Denying the existence of instants of time and the instantaneous

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Extending on an earlier paper [*Found. Phys. Ltt.*, 16(4) 343–355, (2003)], it is argued that instants of time and the instantaneous (including instantaneous relative position) do not actually exist. This conclusion, one which is also argued to represent the correct solution to Zeno's motion paradoxes, has several implications for modern physics and for our philosophical view of time, including that time and space cannot be quantized; that contrary to common interpretation, motion and change are compatible with the "block" universe and relativity; and that time, space, and space-time too, cannot exist. Instead, motion and change become the major players.

1. INTRODUCTION

Physics has a problem with change. Despite it appearing to be an essential feature of Nature, and physics itself—the study of matter, its motion, and the things that derive from this, such as energy and force—essentially being built upon it, physics also denies that motion and change are possible. In some instances this is done knowingly, as is the case with the standard interpretation of the "block" universe provided by relativity. Motion and change are seen to be illusions, incompatible with a fixed, four-dimensional view of reality in which there is no preferred present moment, and all events, past, present, and future, are all laid out together. In other cases, I will argue, it is done inadvertently, with many unaware that making certain physical and mathematical assumptions render theory incompatible with the dynamic, changing universe we observe. Beginning with a discussion of Zeno's motion paradoxes, it is argued that the assumption that zero-duration instants in time and the instantaneous actually exist is at the heart of this quandary, and that once this assumption is dispensed of on the grounds of non-physicality and logical inconsistency, motion and change become entirely compatible with existing physics. Although instantaneous values, functions, and real numbers, remain very useful in physics, denying that the instantaneous exists is shown to resolve a number of paradoxes and problems, including Zeno's motion paradoxes, and the so-called mismatch between the block universe, and motion and change [1]. As a consequence of instants in time not existing, it is argued that time, space, and space-time also cannot exist, while, as it would require the existence of instants and spatial points to bound and determine their magnitudes as intervals, time and space cannot be quantized [2, 3], nor can a so-called non-zero duration instant exist. It should be noted that this by no means negates the operational defining of Planck time = $\sqrt{\hbar G/c^5}$ and Planck length = $\sqrt{\hbar G/c^3}$. Surprisingly, and although publicly anyway, it seems he did not follow the conclusion through to its full implications for physics, late in his life, Einstein also denied the existence of instants [4].

2. ZENO'S PARADOXES

One of the best-known problems in the history of physics, mathematics and philosophy are Zeno's paradoxes, originally conceived by the Greek philosopher Zeno of Elea around 450 BC. They are so well known that I will avoid going over them here.[2] I will, however, outline the historically accepted solutions to the three most famous ones: the Arrow, The Dichotomy, and Achilles and the Tortoise.

Of Zeno's paradoxes, the Arrow is typically regarded as a different type of problem to the others, thus also requiring a different type of solution. Over the past 300 years it has usually been claimed that the Arrow paradox is resolved through calculus, the use of continuous functions, and the idea of "limit". Although Isaac Newton and Gottfried Leibniz were the first to introduce these methods, it was not until the 19th century that a reasonably rigorous foundation to do this was provided with the "epsilon-delta" definition of limit by Augustin-Louis Cauchy and Karl Weierstrass. The essence of what they did was to dispense with infinitesimal-quantities and the infinite altogether, and instead think

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[2] For Zeno's paradoxes, see, for example: Gruenbaun, A. *Modern science and Zeno's paradoxes*. Wesleyan University Press, Middletown, Conn (1967).

in terms of relationships between small, but finite, quantities that can potentially be made arbitrarily small by taking them to an unreachable limit.

A good way to think of this idea is to consider a polygon inside a circle, with the circle representing the limit of the polygon's sides. If the number of polygon's sides is increased, the lengths of the sides decrease, and the polygon gets closer and closer to becoming a circle and to reaching the limit. As it will always still have sides, the polygon can never actually get to be the circle, but it can get arbitrarily close, so for all practical purposes, it is said that it might as well *be* the circle.

In this example, the polygon is analogous to an object's motion and velocity, and the circle, to the limit of the object's velocity at an instant. Thus, when applied to Zeno's Arrow paradox, this means that, although the limit of the arrow's velocity at the instant is never actually reached, as the time interval approaches zero (roughly analogous to the length of the polygon's sides), the arrow can be taken arbitrarily close to it, so for all practical purposes, the arrow is said to have a non-zero velocity at the instant, and thus, not to be motionless. Furthermore, although not actually moving *during* the instant, if the arrow's trajectory is traced out, it can be said to be in motion because it can be seen to occupy different locations at different times. This is the so-called "at-at" theory of motion [5]. As the arrow could be said to have an infinite-number of different positions at different times within this context, it is also sometimes claimed that the arrow is in motion at *all* instants in time (an infinite number of them).

The paradoxes of Achilles and the Tortoise and the Dichotomy, on the other hand, have generally been thought to be solved by the summation of an infinite series, a mathematical technique developed by Cauchy, Weierstrass, and Richard Dedekind. In relation to the paradoxes, this means the summing of an infinite series of progressively small time intervals and distances, so that the time taken for Achilles to reach his goal and overtake the Tortoise, or to traverse the said distance in the Dichotomy, is, in fact, finite. The faulty logic in Zeno's argument is seen to be the assumption that the sum of an infinite number of terms is always infinite, when in fact, an infinite sum, for instance, $1 + 1/2 + 1/4 + 1/8 + 1/16 + 1/32 + ...$, can be mathematically shown to be equal to a finite number, or in this case, equal to 2. Therefore, Zeno's infinitely many subdivisions of any distance to be traversed can be mathematically reassembled to give the desired finite answer, and the body in apparent motion be said to have reached its apparent impossible goal.

2.1 NO INSTANT IN TIME

In an earlier paper [6], it was argued that Zeno's paradoxes assumed, as did physics in general, the existence of a zero-duration instant in time at which a body in relative motion could be said to be in an exactly determined or instantaneous relative position. Further, that if such instants did really exist, motion and change would be impossible. As they represent the present tense version of an instant, by default, this also applies to a "present moment" or "now". If a moving object could be said to have a determined position relative to something else at an instant, as is the very nature of this ethereal notion—a static, durationless "snap-shot" of a physical process—the object would necessarily be frozen at that instant and could not be in motion at all. That is, it is that its relative position is constantly changing that enables a body to be in relative motion in the first place. By wrongly assuming that a moving body could be said to have an exact relative position at an instant—and then dissecting its motion as such—Zeno's motion paradoxes were created. Thus, the solution to the paradoxes lays in recognizing that a body in relative motion cannot possibly have a instantaneous relative position, and as such, that its motion cannot be fractionally dissected as though it does. With its position constantly changing, it has already moved on. This applies to the paradoxes of Achilles and the Tortoise, the Dichotomy, its variations, as well as to the Arrow. As I would like to have a more detailed look at the solutions to the paradoxes, however, let's have a closer look at them.

The way in which calculus was thought to solve the paradoxes of Achilles and the Tortoise and the Dichotomy through the summation of an infinite series, certainly provided the correct answer in a strictly mathematical sense by giving up the desired finite number at the end of calculation. It was dependent, however, on an object in relative motion having an exact relative position at any given instant in time. Moreover, the summation of an infinite series here worked as a helpful mathematical tool to get rid of the infinities, but it did not actually resolve the paradoxes and show how the body's motion was possible. In this physical context, it equated to little more than "rounding up".

The same fault applied to the Arrow paradox's proposed solution, as the "limit" of the arrow's velocity at the instant is never *actually* reached; strictly speaking, the arrow does not have a velocity at the instant. It cannot, as by definition, an instant has no duration, so the arrow cannot have a velocity at an instant if there is no interval of time during which it could cover a distance. Indeed, to say that it could have one was like saying than a stationary body could at the same time be moving, or that a multi-sided polygon could also be a circle. Furthermore, by invoking this model, or the "at-at" theory, people were essentially agreeing that motion and change did not exist and were some sort of strange subjective illusion.

In all three paradoxes, and in the proposed solutions to them by calculus, it was taken for granted that a moving body had a determined relative position at any given instant in time. As explained earlier, this is not the case. Regardless of how small the time interval or slowly a body is moving, its position is constantly changing and undetermined. If this were not the case, it could not be in motion. When this realization is applied to the Arrow paradox, one also recognizes that there can be no instant in time underlying the arrow's motion at which its volume would occupy just "one block of space", and because its position is constantly changing and undetermined, the arrow is never static and motionless.

The paradoxes of Achilles and the Tortoise and the Dichotomy are resolved by this same realization. When the moving body's associated position and time values are fractionally dissected in the paradoxes, an infinite regression can then be mathematically induced and the idea of motion shown to yield paradox, as such values are not representative of instants in time at which the body is actually at each exact position, but rather, of intervals of time during which the body is passing through specified intervals of distance. For example, a time value of 1 second (which indicates the time interval of 1 and 1.99999..., seconds, and not an "instant"), is not indicative of a time at which a body's position might be determined while in motion, but rather, if measured accurately, is a representation of an interval in time during which the body is passing through a particular distance interval, say 1 meter (which indicates the distance interval of 1 and 1.99999..., meters, and not a precise "spatial point"). Incidentally, note that a spatial point is perfectly analogous to an instant, with the difference just being that it has no spatial extent, rather than no duration. As such, if instants or points in time have no physical basis, and an object in relative motion does not have an exact relative spatial position at one, points in space can have no physical basis either.

Finally, William James' variation on the Dichotomy [7], where the emphasis is placed on a specific time not being reached rather than a distance, is also resolved by the same line of reasoning, and by recognizing that, in order to make each time dissection, the paradox assumes the existence of an instant in time in order to freeze and determine an exact time value, when, in fact, interval is constantly changing i.e. the hands of a clock continue to rotate (or even better, the capability for motion always remains present). If the time value in this version of the Dichotomy paradox was perhaps said to represent an interval of time rather than an instant (for example, the interval of 2 seconds, which represents the interval between 2 and 2.999..., seconds), in order to make the dissection, this assumes the existence of two instants (at 2 and 3 seconds) to bound and determine the interval, and the same applies. Interestingly, if the Dichotomy and Achilles and the Tortoise paradoxes were perhaps reformulated so that the focus was placed, not on the distance, but upon the time interval, so that there was always some time remaining rather than a distance, this simply becomes a restatement of William James' version of the paradox.

2.2 NOTHING NEW UNDER THE SUN

As with basically all ideas in science and philosophy, the thoughts underlying these conclusions are not all new. Over the centuries, going all the way back to the birth of Zeno's paradoxes 2500 years ago, it is clear that a number of people were certainly thinking in the right direction about them. Probably the person that this most applied to was the first of them, Aristotle. When confronted with Zeno's Arrow paradox, Aristotle replied that it was moot because "time is not composed of indivisible moments" [3] [*Physics VI*:9, 239b8-9]. Aristotle was clearly right here, although he still maintained that nows and the present existed: "Time, then, also is both made continuous by the 'now' and divided by it [*Physics IV*:11, 220a4-5]. Aristotle also applied this argument solely to the Arrow paradox, and saw the paradoxes of the Dichotomy and Achilles and the Tortoise as being different problems:

> The result of the argument is that the slower is not overtaken: but it proceeds along the same lines as the bisection-argument…. so that the solution must be the same. And the axiom that that which holds a lead is never overtaken is false: it is not overtaken, it is true, while it holds a lead:

[3] In some translations of *Physics*, "nows" replaces "moments".

> but it is overtaken nevertheless if it is granted that it traverses the finite distance prescribed [*Physics VI*:9, 239b20-29].

In his groundbreaking 1781 *Critique of Pure Reason,* Immanuel Kant argued that space and time do not belong to things as they are in themselves, but rather to our way of looking at things. They are forms of our perception, and it is our minds that impose space and time upon objects, and not objects that impose space and time upon our minds [8]. Kant correctly concluded that Zeno's paradoxes could be resolved by this realization. In respect to being on the right track with Zeno's paradoxes, in different ways, the same can also be said for Henri Bergson, William James, Alfred North Whitehead, Leo Tolstoy, Abraham Fraenkel, Karl Popper, Gerald Whitrow, David Robjant, Frank Arntzenius, David Albert, and no doubt a number of others.

3. INSTANTANEOUS MAGNITUDES

Not only does an object in relative motion not have a determined relative position, but all physical magnitudes cannot be determined at an instant either. If relative position is not determined at an instant, neither can velocity (the rate of change in relative position with respect to time).[4] If velocity is not determined at an instant, neither can acceleration (the rate of change in velocity with respect to time), momentum (velocity multiplied by mass), kinetic energy $E_k=½mv^2$, wave speed c, period T, frequency f, wavelength λ, radiation energy per quantum or Planck's relation $E=hf$, force $F=ma$, relativistic mass and relativistic momentum $p=\gamma mv$, according to $E=mc^2$, rest mass and energy, Newton's universal gravitation $F=G(M_1m_2/r^2)$, gravitational potential energy $Ep=mgh$, and through the subsequent derivation of the remainder of the equations of physics, neither can any physical magnitude.[5] Importantly, however, this universal indeterminacy in changeable physical magnitude is not associated with the preciseness of the measurement, or the result of quantum uncertainty.[6] In exactly the same way that an object in motion does not have a determined relative position because its position is constantly changing, and the idea of its motion having a "limit" at an instant is faulty, instantaneous magnitudes do not exist either. Put another, more general way, the whole idea of Nature being frozen and determined at an "instant" is erroneous, as Nature is dynamic and forever changing.

The only situation in which a changeable magnitude would be precisely determined is if there were an instant in time underlying physical processes, and as a consequence, a system was frozen static at that instant. In such a system, an indivisible mathematical time value, say 2 seconds, would correctly represent an instant in time, rather than an interval in time. Fortunately this is not the case, for if it were, this static frame would include the entire universe, and the cosmos' evolution would not be possible. Thankfully, it seems that Nature has wisely traded certainty for continuity, with there being a necessary trade off of determined physical magnitudes at a particular time, for their continuity over interval.

3.1 INSTANTS AND INTERVAL

Before continuing there are some technical issues associated with instants of time that I would like to touch on. Earlier it was explained that an instant in time could not exist, because if it did, as is its very nature, everything would by way of logical necessity also be frozen static at that instant. Although such a situation would enable a body to have a determined relative position, motion and change would be rendered impossible. Furthermore, everything would remain frozen at that instant, as by definition, an instant has no duration, so there could be no progression. Incidentally, the same outcome would also

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[4] There has recently been debate over the existence of instantaneous velocities. See, Arntzenius, F. Are there really instantaneous velocities? *Monist: An International Quarterly Journal of General Philosophical Inquiry*, 83(2):187–208 (2000); and, Smith, S. R. Are instantaneous velocities real and really instantaneous?: An argument for the affirmative. *Studies in History and Philosophy of Modern Physics*, 34B(2):261-280 (2003).

[5] One might ask if constants, such as the speed of light in a vacuum, negate this? Although such constants are exact, their being so is unrelated to the instantaneous. They are not determined at an "instant".

[6] The only connection to quantum uncertainty here is that it is normally assumed that if it were not for the uncertainty principle, physical magnitudes would be exactly determined. The non-existence of instantaneous magnitudes means that, even if there were no such thing as quantum uncertainty, physical magnitudes would still not be exactly determined. The impetus of physics becomes entirely measurement based, whether actual or theoretical, and a question of precocity of such measurement i.e. intervals. That is, magnitudes such as energy and mass only gain their meaning through measurement.

result if an instant in time were hypothetically followed by a continuous sequence of further instants, as again, an instant has no duration, so neither could a further succession of them. In either case, rather than enabling motion, this would perpetuate a static instant in time, and motion and change would be impossible.

However, there are some problems associated with such a conclusion. By definition, for something to be static, it must be unchanging for an extended interval of time. But how then could time be said to be frozen static at an instant when being so would require it to be static and unchanging for an extended interval? It seems a contradiction. In relation to a regular and sensible definition of static, this no doubt is. When the definition is applied to time itself, however, a paradox appears. If there were such things as instants in time, everything, including clocks, would also be frozen static, and interval in time would not be possible either. There could be no interval in time for something to remain unchanging. Thus, the normal definition of static breaks down when it is applied to time itself, and we are forced to search for a revised definition for this special temporal case. Thankfully, such a definition quickly becomes evident, and simply requires one to qualify the use of stasis by defining static in the case of time as not being over duration. In spite of this, it should also be just enough to be aware of the problem of applying the notion of stasis to time itself and to not worry too much about it, including in connection to the use of words such as "remain" in this context.

4. THE EXISTENCE OF TIME, SPACE AND SPACE-TIME

The conclusion that instants in time and instantaneous magnitudes do not exist has some further implications. Perhaps the most striking one relates to the nature of time itself. If there is no such thing as an instant in time, there can also be no "flow" or passage of time, for without a continuous progression through indivisible instants or nows (the things that would constitute the building blocks of time) over an extended duration, there can be no physical progression or flow. In other words, there is nothing there, no temporal stepping-stone, for which time could possibly use to progress. Somewhat similar to how an invisible ether was once assumed to permeate throughout the entire universe, Newton's invisible river of time, assumed by many to enable motion and change as it proceeded, cannot exist either. It has no water. Further, the same can be said for the existence of space due to the lack of spatial points.

What this means is that, not only are time and space not absolute, with judgements of position in space and nows in time being relative (the time aspect being shown by relativity), but there are no such things as relative position, nows, nor things called "time" or "space", existing independently of us at all. This may seem counter-intuitive, for in respect to time, it might suggest that if it were not a fundamental physical entity, the entire universe would be frozen static and motionless at one particular instant as though stuck on pause on a movie screen. However, if the universe were frozen in such a manner, this would constitute an instant of time—time would be a physical thing, rather than not. Indeed, so presumably would space, as such an instant would represent the same thing (i.e. a static block of "something", somehow different from matter, filling the entire universe), while also having the same affect on continuity. Thus, it seems that it is actually due to Nature's exclusion of time and space as fundamental physical things, that motion and change are possible, and that intervals of time and space are able to "represented" by clocks and meters in the first place.

The idea that time might not flow and that the passage of time may be an illusion, is clearly not at all a new one, and from the time of the ancient Greeks, a number of different arguments have been put forward supporting the notion.[7] In addition to the lack of differentiation between past, present and future in relativity, one of the best was the question posed by the Australian philosopher of science, Jack Smart. How fast does time pass? [9]. Speed is defined as the rate of change of position with respect to time. So how then can time possibly move in time? One second per second? This should have really spelt the end to the idea of a flowing time, but as it is the intuitive view—and indeed, no doubt extricably tied up with our conscious perceptions—its existence has continued to be assumed by many. With, perhaps, a perceived lack of a truly fundamental argument against time's passage, some have also seemed happy to sit on the fence about the issue. That many people seem to assume that time and space as they enter general relativity are literally curved by the presence of matter and energy, as if

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[7] Today, Carlo Rovelli is a notable exponent of the hypothesis that both time and space do not exist. See, for example, Rovelli, C. The disappearance of space and time, in Dieks, D. (ed.), *The ontology of spacetime.* The philosophy and foundations of physics, Volume 1, pp. 25—36. Elsevier (2006).

they were actual physical "things" (rather than just interval in time as represented by a clock, and interval in space—length, width and height—as represented by a ruler, being dilated by them, and, among other things, the non-Euclidean geometry of general relativity providing an effective way of modeling the motion of a body within this context), would not have helped much either.

Indeed, the absence of instants in time and spatial points spells bad news not only for time and space, but for space-time as well. As they assume instants and spatial points in order to bound and determine their contributing temporal and spatial values as intervals, time and spatial coordinates in special and general relativity also have no physical reality. This then means that the same can also be said for space-time points (which consist of one time and three spatial coordinates), space-time intervals (the distance between two space-time points on a space-time manifold), and as such, the space-time continuum itself.

In relation to space-time having no physical existence, this is far from a revelation. Late in his life, Einstein himself held this view.[8] It just seems that this point has been lost on a number of subsequent physicists and mathematicians, seemingly unable to make the same differentiation and recognize the limits of applicability of Einstein's model of space and time.[9] As the reality of space-time would have been seen by many physicists and mathematicians as being more of a philosophical question—a distraction to the real business of solving equations—some would also have not been overly concerned with such an issue. The existence of theories that assume the physical reality of space-time—for example, relativistic time-travel [10, 11], imaginary time [12], and arguably, cosmological inflation [13]—would bare witness to this.

Paradoxically, even physicists who held that time or space-time did not exist, seem to have failed to realize that by assuming that events were underpinned by instants and nows, they were inadvertently saying that time and space-time did exist. Perhaps the most striking example of this is the Oxford physicist Julian Barbour, who made instants and nows a central feature of what he saw as being a completely timeless view of the universe [14]. However, the same can also just be said for physicists who assumed that Newtonian mechanics, special and general relativity, or quantum theory (in the context of formalism like Schrödinger's equation), provided an accurate description of Nature, in the sense of assuming that an instant or a space-time event, both static entities, had a physical basis. The same can again be said for the positing of definite positions in Bohmian mechanics [15].

Surprisingly, although also somewhat unsurprisingly, it seems that late his life, not only did Einstein negate the existence of space-time, but the existence of instants too. Up until near the end of his life, Einstein regularly talked meaningfully, in a physical sense, of instants and exact positions and magnitudes, not taking issue with them. Three such examples, two from his 1905 paper on special relativity [16], and one from an essay written on the occasion of his 70th birthday in 1949 [4], are included below:

> ...that is to say that their [synchronized clocks] indications correspond at any instant to the 'time of the stationary system' at the places where they happen to be. [p. 4]

> If the electron is at rest at a given epoch, the motion of the electron ensues in the next instant of time according to the equations...[p. 20]

> A problem arises only when we ascribe group-characteristics to a theory, i.e., if we assume or postulate that the same physical situation admits of several ways of description, each of which is to be viewed as equally justified. For in this case we obviously cannot ascribe complete objective meaning (for example the x [position]-component of the velocity of a particle or its x-coordinates) to the individual (not eliminable) magnitudes. [p. 680]

In relation to not taking exception with instants, however, there is a rather notable exception. Somewhat at odds with the quote just above, in the very same essay, while arguing the statistical interpretation of quantum theory was incomplete, we find this:

> To this the quantum theorist will reply: This consideration stands and falls with the assertion that there actually is such a thing as a definite time of disintegration of the individual atom (an instant of time existing

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[8] "Space-time does not claim-existence in its own right, but only as a structural quality of the [gravitational] field." Einstein, A. *Relativity: The special and general theory*. Appendix V, (1952), p. 155. Methuen & Co Ltd (1920).

[9] This by no means implies all. See, for example, Brown, H. R., Pooley, O. Minkowski space-time: a glorious non-entity, in Dieks, D. (ed.), *The ontology of spacetime*. The philosophy and foundations of physics, Volume 1, pp. 67—89. Elsevier (2006).

> independently of any observation). But this assertion is, from my point of view, not merely arbitrary but actually meaningless. The assertion of the existence of a definite time-instant for the disintegration makes sense only if I can in principle determine this time-instant empirically...
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> One may not merely ask: "Does a definite time instant .for the transformation of a single atom exist?" but rather: "Is it, within the framework of our theoretical total construction, reasonable to posit the existence of a definite point of time for the transformation of a single atom?" One may not even ask what this assertion *means*. One can only ask whether such a proposition, within the framework of the chosen conceptual system - with a view to its ability to grasp theoretically what is empirically given - is reasonable or not. Insofar, then, as a quantum-theoretician takes the position that the description by means of a Psi-function refers only to an ideal systematic totality but in no wise to the individual system, he may calmly assume a definite point of time for the transformation. But, if he represents the assumption that his description by way of the Psi-function is to be taken as the complete description of the individual system, then he must reject the postulation of a specific decay-time. [p. 668]

In other words, here Einstein denied the existence of instants of time on the basis of their not being empirically verifiable, and thus, also rejected that an atom could decay at a definite exact time. With his earlier comment suggesting that he had yet to, and with no further related writings on the topic, one can only speculate whether Einstein later took this conclusion through to its logical ends.

4.1 MOTION VS. INTERVAL

Before continuing, it may be a good idea to briefly reiterate some things. Time, space, and space-time too, do not exist. Physical continuity (i.e. the capability for events to be continuous), and as such, motion and change, do exist, however, and this in turn enables the hands of a clock to rotate, and thus, one to indicate an interval of time. It also enables progression along the length of a ruler, and one to indicate an interval of length or space. This then in turn also provides intervals to use for space-time coordinates and to derive a space-time manifold in relativity. As such, because the presence of physical continuity enables one to indicate intervals with a clock or ruler, interval of time and space, and consequently, space-time too, still have much meaning in physics.

Time is what a clock measures

Despite the above quote, now an oft-cited response by physicists to the question of “What is time?”, it should be noted that, strictly speaking, clocks and rulers do not actually “measure” intervals of time and space. As they do not refer to anything except themselves, they themselves “represent” them. That is, there is no flow of time, and it is physical continuity which is basic and fundamental, not interval, so there is nothing *there* to measure. In a similar sense as running or jumping are secondary to movement and motion, interval is a derivative concept and secondary to physical continuity, and as such, motion and change.

Interestingly, the above quote is often attributed to Einstein. That Einstein would have said this puzzled me, particularly as a key feature of the dilation of time in relativity was Einstein’s treatment of time as being nothing more than that what a clock showed. On locating Einstein’s original quote, it came as no surprise then to find that what he actually said, “Zeit ist das, was man an der Uhr abliest” [17], translates to “Time is what one reads off the clock." Although the difference seems tiny, as “measure” asserts that there is something “there” to be measured, while “reads” neither affirms or denies time’s existence (but leans towards the latter), it is actually quite big. With Einstein not believing that time existed: “Time and space are modes by which we think and not conditions in which we live” [18], and on finally embracing general covariance, “by which time and space are robbed of the last trace of objective reality” [19], I think it doubtful that his choice of words here are a coincidence.

The question of interval’s existence is a very subtle topic, however, especially so because an assertion that is physical continuity which is basic and fundamental rather than interval, could equably be reversed, and interval in time and space be said to have physical existence (something which *could* be measured), this making physical continuity, and as such, motion and change possible. This is because both are completely indistinguishable, in so far as they both represent exactly the same thing (i.e. the capability for events to be continuous). Yet, they are also mutually exclusive, in that only one can be fundamental and come first. This poses a brilliant paradox, as, and although the same cannot be said for a specific interval of time or space due to, by definition, their requiring the existence of instants and spatial points to bound and determine their respective values as intervals, this indistinguishability also makes it impossible, in purely logical sense anyway, to say whether it is physical continuity, and as such, motion and change, which is basic and fundamental (with interval having no physical existence), or if it is the existence of interval which makes continuity possible.

However, I think that once this paradox has been brought to light, it becomes evident that the indistinguishability between the two is the major cause of people mistakenly attributing physical reality to interval in the first place. They have not realized that there is a more basic explanation. I also think it doubtful that Nature would go to the trouble of giving interval in time and space existence, when just the presence of motion would fulfil the same purpose. Finally, unlike us, without a need to "measure" intervals of time and space, Nature also has no reason to bother attributing reality to them!

5. BLOCK TIME

What of the mismatch between the block universe and change? As explained earlier, relativity tells us that all times in the universe, past, present and future, are all laid out together in a fixed, four-dimensional space-time block. This follows as a natural consequence of the lack of a preferred present motion in relativity. However, this "block" view of time seems to be very much at odds with how we as people seem to experience the world where, subjectively, time seems to flow. Indeed, a number of physicists and philosophers view this seeming incompatibility as representing a real problem, because with all events and times already laid out together, they do not see that this allows for motion and change [1]. In an effort to remedy this, some have gone as far to posit that time does indeed flow in relativity, with it being claimed that proper time evolves along families of world lines. It is argued that this then allows for the existence of the present, the past, and for physical evolution, and thus, an "Evolving block universe" [20]. More often, however, people just accept that motion and change are illusions [14, 21]—even though such a view is also incompatible with the need for the continuity and associated motion of neural processes that an observer would require in order to subjectively perceive such an illusion.

However, as long as one recognizes that instants, the instantaneous, and space-time points—all static, discontinuous entities—do not actually exist, motion can still take place with such a "block" view. One must just solely focus on the matter and motion in the universe, and except for the interval as represented by a clock being used as the reference, completely forget about time, the past, present and future, while recognizing that instants and space-time points are simply constructs. Furthermore, one can still assign an order to events in Nature, in the same way one can say that 2 follows 1, and 3 follows 2, without making reference to tense, before and after, past and future.[10] This also naturally applies to the readings of a clock. If interpreted in this way, any potential problem disappears, and motion and change can be seen to be entirely compatible with a timeless view of reality in which there is no preferred present moment. That is, while the lack of differentiation between past, present and future in relativity negates a flow of time, it by no means negates motion and change. The only thing that does this is the assumption that the instantaneous is real, or the presumption that without time, motion is not possible. The "Evolving block universe" explicitly assumes both. Indeed, and although one can certainly sympathise with the motivation behind doing so, by asserting the existence of time and the present, such a model only guarantees that motion and physical evolution would be impossible.

6. TIME AND SPACE'S QUANTIZATION

Lastly, a further implication of the conclusion that instants in time and spatial points do not exist relates to the question of whether time and space may be quantized and come as discrete atoms—particles of time and space [4, 5]. In light of the conclusions discussed in this paper, it becomes evident that the very reason events are continuous in the first place is due to there *not* being an atom or quantum of time or space. As such particles would represent a smallest possible interval—not just the smallest that we are able to operationally define as per Planck time $5.39124(27) \times 10^{-44}$ seconds and Planck length $1.616252(81) \times 10^{-35}$ meters, but which actually physically exist—such intervals would require starting and stopping points to bound and determine them as intervals. As was discussed earlier, if such stops existed, motion and change would be impossible. For this same reason, a so-called non-zero duration instant cannot exist either. This does not mean, however, that the readings of clocks and meters cannot be quantized. With any clock and meter being constituted of matter, they should be. But this has nothing to do with "time" and "space" being quantized. Rather, matter.

7. DISCUSSION

[10] In this same way, the thermodynamic arrow of time becomes a question of the relative order of events (i.e. 1, 2, 3 or 3, 2, 1), rather than of the direction of time.

It has been argued that despite generally being assumed to in physics, instants in time and the instantaneous do not exist. Although reality might disagree, in many cases whether or not instants exist is of no consequence. With or without instants, the equations of physics still work exactly the same and the numbers that they provide remain just as useful. The real problem arises when these faulty assumptions are not recognized and then lead to contradiction and paradox (as with Zeno's paradoxes, or the perceived mismatch between the block universe and change), or they are unknowingly built into theories whose possible validity is dependent on them (as with time and space's quantization). Naturally, the same pothole lays in wait for theories that assume the existence of time, space, or space-time.

It is surprising that the existence of instants and instantaneous magnitudes seem to have always just been assumed, but I think there are at least three good reasons for how this may have come about. The first is attributable to the nature of mathematics, as when applied to physics, it implies that functions and mathematical values are indicative of instants and instantaneous values rather than intervals. Indeed, a similar thing can be said for a photograph, with people often assuming that a picture is representative of an instant of time, rather than a small interval. Secondly, I believe that we actually *think* within the context of an instant in time and project it onto the world around us [22]. For example, if one thinks of a car driving down the road and is asked if it has a determined relative position to the road, one can mentally picture it having one, so assumes that it does. Indeed, one can only mentally picture the moving car in the context of static frames or instants. As with time in general, when something is fundamentally ingrained in the way a person actually thinks, it can be very difficult to see around it. I think this especially applies to the present, with it being irreducibly tied up with our ability to be consciously aware [22]. Lastly, I think that most people just assumed that issues such as the instantaneous and limits were settled and beyond reproach. Their validity was not thought to be in question. This also probably represents the work's greatest obstacle, as a number of people seem to find it very difficult to believe that we could have got it wrong. It just seems a bit too unlikely.

The most common criticism of the work has been that it has no mathematical model to back it up. This has also surprised me. Much of the point of the work is to show that calculus has its limitations when trying to accurately represent Nature—something dynamic—in the sense that it freezes everything upon being applied. To try to employ calculus itself to show this would be impossible; akin to trying to use sound to explain why sound cannot be used to describe taste. The same applies to perhaps employing nonstandard analysis, a branch of mathematics developed by Abraham Robinson during the 1960's, which provides more of a logical foundation for infinitesimals [23].

Finally, it should also be noted that, other than that motion and physical continuity should be possible, and that time and space are not quantized, this work is not able to make any verifiable predictions. That is, we already know that physical continuity is possible, as my being able to write this demonstrates, so predicting that it should be is a bit redundant! Perhaps trying to devise an experiment to prove the non-existence of instants of time, time or space, when none of them will ever show up in an experiment, is also a bit redundant—not to mention slightly paradoxical. This places a firm limit on the work's value to physics as a theory. Indeed, with it being more concerned with the foundations of physical theory, it is not really a theory at all. At the same time, with the instantaneous being so deeply imbedded in them, both overtly and veiled, and with questions relating to the existence of time also being very pertinent in both, I think that some non-trivial work in quantum mechanics and quantum gravity could potentially stem from ideas discussed in this paper.

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REFERENCES

[1] Isham, C. J., Polkinghorne, J. C. *The debate over the block universe.* Conference on Quantum Cosmology and the Laws of Nature: Scientific Perspectives on Divine Action, p. 135 – 144 (1993).

[2] Snyder, H. S. Quantized space-time. *Phys. Rev. 71*, 38 – 41 (1947).

[3] Smolin, L. Atoms of space and time. *Scientific American*, January (2004).

[4] Schilipp, P. A. *Albert Einstein: Philosopher-Scientist.* Cambridge University Press (1949).

[5] Salmon, W. S. An "at-at" theory of causal influence. *Philosophy of Science*, Vol. 44, No. 2, pp. 215-224 (1977).

[6] Lynds, P. Time and classical and quantum mechanics: Indeterminacy vs. discontinuity. *Foundations of Physics Letters*, 16(4). 343-355 (2003).

[7] Morris, R. *Achilles in the quantum universe*. Redwood Books, Trowbridge, Wiltshire (1997).

[8] Kant, I. *Critique of pure reason.* P. Guyer and A. W. Wood (eds.), Cambridge University Press (1999).

[9] Smart, J.J.C. The river of time. In Flew, A. (ed.), *Essays in conceptual analysis.* St. Martin's Press, New York, pp. 213-227 (1966).
[10] Gott, R. J. *Time travel in Einstein's universe: the physical possibilities of travel through time*. Houghton Mifflin; 1st edition (2001).
[11] Thorne, K. S. *Black holes and time warps: Einstein's outrageous legacy*. Picador (1994).
[12] Hawking, S. W., Hartle, J. B. Wave function of the universe. *Phys. Rev. D* 28. 2960 – 2975 (1983).
[13] Guth, A. H. The inflationary universe: A possible solution to the horizon and flatness problems. *Phys. Rev. D* 23, 347 (1981).
[14] Barbour, J. *The end of time*. Oxford University Press (2001).
[15] Cushing, J.T., Fine, A.I., Goldstein, S. (Eds.). Bohmian mechanics and quantum theory: an appraisal. *Boston Studies in the Philosophy of Science*, Vol. 184, Hardcover Dordrecht: Kluwer (1996).
[16] Einstein, A. Zur elektrodynamik bewegter korper. *Annalen der Physik*. 17:891 (1905).
[17] Hunziker, H. *Der jugendliche Einstein und Aarau: Einsteins letztes Schuljahr*. p. 121. Birkhäuser, Basel (2005).
[18] Forsee, A. *Albert* Einstein: *Theoretical physicist.* p. 81. New York: Macmillan (1963).
[19] Einstein, A. Erklarung der perihelbewegung des merkur aus der allgemeinen relativitatstheorie. *Sitz. Ber. Preuss. Akad. Wiss*. Vorg. Am 18 November, p. 831 (1915).
[20] Ellis, G. F. R. *Physics in the real universe: time and spacetime.* http://arxiv.org/abs/gr-qc/0605049 (2006).
[21] Petkov, A. *Relativity and the nature of spacetime*. Springer-Verlag, Berlin Heidelberg (2005).
[22] Lynds, P. Subjective perception of time and a progressive present moment: The neurobiological key to unlocking consciousness. *Cogprints E-print Atchive.* http://cogprints.org/3125 (2003).
[23] Robinson, A. *Non-standard analysis* (Revised edition ed.). Princeton University Press (1996).