What spacetime explains

Metaphysical essays on space and time

GRAHAM NERLICH

Professor of Philosophy, University of Adelaide, South Australia

CAMBRIDGE
UNIVERSITY PRESS

Published by the Press Syndics of the University of Cambridge
The Pitt Building, Trumpington Street, Cambridge CB2 1RP
40 West 20th Street, New York, NY 100111-4211, USA
10 Stamford Road, Oakleigh, Melbourne 3166, Australia

Printed in Great Britain at the
University Press, Cambridge

Library of Congress cataloguing in publication data

Nerlich, Graham, 1929–
What spacetime explains: metaphysical essays on space and time/
Graham Nerlich
p. cm.
Includes bibliographical references and index.
ISBN 0 521 452619 (hardback)
1. Space and time. 2. Relativity (Physics) I. Title
BD632.N47 1994
115 – dc20 93–27336 CIP

GCN

Graham Nerlich is one of the most distinguished contemporary philosophers of space and time. *What spacetime explains* brings together eleven of his essays in a single carefully structured volume, dealing with ontology and methodology in relativity; variable curvature and general relativity; and time and causation. These essays argue that space and time are comprised in spacetime, that spacetime is real, and that its structure forms a main part of the apparatus of the explanation of science. Professor Nerlich provides a general introduction to his collection and also introductions to each part to bring the discussion up-to-date and to draw out the general themes.

What spacetime explains

Metaphysical essays on space and time

For Margaret

Preface

These eleven essays were published between 1979 and 1991 in the following order:

'What can geometry explain?' (1979) *British Journal for the Philosophy of Science* 30: 69–83.

'Is curvature intrinsic to physical space?' (1979) *Philosophy of Science* 46: 439–58.

'How to make things have happened' (1979) *Canadian Journal of Philosophy* 9: 1–22.

'Can time be finite?' (1981) *Pacific Philosophical Quarterly* 62: 227–39.

'Simultaneity and convention in special relativity' (1982) in Robert McLaughlin (ed.), *What? Where? When? Why?* Dordrecht, Reidel: 129–53.

'Special relativity is not based on causality' (1982) *British Journal for the Philosophy of Science* 33: 361–82.

'What ontology can be about: the spacetime example' (1985) *Australasian Journal of Philosophy* 63: 127–42.

'On learning from the mistakes of positivists' (1989) in J. E. Fensted, I. T. Frolov and R. Hipinen (eds.), *Logic Methodology and Philosophy of Science.* Amsterdam, Elsevier: vol. VIII, pp. 459–77.

'Motion and change of distance' (1989) in J. Heil (ed.), *Cause, Mind and Reality.* Dordrecht, Kluwer: 221–34.

'How Euclidean geometry has misled metaphysics' (1991) *Journal of Philosophy* 88: 169–89.

'Holes in the Hole Argument' (1993) in D. Prawitz and D.

Westersthål (eds.), *Logic, Methodology and Philosophy of Science.* Dordrecht, Kluwer: vol. IX.

I acknowledge the help of the original publishers of these papers whose permission to reprint them here made this volume possible. I acknowledge also the help and stimulus of Andrew Westwell-Roper and his permission to reprint §2, 'What ontology can be about', which we wrote jointly.

I have changed several of the essays in minor ways to update them in some respects.

Birgit Tauss, Karel Curran and Margaret Rawlinson have helped in various ways in preparing the papers for republication. I thank them for their work, patience and good humour.

Contents

Introduction

Space, time and spacetime: these are the best candidates for entities which are real, which are central in scientific explanation, but which, in principle, elude any direct observation. Spacetime fuses space and time. It founds the system of spatio-temporal relations which unifies everything of interest to science and common sense; to be spatio-temporal is the touchstone of the real. But space, time and spacetime also seem ideal candidates for bogus entities, plausible but unwanted parasites which the body of ontology is prone to host. To change the metaphor, they look very like hirsute outgrowths on the face of metaphysics which it is the genius of Ockham's Razor to shave smoothly away.

These essays argue that space and time are comprised in spacetime, that spacetime is real, that its structure forms a main part of the apparatus of explanation of science and of plain good sense, but that it may nevertheless confuse us in more ways than one. No serious inquiry into this topic can avoid an involvement with geometry and the spacetime theories of modern physics. Some of these essays look quite searchingly at foundations, particularly of the theory of special relativity, the first and best-confirmed of the theories of Albert Einstein. But surely no one would mistake my work for that of a mathematician or physicist. There is a spattering of sentences in formal notation, but I have been at pains to include but few. Many of the concepts of mathematicians and physicists are of deep philosophical interest, but I have tried to make what I say presuppose as little of this as is consistent with the tolerably brief treatment of the topics which my arguments demand. On the one hand, I like to remind myself of where I think the more technical ideas spring from and, on the other, I want the company of every philosophical reader who might wish to follow me.

All my arguments aim to support, in their different ways, a general thesis about spacetime which is best called *realism* (though sometimes called substantivalism or absolutism): spacetime is a concrete particular and the practice of scientific explanation and invention firmly commits us to its existence. It is fairly generally conceded, I think, that this is the natural attitude to take to the question whether spacetime is part of our ontology, and I think the concession is a judicious one. On the face of things, and in particular on the face of physics, things, events and processes do commune with one another within the arena of space and time. Perhaps it is not so natural to view spacetime as a particular, concrete entity related in close, concrete and even causal or, better, quasi-causal ways to the material hardware of the universe. Perhaps it is, even, *un*natural because we think of spacetime as eluding perception as a matter of its ontic type and because, classically at least, space was not conceived as a substance, 'because it is not among the proper dispositions that denote substances, namely, actions, such as thoughts in the mind and motions in bodies' (Newton 1962, p.132). But, overall, realism about space is our first response. What this adds up to, if it is correct, is that an initial burden of proof lies not with realism but with the views that oppose it.

In any event the burden of proving realism an error of metaphysics has been shouldered with enthusiasm by most of the philosophers who have considered the issue over the last hundred years. Most of this introduction is devoted to a synoptic picture of that work rather than to a summary of what I have tried to argue against it.

One thinks of a modern period of vigorous debate as beginning with Poincaré's arguments (1952) that we can always choose a Euclidean geometry if we choose to make enough sacrifices of convenience to retain it. However, this will commit us to no sacrifice of the factual content of our story of the world. This begins the view called conventionalism, that no choice of geometry is a choice of spatial facts. There are no spatial facts but only conventions which make our world-pictures more elegant without any possible risk of trespassing beyond the bounds of truth.

By far the most important event in this century as far as this study is concerned happened in 1905 with Einstein's seminal paper (1923, §III) introducing the theory of Special Relativity. The theory postulates that Maxwell's equations for the electromagnetic field take the same form for any inertial frame of reference. This means that there can be no absolute simultaneity: what had always been taken as an unshakeable, *a priori*, synthetic necessary truth is false. It is not the case that for any pair of events they are either absolutely simultaneous or one occurs absolutely earlier than the other. Einstein gave an epistemological argument for the falsity of absolute simultaneity, that any attempt to measure the simultaneity of two events in a frame of reference winds up somehow presupposing what it purports to measure. He went on to claim that simultaneity could be decided only as a matter of definition or convention. There were no matters of fact about it. Although it makes sense to adopt the same *form* of definition in every frame, the result will be that each distinct frame will have distinct classes of simultaneous events. Simultaneity as a relation of objective fact was ushered from the scene.

This event, just by itself, darkened philosophical counsel on the content of special relativity for decades and it probably still does. But this was not all. Minkowski's discovery, in 1908, changed our perspective in another way: special theory could best be interpreted not as the unfolding of physical processes in space and time but as their pattern in spacetime. Space and time were to lose substance and become mere shadows of their classical selves, while a fusion of the two took centre stage as a main actor in the world of physics. In particular, space, the bugbear of metaphysics ever since Newton's powerful and insightful arguments for it in *Principia*, was banished from a place in the ontic sunshine.

Lastly, the theory of general relativity was thought at first to hammer the last nails into the coffin of space or spacetime as a real things. There were two main reasons to think so. First, it seemed that the new theory yielded a principle that motion was generally relativistic: that any smooth time-like path (family of paths) fixed an acceptable frame of reference for physics so that motion, defined just on material things, was a strictly symmetrical relation. Closely connected with this but yielding a somewhat different conclusion, was the fact that the laws of general relativity were generally covariant: the form of the laws was invariant under any diffeomorphic (smooth continuous) transformation of coordinates. Confuse this with the idea that the observables of general relativity can consist only of what does not vary when we distort spacetime by any diffeomorphism and you have the momentous conclusion that the world is definite only up to those properties unaffected by such distortions of spacetime. Only spacetime coincidences are real, hard, observable facts. The remnant is only the *seeming* content of physics, a conventional overlay of useful but not factual language.

There were two main consequences of all this for metaphysics. It appeared that the separate streams of philosophy and physics had at last joined in a broad river of discovery and progress. In particular, radical empiricism had enlightened physics as to its epistemology. This liberated it from the chains of *a priori* dogmatism. In turn, physics, in a series of brilliant, creative discoveries, had resoundingly vindicated a variety of empiricist practices and credos which, thus fortified and enlightened, could repay the favour by a yet more stringent and illuminating critique of science. Thus began the vigorous wave of twentieth-century positivism.

A second consequence was more specifically doctrinal. There was broad agreement that progress in physics led (and was led by) a programme of ontic economy, by Ockhamism. There was a series of steps from Newton's absolute space to the classical relative spaces of inertial frames, thence to Special Relativity's relativising of a vast range of physical properties and quantities to these frames together with the dethronement of time from its ancient pedestal, thence to spacetime's collapsing of space and time into a single entity, and finally the giant step to general relativity and general covariance. Each step seemed to leave us with a barer, leaner world, the more frugal ontology of which led to increasing sensitivity of theory to observation and of explanation to the structure of the material world. The progress of modern physics was the same as the diminution of its content and especially of its ontic load. This view of twentieth-century physics gained uncertain confirmation from the rather instrumentalist approach to quantum mechanics found in the Copenhagen interpretation.

The decades have made it increasingly clear that nearly all of this was illusory. Although it was not always my intention to address this illusion when I first wrote the essays in this book, it now seems to me that perhaps this has been my dominant (by no means my only) theme. Newton (Cajori, 1947) had a lucid account of why apparent uniform motion is indistinguishable from real uniform motion: space is Euclidean and its symmetries hide the distinction (as §7 shows). The post-Newtonian classical physicists left the ontic status of inertial frames and the symmetry among them obscure. Without the realism of a physical Euclidean space, the ontic foundation of the relativity of uniform motion was anything but transparent. Nothing sustained it. Yet how could it rest on the *absence* of an entity unless it were an entirely general relativity (as so many philosophers were convinced *a priori* that it must be)? From the standpoint of metaphysics this was not a forward step. Special relativity before Minkowski deepened this obscurity since, in an ontology of enduring three-dimensional objects and time-extended processes there is this anomaly: three-dimensional objects have none of their three-dimensional properties (shape, mass or duration – though charge is an exception) well defined intrinsically, despite the fact that each takes its existence, so to speak, as a shaped or massive or enduring thing. The fundamental material entities were continuants, but had no intrinsic continuant (metrical) properties. Each property had to be related to one of an infinite set of privileged frames of reference, yet the basis of this privilege remained mysterious. This was puzzling indeed. Spacetime clears that fog by fusing space with spacetime and swallowing continuants up into four-dimensional objects. But Minkowski spacetime is not less structured than Newtonian or post-Newtonian classical spacetimes. It is richer: where they are defined only up to affine structure, relativistic spacetimes are metrical. Many of the more striking consequences which apparently flowed from generally covariant formulations of spacetime theories were simply the output of confusions. As one would expect, for much the most part the growth of physics reveals that the world is richer than we used to think it.

Confusion over these last points is the background against which the philosophy of conventionalism flourished. It was extended to embrace almost all of the structures which we ascribe to space, time and spacetime. They were seen as outrunning the actual structure of facts in the world so that the metric, affinity and projective structures of spacetime were regarded as fictitious impositions on a basic, smooth topological manifold. Even that minimal structure has been challenged. Reichenbach, the most distinguished of the positivistic conventionalists, argued that the topology of space is a convention (1958, §12). That strand of argument is not considered here (but see

Nerlich 1994, §§7 and 8). It has also been considered from a quite different point of view much more recently by Earman and Norton (1987) and is discussed in chapter 9.

It is at this point that conventionalism joins hands with an older anti-realist strand in the metaphysics of space and time: relationism. This tradition can be traced back to Leibniz, though it is not at all clear that Leibniz would have welcomed the modern claim to his paternity of this group of doctrines. There is no doubt that Leibniz often reads like a modern relationist, but his thought on space and time springs from the philosophy of monads and is, in that respect, deeply opposed to a fundamental tenet of modern relationism. The tenet is this: we can state all the facts and gain every other advantage for science and metaphysics by eschewing all serious talk of space in favour of a theory which confines itself in one or another way simply to material objects and spatial relations among them. These are real and objective, the rest a colourful fiction which should be understood as such. Leibniz insists on the status of space as a mere representation, quite clearly. What brings in doubt the legitimacy of his parenthood of relationism is just that he regards spatial relations, too, as merely well-founded phenomena, as apparent rather than real. But Leibniz certainly argued that, phenomenal or not, the whole system of spatial relations of things to things may be detached from the system of spatial relations of things to space. Thus the latter may drop out of our metaphysical picture of things as an entity which has no role in our intellectual economy.

Certainly some argument to the effect that spatial relations are not themselves tainted by a commitment to a sustaining space seems to be needed. Else it remains uncertain, at best, whether or not the question is begged. On the face of things, even simple spatial relations such as *x is at a distance from y* cannot hold unless there is a path between *x* and *y*; that is, there must be a point *z*, say, between *x* and *y* and a further point between *z* and *x* and so on without end. The plausibility that spatial relations are mediated by space is just the plausibility that if one thing is at a distance from another then there is somewhere some way between them, whether or not the place is occupied by something. That is not a decisive argument but, I submit, it is a highly intuitive and plausible one (see Nerlich 1994, §1, for an extended discussion). As far as I know modern relationists rely on Leibniz's detachment argument to extricate spatial relations from dependence on such spatial entities as paths. That argument is considered in §6.

Of course, there is the obvious theme of the relativity of motion and the consequences for the reality of space or spacetime of its failure – if it fails. That is the topic of §5 of Part 1.

In 1983 relationism was given, independently, two splendidly lucid and carefully worked out formulations which undertook to show how the programme of the general relationist theory might be carried out in full. The two versions, one by Brent Mundy and the other by Michael Friedman, differ in detail but are fundamentally alike. I shall briefly describe the former here. The latter is described in §9.1.

Consider just the set of all physically occupied spacetime points. Let the spatial relations among them be comprised in quantities which provide an inner product structure among the members of the set. Mundy shows how to construct from this information a partial but concrete 4-vector-space structure for the set of occupied points. This, in turn, enables him to show how to embed the material structure in the complete abstract vector space of real numbers. He shows that this embedding is unique up to an isometry. The point of the unique embedding is to justify the use of the well-understood abstract vector space to describe and predict results for the embedded concrete related points. The full vector space functions simply as a representation. Mundy concludes that it is a mistake of metaphysics to regard it as itself a part of the real concrete world.

This view is considered at some length in §1 of Nerlich (1994). A few observations on it are relevant here. It has the unquestionable advantage that its basis is identical with our epistemological basis for such knowledge as we have of spacetime. Its weakness is, perhaps, that whereas older relationist theories tried to show that space, time and spacetime were objectionable in themselves, involving some absurdity or metaphysical confusion, this version of relationism is committed to the view that spacetime, complete with unoccupied points, is a perfectly intelligible structure. That is how it can be of use to embed the material structure within it. Otherwise the embedding would be absurd. So there is only one ground on which the relationist's reduction can be urged: ontological economy. If this ground is to support the argument built on it, then the role of the full abstract vector space must surely be confined to that of an instrument of calculation. The theory which the embedding allows us to exploit functions