# EINSTEIN'S 1905 RECONCILIATION OF MAXWELLIAN ELECTRODYNAMICS AND STATISTICAL THERMODYNAMICS .

**Abstract.**

To comprehend in what way Einstein's 1905 'annus mirabilis' papers hang together one has to take into account Einstein's strive for unity evinced in his efforts to reconcile maxwellian electrodynamics, statistical mechanics and classical thermodynamics. It is exhibited that special relativity turns out to be a mere milestone of implementation of maxwellian electrodynamics, statistical mechanics and thermodynamics reconciliation programme. Since the ether conception was a snag for Einstein's statistical thermodynamics design, the leading part in the programme was played by Einstein's 1905 light quanta hypothesis.Though influenced in his critical stand against the classical physics by Hume and Mach, Einstein hold an overall eclectic epistemological position.Yet it is contended that when it related to some creative momenta, Einstein's actual 1905 *modus operandi* was close to Kantian epistemology.It is maintained that the most important Kantian concept apt to conceive Einstein's relativity creation and all his 1905 papers *as a whole*, as well as the *order* of their arrangement is Kant's regulative idea of the systematic Unity of Nature.

***Key words*:** light quanta**,** special relativity**,** statistical thermodynamics, maxwellian electrodynamics, regulative principles, Unity of Nature.

## 1. Introduction.

Olivier Darrigol (2001) and Rinat Nugayev (2015) strengthened arguments in favour of the tenet according to which the genesis of maxwellian electrodynamics can be comprehended as a result of the old pre-maxwellian research traditions encounter, intertwinement and reconciliation. The research programmes to coordinate with each other had been the electrodynamics of Ampére-Weber, the wave theory of Young-Fresnél and Faraday's programme. In particular, the crux of Nugayev's paper was that Maxwell's unification design could be successfully implemented since his programme had assimilated the ideas of the Ampére-Weber programme, as well as the presuppositions of the programmes of Young-Fresnél and Faraday. Eventually Maxwell's victory over his rivals became possible since the core of Maxwell's unification strategy had been permeated by the spirit of Kantian epistemology. Maxwell had put forward as a basic synthetic principle the tenet that radically differed from that of the rival approaches by its open, flexible and contra-ontological, genuinely Kantian character (see also Morrison, 2000).

Yet the search for a unified theoretical basis for all of physics had not originated with Maxwell. His celebrated progenitor was Isaac Newton, and no less pre-eminent partisan was Albert Einstein. And, on my view, Newton's writings, as well as the papers of Maxwell and Einstein, were all momenta of common 'de-ontologization' process inherent in modernity. The process had commenced in XV-XVII centuries constituting a hallmark that distinguished the science of Galileo and Newton from that of Aristotle and Ptolemy. It was namely the spirit of science of modernity that was shrewdly comprehended by Immanuel Kant in his "*Critique of Pure Reason*".

"When Galileo rolled balls of a weight chosen by himself down an inclined plane, or when Torricelli made the air bear a weight he had previously thought to be equal to that of a known column of water, or when in a later time Stahl changed metals into calx and then changed the latter back into metal by first removing something and then putting it back again, a light dawned on all those who study nature. They comprehended that reason has insight only into what itself produces according to its *own design*; that it must take the lead with principles for its judgements according to constant laws and *compel nature to answer its questions*, rather than letting nature guide its movements by keeping reason, as it were, in leading strings" ( Kant [1787], 1998 , p.108; my italics ) .

The sensible world, i.e. the world of appearences, is tentatively *constructed* (Konstruieren) by the human mind from subtle combination of sensory matter that one receives passively and *a priori* forms that are supplied by human cognitive faculties. "We can cognize of things a priori only what we ourselves have put into them" ( Kant [1783], 2002). All in all Kant's constructivist foundation for scientific knowledge restricts science to be the realm of appearences and maintains that a priori knowledge of 'things in themselves' is impossible.

Newtonian mechanics, maxwellian electrodynamics and Einstein's relativity were skillfully *fixed into* sweeping de-ontologization of physics grounded on the ultimate rejection of Aristotelian ontology and the corresponding ways of theory building.

Aristotelian physics was an empirical discipline par excellence that accumulated common experience much better than the science of Galileo and Newton (see, for instance, Koyré 1957). Everybody knows that hard bodies quite naturally fall down and fire really soaps up.

Hence the decisive role in modern science genesis was played not so much by 'experience' as by 'experimentation'. And the latter consists not so much in Thorough Observations as in systematic Questioning Nature. The questions should be put on a lucid language celebrated in Galileo's path-breaking work "*The Assayer*" (1623) :

"philosophy is written in that great book which ever lies before our eyes — I mean the universe — but we cannot understand it if we do not first learn the language and grasp the symbols, in which it is written**.** This book is written in the *mathematical language*, and the symbols are triangles, circles and other geometrical figures, without whose help it is impossible to comprehend a single word of it; without which one wanders in vain through a dark labyrinth" (Galilei [1623], quoted from Burtt 2003, 75; my italics ).

At the sake of mathematization Galileo radically transformed methodology of natural science. He boldly elevated 'idealization' and 'thought experiments' up to the ranks of leading scientific methods (McMullin 1985). It made possible for Galileo to formulate "the principle of inertia" and to come close to Newton's second law of dynamics (Mach [1883], 1960).

The very opportunity of implementation of mathematical methods in natural science is grounded on the procedure of idealization. Correspondingly scientists take all natural phenomena as more or less adequate approximations of some 'ideal essences'. The latter lack profound existence within the natural phenomena but can be freely constructed by human mind. And they are the relations between the ideal essences that are described by the Laws of Nature. At the same time the relations between real objects (e.g. rods and clocks) are exhibited by the approximations to strict laws (see, for instance, Husserl [1936], 1970).

As Galileo succinctly put it, "the search for essences, in my judgement, is a vain and hopeless kind of pursuit". But if truth is acquired only in experience and we come to know not the 'things in themselves' but only the 'phenomena', one should flatly reject even an opportunity of attaining the absolute truth. According to the spirit of science of modernity, so keenly grasped by Kant, phenomena of Nature do not constitute the vehicles through which the essences of things show themselves up. On the contrary, natural phenomena constitute the 'essences in themselves' that contain *all* the possible information on the processes under study.

The next step in implementation of Galilean epistemological programme was taken by Newton himself who flatly rejected the search for the essences of gravitation phenomena. He had jettisoned the very opportunity of answering the question "*why* ponderable bodies attract each other?" and had famously provided instead an equation describing *how* ponderable bodies gravitate . As Sir Isaac had put it in a letter to divine Richard Bentley,

"You sometimes speak of gravity as essential and inherent in matter, Pray, do not ascribe that notion to me; for the cause of gravity is what I do not pretend to know" (quoted from Kline 1985, 121).

Then comes James Maxwell who persistently abstained from revealing the essences of electrical and magnetic phenomena. In the path-breaking paper "*On Faraday's Lines of Force*" that moulded the 'hard core' of his electromagnetic research programme he stressed that

"the laws of the attractions and inductive actions of magnets and currents may be clearly conceived, without making assumptions as to the *physical nature* of electricity, or adding anything to that which has been already proved by experiment" (Maxwell [1858/1890] 1952, p. 159 ; my italics ) .

Since primary efforts to introduce the 'aether' as a medium for propagation of electromagnetic waves had failed , eventually Maxwell had to treat the ether as merely a component of the models intended for accumulation and classification of the corresponding electromagnetic ‘facts’.

Yet another function of ether was left inviolable – ‘to be a carrier of absolute system of reference’. And it was Albert Einstein who had emancipated us of it. He demonstrated that the ether conception was a snag that hampered unitary comprehension of electricity and magnetism as different components of one and the same electromagnetic field tensor $F_{ij}$, revealing their symmetry. It was possible since Einstein took the next step after Newton in the direction of refusal of contemplating the essences of space and time. And in 1915 he went even further reducing, for the sake of unification of gravity and inertia, the ‘nature’ of gravitational field to distortion of space and time. The gravitational field strengths and the Coriolis inertia forces began to be comprehended as different components of a single curvature tensor $R_{ij}$. As Michele Janssen emphasizes,

“While the slide into general covariance turns the relativity of non-uniform motion of space-time coordinate systems into a feature general relativity shares with older theories, it does not so trivialize the relativity of the gravitational field. Even in generally covariant reformulations of these older theories, there will be an inertial field and a gravitational field existing side by side. The unification of these two fields into one inertia-gravitational field that splits differently into inertial and gravitational components in different coordinate systems is one of Einstein’s central achievements with general relativity” ( Janssen 2012, 162).

Thus Galilean de-ontologization process consisted in that in the science of modernity Aristotelian essences were gradually replaced by mathematical abstract objects. The latter represented, according to Merab Mamardashvili’s apt remark, “turned inside out” essences of natural phenomena. This is especially apparent in Newton’s “*Principia*”. As Sir Isaac had put it,

“Since the ancients (as we are told by Pappus) made great account of the Science of Mechanics in the investigation of natural things; and the moderns, *laying aside substantial* forms and occult qualities, have endeavored to *subject the phenomena of nature to the laws of mathematics*; I have in this treatise cultivated Mathematics, so far as it regards Philosophy” (Newton [1687], 1846, p.1; my italics ).

In Newton’s adamant methodology the demand ‘to subject the phenomena of nature to the laws of mathematics’ belongs to the most robust ones. One should, while contemplating the phenomena of nature, force his sense data in such a dry and prepared for experimental purposes way as to posit them for analytical treatment. In that way the basic mathematical abstract objects of classical mechanics, i.e. ‘an inertial system of reference’, ‘a material point’, ‘an absolute space’ and ‘an absolute time’ were contrived.

Maxwellian ‘essences’ of electromagnetic phenomena are represented by the abstract objects of Maxwell’s equations: div **E**, rot **E**, div **H**, rot **H, j**, ρ. In Einstein’s special relativity the ‘essences’ of space and time are represented by Minkowski 4-vectors; in general relativity – by second rank metric tensor $g_{ij}$, linked to the Riemann tensor $R_{ij}$ and the stress-tensor $T_{ij}$. In quantum mechanics the ‘essences’ of the micro-processes are constituted by the wave function Ψ, representing a Gilbert space vector, while in Edward Witten’s theory the essences of space and time are 11-dimension superstrings.

It is a commonplace that Einstein’s scientific contributions were highly motivated by the ideal of unity of physical laws, and this had a considerable influence on the whole theoretical physics community (see, for instance, van Dongen 2010). However, all the scientific career of Einstein after 1915, i.e. after the general relativity had been achieved, was precisely the quest for unitary theories, unification of gravitation and electrodynamics, and so on (see, for instance, Vizgin 2011). And it is well-known that the idea of unity of nature is best illustrated by *these* attempts of Einstein towards unitary theories during almost forty years than by the early works.

Yet, in my innermost conviction, Einstein’s mature unification efforts and especially his general relativity are grounded on his early works and especially on his 1905 efforts to create special relativity and on his bold light quanta hypothesis. For instance, as Einstein recalled later, his efforts to set up the basic General Relativity tenet – the principle of equivalence – were drawn upon his experience of creating the SRT (special relativity theory):

“At this point, there occurred to me the happiest thought in my life [der glücklichste Gedanke meines Lebens]. ***Just as in the case with the electric field*** produced by electromagnetic induction, the gravitational field has similarly only a relative existence. For if one considers an observer in free fall, e.g. from the roof of a house, there exists for him during this fall no gravitational field – at least not in his immediate vicinity. Indeed, if the observer drops some bodies, then these remain relative to him in a state of rest or in uniform motion, independent of their particular chemical or physical nature” (quoted from Pais 1982, 178 ; my italics ).

Likewise, his path-breaking 1905a paper on light quanta starts with unfolding “**an *essential formal difference*** between the theoretical pictures physicists have drawn of gases and other ponderable bodies and Maxwell's theory of electromagnetic processes in so-called empty space" (my italics). The paper as a whole aims at unification of the basic research traditions of classical physics.Moreover, his 1905d paper on special relativity commences with scrutinizing a “***deep asymmetry***” in the electromagnetic induction description.

Hence *the overall aim of the present paper is to take the next step and to unfold the abiding influence of regulative idea of Unity of Nature on all Einstein’s 1905 papers and especially on special relativity genesis and advancement.* Thus the next part of this paper deals with the circle of problems that brought Einstein to electrodynamics of moving bodies. The aim of the third part is to answer the question: what was the train of thought that provoked Einstein to invent special relativity. It is argued that special relativity turnes out to be a mere stage of implementation of maxwellian electrodynamics, statistical mechanics and thermodynamics reconciliation programme. The leading part in the programme was played by Einstein's 1905a light quanta paper, since the ether conception put obstacles in realization of Einstein's statistical-thermodynamics design. Finally, my ultimate aim will be to contend that the staple concept necessary to conceive Einstein's relativity creation and all his 1905 papers *as a whole*, as well as the *order* of their arrangement was regulative idea of the systematic Unity of Nature. It is conjectured that, to conceive Einstein's relativity creation and all his 1905 papers *as a whole*, as well as the *order* of their arrangement, it is necessary to take into account the influence of Kantian epistemology.

## *2. Einstein, Helmholtz, Hertz., Poincaré and Mach.*

In Germany Maxwell's strenuous efforts to arrive at a reasonable compromise between the research programmes of Young-Fresnél, Faraday and Ampére-Weber were set forth by Hermann Helmholtz and his pupil Heinrich Hertz. In Helmholtz's paradigm (Helmholtz 1870) charges and currents were treated as the sources of electrical and magnetic fields. It led directly to H.A. Lorentz's dualistic worldview of the field equations and the equations of motion exhibited in his 1892-1900 papers. Lorentz's theory was an ingenious synthesis of Maxwell's field theory and Wilhelm Weber's particle theory of electrodynamics.

And it was Albert Einstein who picked up the problem after Maxwell, Helmholtz, Hertz and Lorentz. In early August 1899 letter to Mileva Marić an ETH (Eidgenossiche Technische Hochschule) student acknowledges that " I admire the original, free mind of Helmholtz more and more"( Doc. № 50 of Einstein, 1987, 129). In 10 August 1899 "Paradies" hotel letter he confesses to his fiancée that

"I am more and more convinced that the electrodynamics of moving bodies, as presented today, is not correct, and that it should be possible to present it in a simpler way. The introduction of the term 'ether' into the theories of electricity led to the notion of a medium of whose motion one can speak without being able , I believe, to associate a physical meaning with this statement. I think that the electric forces can be directly defined only for empty space, which is also emphasized by Hertz […] Electrodynamics would then be the theory of the motion of moving electricities and magnetisms in free space: which of the two conceptions must be chosen will have to be revealed by radiation experiments" (Doc. № 52 of Einstein 1987, 131).

It was Hertz's 1890 paper "*Uber die Grundgleichungen der Elektrodynamik fur bewegter Körper*" that appeared to be the source of the phrase " *bewegter die Elektrodynamik Körper*" in Einstein's 1905d paper. Einstein used these words in the letter and thereafter to designate the complex of problems that led him to special relativity. However, Einstein was not a slavish adherent of Hertz's "*Darstellung*". From the very beginning of his scientific career he had persistently expressed doubts on the role of 'des Namens Aether' in electrodynamics. Yet his skepticism was directed at Hertz's concept of the ether as a medium with a certain state of motion, *not at the ether concept itself*. It was because Einstein attributed basic significance to the concept of 'elektrische Massen' and treated electric currents as motions of such charges in empty space, and not as the 'Verschwinden elektrische Polarisation in der Zeit'. At the start of Einstein's scientific career his views were drawn upon the lectures on electricity of his ETH physics teacher prof. H.F. Weber, as indicated by Einstein's lecture notes (see, for instance, Doc. № 37 and salient comments on it in Einstein 1987, 223-225).

The 'substantive' concept of electricity was developed by Wilhelm Weber and was widely accepted by many German-speaking physicists, including H.F. Weber. Therein, *initially Einstein's views on electrical masses moving in the immobile ether were similar to the dualistic theory of H.A. Lorentz.* Einstein concluded the abovementioned letter punctuating that 'Strahlungversuche' were needed to choose between the two viewpoints he outlined, and his next, 10 September 1899 "Paradise" letter to Marić mentioned an idea for experimentally investigating the influence of motion relative to the ether on light propagation in transparent bodies.

However, Einstein's physics professor showed no enthusiasm for his work, and Albert made no further mention in his correspondence of his activity in the electrodynamics of moving bodies <u>for almost two years</u>. Nevertheless 'die prinzipielle Trennung von Lichtaether und Materie, Definition absoluter Ruhe' were among the topics he vividly discussed with his close friend Michele Besso (Einstein's 4 April 1901 letter to Marić). In March 1901 Einstein wrote Marić that he looked forward to the conclusion of "unsere *Arbeit uber die Relativbewegung*". In September 1901 he informed his boon companion Marcel Grossman on inventing a simpler method for the investigation of the motion of matter relative to ether, based 'auf gewonlichen Interferenzversuchen'. By December 1901 he was 'arbeite eifrigst' on "*die Elektrodynamik bewegter Körper*", that promised to become "eine kapitale Abhandlung" (Einstein's 17 December 1901 letter to Marić). A calculation error had earlier led him to doubt the correctness of his 'Ideen über die Relativbewegung' , but he now believed in these ideas more than ever.

He unfolded the stuff to prof. Kleiner and the latter "thought that the experimental method proposed by me is the simplest and most appropriate and conceivable. I was very pleased with the success. I shall certainly write the paper in the coming weeks" (Einstein's letter to Marić, 19 December 1901, p. 189). Notwithstanding prof. Kleiner's encouragement and Einstein's enthusiasm, <u>no publication on this subject ensued for over three years – till June 1905.</u> - Why? What was the matter? - Einstein really was working hard on a "capital memoir" on the electrodynamics of moving bodies at the end of 1901. Then he had desisted and retraced to the memoir only in 1905. What did happen in that span, and ***why had Einstein, being initially an adherent of the ether, became its strong enemy?***

- To give a sober answer one has first to recall Einstein's derogative evaluation of his early works - "my worthless beginner papers" (Einstein / Marić 1992). All the evidence at hand indicates that the planned "*kapitale Abhandlung*" was a "far cry" from the 1905d preeminent special relativity paper. On the other hand, now one knows for sure (Rynasiewicz 2000) that Einstein arrived at the body of results presented in his 1905d relativity paper, in a 'sudden burst of creativity' and only *after* he had completed his first three works in the spring of 1905. *The key insight – the discovery of the relativity of simultaneity – occurred to Einstein only in late May 1905 after the completion of the 1905c Brownian motion paper.* For instance, when asked by the biographer Carl Seelig, Einstein enunciated:

"Between the conception of the idea of the special theory of relativity and the completion of the corresponding published paper there passed five or six weeks" (Seelig 1960, 114).

Maybe Einstein had renounced the ether concept on finding some uncontestable, especially persuasive argument in the writings of those men of science whose influence he readily and publicly admitted ? The argument could turn out a final straw for growing aversion to apparent metaphysical remnant of the obsolete classical tradition.

To begin with, how important was Poincaré and Mach's influence? - Indeed, in a letter to Michele Besso on 6 March 1952 Einstein recalled:

"These readings were of considerable influence on my development – along with Poincaré and Mach" (Speziali 1972, Doc. 182).

At first, how influential was Poincaré's 'Relativity Principle', that asserted relativity of time and space? Already in 1902 Henri Poincaré contended that

"*There is no absolute time.* To say two durations are equal is an assertion which has by itself no meaning and which can acquire one only by convention. Not only have we no direct intuition of the equality of two durations, but *we have not even direct intuition of the simultaneity of two events occurring in different places*: this I have explained in an article entitled '*La mesure du temps*' " (Poincaré 1902, 114; my italics).

Furthermore, one of the 'Academia Olympia' members – Einstein's close friend Maurice Solovine – took Henri Poincaré's book "*La science et l'hypothese*" (first published in 1902) as one

"that profoundly impressed us and kept us breathless for many weeks" (Solovine 1956; quoted from Howard and Stachel 2000, 6).

Nevertheless, the relativity principle, elaborated by Henri Poincaré, did not prevent the latter from believing in ether as in the medium necessary for propagation of electromagnetic disturbances.

And as for Ernst Mach, the most blatant influence on young Einstein was to be exerted by the eminent Principle of Economy of Science: “Physics is Experience Arranged in Economical Order”. Ernst Mach, in his book *Die Mechanik*, famously argues for the overall *simplicity* and *economy* of Wissenschaft, and unification turns out to be a key to promote that economy and simplicity (Mach [1883], 1960). Furthermore,

“One and the same view underlies both my epistemological-physical writings and my present attempt to deal with the physiology of the senses – the view, namely, that all *metaphysical elements are to be eliminated* as superfluous and as destructive of the economy of science” (Mach [1897], 1984]: p. XXXVIII; my italics).

A startling application of the tenet is possible when two theories, formerly separate, come into contact. For Mach this was a central concern: he was driven to unify psychology and physics. At issue here was the economical requirement of needing a single orienting perspective :

“But anyone who has in mind the gathering up of the sciences into a single whole, has to look for a conception to which he can hold in every department of science “ (Mach [1897] 1984, p. 312).

Or maybe it was David Hume? On the 14th December 1915, Einstein confessed to Moritz Schlick that

“Mach, and even more,Hume, whose Treatise of Human Nature I studied with passion and admiration *shortly before discovering the [special] theory of relativity*.Very possibly, I wouldn’t have come to the solution without those philosophical studies” (quoted from Slavov 2016,247; my italics).

Or, much later, in a letter to Michele Besso in 1948 Einstein again recalled that

“How far [Mach’s writings] influenced my own work is, to be honest, not clear to me.In so far as I can be aware, the *immediate* influence of D.Hume on me was great.I read him with Konrad Habicht and Solovine in Bern (quoted from Speziali 1972,153; my italics).

Yet Mach’s and Hume’s influence should not be overestimated.For instance, Mach’s search for economical relations among the ‘elements of experience’ strongly reflects the method of induction.And Einstein’s aversion to induction is well-known.For instance, in his 1914 inaugural address in Berlin Einstein maintained:

“The methodology of the theoretician mandates implicitly that he use as his basis general assumptions, so-called principles, from which he can then deduce conclusions. His activity, therefore, has two parts: first, he has to *ferret out* these principles, and second, he has to develop the conclusions that can be deduced from these principles. His school provides him with excellent tools which to fulfill the second-named task […]

But the former task, namely to establish these principles which can serve as the basis of his deductions, is one of a completely different kind. *Here there is no learnable, systematically applicable method* which would lead him to the objective. The researcher must rather *eavesdrop* on nature to become privy to these general principles by recognizing in larger sets of experimental facts certain general traits that can then be strictly and precisely formulated" (quoted from van Dongen 2010, 24).

Furthermore, as late Einstein himself had famously recapitulated in his 1949 autobiography,

"The type of *critical reasoning* required for the discovery of this central point [i.e. the denial of absolute time, or simultaneity] was decisively *furthered* , in my case, especially by the reading of David Hume's and Ernst Mach's *philosophical* writings" (Einstein 1949,53; my italics).

It therefore comes at no surprise that no *direct* link between Mach's (and Hertz's) principle of economy of thought and two basic SRT postulates can be traced. For instance, nowhere Einstein had contended that his postulate of the constancy of the velocity of light is a *direct* consequence of the Michelson-Morley experiment, not to forget his numerous declarations that he did know about the experiment while contriving the STR. The "Light Postulate" is introduced almost parenthetically, without any discussion of its experimental grounds. For instance, in his 1905e paper describing his 1905d results Einstein drops a phrase: "the principle of the constancy of the velocity of light used there is *of course* contained in Maxwell's equations" (Einstein 1905e, 172; my italics).

And the last and, it seems to me, the strongest argument against the inductivist explanation of the STR genesis consists in the following. Let us turn to the so-called "emission theories of light" that contested the light-constancy postulate and exchanged it with the Galilean law (that added the velocities of light and of its source).These theories (see Tolman 1912 for details) had no problems in explaining the Michelson-Morley result. They were specially conjured up to explain it. And they did. But they should not, if the inductivists were right.

One can, of course, take the principles of economy of thought and simplicity not in an inductivist, but in falsificationist fashion, contending that the Lorentz-Fitzgerald contraction (LFC) hypothesis, aimed at explaining the Michelson-Morley results within the classical physics research tradition, was an "*ad hoc*" hypothesis .Indeed, presumably following Poincaré's lecture (Rapports du Congres de Physique de 1900, Paris, i, pp.22-23) , Einstein in his 1907 exposition of the STR characterized Lorentz's and Fitzgerald's contraction hypothesis as an "ad hoc" one and "only an artificial means of saving the theory" from the negative results of Michelson and Morley 1887 experiment. However, in his subsequent writings Poincaré, starting from his eminent St.Louis lecture (1904), had irrevocably changed his mind. Correspondingly, Einstein did not label the LFC hypothesis as 'ad hoc" anymore.

Yet it is Elie Zahar's (1973) bona fide account of ad hocness in the context of the Lorentz-Einstein transition that had convincingly exhibited that the Lorentz-Fitzgerald contraction hypothesis was not an ad $hoc_i$ (i=1,2,3) hypothesis. According to Zahar, the most complete and multifareous account of ad hocness is given in Imre Lakatos's methodology of scientific research programmes.

"A theory is said to be ad $hoc_1$ if it has no novel consequences as compared with its predecessor. It is ad $hoc_2$ if none of its novel predictions have been actually 'verified'; for one reason or another the experiment in question may not have been carried out , or - much worse - an experiment devised to test a novel prediction may have yielded a negative result. Finally the theory is said to be ad $hoc_3$ if it is obtained from its predecessor through a modification of the auxiliary hypothesis which does not accord with the spirit of the heuristic of the programme" (Zahar 1973, 217).

Zahar convincingly exhibited that the Lorentz-Fitzgerald contraction hypothesis was not an ad $hoc_1$ one evidently because the STR and the LFC predicted *different* results of the Kennedy-Thorndike experiment. Likewise, LFC was not an ad $hoc_3$ hypothesis too. Lorentz derived the LFC hypothesis from a deeper theory - from the Molecular Forces Hypothesis (MFH): "molecular forces transform and behave like electromagnetic ones". It was quite natural for Lorentz to admit that there is no special "molecular" ether to transmit the interactions between the bodies. All the interactions should be transmitted by the common "luminiferous" ether.

It should be added that, while Zahar correctly takes the LFC hypothesis as non ad $hoc_2$, his arguments are untenable since they are grounded on his notorious definition of the novel fact.

"A fact will be considered novel with respect to a given hypothesis if it did not belong to the problem situation which governed the construction of the hypothesis" (Zahar 1973, 218).

I approve Alan Musgrave (1974, 13-14) in that Zahar's definition is rather dubious since it puts the procedures of empirical justification from the hands of experimentalists to the hands of historians of science. Such a comprehension of the novel fact deviates as a matter of fact from Lakatosian "temporal novelty". On my humble opinion Zahar's redefinition of the novel fact is unnecessary for the defence of the LFC hypothesis.LFC is not an ad $hoc_2$ , but due to the other fine reasons. The following quotation is of importance here:

"This assumption of a shrinkage, although bold and thus far entirely hypothetical, is not impossible and is the only suggestion yet made which is capable of reconciling the negative results of second and third order experiments with a quiescent ether. Poincaré (Rapports du Congres de Physique de 1900, Paris, i, pp.22-23) has raised objection to the electromagnetic theory for moving bodies, that each time new facts are brought to light a new hypothesis has to be introduced. This criticism seems to have been fairly met by Lorentz in his latest treatment of this subject" (Brace 1905, 72).

Advancing Lorentz's arguments, Brace employs the results of Hasenörl (Annalen der Physik, 1903, band 13, p.367). Reasoning from a cyclic process in a moving radiating system, Hasenörl had elicited that the second law of thermodynamics is contradicted unless a second order contraction takes place. Hence not only the Michelson-Morley experiment, but *all* the variety of the experiments establishing the second law of thermodynamics support the LFC. This is an outstanding empirical confirmation.

It is of no wonder that many Lorentz's contemporaries supported Brace's conclusions. For instance, Norman Campbell of Trinity College, Cambridge also took the LFC hypothesis

"as artificial at the first sight. But if one considers it carefully, he can deduce, with Larmor, that the hypothesis has a firm theoretical basis. From this standpoint the negative Michelson and Morley result demonstrates that the optical properties of matter have electrical origin. Nobody doubts it now. Hence the Lorentz-Fitzgerald contraction hypothesis met unanimous support and approval, and all the physicists thought that the difficulties that arose due to the Michelson-Morley experiment were solved sufficiently well" (Campbell 1912, 432-434).

One gradually comes to a conclusion that the principle of economy of thought functioned as a common motto recommending a researcher to be careful with theoretical speculations and to be as close to experience in theoretical discourse as possible. For instance, Einstein eagerly acknowledged that Mach's critical discussion of the foundations of mechanics, which Einstein first read around 1897, helped to protect him from dogmatic "ontological" adherence for the mechanical world-view (Stachel 2000). However, in 13 May 1917 letter to Besso Einstein had to admit that

"I do not inveigh again Mach's little horse: but you know what I think about it. It cannot give birth to anything living; it can only stamp harmful vermin" (Speziali 1972, Doc. 339).

In a 1974 lecture Werner Heisenberg recalled that Einstein confessed to him that

"Perhaps I did use such philosophy [Machism] earlier, and also wrote it, but it is nonsense all the same…it is in fact the theory which first determines what can be observed (quoted fron van Dongen 2010,169).

The cases of Hertz and Hume will be more thoroughly considered in the next sections. All in all, notwithstanding Einstein's fascination by certain modicums of truth in their writings, but taking into account Einstein's aversion to inductivism, their influence also can not be taken as decisive.

### *3. What was the train of thought that brought Einstein to special relativity?*

To give a sound answer one should first delve into the special relativity paper itself (Einstein 1905d). The paper famously commences with scrutinizing a "*deep asymmetry*" in the description of electromagnetic induction. Experience tells us that the induction current caused in the conductor by the motion of the magnet depends only on *relative* motion of the conductor and the magnet. However the Maxwell-Lorentz theory provides one with *two* qualitatively different accounts of the effect that mysteriously lead to one and the same quantitative result.

But for conceiving the true reasons of special relativity genesis it is quite important to take into consideration that *Albert Einstein was by no means the first to note asymmetries in theoretical representation of the induction phenomenon***.** In 1885 the asymmetries were indicated by Oliver Heaviside, in 1894 – by Herman Föppl, and in 1898 – by Wielhelm Wien himself (see Darrigol 2001, 377 for details). One should especially punctuate Heinrich Hertz's thought-provoking papers.For instance, Hertz explicitly used the term 'asymmetry' in his 1884 paper (Hertz 1884). Hence namely Hertz's papers constituted part of the background to Einstein's thinking on issues in electrodynamics (Hon and Goldstein 2005).Indeed, at the outset of his 1905d paper Einstein invoked Maxwell's equations in their Hertzian form, namely, in the symmetrical form that Hertz presented for the first time in his 1884 paper. In his 1905d STR paper Einstein is explicit about this: he appeals to the "Maxwell-Hertz" equations. However, Hertz took this asymmetry as purely formal, and he simply eliminated it by re-writing Maxwell's equations in a symmetrical form.

Thus the pivotal question is not how Einstein became aware of the asymmetries, but *what made them so intolerable to him.* Einstein followed Hertz, Heaviside, Wien et al. in recognition that something was pathological in the Maxwell-Lorentz theory.Yet he had to put a rather different 'diagnosis' and to choose a different 'cure'.

The key to answer the aforementioned question lies in *other* works of Albert Einstein and first and foremost in his papers of 1905 . It is well-known that Einstein published *nothing* on the topic of optics and electrodynamics of moving bodies prior to 1905. Furthermore, it was Albert Einstein himself who had just disclosed *another asymmetry – and of more profound nature –* in the 1905a paper "*On an heuristical point of view concerning the processes of emission and transformation of light*" that was published in the same journal "Annalen der Physik" but three months ***before*** the relativity paper. Look at the outset of his 1905a ground-breaking paper:

"There exist an *essential formal difference* between the theoretical pictures physicists have drawn of gases and other ponderable bodies and Maxwell's theory of electromagnetic processes in so-called empty space" (my italics).

And in the first part of his 1905a masterpiece Einstein excavates that joint application of mechanical and electrodynamic "theoretical pictures" for scrutinizing black-body radiation leads not only to a contradiction with experiment (his paper did not even cite the results of Lummer & Pringsheim or Rubens & Curlbaum), but to the ***paradox*** that cannot be circumvented by common expedients and evasions. To exhibit it, Einstein contrives the gedankenexperiment with both theories. He contemplates a cavity containing free electromagnetic field, gas molecules and Hertz's resonators.In the sequel he arrives at a conclusion that the joint application of mechanics and electrodynamics leads *unavoidably* to Rayleigh-Jeans law for energy density of black-body radiation. However,

"this relation which we found as the condition for dynamic equilibrium does not only lack agreement with experiment, but it also shows that in our picture there can be no question of a definite distribution of energy between aether and matter", since "the greater we choose the range of frequencies of resonators, the greater becomes the radiation energy in space and in the limit we get $\int_0^\infty \rho_\nu \, d\nu = (R/N)\,(8\pi/L^3)\, T \int_0^\infty \nu^2 \rho_\nu \, d\nu = \infty$."

(Here R denotes the universal gas constant, N the number of "real molecules" in one gram-equivalent, T the absolute temperature, L the velocity of light, $\nu$ the frequency, and $\rho_\nu \, d\nu$ the energy per unit volume of that part of the radiation whose frequency lies between $\nu$ and $\nu+d\nu$).

Although it is commonly held that in the 1905a paper Einstein was concerned with an explanation of the photoelectric effect, the tentative study of the masterpiece discloses that this was not the case. The measurements of the effect at that time were not sufficiently accurate to point without any doubt to a violation of classical behavior (Ter Haar 1967). Einstein was worried not so much by the evidence dealing with photoeffect and appealed to fluorescence, photoelectricity and photoionization data only as to *indirect* evidence in favor of his thesis. Rather, Einstein had mostly delved into the contemplation of the *contradiction* between mechanics and electrodynamics and to the ways of resolving it.

Hirosige (1976) shrewdly attributed Einstein's sensitivity to the inconsistencies between mechanics and electrodynamics to influence of Ernst Mach, whose writings supposedly helped the inventor of special relativity to outdo dogmatic adherence to the mechanistic worldview. Einstein could therefore freely juxtapose Newtonian mechanics, statistical thermodynamics and Maxwellian electrodynamics without reducing one to the others.

Jürgen Renn and Robert Schulman (1992) take Einstein's anti-dogmatism as a crucial hallmark of his scientific style of reasoning that enabled a young man to comprehend the conceptual implications in the works of such masters as Lorentz, Hertz, Poincaré and Planck that they themselves were sometimes unable to discern. Unsurprisingly in their Proposal for

Einstein’s Membership in the Prussian Academy of Science (Berlin, 12 June 1913), M. Planck, W. Nernst, H. Rubens and E. Warburg maintained that

“Apart from his great productivity, Einstein has a special talent for getting to the bottom of other scientists’ newly emerging views and assertions, and for assessing their relationship to each other and to experience with surprising certainty”(Doc. № 445 of Einstein 1987, 338).

The other feasible source of Einstein’s unification is Heinrich Hertz’swritings.As is well-known, it was Hermann Helmholtz who convinced Berlin Academy of Science to set up a special prize for experimental confirmation of Maxwell’s theory. And it was Helmholtz’s pupil - Heinrich Hertz- who got the prize in 1888. From two possible explanations of his experiments (see Smirnov-Rueda, 2010, for details) Hertz had chosen the *simplest* one :

“Helmholtz distinguishes between two forms of electric force – the electromagnetic and the electrostatic – to which, until the contrary is proved by experience, two different velocities are attributed. An interpretation of the experiments from this point of view could certainly not be incorrect, but it might perhaps be *unnecessary complicated*. In a special limiting case Helmholtz’s theory becomes considerably simplified, and its equations in this case become the same as those of Maxwell’s theory; only one force remains, and this is propagated with the velocity of light” (Hertz [1889], 1893, 123).

On my view it was namely the attempt to justify the rationality of choosing the simplest explanation that forced Heinrich Hertz after 1888 to give up his electromagnetic experiments fruitful both from heuristic and technological vistas and to devote the last three years of his short life to his extremely ambitious project of classical mechanics rebuilding. As he put it clear in his “*Principles of Mechanics*”

“it is premature to attempt to base the equations of motion of the ether upon the laws of mechanics until we have obtained a perfect agreement as to what is understood by this name “ (Hertz, 1899,p.XXI).

Hertz’s apparent aim was to eliminate the “force” concept. But his ultimate aim consisted in reconciling classical mechanics foundations with positivistic Zeitgeist :

“[…] furthermore, one would expect to find in these [electromagnetic field] equations relations between the physical magnitudes which are actually observed, and not between magnitudes which serve for calculation only” (Hertz [1890], 1893, p.196).

It is important that the methodological principles for classical mechanics rebuilding were to be found by Hertz in Kantian epistemology (Hertz 1899,1,23).Note that even before he met such an outstanding Neo-Kantian teacher as Hermann von Helmholtz, Hertz had attended in Dresden a course on Kantian philosophy.

Hertz's Kantian background manifested itself not only in the epistemological scheme diligently described in "*Priciples of Mechanics*". According to Jed Z. Buchwald, already in 1884 Hertz had proposed a version of Maxwell's equations that was free of the ether notion completely.

"Hertz, one might say, wished in 1884 to remove the ether, even if Maxwell's equations were to be admitted, in order to avoid working with an entity that behaved like a laboratory object but that could not itself be directly manipulated" (Buchwald 1998, 278).

And, what is more important, quite unlikely Maxwellian field theory, in Hertz's theoretical scheme the source continued to exist as an entity in and of itself. In Hertz's diagram the material object remains unknown, whereas the inferred field is known. This diagrammatic inversion encapsulates the originality of Hertz's physics. It was because Hertz ignored the physical character of the object that produced his radiation – "because he boxed it in with a mental quarantine against asking questions against it – he was able to make progress where his British contemporaries had not been able to do so" (Buchwald 1998, 272).

Being a pupil of Helmholtz, Hertz learned to watch for novel interactions between laboratory objects without worrying overmuch about the hidden processes that account for the object's effect-producing power.

Thus the nature of electromagnetic waves appeared to Hertz as a kind of "thing in itself" that admits a variety of interpretations. Researcher chooses the version that is the simplest one to work with. The most important thing is the equations depicting the relations between the objects under investigation.

"To the question, 'What is Maxwell's theory?' I know of no shorter or more definite answer than the following: Maxwell's theory is Maxwell's system of equations. Every theory which leads to the same system of equations and therefore comprises the same possible phenomena, I would consider as being a form of special case of Maxwell's theory" (Hertz 1893, 21).

Hertz's case suggests that an evident source of unification strategy of the scientists of the second half of the XIX-th century is Kantian philosophy.It is no wonder that the papers of all influential for Einstein scientists can be taken as being produced in the wake of Neo-Kantian epistemology.

Just to quote the *Introduction* to Poincaré's eminent book:

"the aim of science is not things themselves, as the dogmatists in their simplicity imagine, but the *relations between things;* outside those relations there is no reality knowable" (Poincaré [1902], 1905, XIX).

Or in the same vein:

“The object of mathematical theories is *not to reveal to us the real nature of things;* that would be an unreasonable claim.Their only object is to co-ordinate the physical laws with which physical experiment makes us acquainted, the enunciation of which, without the aid of mathematics, we should be unable to effect” (Poincaré [1902], 1905, 235).

To recapitulate, “*the true and only aim [of science] is unity*” (Poincaré [1902],1905, 197).

Ernst Mach’s empiricism sprung out of genuinely Darwinian belief that human knowledge is a product of biological evolution. It was simple experience to which early organisms had responded, and it was out of such experiences that the first images of the world were eventually constructed. Eventually these constructions became *a priori,* allowing new and more subtle understandings.Furthermore, in a strict Kantian vein, Mach insisted that the human eye had a mind of its own: we perceive not direct stimuli but *relations* of stimuli. Thus we do not experience ‘reality’ itself but rather conceive the after effects of our nervous system’s adaptation to new stimuli. Obsolete ‘representationalist’ theories of perception, positing direct correspondences between appearance and reality, were untenable for Mach.

Hence it’s no wonder that Mach’s empiricism drew a lot upon Kantianism.Mach credited his philosophical awakening to reading, at age 15, his father’s copy of Kant’s “*Prolegomena*”. As he put it:

“The book made at the time a powerful and ineffaceable impression upon me, the like of which I never afterwards experienced in any of my philosophical reading” (Mach [1897], 1984 , p.30).

Hence one should not be surprised to learn from Jeroen van Dongen’s bona fide, assiduous research “*Einstein’s Unification*” that

“on a number of occasions Einstein actually expressed himself quite appreciative of Kant’s ideas, and some aspects of Einstein’s thought did rather resemble the Kantian philosophy.Both for instance emphasized the virtue of striving for unity in science” (van Dongen 2010, 49).

And I reckon that *for many conspicuous milestones of Einstein’s 1905 activity Kant’s influence could be crucial.*

To begin with, the very possibility of Kant’s influence on Einstein is evident: Kantian philosophy was prevalent among the educated classes in Germany in the late XIX-th century, and the extent to which it was taught in German high school was “overwhelming” (Beller 2000, 84). Accordingly, Neo-Kantianism (Neukantianismus: “Zurück to Kant!”) was the dominant philosophical movement in German universities from the 1870’s until the First World War. It is no surprise that Einstein first read Kant at the age of thirteen and again at the age of sixteen (Howard 1994, 49). Later, being an Eidgenössiche Technische Hochshule (ETH) student in

Zurich, he had an opportunity to continue an acquaintance with Kant's Nachlaß at the lectures of August Stadler, a distinguished neo-Kantian of Marburg school (Einstein 1987, 45-50). Later on Einstein was immersed in Kant again and again. For instance, in his 1936 pre-eminent "*Physik und Realität*" he contended that

"One may say 'the eternal mystery of the world is its comprehensibility'.It is one of the greatest realizations of Immanuel Kant that the postulation of a real external world would be senseless without this comprehensibility" (quoted from Einstein 1954, 292).

Likewise, famously reflecting on basic principles of reasoning in theoretical physics, Einstein avowed that

"the theoretical attitude here advocated is distinct from that of Kant ***only*** by the fact that we do not conceive of the categories as unalterable…They appear to be a priori only insofar as thinking without the positing of the categories and of concepts in general would be as impossible as breathing in the vacuum" (Einstein 1949, 674 ;my italics).

Strictly speaking, as many Einstein scholars had warned (see, for instance, Michael Friedman's writings), he was a kind of an *epistemological opportunist* (see also Einstein 1949, 684) for he would pick those parts of realist, positivist or Kantian philosophies that he thought may be useful for justification of his scientific results and simply paid no attention to any unwelcome consequences of these philosophies. But I *contend* that when it came to *creative*, *'regulative'* principles, Einstein, at least in 1905, derived inspiration first and foremost from Kantian epistemology.

Remember what he confidentially reported in 1918 to Max Born:

"I am reading Kant's Prolegomena here, among other things, and am beginning to comprehend the *enormous suggestive power* that emanated from the fellow and still does" (quoted from Born 1971, 25-26; my italics).

What could attract Einstein in Kantian epistemology?

For Kant it is our freedom from the world that makes science possible. The sensible world conforms to certain basic laws because the human mind skillfully ***constructs*** it according to certain laws. Constructivist foundation for scientific knowledge implies that a priori knowledge of ' things in themselves' is impossible.

Yet in the *Appendix to the "Dialectic" of the first Critique* Kant tried to provide a faint rehabilitation of the ideas of traditional metaphysics ( Wolff, Locke) by maintaining that the ideas of reason have an important function in the conduct of natural science if they are understood *regulatively* ,i.e. if they are taken to represent **not** metaphysical beings or entities, but rather ***goals and directions*** of scientific enquiry.

Kant strictly divided the human intellect into the independent faculties of sensibility, understanding and reason. Correspondingly, the principles governing the aforementioned faculties belong either to *constitutive* principles, or to *regulative* ones. Constitutive principles were considered as rules for the construction of the phenomenal world (e.g. Newton's three laws). Thus, the distinction between constitutive and regulative principles is drawn in the first "Critique" along the following lines: the constitutive principles are those that govern the function of understanding and are necessary conditions of experience, whereas regulative principles – the 'ideas of reason' – govern the function of reason and are not instantiated in experience in the same way. Later Hans Reichenbach took constitutive principles as synthetic a priori ones and argued that to retain a role for such principles they should be *relativized* and comprehended as a priori only from the perspective of a particular theory.

Though constitutive principles are conditions for the possibility of the experience, they do not necessitate our own particular experience of the world. Hence these principles define the space of physical possibilities. It means that there is no possibility of our having an experience that directly contradicts our constitutive principles. That is why the constitutive approach cannot explain how it can be rational to abandon an established conceptual framework ( a" paradigm") in favor of a new one ( Everett 2015).

Thus Kant insisted that the Ideas of Reason can only have a regulative rather than a constitutive role. That is why they can be used *heuristically* as a guide for our investigations, but not substantially as the actual inner principle of what we discover. Reason demands the systematization of our knowledge, i.e. it *strives for unity*. As science advances, it replaces a "narrower aspect of experience by a broader" one. Yet in experimental physics – writes Kant - even the "principles according to which we perform experiments must themselves always be derived from the knowledge of nature, and hence from the theory" (quoted from Buchdahl 1969, p.510, n.1). Hence due to theory-laidenness of observations, science advances by theory unification. As neo-Kantian of Marburg school Ernst Cassirer has put it, "true unity is never thought in things as such, but in intellectual constructions" (Cassirer [1921], 1923, p.36). In genuinely Kantian wake he stressed that unification was a purely regulative demand.

And Kant himself maintained in the *Appendix to the Dialectic* , science must adopt certain ideas of reason as *heuristic (*"as if") devices to encourage systematic unity.

"The concepts of reason are, as we have said, mere ideas, and of course have no object in any sort of experience, but also do not on that account designate objects that are invented and at the same time thereby assumed to be possible. They are merely thought problematically, in order to ground regulative principles of the systematic use of the understanding in the field of experience in relation to them (as *heuristic fictions*)" (Kant [1787], 1998, p.659; my italics ).

Along these lines, Fölsing (1997) keenly observes that Einstein probably first learned to think in terms of this "heuristic viewpoint" from his early reading of Kant. Einstein's heuristic method was to state, or perhaps invent, an assertion from which familiar facts could then be deduced. It is crucial that Einstein's path-breaking, ultra-revolutionary 1905a paper was entitled "*Über einen die Erzeugung und Verwandlung des Lichtes betreffenden **heuristischen** Lesichtspunkt*" ("On a ***Heuristic*** Point of View Concerning the Production and Transformation of Light").

Yet while dissociating himself from Kantian 'synthetic a priori', Einstein strongly endorses the general Neo- Kantian epistemological standpoint:

"The following, however, appears to me to be correct in Kant's statement of the problem: in thinking we use, with a certain 'right', concepts to which there is no access from the materials of sensory experiences" (Einstein 1944, p.22).

Correspondingly I contend that the paramount notion for understanding Einstein's 1905 research activity is *Kant's concept of systematic **Unity of Nature*** as a regulative idea. This unity, for Kant and for Einstein, is not an ontological principle at all. It is meaningless to ask whether Nature in fact possesses such a unity or not. On the contrary, the idea of unity has *epistemological* importance. Systematic unity of nature provides a *benchmark of validity for scientific hypothesis* that complements the empirical idea of confirmation.

Indeed, Kant ([1787], 1998, p.592) discusses the "hypothetical employment of reason", emphasizing repeatedly that the confirmation of a hypothesis by its empirical consequences can never endow such a hypothesis with universality, or 'certainty': "In natural science… there is endless conjecture, and certainty is not to be counted upon" (Kant [1787], 1998, p.608).

Since a given hypothesis cannot obtain the proof of its truth from 'below', from repeated experimental confirmation, something else is needed. One needs the *criterion* that can distinguish contingent and unimportant empirical generalizations from genuine fundamental Laws of Nature, which are endowed with Universality and Necessity. Kantian idea of the "truth" of a proposition is equivalent to its being a law-like statement.

"Such concepts of reason are not created by nature, rather we question nature according to be deflective as long as it is not adequate to them […] The hypothetical use of reason is therefore directed at the systematic unity of the understanding's cognition, which, however, is the touchstone of truth for its rules" (Kant [1787], 1998, p. 592).

Hence from the multitude of different uniformities only those can be regarded as having law-like necessity that can be fitted into a unified, systematized general system.

Compare with Einstein's dictum:

“A system has truth-content according to the certainty and completeness of its coordination-possibility to the totality of experience. A correct proposition borrows its ‘truth’ from the truth-content of a system to which it belongs” (Einstein 1946, 13).

What I want to stress is that it was this ‘holistic’ stand that allowed Einstein as early as in 1906 to disregard the results of Kaufmann’s “crucial” experiments, which seemed to corroborate the Abraham-Bucherer theory and to refute the “Lorentz-Einstein” theory (Holton 1968, 253; Miller 1981, 124).

As Einstein had put it, the rival theories (e.g. Abraham’s electron theory)

“Have rather small probabilities, because their fundamental assumptions (concerning the mass of moving electrons) are not explainable in terms of theoretical systems which embrace a greater complex of phenomena” (Einstein as quoted in Holton 1968, 253).

Einstein readily admitted that there can be empirically equivalent alternative theories for any domain of phenomena. Yet if for conventionalist ‘a la’ Pierre Duhem such an underdetermination of theory by facts meant that there can be no ultimately true theory, the Einsteinian approach in the Kantian wake not only provides a meaning to the regulative ideal of a final theory. It also illuminates Einstein’s remarks that despite this underdetermination at any given time there is *only one* correct theory: *the theory with the greatest power of unification* (Einstein 1918, 226). Thus Einstein’s attraction in the 1905a paper to the subject of theory of quanta was provoked by its *unifying possibilities*, for its capacities to arrive at a *fusion* of Maxwellian electrodynamics and Boltzmann’s statistical thermodynamics. Hence he starts the paper with the heart of what troubled him most – the Rift, *the Duality* in the foundations of physics that was felt most sharply in Lorentz’s Electron Theory. How did Einstein intend to eliminate the pivotal contradiction of his 1905a paper?

While considering Einstein’s solution, one should take into account that *all* Einstein's papers from 1901 to 1905 have one trait in common: statistical-thermodynamics approach. Thomas S. Kuhn had punctuated that *what brought Einstein to idea of photon was a coherent development of a research program 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" (Kuhn 1978, 171). From the outset of his career Einstein was “deeply impressed” (Martin Klein) by the simplicity and scope of classical thermodynamics. But for him thermodynamics included the statistical approach he had learned from Boltzmann's works, and so he began to unfold statistical thermodynamics. The result was a series of three papers published in 1902, 1903 and 1904. It should be stressed that *namely they provide the clue for apprehendnding his 1905a paper on quanta, his 1905b dissertation, 1905c work on Brownian motion and 1905d paper on special relativity.*

The first important result consisted in that for physical systems of extraordinary general sort Einstein has produced, by the summer of 1903, both a generalized measure for temperature T and entropy S, containing some universal constant $\chi$. By the time he finished his 1903 paper, Einstein had recognized that $\chi$ could be evaluated in terms of the values of the gas constant and of Avogadro's number. But the theory that had led him to the constant was, however, applicable to systems far more general than gases. It should therefore have a correspondingly general physical foundation. The basis should reflect statistical-mechanical nature of the approach that led him to the constant, explaining not only its role as a scale factor for temperature, but also its position as a multiplier in the probabilistic definition of entropy. Physical significance of $\chi$ was the central problem attacked in Einstein's third statistical paper "*On the General Molecular Theory of Heat*" , submitted to "Annalen" in the spring of 1904. The solution of the problem consisted in the phenomena of energy fluctuations. Einstein elucidated that $\overline{\varepsilon^2} = 2\chi\, T\, dE/dT$, where $\overline{\varepsilon^2}$ is a measure of thermal stability of the system. And it was comprehension of the constant physical sense that directed his attention to the black-body problem.

"The equation just found would permit an exact determination of the universal constant $\chi$ if it were possible to determine the energy fluctuation of the system. In the present state of our knowledge, however, that is not the case. Indeed, for only one sort of physical system can we presume from experience that an energy fluctuation occurs. That system is empty space filled with thermal radiation" ([Einstein 1904, p.360]; translated in [Kuhn 1978]).

At least one more step in the programme of statistical thermodynamics advancement was needed, and Einstein took it in the ground-breaking 1905a paper. Its content suggests that Einstein had begun to seek a black-body law of his own, that he had quickly encountered the paradox, evinced in the contradiction between statistical mechanics and maxwellian electrodynamics, and that he had dropped the search for the law in favour of an exploration of the paradox itself. This is clear from the very beginning of his already quoted paper (translated in Ter Haar 1967). The first part of the 1905a paper ended by revelation of the "ultraviolet catastrophe". How did Einstein resolve the paradox?

In the second part of his 1905a paper Einstein applies thermodynamics, statistical mechanics and maxwellian electrodynamics to peer at the domain of empirical reality covered by Wien's radiation law. Einstein takes $\beta = h/k = Nh/R$ (R denotes the universal gas constant, N the number of "real molecules" in one gram-equivalent, h is Planck's constant and k is Boltzmann's constant) as undefined constant in 1905a paper and hence he writes $R\beta/N$ everywhere instead of h. Joint application of the three mature theories enables Einstein to arrive at apparently deductive argument: if monochromatic radiation of frequency $\nu$ and energy E is enclosed in the volume $V_0$, then the probability W that at any moment all the radiation energy will be found in the partial volume V of the volume $V_0$ is given by

$$W = (V/V_0)^{E/h\nu} \qquad \text{(i)}$$

Yet in the same paper Einstein had previously demonstrated that in the case of n independently moving particles enclosed in a volume $V_0$ the probability of finding them all momentarily in the subvolume V is

$$W = (V/V_0)^n \qquad \text{(ii)}$$

Comparing equations (i) and (ii), Einstein draws a conclusion that "*monochromatic radiation of small density behaves in thermodynamic respects as though it consists of distinct independent energy quanta of magnitude $h\nu$*".

Thus, the upshot that radiation in the cavity consists of independent energy quanta follows ***directly*** from application of general principles of thermodynamics and statistical mechanics to radiation phenomena.

But in 1905 all the available experimental data, relevant to fluorescence, photoelectricity and photoionization data, provided only indirect evidence in favor of quantum hypothesis. Hence, to check the ultra-revolutionary hypothesis of quanta, Einstein had to perform a "crucial experiment" of a very peculiar, freaky kind .He had to compare the quantum results with the results of another entrenched, 'old' theory contrived *independently* of the 1905a hypothesis. It is important that this theory had to be sufficiently 'old' to accumulate the results of many experiments. So, if the 1905a paper results had matched the results of fairly different theory, that sprung out of different problem situation, they would have provided an especially reliable verification of "photon hypothesis". Remember: "A system has truth-content according to the certainty and completeness of its coordination-possibility to the totality of experience. A correct proposition borrows its 'truth' from the truth-content of a system to which it belongs" (Einstein 1946, 13). In the opposite case the 1905a theory would have 'falsified' not by a single 'critical experiment' but by a whole multitude of the well-established experimental data.

Thus the next - 1905b - result turned out to be crucial for the 1905a verification. In the 1905b paper Einstein assiduously worked out the principles of Brownian motion that were directly verified by Perrin's experiments. The 1905b paper's importance for the 1905a one was promulgated by Einstein much later; he confessed to Max von Laue on 17 January 1952:

"When one goes through your collection of verifications of the special relativity theory, one believes that Maxwell's theory is firmly established. But in 1905 I knew *already with certainty* that it leads to the wrong fluctuations in radiation pressure, and consequently to an incorrect Brownian motion of a mirror in a Planckian radiation cavity" (quoted from Rynasiewicz 2000, 177; my italics).

This blatant for 1905 Einstein result was posited to the scientific community only in 1909 when Einstein applied his theory of Brownian motion to a two-sided mirror immersed in thermal radiation. He posited that the mirror would be unable to carry out a Brownian motion indefinitely, if the fluctuations in the radiation pressure on its surfaces were solely due to the effects of random waves, as predicted by Maxwell's theory. But only the presence of an additional term, corresponding to pressure fluctuations due to the impact of random particles, guarantees the continued Brownian motion of the mirror. Einstein exhibited that similar fluctuation terms in the energy were consequences of Planck's law. He took such fluctuation phenomena as the ***strongest argument*** for ascribing physical significance to the hypothetical light quanta (Stachel 2000). Only after the "crucial experiment", that is only *after* the 1905b paper could Einstein look forward for investigating the consequences of his light quantum hypothesis, and so he returned to his half-forgotten "unsere Arbeit uber die Relativbewegung", eine "kapitale Abhandlung". So far, so good.

"if the monochromatic radiation (of sufficiently small density) in the sense of entropy dependence upon volume behaves itself as a discontinuous medium, consisting of energy quanta $R\beta\nu/N$ , a question occurs: if they are not the laws of creation and conversion of light such as if it consists of similar energy quanta?" (Einstein 1905a, 236).

That is the question put up by Einstein at the end of § 6 of his 1905a. But ***the ether conception turned out to be a snag****. It hampered positive answer and put obstacles in uncoiling Einstein's statistical-thermodynamics programme.* Indeed

"mechanical and purely electromagnetic interpretations of optical and electromagnetic phenomena have in common that in both cases electromagnetic field is considered as a special state of hypothetical medium filling all the space. Namely in that point two interpretations mentioned differ radically from Newton's emission theory, in which light consists of moving particles. According to Newton, space should be considered as possessing neither ponderable matter, nor light rays, i.e. absolutely empty" (Einstein 1905a, 236).

To *contrive* a quantum theory of radiation, one needs electromagnetic fields as *independent* entities that can be emitted by the source " just as in Newton's emitting theory" ( i.e. energy transmitted in a process of emission should not be dissipated in space, but should be *completely* preserved until an elementary act of absorption). However, within the Lorentz programme an electromagnetic field is taken as a specific state of ether - a state of medium that is *continuously* distributed in space. An elementary process of radiation is connected in such a medium only with a spherical wave.

Nevertheless, aversion to ether and acceptance of emission theory should lead to Walter Ritz's 1908 'ballistic hypothesis': velocity of quantum should depend on the velocity of its source. In Ritz's theory velocity of light is not constant, but is equal to v+c, where v is a relative velocity of the observer and the source.

But Einstein, by contrast, never thought of downing Maxwell's theory, just as Newton, the inventor of the emission theory, did not reject the wave theory 300 years earlier. In the 1905a photon paper Einstein had especially underscored that

"Wave theory operating with point continuous functions is excellently justified when describing purely optical phenomena and perhaps would not be replaced by another theory" (Einstein 1905a, 237).

In Lorentz's theory this stumbling block was absent. Indeed, in the reference frame that is at rest relative to the ether light propagates with constant velocity *independent of the velocity of the source.* Hence, if one intends to give up the idea of ether, but to come to terms with Maxwell's theory at the same time, s/he should disown ballistic hypothesis and postulate a special "principle of constancy of velocity of light"(I). Later, in April of 1922, Einstein had confessed to Viscardini:

"I rejected this [emission] hypothesis at that time, because it leads to tremendous theoretical difficulties (e.g. the expectation of shadow formation by a screen that moves relative to the light source)" (quoted from Rynasiewicz 2000, 182).

The second basic principle of STR - "the principle of relativity"(II) - follows immediately from the tenet that there is no ether and, consequently, no absolute system of reference.

The two postulates, (I) + (II), the relativity principle plus the principle of constancy of velocity of light, are quite sufficient, according to Einstein, to contrive the electrodynamics of moving bodies. Yet, since "the theory based on these two principles should not to lead to contradictory results, one must renounce the customary rule of addition of velocities " (Einstein 1910,125).

And namely that was done in the 1905d paper «*On the Electrodynamics of Moving Bodies*", published several months ***after*** the photon paper. Einstein had dug out the hidden assumption - the basis of the Galileo addition law - that the statements of time, as well as of the shapes of moving bodies have the sense independent of the state of motion of the reference frame. He revealed that the acceptance of the "principle of relativity" together with the "principle of constancy of light" is equivalent to modification of the simultaneity concept and to clock delay in moving reference frame. It should be stressed that Einstein was not an idle thinker contemplating on the essence of space and time. He was *forced* to elevated philosophical reflections on the nature of space and time by his *research practice*, by a mundane physical problem of reconciling Principle of Relativity with the Light Constancy Postulate (see Norton 2010 for details) .

Hence, at least in that case, Einstein's use of Hume and Mach's philosophical writings was "*highly selective*" (Norton 2010,359). His ultimate goals were not so much to apprehend Hume's and Mach's refined philosophical reflections as to find in them concrete ideas that may be useful in his mundane research practice. Thus Hume's and Mach's writings provided "the type of critical reasoning" (Einstein 1949) necessary for the clearing the thinking from the remnants of obsolete metaphysical systems "rooted unrecognized in the unconscious" (Einstein 1949). Nevertheless, the *mainspring* had to be found on the other ways. In a letter to Besso on 6 January 1948 Einstein admitted that

"I see his [Mach's] weakness in this, that he more or less believed science to consist of mere 'ordering' of empirical 'material'; that is to say, he did not recognize the ***freely constructive*** *element* in the formation of concepts. In a way he thought that theories arouse through discoveries and not through inventions. He even went so far that he regarded 'sensations' not only as a material which has to be investigated, but, as it were, as the building blocks of the real world" (Speziali 1972, Doc 153; translated by Gerald Holton; my italics).

As for David Hume, it should be stressed that Hume's and Einstein's conceptions of space and time have *substantial* differences (see Slavov, 2016 for details). In Hume's adamant epistemological doctrine, space and time are *direct* abstractions from simple perceptions.On the contrary, Einstein stubbornly and constantly emphasized that the basic concepts of science are *free creations* of the human mind. In that respect Einstein's views were evidently closer to Kant. So, the positive drive for creative work could be found in Kant's ***constructivist*** foundation for scientific knowledge that restricted science to the realm of appearences stating that a priori knowledge of things in themselves is impossible. Much later Einstein had admitted:

"I did not grow up in the Kantian tradition, but *came to understand* the truly valuable which is to be found in his doctrine, alongside of errors which today are quite obvious, quite late.It is contained in the sentence: 'The real is not given [gegeben] to us, but put to us [aufgegeben]' [by way of a riddle] (Einstein 1949,680; quoted from Ryckman 2005; my italics).

Kant comprehended even mathematics – maintained to be most stable and certain because of its being analytical – as an *a priori synthetic judgement.* As he stressed in "*Prolegomena*" (Kant [1783], 2002), the essential feature of pure mathematical cognition, differentiating it from all other a priori cognition, is that it must throughout proceed not from concepts, but always and only through the ***construction*** of concepts. Because pure mathematical cognition, in its propositions, must therefore go beyond the concept to that which is contained in the *intuition* corresponding to it, its propositions can and must never arise through the analysis of concepts, i.e. analytically, and so are one and all synthetic.

Accordingly, on Christmas day of 1919 Einstein published in the *Berliner Tageblatt* the essay "*Induction and Deduction in Physics*" in which he confessed that

> "The truly great advances in our understanding of nature originated in a manner almost diametrically opposed to induction.The *intuitive* grasp of the essentials of a large complex of facts leads the scientist to the postulation of a hypothetical basic law, or select such basic laws […] [The researcher] does not find his system of ideas in a methodical, inductive way; rather, he snuggles up to the facts by *intuitive* selection among the conceivable theories that are based upon axioms"(quoted from van Dongen 2010,41; my italics).

The Kantian thesis of the intuitive character of mathematics means the limiting of mathematics to those objects that are constitutable [Konstruierbar]. 'Intuitive' is equal to 'constitutable'. As Wittgenstein has later put it in genuinely Kantian wake, "But the mathematician is not a discoverer, he is an *inventor*».

It is not accidental that Kant contemplated objectivity of science as resulting from the manner in which the manifold of sensibility was ordered under the categories of the understanding by means of spatial and temporal categories. This is why mathematics could so effectively describe objective reality for Kant: mathematical constructs are related to the pure intuitions of space and time. And this is why natural science must be mathematical.

Hence mathematical statements are true in virtue of their application in experience to exhibit the behavior of empirical bodies. While mathematical judgements are obtained through construction in pure intuition, they count as cognitions only because they are necessary connected to experience in the sense that geometrical space was contemplated as a condition of appearance.

> "Although we know a priori in synthetic judgements a great deal regarding space in general and the figures which productive imagination describes in it, and can obtain such judgements without actually requiring any experience, yet even this knowledge would be nothing but a playing with a mere figment of the brain, were it not that space has to be regarded as a condition of the appearances which constitute the material for outer experience.
>
> Those pure synthetic judgements therefore relate, though only mediately, to *possible experience*, or rather to the possibility of experience; and upon that alone is founded the objective validity of their synthesis" (Kant [1787], 1998, p.196; my italics).

In a sense the abstract objects of a theory are constituted by the laws of the theory. And objectivity is connected not to the existence of things but to the *objective validity of relations*. Accordingly, in the 1905a paper, constructing the mathematical abstract object "light quanta" out of the basic objects of maxwellian electrodynamics and statistical thermodynamics, Einstein was bothered not with grasping the 'essences' of radiation phenomena but with the problems of ***reconciling*** the interrelations of different research traditions, i.e. maxwellian electrodynamics, statistical mechanics and thermodynamics. Let us recall that in their Proposal for Einstein's Membership in the Prussian Academy of Science, M. Planck et al. had shrewdly emphasized that

“ Einstein has a special talent for getting to the bottom of other scientists’ newly emerging views and assertions, and for assessing *their relationship to each other* and to experience with surprising certainty” (Doc. № 445 of Einstein 1987, 338; my italics).

As Einstein recalled later,: ‘The real is not given [gegeben] to us, but put to us ” (Einstein 1949,680), i.e. ‘constructed’ due to our research activity.

In a nutshell, Einstein’s Kantianism can be characterized by a motto of another prominent neo – Kantian of Marburg school - Wilhelm Windelband: “Kant verstehen, heißt über ihn hinausgehen”.It is well-known that Einstein’s philosophical evolution after the General Relativity ,i.e. after 1915 carried him further and further from Humean and Machian empiricist bias toward Neo-Cantian tradition represented by Weyl, Eddington, Cassirer, Husserl et al. and the mathematical speculative methodology embodied in a sequence of unified theories. Thus I am not contending here that Einstein of 1905 was a true (neo) Kantian, trying to implement the tenets of “Critique” into his unification practice.Yet I insist that the seeds of Einstein’s late methodology lie in his 1905 activity connected with his fruitful efforts to reconcile maxwellian electrodynamics and statistical thermodynamics.

Well, if all the aforesaid is true, a question arises: *why Einstein in the 1905d relativity paper did not cite his 1905a paper on light quanta?*

To give a judicious answer one has to dwell into Einstein’s 1905 correspondence. Writing to his close friend Conrad Habicht in 1905 and sending him the fruits of his labours at that time, Einstein called his light quanta paper "*very revolutionary*", while the relativity paper was humbly characterized as “interesting in its kinematical part”. So, *reference in the paper, introducing significant changes mainly of metaphysical character, on the hypothesis that had already introduced revolutionary changes and had obviously* ***contradicted*** *Maxwell's theory, could hardly make the arguments stronger.*

Einstein himself at the first Solvay Congress had to admit "provisional character of this concept [light quanta] which does not seem reconcilable with the experimentally verified consequences of the wave theory" (quoted from Pais 1979, 884). The situation was even worse since *direct experimental evidence* in favour of light quanta existence was absent. It famously appeared only in 1923 (the Compton effect).

Being taken independently, the STR did not explain any *new* experimental fact. Predictions of the Lorentz theory were identical to that of the STR, so that it would not be possible in any case to distinguish between these theories on experimental grounds. Moreover, most of Einstein’s contemporaries had scrutinized the “Lorentz-Einstein electron model”, reflected on the “principle of relativity of Lorentz and Einstein”, etc. At the time of publication of Lorentz’s second order theory (1904) the only data available to test these theories were

Kaufmann's measurements of the masses of slowly moving electrons. But they were initially interpreted as contradicting *both* STR and Lorentz's theory. It took a year for Einstein to answer on Kaufmann's paper. One can imagine how the STR was evaluated by the scientific community in 1905 - 1906!

Furthermore, Einstein did not exhibit the connections between 1905a and 1905d until 1909. However, *without this connections the STR postulates can be evaluated as ad hoc hypotheses. And they were!* (The reaction of Henri Poincaré and of the French school is the most blatant example). So, being confronted with many rival theories, why did Einstein preferred special theory of relativity? What undisguised advantages did it have over the theories of Lorentz, Ritz and others?

The answer leads one to Einstein's Kantian bias once more . The Einsteinian approach in the Kantian vein illuminates Einstein's seemingly puzzling remarks that despite this undetermination at any given time there **is** only one correct theory: the theory with the greatest power of unification at that time (Einstein 1918; see Beller 2000 for details).

We are usually told that in constructing special relativity Einstein had invented a "*theory of principle*", rather than a "*constructive theory*". Yet things are not that simple.

Indeed, it was Einstein himself who made a distinction between 'principle' theories and 'constructive' ones. Constructive theories try to "build up a picture of the more complex phenomena out of the materials of a relatively simple formal scheme from which they start out" (Einstein 1919 as quoted from van Dongen 2010, 49).An example of a constructive theory is kinetic theory that attempts at reducing mechanical and thermal properties of gases to movements of molecules.

On the contrary, principle theories do not start out from hypothetical constructions, but rather from empirically ascertained principles.

"Thus the science of thermodynamics seeks by analytical means to deduce necessary conditions, which separate events have to satisfy, from the universally experienced fact that perpetual motion is impossible'. In *explicitly Kantian* terms Einstein in 1919 distinguishes between the abovementioned kinds of theories: "principal theories employ the *analytic*, not the *synthetic* method" (quoted from van Dongen 2010, 50; my italics).

Prima facie it is to his boon companion Michele Besso that Einstein dedicated the only acknowledgement in his 1905d paper, the paper that stands out for its *lack of any reference to the literature*. Furthermore, in the 1905d paper "the failure of attempts to detect a motion of the earth relative to the 'light medium'" is used as evidential support only for *one* of the two basic postulates – for the "Principle of Relativity". The "Light Postulate" is introduced almost parenthetically, without any discussion of its experimental grounds. Only in the 1905e paper, while describing the 1905d paper results, Einstein drops a phrase: “the principle of the constancy of the velocity of light used there is *of course* contained in Maxwell’s equations” (Einstein 1989, 172). But for him the 1905d paper was only a provisional construct, only a milestone in realizing the unification programme. Einstein himself realized that

“a physical theory can only be satisfactory, if its structures are composed of elementary foundations. The theory of relativity is just as little ultimately satisfactory as, for example, classical thermodynamics was before Boltzmann had interpreted the entropy as probability “(Einstein to Arnold Sommerfeld on 14 January 1909; quoted from Stachel 2000, 10]).

So, the statement that 1905d paper contstututed a theory of principle is merely half of the truth. In reality the 1905d theory was a constructive one that only *posited itself* as a theory of principle (possibly due to tactical reasons for Einstein tried to save the STR from the scathing criticism directed against the light quanta). That is why two years later, trying to explain the STR foundations to broad physical community, Einstein humbly described his relativity theory as “an attempt to summarize the studies that have resulted to date from the *merger* of the H.A.Lorentz’s theory and the principle of relativity” (Einstein 1907, 253).

But the situation could not last over a long period of time. Einstein had to throw his cards up and to unfold the link between his 1905a and 1905d papers four years later. In 1909, in Salzburg, he made a report at the 81-st meeting of German Natural Scientists and Physicians under the heading “*On the Development of our Views on the Nature and Structure of Radiation*”. It represented practically the first effort to comprehend all his works as a whole. And it was one of the first public reports of the STR inventor dedicated to explanation of its foundations. The report starts with a succinct recapitulation of luminiferous ether theory that ends by an important phrase: “However, today we must regard the ether hypothesis as an obsolete standpoint”. Why? – What I want to stress is that for the answer Einstein dwells not to the Michelson-Morley or Fizeau experiments, but elucidates that

"It is even undeniable that there is an extensive group of facts concerning radiation that shows that light possesses certain fundamental properties that can be understood far more readily from the standpoint of Newton’s *emission theory* of light than from the standpoint of the wave theory. It is therefore my opinion that the next stage in the development of theoretical physics will bring us a theory of light that can be understood as a kind of *fusion* of the wave and emission theories of light”( Einstein 1909, 379; my italics).

And the abovementioned experiments are brought into consideration only in the context of the “cardinal aspect in which the electromagnetic theory agrees with, or, more accurately, *seems to agree* with the kinetic theory” (ibid).

### ***4. Conclusions.***

The basic claim to put forward is that to conceive many important facets of Einstein's special relativity creation and all his 1905 papers ***as a whole*** as well as the ***order*** of their presentation one should resort to Einstein's strenuous efforts to reconcile maxwellian electrodynamics and statistical thermodynamics. And to comprehend the importance of the latter one should turn to Neo-Kantian epistemology. However, this is not to assert that Einstein was a committed Neo-Kantian of Baden or Marburg schools.No.For instance, in a letter, written three weeks after the creation of General Relativity, Einstein applauded Moritz Schlick's critique of Kant:

"Truly masterful is your position to the doctrine of Kant and his followers.The trust in the 'apodictic certainty' of 'synthetic a priori judgements' is already heavily undermined if one realizes the invalidity of even just one of these judgements" (14 December 1915, A.Einstein to M.Schlick, quoted from van Dongen 2010, 46).

All in all, Einstein's true overall philosophical standpoint was eclecticism. But I insist that the most important Kantian concept necessary to understand Einstein's 1905 activity is Kant's regulative idea of the systematic Unity of Nature.

The basic problem of the paper is what was the train of thought that brought Einstein to his special relativity. Hence the first question to answer is why Einstein, being initially an adherent of the ether, became its strong enemy. To give a sober answer one has to turn to the very beginning of special relativity paper. It starts with discerning the "deep asymmetry" in the electromagnetic induction description. But Albert Einstein was by no means the first to note asymmetries in theoretical representation of the induction phenomenon**.** Hence the pertinent question is not how Einstein became aware of asymmetries and contradictions, but *what made them so intolerable to him.*

I think that the key answer to the questions posed lies in *other* works of Albert Einstein and first and foremost in his 1905 papers. It was Albert Einstein himself who had unfolded the basic asymmetry - of more deep nature – in the 1905a paper "*On an heuristical point of view concerning the processes of emission and transformation of light*" that was published in the same journal "Annalen der Physik" but three months before the relativity paper. In §1 of this thought-provoking paper Einstein discloses that joint application of mechanical and electrodynamical "theoretical pictures" for description of black-body radiation leads not only to contradiction with experiment, but to the ***paradox*** that cannot be swept under the carpet by common methods. Einstein's attraction to the subject of theory of quanta was provoked by its *unifying possibilities*, for its capacities to arrive at a *unification* of maxwellian electrodynamics and Boltzmann's statistical thermodynamics. Hence he starts the paper with the heart of what troubled him most – the Rift in the foundations of physics that was felt most sharply in Lorentz's Electron Theory (see also Nugayev 1985). How did Einstein intend to eliminate the contradiction?

To answer the question one should immerse himself in Einstein's first papers published in the "*Annalen*". *All* of them have one hallmark in common: statistical thermodynamics approach. Thomas Kuhn had shrewdly punctuated that *what brought Einstein to idea of photon was a coherent development of a research program started in 1902*. Thus, the conclusion that radiation in the cavity consists of independent energy quanta follows directly from application of general principles of thermodynamics and statistical mechanics to processes of radiation .

But all the experiments available in 1905 provided only *indirect* evidence in favour of quantum hypothesis. Hence, to try the ultra-revolutionary hypothesis of quanta, Einstein had to contrive a "crucial experiment" of the very peculiar kind: to compare the quantum results with the results of another entrenched theory build up independently of the 1905a theory. It is important that this theory should be sufficiently 'old' to accumulate the results of many experiments. So, if the 1905a paper results had coincided with the results of fairly different theory, they would have provided an especially reliable verification. It was the point where Kant's idea of the systematic Unity of Nature was applied. "A system has truth-content according to the certainty and completeness of its coordination-possibility to the totality of experience. A correct proposition borrows its 'truth' from the truth-content of a system to which it belongs" (Einstein 1946, 13). In the opposite case the 1905a theory would have been 'falsified' not by a single 'critical experiment' but by a multitude of the well-established experimental data.

Thus the next paper turned out to be crucial for verification of the 1905a one. In the 1905b paper Einstein elaborated the principles of Brownian motion directly verified by Perrin's experiments. Only after this "crucial experiment", that is only *after* the 1905b paper could Einstein look forward for investigating the consequences of his light quantum hypothesis, and so he returned to his forgotten "eine kapitale Abhandlung". Indeed,

> "if the monochromatic radiation (of sufficiently small density) in the sense of entropy dependence upon volume behaves itself as a discontinuous medium, consisting of energy quanta $R\beta\nu/N$ , a question occurs: *if they are not the laws of creation and conversion of light such as if it consists of similar energy quanta*?" (Einstein 1905a, 236; my italics).

That is the question put up by Einstein at the end of one of his 1905a paragraphs . *But the ether conception hampered the positive answer and put obstacles in realization of Einstein's statistical-thermodynamics programme.*

Hence the ether concept had to be abandoned and a special relativity theory based on two postulates should be set up. The two postulates - the relativity principle and the principle of light constancy - were quite sufficient, according to Einstein, to create the electrodynamics of moving bodies. Yet, for "the theory based on these two principles should not to lead to contradictory results, one must renounce the customary rule of addition of velocities " (Einstein 1910,125).

And namely that was done in «*On the Electrodynamics of Moving Bodies*", published several months *after* the photon paper.

To recapitulate, Einstein was undoubtedly influenced by Hume, Mach, Poincare, Hertz et al., that is reflected in innumerous documents that embrace letters, lectures, oral communications, etc. relating to different periods of his life. However, if one dwells into his scientific papers, trying to elucidate Einstein's *modus operandi*, one finds out sober reasons to believe that *actually*, at least in 1905, in his actual research practice, he had held an epistemological position very close to Neo-Kantian epistemology. And the most important Kantian concept necessary to comprehend Einstein's 1905 activity is Kant's regulative idea of the systematic Unity of Nature.

It is crucial that one has to appeal to Kant since the principles of simplicity, economy of thought, etc. are ineffective to resolve the theory-choice situation between the Lorentz ether theory and Einstein's STR. That is, all the abovementioned principles can not make a definite choice in favour of Lorentz's or Einstein's theories.Both theories are empirically-equivalent and mathematically identical. (We use Lorentz's transformations in transition from one inertial system of reference to another, and not Poincaré's).

The ether notion was relinquished not because it was a metaphysical, idle concept, an obsolete superfluous contraption, but since it turned out a snag for reconciliation of maxwellian electrodynamics and statistical thermodynamics that promised to pave the way to theory of quanta.In theory choice situation one chooses the theory that is more fruitful in empirical respect.

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