Einstein and Kant[1]

FRIEDEL WEINERT

I

A Special Date

On September 26, 1905 Einstein published his famous paper 'On the Electrodynamics of Moving Bodies' in the *Annalen der Physik*. It launched the Special theory of relativity and a whole new way of looking at nature. For half a century Einstein's name would become associated with that of Immanuel Kant. Many physicists believed the Special theory provided empirical 'proof' of Kantian views on space and time. Today it is still being discussed whether the theory of relativity is more compatible with objective becoming or static being. The question is whether a *philosophy of becoming* or a *philosophy of being* is a natural consequence of relativity. Throughout his lifetime Einstein remained skeptical towards Kant's apriorism. Yet it is not wholly mistaken to call Einstein a Kantian. The aim of this brief paper is to disentangle the many strands that run together in the association of relativity with idealism. The upshot is that Einstein is a Kantian in the outlines of his philosophy, but not in the details of his physics.

II

Relativity and Idealism

For Kant space and time are pure forms of intuition. Space is the form of outer sense, time the form of inner sense. Kant arrives at this result as an alternative between two equally unpalatable views. He cannot agree with Newton that space and time are absolutes, in the sense that they bear no relation to empirical objects in the world. To establish his laws of motion, Newton had regarded it necessary to imagine space as a container and time as a river. The imaginary container existed without any physical content. And the

[1] *Note:* The author would like to thank Roger Fellows for valuable comments on an earlier draft.

doi:10.1017/S0031819105000483 ©2005 The Royal Institute of Philosophy

https://doi.org/10.1017/S0031819105000483 Published online by Cambridge University Press

metaphorical river flowed at a constant rate, irrespective of material objects. All objects in the empirical world could be placed with respect to absolute space and time. For Kant this is pure metaphysics. Time, as he said repeatedly, cannot be perceived in itself. And the application of the concept of absolute time to the whole universe leads to antinomies. Leibniz had rejected the Newtonian notions of space and time for similar reasons. In particular Leibniz thought that the principle of the identity of indiscernibles showed that there could be no absolute time, no absolute space. Leibniz holds a much more empirical view of space and time: they are relations between events. That is, space is the coexistence of actual and possible events, and time is the order of succession of coexisting events. Humans acquire the notions of space and time through their commerce with the empirical world. They experience coexisting and succeeding events and baptize them space and time. Kant rejected Leibnizian relationism. Space and time, he objected, are presupposed in all our experiences of temporal and spatial events. We cannot perceive events without spatial arrangement and temporal coordination. Space and time can therefore not be derived from our experiences of spatial and temporal events. The way out, so it seemed to Kant, was to regard space and time as pure forms of intuition. Time and space are necessary *a priori* conditions of the possibility of experience.

Einstein's notions of the union of space and time—**space-time**—could not be more different. Einstein is much closer to Leibniz. Space-time is constituted by the distribution of matter and energy. Events in space-time are measured by clock time. Clock time results from any natural process, which possesses enough regularity to define a regular succession of events. For centuries, the orbit of the earth around the sun and the daily rotation of the earth on its own axis served as yardsticks for the measurement of time. Then it was found what Newton had only suspected: that there are irregularities in the earth's motions. To keep time exact, reference to the motions of the earth were replaced by atomic oscillations, which served as a new yardstick. Atoms can travel very fast. Familiar macro-objects move at a slower pace. And some things just stand still. It occurred to Einstein that there was no underlying viewpoint, from which such different events could be described. Einstein became very aware of the fundamental importance of reference systems. These are either at rest, in constant motion or in acceleration with respect to each other. In his Special theory Einstein demanded the physical equivalence of inertial systems. This equivalence is expressed in the principle of relativity. In his

https://doi.org/10.1017/S0031819105000483 Published online by Cambridge University Press

General theory this principle was extended to include non-inertial (accelerated or gravitational) events. A bystander on the pavement and a passenger in a car are attached to two different reference systems. An inertial reference system can be defined as a frame with rigid measuring rods and synchronized clocks. The behaviour of the rods and clocks indicate the coordinates of the respective reference frames. Some reference systems move very fast—some with the speed of light, others approaching this speed. Einstein postulated the speed of light as a limiting speed, which no material event could reach. If we consider reference systems at rest or in constant motion with respect to each other, the Special theory of relativity tells us that spatial and temporal measurements become *relativized* to particular reference frames. The clock on the pavement and the clock in a fast-moving car will not show the same time. A measuring rod in a fast-moving frame will be seen as shrinking from the point of view of a stationary reference frame. Time runs slow for fast-moving objects and objects appear to shorten. According to Kant we represent to ourselves only one time and one space.[2] But for Einstein, 'there are as many times and places as there are reference systems.'[3] Einstein was not particularly impressed with the Kantian solution to the problems of space and time. At times he pleaded ignorance regarding the *a priori* nature of certain categories of thought. At other times he was hostile: Kant's 'denial of the objectivity of space can (…) hardly be taken seriously.'[4]

Yet from the moment the Special theory of relativity saw the light of day, many of Einstein's contemporaries regarded it as supporting the Kantian view on time.[5] We can pinpoint the reason for this association between relativity and idealism in Einstein's concept of relative simultaneity. According to Newton, space and time had two characteristics. They possessed absolute reality—irrespective of concrete events; and they manifested a universal dimension—all observers throughout the whole universe would agree on the timing

[2] I. Kant, *Critique of Pure Reason* [1781, [2]1787] (London: Methuen, 1933; translated by Norman Kemp Smith), A32, A 189, A25.

[3] W. Pauli, 'Relativitätstheorie', in *Encyklopädie der mathematischen Wissenschaften*, Volume **19,** 1921; quoted from the English translation: *Theory of Relativity* (New York: Dover 1981), 15.

[4] *Nature* **112** (1923), 253; A. Einstein, *Relativity: The Special and the General Theory* (London: Methuen 1920), 137.

[5] *Nature* **106** (February 1921); *Nature* **108** (October 1921); A. S. Eddington, 'Gravitation and the Principle of Relativity', *Nature* **98** (1916a), 328-30; A. S. Eddington, 'Gravitation and the Principle of Relativity', *Nature* **101** (1916b), 15-7, 34-6; H. Weyl, *Raum Zeit Materie* (1921); quoted from English translation: *Space, Time, Matter* (New York: Dover 1952), 3.

https://doi.org/10.1017/S0031819105000483 Published online by Cambridge University Press

of events. If two events E_1 and E_2 happen at a time t_1, then all observers, whatever their position in the universe, will agree that E_1 and E_2 happened simultaneously, as recorded at t_1. Not so according to Einstein's theory of relativity. Let bolts of lightning strike the front and rear of a train, which is speeding through a station. For observers on the platform, the lightning will hit the train simultaneously at both ends. For passengers on the train, positioned midway between the front and the rear, the flashes of lightning will not strike the train simultaneously. The reason resides in the finite propagation of light. The train passengers rush towards the light signal from the front and run away from the rear signal. The finite and constant velocity of light is a cornerstone of the Special theory of relativity. As the simultaneity of events is relativized to particular reference frames, to which observers are attached, and they move at relative speeds with respect to each other, they cannot agree when events happen at the same time. What makes matters worse is that clocks in fast-moving reference systems slow down from the point of view of a stationary system. If the observers compare their clocks they will not agree on whose clock shows the 'right' time. According to the principle of relativity, both parties are 'right'.

From these undisputed facts many of Einstein's contemporaries concluded that time could not be part and parcel of the real world. Time passes at different rates for each observer, depending on the respective speeds of their reference frames. Time cannot be an objective property of the material universe. It seems to depend on the perception of observers. The physical universe must be static, a **block universe**. The Special theory seemed to confirm what Kant had claimed: that time was a feature of the human mind. For Kant, of course, observers always agreed on the simultaneity and time of events, because they were either stationary or moving so slowly that relativistic effects went unnoticed. Correct the Kantian view for relativistic effects, and Kant becomes vindicated by the Einsteinian revolution.

In the realm of physics it is perhaps only the theory of relativity which has made it quite clear that the two essences, space and time, entering into our intuition have no place in the world constructed by mathematical physics.[6]

> According to the principle of relativity (…) the space and time of physics are merely a mental scaffolding in which, for our own convenience we locate the observable phenomena of Nature.[7]

[6] Weyl, op. cit. note 5, 3, 227.

[7] Eddington, op. cit. note 5, (1916a), 328.

https://doi.org/10.1017/S0031819105000483 Published online by Cambridge University Press

At times Einstein embraced the block universe and adopted a static view of time. But he was never comfortable with the association of relativity and idealism. When Gödel[8] asserted that the relativity theory provided 'proof' of an idealist view of time, Einstein responded with a dynamic consideration of the flow of events, derived from the Second law of thermodynamics. If a signal is sent from *A* to *B,* which are *time-like* connected events in space-time, this signal requires time and the process of propagation is irreversible. There is an entropy gradient between the state of events at *A* and *B*. The assessment of this differential entropy between the two locations does not depend on a particular reference frame. According to a fundamental result of the Special theory of relativity the entropy of a system is frame-independent. Einstein sees in this an indication of the asymmetrical character of time.

As a matter of fact Einstein did not follow his fellow physicists' leaning towards idealism. As a matter of philosophical logic—had he been serious about the block universe—he should have accepted a Kantian view of time. For the block universe denies any form of physical becoming and relegates the flow of time to the level of a human illusion. But Einstein wavered in his support for the block universe. To Carnap he remarked that there was something essential about the *Now*. He expressed this feeling in writing, as in his entropic argument for the flow of events. So he could be hesitant about the idealist view of time. If his true position was akin to a relational view of space-time, then Einstein could not be an idealist with respect to time.

III

Geometry

Minkowski showed how the theory of relativity can be presented in geometric terms, as four-dimensional space-time. The Special theory of relativity still presents space-time in Euclidean terms. Euclidean geometry establishes its axioms through pure thinking. They become part of our *a priori* knowledge. This axiomatic geometry makes no claims about the empirical world. To make such claims Euclidean geometry has to be connected to the empirical world through physical laws. Kant did not regard the axioms of Euclidean geometry as merely analytic. They constitute synthetic *a*

[8] K. Gödel, 'A Remark about the Relationship between Relativity Theory and Idealistic Philosophy', in P. A. Schilpp *ed*. *Albert Einstein—Philosopher-Scientist* (La Salle: Open Court 1949), Volume II, 557-62.

https://doi.org/10.1017/S0031819105000483 Published online by Cambridge University Press

priori knowledge. It follows that there can be no possible world, in which Euclid's axioms are violated. Euclidean geometry describes a world that human beings can experience. Kant 'thought that Euclidean geometry applied to physical objects, to sense-given things in space'.[9] Einstein was unhappy with this axiomatic view of geometry. Whilst the Special theory had preoccupied him with the notion of time, his General theory turned him towards the notion of space. Geometry therefore became an important tool in his endeavour to understand gravitation. In the light of the development of non-Euclidean geometries in the 19th century, it was no longer possible to regard Euclidean geometry as synthetic *a priori* knowledge of the structure of all possible experience. Rather, the axioms of geometry are free inventions of the human mind. The freely invented axioms define the objects with which geometry deals: points, lines, intersections, triangles. It is no longer evident that such geometries are congruent with geometric objects in the natural world. For geometry to say something about the real world, its statements must be related to the real worlds of objects. For instance:

> Solid bodies are related, with respect to their possible dispositions, as are bodies in Euclidean geometry of three dimensions. Then the propositions of Euclid contain affirmations as to the relations of practically-rigid bodies.[10]

Einstein calls this new interpretation 'practical geometry'. Such a practical geometry is testable. Whether space-time is Euclidean or Riemannian in character is a question, which can be determined by empirical investigations. Consider the calculation of the dimensions of a circle in different reference systems. Following Einstein's insight, we need to introduce an inertial system, K, and a non-inertial system, K´, which rotates uniformly relative to K. The ratio of the circumference of the circle to its diameter is π, in K. But this ratio, C/D, is greater than π in the rotating system, K´, as judged from K. Due to length contraction of the tangential rods, the circumference will appear greater in K´. In non-inertial systems the validity of Euclidean geometry is no longer guaranteed. Einstein regarded this new interpretation of geometry as crucial for the further development of the relativity theory. It enabled him to introduce the idea of the equivalence of inertial and non-inertial systems of reference, and therefore the covariance of the laws of physics.

[9] P. F. Strawson, *The Bounds of Sense* (London: Methuen 1966), 284.
[10] A. Einstein, *Sidelines on Relativity* (London: Methuen 1922b), 32.

https://doi.org/10.1017/S0031819105000483 Published online by Cambridge University Press

Had Einstein been serious about the block universe as a representation of Minkowski space-time, he should have embraced an idealist view of time, like many of his fellow physicists. But had he been a Kantian with respect to geometry, he could not have developed the General theory of relativity. His new interpretation of geometry was a prerequisite for the rise of the General theory. A Kantian understanding would have blocked this vital step. That is, philosophical presupposition can guide and misguide. They guided Eddington, Weyl and others into accepting an idealist view of time, as a consequence of embracing a static view of Minkowski space-time. They would have misguided Einstein into a mistaken interpretation of geometry.

IV

Scientific Knowledge

In his portrayal of Einstein's conception of science, Northrop called Einstein 'a Kantian and a Greek empirical rationalist'.[11] Einstein full-heartedly approved of this epithet, regarding it as an accurate presentation of his views.[12] This has to be read with some care. We have already seen that Einstein rejects Kant's preoccupation with thought necessities. Space and time cannot be regarded as necessary preconditions of the possibility of experience because non-Euclidean worlds can be conceived and perceived. Scientific theories are, like the axioms of geometry, free inventions of the human mind. Nevertheless, there is a distinctly Kantian flavour in Einstein's position on the nature of scientific knowledge. It lies in the synthesis between rationalism and empiricism, which was the hallmark of Kant's critical philosophy. In Einstein's view of scientific knowledge, reason and experience go hand in hand. The rational even enjoys logical priority over the empirical because no amount of inductive generalizations can lead to the complicated equations of the theory of relativity. In this sense, 'every theory is speculative'.[13] The ancient dream to comprehend reality through

[11] F. S. C. Northrop, 'Einstein's Conception of Science', in P. A. Schilpp *ed*. (1949), op. cit. note 8, 390; see also V. F. Lenzen, 'Einstein's Theory of Knowledge', in Schilpp *ed*. (1949), 355-84; A. Wenzl, 'Einstein's Theory of Relativity View from the Standpoint of Critical Realism, and its Significance for Philosophy', in Schilpp *ed*. (1949), 581-6.

[12] A. Einstein, 'Reply to Criticisms', in Schilpp *ed*. (1949), op. cit. note 8, 683-4.

[13] A. Einstein, 'On the Generalized Theory of Gravitation', *Scientific American* **182** (April 1950), 349.

https://doi.org/10.1017/S0031819105000483 Published online by Cambridge University Press

the power of pure thinking can, to a certain extent, be realized. For nature is the realization of mathematical simplicity. But we should not get carried away with the thrust of mathematical rationalism. For scientific theories to be objective, it is necessary to anchor them in the empirical world. The rational must seek a union with the empirical. Experience is the final arbiter of the validity of scientific theories. The scientist proposes, but nature disposes. Einstein's trust in mathematical rationalism makes him confident that among all the possible theoretical constructions, the correct one can be found.[14] This does not mean that such a theory can pretend to possess the universality and necessity, which Kant tried to establish for his categories of thought. For Einstein all knowledge is conjectural. His insistence on finding the one correct theory only means that at a particular stage of scientific progress, out of a number of competing accounts, one will best cope with the available evidence. But there is nothing final about this account. It is fallible. Newton's mechanics was the ruling paradigm in physics until Einstein questioned some of its fundamental assumptions. Soon after 1905 Einstein himself showed the limits of the Special theory of relativity. This theory treats inertial reference frames as preferential for the formulation of the laws of nature. The space-time continuum is still 'Euclidean': the reference frames are in uniform motion with respect to each other. These frames are related by the Lorentz transformations. The motion affects the behaviour of clocks and rods but no physical processes affect the structure of Minkowski space-time. Einstein sought to overcome this restriction. He could find no reason for such a preference of inertial reference frames. In his General theory all reference frames – inertial and non-inertial—are put on a par. Space-time becomes fully dynamic. The presence of non-inertial systems makes space-time non-Euclidean. In accelerated frames clocks slow down and the ratio of C/D becomes greater than π. Gravitational fields even affect the behaviour of light.

V

Conclusion

The primacy of theory and the synthesis of rationalism and empiricism give Einstein's philosophy a distinctive Kantian flavour. But this flavour is not felt in the particulars of the physics. The objectivity of scientific knowledge is achieved through fitting the

[14] A. Einstein, 'Principles of Research' (1918), reprinted in A. Einstein, *Ideas and Opinions* (London: Alvin Redman 1954), 227-32.

https://doi.org/10.1017/S0031819105000483 Published online by Cambridge University Press

'categories of thought' to the demands of mathematical simplicity, logical coherence and empirical testability. Neither the former nor the latter are fixed. The empirical evidence grows and often shows the defectiveness of the theoretical system. Einstein rebuked philosophers for having

> had a harmful effect upon the progress of scientific thinking in removing certain fundamental concepts from the domain of empiricism, where they are under our control, to the intangible heights of the *a priori*.[15]

Yet Einstein's work shows how the evolution of physics has guided the evolution of philosophical ideas.[16] This influence has led to new conceptions of mass, space and time, and reality. Einstein's work demonstrates that there is a true interaction between science and philosophy. Science borrows philosophical ideas, like the ideality of time, to interpret its findings. Philosophy reacts to scientific discoveries by reshaping traditional notions, like mass, time and reality. Some philosophical positions are more in line with scientific discoveries than others. It is the job of philosophers to evaluate the extent to which certain philosophical consequences follow from scientific discoveries. Einstein's discoveries illustrate this dialectic between science and philosophy. Einstein's achievements have underscored the Kantian synthesis of rationalism and empiricism, although this appears in the new guise of fallibility. 'It is one of the great realizations of Immanuel Kant', says Einstein[17], 'that the setting up of a real external world would be senseless' without the mysterious comprehensibility of the external world.

University of Bradford

[15] A. Einstein, *The Meaning of Relativity* (London: Methuen 1922a), 2; italics in original.

[16] H. Reichenbach, 'The Philosophical Significance of the Theory of Relativity' in P. A. Schilpp *ed*. (1949), op. cit. note 8, 301.

[17] A. Einstein, 'Physics and Reality' (1936), reprinted in A. Einstein, *Essays in Physics* (New York: Philosophical Library 1950), §1.

https://doi.org/10.1017/S0031819105000483 Published online by Cambridge University Press