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SPECIAL RELATIVITY AS A STEP IN THE DEVELOPMENT OF THE QUANTUM PROGRAMME: A NEW ARGUMENT FOR PROHIBITION OF THE ETHER

BY

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ABSTRACT

Einstein's three papers of 1905 (including special relativity) were all the parts of a single research programme concerned with the unification of newtonian mechanics and maxwellian electrodynamics. Lorentz tried to solve the unification-problem by reduction of mechanics to electrodynamics. The failure of his ether programme is due to the failure of attempts to build an electromagnetic field—theoretical model of the electron. There were no such things as two independent scientific revolutions—quantum and relativistic—at the beginning of the 20 century. There was only one revolution caused by a clash between the classical theories.

I. INTRODUCTION

As is well-known, Einstein's special theory of relativity and Lorentz's ether theory co-existed in the early twentieth century as empirically equivalent ones. In particular, both of them explained, though in a different way, the results of the Michelson-Morley experiment. Till now the following explanations for the victory of Einstein's theory over that of Lorentz have been given:

(1) The theory of the ether was acknowledged as an unsatisfactory one, because the Lorentz-Fitzgerald contraction hypothesis (that explained the results of Michelson-Morley experiment) was an "ad hoc" hypothesis ([1], [2]).

(2) The theories of Lorentz and Einstein were created within the different competing programmes. That is why each rational reconstruction of Lorentz-Einstein transition must hinge on I. Lakatos's methodology ([3]). According to E. Zahar ([4]), Lorentz's "ether programme" progressed up to 1905, but was superseded by Einstein's "relativity programme" in 1915 due to the explanation of the precession of the perihelion of Mercury.

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However, a more careful historical study ([3]-[8]) discloses the following.

(1) Lorentz-Fitzgerald contraction hypothesis (L.F.C.) was not an "ad hoc" hypothesis at all.

- (1.a) Lorentz deduced the L.F.C. from a more profound theory namely the Molecular Forces Hypothesis.
- (1.b) Several consequences of Lorentz's L' (former ether theory L plus L.F.C.) were already checked in 1902-1908 by the experiments of Rayleigh, Brace and Bucherer.
- (2.a) The scientific community rejected the ether theory as far as in 1910-1912.
- (2.b) There was no "relativity programme" in the scientific community from 1905 to 1910: Einstein's theory had not yet been disentangled from Lorentz's. At the time there was only one theory in existence for the majority of scientists namely the Lorentz-Einstein theory.

Thus, the above explanations for the victory of Einstein's theory over that of Lorentz are not satisfactory. The purpose of this report is to give an explanation which satisfies (2.a)-(2.b).

2. THE FAILURE OF LORENTZ'S PROGRAMME

All the prior to Maxwell descriptions of interactions (Newton, Ampere, Weber, Riemann *et al.*) were the theories of instant action between several material points. Due to Maxwell, the Electromagnetic Field enters physics as an element of physical reality which is equal in rights with the Material Point.

Presumed incompatibility between the laws of mechanics and the laws of electrodynamics ([8]) gave rise to the first programme, which attempted to reduce electrodynamics to mechanics (Maxwell, Rayleigh *et al.*). Newtonian mechanics was acknowledged as a "fundamental theory", while the electrodynamics was acknowledged as a "particular theory".

The purpose of the reductionist programme can be achieved in two steps:

(a) By constructing basic theoretical objects of the particular theory from those of the fundamental theory. (The basic theoretical objects of mechanics are: "the force", "the material point", "the system of reference". The basic objects of electrodynamics are: "the electromagnetic-field-density", "the current density".) (See V. S. Stepin's work [9].)

(b) By means of deduction of the laws of the particular theory from those of the fundamental theory. (Detailed account of reductionist and synthetic programmes is given in [IO].)

The failure of Maxwell's reductionist programme (the most serious difficulty consisted in presence in the ether of transversal as well as longitudinal waves) forced Lorentz to complete the system of Maxwell's equations by the system of Newtonian equations and to incorporate the "Lorentz's force". Basic theoretical objects of both theories were unified in a single theory. But the unification appeared to be unsatisfactory (Einstein, [II]).

However, Lorentz had an opportunity to realise the reductionist programme opposite to Maxwell's. Maxwell's electrodynamics became the fundamental theory, and Newton's mechanics—a particular theory. The fundamental problem of Maxwell's programme consisted of "the consideration of the particles of matter as some local perturbations of the ether" (Lorentz, [12]), i.e. of the construction of an electromagnetic field-theoretical model of an electron.

But, as it was shown in 1906 by H. Poincaré ([13]), the contractile electron could be considered as a stable entity only if a definitely non-electromagnetic counter-pressures were invoked. The only opportunity of further realisation of the reductionist programme was in the construction of structureless electron, but it failed in 1909, when Lorentz calculated the force with the help of which electron acts on itself. If we try in the force-expression to eliminate the structure-dependent terms by letting the radius of the electron approach zero, the energy of selfinteraction will diverge, that is physically meaningless. An attempt to construct an elementary particle from field failes altogether with the programme of reduction of mechanics to electrodynamics.

3. SPECIAL RELATIVITY AS A STEP IN THE DEVELOPMENT OF QUANTUM THEORY

In order to explain why the scientific community accepted special theory of relativity in 1910-1912 (and why until 1910 Einstein's work had not been disentangled from Lorentz's) we must renounce the traditional comparison of Lorentz's "ether programme" solely with Einstein's "On the Electrodynamics of Moving Bodies" ([15], 1905) and other "pure relativity" papers. We must assume that the three papers of 1905 and later statistical papers were all parts of a single but yet unspecified programme. For determination of direction and goal of the programme we must restrict the scope of papers under consideration to the period from 1905 to 1912. The imposed restriction definitely leads to the report "On the development of our views on the essence and structure of radiation'' (SALZBURG, 1909) as to Einstein's practically single serious effort to analyze his works in general. The report begins with a brief account of the theory of ether, which ends with a phrase: ''But today we must consider the hypothesis of the ether as obsolete.'' Why?

It is important that for the answer Einstein resorts not to Michelson-Morley experiment, but to ''numerous facts in the domain of radiation which show that light posesses a number of fundamental properties that can be understood with the help of Newton's emission theory considerably better than with the help of the wave theory. That is why I consider that the further phase of the development of physics will give us the theory of light which would be in some sense the unification of the wave theory with the theory of Newton''.

So, the goal of the Einstein programme is the unification of mechanics and electrodynamics. To determine its direction we must address ourselves to Einstein's ''On an heuristical point of view concerning the processes of occurence and transformation of light'' ([14], 1905) concerning the photoeffect. (The 1905 paper on special relativity was published three months after the paper on photoeffect and is only a part of the programme of unification).

An ascertainment of ''deep formal difference between the theoretical notions of physicists of gases and other weighty bodies and Maxwell's theory of electromagnetic processes'' brings Einstein to hypothesis on discrete energy distribution of free radiation. The hypothesis explains the photoluminescence, the occurence of the cathode rays, etc. But ''if there are not the laws of occurence and transformation of light such as if light consists of similar energy quanta?''. This is the question put up by Einstein at the end of his paper. But the concept of the ether prevents the positive answer. We need the electromagnetic fields as independent formations that can be emitted by the sources ''as well as in Newton's emitting theory'' (i.e. the energy transmitted in the process of emittance should not be dissipated in space, but should be completely preserved until an elementary act of absorption). But within the ether theory the electromagnetic field is considered as a specific state of the ether—a state of medium which is continuously distributed in space. An elementary act of radiation is connected in such a medium only with a spherical wave. While an outgoing spherical wave is radiated by a single oscillating ion, the realization of the ingoing spherical wave needs an infinite number of radiating centres. The process of radiation is irreversible in the ether theory.

But if ether does not exist and the electromagnetic field is an independent formation that propagates in vacuo, the velocity of the field must depend on the velocity of the source. The velocities of light and of source must add in accordance with Galileo's addition formula. But it contradicts with the known experiments as well as with astronomic observations. In Lorentz's theory this difficulty did not even exist because the velocity of light was determined there as the velocity of ether waves. The velocity of waves could not depend on the velocity of their sources. Consequently, if we want to consider the processes of occurence and absorption of light "just as in Newton's emission theory" we ought to replace all the classical kinematics by other laws that yield:

(1) The same velocity of light in any inertial system of reference;

(2) Galileo's addition formula for small velocities;

(3) Lorentz's transformations for space coordinates.

Namely that was done in 1905 paper "On the Electrodynamics of Moving Bodies" which was published three months after the work on photoeffect. Einstein disclosed that acceptance of (1)-(3) is equivalent to the modification of simulteneity concept and to clock delay in the moving systems of reference.

In this paper Einstein did not cite his [14]: the arguments could hardly have been improved if, in the paper introducing revolutionary changes in our understanding of space and time, he had referred to the hypothesis resulting in even more revolutionary shifts in our understanding of physics. Argumentation was hampered by scientists' lack of direct experimental evidence in favor of light quanta. These data appeared only in 1923 (Compton effect). That is why the photoeffect paper differs from the special relativity paper both by a more careful title, "On an heuristic point of view..." and by a less categorical tone in the main conclusion: "In the following, I shall communicate the train of thought and the facts, which led me to this conclusion, in the hope that the point of view to be given *may* turn out to be useful for some research workers in their investigations"; (compare this with [15]: "Insufficient understanding of these peculiarites *is* the root of the difficulties that have to be overcome by electrodynamics of moving bodies").

So, in his [14], Einstein refers neither to his paper on light quanta nor to contradiction in the black-body theory, but instead he starts his special relativity paper with the description of asymmetry between the motions of a conductor and a magnet, which is a manifestation of contradiction between Newtonian mechanics and Maxwell theory in the electrodynamics of moving bodies.

Being taken independently, special theory of relativity did not explain any unexplained experiment and did not predict any new experimental fact. To explain the reasons for Einstein's victory over Lorentz, the comparison of ether programme with a relativistic subprogramme is insufficient. Hence it is necessary to include the quantum subprogramme into the field of consideration.

The history of quanta starts from Planck's heroic attempts to bridge the well-known gap between thermodynamics, statistical mechanics and Maxwell's theory. And it was his quantum theory that was an unexpected product of this 3 lines of 19-th century scientific research. Before 1900 Planck has made important contributions to all three fields that were to interact consequentially within his work. Thermodynamics was his first love: his work in it was well-known before he turned, at age of 36, to electrodynamics. But for him the latter's role was instrumental initially. Electrodynamics provided only tools to solve thermodynamics problems, particularly the problem of black-body radiation. It is very important that statistical technique entered Planck's research later and against much resistance.

Planck was one of the first physicists to note the contradiction between thermodynamics and statistical mechanics (1892, [16]), which induced his long resistance to Boltzmann's ideas. And only in 1897-1898 he begins to study Boltzmann's works with care. Unfortunately, he did not explicitly acknowledge his change of mind for almost 2 years, a delay that has reinforced the almost universal impression that his conversion to a statistical viewpoint was intimately associated with his introduction of quantum hypothesis at the end of 1900. But only the opposite statement is true: his introduction of quantum hypothesis is a firm and unavoidable consequence of his "conversion to a statistical viewpoint", of his application of Boltzmann's technique and ideas in the study of radiation. The following story is especially appropriate here (ref. [17]).

Planck, who intended to broaden statistical thermodynamics domain of validity, developed (with the help of the classical continuous notions) the thermodynamics of electromagnetic radiation and tried to introduce entropy of radiation parallel to its energy. Being an admirer of the famous Boltzmann, Planck informed the founder of statistical mechanics about his work and presented it to his judgement. But Boltzmann answered that *he would never be able to create a correct theory of statistical thermodynamics of radiation without introducing a previously unknown element of discontinuity into processes of radiation!*

Thus, Planck's quantum theory is a result of collision of electrodynamics, statistical mechanics and thermodynamics. It is in this clash that the basis for parallel treatment of radiation and of gas theory begins to emerge. And at the end of 1899 Planck has retraced all but one of the steps taken by Boltzmann. Both scientists had initially sought a deterministic demonstration of irreversibility. Both had been forced to settle for a statistical proof and both had finally recognized that even that method of derivation required recourse to a special hypothesis about nature. But at the beginning of 1900, only one aspect of Boltzmann's treatment of irreversibility was still absent from Planck's approach, the use of combinatorials. And by the end of the year, Planck has embraced that aspect too. But what led him to do so was no longer the problem of irreversibility. It was rather the search for a radiation law that could pass the test of new, more refined experiments of Lummer and Pringsheim.

Einstein's arguments for light quanta presented in his [14] are completely different from those of Planck given 5 years earlier. As was demonstrated by Kuhn (ref. [18]), Planck's first quantum papers were not attempt to supply an entire new theory. They aimed to fill a previously recognized gap in the derivation of Planck's older theory. In particular, the arguments in Planck's first quantum papers did not seem to place any restrictions on the energy of gedankenexperiment resonators introduced to equilibrate the energy distribution in the black-body radiation field. These resonators absorbed and emitted energy continuously at the rate governed by Maxwell's equations.

Contrary to Planck, in [14] Einstein proceeded from the Wien law, using only the Boltzmann law. He cites Planck twice. But one of these citations points on the paper written a year before Planck's quantum paper. In the second citation Einstein quotes Planck's distribution law but only as an expression, adequately describing the experimental radiation spectra. Drawing his conclusions, Einstein did not use Planck's results.

Thus, what brought Einstein to the black-body problem in 1904 was the coherent development of a research programme started in 1902, a programme "so nearly independent of Planck that it would almost certainly have led to the black-body law even if Planck had never lived" ([18], p. 171).

In 1906, P. Ehrenfest and A. Einstein first recognized that Planck's black-body law could not be derived without restricting the resonator energy to integral multiple of $h\delta$. Their demonstrations had little apparent impact, but the paper, presented by Lorentz in 1908, caused a rapid change in the attitude of physicists towards the quantum. By the end of 1910 most of theorists who had studied the black-body problem were convinced that it demanded the ban of continuity.

The first Solvay congress definitely revealed the inability of classical mechanics and classical electrodynamics to solve the problems embodied in radiation theory.

So, in spite of the fact that the light quanta hypothesis had to wait for more than 10 years for general recognition, the successes of the quantum theory revealed the unfittness of the wave theory and ether notion which constituted the foundation of it. The last serious blow was Bohr's theory. Only with its creation did Einstein programme predict the effects that could not be assimilated by Lorentz programme.

Thus, there were no such things as independent development of quantum and relativistic programmes at the beginning of the 20 century. Quantum theory and special theory of relativity were developed within two subprogrammes belonging to a single programme of unification of Newtonian mechanics and Maxwellian electrodynamics. There were no such things as two independent scientific revolutions-quantum and relativistic. There was only one revolution caused by a clash between the two classical theories.

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