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Kant, Reichenbach, and the Fate of A Priori Principles

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Abstract: This article contends that the relation of early logical empiricism to Kant was more complex than is often assumed. It argues that Reichenbach's early work on Kant and Einstein, entitled *The Theory of Relativity and A Priori Knowledge* (1920) aimed to transform rather than to oppose Kant's *Critique of Pure Reason*. One the one hand, I argue that Reichenbach's conception of coordinating principles, derived from Kant's conception of synthetic a priori principles, offers a valuable way of accounting for the historicity of scientific paradigms. On the other hand, I show that even Reichenbach, in line with Neo-Kantianism, associated Kant's view of synthetic a priori principles too closely with Newtonian physics and, consequently, overestimated the difference between Kant's philosophy and his own. This is even more so, I point out, in the retrospective account logical empiricism presented of its own history. Whereas contemporary reconstructions of this history, including Michael Friedman's, tend to endorse this account, I offer an interpretation of Kant's conception of a priori principles that contrasts with the one put forward by both Neo-Kantianism and logical empiricism. On this basis, I re-examine the early Reichenbach's effort to accommodate these principles to the paradigm forged by Einstein.

1. Introduction

Over the past few decades a great number of valuable studies has been devoted to the genesis of logical empiricism and analytic philosophy.[1] These studies have brought out, among other things, that the histories of neo-Kantianism, phenomenology, and logical empiricism have been entangled to a far greater extent than is commonly assumed. It is well-known that logical empiricism established itself as a movement by deploying Einstein's revolutionary physics against a neo-Kantianism deemed to have grown old. The effort of neo-Kantianism to wed transcendental philosophy to Newtonian physics had long seemed a reasonable way of strengthening Kant's position. This position became all the more vulnerable, however, once relativity theory appeared on the scene.

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Viewing Kant through the lenses of neo-Kantianism, Schlick, Reichenbach, and others notably criticized his notion of synthetic a priori principles. Unlike most commentators, I will not take their reasons for criticizing Kant at face value. I will contend, by contrast, that the synthetic a priori principles at stake in the *Critique of Pure Reason*—the principles of pure understanding—are not dependent on Euclidian geometry or Newtonian physics. Seen from this vantage point, the way logical empiricism itself presented its struggle with Kant may well require revision.

The present article aims to contribute to such a revision by examining Hans Reichenbach's early work on Kant and Einstein, entitled *The Theory of Relativity and A Priori Knowledge* (1920). Yet I will not take issue with Reichenbach's account of Kant for its own sake. I rather focus on this remarkable text because of Reichenbach's effort to transform rather than abolish Kant's notion of synthetic a priori principles. Although even Reichenbach, in my view, overrated the extent to which this transformation departed from Kant, this transformation itself marks an important moment in the history of 20th century philosophy. Reichenbach's early conception of scientific knowledge is much more promising, I hold, than the one which soon after 1920 came to be identified with logical empiricism as such. This is true in particular of his reflections on the historicity of a priori principles.

Among those who have investigated the history of logical empiricism Michael Friedman is one of the very few repeatedly to have discussed this intriguing text. According to Friedman, Reichenbach's early work deserves merit for its conception of what he terms the 'relativized a priori', that is, for the idea that constitutive scientific principles can be a priori as well as revisable.[2] This article is by no means intended to question Friedman's interpretation—and further elaboration—of Reichenbach's conception of relativized a priori principles.[3] It does question, however, the retrospective account logical empiricism presented of its relation to Kant, an account Friedman and many other commentators seem to accept.[4] Apart from presupposing a misguided conception of Kant, this account largely ignores the phase of hesitation that preceded the clear-cut rejection of critical philosophy. Thus, in 1920 Reichenbach notes that:

> Kant's theory in its original form ... stands unexcelled by any other philosophy and that only it, in its precisely constructed system, is equivalent to Einstein's theory in the sense that a fruitful discussion can ensue. (Reichenbach 1920: 107/112, note 17)[5]

Moreover, Reichenbach maintains that the basic principles of science, which he terms principles of coordination, 'mean nothing else than Kant's synthetic a priori judgments'.[6] In 1936, by contrast, Reichenbach purports to have argued in 1920 'that the Kantian method at its best was nothing else than an analysis of Newtonian mechanics in the guise of a system of pure reason'.[7] A few pages later, he contends that 'the evolution of science in the last century may be regarded as a continuous process of disintegration of the Kantian synthetic a priori'.[8] In what follows I will consider Reichenbach's early work not as a transient phase in this

process, but rather as a highly interesting attempt to appropriate what he saw as the viable core of Kant's synthetic a priori principles.

Given this aim I will focus as much as possible on the philosophical aspects of Reichenbach's text. In order to assess Reichenbach's reading of Kant, I begin by outlining the two complementary perspectives on the *Critique of Pure Reason* I take to correspond to the two tasks Kant set himself in this work (Section 2). Section 3 offers an interpretation of Kant's conception of synthetic a priori principles that contrasts with the one put forward by both neo-Kantianism and logical empiricism. On this basis, Sections 4 and 5 examine the early Reichenbach's effort to accommodate these principles to the paradigm forged by Einstein.

2. Kant's *Critique of Pure Reason*: Metaphysics or Philosophy of Science?

It is without doubt the great merit of Friedman's ground-breaking work on Kant to have shown how much Kant's critical philosophy is informed by the mathematical exact sciences of his day. Notwithstanding his focus on this aspect of Kant's philosophy, Friedman (1992a) stresses that the *Critique of Pure Reason* is not 'wholly parasitic' on these sciences. Kant's achievement, he notes, 'consists rather in . . . radically transforming . . . metaphysical ideas stemming largely from the Leibnizian philosophical tradition . . . within the essentially new scientific context wrought by Newton' (xiii, cf. 4, 15). Few would disagree with this succinct characterization of Kant's project. It is far from evident, however, how we are to understand the exact nature of this transformation. Whereas Friedman suggests that Kant in his critical period abandoned the metaphysical tradition (37–38), I would contend that Kant even in the first *Critique* itself seeks to bridge the gap between, on the one hand, the task set by the metaphysics of his predecessors and, on the other, the challenge posed by Newton's scientific paradigm.

Clearly, Friedman's reading of Kant is strongly indebted to the neo-Kantian movement inaugurated by Cohen (1871) and the ensuing criticism of Kant put forward by the logical positivists. Both movements saw Kant's project as closely linked to Newton's physics—albeit with opposite intents. Friedman holds, accordingly, that those who read Kant independently of Newtonian physics are 'profoundly mistaken' (xii). Indeed, interpretations focusing exclusively on the first half of the bridge Kant attempted to build between pure thought and the exact sciences threaten to lose sight of the second half. Yet this one-sidedness does not mean that such interpretations should therefore be discarded altogether. Thus, commentators like Gottfried Martin and Hans Fulda are perfectly justified, in my view, to interpret the *Critique* in light of Kant's transformation of the task traditionally assigned to ontology or general metaphysics. On this view, Kant's discussion of the principles of pure understanding aims not only to establish the a priori foundation of the exact sciences. According to Fulda (1988), it achieves at the same time the task traditionally assigned to general metaphysics, namely, the

exposition of the most general determinations of whatever it is that can be known. Contrary to Leibniz and Wolff, however, Kant limits the task of what he terms transcendental philosophy to the investigation of the general determinations of such phenomena as can become objects of scientific knowledge.[9]

These determinations pertain to the possible ways of fixing the relation between given representations. The principles that present these determinations in the form of judgments include the requirement to order such representations in terms of that which remains self-identical over time, in terms of their causal relations, and in terms of their reciprocal interaction. On this account, the synthetic a priori principles treated in the *Critique* merely constitute necessary rules for determining the spatio-temporal, law-governed relations between given representations—whatever the actual content of these relations may be.

Although Friedman would agree with this view, his *Kant and the Exact Sciences* is almost exclusively concerned with the second half of the bridge Kant attempted to build, namely, the half that stretches from the principles of pure understanding treated in the *Critique of Pure Reason* to the laws of Newtonian physics treated in the *Metaphysical Foundations of Natural Science*.[10] For Friedman, the 'abstract' analogies of experience at stake in the *Critique* only become meaningful through their 'instantiation', 'specification' or 'realization' in Newton's laws of motion.[11] He repeatedly refers to Kant's alleged claim in the Preface to the *Metaphysical Foundations* that Newtonian science constitutes 'an example in concreto' of transcendental philosophy.[12] Yet the similarities between both levels do not warrant the conclusion, in my view, that the principles of pure understanding discussed in the *Critique* are themselves completely devoid of meaning.

Within the latter context, Kant states unambiguously that pure concepts owe their meaning to their possible relation to objects, a relation that is established by their schematization.[13] The principles that ensue from these schematized categories are much more formal than Newtonian laws. Yet the difference between these two kinds of synthetic a priori principles is not a matter of degree, as Friedman holds, but a *difference in kind*. Unlike laws of physics, the principles of pure understanding do not depict the world, but constitute the 'rules of the pure thinking of an object'. Yet transcendental logic, Kant notes, is therefore not completely devoid of content (A55/B80). Contrary to empirical laws, the principles it deals with are synthetic not because they tell us something about the world, but merely because they assign determinations to the concept of object—such as causality—that are not contained in this concept itself (cf. A7/B11). Hence, the principles of pure understanding are nothing but perspectives that we must necessarily adopt in order to turn phenomena into objects of knowledge. Together, Kant holds, they merely constitute 'a system that permits research based on principles of unity, research that experience alone can provide with its matter' (A783/B766). In this sense, they provide essential guidance to any effort at understanding the world in a scientific way.

Thus, Kant merely employs the metaphysical term of substance to denote the principle that allows thought to distinguish that which remains self-identical

over time from its variable determinations. This principle does not tell us whether we should employ it to comprehend individual things, matter, mass-energy, or any other content as that which remains self-identical over time.[14] It does preclude, however, an interpretation of the world in terms of Leibnizian monads, which by definition do not belong to the realm of appearances.

Without such synthetic a priori root-principles it would not be possible for us to establish laws of physics proper. Since the former by no means tell us something about the actual world, however, their relation to the latter—whether they are synthetic a priori or empirical—cannot be adequately grasped in terms of 'instantiation' or 'realization'. Such terms fail to account, in my view, for the crucial difference between the various layers of Kant's account of the conditions of possibility of the natural sciences. The principles of pure understanding only function as the 'ground' of these sciences in the sense that they delimit the domain within something can be treated as an object in the first place.

It emerges from this brief discussion, I hope, that Kant's texts—even those of his critical period—testify to a perhaps irresolvable tension between the poles of metaphysics and theory of science. Seen in this way, accounts of Kant such as Friedman's and Fulda's both concentrate on one of these poles, playing down the role of the other. As I will argue below, the tension between these poles even marks the difference between the two editions of the first *Critique*. In my opinion, Kant did not really succeed in resolving this tension. He rather emphasized either the one or the other of the two poles that delimit the trajectory of his critical philosophy, and this in view of the audience he wanted to convince at a particular point.

It is precisely Kant's own wavering between these two poles, I would suggest, that has fuelled the debates concerning the dependence of the *Critique* on the sciences of his day.[15] Contrary to Reichenbach, Friedman, and many other commentators, I do not believe that this issue has been settled. In an article on Cassirer published in 1921, Schlick notes that philosophy should 'avoid the tiresome intrusion of questions concerning the interpretation of Kant'.[16] Yet in order to determine to what extent the fate of Kant's conception of synthetic a priori principles is actually bound up with that of Euclidian geometry and Newtonian physics, one cannot forgo the option of reconsidering this conception itself.[17] The following section does this by focusing on the pole of Kant's thought that concerns his transformation of Leibniz' and Wolff's metaphysics.

3. Kant's Conception of Synthetic A Priori Principles

The *Critique of Pure Reason* basically distinguishes between three kinds of synthetic a priori judgments, namely, geometrical judgments, judgments that concern the ideas of pure reason, and judgments that articulate the root-principles of knowledge as such (B14–18).

For Kant, geometrical judgments are synthetic a priori because the content of geometrical concepts alone, which can be thought, does not suffice to make these judgments meaningful. This requires that the content of these concepts be projected onto the realm of pure spatial intuition.[18] The second kind of judgments attributes predicates to concepts such as the soul, the world, or God, predi cates which are not contained in these concepts themselves. However, since these judgments do not meet the criterion of objectivity laid down in the Transcendental Analytic, Kant dismisses them from the realm of theoretical knowledge altogether.

The question as to what extent Kant's conception of space and time was bound up with Euclidian geometry played a major role in the debate between neo-Kantians and logical empiricists. Given Reichenbach's emphasis on physics, however, I will only consider the third kind of synthetic a priori judgments Kant treats in the first *Critique*. The section of the *Critique* devoted to these judgments—the synthetic a priori principles of pure understanding (A158/B197)—exposes the root-principles by dint of which something can become an object of knowledge in the first place.[19] Kant regards these principles as a priori because they are presupposed in any form of scientific knowledge, and as synthetic because their content cannot be reduced to the content of pure concepts alone. Thus, far from telling us something about the world, the principle based on the pure concept of quantity merely states the rule that every intuited object has an extension and, hence, can be determined mathematically.[20] According to Kant, it is only on the basis of this principle that physics can apply pure mathematics to objects of experience (A165/B206). The category of substance, for its part, yields the rule that scientific knowledge must necessarily distinguish between that which changes over time and that which constitutes the self-identical substrate of such changes.[21] Otherwise scientists would neither be able to determine something as an object, nor to determine the relation between objects.

Without such principles, Kant notes, 'appearances could never amount to cognition of an object corresponding to them' (A159/B198). He leaves no doubt as to the crucial difference between these basic principles and the laws of nature articulated within physics itself:

> Even laws of nature, if they are considered as principles of the empirical use of the understanding, at the same time carry with them an expression of necessity, and thus at least the presumption of determination by grounds that are a priori and valid prior to all experience. But without exception *all laws of nature stand under higher principles of the understanding, as they only apply the latter to particular cases of appearance*. (A159/B198, my emphasis, cf. A216/B263, B294)

Kant here suggests that laws of physics proper are synthetic a priori as well. For even if sense-perception is involved in their discovery, they cannot completely derive from this source.[22] He apparently considered it a future task to show that

these laws in some way depend on the principles of pure understanding. However, this task falls outside the scope of the *Critique* itself and is relegated to the *Metaphysical Foundations of Natural Science*.

While preparing the second edition of the *Critique*, Kant clearly drew on the results of this work, published in 1786, to present his transcendental philosophy in a form more likely to convince the reader of its relevance to contemporary science. Thus, the Introduction to the second edition of the *Critique* maintains that physics, like geometry, 'contains' synthetic a priori principles, including the laws of the conservation of mass and the equality of action and reaction.[23] According to Kant, such laws are synthetic insofar as they cannot be derived from concepts such as matter or movement alone (cf. B765). They are a priori, on the other hand, insofar as they necessarily precede the empirical investigation of nature.

This account is in agreement with the passage from the first edition of the *Critique* quoted above. However, Kant in the second version of the Introduction suspends the answer to the question whether metaphysics contains synthetic a priori principles as well. This text therefore fails to make clear that the synthetic a priori laws proper to the domain of physics ultimately can be traced back to—though not deduced from—the synthetic a priori principles of pure understanding treated in the Transcendental Analytic. Kant here fails to point out that these latter principles belong to the realm formerly treated by ontology or general metaphysics rather than to the realm of (rational) physics.

Kant's silence on this point is quite understandable, however. The Introduction to the second edition of the *Critique* cannot simply identify the concepts and principles of pure understanding with those traditionally treated within general metaphysics, because the *Critique* precisely aims to overcome the traditional elaboration of this discipline. As I noted above, Kant does this by limiting the scope of general metaphysics—which he sometimes equates with transcendental philosophy—to the most general determinations of any possible object of scientific knowledge.[24] Only insofar as metaphysical principles function as the conditions of possibility of scientific knowledge can they withstand the critique of reason.[25] Thus, whereas these principles constitute the ultimate *conditions of possibility* of physics, they constitute the *content* of Kant's transcendental philosophy itself.

On this account, Kant's philosophy is hardly vulnerable to the charge that his conception of synthetic a priori principles *as such* is contingent upon Newtonian physics and, consequently, untenable in the context of contemporary physics. In my view, both logical positivists and commentators such as Friedman tend to overlook the difference in kind between the synthetic a priori principles of pure understanding at stake in the *Critique* and those of physics proper.[26] I would argue, first, that the former do not pertain to given phenomena, but are constitutive of the conceptual scheme that any scientific knowledge must presuppose. Even if Kant sometimes refers to these principles as forms of a priori cognition, they need not be consciously represented by the scientist himself.[27] Second, these principles are apodictic only in the sense that they determine from

the outset whether something can become an element of objective knowledge at all: no empirical fact can contradict the claims that something must be measurable and have a cause in order to count as an object of scientific knowledge (cf. A146/B185). Third, even though Newtonian physics formed a part of the 'context of discovery' of the principles of pure understanding, Kant aimed to trace back the a priori elements contained in this physics to forms of ordering—or synthesis—proper to the understanding as such. It is by means of the metaphysical deduction, I would contend, that Kant established the independence of the principles of pure understanding of any results achieved by the sciences themselves. Fourth, there is no reason why these principles should undergird Newtonian physics alone; the fact that they do so is, as such, no argument against their presence in relativity theory or any other kind of physics.[28]

These four reasons pertain to the most basic kind of synthetic a priori principles involved in the constitution of physics. Yet even the examples mentioned in the 1789 Introduction are not sufficiently bound up with Newtonian physics to overthrow transcendental philosophy.[29] If matter is defined in terms of mass-energy, both laws remain valid within the context of relativity theory. My point is rather, however, that even if Kant had given examples of synthetic a priori laws of physics completely rejected by relativity theory, then one would still not be justified in abolishing Kant's conception of synthetic a priori principles as such.

For the purpose of this article it is not necessary to dwell on Kant's effort to derive these synthetic a priori principles from the logical forms of judgment. The question concerning their constitutive function is, in my view, more pertinent than the question concerning their ultimate origin, for it is this function that distinguishes them from mathematical principles as well as from the laws of physics proper.[30] Although I hold that Kant's conception of the a priori elements of scientific knowledge is more viable than his critics suggest, I do not wish to claim that it is tenable within the context of contemporary physics in all respects. It might turn out, first, that the paradigm of general relativity theory no longer presupposes some of the synthetic a priori root-principles treated in the *Critique*. I have merely argued that this issue cannot be decided by considering either Kant's conception of space and time or his use of examples taken from Newtonian physics. Second, it is clear that Kant's perspective on the principles of scientific knowledge does not really permit of accounting for the historical succession of different scientific paradigms. It is on this latter issue, as Friedman has pointed out, that Reichenbach's early work offers a valuable contribution.

4. Reichenbach's Conception of Coordinating Principles

After 1919 the revolutionary impact of relativity theory provided philosophers associated with the Vienna circle and scientific philosophy at large with an

excellent opportunity to break away from a neo-Kantianism that was considered to thwart the progress of society and science. Along these lines, Reichenbach argues in *The Theory of Relativity and A Priori Knowledge*, first, that Kant presupposed the absolute validity of Euclidian geometry and, second, that the general theory of relativity had shown this geometry to be inapplicable to physical space. This entails, in his view, not only that Kant's conception of space and time is incompatible with relativity theory, but also that the principles of Euclidian geometry cannot be synthetic a priori in Kant's sense.[31]

Starting from Kant's conception of geometry, Reichenbach then takes issue with Kant's notion of synthetic a priori principles as such. Contrary to his retrospective account, however, Reichenbach in 1920 never goes as far as to explicitly equate Kant's synthetic a priori principles with the principles of Newtonian physics proper. He rather proceeds by treating both Kantian and Newtonian principles as a priori 'in the sense of Kant' (Reichenbach 1920: 29/31). This leveling allows him to implicitly extend his attack on the allegedly ubiquitous truth of Newtonian physics to Kant's transcendental philosophy.[32] In order to save Kant's basic insight into the constitution of science from empiricist attacks, on the other hand, Reichenbach distinguishes two meanings of aprioricity in Kant, namely, 'apodictically valid, valid for all times' and 'constitutive of the concept of object' (46/48). This distinction allows him, in principle, to reconcile Kant's conception of a priori principles with their revisability:

> The doctrine of the a priori has been transformed into the theory that the logical construction of knowledge is determined by a special class of principles, ... the significance of which has nothing to do with the manner of its discovery and the duration of its validity. (Reichenbach 1920: 89/94)
>
> 'A priori' means 'before knowledge,' but not 'for all time' and not 'independent of experience'. (Reichenbach 1920: 100/105)

Thus, Reichenbach opposes neo-Kantianism by arguing that relativity theory caused the demise of Newtonian physics and Kantian philosophy alike. On the other hand, however, he adopts Kant's insight into the constitutive role of a priori principles in order to oppose a purely empiricist conception of science (cf. 89/93). Thus using Kant against both neo-Kantianism and empiricism, Reichenbach seeks to provide room for a logical empiricism in which formal logic has not yet completely replaced transcendental logic.

Although, from the point of view elaborated above, Reichenbach's position is closer to Kant than he himself seems to hold, he undoubtedly accomplished a significant modification of Kant's conception of a priori principles. To this end, he interprets these principles as principles of coordination (*Zuordnungsprinzipien*) and distinguishes them from axioms of connection (*Verknüpfungsaxiome*).[33] He uses the term *Zuordnung*, derived from set theory, mainly to refer to the way in which basic mathematical equations are assigned to the realm of experience so as

to order and comprehend the content of what is perceived.[34] By means of this assignment, such mathematical equations are projected, as it were, onto the world as such. It is only on the basis of this preliminary projection that the ensuing physical laws can actually define the order of individual things:

> [I]ndividual things and their order are defined by physical laws. The coordination (*Zuordnung*) itself first creates one of the sets of elements to be coordinated. (Reichenbach 1920: 40/42, cf. 38–39/40–41)

The coordination takes place between a given set of mathematical equations and a completely undetermined reality. According to Reichenbach, it is only the assignment of these equations to the realm of experience that turns this realm into the domain of physics proper. Principles of coordination 'define the individual elements of reality and in this sense *constitute* the real object' (50/53). Thus, Reichenbach follows Kant in arguing that physics must rely on principles that bridge the gap between pure thought, now basically exemplified by mathematics, and experience. As we will see, these coordinating principles themselves do not necessarily belong to formal logic or mathematics.

Reichenbach's distinction between principles of coordination and axioms of connection seems, at first sight, neatly to correspond to Kant's distinction between the principles constitutive of scientific knowledge as such and actual physical laws. Upon closer inspection, however, Reichenbach's distinction deviates from Kant's in a way that will turn out to be quite significant. For he conceives of the axioms of physics proper as axioms of connection insofar as they interconnect specific variables, but as principles of coordination insofar as they pertain to the *general rules* of interconnecting such variables. Thus, since the principle of probability determines, according to Reichenbach, what counts as a physical constant in the first place, it constitutes a principle of coordination rather than an axiom of connection. For one has to assume some distribution of observation errors—such as the Gaussian distribution—in order to view a set of measurements as indication of the underlying measured quantity.[35]

Einstein's equations of gravitation constitute clear-cut axioms of connection. These equations themselves presuppose the axioms of arithmetic, which, Reichenbach holds, function as principles of coordination with regard to the domain of physics (52/54). The latter differ from concrete axioms of physics in that they determine the very way in which purely conceptual structures—whether mathematical or not—can be applied to empirical phenomena.[36]

Reichenbach apparently sees no difficulty in identifying his own conception of these principles of coordination with Kant's conception of synthetic a priori principles:

> [The] principles of coordination ... mean nothing else than Kant's synthetic a priori judgments. (Reichenbach 1920: 45/47, translation modified)

Just like Kant's synthetic a priori principles, principles of coordination assign conceptual structures to the realm of experience. Even when such principles belong to the domain of mathematics, as is the case with the axioms of arithmetic, they actually function as principles of coordination only to the extent that they are employed within physics. Reichenbach uses the term 'synthetic,' however, only when explaining that Kant conceived of judgments in general as assigning a manifold of perceptions to a certain conceptual scheme (46/48-49). Although he does not dwell on the meaning of 'synthetic' in the case of synthetic a priori principles, his explanation of principles of coordination makes it clear that they are just as much as Kant's synthetic a priori principles meant to bridge the gap between the conceptual and the sensible:

> Mathematics is indifferent with regard to the applicability of its theorems to physical things ... A purely mathematical axiomatization never leads to principles proper to a theory of physical knowledge. (Reichenbach 1920: 72–73/76)[37]

According to Reichenbach, physics is distinguished from mathematics by asserting that a specific system of equations is not just possible, but actually holds true of reality:

> [P]rinciples of coordination ... ultimately define real objects and real events. We may call them constitutive principles of experience. (Reichenbach 1920: 47/49, cf. 34/36)[38]

This leads us to the question as to how Reichenbach conceives of the principles of coordination constitutive of classical physics. The answer to this question is less straightforward than one might expect, for it is far from clear whether all a priori principles mentioned as examples in the text actually count as principles of coordination. What is clear, though, is that Reichenbach's set of a priori principles is quite different from Kant's strictly defined set of synthetic a priori principles constitutive of scientific knowledge as such.

Reichenbach, defining 'a priori' as that which is evident according to the forms of intuition or the concept of knowledge (6/6), interprets a number of basic presuppositions of classical physics as a priori principles (15/16) and even as a priori principles in the Kantian sense (29/31). Among them are causality, normal induction, Euclidian metric and absolute time. Reichenbach notes later on that these principles, 'according to Kant's method, would turn out to be principles of coordination' (54/57). Elsewhere he refers to space, time, and the categories as principles of coordination singled out by Kant himself (47/49).

Apparently, Reichenbach's definition of principles of coordination is rather loose: it encompasses principles of a quite different nature, which merely have in common that they are constitutive of actual physical laws.[39] It is not difficult to see that Reichenbach thus completely blurs the distinction between Kant's transcendental notion of synthetic a priori principles and principles specific to an

actual system of physics such as Newton's. Once this Kantian distinction is implicitly replaced by a broad conception of principles of coordination, the way is paved for the decisive step in Reichenbach's encounter with Kant. Before addressing that step, however, I will briefly consider which specific principles of coordination Reichenbach believes to be constitutive of relativity theory.

Principles of coordination which Reichenbach seems to consider as independent of particular modes of physics are probability, normal induction, genidentity,[40] and space and time. Evidently, these principles are not necessarily logical or mathematical. Within relativity theory, he maintains, Euclidian metric no longer has the status of a principle of coordination because objects can no longer be measured independently of their actual relation to other objects, that is, of physical properties such as speed and gravitation. This metric is therefore reduced to a mere axiom of connection.[41] The fact that relativity theory parts with certain principles of both Euclidian geometry and Newtonian physics implies for Reichenbach a fundamental change in the conception of an object as such:

> We understand that today's conditions of knowledge are no longer those of Kant's time, because the concept of knowledge has changed, and the changed object of physical knowledge presupposes different logical preconditions. (Reichenbach 1920: 99/104, cf. 97/102)

Reichenbach does not spell out, however, what these logical preconditions are. Contrary to what this passage suggests, moreover, he does not conceive of relativity theory as radically opposed to classical physics. He rather argues that relativity theory incorporates Newtonian physics as a theory applicable to certain simple cases. Thus, the a priori principles proper to Newtonian physics are not so much abandoned as reduced to subordinate moments of more general ones (66/68-69). In the same way, the Euclidian space-time framework is replaced by a space-time framework drained of all content (cf. 100/104). Near the end of the book, Reichenbach maintains—in line with Cassirer (1910)—that relativity theory has no need of the Kantian category of substance because it is exclusively concerned with the quantifiable relations between objects (97/101).

Reichenbach suggests that relativity theory first and foremost differs from Newtonian physics by the role it grants to mathematical models at the cost of the possibility of intuitively representing physical events.[42] As I see it, however, this view is not necessarily at odds with Kant's conception of the root-principles of any scientific knowledge, because these principles are nothing but necessary guidelines for turning appearances into objects of knowledge. Kant's category of substance, for instance, does not entail that our scientific investigations should be concerned with individual objects rather than quantifiable relations. It merely entails that we must determine *something* as invariable with respect to a set of variable properties, whether in terms of matter, mass-energy, or in any other way.

Likewise, Kant's conception of space and time—insofar as their role in physics is concerned—merely entails that something cannot become an object of scientific knowledge unless it is measurable in terms of extension, speed, and degree.[43] The fact that Kant takes the trouble of spelling out these formal preconditions only makes sense, I hold, if we take into account that the *Critique* is primarily aimed at denying to metaphysics the status of a science, a perspective that disappeared from the scene during the reign of neo-Kantianism.

5. The Revisability of A Priori Principles

I have argued that Reichenbach, in line with neo-Kantianism, failed to distinguish between, on the one hand, the *formal* character of Kant's principles of pure understanding compared to any physical laws and, on the other, the *generality* of relativity theory compared to classical physics. The outcome of this neglect is not merely negative, however, for it impelled Reichenbach to reflect on the revisability of properly *scientific* principles. Thus, Reichenbach used the results of relativity theory to argue against Kant—foreshadowing Quine's holism—that principles of coordination are in principle as revisable as axioms of connection. Just as classical axioms may have to be abandoned in view of variations caused by specific gravitational fields, basic principles of coordination may have to be abandoned if they turn out to yield a non-coherent system of physics, that is, a system that fails to assign mathematical equations to empirical data in such a way that the relation between these data can be fixed univocally. This is, at last, the decisive step in Reichenbach's argument:

> A principle is tested by determining whether or not a unique coordination is achieved by the continuous application ... of the principle in question. If uniqueness is not obtained, the theory is abandoned. This procedure can be applied to principles of coordination in exactly the same way. (Reichenbach 1920: 62/64, translation modified)

While abolishing the allegedly apodictic content of Kant's a priori principles, Reichenbach does not throw out the child of a priori principles with the bathwater of metaphysics altogether. His point is precisely to save their constitutive function.[44] And this is, in fact, *all he needed* to meet the challenge posed by straightforward empiricism. In order to oppose neo-Kantianism, on the other hand, *all he needed to do* was to embrace a qualified mode of empiricism, that is, to grant experience an important role in determining whether the coordinating principles constitutive of a particular scientific system are valid. Once the deviation of light rays predicted by general relativity theory was empirically confirmed, it turned out, Reichenbach suggests, that some of the coordinating principles constitutive of Newtonian physics—such as the homogeneity and Euclidian character of space—prevented that system from establishing a unique coordination between mathematical equations and empirical data (29/31, 51/53).

For this reason these principles had to be denied the function of coordinating principle within the new system.

Evidently, experience as such cannot overthrow the principles constitutive of experience. Yet empirical measurements can put such pressure on a system that the inherent contradiction between the very principles constitutive of this system actually emerges. Reichenbach explains this 'reciprocity' of principles and experience as follows:

> For this reason, individual things and their order are first defined by physical laws ... Strangely enough, the defined side does not carry its justification within itself; its structure is determined from outside. Although the coordination we are concerned with is a coordination to undefined elements, it can only be achieved in a particular way and is far from arbitrary ... We notice the strange fact that it is the defined side that determines the individual things, and that, vice versa, it is the undefined side that prescribes the order of the defined side. (Reichenbach 1920: 40/42, translation modified)[45]

However, the role Reichenbach grants to experience does not preclude that any system must be grounded in a specific set of coordinating principles. This is, then, how Reichenbach sought to preserve a modified notion of synthetic a priori principles:

> Our reflections radically transform the concept of the a priori. Its one meaning, namely, that an a priori proposition obtains eternally, independent of any experience, can ... no longer be maintained. Its other meaning becomes all the more important: that a priori principles are constitutive of the world of experience. Indeed there cannot be a single physical judgment ... unless certain assumptions about the representation of the object in terms of a space-time manifold and its functional connection with other objects are made. It does not follow from this, however, that *the form of these principles is fixed from the outset* and is independent of experience ... What remains for us to be done, is to expose these principles by means of a continuous process of scientific analysis, and to abstain from the question as to how long their specific form remains valid. (Reichenbach 1920: 74/77-78, translation modified, cf. 100/104)

Yet I am not sure that Reichenbach, by means of this decisive move, is able to secure the distance between his position and Kant's. For the end of this passage suggests that only the *specific form* of constitutive principles is revisable. This seems to entail that different kinds of physics can rely on the same set of a priori root-principles.[46] With regard to the only, paradigmatic, example referred to by Reichenbach, we have seen that the shift accomplished by relativity theory consists not so much in the complete rejection of the principles of classical physics as in their subordination to more general ones. It might be argued that

this shift pertains to synthetic a priori principles belonging to the realm of physics rather than to the synthetic a priori root-principles treated in Kant's Transcendental Analytic.

Regardless of the way Reichenbach saw Kant, his struggle with Kantianism resulted in a viable reflection on the constitutive function of coordinating principles. Yet his defense of Kant's insight into this function did not fall on fertile ground. In 1921 Einstein published an article—entitled 'Geometry and Experience'—in which he argues that physics consists of freely created mathematical axioms on the one hand and propositions derived from experience on the other.[47] He did so with explicit reference to Schlick, who as early as 1918 had maintained that sciences are constituted by conventional definitions and empirical propositions alone.[48]

In *The Theory of Relativity and A Priori Knowledge* Reichenbach had explicitly criticized both conventionalism and Schlick's rejection of the constitutive function of Kant's a priori principles.[49] After Reichenbach had published his book, Schlick tried to convince him to embrace Poincaré's view that the choice of such principles is purely conventional.[50] Einstein's article may well have made it more difficult for Reichenbach to hold on to his critique of Schlick on this point. In 1921, Reichenbach asserted that relativity theory consists of assertions capable of empirical verification (axioms) and arbitrary forms of thought (definitions).[51] Although the role of coordinating principles is no longer mentioned, the offered examples do not allow the conclusion that Reichenbach now regards all coordinating principles as mere definitions. In a more elaborate discussion of the philosophical significance of relativity theory published in 1922, Reichenbach notes once again that only the constitutive function of Kant's a priori principles can be preserved in light of the results achieved by relativity theory. While he no longer refers to these constitutive principles as coordinating principles, neither does he regard them as mere conventions.[52] In *The Present State of the Discussion on Relativity*—also published in 1922—he endorses Schlick's criticism of Kant's conception of pure intuition.[53] This is in line with his 1920 monograph. Yet Reichenbach now takes back his earlier criticism of Schlick, suggesting—in rather vague terms—that Schlick's avowed empiricism is not necessarily at odds with the idea of 'the constitutive significance of the categories in the concept of object'.[54] Although Reichenbach still does not accept Schlick's use of the term 'conventionalism' in this respect, he seems to have abandoned the effort to define his conception of scientific knowledge in relation to Kant's.

Whatever Reichenbach's reasons for doing so may have been, clearly the ranks were closing. After Einstein's essay and Schlick's review of Cassirer's monograph it seems to have become almost impossible to present a nuanced view on the significance of Kant's work. 'Thanks in large measure to Schlick's authority and rhetorical ability to pose the issue on his own terms', Ryckman notes, 'the debate between ''empiricist'' and ''critical'' philosophy over relativity theory effectively ended with Schlick's essay'.[55] Seen from the vantage point first established by Schlick, Reichenbach's attempt to transform Kant's

notion of a priori principles emerged as a passing birth pang announcing the true beginning of logical empiricism. It could hardly be perceived, that is, as an aborted effort to shape the historicity of scientific paradigms into a philosophical question.

6. Conclusion

Although relativity theory provided the occasion as well as the context for Reichenbach's reflection on this historicity, its results are not bound to this context alone. Reichenbach's early work is, in my view, important first and foremost because it directs attention to those a priori principles that are constitutive of a particular science and hence liable to revision. Rather than convincingly demonstrating that *all* a priori principles are revisable, Reichenbach's view implies that in order to adequately comprehend the history of scientific revolutions, the principles constitutive of a particular scientific framework are simply much more relevant than the ultimate preconditions of knowledge as such.

The price that Reichenbach paid for this valuable insight is a rather high one however. For, as we have seen, he could incorporate Kant's conception of a priori principles into an empiricist approach to science only by neglecting the specific meaning of 'synthetic' as used in the term 'synthetic a priori'. By replacing this Kantian term with the neutral term *Zuordnungsprinzip*, Reichenbach paved the way for Carnap's reinterpretation of the constitutive principles of a chosen language as purely analytic and hence for the strict opposition between propositions that are a priori, analytic and necessary on the one hand and propositions that are a posteriori, synthetic and contingent on the other.[56] At least until Quine this opposition has largely determined the paradigm of analytic philosophy. Thus, whereas Reichenbach's conception of principles of coordination opened up, *in principle*, a new way of reflecting on the historicity of scientific systems, it *actually* contributed to the emergence of a philosophical paradigm hostile to precisely this historicity.

It is, perhaps, only from a contemporary perspective on the history of post-Kantian thought that the paradigmatic opposition between logic and experience can emerge as a *Zuordnungsprinzip* of philosophy itself which is not necessarily as productive today as it has been in the past. In order to critically question the very philosophical paradigm based on this opposition, one need not necessarily adopt a Quinean holism.[57] If we wish to reflect on the role of a priori principles in the historical development of knowledge it might be more rewarding, I believe, to reconsider the brief moment at which the mode of philosophy that was to become logical empiricism had not yet completely weaned itself from Kantian thought. Reichenbach's effort to bridge the gap between Kant and Einstein may not have been entirely successful. In this respect, his work is akin to Kant's, who, for his part, never completely bridged the gap between Leibniz and Newton. Yet Reichenbach's struggle with Kant's legacy has much more to offer, in my view,

than the straightforward rejection of synthetic a priori principles, which, soon after 1920, became the mark of logical empiricism and continues to stamp 'our' current philosophical predicament.[58]

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NOTES

[1] See, among others, Proust 1986; Coffa 1991; Salmon and Wolters 1994; Richardson 1998; Friedman 1999, 2000a; Hanna 2001; Ryckman 2005.

[2] See Friedman 1999, 2001: esp. 71–82. Offering a lucid and charitable account of Reichenbach 1920, Holland 1992 even claims that Reichenbach basically advances a neo-Kantian position (209).

[3] Friedman 2001, see esp. 23–24, 105–115, for instance, sketches a theory of science based on the systematic distinction between (1) empirical laws, (2) a priori principles constitutive of a particular paradigm, and (3) philosophical meta-paradigms that allow us to reflect on the paradigm-shifts occurring at the second level.

[4] The only exception I am aware of is Ryckman 2005, see esp. 15, 50. In this impressive work he scrutinizes the various epistemological analyses of the theory of general relativity put forward in the 1920s. By contrast, Coffa 1991: 21 straightforwardly maintains that analytic philosophy developed by rejecting Kant's notion of the a priori. Friedman 1999 notes that '[t]he logical positivists or logical empiricists—for present purposes, Reichenbach, Schlick, and Carnap—begin their philosophizing by emphatically rejecting this Kantian analysis of scientific knowledge and, in particular, the idea of synthetic a priori judgments' (60). It is somewhat surprising that Friedman in this context should refer to Kant's *Metaphysical Foundations of Natural Science* from 1786. This is certainly in line with Friedman 1992a. However, Reichenbach 1920 exclusively refers to the *Critique of Pure Reason*. Carnap 1922 only refers to the *Critique* and the *Prolegomena*. Whatever the exact relation between Kant's two texts, it seems that any investigation of Reichenbach's and Carnap's relation to Kant should focus on the first *Critique*.

[5] The page numbers to Reichenbach 1920 refer to the German text and English translation respectively.

[6] Reichenbach 1920, 45/47, translation modified. Carnap 1923 claims as late as 1923 that a system of physics 'contains synthetic a priori propositions, albeit not exactly in Kant's transcendental-critical sense' (97/211).

[7] Reichenbach 1936: 142. Although Reichenbach 1920 notes that Kant should have analyzed knowledge rather than reason (69/72), his only sustained criticism of Kant concerns the status of synthetic a priori principles. Conversely, he values Kant for his 'great discovery' that the object of knowledge is not given, but constructed (47/49) and for having established a *system* of principles (57/59). In his retrospective account of the rise of scientific philosophy published in 1951 Reichenbach maintains that Kant's philosophy, 'erected on the foundations of a physics modeled for an absolute space, an absolute time,

and an absolute determinism of nature, . . . has nothing to say to us who are witnesses of the physics of Einstein and Bohr' (Reichenbach 1951: 44, cf. 48–49, 113).

[8] Reichenbach 1936: 145.

[9] 'Now from this it follows irrefutably that . . . the principles of the pure understanding can be related to objects of the senses only in relation to the general conditions of a possible experience.' These principles 'are merely principles of the exposition of appearances, and the proud name of an ontology that presumes to offer synthetic a priori cognitions of things in general in a systematic doctrine (e.g., the principle of causality), must give way to the modest one of a mere analytic of the pure understanding' (A246-247/B303). See Martin 1969: 44, 110; 1955: 38, 94; Fulda 1988: 51, 53; Höffe 2003: 18–19; and Ficara 2006: 168–188 for readings of Kant that highlight his epistemological transformation of former ontology.

[10] Kant refers to these principles as the *Grundsätze des reinen Verstandes* (Kant 1997). The last main part of the transcendental analytic is devoted to the system of these principles (A148/B187). Since they are not derived from more general principles (A148/B188), I will refer to them as root-principles.

[11] Friedman 1992a: 139, 159–165. Yet Kant himself does not use such terms in the passages Friedman draws on. At B278, Kant merely states that in empirical knowledge we conceive of matter as that which remains self-identical over time. It does not follow from the fact that our empirical use of the concept of substance may result into the conception of matter as self-identical substrate that matter itself—whether defined in Newtonian terms or not—'realizes' the pure concept of substance. Similarly, in order to represent change, that is, the intuition that falls under the concept of causality, we must take recourse, according to Kant, to the 'example' of spatial movement (B292). In this case, the term 'example' refers to change—qua intuition—and not to the pure concept of causality itself. Friedman 1992b also stresses that the metaphysical principles treated in the *Metaphysical Foundations of Natural Science* instantiate, realize, or specify the transcendental principles of the understanding (171, 176, 181, 185). In his view, the latter 'depict a world . . . of spatially extended substances', a world 'closely modeled on . . . the system of heavenly bodies as described by the Newtonian theory of universal gravitation' (185). Even though Friedman is right to point out that Kant had Newton in mind when he treated the transcendental principles in the first *Critique*, I would hold that for Kant these principles determine the necessary structure of our *cognition* of the world rather than depict the world itself.

[12] Friedman 1992a: 136, cf. 159. Actually, Kant merely notes in the relevant passage from the *Metaphysical Foundations of Physics* that the 'metaphysics of corporeal nature'—that is, the investigation carried out in the *Metaphysical Foundations of Physics* itself—provides transcendental philosophy with examples (487). In this context there is no mention of Newtonian physics.

[13] According to Kant, the transformation of the pure categories into synthetic a priori principles presupposes their schematization in terms of time (A136/B175, A142/B181, A155/B194). This schematization 'expresses' (A142/B181) and 'first realizes' the categories (A146/B185-186). It seems to me that Friedman misleadingly quotes these terms in a completely different context, namely, in the context of his effort to demonstrate the tight connection between the principles of pure understanding and Newtonian laws. In line with Cassirer, Friedman thus claims that Kant's philosophy, for all its depth, is contingent upon Newtonian physics and that one should move beyond Kant in order to dissociate the principles of pure understanding from Newtonian physics (cf. Friedman 1994: 27–28, 30–31).

[14] This point is also stressed by Martin 1969: 80; 1955: 69.

[15] See Richardson 2006 for an apt characterization of the on-going debate between those who emphasize Kant's Newtonianism and those who argue that Kant was primarily concerned with the conditions of the possibility of experience as such. According to Richardson, the *Critique of Pure Reason* contains elements that lend support to both positions.

[16] Schlick 1921: 325.

[17] I should note that my criticism of the arguments put forward by logical empiricists against Kant does not amount to a defense of Cassirer, who tried to accommodate Kant's philosophy with general relativity theory. In line with neo-Kantianism as a whole, Cassirer 1921 maintained that Kant shaped his analogies of experience—which belong to the root-principles of possible knowledge—on Newtonian laws (74/415, cf. 5/353). He was obliged to admit, therefore, that relativity theory indeed moved beyond Kant. Cassirer attempted to save Kantianism by stressing that Kant's notion of space and time is independent of any particular geometrical system (431–33, cf. 355, 409) and, on the other hand, by referring to a certain tendency of science and philosophy to become increasingly concerned with relations rather than substances (34/379, cf. Cassirer 1910: 217–220/164–166). In his review of Cassirer's book, Schlick (1921) rightly remarks, it seems to me, that the historical perspective Cassirer adopts can hardly count as a defense of Kantianism (332). Although I believe Cassirer was right to stress the formal character of Kant's conception of space and time, I hold that the issue at stake cannot be settled by either defending or attacking Kant's Transcendental Aesthetics. See on Cassirer's response to Einstein Ryckman 2005: 42–46 and Pätzold 2007.

[18] A26/B42. Although Kant holds geometry to offer 'a splendid example' of synthetic a priori cognitions drawn from pure space and time (A39/B55), the Transcendental Aesthetics, I would suggest, is not so much concerned with geometry as with the primary ways of conveying objectivity to sensory impressions. Since geometry, for Kant, clearly testifies to the a priori origin of spatial intuition, he takes recourse to geometry in order to lay bare the constitutive function of pure spatial intuition in experience and hence in knowledge as such. Kant takes great care to conceive of geometrical principles as independent of sense-perception. On the other hand, he rules out a mode of geometry completely independent of the element of pure spatial intuition. Kant's Transcendental Aesthetics treats space merely as a condition that allows us to assign impressions to things outside of ourselves and outside of one another. This condition is indifferent to any geometrical determination of spatial relations and occurs whenever we relate to objects of experience (cf. Höffe 2003: 104–105, 111). For this reason, his transcendental conception of space *as such* does not rule out the possibility of non-Euclidian geometries. Yet he would not consider such non-Euclidian systems as genuine geometries unless they were applicable to the realm of appearances—a condition which had not been met in his time.

[19] 'The matter of appearances, however, through which things in space and time are given to us, can be represented only in perception, thus a posteriori. The only concept that represents this empirical content of appearances a priori is the concept of a thing in general, and the synthetic a priori cognition of this thing can never yield a priori more than the mere rule of the synthesis of that which perception may give a posteriori' (A720/B748).

[20] A162-163/B202-204. Kant considers the judgment 'all bodies are extended' to be analytic, for the predicate 'extended' is contained in the very concept of a body (A7/B11). Physics, on the other hand, necessarily relies on the principle that the phenomena to which it has access are extensive magnitudes and hence determinable by mathematics (A165/B206). This latter principle is not analytic, but synthetic a priori.

[21] A182/B224. Kant notes that the definition of substance as that which persists is tautological. This analytic judgment becomes applicable to the realm of phenomena, however, only if its content is projected onto the pure representation of time; only if it is thus transformed into a synthetic a priori principle does it express the rule that actually tells us to distinguish at all (if not how) between that which remains self-identical and that which changes over time (cf. A183-184/B227).

[22] See on this Friedman 1992b: 172–174.

[23] B17-18, cf. B20 note.

[24] B113-114, A845/B873. In the Preface to the *Metaphysical Foundations of Physics* Kant calls general metaphysics the transcendental part of metaphysics (478).

[25] On this account it can be explained why the introductory sections of the *Critique of Pure Reason* and the *Prolegomena* (Kant 1993, 1998) offer such different examples of metaphysical synthetic a priori judgments. The *Critique* mentions the claim that the world must have a first beginning (B18), the *Prolegomena* refers to the permanence of substance in all things (273). Whereas the former judgment belongs to former special metaphysics, the latter belongs to former general metaphysics, for it pertains to a determination constitutive of objects as such. For Kant, however, it is only a *valid* judgment insofar as it is conceived as constitutive of (our knowledge of) objects rather than of things themselves.

[26] Friedman 2000b does not hesitate to claim that *all* of Kant's examples of synthetic a priori knowledge have been refuted by the Einsteinian revolution in physics. Since, in his view, there are no longer 'any real examples of *scientific* a priori knowledge, . . . there are in fact no genuine examples of a priori knowledge' at all, so that 'Kant's idea of a characteristically ''transcendental task'' must also be given up' (Friedman 2000b: 368, my emphasis). Although Friedman, in this context, does not endorse the conclusions Quine draws from this view on Kant, he does not refute the view itself. Quine 1976: 211 collapses the two levels altogether. Since he deems the distinction between analytic and synthetic to be untenable, 'ontological questions . . . end up on a par with the questions of natural science'. We will see that Kant's crucial distinction between the ultimate principles of thought and the principles of a particular science already begins to collapse in Reichenbach 1920.

[27] Cf. B2-4. See De Pierris 1992 for an account of Kant's non-foundational conception of constitutive a priori principles. She rightly maintains that Kant considers knowledge to be impossible without sense-perception, but I do not see why this should warrant her conclusion that the relation between the a priori elements of knowledge and sensation is a reciprocal one (cf. 180, 196).

[28] See Höffe 2003: 204. Höffe 2003: 174–75, 183, 201 also emphasizes that the principles at stake in Kant's transcendental philosophy pertain to a much more formal level than the examples taken from Euclidian geometry and Newtonian physics suggest. If they are indifferent to changes occurring at this latter level, it is mistaken, he holds, either to defend or criticize Kant in light of modern physics (202, 205).

[29] Reichenbach 1920: 75/78 points out that Kant's concept of substance need not necessarily be interpreted in terms of mass, even if this is what Kant meant. On his view, even the electron can be regarded as a specific determination of the concept of substance (97/101). Comparing the analogies of experience to the Newtonian laws of motion, Pap 1946, esp. 55–72, argues that the connection between them is far from obvious (63) and stresses the regulative function of Kant's synthetic a priori principles (72, 80).

[30] Reichenbach 1920: 69/72, 89/93 abandons Kant's effort to anchor his transcendental account of knowledge in a quasi-psychological analysis of the faculties of human thought. See also Pap 1946: 59 and Strawson 1966: 16.

[31] Reichenbach 1920: 2-4/3-4, see Friedman 2001: 27.

[32] In section II, Reichenbach lists a number of 'basic presuppositions' of Newtonian physics, among which the principles of absolute time and irreversible causality (15/16, cf. 29/31). Arguing, for instance, that the notion of absolute time cannot be maintained in the face of relativity theory, Reichenbach maintains that this is an a priori principle 'in the sense of Kant' (59/61-62) insofar as it is allegedly based on immediate evidence (6/6). However, Kant's conception of pure intuition has nothing to do with an immediate grasping of some kind of truth, nor can his conception of time be identified with Newton's.

[33] Somewhat confusingly, Reichenbach also refers to the principles of coordination as 'axioms of coordination' (cf. 51/52). I take this to mean that Reichenbach uses the terms 'axiom' and 'principle' indiscriminately. In order to underscore the difference between the two kinds, however, I will refer to Reichenbach's basic distinction between *principles* of coordination and *axioms* of connection.

[34] Reichenbach 1920: 34/36–37. Although I will follow the standard translation, I would like to note that Reichenbach uses the term *zuordnen* basically to refer to the process in which concepts are *assigned* to the realm of experience so as to make it possible to order this realm. This occurs by assigning, for instance, the concept of a circle to a plate, or the concept of causality to two subsequent events (cf. 35/37). Schlick 1918 frequently uses the term *zuordnen* to refer to the relation between concepts and facts established in cognition, but he does not use a term like *Zuordnungsprinzip*.

[35] Reichenbach 1920: 50-51/53. Reichenbach devoted his dissertation (published in 1916–1917) to this topic. From this text onward, he proposed to treat the calculus of probability on a par with scientific principles such as that of causation. He here states that 'the principle of the lawful connection of all events, as performed by causality, is insufficient for the mathematical representation of reality'. This also requires, in his view, the principle of the *lawful distribution* of the quantities determined by empirical measurements, that is, the principle of probability. Reichenbach considers both—complementary—principles as 'synthetic a priori' (Reichenbach 1916–1917: 126–127, cf. 54–57). In a Kantian vein, he contests that the principle of probability is merely subjective and sets out to offer a 'transcendental proof' of this 'metaphysical principle' (106–107). This alleged proof consists in the argument that any knowledge of physical objects must presuppose this principle (which itself cannot be reduced to the realm of logic). See Eberhardt and Glymour 2008 for a clear and informative presentation of Reichenbach's dissertation and its context. They emphasize Reichenbach's attempt to integrate 'the foundational assumptions of probability theory into a more general philosophical—indeed Kantian—account of how scientific knowledge is possible' (4).

[36] Reichenbach 1920: 51/52, cf. 34/36–37.

[37] For Kant, this applicability is covered by the particular synthetic a priori principles called axioms of intuition. Contrary to Reichenbach, he did not yet have to oppose the effort to reduce physical laws as such to the domain of mathematics.

[38] It emerges from this description of principles of coordination, among other things, that Reichenbach underestimated their difference from Kant's principles of pure understanding, which not so much define real objects as that which counts as an object at all.

[39] Padovani 2009 also points out that Reichenbach does not seem to assign the various coordinating principles he mentions the same significance. In her view, he implicitly treats probability and genidentity as 'meta-axioms' of coordination' (13–15). Although this is an interesting point, I would like to add that Reichenbach could not afford to draw attention to such a distinction: given his struggle with Kant, he was primarily concerned to put *all*

coordinating principles—including Kant's—in the basket of a priori principles lacking eternal validity.

[40] Reichenbach 1920: 50–51/53, 64/66. Reichenbach takes 'the principle of genidentity,' elaborated by Kurt Lewin, to indicate 'how physical concepts are to be connected in sequences in order to define the same thing remaining identical with itself in time' (51/53, cf. 106/111, note 14). Lewin argues indeed that the concept of genidentity, contrary to that of logical identity, concerns the relation between various representations of a physical *object*. In order to determine whether various representations of a comet, for instance, refer to the same object, logical categories such as identity or sameness do not suffice (Lewin 1922: 10–14, 20). This requires, in Lewin's view, a particular 'constitutive category' (16), the function of which he considers as partly overlapping with the categories of community and causality (18). The concept of genidentity is not limited to a specific domain of the natural sciences, but characterizes 'the concept of the object of physics as such' (24). It seems to me that Lewin's conception of this concept is perfectly in line with Kant's conception of the categories that allow thought to turn something into an object of physics.

[41] Reichenbach 1920: 51/53–54, 96/100. Friedman 1999, 2001 draws on these passages to put forward his notion of the relativized a priori. Although Reichenbach maintains indeed that all a priori principles are revisable, he actually only refers to the way in which general relativity theory subordinates the principles of classical physics to more general ones.

[42] Cf. Reichenbach 1920: 103/107 and Friedman 2001: 78. Friedman would not agree, though, to interpret this shift by referring to Kant's basic principles of pure understanding instead of focusing, as he does, on the fundamental differences between Newton's and Einstein's physics.

[43] This is the thrust of Kant's treatment of the axioms of intuition and the anticipations of perception (A162-176/B202-218). These principles themselves do not tell us anything about the kind of mathematics to be employed to determine objects in these respects.

[44] See Ryckman 2005: 31–33.

[45] See also Reichenbach 1920: 62/64, 74/77, 99-100/104. Reichenbach's remarks about the role of experience in what we would now call paradigm-shifts are rather vague. It is clear though, that he highlights the role of empirical observations to counter neo-Kantianism as well as conventionalism. If he had in mind the empirical confirmation of general relativity theory, as I think is likely, he may well have overestimated the role of experience in the actual paradigm-shift itself.

[46] See Padovani 2009: 20.

[47] Einstein 1921: 5–6; see Ryckman 2005: 49, 59–67.

[48] Schlick 1918: 327/384, cf. 36/38, cf. Coffa 1991: 171–188. In 1915, Schlick 1915: 172–178 still accepts a priori intuition as the 'heart of the Kantian doctrine' of space and time (178). Schlick 1921: 327 notes with respect to relativity theory that 'the doctrine of synthetic a priori judgments . . . obtains no unambiguous confirmation from the new theory'. This is in line with Schlick 1918: 304/358, 327/384, cf. 1925: 68–69/74–75, where a priori intuition and synthetic a priori judgments are dismissed without substantial references to relativity theory. See on this Howard 1994.

[49] Reichenbach 1920: 3/3, 110/116, note 27.

[50] See Coffa 1991: 201–04; Howard 1994: 56–75; Ryckman 2005: 39, 51 for comments on, and quotes from, the correspondence between Schlick and Reichenbach. Schlick 1921: 110/333 also comments on Reichenbach's position at the end of his 1921 review of Cassirer's book on relativity theory. Reichenbach's conception of a priori principles, he writes here,

'strikes me as a total departure from the basis of critical philosophy, and I should designate Reichenbach's a priori principles as conventions, in Poincaré's sense'.

[51] Reichenbach 1921: 45.

[52] Reichenbach 1922a: 151–154, cf. 1922b: 38. Padovani 2009:18–20 argues as well that Reichenbach never conceived of basic principles such as probability and genidentity as merely conventional.

[53] Reichenbach 1922b: 36.

[54] Reichenbach 1922b: 37.

[55] Ryckman 2005: 50, cf. 15, 39.

[56] Cf. Proust 1994: esp. 37–38.

[57] See, for instance, Friedman 2000, 2001: 33, 35.

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