IS THE CONTEXT OF DISCOVERY A SUBJECT OF METHODOLOGY?

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Abstract

The novelty of scientific discovery is considered. The analysis of problem solving situation concerns the relativistic turn in physics. The Einsteinian special relativity and Poincaré's relativistic kinematics are compared with respect to their theoretical, empirical and heuristic novelty features. It is concluded that the objectively defined novelty of the discovery is not sufficient for grasping of victorious character of a theory because the objective reconstruction of the problem situation is related finally to an individual scientist. This individual recognition influences the activity in lower Popperian worlds which is also responsible for a presentation, propagation and appraisal of the discovery.

Keywords: philosophy of science, rationality of science, situation generating the discovery, novelty of discovery.

1. Introduction

Out of the whole set of problems connected with the rationality of scientific discovery I propose to select only a single question for the subject matter of the paper: What is the essence of novelty in scientific discovery? The attempt to answer this question will throw light both on the groups of problems connected with the specific character of the scientific creativeness and on the situation generating the discovery, which haven't been discussed e. g. by ZAHAR (1983) and PIETRUSKA-MADEJ (1985). The question put here requires the explanation in what sense the term novelty is understood here. I understand it as the novelty of theoretical assumptions, their consequences, mathematical apparatus of the theory and heuristic principles and shall try to show in what degree the novelty of the theory is sufficient to acknowledge the significance of the theory for a scientific discovery.

The term *discovery* comprises the element of novelty in its very name: *to discover* means to show something that before was hidden from the recognizing agent. What was discovered is new in relation to hitherto possessed knowledge. In which sense is it new? If any of knowledge elements is new it is always new in relation to the knowledge before the discovery. The type of the relation between *the new* and *the old* is the subject matter of this article. The attempt to define this relation is given on the example of the so-called Einsteinian revolution.

A more penetrating semantic analysis of the word *discovery* convinces that the revolutionary character of a discovery is not obvious. *To discover* means also to show something new, which was not hitherto known but which was brought about by the purposeful activity of searching for a satisfactory solution, (although in a common-sense meaning the word *to discover* is also *to find something unexpected*, in science when *the unexpected discovery* appears it is recognized as an anomaly which is usually difficult to explain.)

The revolutionary character of the discovery does not consist in the lack of genetic or logical continuity between the old and the new knowledge. If one is to speak about the revolutionary character of the discovery, one means a revolutionary character post factum: the revolutionary discovery finishes a certain stage of the search for the solution of the problem in a given branch of knowledge and it starts a new stage of the development of this branch. I shall try to reconstruct the features which a discovery should possess in order to be a revolutionary one taking the relativistic turn in physics as our example.

2. The Influence of Problem Situation upon the Origination of Special Relativity Theory and Novelty in its Postulates

In his first work, which initiated a new kinematics — special relativity (SR). EINSTEIN (1905a) introduced directly two postulates of a new theory and described briefly their origination. Referring to the 19th c. physics, Einstein quoted Lorentz's work from 1895 in which Lorentz put forward a branch electrodynamics which satisfied the practical principle of relativity. Einstein searched for the way of retaining the physical sense of Lorentz's ether which played the role of the absolute reference system for electrodynamics. His investigations did not aim at the designing of new empirical tests but at understanding the theoretical basis of the assumption about the ether. The need to introduce the practical principle of relativity, the zero result of the Michelson-Morley experiment as well as some theoretical analyses such as considerations about electromagnetic induction spoke against the assumption about the existence and the role of ether. Einstein mentioned the induction experiment as the example that 'electrodynamical and mechanical phenomena do not reveal the properties which would correspond to the idea of the absolute rest. Hertz's idea of the relativity of mechanical motions and electrodynamical phenomena became more probable than the Lorentz's hypothesis about the limited validity of the Galilean relativity principle. But the Hertzian question about the moving ether turned out to be purposeless. According to Einstein ether should be excluded not because it was not experimentally discovered but mainly because the assumption about the invariance of physical laws with respect to inertial frames of references eliminated the question about the existence of ether. It was not the point that ether did not exist as a physical substance with definite properties, but that it was a notion which couldn't be defined in more fundamental terms of physics or, which couldn't have any operational meaning. In consequence to this, Einstein formulated the first postulate (P_1) the so-called relativity principle as the 'generalization of the effect of the first order: the same laws of electrodynamics and optics would be valid in all reference systems in which mechanical equations are also satisfied.'

The second postulate of SR was less obvious from the point of view of the development of pre-Einsteinian physics. It was called the light postulate (P_2) which in the original sounded as follows: 'light is always propagated in empty space with a finite velocity which is independent of the state of motion of the radiating body'. The validity of this postulate and its common logical ground with the first postulate will also be subject of the discussion in this paper.

The light postulate refers to some empirical, physical quantity which is directly subjected to verification. The way expressing it is not comparable with the wording of relativity principle which deals with the form of physical laws in inertial reference systems. The light postulate introduces into physics a new fundamental constant — the light velocity. The essence of the postulate did not raise any doubts either from the point of view of the pre-Einstenian physics in which fundamental constants occurred (e. g. gravitational constant, Boltzmann's constant), or of the hitherto existing empirical evidence. Nevertheless it is possible to put forward two questions about the light postulate one on the formal plane and the other on the functional plane. The formal analysis of the role of the light postulate: in SR requires the answer to the following question: why (P_2) appeared in the fundamentals of SR instead of the postulate about the validity of Maxwell's equations which seemed to be more natural from the point of view of the SR genesis and more suitable as far as the very form of the theory postulates are concerned. This problem can be reconstructed from the point of view of the objective problem situation as well as from the point of view of the SR author. Einstein, who at the same time dealt with the investigations of the nature of light was aware that Maxwell's equations were not sufficient to describe microscopic phenomena. Therefore, as ZAHAR (1976) claims, SR as a new relativistic kinematics of universal importance should not include Maxwell's theory of limited application range in its fundamentals.

The second question about the light postulate refers to its function in the new theory — SR. If we are to adopt that it introduces a new fundamental constant into physics, then this new constant c plays different a part from that of the physical constants existing hitherto: They were only dimensional coefficients (factors) of proportionality in physical equations. The answer to the question about the role of (P_2) in SR results directly from Einstein's pioneer works. Besides the two postulates (P_1) and (P_2), Einstein also placed the assumptions about isotropy of space (the so-called principle of relativity of directions) and about the procedure of clock synchronization. These two components were connected with the function of the light postulate. This function could be called the operational one. It would consist in the fact that the primary character of the signal propagation ensured the operational (physical) interpretation of theoretical quantities, and also enabled the clock synchronization irrespective of the choice of the inertial system as it was shown by IVES (1948) and myself (1992a,b).

A question about the mutual relationship between two postulates of SR is also raised. One of them — the relativity principle abolished ether: the absolute reference system. However, it turned out that in order to develop the new kinematics on its basis in a consequent way it was indispensable to introduce another nonrelativized absolute element, i. e. the universal value (or the measure as PROKHOVNIK (1978, 1985) proposes) of the light velocity c!

Summing up the considerations it can be said that the relativity principle of SR sprang up in a natural way from the tradition of pre-relativistic physics. Its significant novelty consisted in the rejection of ether when describing the electrodynamical phenomena. The light postulate turned out to be an unexpected element of novelty in physics. Nevertheless these two postulates have their genetic preconditions in heuristics and in the empirical-theoretical evidence of the age preceding SR.

3. Novelty in the SR Consequences

EINSTEIN (1905a) divided his work into three parts. At the beginning he introduced two postulates (P_1) and (P_2). The remaining part of his work was devoted to kinematic and electrodynamic parts.

The change of the meaning of *simultaneity* was one of the most significant new results of SR. *Simultaneity* as a relation between phenomena means that they occur at the same instant. It is necessary to ask whether they occur in the same point or in different points of space. If one is to adopt the principle *actio in distans*, which is valid in Newtonian physics, then the answer to the question is explicit: In the Galileo's space-time there are placed simultaneous events in the hyper plane which determines a definite moment of the absolute time. The hyper planes of the identical time are the Euclidean spaces, thus it is possible to determine spatial distances of the simultaneous phenomena. The problem connected with simultaneity appeared when the finite velocity of light signal propagation was established. However, it did not cause at once the revision of space-time properties since practically it was still possible to determine simultaneity of events in the nearest laboratory surrounding, whereas the examination of the simultaneous distant events, occurring in the cosmological scale was not then the matter of physics interest. It was only, when the Einsteinian attempt to co-ordinate the description of mechanical and electromagnetic phenomena by means of the relativity principle (P_1) required the rejection of the concept of absolute time. The relativity of time resulting from the SR postulates involved automatically relativity of simultaneity: simultaneous events in a given reference system do not have to be simultaneous in the other.

The effects of time dilatation and stick contraction resulted directly from the properties of space-time. The quantitative explanation of these phenomena had been known since the time of Fitzgerald's suggestion and had been introduced before Einstein in the works of Lorentz, Larmor, and Poincaré. Nevertheless in Einstein's work it obtained a completely different, purely kinematic character: it resulted directly from the relative character of simultaneity.

The mathematical structure of space-time should be formally described by the group of its automorphisms. Galileo's transformations turned out to be the automorphisms for the space-time of classical mechanics. Einstein derived Lorentz's transformations for SR space-time as those which mutually transform material reference systems: thus the Lorentz's transformations, although known for twenty years, obtained the status of the space-time. The equations of mechanics obtained also a new form.

A new role of velocity composition was the next kinematics consequence of the adopted SR postulates. It was a complete novelty with regard to the hitherto adopted classical composition of velocities. So far I have named the elements of novelty which were brought about by SR. I have limited myself to kinematics and space-time properties. I am of the opinion that mainly in this range SR turned out to be revealing with respect to the pre-relativistic knowledge: The foundations to formulate each of the two postulates (P_1) and (P_2) can be found in the tradition of the 19th c. physics, while the decision to make these two postulates the fundamentals of the theoretical system (SR) turned out to be extremely productive for all branches of physics.

4. Novelty in the Poincaré Relativistic Theory

It is generally known that before Einstein it was Poincaré who independently formulated the postulates which later came to be the fundamentals of SR and that he derived some of their consequences. Therefore one can ask why it was SR and not Poincaré's relativity theory (PR), which was equivalent to it, as far as the theoretical side was concerned, that gave rise to the development of the 20th c. physics. The answer to this question is connected directly with the criterion of the novelty of a theory, which we would try to formulate.

At the end of the 19th c. Poincaré was aware of the failure of some principles accepted hitherto in physics and he arrived at the conclusion that a rebuilding of physics was necessary. POINCARÉ (1958) named it as the evolution *windening of the frames*. According to Poincaré the laws themselves could not undergo absolute falsification since they originated on the basis of definite empirical facts. In the progress of science they would have required reformulating or limitation of applicability to that range of phenomena for which they are appropriate. In comparison with the works of Hertz, Larmor, Lorentz, and also the empirical evidence which was inconsistent with the practical principle as a universal natural law which was to be satisfied both by the theory of electromagnetism and mechanics. However Poincaré's conventionalist attitude did not enable him to identify the relativity principle with the rejection of ether so long as ether remained a convenient tool for the explanation of definite questions of physics and the formulation of the electromagnetic field laws.

The Galilean formulation of the relativity principle was limited to mechanical phenomena while the Galilean space-time of mechanics was characterized by the absoluteness of time and space. POINCARÉ (1898, 1952) thought that these properties restricted space-time relationships: He was in favour of the relativity of time and space and as its consequence — of the relativity of simultaneity.

Even before 1905 Poincaré had put forward the hypothesis that since the relativity principle was obligatory and there were problems connected with the realization of the law of mass conservation (Lavoisier's principle), the velocity of bodies should be limited to the light velocity c, which should be in turn independent of the inertial system. It would involve automatically the change of the velocity composition rule. In the same year Poincaré showed the operational character of velocity c while interpreting the Lorentzian effective time t': Earlier he gave the procedure of clock synchronization by means of the universal velocity c which was very similar to the Einsteinian procedure.

The space-time of which the Lorentz's transformation were automorphisms would refer, according to Poincaré, to a coherent description of mechanical and electromagnetic phenomena. Thus he corrected the transformational rules of electromagnetic quantities (given by Lorentz), settled the ultimate shape of Lorentz's transformations, and indicated their group character. Some years earlier than Minkowski he put forward four dimensional mathematical models of space-time.

Poincaré was in fact the pioneer of a conceptual basis and a formal apparatus of the new kinematics. Einstein did not present anything more in the first part of his work as far as kinematics was concerned. Thus, why was the starting point for relativistic physics the novelty of Einstein's proposal, and not Poincaré's? I will try to formulate the answer to this question from the point of view of a methodologist and philosopher of science. Social, psychological and biographic aspects, which are often considered, and which have undoubtedly influenced a reception of both relativistic kinematics, I shall tentatively replace by the comparison of the problem situations of the two theories which are understood as constituents of the third world in POPPER's (1979) sense.

5. Discussion of the Criterion of Theory Novelty

In chapters 2 and 3 SR was analysed with respect to the novelty of its postulates and their consequences. The relativity principle (P_1) as a postulate heritage of physics of several hundred years was comprised. While the light postulate (P_2), although its essence had some empirical justification before, appeared to be new. The novelty of relativity principle did not consist in its formulation but in its identification with the rejection of ether as the absolute reference system.

Conduction of (P_1) and (P_2) supplemented by the principle of direction equivalence and synchronization procedures, treated by Einstein as the basis for new physics, made it possible to derive the series of consequences referring to the nature of space-time relations, which turned out to be an actual novelty element for the physicists, philosophers and mathematicians on the turn of the 19th c.

The mathematical formulation of SR in its original version was traditional in making use of the classical mathematical Methodist (differential calculus, elements of differential equation theory) elaborated in kinematics and electrodynamics of the past.

The formulae, known up to that time (e. g. for Doppler's effect or aberration) or occasionally derived in the Lorentz's electrodynamics (e. g. for inertial mass), EINSTEIN (1905b) shaped in the generalized and compact deductive scheme of relativistic electrodynamics.

The heuristic principles, which were obligatory in SR, existed also in pre-relativistic physics. Since the problem of electromagnetic theory of bodies in motion was solved in SR the choice and hierarchization of methodological patterns performed by Einstein turned out to be the most effective: the necessity of uniform theoretical interpretation of physical phenomena, simplicity of mathematical formulae, operational interpretation of the fundamental physical quantities. Undoubtedly this set of methodological directions was different from the heuristic principles chosen for the classical electrodynamics theory. Contrary to LAKATOS and ZAHAR (1976), I suppose that it is difficult to evaluate these two heuristics if firstly one makes no mention of the criterion of achieving the primacy of SR over other theories.

If we look again at Poincaré's relativity theory we see that it was not different from Einstein's theory as far as the theoretical assumptions are concerned, whereas as far as the consequences are concerned (although not all of them were formulated explicitly to Poincaré) PR reached repeatedly farther than SR (it foresaw e.g. the modification of gravitational laws). Poincaré's relativity theory exceeded SR (in 1905) also in the range of mathematical and conceptual apparatus: Poincaré discovered the group character of Lorentz's transformations and he put forward a compact four-dimensional description of space-time.

The methodological patterns, which Poincaré followed, differed from the Einsteinian ones only in one aspect — in the conventional treatment of physical models. According to Poincaré the physical models show a provisional character of theoretical constructions. On the other hand they comprise a definite objective physical content, the limited range of which can be finally determined from the point of view of more general models (Poincaré was the forerunner of the correspondence principle).

Thus methodological analysis of theoretical, empirical and heuristic content of SR and PR does not give a convincing answer to the necessity of SR victory over PR at the moment of their appearance. So, I should compare both kinematics in a new way.

PR was treated by its author as a solution of a well-defined problem in physics, but one of many which appeared in the face of the crisis of the hitherto existing principles. In the view of known difficulties in physics the renewing of the known postulates (P_1) and introducing the other one (P_2) solved indeed the electrodynamics problem and some others but they did not seem to be panacea for all weak points of 19th c. physics. For Einstein, whose knowledge of physics at that time was more limited than Poincaré's, the first work from 1905 was to solve an electrodynamics problem essential for physics. Therefore in 1905 Einstein devoted much effort for a simple deductive solution of the well isolated problems and he comprised it in two concise works. In these works he derived many consequences for electrodynamics, optics and dynamics, which were consistent with the hitherto existing empirical evidence.

The method for generalization of classical formulae to the relativistic case, given by Einstein, became the pattern for similar generalizations in other physical problems and even for the anticipation of new laws under only one condition: The covariant principle should be satisfied. Undoubtedly the mathematical re-formulation of SR by MINKOWSKI (1908) increased the interest in it: mathematical simplicity of space-time structure brought SR nearer not only to the physicists dealing with definite problems in the field of e. g. optics, but also to a large group of philosophers and mathematicians. Earlier than Einstein, Poincaré was very close to this description, and he would have been able to bring it to completion: he put forward the four dimensional space-time and determined the time co-ordinate as *ict*. Being a distinguished mathematician he did not need *his own Minkowski*. The only answer why he did not arrive at the didactic description which could attract the attention of the scientific community, is that he had different aims from Einstein's, when he was creating PR. Poincaré — the conventionalist — did not regard the changing of description of nature as sufficient for ontological conclusions.

The mathematization in the spirit of Minkowski's work was an objective necessity and was in line with Poincaré and Einstein's aims to relativize all physical interactions. But it was not before Einstein that the clearly derived and strongly emphasized (especially after Minkowski's model formulation) new properties of space-time influenced interests not only of the physicists with a narrow specialization. MANDELSTAM (1972) claims that paradoxical properties of space-time of SR attracted the attention of scientists due to the clear presentation of new ideas as well as due to the difficulties of their reconciliation with the existing opinions on the properties and role of space-time.

As the mentioned Poincaré's philosophical and methodological attitude was very significant for the evaluation of PR by its author, because he considered his kinematics as a better method than a theory going straight to nature. Moreover Poincaré's accomplishment (PR) in the presence of his achievements in other fields was not of a spectacular character for him as it was for Einstein in the case of SR.

In 1905 Einstein was convinced about the novelty of his own theory: He held a belief about the validity of hypothetical deductive method, the cognitive role of mathematics, and the ontological consequences of universal principles. Thus the way of presentation by Einstein of SR as crucial in the history of physics was completely different if compared with the modest presentation of PR by its author. Later, Einstein's original achievements in other fields (e. g. theory of photo effect) enabled to strengthen forever Einstein's fame as a young versatile inventor. Especially Einstein's discovery of the new gravitational theory and its name *the general relativity theory* (GR) indicated a genetic relationship with SR.

Poincaré published his views on the nature of space-time relativity principle, light propagation, electromagnetism, thermodynamics, etc. in many separate papers and books (often of not strictly scientific character) within the range of several years. Being published in many different sources they did not have much chance to arise the interest of a big circle of scientists. Finally, POINCARÉ (1905, 1906) presented his fundamental work on the relativity theory, which crowned many years of investigations, in journals of not very wide circulation and of local character, whereas Einstein published his first synthetic work in a well-known and esteemed German journal *Annalen der Physik* and from the very beginning he gained a large group of readers among whom there were many authorities.

The popularity of SR is also rooted in other sociological conditioning namely in the fact that at the beginning of the 20th c. theoretical physics and especially electrodynamics were prevalent in the German speaking countries. Then France boasted of distinguished mathematicians and experimenters. However, from the point of view of the theory of knowledge the success of SR as the foundation of modern physics is most strongly connected with relativization and mathematization of physics: gravitational theory (GR), relativistic quantum mechanics, quantum field theory (in the most complete shape realized in quantum electrodynamics) and modern theory of unification of interactions. (This diagnosis given by theory of knowledge is, however, conclusive for evaluation of both kinematics, not because relativization and mathematization of physics were also recorded in PR.)

At the beginning of the paper I decided to study the novelty of relativity theory with regard to prerelativistic knowledge. Now I arrived at the conclusion that the category *novelty* itself does not make it possible to distinguish SR from PR. The *novelty relation* is a relation in the Popperian third world of objective knowledge. It is a relation which connects the empirical, theoretical, and heuristic content of a given theory and this threefold content of its respective predecessor. The introduction of novelty relation, richer by the element of knowledge developed after the SR formation, would be the most convenient solution. It can be attempted to reconstruct the novelty relation limiting oneself to the objective methodological analysis, considering like e. g. Lakatos and Zahar research programmes. However, generally speaking the novelty relation possesses its dimension referred to an individual, intellectual, psychological and sociological position. Thus how to define the novelty criterion on a purely methodological level in the face of this?

Using the Popperian language the novelty criterion refers to the theories understood as constituents of the third world theories which are to solve problems belonging only to the objective knowledge. Each theory (PR or SR) originated on the ground of the same situation generating the discovery. The task of methodologies is to analyse the problem situations exclusively on the level of the third world. However, for complex assessment of novelty role in the success of theory, factors which influenced both the theory formation, and activity of their authors in the sphere of the second world (intellectual activity, beliefs, etc.), and of the first world (the activity aiming at propagation of the theory, giving it this or other shape, which would suit its author's beliefs with regard to the values of the discovered theory) should be analysed.

Both considered theories derive from the same situation generating the discovery, whereas their problem situations, which constitute the solutions are different. Poincaré's problem situation of PR in 1905 was much more complex than the Einstein's problem situation of SR. PR came into being as a result of the studies on the foundations of whole physics and the necessity to reconcile different physical theories and preserve the validity of conservation principles. PR solved the problem of unification of electrodynamics and mechanics descriptions, it satisfied the relativity theory in space-time which was modified by relative simultaneity if compared to the Galilean principle; it preserved the principle of energy conservation by changing the law of composition velocity. However, PR constituted the solution only to one of many questions belonging to the problem situations analysed by Poincaré.

The rich problem situation exceeding the PR solutions as well as the Poincaré's conventional Weltanschaunung together with his cumulative (not revolutionary) attitude to knowledge made it impossible is sufficient for the author of PR to realize the limited significance of the theory.

This attitude admitted the hypothesis of ether-existence and did not let Poincaré break ultimately with the tradition of the 19th c. electrodynamics. Thus the third world of the objective knowledge influenced Poincaré's beliefs about the limited PR significance and these beliefs in turn ruled out any fairly spectacular presentation of the results of his theory.

Einstein, however, considered less extended problems of the situation generating of discovery than Poincaré: the problem of the uniform description of mechanical and electromagnetic phenomena, and the problem of operational interpretation of all physical notions. SR aimed at solving these two general problems and other detailed ones which the Lorentz's electrodynamics struggled against. SR broke with ether and solved everything or almost everything what in 1905 Einstein recognized as kinematics and electrodynamics problems. New result concerning time and space opened a wide horizon for the studies on space-time properties which had been rigid and invariable so far. Such a solution of the problem situation arose in the SR author a belief about the fundamental and revolution significance of his own discovery, and he became aware of new perspectives of physics development. This fact, in turn, caused very careful elaboration of SR lecture and its presentation in the complete form to the big community of scientists.

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