SPECIAL RELATIVITY AS A STEP OF UNCOILING THE QUANTUM PROGRAMME.

Abstract.

To make out in what way Einstein's 1905 'annus mirabilis' writings hang together one has to hang on Einstein's strive for unity evinced in his stubborn attempts to coordinate with one another the basic research traditions of classical physics. Light quanta hypothesis and special theory of relativity turn out to be mere milestones of maxwellian electrodynamics and statistical thermodynamics reconciliation programme. The conception of luminiferous ether was an insurmountable stumbling block for Einstein's statistical thermodynamics programme in which the leading role was played by the light quanta paper . Einstein's 1905 unificationist modus operandi was close to Mach's principle of economy of thought in conjunction with with bashful inclinations of Kantian epistemology.

***Key words*:** light quanta**,** special relativity**,** Mach, Kant.

1. Introduction.

It is a commonplace that Einstein's scientific contributions were highly motivated by the ideal of unity of physical laws. And it is well-known that all the scientific career of Einstein after the general relativity theory had been achieved (1915), was the vehement search for unitary theories. It is no wonder that the quest for unity of nature is best illustrated by *these* attempts of Einstein towards unitary theories during almost forty years than by his early works.

Yet, in my innermost conviction, Einstein's mature unification efforts had sprung out of his early writings and first and foremost out of his 1905 efforts to create special theory of relativity (STR), as well as out of his audacious 1905 light quanta hypothesis.First of all, Einstein's 1905a paper on light quanta starts with unfolding "a *profound formal difference* between the theoretical conceptions physicists have formed about gases and other ponderable bodies and Maxwell's theory of electromagnetic processes in so-called empty space" [Einstein 1905a: 86]. The paper aims at unification of the basic research traditions of classical physics.Moreover, Einstein's 1905d paper on SRT commences with scrutinizing an accordant "*deep asymmetry*" [Einstein 1905d: 140] in the description of electromagnetic induction.

The aim of the present paper is to take the next step and to unfold the abiding influence of unification on ***all*** *Einstein's 1905 writings.* Thus the next part of this paper deals with the circle of unification problems that bothered 1905 Einstein. The aim of the third part is to answer the question: what was the train of thought that provoked Einstein to invent light quanta and STR.

2. Apprehension of Breakthrough.

In Germany Maxwell's efforts to arrive at a reasonable compromise between the research programmes of Young-Fresnél, Faraday and Ampére-Weber [Nugayev 2015] were set forth by Hermann Helmholtz and his pupil Heinrich Hertz. In Helmholtz's paradigm charges and currents were taken as the sources of electrical and magnetic fields. It led 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 artful amalgamation 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 10 August 1899 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. […]
>
> 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].

From the outset of his scientific career Einstein had 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 took electric currents as real motions of such charges in empty space, and not as the 'Verschwinden elektrische Polarisation in der Zeit'. Einstein's views were drawn upon the lectures on electricity of his ETH physics teacher prof. H.F. Weber, as is indicated by Einstein's lecture notes (Doc. № 37 of [Einstein 1987: 223-225]).

The 'substantive' concept of electricity was advanced 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 recapitulating 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.

Though, Einstein's physics professor manifested no enthusiasm for his work, and Albert made no further mention in his correspondence of his activity in the electrodynamics of moving bodies for almost two years. Nevertheless ‘die prinzipielle Trennung von Lichtaether und Materie’, ‘Definition absoluter Ruhe’, etc. were among the topics he discussed with his friend Michele Besso (see Einstein’s 4 April 1901 letter to Marić). In March 1901 Einstein informed Miss 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, grounded ‘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 veracity 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, *no publication on this subject ensued for over three years – till 21 June 1905.* - Why? - 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 a moderate adherent of the ether, became its strong enemy?*

To provide a sober answer one has first to recall Einstein’s derogative evaluation of his ‘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 paper. On the other hand, now one knows for sure [Rynasiewicz 2000] that Einstein arrived at the body of results presented in his SRT 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.* 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].

3. What was the train of thought that brought Einstein to special relativity and light quanta?

To give a reasonable answer one should first delve into the SRT paper itself [Einstein 1905d]. The paper 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 sober reasons of SRT genesis it is quite important to note that *Albert Einstein was by no means the first to note asymmetries in theoretical representation of the induction phenomenon.* In 1885 they were indicated by Oliver Heaviside, in 1894 – by Herman Föppl, and in 1898 – by Wielhelm Wien [Darrigol 2001: 377].

The pivotal question is not how Einstein became aware of the asymmetries, but ***what made them so intolerable to him***.The key to answer 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. Moreover, 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 SRT paper:

"There exists **a *profound formal difference*** between the theoretical conceptions physicists have formed about gases and other ponderable bodies and Maxwell's theory of electromagnetic processes in so-called empty space" [Einstein 1905a: 86].

And in the first part of it Einstein excavates that *joint* application of mechanical and electrodynamic "theoretical pictures" for scrutinizing the black-body radiation leads not only to the contradiction with experiment (his paper did not even cite Lummer & Pringsheim or Rubens & Curlbaum results), but to queer *paradox* that cannot be circumvented by common expedients. To exhibit it, Einstein contrives a gedankenexperiment with both theories. He contemplates an imaginary 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 $\int_0^{\infty} \rho_\nu \, d\nu = (R/N)\,(8\pi/L^3)\, T \int_0^{\infty} \nu^2 \; \rho_\nu \, d\nu = \infty$."

Although it is commonly held that in the 1905a paper Einstein was concerned with an explanation of the photoelectric effect, the 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 delved into the contemplation of the profound *contradiction* between mechanics and electrodynamics and to the ways of resolving it.

So, ***what was a judicious reason of Einstein's deep interest to the contradictions*** between the mature physical theories?

According to '*Autobiographical Notes*'.

"It was Ernst Mach who, in his History of Mechanics, shook this dogmatic faith; this book excercised a profound influence upon me in this regard while I was a student. I see Mach's greatness in his incorruptible skepticism and independence; in my younger years, however, Mach's epistemological position also influenced me greatly…" [Einstein 1949a, 21].

The crucial element of Machian epistemology that persistently forged Einstein's creativity beginning from 1897 and till his last days was Mach's Principle of Economy of Thought. Mach commences his "*Science of Mechanics*" by maintaining that "Economy of communication and of apprehension is of the very essence of science" (Mach 1893/1999: 6).

Accordingly, in many writings, for instance, in his 1940 review of STR genesis, published in "*Science*", Einstein acknowledges that "the theory of relativity arose out of efforts to improve, with reference to *logical economy*, the foundation of physics as it existed at the turn of the century"[Einstein 1940/1954 : 329].

A judicious explanation of Einstein's reasons for arriving at his 1905a paper and its connections with the other 1905 ones can be found in his "*Autobiographical Notes*". The first stage of "the revolution begun by the introduction of the field" [Einstein 1949a : 37] consisted in the invention and in the consolidation of the Maxwellian electrodynamics. All the pre-maxwellian accounts of physical interactions were theories of interactions between several *material points*. Owing to Faraday and Maxwell, the *Electromagnetic Field* entered the classical physics as an element of physical reality having equal rights with the *Material Point*. The problem situation was characterized by

"the dualism which lies in the fact that the material point in Newton's sense and the field as continuum are used as elementary concepts side by side. Kinetic energy and field-energy appear as essentially different things" [ibid, p.37].

As *an inevitable* consequence of the dualism

a "fundamental crisis set in, the seriousness of which was suddenly recognized due to Max Planck's investigations into heat radiation (1900).The history of this event is all the more remarkable because, at least in its first phase**,** it was not in any way influenced by any surprising discoveries of an experimental nature"[ibid, p.37].

Max Planck's form of reasoning [$\varepsilon = h\nu$] apparently contradicted the mechanical and electrodynamical basis upon which his derivation depended.Yet

"My own interest in those years was less concerned with the detailed consequences of Planck's results, however important these might be. My major interest was: What general conclusions can be drawn from the radiation formula … concerning the structure of radiation and even more concerning the *electro-magnetic foundations of physics?*" [Einstein 1949a : 47].

Hence 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 successful *fusion* of electrodynamical (Maxwell) and statistical (Boltzmann) research traditions. Hence he starts the paper with the heart of what troubled him most – the 'Rift in the Foundations of Physics' 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 way out of the predicament, 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 scientific career Einstein was deeply impressed 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 passionately started to unfold statistical thermodynamics. The result was a series of three papers published in 1902 - 1904. *Namely they provide the clue for apprehendnding his 1905a paper on quanta, 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 χ. By the time he finished his 1903 paper, Einstein had recognized that χ 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 χ 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 χ 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 :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 1905a paper. The first part of it came to an end by revelation of the "ultraviolet catastrophe". *How did Einstein resolve the paradox?*

In the second part of 1905a Einstein applies thermodynamics, statistical mechanics and maxwellian electrodynamics to peer at the domain of empirical reality covered by Wien's radiation law. Joint application of the three mature theories enables Einstein to arrive at apparently deductive argument: if monochromatic radiation of frequency ν 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 ascertained 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 startling 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 kind .He had to compare the quantum results with the results of another entrenched theory contrived *independently* of the 1905a hypothesis. 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 substantially different problem situation, they would have provided an especially reliable verification of "photon hypothesis". Let us recall that

"A proposition is correct if, within a logical system, it is deduced according to the accepted logical rules. 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 1949a: 13].

In the opposite case the 1905a theory would have been 'falsified' not by a single 'critical experiment' but by a whole multitude of the well-established experimental data. Note 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].

As he 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]).

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.

"My principal aim in this [1905b work on Brownian motion] was to find facts that would guarantee as much as possible the existence of atoms of definite size… The agreement of these considerations with experience together with Planck's determination of the true molecular size from the law of radiation (for high temperatures) convinced the sceptics, who were quite numerous at that time (Ostwald, Mach) , of the reality of atoms" [Einstein 1949a: 45-47].

The importance of 1905b paper's 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]).

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 demonstrated 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 substantial snag****. It hampered positive answer and put insurmountable 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. In such a medium an elementary process of radiation is connected 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.

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]).

Thus 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, especially underscoring 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. 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 “raise to the rank of a principle the validity of the law of constancy of light velocity for all inertial frames” [Einstein 1936 /1954: 307] , i.e. *postulate a special "principle of constancy of velocity of light"(I).*

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

"Reflections of *this type* [i.e. on molecular structure of radiation] made it clear to me as long as shortly after 1900, i.e. shortly after Planck's trailblazing work, that neither mechanics nor electrodynamics could (except in limiting cases) claim exact validity. By and by I despaired of the possibility of discovering the true laws by means of constructive efforts based on known facts.The longer and the more despairingly I tried, the more I came to the conviction that only the discovery of a *universal formal principle* could lead us to assured results.*The example I saw before me was thermodynamics*" ([Einstein 1949a: 51]; my italics).

The latter point needs elucidation by turning to a basic source of Einstein's information on the history of physics – to Mach's "*Mechanics*".

The most profound case study of the interconnection between the principle of economy of thought and second law of thermodynamics in Mach's "*Mechanics*" is Stevinus's (1548-1620) theoretical scheme of statics. In his trailblazing "*Hypomnemata Mathematica*" (Leyden 1605) Stevinus investigated the mechanical properties of the inclined plane. His ultimate aim was to set up a general theoretical principle and then to proceed to partial cases that can be easily treated by quantitative means. To produce his pivotal gedankenexperiment, necessary to set up his general principle, Stevin contrives a triangular prism with no horizontally placed edges. Over the prism he lays an endless string on which 14 balls of equal weight are strung and tied at equal distances apart. (The string can be advantageously replaced by an endless uniform chain).

Now, the chain will either be in equilibrium or not.If one assumes the latter to be the case, the chain, since the conditions of the event are not altered by its motion, must, when once actually in motion, continue to move forever. In other words, it must present perpetual motion, which Stevin takes apparently absurd. Hence only the first case is conceivable and *the chain always remains in equilibrium.*

In the basic premise from which Stevin starts, that *the endless chain does not move,* there is contained only a *purely instinctive* cognition. He feels at once, and we with him, that we have never observed anything like a motion of the kind referred to . This conviction has so much logical cogency that one accepts the conclusion drawn from it respecting the law of equilibrium on the inclined plane without the thought of an objection, *although the law is slyly presented as the simple result of the experiment*. We cannot be surprised at this when we reflect that all results of experiment are obscured by adventitious circumstances (as friction, etc.), and that every conjecture as to the conditions which are determinative in a given case are liable to error. Thus Stevinus ascribes to instinctive knowledge of this sort a *higher authority* than to simple , manifest, direct observations!

As a result, the following question forces itself upon us: w*hence does this higher authority come?* If one recalls that scientific demonstration , and scientific criticism generally can only have sprung from the consciousness of the individual fallibility of investigators, the explanation is not far to seek. We feel clearly, that we ourselves have contributed *nothing* to the creation of this " *Instinctive Knowledge*", that we have added to it nothing arbitrarily, but that it exists in absolute independence of our participation.

According to "*Mechanics*", Stevinus's deduction is one of the rarest indicators that we possess in the primitive history of mechanics, and throws a wonderful light on the process of the formation of science generally, on its rise from instinctive knowledge. Every experimenter can daily observe in his own person the guidance that Instinctive Knowledge furnishes him. If he succeeds in *abstractly formulating* what is contained in it, he will as a rule have made an important advance in science. And it is perfectly certain for Mach that the union of the strongest instinct with the greatest power of abstract formulation alone constitutes the great natural inquirer [Mach 1893/1999: 27].

But how does this "instinctive knowledge" originate and what are its contents ?

- Everything which we observe in nature imprints itself *uncomprehended* and *unanalysed* in our percepts and ideas. In these accumulated experiences we possess a 'treasure store' which is ever close at hand and of which only the smallest portion is embodied in fine articulate thought. The circumstance that it is far easier to resort to these experiences than it is to nature herself, and they are, notwithstanding this, free, in the sense indicated, from all subjectivity, *invests them with a high value*. "*It is a peculiar property of instinctive knowledge that it is predominantly of a negative nature*" [Mach 1893/1999: 28]**.** We cannot so well say what must happen as we can what cannot happen, since the latter alone stands in devastating contrast to the obscure mass of experience in us in which single characters are not distinguished. Moreover, contends Mach, the other peculiar trait that is extremely important for the philosophy of science consists in that the reasoning of Stevinus has such a strong influence upon us because the result at which he arrives apparently contains more than the assumption from which he starts .

Furthermore, it often happens in the course of the advancement of science that a new principle perceived by some researcher in connection with a fact, is not immediately recognized and rendered familiar in all its generosity. If, throughout all facts, we clearly *see* and *discern* a principle which, though not admitting of proof, can yet be known to *prevail*, we have advanced much farther in the consistent conception of nature than if we suffered ourselves to be overawed by a specious demonstration .

Eventually,

"It is more in keeping, furthermore, with the *economy of thought* and with the aesthetics of science, directly to *recognise* a principle (say that of the statical moments) as the key to the understanding of *all* the facts of a department, and *really* see how it *pervades* all those facts, rather to hold ourselves obliged first to make a clumsy and lame deduction of it from unoblivious propositions that involve the same principle but that happen to have become earlier familiar to us" [Mach 1893 / 1999: 82].

On my view, ***all the abovementioned Stevin-Mach recipes where ingeniously implemented by Einstein in formulating the basic SRT principle – the principle of relativity.*** Though due to ultra-revolutionary and extremely speculative nature of light-quanta hypothesis he could not afford himself to reveal the link with the 1905a paper directly. Hence he applied all the Stevin-Mach technique of conviction *to posit his electrodynamics of moving bodies in phenomenological wake.* One should especially take into account the *negative character of the relativity principle* and the peculiar manner of its connections with experiments and observations that is closer to instinctive knowledge subtle conviction technique than to coarse inductive way of inference. Look at the beginning of the SRT paper:

"Examples of a similar kind , and the failure of attempts to detect a motion of the earth relative to the 'light medium', lead to the ***conjecture*** that not only in mechanics, but in electrodynamics as well, the phenomena ***do not*** have any properties corresponding to the concept of absolute rest, but that in all coordinate systems in which the mechanical equations are valid, also the same electrodynamic and optical laws are valid, as have already been shown for quantities of the first order.We shall raise this conjecture (whose content will be called 'the principle of relativity' hereafter) to the status of a postulate and shall introduce, in addition, the postulate, only seemingly incompatible with the former one, that in empty space light is always propagated with a definite velocity V which is independent of the state of motion of emitting body" ([Einstein 1905d: 140]; my italics).

Appeal to *instinctive knowledge* easily explains the fact that the special relativity paper stands out in all the world scientific literature for the *complete lack of quotations*.

And since, according to "*Autobiographical Notes*", Einstein's new theory was created as a result of encounter of Newtonian mechanics and Maxwellian electrodynamics, its basis should consist of a *minimum* of two postulates, (I) the first drawn from classical mechanics (the principle of relativity) and (II) the second one transferred from the Maxwell-Lorentz electrodynamics (the principle of the constancy of light). Namely,

(I) "*Classical mechanics*, of which it could not be doubted that it holds with a close degree of approximation, teaches the equivalence of all inertial systems or inertial 'spaces' for the formulation of natural laws, i.e., the invariance of natural laws with respect to the transition from one inertial system to another" [Einstein 1954: 369].
(II) "This [the special theory of relativity] takes over from the *theory of Maxwell-Lorentz* the assumption of the constancy of the velocity of light" [Einstein 1940 /1954: 370].

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 elicited 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.

Hence the abovementioned question should be scrutinized: ***why Einstein in the 1905d relativity paper did not cite his 1905a paper on light quanta?***

Writing to his 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, making 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 existence of light quanta was absent. It famously appeared only circa 1923 (the Compton effect).

Moreover, the 1905d paper was for him only a provisional construct, just a milestone in implementing the unification programme:

"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]).

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 self-explanatory heading "*On the Development of our Views on the Nature and Structure of Radiation*". It represented practically the first effort to comprehend all his sundry writings as a whole. And it was one of the first public reports of the SRT inventor dedicated to expounding of its foundations. The report starts with a succinct recapitulation of luminiferous ether theory that ends by an intriguing question: “However, today we must regard the ether hypothesis as an obsolete standpoint”.

Why? - 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].

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” ([Einstein 1909: 379]; my italics).

4. Conclusions.

All of the above is not to assert that 1905 Einstein was a committed Machian incapable to draw upon the other epistemological sources.

No. Sober divergences of opinion with Mach sprung out not only from stubborn development of atomic theory by Einstein through his 1905 scrutinizing of Brownian motion [Einstein 1905b] but also consisted in advancing the similar idea of ‘atoms of light’([Einstein 1905a]; see also [Einstein 1936 /1954: 302] for details) .To understand the more profound reasons of the abovementioned divergences one has to turn to Einstein’s true overall philosophical standpoint. It can be characterized as ‘*eclecticism*’, and one cannot elude from his famous passage from 1949 “*Reply to Criticism”* [Einstein 1949b: 684]. More thoroughly, Einstein’s own philosophy of science can be characterized as an ingenious *fusion* of the elements drawn from sources as diverse as Machian empiricism, Duhemian conventionalism and neo-Kantianism [Howard 1994].

Yet the 1905a light quanta hypothesis turned out a ***constructive*** model of radiation; so later Einstein recalled of Mach’s legacy:

“He [Mach] did not place in the correct light the ***essentially conctructive*** and speculative nature of all thinking and more especially of scientific thinking; in consequence, he condemned theory precisely at those points where its ***constructive-speculative*** character comes to light unmistakably, such as in the kinetic theory of atoms” ([Einstein 1949a : 13]; my bold italics).

The constructive character of light quanta hypothesis brings Einstein’s thought closer to Kantian epistemology, the proximity to which was already accentuated by many Einstein scholars ([Lenzen 1949 : 380]; [Northrop 1949: 390]; [van Dongen 2010: 49]).

It is a platitude that Einstein emphasized that the basic concepts of science are *free creations* of the human mind. In that respect Einstein's views were evidently close to Kant. And 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. Even mathematics – maintained to be most stable and certain because of its being analytical – was comprehended by Kant as an *a priori synthetic judgement.* According to "*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.

The Kantian tenet of the intuitive character of mathematics means the limiting of mathematics to those objects that are constitutable [Kant 1787/1998: 196]. 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. He grappled with the problems of ***reconciling*** the interrelations of different classical physics 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 famously 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]).

As Einstein recalled later: 'The real is not given [gegeben] to us, but put to us " [Einstein 1949b: 680], i.e. 'constructed' by our research activity.

It is well-known that Einstein's philosophical evolution after the General Relativity (1915) carried him 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. I am not contending here that Einstein of 1905 was a thorough (neo) Kantian, trying to implement the abstracts tenets of

“Critique” into his mundane research practice. Yet *the Kantian seeds of Einstein’s late methodology lie in his 1905 fruitful efforts to reconcile the basic classical physics research traditions.*

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