

## 5.

**MASSES IN THE THEORY OF RELATIVITY**

“Le masses nella teoria della relatività,”  
from A. Kopff, *I fondamenti della relatività Einsteiniana*,  
Eds. R. Conti and T. Bembo, Hoepli, Milano, 1923, pp. 342–344

The grandiose conceptual importance of the theory of relativity as a contribution to a deeper understanding of the relationships between space and time and the often lively and passionate discussions to which it has as a consequence also given rise outside of the scientific environment, have perhaps diverted attention away from another of its results that, even though less sensational and let's say, even less paradoxical, nevertheless has consequences for physics no less worthy of note, and whose interest is realistically destined to grow in the near term development of science.

The result to which we refer is the discovery of the relationship that ties the mass of a body to its energy. The mass of a body, says the theory of relativity, is equal to its total energy divided for the square of the speed of light. A superficial examination already shows us how, at least for the physics that is observed in the laboratories, the importance of this relationship between mass and energy is such that it considerably overshadows that of the other consequences, quantitatively much lighter, but to which the mind gets used to with more effort. This merits an example: a body one meter long that moves with the respectable enough speed of 30 km per minute (equal more or less to the speed of the earth through space) would always appear to be one meter long to an observer carried along by its motion, while to a fixed observer it would appear to be one meter long less five millionths of a millimeter; as one sees the result, however strange and paradoxical it can seem, is nevertheless very small, and it is hard to believe that the two observers would start quarreling over so little. The relationship between mass and energy brings us instead to enormous figures. For example if one succeeded in releasing the energy contained in a gram of matter, one would obtain an energy greater than that developed over three years of nonstop work by a motor of a thousand horse power (useless to comment!). One might say with reason that it doesn't appear possible, at least in the near future, to find a way to liberate these incredible quantities of energy, something that moreover one would hope not to be able to do, since the explosion of such an incredible quantity of energy would have as its first result reducing to pieces the physicist who had the misfortune to find a way to produce it.

But even if such a complete explosion of matter doesn't appear possible for now, there are already in progress during the past few years some experiments directed towards transforming the chemical elements into each other. Such a transformation, which happens naturally in radioactive bodies, has been recently done artificially by Rutherford who, bombarding some atoms with some  $\alpha$  particles (corpuscles launched with huge speed by radioactive substances), has succeeded in obtaining their decomposition. Now to these transformations of the elements into each other are associated energy exchanges that the relationship between mass and energy allows us to study in a very clear way. To illustrate this it is worth another numerical example. We have reason to think that the nucleus of an atom of helium is composed of four nuclei of the hydrogen atom. Now the atomic weight of helium is 4.002 while that of hydrogen is 1.0077. The difference between four times the mass of hydrogen and the mass of the helium is therefore due to the energy of the bonds that unite the four nuclei of hydrogen to form the nucleus of helium. This difference is 0.029 corresponding, according to the relativistic relationship among mass and energy, to an energy of around six billion calories per gram-atom of helium. These figures show that the energy of the nuclear bonds is some million times greater than those of the most energetic chemical bonds and explains to us how against the problem of transformation of matter, the dream of alchemists, for so many centuries the efforts of the best minds have been useless, and how only now, using the most energetic means to our disposition, one has succeeded in obtaining this transformation; moreover in such a small quantity as to illude the most delicate analyses.

These brief indications are enough to show how the theory of relativity, besides giving us a clear interpretation of the relationships between space and time, will be, perhaps in the near future, destined to be the keystone for the resolution of the problem of the structure of matter, the last and more difficult problem of physics.