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

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Abstract

Written entirely from an untutored viewpoint, this essay can only very tentatively venture some thoughts about a concept that very much belongs to the discipline of physics. This is the classical notion of naturally-moving reference systems; a concept central to thought experiments published a century ago, by Albert Einstein. A critical reading of one of these original accounts forms a springboard for detailed discussions; eventually they give rise to an argument for re-appraising the reference system concept. In the account in question, Einstein famously uses an imaginary train struck by lightning to illustrate his reasoning for the relativity of simultaneity. It seems this argument has been received with a widespread and almost unanimous approval, over the years. Yet it's equally apparent that Einstein's argument drew solely on classical mechanics; and it's troubling that in preferring this simple logic, he allowed it to contradict the predictive force of his own famous postulates. So a sort of remedial analysis was undertaken: it accepted his postulates and applied them to the train scenario, independently of the classical transformation he chose. It is shown how this meticulous reanalysis leads unambiguously to the conclusion, not that simultaneity is relative, but that simuitaneity is conserved. Evaluating what to make of this disparate outcome leads to pursuing its resolution in much more philosophical terms. First, a review portrays how theoretical physicists' views on the status of space have radically evolved over the last century. Adopting and adapting their current understanding, it's suggested how naturally-moving systems might be newly characterised, not only in the old sense, by a spatial framework of material bodies, all moving uniformly in unison, but also by an additional content of equally co-moving segments of spatial field — areas which hitherto were seen only as abstractions from a stationary and homogenous background of empty space, through which the framework of matter moved. From the much newer perspective, these additional co-moving frame contents have highly dynamic substance. Taken together across multiple moving frames, they constitute super-plastic and holistically extended dynamic fields — such as electric and magnetic fields. On this speculative basis it's explained how light waves would indeed show a constant 'vacuum' velocity in all frames, just as Einstein and Maxwell required — but would also be Galilean in nature, just like sound. A recent report of measurements directly supporting the reality of a Galilean view of light is cited.

Introduction

The main idea that surfaces during the course of this essay is to do with the nature of space — and the thought that everywhere and at all scales, it may take the form of moving areas of field.

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 anything can readily move through the 'nothingness' of space, from massive heavenly bodies to the most ephemeral ray of light. But surely, this immaterial arena of space can't itself have individual forms — forms that actually move about, like some sort of supernatural ghost? It would seem very counter-intuitive to suggest what commonly moves freely in our general arena of space — in addition to its normal content of solid, liquid and gaseous matter, together with its more ethereal aspects such as rays of light — is a further content of specific areas of space itself. Surely such an improbable twist in metaphysical perspective would run completely counter to 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, as a real 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 that's linked to a keystone concept that underpins 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 are just ordinary reasoning of a non-technical and non-mathematical sort; they aren't those of a trained physicist, nor of a scholarly philosopher. I write with my peers in mind, making every effort to communicate to any ordinary but scientifically-minded reader. First though, let me explain 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, published exactly a century ago (Einstein, 1920). In particular, I wanted to read his explanation of a crucial scientific discovery about time; he'd designed a simple line of reasoning to show how any of us can recognise that Isaac Newton's theory of absolute time must clearly be mistaken. Previously, I'd only read third hand about this achievement. 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 clearer enlightenment, flowing from the pen of the master physicist himself.

An encounter with Einstein's train

Famously, Einstein's popular explanation is based on an ultra-simple 'thought experiment' about lightning that strikes a moving train (Einstein, 1920, pp. 30-32). His purpose for this device was to illustrate in a transparent and accessible way — in a way even a person with little training in the expertise of the physicist might readily understand — how the simultaneity of the passage of time cannot really be one of our universe's physically defining characteristics. Hitherto, Newton and many others had thought time's simultaneous passage 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 seen as sequential. Thus our everyday perception of the passage of time — of things always happening in a passing 'now' — cannot truly reflect an objective and universal fact. Such perceptions must instead be 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 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 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 conventional way: purely by applying classical mechanics. And in showing a preference for this approach, he seemed content to allow the distinctive force of the new combination of theoretical postulates he had established to be completely overridden and negated.

In a nutshell, the thought experiment involved an analysis of judgements about the timing of two events — 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 relative to another that was stationary. Einstein's argument relied on a prediction that in the case where light rays were moving through both frames, the moving observers would experience the speed of the light rays (as measured within the stationary frame) to be either augmented or diminished within their own frame, in accordance with its speed and direction of movement. The trouble is, this central prediction — which reflects the very simple application of theory for transforming velocities established by classical mechanics — runs totally counter to the postulates of his own theory. Designed to supersede this older transformation theory, Einstein's famous Special Relativity theory predicts that an observer, located in either of the sort of frame contexts he described in his thought experiment, must always directly measure the velocity of light as unaltered, always with the same constant value — thus never being able to experience and measure it directly as either augmented or diminished. In fact, as I will discuss in detail later, Einstein was very well aware that such an unacceptable contradiction was a consequence of applying his postulates, and he'd found a solution to overcome it. Even so, he chose to ignore this fact during the presentation of his argument for the relativity of simultaneity.

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, I had decided to have a look myself at how the same thought experiment would turn out if this contradiction was directly remedied. 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 classical approach he chose —

and thus be applied directly to the the bare bones of the train scenario he'd so clearly laid down. To start with, it's these personal explorations that I wish to report, in the clearest way I can.

Before reviewing the form of Einstein's train scenario, it should be noted that although 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 idealised sort of way. This strategy helped sharpen the analysis without misrepresenting the key physics his simple picture embodied. In particular, the whole thing was 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 fully specific or veridical 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 been spiced up, just a little. However, none of these small embellishments conflict in any way with the simple form of the original account. The original provided an ultra-simple diagram; I have chosen not to. It's the experiences that can be imagined from a position internal to each perspective frame I particularly wish to invoke.

There is an open-plan train carriage, gliding along completely steadily (we wish!), neither accelerating nor slowing, but travelling in a straight line along its track on a level railway embankment. As it travels along, we imagine two bolts of lightning suddenly striking down so there is a bright flash, right at each end of the carriage at precisely the same moment. A most unlikely coincidence, you may scoff. But the beauty of a thought experiment is we are free simply to say it is so! Similarly, we can blithely ignore the lack of oxygen and say that as a result of the lightning strikes, there is a visible burn trail down the perpendicular window at each end of the carriage — and 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 burn onto the track; the other 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 light flash as it emanates from where each lightning bolt struck and then continues 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 each serve to mimic what is known in physics as an inertial reference frame, in relative motion. It was recognised long ago (by Galileo and Newton) that the laws of physics 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 in just the same normal way, despite the fact that their relative motion affords very different perspectives on what is happening. (Of course a train doesn't really move completely naturally, exactly as an inertial object in free space continues to move in the absence of any application of force; in its real situation, a train has to be driven. Nonetheless, it serves well as a practical approximation to inertial motion, due to the way it can 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 years ago, sailing in his ship — the more it can be recognised as a truly remarkable and deeply revealing state of metaphysical affairs. Let's update things a little to consider a much better and more modern example. For instance, imagine we're high in the atmosphere, lounging in a comfortable jet airliner. It's on course and cruising steadily, at say 500 knots. Few of us will ever experience ourselves moving much faster! Even so, apart from during any minor deviations in flight, it actually feels pretty much as if we were seated in a reclining chair back at home. We simply feel stationary, as does our immediate world of the plane around us. We can drink a cup of coffee and then get up and walk along the aisle, all in a remarkably normal way. And If we toss a book into the empty seat in front of us, we certainly don't expect to see it travelling there at over 500 knots! Only when we peer through the window into the other reference frame outside are we reminded that things look very different out there. The nearby clouds are positively zipping by. Yet our sense of common knowledge soon reminds us that despite the way it seems, we should accept it's the plane that's flying at great speed, through an environment which, when we are earthbound, we always take to be stationary. This whole situation may tempt us to ask, which of these frame experiences actually shows the truest world?

In the most deeply metaphysical sense, surely the answer must be that what is happening in both frames is different, but somehow also the same, reflecting the presence of a symmetrical and entirely equivalent reality. It makes sense to assume both the plane and its environment are aspects of one dynamic and extraordinarily balanced but unified world, just as the train and embankment are too.

Einstein is well known for the main postulates of his Special Theory of Relativity: it was in his famous and seminal paper (Einstein,1905) that he first asserted that a pair of firm scientific truths should be regarded as governing our physical world. The first of these wasn't new, simply embracing what we've just discussed — how physical laws operate just the same within relatively moving inertial systems. Briefly, this is known as the principle of relativity. Although his second postulate was linked to this principle, it was a more specific and original stipulation. For current purposes, it can be expressed in this scientific way: when measured in any inertial frame of reference, light must always propagate through empty space (a vacuum) with a standard velocity, labelled as c; and this outcome is independent of the state of motion of either the emitting source or any receiver of the light.

Accepting these two very foundational postulates as linked premises, we can now use them to highlight and thus trace what should happen in Einstein's train scenario. This can be done without needing to draw on any very technical analysis. The task is instead approached very simply in a logical way; also perhaps in a more obviously even-handed way than the original, by focussing on sampling the differing perspectives afforded by each reference frame to the viewer fixed within it — each frame being considered an equal aspect of reality, as we've discussed. Then, in terms of judgements about simultaneity made 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 what happens in a very meticulous way; it's in the nature of an objective scientific analysis — albeit a simple and imaginary one.

My alternative thought experiment report

Firstly, let's consider the embankment viewer. Let's call her Jane.

As Jane looks out from what she knows is her middle position by the track at what is happening to the passing train, one of the light flashes will radiate towards Jane from where its source was at one of the railway burn marks, out along the track to one side of her. In accordance with the postulates, this flash of light must be measurable as travelling at speed c, with reference to Jane's embankment frame. The same will be true for the flash coming from the second burn mark that's out on Jane's other side. Because she is standing halfway, the two equal-speed light flashes will radiate until they reach Jane at the same moment. She will therefore see the two signals arriving simultaneously. She will then have no doubt about coming to the judgement, because of her halfway position, that the lightning strikes themselves must also have occurred simultaneously.

Now we can turn to the train viewer who, with respect to the embankment, is travelling rapidly along. Let's call him Joe.

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

As we know, one of the lightning bolts struck down the rear window of Joe's carriage and thence straight onto the track. As the train rolled steadily by, these two locations showing the source of the flash corresponded in both space and time for only one passing instant. At exactly that same instant the light generated by the bolt 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 it explodes directly into the carriage, spreading quickly down its whole axis. This journey thus entails the light radiating very rapidly outwards from its starting point at the window until, on its way, it reaches 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 has 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 has been zooming ahead, the rear window has been moving steadily — if only a little — away from its source at the burn marks on the track outside. Of course Joe too has moved away similarly, by the same small amount. But all these shifts in location of all parts of the carriage relative to the track are entirely immaterial; for Joe, they do not change the length of the light's 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 the light signal with reference to an inertial frame in a vacuum (i.e. the carriage) it must be found to remain at c, regardless of any motion of either its source or receiver, once it has been emitted.

For the other explosion of light — the one emanating from the window at the front end of the carriage — exactly the same considerations apply. Although radiating in the opposite direction, it too will measure at c as it travels over the same distance 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 flash is radiating within and with respect to the carriage at equal speed c towards the middle of the carriage from each of its end windows — where, at the instant of the simultaneous strikes, we know light started spreading simultaneously. Hence the two flashes will be seen by Joe to arrive simultaneously, just where he is seated, halfway along the carriage. Joe will therefore have no doubt in judging that the lightning bolts had hit each end of the carriage simultaneously with each other — just 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 hit simultaneously. One possible query remains though: can that judgement be matched after the event with a more ‘one world view’ covering both frames?

The answer lies in reconstructing the historical evidence provided by the pairs of burn marks on both the train and the railway track. It can be reviewed and readily agreed by both Jane and Joe, once the whole scenario is over, when the train and embankment are no longer in relative motion. Looking at each end separately, examining the way in which the burn trail down the carriage window and the scorch mark on the track are closely matched, shows how, at each end, the carriage window and railway line must have been struck in a shared location in space at the same time. Finally, Jane and Joe can check the distance separating the pair of burn marks on the track and compare it with the length of the carriage. These measurements will of course prove to be equal; it can be concluded that the bolts indeed struck at both ends simultaneously with each other.

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, not empirically; this wasn’t a real experiment) how the quality of simultaneity would be thoroughly conserved in both 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 harmonious 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 faithful to Einstein’s postulates and not in any way misleading, its conclusions are of course 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 shows the exact opposite.

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, a countless number of readers with a very much greater expertise than me have obviously found no difficulty with the master physicist’s reasoning and conclusions on this matter. Having said that, a subsequent search on the internet showed me that there actually are a few writers who shared my reservations about this particular argument by Einstein. Spread over the century that's passed since Einstein first presented his train illustration, I found that just a handful of similar but more expert critical commentaries have been published. Examples of such critical analyses are to be found in a paper from a reputable American philosopher (Evans, 1962, especially pp. 73-74); also very recently from a seasoned Indian physicist (Unnikrishnan, 2020a, pp. 14-17 and similarly, Unnikrishnan, 2020b). Both the latter papers discuss Einstein's thought experiment, and include concerns rather like mine that were raised by the French philosopher, Henri Bergson, way back in 1922. I conducted a further search hoping to find published peer responses to the authentic criticisms I'd found; sadly, the little I've found so far suggests they may have been largely ignored rather than actively evaluated or refuted. Perhaps I need to search further.

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, he used a version of the train device to portray the nature of this problem (Einstein, 1920, pp. 21-24). Before briefly looking at the details, we can first 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 extension that was both homogenous and isotropic in character, i.e. evenly distributed in all directions. In those days, a stationary aether acting as a light-conducting medium was still believed by many to fill all of this extension of space. However, 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" (Einstein, 1905, p. 141). I interpret all this to mean that a stationary, homogenous and empty space was considered as the only background for the passage of light along both the embankment and the train.

In the thought experiment in question, this time there aren't any lightning strikes. Einstein simply asks us to consider both a light ray and a train travelling steadily along an embankment in the same direction — again in a vacuum. The tip of the light ray will be travelling at c, with respect to the embankment. But in line with the assumptions considered above, as it rapidly overtakes the train the speed of the tip of light can be predicted to be somewhat less than c, relative to the train (even if only by a very tiny margin). In providing this particular illustration, Einstein's whole purpose is to emphasise exactly why this is such a crucial problem. He points 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 is a very clear — and unacceptable — contradiction. 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, an application of these newer equations, which were based on the contraction of moving material bodies and their time dilation, allowed the contradiction to be seen as apparent, rather than real.

In case it's not already obvious, I must swiftly point out that this is the very same sort of contradiction I was so concerned about when Einstein argued for the relativity of simultaneity. But the remarkable thing is, when drawing this momentous conclusion, the argument he displayed bore not the slightest acknowledgment or reminder of exactly this unacceptable contradiction; nor did he make any reference at all to having overcome it with his Lorentzian transformations. Instead, he simply showed a preference for the old Galilean transformation. All this is what bothered me so much; for me, these were crucial issues that seemed conspicuous by their absence from the line of reasoning he actually put forward. The fact remains, Einstein's reasoning — and therefore his very radical conclusion about the relativity of simultaneity — relied completely on a statement that amounted to a direct negation of his own postulates. While it might be objected that he did refer back briefly to the contradiction problem in a follow-up discussion, by then he had already established and confidently announced his major conclusion — which, as we've seen, was a conclusion based on a different theory.

When making his argument for the relativity of simultaneity, had Einstein at the same time warned us of the apparent contradiction it entailed, then he could also have advised us not to be too concerned about it: all we needed to do was abandon any pre-conceived ideas we might have about fixed lengths and times and thus see that the classical transformation, despite its apparent veracity, was actually misleading. In consequence, both observers could indeed measure light to remain at speed c from their own perspective. But instead, he chose to accept the classical transformation at its face value, so that he could predict that both observers would *not* see the speed of light as equally remaining at c. Only by making this choice was he able to infer that simultaneity was obviously relative.

The deep confusion inherent in all this is what 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 unanimously well received by experts — barring just the few clear exceptions I found later. The truth is, the presence of this profound consensus made me check again and again for some naive but serious error of interpretation on my part — a doubt considerably magnified by the fact that I cannot pretend to have any trained expertise in physics. Should these natural self-doubts turn out not be justified, then historically speaking, this whole situation would have to be seen as remarkably anomalous.

I can offer a possible insight as to how the consensus effect I've referred to may have arisen, at least in part. Having had the experience of trialling my critical position with regard to Einstein's argument with a fully qualified high energy physicist, I can report how he responded. Instead of seeing the Special Theory of Relativity — which includes all its key concepts, such as the relativity of simultaneity — as having the status of a scientific theory (which means ultimately, it always remains provisional in nature), it was clear that by virtue of his training and his view of its supporting evidence, my physicist friend saw it simply as an absolutely true fact. Consequently, when evaluating any analysis of Einstein's thought experiment, in effect he automatically took the relativity of simultaneity as a premise. For him, whatever is offered as an analysis of the thought experiment must always end up proving this premise to be true — or if not, it simply proves the analysis itself to be wrong. One should of course look at any argument from a thoroughly open basis: the final conclusion must always be free to go either way.

The role of the Lorentzian transformations

Anyway, wherever the proper truth of these matters may lie, the fact remains that by inventing his theory of Special Relativity, Einstein found a solution to his contradiction problem. As I've said, this involved employing the transformation equations he'd adopted from Lorentz, applying them to relatively moving frames. For this purpose, reference frames such as the train could legitimately be considered as moving at a specific speed, relative to a frame that's simply stipulated to be stationary, such as the embankment. Thus an application of these equations to our familiar train situation would have predicted that the train, in terms of the stationary embankment perspective, would be contracted in length and its passage of time would be dilated. These physical changes are shown by the calculations to occur systematically in such a way that they result in the measurement of the velocity of light made within both frames remaining at c. The cost of thus coming to understand how the velocity of light through space can remain at the same standard value in all frames, is to accept that in relative terms, time is something that can truly dilate and the length of bodies can really contract, simply because they are in relative inertial motion.

Applying Special Relativity to Einstein's train

We could, then, accept that these relative physical changes predicted by the equations, 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 (from Jane's perspective) would be so tiny as to be completely indiscernible by Jane. They would be truly negligible, given the slow speed of any real train in comparison with the phenomenal speed of light. Nevertheless, drawing once again on the magic of the thought experiment method, we can still consider the implications of these 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 in the light of the predicted impact of not only Einstein's postulates, but also his 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, which, as we now know, is predicted to have its length contracted and its time dilated (from the point of view of Jane's frame), Joe himself wouldn't perceive anything as changed. (This would still be the case, even were the changes large enough to be perceived; it's actually the theory which says that from his perspective, all would be normal.) But, imagine Joe managed to measure the speed of the light rays from his position half-way along the train. What would he find? Would he measure both light rays as travelling exactly at c, in accordance with Einstein's postulates? If so, the careful analysis I provided earlier would clearly apply and Joe would judge the lightning strikes to have been simultaneous, just like Jane. Simultaneity would have been conserved — despite the prediction from Special Relativity of a differing measure of the passage of time between the two observers.

Or — still with the predicted changes in the carriage's length and time, from Jane's perspective — would it after all be the case that Joe would measure one of the light rays travelling through his carriage as slightly augmented above c, with the other diminished below c, just as Einstein had previously preferred to predict from classical mechanics? If so, then Joe would judge the lightning strikes not to have occurred simultaneously, just as Einstein inferred. Simultaneity would have been lost.

If you were tempted to venture an answer to my question, which alternative would you reckon to be the right one to choose? Which seems the most completely coherent answer? In the end, perhaps you might pick neither — and just start to wonder if it could be that neither transformation theory alone has it quite right.

Thoughts about taking a different road

Up to this point in my discussions, I've made every effort to pursue things in a convergent style, aiming to stay both properly logical and as precise as I reasonably could. But now, in order to take things forward, I need to indulge in a far 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 in applying them — and then discuss a quite different road towards its solution. Unavoidably, this solution would differ from Einstein's; but only insofar as he drew on the work of Lorentz as his answer to the problem. I will pursue this task from the point of view of a speculative 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.

Reviewing changes in the status of Space

Any notion that space is essentially nothing — just an empty background void — seems to be well 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 the older perspectives; as did the quantum revolution — especially with the advent of Quantum Field Theory. But, inasmuch as space used to be taken as a stationary 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 naked extension. As such, in physics it was dealt with in a rather abstract and mathematical way, as a necessarily homogenous and isotropic background in relation to all the material bodies moving around independently within it.

As I touched on earlier, 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's apparent that many physicists consider the older understandings of space 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 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 space. Instead, space is now considered more as a unified entity: matter in its multitude of forms is regarded as highly developed field disturbances — as energetic foci in holistic aspects of the extended but super-plastic materiality of space. A very accomplished voice from the discipline of modern theoretical physics, Professor Frank Wilczek, succinctly expresses the generality of this evolution to a modern view:

> 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. (Wilczek, 2009)

Far from space functioning as a sort of abstract, background existence, having few of the properties of a material in its own right, it seems it may in reality be quite the opposite — it may actually be the only universal physical material, at all scales harbouring a vast range of highly mobile sub-forms within its extended but super-plastic form. Despite the way it may always look to us, in any final analysis there is no true duality of background and foreground realities. 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 cricket balls tossed in an empty sky.

Presenting a modernised world

What I now wish to discuss belongs within such a modern worldview: the materiality of the spatial field of our universe is considered to be both holistic and ubiquitously energetic. This means that Space is really just one unified thing, a universe, a plenum; but throughout by nature it's in simultaneous flux. It's in a perpetual state of coherent change that signifies the passage of time.

Space is thus differentiated by its regular and unceasing internal movement into a multiplicity of spaces at every scale, small and large — all spaces within spaces. Again, if you like, like a multitude of fluctuations in a single but regularly turbulent sea. Essentially, parts of spaces 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 spaces are ever moving through empty space, any more than water waves move through an empty sea. Like the ocean, Space — our universe — is a plenum; it's 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, individuated spaces are never at 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 measure of being at rest.

Inertial reference systems cast in a new light

It's against the backdrop of this very speculative conception of both space and time that I suggest the classical notion of an inertial reference system should be re-construed in a more modern light: as packets of space that flow about, in a coherent and natural way. Such a reference system would be a steadily moving sub-field of the material of Space itself. In turn it would be full of numerous sub-spaces, all 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 localised and potentially detectable — but others would persist as much more space-like and invisible forms, as whole segments of flexing and flowing holistic fields. Both, though, are equally just energetic aspects 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, sat in a plane or a train, or a car — or even, maybe, an old Galilean ship. What would be co-moving with us?

Now here's the thing: in the new way of seeing the world I'm suggesting, the answer is that every aspect of Space which falls within our cruising reference system, is co-moving with it. This means not only all our vehicle's 'material' parts at all scales, such as all the constituents of it's plastic and metal parts and, say, all the people and oil and air within it; now we should also include what in the old days were regarded as no more than aspects of the 'immaterial' or 'empty' space the vehicle was moving through, such as stationary areas of electric and magnetic field. These latter areas will now be parts of space that are flowing along with us too.

We can all cruise about on the surface of our planet, independent and secure in our own mobile mini-universe bubbles, where happily, all physical laws stay just the same! Though these bubbles of material space are moving relative to other material bubbles, none of them is moving through some ‘extra’ medium or background. They are all just systems of localised fluxes in the chameleon materiality of Space itself. Like bubbles of sea in an ever-changing and regularly turbulent ocean.

Some of the smallest localised fluxes are the light particles known in physics as photons: individuated fluctuations between electric and magnetic fields, zipping along as a wave-train at a regular rate, always localised in areas of these fields wherever they find them — perhaps where they are located within our cruising vehicle. Despite their movement relative to other frames, these localised area of field are functionally continuous with their far broader but super-plastic form — holistic fields, located everywhere, in all the frames.

Revisiting Einstein’s problem

In the light of this universe of Space and its moving sub-spaces I’ve posited, I’d now like to return to Einstein’s basic contradiction problem — and to his imaginary train that’s struck by lightning. The train and the embankment would each be frames of uniformly co-moving space, each including both matter-like and space-like extended material, all moving together in harmony. The train would be a whole frame; the embankment would be just a small part of a very much larger co-moving frame, the surface of planet earth. The light ray would be a stream of the very small parts of space called photons, moving as disturbances in their electric and magnetic fields, wherever their parts are located.

Now, as the 19th century physicist and mathematician James Clark Maxwell showed so very convincingly, the velocity of light must have a finite and constant value c, set by the way it physically propagates as a linked pattern of regular electric and magnetic field fluctuations within a given area of stationary space. Within a steadily co-moving frame, say the embankment, Jane feels stationary because, within that context, she actually is stationary. The light from the lightning will transmit at c in the space-like parts of her frame, areas of electric and magnetic field. In the same sense as Jane, these areas of field are 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 wider fields. These holistic fields are everywhere; they are potentially fluid and flexing — a highly plastic and unbroken pathway for the continuous transmission of light across all the moving frames it meets and passes through, as it propagates at lightning speed.

On this basis, there would 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 location, not to his. The two internally stationary frames both transmit light at c; externally, only the relative speed of the frames as a whole actually differ. Therefore, for Jane the calculation would simply be c, plus or minus the velocity of Joe's frame, relative to her. And, of course, vice versa. A rather familiar calculation, belonging to the classical mechanics of Galileo and Newton.

Before I conclude my essay, there's a sort of footnote that needs inserting here. The simple calculation of a relative velocity that's just been described might seem to suggest that a direct measurement can show light to have a 'superluminal' velocity, i.e. greater than c. (Theoretically, the same could be said of Jane herself, reciprocally speaking.) However, it's important to see that the calculation is actually not a direct measurement. When we considered the relative movement between reference frames, we were dealing with areas of flowing space that directly interface with each other — no 'old' space in between! Only their relative movement acts to separate them. The measurements of their relative speed are physically direct and completely local in nature. In contrast, the light travelling through Joe's carriage frame is not a part of it; it's not co-moving with it, but is moving through it. Therefore the light is interfacing with Joe's frame, but not with Jane's. To some degree, it's remote from her frame. This means the measurement of relative motion between Jane and the light in Joe's frame is not local in nature. It cannot be made as a direct physical measurement, but has to be abstracted from the wider situation via calculation. So in this posited reality, the local speed of light through space remains everywhere at c, just as Jane's local speed at any moment remains at the value it has in relation to Joe.

A problem dissolved? Galilean light?

The main point is this: if any of the speculations I've presented were to reflect something real about the physics of our universe, the original problem of contradiction — the one that Einstein sought to tackle head-on with his Lorentzian equations — would just dissolve. It would simply vanish. Not only would the speed of light be constant when measured in all frames (just as Einstein postulated and as Maxwell required) but also, the motion of light would indeed be in accordance with classical mechanics. It would be Galilean. Its motion would be that of a wave dependent on the state of motion of its medium at the location where it's propagating, just like sound. Sound is a particular type of wave moving at a constant rate in the medium of a field of steadily co-moving air molecules, irrespective of the speed of its source. Similarly, light would be a type of wave propagating constantly in the medium of all electric and magnetic spaces — including where these spaces are stationary in relation to the other parts co-moving in an inertial frame. And, of course, it would propagate in this way irrespective of the speed of its source.

There's one further and significant consequence of the speculative view of the world I've offered. The analysis I presented earlier — the one based on applying Einstein's two postulates alone to the train and embankment perspectives — would stand. Simultaneity would be conserved.

A report of a measurement of the relative speed of light undertaken in a high energy department in India (Unnikrishnan, 2020a, pp 9-13), details how it was found it to be clearly Galilean, just like sound. This work was actually first reported a few years ago; it would be most helpful to see the publication of careful and objective evaluations.". of this result by his peers, in the normal scientific way.

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