through this 'nothingness' of space, from massive heavenly bodies to the smallest, most minuscule particles or even the ethereal rays of light. Given this sort of Newtonian legacy of a universe-wide, physically separate, inert and immaterial backdrop for the motion of matter, it might seem very counter-intuitive to suggest that what commonly moves freely in our universal, spatial arena — in addition to its normal content such as solids, liquids, gases and plasmas, together with its less substantial aspects like the radiation of light rays — is a further content of discrete areas of space itself. Surely this is a highly improbable twist in metaphysical perspective? It would seem to run completely counter both to common-sense and to normal physical science. Yet it's just this sort of very unfamiliar way of thinking about our physical world that I now wish to discuss at some length, promoting it as a real and explanatory possibility.

To start with, acting as a springboard for the task of opening up these complex discussions, I wish to report some reflections on a well-known historical analysis; one linked to a keystone concept underpinning much of the structure of modern physics. In so doing, in effect I'm reprising the way in which for me, a whole line of thinking started to emerge. Throughout, the reflections I express have to rely on ordinary reasoning of a non-technical and non-mathematical sort. I take pains to acknowledge that the views provided are not at all those of a trained physicist or mathematician, nor really of a truly scholarly philosopher. It is in this light that I write with my peers very much in mind, making every effort to communicate to any ordinary but scientifically-minded reader. So let me relate what prompted all these reflections and the critical position they came to represent.

Because I have a longstanding curiosity with regard to the philosophy and physics of time, like so many before me I had decided to access an original piece of writing by Albert Einstein. Namely, his popular book about his theories of Special and General Relativity, first published just over a century ago [1]. In particular, I wanted to read his own explanation of a crucial scientific discovery about the nature of time. He had designed a simple line of reasoning to illustrate how any of us can recognise that Isaac Newton's long-reigning theory of absolute time should clearly be seen as mistaken. If you like, to see it as a convenient and very persuasive fiction, rather than any sort of physical reality. Previously, I'd only read third hand about this remarkable achievement. However, none of the summaries I read fully satisfied my desire to understand. To me, none of them seemed quite so obviously persuasive as their authors seemed to imply. In deciding to consult the original I looked forward to a much clearer enlightenment, flowing straight from the pen of the master physicist himself.

2. An Encounter with Einstein's Train

Famously, Einstein's popular explanation is based on an ultra-simple 'thought experiment'. This is about two bolts of lightning that strike simultaneously at each end of a moving train. His purpose for this fictional device was to illustrate in a transparent and accessible way how the perceived simultaneity of such physical events cannot really reflect one of our universe's general and physically defining characteristics. Hitherto, Newton and many others had thought the generality of the simultaneous passage of time must be an absolute and universal physical fact. Einstein aimed to expose this position as untenable, for all to clearly see. He argued that his device showed that while events viewed from one physical perspective may clearly be judged as simultaneous, it equally showed how exactly the same events, when viewed from a different physical perspective, may just as clearly be judged as occurring sequentially. Thus our everyday perception of the passage of time — of things always happening in a ubiquitous but passing 'now' — cannot truly reflect an objective and universal physical fact. Such perceptions must instead be more in the nature of a subjective illusion, albeit one that seems deeply ingrained and very widely shared.

But when I studied the logical argument Einstein had set out in his thought experiment about the train, I was mystified. I found his explanations both more mundane and more perplexing than I had been led to expect. I have to admit, to me his argument seemed deeply self-contradictory rather than lucidly persuasive in the way a non-expert reader like myself might have hoped. He pursued his main argument for the relativity of simultaneity in a surprisingly classical and conventional way: purely by applying normal Galilean mechanics. And in showing an overriding preference for this old and rather intuitive approach, he seemed content to allow the distinctive force of the new combination of theoretical postulates he had established to be not only neglected, but also clearly and directly negated.

In a nutshell, Einstein's thought experiment involved an analysis of judgements about the timing of two events: the two lightning strikes. It described the judgements that would be expected from observers taking the differing perspectives offered by two different reference frames, one of which was considered as moving steadily (the train) relative to another which was conceived as stationary (the embankment). In view of the fact that the light rays emitted by two bolts of lightning would be propagating opposite ways and also through both these frames, Einstein's argument relied on a very specific prediction. His analysis is summarized in the following paragraph.

Firstly, measuring and recording the rate of travel of the light rays within the stationary embankment frame would result in the judgment of a specific and constant speed. This speed would be the same for the light rays travelling through empty space in either direction from the two lightning strikes. In contrast, in comparison with the embankment observer's measurements, when measuring from within the moving train the observer aboard would experience the speed of the light rays to be either augmented or diminished from this perspective. Their speed measured within the train would vary in accordance with their differing direction and the one-way motion of the train through empty space. Within the train perspective, the actual speed of the light rays in each direction would thus be a combined effect. An effect arising from the light's constant two-way motion combined with the constant speed and single direction of the train's movement. This constant train speed would be viewable and measurable as such from the stationary embankment.

The trouble is, as already noted, this central, classically based prediction of the combination of velocities, which his argument relied on, runs totally counter to the direct prediction given by the postulates of his own theory. Designed to supersede the limitations of the old Galilean transformation theory, Einstein's famous Special Theory of Relativity predicts that an observer, located in either of the sort of matter-framed contexts he described in his thought experiment, must always directly measure the speed of light as unaltered. Such measurements must always result in exactly the same constant value. Thus, under the vacuum conditions he described, it is never possible for inertial observers to experience and directly measure the speed of light waves as either augmented or diminished in even the slightest degree.

In fact, as I will discuss in detail later, Einstein was very well aware of the existence of such a radical contradiction between the outcome of a classical analysis compared with that provided by faithfully applying his own revolutionary combination of postulates. His Special Theory of Relativity proposed a solution to overcome this apparent difficulty. Unfortunately, though, and crucially, he chose to set aside and ignore this whole contradiction issue entirely during the presentation of his argument for the relativity of simultaneity. This is true for both the original 1905 publication of his reasoning and his thought experiment published for popular consumption much more widely, over a decade later.

3. Introducing a Different Analysis for Einstein's Train

Meanwhile, in an attempt to resolve my personal difficulty with the contradictory position that seemed to have been accepted as a basis for such a very momentous conclusion about the nature of time, I had decided to take a look myself at how the same thought experiment would turn out if this contradiction was directly avoided. I simply worked through to my own satisfaction how just Einstein's two postulates alone might be harnessed in their own right, independently of any transformation theory, including the old classical approach he chose to adopt. Thus I applied them directly to the the bare bones of the train scenario he had so clearly laid down. To start with, it is these simple and personal explorations I wish to report.

Before I recapitulate the form of Einstein's train scenario, it should be noted that while it was very simple and distinctly imaginary, it was posed with considerable precision. To achieve this scientific quality it had to be presented in a quasi-real or idealized sort of way. This strategy helped sharpen the analysis without seriously compromising the key physical principals his simple picture was designed to embody. In particular, the whole thing had to be regarded as taking place in empty space (that is, in a vacuum). Likewise, the various velocities and measurements involved could only be considered in principle. In useful comparative terms, but not in any numerically or mathematically specified way.

I will now describe the sort of scene that was only very briefly sketched by Einstein. For ease of accurate discussion, the details have actually been enlarged and spiced up, just a little. However, none of these small embellishments conflict in any way with the more Spartan form of the original account. The original also provided a minimal sort of diagram; I have chosen not to. It's the experiences that can be imagined from a position linked to each perspective frame I particularly wish to invoke.

There is an open-plan train carriage, gliding along very rapidly but completely steadily (we wish!). It is neither accelerating nor slowing, but travelling in a straight line along its track on a level railway embankment. As it cruises along at great speed, we imagine two bolts of lightning suddenly striking down at precisely the same moment, so there's a bright flash, right at each end of the carriage. A most unlikely coincidence, you may well scoff. But the beauty of a thought experiment is we are free to say it simply was so! Similarly, we can blithely ignore the lack of oxygen and say that as a result of each of the lightning strikes, there is a visible burn trail down the perpendicular window at each end of the carriage. And two exactly corresponding scorch marks on the railway track, directly below. Finally, the scenario includes two viewers. One is standing on the embankment, purposely positioned at a precise midway point between where the lightning bolts strike the train and burn immediately onto the track. The other observer is on the train, sitting in the carriage. This viewer is also fixed at its exact midpoint.

Now we need to borrow a bit of Einstein's own physics. We need it to describe what happens to the flash as its light rays emanate from where each lightning bolt struck and then continue to radiate steadily outwards in all directions.

First though, it's important to understand that because of their steady and unchanging rate of movement relative to each other, the train and the embankment serve to mimic what is known in physics as two inertial reference frames (or systems) in relative motion. It was recognized long ago (by Galileo and then Newton) that the laws of mechanics seem to apply without change when considered with reference to such naturally moving frames. In other words, viewers positioned either in the train or on the embankment, will both experience the operation of all these laws within their own perspective in just the same normal way, despite the fact that their relative motion affords a very different view on what is happening elsewhere. (Of course, a train does not really move completely naturally, exactly as an inertial object in free space continues to move in the absence of any continued application of force. In its real situation, a train has to be powerfully driven, even along a level embankment. Nonetheless, it serves well as an imaginary approximation to inertial motion, due to the way the train's power allows it to cruise at a uniform rate along a straight track.)

As I will show in a moment, these days most of us are in fact very familiar with experiencing the reality that approximates the inertial reference frame situation described within physics. The more one reflects on what underlies this familiar sort of experience — as did Galileo Galilei, all those centuries ago, sailing in his ship — the more it can be recognised as a truly remarkable and deeply revealing state of metaphysical affairs. However, let us update things a little in order to consider a much more striking and modern example.

For instance, imagine you are high in the atmosphere, lounging in a comfortable jet airliner. It is on course at a cruising altitude and flying steadily, at say 500 knots. By current everyday standards, few of us on this earth will experience ourselves moving very much faster. Even so, apart from during any minor deviations in flight, it actually feels pretty much as if you were seated in a reclining chair back at home. You simply feel stationary. As does your immediate world of the plane around you. You can drink a cup of coffee, then get up, walk along the aisle, and go to the toilet, all in a remarkably normal way. And If you toss a book into the empty seat in front of you, you certainly don't expect to see it travelling there at 500+ knots! Only when you peer through the window into the other reference frame outside are you reminded that things look radically different out there. The nearby clouds are positively zipping by. Seeing this, your sense of common knowledge soon reminds you that despite the way it seems, you should accept it's really the plane that's flying at great speed, through an environment which, when we are earthbound, we always take to be stationary. Yet this whole contrasting situation may tempt you to ask yourself, which of these frame experiences actually reveals the truest world?

In the most deeply metaphysical sense, surely the answer must be that what is happening in both frames, while differently based, is equally real. Somehow, in some respects they are the same, reflecting the presence of a symmetrical and entirely equivalent sort of reality. It makes sense to assume that both the whole of the plane and its contrasting outside environmental framework are actually equivalently real aspects of one very dynamic but extraordinarily balanced and fundamentally unified world. Just as the train and embankment are too.

Amongst a whole range of other revolutionary contributions, Einstein is well known for the main postulates of his Special Theory of Relativity. It was in one of his very famous and seminal papers that he first asserted that a pair of firm scientific postulates should be regarded as governing our physical world [2]. The first of these wasn't really new. It simply embraced and extended what we've just discussed : how all physical laws operate in just the same way within all relatively moving inertial systems. Briefly, this has long been known as the principle of relativity — but was previously recognised in terms only of the laws of classical mechanics.

His second postulate, although linked to this fundamental physical principle, was a more specifically predictive stipulation. Basically, it simply said that light rays always travelled through empty space at an exact and unvarying speed, identified as a universal constant, c. (Numerically, this speed is well established to be just short of 300,000 kilometres per second. A simply unimaginable speed by a very wide margin.) Generally, this second postulate soon became expressed in a particularly scientific and empirical form, as an operational or instrumental statement. Einstein and many scientists at that time considered this approach to be indispensable for the scientifically meaningful statement of measurement variables. A good example of the latter is speed. Operationally speaking, then, Einstein's second postulate says that when measured with respect to any inertial frame of reference, light will always be found to propagate through empty space (a vacuum) with a standard velocity,

labelled as c; and this outcome will be independent of the state of motion of either the emitting source or the receiver of the light.
Accepting these two very foundational postulates as linked premises, we can now use them to highlight and trace what should happen in Einstein's train scenario. This task is approached very simply, in a logical way. Also perhaps in a more obviously even-handed way than the original. It focusses on sampling the differing perspective afforded by each reference frame for the viewer fixed within it. In my analysis each frame is considered an equal aspect of reality, just as we've discussed — and in agreement with the principle of relativity. Then, in terms of judgements about simultaneity made from within two reference frames in relative motion, we can see if there are similarities or differences in the outcomes the postulates direct us to. Please bear with me as I now trace, in a highly meticulous and comprehensive fashion, what they predict will happen for each observer.

4. Report of the Outcome of the Alternative Analysis

Firstly, let's consider what will happen for the embankment viewer. Let's call her Jane.

As Jane looks out from what we know is her middle position by the track at what is happening to the passing train, one of the light flashes will radiate as rays of light along the railway track towards her. They will emanate from where its source was right by one of the railway burn marks, well out along the track to one side of her. In accordance with the postulates, these rays of light must be measurable as travelling at constant speed c with reference to Jane's embankment frame. The same will be true for the flash originating by the second burn mark that's way out on Jane's other side. Because she is standing halfway, the two equal-speed rays of light from the coinciding flashes occurring at each end of the carriage will radiate in opposite directions until they reach Jane at the same moment. She will see the two signals arriving simultaneously. Given her halfway position, she will then have no doubt about judging the two lightning strikes themselves to have occurred a fraction earlier, simultaneously.

Now we can turn to the viewer on the train who, with respect to the embankment, is cruising rapidly along later by Joe.

In the way we've already discussed, Joe himself will feel seated in a stationary way, in a carriage within which everything else is pretty much stationary too. Of course Jane, looking in through the carriage windows, wouldn't see Joe as stationary at all. She would see him whizzing by. But then, she is not within his reference frame. For Joe sitting in his different frame, looking out through a side window over towards Jane's position, he sees it to be her that's whizzing by. So, what analysis can be applied for the light rays travelling within Joe's frame?

As we know, one of the lightning bolts seared down the rear window of Joe's carriage and thence straight on, to scorch the track immediately below. As the train rolled steadily by, these two locations which marked the source of the flash corresponded in both space and time, but only for one passing instant. At exactly that same instant the light rays generated by one of the bolts will have been emitted right at the rear carriage window. This moment therefore marks the immediate start of a very rapid journey for the light, as some of its radiating rays explode directly into the carriage, spreading quickly down its whole axis. This journey thus entails light rays radiating very rapidly outwards from their starting point at the rear window until, on their way, they reach Joe's seat, which he knows is in the exact middle of the carriage.

It may be noted that during this period when the light rays have been travelling rapidly towards Joe, there's been a very much slower motion made in the same direction by the train, rolling along its track. This means that while the light rays have been zooming ahead, the rear window has been moving steadily — if only by a tiny fraction — away from its source by the burn marks on the track outside. Of course Joe too has been moving away similarly, by the same very small amount. But all these shifts in location of all parts of the carriage relative to the track are entirely immaterial for Joe's measurement. For him, they do not change what he sees as the length and duration of the light's spatial journey from the window to his seat. But what does matter (in order for us to to adhere to the postulates) is that when measuring the speed of a light signal with reference to the physical parameters integral to an inertial frame moving in a vacuum (i.e. the carriage) it must be found to remain at c, regardless of any motion of either its source (the window) or it's receiver (Joe) when it was emitted.

For the other explosion of light rays — the one emanating from the window at the front end of the carriage — exactly the same considerations apply. Although radiating down the axis of the carriage in the opposite direction, these rays too will measure at c as they travel over the same spatial path from window to Joe. Again it is true that since the moment when the flash happened at the front window, this location and Joe's have been moving forward slightly from where the lightning hit the track. And again this is entirely immaterial, for exactly the same reasons as before.

To summarise: the light rays are radiating within and with respect to the carriage at equal speed c towards its middle from each of its end windows. From where, at the instant of the strikes, we know the light rays started spreading. Hence the two flashes will each be seen a trifle later by Joe. They will be seen as arriving simultaneously, just where he is seated, halfway along the carriage. Joe will therefore have no doubt in judging that the lightning bolts had struck a little earlier at each end of the carriage, simultaneously with each other. Exactly as Jane judged in her frame.

So, we now have a clear outcome from each viewer, with very strict reference to how things are in their own relatively moving frame, according to the postulates. They are both equally certain that the lightning bolts struck down simultaneously. One possible query remains though: can that judgement be matched with a more 'one world view' covering both frames?

The answer lies in reconstructing the original event situation on the basis of the objective historical evidence provided by the two pairs of burn marks on both the train and the railway track. This evidence can be reviewed and readily agreed by both Jane and Joe, once the whole scenario is over and the train has come to a halt. Examining the situation at one end of the carriage, and then the other, seeing how the burn trails down each of the carriage windows and the scorch marks on the track are closely matched, shows how, at each end, the window and railway line must have been instantly struck in a shared location. Jane and Joe can then check the distance separating the pair of burn marks on the track and compare it with the length of the carriage. These measurements can be expected to be exactly equal. It can then be concluded by Jane and Joe that the two lightning bolts did indeed strike at each end simultaneously with each other as the carriage passed. Exactly as Jane and Joe had both judged from their differentially moving perspectives.

So, after all this rather scientific and exhaustive analysis, based just on a careful application of the postulates to the task of envisaging the events in a thought experiment, there appears to be an unequivocal result. This outcome demonstrates (in logical terms only, not empirically, we must remember this wasn't a real experiment) how the quality of simultaneity would be thoroughly conserved in both observational frames, despite the sort of relative motion and differing viewpoints we've discussed. A reassuring outcome, it might be said, to see that in a truly unified world it may all continue to fit together so very nicely, despite the motion involved. Providing, that is, we accept the truth of the two governing postulates established by Einstein.

However, while I feel as confident as I can that my account is entirely faithful to Einstein's postulates and is not in any way seriously misleading, its conclusions are in direct contradiction to those that Einstein argued were true. Where he confidently asserted that his logic exposed the relativity of simultaneity, my direct application of his own postulates seems to support exactly the opposite idea. In fact, it suggests there is a significant correlate of the universal constancy of the measured speed of light through the free space of inertial frames. The simultaneous quality of events physically coinciding at different spatial locations was conserved when judged from differing reference perspectives — even though these observations were made by two observers in relative motion with each other. The observations were therefore also made from a point some distance from the location of the lightning strikes. Due to the finite speed of light signal transmission, they were necessarily made later than the moment when the coinciding events physically occurred.

Einstein's contradictory result and inference suggested his postulates correlate very positively with the notion of the relativity of simultaneity. My analysis, faithful to his postulates, suggests the exact opposite: that they are mutually exclusive conceptions.

Had Jane simply assumed both Joe and the light rays to be travelling in the same absolute space as her, she would also have assumed when seeing his motion along the track, compared to her absolutely stationary embankment, that the durations and lengths of light paths travelled would both have differed for Joe. Of course the reciprocal assumptions could have been made by Joe. Seeing her whizzing by him, he would reckon her light paths must be changed compared to his. However, Both Jane and Joe would be very surprised to find their empirical observations were in direct conflict with their assumptions.

On the other hand, if Jane and Joe both assume neither of them are really absolutely stationary, but are actually both simply in relative motion, each inhabiting their own discrete and separately moving but equivalent space (one they each certainly experience as stationary) then of course they would expect their respective light paths to be entirely equivalent. They would not be the slightest bit surprised to find their observations were in exact accord with both the ancient principle of relativity represented in Einstein's first postulate, and with his second postulate with regard to the constant speed of light when measured within the free space of any inertial system.

5. Discussion of the Disparate Outcome

So, far from helping to resolve my perplexity with regard to Einstein's form of argumentation, this outcome considerably deepened it! Not least, because over the period of the last hundred years or so, a countless number of readers with a very much greater expertise than me have obviously found no difficulty with the master physicist's reasoning on this matter. Having said that, a subsequent search on the internet showed me there were some scientific writers who shared my strong reservations about this particular argument by Einstein. Spread over the century or so that's passed since he first presented his train illustration, I found a handful of similar but rather more expert critical commentaries than mine had been published [3]. See particularly p.19, for some further information and referencing. One paper especially, written in 1962, provides a very full and careful critique of Einstein's logic in this regard. This paper was provided by a reputable philosopher of science, Melbourne G. Evans (See especially pp. 73-74) [4]. I conducted a further search hoping to find published peer responses to the authentic criticisms I'd found. Sadly, the little I've come up with so far suggests they were largely ignored within the scientific community, rather than actively evaluated or soundly refuted. Perhaps I need to search further.

6. Einstein's Contradiction Problem

By deploying the mathematical Lorentz transformations to replace the classical approach when presenting his theory of Special Relativity, Einstein was able to solve a crucial problem that he knew otherwise arose when applying his postulates. Elsewhere in the same popular book I have referred to (and prior to the pages arguing for the relativity of simultaneity) he used an even more simple version of the train device to portray the nature of this problem (pp. 21-24). [1]. Before briefly looking at the details of this previous thought experiment, first we should quickly consider some of the background assumptions about space that would have been involved.

The train and embankment would have been seen as situated in the same overarching background of empty space. A sort of pure physical extension which, being independent from matter and totally empty, was effectively immobile and both homogenous and isotropic in character, i.e., evenly distributed in every direction. In those days, a stationary aether acting as a light-conducting medium was also believed by many physicists to fill all of this extension of empty space. Einstein declined to assume the presence of such a stationary medium; on the other hand, he also said, "nor will a velocity vector be assigned to a point of empty space where electromagnetic processes are taking place" (p. 141) [2]. I believe this latter avowal is crucial for understanding Einstein's views in that era.

Let me say what I interpret all this to mean. Despite Einstein's rejection of the scientifically meaningful nature of any absolute conception, it was still a motionless, homogenous, isotropic and empty space he assumed to be the background for all moving matter. Just like his contemporaries, he seemed at that time to regard this as the fundamental backdrop for the passage of light along both the embankment and the train. Note how this assumption contrasts very strongly with Einstein's much later conviction that what seems to exist objectively in this world is not a Newtonian sort of inert and entirely separate background physical reality, one that's independent from the presence of matter. Instead, it would seem he had come to believe that what really exists is simply an infinity of relatively moving spaces.

In any case, I will be arguing that in the context of modern physics, assumptions about space have generally become radically changed from those of the earlier Einstein.

7. The 'Contradiction' Thought Experiment

In this very simple version of his thought experiment paradigm, this time there aren't any lightning strikes. Einstein just asks us to consider both a light ray and a train travelling steadily along an embankment, in the same direction. And again, in a vacuum. The tip of the light ray will be travelling at speed c, with respect to the embankment. But, according to the classical physics of Galileo and Newton, and in line with their classical assumptions considered above, as it rapidly overtakes the train the speed of the tip of the light ray relative to the train can be predicted to be somewhat less than c (even if only by a trifling margin). In providing this particular illustration, Einstein's whole purpose was to emphasise exactly why this is such a crucial problem. He pointed out that in view of the fact that his postulates say the measured speed of light in all frames must remain exactly at c, there seems to be a very clear contradiction — something he saw as unacceptable. And it's this problem which he then overcame by incorporating the Lorentz transformations into his theory, in a way which superseded the old Galilean transformation. In effect, these newer equations were based on presuming that increased inertial speed (as observed from the 'rest' perspective of a relative inertial reference frame) was associated with material bodies physically contracting in length. They contracted in a manner that corresponded with the extent of their increase in motion. In much the same proportional way, their 'experience' of time would also dilate (meaning, compared to the 'rest' frame, time would physically pass more slowly in the 'moving' frame). These regular and proportionate physical changes to the distance and duration variables which define speed in the moving frame allowed the contradiction in speed measurements to be seen as only apparent, rather than real. In this way, light would indeed measure as travelling at c in both stationary and moving systems, despite their relative motion. Exactly as his postulates firmly predicted.

In case it's not already obvious, I must swiftly point out that the unacceptable contradiction Einstein was concerned with is the very same sort of contradiction I was so troubled by when Einstein argued for the relativity of simultaneity. His argument depended entirely on Joe experiencing the light rays which were arriving at his position from each end of his carriage as showing a varied rather than constant measure of speed within his carriage perspective. But the remarkable thing is, when drawing his particular and truly momentous conclusion about the relativity of time, the argument Einstein displayed bore not the slightest acknowledgment or reminder of exactly the unacceptable contradiction he'd previously taken such pains to clearly expose. Nor did he make any reference at all to having overcome it with his Lorentz transformations. As I've already discussed, instead (and to my amazement) he simply showed a preference for the reality of the variable velocity outcome for the light rays travelling through the train. He simply relied on directly applying the old Galilean assumptions and methodology. Einstein effectively ignored and rode rough shod over all the main tenets of his own new theory.

It might be objected that after presenting and making his final inferences from the train and lightning experiment, he did refer back briefly to the contradiction problem in a follow-up discussion. However, by then he had already established and confidently announced the logical veracity of his major conclusion about the nature of time. Even though, as we've seen, this was just an inference based entirely on an old but intuitively very attractive theory, one which he actually knew provided predictions in direct conflict with his own.

If, when making his argument for the relativity of simultaneity, Einstein had at the same time reminded and warned us of the apparent contradiction he knew it entailed, then he could also have advised us not to be overly concerned about it. All we needed to do was abandon any preconceived ideas or intuitions we might have about universally fixed lengths and times and thus see that the outcome of the classical transformation, despite its apparent veracity, was actually very misleading (especially in the case of very high speed relative motion). In consequence, both observers would actually measure light to remain at speed c from their own perspective. Thus they would be in a position to confirm how their experience matched the prediction directly afforded by his second postulate.

But of course, there is a snag. Allowing such unchanging observations from both perspectives wouldn't have provided any support for the relativity of simultaneity. So Einstein chose instead to accept the old classical transformation at its face value. This allowed him to make a prediction that seemed coherent with a particularly dominant intuition and therefore simply seemed right. Both observers would actually not see the speed of light as equally remaining at c. But it was only by making such a self-immolating choice that Einstein was able to infer that simultaneity was obviously relative.

The deep confusion inherent in all this is what originally led me to feel so generally baffled by what I read. However, as I noted previously, what heightened this sense of perplexity was the fact that to this day, Einstein's argument for the relativity of simultaneity seems to have remained almost unanimously well received by experts. Indeed, it is often held up as one of the best examples of his brilliant and original thinking.

As I've already indicated, I did eventually find there where others who had presented some clearly argued exceptions to this apparently sizeable consensus. Nevertheless, the truth is, it was the presence of a seemingly profound level of scientific agreement with Einstein's reasoning that made me search again and again for some naive but serious error of interpretation on my part (and on the part of the other critics I'd found). This not unreasonable doubt was magnified considerably, not only by Einstein's legendary scientific and philosophical status, but also by the fact that I have never pretended to have any proper and comprehensive training or expertise in the disciplines of either physics or mathematics. However, should these very natural anxieties turn out not to be really warranted in this case, then this whole situation would have to be seen as a remarkable anomaly in the relatively recent history of science.

8. The Role of the Lorentz Transformations

Anyway, wherever the proper truth of all these matters may actually lie, the fact remains that by inventing his theory of Special Relativity, Einstein seemed to have found a solution to his contradiction problem. As I've said, this involved employing the transformation equations he'd adapted from those of Lorentz, applying them to adjust the observational data differences between relatively moving frames. For this purpose, reference frames such as the train were considered as moving at a specific speed, relative to a frame that's simply stipulated to be completely at rest, such as the embankment. Thus an application of these equations to our familiar train situation would have predicted that the train, considered as moving from the stationary embankment perspective, would be shown to contract in length and its passage of time would be dilated. As we've seen, these physical changes are predicted by the calculations to occur systematically in such a way that they result in the direct measurement of the speed of light, made from within the parameters of either frame, remaining firmly at c.

The cost of thus coming to understand how the speed of light through space can remain at the same standard value in all frames, is to accept a 'hidden' fact. One that is only recognizable empirically from the particular observational distortions experienced from any comparative and stationary perspective. Time is something that can truly dilate and the length of material bodies can really contract. Simply because there is a relative inertial motion situation.

9. Applying Special Relativity to Einstein's train

We could, then, opt to accept that these relative and regular physical changes that the equations predict, do indeed take place where there is relative motion of an inertial sort. We could accept that the theory of Special Relativity and its predictions would apply, even in our imaginary train scenario. Of course, in the case of any real-life version, the changes of the carriage's length and time (identifiable from Jane's perspective) would be so utterly and vanishingly tiny as to be completely indiscernible by Jane. They would be truly negligible, given the extremely slow speed of any real train in comparison with the absolutely phenomenal speed of light. Nevertheless, drawing once again on the magic of the thought experiment method, we can still consider the implications of these minuscule changes, if only in principle.

Briefly reverting once more to the familiar lightning-strike scenario, let's again focus on Joe's experience on the train. This time, with due regard to the predicted impact of not only Einstein's postulates, but also his Lorentz transformation equations. That is, in the light of applying the Special Theory of Relativity.

In this new light, and in a rhetorical spirit, all I wish to do is pose you some challenging questions about Joe's experience. As each of the light rays passes through his moving carriage from each end — a carriage which, as we now assume (from the point of view of observational judgements made from Jane's frame) to have its length contracted and its time dilated — Joe himself wouldn't recognise anything as changed. This would still be the case, even were the changes large enough to allow their perception. It's actually the theory which says that from his perspective, all would appear to be entirely normal and unchanged.

But, imagine Joe managed to measure the speed of the light rays, basing them on the length and duration parameters he records for the passage of light from each end window to his position halfway along the train. What would he find? Would he measure both light rays from each end of the carriage as travelling exactly at c, in accordance with Einstein's postulates? If so, this would clearly also accord with the careful analysis I provided earlier, including its use of the postulates and its conclusions about the conservation of simultaneity. Similarly, it would confirm the predicted outcome of applying, from Jane's perspective, the data adjustments represented within the Lorentz transformations. So, this measurement by Joe would confirm the simultaneity of the coinciding events when viewed from either frame of reference.

However, this firmly equivalent empirical finding from Jane and Joe would contrast very awkwardly with one of the key predictions from Special Relativity. Based on Lorentz's work, it accepts there is a differing reality for the rate at which time passes for the two observers. This variable is an essential and keystone concept for the coherence of Einstein's theory as a whole.

Or — still with the predicted changes in the carriage's length and time, considered from Jane's perspective — would it after all be the case that Joe would measure the speed of light as variable? Would the speed of one of the light rays travelling through his carriage be recorded as very slightly augmented above c, while the other was diminished below c? Exactly as Einstein had previously preferred to predict by simply applying classical mechanics? If so, then Joe — presumably basing his decision on Einstein's definition of c as a measurement constant — would judge the lightning strikes to have occurred sequentially. In effect, this would be exactly as Einstein's 1905 argument also inferred. The simultaneity observed by Jane would have been lost.

However, this would be in direct conflict with the predicted outcome of applying the Lorentz transformations. They say the presence of length contraction and time dilation should lead to Joe measuring the light reaching him as travelling at exactly c. Moreover, the variable result that Joe found would also present an awkward paradox. Although Joe's sequential decision for the strikes was based on accepting the truth of Einstein's second postulate of a universally constant measure for the speed of light, from his perspective he had also just judged it empirically to clearly be otherwise. The rays from each end varied in speed.

If you were tempted to venture an answer to my questions, which alternative would you reckon to be the right one to choose? Which seems the most completely coherent outcome? In the end, perhaps you might be rather reluctant to pick either. You might just start to wonder if it could be that neither transformation theory alone has everything completely right.

10. Thoughts about Taking a Different Road

Up to this point in my discussions, I have made every effort to pursue things scientifically, in a convergent and logical style. But now, in order to move things forward, I need to indulge in a more divergent and philosophically speculative approach. I wish to take on board Einstein's two postulates, just as he stated them, as well as the original contradiction problem he thought this caused when applying them — but discuss a quite different road towards its resolution. Unavoidably, this solution will differ from Einstein's; but mainly insofar as he posited the physical reality of the Lorentzian conception of length contraction, and also time dilation, as being the answer to the problem. I do believe it's still pretty clear the mathematical Lorentz transformations themselves must harbour an important truth about the similarities and differences between inertial systems. However, I believe the nature of this important truth has — perhaps — been misunderstood.

I will pursue this speculative task from the point of view of a posited world, one where simultaneity might well be conserved. In order to describe such a world, first I will focus on how physicists' views on the nature of space have evolved in deeply radical ways since Special Relativity was first formulated and accepted.

11. Changes in the Status of Space

Any notion that space is essentially nothing — just an empty background void — seems to be well and truly out of fashion in today's physics. Over the last century, I believe the General Theory of Relativity contributed strongly to this shift away from many of the older perspectives, as did the quantum revolution — especially with the advent of Quantum Field Theory. Insofar as space used to be taken as an absolute and motionless background to moving objects, the extension of space itself clearly couldn't be any sort of truly substantial material. It wasn't possible for space to have hardly any of the properties we associate with matter. If you like, empty space seemed to show nothing more than the rigid character of a completely naked extension. As such, in physics its apparent reality was commonly dealt with in a rather abstract and mathematical way, as a necessarily homogenous and isotropic, geometric background in relation to all the material bodies moving around independently within it.

As I touched on earlier, and acting as a sort of overlay to this view, aether theories were still widely entertained at the start of the 20th century. The aether was regarded as a rarefied and undetectable medium. It was thought normally to be stationary and to fill all the space of the universe. It provided a quasi-substantial pathway for the transmission of physical waves such as light. But in the way they were articulated at that time, these aether theories haven't really survived. Rather than get bogged down in discussing their pros and cons here, I prefer to move on — and look to how space is viewed now, in the current era, the 21st century.

Nowadays, it seems many physicists consider in some respects that the older understandings of space now seem to have turned full circle. It's now widely thought that space itself is more likely to be the basic physical reality of the universe, with the concept of matter relegated to a secondary place. What's called matter is no longer seen as a truly separate domain of objects, existing independently and travelling through an otherwise empty extension of inert space. Instead, considered fundamentally, space and its matter is now considered more as a unified and profoundly energetic entity. Matter in its multitude of sizes and forms is regarded as a set of highly developed field disturbances — as energetic foci in holistic aspects of the extended but superplastic substances of space.

Frank Wilczek is recognised as a highly accomplished voice from the discipline of modern theoretical physics. He succinctly expresses his assessment of the generality of this evolution to a modern view of space:

What is space: An empty stage, where the physical world of matter acts out its drama; an equal participant, that both provides background and has a life of its own; or the primary reality, of which matter is a secondary manifestation? Views on this question have evolved, and several times changed radically, over the history of science. Today, the third view is triumphant [5].

Far from space functioning as a sort of abstract and inert background, having very few of the properties of matter in its own right, it seems it may in reality be quite the opposite. It may actually be the only universal physical fabric, at all scales harbouring a vast range of highly mobile subforms within its extended but super-plastic formations. Such sub-forms would include the discrete constituents of what we call matter. Despite the way it may always look to us, in any final analysis it seems there is no true duality of background and foreground realities. If you like, just as individual waves can clearly be seen as they march across the sea — when in fact, we know all is just water. In this modern view, there really is no totally insubstantial space through which substantial particles or objects fly, like solid cricket balls tossed into an empty sky.

12. Presenting a Modernized World

What I now wish to discuss may belong within such a modernized worldview: the physical nature of the spatial fields of our universe can be posited to be both holistic and ubiquitously energetic. This means that fundamentally, the entirety of our world — what we may think of as matter in space — may really be just one unified thing, a universe, a plenum. But throughout by nature, everywhere it may be in simultaneous flux. In a perpetual state of universally coherent change that signifies the passage of time.

Space is thus differentiated by its regular and unceasing internal motion into a multiplicity of discrete spaces at every scale, both very small and very large — all spaces, moving within spaces. Again, if you will, like a multitude of fluctuations in a single but regularly turbulent sea. Essentially, parts of space are individuated from each other only by exhibiting differing relative motions. All motion would involve a reduced part of the whole of space moving in relation to other reduced parts. But none of these reduced spaces are ever moving through empty space, any more than water waves move through an empty sea. Like the ocean, Space — our universe — is always full. While Space is extended in a unified and continuous way, it comes in packets of all sizes and they naturally and coherently flow about.

In this posited world, its individuated spaces are never at absolute rest. Having said that, as individuated spaces ourselves, we all know the feeling of what it's like to be stationary — in the sense of being firmly anchored within a steadily co-moving spatial reference frame. For us Earthlings, the movement of our bodies in harmony with the co-moving surface of Earth is our common measure of being at rest.

There is a further important characteristic to be assumed for my posited world. The individuated, discrete and mobile spaces are physical 3-D extensions. They have basic characteristics very comparable with those that were accepted as the physical properties of Newton's unified, immobile and absolute space. In accordance with the principle of relativity, all spaces would exhibit the same sort of property of regular and 'rigid' extension, serving as a reliable and shareable metric. Each space is equivalent to all others in terms of its physical extension in a homogenous and isotropic way. As is true in current physics, it is also recognised that any extension of free space has properties known as its permeability and permittivity. These physical properties, crucially, reflect its response to the presence of electric and magnetic fields. It is these characteristics of the free aspect of any discrete and inertial space that governs the self-sustaining and constant but limited speed at which light propagates throughout its extension.

13. Inertial Reference Systems Cast In A New Light

Against the backdrop of this very speculative conception of both space and time, I suggest the classically grounded notion of an inertial reference system could be re-construed in a much more modern light. Such systems can be seen as packets of space that flow about, in a coherent and natural way. Each would be a steadily moving and discrete sub-field of the material of Space itself. In turn each would contain numerous sub-spaces, many of them moving as one in harmony. Some of these sub-spaces would persist as what we normally call sets of material bodies or particles. They are matter-like, highly localized and potentially detectable. But others would persist as much more space-like and invisible forms, as segments of a flexing and flowing holistic, universal field. Both matter-filled spaces and space-filled spaces, as we more less distinguish them via our perceptions, would, in a totally fundamental sense, in fact just be energetic manifestations of the extended but dynamic materiality of Space, our universe.

Let's try to describe things in slightly more prosaic terms. Suppose we are out cruising steadily, sat in a plane or a train, or a car. Or even, maybe, something like an old Galilean ship. What would be co-moving with us?

In the new way of seeing the world I'm suggesting, the answer is that every aspect of Space which comprises our cruising reference system is co-moving along with us. This includes all our vehicle's 'material' parts at all scales, such as all the constituents of all its plastic and metal parts. And also, say, all the components of the people and oil and air within it. But now we should also include what in the old days were regarded as no more than insubstantial aspects of the 'separate' and 'immaterial' or 'empty' space the vehicle was moving through. Such as areas of what were once considered as separate, 'absolutely stationary' electric and magnetic fields. Now these latter system areas will no longer be seen as stationary abstractions, but as parts of spatial fields that are physically flowing along with the system too. (Of course any reference system may well have sub-spaces which are not a co-moving part, but are actually moving through it. By definition, these non-co-moving aspects actually represent different spatial systems.)

In our vehicles, we can all cruise steadily about on the surface of our planet, independent and seeming secure in our own mobile mini-universe bubbles, where happily, all physical laws stay just the same! The danger of course lies in the fact that these bubbles of material space are moving relative to other material bubbles. However, none of them is moving through some 'extra' medium or background. In any final analysis, they are all just systems of localized fluxes in the chameleon physicality of Space itself. Like bubbles of sea in an ever-changing and regularly turbulent ocean.

Some of the smallest localized and discrete fluxes are the light particles known in physics as photons. Individuated and perpetual fluctuations between electric and magnetic fields, zipping along as a wave train at a regular rate, always localized but in motion through areas of these fields, wherever they extend. Including where segments of these fields are individuated and localized within our cruising vehicle. Photons, as discrete sub-areas, would be localized and stationary — but only if they were considered as a frame of reference themselves. They are however, always dynamic and in self-sustaining motion through any extension of free space. This was the unique conception that Maxwell identified so brilliantly, back in the middle of the 19th century (see below, shortly). Despite their discrete nature (the universal product of sustained relative motion) and like all subspaces, photons remain functionally continuous with their very much broader and super-plastic, universal fields. They are a sub-part of holistic fields which are located everywhere, in all frames.

14. Revisiting Einstein's Problem

In the light of such a holistically extended universe of Space, existing in the form of its infinity of moving sub-spaces, I'd now like to return to Einstein's basic contradiction problem — and to his imaginary train that's been struck by lightning. The train and the embankment would each be frames of uniformly co-moving space. Each would include both matter-like and space-like extended material, all moving together in unison. The train would be a whole individuated frame; the embankment just a small part of a very much larger co-moving frame, the surface of planet earth. The light rays would not be a part of these systems, but streams of the very small discrete parts of space called photons, all moving through both the train and the embankment as regular disturbances in their segments of electric and magnetic fields, wherever these extend. These fields would extend flexibly, allowing their location as a co-moving part of the inertial embankment system and likewise as a co-moving part of the inertial train system.

Now, as the 19th century physicist and mathematician James Clark Maxwell showed so very convincingly (and partly based on the properties of space we discussed), the speed of light must have a finite and constant value c, set by the way it always exists as perpetually propagating fluctuations. It exists as a linked pattern of regular and self-sustaining electric and magnetic field oscillations within a given area of stationary space. Within a steadily co-moving frame, say the embankment, Jane feels stationary because, within that context, she simply is stationary. The light from the lightning will transmit at c in some of the co-moving, space-like parts of her frame, i.e., in areas of electric and magnetic field. In the same sense as Jane, these discrete areas of field are physically stationary too.

Likewise, Joe also feels stationary within his co-moving frame, simply because he too is stationary within the rest of the spatial material in his train frame, all of which is moving coherently with him. The light will also transmit at c in the stationary, space-like parts of his frame — which again, are areas of their very much wider fields. These holistic fields are everywhere. They are potentially fluid and flexing. A highly plastic but unbroken pathway for the continuous transmission of light across all the 'stationary' but relatively moving spaces it meets. As it passes through, it's propagation is sustained in each, at the locally measurable and lightning speed of c.

On the face of it, there should be no great complexity about how Jane should calculate the relative velocity of any light ray travelling in Joe's train frame. That is, its velocity relative to her different inertial location, not to his. The two internally stationary frames both transmit light at c. But externally, the relative velocity of the frames as a whole do appear to differ. Therefore, for Jane, considering herself as stationary, the calculation should simply be c, plus or minus the velocity of Joe's frame, relative to her. A rather familiar sort of calculation, belonging to the classical mechanics of Galileo and Newton. Of course, to be authentically applied in this way, we must first decide to exclusively adopt and prefer Jane's view of her situation as absolutely stationary. In this way we can attribute all their combined motion in an asymmetrical way, to Joe's speed. However, at extremely high relative speeds, this Galilean type of methodology has proved to be too artificial. Einstein's Lorentz transformations clearly work better — a point I will be returning to shortly.

This last analysis may sound suspiciously like the one Einstein drew on for his relativity of simultaneity argument. However, there is a distinct and crucial difference. In the example above, it's true that Jane's calculations result in the speed of the light rays that are travelling through the train frame from each end as being c - v and c + v (v being the velocity of the train when observed from her stationary perspective.) But this speed she calculates is exclusively the assumed speed of the rays relative to her space, not their actual speed in the space they are travelling in. Her calculation is based on accepting Einstein's theory that the rays will always travel at c relative to their spatial frame. It would hardly make sense, therefore, for Jane to think the variable speed results of her calculation might also be correct for anyone sitting, not with her, but over in the train!

Before moving on towards completing my essay, there's a sort of footnote that needs inserting here. The simple Galilean calculation of a relative velocity that's just been described might seem to suggest that a measurement can show light to have a 'superluminal' velocity through space, i.e. greater than c. However, it's important to see that the calculation is actually not a direct measurement of what is happening in the spatial system comprising the train. When we consider the relative motion between contiguous reference frames, we are dealing with areas of flexing and flowing space that thus both achieve a separate and discrete identity. Nevertheless, they directly interface with each other — no 'old' inert space in between! Despite their individuated state, they also remain as part of the continuum of the holistic spatial fabric of the universe. The measurements of their relative speed are via direct physical contact at their common boundaries They are fundamentally local in nature.

In contrast, the rays of light travelling down the axis of Joe's carriage frame are not a part of it. They're not co-moving with it, but represent other frames moving through it. Therefore, although the light rays are directly interfacing with Joe's frame, this is not the case in relation to Jane's frame. Being in Joe's frame, to some degree the axial light rays are remote from her frame. Indeed, such axial rays won't be visible (observable) from Jane's viewpoint. This means the measurement of relative motion between Jane and the light rays travelling axially in Joe's frame cannot be directly local in nature. It cannot be made as a direct, empirically-based measurement, but has to be abstracted from the wider context via assumption-based calculation.

So, in my posited reality, the local, directly measurable speed of light through space remains everywhere at c. Just as, for both Jane and Joe, the reality of their local speed at any moment lies equally in their combined velocity.

Given the very important but perhaps unfamiliar and confusing application of the word 'stationary' in many of the foregoing paragraphs, at this point I believe it will be helpful to briefly linger and indulge in a little informal semantic analysis. I hasten to add this analysis is informed not simply by the common-sense use of language, but also by a more scientific understanding.

15. What could "stationary" really mean?

To call any sort of entity inertial is of course to suggest that in some sense it is without energy. It is inactive, immobile and therefore effectively stationary. So, in a universe of the ubiquitous energy of relative motion, what could it possibly mean to state that any form of physical entity or object "remains stationary"? Firstly, there is a point that may seem merely pedantic. But perhaps it should really be seen as essential and primary. Above all, the statement means the object must simply remain! It must continue existing, its basic identity staying unchanged in step with the passage of time. If not, it no longer exists and of course cannot be found to be stationary anywhere.

So, providing its discrete identity remains through time, then in order also to be considered stationary it has to continue this existence while remaining in the same position. But what sort of position, relative to what datum?

Well, the answer is a location where its relation to all three dimensions of the space it is inhabiting through time stays unchanging. Now, of course, this answer, while not inaccurate, depends on which space it's regarded as inhabiting. Is this the local space identifiable as an inertial system?

Well yes, it certainly would be. An example is our common sense, instinctual perception of definitely being completely stationary when we stand still on the surface of Earth — good old terra firma. Another example then seems a little paradoxical by comparison: we perceive ourselves as stationary when we are cruising in a jet airliner way above the same surface. (Of course, neither Earth's surface nor the plane may be absolutely perfect inertial systems. But that's beside the point for the current discussion.)

Could it also be the space of a different inertial system through which the object is immediately passing? Well, normally speaking, definitely not. Unless, maybe, if the object in question, for some very good reason, does have to be identified as stationary. In which case it's the surrounding system which must be seen as passing by and not stationary. (In real world, seagoing and navigational situations, I can certainly recall the importance of making such decisions correctly.)

Is it the space of any of the other increasingly remote inertial systems within which it's also locatable? Well, yes, providing the inertial object is not moving relatively to these wider spaces. In that case, it can be legitimately regarded as part of their wider co-moving system. Otherwise, no, since the object is not co-moving in this way.

Or finally, is the space it inhabits the overall, absolute spatial extension that may comprise the whole of the otherwise dynamic universe? And could even that space possibly be moving in some very hard to imagine sense...? Well, I'm sure the true response to that question is very clear. Absolutely no-one really knows the answer.

It is the last of these queries that is by far and away the trickiest. Scientists and philosophers might continue to argue (if so inclined) about whether or not our universe comprises an absolute space. But, linked as it is with the age-old and unsolved problem of the infinite versus the finite, I believe they're really not a jot closer to a proper solution to this ancient philosophical conundrum than they ever were. So, in contrast to any optimistic attempt at scientifically establishing an absolute conception of space, the more limited conception of relatively moving inertial systems is much more open to rational and scientific investigation. And, of course, I believe this sort of investigation should be carried much further. But my essay is very tentatively promoting the idea that first — perhaps — such scientific research may need to be established on a rather different, more modernized theoretical footing.

[Purely for the sake of the record, I do still continue to wonder to what degree it might be the case that what you might call "space-like" spaces are capable of retaining their discrete identity and properties while in fact completely overlapping other similar spaces. I mean so that in some sense they are superimposed. Literally, spaces within spaces. Comparable — maybe — with the capabilities of bosons, as identified in physics. In contrast, "matter-like" spaces might conform more to the principle of fermions, not overlapping with contiguously moving spaces, but displacing them. This idea, hard to articulate clearly, would certainly provide an interesting but added complexity!]

16. A Problem Dissolved?

Returning to the previous discussions in this essay, the main point arising is this. If the speculations I've presented were to reflect something at all real about the physical nature of our universe, the original problem of contradiction — the one that Einstein sought to tackle head-on with his use of Lorentzian concepts — would effectively dissolve. Not only would the speed of light be constant when measured locally within an internally stationary spatial frame (just as Einstein postulated and as Maxwell's calculations required) but also, in non-local, more remote measurement terms, the motion of light could indeed be practically regarded as basically Galilean in nature — insofar as its motion would be that of a wave dependent on the state of motion of its medium in the locality where it's propagating, just like sound. However, for either Galilean light or Galilean sound to be appropriate descriptions, we have to assume that one of the inertial systems is truly stationary. In our everyday world, where the surface of Earth is simply accepted as absolutely stationary, this makes sense. But from a more scientific perspective, it seems it won't do.

17. Conclusion

I come now to two final issues. They are intended to challenge certain received views in physics. Admittedly, as always I can only argue about physics principles from my very untutored, limited and necessarily highly tentative perspective. And it's true that many key phenomena, like rotation, acceleration and gravity, figure in the discussion hardly at all. Let alone the more recent quandaries provided by concepts such as non-local entanglement and dark matter. Still, like anyone, I can draw on the considerable power of ordinary logic.

But then the trouble with this approach is that the value of deductive inferences — just like those in mathematics — are by definition dependent on the assumptions they embody as premises. In both cases, their essential premises are not always easy to identify for what they truly are. Throughout this essay — and also in this final conclusion — I have tried to highlight and clarify such foundation issues. It is in this light I offer some criticisms for aspects of Einstein's earliest contributions to physics; while at the same time fully acknowledging, and indeed relying on, some of the extraordinarily powerful and seminal insights his wider legacy has clearly provided.

Firstly, as I have indicated, modern physics fully accepts there are limits to the veracity of the classical Galilean transformation that still lives on in everyday mechanics. For truer accuracy and better precision it recognizes the need to prefer the application of Einstein's Lorentz transformations between reference systems. Especially so when they're travelling at extremely high and 'unearthly' relative speeds. Applied to such so-called 'relativistic speeds', the equations would seem to take account of the considerable perspectival distortions of both time and space that can appear when undertaking observations of a relatively and very rapidly moving system. These observations of course being made from a different inertial system. That is, from the one designated as the 'rest' frame. The evidence is very strong that these equations work universally in this way, in preference to the more limited Galilean transformations.

The latter are linked to Newton's conception of both absolute space and absolute time. But, just as crucially perhaps, they are also based on Galileo's outdated acceptance of observation as effectively being instantaneous. In this respect his view was governed by the limitations of the then current and early state of technological development. From the perspective of a much more technologically advanced and modern age, we can be pretty sure he got that one very wrong — even though it seems very much in line with the dominating effect of some of our more or less instinctual, everyday intuitions. Galileo's simple procedure remains true enough when dealing with the mechanics of the relatively slow moving systems we encounter in daily, earthbound life. In this practical context, his transformations still seem to serve well.

The basic purpose of such transformation procedures is to establish a reliable basis for adjusting data in order to obtain inter-frame measurements which can conform to the principle of relativity in all inertial systems. If you like, providing a coherent link between all the spaces where the principle of relativity holds, so all the laws of physics can be universally and coherently applied.

But, in any concretely physical sense, is the success of the Lorentz transformation procedures truly founded on either the length contraction of moving matter or on the dilation of time? We should keep on remembering, of course, that observations are typically based on the finite passage of light (or rather, of the electromagnetic spectrum). Thus no observation can ever be truly instantaneous. Could it be that fundamentally, the real basis of the practical efficacy of the Lorentz transformations simply lies in making due allowance for the perspectival — and potentially extreme — observational effects of linear motion between physically moving and interfacing spatial fields? Not between abstract system spaces, derived from frameworks of matter moving uniformly through a single, absolutely stationary background. But rather, between concretely individuated physical spaces, each of which is equally real and equally extended — and also, conveniently for operational purposes, experienced as equally stationary. However, this stationary state is only evident from a viewpoint located within its own extension. I'm talking about physical spaces that are discrete in nature but nonetheless reflect and exhibit their further identity as sub-spaces of the energetic flexibility and flowing of the very much wider and holistic, super-plastic fields. Fields that comprise both physical space and matter as we know them.

In this case, conceiving both matter length contraction and time dilation as real and fundamental physical processes might be rather misleading. In a posited world where neither of these ideas are ever really true, what might seem like physically real empirical phenomena would really reflect inter-spatial observational distortions, caused by combined motion. Such distortions of the observational field could be linked to any observational modality (such as the travelling signals provided by any part of the electromagnetic spectrum, or, perhaps, by gravitational waves). These distortions only appear when such signals are employed to view one inertial frame from the assumed vantage point of another. Viewed as physical space and time distortions, they would really be just the direct but necessary consequence of adopting a particular perspective in the midst of a universe of unceasing relative motion. They would also be especially evident when the relative speed of the frames is extremely high.

Thus length contraction and time dilation could well be solely perspectival effects. They're suspect nature may link with the methods involved in accessing them. In order to make specific observations and empirical judgements which pertain to other inertial spaces, it seems it's always necessary to employ a particular but fundamentally artificial methodology. As we've discussed, this involves arbitrarily adopting an inertial location to treat as if it really is absolutely stationary. In other words, stationary within the universe considered as if it really is a single, absolutely stationary place. It thus becomes the system identified as the so-called 'rest' frame for measurements. But the fact is, throughout the wider world of relatively moving but individually stationary spaces that we all seem to experience inhabiting, there appears to be no such thing as an entirely stationary, perspective-free location and viewpoint. At least, not in any concrete, physical sense. The mythical 'view from nowhere', as I believe it's been dubbed.

Any length contraction and time dilation appearing to occur for the observed frame may actually not be the true asymmetrical physical changes they might seem when they're judged from a frame that's only designated as being at absolute rest. Rather, the objective phenomenon behind the distortions in the observational field could simply be the presence of constant and concretely real inter-space motions. Relative motions between what are in fact systems in a wholly equivalent state of spatial extension and motion — but also existing in different and changing relative locations. Just as there are real extended spaces within real extended spaces, so there are real states of motion within real states of motion.

The 4-D spacetime world-view established within physics as a result of Einstein's early theorising is said to be Lorentz covariant. This model appears to boil down to being the result of mathematically employing the assumptions that underpin Einstein's Special Relativity. They are employed to extract a unified but entirely abstract conception of a universal foundation. Putatively, finding an ultimate and objective reality. A holistic conception which then provides an explanatory base for what would seem the very different and subjective reality accessible to human experience. This goes too for the full scope of that communal experience when technologically extended into both micro and macroscopic domains of our universe. The latter much more extensive empirical reality seems to show the physically real world that provides and is open to all the pleasures, pains and other cognitive propensities of normal and vital human experiences. From human viewpoints — which are both individuated and communal — we seem to live within a vast and complex physical world of discrete and energetic, 3-D spaces, all of which are constantly in relative motion.

However, as a result of mathematically encapsulating the universe-wide application of the Lorentz transformations, what is suggested is an ineffable sort of physically 'overarching vista'. A unified setting for all the dynamics of the time-bound and material world that humanity observes. A sort of background that actually lies entirely beyond any sort of direct intuition or transparent comprehension via the sharing of ordinary language. The use of this abstract mathematical approach seems to reveal the presence of a single, all-embracing and frozen spacetime world. A continuum, with the same unchanging 4-D spacetime geometrical coordinates. A sort of absolute and timeless background universe, where there is no change, no cause and effect and no possibility of chance occurrences. Somehow, an already determined, fixed and eternal sort of place, impossible to truly imagine or properly describe without resorting back to solely mathematical representation.

Presumably reflecting its derivation on the the basis of Einstein's assumptions that underpin Special Relativity, there would perhaps be a major consequence of applying these concepts to the whole universe — especially to the sort of universe of perpetually moving spaces I've posited. As a result of incorporating Lorentz invariance, the ubiquitous effects of the inter-space inertial motion present in the real physical world we inhabit would all effectively be cancelled out and nullified. From this unified but totally abstract 4-D 'viewpoint', the separation between past, present and future that we seem to experience so vividly in our world of regular change, no longer really exists. It is demoted to the status of a subjective and merely human illusion.

The mathematically coherent but transcendent 4-D foundation that emerges provides its many adherents within physics with the fabled 'view from nowhere'. The spacetime model is applied as if it has provided the mythically objective perspective that lies behind and beyond all the subjective, viewpoint-bound and perhaps stranger nature of our beautiful but occasionally sad and painful world of human experience.

This is not to say, pragmatically speaking, that what I am told is the product of extraordinarily elegant and beautifully cohesive mathematics — an outcome which clearly acts to unify and supersede the previous assumptions of time and space — is not an extremely powerful and useful fiction. Not least in the way it has provided the conceptual and mathematical basis for Einstein's very successful General Theory of Relativity. This theory, in parallel with its provision of very complex gravitational field equations, is interpreted as the gravitational effects of matter occurring holistically. Many regard gravity not as a force field, but as the universal warping effect of clustered, energetic matter on the geometry of the mathematically generated and ever-present 4-D continuum.

Nonetheless, and having due regard for all of Einstein's empirical successes, I believe a useful mathematical fiction is what 'spacetime' may really remain. It does not truly represent a 'physical vantage point', translating into any sort of veridical and transparent description explaining the true nature of reality. I mean explaining the concrete and very dynamic, ever-changing physical and spatial reality we all know in empirical terms.

Despite its mathematical nature being based in what I believe are probably somewhat false physical assumptions, there can be little doubt that the use of the abstract 4-D model has considerably advanced our practical understanding of the much wider physical universe, compared with the model it superseded. This previous model was another long-established and remarkably powerful applied idea which, in key respects now seems essentially fictional. Namely, Issac Newton's long-accepted and empirically very successful assumption of the independent presence of absolute space. (A model tainted somewhat, it could be argued, by Galileo Galilei's acceptance of the effectively instantaneous nature of observation.) As discussed earlier, an objective 'reality' which Newton posited to exist totally independently from matter, forming an inert, homogenous, isotropic and completely empty background extension to everything we could possibly experience in our more dynamic, material world. By comparison, and in terms of its wider empirical successes, the superseding nature of the 4D model suggests the physical assumptions this newer model embodies, although fictional, have also allowed it to edge closer to the truth than Newton's.

However, Newton also formalised the pre-existing communal assumption of a very different sort of truth from his absolute space: the universal operation of another quite independent and unique sort of omnipresent physical reality. He posited the absolute nature of the universal passage of time. It was of course this idea that seemed to be rendered instantly obsolete by Einsteins's 'proof' of the relativity of simultaneity.

Unlike many but certainly not all present-day physicists, I feel personally — as an 'outsider', certainly not as any sort of qualified physicist! — that the jury should be seen as very much still out on this second reality posited by Newton. With the advent of Einstein's revolutionary and famous theorising and the subsequent recognition of its continually increasing and successful empirical record, I believe it shouldn't therefore also be too readily accepted that something like Newton's universal time — albeit suitably modernised — will necessarily always prove to be nothing more than simply an obsolete fiction.

Which leads to the second of my two final issues. Whether or not my untutored physics is often naive and inaccurate or much too incomplete, or my personal interpretations of experiencing my life amongst the relative motions of a time-bound and very dynamic spatial world are really just nothing more than simplistic personal fantasies, the logical analysis I presented earlier — the one based on accepting and applying Einstein's two famous and penetrating postulates to the task of envisaging both the train and embankment perspectives — would still stand. In terms of the power of ordinary logic, the outcome of this analysis, based squarely on its two main assumptions, seems very clear. And these assumptions have a very strong track record. They still reign at the heart of physics.

As has been discussed already at some considerable length, the logic of the imagined situation showed the simultaneous nature of the passage of time to be conserved in observational judgements with regard to spatially separated but physically coinciding events. This inference was true even though these observations were based only on the reception of transmitted electromagnetic signals. Like all observations, they were actually made subsequently to the coinciding occurrence of the events themselves. Crucially, the inference remained true even when these delayed observations were made from the quite differing perspectives afforded by relatively moving inertial spaces.

There is a further way to magnify and highlight the observational physics present in Einstein's train and embankment representation. Imagine a version where the constant linear separation speed of these two systems actually started to approach the speed of light. The simultaneity inference would still remain true — even though in some respects the inter-spatial effects of their combined inertial motion on inter-spatial observations would now be quite extreme.

The task of summarising what happens in an overall sense in this situation, in simplified but accurate terms, is quite challenging. Reading the resulting description is likely to be equally demanding — and here's why.

To follow and appreciate the logical force of the following descriptions, one needs very carefully to bear in mind that in true and uncompromising relativistic terms, the embankment really is no more absolutely stationary than the train is. We must do our best to quell all the inner shouts to the contrary that arise from our Earthling instincts! Remember how clearly both Jane and Joe saw each other whizzing by? Or remember the very dynamic view of your hitherto 'stationary' world through the window of your 'stationary' aeroplane, cruising high in the sky at 500 knots? Therein lies the true reality. One where entirely symmetrical motions, between entirely equivalent realities, is the key. And one where the principles of inertia and relativity bequeathed to us by Galileo, still reign supreme.

However, if it is accepted that there is no such thing as any sort of entity being absolutely stationary (as indeed did Einstein) then there is an even more challenging corollary that immediately follows. Once again, our instincts rebel. There really is no such thing as having an absolute spatial location.

In this light, here is my summary description. Firstly, at each of the two observers' differing locations (within the train and on the embankment) the reception of the light signal coming from the two coinciding lightning strikes would have taken place only after each of the observers' inertial spaces had become linearly separated from each other, to an exactly equal extent. And that would be a very considerable distance, given their phenomenal combined motion. (A relative distance between them which could perhaps be best conceived as based on the metric represented by the known extension characteristics of spaces in general.)

The bolts of lightning are not a co-moving part of either the embankment or the train. They are passing through the embankment system. But right at the moment of striking, they're contiguous with both systems. This dual and simultaneous contact is evidenced by the trails burned down the carriage window and the corresponding scorch marks on the track. So, it is this momentarily coinciding location, in terms of both reference spaces, from which both embankment and train are each moving away at a constant and equal rate. Remember, in a world of ubiquitous but coherent relative motion between spaces, nothing is ever really absolutely stationary. Certainly not the surface of Earth.

A consequence of the equality of the spatial separation distance for both observers, is that they would both receive the light with the same duration of signal delay from the instant of its emission at the simultaneous lightning strikes.

At this same delayed instant of signal reception and observation, the system separation distance would be much, much greater than the separation distance each observer measured at that moment from their own position relative to that of the source of the flashes. For both observers, they would see and measure these latter distances relatively, according just to the metric of their own space. For the train observer, and with regard to either flash, this is simply half the perceived length of the carriage, from window to window. For the embankment observer it's an equivalent distance, but in this case in terms of being halfway between each of the scorch marks on the track. If each observer then applies the speed of light constant c to these equivalent distances, they thereby both judge the flashes to have originally occurred simultaneously.

There is another interesting feature of this situation. There can be little doubt that each observer would have the strong experience of feeling stationary. They are both localised in a place where the normally invariant nature of all basic physical properties and physical laws continues to remain completely unchanged. They are each inhabiting thoroughly equivalent but distinctly local worlds. At the same time, we can be equally certain these worlds were differentiated by also being in a state of extremely rapid relative motion.

The emanating rays of light in this story are themselves composed of a multiple set of discrete spatial systems, all constantly co-moving along together. The light rays propagate constantly as linear and entirely separate streams through each of our discrete but relatively moving spatial systems. Each stream in particular is only propagating through one inertial reference system. Not through both, as if they were moving through the same background, amalgamated space. These separate streams, each moving at speed c through each separate system, are however, inhabiting spaces which are moving equivalently apart, in time with each other. These separate streams do not in reality each have a relative speed difference of a Galilean 'addition of velocities' sort. Only if one artificially identifies one of their spaces as truly stationary in an absolute location, while the other is attributed with all their combined motion (a decision made either for a 'real life' purpose or in purely methodological terms) does their state of motion come to be seen as asymmetric. Then the two streams of light in each space would seem to show different speeds, in accordance with the Galilean 'addition of velocities' procedure.

In itself, there is nothing in this whole account which suggests any necessity for postulating the physically asymmetric, contracting length of matter. Likewise, nothing that looks anything like the asymmetric and physical dilation of the regular passage of time. None of the entirely equivalent spaces needed to shrink in any way, not even linearly. They just moved apart in a natural and coherent way, relatively speaking. And throughout, it seems time continued in both to pass in a simultaneous way, according to the evidence provided by the signal reception timings. [Whether this unvarying and conserved passage of 'now' is a cause or an effect within this scenario, is an open and very interesting question.]

More parsimoniously than the asymmetric contraction/dilation hypothesis, I suggest this account simply shows the sort of spatial displacement effects to be expected when making observations between physically discrete and equivalent inertial spaces when they are physically separating at a phenomenal rate. This displacement effect is a function of both inter-spatial motion and the fact that observations have to rely on a delayed signal reception. It is quite possible (I conjecture) that the Lorentz transformations mathematically capture such purely spatial, motion-generated displacements, in a remarkably effective way. But their deductive basis in physically altered lengths of matter and a physically altered passage of time may well be in the nature of nothing more than a rather exaggerated but useful myth.

Above all, however, I consider Einstein's powerful postulates, their operation having been faithfully and logically demonstrated in my lightning, train and embankment account, suggest very strongly that the passage of time might well reflect a general and simultaneously occurring physical process. By the same token, I have concluded his pair of postulates and the relativity of simultaneity should in logical terms be seen as mutually exclusive assumptions. From a point of view which is prepared to assume the veracity of his postulates, then surely, Einstein got that particular one spectacularly wrong … Didn't he?

As an outsider from the various disciplines of physics, my gripe with some key aspects of Einstein's thinking, at least in his younger days, is not that generally it was too relativistic. It seems to me that sometimes, it actually wasn't quite relativistic enough.

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