

Conventionality and Relationality in Relativistic Space-Time¹

Convencionalidad y relacionalidad
en el espacio-tiempo relativista

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ABSTRACT

The actual information concerning the geometric structure of the world, i.e. the structure of spacetime that is conveyed to us through the theory of general relativity, is discussed. Different proposals related to several philosophical schools (conventionalism, empiricism, etc.) are dealt with. The conclusion —still open to further debate— seems to point to the fact that although space-time has an objective existence, its metric shows a relational or non-absolute character.

Keywords: relativity, conventionalism, empiricism, space-time, relationalism

RESUMEN

En este artículo se discute la información concerniente a la estructura geométrica del universo —es decir, la estructura del espacio-tiempo— que conocemos principalmente a través de la teoría de la relatividad general. Se consideran por ello las distintas propuestas planteadas por diferentes escuelas filosóficas (convencionalismo, empirismo, etc.). La conclusión —abierta a posteriores controversias— parece señalar al hecho de que aun cuando el espacio-tiempo posee una existencia objetiva, sus propiedades métricas tienen un carácter relacional.

Palabras clave: relatividad, espacio-tiempo, convencionalismo, empirismo, relacionalismo

¹ Fecha de recibido: 23 de octubre de 2011. Fecha de aceptación: 15 de marzo de 2012.

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INTRODUCTION

In what sense are we being informed about the structure of physical reality when we are told that spacetime is a pseudo-Riemannian manifold of variable curvature? It can hardly be overemphasized that the question is a deep one whose treatment may lapse into unedifying obscurity when one is less than completely clear as to its precise meaning. It is significant that expert opinion on the mutual relevance of general relativity and geometry ranges all the way from J. A. Wheeler's celebrated slogan, «Physics is geometry», to the no less remarkable comment of J. L. Anderson that “[...] Einstein succeeded actually in eliminating geometry from the space-time description of physical systems by letting the gravitational field take over all its functions” (Anderson 1967, 329). When two eminent authorities offer such apparently diverse interpretations of so fundamental an issue one may suspect that the problem cannot be resolved by simple recourse to the facts of science but requires a serious conceptual analysis.

General relativity has been characterized as the geometrization of physics. Unfortunately, this familiar dictum is more dazzling than illuminating. It is suggestive of the particularly close fit that obtains between physical and geometric model. The latter is due to the contingent fact of the equivalence of gravitational and inertial mass, which is the basis for the geodesic hypothesis. In brief, general relativity, from the standpoint of applied mathematics, is the coordination of a physical model of the gravitational interaction as determined by matter with a mathematical model of a four-dimensional pseudo-Riemannian manifold of variable curvature such that ideal gravitational test particles traverse timelike geodesics and photons traverse null geodesics. The success of this coordination, i.e. the closeness of the fit, possibly exceeds that of any other scientific theory. Consequently, the geometric machinery is a particularly apt instrument for the prediction of physical consequences. Nevertheless, one cannot simply read the physics from the geometric formalism. For example, the spacelike geodesics play no less a mathematical role than the timelike ones. Accordingly, the impossibility of spacelike motion does not follow from the geometry but has to be inserted as a physical hypothesis. General relativity vindicates Pythagoras no more than Kant.

GEOMETRIC CONVENTIONALISM

Riemann's generalization of Euclidean geometry may be interpreted as showing that a system of metric geometry is determined by the choice of metric function $g_{ik} dx_i dx_k$, of which there are in principle infinitely many. Equivalently, it may be interpreted as the claim that a system of geometry is

determined by a standard of congruence. To say that a line segment AB is congruent to a line segment CD is to affirm that a rigid rod which coincides with AB will, after transportation, also coincide with CD . However, one's mathematical predictions as to the partitioning of point pairs into equivalence classes of congruent intervals depend on the choice of g_{ik} . Moreover, the standard of rigidity would itself appear to presuppose a standard of congruence. Given that AB is congruent to CD according to the choice of g_{ik} , a rod would be regarded as rigid if it were found to undergo no deformation when transported from the one to the other. Thus, it appears that one simply stipulates which line segments are congruent, with different stipulations generally giving rise to different geometries.

One of the most celebrated protagonists of the philosophical crisis engendered by the new geometries at the end of the XIXth century was Jules-Henri Poincaré (1854-1912). Briefly, the problem confronting Poincaré is that geometric assertions are conventions. However, Poincaré's doctrine of conventionalism has sometimes been misrepresented in the literature of philosophy. While it is true that he argued that the propositions of geometry have the logical character of conventions or definitions, which can never be overthrown on experimental grounds, he goes to considerable lengths to account for our geometrical beliefs in terms of their experiential origins. His position is to the effect that although experience can never impose a particular system of metric geometry, the content of experience is such that one geometric system will be adopted as the most natural one for the expression of physical laws, on the grounds of descriptive simplicity and convenience. Moreover, experience is such that Euclidean geometry, although conventional, is the natural choice (Poincaré 1952; 1956; 1963).

In the final analysis, for Poincaré, the space of pure mathematics is completely amorphous. It makes no sense, in his view, to ascribe congruence relations to the mathematical continuum. Claims about the structure of space which are ostensibly factual are, in fact, assertions not about space in isolation but pertain to the combination of space and the patterns of phenomena, especially to the behaviour of our measuring instruments. Physics and geometry are inseparable. An experimental result which seems to confute the one may always be accounted for by a compensating adjustment in the other

Under these conditions, does space possess geometric properties independent of the instruments used to measure it? It can, we have said, undergo any deformation whatever without our being made aware of it if our instruments undergo the same deformation. In reality, space is there-

fore amorphous, a flaccid form, without rigidity, which is adaptable to everything: it has no properties of its own. To geometrize is to study the properties of our instruments, that is, of solid bodies (Poincaré 1963, 17).

GEOMETRIC EMPIRICISM

Since the advent of the theory of relativity, its most painstaking philosophic interpreter in the first half of the century was Hans Reichenbach. He wrote several books and papers on the content and epistemology of relativity theory. Reichenbach once illustrated an aspect of his philosophy of geometry by means of a well-known parable about a curved line projected onto a flat one. A scientific theory, he would argue, unlike a system of pure mathematics, requires that its basic concepts be related to the physical world. More precisely, such a theory stands in need of what he calls coordinative definitions. Unlike the usual dictionary definition, a coordinative definition does not relate a new concept (*definiendum*) to antecedently understood concepts but establishes a relationship between a concept and a thing. For example, the coordination of the concept of unit length with the standard platinum metre bar in Paris is an instance of a coordinative definition. What is more to the point in the present context is that if geometry is to acquire the status of a system of statements about the world, it too must be augmented by such a semantic interpretation (Reichenbach 1958). Such notions as «congruence» and «straight line» must be linked to the physical world by means of coordinative definitions which typically involve material measuring rods and light-rays.

Suppose that the measurement of a sufficiently large triangle had been carried out by optical means and revealed an angle-sum of 180.05° . In effect, one would have been investigating a triangle whose sides are composed of light-rays. Consequently, the outcome of the experiment could be interpreted as signifying not that Euclidean geometry is false but that the paths of light-rays are not Euclidean line-segments, being subject to the distorting influence of universal forces. What was measured, having curvilinear sides, was simply not a Euclidean triangle. In short, one would appear to be saving the geometry by modifying the physics in the manner of Poincaré. However, Reichenbach would argue that such a procedure fails to constitute a genuine alteration of the laws of physics. “The assumption of such forces means merely a change in the coordinative definition of congruence” (Reichenbach 1956, 133). So Reichenbach now appears to be saying that it is possible to preserve the free choice of geometry by resorting to an appropriate semantic reinterpretation.

Like most verificationists, Reichenbach would appear to harbour a characteristic distrust of theories, which are, virtually by definition, transempirical. It is quite true that theories assert and entail propositions which cannot be known with certainty. No responsible theorist would, in fact, claim certainty for any theory. However, although theories typically go beyond immediate experience, they will always, considered as systematic wholes, be subject to the test of experience. In the final analysis, even transempirical concepts must indirectly withstand the test of experience. In the case of general relativity, the specific parts of the theory that may have to be revised in the light of experience include those elements which are commonly regarded as geometric.

In spite of his considerable knowledge of theoretical physics, Reichenbach appears to hold a somewhat simplistic view of the methods of experimental physics. He conveys the impression of being sceptical, in principle, of the validity of measuring instruments. It is clearly the case that some measuring rods, clocks and similar devices are more reliable than others. The experimental physicist, when employing a measuring instrument to test a theory, will place reliance on that instrument in virtue of theoretical considerations which are independent of the theory which is under investigation.

GEOCHRONOMETRIC CONVENTIONALISM

Geochronometric conventionalism is the name which Grünbaum attaches to his own brand of conventionalism, which is distinct from both of the versions which we have so far examined. In particular, whereas Reichenbach bases his views on epistemic matters, Grünbaum claims his own version of geometric conventionalism to have an ontological basis. That is to say, that he is able to envisage a world in which geometric conventionalism would be false as a matter of ontological fact.

The crucial feature of Grünbaum's position is that the thesis of geometric conventionalism should be construed neither as an epistemological claim nor as a semantic one but as a claim about the very nature of space itself (Grünbaum 1973). He draws a distinction between those properties of an entity which are intrinsic to it and those which are extrinsic or relational. Grünbaum would argue that the metric properties of space are all of the extrinsic variety. By this, he has in mind that it is conceivable that space might have had a «built-in» metric in a sense in which the natural numbers may be said to possess an intrinsic or built-in metric whereby the interval between 7 and 3 is objectively equal to that between 18 and 14. He argues

that there is no counterpart to this natural standard of equality in the case of space due to the following considerations.

In the first place, every spatial interval is continuous. The continuity of space entails the impossibility of comparing the magnitude of two such intervals by a process of counting, since all continuous intervals have the same cardinality. That is to say, that technically they all contain the same number of points, namely, a non-denumerable infinity of them. Continuity is a necessary but not a sufficient condition for the extrinsicity of the spatial metric. For example, although the real number system is continuous it is, nevertheless, possible to make an objective comparison of the size of two intervals in the real number system. This is because the elements of the set of real numbers are intrinsically distinct from each other. The real number 6 is greater than the real number 2, which is why one may say that the interval from 0 to 6 is three times greater than the interval from 0 to 2. On the other hand, there is no intrinsic difference among the various points of space. All spatial points, or the unit sets which contain them, are qualitatively homogeneous. Thus, in virtue of the combination of continuity and homogeneity, there is no intrinsic basis for spatial congruence comparisons. That is to say, that space has no intrinsic metric. As Grünbaum puts it, space is metrically amorphous.

On the ground, therefore, of the dual claim that the basis for the ascription of equality of length to two line segments is both external and conventional, Grünbaum concludes that the choice of a spatial metric must be conventional. It must be emphasized that the significance of Grünbaum's claim is not merely epistemological. It is not to the effect that the true metric of space is empirically inaccessible but that space has no true metric: it is metrically amorphous! Furthermore, it should not be construed as asserting that space is a non-entity or methodological fiction but merely that it is not the sort of entity which could possess objective metric properties.

To emphasize the ontological or factual character of his thesis, Grünbaum employs an argument which is derived from Riemann. He contrasts the case of continuous physical space with that of a hypothetical space which is discrete or granular. In such a space, every interval would comprise a countable number of basic space atoms or quanta. Space, itself, would then be disposed to admit of an intrinsic standard of length which would be defined as the arithmetic sum of spatial quanta. Space intervals would then be compared in the same manner as arithmetic intervals. Grünbaum intended the foregoing to serve as an illustration of an intrinsic and factual metric as distinct from one which is extrinsic and conventional. However, as several critics have remarked, although such a standard of congruence would be in

some sense intrinsic, it could still be held to be based on the convention that all space atoms have the same magnitude. Any attempt to establish that fundamental equality by some form of measurement carried out by means of an extrinsic standard would presumably deprive the metric of its strictly objective character. However, this criticism does not seem to be particularly damaging to Grünbaum's principal thesis.

A CRITIQUE OF GEOCHRONOMETRIC CONVENTIONALISM

Despite the enormous critical controversy over Grünbaum's distinction between intrinsic and extrinsic features of the manifold and granting the difficulties attendant on a formal characterization of this distinction, I believe that its intent is reasonably clear. There are properties which a thing may possess in its own right and others which it may only possess in relation to something else which is external to it. Another way of putting it is simply that things possess both absolute and relational properties. Certain properties, such as chemical composition, are clearly absolute, whereas others, such as «being to the left of» are just as obviously relational (Torretti 1978).

It makes no sense to claim that space and spacetime are intrinsically curved or, for that matter, intrinsically flat. There simply is no basis for attributing a «built-in» metric to spacetime any more than there is a basis for endowing it with built-in coordinates. Furthermore, it should be obvious that the lack of an intrinsic metric for spacetime is precisely the message of general relativity. To use the orthodox terminology, the metric of general relativity is not an absolute object but a dynamical one. That is to say, that the space-time metric is determined by the matter-energy of the universe. The metric and affine properties of spacetime are, on this theory, clearly relational.

On the other hand, the argument against geometric conventionalism is that the physicist is always concerned with the geometry of a physical system of some kind and never with the geometry of pure space (Sklar 1974). To argue, for example, that the surface of my desk is Euclidean if the geometry of space is flat, but curved if the spatial geometry is curved is, in my opinion, to commit a methodological fallacy. A differentiable manifold, *qua* abstract mathematical space, is not disposed to accept one affinity more than another. That, however, is not to say that an affinely connected manifold is affinely amorphous.

The applied geometer will be concerned with such physical entities as table tops, spheroids such as the earth and, in particular, physical fields such as that of gravitation (Cohen & Seeger 1970). He is not directly concerned

with investigating the properties of mathematical manifolds. Such properties are simply decreed or freely chosen. Therein lies the essential truth of geometric conventionalism. It does not follow that the structure of a physical entity is determined by convention. It is not the case, for example, that the gravitational field is metrically amorphous and, hence, accessible to conventional metrization. To the extent that gravitational phenomena are successfully coordinated with a particular metric space, the field itself may be said, *qua* physical manifold, to possess that metric objectively. One may, of course, argue that a theory which associates the gravitational field with a particular metric space may be abandoned in favour of another theory which associates that field with a different metric.

However, the familiar circumstance of one theory's being supplanted by another should not be construed as evidence favouring conventionalism. The latter is not an instance of freely replacing one convention by another but is rather a case of one factual conjecture or postulate being replaced by another which is deemed to be more accurate. The fact that the metric of a physical manifold may not be known with certainty should not be taken to indicate that such manifolds lack an objective or determinate metric. The appropriate place for conventions is in pure mathematics not in factual science. Indeed, one may suspect that geometric conventionalism has been fostered by the all too frequent confusion that exists between a physical theory and the mathematical theory in terms of which it is expressed.

GENERAL RELATIVITY AND SPACE-TIME STRUCTURE

In line with the general view of applied mathematics, the theory of general relativity should be interpreted to be essentially an attempt to coordinate a conceptual or mathematical entity, namely a pseudo-Riemannian manifold of variable curvature and Lorentz signature with a physical process, namely the gravitational interaction (Earman 1970; Earman et al. 1977). In virtue of the identity of gravitational and inertial mass, the motion of a particle under the influence of a gravitational field may be formally treated as a force-free or «natural» motion. The geodesic hypothesis is an immediate consequence. The latter states that the trajectory of a gravitational monopole is a geodesic in spacetime.

Various workers in the field of general relativity have proposed that the appropriate way to measure the gravitational field is not by means of rods and clocks, as suggested by Einstein, but by means of freely falling massive particles and photons, which reveal respectively the timelike and null geodesics of the

field (Erich 1976). Grünbaum has argued that such methods should be interpreted not realistically but conventionally. His point is that the aforementioned geodesics are not to be regarded as constitutive of the gravitational field. Rather, it is by human decree that the trajectories of photons and gravitational monopoles are associated with geodesics. The rationale of Grünbaum's argument seems to be that the aforementioned probes of the field, like measuring rods, are extrinsic standards. Hence, just as it is conventionally decreed that two intervals of space which are successively occupied by a measuring rod are congruent, so in this instance it is decreed that the spacetime trajectory of a free particle is a geodesic. Grünbaum grants that general relativity imposes a definite metric on spacetime but argues that it is to be construed not descriptively but normatively. He here uses the epithet «descriptive» in the sense of objective rather than in his customary use of it when speaking of descriptive simplicity.

It would seem that Grünbaum may be guilty, perhaps unknowingly, of a misinterpretation of the methodology of general relativity. This misinterpretation probably runs along the following lines. One observes the trajectories of massive and massless particles and adopts the convention of treating them as timelike and null geodesics, respectively. One then asserts that the gravitational metric is whatever manifold happens to possess that particular geodesic structure. This may be shown to be erroneous on at least two counts.

In the first place, on this view the geodesic hypothesis, which is an essential ingredient of the theory, would fail to have the status of a physical law but would be a mere convention such that the theory as a whole would be rendered practically immune to revision. For example, one of the classical predictions of general relativity was the bending of starlight in the sun's gravitational field. Now on the interpretation which I have putatively attributed to Grünbaum, this prediction would not have constituted a critical test of the theory, since whatever the trajectory of a light-ray might be, that trajectory would have been conventionally decreed to be a geodesic. The famous expedition of Eddington in 1919 which was conducted for the purpose of testing Einstein's prediction would therefore have been pointless. What is overlooked is that Einstein predicted the path of starlight before the fact and with a high degree of numerical precision. The geodesic trajectories of the theory are deductive consequences of the field law, which is the heart and soul of the theory (Glymour 1977). If the status of these trajectories as geodesics is merely conventional, then the entire theory must be little more than a web of conventions. But Grünbaum would surely wish to reject such an unbridled conventionalism as that. However, one of the inherent dangers of conventio-

nalism appears to be that once one has put a foot on its path one can hardly stop until one is caught in the web of Quinean pragmatism.

In the second place, such an interpretation fails to take account of the rich experimental resources of general relativity. In particular, there are now instruments at one's disposal by means of which the Riemann-Christoffel tensor may be directly measured. Next to the metric tensor from which it is formed, the Riemann-Christoffel or curvature tensor provides the most information about the structure of the manifold. In general relativity it plays the role of representing the so-called tidal forces. Due to the inhomogeneous character of the gravitational field, two freely falling particles which traverse initially parallel paths will eventually cross or diverge from each other.

From this, one may then derive the geodesics (Graves 1971). Accordingly, the geodesics can be no more conventional than the observable phenomenon of geodesic deviation, and it also provides a basis for the possible detection of gravitational waves, another phenomenon which only makes sense on the basis of a realistic as distinct from a fictionalistic interpretation of gravitation. Therefore, to treat the paths of gravitational probes as anything other than geodesics is not simply to opt for a semantically equivalent redescription of physical reality but is rather to take the more radical course of abandoning the theory of general relativity. This is the basic reason why geochronometric conventionalism must be judged a failure in its capability to provide a philosophic interpretation of general relativity.

It could be properly made a bipartite distinction of physical (gravitational) metric field and spacetime as the arena in which gravitational and other processes take place. The recognition of the last of these as a distinct mode of existence has long been highly unfashionable, although much less so in the more recent philosophical literature. By locating the metric in the gravitational interaction I am opting for a relational view of the metric. That is to say, that I am viewing the metric not as an intrinsic property of spacetime but as a relational property of the process which is determined by the distribution of matter-energy. If matter-energy were non-existent, i.e. the energy tensor were null, then there would be no gravitation and consequently no metric.

The more commonly held view among physicists is that matter is not the source of the metric, per se, but rather the cause of its curvature or deviation from flatness. Thus, it would be held that if the energy tensor were everywhere zero, the universe would be represented in the form of flat Minkowski spacetime. Flat spacetime is imposed as a boundary condition for the celebrated Schwarzschild solution of the field equation for an insular spherically symmetric mass. The solution was obtained by assuming that at infinity the geometry of the field

would be Minkowskian. A rational view of the gravitational phenomenon is quite literally that it constrains particles to traverse space-time geodesics. Consequently, if an hypothetical particle of inappreciable mass were introduced into the empty universe it would be guided along a timelike geodesic.

Anyway, the geometric formalism which best fits gravitation compels us to take on an interpretation of physical phenomena that *prima facie* can be hardly unified with the quantum realm. For instance, some effects, typical of general relativity, which find a natural explanation in terms of geometric concepts (as gravitational time-delay) are very difficult to understand from the point of view of quanta exchange (Isham 1997).

NEW TRENDS

Two other traits of space-time geometry are usually taken for granted, that is, dimensionality and continuity. But perhaps we should not be so confident about them. Today string theorists and others are arguing that the most natural dimensionality is 10 or 11, since these dimensions allow for the existence of various symmetries and also allegedly unify and explain the existence of basic forces. Note that one need not be a conventionalist to make these kinds of arguments. Naturalness, simplicity, consilience, unification, etc., might be marks of truth rather than marks of convenience. Even the conventionalists were not so conventionalist about spatial dimensionality (Poincaré suggests that biology might «hard-wire» us into believing in three spatial dimensions). Absent a developed physical theory that takes dimensionality as contingent and offers principled physical constraints on what can happen in different dimensions, there seem to be no standards for knowing which laws hold in what dimension. Some authors, for instance, propose a dynamical theory of dimension creation that would, I suppose, take dimensionality as something to be appropriately explained via the dynamics of physical processes (Arkani-Hamed et ál. 2001). But such theories are far too speculative for us to have much faith in today.

Reviewing the different approaches we find on searching an unification of general relativity and quantum physics, they split into four categories (Callender & Huggett 2001). First, there are the Quantum Field Theory-like approaches, such as string theory and its relatives. Here General Relativity is to be an emergent description; however, the spacetime that appears in the initial formulation of the theory is fixed and not dynamical. Next are the so-called background independent approaches to Quantum Gravity, such as loop quantum gravity, spin foams, causal sets and causal dynamical triangulations. Geometry and gravity here are

fundamental, except quantum instead of classical. These approaches implement background independence by some form of superposition of spacetimes, hence the geometry is not fixed. Third, there are condensed matter approaches. These are condensed matter systems, so it seems clear that there is a fixed spacetime in which the lattice lives; however, it can be argued that it is an auxiliary construction.

There is also a new, fourth, category that is currently under development and constitutes a promising and previously unexplored direction in background independent quantum gravity (Rovelli 2004). This is *pre-geometric* background independent approaches to quantum gravity. These approaches start with an underlying microscopic theory of quantum systems in which no reference to a spatiotemporal geometry is to be found. Both geometry and hence gravity are emergent. The geometry is defined intrinsically using subsystems and their interactions. The geometry is subject to the dynamics and hence itself dynamical. It is clear that in all those approaches, space-time geometry as a whole would be entirely relational but not conventional.

Some other works in search of unification have attempted to obtain a discrete, or quantized, model for space-time (Loll & Westra 2003). The spirit is very much that of the standard lattice formulation of quantum field theory where (flat) spacetime is approximated by a hypercubic lattice. The ultraviolet cut-off in such field theories is given by the lattice spacing, *i.e.* the length of all one-dimensional lattice edges. We can in a similar and simple manner introduce a *diffeomorphism-invariant* cut-off in the sum over the piecewise linear geometries by restricting it to the *building blocks* mentioned earlier. A natural building block for a d -dimensional spacetime is a d -dimensional equilateral simplex with side-length a , and the path integral is approximated by performing the sum over all geometries (of fixed topology) which can be obtained by gluing such building blocks together, each geometry weighted appropriately. It has not been possible, up to now, to define constructively a Euclidean path integral for gravity in four dimensions by following the philosophy just outlined. One simply has not succeeded in identifying a continuum limit of the (unrestricted) sum over Euclidean building blocks. Among the reasons that have been advanced to explain this failure, it is clear that the *entropy* of the various geometries plays an important role that is not completely clarified.

CONCLUDING REMARKS

Let us conclude this paper by underlining its principal philosophic message. It is that talk of the curving of space-time and the slowing down of time in

the context of general relativity ought to be treated as an equivalent or indirect way of referring to various properties of gravitation. Grünbaum was convinced that spacetime is, in itself, metrically amorphous. But whereas he would seem to hold that in the absence of an objective metric for spacetime it is necessary to introduce a freely chosen metric convention, another possible view is that since spacetime lacks metric properties, it is simply a mistake to ascribe them either conventionally or otherwise. Talk of the curvature of spacetime is not a convention but rather a linguistic expression for a physical phenomenon. On the other hand, general relativity provides abundant support for the view that the gravitational metric of space-time is not conventional but objective.

For several decades following the inception of the two theories of relativity, the majority of scientists and well-informed philosophers supposed that the question of the absolute existence of spacetime—the ontology of space-time—as debated by Leibniz and Clarke had at last been laid to rest, with Leibniz the obvious victor. Maxwell's aether, which was the embodiment of physical space, was shown in the context of special relativity to have been a gratuitous notion. The ultimate *coup de grâce* for the notion of absolute or substantial spacetime was taken to have been delivered in the theory of general relativity. Einstein's arguments for the relativity of space and time were unhesitatingly accepted as arguments for their relationality.

Today, however, increasingly many philosophers are coming to recognize that the situation is not as clear as had once been supposed. It is possible, for instance, to define an absolute four-dimensional rotation vector on the space-time manifold of general relativity. In fact, Gödel has shown that the notion of an intrinsic rotation of the universe as a whole is compatible with the formal structure of general relativity. It is obvious that if spacetime were entirely dependent on matter, then it would simply make no sense to ascribe a rotation in spacetime to the universe as a whole. A balanced interpretation of the available evidence would seem to suggest that although general relativity does not exclude some absolute space-time structures, it rather convincingly supports the relational or non-absolute character of the metric.

The conventional element is not an exclusive feature of the geometric methods here involved, but a general condition of any mathematical theory when applied to the real world. There are indeed intrinsic (absolute) and extrinsic (relational) properties of the physical processes described by means of space-time geometry. And progress in theoretical physics focuses us to face the astonishing fact that some traits regarded as intrinsic -i.e., dimensionality or continuity- might not be finally that way. All those features are not conventional, but an empirical matter of fact whose ultimate characterization a philosopher must seek inside

the circle of scientific Knowledge. Even though science can only provide us with knowledge that will never be complete, perfect or permanent.

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