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"And nothing else exists to constitute the Universe": Augusto Righi and the ultimate physical reality at the dawn of the 20th Century

Eugenio Bertozzi(*)

Department of Physics and Astronomy and University Museum Network, University of Bologna - Bologna, Italy

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Summary. — On 12 April 1907, the well-known physicist Augusto Righi gave a lecture-demonstration for the opening of the Institute of Physics of the University of Bologna and engaged the audience with the notion of "electrical constitution of matter". The paper reconstructs Righi's explanation and shows how the subject stimulated interesting philosophical debates at the dawn of the Century.

1. – Introduction

At 10 o'clock in the morning of 12 April 1907, the well-known physicists Augusto Righi entered the lecture hall of the brand-new Institute and Museum of Physics of the University of Bologna to give the inauguration lecture. Particularly interesting was Righi's choice for the topic of the lecture. Righi was well-known for completing the Hertz program showing that light and electric waves display the same behavior. To the task, in 1897 Righi had invented special apparatuses such as the three-sparks oscillators and the electromagnetic bench and published a compendium of his experiments [1]. Instead, for that special occasion he decided to go for something recently developed "in a book of some success and concerning the modern views on the constitution of matter and the causes of the phenomena of the physical world" [2]: *The Modern Theory of Physical Phenomena* published in 1904 had already become one of Righi's most successful books and was going to have several editions and translations, among which German and Russian [3]. Therefore, after being a successful experimental physicist, Righi was considering more theoretical and philosophical questions which were central for the physics community. In fact, not only the second half of the 19th Century had brought the discovery of the electromagnetic waves but also the one of the long-predicted "atom of electricity", detected by Thomson in 1897. By the end of the Century, on the basis of these two new fundamental elements of physical reality —and to repair Maxwell's avoidance of microscopic analysis in his *Treatise*— some physicists developed successful theoretical attempts to combine the electromagnetic ether and the electron in order to account for the observed properties of matter [4]. More to the point, the new Century opens with the award of the Nobel Prize in Physics to Hendrik Lorentz and Pieter Zeeman for "their researches into the influence of magnetism upon radiation phenomena" (1902), the publication of Thomson's books *Electricity and Matter* (1904) with a celebrated realistic interpretation of the Faraday lines and outstanding atomic models.

(*) E-mail: eugenio.bertozzi2@unibo.it

Righi's views on these themes should be rather seen on the level of the popularization of physics. But this is precisely the reason why Righi's work was noticed by his contemporaries and had an effect beyond the specialized circle of the physicists. Soon after Righi's death in 1920, at the commemoration held at the Senate, the philosopher and Ministry of Instruction Benedetto Croce prized Righi's attitude toward grand theoretical views, by saying that [5]

"As a pure scientist, he did not limit himself to particular concepts of science, but he tried a general cosmic theory, the theory of the electrical constitution of matter, with which physics extends its hand to philosophy"

More impressive and apparently bizarre is the reference to Righi made by Vladimir Il'ič Ul'janov —better known as Lenin— in his work *Materialism and Empiriocriticism*, published in 1909. In this philosophical-political treatise which was part of Lenin's program to take the lead of the Bolshevik party Lenin dedicates to the "great Italian scientist" a consistent part of the section entitled "the matter has disappeared" ([6], p. 253). For Lenin, modern physics had provided the proof for an objective reality located outside the human conscience and whose existence, according to Lenin, was the essence of the philosophical materialism. Lenin's intention was to criticize Mach's perspective about the impossibility of disregarding senses and theories in the interpretation of nature and, more to the point, to move an attack to his political adversary Nikolai Vladislavovich Valentinov, author of the book *Ernst Mach and Marxism*, published in 1907. One specific statement by Righi is particularly debated in this regard: *"we can say that the theory of the electrons is a theory of matter, rather than a theory of electricity: more to the point, in the new system electricity replaces matter"* [8]. Both Lenin and Valentinov agreed that to say that the matter has an electrical origin meant to recognize electricity, instead of mechanics, as fundamental theory in the description of the Universe. However, if for Mach/Valentinov this implied to consider physical laws as organizational schemata of sensorial and instrumental data, for Lenin the point was exactly the opposite. Drawing directly from Righi's book, Lenin argued that a theory should not only be considered as a convenient way to ordinate and coordinates facts, and that the electrical origin of matter had another interpretation ([6], p. 255):

"The matter disappears": this means that what disappears is the limit to which our understanding of matter used to stop, it means that our knowledge deepens; it means that some properties we thought absolute and immutable (impenetrability, inertia, mass, . . .) are now relative, inherent only to certain states of matter"

If physics was succeeding in reducing the understanding of the world from several to few elements —such as ether and electrons— this was a progress in the understanding of matter itself. Hopefully, by following this route, physics would have revealed the last and ultimate property of matter, *i.e.*, to be an objective reality located outside the human conscience —Lenin's interpretation of the philosophical materialism. Lenin could not resist to conclude his political mobilization of Righi's work with a "jab" to Righi's own country ([6], p. 258):

"If this physicist had known the dialectical materialism, his judgment [. . .] could have probably been the starting point of a right philosophy. But the environment in which all they live keeps them away from Marx and Engels and throw them into the arms of the trivial, official philosophy".

We do not know whether Righi ever knew of his role in this resonant debate. Be that as it may, on that morning of 12 April 1907 he was going to talk about important things which are now summarized by following Righi's and not Lenin's argument.

2. – "On a hypothesis on the electrical nature of matter"

Thinking about what reality is and what is the image of reality that one can get from scientific theories is the way through which Righi addresses the audience in the opening of the lecture. Righi's perspective on the subject is inflexible: experimental science imposes to believe in a precise correspondence between reality and the mental image of reality that humans are driven to create because of their senses. The epistemological-oriented introduction is then followed by a short historical account to show that, until recent times, three entities occurred to explain the physical world: ponderable matter, ether and electrical fluid. As for the first, Righi briefly recalls Faraday's studies on electric ions in liquids, molecular hypothesis in gases and solids. Then, moving from matter to radiation, he recalls Melloni's studies on the identity between calorific and luminous radiation. Finally, Righi introduces the interesting class of "electric and magnetic phenomena" for which the hypothesis on the electric fluid (or electricity) had been imposed. It is only at this point that Righi makes explicit the goal of the lecture which consisted in showing how the recent advancements in physics allowed to reduce the three fundamental entities to only one of the three: the ether itself. Throughout the lecture, Righi will pursue this specific goal by developing two main lines of arguments: a) investigating the relationship between electricity and ponderable matter; b) drawing an overall picture encompassing electrons and cosmic ether. Regarding the first line of reasoning Righi points out how the ancient "electrical fluid" had been recently replaced with a substance —still called "electricity"— but of atomic constitution. Electrons, definite in charge, could in principle exist in both states —positive and negative— but only the latter has been really detected. The way how physicists became convinced of the electrons' existence is then illustrated by focusing on the Zeeman effect —the first suggestion for the electrons' existence— and Thomson's cathode tube —the definitive proof. The Zeeman effect shows that the coupling between the ether and ponderable matter is guaranteed by the electrical charges of the ions in molecules which, through their vibrations, make the waves produced or absorbed. Righi remarks that it was Lorentz to see that the Zeeman effect completed Maxwell's theory. After explaining that the discrete spectrum of a gas should be seen as a musical instrument producing only certain definite notes, Righi points out how the lines split when the gas is immersed in a magnetic field. By delving more and more into the topic, Righi goes by recalling Lorentz's suggestion (and Zeeman verification) that, in this condition, each line splits in two or three and the light is circularly polarized in the case of a doublet and linearly polarized in the other case.

To illustrate Thomson's experiment Righi presents to the audience an experiment made with a 4 meters long cathode tube. By gradually varying the pressure within the tube, Righi draws the audience's attention to the observation that the initial sparks progressively transform as the pressure is lowered: at a certain value of the pressure two portions of different light (red and violet) appear on the two half of the tube and, as the pressure goes down, the second becomes more prominent. Going on with the process, the violet (or negative light) splits in two parallel portions which appear divided at their base by "the black space of the cathod". As the violet light —which in the meanwhile had continued to grow— reaches the anode, its luminosity disappears and another phenomenon, a green light, is observed: electrons appear. However, for electrons replacing matter, it was necessary to show that particles of electricity were *also* particles of matter, *i.e.*, that they have *inertia*. The key phenomenon in this respect is then the "autoinduction": as physicists know very well, Righi goes on, an "extra-current" opposed to the principal current appears when the intensity of this latter is suddenly increased.

Single electrons then, display *inertia*, a fundamental quality of ponderable matter which made them very good candidates to be the origin, the essence of matter itself ([7], p. 26):

"In this way it can be said that, besides the ether, nothing else exists to constitute the Universe if not an exterminated number of electrons, attracting or repulsing each other and assembling on thousands of ways to compose the atoms of the bodies all. They can be considered as local modification of the universal ether and the forces existing between them can be attributed to special elasticities which are formed within the ether itself by virtue of their presence [...]. Every phenomena of the physical world is then caused by electrons".

Righi's account of the two main atomic models of the time proposed by Thomson and Nagaoka is the natural follow-up of the electrical theory of matter: Righi remarks that both the models presented the problem of stability, either the positive charge is uniformly distributed within the atom (as in Thomson's) or concentrated in the center (Nagaoka's)(1). The closing part of the lecture however suggests that the *instability* of the atomic models, instead of being a weakness might be a proof in favor of the electrical constitution of matter: in fact, the discovery of radioactivity by Becquerel had shown that the collapse of the atomic building might be in accordance with natural phenomena and how the three types of radioactive emission allowed to track these transformations. Righi's conclusions on the matter are confident but not naïve ([7], p. 34):

"Looking at the more recent achievements of physics, one gets ecstatic by their splendor; but then, one should think that more than one Century ago, at the time of the discoveries of Galvani and Volta the feeling must have been the same; and perhaps, in a Century, what we know today will appear as a very little thing. It has been said that the more science grows, the more its surface of contact with the surrounding unknown extends".

Who knows for how much longer new discoveries will open to new mysteries? With this still open question Righi thanks the audience and closes the lecture.

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(1) At the same time, Righi skips over the fact that already in 1901 Perrin had anticipated Nagaoka's model in a popular writing published on the *Revue Scientifique* (*Division de l'atome en corpuscles*). Great supporter of the hypotheses on the corpuscular nature of cathodic rays since 1895, Perrin had perhaps anticipated the times and generally did not get the deserved recognition.