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On the Grammatical Aspects of Radical Scientific Discovery*

Aristides Baltas

National Technical University, Greece

Résumé : La découverte scientifique radicale, et le changement radical de paradigme associé, sont traités ici comme découlant de la mise à jour de ce qu'on appelle des 'assomptions' d'arrière-plan. Celles-ci sont considérées comme plus ou moins équivalentes aux 'propositions charnières' discutées par Wittgenstein dans *De la certitude*. Sur cette base, diverses questions liées aux changements de signification, au changement théorique, à l'incommensurabilité, etc., sont discutées. On montre que la conception d'ensemble de Kuhn, une fois précisée, n'implique ni l'idéalisme ni le relativisme, et que la rationalité

*A first version of the present paper was presented at the conference on "The Legacy of Thomas S. Kuhn", organized by Jed Buchwald at the Dibner Institute, MIT, Cambridge, Mass., on November 20-22, 1997. In addition to Jed, it is both a duty and a pleasure to thank all the participants, and especially Jim Conant (and, as he well knows, for more reasons than this), Mike Mahoney and Norton Wise for their comments and criticisms. A second version of the paper was presented at the workshop on Kuhn organized by Alexander Bird and Rupert Read in Norwich, U.K., on August 30, 2002. It is again both a duty and a pleasure to thank my hosts both for the workshop itself and for their active interest in the paper. All the participants helped me with their criticism but I feel I should single out Vasso Kindi, Jean-Philippe Narboux and Léna Soler. At home, the comments of Aristidis Arageorgis, Charis Chronis, Andreas Karitzis, Dimitri Papagiannakos, Stathis Psillos, Kostas Stergiopoulos, George Fourtounis and, of course, Peter Machamer were, as always, to the point. Last but by far not least, the copious and incisive comments of Léna Soler, once again, as well as those of a particularly generous anonymous referee, of the kind justifying the existence of the refereeing system, obliged me to revise substantially the paper and make it much clearer. At least this is how I see it now.

et le progrès scientifique peuvent être sauvés d'une manière acceptable par les scientifiques praticiens.

Abstract: Radical scientific discovery and the associated radical “paradigm change” are treated here as following from the disclosure of what I call *background ‘assumptions’*. These are taken as more or less equivalent to the “hinge propositions” that Wittgenstein discusses in his *On Certainty*. On this basis, various issues connected to meaning variance, theory change, incommensurability and so forth, are discussed. It is shown that Kuhn’s overall account need not, with qualifications, imply either idealism or relativism while rationality and scientific progress can be saved in a way that may be acceptable by practising scientists.

More and more signs are pointing nowadays at a revival of the issues opened by Kuhn’s work. Although social constructivism, in one or another form or guise, still holds center stage, a mounting series of essays, books or workshops try to raise again, in philosophically novel and interesting ways, questions of his that the prevalence, precisely, of social constructivism has more or less managed to push under the table. Central among such issues is the complex net of philosophical *aporias* which, to go quickly, we can call “radical scientific discovery”, without needing for the moment to presume anything regarding the discovery/invention debate and its cognates. To stay with Kuhn’s terminology, we can simply say that a “radical scientific discovery” is the kind of event or episode — without, again, needing to presume anything of its temporal or other features — inducing¹ a “paradigm change”.

Among the various puzzling features of paradigm change, the ones concerning language (meaning variance and meaning change, incommensurability and so forth) have received most attention. However, no general consensus regarding their resolution has been attained despite the valiant efforts dispensed for the purpose, not least of which were those deployed in Kuhn’s own later work. Trying to discuss some of the linguistic aspects of “scientific discovery” is what the present paper aims at. Kuhn’s recognized relation to Wittgenstein’s later philosophy² offers an initial justification for my talking of *grammatical* aspects and allows me to proceed without further ado.

¹“Induces” is here taken to refer as vaguely as necessary to the more or less causal relation holding between the event or episode of radical scientific discovery and the more complex and variously more extended process of paradigm change. Which is to say that, at least in the present stage of the discussion, “produces”, “causes”, “brings about” and so forth would be too strong.

²See, for example, [Kindi 2004].

1. Radical Scientific Discoveries: Giving Names to the Ungrammatical?

Let me start by recounting a personal experience as succinctly as possible. This occurred in three stages.

In the first stage, I was trying to present to my students some of the deeper motivations leading to the constitution of the new philosophical tradition that bears the name “analytic philosophy”. Behind Russell’s and Frege’s work lies, of course, Cantor’s theory of sets and the question of the infinite. Thus, in trying to explain Cantor’s main achievements to students who had never before heard anything of this, I tried to ‘reconstruct’ the logical — or rather grammatical — move that Cantor made in giving his famous definition of the infinite: a set is of infinite cardinality if and only if its elements can be put into one-to-one correspondence with the elements of one of its proper subsets. What our author was up against before offering this definition was a total deadlock: on the one hand, since the set, say, of even numbers is a proper subset of the set of natural numbers, it *obviously* contains ‘fewer’ elements while, *obviously again*, the two contain an ‘equal’ number of elements, since these can be put into one-to-one correspondence. What Cantor did in order to escape was then very ‘simple’: he did not try to resolve or in any way overcome the contradiction but merely turned the very deadlock into a definition! “The paradise that Cantor has offered us”, to use Hilbert’s formulation, finds its initial grounds at precisely this point.

At the time I did not think much about this. But later in the same course, I passed through the second stage of my experience. Now I was trying to provide a cursory account of the revolutions in physics that motivated, at least indirectly, much of the Vienna Circle philosophy of science. The name of Bohr thus inevitably appeared. In trying to reconstruct Bohr’s move now, the one that led to his theory of the atom, I ‘discovered’ myself following unawares the same explanatory pattern as in the case of Cantor. For reasons too complex to enter into either there or here, I took it for granted that Bohr could not — or would not — question either the electromagnetic theory of his time or the planetary model of the atom. But the two together demonstratively lead to an unstable atom: the accelerated motion of the revolving electrons makes them radiate and thus obliges them to fall onto the nucleus. If we deem unstable atoms unacceptable at any price, we have again a contradiction. For it is obviously contradictory to maintain together the electromagnetic theory, the planetary model of the atom and the latter’s stability. Bohr’s escaping from this deadlock can then be reconstructed

as similar in structure to Cantor's. He refuses to succumb to or try to overcome the contradiction but goes unconcernedly forward by 'simply' turning this very deadlock into the definition of a new physical concept: atoms in the "*ground state*" do not radiate. Period. Which implies that the trajectories of the electrons in that newly defined state do not obey the classical electromagnetic laws and hence these can be no 'real' trajectories, whatever this might mean or imply. What exactly are they and where does their existence rely? Bohr gives no answer. Electronic 'trajectories' are precisely such that atoms in the "ground state" are stable analytically, by definition, and that is that. In other words, the electromagnetic theory and the planetary model of the atom both hold *and* there exist particular atomic states that are fully stable. Only that the latter are such simply because Bohr declares it! By mere *fiat*, with no reasons either sought or given³. There can be no doubt that this groundless decree made the then emerging quantum mechanics take a huge step forward.

The third stage of my experience had nothing to do with the course in question. But it gave unexpectedly a name to what I had been experiencing. Thus, while I was reading a book on Lacan's approach to psychoanalysis, I fell upon the following passage (I am translating from the original French):

(...) What is the object *a*?⁴ It is only a letter, nothing more than the letter *a*, a letter whose central function is to name a non resolved problem or, even better, to name an absence. Which absence? The absence of an answer to a question that persists unceasingly. Since we could not find the solution, which we required and we expected, we mark with a written sign — a simple letter — the opaque hole of our ignorance, we put a letter in the place of the answer we could not get. The object *a* signifies therefore an impossibility, a point of resistance to the theoretical development. Thanks to this notation, we can continue our research — despite our having stumbled— without breaking the chain of our knowledge. You see, the object *a* is finally an artifice of analytic thought designed to circumvent the rock of the impossible: we overcome the real by representing it by a simple letter (...) [Nasio 1992, 125].

³Evidently, this simple picture does not intend to exhaust Bohr's logical, conceptual or experimental motivations for proposing his model of the atom; it does not seek to trace the history of this proposal, be it even in such a summary fashion; nor does it aim at reconstructing Bohr's way of thinking on the issue. It only wants to suggest that radical scientific discovery carries important grammatical moves, the understanding of which may help us coming to grips with the philosophical issues involved.

⁴This is a Lacanian technical term the precise sense of which need not concern us here.

With this everything fell into place. I now had at my disposal a concrete formulation, a name, for what I had been experiencing: radical scientific discovery, it seems, consists of a leap into the ungrammatical; it amounts to giving *it* a name by means of a novel definition.

Let me formulate the point. Before the leap in question is taken, research within a given paradigm stumbles on a deadlock. In the preceding examples this deadlock takes the form of an explicit contradiction and, as such, it constitutes a Kuhnian “anomaly” of the severest kinds, an anomaly that, for the cases that interest us here and as can be assessed *ex post facto*, cannot be handled by the means of the board, i.e. by the conceptual resources provided by the paradigm in place. However, research does not stop for that matter. It takes cognisance, so to speak, of this impossibility and leaps forward by ‘simply’ giving it a new name, i.e. by turning that very deadlock or contradiction into a new positive definition. This new definition is positive in the sense that, by construction, it is in the position to ‘forget’, or, more psychoanalytically, to ‘repress’, its impossible origin while providing in this way the starting point of the succeeding paradigm.

Given this, the view to be developed here boils down to the following: *post festum*, i.e. after the new paradigm has been set up and from the vantage point it defines, the anomaly in question can be characterized as an encounter with the *grammatical bounds* of the old paradigm while the new definition starts instituting a *novel grammatical space*, the grammatical space supporting the new paradigm. This novel grammatical space *enfolds*, as it were, *the very impossibility of the old paradigm to handle that anomaly* and thus bears intricate relations to it, relations that we have to make precise⁵. To start doing this, we can consider such opening of a novel grammatical space as tantamount to the disclosure of what we will call *background ‘assumptions’*.

2. Scientific Concepts, Background ‘Assumptions’ and Grammatical Conditions

One more argument as to why the notion of paradigm — in the sense of “disciplinary matrix” — should replace the more traditional notion of theory is the following: no concept, either simple and intuitive or abstract and highly formalized, can exist, i.e. be understood and function within a process of inquiry, unless it carries along with it an amorphous

⁵Hence the two succeeding paradigms are *not* totally unrelated, as some views tend to present them. We will elaborate on this below.

plethora of what we can call *background ‘assumptions’*. These work ‘behind’ or ‘below’ the explicit definition of the concept to mutely adjust it to the language games it can partake, inside — but also outside — the scientific process of inquiry. We can say that these ‘assumptions’ support the concept’s manifest meaning by noiselessly dictating the conditions under which it makes sense; it is they that make up the latent *grammatical conditions* of the concept’s meaningfulness in the various contexts of its use. These ‘assumptions’ remain in the background for they perform their work silently, inexpressibly, hiding their work from view.

Since on most views the meaning of a concept derives from the propositions engaging it, it is to propositions we have to turn in order to assess the role and character of such ‘assumptions’ in respect to our present concerns. Thus some background ‘assumptions’ may render a proposition’s truth perfectly obvious while hiding themselves and the role they are silently playing in doing this behind the glare, so to speak, of that very obviousness. For example, on some such ‘assumptions’, the earth cannot but be immobile for anybody possessing her senses. On the other hand, some other background ‘assumptions’ may lie well concealed beneath our taking another proposition as totally inconceivable. For example, again on some background ‘assumptions’, no action at a distance can be conceived, for how can bodies react instantaneously to the presence of another faraway body when, in addition, there is nothing in between? As it is well known and as we will elaborate at length below, the development of classical mechanics has unearthed the ‘assumptions’ lying silently beneath the above propositions. And it has done that in a way making both this old obviousness and that old inconceivability appear today as astonishingly short sighted to almost everybody, i.e. to all those having gone through an elementary physics course.

Moreover, such ‘assumptions’ may also work under a tautology, a contradiction, a deductive consequence or an analytic truth, mutely assuring the logical status of the propositions concerned while again hiding themselves and their role from view⁶. Putnam’s example [Putnam 2000]

⁶For reasons that will become clearer below, I hesitate to use the qualification “apparent” in talking about such tautologies, contradictions etc, as I was at first inclined to: if logic is what it is standardly taken to be, tautologies, contradictions, etc. that depend for their logical status on background ‘assumptions’ can only be *apparent* tautologies, contradictions etc. Moreover, they are shown to be just that (or, at least, so it seems at first sight) after the disclosure of such ‘assumptions’, as I will be discussing shortly. However, the present paper looks to me as implying that we can never be logically or metaphysically certain that *any* tautology, contradiction, etc that we *actually* encounter will *never* turn into an apparent one in this sense. If

is that somebody can be either naked or not naked and certainly not both, but only on at least the silent background ‘assumption’ that she is not wearing a net. It is well known that Lakatos’s “hidden lemmas” [Lakatos 1976] mess up rigorous deductive chains while it is *analytically* the case that the earth cannot be a planet, if the concept “planet” is indeed *defined* as referring to celestial bodies moving around the earth. This last example is to say that one of the obstacles physical astronomy (i.e. not that of merely “saving the phenomena”) had to overcome was that the empirical import of this definition was rendered perfectly obvious by the work silently performed by some background ‘assumptions’ whilst such obviousness was going hand in hand with the self-evidence of the immobility of the earth and the background ‘assumptions’ assuring this self-evidence. The above entail that such ‘assumptions’ work in similar ways⁷ both for everyday concepts and those that mathematics and logic strive to define and to formalize rigorously, so as to strip them, precisely, of such possibly misleading background. On the present account, even the most highly elaborated and worked out concept cannot but keep concealing the background ‘assumptions’ mutely assuring its meaningfulness.

As Wittgenstein has shown (especially in his *On Certainty*), these are not proper assumptions — hence they should be placed within quotes. They are neither *a priori* and indubitable nor *a posteriori* and open to doubt. In normal circumstances, the role they are playing remains veiled and they cannot be moved around in the space of justifications. In Wittgenstein’s felicitous phrase [Wittgenstein 1969, §341-343] (see also [Morawetz 1980]), they are the “hinges” that have to stay put for the door of inquiry (its questions, its reasons, its doubts) to open and to remain open. It is in this sense that they constitute the latent quasi-logical, that is, precisely, grammatical, conditions allowing the concepts they support to have the meaning they do. Let me give a simple example by placing some of Putnam’s cats in this Wittgensteinian context.

Normally, that is in Kuhn’s sense of “normal science”, the zoology of cats is not obliged to inquire, first, whether each of our purring companions comes from two parents, whether they are all highly sophisticated robots or extra-terrestrials in disguise and so forth; to run, second, the appropriate tests; and to present, finally, explicit arguments to the effect that they are not. That our pets are no such things the zoology of cats

this were indeed the case, the use of “apparent” here would become almost empty. All this needs, of course, a lot of clarification. See however [Putnam 2000].

⁷A deeper analysis would probably show that such similarity might require various qualifications.

takes silently for granted. In other words, the ‘assumption’ that they are not belongs to the amorphous plethora of the latent grammatical conditions allowing the concept “cat” to make the kind of sense necessary for our employing it with confidence in the relevant inquiries as well as in all the germane language games. However, that such ‘assumptions’ are not *a priori* signifies that, under very particular circumstances, any one of them can become distinctly formed and ‘illuminated’, emerge from out of the background and be put to the test. It will appear then as a proper assumption (without quotes) that had been ‘unjustifiably’ and unawares taken for granted, necessitating thereby an investigation as to its warrants. The completely baffling and totally unaccountable behaviour of some particular cats may thus indeed force us in the long run to consider an extravagant hypothesis like the above. When this happens, such an ‘assumption’ will appear *ex post facto* as an illegitimate pre-judgment, as a bias, as a prejudice, as an unwarranted presupposition⁸.

In forming the latent grammatical conditions allowing the concepts involved in a scientific inquiry to make sense, these ‘assumptions’ underwrite the ‘natural’ interpretation of the corresponding conceptual system (and, by means of it, everything this interpretation determines as, for instance, the sense in which the corresponding experimental transactions and their results are to be taken). More specifically, they are involved in the pictures, the analogies, the metaphors — or the intuitions — which scientists are based on in order to understand the concepts their own work produces, and to communicate their results. As such, they are not mere Wittgensteinian ladders, to be thrown away after the system is established, nor Fregean hints or elucidations (*Winke*), that do not belong to the conceptual system proper [Weiner 1990]. Through the work done by those ‘assumptions’, some of the connotations of those pictures, analogies and metaphors tarry, as indelible vestiges, on the concepts involved, forming the latent conditions of their grammaticality and the concomitant bounds of their meaning. In this way, while channelling the relevant investigations away from the ungrammatical, they *surreptitiously close the horizon of that meaning*.

The leap into the ungrammatical we have been talking about and its

⁸These background ‘assumptions’ are not so exotic as they might appear at first sight. Although admittedly it has not placed much emphasis on them, philosophy of science has come to recognize their existence in various forms and guises: apart from Lakatos’s “hidden lemmas” that we mentioned, Bacon’s “idola”, Feyerabend’s “natural interpretations”, Laudan’s “ontological commitments”, Kuhn’s “historically changeable Kantian categories” constitute as many attempts to name the ‘assumptions’ in question and to cope theoretically with their inescapable existence. I owe this remark to Marcello Pera.

consequences can be assessed *ex post facto* as tantamount to the disclosure of precisely such an ‘assumption’ (or a set thereof) and to the effects of such a disclosure. Which is to say that an episode of radical scientific discovery observes something like the following pattern. First, a process of inquiry stumbles on a deadlock or contradiction. What confronts the scientists involved makes no real sense to them and hence they find themselves confronting a total impasse. On the point above, we can say that, one, such a deadlock or contradiction surfaces when the grammatical bounds of the concepts involved tend to be trespassed and that, two, it is the background ‘assumptions’ implicated that silently determine these grammatical bounds, since their function is precisely to steer the process of inquiry clear of the ungrammatical. Hence *it is they that silently determine what is a deadlock or contradiction in the given context*. Given this, the second step of radical scientific discovery amounts to the illumination of such an ‘assumption’ and to its emergence from out of the background. Such a disclosure transgresses the bounds in question — amounting thus to a leap into the ungrammatical — and retraces accordingly — both widens and modifies — the grammatical space available to the inquiry. In short, an episode of radical scientific discovery turns an ‘assumption’ which, as we have said, is formlessly taken along as a matter of course and to which, accordingly, questions could *not* be addressed (i.e. an ‘assumption’ with quotes) into a distinct proposition that can be doubted and thence conceptually and experimentally examined (i.e. a proper assumption without quotes). This proposition thus becomes open to rejection, revision, justification, and so forth⁹. It is these new possibilities for the development of the corresponding process of inquiry that activate the novel grammatical space opened by the radical scientific discovery. Thereby, the conceptual system concerned is itself not only enriched but also transformed substantially.

The reason why such a disclosure transforms substantially the conceptual system in question resides in the fact that no scientific concept can perform its work in isolation from other scientific concepts; these are always interdependent within the system they form¹⁰. This inter-

⁹And not just to a simple dismissal and replacement, as would have happened, for example, in the ideological change involved in a religious conversion. This distinction opens various important issues which I cannot enter to here.

¹⁰For an account of why and in what sense scientific concepts are always interdependent within the system they form see [Baltas 1988]. The effects that this ‘property’ has on the meaning of scientific concepts are presented in [Baltas 1990]. I should add that both these papers are concerned with physics. In this discipline, the interdependence in question is all the more manifest because of the *mathematical* relations that tie physical concepts together.

dependence implies that background ‘assumptions’ do not perform their function in respect to one or another concept alone, for these underlie, as we have implied above, the ‘natural’ interpretation of the conceptual system *as a whole*. In other words, it is they that assure behind the screens the coherence and the self-consistency of the conceptual system, it is they that form the invisible grammatical glue allowing the system to be ‘naturally’ understood in all the mutual relations among its parts. Given this, although the deadlock or contradiction from which the process starts is always more or less centred at a particular site of the conceptual system, the effects of the illumination of the corresponding ‘assumption’ and of its emergence from out of the background are diffused throughout the system, finally leaving no concept totally unscathed. This destabilizes the conceptual system in its entirety and thereby opens radically novel and extremely pressing problems, both in respect to the coherent articulation of the concepts themselves and in respect to the empirical reality these intend to capture. The successful resolution of enough of these problems is tantamount to the establishment of a radically novel conceptual system, the one articulating the new Kuhnian paradigm.

We should stress that the disclosure of such an ‘assumption’ accomplishes, when it happens, two distinct things. On the one hand, it clears, as we have just said, *novel grammatical space*. As the horizon of inquiry is no longer closed by the dumb existence of this ‘assumption’, new avenues of research are opened, new questions are asked and new answers are given, the ones, precisely, that deploy the new paradigm. On the other hand, such a disclosure creates a *novel vantage point* from where the preceding state of the investigation can be looked at anew. This is a vantage point whereby the anomalies whose unaccountable existence had induced the disclosure in the first place appear as misconstruals due to the work that the disclosed ‘assumption’ had been silently performing. Hence reasons can be adduced *post hoc* for the change that has occurred, reasons that appear as correcting previous inadvertences or oversights and hence reasons that tend to assess this change as invariably progressive. The spontaneous whiggism of practicing scientists is based precisely on this.

Let us look again at our previous examples. First, Cantor’s radical scientific discovery, if looked at from the novel vantage point it itself created, appears as follows. The deadlock Cantor encountered was determined as that by some background ‘assumption’ working under the time honoured conception of the part/whole relation. Within the then emerging language of set theory, this relation is defined like this: a “proper subset” of a given set is one included in that set without exhausting it;

a non-empty remainder is left. Thus the set, say, of even numbers is in that sense smaller, and cannot be but smaller, than the set of natural numbers, since the latter includes the odd numbers as well. On the other hand, within the same language and again by definition, sets have elements, i.e. they are the sets *of* their elements. And another time honoured idea is that the even numbers can be put into one-to-one correspondence with the natural numbers: the even number $2n$ corresponds one-to-one to the natural number n . But then the set of even numbers has the same number of elements as the set of natural numbers although a moment ago we demonstrated that the former is smaller than the latter and hence — how else could “smaller” be cashed in here, if it is *only* elements that sets can have? — it cannot but have fewer elements! Cantor’s leap into the ungrammatical, his giving a name to the ungrammatical, amounts then to his accepting this contradiction — for he cannot escape it or conceivably do otherwise — and go on defining infinite sets as precisely those for which both of the contradiction’s horns hold simultaneously. The well-entrenched background ‘assumption’ disclosed through this move is that always and without exception, *analytically* so to speak, a collection of items that is smaller than another — one that forms a proper part of its corresponding whole — cannot but include fewer items. Cantor’s definition opens up the grammatical space where it is not necessarily the case that the relation “*properly included in*” coincides with the relation “*has fewer elements than*”: for finite sets the two relations are equivalent but for infinite sets they are not¹¹. Giving room to this distinction — a distinction literally unthinkable before — sets up this novel grammatical space, a space wherein the old contradiction becomes automatically resolved¹². The articulation of the new paradigm, i.e. Cantor’s theory of sets and what follows from there, is nothing but the exploitation of this novel grammatical space through the deployment of that distinction’s far reaching consequences. We have to note, however, that after all is said and done, after the radical novelty of Cantor’s proposal has become absorbed and assimilated into the common wisdom of logicians and mathematicians, his move can appear only as simple and natural: why expect that the infinite should obey the same ‘laws’ as the finite? *Post festum*, but only *post festum*, the question is, of course, totally justified in its disarming candidness: why indeed?

Second, Bohr’s radical scientific discovery, again as regarded from the new vantage point it itself created, follows the same pattern. Bohr

¹¹I am grateful to my anonymous referee for clarifying this for me.

¹²Should or should not I place “resolved” in scare quotes? See note 6 above.

refuses to go against the physical understanding of his day by tinkering with the planetary model of the atom, Maxwell's electromagnetic theory and the atom's stability. His leap into the ungrammatical, his giving a name to the ungrammatical, amounts then to his accepting the manifest contradiction among these theories by positively decreeing that electrons rotating within atoms in their "ground state" — his name for the ungrammatical — do not radiate. And just as in the case of Cantor, this ungrammatical decree opened a novel grammatical space, the space capable of hosting a distinction literally unthinkable before, namely that between moving 'classical' bodies — which do emit radiation when following particular trajectories — and newly defined "moving quantum bodies", that do not when following apparently similar trajectories. Distinguishing in this way 'classical' from quantum motion unavoidably puts under fire the fundamental concept of "trajectory", leading thereby, grammatically if not historically, to the follow up distinction between 'classical' trajectories, where position and velocity (or momentum) can be determined simultaneously with arbitrary precision, and quantum 'trajectories' where they cannot¹³. Given that "trajectory" is, *by definition*, the sequence in time of the *determined* positions and velocities (the tangents of the corresponding curve) of a moving body, this further distinction is tantamount to the disclosure and the subsequent questioning of a quasi elemental background 'assumption': it is not necessarily the case, as it had been silently 'assumed' up to then, that the trajectories of *all* physical bodies do possess this, their *defining*, property. Although this makes quantum 'trajectories' impossible to strictly represent in space, cloud chambers and other experimental artefacts demonstrate that the concept should not be altogether jettisoned and hence that classical and quantum concepts bear very complex relations to one another. Concurrently, the disclosure of this 'assumption' opens the grammatical connection between quantum 'trajectories' and the particle/wave duality thus placing the articulation of the new paradigm of quantum mechanics well on its track. And again, after Bohr's initial move and its various direct or indirect grammatical implications have become assimilated into the common wisdom of at least the practising physicists, the corresponding candid question inevitably surfaces: why expect that the exceedingly small should obey the laws governing the medium sized bodies of our everyday experience? The whole practice of teaching introductory quantum mechanics is founded on the apparent naturalness of precisely this question.

Let us have a quick look at one last example. Classically speaking,

¹³My anonymous referee helped in this as well.

the concept “wave” is defined as the propagation of a medium’s disturbances. This is to say that, within the grammatical space supporting this definition, i.e. is within the grammatical space available to classical physics, the concept “wave” is *analytically* related to the existence of a material medium. To say, then, that some waves can propagate *in vacuum*, i.e. in absence of the material medium *whose disturbance they are*, is literally inconceivable. However, speaking very roughly, the theory of relativity can be seen *ex post facto* as resulting from the disclosure of some of the background ‘assumptions’ silently underlying the classical concepts of motion and the concomitant postulation¹⁴ – again a name for the ungrammatical — of a new kind of entity, the *electromagnetic field*. This is a kind of ‘non-classical’ wave that *can* propagate without any material medium being disturbed, amounting thus to a ‘disturbance’ of nothing that ‘propagates’ in itself! And once again, always *post festum*, we can repeat with both the practicing physicist and the teacher of modern physics: why expect that the exceedingly fast should obey the laws governing the kinds of motion we encounter daily?

3. Some consequences

The rough picture I have been trying to sketch has consequences. For our present concerns and to my view at least, most noteworthy are those permitting us to have another look at the insights opened up by Kuhn’s work. With the help of some clarifications and modifications, practically all of them can be rescued from most of the charges that had been besieging them from the very beginning. As a result, the guiding ideas of rationality and of scientific progress, ideas Kuhn never wanted to abandon, can be salvaged in ways that may be philosophically sound while agreeable to practicing scientists.

First, from the psychological point of view, the disclosure of a background ‘assumption’ does amount, as Kuhn would have it, to a “*Eureka!*” experience inducing a gestalt shift, a shift making one see the world under a new light. However here we have to be careful. Given that the main ingredients of paradigms cannot but be ideas, Kuhn’s maintaining that people residing in different paradigms “live in different worlds” seems to imply that it is ideas in general that determine the world — if, *pace* Berkeley, it does have some kind of existence of its own — and hence are in some sense primary in respect to it. As this is the core thesis of idealism, Kuhn has been charged, apparently with good reasons,

¹⁴Of course, this is not historically accurate.

for offering an idealist account of science. However, on a closer look, this charge is totally misguided. For, given the above, Kuhn's account of paradigm change can only imply that it is the world, not only as fully independent of ideas but also as absolutely primary in respect to them, that can be *the only agency* responsible for Kuhnian anomalies, that is for the deadlocks or contradictions on which paradigms stumble. This is to say that it is only the world that can display, be it in such an indirect and negative way, the inadequacy of a conceptual system, the fact that such a system does not possess the resources for coping with such deadlocks or contradictions, and hence for accounting for the world in the corresponding respect. In short, it is only the world, as fully independent of the ideas articulating the various paradigms, which, by resisting them, can force us into accepting that those very ideas fall short of it and thence are subordinate to it and fully reliant upon it, for better or for worse. Ideas are at peace with the world, allowing scientific, or even naïve, realism to appear as compelling, only as long as no dire anomalies surface to exert their full pressure¹⁵. It follows that Kuhn's position on paradigm change not only cannot be charged as idealist but, on the contrary, that it is a position vindicating with a vengeance the sovereignty of the world in respect to ideas, i.e. the absolute primacy that all forms of naturalism¹⁶ demand of it.

To go on, let us look at the phenomenon Kuhn calls "communication breakdown". On the present view, communication between scientists invariably breaks down in the relevant respect when these reside in succeeding paradigms. (As well as, with qualifications, in altogether different ones; but for reasons we will explicate, this need not concern us here). Why this is the case should by now be obvious. The scientist residing in the old paradigm has not undergone the pertinent "*Eureka!*" experience and still holds fast to the corresponding 'assumption', while remaining unaware that she is doing such a thing, i.e. that a questionable assumption is involved in the first place. Given the way we explicated the role and character of such an 'assumption', it follows that continuing to hold fast to it implies that this scientist cannot understand how it could be possibly questioned. Such questioning is literally unthinkable

¹⁵Such resistance of the world to the theories or paradigms trying to account for its various aspects should form, at least according to me, the starting point for a viable realist position, a position which, for reasons related to the above argument, I call "negative realism". I have tried to explore this idea in [Baltas 1997].

¹⁶This argument does not, of course, exhaust the issue of how ideas connect to the world. As I cannot enter into the matter here, I simply state that the kind of naturalism I would defend would reserve a place for what [McDowell 1996] calls "second nature".

from the old vantage point, as it would amount, for example, to the destruction of an analytic relation between concepts, i.e. of a relation that is inconceivable otherwise. It would be like being capable of entertaining the possibility that some bachelors may indeed be not unmarried males while the concept “bachelor” is *defined* as meaning precisely “unmarried male”¹⁷. Accordingly, the scientist still residing in the old paradigm can literally not understand the effects of the disclosure in question and hence neither the concepts the colleague residing in the new paradigm is using nor much of her way of talking. It should be clear nevertheless that no kind of simple-mindedness is involved here. To say it provocatively, Lorentz’s, say, continuing to admit till the end that he never came to understand relativity theory may even make him more ‘rational’ than Einstein: the old man had precise well articulated reasons — logical, conceptual, empirical and historical — for clinging, even unawares, to the ‘assumptions’ assuring the meaning of the old concepts while his young colleague only made a wild leap into the ungrammatical¹⁸. That Lorentz never underwent the appropriate “*Eureka!*” experience in no way demonstrates some kind of intellectual inferiority.

Lest the above be misunderstood, we should stress that the communication breakdown under consideration is no global breakdown. Although, as we have said above, the grammatical change induced by the ungrammatical leap rebounds to a greater or lesser extent throughout the old conceptual system, the two parties continue sharing the enormous grammatical space of their common language (Latin, Italian, German or whatever) within which the blind spots of their communication can be circumscribed, even if very hazily. For example, both parties can agree that explaining phenomena is what they are after while remaining completely at odds, not only on what such explanations should exactly amount to, but also on which are the phenomena to be explained¹⁹.

¹⁷For a discussion of analyticity that may shed more light on this argument, see [Putnam 2000].

¹⁸This does not render Einstein’s move irrational *per se*. It can be perceived as a wild, since ungrammatical, conjecture perhaps worthy of exploration, i.e. as an extremely far-fetched promise for advancing the investigation beyond the obstacles encountered that can be justified retrospectively from its *ex post facto* results. As it will become clearer below, the specifics of such *ex post facto* justification can only lie within and be supplied by the novel grammatical space as opened by the leap in question. In the terms of the political metaphor proposed by Kuhn, the jurisprudence governing such justification is the one established by post revolutionary law. Lorentz and all those still in the grips of the old regime refuse to submit themselves to such jurisprudence, for they literally don’t understand it.

¹⁹The communication gap between Galileo and the Aristotelians, or even that between Frege and Hilbert on what a mathematical definition should amount to, are

We should add that the communication situation is not totally hopeless even in respect to such ‘dialogues’. Since the disclosure of a background ‘assumption’ creates, as we have said, a novel vantage point whereby one can see what prevented this new way of looking before, one is armed with important *rhetorical* ammunition²⁰. Although such ammunition cannot compel logically those holding the old paradigm to undergo the pertinent “*Eureka!*” experience, it can serve to surround, so to speak, the corresponding background ‘assumption’ so as to force those opponents to realize, at least indirectly and in the long run, that they are unwittingly harbouring unwarranted biases. (Unwarranted, of course, from the point of view of the new paradigm). This is, I believe, the logical, or rather grammatical, niche of Galileo’s “propaganda” and of most scientists’ rhetoric and this, *pace* Feyerabend, is the way the rational import of this propaganda and of this rhetoric should be assessed. Our pedagogical practices when we are teaching counterintuitive theories do bear an eloquent witness to the need for exerting such violence.

The next point we should note is that the relation between the two succeeding paradigms is *not symmetrical*, and this in many senses. For one, it is not grammatically, and hence epistemically, indifferent within which paradigm one resides. Since the grammatical space available to the new paradigm includes the possibility of examining (of negating, of modifying or accepting, etc) an additional assumption unavailable to the old, namely the one resulting from the disclosure of the ‘assumption’ that had been silently taken for granted, it is a grammatical space *objectively* (i.e. independently of the relevant beliefs and convictions) *wider* than that available to the old paradigm.

It should be clear, however, that this does not imply either that the new paradigm has unearthed all the background ‘assumptions’ of the old or that it does not carry background ‘assumptions’ of its own. The concepts the new paradigm invariably introduces cannot be understood and function in absence of their own proper background. Nonetheless, this cannot make the horizon of inquiry accessible to the new paradigm narrower than that accessible to the old. The newly introduced background ‘assumptions’ simply have to silently coalesce with the still undisclosed old to assure the coherent and self-consistent overall interpretation of the new conceptual system as well as to ground the understanding that an ungrammatical leap had been involved and what its upshot was. It follows that some of the undisclosed old ‘assumptions’ may be covered up more and hence their entrenchment become strengthened. But this

cases in point.

²⁰See, for example, [Pera 1994].

need not impair the future success of the new paradigm; it may only render objectively more difficult the next possible paradigm change.

In any case, it is crucial to underline that the assessment of an objectively greater width is possible *only* from the vantage point determined by the new paradigm. Those clinging to the old continue to be unwittingly constrained by the background ‘assumption’ in question, to remain blind to the possibility of its interpellation and, therefore, incapable of surveying the greater width attained. Accordingly, if we keep Kuhn’s metaphor of the “gestalt switch”, we should be careful to note that, unlike the duck/rabbit case and at least thus far in our discussion, this is not a switch that allows one to go back and forth. It is a semi-conducting switch, directing from the old paradigm to the new through the relevant “*Eureka!*” experience. This is to elaborate the asymmetry we noted above: if we continue residing within the old paradigm, we are blocked in our understanding at least parts of what our interlocutors are talking about. In fact we even consider what they are telling us as literally incomprehensible, since ungrammatical. If we reside within the new paradigm, we can understand both what our interlocutors are talking about and why they are talking this way. We are not blocked because, to go one step further, the grammatical space available to us can accommodate *an explicit interpretation in our terms* of the old conceptual system as a whole, an interpretation concomitant with the *reinterpretation* of the empirical phenomena involved. In the case of post Galilean physics, where a mathematical structure always underpins the physical conceptual system thus rendering concepts and conceptual relations more precise, the interpretation in question is based on an *explicit, although imperfect, translation* of at least a crucial part of the old conceptual system in the terms of the new²¹. The case of mathematics, where no empirical phenomena are involved, should be treated separately and will not concern us in the remainder of the paper²².

²¹Two remarks are in order. 1. I am aware that I am mixing up “translation” and “interpretation” here against Kuhn’s careful distinction of the two terms in his [Kuhn 1983a]. My reasons for doing this will be clarified below. 2. My formulation seems to imply that, to the extent that phenomena become ‘merely’ reinterpreted across paradigm change, they, *pace* Kuhn, remain *per se* invariant. I will try arguing below why this implication need not follow although the kind of continuity suggested by my formulation seems to me inescapable.

²²However I do believe that some of what follows can, with qualifications, concern mathematics as well. In any case, the irreducible differences in question imply that, for tackling adequately scientific discovery and all the associated issues, it is necessary to assess carefully the characteristics of each different scientific discipline separately and not deal with science indistinctly in the more or less standard general terms. Although I cannot enter into the matter here, I presume referring the interested

What I mean can be spelled out as follows. In the passage from the old paradigm to the new, what first²³ opens up is the grammatical space tied to the particular concepts located at the core of the deadlock or contradiction on which the old paradigm stumbled in the first place (“proper part”, “rotating charged body”, “trajectory”, “wave” and so forth). This opening up blows up and changes dramatically the meaning of these concepts. Some of them may become fully discarded (as phlogiston or caloric) while some others acquire a radically new meaning, even as their names, and for good reasons as we will see, remain the same. The novel grammatical space is such, however, that three closely connected things become possible within it. First, one can understand on its basis the role the disclosed ‘assumption’ had been playing in assuring the coherence and self-consistency of the old conceptual system. Thereby that old system can be *interpreted* in a way making clear the reasons for both its successes and failures in accounting for the empirical phenomena in its domain. Second and concurrently, the novel grammatical space can host a *reinterpretation* in the new language of the empirical phenomena that had been countenanced, and as they had been countenanced, by the old²⁴. The relevant parts and aspects of nature are being understood now in the terms of the new conceptual system and of the novel grammatical space supporting it. Third, the new conceptual system can account *successfully* for at least some aspects of at least some of the phenomena (as reinterpreted) that were *at the heart of the deadlock or contradiction* from which the whole process started — i.e. those that the old conceptual system found impossible to handle — as well as for at least some aspects of at least some phenomena (as reinterpreted) that had been considered up to then as being *successfully* accounted for by the old conceptual system.

To see what is involved, let us concentrate on the case of physics. For post Galilean physics, then, we can detail the above by adding that, when more or less strictly specifiable *limit conditions* are satisfied, some crucial concepts coming out of the ungrammatical leap appear as almost identical to the old and hence they can be considered as their (imperfect) translations into the new language. Within the novel grammatical space, we can then talk of, say, “classical angular momentum” (if Plank’s constant tends to zero) or “classical mass” (if the speed of light tends to

reader to my paper “Physics as Self-Historiography *in Actu*: Identity Conditions for the Discipline”, still in progress but available as a draft on request.

²³Not necessarily in the temporal or historical sense. We will comment on this distinction in the conclusion of the paper.

²⁴The continuity at issue here, mentioned in note 21, will be discussed shortly.

infinity) as limiting cases of the corresponding quantum or relativity concepts and therefore as special cases, distinct in this sense from the general ones. Concurrently, within the novel grammatical space, appropriate conceptual relations can be produced which, *under exactly the same limit conditions*, appear as almost identical to some crucial old relations and hence as their translations into the new language. (Conservation laws are a case in point)²⁵. This (imperfect) translation, together with the attendant reinterpretation of empirical phenomena in the new language, allows us to see why the old conceptual system failed in accounting for the phenomena involved in the corresponding deadlock or contradiction — these (as reinterpreted) did not and could not satisfy the limit conditions — as well as why it can be still considered as having succeeded, for all practical purposes, in accounting for some other phenomena — these (as reinterpreted) did satisfy, if only imperfectly, the limit conditions. At the same time, the new conceptual system is in a position to account successfully in its own terms for both these categories of phenomena (as reinterpreted), or at least for some crucial aspects thereof. We should add that, in disciplines other than physics, where mathematics does not play such a constitutive role, this ‘relation’ between the two conceptual systems might not be capable of pinning down precise translation conditions of concepts and conceptual relations, failing to situate determinate correspondents even for its key terms. (Phlogiston has no counterpart in post Lavoisier chemistry). Nonetheless, if we are to talk of the change in grammatical space at issue, the interpretation, at least, of the old conceptual system as a whole, together with the concurrent reinterpretation of phenomena, should be assured in one way or another.

Whatever the case might be, we should emphasize that such a translation can be only imperfect. As we have said, practically all the systemic connections within the old conceptual system are variously accountable to the ‘assumption’ disclosed through the passage of the old paradigm to the new; hence the elimination of the grammatical glue among the old concepts — as we have characterized the ‘assumption’ in question — makes the new conceptual system independent of the old in a way allowing it to develop on its own, without being compelled to espouse all the concerns of the old, to follow strictly on its tracks or even to provide translations or determinate counterparts at all for its particular parts and facets. Thus not all *old* concepts and relations may or need

²⁵Such passage to the limit need not carry along, and hence need not preserve, the conceptual structure implicated; the existence of a mathematical limit does not imply a *conceptually* well-defined relation between the general case and the limit case.

find a correspondent in the new conceptual system²⁶ while not all parts of the *new* conceptual system may or need find opposite numbers in the old²⁷. In the case of physics, not all concepts and conceptual relations of the new system may or need possess mathematical limits that appear as identical to some of the old²⁸. In that particular discipline, even the limit cases of the new concepts and relations that *do* appear as identical to the old may not or need not be strict translations, for the overall conceptual structure is standardly very different²⁹. In other disciplines, where determinate correspondents can be lacking, the imperfection in translation may be so serious that the very meaning of the term fades out in favour of interpretation. In such cases translation cannot properly be said to exist³⁰.

At any rate, the required existence of the interpretation/translation at issue adds another dimension to the asymmetry we are discussing. That the grammatical space available to the new paradigm is objectively wider than that available to the old implies that *only* the interpretation/translation of the old conceptual system into the language of the new is possible while the reverse interpretation/translation is blocked. The new concepts of “angular momentum” or of “mass” can accommodate as limiting cases classical angular momentum and mass once the latter are (imperfectly) translated into the new language while relativistic or quantum concepts and relations cannot be interpreted/translated into the language of classical mechanics, for the work performed by the yet undisclosed ‘assumptions’ makes such an interpretation/translation literally unthinkable. In the same vein, modern chemistry would be unthinkable for Priestley while within the grammatical space available to it we can interpret phlogiston theory in a manner allowing us to understand fully its conceptual structure and hence the reasons for both its successes and its failures.

²⁶These amount more or less to “Kuhnian losses”.

²⁷For example, oxygen can have no possible counterpart in the language of phlogiston theory.

²⁸For example, quantum mechanical spin has no classical counterpart and the relation $E=mc^2$ cannot possess a classical limit.

²⁹For example, Planck’s constant tending to zero can have no effect at all on the underlying structure of quantum mechanics, namely Hilbert space vectors and operators, while the low velocity limit of relativity theory cannot but preserve the conceptual interdependence of space and time. Both this underlying structure and that conceptual interdependence are unthinkable within classical mechanics as such.

³⁰The conceptual structure of phlogiston theory is very different from that of modern chemistry and cannot be accommodated *as such* within the grammatical space supporting the latter. This is also the case for caloric theory in respect to classical thermodynamics.

Let us turn now, as we have promised, to the issue of *continuity* across paradigm change, i.e. what we had been envisaging when we decided to confine our discussion to succeeding and not generally different paradigms. We start by stating explicitly what we have already implied, namely that a kind of continuity is assured between two succeeding paradigms by the fact that the passage from the old paradigm to the new occurs on the basis of a deadlock or contradiction implicating some *particular phenomena*. We can identify two closely connected grounds at the root of such continuity.

First, and by definition so to speak, the new paradigm resolves the Kuhnian anomaly these phenomena exhibit; it is precisely this feat that provides the initial fuel required for the new paradigm to proceed with its deployment. But as we have said early in our discussion, the corresponding novel grammatical space becomes instituted by the act of *repressing the memory* of a grammatical *impossibility*, that encountered by the old conceptual system in trying to account for the phenomena in question. Giving a name to the ungrammatical by means of a novel positive definition amounts precisely to this. This is also to say, however, that the novel grammatical space *continues to enfold* the same impossibility within it, if only in the guise of that repressed memory. And the survival of this impossibility, even in merely that guise, keeps the novel grammatical space *linked* to the old, thus rendering it continuous with it in that sense.

What I mean is the following. We saw in our examples³¹ that the concept positively defined by the ungrammatical leap can host, directly or indirectly, a distinction between itself and the interpretation/translation of some old concept located at the core of the deadlock or contradiction at issue. That the old concept has to be interpreted/translated for becoming thus accommodated is a direct consequence of its impossibility of overstepping the corresponding grammatical bounds. Thus this interpretation/translation, *in being precisely an interpretation/translation*, retains the memory of this impossibility. But the fact that the positive definition in question institutes a novel *grammatical* space, wherein the ensuing new concept functions *fully grammatically* in tandem with the interpretation/translation of the old, makes the ungrammaticality disappear from sight and represses its memory³².

³¹As it can be readily ascertained, what follows applies *mutatis mutandis* to disciplines where no direct counterparts are available and hence no translation can be properly said to exist.

³²It follows that this ungrammaticality becomes eventually forgotten, fully covered under what the resultant grammatical space starts compelling everyone to take for

Now, repressing the memory of this impossibility goes hand in hand with the *reinterpretation* of the implicated phenomena by the new conceptual system in the terms of the novel grammatical space. But in what way is this a reinterpretation of the phenomena exhibiting the Kuhnian anomaly? If we don't raise the issue we cannot but be silently assuming that these are *merely* reinterpreted and thus that they retain *as such* their identity, which inevitably begs the question. To answer, we repeat that, on our account, the appearance of a deadlock or contradiction in respect to some phenomena means *only* that the world *manifests its resistance* to the conceptual system intending to capture them. This is to say, first, that it is the force of this resistance that the ungrammatical leap has to overcome and, second, that the success of the leap *appeases* this resistance by making the new conceptual system *conform* to the world in the relevant respect. But this can only mean that 'something' of the world, 'something' of the materiality of the phenomena concerned, is *carried invariant* across the leap³³. For, appeasing such resistance and making the new conceptual system conform to the world can only mean that this new system manages to capture adequately the *very same* 'something' that resisted its capture by the old conceptual system. In other words, the same 'something' is being conceptualised in the terms of an inadequate system at one of the leap's ends and in the terms of a correspondingly adequate one at the other end³⁴. The novel grammatical space is itself stamped by the persistence of this 'something': the fact that what is at issue is an impossibility *having concerned* the phenom-

granted. Thus, in the long run, the achievements of the superseded paradigm appear retrospectively as trivial, as obviously mistaken or as fully incomprehensible. It is then up to the historian of science to reveal the revolutionary character of the corresponding ungrammatical leap and to dispense intellectual justice.

³³This is the 'something' that any brand of naturalism would minimally require, if the world is to be independent of ideas and primary in respect to them. For an argument why this 'something' need not amount to a Kantian "thing in itself", even if it cannot be described or formulated by any conceptual system at all, see [Baltas 1997].

³⁴I should note that no "convergence to the truth" is implied by such a passage from the inadequate to the adequate. As we will explicate below, a kind of progress may indeed be involved, but it amounts only to a relation between two grammatical spaces while the world remains, so to speak, gravely silent in the background, permanently refusing to pronounce itself otherwise than through *resisting* inadequate conceptual systems. This is to say that, as concerns the world, the kind of progress involved is 'negative': the new conceptual system merely shows that the world in the relevant respect is *not* in fact as the old system takes it to be. And that is that. The novel grammatical space inevitably carries background 'assumptions' of its own that another, perhaps much more radical, ungrammatical leap may eventually disclose, showing thereby that the new conceptual system too is grossly inadequate. For more details see below as well as [Baltas 1997].

ena exhibiting the anomaly, an impossibility, moreover, that *continues to survive* — even only as a repressed memory — within the grammatical space having overcome the resistance *they* had exhibited marks precisely the elusive passage of the same ‘something’ across the ungrammatical leap. We can add that the fact that this ‘something’ remains invariant is faithfully reflected in the pertinent “*Eureka!*” experience, for this is an experience that cannot engage but a single thing at both its ends: after having undergone it, we understand *exactly what* we were incapable of understanding before. In one word, it is the invariance of this ‘something’ across that leap that allows maintaining that the new conceptual system indeed reinterprets *the* phenomena exhibiting the Kuhnian anomaly.

To sum up our first point, we can say the following. By construction, the grammatical space of the new paradigm enfolds the impossibility of the old to handle the Kuhnian anomaly and that it enfolds it by repressing its memory. In repressing this memory, it resolves the anomaly and becomes the grammatical space of a new paradigm; but by still enfolding it, it remains linked to the old and thence continuous with it in this sense. Concurrently, the resistance of the world manifested by the anomaly becomes appeased through the reinterpretation of the phenomena exhibiting it in the terms of the novel grammatical space and through their becoming adequately captured by the new conceptual system. Despite the radical difference in the way they are being captured, the identity of the phenomena is preserved across the change in grammatical space because ‘something’ of their materiality remains invariant. The simple idea that two succeeding paradigms are continuous because the new is born out of the old can be fleshed out in this way.

Our second point is that the connection between the two paradigms assured by the interpretation/translation and reinterpretation we have been discussing expresses another form of such continuity. And this too is absolutely crucial: in its absence, i.e. in absence of the new paradigm’s capacity for deploying itself as connected through this interpretation/translation and reinterpretation with the old, the resolution of the anomaly would carry no scientific weight whatsoever; the corresponding leap into the ungrammatical would amount to an isolated ungrammatical definition that institutes no grammatical space, remaining thus perfectly idle. This is also to say that this continuity through interpretation/translation and reinterpretation makes the phenomena captured by the old conceptual system appear as ‘at bottom’ identical with their reinterpretation in the new system. In conjunction with our previous point, it is precisely this that makes the new paradigm, not merely different from the old, but the one that *succeeds* it. We can add that the grounds

of this continuity provide also the reasons why it is not only historically but also grammatically required that the names of the old concepts be preserved in the novel grammatical space as far as its continuity with the old calls for: these names constitute the necessary grammatical reminder of this continuity, i.e. of its inescapability, if the new paradigm is to be a paradigm at all in the above sense.

We have to acknowledge that such continuity is close enough to a continuity of reference to almost compel us, together with most practising scientists, to say that the two paradigms talk about the *same phenomena tout court*. Yet on the above this cannot be strictly correct. If, as we have said, the world manifests itself *only* through its resistance to our conceptual systems, then the phenomena we are considering cannot provide a firm hold to the relation of reference, at least as it is has been standardly discussed. Viewed from another angle, this is to say — as Kuhn too would have it — that no phenomena can be given to our experience and to our perception independently of the concepts capturing them³⁵, for, to use received terminology, they are always, in a sense, theory laden³⁶. In our terms, this simply means that the ‘something’ of their materiality that remains invariant across paradigm change cannot be captured independently of some conceptual system or other, with all the corresponding background ‘assumptions’ inevitably entering into play and the attendant threat of an anomaly always lurking in the shadows.

At any rate these remarks cannot, of course, exhaust the issue. A fuller account of the ‘something’ that persists across paradigm change is called for, an account that would spell out the continuity we have been discussing and the associated identity conditions for phenomena in a manner clarifying, precisely, the ways we refer to them. Our story thus far seems to suggest that the continuity and the identity conditions at issue should perhaps be explicated in terms of some kind of constancy of the general conceptual fabric of everyday language — for it is only in its terms that the world can be captured at all — as this works in concert with some kind of stability of experience and of perception — for it is only such stability that can allow our everyday language to function at all in respect to the world. Yet the fact that, on the above, radically novel concepts can be introduced, novel grammatical spaces can become instituted while, concomitantly, our overall experience, and

³⁵ As [McDowell 1994] phrases it, the “conceptual goes all the way down”.

³⁶ For an interesting way to distinguish the conceptual from the theory-laden that is consonant with the present account and on the basis of which the continuity we are talking about can perhaps be spelled out, see [Pagondiotis 2004].

hence perhaps even our perception, can be broadened and become more sophisticated tend to show that such constancy should be somehow imperfect and such stability should be somehow supple. Going beyond this admittedly vague pointer, however, would take us too far outside the scope of the present paper.

In any case, the above entail that the continuity of succeeding paradigms through the interpretation/translation and reinterpretation we have been discussing is always a vital feature of radical scientific discovery, accomplishing at least two purposes. First, such continuity is essential for justifying the use of the *old* conceptual system when translatable counterparts exist or when the corresponding limit conditions are satisfied: after relativity theory and/or quantum mechanics became the reigning paradigms, classical mechanics can be used without many scientific or philosophical qualms (which does not mean straightforwardly or unproblematically) thanks to the continuity assuring the corresponding interpretation/translation and reinterpretation. Second, for assessing the role the disclosed ‘assumption’ had been playing within the old conceptual system and hence for accounting for the successes and failures of the old paradigm as well as for the coming to being of its successor. As specifically in the case of physics this translation saves — sanctions³⁷ — as limiting cases the translatable, precisely, concepts and conceptual relations of the old paradigm, its existence allows us to understand how that paradigm could have been successful in the relevant respects *despite* the role being played by the ‘assumption’ in question. Concurrently, that not all parts of the old conceptual system are saved through this translation³⁸ allows us to understand the ways in which the horizon of inquiry had been closed by the silent work performed by the same ‘assumption’. In particular, we can understand why the new paradigm could not have come into being *without* the relevant ungrammatical leap, a kind of leap, however, that preserves the continuity between the two paradigms precisely through the interpretation/translation and reinterpretation at issue. Surreptitiously shifting this logical “without” to a temporal “before” obliterates such imperfection in translation as well as other telling differences between two succeeding paradigms and makes us perceive the old paradigm *tout court* — *per se* and as a whole — as either totally discardable or as just a limiting case of the new. As we have implied above, this misconception lies at the roots of the ways we tend

³⁷The use of this term intends an allusion to Bachelard’s “*histoire sanctionnée*”. It lies outside the scope of the present paper to develop the proximity (and the differences) between the approaches of Bachelard and of Kuhn.

³⁸Bachelard’s “*histoire périmée*” finds its correspondent here.

to teach modern physics and modern science in general while simultaneously feeding the spontaneous whiggism of practicing scientists. To sum up, the interpretation/translation and reinterpretation manifesting and substantiating the continuity in question reveals the two aspects in which the grammatical space attached to the new paradigm is *objectively* wider than that attached to the old. Yet another dimension of the asymmetry we are discussing involves the consequences of this objectively greater width.

For one, it is imperative to emphasize that attaining this greater width is an *irreversible* achievement. Once a new grammatical possibility becomes available through the disclosure of a background 'assumption' and once the corresponding implications become domesticated through the successes of the new paradigm, scientific reason cannot, grammatically if not historically, wipe out this possibility, forget its existence and act as if it were not there. Forsaking the "*Eureka!*" experience, retracing the steps of radical scientific discovery and making the disclosed assumption re-enter the amorphous background supporting grammatically the old conceptual system is obviously impossible. This is to say that the route for regaining the lost innocence, the route leading back to conceiving the old concepts strictly the way they were being conceived before the disclosure, is blocked. At least part of the grammatical glue assuring the coherence and self-consistency of the old conceptual system has been found out and, to that extent, it has lost for good the corresponding gripping power. The two succeeding paradigms are asymmetrical also in the sense that the old paradigm has become *definitively* superseded.

If this is indeed the way one paradigm succeeds another, then no room is left for an extra-paradigmatic vantage point, i.e. a point from where one could impartially assess the relative merits and demerits of paradigms, biased by none. As Kuhn would have it, nothing at all can be conceived outside a paradigm and as [McDowell 1994] would formulate it, no view "from sideways on" can ever be available: we can reason only in the terms of a paradigm, on the appropriate more general understanding of the term. But if we always find ourselves within a paradigm without the possibility of acceding to extra-paradigmatic neutral ground, it seems to follow that a paradigm is as good as any other. And if that is indeed the case, rationality receives a lethal blow while all kinds of relativist positions, from social constructivism to various forms of alleged 'post-modernism', find a privileged soil on which to thrive: if rationality cannot be saved even within science, then it cannot be saved anywhere and hence we are free to choose the paradigm that suits best our conventions, our interests, or even our whims. However, this is a *non sequitur*

and the corresponding charge is, once again, totally misguided. Once we accept that we cannot access God's standpoint, *where no latent grammatical conditions need exist and all background 'assumptions' without exception lay bare to the gazing*, no peril whatsoever to rationality can be forthcoming and no kind of relativism can be implied from our account. Both Lorentz and Einstein can be as rational as we wish while the change from a paradigm to its successor is as rational a procedure as any in human thought and action. The catchword is what we have been repeating almost *ad nauseam* above: there is an *inherent asymmetry* between succeeding paradigms in the sense that the grammatical space available to the new paradigm is *objectively* wider than that available to the old. That the new paradigm supersedes *definitively* the old means that, after having undergone the "*Eureka!*" experience, we *necessarily* reside within the novel grammatical space with no possibility of going back and hence that no real choice between the two paradigms can be at issue. In that precise sense, objectivity need not imply neutrality in respect to paradigms and the attendant impartiality; their tie may appear unbreakable only from the point of view of God.

But if that is the case, then our Kuhnian account appears as open to the opposite charge: do we endorse cumulative progress? The answer is no, for that the old paradigm has become definitively superseded does not imply that the new paradigm can do better than its predecessor in respect to *all* the (reinterpretations of the) empirical issues that the old had confronted, successfully or not, by its own standards and through its own means. After the ungrammatical leap and the initial empirical successes securing the irreversible character of the expansion in grammatical space, the new paradigm may indeed solve the (reinterpretations of) some outstanding old puzzles, it may dissolve and completely discard through the corresponding interpretation/translation some others, or it may stumble in its efforts to solve (the reinterpretations of) some of the puzzles that the old paradigm had successfully tackled in its own terms. It may even prove the case that, apart from the inaugurating initial successes, no substantial claim of the new paradigm can survive future empirical trials or that the inaugurating successes themselves need to be reinterpreted. A new paradigm change may be called for, a paradigm change that will disclose additional background 'assumptions', those that will appear, *ex post facto* and from the resulting novel point of view, as responsible for the trouble this new paradigm had been encountering. This implies that there is no paradigm-free way to assess the successes and failures of paradigms so as to come up with the conclusion that the new paradigm performs unqualifiedly better than the old. For the

same reason as above, namely that God's standpoint is unavailable, no neutral scale can exist, as the idea of cumulative progress would have it, on which to place such successes and failures, count them impartially and draw the balance. Nevertheless, progress *does* occur. As we have been repeating, the novel grammatical space is *objectively* wider and the old paradigm has become *definitively* superseded. Progress concomitant with radical scientific discovery amounts 'merely' to this.

On the basis of what precedes, let us have a cursory look at the issues of theory comparison, incommensurability and theory choice as they have been more or less standardly discussed. As we have said, the novel grammatical space can accommodate a one-way interpretation/translation of the old conceptual system allowing us to understand the role the corresponding disclosed 'assumption' had been silently playing in respect to it. This implies that we are in a position to understand fully the language of the old paradigm and thus become bilingual in the sense that Kuhn would have it, i.e. become capable of switching back to the old language and reason in its terms. In doing this, we can assess the old paradigm as indeed incommensurable with the new, again in Kuhn's sense of the term: the interpretation/translation in question is not word for word, it need not preserve either reference or meaning, it uses approximations and circumlocutions of all sorts and kinds, it carries inevitable losses³⁹. Hence the concepts of the old paradigm cannot be placed alongside those of the new and be compared with them through some common measure. Given this, the gestalt switch Kuhn is talking about can then be indeed bi-directional in the corresponding sense, i.e. in allowing such a movement between the two incommensurable languages.

What Kuhn does not make sufficiently clear, however, is that all this

³⁹As we recall from note 32, once a given paradigm (say classical mechanics) has been entrenched deeply and long enough through scientific practice and many years of education, most older approaches tend to appear either as trivially simple and obvious (those sanctioned by the interpretation/translation and reinterpretation we are talking about) or as self-evidently wrong, if not fully incomprehensible (those not saved by that interpretation/translation and reinterpretation). This is to say that the historian of science has to expend a lot of intellectual effort in order to understand *superseded* paradigms in their own terms. This is a kind of effort that re-dis-covers, as it were, the background 'assumptions' at work in the old paradigm, the 'assumptions' whose disclosure has led to the current deeply entrenched paradigm, i.e. the one that the present day historian of science tends *herself* to take for granted. Arriving to understand the old paradigm in such a way constitutes, of course, a major gestalt shift of the purest kind. In his [Kuhn 1987], Kuhn describes eloquently the "*Eureka!*" experience and the gestalt shift he had himself undergone in respect to Aristotelian physics. And it is only fair to add that Kuhn's "*Eureka!*" experience opened another kind of novel grammatical space, the one that, among many other things, provided the necessary grounds for writing the present paper. . .

can happen *only within the wider grammatical space* irreversibly established by the disclosure of the corresponding background ‘assumption’. In this sense, there is really *only one* language at play, namely that supported by the novel grammatical space. This is to say that bilingualism, the concomitant bi-directional gestalt switch and incommensurability acquire the characteristics that Kuhn and others highlight *only after* the old paradigm *as such*, i.e. as still harbouring the ‘assumption’ in question in its background, has become definitively superseded and only on the basis of the novel grammatical space. We can add that within this wider grammatical space, that ‘assumption’, by having become an assumption, can, as we have said, be *explicitly* negated, modified, or even accepted *post hoc*, depending mostly on the empirical grounds that have become available to the novel grammatical space⁴⁰. Theory *choice* enters at this point and can enter only at this point, for, on the present account, the disclosure of a background ‘assumption’ and the corresponding paradigm change and expansion of grammatical space involve no choice at all. But once a literal choice of theory can only take place within a *given* grammatical space, it is not a ‘big’ choice. It can never be a *paradigm* choice, if “paradigm” is taken in the sense of “disciplinary matrix”. As a choice of theory within a given grammatical space, it is choice of the sort scientists make all the time within what Kuhn calls “normal science”.

Our departure from Kuhn’s account, then, boils down to our considering that he is running together asymmetry and incommensurability⁴¹, as we have been discussing them. Two succeeding paradigms are asymmetrical in the sense that the grammatical space available to the new is objectively wider than that available to the old while phenomena of incommensurability (together with the processes of theory comparison and theory choice) really appear only within the novel grammatical space on the basis of the one-way interpretation/translation we have been talking about⁴². But then incommensurability is not that dramatic after all, for it is in absolutely no position to support relativism or endanger (human and not Godlike) rationality.

⁴⁰[Earman 1989] can formulate and assess the merits and demerits of all kinds of space-time theories, old and new, in the language of current mathematics on this basis and only on this basis.

⁴¹I pity the intrepid translator who may attempt capturing this distinction into Greek, for the Greek *a-syn-metron* is the exact translation, fragment by fragment, of *in-con-measure*!

⁴²Earman notes, I take it, the same point: “Incommensurabilities have a way of disappearing when the *initially* seeming incommensurable set of propositions is fitted into an *appropriately enlarged possibility set*” ([Earman 1989, p.27], my emphasis). This “enlarged possibility set” is almost synonymous to what I call a “wider grammatical space”.

I could go on elaborating. But having almost exhausted the space available, I stop here hoping that the above succeeded in offering a rough idea that both the devil of relativism and the deep blue sea of whiggism⁴³ can be avoided while maintaining firmly most, if not all, of Kuhn's fundamental insights. Both rationality and scientific progress can be vindicated at a price that is not really one. *Pace* Leibniz, Frege, the Vienna Circle positivists and many others, we should come to accept, and this with joy, that the groundings of our science can neither be made totally explicit nor become subsumed fully to a kind of algorithmic control. If *per impossibile* they could, life would be incredibly poorer.

4. To Conclude: Reservations and Qualifications

Lest the above be over-interpreted, I believe I should make explicit that I don't want to argue that every radical scientific discovery follows necessarily the kind of pattern I have been trying to sketch. Although more examples can be forwarded, I believe that much more research is required before advancing vast claims such as this. Such research may go along two main directions. The first concerns the overall philosophical coherence of the story I am trying to tell; this can be assessed if the present point of view becomes fleshed out and articulated in a way allowing it to be tested against the various questions still pestering the philosophical issue of scientific development. The second direction concerns a fuller reconstruction of particular episodes of radical scientific discovery along the lines I am suggesting. Such research, even if it does not demonstrate that my story is down and out incoherent, will most probably compel it to change substantially by recognizing, at the very least, telling differences in the patterns followed⁴⁴.

To go on, it is evident that all my examples are only summary reconstructions of particular episodes in the history of science, more or less in the spirit of Lakatos. However, history of science forms indeed a subject in its own right and cannot be reduced to a depository of self-serving examples and even less to a "set of footnotes". Accordingly, if what I have to say is to be of some value to historians of science, it requires some important qualifications.

⁴³Earman continues his previous remark by adding: "[N]o fear of being labelled Whigs should prevent us from taking advantage of an 'apparatus' that can (...) provide [such a] larger possibility set". Exactly! But, again, on the basis of the caveat that this "larger possibility set" becomes available only after the disclosure I have been talking about has effectively taken place.

⁴⁴I have tried to walk some steps in that direction in [Baltas 2000].

These qualifications concern for the most part the division of labour between the philosopher and the historian of science. Their different tasks will come out more clearly if I try relate the present account with an historical study which I find particularly consonant with what I have been trying here to convey. This is a study of the development of low temperature physics published by [Gavroglu & Goudaroulis 1989].

The two authors suggest that in actual scientific practice, the deadlock or contradiction I have been talking about (they don't use this terminology) usually presents itself to the scientists involved through a whole set of interrelated puzzles, each of which may exhibit a different unaccountable property. The problem situation confronting those scientists is thus variously and complexly structured. The two authors then go on to classify such properties so as to show concretely that only one such puzzle and/or one such property is the 'right' one. By this they mean that it is their effective (possibly serendipitous) coming to grips with this particular puzzle and/or property that allows the scientists involved to proceed towards radical scientific discovery. According to the two authors, the process in question is one that leads the concepts implicated within the problem situation *out of* their initial contexts, where this "out of" is one of those terms, made famous by Derrida (who is not mentioned), that possess simultaneously two contrary meanings. On the one hand, the concepts in question come out of, in the sense that they belong to and are derived from, the context of the initial paradigm that supplies them with their established meaning. On the other hand, during the process of discovery, the same concepts come out of, in the sense that they become foreign to and get away from, this initial context while creating a new context and hence a new paradigm⁴⁵.

If this picture holds water, then the task of historians is to examine the particular processes that have led to the isolation of the 'right' puzzle and/or property and to its subsequent solution or dissolution. The task of philosophers is very different. They can start immediately from what has emerged *post hoc* as the 'right' puzzle and/or property — or even they can concoct one suiting the purposes at hand — and then try to pinpoint the background 'assumptions' at work which used to constitute as many latent grammatical conditions on the concepts implicated and, concomitantly, as much resistance to the problem's solution or dissolution⁴⁶.

⁴⁵See [Gavroglu & Goudaroulis 1989], especially pages 25 to 30.

⁴⁶However, if it is a philosopher's task to assess the role of various factors in scientific development, as is the case, for example, in the internalist/externalist debate, philosophers too are obliged to follow the details of a particular historical episode so

The distinction between solution and dissolution should be taken seriously. It aims at distinguishing puzzles that appear totally irresolvable but which are eventually shown to conform to the paradigm in place (superconductivity and superfluidity are excellent cases in point, for quantum mechanics proved fully capable of accommodating them) and those that resist such efforts to the end, thereby inducing the leap into the ungrammatical. The first of these are the puzzles solved and the second the puzzles dissolved. The fact, now, that in *both* cases the recalcitrant puzzle appears as a total deadlock or contradiction implies that there is no way of knowing beforehand whether it belongs to the first or to the second variety and hence the distinction in question can be drawn only *ex post facto*. This is to say that there cannot exist any definitive scheme telling scientists what to expect and to prepare accordingly. In all circumstances, everybody concerned is bathing within more or less the same ocean of background ‘assumptions’⁴⁷, whose character is precisely such that it forbids scientists from realizing that they can start questioning them. Radical scientific discovery is so rare precisely because of this. To say it in one word, there is no definite method leading to radical scientific discovery and there is no advice that can be given to the scientists from the outside, even if one manages to muster for the purpose all philosophical ingenuity and all historical knowledge available. In this respect, philosophy of science is totally powerless. The best it can do, which is already precious enough, is to throw some light on the situation after the upheaval has settled down and everything important has been set into place.

On the other hand, the fact that the problem situation confronting such scientists is variously and complexly structured shows that the process of scientific discovery is no instantaneous act. For it may involve false starts of all sorts, research undertaken leading to a dead-end, telling but coincidental insights, bitter conflicts and discords, and all kinds of such things. As Kuhn puts it [Kuhn 1978, 369], “Discoveries are extended processes, seldom attributable to a particular moment in time and sometimes not even to a single individual”. [Damerow, Freudenthal, McLaughlin & Renn 1992] stress exactly the same point. Their work shows convincingly that the process leading to the formulation of classical mechanics was effectively such that both the ‘moment’ of discovery and its single particular instigator are impossible to isolate. No relevant text of the period and no phrase within any of these texts can be sin-

as to distinguish determinative from anecdotic factors and so forth. I owe this remark to Léna Soler.

⁴⁷Not necessarily the same in the strict sense. See [Baltas 2000].

gled out as constituting *the* precise moment of the break. The precise moment in question simply does not exist. Surreptitiously, within the relevant texts and from one text to another, surely ‘something’ important is indeed taking place. Only this ‘something’ becomes recognizable as radically different from what existed before only after the ‘event’. But this ‘event’ has no assignable beginning or end.

If this is a fact for The Great Revolution itself, it should sober us down. It brings with it a demand for humility that goes very much against the grain in the sense that too many practicing scientists would regard it with disfavour. To quote Kuhn again

[w]hat is at stake for them, implicitly or explicitly, is the concept of the unit discovery, a concept that will not withstand application to actual practice, but on which much of the reward system of science as well as important elements of the scientist’s conception of self are nevertheless based. [Kuhn 1978, 369].

This is a moral principle that both philosophically sophisticated history of science and historically informed philosophy of science carry to the practice of science. These twin disciplines then, although humble enough to admit that they cannot help much the effective process of scientific discovery, do have moral principles to bring to the world of science. And this is indeed a good thing for us all.