COMMENTARY FROM THE COLLECTED PAPERS OF ENRICO FERMI

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No. 1 and No. 2

Paper No. 1 (related to No. 2) deals with the inert mass of a rigid system of electric charges, and derives it from the reaction on the moving charges of their own electromagnetic field. The result is that, in the most general case, the mass is expressed by a tensor. In the particular case of a spherically symmetric system, the tensor degenerates into a scalar equal to $(4/3)U/c^2$. Thi salue, while in agreement with a well known calculation of the electromagnetic mass of a spherical homogeneous shell performed by Lorentz, contradicts Einstein's principle of equivalence (see papers 4a,4b,6).

Paper No. 2 determines, by the methods of general relativity, the effect of a uniform gravitational field on a system of electric charges. It turns out that the charges have a weight equal to that of a materical mass U/c^2 (where U is the electrostatic energy of the system), in perfect agreement with Einstein's principle of equivalence between mass and energy.

— E. Persico

No. 3

The origin of this paper is probably related to that of No. 2, although neither of the two papers contains an explicit reference to the other. It can be supposed, in fact, that Fermi, after the study of the relations between gravitational and electromagnetic fields, made in No. 2 under rather restrictive conditions, felt the opportunity of a more systematic treatment of this and other similar problems, by means of a system of spacetime coordinates particularly fitted to follow the behaviour in time of phenomena happening in a small spatial region. He was so conducted to this paper, which, except in the last part, is essentially the demonstration of a theorem of absolute differential calculus. This theorem is of considerable interest for the applications, and is therefore reproduced in the most important treatises of absolute differenital calculus (see, e.g.: T. Levi-Civita, *Calcolo Differenziale Assoluto*, Roma, 1925, p. 190; also, in English translation: *Absolute Differential Calculus*, Glasgow 1927, p. 167). Later, it has been extended by L.P. Eisenhart to a certain class of non-Riemannian spaces (see L.P. Eisenhart, *Non-Riemannian Geometry*, New

York 1927)and by P. Dienes to any lienarly connected space (see *Rend. Acc. Linc.* **18**, (6), p. 369 (1933)). A possible extension to Weyl's space is also suggeted in Fermi's paper. For a detailed derivation and discussion see also: L.O. Raifertaight, *Fermi's Coordinates*, *Proc. Roy. Acad.* **59A**, p. 15 (1958). Extensive use of "Fermi coordinates" is made in J.L. Synge, *Relativity, the General Theory* (Amsterdam, 1960).

— E. Persico

No. 4a, 4b, 4c, 10.

The results of papers No.'1 and 2 puzzled Fermi, because they contradict each other if it is assumed, as required by general relativity, that the gravitational and inertial mass are the same. Moreover, the value $(4/3)(U/c^2)$, obtained by Lorentz as well as by Fermi for the inert mas of a rigid, spherically symmetrical system of electric charges, was a variance with Einstein's principle of equivalence of mass and energy. It is now well known that the factor 4/3 can be interpreted as due to the part of the energetic tensor contributed by the internal non-electromagnetic stresses, whose existence must be assumed toa ssure the equilibrium of the charges. However, in the books known to Fermi, this discrepency was not explained (he had eveidently overlooked the explanation contained in M. von Laue, *Die Relativitätstheorie*, I, 3rd ed., 1919, p. 218), and so he found for it an explanation of his own, essentially equivalent to the former but obtained through Weyl's variational method.

Prof. Polvani remembers that the question was debated, one winer evening of 1922, in Pisa, while Fermi, Puccianti, olvani and other friends walked through via San Frediano from the University to the Scuola Normale Superiore. Here the company parted without having reached any satisfactory conclusion. In the following two days, Fermi did not appear at the Institute of Physics. The third day he arrived with a paper, ready for publication, entitled *Correzione di una grave discrepanza* . . .. Puccianto, who had emphasized the need for a clarification, was enthusiastically happy.

This result, of which Fermi was particularly proud, was published by him, with minor alterations, in three different journals (No. 4a, 4b, 4c). Subsequently, in collaboration with A. Pontremoli (a young physicist, then an assistant at the University of Rome, who later was to disappear tragically in the Nobile polar expedition of 1928) Fermi applied the same method to the calculation of the mass of radiation contained in a cavity with reflecting walls, for which Abraham and others had found an expression containing the same factor 4/3 (see paper No. 10).

— E. Persico

No. 5

This little article is remarkable in two respects. The date shows that already by 1923 Fermi was known well enough, at least in some circles, that his opinion was requested for an appendix to a translation of a book on relativity. I do not know how and why the publisher and the translator had the insight to request comment by a practically unknown young Ph.D. Also remarkable is the strange and almost prophetic premonition of things to come shown in this article. There were about a dozen more similar articles by other generation Italian physicists in the apendix to the same book and almost all of them were very sceptical and hostile to relativity. A preusal of these articles shows the state of mind of official physics in Italy at the time.

— E. Segrè

No. 7

Too long to reproduce in full??

— E. Persico

38b

— G. Polvani

43–48

to do...

80a

no commentary

240–3

commentary in italian..??