Semantic Incommensurability and Empirical Comparability:
The Case of Lorentz and Einstein

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1. Introduction

Incommensurability is among the catchwords of later 20th century philosophy of science. The notion of incommensurability in the non-geometrical sense relevant here was simultaneously introduced by Thomas S. Kuhn and Paul K. Feyerabend in 1962 (Kuhn 1962, 103; Feyerabend 1962, 58). Kuhn conceived of incommensurability as arising from a deep-reaching conflict between paradigms or comprehensive theoretical traditions, a conflict supposedly transcending mere incompatibility. The adoption of a new paradigm entails the restructuring, as it were, of the relevant universe of discourse; the adherents of the two paradigms tend to talk past one another. In particular, incommensurability is intended to express that, first, disparate concepts are employed in each of the theories at hand, second, distinct problems are tackled, third, the suggested problem solutions are evaluated according to different standards, and, finally, perceptions are structured differently (Kuhn 1962, 103-110, 148-150). Feyerabend, by contrast, focused on the "inexplicability," that is, the non-translatability of a term taken from one theory into the conceptual framework of another one incompatible with the first (Feyerabend 1962, 52-62).

While the initial use of the term "incommensurability" varied significantly, it came to be restricted, subsequently, to two features. "Methodological incommensurability" was intended to express the claimed indeterminacy of judgment as to the comparative merits of different theoretical approaches. "Semantic incommensurability" was supposed to denote the non-translatability of statements from incompatible, strongly contrasting theories. In the following, I exclusively address this second notion of semantic incommensurability. This notion agrees with the one entertained by Feyerabend and the later Kuhn. My aim is to give a systematic reconstruction of the nature and impact of semantic incommensurability.

Underlying the conception of incommensurability is the theoretical context account of meaning which both authors adopted for explaining the meaning of scientific terms in general. I try to show, first, that incommensurability can be reconstructed coherently on the basis of the context account. I present incommensurability as a consequence of this semantic theory along with the historical observation that substantial theoretical revisions occur indeed. My conclusion is that incommensurability qualifies as a sensible notion. Second, I defend the coherence of the notion of incom-

mensurability by offering relevant examples. My chief case concerns the non-translatability of concepts of Lorentzian electrodynamics and Einsteinian special relativity theory. This presentation is intended to buttress the claim that incommensurability is real and instantiated. Third, I explore the impact of incommensurability on empirical comparability. Incommensurability was perceived as a major threat to the possibility of rational theory evaluation. My aim is to dispel such worries. Incommensurable theories allow empirical comparison. The argument proceeds on the basis of the semantic principles adopted by Kuhn and Feyerabend. That is, given their own linguistic approach, incommensurability does not result in a breakdown of comparing empirical achievements of the theories in question. Empirical comparison does not require translation and remains largely unaffected by incommensurability.

2. Meaning, Theoretical Context, and Adequate Translation

Kuhn and Feyerabend accept the context theory of meaning. According to this account, the meaning of a concept is determined by its relations to other concepts and the meaning of a statement results from its integration in a network of other statements. Another way of putting this is to say that the *use* of a concept determines its meaning. What a concept means is represented by the way in which it is applied to different situations. The use of scientific concepts is specified by the laws of nature in which these concepts figure. The meaning of a concept like "electric field" is given by its lawful connections to related concepts such as electric current, charge or magnetic field. The concept "electric field" is understood if it is known, for instance, that such fields are produced by electric currents or variable magnetic fields and generate changes in the motion of charges, and so forth. Laws and theories supply a concept with a network of relations to other concepts, and this network determines to which situations the concept is properly applied. Such generalizations add to the meaning of the relevant concepts (Kuhn 1983, 576-577; Kuhn 1987, 8; Kuhn 1989, 12, 15-20; see also Irzik & Grünberg 1995, 297-298; Feyerabend 1962, pp. 76-81; Feyerabend 1965, 180; see also Papineau 1979, pp. 36-45; Sankey 1994, pp. 6-10).

Translation in the sense relevant here concerns concepts of different theories. Translation requires the coordination of a linguistic item with another one taken from a different theoretical framework but possessing the same meaning. The understanding underlying the entire discussion of the incommensurability thesis is that translation needs to be precise (clumsy paraphrases don't suffice) and provide a one-to-one correlation between expressions. The latter condition does not demand that one word is assigned to exactly one word; rather, coordinating strings of words with one another is quite legitimate. The issue is not about words but about semantic resources. It is not

about terminology but about what can be expressed within a conceptual framework (Sankey 1994, 76-77).

On the basis of the context theory, the requirement of meaning preservation is to be interpreted as unchanged use. This notion of use comprehends two features which should both be retained in translation. First, theoretical integration should coincide for the two items at issue. This applies, in particular, to the reproduction of standing inferential relations among predicates or the statements formed by them. After all, it is such relations that provide the context relevant to the ascription of meaning. For example, the sentence "the tree over there is losing its foliage" implies: "there is a deciduous tree." Analogously, "Wilfried is a bachelor" entails "Wilfried is not divorced." The network of such relations supplies predicates with their content; consequently, these relations should be preserved among supposedly synonymous expressions. Second, the conditions of application of concepts should remain unaltered. One of the reasons why the French predicate "*x roule un deux chevaux*" is disqualified as a translation of "*x* loves cats" is that their conditions of application exhibit hardly any correlation. The two predicates are only accidentally applied to the same objects; they differ in meaning for this reason. Synonymous concepts should refer to the same states of affairs.

On the whole, then, the theoretical context account recognizes two chief determinants of the meaning of concepts. First, the inferential integration of a concept which is specified by its relations to other concepts. The integration of scientific concepts, in particular, is provided, among other things, by the relevant laws or theories. Second, the conditions of application which are determined by the set of situations to which a concept is thought to apply (or not to apply, respectively). To these two sources of meaning correspond two constraints on adequate translations. Rendering a concept appropriately demands, first, the preservation of the relevant inferential relations, and, second, the retention of the conditions of application (Carrier 2001a, sec 4).

One of Kuhn's most prominent historical claims is that science proceeds at least sometimes through stages of significant and deep-reaching conceptual and theoretical alteration. There is drastic theoretical change in science. This view finds its most prominent expression in Kuhn's characterization of scientific revolutions. Kuhnian revolutions are conceived as non-cumulative transitions. They do not involve the sustained elaboration of an accepted conceptual framework. On the contrary, a scientific revolution *à la* Kuhn consists in the revocation of fundamental principles of a discipline and their replacement by disparate ones. Furthermore, the disparity between pre- and post-revolutionary principles prohibits any smooth integration of the former into the framework of the

latter. As a result of the far-reaching divergence between them, the pre-revolutionary theory cannot be reconstructed as the limiting case of the post-revolutionary one (Kuhn 1962, Chap. VIII-X).

Kuhn initially located the chief origin of theoretical disagreement in revolutionary periods in perceptual, methodological, and ontological changes, but later distinguished linguistic deviation as the crucial feature of scientific revolutions. Incommensurability or non-translatability is shifted to center stage (Kuhn 1983, 684; Kuhn 1987, 19-20). A theory is thought to comprise a series of terms that are supposed to denote natural kinds. Such kind-terms indicate what is assumed to be of the same kind within the theoretical framework. Kind-terms represent accepted similarity relations among objects or processes. Incommensurability is said to arise from the non-translatability of kind-terms which is attributed, in turn, to divergent judgments about similarity relations (Kuhn 1993, 315-318, 328, 336; Irzik & Grünberg 1998, 211-212).

I wish to address Kuhnian relations of sameness in kind indirectly by examining first the relations among seemingly analogous concepts from theories separated by a scientific revolution and by exploring the options for giving adequate translations. Kuhn recognizes that the kind-terms of a theory are connected to the laws of this theory (Kuhn 1987, 20; Kuhn 1993, 316-317). I will deal with conceptual relations first and come back to sameness in kind later. An often quoted instance of a Kuhnian revolution is the Einsteinian Revolution, a part of which involved the substitution of Hendrik Lorentz's classical electrodynamics by Albert Einstein's special relativity theory. This is a revolutionary change by any measure so that the emergence of incommensurable concepts can be expected—provided that incommensurability is instantiated at all. I begin by giving a brief sketch of the relevant theories.

3. Shifting Theoretical Ground: The Example of the Einsteinian Revolution

One of the characteristics of Lorentz's electrodynamic theory was the assumption of an immovable ether. The ether was held to be at absolute rest; it is not displaced through the motion of charged bodies. But such motions produce changes in the state of the ether, and these changes propagate through the ether with the velocity of light. The ether mediates in this way the interaction between charged objects. True motion is motion with respect to the ether. The equations of electrodynamics were restricted to frames at rest in the ether; they were thought not to hold for moving systems without adaptation. For instance, the velocity of light, as it features in Maxwell's equations, was construed as its velocity relative to the ether. The measured value of this velocity should depend on the motion of the observer. However, no such dependence was found empirically. After Michelson and Morley had shown with high numerical precision in 1887 that no effect of the Earth's motion on the velocity of light was detectable, Lorentz (following Fitzgerald) introduced

his contraction hypothesis. The length of a moved body in the direction of motion shrinks to such a degree that the change in the velocity of light induced by the motion is precisely compensated—as the Michelson-Morley null result demands. This length reduction is produced by the interaction between moved matter and the ether. The resting ether compresses the body in passage through it, and this contraction precisely compensates the effect of the motion on the measurement of electromagnetic quantities. As a result of this double influence, no effect of the motion on the moved body will be registered (Lorentz 1899, 268-270; Drude 1900, 482; McCormmach 1970, 47-48; Nersessian 1986, 224; Schaffner 1972, 113; see Carrier 2001b, sec. 3).

Lorentz succeeded in deriving the contraction hypothesis from the principles of his theory by drawing on the additional assumption that the intermolecular forces that were supposed to hold a body together and were thus responsible for the body's dimensions transform like electromagnetic forces. This assumption is made plausible by the notion that these intermolecular forces are similar in kind to electromagnetic forces or even of the same nature. Lorentz did not rule out the existence of tangible effects of the motion of bodies through the ether. Only "many" electromagnetic phenomena were thought to appear in the same way irrespective of the observer's state of motion (Schaffner 1974, 48). In addition, Lorentz's theory entailed that the frame of reference at rest in the ether was distinguished among the class of inertial frames in that it alone yields the true measures of lengths and velocities. The motion through the ether distorts spatiotemporal quantities. An optics textbook of the period put it this way:

> Another way of explaining the negative results of Michelson's experiment has been proposed by Lorentz and Fitzgerald. These men assume that the length of a solid body depends upon its absolute motion in space. (Drude 1900, 481)

On the other hand, the motion produces further effects that precisely offset the initial distortion—at least in "many" relevant phenomena. Lorentz's account involves a sort of conspiracy among different factors brought forth by the motion of charged bodies. These factors are so contrived as to cancel each other out, concealing in this way the true motion of bodies from the unbefitting curiosity of human observers.

While it is true that Einstein worked out his special theory of relativity within the electrodynamic program and as a revision of Lorentz's theory (McCormmach 1970, 74; see Darrigol 1996, 242-243), full-fledged special relativity is conceptually distinct from Lorentz's account. There is historical continuity, to be sure, but the end-product of Einstein's struggle with classical electrodynamics was markedly different from its Lorentzian ancestor. In spite of their common origin and their close historical ties, the conceptual resources invoked in both accounts exhibit semantic incommensurability.

In contradistinction to Lorentzian electrodynamcis, Einstein's relativity theory proceeds from the so-called special principle of relativity which says that all inertial frames of reference are equivalent in every physical respect. As a part of classical mechanics, this principle had long been accepted. But the version suggested by Einstein was supposed to include electrodynamic processes; it implied that there is no privileged rest frame for electromagnetic phenomena. It follows that there are no absolute velocities; all velocities are relative to other bodies or frames of reference. The second axiom Einstein cites is the constancy of the velocity of light which says that the velocity of light is independent of the velocity of the light source. This constancy axiom follows from Maxwell's theory; it is a theorem of pre-relativistic electrodynamics. The special principle and the constancy axiom together imply the invariance of the velocity of light according to which this velocity assumes the same value for all inertially moved observers. The special principle of relativity entails that the inertial motion of a system of charged bodies or of an observer has no impact on electromagnetic processes. That is, Einstein abolished both the distorting influence of the motion and the counteracting factor. According to special relativity, all inertial frames are equivalent right from the start; their equivalence does not require the action of a compensating mechanism.

Special relativity likewise entails a contraction of moved bodies. In fact, Einstein's formula precisely agrees with Lorentz's; both give the same ratio of length reduction for a moved body. But in spite of their mathematical identity, the Lorentzian and Einsteinian equations differ in meaning. Their semantic difference is rooted in the divergent understanding of "velocity" in both sets of equations. For Lorentz it means "absolute velocity," that is, velocity of the relevant body with respect to the ether rest frame. But for Einstein there is no such rest frame. The velocity in question is rather the relative velocity between body and observer.

This contrasting understanding has important ramifications. Consider a body and an observer moved at different speeds and assume that the observer registers a contraction of the body's dimensions. It follows from Lorentzian electrodynamics that viewed from the angle of the moved and seemingly shortened body, the observer should appear expanded. After all, the moved body is compressed by the passage through the ether, and any length measurement using such shortened rods as standard should create the impression of expanded bodies. But on the basis of the principle of relativity, no states of absolute motion are admitted. Relative velocity is all that counts. Consequently, judged from Einstein's perspective, the observer should appear contracted as well. All that can be said is that the two bodies are in relative motion so that they are both subject to length contraction. This means that Lorentz-contraction proper is asymmetric whereas Einstein-contraction is reciprocal. These considerations suggest the existence of significant conceptual discrepancies be-

hind the superficial, specious identity of the formulas. I take a closer look at the relevant conceptual relations in the following section.

4. Incommensurable Quantities in Classical Electrodynamics and Special Relativity

The challenge is to give appropriate translations for Lorentzian concepts in terms of special relativity and vice versa. The spatiotemporal and dynamic measures in each theory constitute candidates for translation. Thus, the issue is whether counterparts for concepts like length, duration, velocity, and mass can be specified in the two theories at hand. I leave temporal quantities out of consideration. The reason is that Lorentz retained universal time but later learned from Einstein that it is his local time, rather than universal time, that the clock readings provide. Even after this recognition, however, Lorentz endeavored to stick to universal time and never reached a clear position in this matter. Unlike time dilation, Lorentz clearly endorsed length contraction and his pertinent formula agrees mathematically with Einstein's.

The issue, then, is translation. As I argued earlier, in light of the theoretical context account, a translation has to preserve the application conditions and the inferential relations of a term (see sec. 2). Let's see how *prima-facie* translations fare in light of these requirements.

The first attempt is to focus on conditions of application and to translate according to equality of measuring procedures: quantities that are determined empirically in the same way can be translated into one another. I won't go into the details and simply state that length measurements based on rod transport or transmission time of light signals are equally accepted within both theories. That is, classical electrodynamics and special relativity roughly agree on the acceptability of length measurements. Measuring lengths by registering the round-trip travel time of a light signal, as it is done, for instance, in a Michelson-Morley setup is endorsed within the two accounts, and the results of the procedure are unanimously acknowledged as reliable. For Lorentz, the velocity of light would be altered by a possible motion of the observer, to be sure, but since the traversed spaces would change as well, the length ratios measured are trustworthy in any event. For Einstein, both the distortion and the counteraction are missing so that the procedure operates reliably anyway.

However, the inferential relations fail to be retained. The crucial divergence concerns the interpretation of the relevant velocities. In Lorentz's contraction formula the significant quantity is the velocity between the moved body and the ether; in Einstein's mathematically identical equation the important magnitude is the velocity between the body and an observer. The disparate conceptual integration of the seemingly identical concepts of length and velocity becomes conspicuous

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once the relevant types of situation, as they emerge in the Lorentzian framework, are reconsidered in Einsteinian terms.

(1) *Lorentzian situation*: body and observer are equally at rest in the ether: no contraction.

  Einsteinian reconsideration: body and observer are at relative rest: no contraction.

(2) *Lorentzian situation*: the body is in absolute motion, the observer is at rest in the ether: contraction of the body.

  Einsteinian reconsideration: body and observer are in relative motion: reciprocal contraction.

(3) *Lorentzian situation*: the observer is in absolute motion, body is at rest in the ether: contraction of the observer issuing in an apparent spatial dilation of the body.

  Einsteinian reconsideration: body and observer are in relative motion: reciprocal contraction.

(4) *Lorentzian situation*: both body and observer are in equal absolute motion: shrinkage of both body and observer but no net effect due to compensation (Michelson-Morley situation).

  Einsteinian reconsideration: body and observer at relative rest: no contraction.

The Lorentzian and Einsteinian approaches differ in judgment as to whether or not contraction occurs in a particular type of situation.

Items #2 and #3 bring out the contrast between asymmetric Lorentz-contraction proper and reciprocal Einstein-contraction. If a moved body appears contracted to an observer, it is the observer which moves as viewed from the perspective of the seemingly shortened body. The relativity principles entail that the observer appears contracted, he does not look stretched. This is different for Lorentz-contraction. Consider an observer moved with respect to the ether who measures the dimensions of a body at rest in the ether. In this situation, the observer's extension is reduced so that he will register an increased length of the body. The body appears enlarged, not contracted. Regarding item #4, when an observer is moved along with a body so that the two are at relative rest, Lorentz contraction occurs, to be sure, but remains hidden because of an equal contraction of the measuring rods. By contrast, Einstein contraction is entirely absent under such circumstances.

Such differences in judgment indicate a change in the theoretical integration of the concept of length. Consider a case of curvilinear (but approximately rectilinear) motion such as the annual revolution of the Earth around the Sun. In Lorentzian terms, the change in the direction of motion entails that the body cannot be at rest in the ether all the time. This implies that contraction occurs. In special relativity, by contrast, this inferential tie is severed. The occurrence of a change of motion entails nothing as to contraction. All depends on the choice of the frame of reference. Conversely, whereas in special relativity the introduction of such a frame in a particular state of motion is sufficient for implying judgments as to the occurrence of contraction, no such unambiguous conse-

quences ensue from classical electrodynamics. In the latter framework absolute velocities are needed for making clear assessments possible so that the relativistic connection between relative motion and contraction is lost. I conclude that characteristic inferential relations for the concept of length are different in the two theories.

This first approach invoked sameness of measuring procedures as the basis for translation and involved the rule to retain as far as possible the conditions of application of the relevant terms. On this basis the electrodynamic concept of length appears roughly synonymous to the relativistic one. However, this translation rule fails to reproduce the relevant inferential relations. It falls short of underwriting adequate translations for this reason.

The second attempt is directed at the preservation of these inferential relations. The pursuit of this line of thought amounts to explicating the terms "velocity" and "contraction" by delineating the role they play in classical electrodynamics or special relativity, respectively. Adopting the relativistic point of view, one could say that Lorentzian velocities are no relative velocities but refer to the motion of a body with respect to the ether, and one could add that these absolute velocities are allegedly responsible for length contraction phenomena. However, adopting such a translation rule drastically changes the conditions of application of the translated concepts. According to special relativity, there is no such thing as absolute velocity or as ether-caused contraction (let alone the converse spatial dilation). If the Lorentzian concepts of velocity and length reduction are simply grafted upon relativity theory, these concepts become empty. They are no longer legitimately applied to any phenomenon. The retention of the inferential relations is purchased at the expense of losing the conditions of application. This second approach also fails to provide an appropriate translation for this reason.

The relationship between electromagnetic and relativistic mass constitutes a second, analogous example. According to the so-called electromagnetic mass concept, the inertial properties of bodies arise at least partially from the interaction between charges and fields. In this vein, Lorentz distinguishes between "real" and "total" mass. Real mass is of mechanical origin and invariantly characterizes a given body. Total mass is real mass together with a variable increase in the inertia of a charged body in motion as a result of its interaction with the ether (Miller 1981, 46-47). Total mass governs the dynamic behavior of a body. Analogously, special relativity introduces rest mass and relativistic mass. Rest mass, like real mass, is an invariant characteristic of a body. Relativistic mass comprehends rest mass and a variable increase in inertia as a result of the relative motion of a body. Relativistic mass, like total mass, determines the dynamic behavior of a body. Further, the dependence of relativistic mass on rest mass and velocity is mathematically identical to the depend-

ence of total mass on real mass and velocity. In addition, mass is evaluated in the same way in the two accounts in question. They both endorse determining mass values using a balance or collision processes (thereby drawing on momentum conservation). Therefore, the theoretical integration of the Lorentzian and Einsteinian mass concepts coincide in some respect and the conditions of application agree, too. Accordingly, it appears that Lorentz's "total mass" and Einstein's "relativistic mass" are corresponding quantities, and that Lorentz's "real mass" and Einstein's "rest mass" are conceptually analogous as well.

However, there are other features of the theoretical integration of these concepts of mass that differ considerably. Lorentz's real mass is assumed to become manifest when the relevant body is at rest with respect to the ether. Einstein's rest mass, by contrast, is obtained by an observer at rest relative to the body. Analogously, the value of total mass is supposed to be determined by the velocity of the body with respect to the ether, while the value of relativistic mass is assumed to depend on the difference between the velocities of body and observer. Consider a charged body which is moved through the ether at the same speed as an observer. The electrodynamic judgment is that the mass of the body departs from its real value. It does so for all observers, and consequently also for the observer moved with the body. In relativity theory, by contrast, relative motion is all that matters, so that an observer at relative rest measures the body's rest mass. Electrodynamics draws on total mass for capturing this situation, special relativity takes rest mass to be the relevant quantity. Conversely, consider a body at rest in the ether as viewed from a moved observer. From the electrodynamic point of view, the dynamic behavior of the body is governed by its real mass whereas special relativity assumes that relativistic mass is the relevant magnitude.

Underlying such differences in judgment is the divergent nomological integration of the mass concepts (which is veiled by the mathematical indistinguishability of the pertinent formulas). This divergence concerns the conception of the relevant velocities. Lorentzian electrodynamics takes the velocity between body and ether as the crucial parameter; Einsteinian special relativity assumes the velocity between body and observer to be of critical importance. As a result of this discrepancy in the nomological integration, the inferential relations between the mass concepts and other theoretical magnitudes disagree. For instance, the information that body and observer are in relative motion makes it impossible to employ the concept of rest mass in order to account for the situation. Within a Lorentzian framework, nothing of this sort follows. In particular, it is not ruled out to invoke the supposedly analogous concept of real mass. Namely, the body might be at rest and the observer in motion. The Einsteinian inferential bond is missing in Lorentz.

This consideration shows that these allegedly intertranslatable concepts are used differently. Actually, the semantic features can be expressed in analogy to the above-mentioned relations among spatial quantities. The attempt to translate concepts from disparate theories leaves one with the choice between two equally unacceptable alternatives. The first one is to translate according to the relevant conditions of application. That is, the two terms are applied under the same circumstances. The catch is that the corresponding predicates do not exhibit the same inferential relations. In contradistinction to special relativity, classical electrodynamics does not license any relevant inference to be drawn from the fact that body and observer are in relative motion. The second option is to translate such that the inferential relations are retained. This amounts to giving a description of ether-based electrodynamics. But the mass concepts specified in this framework are empty from a relativistic perspective: there is no motion relative to the ether. Thus, the conditions of application fail to be preserved. On the whole, then, the mass concepts in classical electrodynamics are incommensurable with the mass concepts in special relativity (see Carrier 2001b, sec. 4).

5. Incommensurability, Split-Up of Natural Kinds and Shifts in Reference

Kuhn featured shifts in the assumed similarity relations as the primary characteristic of incommensurability. He claimed that the discrepancy between the taxonomies of natural kinds is the chief obstacle to translation (Kuhn 1983, 683; see Hoyningen-Huene 1989, 211-212). Such kind-terms denote classes of entities that are judged to be of the same kind in light of a theory (see sec. 3). Incommensurable theories introduce partially overlapping classes of natural kinds. Such theories agree in judgments about the sameness in kind of some of the relevant entities, but disagree as to the sameness in kind of others. The shift toward a novel theory, incommensurable with the received one, produces a reshuffle of the classes of natural kinds. Such classes are torn into pieces, and the debris is reassembled to form novel, disparate classes. What is considered as being of the same nature before a revolution may be regarded as different afterward. Conversely, what was thought to be different in kind may be taken as being alike in the new theory. It follows that two items which fall under the same category in one account are possibly to be expressed using different concepts in the other account. And two items labeled distinctly in one approach might be designated using the same concept in the other approach. Partial overlap or cross-classification of this sort vitiates translation and generates incommensurability (Kuhn 1990, 4; see Irzik & Grünberg 1995, 299).

This cross-over of equivalence relations is manifest in the list of Einsteinian reconsiderations of Lorentzian types of situations (see sec. 4). Ties of similarity are unraveled, and others are established in their stead. For instance, from a Lorentzian perspective, a body in absolute motion registered by an observer at rest in the ether (situation-type #2) is of the same type as a situation in

which both body and observer are in equal absolute motion (the Michelson-Morley situation #4). The two situations are equally characterized by a contraction of the body—although it fails to become manifest if the observer is moved with the body. From Einstein's point of view, by contrast, the two situations are distinct in kind in that relative motion, and consequently contraction, is only present in the former, but not in the latter. Conversely, in Einstein's framework all states of affairs that involve a relative motion between body and observer are of the same type (situations #2 and #3). By contrast, against the backdrop of Lorentz's theory, it makes a difference whether the body or the observer is in motion. The observer will register a contraction if the body is moved but a dilation if she is in motion herself.

This consideration brings to the fore the Kuhnian partial overlap of kind-terms. In Lorentz, situation-type #4 is considered similar to situation-type #2, whereas in Einstein, situation-type #3 is taken to be so related to situation-type #2. The first natural kind is "being in absolute motion," the second is "being in relative motion." Both the Lorentzian and the Einsteinian kind-terms contain situation-type #2, but otherwise include different circumstances. This exemplifies that disparate systems of laws can tie different states of affairs together. Conflicting theories tend to collect nomologically relevant properties into incompatible classes of natural kinds.

The same reasoning applies to mass. In the Lorentzian framework, situations of the same type are characterized by equality of body velocity with regard to the ether—irrespective of the motion of the observer. Such Lorentzian kinds are dissolved in relativity theory through the introduction of the motion relative to an observer as the salient quantity. Conversely, Einstein forged other relations of natural kinds instead. Situations of the same type are characterized by equal velocity with regard to an observer—irrespective of the motion relative to the ether. That is, what was formerly conceptually united crumbled into separate pieces. And what was considered distinct previously was integrated conceptually.

Incommensurable concepts emerge if, owing to nomological change, natural kinds are restructured. If a new system of laws is adopted that conflicts with a previous one, the former equivalence classes split up into heterogeneous components and realign to form new taxonomic structures. This change of the class of properties to which a concept is rightly applied goes back to a change in the nomological integration of this concept. The use of electrodynamic and relativistic concepts is governed by contrasting sets of laws. It is this nomological contrast that constitutes the ultimate reason for the translation failure. The dissolution and the new formation of natural kinds which is placed at center stage by Kuhn is a proximate reason that follows from the divergence of the relevant inferential relations.

6. Empirical Comparison of Theories with Incommensurable Concepts

Meaning discrepancy due to nomological divergence has a wider impact on the notion of scientific rationality. It affects the understanding of scientific progress and empirical comparison. Most linguistic theories accept the principle that meaning determines reference. Given this connection, a change in meaning suggests a shift in reference. Consequently, incommensurable concepts are likely to differ in reference. Barring the occurrence of coextensional terms like "rational animal" and "featherless biped," theory change goes along with reference change so that the successor theory says different things about different objects—rather than different things about the same objects. This feature would certainly undermine a cumulative view of scientific progress. Progress could not be regarded as involving a better understanding of the *same* entities.

Incommensurability appears to threaten, in addition, the comparability of the empirical achievements of rivaling theories. Without a common referential ground, no overlap among the empirical findings and problems can be identified—or so it seems. Incommensurability appears to rule out any agreement as to which problems are to be tackled and which facts are relevant. Actually, it is not even clear whether the theories at hand are competing with one another. A competition requires sameness of reference; competing theories entail divergent predictions about the same entities. But in the case of incommensurable theories, as the argument runs, sameness of reference can never be ascertained.

The line of reasoning leading from translation failure to the exclusion of empirical comparison roughly runs as follows. Non-translatability implies that the content of one theory cannot be expressed within the conceptual framework of the other. But if it remains obscure what the allegedly rival theory says, there is no way to judge if it agrees or conflicts with the theoretical assumptions under scrutiny. If comparison of content is ruled out, no comparison of the pertinent empirical consequences can be accomplished.

In fact, however, empirical comparison remains a live option. Incommensurable theories need to be comparable in some respect in order to generate a non-trivial translation problem in the first place. A host of theories is not translatable into one another without anything significant coming out of it. Lorentzian electrodynamics cannot be expressed using concepts from Darwin's theory of natural selection, special relativity cannot be translated into game theoretical vocabulary. This is a rather unexciting feature. In order for non-translatability to become a non-trivial issue at all, such cases need to be excluded. The obvious way to do this is to draw on one of the defining features of incommensurability, namely, incompatibility of the laws involved. Incommensurable concepts are untranslatable since the relevant laws, as specified within each of the theories at hand, contradict

one another (see sec. 1). But no such incompatibility occurs in anyone of the just-mentioned cases (Feyerabend 1972, 304; Hoyningen-Huene 1989, 213).

But a conflict between two theories only emerges if there is some shared realm which they jointly address. The non-triviality of incommensurability requires that there is some range of phenomena that can be considered relevant for both theories. This common ground is sufficient for making empirical comparison possible. Consider a particular experiment for which both theories claim responsibility. Each of them captures the outcome by using its own observational vocabulary. Assume that the outcome is such that it is justified, on the basis of one account, to conclude that a certain process, as specified in terms of this account, has actually taken place, while it is illicit, on the basis of the rivaling theory, to judge that the process required by this theory has occurred. The experiment and its result, are described within the conceptual frameworks of each of the theories involved.

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The series of experiments Walter Kaufmann conducted between 1901 and 1905 constitutes an example. Kaufmann's experiments were intended to measure the dependence of the mass of electrons upon their velocity. Considered with hindsight, they were relevant for the relativistic dependence of mass on velocity—although they issued in the erroneous refutation of this dependence (Hon 1995, 194-195; Cushing 1998, 210-215).

Mass in Lorentz and mass in Einstein are incommensurable quantities (see sec. 5). Still, Kaufmann's findings were taken to be relevant for both classical electrodynamics and special relativity. The measurement was performed by registering electron trajectories in electromagnetic fields. The electron paths were detected using a photographic plate. Kaufmann managed to obtain a visible curve on the plate whose precise shape was supposed to indicate the sought-for quantity. This effect was positively identified irrespective of the theoretical background. The reliability of the result was contentious, to be sure; actually, it was abandoned later. But this issue had nothing to do with the dissent as to the overarching background principles. Lorentzians and Einsteinians had no trouble, identifying the traces left by incident electrons.

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Another case in point is the Kennedy-Thorndike experiment of 1932 which constituted a refinement of the Michelson-Morley experiment and was undertaken so as to compare Lorentz's and Einstein's theories empirically. Lorentz's account entailed a negative result of the Michelson-Morley experiment only on the condition that the lengths of the interferometer arms were equal (when unaffected by the motion through the ether). Only under such circumstances, the changes in the velocity of light induced by the motion of the observer and the contraction of optical apparatus canceled each other out precisely. Interferometers equipped with unequal arms, by contrast, should

exhibit a net effect. Electrodynamic theory yields an equation that connects the ensuing shift in the interference fringes with the difference in the lengths of the interferometer arms (resting in the ether) and the velocity of the apparatus with respect to the ether. The prediction was that if these two quantities did not vanish, a shift should occur during the seasonal change in the direction of the Earth's motion. The reason is that however the Earth moves precisely through the ether, it cannot be at rest all the time (see sec. 4; French 1968, sec. 3.1, 3.6).

The partisan of classical electrodynamics may feel free to determine the relevant quantities in whichever way she prefers. The point is that the circumstances can easily be arranged such that her theory entails the appearance of fringe shifts. The only thing she has to acknowledge is the un-equality of the interferometer dimensions and the attribution of a non-vanishing absolute velocity to the Earth. The realization of the former condition can be left completely to her, the fulfillment of the latter follows from her theory. By contrast, the adherent of special relativity anticipates that no fringe shifts occur. From his point of view, the Kennedy-Thorndike experiment is but a trivial modi-fication of the Michelson-Morley experiment so that the same null result can safely be expected. As it turned out, the prediction of the latter was confirmed and the expectation of the former disap-pointed.

The crucial aspect is that the success or failure of the empirical test may be judged against the background of one's own commitments and standards. No need for translation arises. A theory may well be tested by its own followers, and to them the relevant claims are by no means obscure.[1] To be sure, it is necessary that a shared realm of relevant phenomena is recognized. Advocates of each theory have to acknowledge responsibility for coping with these phenomena (which may be disparately understood in either theory). But this much of a common ground is secured by the mere fact that we are dealing with incommensurable theories.

7. Theoretical Contrast and Partial Overlap of Natural Kinds

These considerations make the relations between incommensurable concepts more perspicu-ous. The translation failure arising between incommensurable concepts is of a particular sort. It is based on incompatibility rather than unrelatedness. Within the theoretical context account of mean-ing two constraints guide translations: empirical indications and theoretical integration have to co-incide. Synonymous concepts need to apply to the same observations or situations and need to be

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[1] Intersubjective control of theories containing incommensurable concepts is still feasible. Kuhn rightly distinguishes between translation and language acquisition (Kuhn 1983, 676-677). It is a consequence of the context account that concepts can be learned by familiarizing oneself with the pertinent theoretical context. One may become bilingual—and yet be at a loss to translate. It follows that the empirical comparison of theories with incommensurable concepts can be performed by a single person (Carrier 2001a, 85–86).

embedded at the same time in nomological frameworks exhibiting the same structure. Incommensurable concepts are distinguished by the fact that there is some agreement on both counts. In order to qualify as prima-facie analogs and candidates for translations, such concepts need to be applicable to some shared domain and display some relatedness as to theoretical integration. I underscored earlier that incommensurable concepts do not satisfy both these demands. But the converse aspect deserves emphasis as well: Incommensurable concepts exhibit a particular type of relationship to one another; they are connected with one another by empirical or theoretical ties. This sort of connectedness makes translation failure due to incommensurability a distinctive notion.

Let me explore these connections a bit more thoroughly. Kuhn's notion of a partial overlap among the referents of incommensurable concepts provides a basis for further clarification. This notion suggests that incommensurable concepts need to share some domain of application, on the one hand, but that this core domain is expanded in different ways for each of the conceptual counterparts in question, on the other. This means that incommensurable concepts do not denote precisely the same states of affairs. There is a shared realm of application and there are deviations. Take the Lorentz-Einstein example. Although the two theories accept the same measuring procedures for spatiotemporal and mass relations, the predictions regarding these relations do not always agree. Rather, as I argued before, differences in judgment about the prevailing length relations obtain. It makes a difference, after all, whether the expected contraction relations are reciprocal or asymmetric (see sec. 4-5).

The point is, then, that these divergent anticipations cannot be brought into harmony because of an underlying theoretical dissent. Lorentzian electrodynamics and Einsteinian special relativity disagree over the appropriate natural kinds (see sec. 5). The accepted relations of similarity diverge in both accounts, with the result that it is impossible to define conceptual analogs of Lorentzian spatiotemporal and mass terms in Einstein's theory. It is a distinctive feature of incommensurability that the relevant classificatory discrepancies resist reciprocal adaptation because they arise from fundamental theoretical divergence. Non-translatability due to incommensurability is not the result of a simple conceptual gap. Incommensurability is not about an accidentally missing word; it is rather about an in-principle rift. Underlying incommensurability is a theoretical dissent which makes it impossible to conceive an *ersatz* concept that could play the empirical and theoretical role of a term of the other theory in question. There is no way to define a something akin to "absolute motion" or "total mass" in special relativity short of running into a contradiction with the principles of this theory. Consequently, not any old taxonomical disagreement is sufficient for pro-

ducing incommensurability. Rather, the relevant sort of disagreement needs to be induced by theoretical contrast and resist easy resolution.

Consider Kuhn's own example of a shift in meaning and reference of the concept "planet" as a result of the Copernican Revolution. Geocentrically speaking, "planet" means celestial body rotating around the Earth. Mars, Sun and Moon equally qualify as planets in this sense while the Earth does not. Heliocentrically speaking, "planet" means celestial body revolving around the Sun. According to this changed understanding, Earth and Mars pass as planets, while neither Sun nor Moon do. These changes in meaning are intertwined with a shift in the taxonomy of the relevant bodies. Geocentrically, Mars, Sun and Moon form part of the same natural kind, whereas the Earth was placed in a different category. After the revolution, Earth and Mars were equal in kind, while Sun and Moon shifted in kind in becoming a star and a satellite, respectively. The members of the geocentric kind "planet" were scattered into distinct taxa and placed alongside entities which were formerly taken to be of heterogeneous nature (Kuhn 1962, 115, 128-129; Kuhn 1987, 8).

This example of Kuhn's regarding incommensurable concepts illustrates, first, that such concepts share a core domain of application. A large number of geocentric planets are also heliocentric planets and vice versa. Second, this core domain is expanded differently for the two concepts. Geocentric planets include the Sun and the Moon, heliocentric planets instead encompass the Earth. It follows that the two domains of application overlap only partially. Third, this classificatory discrepancy resists resolution because of the underlying theoretical contrast. It is this contrast which makes it impossible to reciprocally assimilate the two domains and to apply the concept indiscriminately to all entities in question. This incompatibility between the theories involved lies at the root of incommensurability.

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8. Conclusion

There are three conclusions to be drawn from these considerations. First, incommensurability is real. The notion can coherently be reconstructed and positive instances of theories with incommensurable concepts can be specified. Second, incommensurability does not pose a serious threat to the objectivity of science or its commitment to experience. In order to make their conception non-trivial, advocates of incommensurability have to grant—in contrast to their declared intention—that empirical comparison of theories with incommensurable concepts is possible. Third, incommensurability is of lasting importance as a problem in the philosophy of language. Incommensurability gives rise to the translation problem associated with the context account of meaning. It constitutes the successor problem to Quine's indeterminacy of translation. Whereas Quine's claim was based on the verification theory of meaning, Kuhn's and Feyerabend's views emerge within the

context account. And whereas Quine is prepared to accept a large number of distinct but equally appropriate translations, Kuhn and Feyerabend suggest that there is not a single adequate rendering. Thus, basis and substance of the two positions are fairly disparate. Incommensurability is the follow-up paradox of translation which continues to haunt us after the demise of verificationism.

Fourth, in one respect incommensurability continues to be of epistemic significance. My argument does nothing to defuse the above-mentioned worry that incommensurability contributes to undermining a cumulative view of scientific progress according to which science manages incessantly to pile up truths upon one another. The lesson incommensurability teaches is that in the course of theory change, scientific achievements may be conceptually reframed beyond recognition. In particular, the occurrence of reference shifts poses a serious threat to the claim that scientific theories accomplish an ever deeper understanding of the same objects and processes. In this respect the incommensurability thesis retains some epistemic significance after all.

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