Einstein's Space-Time Continuum

K. D. Sethna

Modern man is increasingly intrigued by the problem and the natu[re] of time. In this article the author suggests not only that modern relativi[ty] theory bridges between such metaphysical concepts as "the eternal now" and time as we know and measure it in the everyday world, but also tha[t] according to this theory ultimate reality would seem to be a "play o[f] consciousness" rather than a material structure. In part I the scientifi[c] background is reviewed briefly and the philosophical implications of relativity theory are discussed in part II.

I

THE most notable contribution by Einstein's scientific work to the world of thought is the concept of a four dimensional continuum of space-time to replace Newton's of a three-dimensional space and a one-dimensional time. But the exact significance of it is seldom realised.

We may remember that it arose out of Einstein's first or restricted theory of relativity. This theory showed that space-calculations and time-calculations are relative to, or vary with, motion in a close cooperation among themselves: when the space numbers change, the time numbers change too, and *vice versa*, as if space and time were quantitites perfectly analogous though not of the same kind, instead of being, as in Newton's physics, non-analogous though never dissociated. In other words, the two quantities depend on motion as if they were differentiations of one and the same quantity: the rod measuring space and the clock measuring time seem two distinguishable modes of measuring a single system of dimensions. Briefly, space and time appear to be somehow the same in spite of being dissimilar: they give the impression of being an identity-in-difference.

This impression gets completely confirmed by the mathematical form on which Minkowski struck in order to find, for the various conjoint time-and-space readings obtained at different rates of motion for an event, a common quantity which would be an invariant reading, an absolute measurement unifying the relativities. He was intuitively guided by the fusion of some sort which Einstein's theory had suggested in regard to space and time. He showed that the invariant reading, the absolute measurement, which he called the "interval," would be yielded if the time-quantity obtained within each moving frame of reference were subtracted in a certain way, from the space-measurement. Mathematically, this not only unified the relativities but also illuminated the nature of space and time. For it is a platitude in mathematical physics that we cannot add one quantity to, or subtract it from, another unless the two quantities are of the same kind. We can multiply one kind of quantity by another, as mass by velocity to give momentum. We can divide one kind of quantity by another, as energy by time to give horse-power.

But we cannot add mass to velocity or subtract energy from time to give any physical quantity unless they are somehow identical. Similarly we cannot add inches to seconds or subtract seconds from inches unless we mean to imply that somehow the same entity is measured partly by a rod and partly by a clock. There cannot be two entities: space and time. There must be only one entity: space-time.

However we must not forget that the numbers for space and for time are obtained in wholly different manners: a rod is used in the one case and a clock in the other. And it is because of these different manners that Minkowski spoke of subtracting the time-measurements from the space-measurements. If the manners were identical, the measurements would simply be added together, just as we add together the quantities of length, breadth and height—all of them space quantities. The space-time demanded by relativity theory is an irregular and not a regular four-dimensional continuum, or rather, since there is fusion of the components as well as differences in them, it is a four-dimensional continuum irregularly regular.

No doubt, Minkowski finally subjected his formula to a couple of mathematical operations which tended to cover up this point. He employed a special technical procedure to alter the minus sign, between the space numbers and the time number, to a plus sign; and he substituted the number of miles light travels in one second—a constant 186,000 in all frames of reference—for the one second itself. So the time-dimension was made equivalent to a space-dimension. These operations are justified since thus alone the four dimensional continuum becomes the absolute of Einstein's relativities in the simplest form possible, and best explains the facts of scientific observation and experiment and turns most apt for practical calculations. But all that was done by Minkowski's analytic insight does not add really a fourth space-dimension to the other three. The very need of those mathematical operations which brought about an "isotropy" (or similarity in all directions) is proof enough of a certain difference between the triple component and the single component in spite of their fusion. A true fourth dimension of space would require no such strange treatment. The treatment is administered just because space-time is irregularly regular.

But, we must add, the irregular element makes no odds to the revolutionary character of this four-dimensionality. Here is no longer a four-dimensional continuum such as may be thought to have always been constituted by the fact that nothing happens at any place except at a particular time, and nothing happens at any time except at a particular place. Much more is involved here than that space and time are co-existent, and inseparable and that science therefore has always used four numbers to describe events in nature —three to characterise the position and one to characterise the instant of an event. Science in the past never took its four co-ordinates of measurement to connote a fusion of space and time. The general framework of physical thought is not at all the same as before. Einstein's theory leads us to a radically revolutionary reality.

II

Now we may ask: Is the revolution introduced by Einstein's four-dimensional continuum confined to physics, with no bearing on a philosophical view of the world, or does the fusion of space and time call for a look by us in a direction beyond materialism?

As already remarked, the fusion does not, of course, reduce time to a space-dimension: time is still time—but it acquires the properties of space. A fourth dimension of space would break the limitations of the three space-dimensions: for instance, if one had a fourth space-dimension to move in, one would not be limited by being enclosed in a room covered in the directions of length, breadth and height, for one more direction would remain without any cover and one could enter the room from it. But the time-element would not be changed in any basic sense: time would continue to be a movement from past to present to future just as much as it is now in our normal vision of it. When the dimension of time enters into a four-dimensional continuum and is welded on to space in the way in which within space itself the three dimensions of length, breadth and height are welded to one another, then it is not the spatial limitations of these dimensions that are broken. What are broken are the limitations of time itself for those dimensions—limitations due to time's being a separate dimension from them. If time is fused with space in the continuum whose mathematical structure is specified by Minkowski, time without ceasing to be time gets spatialised. To put it more concretely: just as all points of space are co-existent, all instants of time are co-existent—the past and present and future of spatial points co-exist as if they themselves were spread out in space.

Our heads are bound to grow dizzy with this import. But that is no test of its not being the truth. Nor can truth stop being truth when our heads grow dizzier still on our understanding what the scientific concept of causality and determinism becomes in connection with this import. Strict causality and determinism are there in the sense of an unseverable hanging together: the very word "continuum" ensures unbrokenness. But pre-relativity physics took causality and determinism to be working from past to present to future. In the four-dimensional continuum of actually fused space and time, where the three times co-exist, there is evidently no one such unique direction for causality and determinism to work in. So the scientific use of causality and determinism may be considered as representing for practical purposes the truth only if the experience which leads us to this use is the sole or the predominant one. It certainly is not the sole one. We have the experience in which we feel a sense of freewill: there we appear to be to some extent unbound by the past and creative of the future and able to re-create the past by depriving it of the effect the scientific use of causality and determinism would ascribe to it as inevitable. We have also the experience in which we feel a sense of goals or ends, of a purpose that seeks realisation as if from a future through the present and which, by causing the present, determines also the past which the present constantly becomes. The whole time-flow then seems in the direction opposite to that which is assumed by science. But, inasmuch as the latter is also never absent in our experience even when we have a sense of freewill and the sense of a pre-existing and purpose-realising future and inasmuch as there has been no sure ground for not regarding the future as still to be born rather than as something already real and for regarding the present as co-existent with the past no less than with the future, we have allowed the experience leading to the scientific use of causality and determinism to bulk in our minds above any other. We have let this experience cast on the others a colour of unreality or lesser reality, things to be somehow brought into line with it. With the concept of the four-dimensional continuum we find that there is no reason to give that experience any predominance. So the direction dictated by that experience to causality and determinism can have only a certain degree of truth. Degrees of truth are possessed also by the directions suggested by our sense of freewill and our sense of a pre-existing and purpose-realising future.

Perhaps the greatest degree of truth is given by what is actually our time-experience. What we know as time is a continuous present with projections into both the past and the future, projections concealed in the one case except in the form of memory and in the other except in the form of imaginative or predictive anticipation. The primary datum is the present, from which past and future are arrived at by means of theoretical constructions. If this is so, then in view of the impartiality of the four-dimensional continuum, our sense of limited freewill which is associated with the present may be taken by us as the truth predominantly supported by the absolute arrived at in Einsteinian physics.

We may even say that the four-dimensional continuum is precisely such as predominantly must support this truth in the world of threefold time-experience that is ours. For, what do we mean by a co-existence of the past and present and future? Do we not mean an all-comprehensive Now, with no succession of events —a Now of which our continuous present is a faint inkling?

And taking a cue from our own limited Now and its sense of freewill we may surmise that the comprehensive Now of the ordered totality of events in all the three times is an immense multiple creativity. Such a conception does full justice to both the truths involved in the irregular regularity of the four-dimensional continuum: the truth of space by which points stand together and the truth of time by which instants succeed each other—a co-existence coupled with dynamism so that the spread-out events of the three times are the signs of an ordering creativity immense and multiple though non-successive.

It is difficult not to think this creativity the physical counterpart or expression of the freewill of a cosmic consciousness. We have definitely to look beyond materialism if we accept Minkowski's fusion of space and time to be actual. And Einstein's general relativity theory, which came ten years after his special or restricted one, does not in the least forbid us to do so. What that theory does is just to link up material masses with the four-dimensional continuum: it establishes a certain relation between these masses and space-time in the sense that the amount of material mass is proportional to a degree of geometrical structure of space-time and that the accelerations of the masses can be calculated according to the overall space-time structure answering to the comparatively larger or smaller mass-amounts neighbouring one another. Thus the movements of the planets around the sun are said to be in accordance with the more dominating structure in space-time answering to the sun's greater mass than the one answering to the smaller masses of the planets. Newton's force of gravitation which was supposed to act directly from mass to mass is dispensed with and an entirely new notion comes in by which the state of space-time between the disproportionate masses explains their mutual "gravitational" behaviour—a new notion which has passed some crucial tests in which Newton's calculations proved wrong.

The state of space-time involved is called in technical mathematical language "curvature." Newton had considered space to be "flat": just as on a flat surface the natural motion, as well as the shortest line between two points, is straight, so also in flat space the natural motion is straight and a straight line is the "geodesic" or shortest distance between two points. Space thus considered is known as Euclidian. Although some geometricians in the nineteenth century had evolved non-Euclidian geometries of space, nobody ever imagined that these could correspond to reality. But when Minkowski set up the formula of an irregularly regular four-dimensional continuum, the minus sign of the fourth dimension prevented the geometrical properties from being quite Euclidian as they would have been if no irregular feature had been there. His geometry was semi-Euclidian or hyperbolic rather than non-Euclidian. However, it opened Einstein's eyes to further possibilities and, when he attempted to bring into his scheme the accelerated motion characteristic of "gravitational" effect, he applied to the four-dimensional continuum the spherical geometry of Riemann, the geometry which Riemann had extended to space of three or more dimensions from a curved surface instead of the Euclidian geometry which had been extended to space from a flat surface. Einstein discovered that in space-time the simplest analogue of the quantity which for a curved surface is termed "curvature" solved his problem if he made the curvature proportional in a certain manner to the amount of material mass present. The curvature of space-time calculated in the region of the sun's neighbourhood gave in space the exact orbits of the planets and in time the exact change of speed-rhythm which the planets exhibit as they move nearer or farther from the sun in their various ellipses.

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What bearing have the several features of the general realtivity theory on the beyond-materialism interpretation ? First if the continuum is capable of geometrical structure, it must be "substantial" in some sense: the ordering—immense and multiple though non-successive—would represent not only a cosmic consciousness but also a cosmic being. The pointer away from materialism seems strengthened. Secondly, the material masses by being brought into relation with the "substantial" continuum may themselves be thought not only integrated with it in one whole but also identical with certain characteristics of it and appearing otherwise by simply being a certain manifestation of it. Of course, until all the characteristics of matter, particularly its atomicity, are explicable in terms of space-time structure, we cannot affirm this last possibility. Signs, however, are not lacking to persuade us that we are on the right track. They are noticeable in connection with the invariant "interval" in space-time which is the aboslute of the relative distances and durations.

Sullivan, in his *Aspects of Science* (Second Series) puts the case very well. "From this relation, the interval," he writes, "various complicated mathematical expressions may be built up by purely mathematical analysis. At a certain stage in this process we reach expressions which obey exactly the same equations as density, stress, momentum, etc. Now these latter quantities, density and so on, form what a physicist means by a piece of matter. But the mathematical expressions derived from the interval refer to geometrical properties of the continuum—to its curvature, for example. What is the meaning of the fact that certain geometrical properties of the four-dimensional continuum and certain physical quantities, characteristic of matter, obey the same equations ? The suggestion is that the physical quantities and the geometrical properties are the same thing..."

Their being the same and yet seeming different is explained by Sullivan in the immediately next phrase in terms that are a little doubtful. He states the above suggestion in other words as "that what we call matter is, indeed, only the way in which our minds perceive the existence of these geometrical peculiarities of the four-dimensional continuum." No doubt, the human mind has a good deal of say in the perceptual experience that it has of reality; but the more balanced view would appear to be that the world of matter and of relative space and time is itself an actual manifestation of the four-dimensional continuum and certain aspects of this manifestation are discovered and interpreted by the human mind rather than completely created by it in response to that hidden reality. That reality and this manifestation have both of them the look of a physical counterpart or expression of a Conscious Being at work; so the granting of an "objective" status to the world of matter and of relative space and time does not diminish the primacy of Consciousness and what the human mind does in its perceptual experience is just to get into a particular sort of communication with the ultimate Consciousness. All is play of Consciousness, but a complex multifold play. And part of the play is the actual existence of Sullivan's "matter" and of scientifically measured space and time as differentiations of one and the same quantity, differentiations which seem distinctions as of two quantities so long as an event is studied in reference to a frame in relative motion at a rate very far from that of light but which reveal their true nature as soon as velocities nearing that of light are met with. The world of perceptual experience is very different really from our older pre-Einsteinian picture of it, yet it still remains objective in a certain valid sense so far as the human mind is concerned.

But, objective or no, the main point stands that material properties appear to be basically identical with space-time structure. And we may add that the whole implication of Einstein's repeated effort to create a "unified field theory" taking into its sweep electro-magnetism no less than gravitation and accounting for the particle-nature of matter is this very point. So the curving that the general relativity theory gave to space-time has brought in its train a many-sided accession of strength to the interpreters who feel drawn by the special relativity theory beyond the confines of physics and beyond a materialistic world-view.