100 YEARS of RELATIVITY: CRUCIAL POINTS

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This is a concise review of the main steps in the process of making the relativity theory.

§1. Introduction

The theory of relativity is, probably, a unique theory in the history of human knowledge that attracted so much attention of the general public. The reasons of such an interest are quite diverse and we are not going to discuss them here. We have only to regret that at present physics seems to lose the credit it had not so many years ago. That is why it was very to the point that the year 2005 was declared the World Year of Physics as a sign of a worldwide celebration of the "Annus Mirabilis", i.e. 1905, the year marked by many outstanding discoveries including the theory of relativity.

Unfortunately this very good move was largely spoiled and depreciated by reducing this celebration to glorification of one single person while other contributors to the powerful breakthrough in physics which happened in the beginning of the XXth century were unfairly put in oblivion.

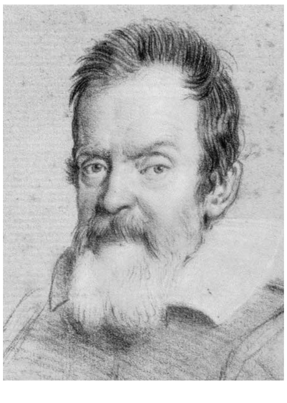
I am aware that I can hardly improve the general trend but I will try, at least in my talk, to correct this unfairness and to give a more balanced vision of the genesis of the theory of relativity.

§2. Prehistory

Relativity was known in physics long before 1905. Some vague ideas on this subject can be found already in writings of ancient Greek and Arab philosophers or of medieval European scholastics.

Actually **the principle of relativity** can be traced back to Galileo Galilei. In his famous "Dialogo sopra i due Massimi Sistemi del Mondo, Tolemaico e Copernicano"("Dialogue concerning the two Chief World Systems, Ptolemaic and Copernican"), appeared in 1632 and banned by Pope Urban VIII, the great Italian wrote:

"...have the ship proceed with any speed you like, so long as the motion is uniform and not fluctuating this way and that. You will discover not the least change in all the effects named, nor could you tell from any of them whether the ship was moving or standing still "[1]. In modern language the mentioned observation of "all the effects" meant all possible physical experiments inside a uniformly moving ship.



Galileo Galilei (1564-1642)

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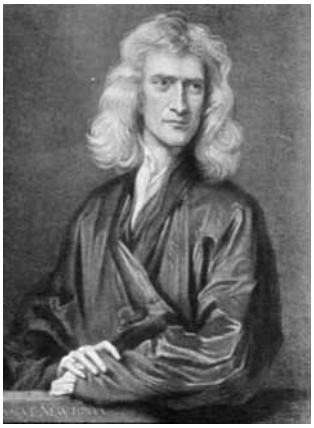
Sir Isaac Newton was also aware of the relativity of the uniform rectilinear motion. He wrote in his famous "Philosophia Naturalis Principia Mathematica" (1687) [2]:

"The motions of bodies included in a given space are the same among themselves, whether that space is at rest, or moves uniformly forwards in a right line without any circular motion."



Sir Isaac Newton (1642-1727)

Nonetheless Newton devoted special attention to the fundamental concepts of absolute time and absolute space.

"Absolute Space, in its own nature, without regard to anything external, remains always similar and immovable."

"Absolute, True and Mathematical Time, of itself and from its own nature flows equably without regard to anything external, and by another name is called Duration."

These Newton's basic statements survived till the end of the XIXth century. Why did he keep so to these fundamentals? He must have a serious reason for that. The reason was that while one can relatively easily accept the equivalence of the reference systems moving rectilinearly and uniformly relative to each other, it is impossible for reciprocally accelerated systems. The famous "bucket argument" of Newton was quite impressive and persuasive. There just must exist "something" relative to which the rotation proceeds. And this was the Newton Absolute Space.

Many years later Ernest Mach dared to challenge this notion and pushed forward some (a bit vague) argument that the acceleration has to be referred to "distant fixed stars" the interaction with which should give to "ponderable bodies" their inertia. He also was quite severe to the absolute time:

"This absolute time can be measured by comparison with no motion; it has therefore neither a practical nor a scientific value; and no one is justified in saying that he knows aught about it. It is an idle metaphysical conception."

Ernest Mach was neither the first nor the only, who treated these notions quite critically. Nonetheless his writings rendered quite a strong impression on his contemporaries and gave a definite new impetus to further speculations on fundamental issues of time and space.

Ernest Mach (1838-1916)

§3. Aether

Newton, who expressed interbody interactions quantitatively in his Second Law and gave a universal gravitation law, accepted the action at a distance because he, probably, saw that for practical purposes it is quite sufficient while the very nature of the interaction asks for new hypotheses which he endeavoured to avoid ("Hypotheses non fingo"). The problem had been identified long before Newton. Say, Aristotle (in contrast with Leukippus and Democritus) argued that the empty space is absurd and there must exist some medium which fills the whole space and which was considered as a " fifth element" or " quintessence". The idea of "aether" (below we will use the simplified spelling "ether" as well) was strongly advocated by René Descartes and then by one of the founders of the wave theory of light Christiaan Hyugens (followed by Thomas Young and Augustin Fresnel more than hundred years later). Newton, who vigorously objected Hyugens' theory, later himself advanced some aether-like model to explain optical phenomena.

There were many attempts to construct a mechanical model of the ether (they still continue in our days). Great Scottish physicist James Clerk Maxwell, who systematized a huge number of various results concerning electromagnetic phenomenae and formulated his famous system of differential equations for electric and magnetic fields, invented quite a complicated model of ether to mechanically interpret his equations. Now some "wise and clever" historians of science often consider these attempts in a quite arrogant manner as evidently wrong and naïve. We can hardly agree with such an attitude if we try to place ourselves into the XIII-XIX centuries marked by enormous successes of Newton's mechanics. Moreover mechanical models of the ether were, even if transient, unavoidable and necessary trial steps towards new horizons. And the very idea of the ether played a progressive role.

Some discontent had been felt, though, about this important element of nature. Thereof the growing need in more direct manifestations of the ether. As the aether was associated with Newton's absolute space it was understood quite early that one could detect the effects of motion through the aether experimentally. And this concerned first of all the light propagation which was identified as a propagation of perturbations of the aether.

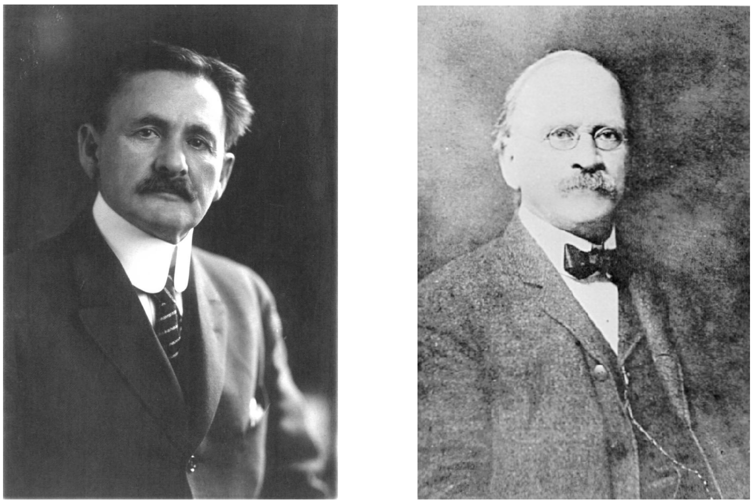
§4. New turn

And it was J.C. Maxwell who initiated a new turn in the search for the ether effects when he suggested (1878) to measure the effect of the "aether wind".

James Clerk Maxwell (1831-1879)

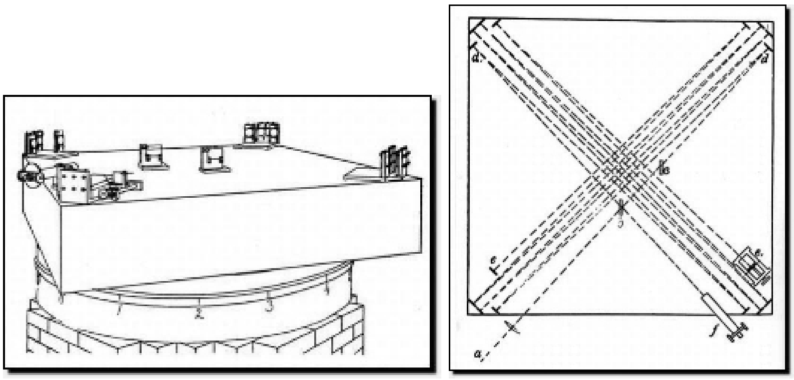
He did this in a year to his death as if indicating to his successors the way to unravel the mystery hidden in his legacy, the Maxwell equations. The way led them in the right direction.

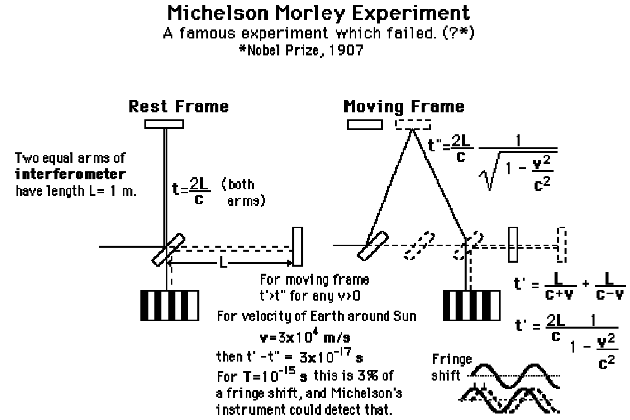
The experiment was conducted by American Albert Abraham Michelson in 1881 and later, with better accuracy, in 1887 (together with Edward Williams Morley).



Albert A. Michelson (1852-1931) and Edward W. Morley (1838-1923)

The scheme of experiment was remarkably simple but Michelson and Morley had to use all their skill and exert their every effort to achieve the necessary accuracy to measure the shift of the interference fringes due to would-be the “aether wind”. Just look at their facility and the scheme of the experiment.





The data obtained indicated that within the error bars the effect of the shift was absent, i.e. there was no an "ether wind".

The conclusion was: ***"It appears, from all that precedes, reasonably certain that if there be any relative motion between the earth and the luminiferous ether, it must be small; quite small enough entirely to refute Fresnel's explanation of aberration*** (*So called "partial ether drift" hypothesis with help of which A. Fresnel explained the visible position of stars accounting for the Earth movement. V.P.*). And further: ***"If now it were legitimate to conclude from the present work that the ether is at rest with regard to the earth's surface, according to Lorentz there could not be a velocity potential, and his own theory also fails."***

What was the theory of Lorentz mentioned above? We shall concern it a bit later.

Just the same year 1887 as of the Michelson - Morley experiment an article of Göttingen professor Woldemar Voigt appeared. This article dealt with some "elastic theory of light" and was not devoted to the problem of the "aether wind". But in the course of consideration of the invariance of the wave equation in moving reference systems Voigt has found that corresponding transformations from a system at rest to a system moving with constant velocity **v** included not only the change of coordinates (Galilei transformations) but also the change of time!

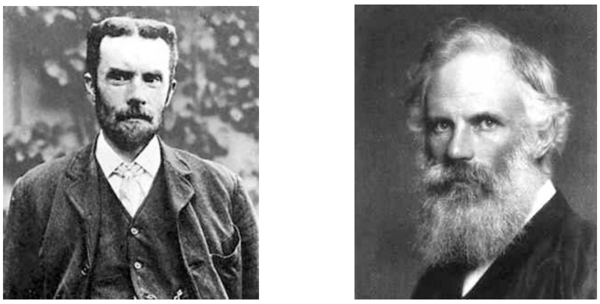
Here are Voigt's transformations (**c** stands for the velocity of light):

$$x' = x - vt, \quad y' = y\sqrt{1 - v^2/c^2}, \quad z' = z\sqrt{1 - v^2/c^2}, \quad t' = t - vx/c^2 \qquad (V)$$

Woldemar Voigt (1850-1919)

For the first time in history of physics time was subjected to a non-trivial change dependent on space. What was the meaning of this new time t'? Voigt did not provide an answer, he even did not pose the question. As to the Michelson-Morley experiment Voigt tried to explain it a year earlier, in 1886, but the arguments were not very persuasive.

Meanwhile the British physicists made some very important steps. First, Oliver Heaviside managed to calculate the form of electromagnetic field of a charge moving with constant velocity smaller than that of light. The field, according to Heaviside's solution, becomes flattened in the direction of motion, so that the equipotential surfaces are not spherical, as in rest, but form ellipsoids. The result was obtained in 1889 and soon the friend and colleague of Heaviside, George Francis FitzGerald, wrote an extremely short note without a single formula (but everybody could easily derive it) in which he argued that if the ***"electric forces are affected by the motion of the electrified bodies relative to the ether"*** then the molecular forces have to be affected too and ***"so the size of a body alters consequently".*** This length contraction exactly compensated the imbalance in optical paths, which was expected to give the shifts of the interference fringes in the Michelson-Morley experiment. The measure of such a shortening had been given by the same factor $\sqrt{1 - v^2/c^2}$ as in Voigt transformations (V). (It is worth noticing that this factor named later "Lorentz factor" had been contained already in Heaviside's papers of 1888-1889 in which many ideas and results of the relativity theory were anticipated and obtained.)



Oliver Heaviside and George Francis FitzGerald
(1850 -1925) (1851-1901)

Thus by the end of the XIX century quite important fragments of a completely new understanding of the electrodynamics of moving bodies related with invariance of Nature under some space-time transformations begun to show up.

A very impressive breakthrough was made by Cambridge professor Sir Joseph Larmor. In 1900, just between the two centuries, he published a book "Aether and Matter" in which he summarized his results, obtained in 1894-97 and published in the articles in "Philosophical Transactions".

Sir Joseph Larmor (1857 -1942)

First of all Larmor had found the space-time transformations which differed from the Voigt ones (V) by different placing of the factor $\sqrt{1 - v^2/c^2}$:

$$x' = (x - vt)/\sqrt{1 - v^2/c^2}\ , \quad y' = y, \quad z' = z, \quad t' = (t - vx/c^2)/\sqrt{1 - v^2/c^2} \qquad \text{(L)}$$

In fact these transformations were presented not directly in this form but rather as a combination of two consequent transformations which nonetheless result exactly in the form (L). Larmor proved that the transformations (L) left the Maxwell equations form-invariant and that the FitzGerald-Lorentz contraction is a direct consequence of these transformations.
He also had found that one had to use a new addition rule for velocities which is now known as "relativistic addition rule".

And, finally, he discovered that time runs differently in different reference systems ("relativistic time dilation").

§5. Lorentz

In 1892, i.e. three years after the article of FitzGerald, the very same idea about the length contraction was pushed forward by a Dutch physicist Hendrik Antoon Lorentz. As early as 1886 he argued that the first Michelson's experiment had too low accuracy for measurements of the "ether wind" effects, and it was his theory mentioned in the Michelson-Morley article as ruled out by new measurements of 1887.

The argument with the length contraction "saved" the theory of immovable ether but some new experiments were suggested where this argument was not sufficient and the ether still had to be "seen". For instance, the famous Trouton and Noble's experiment (1903) with moving electric condenser which had to show effects sensitive to the absolute motion of the Earth, gave the negative result as well but in this case the FitzGerald-Lorentz contraction already did not work to explain the data. Rayleigh (1902) and then Brace (1904) had found that optical properties of moving bodies did not change in spite of their spatial contraction.

One has to add the experiments with cathode or β-rays (electrons) performed by W. Kaufmann (1902) which revealed a striking feature: electrons, when their velocities were high enough, moved as if their mass depended on their velocity!

This undermined Newton's mechanics, which was one of the cornerstones of the "electron theory". Lorentz accepted the challenge and looked for explanations of new difficulties. We have to keep in mind that Lorentz completed a hard work on erecting a universal theory , "electron theory" of matter and fields which explained a huge amount of observed phenomena; contemporaries even called it the "Maxwell-Lorentz theory". Here is Poincaré's opinion: "***The most satisfactory theory is that of Lorentz; it is unquestionably the theory that best explains the known facts, the one that throws into relief the greatest number of known relations…"***

It would be natural for Lorentz to rectify and improve this powerful instrument to account for phenomena in moving media and to make his theory universal. As early as 1895 he published the article "Versuch einer Theorie der elektrischen und optischen Erscheinungen in bewegten Körpern" ("Inquiry into a Theory of Electrical and Optical Phenomena in Moving Bodies"). In this paper he rediscovered the time transformation suggested by W. Voigt 8 years before (see at $\mathbf{t'}$ in Eq. (V)). He called this combination "local time" and considered it as an auxiliary mathematical notion that has nothing to do with a "real" (absolute) time **t**. New challenges initiated the next (and in some sense decisive) step which was made in 1904.

Hendrik A. Lorentz (1853-1928)

Lorentz managed to come to the correct space-time transformations (L), which left Maxwell equations invariant, i.e. he showed that the movement through the ether was artfully compensated by this very movement as the ether influenced the moving bodies exactly in such a way which enabled it to remain “hidden”.

Though his proof contained some errors, and was not quite a general, *grosso modo* Lorentz came to the theory which could explain and describe the observed phenomena, including those in moving bodies without limitation on their velocities except that imposed from above by the velocity of light.

It is worth noticing that neither Lorentz nor Larmor put the principle of relativity into the basis of their theories.

§6. Poincaré

The personality of Jules Henri Poincaré cannot be labeled by usual terms “physicist, mathematician, philosopher” or else. I would prefere the term “thinker” or even “great thinker” of the stature of Plato, Newton or Descartes.

Since the 90-ies of the XIX century he watched closely and with growing interest the attempts to understand the absence of the “ether wind” and to reconcile it with the Galilei-Newton relativity principle. It was not a passive watch, though. Due to his profound intuition, philosophical attitude and mathematical experience (he was himself creator of many mathematical disciplines) Poincaré possessed a much more wide and general vision of the situation than others. Thus, in 1898 he put under a thorough logical analysis the notions of time and simultaneity, a key element to define the former. It is in this paper he postulated the constancy of the speed of light as an improvable convention to give a sense to our reasonings. So the non-absolute character of time became evident. Nobody before reflected on time in such a way. It is not astonishing that the Voigt-Larmor-Lorentz “local time” $\mathbf{t' = t - vx/c^2}$ became the next target of his speculations.

In 1900 he wrote an article (a contribution to a jubilee volume in honor of Lorentz), in which he showed that this “local time” $\mathbf{t'}$ is in no way less physical that the “rest time” $\mathbf{t}$ and that this is the time which is measured by the observers in a moving reference system. One of the “byproducts” of this article was establishing of the fact that any radiation possesses inertia, i.e. now so famous $\mathbf{E=mc^2}$ (rederived by Einstein in 1905, in a wrong way, though).

In the same 1900 he warned that even skilful use of new and new *ad hoc* hypotheses to save the theory is inadmissible and one has probably to completely change the paradigm.

His general views were presented in a world-wide known book “La science et l’hypothèse”, a genuine masterpiece published in 1902 and then republished and translated in other languages many times.

Henri Poincaré (1854-1912)

Just one citation from this book:

"There is no absolute uniform motion, no physical experience can therefore detect any inertial motion (no force felt), there is no absolute time, saying that two events have the same duration is conventional, as well as saying they are simultaneous is purely conventional as they occur in different places ".

These lines remind those of Galilei. But now they meant that impossibility to detect the absolute motion referred not only to the mechanical effects but to any kind of natural forces.

The statement was reinforced 2 years later in 1904 at the International Congress on Art and Sciences in St. Louis (USA), where he paid a special attention to:

"The principle of relativity, according to which the laws of physical phenomena should be the same, whether to an observer fixed, or for an observer carried along in a uniform motion of translation, so that we have not and could not have any means of discovering whether or not we are carried along in such a motion".

The principle was put into the basis of a new theory, which was presented in less a year, in 1905.

First as a short, signal version (June 1905) and then as an extended, detailed article (sent to the journal "Rendiconti del Circolo Mathematico di Palermo" in July 1905, published in 1906).

In these articles beared the common title "Sur la dynamique de l'électron" Poincaré provided the general basis for what is called now relativistic physics. The mathematical apparatus presented in these articles was a new, powerful tool for further exploration of Nature and which is in active use up to now. I do not enlist in detail numerous striking results by Poincaré, they are commented in detail in Refs [5, 6]. I would like only to specially mention the first relativistic treatment of gravitation given by Poincaré that proved once more that he designed a universal theory valid for every kind of force, even still unknown.

If you have a chance to read Poincaré's articles you can get the impression that he was somehow uncertain about the ether. This uncertainty, as we can see at present, was not groundless. The further development of the quantum relativistic theory led to the awareness that "empty space" does not take place in Nature, and that the substance we call "vacuum" is a complicated medium in which, say, fluctuations of electromagnetic fields or averages of other fields by no means are zero. Probably, Poincaré intuitively understood or felt this. That is why he even did not try to give a mechanical model for the ether and actually denied it. Nonetheless, he preserved such a notion for the time being, at least for "metaphysicists". As to some attempts to ascribe to Poincaré the adherence to the "ether" as a privileged reference system, we have only to mention the group character of the Lorentz transformations discovered by Poincaré.

However that might be, for the further development of physics and technology "the problem of ether", as it was posed in the XIXth century, was absolutely irrelevant. Equations gave all the necessary.

Now I feel that some of you are a little bit worried that one name is still not mentioned. And, yes, this is the name of a person in honour of whom the Year 2005 was named.

§7. Einstein

It is difficult to find any other person in history of physics whose popularity and fame were so immense. His name became synonymous of human geniality and the "pedestrian" will reply without delay to the question: "Who is the greatest scientist of all times?"

If you ask him why, he, poor victim of the mass media, will, most probably, refer to "scientists". Well, you go to the scientists and quickly learn that most of them, indeed, keep the same opinion about Einstein, mostly because of his pioneering paper on relativity, though… they never read his papers. For instance, the famous mathematician, A. Grothendieck, after having said a lot of lofty words about the greatness of Einstein and his own congeniality to the latter, in his

"Récoltes et Semailles", writes then: ***" Je ne prétends nullement être familier de l'oeuvre d'Einstein. En fait, je n'ai lu aucun de ses travaux, et ne connais pas ses idées que par ouïe-dire et très approxomativement." ("In no way I pretend to be familiar with the work of Einstein. In fact I have read none of his works and know about his ideas by hearing only and quite approximatively.")*** Quite a typical example.

We can also hear that Poincaré was "close" but could not "make a decisive step" to formulate the theory of relativity, but now again you learn quickly that your interlocutors…did not read Poincaré's papers either! But in spite of this, all your arguments will be in vain because "everybody knows that…" or "it is impossible that so many famous authors in so many books…" etc.

As is known, Albert Einstein's paper "Zur Elektrodynamik bewegter Körper" ("On the Electrodynamics of Moving Bodies") was finished and sent for publication in "Annalen der Physik" exactly between the submissions of the two Poincaré's papers mentioned above, 23 June 1905.

In this paper the author presented his derivation of the space-time transformations (L) from the "first principles": the relativity principle and "principle of the constancy of the speed of light".

The starting point for such a derivation was a procedure of clocks synchronization that appealed to the argument about the non-absolute character of simultaneity. With transformations (L) so derived it was also emphasized that there was no need in any kind of a "luminiferous" milieu or "ether". The article also contained important physical examples and consequences, such as "time dilation", new aberration formula, relativistic Doppler-effect, new addition rule for velocities etc. While all the authors we considered above had taken the transformations (L) as a fact related, e.g., to the invariance of the Maxwell equation or abstracted step-by-step from observations, Einstein had made an attempt to derive them from some more general premises.

Albert Einstein (1879-1955)

As we have seen all these results were obtained by others, sometimes much in advance. The only distinctive feature could be the explicit formulation and the use of the relativity principle. But this principle was formulated by Poincaré at least one year earlier. One of the statements in Einstein's paper, which is often considered as its special merit and Einstein's great and bold idea, was the elimination of the ether. It was actually declared that particles and fields are immersed into the "empty space". So to say, "back to Democritus".

Einstein did not give any direct references to other authors, who worked on the problem. This causes many disputes up to now. Sometimes one can read that Einstein was a young researcher who worked in isolation from the "big science" and had a very limited access to the current literature, journals first of all. So that he just did not know about other papers. He is often pictured as a poor (but strikingly talented) clerk at the Patent Office in Bern who just due to an enormous power of his mind managed to achieve that, what all those old, highly paid and honored professors and members of academies failed to do. Such a romantic and touching picture must impress very much petty-bourgeois Philistines whose taste was formed by happy-end cinema and novels.

Reality was, as always, different. First of all Einstein was not a beggar being an employee of one of the most respectable European agencies of intellectual property. We also have to keep in mind that all the newest information on sciences and technology passed regularly through this agency, including all most important scientific journals and reviews. To work actively on one of the most discussed subject in physics and not to read the last news in this field to which you have a full access? Come on! Just try to imagine yourself in such a situation.

As was said, Einstein "killed" the ether ruthlessly, while Poincaré hesitated. This fact is often used as a proof of the ideological superiority of Einstein over Poincaré. But here is a quotation from Einstein's talk given in 1920, i.e. 15 years since his first article on relativity:

"There are weighty arguments to be adduced in favor of the ether hypothesis. To deny the ether is ultimately to assume that empty space has no physical qualities whatever, the fundamental facts of mechanics do not harmonize with this view. According to the General Theory of Relativity, space is endowed with physical qualities; in this sense, therefore, there exists an ether. According to the General Theory of Relativity space without ether is unthinkable."

It does not mean that Einstein in 1920 contradicted to Einstein in 1905. In the latter case the matter concerned some simplistic, mechanical ether models, which had nothing to do with a still in many respects unknown "new ether" (it remains largely unknown at present, though) understood as a physical space which is by no means "empty". For Einstein it was the curved space whose geometry reacts to the presence of matter. As to the "general" relativity, would-be generalizing the "special " one, we only can quote from the Russian scientist V.A. Fock:

"Since the greatest possible uniformity is expressed by Lorentz transformations there cannot be a more general principle of relativity than that discussed in ordinary relativity theory. All the more, there cannot be a general principle of relativity which would hold with respect to arbitrary frames of reference."

In spite of all that, there is no doubt, Einstein was one of the original and outstanding contributors to the relativity theory as well as many other fields of contemporary physics.

I would like to emphasize that his special role (maybe not always voluntary) was also that, due to his personal glorification (often close to idolization) and to his image of a scientist "not of this world", the very subject of physics in general, and of the relativity theory in particular, became worldwide known and winning for general public. This fancy story attracted to the research work in physics a lot of new talented women and men who made afterwards their own significant contributions in various fields.

§8. Minkowski

In his second memoir of 1905 on the relativity theory (published in only 1906) Poincaré, among other important ideas, assimilated the Lorentz transformations to the rotation in some 4-dimensional space where the role of the fourth coordinate is played by $\mathbf{ct\sqrt{-1}}$, i.e. purely imaginary number.

This idea was essentially developed by the German mathematician Hermann Minkowski. He gave an overall geometrical, "pseudoeuclidean" vision of the 4-dimensional world in which, according to him, time and space had lost their individuality:

"From henceforth, space by itself, and time by itself, have vanished into the merest shadows and only a kind of blend of the two exists in its own right."

Hermann Minkowski (1864-1909)

Contrary to the widely spread conviction, Einstein had a very vague understanding of the geometrical meaning of the relativity (it was mentioned, e.g., by Minkowski himself) as a theory of the pseudoeuclidean spacetime. Only by 1912 Einstein could appreciate all the power of the Minkowski formulation.

Minkowski elaborated the mathematical apparatus (4-dimensional tensor calculus) which helped to cast all formulas of the relativity theory and of physics in general into quite a concise and elegant form. Minkowski introduced many other new notions that appeared very well adapted to relativistic physics and are in active use up to now: ***Minkowski tensor, Minkowski space*** *(it was actually introduced by Poincaré)****, timelike and spacelike vectors, light cone, proper time etc.***

§9. Russian connexion

By no means 1905 was the year of the end of the relativity theory completion. Many things remained to be done and understood and were done and understood afterwards.

In this respect we find it opportune to recall the Russian physicist Vladimir Sergeyevitch Ignatowski, a renowned researcher in electrodynamics and theory of optical measurements. He worked in Berlin just in the time of active work of European scientists on relativity. His concern was the derivation of the "Lorentz transformations" (L). As was said above it was also Einstein's concern in his famous 1905 paper on relativity. Unfortunately his derivation was correct for only one special case: for the front of the light wave (or for the photon in modern terms). For massive bodies the derivation of Einstein does not go through, i.e. actually he conjectured the Lorentz transformations for the general case.

His postulate of the constancy of the speed of light was perceived by many readers of his paper as unnecessary. V.S. Ignatowski was the first who managed, in 1910, to derive the Lorentz transformations from such general inputs as the relativity principle, reversibility of transformation (which results from the group property discovered by Poincaré, though), isotropy and homogeneity of space and time. He proved then that Lorentz transformations follow from these inputs with one unknown "world constant" which can be readily identified with the maximum possible speed (in inertial frames). The application of these transformations to the Maxwell equations shows that this is also the speed of light.

Vladimir Sergeyevitch Ignatowski (1875-1943)

In other words, Ignatowski proved that the second Einstein's postulate was superfluous. For instance, if the photons were massive all the arguments based on the light signals would be false. But the upper limit on the velocities in inertial frames would remain intact.

§10. Conclusion

The history of relativity (as any other history) was, is and will be the subject of many different opinions and disputes.

The widely spread opinion which we mentioned already above is exemplified by the following citation from the talk of the famous German-American mathematician Hermann Weyl in Munich 24 October 1950 devoted to the 45-th anniversary of the relativity theory:

"…Grundlagen und Ausbau der Relativitätstheorie das Werk eines Mann sind: Albert Einstein."

("Foundation and creation of the theory of relativity are the work of a single person: Albert Einstein.")

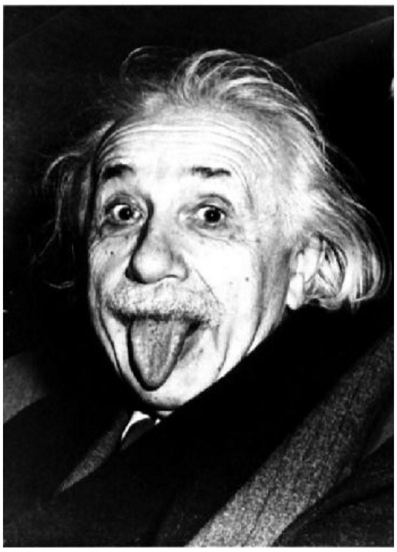
However the facts witness that "foundation and creation of relativity" was a long and hard work of many what is in a blatant contradiction to the writings of professional myth-makers who try instead to imply, with a false pathetic, the image of a lone genius who won from a crowd of "loosers".

That is why it seems more appropriate to conclude my talk with another citation:

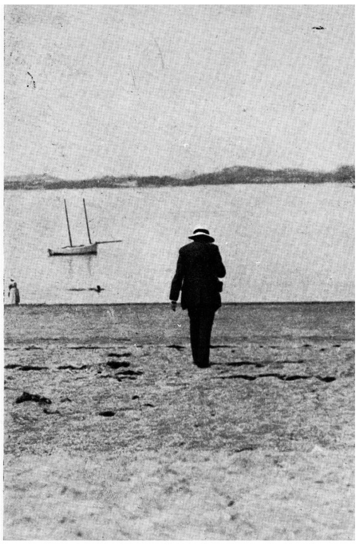
"***Science …is a collective creative work, and it cannot be anything else; it is like a monumental construction that has to be constructed for centuries, and where everybody must bring a stone to, and this stone can cost him a whole life.***

Hence, it gives us a feeling of a necessary cooperation, solidarity of our labour with the labour of our contemporaries, our predecessors and our followers."

H. Poincaré



2005, the Einstein Year.



Götterdämmerung?
(Poincaré. Summer, 1910)

§ 11. Acknowledgements

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§12. Sources

In my talk I did not dwell so much upon the numerous and interesting details of the work of other scientists who contributed into the relativity theory as well as I did not expatiate on many interesting details of the history of relativity.

I have drawn only a small part of the extremely rich information contained in the following sources.

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