Einstein and the ether

Relativistic theory does not reject the existence of an ether. Dr Kostro, of the Institute of Experimental Physics, Gdansk University, has undertaken extensive research into Einstein's views; that his model of space-time is a model of a new ether.

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Viewpoints are often expressed in *Electronics and Wireless World* which assume that Einstein's theory and the existence of an ether are conflicting and incompatible. It is time, therefore, that some of the truths of historical record, concerning Einstein's views on the ether, were given a hearing.

'ETHER' TERMINOLOGY

This is a distortion of the truth. Einstein did deny the existence of the fixed and immobile ether of the nineteenth century, but he, nevertheless, in 1916, proposed a completely new conception of the ether. In a sense, one can say that he was provoked into doing this by the influence of H.A. Lorentz and P. Lenard.

Lorentz wrote a letter to Einstein in which he maintained that the general theory of relativity admits of a stationary ether hypothesis. In reply, Einstein introduced his new non-stationary ether hypothesis. He wrote to Lorentz on the 17th June 1916:

***I agree with you that the general relativity theory is nearer to an ether hypothesis than is the special relativity theory. However, this new ether theory would not violate the principle of relativity, because its state $g_{\mu\nu}$ = aether would not be that of a rigid body in an independent state of motion, but its state of motion would be a function of position determined via the material processes*[1].**

Physical space (connected closely with time) whose state, in relativity theory, is described by the fundamental metrical tensor $g_{\mu\nu}$ is regarded by Einstein as the relativistic ether. Einstein did not publish his new ideas on this in 1916 or 1917 as he advanced his work on the general theory. The first appearance of the new conception in print was provoked by Lenard. In 1918 Lenard published a paper opposing Einstein's relativity theory[2] in which he maintained that in the general theory the disqualified ether came back under the new name 'space'. In reply Einstein wrote an essay[3] in which he published the above-presented new definition of the ether. Indeed, in the period 1918-1955 Einstein published about 15 papers in which he interpreted his models of space-time as models of a new ether.

In these papers we can discriminate three models of the relativistic ether:

The first is that of the special relativity theory. In the mathematical description of this ether the ten components of the $g_{\mu\nu}$ tensor are constant. The related ether is rigid, flat and infinite. Its metric is pseudo-Euclidean.

The second is that of the general relativity theory. In its mathematical description the ten components of the $g_{\mu\nu}$ tensor are no longer constant. The states described by the tensor can change not only from one place to the other, but also in time. This ether is no longer rigid and flat. Its metric is pseudo-Riemannian.

The third ether is that of the unitary relativistic field theory. In the mathematical description of this ether the symmetrical tensor $g_{\mu\nu}$ (where $g_{\mu\nu}=g_{\mu\nu}$) no longer describes the ether completely, because the geometrical structure of it is more than Riemannian. New structural elements have to be introduced for a complete description of the ether because it has to determine not only the inertio-gravitational phenomena, but also electromagnetic actions.

Thus, since 1916, Einstein's physics of space, albeit incorporating time within the space dimension, became the physics of a new ether, a physical ether and not just a mathematical formulation. In this physics the three physical notions: 'space', 'ether' and 'field' have found their complete unification through consequent identification.

***'Physical space and the ether are only different terms for the same things; fields are physical states of space'*[4].**

Einstein's conception of the ether constitutes a gradual conceptual activation, dynamization and materialization of the physical space. According to the new conception, in its most developed form, the physical space closely connected with time is not a passive and static container of events, nor is it a physically-indifferent or neutral arena of physical phenomena. It is an active dynamic field medium which determines the inertio-gravitational, electromagnetic and other processes, which include the production of elementary particles. The real physical space, as an active field medium of this kind, possesses energy and therefore mass as well and that is why it is itself of a material nature. It constitutes active matter *sui generis* for which the term 'ether' is the most appropriate name.

It must be mentioned, however, that the three synonyms: 'physical space', 'ether' and 'total field' were used by Einstein with different frequency in different periods:

In the period 1916-1925 (see e.g. refs 5,6) the term 'ether' was used very often. He maintained even that 'in a consequent field theory all objects of physics must be embraced in the notion of ether'[6].

In the period 1926-1935 (see e.g. refs. 7,8,9) the term 'physical space' played the principal part in Einstein's papers. He wrote: ***'Space, brought to light by the corporeal object, made a physical reality by Newton, has in the last few decades swallowed the ether and time and seems to swallow also field and corpuscles, so that it remains as the sole carrier of reality'*[7].**

In the third period 1936-1955 (see e.g. ref 10) the term 'total field' or 'entire field' was the term preferred by Einstein. After 1925 Einstein began to use the word 'ether' less and less often, although he still wrote in 1938:

***'This word ether has changed its meaning many times in the development of science... Its story, by no means finished, is continued by relativity theory'*[11].**

and although, in 1954, he still indicated that:

***'rigid four-dimensional space of the special theory of relativity is to some extent a four-dimensional analogue of H.A. Lorentz's rigid three-dimensional ether'*[12].**

Yet, underlying all this was his statement dating from 1920, made in the light of his early work on both the Special and General Theories of Relativity that:

***'There is an important argument in favour of the hypothesis of the ether. To deny the existence of the ether means, in the last analysis, denying all physical properties to empty space'*[5].**

According to Einstein's new conception, it was impossible to formulate a complete physical theory without an (at least latent) ether hypothesis, because every complete physical theory must take into consideration the real properties of the physical space i.e. the 'Milieu-Einflusse[6]'. One might not use the word 'ether' but one has still to recognize that physical space has real properties which play an active part in physical happenings and, therefore, Einstein maintains:

***'The ether hypothesis was bound always to play a part even if it is mostly a latent one at first in the thinking of physicists'*[5].**

THE PHYSICAL ETHER

In Einstein's special relativity ether model the physical space accomplishes its active function by 'determining the inertial behaviour of a test body introduced into it'[12] and possesses 'the physical property of transmitting electromagnetic waves'[11], but 'it no longer stands as a medium built of 'particles'[11] or 'points'[6] and is no longer regarded as an immobile or stationary

medium. The concept of motion cannot be applied to it, but:

'According to special relativity, the ether remains still absolute because its influence on the inertia of bodies and on the propagation of light is conceived as independent of every kind of physical influence'[6].

In Einstein's general theory the ether is no longer absolute in the above sense, because:

'it not only conditions the behaviour of inert masses but is also conditioned, as regards its state, by them'[5].

The general theory is incomprehensible without an active ether:

'According to the general relativity, space is endowed with physical qualities; in this sense, therefore, an ether exists. In accordance with the general theory of relativity space without an ether is inconceivable. For in such a space there would not only be no propagation of light, but no possibility of existence of scales and clocks, and therefore no spatio-temporal distances in the physical sense. But this ether must not be thought of as endowed with the properties characteristic of ponderable media, as composed of parts, the motion of which can be followed: nor may be the concept of motion be applied to it'[5].

The general relativity ether manifests its activity through its function determining the inertio-gravitational behaviour of material bodies and through the creation of elementary particles. A test body which is only under the influence of this physical space is at rest or follows a geodetic, curved or straight, respectively, in curved or locally-flat spaces of reference.

Einstein made several attempts to find solutions of general relativity field equations free of singularities which might be interpreted as presenting corpuscles. Together with Rosen, he found such solutions of the centrally-symmetrical gravitational field equations for both neutral and electrically-charged particles:

'The neutral, as well as electrical, particle is a portion of space'[13].

In Einstein's special and general theories the electromagnetic field appears as something which 'fills space'[12], i.e. as something which does not belong to the structure of the physical space described by the metrical tensor $g_{\mu\nu}$. Since Einstein came to regard real physical space as the 'total field' of all physical actions and not only the inertio-gravitational ones, he began to look for a unitary field theory, i.e. for:

'a theory of the continuum in which a new structural element appears side by side with the metric such that it forms a single whole together with the metric'[4].

Einstein often emphasized that the pseudo-Riemannian space-time described by the tensor $g_{\mu\nu}$ does not constitute a complete description of the physical space connected with time. He made several attempts to generalize it, e.g. through enriching 'Riemannian space by adding the relation of direction or parallelism.'[4] He was even convinced that he had 'found the most natural form for this generalization'[12] in his 'theory of the unsymmetrical field'.

However, although activity of the ether described by Einstein's unitary field theory is richer than that described by his general theory, because it also includes electromagnetic interactions, the view today is that Einstein's unitary field theory is unsatisfactory.

EVOLVING ETHER

On the basis of the principle of equivalence of energy and mass Einstein arrived at the conclusion that there is no qualitative difference between the real physical space and ponderable matter composed of particles. Real physical space, as an active field possessing energy (and therefore also mass) constitutes an active matter *sui generis* i.e. an ether. According to Einstein:

'The strange conclusion to which we have come is this – that now it appears that space will have to be regarded as a primary thing and that matter is derived from it, so to speak, as a secondary result. Space is now having its revenge, so to speak, and is eating up matter'[9].

The message here is that we are involved with an ether that can materialize as matter, but although time is merged with space in Einstein's theories and the time dimension appears in the connection between mass and energy, the question of a state of motion of the ether poses problems. Although the notion of motion cannot be applied to space as such, space is never passive. It is an ever-active medium conceived by Einstein as non-atomic and non-mechanical in character but yet as being the fundamental source of every physical activity, the creation of particles included.

In following Einstein's research on this theme one finds that Einstein's relativistic ether is something ultra-referential. It does not constitute a reference frame and has not a proper reference frame. If it had it would be at rest in it, and yet it is not a stationary ether. The ultra-referential time is not composed of moments, just as the ultra-referential space is not composed of points. A moment constitutes a set of simultaneous events which belong to it. Since, in the theory of relativity, simultaneity is a strictly relative thing, the ultra-referential time cannot be composed of moments. Nevertheless, the ultra-referential time is something 'extended' composed of past, present and future. With respect to a freely chosen event considered as present, there exists always a set of events which are absolutely past and a set of events which are absolutely future. Every reference time is one of the possible orientations in the ultra-referential time. It is analogous to the relationship that exists between reference spaces in the ultra-referential space. These reference spaces are quasi-objects which move with respect to each other but not with respect to the ultra-referential space. Yet it is the physical characterization of the latter that is what may be said to be a more fundamental reality. According to Einstein, the ultra-referential space identified with ether is not something that can be divided into separate parts, nor does it constitute a universal quasi-object.

Einstein's presentation of this activity (which extends beyond his treatment of the inertio-gravitational effects) cannot be considered today as satisfactory. His research on this point cannot be regarded as accomplished in any definite way. Nowadays, this programme is continued in those hypotheses in which the elementary particles are presented as solitons superimposed on Einstein's relativistic ether. We find models of elementary particles in which de Broglie waves are interpreted as real waves in Einstein's relativistic ether e.g. in the works of J.P. Vigier[14] and L. Kostro[15,16,17]. The author's 'three-wave model of the elementary particle' constitutes an attempt to develop some ideas of Einstein in which elementary particles are conceived as 'fields of a particular kind which are particular states of space'[6]. In the 'three-wave model' elementary particles are presented as particular threefold wave fields in Einstein's relativistic ether.

Einstein's ether is not the unique ether conception of the twentieth century. We find similar relativistic ethers in the works of H. Weyl and A.S. Eddington. In 1951 a new ether conception was introduced by P.A.M. Dirac[18]. The most recent ether conception is that of H. Aspden[19,20], in which the ether constitutes 'a structured vacuum determining universal physical constants.'[19]. As we see, therefore, the notion of the ether was not destroyed by Einstein, as the general public believe. Research on the ether question is very much alive and it remains to be seen how much of Einstein's influence will feature in the future development of ether theory.

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