ALBERT EINSTEIN'S NEW ETHER AND HIS GENERAL RELATIVITY

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Abstract

In 1905 A. Einstein banished the ether from physics in connection with the formulation of his Special Relativity. This fact is very well known but it is almost unknown that in in 1916 he reintroduced the ether in connection with his General Relativity. He denominated it ,,new ether" because, in oppposition to the old one, the new one did not violate his Principle of Relativity. The purpose of this paper is to present a short outline of the history of Einstein's new concept and to show which elements of the mathematical formalism of General Relativity were considered by Einstein as mathematical tools describing the relativistic ether.

AMS Subject Classification: .
Key words: Special Relativity, General Relativity, Unified Field Theory, Einstein's new ether, differential manifold, metrical tensor, g- field

1 Introduction

In December 2000 was published my book Einstein and the Ether [1] with the ,,Foreword" by the famous historian of physics Max Jammer. Recently, in June 2001, it was published in Italian [2] and a Greek version is in preparation. In this book I present the history of Einstein's attitudes toward the notion of the ether begining from 1894, when he wrote his first youthfull ,,scientific work" on the ether and magnetic field, until 1955 (i.e. the end of his life) when he formulated the new version of his asymmetric unified field theory (gmn gnm) of graviational and electromagnetic interactions. I did it on the basis of the documents that are collected by the library of the Museum of Science and Technology in Munich (Deutsches Museum) and in the Bayerische Staatsbibliothek in Munich and also on the basis of the documents received from Albert Einstein Archives.

In the present paper I am going to present a short story of Einstein's new relativistic ether and I would like to indicate which elements of the differential geometry

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used now in General Relativity are interpretated as mathematical tools describing the Einstein's ether.

2 Einstein denies the existence of the ether (1905-1916)

In his ,,On the Electrodynamics of Moving Bodies" [3], in which Einstein published his Special Theory of Relativity, there are two comments on the ether, and the word ,,ether" itself is used only once. Both comments can be found in the introduction to the article. The first is as follows:

,,...the unsuccessful attemps to discover any motion of the earth relatively to the ,,light medium," suggest that the phenomena of electrodynamics as well as of mechanics possess no properties corresponding to the idea of absolute rest"[3]

Here Einstein mentions the results of the Michelson-Morley experiments althought he did not mention the names of the two physicists. This comment about the ether shows also a clear influence on Einstein of the positivistic cognitive theory of E. Mach, W. Ostwald, and R. Avenarius. Einstein inducated that ,,no attribute characteristic of the phenomena corresponds to the notion of absolute rest," in other words, absolute rest remains beyond any experimental test, ,,not only in mechanics, but also in electrodynamics." Since it lacked the typical attribute of a phenomenon, it became a metaphysical interpolation which, according to Mach and other positivists, had to be eliminated from physics. The young Einstein, delighted with the cognition theory of Mach and with other positivist views as well, found reasons to doubt the existence of the ether. The ether of H. A. Lorentz's electromagnetism, identified with absolute space at absolute rest became something metaphysical in Einstein's eyes, i.e., experimentally inaccessible and in such a way he found a philosophical reason to reject the ether completely. As regards the physical reasons that impeled Einstein to reject the absolute space and the ether identified with it, they are two: the assymetry between mechanics (no privileged system of reference) and electromagnetism (with privileged system of reference) and the mentioned Michelson-Morley experiments.

As is well known Einstein's Special Relativity is based upon two assumptions:

1) equivalence of all inertial systems for formulating laws of both mechanics and electrodynamics and optics;

2) constancy of light speed in these systems independent of the movement of the source of light.

The other comment by Einstein about the ether is related especially to the first asumption:

,,The introduction of a ,,lumoniferous ether" will prove to be superfluous inasmuch as the view here to be developed will not require an ,,absolutely stationary space" provided with special properties, nor assign a velocity-vector to a point of the empty space in which electromagnetic processes take place."[3]

As we can, Einstein found the luminiferous ether unnecessary, because his theory, based upon the assumptions set out above, did not need a space at an absolute

rest characterised by any specific attributes. The existence of such a space would contradict his first assumption, which he would call the Special Principle of Relativity.

It must be stressed that in both his comments on the ether, Einstein had in mind nothing other than Lorentz's ether. This ether was identified with ,,space at absolute rest characterised by specific attributes," and a velocity vector had to be attributed to points of this ether when electromagnetic processes were considered in the reference system moving with respect to the absolute space.

Having pointed out to the reader in the introduction to his article that the ether proved unnecessary under the present arguments, Einstein stopped discussing it in the later part of his work. With this silence he treated the problem of the ether as absolutely settled.

Having treated the ether as something absolutely superfluous, Einstein made no further mention of it in any of his works of the years 1905-1907. At the end of 1907, however, Einstein had to break his silence about the ether,because it was not easy to convince everyone that the ether was unnecessary. For exemple, Einstein's works failed convince Lorentz that the ether was superfluous; Lorentz defended the concept of the ether until the end of his life, and his tenacy led Einstein to introduce a new concept of the ether in 1916. Einstein broke his silence about the ether, in some his papers after 1907, in order to reject it once again.

3 Einstein introduces his new concept of the (1916)

It often happens that new ideas and concepts are born and mature through discussions and polemics. Einstein's new concept of the ether was born out of an exchange of letters with H.A. Lorentz and his polemics with Ph. Lenard. We could even say that Einstein was provoked to introduce, and stimulated to develop, a new relativistic concept of the ether by these two physicists. Also H. Weyl, who in 1917 presented a version of the relativistic ether similar to Einstein's, may have inspired him to some extend.

On June 6th, 1916, Lorentz [4] wrote a long, article-like letter, in which he tried to convince Einstein that the General Relativity Theory allows the hypothesis of a immobile stationary ether. In his reply, Einstein proposed a definition of a new relativistic ether that can be expressed in the following short form:

$$\text{field } g_{\mu\nu} = \text{ether}.$$

In his letter to Lorentz of June 17th, 1916 we read:

,,I agree with you that the general theory of relativity is closer to the ether hypothesis than the special theory. This new ether theory, however, would not violate the principle of relativity, because the state of this gmn = ether would not be that of rigid body in an independet state of motion, but every state of motion would be a function of position determined by material processes."[5]

As we can see, physical spacetime the local state of which is described in General Relativity by the fundamental covariant metrical tensor gmn was regarded by Einstein as the new relativistic ether. Einstein did not publish this new conception in

either 1916 or 1917. A controversy between Einstein and Lenard provoked the first appearance of the new view in print. In a lecture in 1917 and the next year in a published paper [6] , Lenard raised the objection against Einstein's general theory of relativity that in this theory the disqualified ether came back under the new name ,,space." In reply, Einstein wrote an assay [7] in which he published for the first time his new conception.

,,Whereas according to the special theory of relativity a part of space without matter and without electromagnetic field seems to be completely empty, that is to say not characterised by any physical properties, according to the general theory of relativity even space that is empty in this sence has physical properties. These are characterised mathematically by the components of the gravitational potential [$g_{\mu\nu}$ tensor - L.K.], which describe the metric behaviour of this part of space, as well as its gravitational field. This state of things can be easly understood by speaking about an ether, whose state varies continuously from point to point. One must only be careful not to attribute to this ,,ether" the properties of ordinary material bodies (e.g., a well defined velocity at every point)." [7]

At the same time, Einstein proclaimed once again that the ,,ether in the old sense does not exist"[7]. Therefore, we can say following John Stachel reviewing my book:

,,The ether he reintroduced differed fundamentally from the ether he had banished."[8]

An interesting Einstein's statement on the new ether can be find in the so-called ,,Morgan Manuscript" from 1920. In the section 22 entitled General relativity and ether we read:

,,It is not difficult to incorporate the laws of nature, already known from special relativity, into the broader framework of general reloativity. The mathematical methods were readily available in the ,,absolute differential alculus," based on the work of Gauss and Riemann and further developed by Ricci and Levi-Civita in particular. It represents a rather simple way of generalising the equations from the special case of the constant gmn to the case of the spatio-temporary varing gmn. In all laws generalised in this way, a role is played by the gravitational potentials gmn which, in a word, express the physical properties of empty space.

Thus, once again ,,empty" space appears as endowed with physical properties, i.e., no longer as physically empty, as seemed to be the case according to special relativity. One can thus say that the ether is resurrected in the general theory of relativity, though in a more sublimated form."[17]

Afterwards, in the period from 1920 until 1938, Einstein published his new conception in an extensive way in several papers [9]-[14]. In his paper of 1924 entitled *Über den Äther* Einstein concluded:

,,[...] we will not be able to do without the ether in theoretical physics, i.e., a continuum which is equipped with physical properties; for the general theory, whose basic points of view physicists surely will always maintain, excludes direct distant action. But every contiguous action theory presumes continuous fields, and therefore also the existence of an ,,ether." [10]

And in 1938 he wrote together with L. Infeld:

,,We may still use the word ether, but only to express the physical properties of space. The word ether has changed its meaning many times in the development of

science. At the moment, it no longer stands for a medium built up of particles. Its story, by no means finished, is continued by the relativity theory." [15]

The new ether presented in the framework of the General Relativity was called by Einstein ,,gravitational ether". The further history of the new ether is connected with Einstein's attempts to formulate a Unified Relativistic Field Theory. The gmn -field of General Relativity did not include electromagnetic fields in its structure, since it was only a gravitational field. Thus the ether of General theory of Relativity turned out to be a gravitational ether only. From 1929 until the end of his life in 1955, Einstein tried to build electromagnetic fields into the structure of the space-time continuum in order to unify the gravitational and electromagnetic interactions. On occasion, he was convinced that he had managed to find a satisfactory solution to the problem of unification. This happened, for instance, when he enriched Riemann's geometry with socalled teleparallelism, and used the geometry developed in this way to search for unification. During this time, Einstein's produced a veritable flood of lectures and papers [11-14] on the issues of space, the ether, and field, where the ether - identified with a space characterised by metrics and teleparallelism - was understood as a total field (Gesamtfeld) for transmiting both gravitational and electromagnetic interactions. I one of these papers Einstein therefore wrote:

,,Physical space and ether are only different terms for the same thing; fields are physical states of space."[14]

As we can see, at that time, Einstein considered the gravitational and elektrrognetic fields as states of space i.e. of the new ether.

4 Elements of differential geometry used in General Relativity that serve to describe mathematically the new ether

Einstein's works refering to the new ether are of a purely interpretative nature,and therefore they do not contain any mathematical formulae except the symbole gmn of the metrical tensor and the basic square formulae, which define the space-time metrics of his theories. Moreover, his papers on ether lack any novel mathematical ideas which could be used to muster the formalism of the theory. They serve simply to uncover the physical meaning hidden under - or perhaps behind - the mathematical apparatus of the Special Theory of Relativity, The General Theory of Relativity, and the attempts to formulate the Unified Field Theory.

Nevertheless, it is interesting to investigate which elements of the mathemtical formalism of his theories serve to describe mathematically the new ether. We find a good indication of such elements in the following comment by Peter Bergmann, Einstein's collaborator in the years 1936-1944.

,,Oh, I try to add to this discussion that in the last decades ofhis life Einstein was concerned with unitary field theories of which he created a large number of models. So I think he was very conscious of the distinction between the differential manifold (though he did not use that term) and the structure you have to impose on the differential

manifold (metric, affine or otherwise) and that he conceived ofthis structure, or set of structures, as potential carriers of physical distinctiveness and including the dynamics of physics.

Now, whether it is fortunate or unfortunate to use for the later the term like ether? I think simply from the point of view of Einstein and his ideas that in the distinction between the differential manifold as such and the geometrical structures imposed on it we could, if we want, usethe term ether for the latter."[15]

Bergmann was right when he claimed in his comment that the differential manifold as such, which is used to model space-time without imposing upon it such structures as metric, etc., cannotbbe treated as a mathematical structure representing Einstein's new ether. Bergmann was right, because the four-dimensional differential manifold as such is a mathematical structure of too general a nature, and it cannot physically define distinctive features of space-time continuum without imposing metrics and other structures upon it. It is too general, because it can serve as an arena or a background for any macroscopic physical theory (and even perhaps a microscopic one, because the debate over the status of the differential manifold in microphysics is ongoing). By the act of imposing metrics (i.e., the recipe for mesuring space and time intervals) and other structures upon it, the structure enriched in such a way turns into something that represents distinctive physical features of the real space-time continuum. In the case of Einstein's ether, the issue concerned imposing metrics and other structures which are presently used with the Special Theory of Relativity and General Theory of Relativity. In this context, let's quote a passage from Einstein's lecture delivered at Leiden in 1920.

,,According to the general theory of relativity, space without ether is unthinkable; for in such space, not only would there be no propagation of light, but also no possibility of existence for standards of space and time (measuring rods and clocks), nor therefore any space-time intervals in the physical sence."[9]

Although in the above quotation Einstein did not use the terminology of contemporary mathematics, the quotation tends to confirm Bergmann's statement. I believe, however that it would be more consistent with Einstein's ideas if we assumed that the new ether is represented in the contemporary mathematical formalism not only by the very structures themselves (metrics and others) which are imposed on the four-dimentional differential manifold, but by all these elements together. Thus, in my opinion, the ether of Einstein's relativity theory - provided we agree to introduce the term - is represented in the contemporary mathematical formalism of the theory by the structures imposed upon the differential manifold together with the latter.

In the interpretative works by Einstein on the new concept of the ether we can distinguish three basic models of the relativistic ether, and the third comes in several versions.

(1) The first is the model of the Special theory of Relativity. Einstein identified it with the flat space-time of the Special Theory of Relativity, which - according to the terminology used in his time, and often used today as well - has pseudo-Euclidian metrics. Since, within the flat space-time continuum of the Special Theory of Relativity, there exist systems of co-ordinates in which the components of the

metric tensor gmn are constant and represented by the symbol $\eta_{\mu\nu}$

$$(g_{\mu\nu}) = (\eta_{\mu\nu}) = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & -1 \end{pmatrix}.$$

Einstein gives the components $\eta_{\mu\nu}$ as the mathematical tool for describing the basic metrical behaviour of the ether of the Special Theory of Relativity. Since in reference systems in which $g_{\mu\nu} = \eta_{\mu\nu}$ (i.e., in the class of inertial reference systems) test particles behave according to the first Newtonian principle of dynamics, i.e., they are at rest or move along straight lines with constant velocity, Einstein called the ether of the Special Theory of Relativity ,,the inertial ether" and he pointed out that it shared a feature in common with the ,,ether of Newtonian mechanics." Both of them determine the inertial behaviour of test particles. Due to its flatness, the inertial ether is extandable to infinity. It is also rigid and abslute (in the sense that presence and motion of matter do not exert any influence on its structure).

,,The four-dimentional space of the special theory of relativity is just as rigid and absolute as Newton's space." [14]

Using contemporary terminology and symbols we can say that the pair (M, η), where M is the four-dimentional manifold, and η is the Minkowski metric on M, represents the new Einstein's inertial ether in the mathematcal formalism of Special Relativity.

(2) The second model of the relativistic ether is the model of General Relativity. Einstein called it ,,gravitational ether" because it determines the inertio-gravitational behaviour of the test particles. Einstein identified it with the space-time continuum of General Relativity and mentioned that the mathematical tool for describing it was the symmetrical metrical tensor g with the components $g_{\mu\nu}$ which are continous functions of the coordinates of the arbitrary introduced systems.

Using contemporary terminology and symbols we could say that the ether of the General Theory of Relativity is represented by the differential manifold M, upon which is imposed a differentiable field of the metric tensor g, in other words the Lorentz metric (also called the pseudo-Riemanian metric; therefore we may label it with the pair of symbols (M, g).

(3) The third model of the relativistic ether arises from Einstein's attempts to formulate the Unified Field Theory. The model had as many versions as Einstein made attempts to carry out the unification, i.e., seven. Their common feature was the fact that the symmetrical metric tensor was replaced by other mathematical entities because its componets $g_{\mu\nu} = g_{\nu\mu}$ no longer were considered as fully describing the structure of the relativistic ether. Which were these mathematical entities? For example, in the asymmetric field version the entity was an asymmetrical metric tensor with sixteen components $g_{\mu\nu} \neq g_{\nu\mu}$, in the bivector field version, the mathematical entity called the basic symmetrical bivector $g^{\mu\nu}_{\alpha\beta}$, and in the still another version, the complex Hermitian metric tensor $g_{\mu\nu} = \bar{g}_{\nu\mu}$. As is well known Einstein's attempts to formulate a Unified Field Theory failed. Also his terminology ,,new ether" to

denominate space-time of relativity theory is no longer used. It is, however, interesting to note that Einstein called the space-time continuum of his relativity theory during long time ,,new ether" because in his relativity theory, especially in General Relativity, space-time is presented as entity with physical properties.

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